Our Children's Trust
Youth v. Gov

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In response to Docket No. 20200181-EU Proposed Amendment of 25-17.0021, F.A.C., Goals for Electric Utilities

On behalf of Florida's youth, Our Children's Trust provides these comments on Docket No. 20200181-EU Proposed Amendment of 25-17.0021, F.A.C., Goals for Electric Utilities to the Florida Public Service Commission ("PSC"). Our Children's Trust is the only law firm in the United States dedicated to representing youth whose fundamental, constitutional rights to life, liberty, property, and equal protection of the law are being infringed by their government's climate change-causing conduct, including the PSC's energy policies that exacerbate the climate crisis.

We write to advise the PSC to revise its draft rule so as to properly ensure the protection of the fundamental constitutional rights of Florida's children, particularly children within communities of color, low-income communities, and indigenous communities in keeping with principles of environmental justice. As it stands, the PSC's draft rule violates FEECA and perpetuates the Florida government's infringement of fundamental, constitutional rights of young people and future generations. Increasing renewable energy generation and improving energy efficiency are two of the most important and cost-effective ways to facilitate the decarbonization of Florida's energy system, which is desperately needed to protect Florida's children from the dangers of climate change.

Specifically, in revising its draft rule, the PSC should: (1) consider all criteria required by FEECA in establishing energy efficiency goals and abandoning the reliance on the RIM test; (2) establish steadily increasing annual energy savings goals in line with states that have documented success with respect to energy efficiency gains; (3) comply with FEECA-mandated timelines to establish energy efficiency goals; (4) establish energy efficiency goals instead of improperly delegating authority to utilities to do so; (5) eliminate the use of a "reasonably achievable" standard that does not appear within FEECA; (6) align its energy efficiency goals with the national goal of 100% carbon-free electricity by 2035; and (7) use this rulemaking process to require the utilities to implement key energy efficiency measures that facilitate the decarbonization of Florida's energy system.

The premier scientific experts on climate change and its impacts are clear on three key points that are relevant to the PSC's task at hand.

1. Children are uniquely vulnerable to human-caused climate change because of their developing bodies, higher exposure to air, food, and water per unit body weight, unique behavior patterns, dependence on caregivers, and longevity on the planet.[1] Climate change is causing a public health emergency that is adversely impacting the physical and mental health of American children through, among other impacts, extreme weather events, rising temperatures and increased heat exposure, decreased air quality, altered infectious disease patterns, and food and water insecurity.[2]

2. "Earth energy imbalance (EEI) is the most critical number defining the prospects for continued global warming and climate change."[3] EEI (and more global warming),[4] can only be stopped by returning the atmospheric carbon dioxide ("CO_2") concentration to below 350 ppm by 2100. This is the best scientific standard for "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. . . . within a time-frame" sufficient to protect life and liberties.[5] Achieving this standard requires rapid decarbonization of state energy systems.

3. Current increased average temperatures of 1.1°C are already dangerous. Basing decisions on temperature targets of even more heat at 1.5 to 2°C stokes more danger and is exponentially more catastrophic for our children and posterity. The IPCC Special Report on *Global Warming of 1.5°C* (2018) stated that allowing a temperature rise of 1.5°C "is not considered 'safe' for most nations, communities, ecosystems, and sectors and poses significant risks to natural and human systems as compared to current warming of 1°C (*high confidence*)."[6]

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[1] Samantha Ahdoot, Susan E. Pacheco & Council on Environmental Health, *Global Climate Change and Children's Health*, 136 Pediatrics e1468 (2015); Rebecca Pass Philipsborn & Kevin Chan, *Climate Change and Global Child Health*, 141 Pediatrics e20173774 (2018); Perry E. Sheffield & Philip J. Landrigan, *Global Climate Change and Children's Health: Threats and Strategies for Prevention*, 119 Envtl. Health Persp. 291 (2011).

[2] Ahdoot, Pacheco & Council on Environmental Health, *supra* note 1.

[3] Karina von Schuckmann et al., *Heat Stored in the Earth System: Where Does the Energy Go?*, 12 Earth Syst. Sci. Data 2013, 2014 (2020) (**Exhibit 1**).

[4] *Id.*; *see also* Ryan J. Kramer et al., *Observational Evidence of Increasing Global Radiative Forcing*, 48 Geophysical Res. Letters, e2020GL091585 (2021), https://doi.org/10.1029/2020GL091585 (finding radiative forcing has increased 0.53 +/- 0.11 W/m^2 from 2003 to 2018 and confirming "that rising greenhouse gas concentrations account for most of the increases in the radiative forcing, along with reductions in reflective aerosols. This serves as direct evidence that anthropogenic activity has affected Earth's energy budget in the recent past."); Norman G. Loeb et al., *Satellite and Ocean Data Reveal Marked Increase in Earth's Heating Rate*, 2021 Geophysical Res. Letters, doi: 10.1029/2021GL093047 (satellite and in situ observations independently show an approximate doubling of Earth's Energy Imbalance from mid-2005 to mid-2019 ("Because EEI is such a fundamental property of the climate system, the implications of an increasing EEI trend are far reaching. A positive EEI is manifested as 'symptoms' such as global temperature rise, increased ocean warming, sea level rise, and intensification of the hydrological cycle.")).

[5] United Nations Framework Convention on Climate Change art. 2, May 9, 1992, 1771 U.N.T.S. 107.

[6] Joyashree Roy et al., *Sustainable Development, Poverty Eradication and Reducing Inequalities, in* Global Warming of 1.5°C, at 447 (2018); *see also* James Hansen et al., *Assessing "Dangerous Climate Change": Required Reduction of Carbon Emissions to Protect Young People, Future Generations and Nature*, 8 PLOS ONE e81648 (2013).

Decarbonizing Florida's energy system, which is essential to preserve the lives and liberties of Florida's children, rests on four principal strategies ("four pillars"):

(1) Electricity decarbonization, the reduction in emissions intensity of electricity generation by about 95% below today's levels by 2050;
(2) **Energy efficiency, the reduction in energy required to provide energy services such as heating and transportation, by about 50% below today's level;**
(3) Electrification, converting end-uses like transportation and heating from fossil fuels to low-carbon electricity, so that electricity doubles its share from 25% of current end uses to approximately 50% in 2050; and
(4) The use of captured carbon that would otherwise be emitted from power plants and industrial facilities rising from nearly zero today to as much as 70 million metric tonnes in 2050.[7]

Energy experts have opined that "achieving a trajectory of emissions in Florida consistent with 350 ppm globally is technically feasible and the cost of realizing emissions reductions is affordable in the context of historical energy system spending within the state."[8] Transitioning off of fossil fuels and to renewable sources also creates more than 350,000 long-term, full time jobs, saves 2,840 lives from air pollution per year in 2050, and reduces 2050 annual energy costs by 52.5-55.6%.

Given these benefits, and the well-established costs and harms maintaining a fossil-fuel based energy system will inflict on both the state and its youth citizens, the PSC should adopt common sense and legally compliant energy efficiency goals that move the state towards a robust renewable energy system that prioritizes and increases energy efficiency. Transformation of Florida's energy system so that it no longer imperils the lives and liberties of children, and the very existence of the state, requires "ambitious early action."[9] Therefore, the PSC cannot waste this opportunity and must establish energy efficiency goals that put Florida on a path towards climate stabilization.

Florida's Youth Are Being Harmed by Energy Policies that Cause Climate Change

A draft report just obtained from the United Nations Intergovernmental Panel on Climate Change has warned that "[t]he worst is yet to come, affecting our children's and grandchildren's lives much more than our own."[10] Below are a few examples of how youth in Florida are being harmed by Florida's energy policies that are contributing to the climate crisis.

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[7] Evolved Energy Research, 350 ppm Pathways for Florida (October 6, 2020) [hereinafter 350 ppm Pathways], at 8 (emphasis added) (**Exhibit 2**); Mark Z. Jacobson, *Zero Air Pollution and Zero Carbon From All Energy Without Blackouts at Low Cost in Florida* (April 24, 2021), http://web.stanford.edu/group/efmh/jacobson/Articles/I/21-USStates-PDFs/21-WWS-Florida.pdf (**Exhibit 3**); Mark Z. Jacobson et al., *100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for the 50 United States*, 8 Energy Envtl. Sci. 2093 (2015), https://web.stanford.edu/group/efmh/jacobson/Articles/I/USStatesWWS.pdf.

[8] 350 ppm Pathways, *supra* note 7, at 62.

[9] *Id.*

[10] William Brangham & Murrey Jacobson, *A Leaked UN Report Warns 'Worst Is Yet To Come' on Climate Change. Here's How You Can Help*, Pub. Broadcasting Serv. (June 23, 2021), https://www.pbs.org/newshour/show/a-leaked-un-report-warns-worst-is-yet-to-come-on-climate-change-heres-how-you-can-help.

Delaney Reynolds is a 21-year-old U.S. citizen and a resident of Miami, Florida. Delaney is being harmed by climate change and ocean acidification and those impacts are only getting worse. Delaney is now an educated young scientist having earned her bachelor's degrees in Marine Science and Geology from the University of Miami's Rosenstiel School of Marine and Atmospheric Science. She is continuing her education as a graduate candidate in the University of Miami's Abess Center for Ecosystem Science and Policy where she's pursuing dual degrees as a jurist doctorate in law and a Ph.D. in environmental sciences.

Delaney is a fourth generation Miamian, her family has lived in South Florida since 1910, where her home is a mere 9-10 feet above sea level. She also has grown up in her family's home on No Name Key in the Florida Keys. In Miami, climate change and sea level rise are impacting the aquifers and will cause irreparable damage to the groundwater well systems that Delaney relies on for drinking water without immediate action to reduce GHG pollution.

She calls both Miami and No Name Key home. Her home in the Florida Keys is approximately 3 feet above sea level and is located on a canal that connects to the ocean. While hiking on No Name Key, Delaney has recently noticed rising seas and saltwater in places where it did not used to be. Without drastic steps to reduce GHG pollution, Delaney's home on No Name Key, and the places where she recreates there, will be devastated by flooding, erosion and further inundated by rising seas. Delaney's ability to continue to access her home and community in the Florida Keys is in grave danger. Just this week, residents of the Florida Keys held a seven-hour public meeting in the city of Marathon where government officials voted to elevate streets from the rising waters in the Keys, even though they have no source of funding for this huge endeavor.[11] This illustrates the vast financial burden being placed on Floridians by PSC's energy decisions that cause climate change.

In Delaney's lifetime, sea levels have noticeably risen at places where she visits and recreates. For example, Matheson Hammock Beach, just one mile from her Miami home, is an area where Delaney likes to ride her bike, but the trail she uses is increasingly flooded with salt water due to sea level rise. She is not able to use, access, and enjoy the trail when it is flooded. Miami Beach, the Everglades, and other areas in South Florida that Delaney visits and plans to continue to visit, also have experienced increasingly common and disruptive floods and other impacts as a result of climate change, thus minimizing her ability to recreate there and enjoy such places.

Delaney loves fishing for snapper, grouper, lobsters, and other fish, which afford both recreation and food for Delaney and her family. However, Delaney's ability to fish is being negatively affected as marine species are impacted by ocean acidification and warming. Delaney also loves to swim and snorkel and see dolphins, sea turtles, sharks, barracudas, and other marine life in places like Biscayne Bay National Park. Florida's coral reefs already experience bleaching – almost every time Delaney goes swimming or snorkeling she sees coral bleaching in new areas – and without government action, she will not be able to see and enjoy all the marine life that she does now in the future.

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[11] Oliver Milman, *'The Water Is Coming': Florida Keys Faces Stark Reality As Seas Rise*, The Guardian (June 24, 2021, 7:00 AM), https://www.theguardian.com/us-news/2021/jun/24/florida-keys-climate-change-sea-level-rise.

When Hurricane Irma struck in the summer of 2017, Delaney lost power for 11 days and her college studies were significantly disrupted. Her home on No Name Key and the surrounding lower Keys region suffered tremendous damage as it is located where the northern eyewall of Hurricane Irma hit Florida. Delaney was out of school for two weeks and is concerned about scientists' predictions that climate change is leading to more frequent, more powerful hurricanes in the future that will impact her ability to live in places that she loves such as Miami and No Name Key. Delaney consistently experiences anxiety, depressed thoughts, terror and high stress because she fully understands the gravity and urgency of climate change and ocean acidification and its impacts on her life.

Levi D. is a 13-year old Florida youth residing in Melbourne, Brevard County, Florida, whose personal and economic wellbeing is, and will continue to be, threatened with injury from the Climate Change Impacts. Levi grew up in Indialantic and Satellite Beach, Florida on a southeastern Florida barrier island, much of which is less than 6 feet above sea level. His grandparents still live in Indialantic, and Levi used to live with them but now visits there frequently. Their home is right at sea level and is located about half a mile from the Atlantic Ocean and a quarter mile from the Indian River Lagoon. The barrier island is made up of unconsolidated sand that sits on top of porous limestone bedrock. Because of that, Levi has been told that it would be impossible to build a seawall to try to protect his hometown from the rising seas.

Levi's home is facing impacts from sea level rise and increased inundation during storms. With just 3 feet of sea level rise, Levi's hometown will be in the sea. Long before 3 feet of sea level rise, Levi's grandparents, who still live on the island, will be forced out of their home because of the increasing frequency and depth of flooding, infrastructure failure in their home and community from sunny day flood events (King Tides and heavy rainfalls), and storm surges from tropical storms and hurricanes. Levi's family decided to move off the island due to these concerns, and while they live further inland, Levi is still in harm's way.

During the summer of 2017, Levi was forced to evacuate his home due to Hurricane Irma. Due to flood and other damage from Hurricane Irma, Levi's hybrid school was shut down permanently. Levi is homeschooled now. His mother also worked at the school, and its closing resulted in her losing that job. The loss of his school community is devastating to Levi. During fall 2017 storms, Levi's home had at least 18 inches of flood water in the front yard. Levi was literally up to his knees in the flood water and had to put sandbags around the house to protect it from water damage.

The beaches on the island are Levi's backyard. During the summer months, he spends time at the beach regularly and, during the remainder of the year, beach visits and recreation are common. However, Sargassum seaweed invasion, with seaweed covering the beaches along the island, is now common due to climate change and higher water temperatures, as are many fish kills in the waters where Levi recreates. Levi's ability to access the beach and participate in beach activities has thus been reduced because the rotting seaweed smells like sulfur, and the rotting fish create unsafe and unpleasant conditions. Levi's ability to swim in the Indian River Lagoon is often limited because of increasing flesh-eating bacteria and dead fish, also due to climate change and higher water temperatures. Levi and his family are able to routinely smell the dead fish in their community. Levi is now limited in where he can access and swim in the Atlantic Ocean, due to an increase in flesh-eating bacteria, Sargassum seaweed invasion, and other Climate Change Impacts.

During the Red Tide outbreak along the Florida coastline in 2018, Levi felt physically sick because the contaminated air made him cough, and he wasn't able to go to many of the beaches he would usually visit, like Paradise Beach, Pelican Beach, and Cocoa Beach. When he tried to go to the beach during the Red Tide outbreak, he felt scared and upset by the dead fish and other dead animals on the beaches. The air was so bad he started coughing, it was difficult to breathe, and his eyes were burning. He ended up having to wear a gas mask just to go to the beach. Because of the Red Tide, he couldn't go on pre-planned field trips to the beach with Explorer's Club, which is his home school group, and even had trouble being outside of his home for more than five minutes at a time. It was a really scary experience for him.

He has also seen the negative effects of climate change on other parts of the beach environment that he loves. There are fewer sea turtles in the area, which he used to enjoy watching. He recently learned that there are more mature female sea turtles than male sea turtles. Turtle gender is determined by the temperature of the sand the turtle eggs are buried in. Because of increased temperatures, most sea turtles are born female instead of male, and this imbalance harms an already delicate species. The area is one of the few places that sea turtles come to nest, so its protection is critical.

Levi often waded and kayaked in the Indian River Lagoon on the west side of the barrier island but can no longer do so because of increasing flesh-eating bacteria and dead fish. Because of rising sea level and outdated infrastructure on the barrier island, raw sewage has been dumped into the Indian River Lagoon. The local government is forced to choose between sewage coming up into homes or dumping sewage into the water. Increased rainfall and rain at unusual times of the year also means that more fertilizers are washed into the Indian River Lagoon. This combination has caused more bacteria in the water, more algal blooms, and more fish kills, which has made the water dirtier and unsafe to spend time in and around. Levi and his family are able to smell the dead fish in the community whenever there is a fish kill.

Satellite Beach and Indialantic both have "worm rock" reefs along their coastlines. These reefs are habitat for sea turtles and other marine life. Because of beach erosion from sea level rise, new sand has been poured along the coast, but the new sand hurts the existing reef. An artificial reef was also built further offshore in the hopes that sea life would use the fake reef instead of the natural reef, but it just isn't the same. The artificial reef is much deeper and made of cement with some natural rock stuck into it, so it looks really different than a natural limestone reef. Levi is afraid that if government agencies like the Public Service Commission continue to pursue energy policies that result in high levels of greenhouse gas emissions, he will have to grow up in a world with only fake "coral" reefs. In the last two years, Levi's severe allergies have made it harder for him to spend time outdoors. Among the adverse effects of climate change are an increase in allergies and adverse psychological impacts, both of which Levi is experiencing.

Isaac A. is a 16-year-old U.S. citizen and resident of Alachua, Florida, one of the Florida counties most severely impacted by inland flooding due to significantly high volumes of rain and river flooding. Isaac is psychologically harmed by the overwhelming fears caused by climate change, and at times he feels hopeless and extremely sad; particularly since he sees his government continue to pursue energy policies that exacerbate the climate crisis and make it harder to engage in the agricultural activities that he has grown up doing. Isaac lives on 20 acres of forest and farmland, which his family has owned for over 20 years. The warmer, more humid weather associated with climate change is harming the animals that Isaac and his family raise and depend on. Hotter weather makes it harder to work on the farm and allows more parasites and diseases to spread, such as those that killed off all but one of Isaac's new baby goats born in 2015. This year they had to treat their baby goat and do a blood transfusion because of the parasites.

Isaac regularly plants a wide variety of plants and vegetables on his farm and spends a lot of his free time in the garden. He has had to adjust planting dates and prevent pests in the garden much earlier in the season because of changing temperature patterns. Isaac and his family enjoy and recreate on many of Florida's northeastern beaches and coastal ecosystems, but their ability to do so is negatively impacted by climate change and sea level rise. The Florida Keys and surrounding ocean life is very important to Isaac and his father. On a recent snorkeling trip to the Keys, Isaac and his father noticed that ocean acidification has drastically changed the coral reefs over the years since his childhood. Isaac worries that he may not be able to continue to see and experience coral reefs and certain fish species as he grows up due to ocean warming and acidification caused by CO_2 emissions. The increasing prevalence and severity of toxic algal blooms off the coast of Florida due to climate change also limits Isaac's access, swim, and recreate in the ocean due to the serious associated health threats. Isaac frequently visits the Blue Springs and Ginnie Springs a few miles from his home. Isaac has noticed a significant decrease in the flow of the springs, which causes him stress and reduces his ability to access, use, and enjoy the springs.

When Hurricane Irma struck Florida, there was a tremendous amount of flooding around Isaac's home. They lost power for about a day and did not have Internet service for over a week, interrupting Isaac's school schedule. Isaac's grandpa's property, which he frequently visits, received so much water that it flooded about 8-9 acres. The water came up to the first step of his grandpa's house, just below his backdoor.

Valholly F. is an 18-year-old U.S. citizen, resident of Big Cypress, Florida. Her father is a member of the Panther Clan of the Seminole Tribe of Florida. She grew up and continues to work and spend a significant amount of time on the Big Cypress Indian Reservation. Her tribal heritage is closely linked to nature, and many in her tribal community believe that if the land dies, so will the tribe. With the increasing temperatures in Florida, Valholly finds it harder to go outside and engage in her normal activities, such as going to the beach and exploring nature on the reservation. On the reservation, she has witnessed many native plants, some of which have traditional medicinal purposes, struggling to survive and has noticed there are a lot fewer animals, such as frogs, toads and butterflies. She has also noticed an increase in mosquitoes. Valholly currently works outside on the reservation and is exposed to extreme heat conditions, which are getting worse as the climate crisis worsens.

The Everglades ecosystem is a vital part of Valholly's cultural heritage and it has sustained her tribal community for centuries. She grew up in the Everglades and has been surrounded by its ecosystem her entire life. She has witnessed climate change impacts, including salt water intrusion, sea level rise, and worsening extreme weather events, all of which are negatively affecting many of her traditional cultural areas and practices in the Everglades. She is also witnessing how oil and gas development, permitted by her state government, imperils reservation land and traditional ceremonial grounds. She has seen how climate change is decimating endangered species that can only live in the Everglades and fears seeing the loss of these species within her lifetime. Ceremonial grounds within the Everglades, which are used for traditional cultural purposes and are of tremendous importance to Valholly and her community, are in jeopardy of disappearing altogether. In addition, there are many Seminole reservations throughout the state of Florida; all of which are experiencing severe climate change impacts, which are negatively affecting her and her community's wellbeing and ability to live healthful lives in Florida.

When she was living at her house in Weston, Florida, which is at sea level, Valholly and her family were forced to evacuate to their home on the Big Cypress Reservation during Hurricane Irma. Her neighborhood in Weston flooded and the lake adjacent to their home rose into their back yard, within several inches of their house. She lost power at her homes in both Weston and Big Cypress for several days and missed an entire week of school because the school was closed due to significant flooding. Experiencing these hurricanes has been a terrifying experience, particularly given her young age, because she knows that these kinds of extreme weather events are getting more severe and will become even more life threatening if her state continues to promote policies that cause climate change.

Oliver C. is a 17-year-old U.S. citizen and a resident of Pensacola, Florida. He and his family live on Bayou Grande, where he grew up swimming, kayaking, and fishing. In his lifetime, there have been three historic weather events that have adversely affected his enjoyment of the bayou, including Hurricane Ivan in 2004 and a heavy rain in 2014 that broke historic records. Hurricane Ivan destroyed a boathouse, and the boat and canoe inside, on the Chamblin property. The 2014 rain event flooded several houses in the neighborhood and resulted in stormwater runoff that exacerbated a trend of increasing pollution of the bayou. As a result of increased pollution, Oliver has been unable to enjoy swimming, kayaking, and fishing as he once did. Oliver and his family have also enjoyed visits to beaches in the Gulf Islands National Seashore, which have seen increases in populations of jellyfish due to warmer temperatures in the Gulf. In September 2020, Hurricane Sally made landfall a few miles west of the Chamblin property and caused severe damage to the roof of the Chamblin house and dock. All of these major weather events—the two hurricanes, the historic rain of 2014, and the increasing pollution from stormwater runoff—were made more intense by climate change.

Climate Change Impedes the Prosperity of Floridians

Overwhelming scientific consensus confirms climate change is occurring as a result of human activity, primarily the emission of greenhouse gases from the burning of fossil fuels.[12] States like Florida are particularly vulnerable to rising coastline degradation, worsening natural disasters, and ocean acidification.[13]

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[12] John Cook et al., *Consensus on consensus: a synthesis of consensus estimates on human-caused global warming*, 11 Env't Res. Letters 1, 5 (2016).

[13] Env't Protection Agency, What Climate Change Means for Florida (2016), https://www.epa.gov/sites/production/files/2016-08/documents/climate-change-fl.pdf.

There is no longer any question that climate change is impeding the prosperity of Florida's citizens. Florida is the third most populated state in the United States,[14] with the fourth highest current-dollar Gross Domestic Product.[15] Approximately three-fourths of Florida's residents live in shoreline and coastal areas[16] and climate change is a dire threat to these increasingly vulnerable areas. Specifically, rising sea level is damaging Florida's economy and its ability to provide Floridians with essential human services. A recent assessment found that within the next 12 years, property values in Florida will decline by $15 billion due to flooding.[17] In 2019, the National Oceanic and Atmospheric Administration reported that "Florida alone is estimated to have a 1-in-20 chance of having more than $346 billion (in 2011 dollars) in property value (8.7%) below average sea level by 2100."[18] The best scientific information available projects a 15-30 foot rise in sea level by 2100 if current GHG emission trends continue, with ever greater rises and acceleration in subsequent centuries until such time as levels of CO_2 in the atmosphere are dramatically reduced and steps are taken to cool the upper portion of the ocean.[19] A one-meter rise in sea levels—which is at the low end of projections under business-as-usual emissions scenarios[20]—would result in a nine percent loss of Florida's landmass, impacting ten percent of the state's population.[21] Florida will lose more homes and land than any other state in the United States if CO_2 and GHG emission levels continue as projected.[22]

Climate change similarly threatens Florida's tourism industry, which is a huge economic driver for the state. In 2018, Florida welcomed 127 million tourists[23] who spent $94 billion in the state.[24] Climate change is negatively affecting the natural resources that bring tourists to Florida. For example, Florida's coral reefs are anticipated to disappear by the end of the century due to ocean warming and acidification[25] and are currently valued at $1.1 billion annually, providing

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[14] U.S. Census Bureau, U.S. and World Population Clock (2021), https://www.census.gov/popclock/.

[15] Bureau of Econ. Analysis, Economic Profile for Florida (2021), https://apps.bea.gov/regional/bearfacts/action.cfm.

[16] Nat'l Oceanic and Atmospheric Admin., Fast Facts Florida (2021), https://coast.noaa.gov/states/florida.html.

[17] McKinsey Glob. Inst., Will mortgages and markets stay afloat in Florida? 19 (2020), https://www.mckinsey.com/~/media/mckinsey/business%20functions/sustainability/our%20insights/will%20mortgages%20and%20markets%20stay%20afloat%20in%20florida/mgi-will-mortgages-and-markets-stay-afloat-in-florida.pdf.

[18] Michon Scott & Rebecca Lindsey, Nat'l Oceanic and Atmospheric Admin., National Climate Assessment: Hurricanes and hospital flooding (2019), https://www.climate.gov/news-features/featured-images/national-climate-assessment-hurricanes-and-hospital-flooding.

[19] Decl. of Dr. Harold Wanless in Supp. of Answer of Real Parties in Interest to Pet. for Writ of Mandamus at ¶ 38, *Juliana v. United States*, No. 17-71692 (9th Cir. filed Aug. 28, 2017); Decl. of Dr. Harold Wanless in Supp. of Pls.' Opp'n to Defs.' Mot. for Summ. J., *Juliana v. United States*, No. 6:15-cv-01517-AA (D. Or. filed June 18, 2018) (**Exhibit 4**).

[20] Jonathan L. Bamber et al., *Ice sheet contributions to future sea-level rise from structured expert judgment*, 116 Proc. of the Nat'l Acad. of Sci. of the U.S. 1195, 1199 (2019).

[21] Fla. Oceans and Coastal Council, Climate Change and Sea-Level Rise in Florida 15 (2010).

[22] Union of Concerned Scientists, Underwater 5-7 (2018).

[23] *Record number of Florida tourists but overseas visits down*, AP News (Aug. 16, 2019), https://apnews.com/article/81ea2d5e78e946e591e34188c12c8759.

[24] Rockport Analytics, Picking up the Pace: Florida's Tourism Performance Jumps into a Higher Gear 3 https://www.visitflorida.org/media/30679/florida-visitor-economic-impact-study.pdf (last visited June 23, 2021).

[25] World Econ. F., By 2100, coral reefs might completely disappear (Feb. 20, 2020), https://www.weforum.org/agenda/2020/02/coral-reefs-climate-crisis-environment-oceans.

71,000 jobs, and offering more than $335 million in flood protection each year.[26] The most recent National Climate Assessment states that "the impacts to coral reef ecosystems in the [Southeast] region have been and are expected to be particularly dire."[27]

Additionally, tropical storms and hurricanes will become increasingly common and destructive as climate change continues. These storms cause flooding, coastal erosion, damage to property and infrastructure, salt water contamination of freshwater supplies, and the loss of lives.[28] Climate change induced natural disasters costs Florida tourism revenue, hurricane damages, value of at-risk residential real estate, and increase the cost of electricity generation.[29] These expenses are projected to total at least $92 billion by 2050 and at least $345 billion by 2100, constituting 2.8 percent and 5.0 percent of Florida's projected Gross State Product respectively.[30]

Florida's citizens are being increasingly exposed to various human health threats associated with climate change. Rising temperatures will increase marine-borne illnesses[31] and mosquito-transmitted diseases.[32] Floridians will also have to endure more dangerously hot days.[33] In addition to missed workdays for outdoor workers and military personnel, extreme heat is associated with illnesses ranging from mild cramps to life-threatening heat stroke.[34] A 2019 scientific report projected that climate change will increase Florida extreme heat, subjecting citizens to 105 days per year with a heat index over 100°F, with Tallahassee ranking among the most severe in the nation.[35]

In promulgating the energy efficiency goals, the PSC has an obligation to take into account the aforementioned social and economic costs and burdens as they are well documented and strongly support robust energy efficiency goals. Accordingly, PSC should fulfill, not thwart, the legislature's command "to promote the development of renewable energy; protect the economic viability of Florida's existing renewable energy facilities; diversify the types of fuel used to generate electricity in Florida; lessen Florida's dependence on natural gas and fuel oil for the production of electricity; minimize the volatility of fuel costs; encourage investment within the

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[26] Fla. Dept. of Envtl. Prot., Coral Reef Conservation Program, https://floridadep.gov/rcp/coral (last visited June 23, 2021).

[27] U.S. Glob. Change Research Program, Fourth National Climate Assessment Chapter 19: Southeast, https://nca2018.globalchange.gov/chapter/19/ (last visited Dec. 5, 2018).

[28] Fla. Dept. of Envtl. Protection, Flooding and Erosion, (Mar. 16, 2021, 3:14 PM), https://floridadep.gov/fgs/geologic-topics/content/flooding-and-erosion.

[29] Tatiana Borisova et al., *Economic Impacts of Climate Change on Florida: Estimates from Two Studies*, U. Fla. 1, 3-4 (Mar. 25, 2018), https://edis.ifas.ufl.edu/pdf/FE/FE78700.pdf.

[30] *Id.* at 10.

[31] Nat'l Inst. of Envtl. Health Sci., Waterborne Diseases, https://www.niehs.nih.gov/research/programs/geh/climatechange/health_impacts/waterborne_diseases/index.cfm (last updated Jul. 21, 2017).

[32] Walter Leal Filho et al., *Climate Change, Health and Mosquito-Borne Diseases: Trends and Implications to the Pacific Region*, Int'l J. of Envtl. Res. And Pub. Health 1 (2019).

[33] Union of Concerned Scientists, Killer Heat in the United States 4 (2019), https://www.ucsusa.org/sites/default/files/2020-12/UCS_extreme_heat_report_190712b_low-res_corrected12-20.pdf.

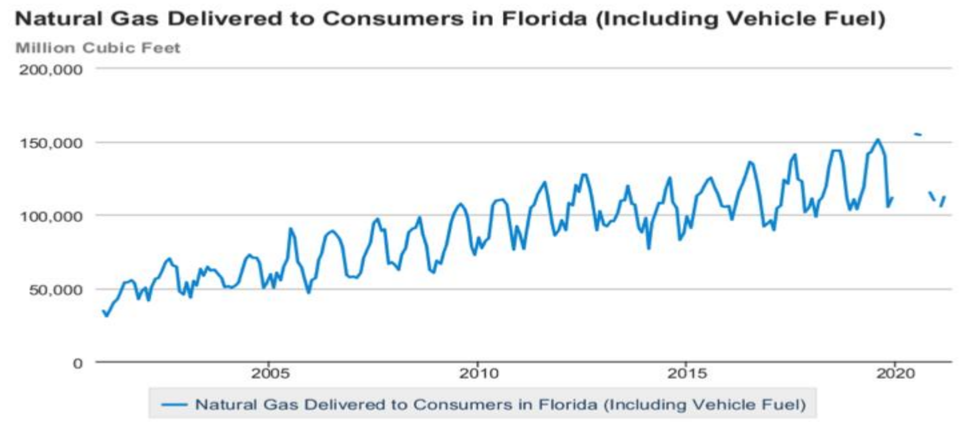
[34] *Id.*

[35] *Id.*

state; improve environmental conditions; and, at the same time, minimize the costs of power supply to electric utilities and their customers."[36]

Florida's GHG Emissions that Result from the State Energy System and PSC Energy Policies

The high levels of greenhouse gas (GHG) emissions that result from Florida's energy system illustrate that the PSC is out of compliance with the legislature's mandated renewable energy policy.[37] The PSC plays a key role in shaping Florida's energy system, including setting goals and approving plans to promote renewable energy systems and to conserve electric energy and natural gas. Despite Florida's impressive solar production capability, the PSC is failing to fulfill the legislature's mandate "to promote the development of renewable energy" and "lessen Florida's dependence on natural gas and fuel oil for the production of electricity."[38] Only about 4% of Florida's net energy generation comes from renewable sources,[39] and "in 2019, solar photovoltaic and solar thermal energy accounted for almost 4.6 million megawatthours of electricity generation in Florida, about half of the state's renewable-sourced generation."[40] Yet, natural gas accounts for about 74% of Florida's electricity net generation,[41] and Florida's consumption of natural gas is *increasing* not lessening as required by Fla. Stat. § 366.92(1):



eia Source: U.S. Energy Information Administration

The facts speak for themselves. The PSC is not only failing to maximize clean and cost-effective solar energy potential to the detriment of the prosperity, health, and welfare of Florida citizens, but it also continues to promote and encourage reliance on fossil fuels. Florida, the nation's second-largest producer of electricity, is the third-largest energy-consuming state and uses

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[36] Fla. Stat. § 366.92(1) (2020).

[37] Fla. Stat. § 366.92 (2020).

[38] Fla. Stat. § 366.92(1) (2020).

[39] U.S. Energy Info. Admin., Florida, https://www.eia.gov/state/analysis.php?sid=FL (last updated Nov. 19, 2020).

[40] *Id.*

[41] U.S. Energy Info. Admin., Florida, https://www.eia.gov/state/?sid=FL#:~:text=Florida%20is%20the%20second%2Dlargest,electricity%20net%20generation%20in%202019.

almost eight times as much energy as it produces.[42] Florida's "residential sector, where almost all homes use air conditioning, accounted for more than one-fourth of state energy consumption."[43] After Texas, Florida ranks second in electricity production.[44] Florida's reliance on natural gas is double the 2018 national average and is directly contrary to the legislature's mandate to "lessen Florida's dependence on natural gas."[45] The residential sector, where more than 9 in 10 Florida households use electricity as their primary energy source for home heating and air conditioning, consumes more than half of the electricity used in Florida.[46] Currently, Florida is projected to remain fossil fuel-reliant unless agencies such as the PSC come into compliance with the legislature's mandate to promote renewable energy and increase energy efficiency.

Of the state's ten largest power plants, seven are natural gas fired.[47] In 2020, Florida utility companies planned numerous natural gas projects.[48] In addition, for every four dollars residents pay Floridian electric companies, one dollar goes directly out of state to import gas.[49] By continuing to promote and facilitate an energy system predominantly based on fossil fuels such as natural gas and failing to establish robust energy efficiency goals, the PSC is in violation of its statutory obligation to "utilize the most efficient and cost-effective demand-side renewable energy systems and conservation systems in order to protect the health, prosperity, and general welfare of the state and its citizens."[50]

The PSC Must Establish Energy Efficiency Goals that Protect Florida Youth's Constitutional Rights to Life, Liberty, Property, and Equal Protection of the Law

In promulgating the draft rule, the PSC must be cognizant of its constitutional responsibility not to infringe upon Floridian's rights to life, liberty, and property, as well as its statutory responsibility "to protect the health, prosperity, and general welfare of the state and its citizens."[51] As the U.S. Supreme Court recognized nearly 80 years ago, "[t]he very purpose of a Bill of Rights was to withdraw certain subjects from the vicissitudes of political controversy, to place them beyond the reach of majorities and officials and to establish them as legal principles to be applied by the courts. One's right to life, liberty, and property . . . and other fundamental rights may not be submitted to vote; they depend on the outcome of no elections."[52] The Florida Supreme Court has similarly acknowledged that "[i]t matters not whether the usurpation of power and the violation of rights guaranteed to the people by the organic law results from the activities of the executive or legislative branches of the government or from officers selected to enforce the law,

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[42] *Id.*

[43] *Id.*

[44] *Id.*

[45] Vote Solar, The Costs & Risks of Florida's Dependence on Natural Gas 2 (Jul. 2020), https://votesolar.org/wp-content/uploads/2020/12/The_Costs_and_Risks_of_Floridas_Dependence_on_Natural_Gas_-_FINAL.pdf; Fla. Stat. § 366.92(1) (2020).

[46] U.S. Energy Info. Admin, *supra* note 39.

[47] U.S. Energy Info. Admin, *supra* note 39.

[48] Vote Solar, *supra* note 45, at 6.

[49] *Id.*

[50] Fla. Stat. § 366.81 (2020).

[51] Fla. Const. art. I, §§ 1, 2, 9; Fla. Stat. § 366.81 (2020).

[52] *W. Virginia State Bd. of Educ. v. Barnette*, 319 U.S. 624, 638 (1943).

the rights of the people guaranteed by the Constitutions must not be violated."[53] As an administrative agency of the state, the PSC is constrained by the Florida Constitution when it exercises its statutory authority to promulgate a rule.

Increasing energy efficiency is one of the four principal strategies to decarbonize Florida's energy system and mitigate against the effects of climate change that are endangering the lives, liberties, and property of Florida's children.[54] Florida's children have constitutional rights to life, liberty, and property that are explicitly protected from government intrusion by the Florida Constitution.[55] By failing to establish robust energy efficiency goals as statutorily required, the PSC is perpetuating Florida's dependence on fossil fuels, which directly contributes to climate change impacts that infringe upon Florida children's fundamental rights to life and liberty.

The United Nations ("UN") and courts around the world agree that government energy policies promoting the use of fossil fuels and thereby causing climate change violate fundamental human rights. On September 16, 2019, the United Nations Human Rights Office of the High Commissioner issued a Joint Statement on Human Rights and Climate Change.[56] The UN recognized that climate change poses significant risks to the enjoyment of human rights, including "the right to life, the right to adequate food, the right to adequate housing, the right to health, the right to water and cultural rights."[57] The UN found that "[c]hildren are particularly at heightened risk of harm to their health, due to the immaturity of their body systems" and that "[s]uch adverse impacts on human rights are already occurring at 1° of warming and every additional increase in temperatures will further undermine the realization of rights."[58] The UN stated that "[f]ailure to take measures to prevent foreseeable human rights harm caused by climate change, or to regulate activities contributing to such harm, could constitute a violation of States' human rights obligations" and declared that protecting fundamental rights requires the adoption and implementation of "policies aimed at reducing emissions," "phasing out fossil fuels," and "promoting renewable energy."[59]

Numerous courts around the world have similarly acknowledged the government's obligation to address climate change in order to protect fundamental rights to life, health, and privacy.[60]

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[53] *Boynton v. State*, 64 So. 2d 536, 552 (Fla. 1953) (emphasis added).

[54] 350 ppm Pathways, *supra* note 7, at 8.

[55] Fla. Const. art. I, § 1 ("All political power is inherent in the people. The enunciation of certain rights shall not be construed to deny or impair others retained by the people."); Fla. Const. art. I, § 2 ("All natural persons, female and male alike, are equal before the law and have inalienable rights, among which are the right to enjoy and defend life and liberty . . . ."); Fla. Const. art. I, § 9 ("No person shall be deprived of life, liberty or property without due process of law . . . .").

[56] U.N. Human Rights Office of the High Commissioner, Joint Statement on Human Rights and Climate Change (September 16, 2019), https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=24998 (**Exhibit 5**).

[57] *Id.*

[58] *Id.*

[59] *Id.*

[60] *See, e.g., Klimaatzaak v. Belgium et al.*, Tribunal de Première Instance [Civ.] [Tribunal of First Instance] 2015/4585/A, June 17, 2021 (Belg.) (holding "in pursuing their climate policy, the [government] infringe[s] the fundamental rights of the plaintiffs[] . . . by failing to take all necessary measures to prevent the effects of climate

By and through this rulemaking, the PSC has an unprecedented opportunity and legal obligation to establish energy efficiency goals that facilitate (as opposed to hinder) decarbonization of Florida's energy system because that is what is required to protect the constitutional rights of Florida's children and "to protect the health, prosperity, and general welfare of the state and its citizens."[61]

The Florida Energy Efficiency and Conservation Act

In 1980, Florida's legislature codified the aims of reducing Florida's peak electric demand and energy consumption with the enactment of the FEECA.[62] FEECA articulates the legislature's view that it is "critical to utilize the most energy efficient and cost-effective demand-side renewable energy systems and conservation systems **in order to protect the health, prosperity, and general welfare of the state and its citizens**."[63]

To achieve these aims, the legislature directed the PSC to "develop and adopt overall goals" related to the promotion of demand-side renewable energy systems and to the conservation of electricity and natural gas usage.[64] Importantly, the legislature directed the PSC, *not state utilities who are regulated by the PSC,* to adopt the energy efficiency goals.[65] Under FEECA, PSC is authorized to "require each utility to develop plans and implement programs for increasing energy efficiency and conservation and demand-side renewable energy systems within its service areas."[66]

The stated legislative intent of FEECA is that PSC encourage the adoption of a wide array of energy efficiency and conservation approaches, including "solar energy, renewable energy sources, highly efficient systems, cogeneration, and load-control systems."[67] Importantly, the legislature intended that FEECA be "liberally construed" in order to meet the complex problems of (1) "reducing and controlling the growth rates of electric consumption and reducing the growth rates of weather-sensitive peak demand;" (2) "increasing the overall efficiency and cost-effectiveness of electricity and natural gas production and use;" (3) "encouraging further development of demand-side renewable energy systems;" and (4) "conserving expensive resources, particularly petroleum fuels."[68]

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change on the plaintiffs' life and privacy[.]");[60] *Neubauer et al. v. Germany*, Bundesverfassungsgericht [BVerfG] Mar. 24, 2021 (Ger.) ("The state's duty to protect . . . also includes the [constitutional] obligation to protect life and health from the dangers of climate change[.]");[60] *Urgenda Foundation v. The State of the Netherlands*, HR 20 Dec. 2019, NJ 2020 19/00135 m.nt (Staat der Nederlanden/Stitchting Urgenda (Neth.) (establishing a legal duty to reduce GHG emissions "by virtue of the protection it must provide to residents of the Netherlands on the basis of Articles 2 and 8 [European Convention on Human Rights] in order to protect their right to life and their right to private and family life.").[60]

[61] Fla. Stat. § 366.81 (2020).

[62] Fla. Stat. §§ 366.80 – 366.83, 403.519 (2020).

[63] *Id.* § 366.81 (emphasis added).

[64] *Id.*

[65] *See id.* § 366.82(2).

[66] *Id.* § 366.81.

[67] *Id.*

[68] *Id.*

FEECA operates through a two-step process. First, FEECA requires the PSC to adopt "appropriate goals for increasing the efficiency of energy consumption and increasing the development of demand-side renewable energy systems[.]"[69] In developing these goals, the PSC is directed to evaluate "the full technical potential of all available demand-side and supply-side conservation and efficiency measures, including demand-side renewable energy systems."[70]

Second, once the PSC has established these energy efficiency goals, the PSC "shall require each utility to develop plans and programs to meet the overall goals within its service areas."[71] The PSC has the authority to require modifications or additions to a utility's plans and programs "at any time it is in the public interest consistent with this act."[72] If the PSC disapproves a utility's plan, the Commission must provide the reasons for disapproval and the utility must resubmit a modified plan within thirty days.[73]

In order to evaluate the regulated utilities' compliance with FEECA, PSC "shall require periodic reports from each utility and shall provide the Legislature and Governor with an annual report by March 1 of the goals it [i.e., PSC] has adopted and its progress towards meeting those goals."[74] PSC is also authorized to issue financial rewards for utilities who exceed their energy efficiency or conservation goals, as well as financial penalties for utilities that fail to meet their energy efficiency or conservation goals.[75]

The PSC's Draft Rule is Inconsistent with FEECA and the Florida Constitution

The PSC too Narrowly Defines its Energy Efficiency and Conservation Duties in Violation of Fla. Stat. § 366.82 and Improperly Relies on the RIM Test.

FEECA prescribes very clear criteria that the PSC must consider when establishing energy efficiency goals, but PSC's draft rule blatantly contradicts FEECA by not requiring the PSC to consider all of these criteria. Under FEECA, the PSC must "evaluate the full technical potential of all available demand-side and supply-side conservation and efficiency measures" while simultaneously "tak[ing] into consideration:

- The costs and benefits to customers participating in the measure.
- The costs and benefits to the general body of ratepayers as a whole, including utility incentives and participant contributions.

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[69] *Id.* § 366.82(2).

[70] *Id.* § 366.82(3).

[71] *Id.* § 366.82(7). *See also* Fla. Pub. Serv. Comm'n, Annual Report on Activities Pursuant to the Florida Energy Efficiency and Conservation Act 1, (Feb. 2021), http://www.psc.state.fl.us/Files/PDF/Publications/Reports/Electricgas/AnnualReport/2020.pdf (noting there are seven electric utilities and one natural gas utility currently subject to FEECA. These are: Florida Power & Light Company, Duke Energy Florida, LLC, Tampa Electric Company, Gulf Power Company, Florida Public Utilities Company, JEA, Orlando Utilities Commission, and Peoples Gas System.).

[72] Fla. Stat. § 366.82(7) (2020).

[73] *Id.*

[74] *Id.* § 366.82(10).

[75] *Id.* § 366.82(8).

- The need for incentives to promote both customer-owned and utility-owned energy efficiency and demand-side renewable energy systems.
- The costs imposed by state and federal regulations on the emission of greenhouse gases."[76]

However, although the PSC's draft rule mandates only that "[t]he Commission will establish goals based on an assessment of the technical potential of available measures, and an estimate of the total cost-effective KW and KWH savings reasonably achievable through demand-side management programs in each utility's service area over a ten-year period[,]"[77] there is no indication as to how the PSC will consider the other criteria that FEECA requires in Fla. Stat. § 366.82(3).

The absence of any PSC-driven analysis regarding all statutorily mandated considerations in the draft rule goes against other general requirements under FEECA as well. As specified in FEECA, Fla. Stat. § 366.82(3), the PSC must consider the incentives, costs, and benefits of energy efficiency measures in order to ensure that the goals it ultimately sets are in line with FEECA's explicit intention to establish robust and expansive energy efficiency and conservation measures in Florida. FEECA makes it clear that the PSC should "develop and adopt overall goals" that foster the use of "the most efficient and cost-effective demand-side renewable energy systems and conservation systems in order to protect the health, prosperity, and general welfare of the state and its citizens."[78] To achieve this mandate, the legislature directs the PSC to pursue a multitude of energy diversification and conservation strategies including "the use of solar energy, renewable energy sources, highly efficient systems, cogeneration, and load-control systems[.]"[79]

By neglecting to consider all of the elements required to set robust, well-informed energy efficiency goals, the PSC is out of compliance with its statutory requirements. The draft rule only mandates the consideration of two criteria for energy efficiency measures: technical potential and total cost-effectiveness. Both of these are limiting criteria that, when considered in the absence of other criteria, will lead to restrictive rather than "liberal" energy efficiency policies that exclude many viable tools and strategies. In addition, the PSC is out of compliance with its requirement to prepare "all reports, information, analyses, recommendations, and materials related to consumption, utilization, or conservation of electrical energy[.]"[80] No such information is contained within the rulemaking docket, making it difficult to understand the thought process behind the draft rule's provisions for goal-setting.

A more full-bodied, transparent consideration of the many incentives, costs, and benefits implicated by energy efficiency measures will counteract these constrictive tendencies, thereby expanding the PSC's energy efficiency goals, policies and practices and bringing the PSC into compliance not only with its obligations under FEECA but also with FEECA's higher order

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[76] *Id.* § 366.82(3).

[77] Fla. Admin. Code R. 25-17.0021 (1).

[78] Fla. Stat. § 366.81 (2020).

[79] *Id.*

[80] *Id.* § 366.82(12).

intentions.[81] For example, the costs required to implement energy efficiency measures are far outweighed by the social costs of allowing climate change to continue to cause severe damage to Florida's economy as well as the general wellbeing of its citizens.[82] Despite the undeniable social costs of its inefficient, fossil-fuel based energy production practices, the PSC completely ignores those costs when setting its energy efficiency goals, even though it is not unmanageable to account for these costs as demonstrated by the U.S. Office of Management and Budget's use of a social cost of carbon in policy planning for over a decade.[83] The PSC also neglects to account for the corresponding long-term benefits of implementing energy efficiency policies that help stop run-away climate change (benefits that dwarf the short-term costs of the policies' implementation).

Although the PSC's draft rule doesn't account for such cost-benefit analysis in the setting of its goals, the PSC has traditionally utilized an incomplete and inappropriate consideration of energy efficiency policies' costs through its use of the Ratepayer Impact Measure ("RIM") test. No other state besides Florida uses the RIM test.[84] By its own terms, this test contradicts the intent of FEECA because "[t]he more energy a program saves, the worse it will do on the RIM test[] because the test treats the lost sales revenue as a cost."[85]

Relying on the RIM test prevents the implementation of common sense, socially beneficial energy efficiency goals that are contemplated under FEECA. As of 2020, "Florida has more cost-effective energy efficiency available than any other state[;]"[86] yet, Florida ranks 27th in the nation for energy efficiency, and is near the bottom in capturing energy savings as a percentage of utility sales.[87] The fact that the PSC hasn't acted on these opportunities to reduce costs for electricity consumers and to reduce harmful greenhouse gas pollution contravenes the goals and intent of FEECA. Since Florida is the only state that continues to use the RIM test, it is clear that there are other viable alternatives available, such as the Utility Cost Test.

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[81] Dan York & Charlotte Cohn, *Unrealized Potential: Expanding Energy Efficiency Opportunities for Utility Customers in Florida*, ACEEE White Paper 7 (Jan. 2021) (noting that "[e]stablishing *significant*, measurable, and achievable goals for utilities is a critical regulatory tool for delivering widespread energy savings. . . . [S]uch [energy efficiency] resource standards are the policy most closely correlated with higher energy savings") (emphasis added) **(Exhibit 6)**.

[82] *See supra* text accompanying notes 11-33.

[83] *See* Interagency Working Group on Social Cost of Carbon, Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, U.S. Gov. (2010); *see also*, Interagency Working Group on Social Cost of Greenhouse Gases, Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide, Interim Estimates Under Executive Order 13990, U.S. Gov. 17 (Feb. 2021) (incorporating a social cost of various greenhouse gases into federal government policy planning).

[84] George Cavros, *The Fate of Efficiency Programs for Over 6 Million Florida Families Hangs in the Balance*, CleanEnergy.org (Sept. 25, 2019) https://tinyurl.com/w9466dfr ("The RIM test – **no other state** uses this outdated test in setting energy savings goals.").

[85] Dan York & Charlotte Cohn, *Unrealized Potential: Expanding Energy Efficiency Opportunities for Utility Customers in Florida*, ACEEE White Paper 8 (Jan. 2021).

[86] Cyrus Bhedwar, *In Response to Docket No. 20200181-EU Proposed Amendment of 25-17.0021, F.A.C., Goals for Electric Utilities*, Southeast Energy Efficiency Alliance 5 (Feb. 15, 2021) (citing Lawrence Berkeley National Lab 2020 article).

[87] ACEEE, The State Energy Efficiency Scorecard for 2020, https://www.aceee.org/state-policy/scorecard **(Exhibit 7)** at 32.

The PSC Should Establish Steadily Increasing Annual Energy Savings Goals and Follow the Lead of Other States That Have Robust Energy Efficiency Goals.

While Florida currently ranks 27th in the nation in terms of energy efficiency, its ranking is even lower for capturing energy efficiency through utility efficiency programs.[88] This is unacceptable since research shows that Florida has more cost-effective energy efficiency available than any other state.[89] The PSC should take this opportunity to set steadily increasing energy savings goals that maximize the state's potential for cost-effective energy efficiency. As described above, energy experts have already modeled the pathways available for Florida to decarbonize its energy system in a cost-effective manner that aligns with what scientists say needs to be done to stabilize the climate system.[90] This analysis should play a pivotal role in establishing Florida's energy efficiency goals.

Other states around the country are already implementing energy efficiency practices and policies that Florida's PSC could emulate or adapt to bring itself into compliance with its statutory requirements around energy conservation and efficiency. For example, California has established performance incentives for electric and natural gas utilities that have kept the state on track to achieve its goal of doubling 2015 energy savings levels by 2030.[91] According to the American Council for an Energy-Efficient Economy, California "continues to set the pace in advancing energy efficiency on a variety of fronts at the national level and among other states who model their own policies after California's example."[92] Similarly, "Massachusetts utilities continue to achieve among the highest-reported levels of electric savings in the country."[93] By following the lead of states like California and Massachusetts, perhaps even by directly adapting their policies for Florida, the PSC could capitalize on Florida's vast potential for improved energy efficiency and come into compliance with its obligations under FEECA.

The PSC Is Out of Compliance with Statutorily Mandated Deadlines to Promulgate Energy Efficiency Rules

In order to facilitate the legislature's energy efficiency and conservation aims, FEECA expressly requires PSC to review and develop new FEECA goals at least every five years.[94] This periodic renewal requirement makes sense as more technologies that facilitate increased energy efficiency become available and the cost of implementing such measures changes. Yet, the current energy efficiency rulemaking is occurring over seven years after the PSC's last energy efficiency

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[88] *Id.*

[89] Charles A. Goldman et al., *The Cost of Saving Electricity: A Multi-Program Cost Curve for Programs Funded by U.S. Utility Customers*, 2020 Energies 13(9), https://eta-publications.lbl.gov/sites/default/files/manuscript.v9_nmf.pdf.

[90] *See supra* note 7.

[91] ACEEE, 2020 State Energy Efficiency Scorecard California, https://www.aceee.org/sites/default/files/pdfs/ACEEE_ScrSht20_California.pdf.

[92] *Id.*

[93] ACEEE, 2020 State Energy Efficiency Scorecard Massachusetts, https://www.aceee.org/sites/default/files/pdfs/ACEEE_ScrSht20_Massachusetts.pdf.

[94] Fla. Stat. § 366.82(6) (2020).

rulemaking, in 2014.[95] Although the PSC initiated a FEECA rulemaking process in 2019, the 2019 rulemaking resulted in the PSC simply continuing the 2014 goalsetting proceeding for the period of 2020 through 2024.[96]

The PSC Improperly Delegates Authority to the Utilities to Propose Goals

The PSC has improperly delegated much of its statutory responsibilities to individual utilities who have no statutory duty "to protect the health, prosperity, and general welfare of the state and its citizens."[97] For example, instead of "adopt[ing] appropriate goals" as mandated by FEECA,[98] the PSC illegally delegates the responsibility to set goals to "each utility[.]"[99] Even further, the PSC's draft rule requires utilities to "provide ten year projections[]" that "reflect consideration of overlapping measures, rebound effects, free riders, interactions with building codes and appliance efficiency standards, and the utility's latest monitoring and evaluation of conservation programs and measures" as well as an assessment of multiple "market segments and major end-use categories."[100] Such delegation is unlawful because the legislature has commanded that such analysis and evaluation activities be conducted by the PSC, not the utilities.[101]

The PSC's draft rule further improperly delegates the PSC's responsibilities to utilities. In addition to requiring utilities to establish broad goals for each utility, the draft rule also requires utilities to submit "a technical potential study, proposed demand-side management goals, plans, and programs for Commission approval."[102] It further mandates that "[e]ach utility's goal projections must be based upon the full technical potential of all available demand-side conservation and energy efficiency measures" and "must reflect the savings from proposed demand-side management programs."[103] In other words, the PSC's draft rule requires utilities to conduct much of the analysis and many of the development activities that *it* is mandated to perform

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[95] *See* Fla. Pub. Serv. Comm'n, *Order No. PSC-14-0696-FOF-EU*, (Dec. 16, 2014), http://www.psc.state.fl.us/library/filings/2014/06758-2014/06758-2014.pdf.

[96] *See* Fla. Pub. Serv. Comm'n, *Order No. PSC-2019-0509-FOF-EG*, (Nov. 26, 2019), https://www.psc.state.fl.us/library/filings/2019/11134-2019/11134-2019.pdf; *see also* Fla. Pub. Serv. Comm'n, *Annual Report on Activities Pursuant to the Florida Energy Efficiency and Conservation Act* 2, (Feb. 2021), http://www.psc.state.fl.us/Files/PDF/Publications/Reports/Electricgas/AnnualReport/2020.pdf ("On November 5, 2019, the Commission chose to reject the goals proposed by the electric FEECA utilities. Instead, the Commission opted to continue with the goals that were established in the 2014 goalsetting proceeding for the period 2020-2024 and directed its staff to review the FEECA process for potential updates and revisions as may be appropriate.").

[97] Fla. Stat. § 366.81 (2020).

[98] Fla. Stat. § 366.82(2) (2020) ("The commission shall adopt appropriate goals for increasing the efficiency of energy consumption and increasing the development of demand-side renewable energy systems, specifically including goals designed to increase the conservation of expensive resources, such as petroleum fuels, to reduce and control the growth rates of electric consumption, to reduce the growth rates of weather-sensitive peak demand, and to encourage development of demand-side renewable energy resources.").

[99] Fla. Admin. Code R. 25-17.0021(3) (1993).

[100] *Id.*

[101] *See* Fla. Stat. § 366.82(3), (12) (2020).

[102] Fla. Pub. Serv. Comm'n, *Notice of Development of Rulemaking and Workshop*, Doc. No. 13530-2020 (Dec. 15, 2020) 3, http://www.floridapsc.com/library/filings/2020/13530-2020/13530-2020.pdf.

[103] *Id.*

by the legislature.[104] While FEECA directs the PSC to "require each utility to develop plans and implement programs for increasing energy efficiency and conservation and demand-side renewable energy systems within its service area,"[105] it does *not* allow the PSC to offload all goal-setting and technical analysis duties onto regulated utilities. Delegating its responsibilities in this way amounts to an unjustified and illegal abandonment of the PSC's statutory obligations.

Such blatant neglect of the PSC's legislatively mandated responsibilities violates the law. The PSC is statutorily required to enact and manage energy efficiency and conservation goals and practices, not to require utilities to do so. This abdication of duty is especially egregious given the counteracting motivations of the utilities to undermine energy conservation and efficiency policy. Utilities have strong market incentives to resist energy conservation and efficiency policy given that they make money by using capital assets to convey electricity to customers[106] (and therefore are financially disinterested in promoting activities that would reduce the need for or use of those capital assets).[107] By placing these utilities in charge of setting their own energy conservation and efficiency goals and policies, the PSC is essentially placing the fox in charge of the henhouse. For these reasons, the PSC's draft rule does not comply with FEECA's intention to promote energy conservation and efficiency.

In addition to having misaligned incentives for the setting of energy conservation goals, the utilities don't have a responsibility to protect the health, welfare, and constitutional rights of Florida citizens. The PSC, as a governmental entity, *does* have this responsibility; the PSC cannot simply abdicate its statutory duty to set energy efficiency goals necessary "to protect the health, prosperity, and general welfare of the state and its citizens."[108] In addition, state officers, like those serving on the PSC, must swear and affirm that they "will support, protect, and defend the Constitution and Government of the United States and of the State of Florida" before commencing

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[104] *See* Fla. Stat. § 366.81 (2020) ("The Legislature further finds that the Florida Public Service Commission is the appropriate agency to adopt goals and approve plans related to the promotion of demand-side renewable energy systems and the conservation of electric energy and natural gas usage."); Fla. Stat. § 366.82(3) (2020) ("[T]he commission shall evaluate the full technical potential of all available demand-side and supply-side conservation and efficiency measures, including demand-side renewable energy systems."); Fla. Stat. § 366.82(12) (2020) ("[T]he commission shall have exclusive responsibility for preparing all reports, information, analyses, recommendations, and materials related to consumption, utilization, or conservation of electrical energy[.]"). *But see* Fla. Pub. Serv. Comm'n, *Notice of Development of Rulemaking and Workshop*, Doc. No. 13530-2020 (Dec. 15, 2020), 3 http://www.floridapsc.com/library/filings/2020/13530-2020/13530-2020.pdf (minimally establishing requirements for the PSC to set "kilowatt (KW) and kilowatt-hour (KWH) goals" as well as "goals based on an assessment of the technical potential of available measures[]").

[105] Fla. Stat. § 366.81 (2020).

[106] Inara Scott, *"Dancing Backward in High Heels": Examining and Addressing the Disparate Regulatory Treatment of Energy Efficiency and Renewable Resources*, 43 Envtl. L. 255, 265 (2013) ("The more rate base the utility accumulates, the more it can profit.[] . . . Given this rate-setting structure, it does not take an advanced degree in economics to understand that investor-owned utilities seek to maximize capital investment, cut operating expenses between rate cases, and sell as many units of energy as possible.").

[107] *Id.* at 277 ("Money spent on energy efficiency is generally treated as an annual expense item and is not added to the rate base.[] This presents an enormous challenge to the adoption of energy efficiency policies. As explained above, utility profits come primarily from returns on invested capital. The more investment the utility is able to include in its rate base, the higher its returns to investors.[] The utility has no opportunity to profit from expense items, unless it is minimizing those expenses between rate cases. Choosing to steer financial resources toward energy efficiency programs therefore presents a significant and daunting opportunity cost to utilities.[]").

[108] Fla. Stat. § 366.81 (2020).

the duties of their office.[109] In keeping with this declaration, the officers of the PSC cannot ignore their constitutional duty to not act in a way that infringes the rights of young people and future generations to life, liberty, and property unravaged by climate change through the implementation of its statutory mandates.

Substantial improvements in energy efficiency across the state are required to decarbonize Florida's energy system and ensure that Florida's youth and future generations are able to exercise their constitutionally protected rights to life, liberty, and property in Florida. Yet, the PSC irresponsibly and unconstitutionally delegates the important task of setting crucial energy efficiency targets to the utilities.[110] As an example of the dangers of this approach, despite the importance of energy efficiency practices, three electric utilities proposed zero (0) percent energy efficiency savings targets in 2019 for the 2020-2029 period.[111] Although the PSC rejected these proposals, it opted simply to maintain the energy efficiency savings goal that was already in place from the 2014 goal-setting proceeding, which is now seven years old.[112] "These low savings targets reflect [energy efficiency's] undervaluation and the resulting underperformance of Florida's programs compared to other states."[113] More importantly, these goals are insufficient to protect the health, prosperity, and general welfare of Florida's current and future youth, who are particularly vulnerable to climate change impacts[114] and whom the PSC is constitutionally constrained from affirmatively harming by and through their energy policies.[115]

The PSC Improperly Imports a "Reasonably Achievable" Standard into the Goal Setting Process

The PSC has administrative authority to "establish numerical goals for each affected electric utility[]" in order "to reduce the growth rates of weather-sensitive peak demand, to reduce and control the growth rates of electric consumption, and to increase the conservation of expensive resources, such as petroleum fuels."[116] The PSC's draft rule illegally limits the scope of the goals to only include measures that are "reasonably achievable" both within the existing administrative code[117] and the draft rule.[118] This "reasonably achievable" standard appears nowhere in the text of

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[109] Att'y Gen. Jim Smith, Advisory Legal Opinion AGO 85-94 (Nov. 18, 1985), https://www.myfloridalegal.com/ago.nsf/Opinions/6EBD175501A0800F8525657600566A86.

[110] *See supra* notes 95-107 and accompanying text.

[111] *Id.*

[112] *Id.*

[113] *Id.*

[114] *See supra* notes 11-35 and accompanying text.

[115] *See D.D. v. Dep't of Children & Families*, 849 So.2d 473, 476 (Fla. Dist. Ct. App. 2003) (state has compelling interest in protection of children and does not violate that test when it interferes with father's fundamental right to parent child through exercise of its authority under Chapter 39 of the Florida Statutes); *State v. J.P.*, 907 So. 2d 1101, 1107-08 (Fla. 2004) (applying strict scrutiny to claim involving alleged infringement of fundamental rights of children).

[116] Fla. Admin. Code R. 25-17.0021(1).

[117] Fla. Admin. Code R. 25-17.0021(1) ("The goals shall be based on an estimate of the total cost effective kilowatt and kilowatt-hour savings reasonably achievable through demand-side management in each utility's service area over a ten-year period.").

[118] Fla. Pub. Serv. Comm'n, *Notice of Development of Rulemaking and Workshop*, Doc. No. 13530-2020 (Dec. 15, 2020), 3 http://www.floridapsc.com/library/filings/2020/13530-2020/13530-2020.pdf ("The Commission will

FEECA.[119] By limiting the scope of its energy conservation and efficiency measures to only those that are "reasonably achievable," the PSC rewrites FEECA and thwarts the PSC's ability to promulgate energy efficiency goals that "protect the health, prosperity, and general welfare of the state and its citizens."[120]

Not only is the "reasonably achievable" standard that the PSC sets for itself not within the text of FEECA, it is also undefined and, thus, legally meaningless (compounding its fundamental illegality). The term "reasonable" itself is subjective and ripe for severe abuse. One could argue that no energy efficiency efforts are "reasonably achievable" (as several Florida utilities have tried to do in the past when they urged adoption of a zero-energy efficiency standard),[121] thus sidestepping the need to engage in such efforts entirely.

The State Must Align its FEECA Goals with Achieving the Federal Requirement of 100% Carbon Pollution-Free Electricity by 2035 (U.S. NDC, 2021).

The United States has entered into the United Nations Framework Convention on Climate Change treaty and its "related legal instrument[,]" the Paris Agreement, both of which share the objective to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system."[122] The U.S. government has adopted a Nationally Determined Contribution to this framework, establishing a target to obtain 100% of the country's electricity from sources that do not emit carbon-based pollution by 2035.[123]

These national commitments align with Florida's renewable energy policy:

> [i]t is the intent of the Legislature to promote the development of renewable energy; protect the economic viability of Florida's existing renewable energy facilities; diversify the types of fuel used to generate electricity in Florida; lessen Florida's dependence on natural gas and fuel oil for the production of electricity; . . . [and] improve environmental conditions[.][124]

Yet, despite these national and state-level objectives and mandates, the PSC's draft rule does nothing to encourage "the use of solar energy, renewable energy sources, highly efficient

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establish goals based on an assessment of the technical potential of available measures, and an estimate of the total cost-effective KW and KWH savings *reasonably achievable* through demand-side management programs in each utility's service area over a ten-year period.") (emphasis added); pp. 3-4 ("Such goal projections must be based upon the utility's most recent planning process, of the total, cost-effective, winter and summer peak demand (KW) and annual energy (KWH) savings *reasonably achievable* in the residential and commercial/industrial classes through the utility's proposed demand-side management programs.") (emphasis added).

[119] Fla. Stat. § 366.81 (2020).

[120] *Id.*

[121] *See* George Cavros, *Florida PSC Holds the Line on Energy Efficiency*, CleanEnergy.org (Nov. 7, 2019), https://cleanenergy.org/blog/florida-psc-holds-the-line-on-energy-efficiency/ (noting that regulated utilities subject to FEECA had proposed "energy savings goals of zero, or near zero.").

[122] United Nations Framework Convention on Climate Change art. 2, May 9, 1992, 1771 U.N.T.S. 107.

[123] U.S. Nationally Determined Contribution 2021 p. 3 (2021).

[124] Fla. Stat. § 366.92(1) (2020).

systems, cogeneration, and load-control systems" as intended by the legislature.[125] Without establishing concrete numeric goals, or an adequate process to identify what those numeric goals will be, the PSC will remain out of compliance with both the plain language of FEECA and stands in the way of the U.S. complying with its international commitment to achieve 100% carbon-free electricity by 2035.

The PSC Should Promote Key Energy Efficiency Measures

In setting the energy efficiency goals, the PSC should do everything in its power to facilitate the transition from AC units into heat pumps. This is one of, if not the, most critical energy efficiency programs for the state of Florida. "Much of Florida's heating is already electrified, and so a transition to heat pumps represents efficiency as opposed to the electrification found elsewhere in the country."[126] Energy experts have concluded that "[r]eplacing air conditioners or furnaces with heat pumps in existing buildings is also a priority, pushing a technology that has improved markedly in recent years to further maturation. In Florida, this will represent efficiency gains, as most current heating is performed with electric resistance heating."[127]

Conclusion

In conclusion, we ask that the PSC revise its draft rule by (1) considering all criteria required by FEECA in establishing energy efficiency goals and abandoning the reliance on the RIM test; (2) establishing steadily increasing annual energy savings goals in line with states that have documented success with respect to energy efficiency gains; (3) complying with FEECA-mandated timelines to establish energy efficiency goals; (4) establishing goals instead of improperly delegating authority to utilities to do so; (5) eliminating the use of a "reasonably achievable" standard that does not appear within FEECA; (6) aligning its energy efficiency goals with the national goal of 100% carbon-free electricity by 2035; and (7) using this rulemaking process to require the utilities to implement key energy efficiency measures.

Thank you for your consideration. We are happy to provide any of the cited evidence on request for the administrative record. Please send us a response to our comments and decision documents to the emails listed below.

Respectfully,

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[125] *Id.* § 366.81.

[126] 350 ppm Pathways, *supra* note 7, at 33.

[127] *Id.* at 65.

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Enc. Exhibits

Exhibit 1: Karina von Schuckmann et al., Heat Stored in the Earth System: Where Does the Energy Go? (2020).

Exhibit 2: Evolved Energy Research, 350 ppm Pathways for Florida (Oct. 6, 2020).

Exhibit 3: Mark Z. Jacobson, Zero Air Pollution and Zero Carbon From All Energy Without Blackouts at Low Cost in Florida (April 24, 2021).

Exhibit 4: Expert Report of Dr. Harold R. Wanless (filed in support of *Juliana v. United States* Plaintiffs' Opposition to Defendants' Motion for Summary Judgment) (Jun. 28, 2018).

Exhibit 5: United Nations Human Rights Office of the High Commissioner, Joint Statement on "Human Rights and Climate Change" (Sept. 16, 2019).

Exhibit 6: Dan York & Charlotte Cohn, Unrealized Potential: Expanding Energy Efficiency Opportunities for Utility Customers in Florida (Jan. 2021).

Exhibit 7: Weston Berg et al., The 2020 State Energy Efficiency Scorecard (Dec. 2020).

Exhibit 1

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Open Access Earth System Science Data

Heat stored in the Earth system: where does the energy go?

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Abstract. Human-induced atmospheric composition changes cause a radiative imbalance at the top of the atmosphere which is driving global warming. This Earth energy imbalance (EEI) is the most critical number defining the prospects for continued global warming and climate change. Understanding the heat gain of the Earth system – and particularly how much and where the heat is distributed – is fundamental to understanding how this affects warming ocean, atmosphere and land; rising surface temperature; sea level; and loss of grounded and floating ice, which are fundamental concerns for society. This study is a Global Climate Observing System (GCOS) concerted international effort to update the Earth heat inventory and presents an updated assessment of ocean warming estimates as well as new and updated estimates of heat gain in the atmosphere, cryosphere and land over the period 1960–2018. The study obtains a consistent long-term Earth system heat gain over the period 1971–2018, with a total heat gain of 358 ± 37 ZJ, which is equivalent to a global heating rate of $0.47 \pm 0.1\,\mathrm{W\,m^{-2}}$. Over the period 1971–2018 (2010–2018), the majority of heat gain is reported for the global ocean with 89 % (90 %), with 52 % for both periods in the upper 700 m depth, 28 % (30 %) for the 700–2000 m depth layer and 9 % (8 %) below 2000 m depth. Heat gain over land amounts to 6 % (5 %) over these periods, 4 % (3 %) is available for the melting of grounded and floating ice, and 1 % (2 %) is available for atmospheric warming. Our results also show that EEI is not only continuing, but also increasing: the EEI amounts to $0.87 \pm 0.12\,\mathrm{W\,m^{-2}}$ during 2010–2018. Stabilization of climate, the goal of the universally agreed United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the Paris Agreement in 2015, requires that EEI be reduced to approximately zero to achieve Earth's system quasi-equilibrium. The amount of CO_2 in the atmosphere would need to be reduced from 410 to 353 ppm to increase heat radiation to space by $0.87\,\mathrm{W\,m^{-2}}$, bringing Earth back towards energy balance. This simple number, EEI, is the most fundamental metric that the scientific community and public must be aware of as the measure of how well the world is doing in the task of bringing climate change under control, and we call for an implementation of the EEI into the global stocktake based on best available science. Continued quantification and reduced uncertainties in the Earth heat inventory can be best achieved through the maintenance of the current global climate observing system, its extension into areas of gaps in the sampling, and the establishment of an international framework for concerted multidisciplinary research of the Earth heat inventory as presented in this study. This Earth heat inventory is published at the German Climate Computing Centre (DKRZ, https://www.dkrz.de/, last access: 7 August 2020) under the DOI https://doi.org/10.26050/WDCC/GCOS_EHI_EXP_v2 (von Schuckmann et al., 2020).

1 Introduction

In the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC), article 7 demands that "Parties should strengthen [. . .] scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems, in a manner that informs climate services and supports decision-making". This request of the UNFCCC expresses the need of climate monitoring based on best available science, which is globally coordinated through the Global Climate Observing System (GCOS). In the current Implementation Plan of GCOS, main observation gaps are addressed and it states that "closing the Earth's energy balance [. . .] through observations remain outstanding scientific issues that require high-quality climate records of Essential Climate Variables (ECVs)." (GCOS, 2016). GCOS is asking the broader scientific community to establish the observational requirements needed to meet the targets defined in the GCOS Implementation Plan and to identify how climate observations could be enhanced and continued into the future in order to monitor the Earth's cycles and the global energy budget. This study addresses and intends to respond to this request.

The state, variability and change of Earth's climate are to a large extent driven by the energy transfer between the different components of the Earth system (Hansen, 2005; Hansen et al., 2011). Energy flows alter clouds, and weather and internal climate modes can temporarily alter the energy balance on subannual to multidecadal timescales (Palmer and McNeall, 2014; Rhein et al., 2013). The most practical way to monitor climate state, variability and change is to continually assess the energy, mainly in the form of heat, in the Earth system (Hansen et al., 2011). All energy entering or leaving the Earth climate system does so in the form of radiation at the top of the atmosphere (TOA) (Loeb et al., 2012). The difference between incoming solar radiation and outgoing radiation, which is the sum of the reflected shortwave radiation and emitted longwave radiation, determines the net radiative flux at TOA. Changes of this global radiation balance at TOA – the so-called Earth energy imbalance (EEI)

– determine the temporal evolution of Earth's climate: If the imbalance is positive (i.e., less energy going out than coming in), energy in the form of heat is accumulated in the Earth system, resulting in global warming – or cooling if the EEI is negative. The various facets and impacts of observed climate change arise due to the EEI, which thus represents a crucial measure of the rate of climate change (von Schuckmann et al., 2016). The EEI is the portion of the forcing that has not yet been responded to (Hansen, 2005). In other words, warming will continue even if atmospheric greenhouse gas (GHG) amounts are stabilized at today's level, and the EEI defines additional global warming that will occur without further change in forcing (Hansen et al., 2017). The EEI is less subject to decadal variations associated with internal climate variability than global surface temperature and therefore represents a robust measure of the rate of climate change (von Schuckmann et al., 2016; Cheng et al., 2017a).

The Earth system responds to an imposed radiative forcing through a number of feedbacks, which operate on various different timescales. Conceptually, the relationships between EEI, radiative forcing and surface temperature change can be expressed as (Gregory and Andrews, 2016)

$$\Delta N_{\mathrm{TOA}} = \Delta F_{\mathrm{ERF}} - |\alpha_{\mathrm{FP}}| \Delta T_{\mathrm{S}}, \qquad (1)$$

where ΔN_{TOA} is Earth's net energy imbalance at TOA (in $\mathrm{W\,m^{-2}}$), ΔF_{ERF} is the effective radiative forcing ($\mathrm{W\,m^{-2}}$), ΔT_{S} is the global surface temperature anomaly (K) relative to the equilibrium state and α_{FP} is the net total feedback parameter ($\mathrm{W\,m^{-2}\,K^{-1}}$), which represents the combined effect of the various climate feedbacks. Essentially, α_{FP} in Eq. (1) can be viewed as a measure of how efficient the system is at restoring radiative equilibrium for a unit surface temperature rise. Thus, ΔN_{TOA} represents the difference between the applied radiative forcing and Earth's radiative response through climate feedbacks associated with surface temperature rise (e.g., Hansen et al., 2011). Observation-based estimates of ΔN_{TOA} are therefore crucial both to our understanding of past climate change and for refining projections of future climate change (Gregory and Andrews, 2016; Kuhlbrodt and Gregory, 2012). The long atmospheric lifetime of carbon dioxide means that ΔN_{TOA}, ΔF_{ERF} and ΔT_{S} will remain positive for centuries, even with substantial reductions in greenhouse gas emissions, and lead to substantial committed sea-level rise (Cheng et al., 2019a; Hansen et al., 2017; Nauels et al., 2017; Palmer et al., 2018).

However, this conceptual picture is complicated by the presence of unforced internal variability in the climate system, which adds substantial noise to the real-world expression of this equation (Gregory et al., 2020; Marvel et al., 2018; Palmer and McNeall, 2014). For example, at timescales from interannual to decadal periods, the phase of the El Niño–Southern Oscillation contributes to both positive or negative variations in EEI (Cheng et al., 2019a; Loeb et al., 2018; Johnson and Birnbaum, 2017; Loeb et al., 2012). At multidecadal and longer timescales, systematic changes in ocean circulation can significantly alter the EEI as well (Baggenstos et al., 2019).

Timescales of the Earth climate response to perturbations of the equilibrium Earth energy balance at TOA are driven by a combination of climate forcing and the planet's thermal inertia: the Earth system tries to restore radiative equilibrium through increased thermal radiation to space via the Planck response, but a number of additional Earth system feedbacks also influence the planetary radiative response (Lembo et al., 2019; Myhre et al., 2013). Timescales of warming or cooling of the climate depend on the imposed radiative forcing, the evolution of climate and Earth system feedbacks, with ocean and cryosphere in particular leading to substantial thermal inertia (Clark et al., 2016; Marshall et al., 2015). Consequently, it requires centuries for Earth's surface temperature to respond fully to a climate forcing.

Contemporary estimates of the magnitude of the Earth's energy imbalance range between about 0.4 and $0.9\,\mathrm{W\,m^{-2}}$ (depending on estimate method and period; see also conclusion) and are directly attributable to increases in carbon dioxide and other greenhouse gases in the atmosphere from human activities (Ciais et al., 2013; Myhre et al., 2013; Rhein et al., 2013; Hansen et al., 2011). The estimate obtained from climate models (CMIP6) as presented by Wild (2020) amounts to $1.1 \pm 0.8\,\mathrm{W\,m^{-2}}$. Since the period of industrialization, the EEI has become increasingly dominated by the emissions of radiatively active greenhouse gases, which perturb the planetary radiation budget and result in a positive EEI. As a consequence, excess heat is accumulated in the Earth system, which is driving global warming (Hansen et al., 2005, 2011). The majority (about 90 %) of this positive EEI is stored in the ocean (Rhein et al., 2013) and can be estimated through the evaluation of ocean heat content (OHC, e.g., Abraham et al., 2013). According to previous estimates, a small proportion ($\sim 3\,\%$) contributes to the melting of Arctic sea ice and land ice (glaciers, the Greenland and Antarctic ice sheets). Another 4 % goes into heating of the land and atmosphere (Rhein et al., 2013).

Knowing where and how much heat is stored in the different Earth system components from a positive EEI, and quantifying the Earth heat inventory, is of fundamental importance to unravel the current status of climate change, as well as to better understand and predict its implications, and to design the optimal observing networks for monitoring the Earth heat inventory. Quantifying this energy gain is essential for understanding the response of the climate system to radiative forcing and hence to reduce uncertainties in climate predictions. The rate of ocean heat gain is a key component for the quantification of the EEI, and the observed surface warming has been used to estimate the equilibrium climate sensitivity (e.g., Knutti and Rugenstein, 2015). However, further insight into the Earth heat inventory, particularly to further unravel where the heat is going, can have implications on the understanding of the transient climate responses to climate change and consequently reduces uncertainties in climate predictions (Hansen et al., 2011). In this paper, we focus on the inventory of heat stored in the Earth system. The first four sections will introduce the current status of estimate of heat storage change in the ocean, atmosphere, land and cryosphere, respectively. Uncertainties, current achieved accuracy, challenges and recommendations for future improved estimates are discussed for each Earth system component and in the conclusion. In the last chapter, an update of the Earth heat inventory is established based on the results of Sects. 1–4, followed by a conclusion.

2 Heat stored in the ocean

The storage of heat in the ocean leads to ocean warming (IPCC, 2020) and is a major contributor to sea-level rise through thermal expansion (WCRP, 2018). Ocean warming alters ocean stratification and ocean mixing processes (Bindoff et al., 2020), affects ocean currents (Hoegh-Guldberg, 2020; Rhein et al., 2018; Yang et al., 2016), impacts tropical cyclones (Hoegh-Guldberg, 2020; Trenberth et al., 2018; Woollings et al., 2012), and is a major player in ocean deoxygenation processes (Breitburg et al., 2018) and carbon sequestration into the ocean (Bopp et al., 2013; Frölicher et al., 2018). Together with ocean acidification and deoxygenation, ocean warming can lead to dramatic changes in ecosystems, biodiversity, population extinctions, coral bleaching and infectious disease, as well as redistribution of habitat (García Molinos et al., 2016; Gattuso et al., 2015; Ramírez et al., 2017). Implications of ocean warming are also widespread across Earth's cryosphere (Jacobs et al., 2002; Mayer et al., 2019; Polyakov et al., 2017; Serreze and Barry, 2011; Shi et al., 2018). Examples include the basal melt of ice shelves (Adusumilli et al., 2020; Pritchard et al., 2012; Wilson et al., 2017) and marine-terminating glaciers (Straneo and Cenedese, 2015), as well as the retreat and speedup of outlet glaciers in Greenland (King et al., 2018) and in Antarctica (Shepherd et al., 2018a) and of tidewater glaciers in South America and in the High Arctic (Gardner et al., 2013).

Opportunities and challenges in forming OHC estimates depend on the availability of in situ subsurface temperature measurements, particularly for global-scale evaluations. Subsurface ocean temperature measurements before 1900 had been obtained from shipboard instrumentation, culminating in the global-scale Challenger expedition (1873–1876) (Roemmich and Gilson, 2009). From 1900 up to the mid-1960s, subsurface temperature measurements relied on shipboard Nansen bottle and mechanical bathythermograph (MBT) instruments (Abraham et al., 2013), only allowing limited global coverage and data quality. The inventions of the conductivity–temperature–depth (CTD) instruments in the mid-1950s and the expendable bathythermograph (XBT) observing system about 10 years later increased the oceanographic capabilities for widespread and accurate (in the case of the CTD) measurements of in situ subsurface water temperature (Abraham et al., 2013; Goni et al., 2019).

With the implementation of several national and international programs, and the implementation of the moored arrays in the tropical ocean in the 1980s, the Global Ocean Observing System (GOOS, https://www.goosocean.org/, last access: 7 August 2020) started to grow. Particularly the global World Ocean Circulation Experiment (WOCE) during the 1990s obtained a global baseline survey of the ocean from top to bottom (King et al., 2001). However, measurements were still limited to fixed point platforms, major shipping routes, and naval and research vessel cruise tracks, leaving large parts of the ocean undersampled. In addition, detected instrumental biases in MBTs, XBTs and other instruments pose a further challenge for the global scale OHC estimate (Abraham et al., 2013; Ciais et al., 2013; Rhein et al., 2013), but significant progress has been made recently to correct biases and provide high-quality data for climate research (Boyer et al., 2016; Cheng et al., 2016; Goni et al., 2019; Gouretski and Cheng, 2020). Satellite altimeter measurements of sea surface height began in 1992 and are used to complement in situ-derived OHC estimates, either for validation purposes (Cabanes et al., 2013) or to complement the development of global gridded ocean temperature fields (Guinehut et al., 2012; Willis et al., 2004). Indirect estimates of OHC from remote sensing through the global sea-level budget became possible with satellite-derived ocean mass information in 2002 (Dieng et al., 2017; Llovel et al., 2014; Loeb et al., 2012; Meyssignac et al., 2019; von Schuckmann et al., 2014).

After the OceanObs conference in 1999, the international Argo profiling float program was launched with first Argo float deployments in the same year (Riser et al., 2016; Roemmich and Gilson, 2009). By the end of 2006, Argo sampling had reached its initial target of data sampling roughly every 3° between 60° S and 60° N. However, due to technical evolution, only 40 % of Argo floats provided measurements down to 2000 m depth in the year 2005, but that percentage increased to 60 % in 2010 (von Schuckmann and Le Traon, 2011). The starting point of the Argo-based best estimate for near-global-scale (60° S–60° N) OHC is either defined in 2005 (von Schuckmann and Le Traon, 2011) or in 2006 (Wijffels et al., 2016). The opportunity for improved OHC estimation provided by Argo is tremendous and has led to major advancements in climate science, particularly on the discussion of the EEI (Hansen et al., 2011; Johnson et al., 2018; Loeb et al., 2012; Trenberth and Fasullo, 2010; von Schuckmann et al., 2016; Meyssignac et al., 2019). The near-global coverage of the Argo network also provides an excellent test bed for the long-term OHC reconstruction extending back well before the Argo period (Cheng et al., 2017b). Moreover, these evaluations inform further observing system recommendations for global climate studies, i.e., gaps in the deep ocean layers below 2000 m depth, in marginal seas, in shelf areas and in the polar regions (e.g., von Schuckmann et al., 2016), and their implementations are underway, for example for deep Argo (Johnson et al., 2019).

Different research groups have developed gridded products of subsurface temperature fields for the global ocean using statistical models (Gaillard et al., 2016; Good et al., 2013; Ishii et al., 2017; Levitus et al., 2012) or combined observations with additional statistics from climate models (Cheng et al., 2017b). An exhaustive list of the pre-Argo products can be found in, for example, Abraham et al. (2013), Boyer et al. (2016), WCRP (2018) and Meyssignac et al. (2019). Additionally, specific Argo-based products are listed on the Argo web page (http://www.argo.ucsd.edu/, last access: 7 August 2020). Although all products rely more or less on the same database, near-global OHC estimates show some discrepancies which result from the different statistical treatments of data gaps, the choice of the climatology, and the approach used to account for the MBT and XBT instrumental biases (Boyer et al., 2016; Wang et al., 2018). Argo-based products show smaller differences, likely resulting from different treatments of currently undersampled regions (e.g., von Schuckmann et al., 2016). Ocean reanalysis systems have been also used to deliver estimates of near-global OHC (Meyssignac et al., 2019; von Schuckmann et al., 2018), and their international assessments show increased discrepancies with decreasing in situ data availability for the assimilation (Palmer et al., 2017; Storto et al., 2018). Climate models have also been used to study global and regional ocean heat changes and the associated mechanisms, with observational datasets providing valuable benchmarks for model evaluation (Cheng et al., 2016; Gleckler et al., 2016).

International near-global OHC assessments have been performed previously (e.g., Abraham et al., 2013; Boyer et al., 2016; Meyssignac et al., 2019; WCRP, 2018). These assessments are challenging, as most of the gridded temperature fields are research products, and only few are distributed and regularly updated operationally (e.g., https://marine.copernicus.eu/, last access: 7 August 2020). This initiative relies on the availability of data products, their temporal extensions and direct interactions with the different research groups. A complete view of all international temperature products can be only achieved through a concerted international effort and over time. In this study, we do not achieve a holistic view of all available products but present a starting point for future international regular assessments of near-global OHC. For the first time, we propose an international ensemble mean and standard deviation of near-global OHC (Fig. 1) which is then used to build an Earth climate system energy inventory (Sect. 5). The ensemble spread gives an indication of the agreement among products and can be used as a proxy for uncertainty. The basic assumption for the error distribution is Gaussian with a mean of zero, which can be approximated by an ensemble of various products. However, it does not account for systematic errors that may result in biases across the ensemble and does not represent the full uncertainty. The uncertainty can also be estimated in other ways including some purely statistical methods (Levitus et al., 2012) or methods explicitly accounting for the error sources (Lyman and Johnson, 2013), but each method has its caveats, for example the error covariances are mostly unknown, so adopting a straightforward method with a "data democracy" strategy has been chosen here as a starting point.

Table 1. Linear trends (weighted least square fit; see for example von Schuckmann and Le Traon, 2011) as derived from the ensemble mean as presented in Fig. 1 for different time intervals, as well as different integration depth. The uncertainty on the trend estimate is given for the 95 % confidence level. Note that values are given for the ocean surface area between 60° S and 60° N and are limited to the 300 m bathymetry of each product. See text and Fig. 1 caption for more details on the OHC estimates.

Period	0–300 m ($\mathrm{W\,m^{-2}}$)	0–700 m ($\mathrm{W\,m^{-2}}$)	0–2000 m ($\mathrm{W\,m^{-2}}$)	700–2000 m ($\mathrm{W\,m^{-2}}$)
1960–2018	0.3 ± 0.03	0.4 ± 0.1	0.5 ± 0.1	0.2 ± 0.03
1993–2018	0.4 ± 0.04	0.6 ± 0.1	0.9 ± 0.1	0.3 ± 0.03
2005–2018	0.4 ± 0.1	0.6 ± 0.1	1.0 ± 0.2	0.4 ± 0.1
2010–2018	0.5 ± 0.1	0.7 ± 0.1	1.3 ± 0.3	0.5 ± 0.1

However, future evolution of this initiative is needed to include missing and updated in situ-based products, ocean reanalyses and indirect estimates (for example satellite based). The continuity of this activity will help to further unravel uncertainties due to the community's collective efforts on detecting/reducing errors, and it then provides up-to-date scientific knowledge of ocean heat uptake.

Products used for this assessment are referenced in the caption of Fig. 2. Estimates of OHC have been provided by the different research groups under homogeneous criteria. All estimates use a coherent ocean volume limited by the 300 m isobath of each product and are limited to 60° S–60° N since most observational products exclude high-latitude ocean areas because of the low observational coverage, and only annual averages have been used. 60° S–60° N constitutes $\sim 91\,\%$ of the global ocean surface area, and limiting to 300 m isobath neglects the contributions from coastal and shallow waters, so the resultant OHC trends will be underestimated if these ocean regions are warming. For example, neglecting shallow waters can account for 5 %–10 % for 0–2000 m OHC trends (von Schuckmann et al., 2014). A first initial test using Cheng et al. (2017b) data indicates that OHC 0–2000 m trends can be underestimated by $\sim 10\,\%$ if the ocean warming in the area polewards of 60° latitude is not taken into account (not shown). This is a caveat of the assessment in this review and will be addressed in the future.

The assessment is based on three distinct periods to account for the evolution of the observing system, i.e., 1960–2018 (i.e., "historical"), 1993–2018 (i.e., "altimeter era") and 2005–2018 (i.e., "golden Argo era"). In addition, ocean warming rates over the past decade are specifically discussed according to an apparent acceleration of global sur-

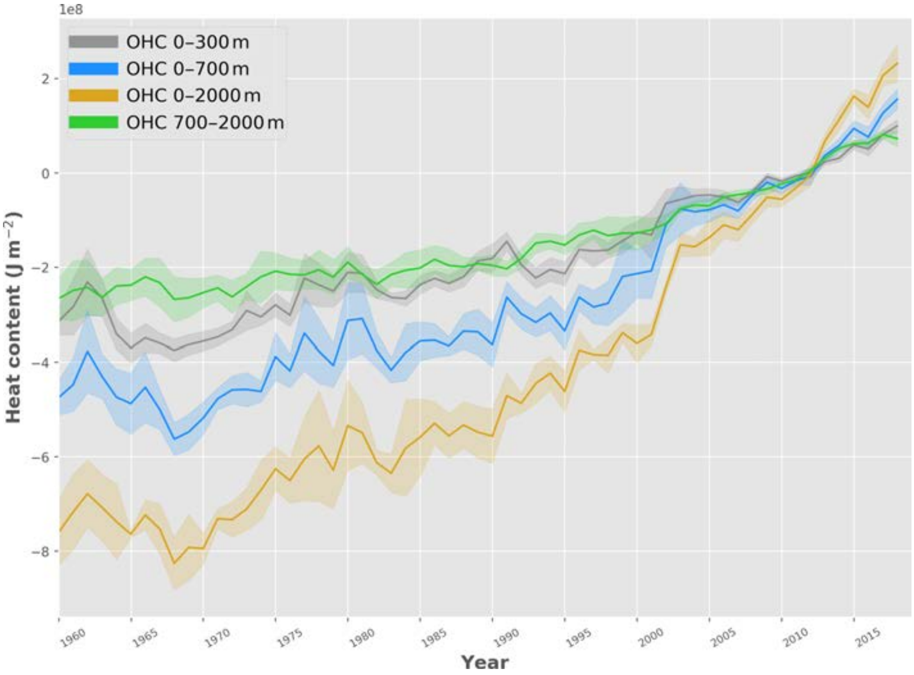

Figure 1. Ensemble mean time series and ensemble standard deviation (2σ, shaded) of global ocean heat content (OHC) anomalies relative to the 2005–2017 climatology for the 0–300 m (gray), 0–700 m (blue), 0–2000 m (yellow) and 700–2000 m depth layer (green). The ensemble mean is an outcome of an international assessment initiative, and all products used are referenced in the legend of Fig. 2. The trends derived from the time series are given in Table 1. Note that values are given for the ocean surface area between 60° S and 60° N and are limited to the 300 m bathymetry of each product.

face warming since 2010 (WMO, 2020; Blunden and Arndt, 2019). All time series reach the end in 2018 – which was one of the principal limitations for the inclusion of some products. Our final estimates of OHC for the upper 2000 m over different periods are the ensemble average of all products, with the uncertainty range defined by the standard deviation (2σ) of the corresponding estimates used (Fig. 1).

The first and principal result of the assessment (Fig. 1) is an overall increase in the trend for the two more recent study periods, e.g., the altimeter era (1993–2018) and golden Argo era (2005–2018), relative to the historical era (1960–2018), which is in agreement with previous results (e.g., Abraham et al., 2013). The trend values are all given in Table 1. A major part of heat is stored in the upper layers of the ocean (0–300 m and 0–700 m depth). However, heat storage at intermediate depth (700–2000 m) increases at a comparable rate as reported for the 0–300 m depth layer (Table 1, Fig. 2). There is a general agreement among the 15 international OHC estimates (Fig. 2). However, for some periods and depth layers the standard deviation reaches maximal values up to about 0.3 W m^{-2}. All products agree on the fact that ocean warming rates have increased in the past decades and doubled since the beginning of the altimeter era (1993–2018 compared with 1960–2018) (Fig. 2). Moreover, there is a clear indication that heat sequestration into the deeper ocean layers below 700 m depth took place over the past 6 decades linked to an increase in OHC trends over time (Fig. 2). In agreement with observed accelerated Earth surface warming over the past decade (WMO, 2020; Blunden and Arndt, 2019), ocean warming rates for the 0–2000 m depth layer also reached record rates of 1.3 (0.9) $\pm$ 0.3 W m^{-2} for the ocean (global) area over the period 2010–2018.

For the deep OHC changes below 2000 m, we adapted an updated estimate from Purkey and Johnson (2010) (PG10) from 1991 to 2018, which is a constant linear trend estimate (1.15 ± 0.57 ZJ yr^{-1}, 0.07 ± 0.04 W m^{-2}). Some recent studies strengthened the results in PG10 (Desbruyères et al., 2016; Zanna et al., 2019). Desbruyères et al. (2016) examined the decadal change of the deep and abyssal OHC trends below 2000 m in the 1990s and 2000s, suggesting that there has not been a significant change in the rate of decadal global deep/abyssal warming from the 1990s to the 2000s and the overall deep ocean warming rate is consistent with PG10. Using a Green function method, Zanna et al. (2019) reported a deep ocean warming rate of ~ 0.06 W m^{-2} during the 2000s, consistent with PG10 used in this study. Zanna et al. (2019) shows a fairly weak global trend during the 1990s, inconsistent with observation-based estimates. This mismatch might come from the simplified or misrepresentation of surface-deep connections using ECCO reanalysis data and the use of time-mean Green functions in Zanna et al. (2019), as well as from the limited spatial resolution of the observational net-

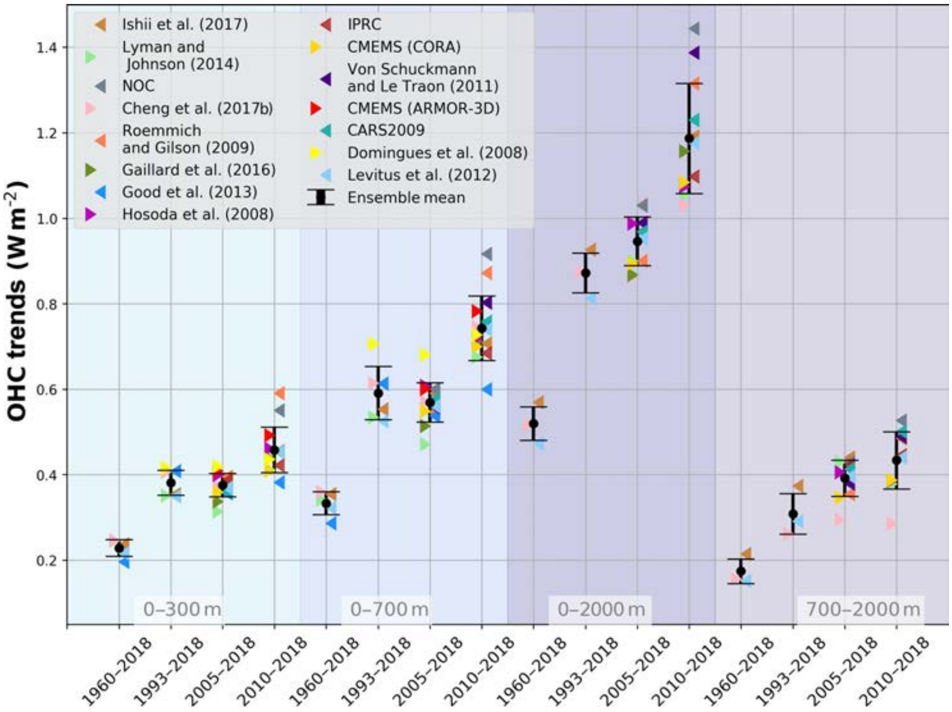

Figure 2. Linear trends of global ocean heat content (OHC) as derived from different temperature products (colors). References are given in the figure legend, except for IPRC (http://apdrc.soest.hawaii.edu/projects/Argo/, last access: 7 August 2020), CMEMS (CORA and ARMOR-3D, http://marine.copernicus.eu/science-learning/ocean-monitoring-indicators, last access: 7 August 2020), CARS2009 (http://www.marine.csiro.au/~dunn/cars2009/, last access: 7 August 2020) and NOC (National Oceanographic Institution, Desbruyères et al., 2016). The ensemble mean and standard deviation (2σ) are given in black. The shaded areas show trends from different depth layer integrations, i.e., 0–300 m (light turquoise), 0–700 m (light blue), 0–2000 m (purple) and 700–2000 m (light purple). For each integration depth layer, trends are evaluated over the three study periods, i.e., historical (1960–2018), altimeter era (1993–2018) and golden Argo era (2005–2018). In addition, the most recent period 2010–2018 is included. See text for more details on the international assessment criteria. Note that values are given for the ocean surface area (see text for more details).

work for relatively short time spans. Furthermore, combining hydrographic and deep-Argo floats, a recent study (Johnson et al., 2019) reported an accelerated warming in the South Pacific Ocean in recent years, but a global estimate of the OHC rate of change over time is not available yet.

Before 1990, we assume zero OHC trend below 2000 m, following the methodology in IPCC-AR5 (Rhein et al., 2013). The zero-trend assumption is made mainly because there are too few observations before 1990 to make an estimate of OHC change below 2000 m. But it is a reasonable assumption because OHC 700–2000 m warming was fairly weak before 1990 and heat might not have penetrated down to 2000 m (Cheng et al., 2017b). Zanna et al. (2019) also shows a near-zero OHC trend below 2000 m from the 1960s to 1980s. The derived time series is used for the Earth energy inventory in Sect. 5. A centralized (around the year 2006) uncertainty approach has been applied for the deep (> 2000 m depth) OHC estimate following the method of Cheng et al. (2017b), which allows us to extract an uncertainty range over the period 1993–2018 within the given [lower ($1.15-0.57\,\mathrm{ZJ\,yr^{-1}}$), upper ($1.15+0.57\,\mathrm{ZJ\,yr^{-1}}$)] range of the deep OHC trend estimate. We then extend the obtained uncertainty estimate back from 1993 to 1960, with 0 OHC anomaly.

3 Heat available to warm the atmosphere

While the amount of heat accumulated in the atmosphere is small compared to the ocean, warming of the Earth's near-surface air and atmosphere aloft is a very prominent effect of climate change, which directly affects society. Atmospheric observations clearly reveal a warming of the troposphere over the last decades (Santer et al., 2017; Steiner et al., 2020) and changes in the seasonal cycle (Santer et al., 2018). Changes in atmospheric circulation (Cohen et al., 2014; Fu et al., 2019) together with thermodynamic changes (Fischer and Knutti, 2016; Trenberth et al., 2015) will lead to more extreme weather events and increase high-impact risks for society (Coumou et al., 2018; Zscheischler et al., 2018). Therefore, a rigorous assessment of the atmospheric heat content in context with all Earth's climate subsystems is important for a full view on the changing climate system.

The atmosphere transports vast amounts of energy laterally and strong vertical heat fluxes occur at the atmosphere's lower boundary. The pronounced energy and mass exchanges within the atmosphere and with all other climate components is a fundamental element of Earth's climate (Peixoto and Oort, 1992). In contrast, long-term heat accumulation in the atmosphere is limited by its small heat capacity as the gaseous component of the Earth system (von Schuckmann et al., 2016).

Recent work revealed inconsistencies in earlier formulations of the atmospheric energy budget (Mayer et al., 2017; Trenberth and Fasullo, 2018), and hence a short discussion of the updated formulation is provided here. In a globally averaged and vertically integrated sense, heat accumulation in the atmosphere arises from a small imbalance between net energy fluxes at the top of the atmosphere (TOA) and the surface (denoted s). The heat budget of the vertically integrated and globally averaged atmosphere (indicated by the global averaging operator $\langle . \rangle$) reads as follows (Mayer et al., 2017):

$$\left\langle \frac{\partial \mathrm{AE}}{\partial t} \right\rangle = \langle N_{\mathrm{TOA}} \rangle - \langle F_{\mathrm{s}} \rangle - \langle F_{\mathrm{snow}} \rangle - \langle F_{\mathrm{PE}} \rangle, \tag{2}$$

where, in mean-sea-level altitude (z) coordinates used here for integrating over observational data, the vertically integrated atmospheric energy content AE per unit surface area [$\mathrm{J\,m^{-2}}$] reads

$$\mathrm{AE} = \int_{z_{\mathrm{s}}}^{z_{\mathrm{TOA}}} \rho \left(c_{\mathrm{v}} T + g \left(z - z_{\mathrm{s}} \right) + L_{\mathrm{e}} q + \frac{1}{2} V^2 \right) \mathrm{d}z. \tag{3}$$

In Eq. (2), AE represents the total atmospheric energy content, N_{TOA} the net radiation at TOA, F_{s} the net surface energy flux defined as the sum of net surface radiation and latent and sensible heat flux, and F_{snow} the latent heat flux associated with snowfall (computed as the product of latent heat of fusion and snowfall rate). Here, we take constant latent heat of vaporization (at 0 °C) in the latent heat flux term that is contained in F_{s}, but variations in latent heat flux arising from the deviation of evaporated water from 0 °C are contained in F_{PE}, which additionally accounts for sensible heat of precipitation (referenced to 0 °C). That is, F_{PE} expresses a modification of F_{s} arising from global evaporation and precipitation occurring at temperatures different from 0 °C.

Snowfall is the fraction of precipitation that returns originally evaporated water to the surface in a frozen state. In that sense, F_{snow} represents a heat transfer from the surface to the atmosphere: it warms the atmosphere through additional latent heat release (associated with freezing of vapor) and snowfall consequently arrives at the surface in an energetic state lowered by this latent heat. This energetic effect is most obvious over the open ocean, where falling snow requires the same amount of latent heat to be melted again and thus cools the ocean. Over high latitudes, F_{snow} can attain values up to $5\,\mathrm{W\,m^{-2}}$, but its global average value is smaller than $1\,\mathrm{W\,m^{-2}}$ (Mayer et al., 2017). Although its global mean energetic effect is relatively small, it is systematic and should be included for accurate diagnostics. Moreover, snowfall is an important contributor to the heat and mass budget of ice sheets and sea ice (see Sect. 4).

F_{PE} represents the net heat flux arising from the different temperatures of rain and evaporated water. This flux can be sizable regionally, but it is small in a global average sense (warming of the atmosphere $\sim 0.3\,\mathrm{W\,m^{-2}}$ according to Mayer et al., 2017).

Equation (3) provides a decomposition of the atmospheric energy content AE into sensible heat energy (sum of the first two terms, internal heat energy and gravity potential energy), latent heat energy (third term) and kinetic energy (fourth term), where ρ is the air density, c_{v} the specific heat for moist air at constant volume, T the air temperature, g the acceleration of gravity, L_{e} the temperature-dependent effective latent heat of condensation (and vaporization) L_{v} or sublimation L_{s} (the latter relevant below 0 °C), q the specific humidity of the moist air, and V the wind speed. We neglect atmospheric liquid water droplets and ice particles as separate species, as their amounts and especially their trends are small.

In the AE derivation from observational datasets based on Eq. (3), we accounted for the intrinsic temperature dependence of the latent heat of water vapor by assigning L_{e} to L_{v} if ambient temperatures are above 0 °C and to L_{s} (adding in the latent heat of fusion L_{f}) if they are below −10 °C, respectively, with a gradual (half-sine weighted) transition over the temperature range between. The reanalysis evaluations similarly approximated L_{e} by using values of L_{v}, L_{s}, and L_{f}, though in slightly differing forms. The resulting differences in AE anomalies from any of these choices are negligibly small, however, since the latent heat contribution at low temperatures is itself very small.

As another small difference, the AE estimations from observations neglected the kinetic energy term in Eq. (3) (fourth term), while the reanalysis evaluations accounted for it. This as well leads to negligible AE anomaly differences, however, since the kinetic energy content and trends at a global scale are more than three orders of magnitude smaller than for the sensible heat (Peixoto and Oort, 1992). Aligning with the terminology of ocean heat content (OHC) and given the dominance of the heat-related terms in Eq. (3), we hence refer to the energy content AE as atmospheric heat content (AHC) hereafter.

Turning to the actual datasets used, atmospheric energy accumulation can be quantified using various data types, as summarized in the following. Atmospheric reanalyses combine observational information from various sources (radiosondes, satellites, weather stations, etc.) and a dynamical model in a statistically optimal way. This data type has reached a high level of maturity, thanks to continuous development work since the early 1990s (Hersbach et al., 2018). Especially reanalyzed atmospheric state quantities like temperature, winds and moisture are considered to be of high quality and suitable for climate studies, although temporal discontinuities introduced from the ever-changing observation system remain a matter of concern (Berrisford et al., 2011; Chiodo and Haimberger, 2010).

Here we use the current generation of atmospheric reanalyses as represented by ECMWF's fifth-generation reanalysis ERA5 (Hersbach et al., 2018, 2020), NASA's Modern-Era Retrospective analysis for Research and Applications version 2 (MERRA2) (Gelaro et al., 2017) and JMA's 55-year-long reanalysis JRA-55 (Kobayashi et al., 2015). All these are available over 1980 to 2018 (ERA5 also in 1979), while JRA-55 is the only one covering the full early timeframe 1960 to 1979. We additionally used a different version of JRA-55 that assimilates only conventional observations also over the satellite era from 1979 onwards, which away from the surface only leaves radiosondes as data source and which is available to 2012 (JRA-55C). The advantage of this product is that it avoids potential spurious jumps associated with satellite changes. Moreover, JRA-55C is fully independent of satellite-derived Global Positioning System (GPS) radio occultation (RO) data that are also separately used and described below together with the observational techniques.

In addition to these four reanalyses, the datasets from three different observation techniques have been used for complementary observational estimates of the atmospheric heat content. We use the Wegener Center (WEGC) multisatellite RO data record, WEGC OPSv5.6 (Angerer et al., 2017), as well as its radiosonde (RS) data record derived from the high-quality Vaisala sondes RS80/RS92/VS41, WEGC Vaisala (Ladstädter et al., 2015). WEGC OPSv5.6 and WEGC Vaisala provide thermodynamic upper air profiles of air temperature, specific humidity and density from which we locally estimate the vertical AHC based on the first three integral terms of Eq. (3) (Kirchengast et al., 2019). In atmospheric domains not fully covered by the data (e.g., in the lower part of the boundary layer for RO or over the polar latitudes for RS), the profiles are vertically completed by collocated ERA5 information. The local vertical AHC results are then averaged into regional monthly means, which are finally geographically aggregated to global AHC. Applying this estimation approach in the same way to reanalysis profiles subsampled at the observation locations accurately leads to the same AHC anomaly time series records as the direct estimation from the full gridded fields.

The third observation-based AHC dataset derives from a rather approximate estimation approach using the microwave sounding unit (MSU) data records (Mears and Wentz, 2017). Because the very coarse vertical resolution of the brightness temperature measurements from MSU does not enable integration according to Eq. (3), this dataset is derived by replicating the method used in IPCC AR5 WGI Assessment Report 2013 (Rhein et al., 2013; chap. 3, Box 3.1 therein). We used the most recent MSU Remote Sensing System (RSS) V4.0 temperature dataset (Mears and Wentz, 2017), however, instead of MSU RSS V3.3 (Mears and Wentz, 2009a, b) that was used in the IPCC AR5. In order to derive global time series of AHC anomalies, the approach simply combines weighted MSU lower tropospheric temperature and lower stratospheric temperature changes (TLT and TLS channels) converted to sensible heat content changes via global atmospheric mass, as well as an assumed fractional increase in latent heat content according to water vapor content increase driven by temperature at a near-Clausius–Clapeyron rate ($7.5\,\%\,^{\circ}\mathrm{C}^{-1}$).

Figure 3 shows the resulting global AHC change inventory over 1980 to 2018 in terms of AHC anomalies of all data types (top), mean anomalies and time-average uncertainty estimates including long-term AHC trend estimates (middle), and annual-mean AHC tendency estimates (bottom). The mean anomaly time series (middle left), preceded by the small JRA-55 anomalies over 1960–1979, is used as part of the overall heat inventory in Sect. 5 below. Results including MSU in addition are separately shown (right column), since this dataset derives from a fairly approximate estimation as summarized above and hence is given lower confidence than the others deriving from rigorous AHC integration and aggregation. Since MSU data were the only data for AHC change estimation in the IPCC AR5 report, bringing it into context is considered relevant, however.

The results clearly show that the AHC trends have intensified from the earlier decades represented by the 1980–2010 trends of near 1.8 TW (consistent with the trend interval used in the IPCC AR5 report). We find the trends about 2.5 times higher over 1993–2018 (about 4.5 TW) and about 3 times higher in the most recent 2 decades over 2002–2018 (near 5.3 TW), a period that is already fully covered also by the RO and RS records (which estimate around 6 TW). Checking the sensitivity of these long-term trend estimates to El Niño–Southern Oscillation (ENSO) interannual variations, by comparing to trends fitted to ENSO-corrected AHC anomalies (with ENSO regressed out via the Nino 3.4 index), confirms that the estimates are robust (trends consistent within about 10 %, slightly higher with ENSO correction).

The year-to-year annual-mean tendencies in AHC, reaching amplitudes as high as 50 to 100 TW (or 0.1 to $0.2\,\mathrm{W\,m^{-2}}$, if normalized to the global surface area), indicate the strong coupling of the atmosphere with the uppermost ocean. This is mainly caused by the ENSO interannual variations that lead to net energy changes in the climate system including the atmosphere (Loeb et al., 2012; Mayer et al., 2013) and substantial reshuffling of heat energy between the atmosphere and the upper ocean (Cheng et al., 2019b; Johnson and Birnbaum, 2017; Mayer et al., 2014, 2016).

4 Heat available to warm land

Although the land component of the Earth's energy budget accounts for a small proportion of heat in comparison with the ocean, several land-based processes sensitive to the mag-

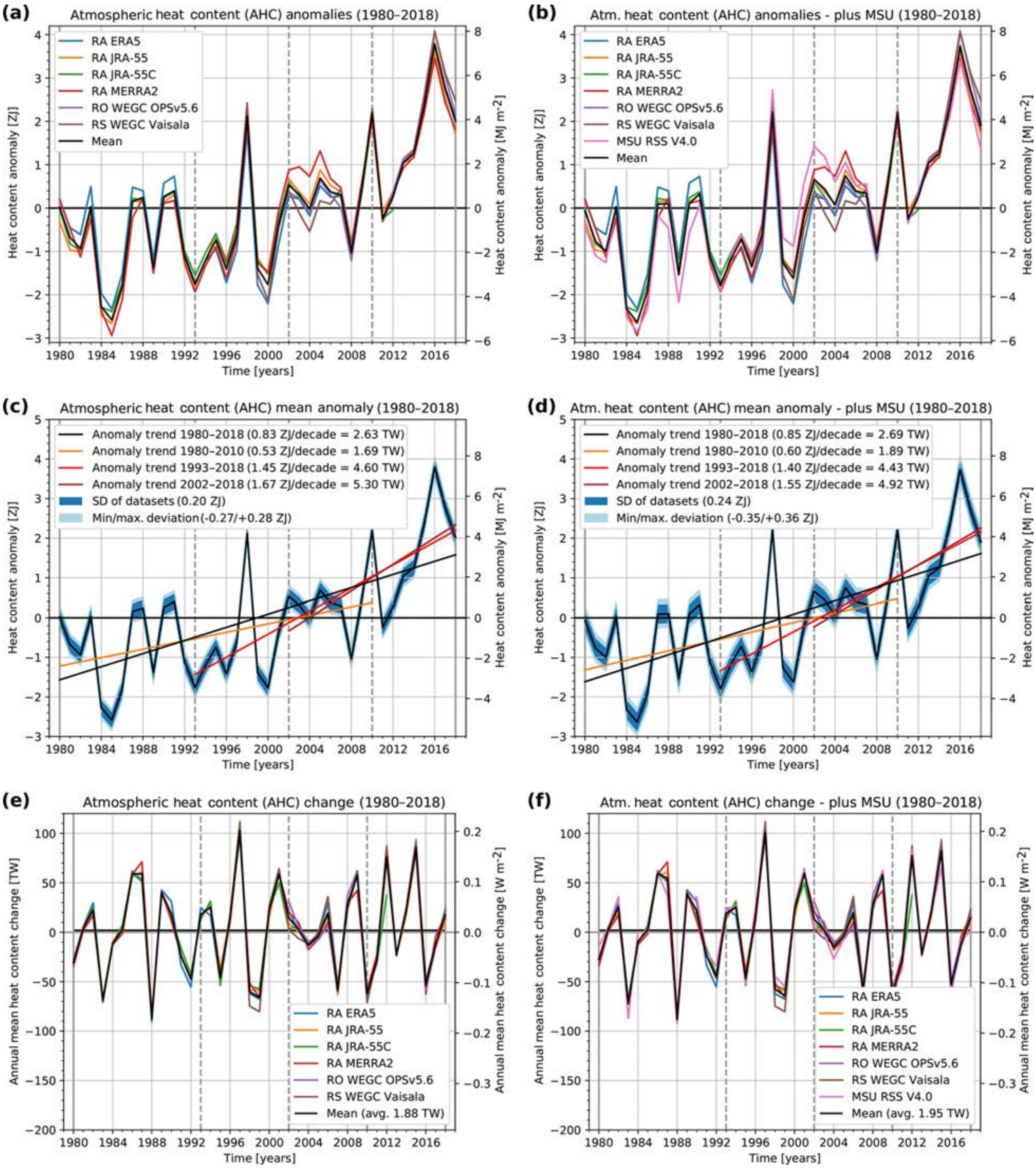

Figure 3. Annual-mean global AHC anomalies over 1980 to 2018 of four different reanalyses and two **(a, c, e)** or three (**b, d, f**, plus MSU) different observational datasets shown together with their mean **(a, b)**, the mean AHC anomaly shown together with four representative AHC trends and ensemble spread measures of its underlying datasets **(c, d)**, and the annual-mean AHC change (annual tendency) shown for each year over 1980 to 2018 for all datasets and their mean **(e, f)**. The in-panel legends identify the individual datasets shown (**a, b** and **e, f**) and the chosen trend periods together with the associated trend values and spread measures **(c, d)**, with the latter including the time-average standard deviation and minimum/maximum deviations of the individual datasets from the mean.

nitude of the available land heat play a crucial role in the future evolution of climate. Among others, the stability and extent of the continental areas occupied by permafrost soils depend on the land component. Alterations of the thermal conditions at these locations have the potential to release long-term stored CO_2 and CH_4 and may also destabilize the recalcitrant soil carbon (Bailey et al., 2019; Hicks Pries et al., 2017). Both of these processes are potential tipping points (Lenton et al., 2008, 2019; Lenton, 2011) leading to possible positive feedback on the climate system (Leifeld et al., 2019; MacDougall et al., 2012). Increased land energy is related to decreases in soil moisture that may enhance the occurrence of extreme temperature events (Jeong et al., 2016; Seneviratne et al., 2006, 2014, 2010; Xu et al., 2019). Such extreme events carry negative health effects for the most vulnerable sectors of human and animal populations and ecosystems (Matthews et al., 2017; McPherson et al., 2017; Sherwood and Huber, 2010; Watts et al., 2019). Given the importance of properly determining the fraction of EEI flowing into the land component, recent works have examined the CMIP5 simulations and revealed that Earth system models (ESMs) have shortcomings in modeling the land heat content of the last half of the 20th century (Cuesta-Valero et al., 2016). Numerical experiments have pointed to an insufficient depth of the land surface models (LSMs) (MacDougall et al., 2008, 2010; Stevens, 2007) and to a zero heat-flow bottom boundary condition (BBC) as the origin of the limitations in these simulations. An LSM of insufficient depth limits the amount of energy that can be stored in the subsurface. The zero heat-flow BBC neglects the small but persistent long-term contribution from the flow of heat from the interior of the Earth, which shifts the thermal regime of the subsurface towards or away from the freezing point of water, such that the latent heat component is misrepresented in the northern latitudes (Hermoso de Mendoza et al., 2020). Although the heat from the interior of the Earth is constant at timescales of a few millennia, it may conflict with the setting of the LSM initial conditions in ESM simulations. Modeling experiments have also allowed us to estimate the heat content in land water reservoirs (Vanderkelen et al., 2020), accounting for 0.3 ± 0.3 ZJ from 1900 to 2020. Nevertheless, this estimate has not been included here because it is derived from model simulations and its magnitude is small in relation to the rest of the components of the Earth's heat inventory.

4.1 Borehole climatology

The main premise of borehole climatology is that the subsurface thermal regime is determined by the balance of the heat flowing from the interior of the Earth (the bottom boundary condition) and the heat flowing through the interface between the lower atmosphere and the ground (the upper boundary condition). If the thermal properties of the subsurface are known, or if they can be assumed constant over short-depth intervals, then the thermal regime of the subsurface can be determined by the physics of heat diffusion. The simplest analogy is the temperature distribution along a (infinitely wide) cylinder with known thermal properties and constant temperature at both ends. If upper and lower boundary conditions remain constant (i.e., internal heat flow is constant and there are no persistent variations on the ground surface energy balance), then the thermal regime of the subsurface is well known and it is in a (quasi-)steady state. However, any change to the ground surface energy balance would create a transient, and such a change in the upper boundary condition would propagate into the ground, leading to changes in the thermal regime of the subsurface (Beltrami, 2002a). These changes in the ground surface energy balance propagate into the subsurface and are recorded as departures from the quasi-steady thermal state of the subsurface. Borehole climatology uses these subsurface temperature anomalies to reconstruct the ground surface temperature changes that may have been responsible for creating the subsurface temperature anomalies we observe. That is, it is an attempt to reconstruct the temporal evolution of the upper boundary condition. Ground surface temperature histories (GSTHs) and ground heat flux histories (GHFHs) have been reconstructed from borehole temperature profile (BTP) measurements at regional and larger scales for decadal and millennial timescales (Barkaoui et al., 2013; Beck, 1977; Beltrami, 2001; Beltrami et al., 2006; Beltrami and Bourlon, 2004; Cermak, 1971; Chouinard and Mareschal, 2009; Davis et al., 2010; Demezhko and Gornostaeva, 2015; Harris and Chapman, 2001; Hartmann and Rath, 2005; Hopcroft et al., 2007; Huang et al., 2000; Jaume-Santero et al., 2016; Lachenbruch and Marshall, 1986; Lane, 1923; Pickler et al., 2018; Roy et al., 2002; Vasseur et al., 1983). These reconstructions have provided independent records for the evaluation of the evolution of the climate system well before the existence of meteorological records. Because subsurface temperatures are a direct measure, which unlike proxy reconstructions of past climate do not need to be calibrated with the meteorological records, they provide an independent way of assessing changes in climate. Such records are useful tools for evaluating climate simulations prior to the observational period (Beltrami et al., 2017; Cuesta-Valero et al., 2019, 2016; García-García et al., 2016; González-Rouco et al., 2006; Jaume-Santero et al., 2016; MacDougall et al., 2010; Stevens et al., 2008), as well as for assessing proxy data reconstructions (Beltrami et al., 2017; Jaume-Santero et al., 2016).

Borehole reconstructions have, however, certain limitations. Due to the nature of heat diffusion, temperature changes propagated through the subsurface suffer both a phase shift and an amplitude attenuation (Smerdon and Stieglitz, 2006). Although subsurface temperatures continuously record all changes in the ground surface energy balance, heat diffusion filters out the high frequency variations of the surface signal with depth; thus the annual cycle is detectable up to approximately 16 m of depth, while millennial changes are recorded approximately to a depth of 500 m. Therefore, reconstructions from borehole temperature profiles represent changes at decadal-to-millennial timescales. Additionally, borehole data are sparse, since the logs were usually recorded from holes of opportunity at mining exploration sites. As a result, the majority of profiles were measured in the Northern Hemisphere, although recent efforts have been taken to increase the sampling rate in South America (Pickler et al., 2018) and Australia (Suman et al., 2017). Despite this uneven sampling, the spatial distribution of borehole profiles has been able to represent the evolution of land surface conditions at global scales (Beltrami and Bourlon, 2004; Cuesta-Valero et al., 2020; González-Rouco et al., 2006, 2009; Pollack and Smerdon, 2004). Another factor that reduces the number of borehole profiles suitable for climate analyses is the presence of nonclimatic signals in the measured profiles, mainly caused by groundwater flow and changes in the lithology of the subsurface. Therefore, all profiles are screened before the analysis in order to remove questionable logs. Despite all these limitations, the borehole methodology has been shown to be reliable based on observational analyses (Bense and Kooi, 2004; Chouinard and Mareschal, 2007; Pollack and Smerdon, 2004; Verdoya et al., 2007) and pseudoproxy experiments (García Molinos et al., 2016; González-Rouco et al., 2006, 2009).

4.2 Land heat content estimates

Global continental energy content has been previously estimated from geothermal data retrieved from a set of quality-controlled borehole temperature profiles. Ground heat content was estimated from heat flux histories derived from BTP data (Beltrami, 2002b; Beltrami et al., 2002, 2006). Such results have formed part of the estimate used in AR3, AR4 and AR5 IPCC reports (see Box 3.1, chap. 3 Rhein et al., 2013). A continental heat content estimate was inferred from meteorological observations of surface air temperature since the beginning of the 20th century (Huang, 2006). Nevertheless, all global estimates were performed nearly 2 decades ago. Since, those days, advances in borehole methodological techniques (Beltrami et al., 2015; Cuesta-Valero et al., 2016; Jaume-Santero et al., 2016), the availability of additional BTP measurements and the possibility of assessing the continental heat fluxes in the context of the FluxNet measurements (Gentine et al., 2020) require a comprehensive summary of all global ground heat fluxes and continental heat content estimates.

The first estimates of continental heat content used borehole temperature versus depth profile data. However, the dataset in those analyses included borehole temperature profiles of a wide range of depths, as well as different data acquisition dates. That is, each borehole profile contained the record of the accumulation of heat in the subsurface for different time intervals. In addition, the borehole data were analyzed for a single ground surface temperature model using a single constant value for each of the subsurface thermal properties.

Although the thermal signals are attenuated with depth, which may partially compensate for data shortcomings, uncertainties were introduced in previous analyses that may have affected the estimates of subsurface heat change. A continental heat content change estimate was carried out using a gridded meteorological product of surface air temperature by Huang (2006). Such work yielded similar values to the estimates from geothermal data (see Table 2). This estimate, however, assumed that surface air and ground temperatures are perfectly coupled everywhere, and it used a single value for the thermal conductivity of the ground. Studies have shown that the coupling of the surface air and ground temperatures is mediated by several processes that may influence the ground surface energy balance and, therefore, the air–ground temperature coupling (García-García et al., 2019; Melo-Aguilar et al., 2018; Stieglitz and Smerdon, 2007). In a novel attempt to reconcile continental heat content from soil heat-plate data from the FluxNet network with estimates from geothermal data and a deep bottom boundary land surface model simulation, Gentine et al. (2020) obtained a much larger magnitude from the global land heat flux than all previous estimates. Cuesta-Valero et al. (2020) has recently updated the estimate of the global continental heat content using a larger borehole temperature database (1079 logs) that includes more recent measurements and a stricter data quality control. The updated estimate of continental heat content change also takes into account the differences in borehole logging time and restricts the data to the same depth range for each borehole temperature profile. Such depth range restriction ensures that the subsurface accumulation of heat at all BTP sites is synchronous. In addition to the standard method for reconstructing heat fluxes with a single constant value for each subsurface thermal property, Cuesta-Valero et al. (2020) also developed a new approach that considers a range of possible subsurface thermal properties – several models, each at a range of resolutions yielding a more realistic range of uncertainties for the fraction of the EEI flowing into the land subsurface.

Global land heat content estimates from FluxNet data, geothermal data and model simulations point to a marked increase in the amount of energy flowing into the ground in the last few decades (Figs. 4, 5 and Table 2). These results are consistent with the observations of ocean, cryosphere and atmospheric heat storage increases during the same time period as well as with EEI at the top of the atmosphere.

5 Heat utilized to melt ice

The energy uptake by the cryosphere is given by the sum of the energy uptake within each one of its components: sea ice, the Greenland and Antarctic ice sheets, glaciers other than those that are part of the ice sheets (“glaciers”, here-

Table 2. Ground surface heat flux and global continental heat content. Uncertainties in parenthesis.

Reference	Time period	Heat flux (m W m^{-2})	Heat content (ZJ)	Source of data
Beltrami (2002b)	1950–2000	33	7.1	Geothermal
Beltrami et al. (2002)	1950–2000	39.1 (3.5)	9.1 (0.8)	Geothermal
Beltrami et al. (2002)	1900–2000	34.1 (3.4)	15.9 (1.6)	Geothermal
Beltrami (2002b)	1765–2000	20.0 (2.0)	25.7 (2.6)	Geothermal
Huang (2006)	1950–2000	–	6.7	Meteorological
Gentine et al. (2020)	2004–2015	240 (120)	–	FluxNet, geothermal, LSM
Cuesta-Valero et al. (2020)	1950–2000	70 (20)	16 (3)	Geothermal
Cuesta-Valero et al. (2020)	1993–2018	129 (28)	14 (3)	Geothermal
Cuesta-Valero et al. (2020)	2004–2015	136 (28)	6 (1)	Geothermal

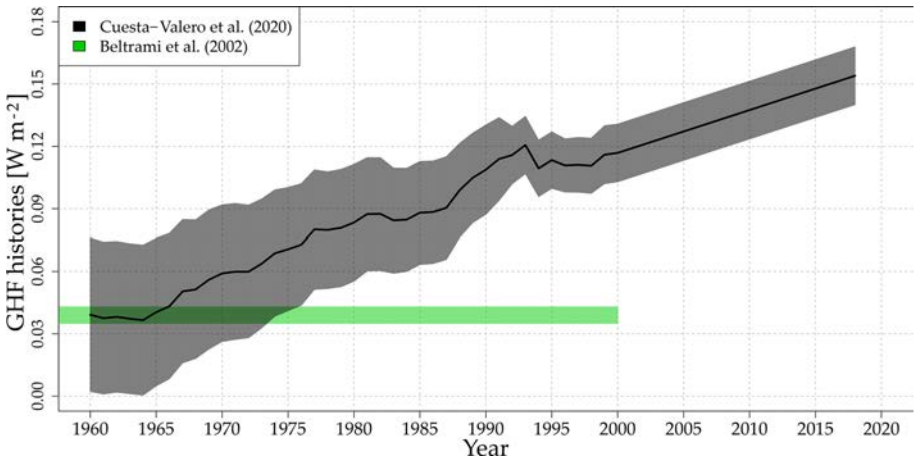

Figure 4. Global mean ground heat flux history (black line) and 95 % confidence interval (gray shadow) from BTP measurements from Cuesta-Valero et al. (2020). Results for 1950–2000 from Beltrami et al. (2002) (green bar) are provided for comparison purposes.

after), snow, and permafrost. The basis for the heat uptake by the cryosphere presented here is provided by a recent estimate for the period 1979 to 2017 (Straneo et al., 2020). This study concludes that heat uptake over this period is dominated by the mass loss from Arctic sea ice, glaciers, and the Greenland and Antarctic ice sheets. The contributions from thawing permafrost and shrinking snow cover are either negligible, compared to these other components, or highly uncertain. (Note that warming of the land in regions where permafrost is present is accounted for in the land warming; however, the energy to thaw the permafrost is not.) Antarctic sea ice shows no explicit trend over the period described here (Parkinson, 2019). Here, we extend the estimate of Straneo et al. (2020) backwards in time to 1960 and summarize the method, the data and model outputs used. The reader is referred to Straneo et al. (2020) for further details.

Within each component of the cryosphere, energy uptake is dominated by that associated with melting, including both the latent heat uptake and the warming of the ice to its freezing point. As a result, the energy uptake by each component is directly proportional to its mass loss (Straneo et al., 2020). For consistency with previous estimates (Ciais et al., 2013), we use a constant latent heat of fusion of 3.34×10^5 J kg^{-1}, a specific heat capacity of 2.01×10^3 J/(kg °C) and an ice density of 920 kg m^{-3}.

For Antarctica, we separate contributions from grounded ice loss and floating ice loss building on recent separate estimates for each. Grounded ice loss from 1992 to 2017 is based on a recent study that reconciles mass balance estimates from gravimetry, altimetry and input–output methods from 1992 to 2017 (Shepherd et al., 2018b). For the 1972–1991 period, we used estimates from Rignot et al. (2019), which combined modeled surface mass balance with ice discharge estimates from the input/output method. Floating ice loss between 1994 and 2017 is based on thinning rates and iceberg calving fluxes estimated using new satellite altimetry reconstructions (Adusumilli et al., 2020). For the 1960–1994 period, we also considered mass loss from declines in Antarctic Peninsula ice shelf extent (Cook and Vaughan, 2010) using the methodology described in Straneo et al. (2020).

To estimate grounded ice mass loss in Greenland, we use the Ice Sheet Mass Balance Intercomparison Exercise for the

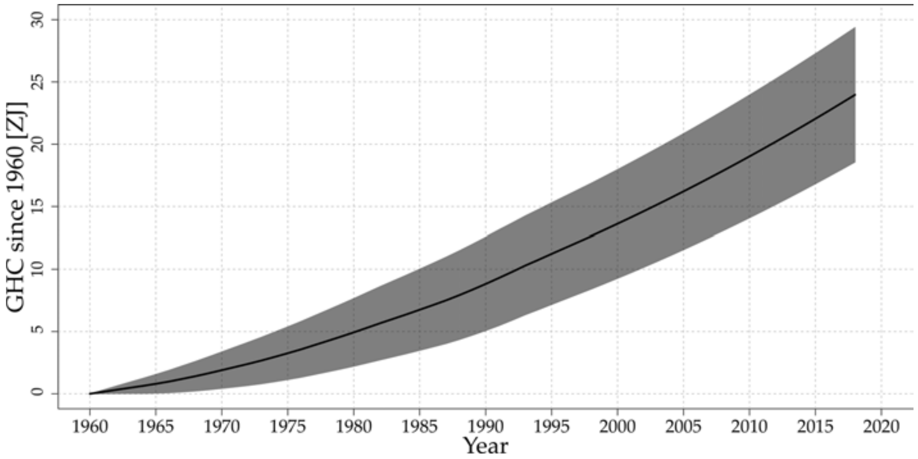

Figure 5. Global cumulative heat storage within continental landmasses since 1960 CE (black line) and 95 % confidence interval (gray shadow) estimated from ground heat flux results displayed in Fig. 4. Data obtained from Cuesta-Valero et al. (2020).

time period 1992–2017 (Shepherd et al., 2019) and the difference between surface mass balance and ice discharge for the period 1979–1991 (Mankoff et al., 2019; Mouginot et al., 2019; Noël et al., 2018). Due to a lack of observations, from 1960–1978 we assume no mass loss. For floating ice mass change, we collated reports of ice shelf thinning and/or collapse together with observed tidewater glacier retreat (Straneo et al., 2020). Based on firn modeling we assessed that warming of Greenland's firn has not yet contributed significantly to its energy uptake (Ligtenberg et al., 2018; Straneo et al., 2020).

For glaciers we combine estimates for glaciers from the Randolph Glacier Inventory outside of Greenland and Antarctica, based on direct and geodetic measurements (Zemp et al., 2019), with estimates based on a glacier model forced with an ensemble of reanalysis data (Marzeion et al., 2015) and GRACE-based estimates (Bamber et al., 2018). An additional contribution from uncharted glaciers or glaciers that have already disappeared is obtained from Parkes and Marzeion (2018). Greenland and Antarctic peripheral glaciers are derived from Zemp et al. (2019) and Marzeion et al. (2015).

Finally, while estimates of Arctic sea ice extent exist over the satellite record, sea ice thickness distribution measurements are scarce, making it challenging to estimate volume changes. Instead we use the Pan-Arctic Ice Ocean Modeling and Assimilation System (PIOMAS) (Schweiger et al., 2011; Zhang and Rothrock, 2003) which assimilates ice concentration and sea surface temperature data and is validated with most available thickness data (from submarines, oceanographic moorings, and remote sensing) and against multidecadal records constructed from satellite (for example, Labe et al., 2018; Laxon et al., 2013; Wang et al., 2016). A longer reconstruction using a slightly different model version, PIOMAS-20C (Schweiger et al., 2019), is used to cover the 1960 to 1978 period that is not covered by PIOMAS.

These reconstructions reveal that all four components contributed similar amounts (between 2 and 5 ZJ) over the 1960–2017 period, amounting to a total energy uptake by the cryosphere of 14.7 ± 1.9 ZJ. Compared to earlier estimates, and in particular the 8.83 ZJ estimate from Ciais et al. (2013), this larger estimate is a result both of the longer period of time considered and, also, the improved estimates of ice loss across all components, especially the ice shelves in Antarctica. Approximately half of the cryosphere's energy uptake is associated with the melting of grounded ice, while the remaining half is associated with the melting of floating ice (ice shelves in Antarctica and Greenland, Arctic sea ice).

6 The Earth heat inventory: where does the energy go?

The Earth has been in radiative imbalance, with less energy exiting the top of the atmosphere than entering, since at least about 1970, and the Earth has gained substantial energy over the past 4 decades (Hansen, 2005; Rhein et al., 2013). Due to the characteristics of the Earth system components, the ocean with its large mass and high heat capacity dominates the Earth heat inventory (Cheng et al., 2016, 2017b; Rhein et al., 2013; von Schuckmann et al., 2016). The rest goes into grounded and floating ice melt, as well as warming the land and atmosphere.

In agreement with previous studies, the Earth heat inventory based on most recent estimates of heat gain in the ocean (Sect. 1), the atmosphere (Sect. 2), land (Sect. 3) and the cryosphere (Sect. 4) shows a consistent long-term heat gain since the 1960s (Fig. 6). Our results show a total heat gain of 358 ± 37 ZJ over the period 1971–2018, which is equivalent to a heating rate of 0.47 ± 0.1 W m^{-2}, and it applied continuously over the surface area of the Earth (5.10×10^{14} m^2). For comparison, the heat gain obtained in IPCC AR5 amounts to 274 ± 78 ZJ and 0.4 W m^{-2} over the period 1971–2010

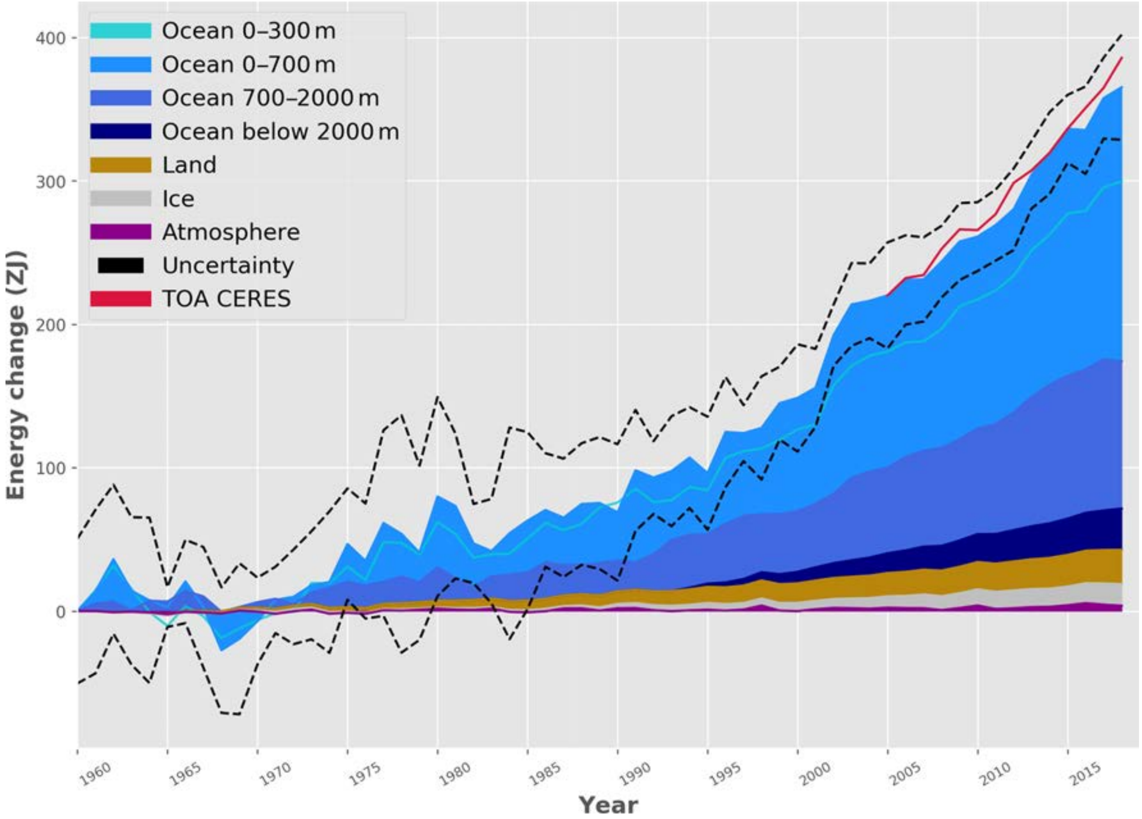

Figure 6. Earth heat inventory (energy accumulation) in ZJ ($1\,\mathrm{ZJ} = 10^{21}\,\mathrm{J}$) for the components of the Earth's climate system relative to 1960 and from 1960 to 2018 (assuming constant cryosphere increase for the year 2018). See Sects. 1–4 for data sources. The upper ocean (0–300 m, light blue line, and 0–700 m, light blue shading) accounts for the largest amount of heat gain, together with the intermediate ocean (700–2000 m, blue shading) and the deep ocean below 2000 m depth (dark blue shading). Although much lower, the second largest contributor is the storage of heat on land (orange shading), followed by the gain of heat to melt grounded and floating ice in the cryosphere (gray shading). Due to its low heat capacity, the atmosphere (magenta shading) makes a smaller contribution. Uncertainty in the ocean estimate also dominates the total uncertainty (dot-dashed lines derived from the standard deviations (2σ) for the ocean, cryosphere and land; atmospheric uncertainty is comparably small). Deep ocean (> 2000 m) is assumed to be zero before 1990 (see Sect. 1 for more details). The dataset for the Earth heat inventory is published at the German Climate Computing Centre (DKRZ, https://www.dkrz.de/) under the DOI https://doi.org/10.26050/WDCC/GCOS_EHI_EXP_v2. The net flux at TOA from the NASA CERES program is shown in red (https://ceres.larc.nasa.gov/data/, last access: 7 August 2020; see also for example Loeb et al., 2012) for the period 2005–2018 to account for the golden period of best available estimates. We obtain a total heat gain of 358 ± 37 ZJ over the period 1971–2018, which is equivalent to a heating rate (i.e., the EEI) of $0.47 \pm 0.1\,\mathrm{W\,m^{-2}}$ applied continuously over the surface area of the Earth ($5.10 \times 10^{14}\,\mathrm{m^2}$). The corresponding EEI over the period 2010–2018 amounts to $0.87 \pm 0.12\,\mathrm{W\,m^{-2}}$. A weighted least square fit has been used taking into account the uncertainty range (see also von Schuckmann and Le Traon, 2011).

(Rhein et al., 2013). In other words, our results show that since the IPCC AR5 estimate has been performed, heat accumulation has continued at a comparable rate. The major player in the Earth inventory is the ocean, particularly the upper (0–700 m) and intermediate (700–2000 m) ocean layers (see also Sect. 1, Fig. 2).

Although the net flux at TOA as derived from remote sensing is anchored by an estimate of global OHC (Loeb et al., 2012), and thus does not provide a completely independent result for the total EEI, we additionally compare net flux at TOA with the Earth heat inventory obtained in this study (Fig. 6). Both rates of change compare well, and we obtain $0.7 \pm 0.1\,\mathrm{W\,m^{-2}}$ for the remote sensing estimate at TOA and $0.8 \pm 0.1\,\mathrm{W\,m^{-2}}$ for the Earth heat inventory over the period 2005–2018.

Rates of change derived from Fig. 6 are in agreement with previously published results for the different periods (Fig. 7). Major disagreements occur for the estimate of Balmaseda et al. (2013) which is obtained from an ocean reanalysis and known to provide higher heat gain compared to results derived strictly from observations (Meyssignac et al., 2019). Over the last quarter of a decade this Earth heat inventory reports – in agreement with previous publications – an increased rate of Earth heat uptake reaching up to

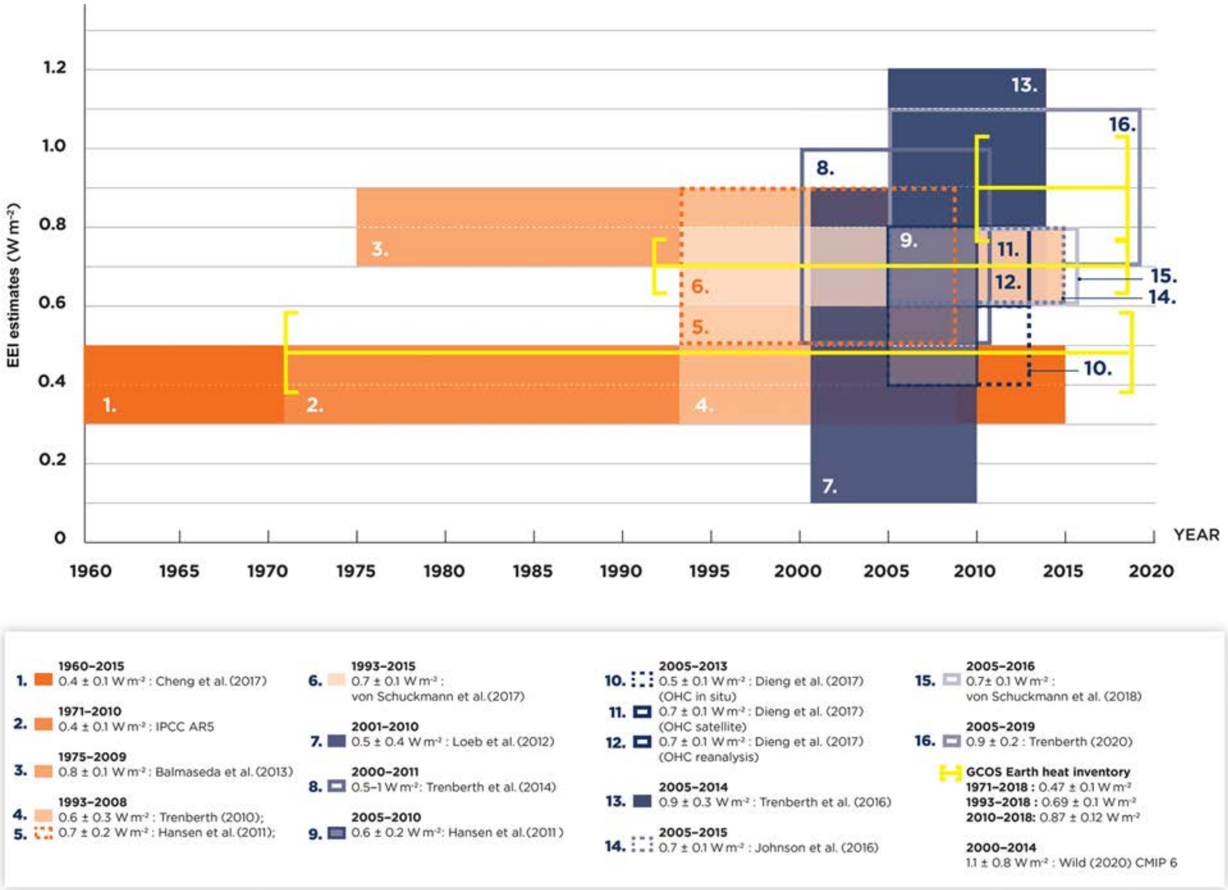

Figure 7. Overview on EEI estimates as obtained from previous publications; references are listed in the figure legend. For IPCC AR5, Rhein et al. (2013) is used. The color bars take into account the uncertainty ranges provided in each publication, respectively. For comparison, the estimates of our Earth heat inventory based on the results of Fig. 6 have been added (yellow lines) for the periods 1971–2018, 1993–2018 and 2010–2018, and the trends have been evaluated using a weighted least square fit (see von Schuckmann and Le Traon, 2011, for details on the method).

$0.9\,\mathrm{W\,m^{-2}}$ (Fig. 7). This period is also characterized with an increase in the availability and quality of the global climate observing system, particularly for the past 2 decades. The heat inventory as obtained in this study reveals an EEI of $0.87 \pm 0.12\,\mathrm{W\,m^{-2}}$ over the period 2010–2018 – a period which experienced record levels of Earth surface warming and is ranked as the warmest decade relative to the reference period 1850–1900 (WMO, 2020). Whether this increased rate can be attributed to an acceleration of global warming and Earth system heat uptake (e.g., Cheng et al., 2019a; WMO, 2020; Blunden and Arndt, 2019), an induced estimation bias due to the interplay between natural and anthropogenically driven variability (e.g., Cazenave et al., 2014), or underestimated uncertainties in the historical record (e.g., Boyer et al., 2016) needs further investigation.

The new multidisciplinary estimate obtained from a concerted international effort provides an updated insight in where the heat is going from a positive EEI of $0.47 \pm 0.1\,\mathrm{W\,m^{-2}}$ for the period 1971–2018. Over the period 1971–2018 (2010–2018), 89 % (90 %) of the EEI is stored in the global ocean, from which 52 % (52 %) is repartitioned in the upper 700 m depth, 28 % (30 %) at intermediate layers (700–2000 m) and 9 % (8 %) in the deep ocean layer below 2000 m depth. Atmospheric warming amounts to 1 % (2 %) in the Earth heat inventory, the land heat gain amounts to 6 % (5 %) and the heat uptake by the cryosphere amounts to 4 % (3 %). These results show general agreement with previous estimates (e.g., Rhein et al., 2013). Over the period 2010–2018, the EEI amounts to $0.87 \pm 0.12\,\mathrm{W\,m^{-2}}$, indicating a rapid increase in EEI over the past decade. Note that a near-global (60° N–60° S) area for the ocean heat uptake is used in this study, which could induce a slight underestimation, and needs further evaluation in the future (see Sect. 1). However, a test using a single dataset (Cheng et al., 2017b) indicates that the ocean contribution within 1960–2018 can increase by 1 % if the full global ocean domain is used (not shown).

7 Data availability

The time series of the Earth heat inventory are published at DKRZ (https://www.dkrz.de/, last access: 7 August 2020) under the DOI https://doi.org/10.26050/WDCC/GCOS_EHI_EXP_v2 (von Schuckmann et al., 2020). The data contain an updated international assessment of ocean warming estimates as well as new and updated estimates of heat gain in the atmosphere, cryosphere and land over the period 1960–2018. This published dataset has been used to build the basis for Fig. 6 of this paper. The ocean warming estimate is based on an international assessment of 15 different in situ data-based ocean products as presented in Sect. 1. The new estimate of the atmospheric heat content is fully described in Sect. 2 and is based on a combined use of atmospheric reanalyses, multisatellite data and radiosonde records, and microwave sounding techniques. The land heat storage time series as presented in Sect. 3 relies on borehole data. The heat available to account for cryosphere loss is presented in Sect. 4 and is based on a combined use of model results and observations to obtain estimates of major cryosphere components such as polar ice sheets, Arctic sea ice and glaciers.

8 Conclusions

The UN 2030 Agenda for Sustainable Development states that climate change is "one of the greatest challenges of our time ..." and warns "... the survival of many societies, and of the biological support systems of the planet, is at risk" (UNGA, 2015). The outcome document of the Rio+20 Conference, *The Future We Want*, defines climate change as "an inevitable and urgent global challenge with long-term implications for the sustainable development of all countries" (UNGA, 2012). The Paris Agreement builds upon the United Nations Framework Convention on Climate Change (UN, 1992) and for the first time all nations agreed to undertake ambitious efforts to combat climate change, with the central aim to keep global temperature rise this century well below 2 °C above preindustrial levels and to limit the temperature increase even further to 1.5 °C (UN, 2015). Article 14 of the Paris Agreement requires the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA) to periodically take stock of the implementation of the Paris Agreement and to assess collective progress towards achieving the purpose of the agreement and its long-term goals through the so-called global stocktake based on best available science.

The EEI is the most critical number defining the prospects for continued global warming and climate change (Hansen et al., 2011; von Schuckmann et al., 2016), and we call for an implementation of the EEI into the global stocktake. The current positive EEI is understood to be foremost and primarily a result of increasing atmospheric greenhouse gases (IPCC, 2013), which have – according to the IPCC special report on Global Warming of 1.5 °C – already "caused approximately 1.0 °C of global warming above preindustrial levels, with a likely range of 0.8 °C to 1.2 °C" (IPCC, 2018). The IPCC special report further states with high confidence that "global warming is likely to reach 1.5 °C between 2030 and 2052 if it continues to increase at the current rate". The EEI is the portion of the forcing that the Earth's climate system has not yet responded to (Hansen et al., 2005) and defines additional global warming that will occur without further change in forcing (Hansen et al., 2017). Our results show that EEI is not only continuing, but also increasing. Over the period 1971–2018 average EEI amounts to $0.47 \pm 0.1\,\mathrm{W\,m^{-2}}$, but it amounts to $0.87 \pm 0.12\,\mathrm{W\,m^{-2}}$ during 2010–2018 (Fig. 8). Concurrently, acceleration of sea-level rise (WCRP, 2018; Legelais et al., 2020), accelerated surface warming, record temperatures and sea ice loss in the Arctic (Richter-Menge et al., 2019; WMO, 2020; Blunden and Arndt, 2020) and ice loss from the Greenland ice sheet (King et al., 2020), and intensification of atmospheric warming near the surface and in the troposphere (Steiner et al., 2020) have been – for example – recently reported. To what degree these changes are intrinsically linked needs further evaluations.

Global atmospheric CO_2 concentration reached 407.38 ± 0.1 ppm averaged over 2018 (Friedlingstein et al., 2019) and 409.8 ± 0.1 ppm in 2019 (Blunden and Arndt, 2020). WMO (2020) reports CO_2 concentrations at the Mauna Loa measurement platform of 411.75 ppm in February 2019 and 414.11 ppm in February 2020. Stabilization of climate, the goal of the universally agreed UNFCCC (UN, 1992) and the Paris Agreement (UN, 2015), requires that EEI be reduced to approximately zero to achieve Earth's system quasi-equilibrium. The change of heat radiation to space for a given greenhouse gas change can be computed accurately. The amount of CO_2 in the atmosphere would need to be reduced from 410 to 353 ppm (i.e., a required reduction of -57 ± 8 ppm) to increase heat radiation to space by $0.87\,\mathrm{W\,m^{-2}}$, bringing Earth back towards energy balance (Fig. 8), where we have used the analytic formulae of Hansen et al. (2000) for this estimation. Atmospheric CO_2 was last 350 ppm in the year 1988, and the global Earth surface temperature was then +0.5 °C relative to the preindustrial period (relative to the 1880–1920 mean) (Hansen et al., 2017; Friedlingstein et al., 2019). In principle, we could reduce other greenhouse gases and thus require a less stringent reduction of CO_2. However, as discussed by Hansen et al. (2017), some continuing increase in N_2O, whose emissions are associated with food production, seems inevitable, so there is little prospect for much net reduction of non-CO_2 greenhouse gases, and thus the main burden for climate stabilization falls on CO_2 reduction. This simple number, EEI, is the most fundamental metric that the scientific community and public must be aware of as the measure of how well the world is doing in the task of bringing climate change under control (Fig. 8).

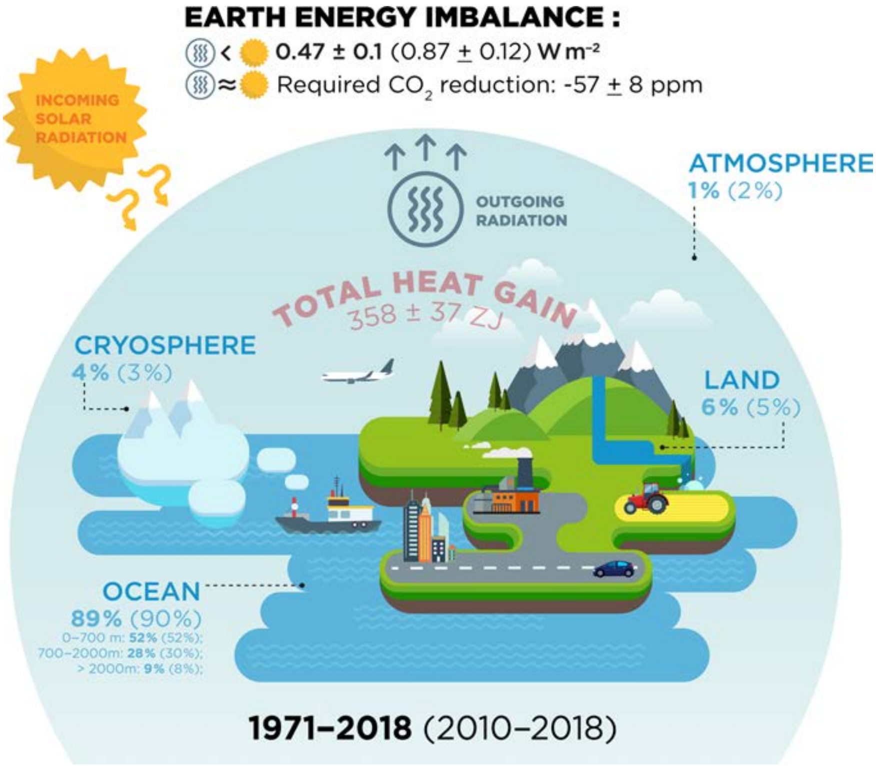

Figure 8. Schematic presentation on the Earth heat inventory for the current anthropogenically driven positive Earth energy imbalance at the top of the atmosphere (TOA). The relative partition (in %) of the Earth heat inventory presented in Fig. 6 for the different components is given for the ocean (upper: 0–700 m, intermediate: 700–2000 m, deep: > 2000 m), land, cryosphere (grounded and floating ice) and atmosphere, for the periods 1971–2018 and 2010–2018 (for the latter period values are provided in parentheses), as well as for the EEI. The total heat gain (in red) over the period 1971–2018 is obtained from the Earth heat inventory as presented in Fig. 6. To reduce the 2010–2018 EEI of $0.87 \pm 0.12\,\mathrm{W\,m^{-2}}$ towards zero, current atmospheric CO_2 would need to be reduced by -57 ± 8 ppm (see text for more details).

This community effort also addresses gaps for the evolution of future observing systems for a robust and continued assessment of the Earth heat inventory and its different components. Immediate priorities include the maintenance and extension of the global climate observing system to assure a continuous monitoring of the Earth heat inventory and to reduce the uncertainties. For the global ocean observing system, the core Argo sampling needs to be sustained and complemented by remote sensing data. Extensions such as into the deep ocean layer need to be further fostered (Desbruyères et al., 2017; Johnson et al., 2015), and technical developments for the measurements under ice and in shallower areas need to be sustained and extended. Moreover, continued efforts are needed to further advance bias correction methodologies, uncertainty evaluations and data processing of the historical dataset.

In order to allow for improvements on the present estimates of changes in the continental heat and to ensure that the database is continued into the future, an international, coordinated effort is needed to increase the number of subsurface temperature data from BTPs at additional locations around the world, in particular in the Southern Hemisphere. Additionally, repeated monitoring (after a few decades) of existing boreholes should help reduce uncertainties at individual sites. Such data should be shared through an open platform.

For the atmosphere, the continuation of operational satellite- and ground-based observations is important, but the foremost need is sustaining and enhancing a coherent long-term monitoring system for the provision of climate data records of essential climate variables. GNSS radio occultation observations and reference radiosonde stations within the Global Climate Observing System (GCOS) Reference Upper Air Network (GRUAN) are regarded as climate benchmark observations. Operational radio occultation missions for continuous global climate observations need to be maintained and expanded, ensuring global coverage over all local times, as the central node of a global climate observing system.

For the cryosphere, sustained remote sensing for all of the cryosphere components is key to quantifying future changes over these vast and inaccessible regions but must be complemented by in situ observations for calibration and validation. For sea ice, the albedo, the area and ice thickness are all essential, with ice thickness being particularly challenging to quantify with remote sensing alone. For ice sheets and glaciers, reliable gravimetric measurements, ice thickness and extent, snow/firn thickness and density are essential to quantify changes in mass balance of grounded and floating ice. We highlight Antarctic sea ice change and warming of firn as terms that are poorly constrained or have not significantly contributed to this assessment but may become important over the coming decades. Similarly, there exists the possibility for rapid change associated with positive ice dynamical feedbacks at the marine margins of the Greenland and Antarctic ice sheets. Sustained monitoring of each of these components will, therefore, serve the dual purpose of furthering the understanding of the dynamics and quantifying the contribution to Earth's energy budget. In addition to data collection, open access to the data and data synthesis products as well as coordinated international efforts are key to the continued monitoring of the ice loss from the cryosphere and related energy uptake.

Sustained and improved observations to quantify Earth's changing energy inventory are also critical to the development of improved physical models of the climate system, including both data assimilation efforts that help us to understand past changes and predictions (Storto et al., 2019) and climate models used to provide projections of future climate change (Eyring et al., 2019). For example, atmospheric reanalyses have shown to be a valuable tool for investigating past changes in the EEI (Allan et al., 2014) and ocean reanalyses have proven useful in estimating rates of ocean heating on annual and subannual timescales by reducing observational noise (Trenberth et al., 2016). Furthermore, both reanalyses and climate models can provide information to assess current observing capabilities (Fujii et al., 2019) and improve uncertainty estimates in the different components of Earth's energy inventory (Allison et al., 2019). Future priorities for expanding the observing system to improve future estimates of EEI should be cognizant of the expected evolution of the climate change signal, drawing on evidence from observations, models and theory (Meyssignac et al., 2019; Palmer et al., 2019).

A continuous effort to regularly update the Earth heat inventory is important to quantify how much and where heat accumulated from climate change is stored in the climate system. The Earth heat inventory crosses multidisciplinary boundaries and calls for the inclusion of new science knowledge from the different disciplines involved, including the evolution of climate observing systems and associated data products, uncertainty evaluations, and processing tools. The results provide indications that a redistribution and conversion of energy in the form of heat is taking place in the different components of the Earth system, particularly within the ocean, and that EEI has increased over the past decade. The outcomes have further demonstrated how we are able to evolve our estimates for the Earth heat inventory while bringing together different expertise and major climate science advancements through a concerted international effort. All of these component estimates are at the leading edge of climate science. Their union has provided a new and unique insight on the inventory of heat in the Earth system, its evolution over time and a revision of the absolute values. The data product of this effort is made available and can be thus used for model validation purposes.

This study has demonstrated the unique value of such a concerted international effort, and we thus call for a regular evaluation of the Earth heat inventory. This first attempt presented here has been focused on the global area average only, and evolving into regional heat storage and redistribution, the inclusion of various timescales (e.g., seasonal, year to year) and other climate study tools (e.g., indirect methods, ocean reanalyses) would be an important asset of this much needed regular international framework for the Earth heat inventory. This would also respond directly to the request of GCOS to establish the observational requirements needed to monitor the Earth's cycles and the global energy budget. The outcome of this study will therefore directly feed into GCOS' assessment of the status of the global climate observing system due in 2021, which is the basis for the next implementation plan. These identified observation requirements will guide the development of the next generation of in situ and satellite global climate observations by all national meteorological services and space agencies and other oceanic and terrestrial networks.

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Author contributions to the atmosphere section include GK, MG, AKS, MM and LH.

Author contributions for the land section include AGG, FJCV, HB, SIS and PG.

Author contributions for the cryosphere section include FS, SA, DAS, MLT, BM, AS and AS.

All authors have contributed to the Earth energy inventory section, with specific contributions from KvS, AGG, FJCV, JH and MM.

All authors have contributed to the conclusion, with specific contributions from KvS, JH, CT, VA, LC, MDP, GK, AKS, AGG, FJCV, HB and FS.

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Exhibit 2

350 PPM PATHWAYS FOR FLORIDA

October 6, 2020

EVOLVED
ENERGY
RESEARCH

350 PPM Pathways for Florida

Prepared by

Ben Haley, Gabe Kwok, and Ryan Jones

Evolved Energy Research

October 6, 2020

Version 1

Table of Contents

Key Terms

100% Renewable Primary Scenario – a scenario that requires all primary energy source be renewable by 2050 (wind, solar, geothermal, hydro, and biomass)

1.0ºC – One degree Celsius (1.8ºF) of global warming over pre-industrial temperatures.

1.5°C – One-and one-half degrees Celsius (2.7ºF) of global warming over pre-industrial temperatures, an aspirational goal in the Paris Agreement climate accord.

2°C – Two degrees Celsius (3.6ºF) of global warming over pre-industrial temperatures. The Paris Agreement States the intention of parties to remain "well under" this upper limit.

350 ppm – An atmospheric CO_2 concentration of 350 parts per million by volume

80 x 50 – A commonly used target in the U.S. and other countries for reducing CO_2 emissions, referring to an 80% reduction below 1990 levels by 2050.

AEO – The Annual Energy Outlook a set of modeled results released annually by the U.S. government that forecasts the energy system under current policy for the next three decades.

Central Scenario – The primary deep decarbonization pathway with all technologies and resources available according to best scientific estimates.

BECCS – Bioenergy with carbon capture and geologic sequestration

BECCU – Bioenergy with carbon capture and utilization of that carbon somewhere in the economy

Bioenergy – Primary energy derived from growing biomass or use of organic wastes

Bunkering CO_2 – Offset to gross CO_2 emissions to account for emissions are not considered the responsibility of the U.S. under UNFCC accounting rules (bunkered fuels for international shipping and air travel).

CCE – Circular carbon economy, a term that refers to the capture and reuse of CO_2 within the energy system

CCS – Carbon capture and storage (also called carbon capture and sequestration)

CCU – Carbon capture and utilization (for economic purposes)

CO_2 – Carbon dioxide, the primary greenhouse gas responsible for human caused warming of the climate

DAC – Direct air capture, a technology that captures CO_2 from ambient atmosphere

DDPP – Deep Decarbonization Pathways Project

DOE – U.S. Department of Energy

EER – Evolved Energy Research, LLC.

eGRID – Emissions & Generation Resource Integrated Database maintained by the Environmental Protection Agency. eGRID divides the country into regions used in this study that are relevant for electricity planning and operations

EnergyPATHWAYS – An open-source, bottom-up energy and carbon planning tool for use in evaluating long-term, economy-wide greenhouse gas mitigation scenarios.

EPA – U.S. Environmental Protection Agency

FT – Fischer-Tropsch process

Gt(C) – Gigatons (billions of metric tons) of carbon

GW – Gigawatt (billion watts)

GWh – Gigawatt hour (equivalent to one million kilowatt hours)

IAM – Integrated Assessment Model, a class of model that models the energy system, economy, and climate system, to incorporate feedback between the three.

Intertie – Electric transmission lines that connect different regions

IPCC – the Intergovernmental Panel on Climate Change, is the body of the United Nations that provides regular assessments of the scientific basis of climate change, its impacts and future risks, and options for adaptation and mitigation.

Land NET – Negative CO_2 emissions as the result of the update of carbon in soils and terrestrial biomass

Low Biomass Scenario – A scenario that limits the use of biomass for energy

Low Electrification Scenario – A scenario with a slower rate of switching from fuel combustion technologies to electric technologies on the demand-side of the energy system

MMT – Million metric tonnes

NET – Negative emissions technology, one that absorbs atmospheric CO_2 and sequesters it

Net-negative CO2 - A condition in which human-caused carbon emissions are less than the natural uptake of carbon in land, soils, and oceans such that atmospheric CO_2 concentrations are declining.

Net-zero – A condition in which human-caused carbon emissions equal the natural uptake of carbon in land, soils, and oceans such that atmospheric CO_2 concentrations remain constant.

No New Regional Transmission (TX) Scenario– A scenario that disallows new inter-regional transmission lines

NWPP – Northwest Power Pool

Oxyfuel - A combustion process where fuel is burned using pure oxygen rather than air, and the resulting flue gas is primarily CO2 appropriate for sequestration

Pg(C) – Peta (10^{15}) grams

ppm – parts per million

Product CO_2 – Offset to gross CO_2 emissions to account for sequestration in products (like plastics)

ReEDS – Renewable Energy Deployment System – a capacity planning and dispatch model build by the National Renewable Energy Laboratory

Reference Scenario – A scenario derived from the U.S. Department of Energy's *Annual Energy Outlook* projecting the future evolution of the energy system given current policies

RIO – Regional Investment and Operations Platform, an optimization tool built by Evolved Energy Research to explore electricity systems and fuels

SDSN – Sustainable Development Solutions Network

SNG – Synthetic natural gas

TBtu – Trillion British thermal units, an energy unit typically applied to in power generation natural gas

Tech NET – Negative emission technologies composed of either biomass with carbon capture and sequestration or direct air capture with sequestration.

TX – Transmission

VMT – Vehicle miles traveled

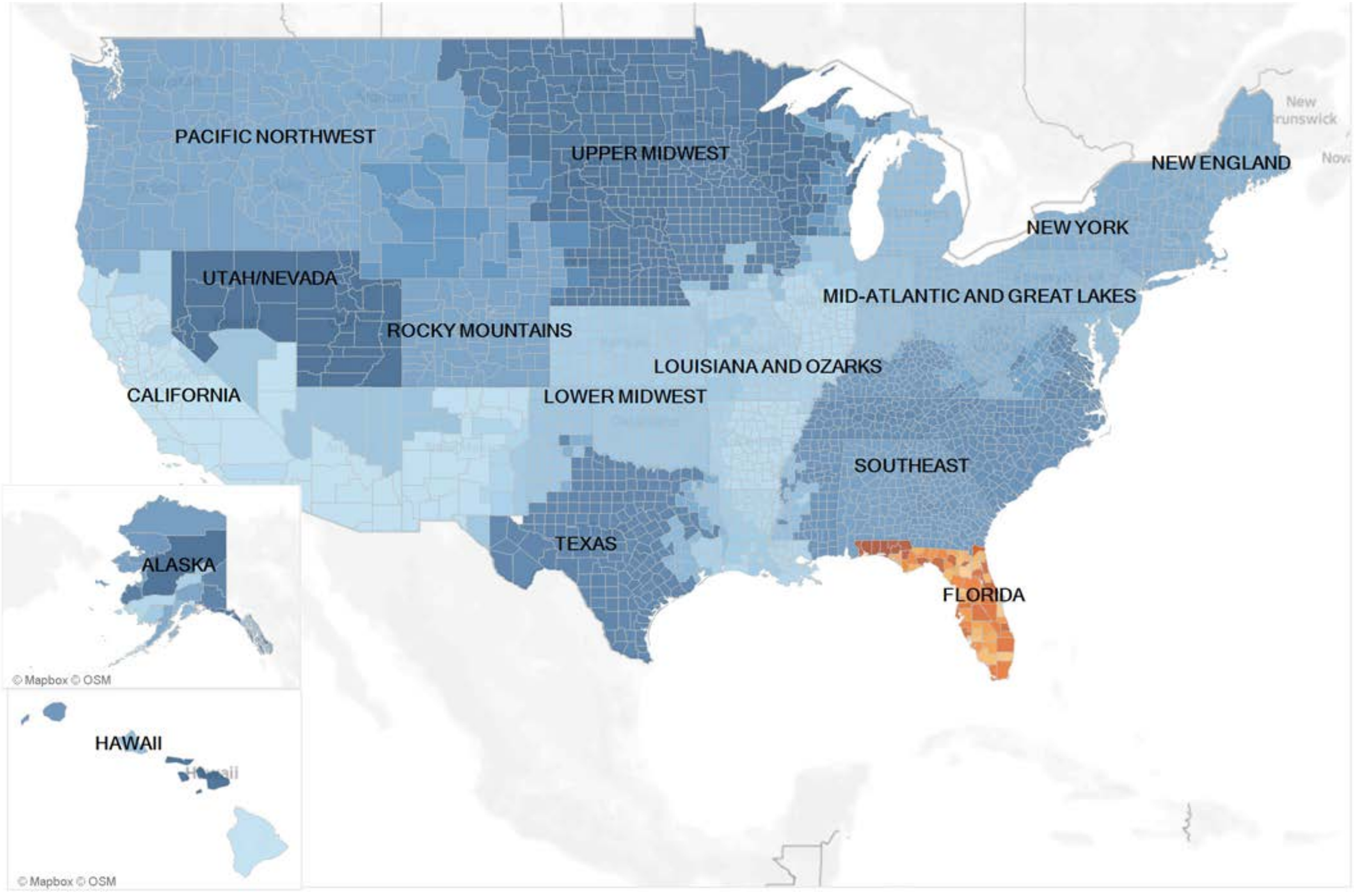
WECC – Western electricity coordinating council

Executive Summary

This study builds off the report issued by Evolved Energy Research and the Sustainability Development Solutions Network (SDSN) on May 8, 2019 titled *350 PPM Pathways for the United States*. The national report described the changes in the U.S. energy system required to reduce carbon dioxide (CO_2) emissions to a level consistent with returning atmospheric concentrations to 350 parts per million (350 ppm) by 2100, achieving net negative CO_2 emissions by mid-century, and limiting end-of-century global warming to 1ºC.

This study focuses on the State of Florida and evaluates new scenarios that strongly affect energy system outcomes for the state. As shown in Figure ES1, the analysis covers all regions of the U.S. in order to maintain consistency with the national report's 350 ppm emissions target and includes key analytical updates made to reflect evolved understandings of technology costs.

Figure ES1 Study Geographies (Florida highlighted here for visual emphasis)



Scenarios

For the Florida-specific analysis, we evaluated five scenarios that represent important and relevant national context for the State's energy system decisions. Brief descriptions of the decarbonization scenarios are included below.

1. **Central**: This is our least-constrained scenario designed to assess an all-options approach to decarbonization.

2. **Low Biomass**: This scenario assesses the robustness of our decarbonization strategy to limited zero-carbon biomass resources with a 50% reduction in the development of new biomass feedstocks.

3. **Low Electrification**: This scenario assesses the robustness of our decarbonization strategy to a twenty-year delay in the adoption of electrified demand-side technologies (electric vehices, heat pumps, etc.)

4. **100% Renewable Primary**: This scenario restricts the use of all non-renewable primary energy sources (fossil and nuclear) to zero by 2050. The economy derives all of its energy from biomass, wind, solar, hydro, and geothermal sources.

5. **No New Regional Transmission (TX)**: This scenario limits new development of inter-regional transmission across the U.S. This restricts the ability of regions to access higher quality renewables.

All of these scenarios remain within the 350ppm carbon budget described above while providing the same energy services for daily life and industrial production as the *Annual Energy Outlook (AEO)*, the Department of Energy's long-term forecast. The scenarios explore the effects of limits on key decarbonization strategies: bioenergy, electrification, residual fossil with carbon capture, nuclear energy, and interstate transmission development. The emissions constraints were applied to the U.S. as a whole, given that the ultimate achievement of a U.S. wide reduction pathway is likely to differ substantially by region based on initial energy system conditions, current and future economic structures, and resource endowments. This makes the cumulative emissions trajectory of Florida consistent with 350 PPM target achievement in the U.S. an output of the modeling exercise.

Table ES1 U.S. Emissions Targets

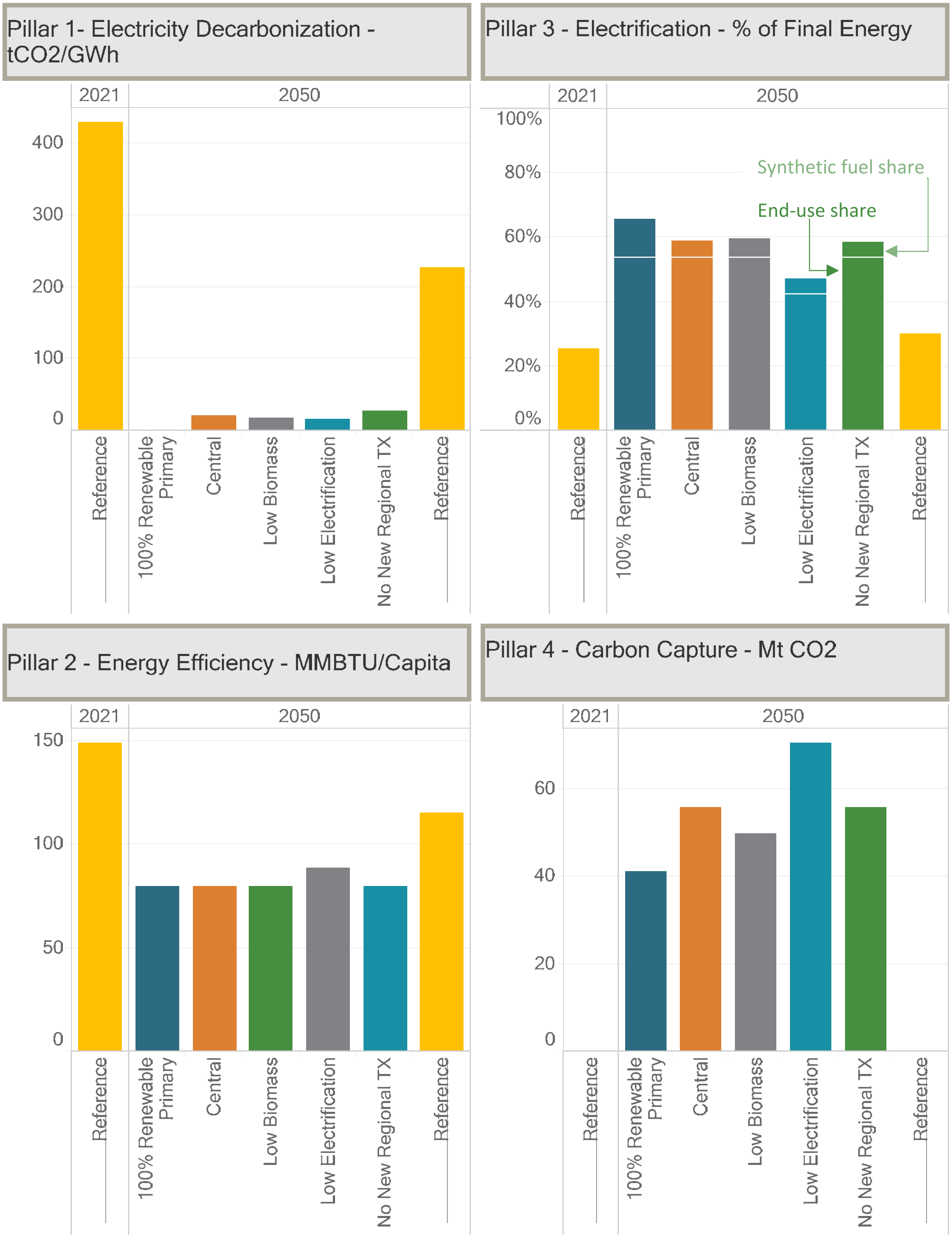
Category	Constraint
2021-2050 Average annual rate of CO_2 emission reduction	6%
2021-2050 maximum cumulative fossil fuel CO_2 (billion metric tonnes)	70.06
2050 Maximum fossil fuel CO_2 (million metric tonnes)	830
2050 Assumed land sink (million metric tonnes)	1080
2050 Maximum net CO_2 (million metric tonnes)	-250

The scenarios were modeled using two analysis tools developed for this purpose, EnergyPATHWAYS and RIO. As described in the Appendix, these are sophisticated models with a high level of sectoral, temporal, and geographic detail, which ensure that the scenarios account for factors such as the inertia of infrastructure stocks and the hour-to-hour dynamics of the electricity system, separately in each of sixteen electric grid regions of the U.S. The changes in energy mix, emissions, and costs for the five scenarios were calculated relative to a high-carbon baseline based on the *AEO*.

Florida Energy System Results

Energy decarbonization in Florida rests on four principal strategies (‘four pillars”) as shown in Figure ES2 for Florida: (1) electricity decarbonization, the reduction in emissions intensity of electricity generation by about 95% below today’s level by 2050; (2) energy efficiency, the reduction in energy required to provide energy services such as heating and transportation, by about 50% below today’s level; (3) electrification, converting end-uses like transportation and heating from fossils fuels to low-carbon electricity, so that electricity doubles its share from 25% of current end uses to approximately 50% in 2050; and (4) the use of captured carbon that would otherwise be emitted from power plants and industrial facilities rising from nearly zero today to as much as 70 million metric tonnes in 2050. This captured carbon is either directly sequestered in-state or is a component (along with hydrogen) of synthetic renewable fuels consumed in the State.

Figure ES2 Four pillars of deep decarbonization – Central scenario – Florida[1]



Achieving this transformation by mid-century requires an aggressive deployment of low-carbon technologies. Key actions include retiring all existing coal power generation, approximately doubling electricity generation, primarily with solar and wind power, and electrifying virtually all passenger vehicles and natural gas uses in buildings. It also includes creating new types of infrastructure, namely large-scale industrial facilities for carbon capture and storage, the production of gaseous and liquid biofuels with zero net lifecycle CO_2, and the production of hydrogen from water electrolysis using excess renewable electricity.

Figure ES3 (Florida) shows that all scenarios achieve the steep reductions in net fossil fuel CO_2 emissions required to reach the cumulative emissions targets. These include four scenarios that are limited in the availability of one key decarbonization strategy. This indicates that the feasibility of reaching the emissions goals is robust due to the availability of alternative strategies. At the same time, the more limited scenarios are, the more difficult and/or costly they are relative to the base scenario with all options available. Severe limits in two or more strategies could make the emissions goals very difficult to achieve in the mid-century time frame, but these combinations were not analyzed here.

Figure ES3 2021-2050 CO_2 emissions for the scenarios in this study – Florida

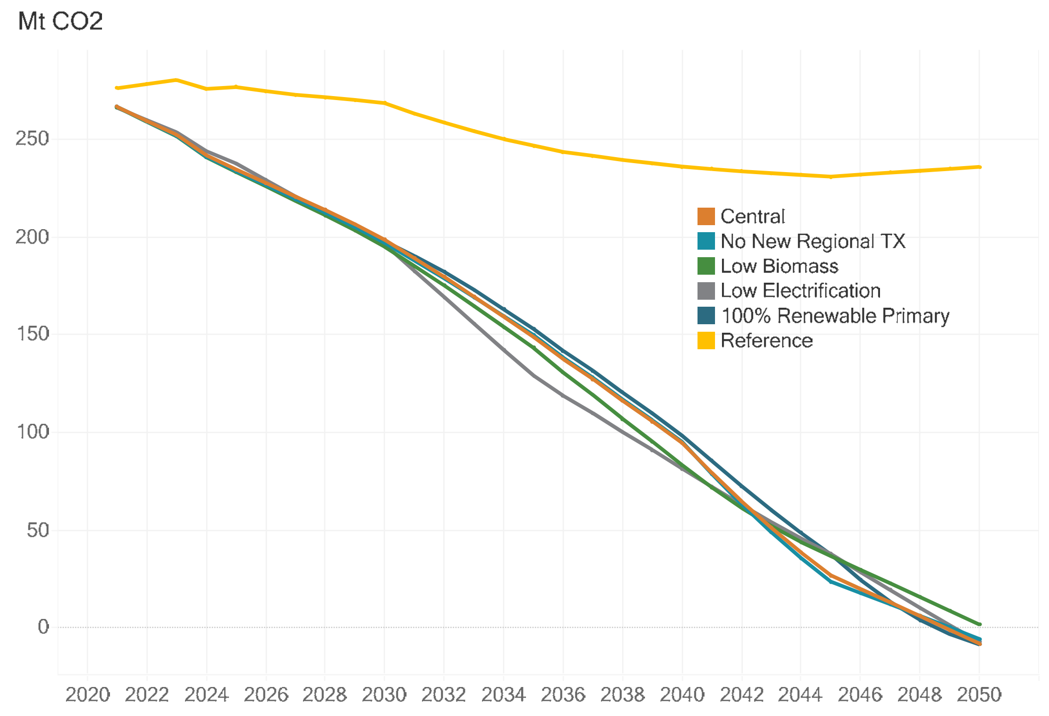
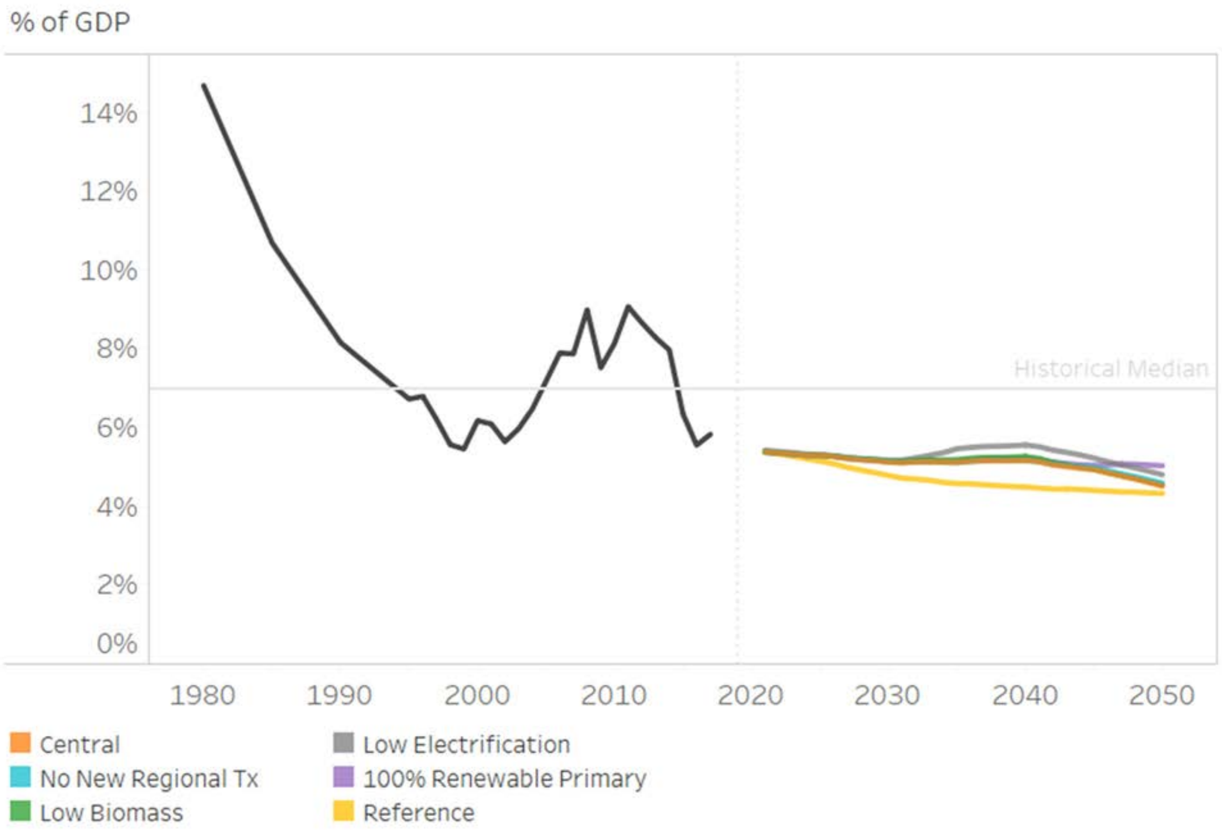


Figure ES4 shows historical and projected energy system costs as a share of State GDP. Decarbonized energy system costs are not out of line with historical energy costs in Florida in any scenario and even with decarbonization, energy system costs are anticipated to decline as a share of GDP. The highest cost scenario is the 100% Renewable Primary pathway due to the emphasis on displacing instead of offsetting (through geologic sequestration) even the lowest-cost fossil in 2050. The lowest cost scenario is in the Central scenario, which allows for the most flexibility in terms of key decarbonization strategies. These costs exclude any potential economic benefits of avoided climate change or pollution, energy price predictability, or energy security which could equal or exceed the net costs shown here. In addition, the analysis does not incorporate any behavioral changes or energy service demand reductions (e.g., lower vehicle miles traveled or modal shifting), but these would contribute to lower costs, lower infrastructure needs and could improve quality of life in ways not quantified by this analysis.

Figure ES4. Total energy system costs as percentage of GDP, historical and projected for Florida



Key Actions by Decade

This study identifies key actions that are required in each decade from now to mid-century in order to achieve net negative CO_2 emissions by mid-century, at least cost (the Central scenario), while delivering the same level of energy services projected in the U.S. Department of Energy *Annual Energy Outlook*. Such a list inherently relies on current knowledge and forecasts of unknowable future costs, capabilities, and events, yet a long-term blueprint remains essential because of the long lifetimes of infrastructure in the energy system and the carbon consequences of investment decisions made today. As events unfold, technology improves, energy service projections change, and understanding of climate science evolves, energy system analysis and blueprints of this type must be frequently updated.

From a policy perspective, this provides a list of goals that policy needs to accomplish, for example the deployment of large amounts of low carbon generation, rapid electrification of vehicles, buildings, and industry, and building extensive carbon capture, biofuel, hydrogen, and synthetic fuel synthesis capacity. Some of the policy challenges that must be managed include: land use tradeoffs related to carbon storage in ecosystems and siting of low carbon generation and transmission; electricity market designs that maintain natural gas generation capacity for reliability while running it very infrequently; electricity rate designs that reward demand side flexibility in high-renewable electricity systems and encourage the development of complementary carbon capture and fuel synthesis industries; coordination of planning and policy across sectors that previously had little interaction but will require much more in a low carbon future, such as transportation and electricity; coordination of planning and policy across jurisdictions, both vertically from local to state to federal levels, and horizontally across neighbors and trading partners at the same level; mobilizing investment for a rapid low carbon transition, while ensuring that new investments in long-lived infrastructure are made with full awareness of what they imply for long-term carbon commitment; and investing in ongoing modeling, analysis, and data collection that informs both public and private decision-making. These topics are discussed in more detail in *Policy Implications of Deep Decarbonization in the United States.*

The key actions listed below apply for the U.S., and, although specific to the Central scenario, they are generally applicable to all 350 ppm-compatible scenarios barring the specific implementation challenges assumed in each scenario. For the State of Florida, decarbonizing its energy system consistent with the U.S.'s pathway is also feasible. The State's relative position as an energy consumer and producer doesn't dictate serious deviations away from the Country's overall pathway, and we have provided additional detail specific to Florida below.

2020s

- Begin large-scale electrification in transportation and buildings
- Switch from coal to gas in electricity system priority dispatch and retire coal assets
- Ramp up construction of renewable generation and reinforce transmission
- Allow strategic replacement of natural gas power plants to support rapid deployment of low-carbon generation. These plants must be built with the understanding that they will run very infrequently to provide capacity, not as they are operated today.
- Maintain existing nuclear fleet
- Pilot new technologies that will need to be deployed at scale after 2030
- Stop developing new infrastructure to transport and process fossil fuels
- Begin building carbon capture for large industrial facilities

2030s

- Maximum build-out of renewable generation
- Attain near 100% sales share for key electrified technologies (e.g. EVs) in technology and building heating
- Begin large-scale production of biodiesel and bio-jet fuel
- Large scale carbon capture on industrial facilities
- Build out electrical energy storage
- Deploy fossil power plants capable of 100% carbon capture if they exist
- Maintain existing nuclear fleet
- Continue to reduce generation from gas-fired power plants

2040s

- Complete electrification process for key technologies, achieve 100% stock penetration
- Produce large volumes of hydrogen for use in freight trucks and fuel production
- Use synthetic fuel production to balance and expand renewable generation
- Fully deploy biofuel production with carbon capture
- Further limit gas generation to infrequent periods when needed for system reliability

1. Introduction

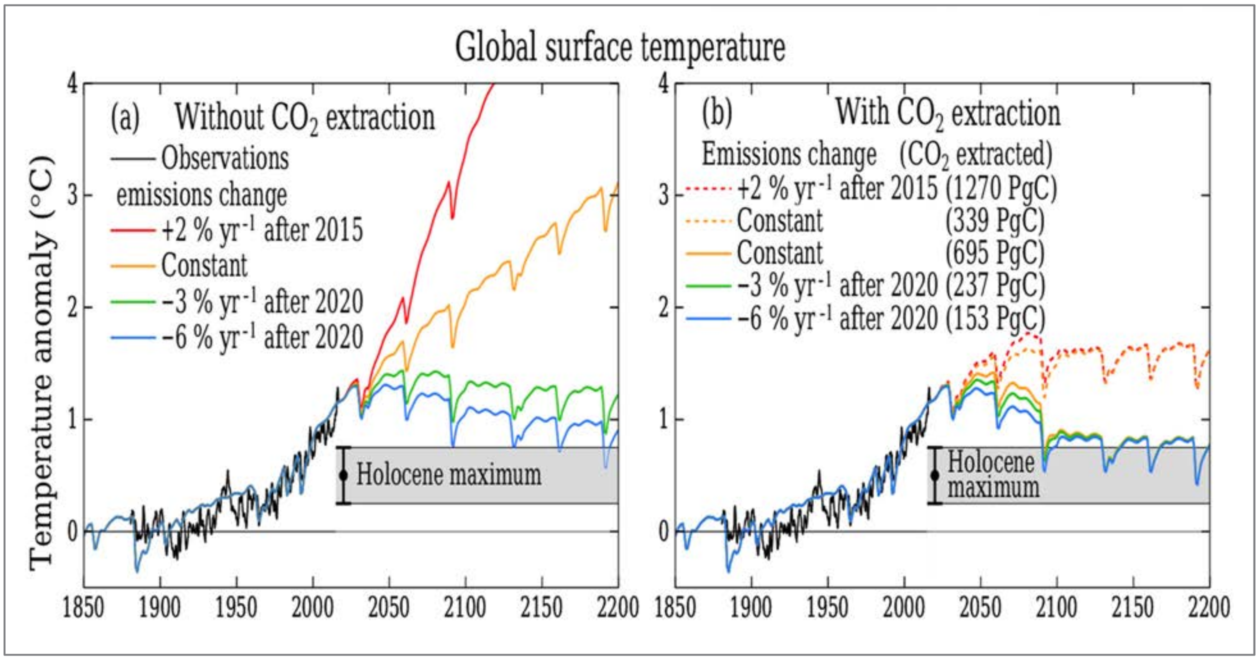
This report builds on previous analytical work in *350 ppm Pathways for the United* States (Haley et al. 2019) that described the changes in the U.S. energy system that, in concert with related actions in land use, will be required to reduce U.S. carbon dioxide (CO_2) emissions to a level consistent with returning atmospheric concentrations to 350 parts per million (350 ppm) by 2100, achieving net negative CO_2 emissions by mid-century, and limiting end-of-century global warming to 1°C. This study focuses on the State of Florida within that national context and identifies concrete actions needed to contribute to this nationwide decarbonization strategy. The study also builds on the previous work - *Pathways to Deep Decarbonization in the United States* (J. Williams et al. 2014) and *Policy Implications of Deep Decarbonization in the United States* (James H. Williams, Benjamin Haley, and Ryan Jones 2015) - which examined the requirements for reducing GHG emissions by 80% below 1990 levels by 2050 (“80 x 50”).

Over the last decade, as CO_2 concentrations have risen toward and then passed 400 ppm, the question of what constitutes a “safe” concentration relative to dangerous anthropogenic impacts on the climate system has become an urgent focus of the scientific community. A recent report by the Intergovernmental Panel on Climate Change emphasizes the potential risks associated with allowing 1.5°C warming above pre-industrial temperatures: “warming of 1.5°C is not considered ‘safe’ for most nations, communities, 28 ecosystems and sectors and poses significant risks to natural and human systems” (Intergovernmental Panel on Climate Change 2018). The U.S. Government’s Fourth National Climate Assessment documents an acceleration of climate change impacts already underway with 1.0°C warming above pre-industrial temperatures (U.S. Global Change Research Program 2017). Studies using global climate models and integrated assessment models (IAMs) indicate that limiting warming to a short-term peak of 1.5°C will require reaching net-zero emissions of CO_2 globally by mid-century or earlier (Intergovernmental Panel on Climate Change 2018). Reflecting these findings, a number of jurisdictions around the world have already announced more aggressive emissions targets, for example California’s recent executive order calling for the State to achieve carbon neutrality by 2045 and negative net emissions thereafter (State of California 2018).

Climate studies have concluded that the best chance of avoiding the most catastrophic and irreversible climate change impacts requires CO_2 concentrations to be reduced to 350 ppm or less by the end of the 21st century (Veron et al. 2009; Hansen et al. 2013; 2016a). The emission trajectories associated with reaching 350 ppm have lower allowable emissions ("emissions budgets") in the 21st century than comparable trajectories that would peak at 2.0 or 1.5 °C. These trajectories are intended to minimize the length of time the global temperature increase remains above 1°C in order to prevent the initiation of irreversible climate feedbacks indicated by paleoclimate evidence. In a recent article, Hansen and colleagues describe several possible trajectories for fossil fuel emission reductions that, in combination with specified levels of atmospheric CO_2 removal, could achieve 350 ppm by 2100, thereby restoring the energy imbalance of the Earth (Hansen et al. 2016b).

In this study we modeled pathways – the sequence of technology and infrastructure changes – for the United States that result in net negative CO_2 emissions before mid-century and that follow a global emissions trajectory consistent with a return to 350 ppm globally by 2100 (Figure 1). The scenarios modeled are a 6% per year reduction in net fossil fuel CO_2 emissions after 2020. These equate to a cumulative emissions limit for the U.S. during the 2021 to 2050 period of 70.06 billion metric tonnes of CO_2. (For comparison, current U.S. CO_2 emissions exceed 5 billion metric tonnes per year.) The emissions reductions in both scenarios must be accompanied by global increased extraction of CO_2 from the atmosphere of 153 Pg(C) above and beyond the current global CO_2 sink from 2020 to 2100. In our scenarios, the removal of 153 Pg(C) is assumed to be accomplished through land-based negative emissions technologies ("land NETs") (Griscom et al. 2017). These numbers imply an increase in the current global land sink of about 60% (Quéré et al. 2018). Additional extraction of atmospheric CO_2 using technological negative emissions technologies ("tech NETs"), meaning direct air capture (DAC) and bioenergy with carbon capture and storage (BECCS), is deployed in some of our scenarios. DAC is the removal of diffuse CO_2 directly from the air, while BECCS involves capture of concentrated streams of CO_2 from the effluent at industrial facilities that use biofuels. The captured CO_2 is stored in geologic structures and/or used as a carbon feedstock for electric fuel production.

Figure 1 Global surface temperature and CO2 emissions trajectories[2].



Our study differs from recent IAM studies of 1.5°C in that it has a tighter emissions budget, concentrates on concrete actions at a regional and State level, and provides a greater level of technical detail on the transformation to a low carbon economy, including detailed treatment of costs by sector (Rogelj et al. 2015).

The goal of this study is to understand how realistic 350 ppm-compatible scenarios would concretely change Florida' energy system and industrial fossil fuel use. In addition to continuing to develop our understanding of the 350 ppm target for the U.S., the principal additional research questions addressed by this study are the following:

1. What concrete actions are necessitated in the State of Florida to achieve emissions reductions consistent with national 350 ppm pathway achievement?

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[2] The solid blue line in (b) illustrates a 350 ppm trajectory based on 6% per year reduction in net fossil fuel CO_2 emissions combined with global extraction of 153 PgC from the atmosphere. Reprinted from Hansen, *ESD*, 2017.

2. What are the key national conditions (electrification levels, biomass availability, restriction on the use of fossil and nuclear primary energy, and limited ability to construct new inter-regional transmission) that may influence decisions in Florida?

3. What are the costs to Florida of achieving 350 ppm-comaptible pathways?

To answer these questions, we developed five deep decarbonization scenarios using two models built for this purpose, EnergyPATHWAYS and RIO. These are sophisticated analysis tools with a high level of sectoral, temporal, and geographic granularity. We use these tools to rigorously assess the technical feasibility and cost of rapidly reducing CO_2 emissions through the deployment of low carbon technologies and NETs, year by year from the present out to 2050.[3] Changes in energy mix, technology stocks, emissions, and costs for the 350 ppm scenarios were calculated relative to a high-carbon baseline drawn from the Department of Energy's *Annual Energy Outlook (AEO)*, the U.S. government's official long-term energy forecast.

The concrete actions necessitated in Florida are an output of our modeling tools. Their richness, both in terms of the granularity referenced above as well as their technological detail provide the basis of a concrete blueprint for the region to achieve deep levels of decarbonization of their economy.

The second research question reflects the reality that many of the decisions Florida will have to make in decarbonizing their energy system will be informed and affected by a broader national context. Achievable levels of electrification and biomass deployment are likely to be influenced by national decisions; restrictions on the use of fossil fuels as a primary energy source is also likely to be influenced by national policy; and the ability to construct large inter-regional transmission corridors is a multi-region question. Therefore, we investigate these questions as variations off of our Central scenario.

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[3] Evolved has worked with the state of New Jersey and is currently working with the states of Massachusetts and Washington to analyze plans for decarbonization.

In order to answer our third question, we calculate the costs of implementing this transition in the United States as a whole and for the State of Florida over the next three decades, with detailed year-by-year modeling of the energy economy. The 350 ppm-consistent scenarios are compared to a high-carbon scenario based on the *AEO.* This comparison is made “apples-to-apples” by ensuring that the energy services provided in the 350 ppm scenarios are the same as those provided in the *AEO*, and that the cost analysis reflects the differences in capital and operating costs for the low carbon technologies used in the 350 ppm scenarios relative to the business-as-usual technologies in the *AEO.*

The temporal, spatial, and sectoral detail in our modeling provides unique insights into how energy is supplied and used, and how carbon is managed throughout the U.S. economy on a 350 ppm pathway. It improves current understanding of how energy and carbon removal interact technically, and how fossil fuel emissions, land NETs, and tech NETs trade off economically. Interactions between these different components of the energy-and-emissions system become increasingly important with tighter emissions constraints, so we account for them separately to avoid confusion and double-counting. Each of the scenarios demonstrates a different mode of utilizing infrastructure, balancing the electricity grid, and producing fuels as a single interactive system for least cost energy production.

This study does not model land NETs, instead stipulating the global 100 Pg(C) and 153 Pg(C) scenarios mentioned above as boundary conditions for our scenarios. Some credible global evaluations indicate that achieving 153 Pg(C) of land-based C sequestration is potentially feasible (Griscom et al. 2017). Achieving this level of sequestration will require changes in current policy and practices that not only improve carbon uptake but address such concerns as indigenous land tenure and competition with food production. Recent assessments of U.S. land-based negative emission potential indicate that a significant share of the required global land NETs, 20 Pg(C) or more of additional land sinks in the 21st century, is possible in the U.S. (Fargione et al. 2018).

For this analysis, an enhanced land sink in the United States on average 50% larger than the current annual sink of approximately 700 million metric tonnes was assumed.[4] This would require additional sequestration of 25-30 billion metric tonnes of CO_2 from 2020 to 2100. The present study does not address the cost or technical feasibility of this assumption but stipulates it as a plausible value for the purpose of calculating an overall CO_2 budget, subject to revision as better information becomes available.

The costs we calculated in this study include the net system cost of the transformation in the supply and end use of energy, including tech NETs. They do not include the cost of land NETs or the mitigation of non-CO_2 greenhouse gases. Macroeconomic effects are not explicitly considered. There are a variety of other benefits ("co-benefits") of avoided climate change that are not within the scope of this study, including impacts on human health, ecosystems, the built environment, and economic productivity. Such co-benefits are addressed in other studies[5].

The remainder of this report is organized as follows: Chapter 2, Study Design, including descriptions of the EnergyPATHWAYS and RIO modeling platforms, key data sources used, and the scenarios studied; Chapter 3, Results, including emissions, energy supply and demand, infrastructure, costs, and sector-specific results; and Chapter 4, Conclusions, including key actions by decade. The Appendix describes the scenarios and modeling methodology in detail.

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[4] U.S. EPA, *Inventory of U.S. Greenhouse Gas Emissions and Sinks 1990-2016,* available at https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2016

[5] Union of Concerned Scientists, *Underwater: Rising Seas, Chronic Floods, and the Implications for U.S. Coastal Real Estate*, available at https://www.ucsusa.org/sites/default/files/attach/2018/06/underwater-analysis-full-report.pdf

2. Study Design

2.1. Scenarios

This analysis explores the technical feasibility and cost of achieving a 350 ppm-compatible trajectory in the United States, transforming the energy system and achieving significant CO_2 emissions reductions by mid-century. All scenarios hit the same cumulative and annual emissions constraints, which are described in Table 1 below:

Table 1 Scenario definitions and emissions limits

Category	Constraint
2021-2050 Average annual rate of CO_2 emission reduction	6%
2021-2050 maximum cumulative fossil fuel CO_2 (billion metric tonnes)	70.06
2050 Maximum fossil fuel CO_2 (million metric tonnes)	830
2050 Assumed land sink (million metric tonnes)	1080
2050 Maximum net CO_2 (million metric tonnes)	-250

This is accomplished by developing a set of scenarios, subject to a variety of constraints (required outcomes and allowable actions), in the EnergyPATHWAYS and RIO models. In total we developed five 350 ppm-compatible scenarios: a core scenario called the Central scenario, which is the least constrained, and four variants on this scenario to address potential alternatives for the State of Florida depending on differing national and local concerns. The decarbonization scenarios are described below.

1. Central: This is our least-constrained scenario designed to assess an all-options approach to decarbonization.
2. Low Biomass: This scenario assesses the robustness of our decarbonization strategy to limited zero-carbon biomass resources with a 50% reduction in the development of new biomass feedstocks.

3. Low Electrification: This scenario assesses the robustness of our decarbonization strategy to a twenty-year delay in the adoption of electrified demand-side technologies (electric vehices, heat pumps, etc.)

4. 100% Renewable Primary: This scenario restricts the use of all non-renewable primary energy sources (fossil and nuclear) to zero by 2050. The economy derives all of its energy from biomass, wind, solar, hydro, and geothermal sources.

5. No New Regional Transmission (TX): This scenario limits new development of inter-regional transmission across the U.S. This restricts the ability of regions to access higher quality renewables.

Although the modeling tools, approach and a subset of the scenarios are the same or similar to the May 2019 report, there are key analytical differences between this study and the May 2019 report that are described in the table below.

Key Updates Between April 2020 and May 2019 Analyses

Category	Description	Impact
End-use electrification	Continued and anticipated progress in battery costs has lowered the costs of end-use electrification, which has a significant impact on estimates of overall net costs.	Reduced costs of transportation electrification and reduced overall costs of decarbonization.
Hydrogen for end-use demand	Previous analysis relied on hydrogen exclusively as a feedstock for synthetic fuels. Subsequent research and analyses have identified high value direct hydrogen applications in freight applications (on-road and off-road) and process heating. Additionally, we have decomposed the need for hydrogen from chemical feedstocks demand values the AEO, allowing for substitution of green hydrogen.	Lower demand for liquid fossil substitutes reduces overall demand for biomass as a feedstock as well as reducing dependence on DAC in Low Biomass and Low Electrification scenarios.

Geographic granularity	Increased number of regions, including: (a) separating the northwest into the pacific northwest and Utah/Nevada; (b) separating the Midwest into two regions; (c) separating the Southeast; and (d) including Alaska and Hawaii separately.	Renewable resource endowments are more accurately reflected. Specifically, limited deployment of onshore wind in the Southeast, with a higher reliance on offshore wind.
Wind performance	Current analysis relies on NREL's Annual Technology Baseline 2019, which assumes wind technology cost reductions and improved performance (i.e., capacity factor) projections that are more optimistic than its predecessor.	Onshore wind is economical in more locations than it previously was, and offshore wind plays a large role particularly beginning in the 2040s. This has outcompeted nuclear economically in regions where our scenarios allow it to be built. These results are sensitive to availability of onshore wind resources as well as modeled costs of new wind vs. new nuclear and so should be interpreted as indicative of future resource competition but not declarative.
Expanded conversion technology options	More comprehensive bio and synthetic fuel representations allow for displacement of liquefied petroleum gas; residual fuel oil; petroleum coke; coal; and other petroleum with zero-carbon alternatives.	Allows for the modeling of 100% renewable energy economy, without fossil or nuclear primary energy.

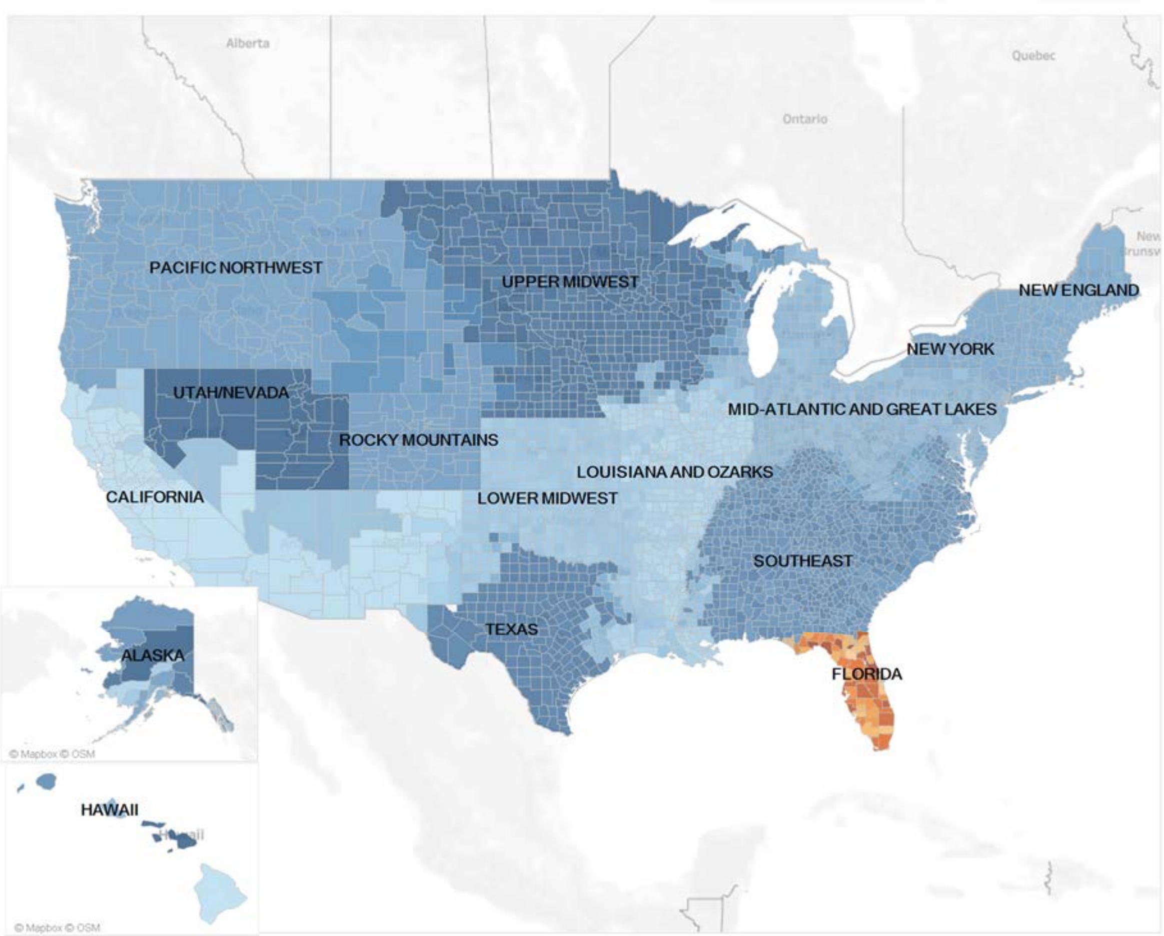
2.2. Modeling Methods and Data Sources

This section summarizes the modeling methods used in this analysis. Further detail on all modeling tools and data sources is available in the Technical Appendix to this report.

2.2.1. EnergyPATHWAYS

EnergyPATHWAYS is a bottom-up energy sector scenario planning tool. It performs a full accounting of all energy, cost, and carbon flows in the economy and can be used to represent both current fossil-based energy systems and transformed, low-carbon energy systems. It includes a granular technology representation with over 300 demand-side technologies and 100 supply-side technologies in order to represent all producing, converting, storing, delivering, and consuming energy infrastructure. It also has very high levels of regional granularity, with detailed representations of existing energy infrastructure (e.g., power plants, refineries, biorefineries, demand-side equipment stocks) and resource potential. The model is geographically flexible, with the ability to perform State-level and even county-level analysis. For this report, the model was run on a customized geography based on an aggregation of the EPA's eGRID (U.S. Environmental Protection Agency 2018) geographies, as shown in Figure 2. The aggregation was done for computational purposes to reduce the total number of zones to a manageable number. EnergyPATHWAYS and its progenitor models have been used to analyze energy system transformations at different levels, starting in California (J. H. Williams et al. 2012) then expanding to U.S. wide analysis (J. H. Williams et al. 2012; Risky Business Project 2016; Jadun et al. 2017) and other state analyses conducted for governments (New Jersey, Massachusetts (ongoing), Washington (ongoing)). The model has also been used internationally in Mexico and Europe. In each context, it has been successful in describing changes in the energy system at a sufficiently granular level to be understood by, and useful to, sectoral experts, decision makers, and policy implementers.

Figure 2 Regional granularity of analysis



2.2.2. Regional Investment and Operations (RIO) Platform

EnergyPATHWAYS, described in the previous section, focuses on detailed and explicit accounting of energy system decisions. These decisions are made by the user as inputs to the model in developing scenarios. The Regional Investment and Operations (RIO) platform operates differently, finding the set of energy system decisions that are least cost. The rationale for using two models in this study is that energy demand-side decisions (e.g. buying a car) are typically unsuited to least cost optimization, because they are based on many socioeconomic factors that do not necessarily result from optimal decisions and are better examined through scenario analysis. However, RIO's strength is in optimization of supply-side decisions where least cost economic frameworks for decision making are either applied already (e.g., utility integrated resource planning) or are regarded as desirable in the future. RIO is therefore complementary to EnergyPATHWAYS. We use RIO to co-optimize fuel and supply-side infrastructure decisions within each scenario of energy demand and emissions constraints. The resulting supply-side decisions are then input into EnergyPATHWAYS for energy, emissions, and cost accounting of these optimized energy supplies. RIO is the first model we are aware of to integrate the fuels and electricity directly at a highly resolved temporal level, resulting in a co-optimization of infrastructure that is unique and critical for understanding the dynamics of low-carbon energy systems.

RIO works with the same geographic representation as EnergyPATHWAYS. Each zone contains: existing infrastructure; renewable resource potentials and costs; fuel and electricity demand (hourly); current transmission interconnection capacity and specified expansion potential and costs; biomass resource supply curves; and restrictions on construction of new nuclear facilities.

2.2.3. Key References and Data Sources

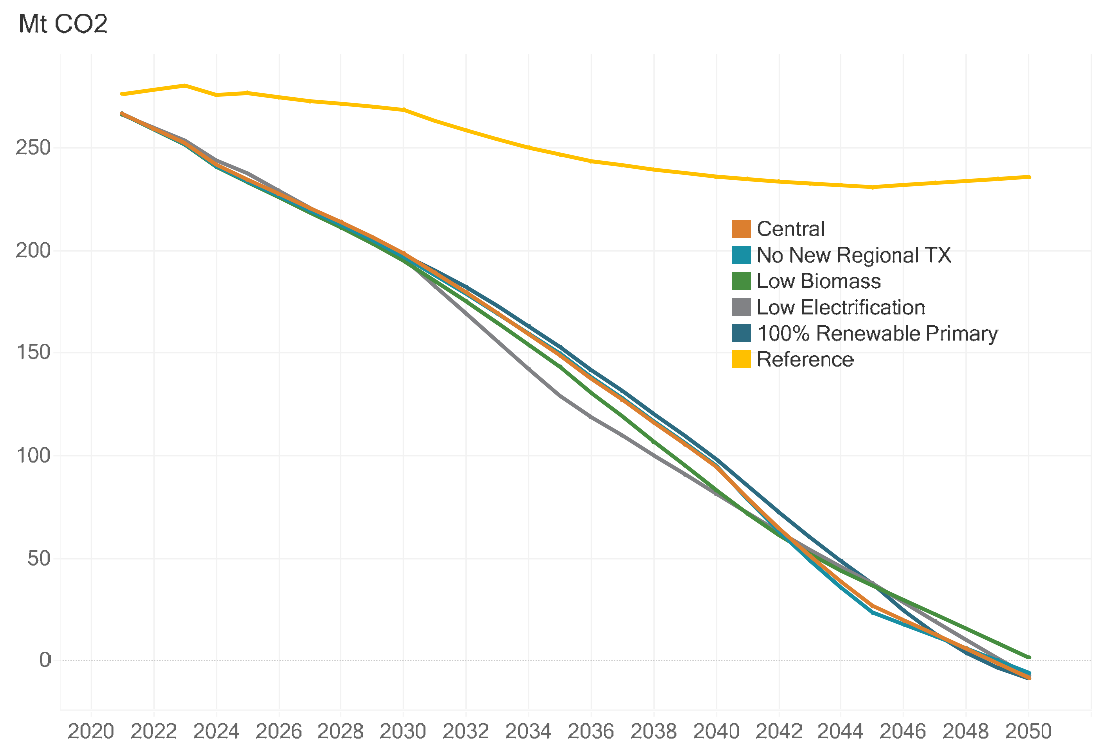
The parameterization of EnergyPATHWAYS and RIO to perform U.S. economy-wide decarbonization analysis requires a wide variety of inputs and data sources. We describe the full breadth of these data sources in the Appendix. There are, however, a few principal sources that are central to understanding and contextualizing our results. First and foremost, we utilized the 2019 *Annual Energy Outlook* (U.S. Energy Information Administration 2019), which includes detailed long-term estimates of economic activity, energy service demand, fuel prices, and technology costs. This allows us to compare our results to the principal energy forecast provided by the United States Government. We derive renewable costs and resource potentials from National Renewable Energy Laboratory sources including the 2019 Annual Technology Baseline (National Renewable Energy Laboratory 2019) and input files to their ReEDS Model (Eurek et al. 2017). We take biomass resource potential and costs the U.S. Department of Energy's Billion Tons Study Update (Langholtz, Stokes, and Eaton 2016). In all scenarios we have sought to use thoroughly vetted public sources, which tend to be conservative about cost and performance estimates for low-carbon technologies.

3. Results

3.1. Emissions

Emissions trajectories for energy and industrial (E&I) CO_2 emissions in Florida are shown below for the 350 ppm scenarios. Instead of relying on a Florida-specific emissions target, the emissions reductions in Florida are a result of a U.S.-wide optimization for a 350 ppm pathway. Florida's emissions[6] must follow a similar trajectory to those of the United States as a whole. Net E&I emissions approach zero by 2050 in all scenarios, with the 100% Renewable Primary scenario having negative E&I emissions by 2050.

Figure 3 CO2 Emissions Trajectories – Florida



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[6] Emissions are accounted for on a consumption basis. This means that upstream emissions associated with fuels refining and out-of-State electricity generation (imports) are allocated to Florida.

In all other scenarios, some gross fossil emissions are offset by geologic and product sequestration. In all scenarios, we find it to be technically feasible, from the standpoint of a reliable energy system that meets all forecast energy service demand, to reach emission levels consistent with the 350 ppm target.

Figure 4 CO2 Emissions by Final Energy/Emissions Category – Florida

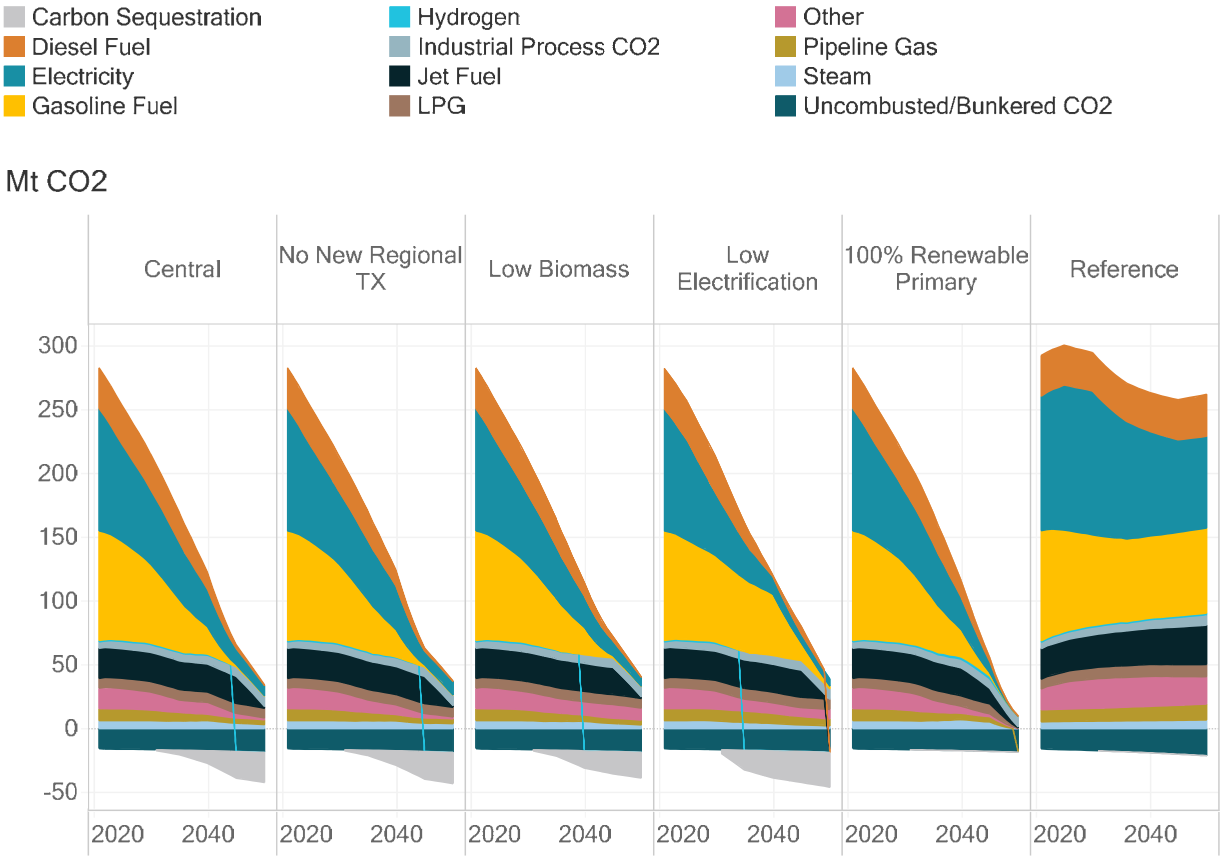
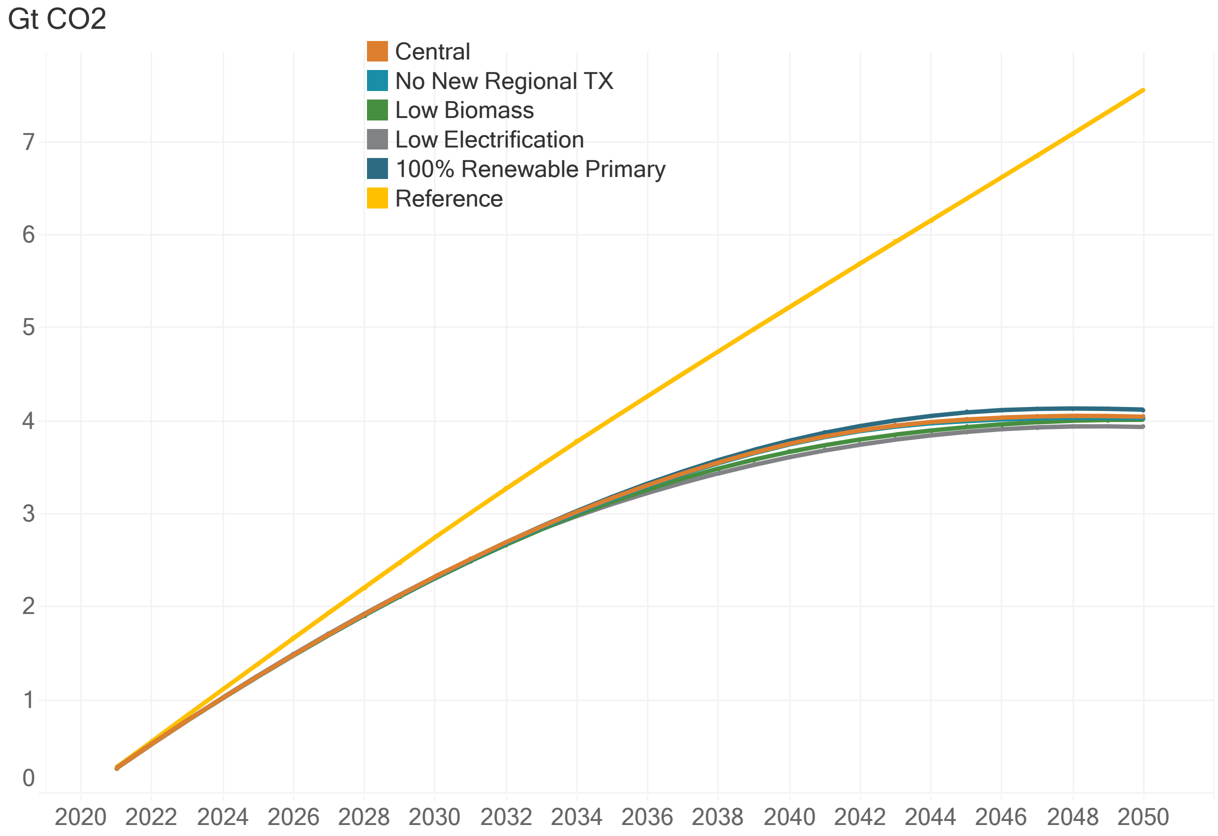


Figure 5 Cumulative CO2 emissions trajectories – Florida



3.2. System Transformation

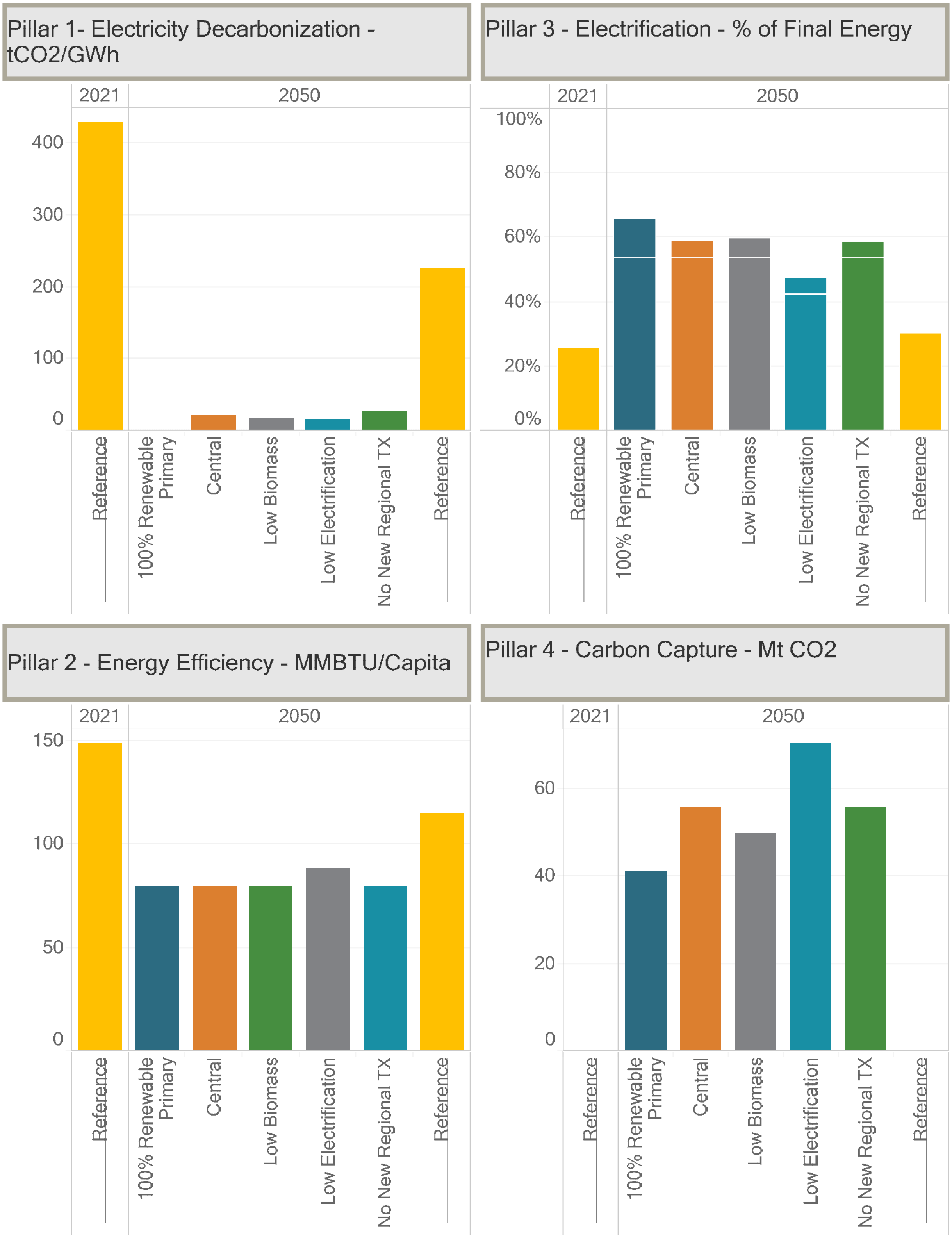
3.2.1. Four Pillars

Deep decarbonization analyses have relied on three primary strategies for achieving emissions targets: (1) electricity decarbonization, the reduction in the emissions intensity of electricity generation; (2) energy efficiency, the reduction in units of energy needed to supply energy service demands; and (3) electrification, the conversion of end-uses from fuel to electricity. These have been referred to as the “three pillars” and the use of these strategies to achieve deep decarbonization is a robust finding across many jurisdictions both domestically and internationally. Under our scenarios, which assume EIA projections for economic growth and increased consumption of “energy services”, achieving 350 ppm requires the inclusion of a fourth pillar, carbon capture, which includes the capture of otherwise emitted CO_2 from power plants, industrial facilities, and biorefineries. It also includes the use of direct-air capture facilities to capture carbon from the atmosphere. Once captured, this CO_2 can either be utilized in the production of synthesized electric fuels or it can be sequestered. Both strategies are used extensively in the scenarios analyzed here.

Figure 6**Error! Reference source not found.** below shows the four pillars of decarbonization employed in the Central scenario. The emissions intensity of electricity has declined to less than 30 tonnes/GWh in 2050 in all secnarios from over 400 tonnes/GWh in 2021 in the Reference scenario. The 100% Renewable Primary scenario has truly carbon-free electricity emissions, with all generation from thermal plants using carbon capture technology or consuming zero-carbon fuel substitutes (biofuels, hydrogen, or synthetic methane).

Limited heating demands in Florida means that overall demand per-capita is below the national average in 2050 (88 MMBTU/capita – Low Electrification; 79 MMBTU/capita – All Other DDP scenarios). Direct electrification share exceeds 50% in 2050 in all but the Low Electrification scenario, with limited industrial energy demands requiring residual fuel usage. Florida utilizes up to 70 tonnes of captured CO_2 (in-state or out-of-state) by 2050, with the volumes depending on available biomass (Low Biomass), progress in electrification (Low Electrification), and limits to fossil energy use (100% Renewable Primary).

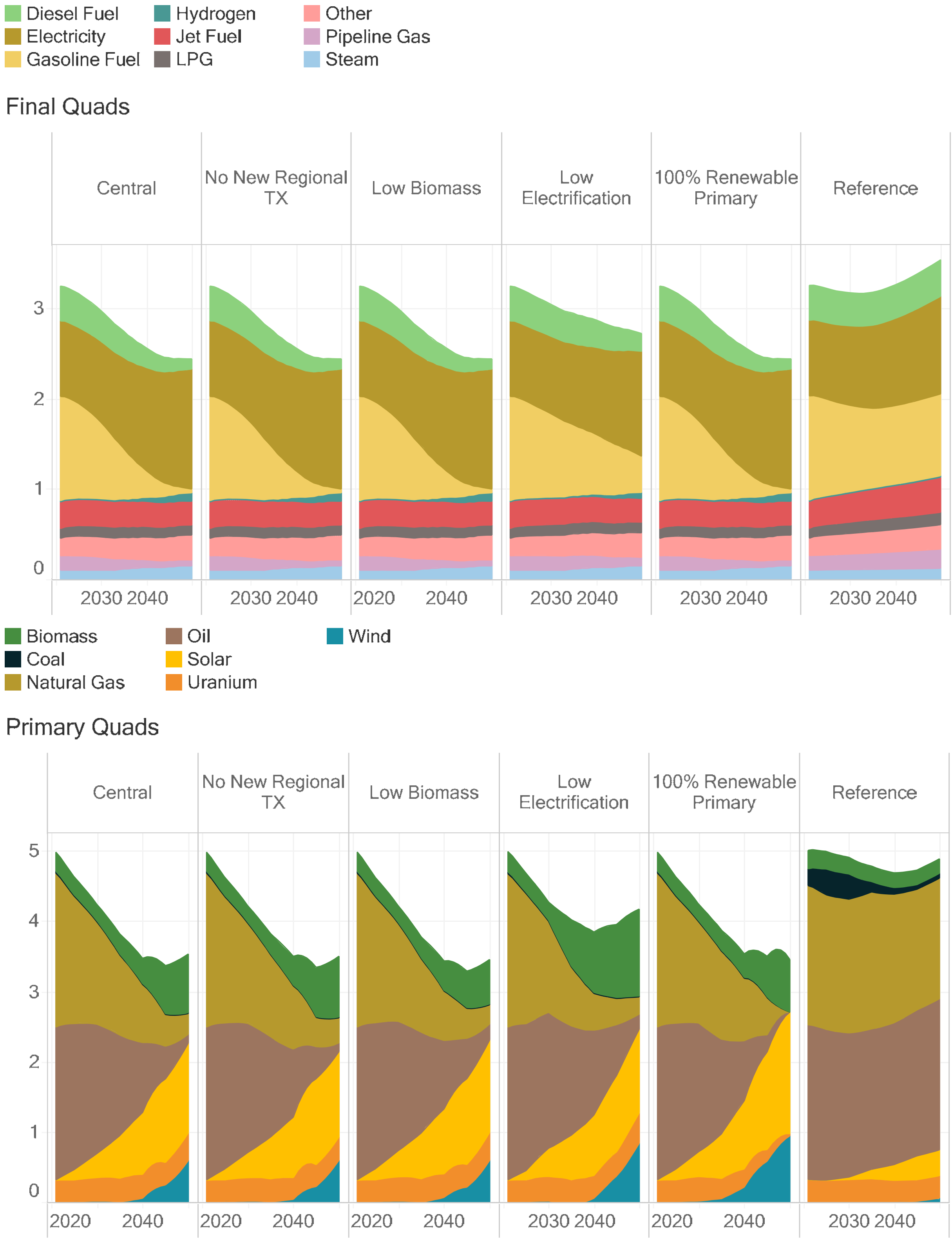
Figure 6 Four pillars of deep decarbonization – Florida



3.2.2. Energy Flow Transformations

Transformation of the energy system occurs on both the demand and supply side of the system. Final energy consumption rapidly transitions away from direct combustion of fossil fuels towards the use of electricity (e.g. from gasoline powered vehicles to EVs) and other low carbon energy carriers, accompanied by a supply-side transition from primarily fossil sources of energy towards zero-carbon sources such as wind, solar, biomass, or uranium. Figure 7 shows these simultaneous transitions, with the top panel showing final energy demand and the bottom panel showing primary energy supply.

Figure 7 Final and primary energy demand for all scenarios from 2021 – 2050 – Florida

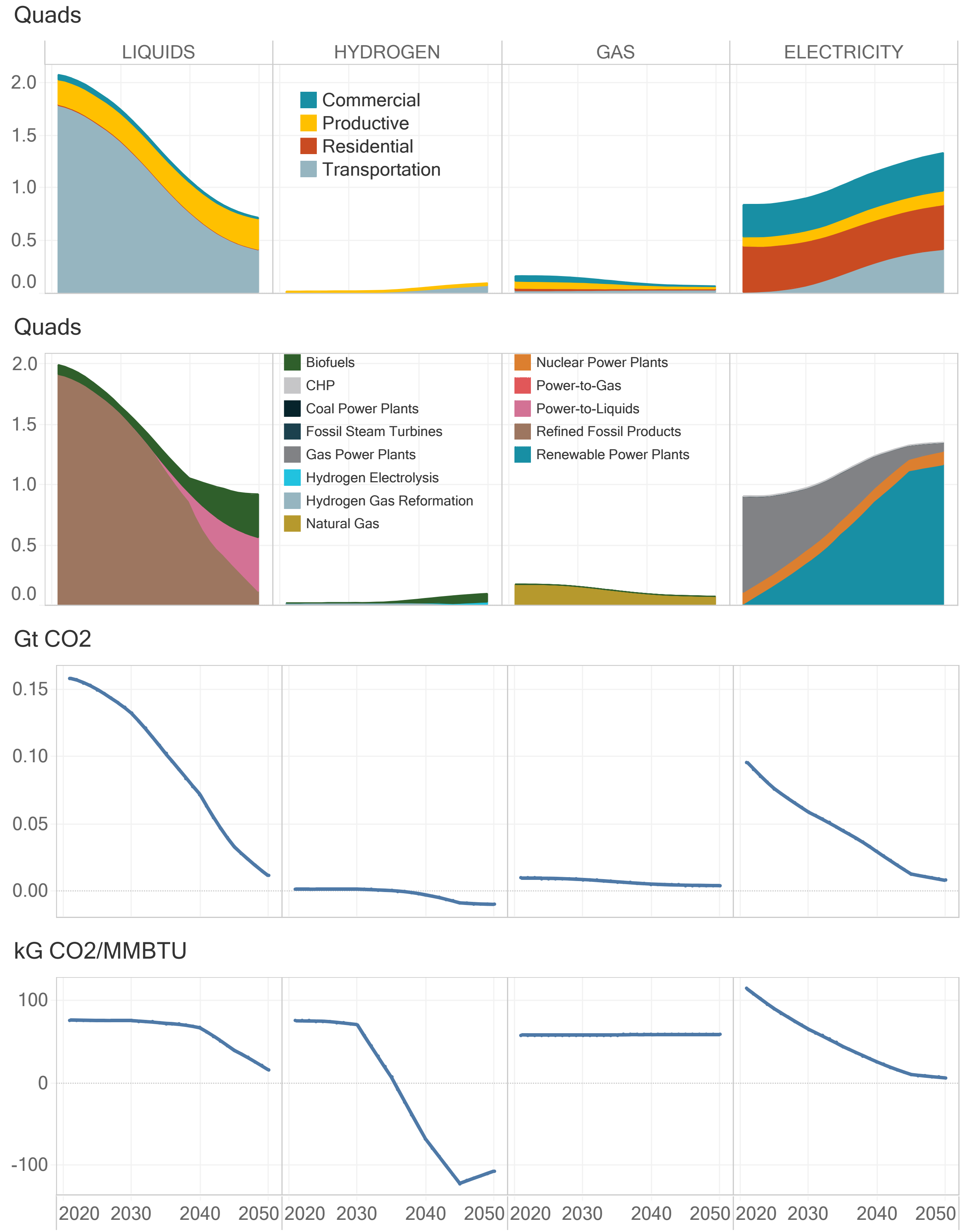


Florida’s uniqueness compared to the rest of the country in terms of final energy demand is its limited use of direct natural gas. Much of Florida’s heating is already electrified, and so a transition to heat pumps represents efficiency as opposed to the electrification found elsewhere in the country. Florida also has a higher share of jet fuel for aviation and distillate/residual fuel (other) used in international shipping.

Florida has a similar initial makeup to the rest of the country in terms of primary energy usage, though as noted it has more limited use of natural gas in heating and more use in power than the country as a whole. This natural gas in power means there is less coal primary usage than elsewhere in the country initially, though the transition from coal happens in all regions during the 2020s.

Figure 8 shows the transition of the energy mix over time, as reflected on both the supply and demand sides of the system. The four columns show energy divided into the main energy carrier types (liquids, hydrogen, gas, and electricity). The top row shows the transition in final energy demand over time, broken down by sector. The use of liquids and gases falls dramatically over time as a result of electrification, while electricity use increases for the same reason. Hydrogen also takes over as an energy carrier in industrial and on-road transportation applications. The second row shows the evolving mix of energy types used to meet the final demand shown in the first row. The third row shows the average emissions intensity of the energy supply mix in the second row, which declines over time as lower carbon sources are used. The bottom row shows the total emissions over time from each of the main energy carriers, the product of the total amount of each used times its emissions intensity.

Figure 8 Components of emissions reductions by energy form in the Central scenario - Florida



Liquid fuels are prioritized over gaseous fuels for decarbonization due to their higher CO_2 emissions intensities and higher dollar per MMBtu costs. Hydrogen transitions from a product made through natural gas reformation today to one that utilizes electricity (electrolysis) or biomass (BECCS) in the future with commensurate zero or negative emissions intensities. Electricity production is primarily from renewables by 2050, with coal transitioning out by 2025, and gas generation reducing steadily over the period. Existing nuclear is maintained in the Central scenario, so the contribution from nuclear stays constant through 2050. The Turkey Point units are already licensed through 2052 and 2053 (80-year) and we assume the St. Lucie units will also be relicensed to 80-years (currently operating on licenses to 2036 and 2043).

3.3. System Costs

Cost assessment is critical for assessing the potential economic and societal impacts of achieving a 350 ppm-compatible pathway, even if the technical feasibility of the pathway can be demonstrated. We examine a series of alternative cost metrics to assess the economic feasibility of such a transition. First, we find the net cost of decarbonizing energy and industry to be consistent with results from other analyses of this type, using the metrics of incremental costs ($ per year) and incremental costs as a percentage of State GDP[7] per year (Figure 9). Incremental costs are calculated by comparing the annual cost of producing and using energy in each scenario compared to the baseline scenario derived from the *AEO*, which has no carbon constraint. Incremental cost includes the capital and operating costs of all low carbon energy supply infrastructure and demand-side equipment (e.g. electric vehicles and heat pumps) in comparison to the cost of the less efficient or carbon emitting reference technology that it replaces.

Net annual system costs exceed $12B per year only in the 100% Renewable Primary Energy and Low Electrification scenarios. In the Central scenario, costs never exceed $12B per year and peak at less than 0.8% of projected GDP in all of the remaining 350 ppm-compatible pathways.

While the overall net costs are small compared to projections of GDP, where this money is spent changes substantially. Reduced spending on fossil fuels, primarily refined liquid fossil fuels, offsets incremental investments in the electricity grid (to support electrification), renewable power plants, alternative fuel production, and carbon capture.

In addition to net costs from the Reference scenario, we assess the total (gross) spending on the energy system (including carbon capture costs) as a share of GDP and compare that to historical levels of spending on energy. Incremental demand-side costs, such as the cost premium to purchase a high efficiency appliance, are assessed as an energy resource in this context, so that the incremental costs of electrification and efficiency are also treated as spending on energy. The top panel in Figure 9 shows the historical energy spending in the Florida compared to GDP[8]. Modeled results are shown in the bottom panel. In the Reference scenario, we can see that overall spending as a % of GDP is set to decline. This is a result of anticipated continued economic growth; relatively muted growth in the price of fossil fuels; and continued growth in services as a share of GDP.

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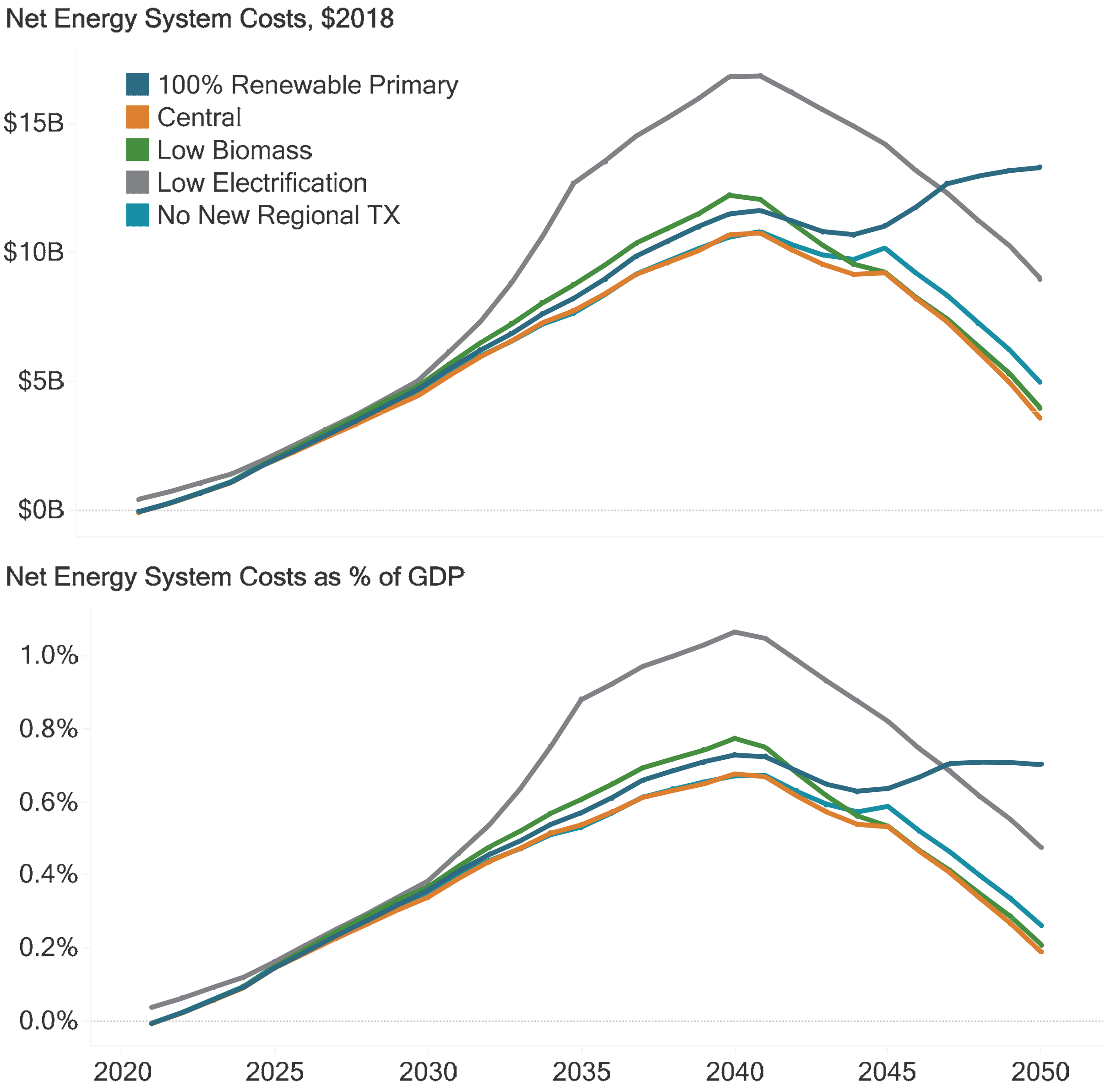
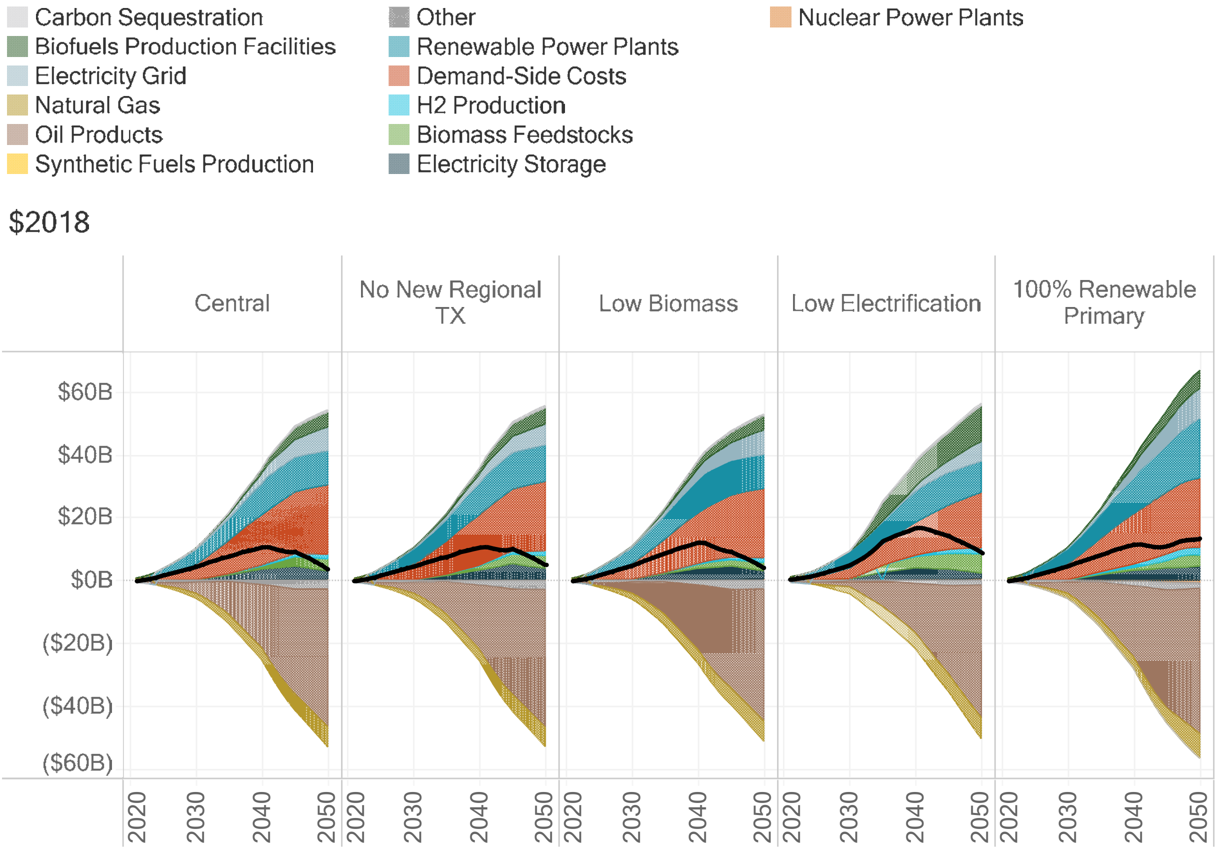
[8] These values are inclusive of taxes and subsidies. Our modeled values do not included taxes (i.e. gasoline tax) or subsidies (i.e. ITC/PTC, etc.). This difference is not substantial enough to alter the fundamental comparison.

Figure 9 Annual net system cost premium above baseline in $2018 and as % of GDP – Florida



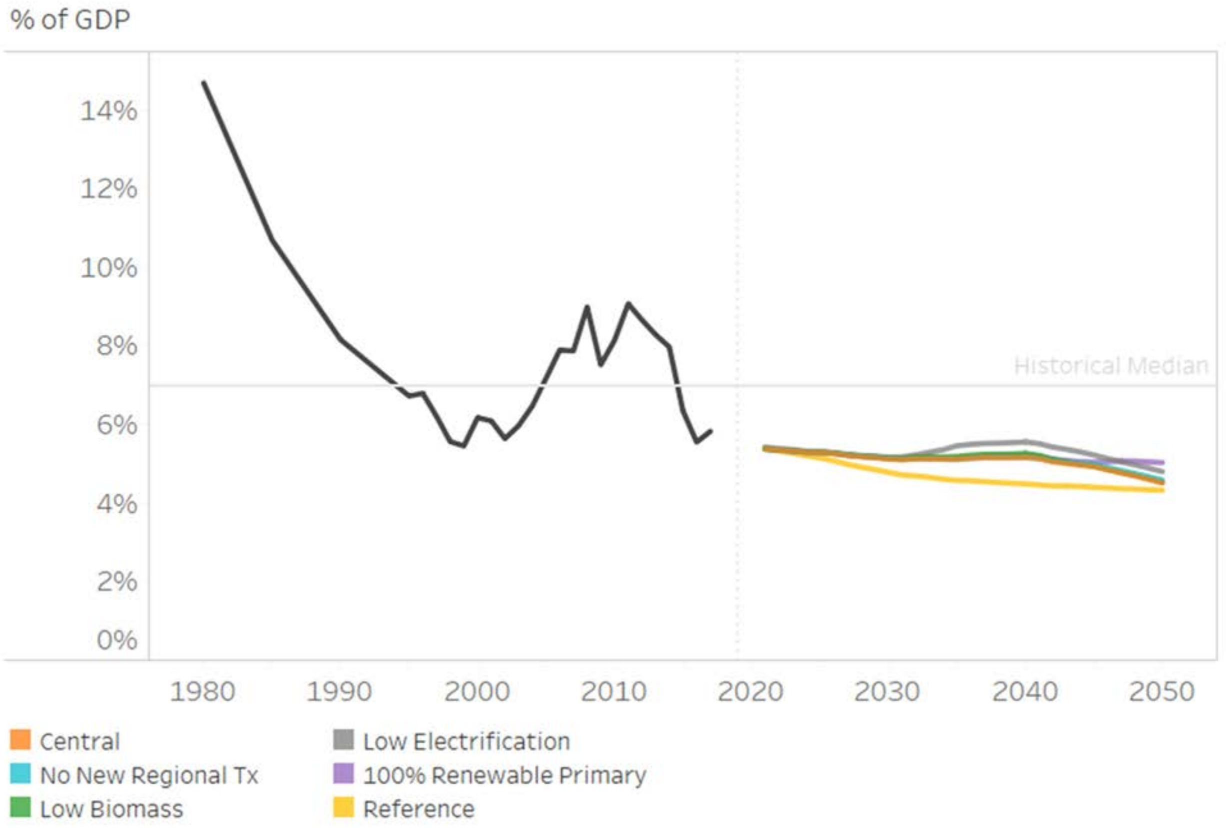
The spending category where Florida differs significantly than the U.S. as a whole is the investment in electricity storage. Florida is unique given its high-quality solar resource and lack of onshore wind potential. These renewable resource endowments combined with the lack of seasonality in load and solar production means that a high percentage of its electric load can be satisfied with solar and storage. This is not the scenario in most areas of the United States. This fact accounts for the large share of investment in stationary electricity storage in Florida.

Figure 10 Net Change in E&I System Spending – Florida



In no scenarios analyzed here does Florida energy system spending approach the historical median. This is due to a saturation of energy services relative to GDP as well as the relative cost-effectiveness of decarbonized technologies compared to their fossil alternatives.

Figure 11 Total energy system costs as % of GDP – historical and projected - Florida



3.4. Sector Results

3.4.1. Electricity

3.4.1.1. Low – Carbon Generation

In Florida, renewable growth is entirely solar PV through 2040[9] and then offshore wind complements the low-carbon mix. Limits on new regional transmission between Florida and Southeast results in double the amount of offshore wind deployed.

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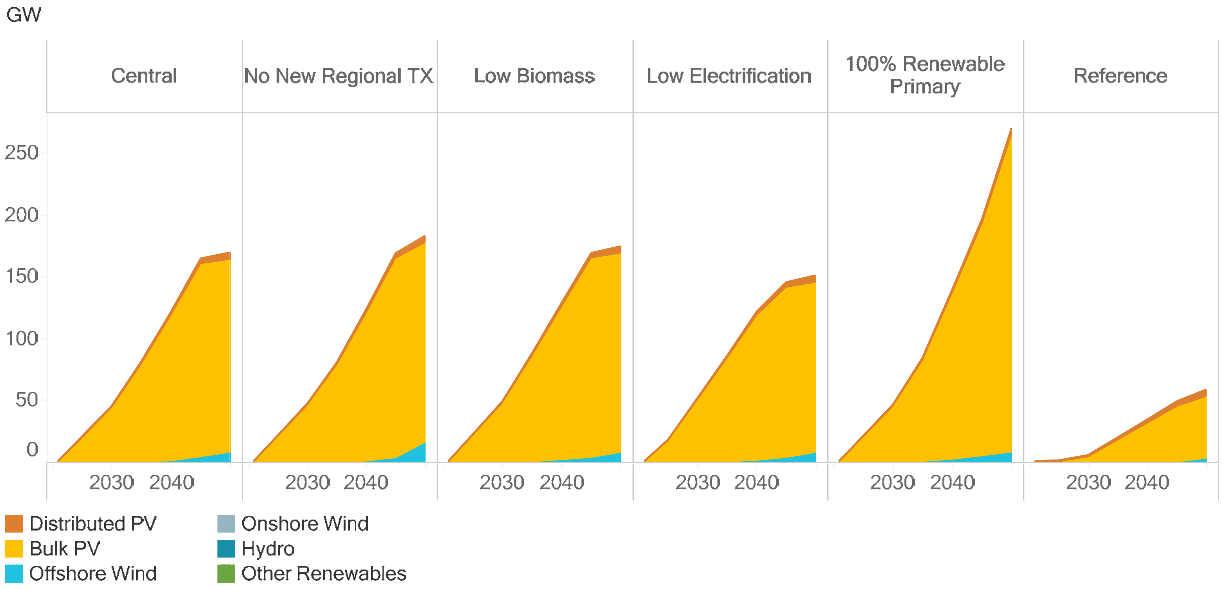
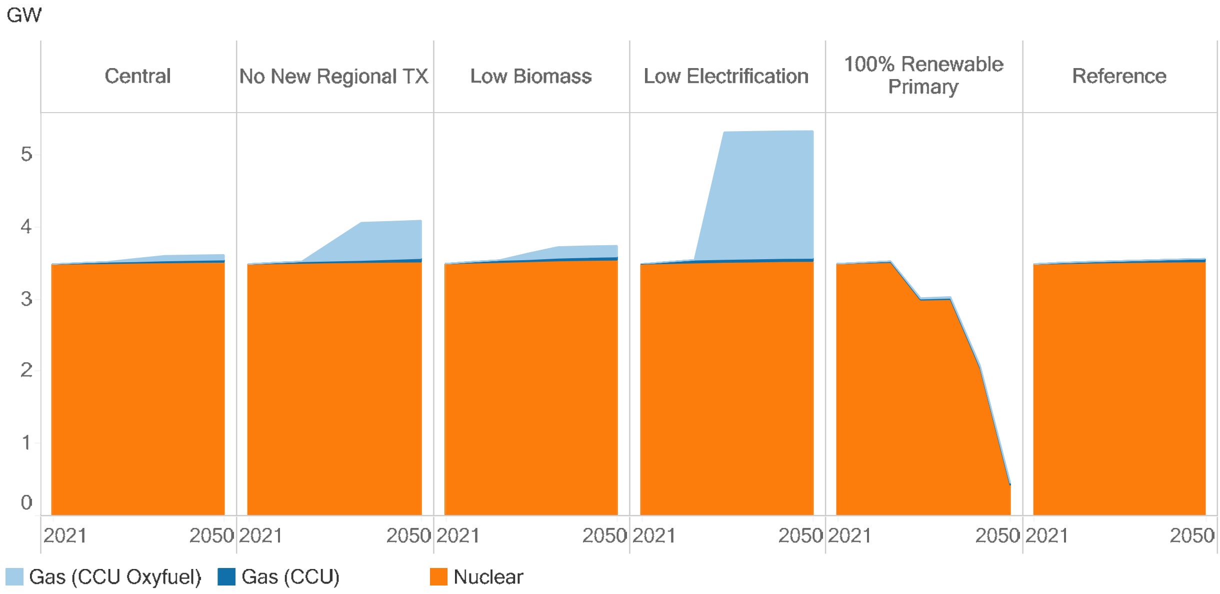
[9] This would represent a maximum of slightly more than 1% of available land in Florida devoted to solar production in the 100% Renewable Primary scenario using a power density of 7.5 square kilometers/gigawatt

Figure 12 Renewables installed capacity - Florida



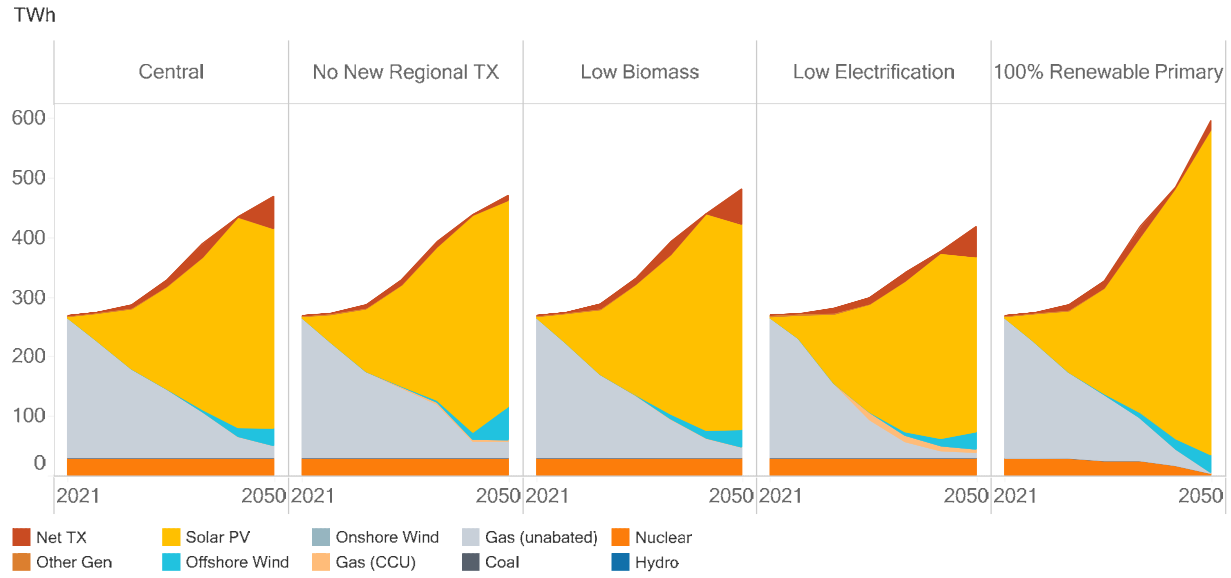
Low-carbon thermal capacity, including existing and new nuclear plants and gas plants equipped with CCU, varies significantly by scenario due to the constraints imposed. Generally, existing nuclear plants are relicensed through 2050 unless they have a planned retirement date. This is the scenario in Florida, where Turkey Point has already received relicensing to continue operations beyond 2050 (e.g., 80-year lifetime). Carbon capture and utilization (CCU) with oxy-fuel combustion is deployed in scenarios where implementation failures relative to the Central scenario persist, such as lower-than-expected end-use electrification.

Figure 13 Low-carbon thermal installed capacity - Florida



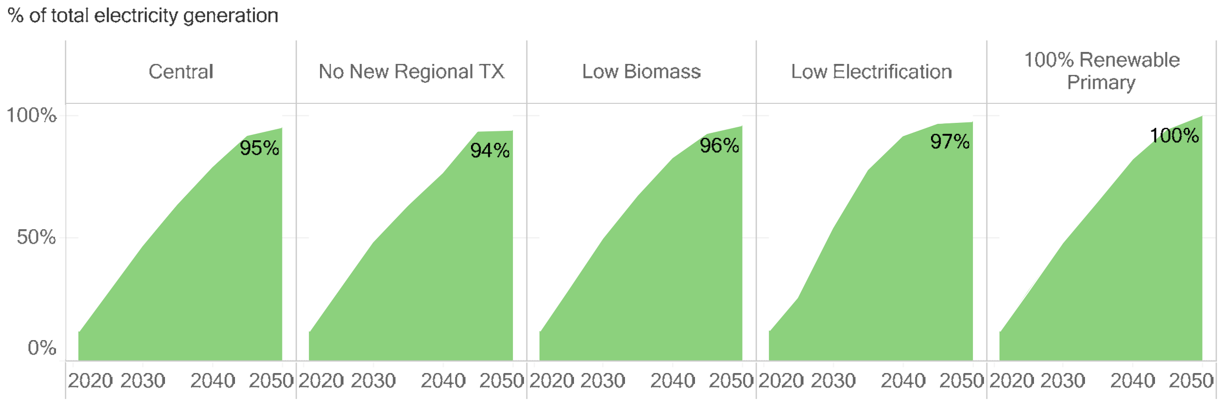
The result of deploying renewables and other low-carbon resources at scale is an electricity generation mix that is nearly zero-carbon in all 350-ppm scenarios. Florida's electricity mix maintains nuclear generation at today's levels, while gas-fired generation in the early years is replaced mainly by solar with more limited energy contributions from offshore wind and imports from the Midwest (transmitted through the Southeast). Coal-fired electricity generation is eliminated from the power sector by 2025.

Figure 14 Annual electricity generation



350-ppm compatible scenarios provide insights into how clean the electricity sector needs to be to facilitate carbon reductions across the economy. We quantify the clean electricity standard (CES) that must be reached in each year by measuring the share of total electricity generation that comes from: renewables, nuclear, hydro and gas-fired resources with CCU oxyfuel. Today (2021), the implied CES for the U.S. is approximately 40% with most of this being met by nuclear, hydro and onshore wind. The CES rises to approximately 75% by 2030, 85% by 2040 and 95% or more by 2050. This excludes thermal fuel substitution (e.g., burning zero-carbon fuel instead of natural gas), which would be employed as a strategy had we chosen to enforce 100% clean electricity standards in the scenarios.

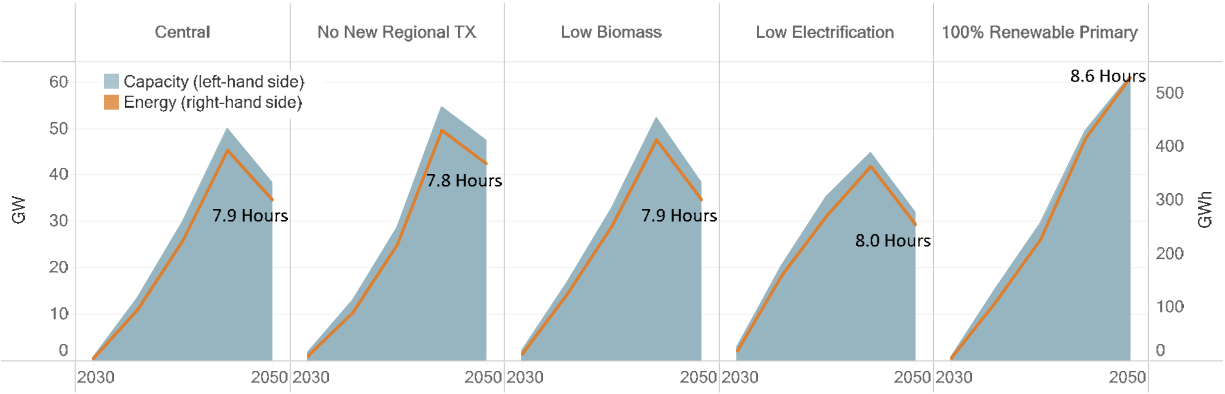
Figure 15 Implied Zero-Carbon Generation Share



3.4.1.2. Electricity Storage

Electricity storage provides capacity to balance the electricity system during times of low renewable energy output. Battery storage is the lowest-cost capacity resource available to address system peaks of limited duration. We find that significant amounts of new electricity storage are needed in all 350 ppm-compatible scenarios starting in 2030 (Figure 16), and this storage is deployed with an average duration of approximately eight hours. Without a significant technological breakthrough, however, the high cost of stored electricity limits its value as a long-duration balancing resource (i.e. on scales from days to months of energy shortfalls from renewables). Thus, it operates primarily as a diurnal resource, using excess solar generation in the middle of the day on a consistent basis to avoid curtailment and to displace off-peak thermal generation (capacity and energy). As noted, Florida is particularly attractive to deploy energy storage due to its heavy reliance on solar, lack of load seasonality, and limited regional interconnectivity.

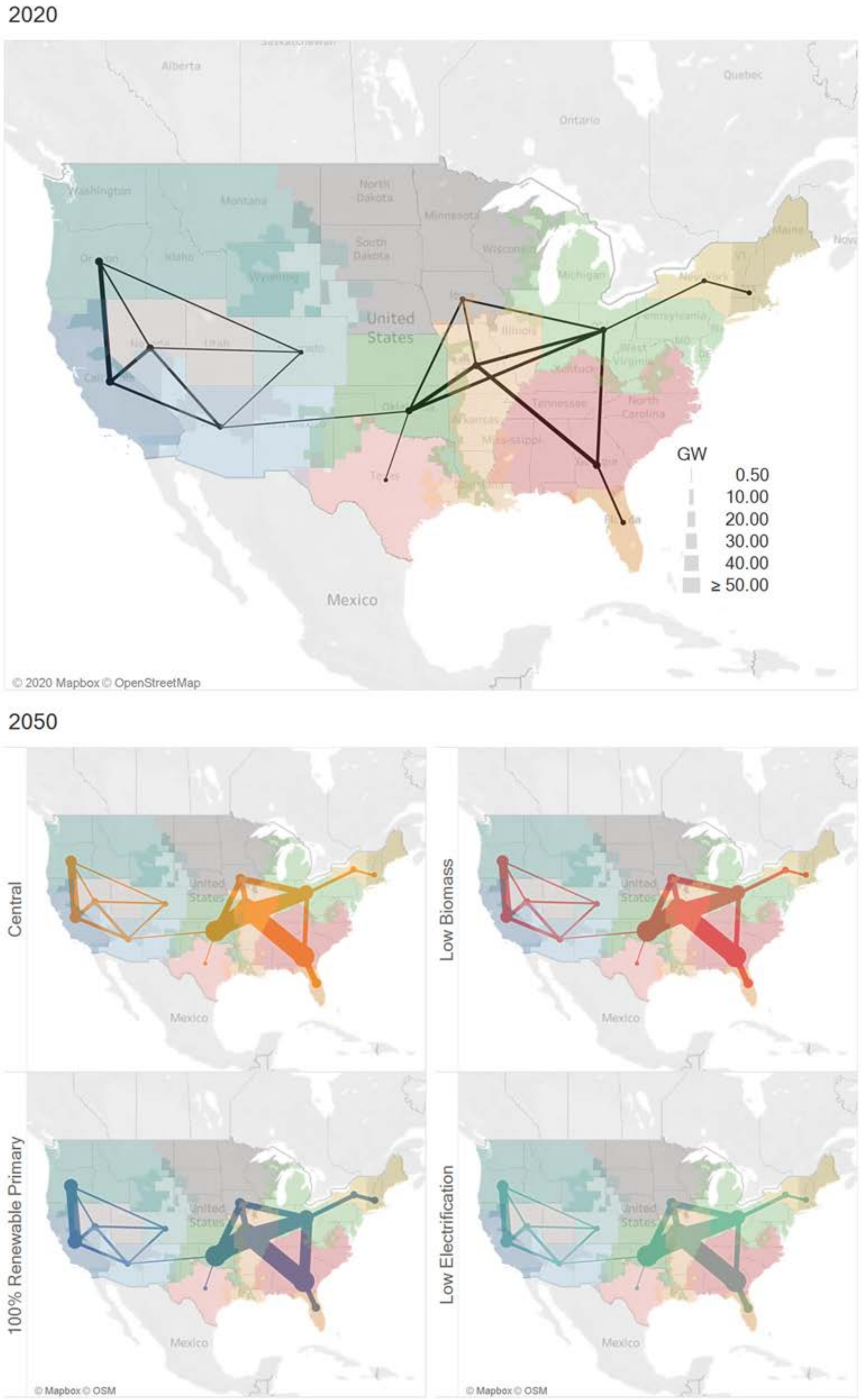
Figure 16 Energy storage capacity in gigawatts, gigawatt-hours, and average duration



3.4.1.3. Electricity Transmission

Many deep decarbonization analyses emphasize the importance of transmission to match the supply and demand for renewable electricity spatially across the country. Our findings are consistent with these studies in terms of the value of transmission as a resource. However, transmission has historically proven difficult to permit, site, and build in the U.S., especially in the case of large inter-regional lines. The map below shows that the principle reason new transmission capacity is developed across the analysis is to deliver wind to regions with limited resources of their own, such as Florida, California, New England, and Southeast. However, assumed technology progress through mid-century in both onshore and offshore wind has somewhat muted the imperative of developing these lines. This is shown in the limited impact on net costs seen in the No New Regional TX scenario (Figure 9). This isn't to underestimate the need for new intra-regional transmission, which is significant at the scales we project for renewables deployment.

Figure 17 Transmission capacity by corridor



3.4.1.4. Electricity Operations in Florida

Today, Florida supplies almost all of its electricity with gas generators and a limited amount of coal. There is very little renewable deployment. However, in a 350 ppm-compatible future the operations of the grid become much more dynamic. Florida has a unique resource endowment, with significant available solar but limited onshore and near-offshore wind resources (most viable offshore wind is located far from shore and in deep water depths requiring floating technology). Coupled with a temperate climate that results in little seasonal load variability, Florida is able to satisfy a large amount of its load with a combination of solar and storage.

Figure 18 Average Hourly Generation and Load: 2021, Florida (Baseline)

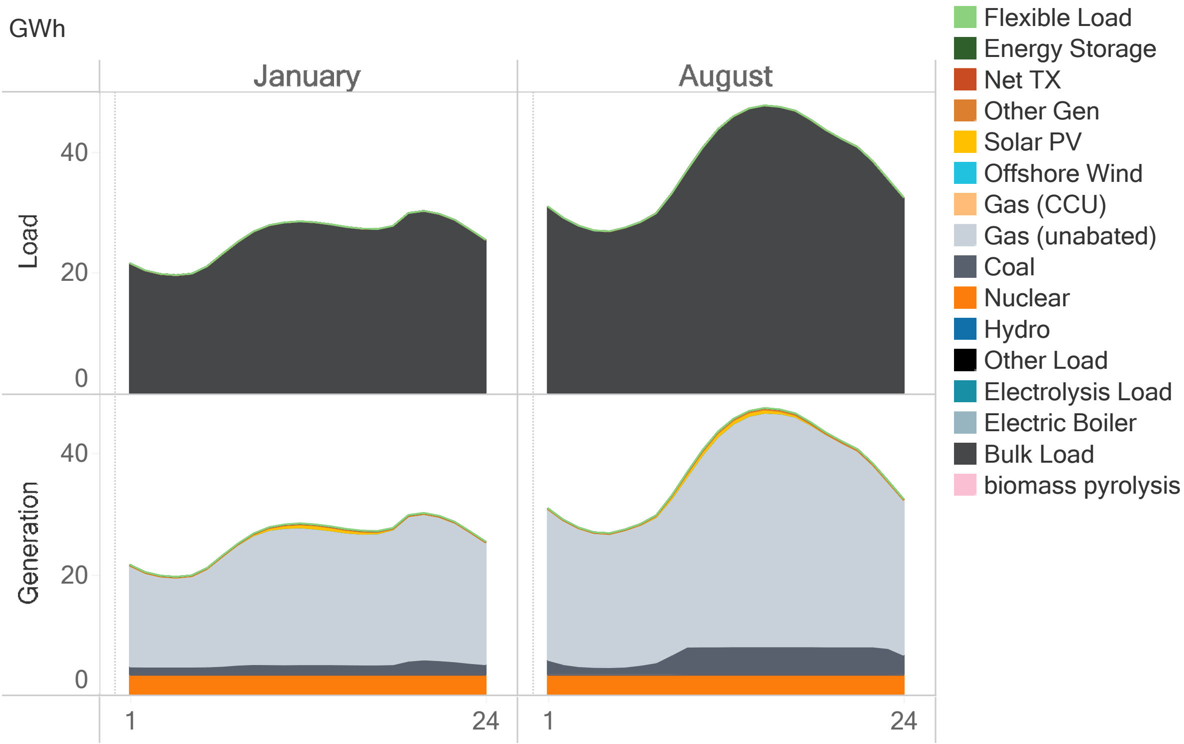
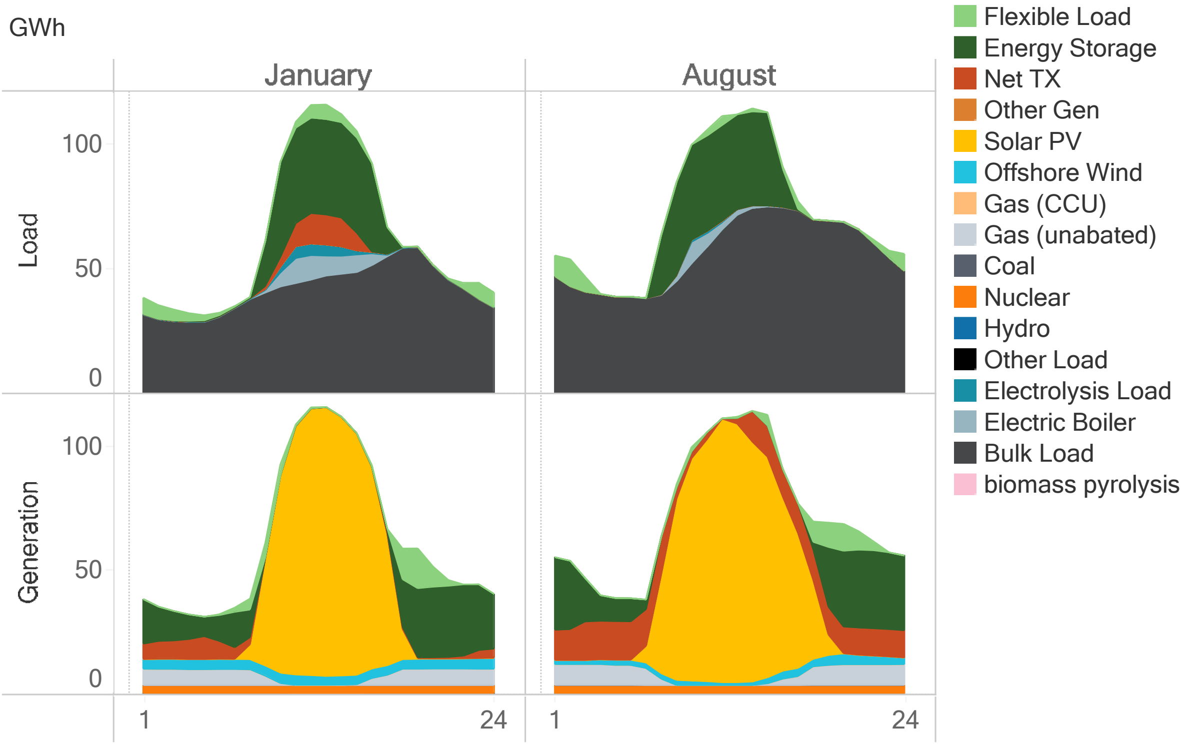


Figure 19 Average Hourly Generation and Load: 2050, Florida (Central)



The importance of flexible end-use loads is also clear from the chart above where flexible load is: (a) shown as generation when flexible load is reduced from its initial operating point, and (b) shown as load when it is increased from its initial operating point. In the absence of flexibility from those resources, these early-evening hour load peaks (after the evening commute) would necessitate a significant buildout of additional gas and storage resources to support them. Instead, the grid utilizes flexible end-use loads to move electricity demands either towards the middle of the day (pre-cooling or pre-heating with heat pumps) when the sun is shining or to moderate the charging of EVs across the night-time hours.

In addition to these flexible end-use loads, the model deploys “opportunistic loads” from electrolysis and electric boilers that deploy in concert with the higher renewable penetrations. They’re able to economically use otherwise curtailed energy from days with high solar output and produce high-value products of steam and hydrogen, which is then used in other sectors to aid in their decarbonization.

The model builds new transmission resources to Florida in all scenarios where it is allowed. This new transmission helps to diversify loads and generation and import wind resources from the U.S. Midwest through our Southeast region. Once built, these lines provide bidirectional value, allowing for solar export during periods of high generation, while allowing the import of wind during other periods. Specifically, this generation is utilized during off-peak periods, where Florida otherwise must rely on battery storage with limited durations that it can discharge.

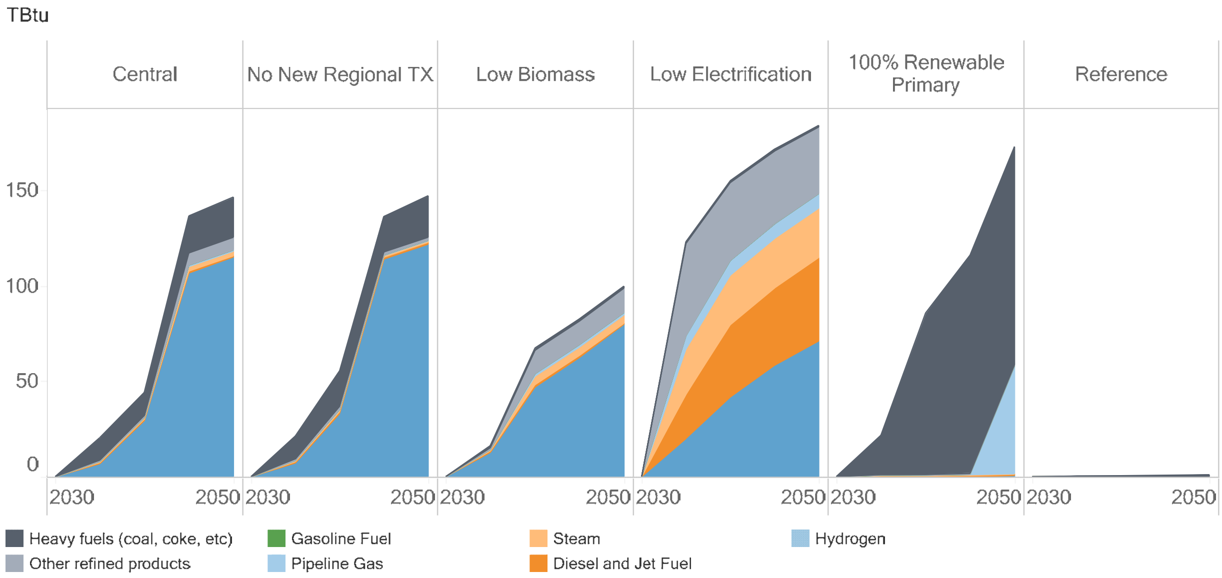
3.4.2. Fuels

3.4.2.1. Biofuels

The expansion of biofuels production is a critical strategy to mitigate emissions even with aggressive end-use electrification. The United States already has a biofuels industry of significant size, but it primarily produces corn-derived ethanol, a relatively high carbon form of biofuel over its lifecycle. As light-duty vehicle travel is electrified, the demand for liquid transportation fuels decreases, and this sector is reduced in importance. This analysis did not find cellulosic ethanol to be a critical strategy during the transition from gasoline to electricity due to the high cost of developing cellulosic refining and distribution, and the pace of electrification (the market-size for gasoline alternatives shrinks very quickly).

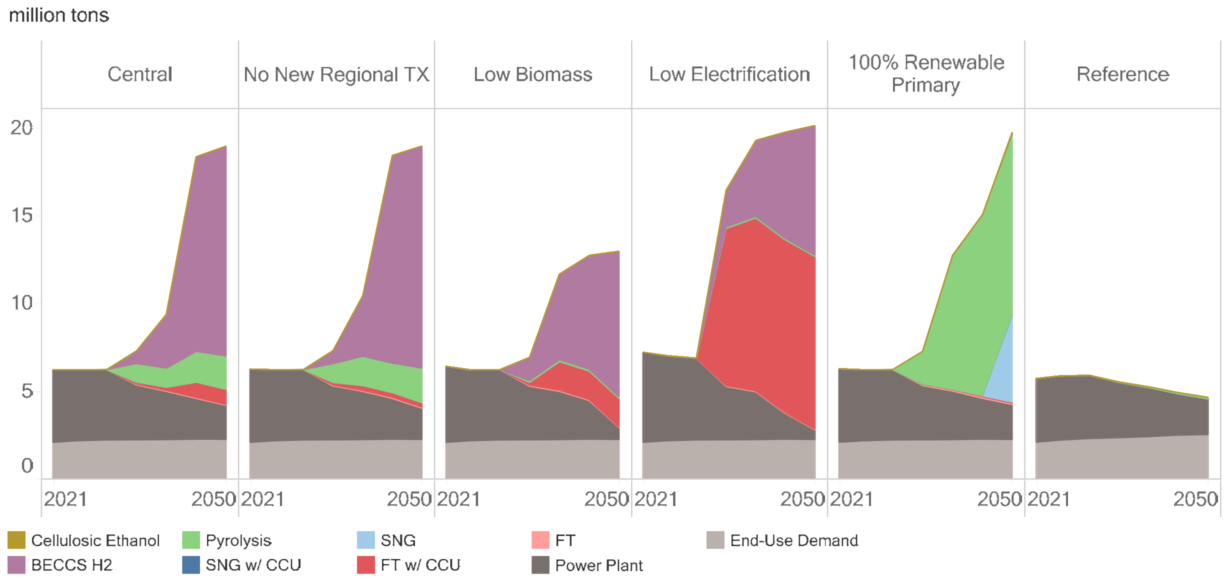
The analysis finds that scarce biomass feedstocks are economically allocated to producing negative-emissions hydrogen and displacing liquid fossil fuels (e.g., diesel and jet fuel) and "heavy fuels" such as coal, coal- and petroleum-derived coke and oil. Liquid fossil fuels are ideal for displacement rather than gaseous fuels since: (a) natural gas has a lower cost per MMBtu than refined liquid fuels; (b) natural gas CO_2 emissions are lower than liquid fossil fuels on an energy basis; and (c) the carbon from converting biomass into liquid fuels can be captured and utilized as a feedstock for producing synthetic fuels or sequestered. Heavy fuels are decarbonized using biofuels produced from pyrolysis since they are primarily consumed in hard-to-electrify end-uses such as heavy industry.

Figure 20 Next-generation Biofuels Produced



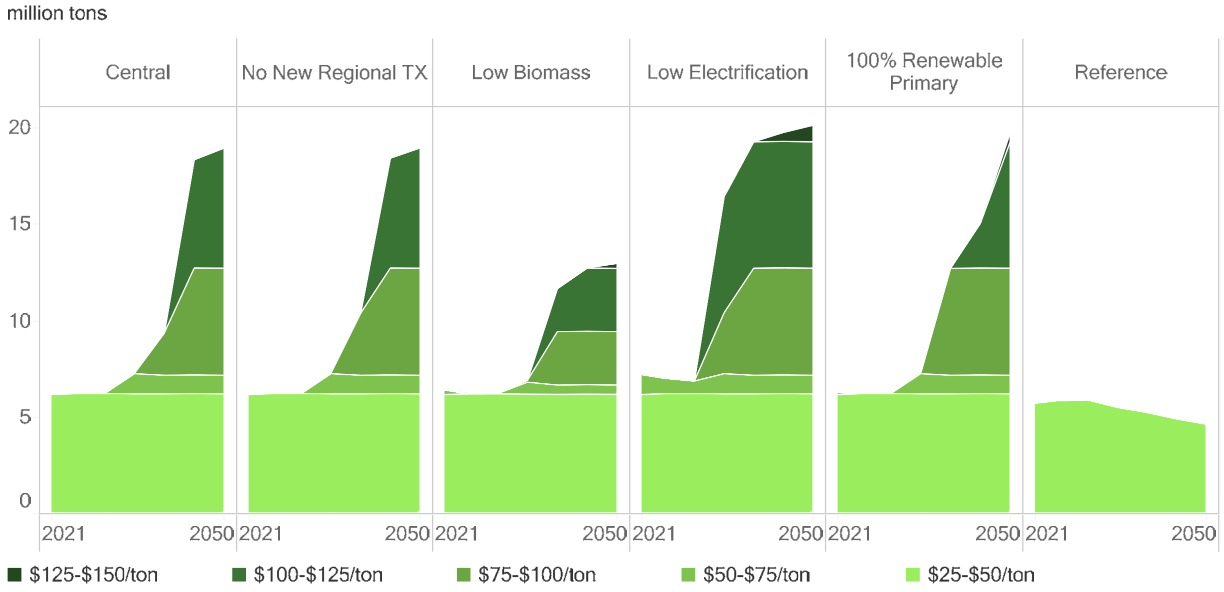
In order to produce next-generation biofuels, biomass feedstocks are directed towards new biorefineries. Most of the biomass feedstocks are used in pyrolysis and BECCS hydrogen production. The Central scenario uses approximately 80% of Florida's biomass feedstock of over 20 million dry tons. Low levels of electrification necessitate a greater reliance on biofuels both in terms of magnitude and timing. The Low Electrification scenario consumes more than double the amount of biomass in 2035 relative to the Central scenario (+10 million tons) and nearly all the available feedstocks by mid-century. An economy that relies on 100% renewables for primary energy requires similar levels of biomass by mid-century, but the lowest levels among the scenarios in this analysis due to a lack of carbon sequestration.

Figure 21 Biomass Feedstock Consumed



The implication of increased biofuels production is the need to harvest increasingly expensive biomass feedstocks, as shown in Figure 22. Initially, most biofuels are produced using the cheapest available feedstocks that range from $25 to $50/ton (~$1.5-$3.0/MMBtu), most of which are low-cost waste resources that doesn't require additional land and fertilizer inputs. In the 2030s, biofuel production escalates and requires feedstocks costing between $50 to $100/ton ($3 to $6/MMBtu), and this includes a variety of waste, wood and herbaceous energy crops. Scenarios that are heavily reliant on biofuels for mitigation (Low Electrification and 100% Renewable Primary) must access the most expensive herbaceous energy biomass feedstocks, which cost between $7-$9/MMBtu.

Figure 22 Biomass Feedstock by Cost Bin



3.4.2.2. Hydrogen Uses and Sources

Hydrogen plays a multifaceted role to ensure that Florida can achieve a 350 ppm-compatible economy and these roles generally fall into three distinct categories. First, hydrogen can be directly combusted in vehicles and power plants. In this analysis, hydrogen fuel cell vehicles (HFCV) are a prominent component of the freight truck fleet (the remainder of the fleet is electric) and hydrogen is directly burned in gas-fired power plants to serve as a low-carbon means of electricity balancing. Second, hydrogen can be combined with captured carbon dioxide to produce methane, the main component of natural gas, and further chemical synthesis using the Fischer-Tropsch process can produce synthetic liquid fuels comparable to (and interchangeable with) refined petroleum products, including diesel, gasoline, and jet fuel.[10] Third, producing hydrogen from the electrolysis of water plays a key role in balancing the electricity system during periods of renewable overgeneration.

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[10] A schematic of this process is shown here: https://cleanenergytransition.github.io/mtc-report-graphic-p2x/

The demand for hydrogen and its applications is summarized in Figure 23, which separates the amount of hydrogen used by end-uses (e.g., heavy-duty trucks), power plants and power-to-X processes. An energy system with 100% renewable primary energy requires nearly twice the energy of all the other scenarios in order to use additional hydrogen as a feedstock for synthetic fuels. In the near-term, hydrogen demand is primarily met by natural gas reformation (Figure 25). However, electricity sector balancing with high levels in the 2030s and stringent emissions constraint result in BECCS and electrolysis as the primary technologies for hydrogen production beyond 2035.

Figure 23 Hydrogen Demand

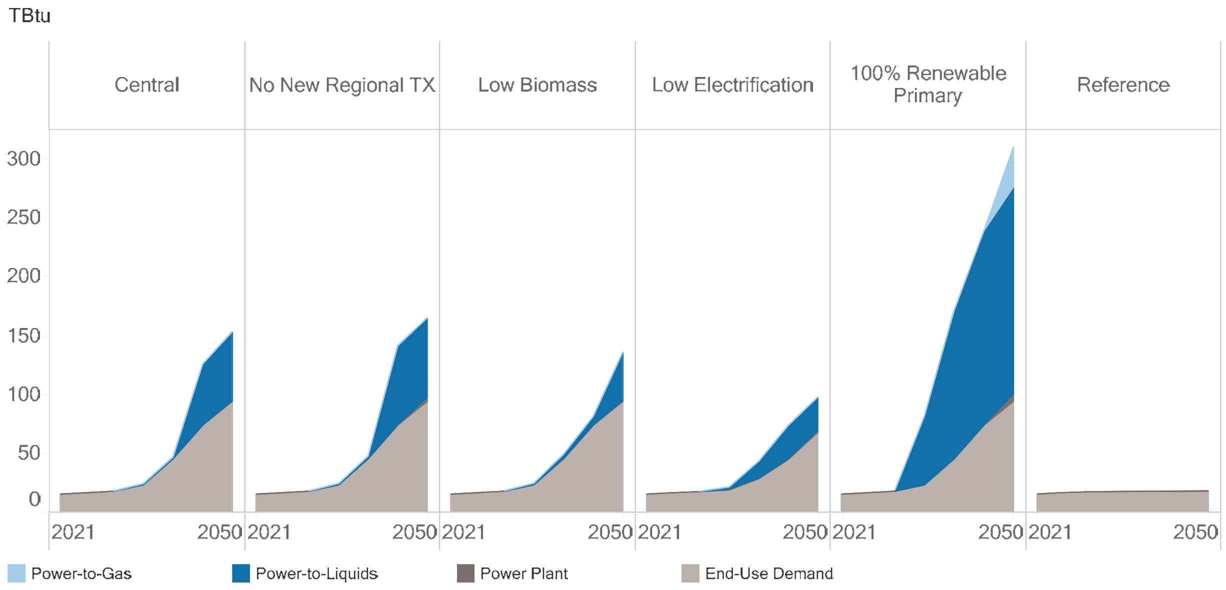
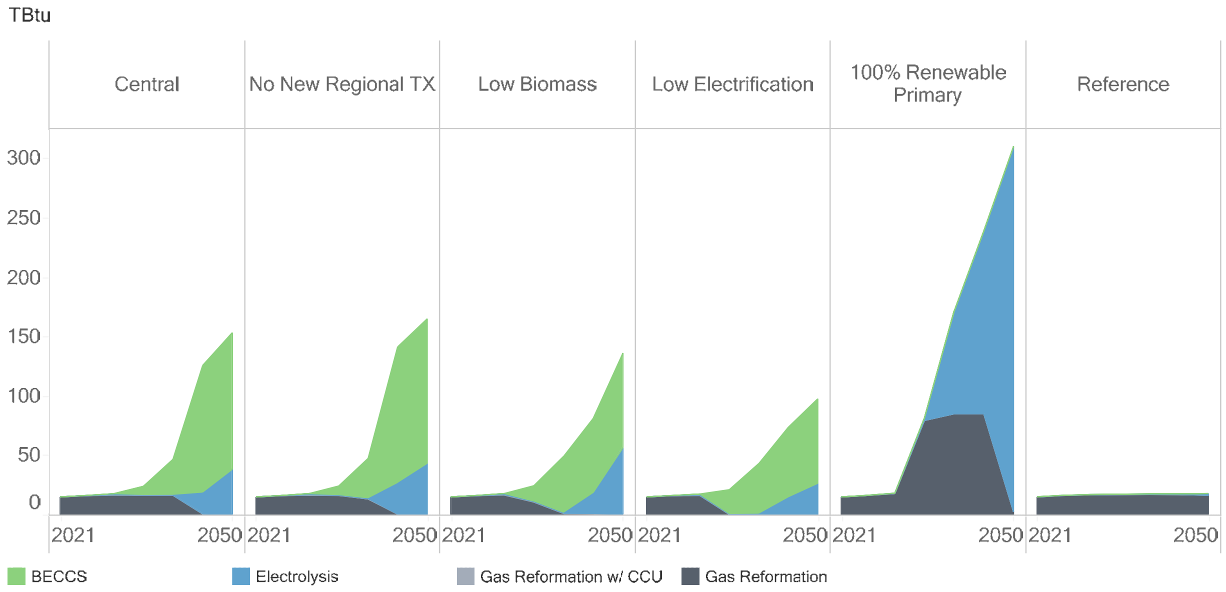


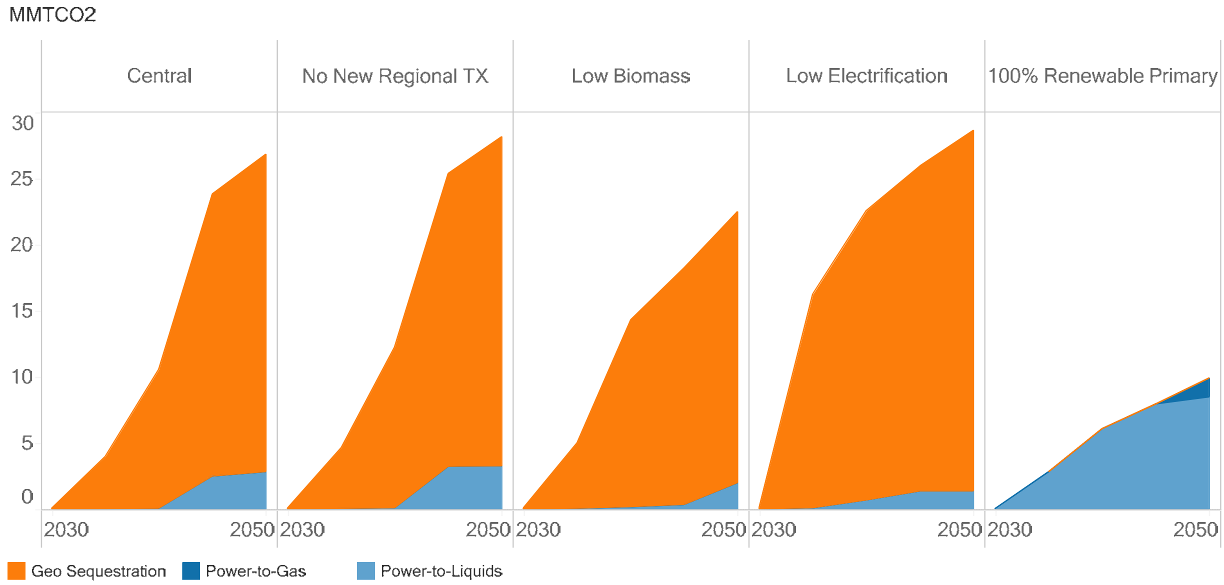
Figure 24 Hydrogen Supply



3.4.3. Carbon Uses and Sources

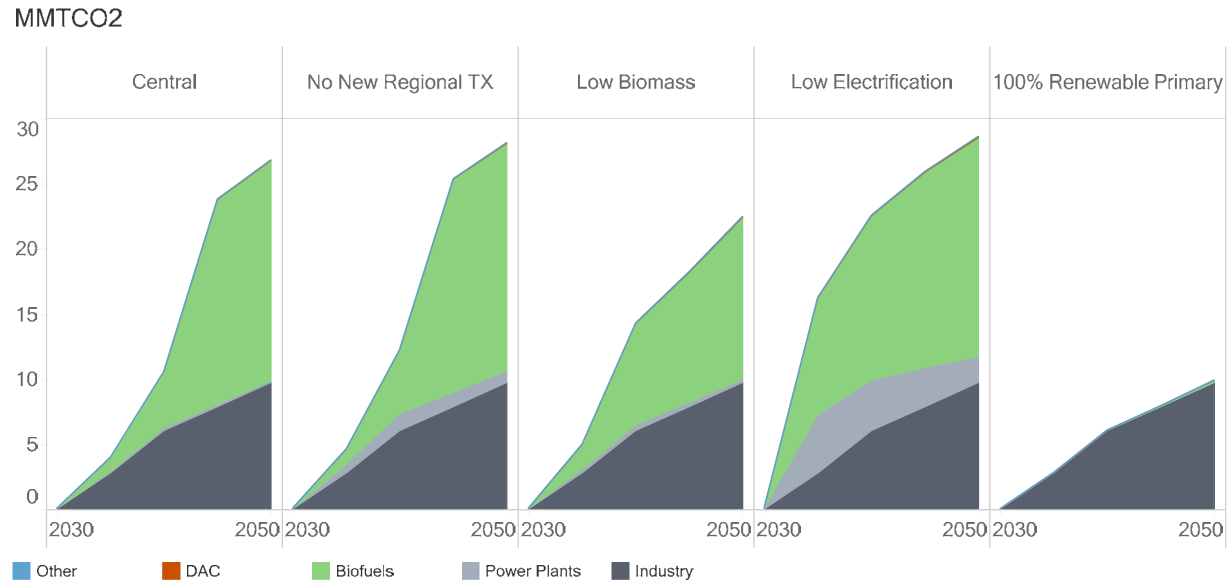
A 350 ppm-compatible energy economy requires millions of metric tonnes of CO_2 to be captured and/or sequestered. Approximately 30 MMT of CO_2 is captured in Florida by mid-century under the Central scenario with the majority sequestered. In areas with better renewable resource endowments, a higher share of captured carbon is directed towards synthetic fuel production. Low levels of end-use electrification require both additional sequestration and utilization, whereas the 100% Renewable Primary energy economy does not rely on sequestration and uses significant volumes of carbon to produce both liquids and gaseous fuels.

Figure 25 Uses for captured carbon



Captured carbon is derived from a variety of sources, including: (1) industrial facilities; (2) power plants; (3) biofuels production facilities; and (4) direct air capture. Across all scenarios, the U.S. primarily relies on capturing carbon from industrial facilities and bioenergy facilities producing hydrogen, heavy fuels and liquid fuels. Direct air capture (DAC) doesn't play a role in Florida, instead any DAC plants are sited in other areas of the U.S. with more favorable renewable resource endowments (primarily areas with high-quality onshore wind).

Figure 26 Sources of captured carbon

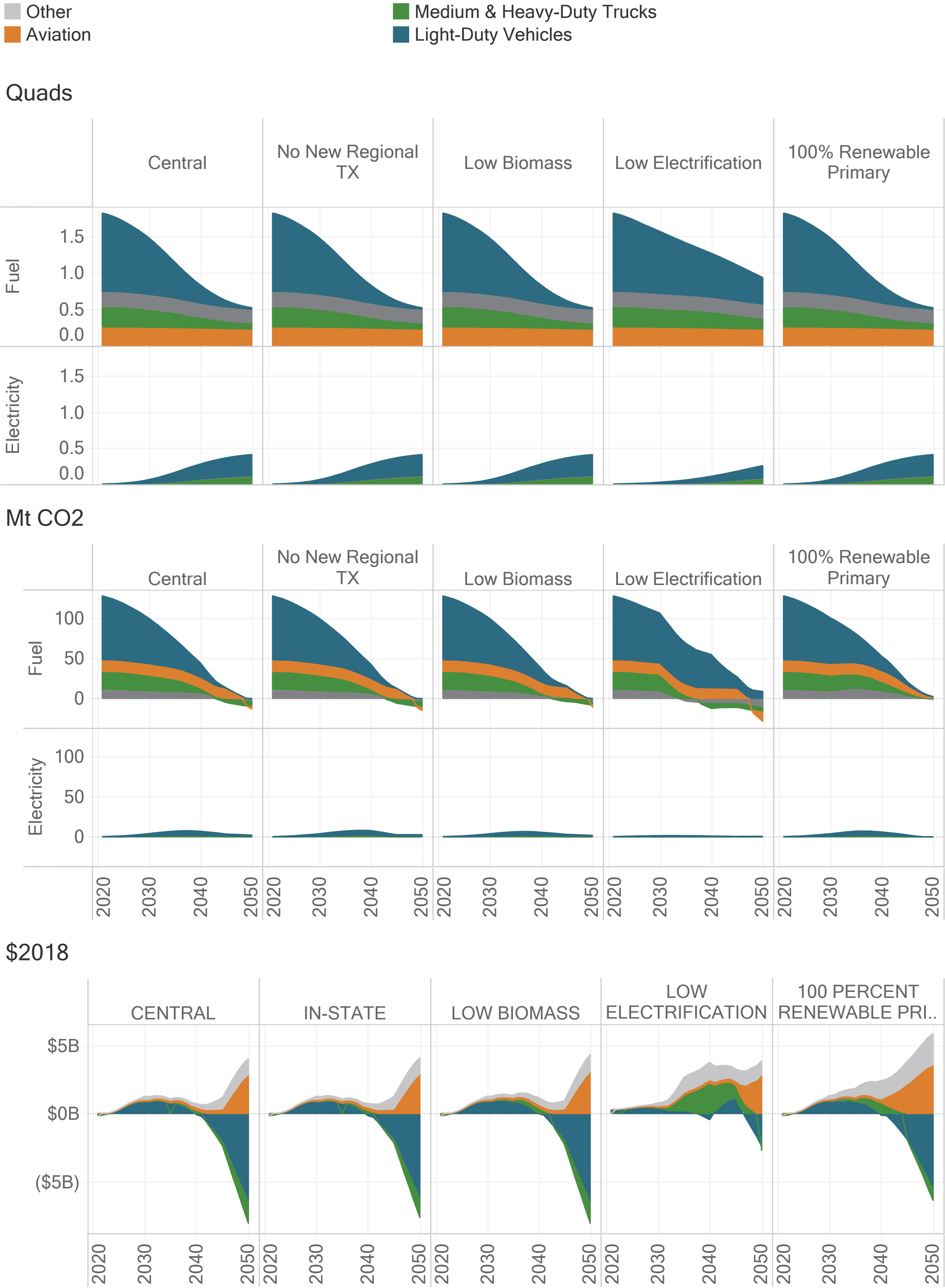


3.4.4. Transport

Transportation decarbonization relies on the 1) electrification of the majority of on-road vehicle miles traveled and 2) decarbonization of residual fuel in on-road and off-road end-uses like aviation. By 2050, in all but the Low Electrification scenario, electricity is half of delivered transportation energy. Emissions associated with this new electric load are negligible due to the decarbonization of electricity supply. Emissions associated with residual fuel use also decline precipitously past 2030, with the use of biofuels and electric fuels to displace fossil use. Biofuels produced with carbon capture supply negative carbon fuels to the transportation sector, allowing overall emissions contributions to go net negative.

Given the current trajectory of battery costs, a concerted effort towards transportation electrification offers the greatest cost savings of a decarbonized economy over Reference scenario projections. Electrification, of light-duty travel in the near- to medium-term and in the medium to long-term of the majority of freight transportation, represents an opportunity to reduce the costs of these energy services. Similar to energy efficiency today, overcoming any initial cost premiums on these vehicles in order to save money and emissions in the longer-term is critical. Although the transition to electrification comes with a small cost before 2030 (which contributes to emissions reductions), by 2035 the electrification transition is negative cost. By 2045, the electrification transition in medium and heavy-duty vehicles also is negative cost.

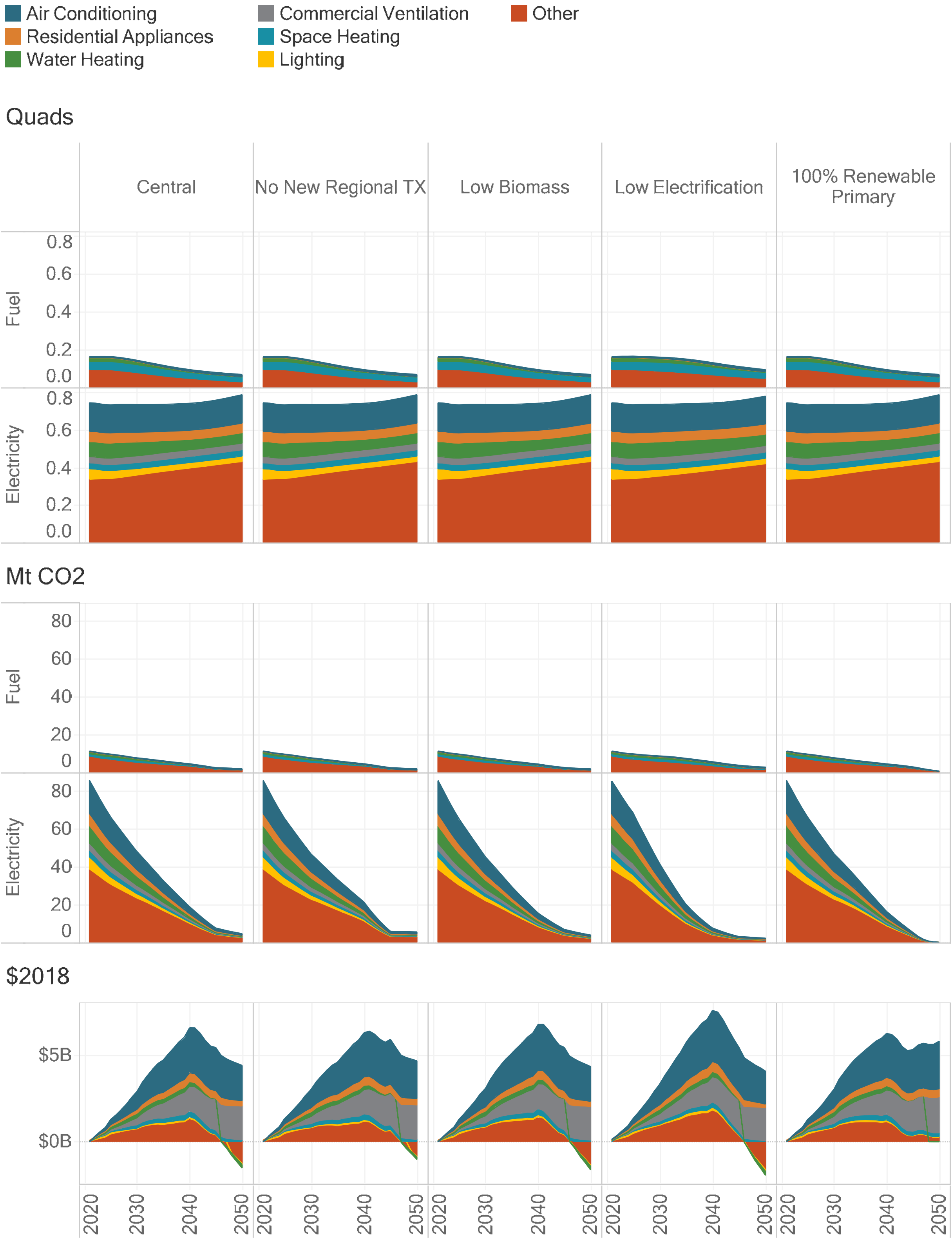
Figure 27 Transportation Energy, Emissions, and Net Costs by Key Subsector – Florida



3.4.5. Buildings

Buildings electrify end-uses like space heating, water heating, and cooking, allowing services in these end-uses to access zero-carbon energy from wind and solar. This reduces emissions from on-site combustion, and the decarbonization of electricity means that emissions associated with this electrification do not increase significantly. The costs of these electrified end-uses once the transition is complete are generally moderate, with the increased efficiency of electric delivery of these services offsetting the increased costs per unit of energy. In end-uses where electricity is already used, this story is somewhat different, with efficiency unable to keep pace with the increasing cost of decarbonized electricity. These end-uses generally see the largest cost impacts (appliances, ventilation, refrigeration). Lighting is an exception, with the transition to LEDs seeing such a large efficiency gain that costs are offset.

Figure 28 Building Energy, Emissions, and Net Costs by Key Subsector – Florida



3.4.6. Productive

The productive sector experiences limited transformation of end-use consumption relative to building and transportation sectors. Electrification is limited outside of the expansion of dual-fuel boilers, building electrification, and some process heating. This can be seen in the relatively limited increase in electricity, with most electrification offset by energy efficiency. Increases in fuel demand shown for the cement & lime subsectors are associated with the energy demands of carbon capture (primarily steam).

While the overall changes in energy demand compared to the Reference scenario are relatively limited compared to other sectors, emissions reductions are significant due to the decarbonization of electricity and the application of carbon capture in heavy industry. Additionally, in the bulk chemicals subsector, deployment of alternative, bio-based feedstocks to displace LPG and other petroleum results in net negative emissions from the subsector (when considering the sequestration of the carbon in products like plastics).

Increased costs for industry are primarily due to the increased upstream costs of providing low-carbon fuels and electricity. They're also related to the costs of carbon capture in cement as well as iron and steel production. Energy efficiency moderates these increased industrial costs to some extent and where there is residual fossil use in the energy system, it is generally natural gas used in these industrial applications. Bulk chemical production sees a large increase in costs in the 100% Renewable Primary scenario due to the need to decarbonize chemical feedstocks entirely. Specifically, this removes the residual natural gas at a high net cost.

Figure 29 Productive Energy, Emissions, and Net Costs by Key Subsector – Florida

4. Conclusions

Based on the analyses described in this report, we maintain the conclusion that achieving a trajectory of emissions in Florida consistent with 350 ppm globally is technically feasible and the cost of realizing emissions reductions is affordable in the context of historical energy system spending within the state. This result is robust against four key scenario variants – Low Biomass, Low Electrification, 100% Renewable Primary, and No New Regional TX. While feasible, achieving the outcomes modeled here requires ambitious early action in order to maintain reasonable trajectories towards mid-century. Without this ambitious early action, it will require the achievement of net-negative emissions energy economies before mid-century and then sustain them at these low-levels through the end of the century.

For the State of Florida, decarbonizing its energy system consistent with the country's pathway is also feasible. The State's relative position as an energy consumer and producer doesn't dictate serious deviations away from the Country's overall pathway, but there are a few unique characteristics that bear mention:

1. While the State's renewable resource potential is more heavily weighted towards solar than wind energy, the availability of offshore wind, and the lack of seasonality in its load, means that developing a deeply decarbonized electricity system to support these emissions constraints is possible.

2. The State will continue to rely on fuel imports, as it does now, however much of that fuel will be zero-carbon variants as opposed to refined fossil.

3. Heating electrification is not as important as it is elsewhere in the country. Firstly, electric heating is already prevalent in 2020, moderating electric load growth. Secondly, lower total heating loads because of milder winters in Florida than other parts of the country limit the imbalance between winter and summer electric loads. This mitigates the need for longer duration balancing resources, allowing more capacity provision to be provided by batteries.

These scenarios are intended to answer the question of whether the U.S. as a whole and Florida individually, with the anticipated growth in consumption of energy services, can develop an energy system that is consistent with 350 ppm in the atmosphere and we conclude that both are achievable. We do not assert the necessity of, nor model the effects of, behavioral changes and energy service demand reductions (i.e. lower VMTs, lower temperature setpoints, lower consumption of material goods) though all would contribute to lower system costs, lower material requirements, lower infrastructure needs, and could improve quality of life in ways not measured by this analysis for all regions. There are co-benefits aside from CO_2 including improved air quality, energy price predictability, job creation and energy security that are not modeled here.

We observe large shifts in energy spending away from fossil fuels towards fixed infrastructure, both demand-side (electric vehicles, heat pumps, etc.) and supply-side (low-carbon generation, hydrogen electrolysis, electric storage, etc.). That said, the overall net costs of decarbonization found here are well within the range that a major industrial economy can manage, and indeed that the U.S. and Florida have managed historically. Based on this analysis, achieving 350 ppm-compatible pathways would maintain energy system costs within the low-range of historical values.

Key Actions by Decade

In conclusion, “Key Actions by Decade” below describes the sequence of actions needed to achieve a 350 ppm trajectory in Florida. The list is by no means comprehensive, but it does highlight the most important physical transformations required and when each needs to occur. These actions make up a general blueprint for Florida, with some differences in terms of scenarios and some decisions in terms of infrastructure preference likely to drive different pathway outcomes. In some scenarios, these actions need to build on one another, so that later actions are path dependent on earlier successes.

This and previous research have indicated that many pathways to decarbonize the energy system exist. The list below represents our current best understanding of how to achieve mid-century carbon targets at lowest cost while delivering the energy services projected in the EIA’s

AEO. Inherently this blueprint relies on projections of cost and performance that are unknowable. Despite this, a long-term blueprint is essential because of the long lifetimes of infrastructure in the energy system—making decisions that have long-term consequences using imperfect information is an enduring challenge. Uncertainty means an energy system plan is never static. Thus, we expect future work to revise this plan as decisions get made, technology improves, energy service projections change, and as our understanding of the climate science evolves.

From a policy perspective, this provides a list of the things that policy needs to accomplish, for example the deployment of large amounts of low carbon generation, rapid electrification of vehicles, buildings, and industry, and building extensive carbon capture, biofuel, hydrogen, and synthetic fuel synthesis capacity. Some of the policy challenges that must be managed include: land use tradeoffs related to carbon storage in ecosystems and siting of low carbon generation and transmission; electricity market designs that maintain gas capacity for reliability while running very infrequently; electricity rate designs that rewards demand side flexibility in high-renewables electricity systems and encourages the development of complementary carbon capture and fuel synthesis industries; coordination of planning and policy across sectors that previously had little interaction but will require much more in a low carbon future, such as transportation and electricity; coordination of planning and policy across jurisdictions, both vertically from local to state to federal levels, and horizontally across neighbors and trading partners at the same level; mobilizing investment for a rapid low carbon transition, while ensuring that new investments in long-lived infrastructure are made with full awareness of what they imply for long-term carbon commitment; and investing in ongoing modeling, analysis, and data collection that informs both public and private decision-making. These topics are discussed in more detail in *Policy Implications of Deep Decarbonization in the United States* (Williams et al. 2015).

2020s

- **Begin electrification** – Electrification of buildings, transportation, and industry is necessary for affordable decarbonization. The initial focus should be on requiring new buildings to be all-electric and developing markets to electrify vehicles of all types. The transportation electrification goal is not near-term carbon emissions reductions but instead transformation of an industry to eliminate carbon emissions in the long term as the carbon intensity of electricity drops. Replacing air conditioners or furnaces with heat pumps in existing buildings is also a priority, pushing a technology that has improved markedly in recent years to further maturation. In Florida, this will represent efficiency gains, as most current heating is performed with electric resistance heating.

- **Switch from coal to gas in electricity system dispatch** – Dispatching gas in preference to coal is one of the most impactful and cost-effective ways to curtail carbon emissions in the near-term. Natural gas has approximately half the carbon intensity of coal but costs only slightly more on an energy basis at time of writing and is generally burned more efficiently than coal. Coal to gas switching in dispatch is distinct from retiring all coal, which will happen more gradually due to considerations on reliability and speed at which replacement generation can be built. Gas plants also are better complementary resources in the medium-term as renewable generation is deployed.

- **Build renewables and reinforce TX where possible** – Due to their abundance and based on current cost projections, wind and solar will form the backbone of a future low carbon energy system. Meeting 2050 goals requires a truly enormous quantity of renewable deployment, which must accelerate. Offshore wind should be emphasized given its complementarity with solar resources and the lack of onshore wind potential in Florida. Transmission that connects renewable resources to loads takes time to permit and build and thus planning must start early for this critical infrastructure.

- **Allow gas build to replace retiring gas plants** – Even in a future electricity system with 80%+ energy coming from renewables, difficult long-duration (seasonal) electricity balancing challenges mean that dispatchable thermal capacity that can be dispatched during fallow periods of renewable production will be a part of a low-cost energy system. This means that it will be necessary to use gas (first fossil gas, shifting to synthetic renewable gas over time) for short durations to fill in gaps in renewable generation. While significant gas generation *capacity* will remain, these gas plants will be used very little so their *utilization rate* will be low and by 2040, very little gas will be consumed for this purpose. Our modeling shows that an optimized pathway to deep decarbonization shows little change to gas capacity relative to today over the next 30 years but eventual retirement of all other fossil electricity generation.

- **Start planning and rate reforms to prepare for a changing load & resource mix** – Future electricity systems must accommodate rapid load growth from electrification, increasingly flexible demand, and increasingly inflexible supply resources. Fossil generation in the future without carbon capture will operate for far fewer hours than today making capacity markets more and more attractive. In those capacity markets the need to distinguish resources that can offer capacity over long durations will become important. Future planning processes must also anticipate the need for balancing services, with full symmetry between supply and demand side balancing to avoid significant periods of curtailment**.**

- **Maintain existing nuclear** – While building new nuclear would not be cost effective, existing nuclear is an important source of low-cost carbon free electricity and when possible to do safely, the lowest cost path to decarbonization involves maintaining these resources. Retiring nuclear to 'make room' for renewable resources is ultimately self-defeating. Reducing climate change should be the priority when weighed against nuclear accidents given relative risk and consequence except where specific circumstances dictate otherwise (e.g., reactors in active seismic zones and those exposed to rising sea levels). This is not an assertion of the safety of generation III nuclear but rather a recognition of the urgency of the latest climate science.

- **Pilot new technologies that will be deployed at scale after 2030** – Among these are carbon capture of many varieties including from power plants and biofuel production facilities. Carbon storage and utilization of this carbon, including creating drop-in replacement fuels through methanation or Fischer-Tropsch process all need to be demonstrated commercially before they can be scaled up.

- **No new infrastructure to process and transport fossil fuels** – Consumption of every fossil fuel declines in a pathway to 350 ppm. Thus, new infrastructure associated with the consumption of fossil fuels run a high risk of either becoming stranded or locking in a higher emission pathway. Some infrastructure built for a 20th century energy system is still useful in the 21st century such as natural gas storage and transmission pipelines and should be maintained.

- **Start building carbon capture on industrial facilities** – Carbon capture on industrial processes should be prioritized because many processes result in higher CO_2 concentrations than post-combustion capture on electricity generation and operate at higher utilization factors, reducing cost, and because some industrial processes offer no ready alternatives making this type of carbon capture a necessary long-term strategy. In Florida, this is particularly important for the cement industry.

2030s

- **Large renewables push** – The 2030s is when the bulk of new renewable generation is built. Renewable curtailment is a necessary transient balancing solution until transmission is expanded, market rules with high variable generation mature, and other balancing solutions get built.

- **Reach near 100% sales on key electric technologies** – All new vehicle sales must become electric or zero carbon compatible, for example fuel cells or biodiesel for heavy equipment. Similar transitions must occur in buildings for heating and cooking equipment. In industry electric or dual-fuel equipment should be installed for process heating and steam production which can be called upon based on electric system conditions (i.e. they can utilize overgeneration).

- **Start significant biofuel production in diesel & jet fuel** – Diesel and jet fuel are two of the largest residual fuels after high electrification. Bio-fuels used as drop-in replacements for fossil are a major strategy for reducing emissions. In the 2030s both are beginning to be produced in significant quantities, often with carbon capture on the biorefineries.

- **Large scale carbon capture on industrial facilities** – This completes the carbon capture on industry begun in the 2020s. By the late 2030s the marginal carbon abatement cost exceeds the capture cost for most industrial processes making this a cost-effective measure to pursue. The main challenge becomes geographic mismatch between where industry is located and where CO_2 is sequestered or used.

- **Electrical energy storage for capacity** – As fossil capacity retires, electric energy storage technologies are deployed at a modest scale for reliability and to assist with diurnal balancing between electricity supply and demand. The phrase 'modest' is used because energy storage technologies cannot cost effectively replace all types of other dispatchable generation without a major cost breakthrough in long duration storage. Just like in the 2020s, some new gas power plant capacity is needed. When the duration of need for dispatchable capacity is less than 8 hours, energy storage will most likely be the most cost-effective option, for anything longer than 8 hours, gas turbines are the cheapest option for the system.

- **Fossil power plants with 100% capture** – If competitive with renewables and nuclear, fossil power plants with pre-capture or oxy technologies should start to be deployed. It's possible that CCS technologies in electricity are unable to compete with a combination of renewables and energy storage, in which scenario most carbon capture stays focused on industry and refining.

- **Maintain nuclear** – As in the previous decade, continue to maintain nuclear where safe and cost-effective to do so.

2040s

- **Reach near 100% stock penetration on electric technologies** – The key building heating and transportation technologies that approached 100% new technology adoption in the 2030s have lifetimes of 10-15 years; and therefore, stock shares of these technologies should approach 100% in the 2040s based on natural replacement.

- **Maintain/grow renewables together with new flexible loads** – As synthetic fuel industrial loads grow it gives a new tool for balancing a grid composed of large amounts of variable generation. This, in turn, allows for further increases in renewables at low cost. Distributed fuel production also avoids the need for some new transmission.

- **Fully deploy biofuels including bio-energy with carbon capture** – Biofuel production and deployment reaches its limit in the 2040s. Biofuels find only marginal application in electricity because of higher value uses in transport and industry. Those industrial applications that can also deploy carbon capture allow opportunities of negative life-cycle emissions. Carbon capture on biofuel refining becomes an important technology.

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Technical Supplement

The following technical supplement shows results for the U.S. as a whole as well as scenario figures not shown in the body of the main report for Florida.

U.S. Results

Figure 30 E&I CO2 emissions trajectories – U.S.

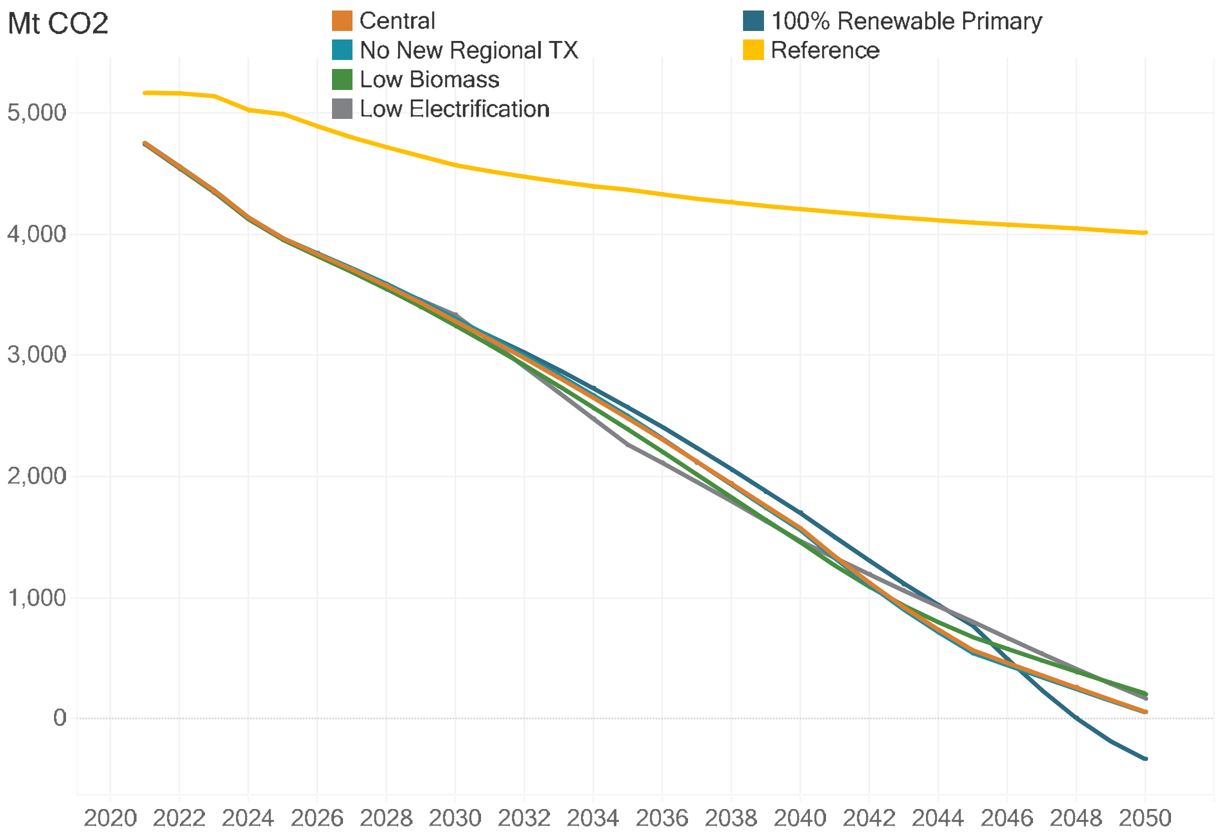


Figure 31 CO2 emissions by final energy/emissions category

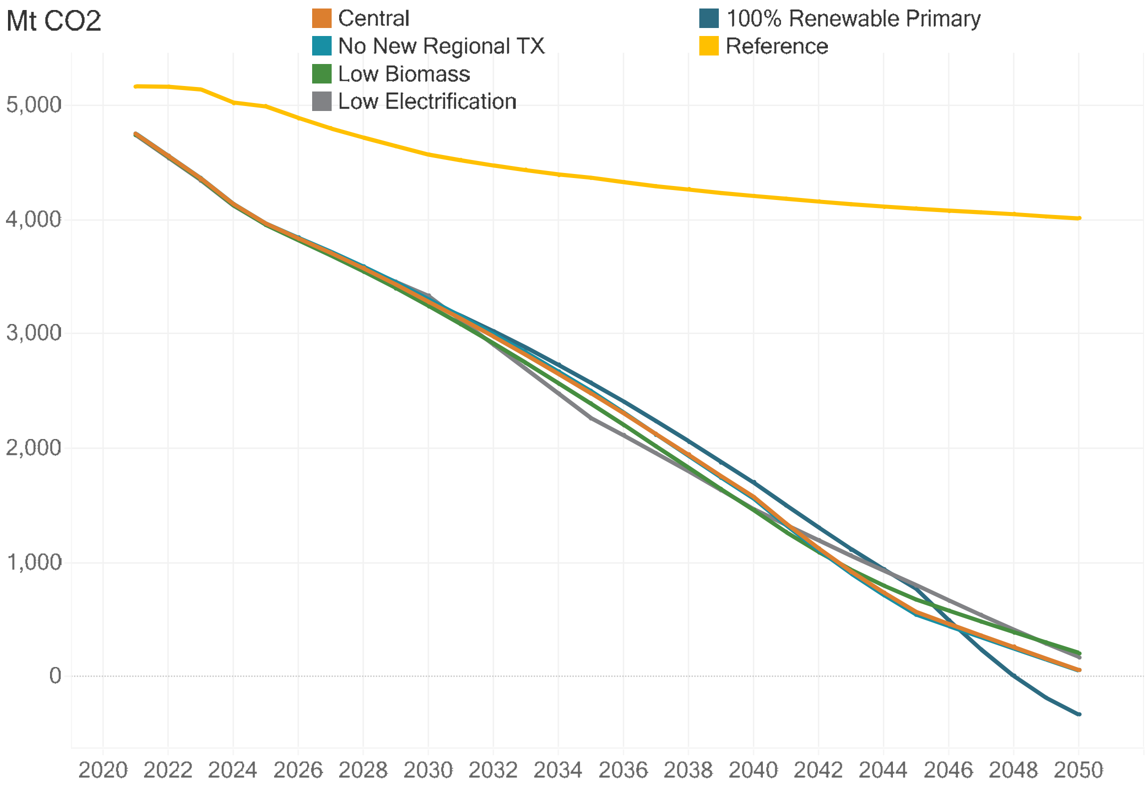


Figure 32 Cumulative E&I CO2 emissions trajectories

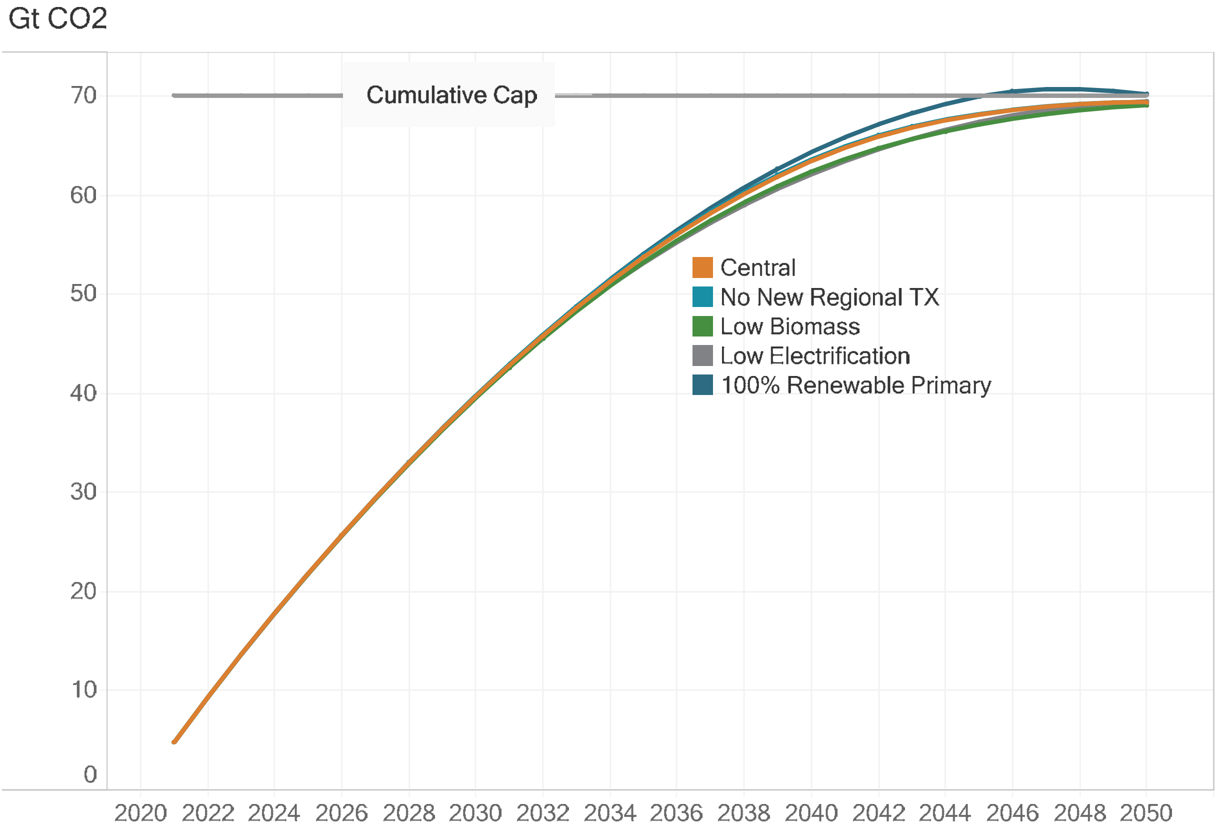


Figure 33 Four pillars of deep decarbonization – U.S.

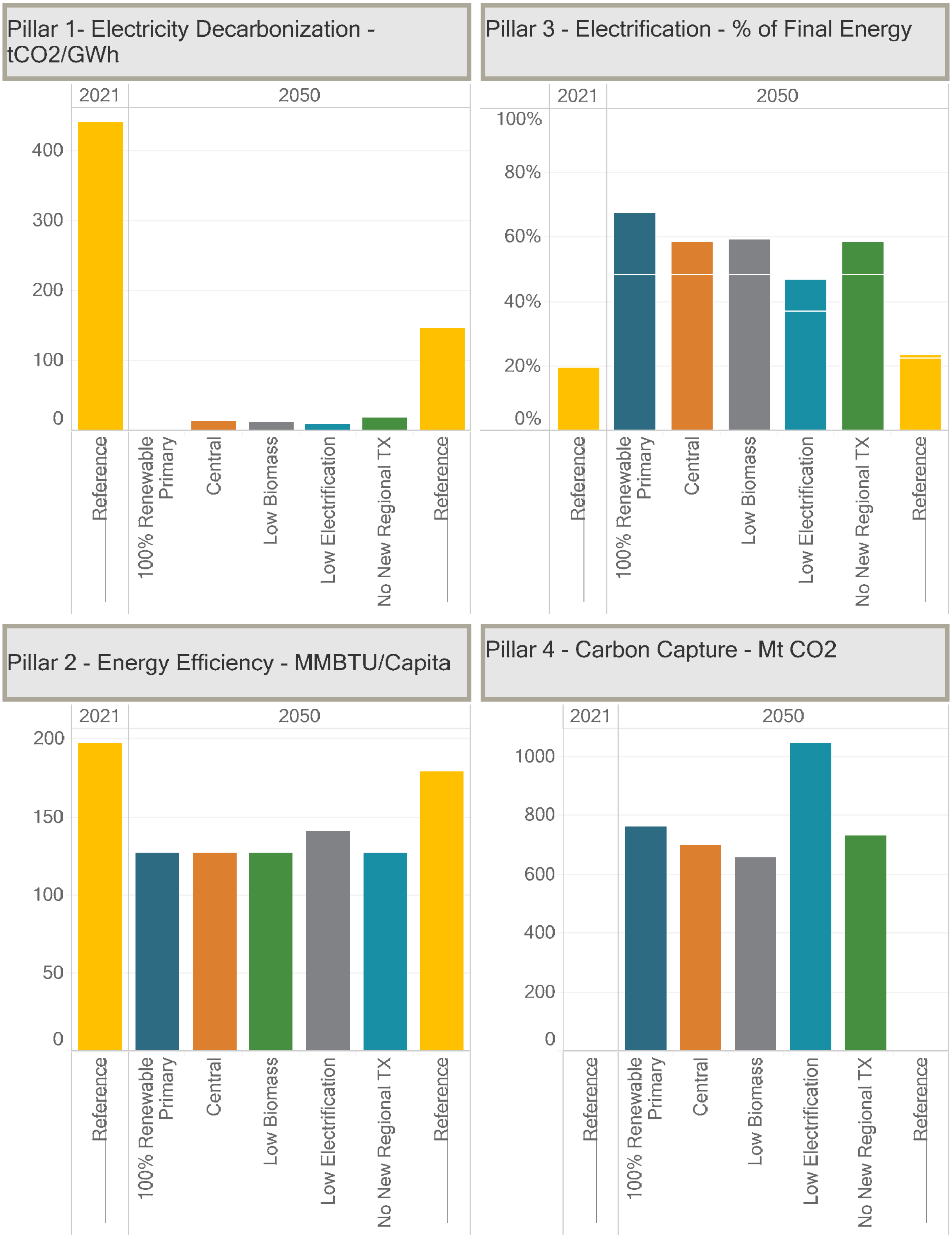


Figure 34 Final and primary energy demand for all scenarios from 2021 – 2050 – U.S.

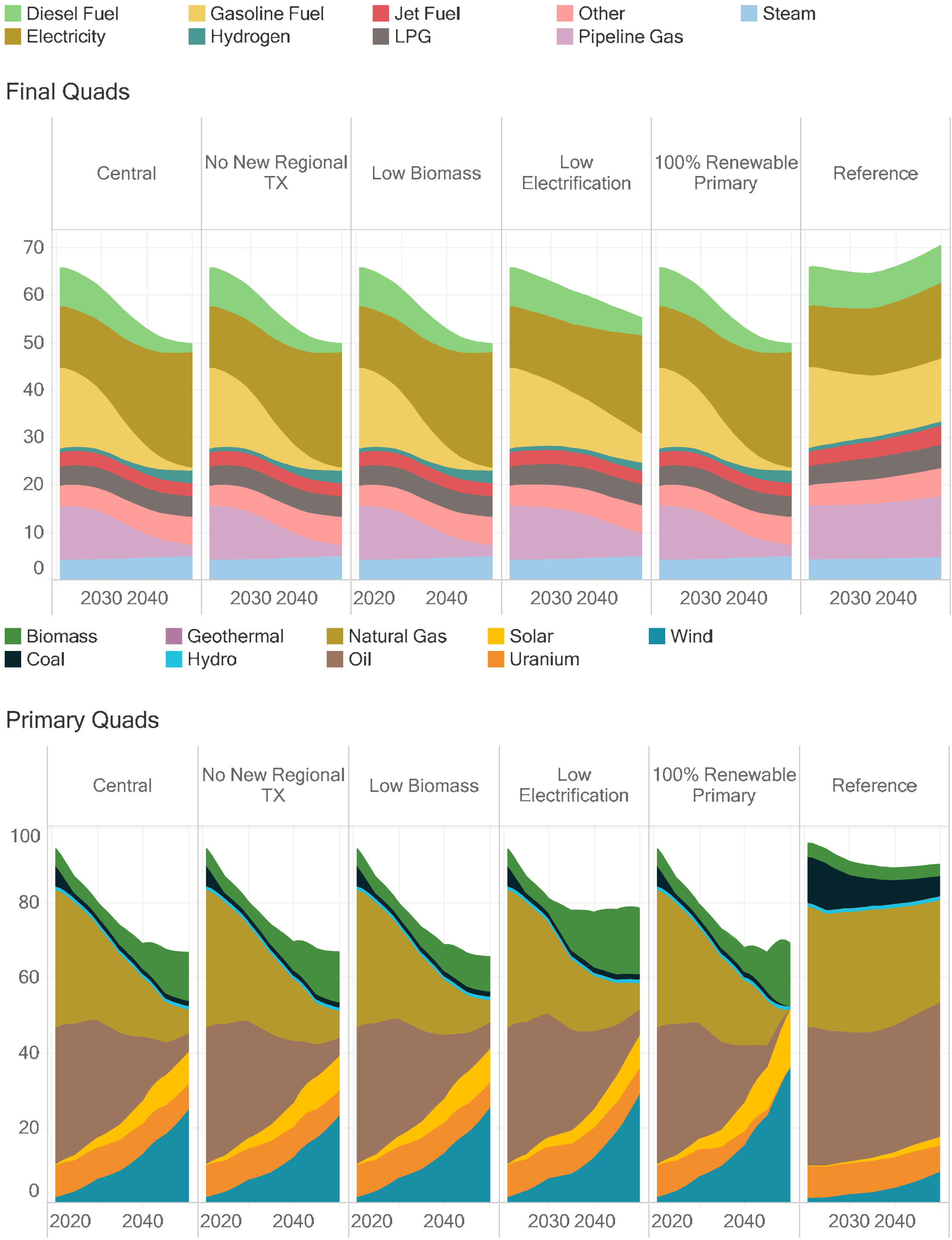


Figure 35 Components of emissions reductions in the Central scenario – U.S.

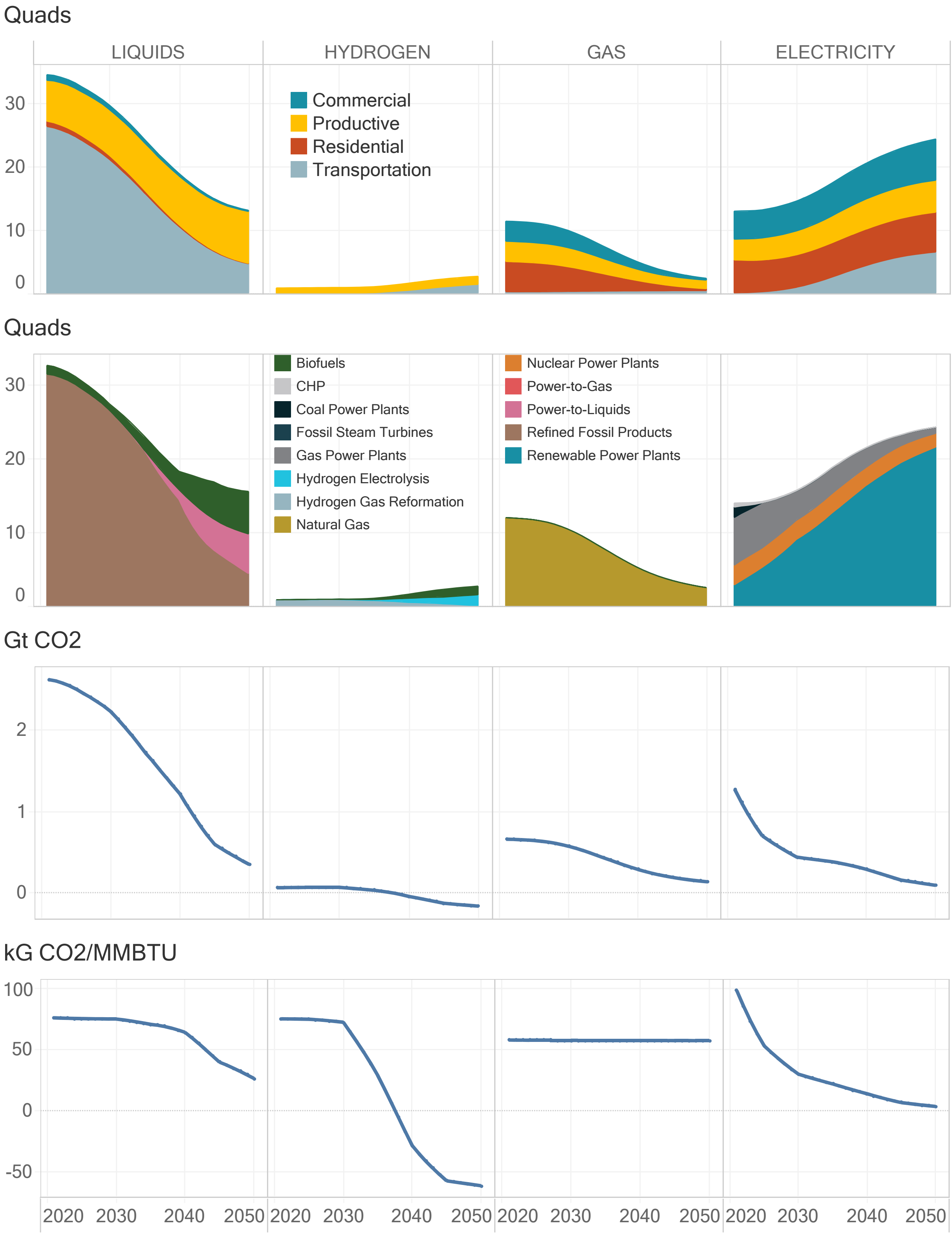


Figure 36 Components of emissions reductions in the Low Biomass scenario – U.S.

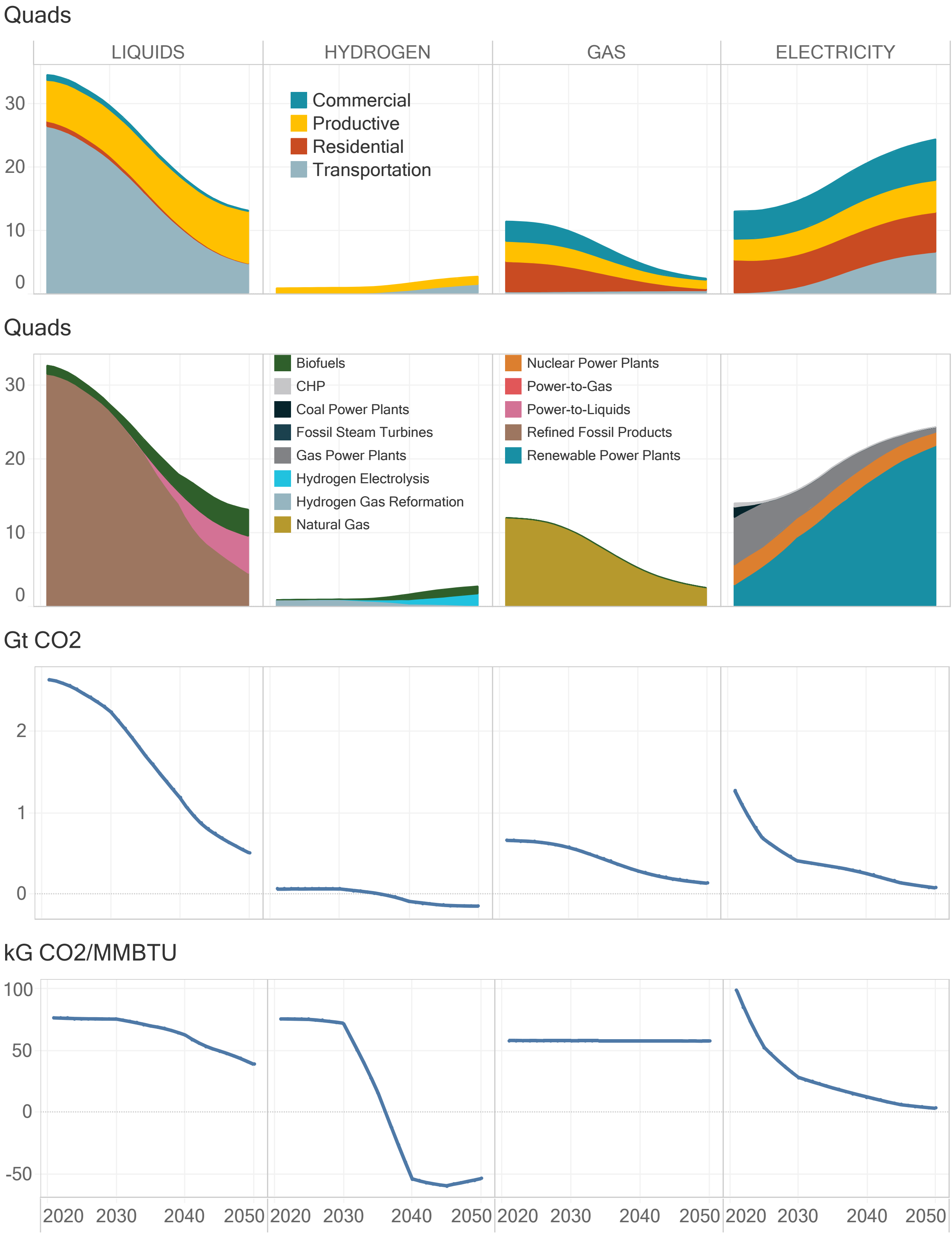


Figure 37 Components of emissions reductions in the Low Electrification scenario – U.S.

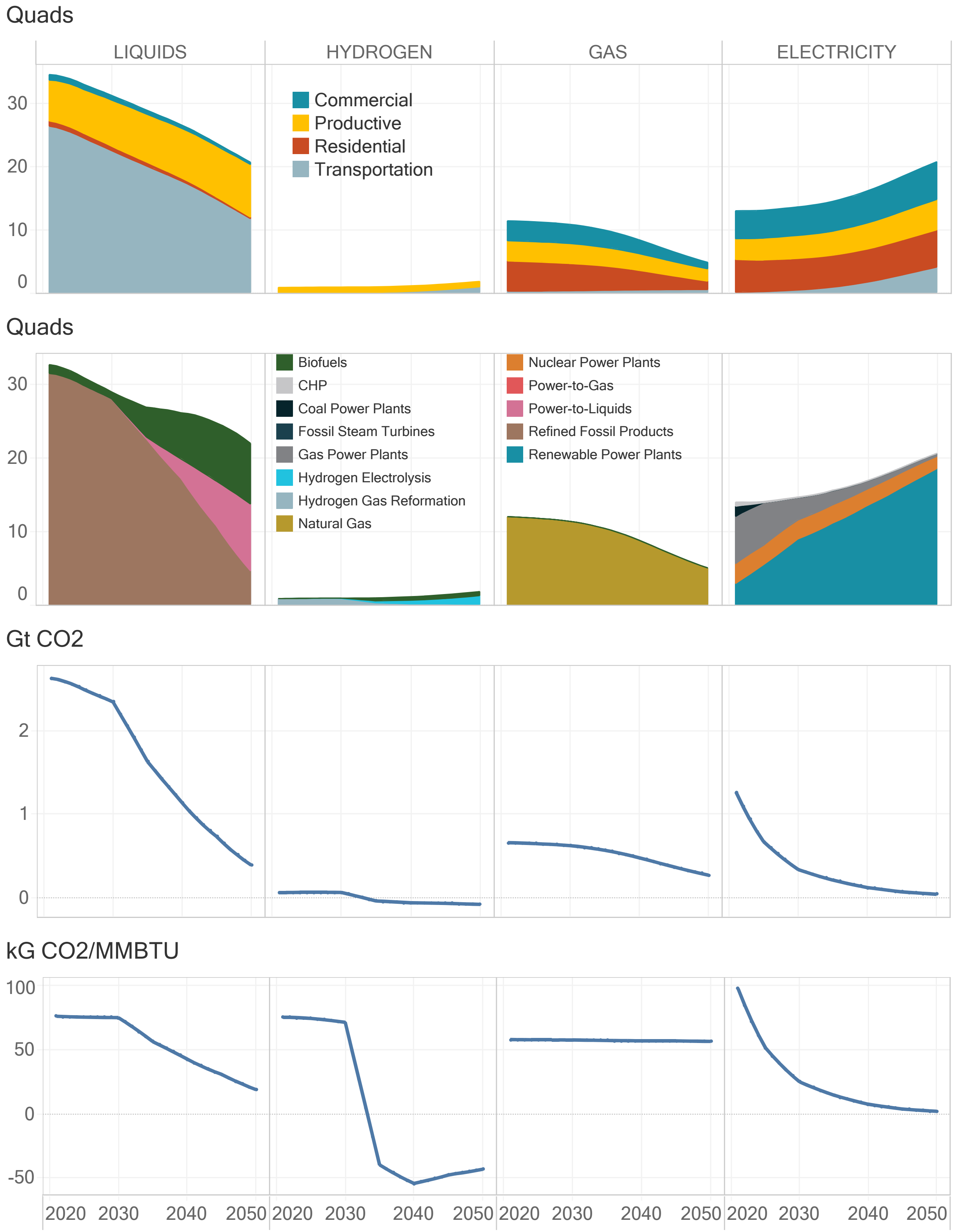


Figure 38 Components of emissions reductions in the No New Regional TX scenario – U.S.

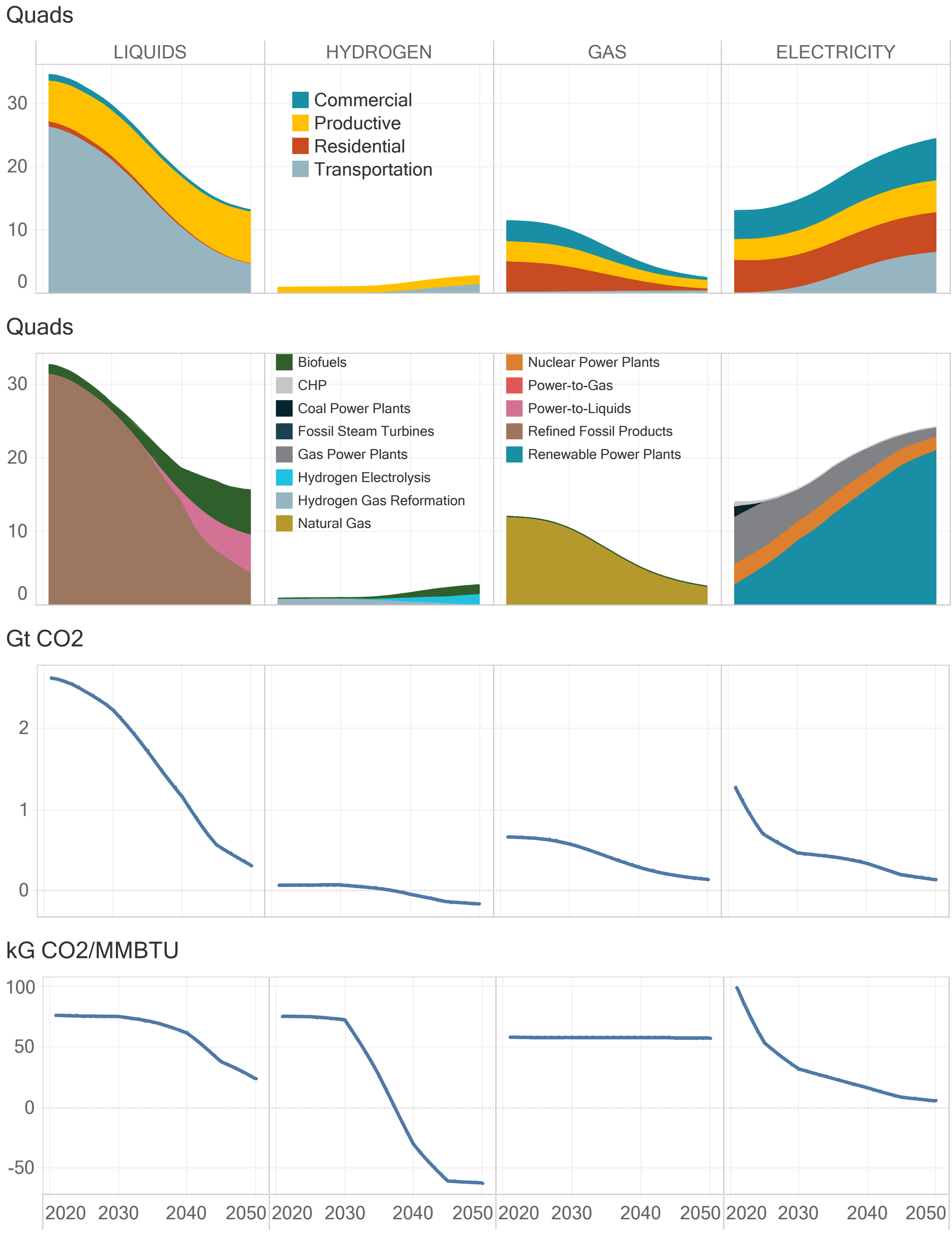


Figure 39 Components of emissions reductions in the 100% Renewable Primary scenario – U.S.

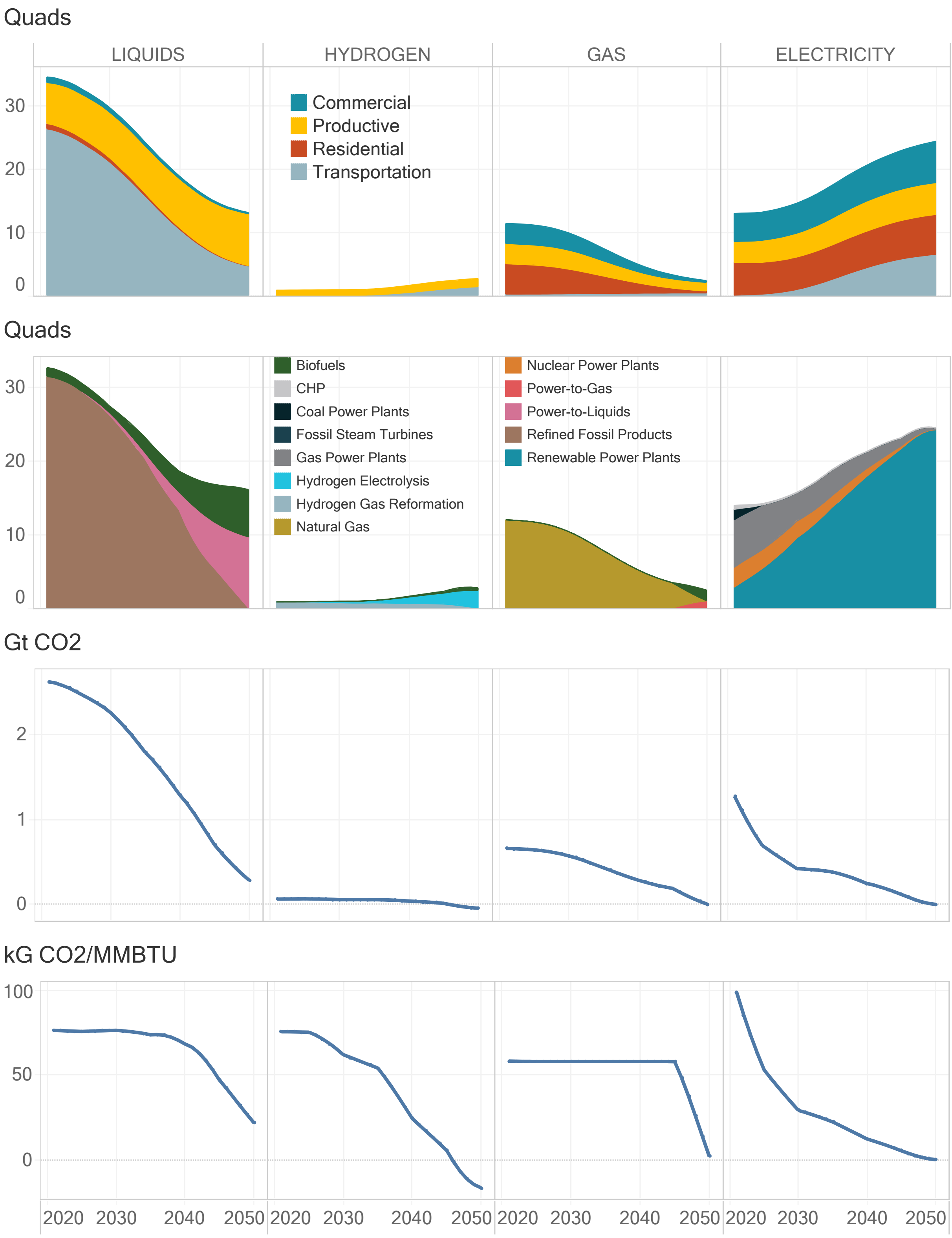


Figure 40 Annual net system cost premium above baseline in $2018 and as % of GDP – U.S.

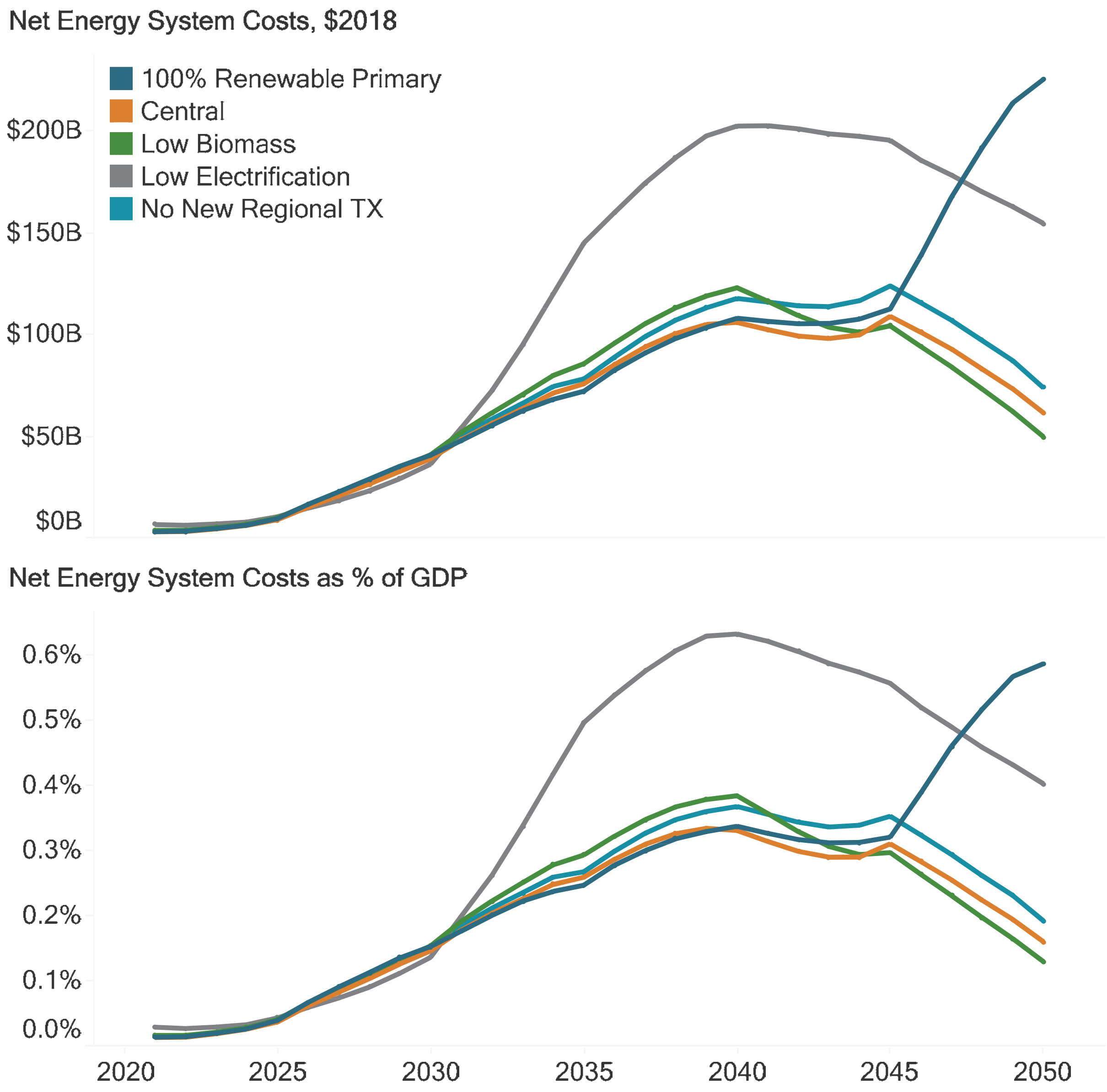


Figure 41 Net Change in E&I System Spending – U.S.

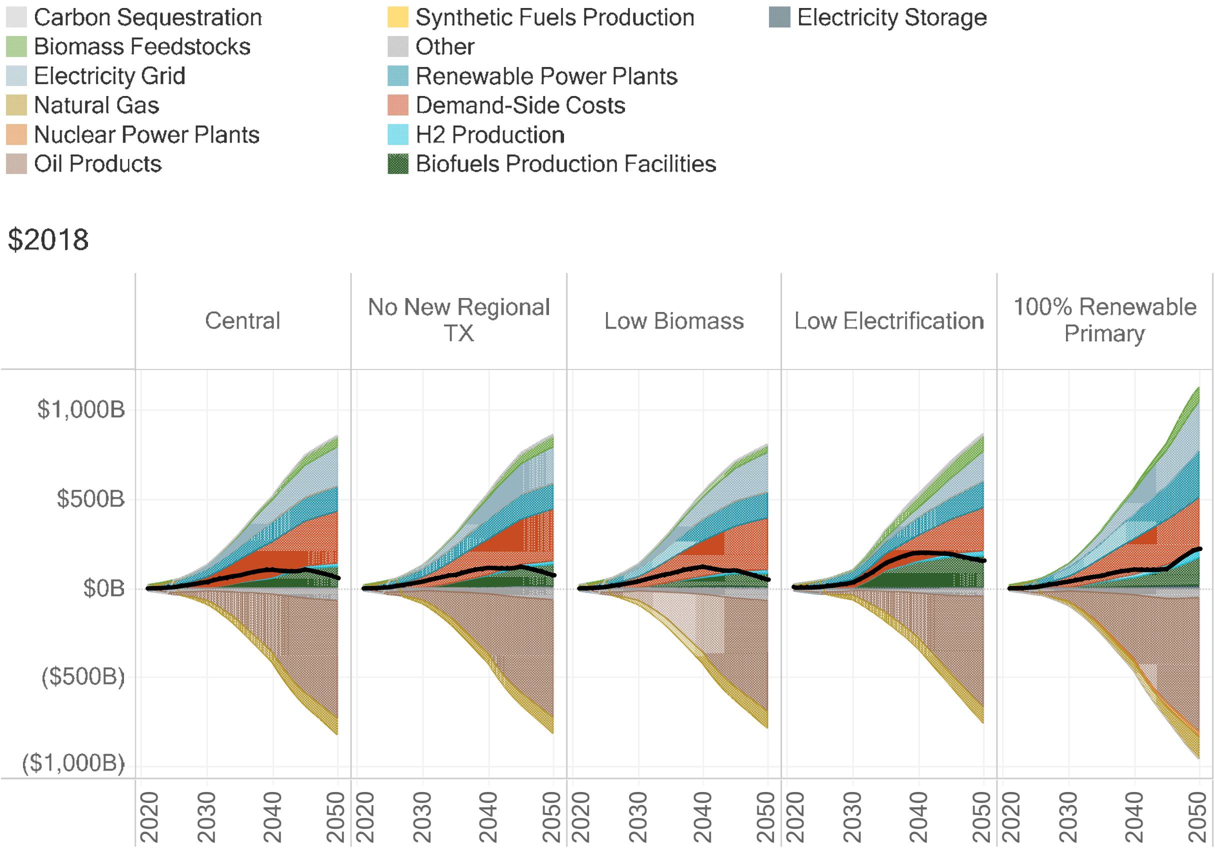
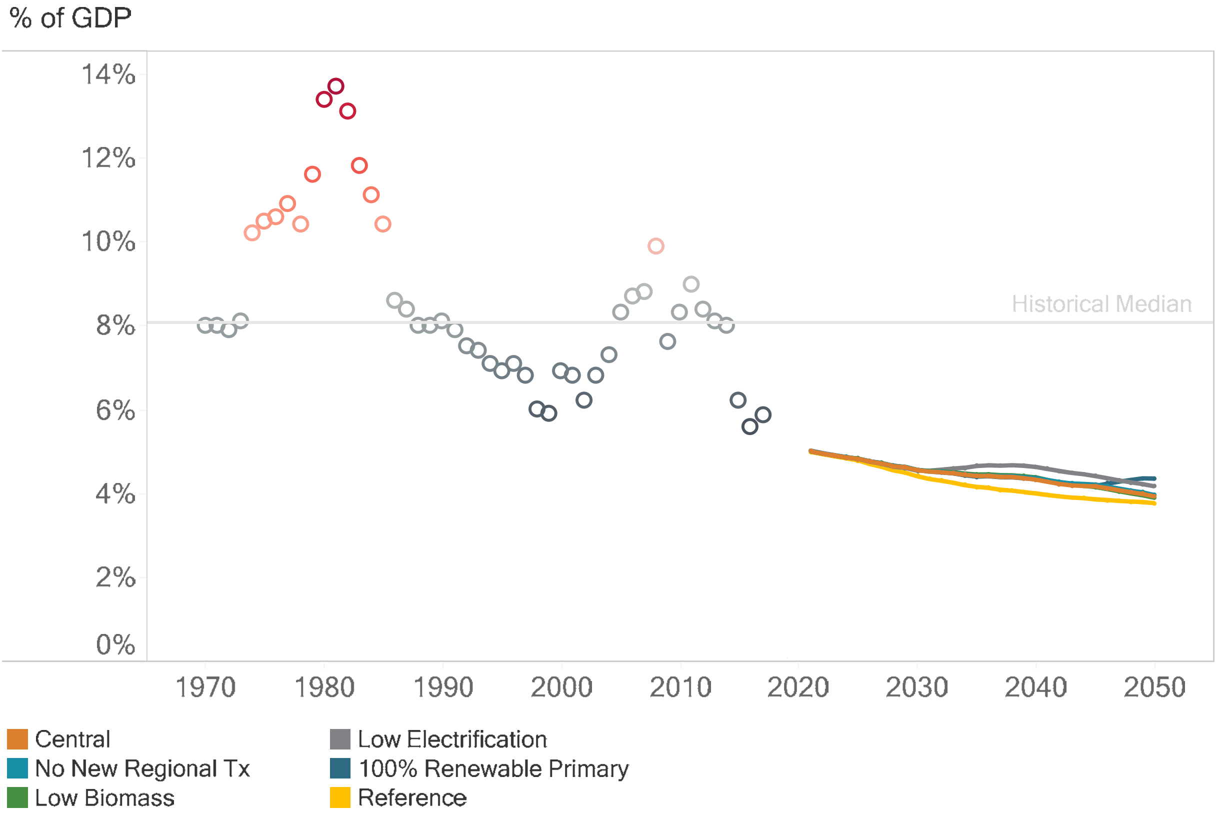


Figure 42 Total energy system costs as % of GDP –historical and projected – U.S.



Florida Results

Figure 43 Components of emissions reductions in the Low Biomass scenario - Florida

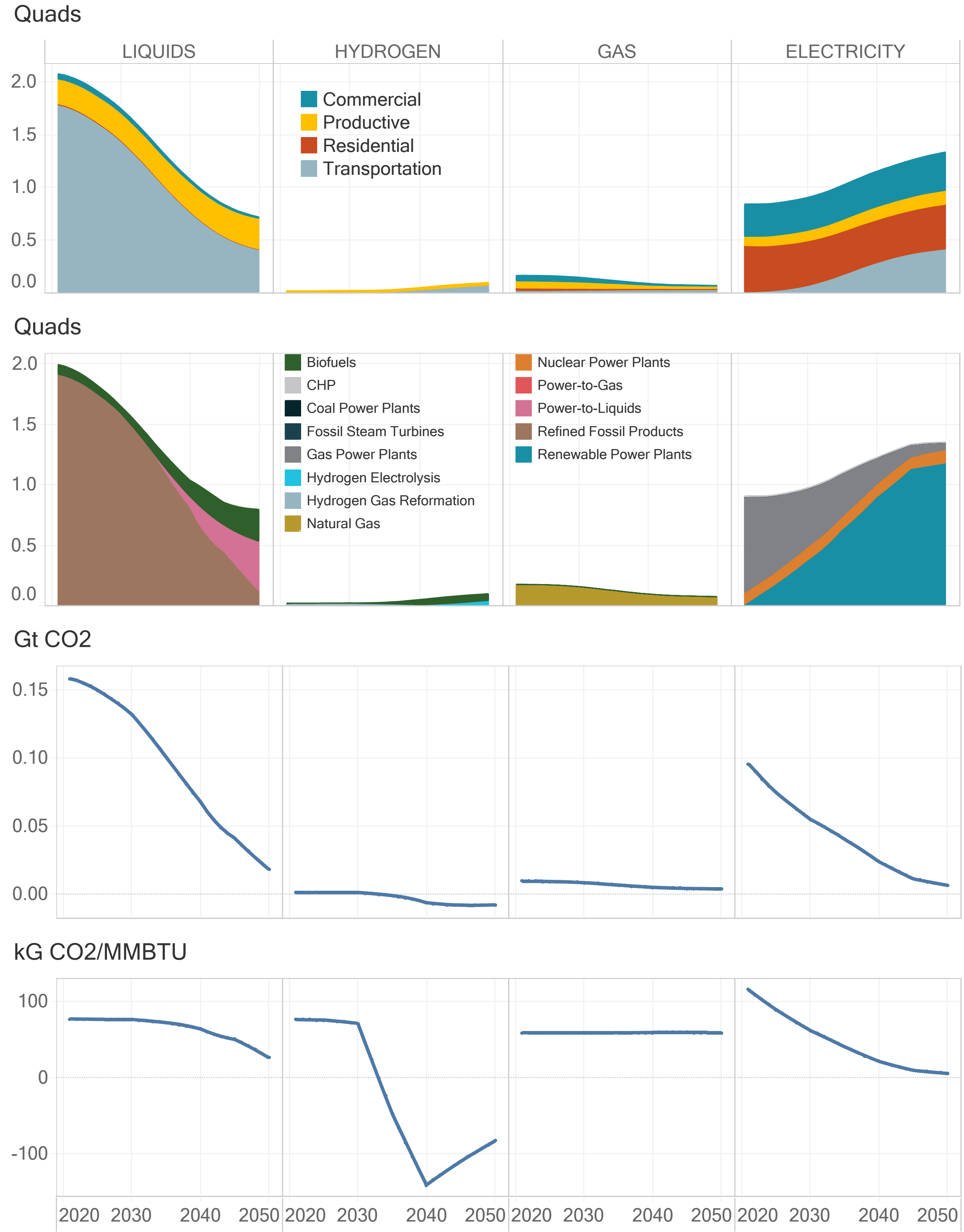


Figure 44 Components of emissions reductions in the Low Electrification scenario - Florida

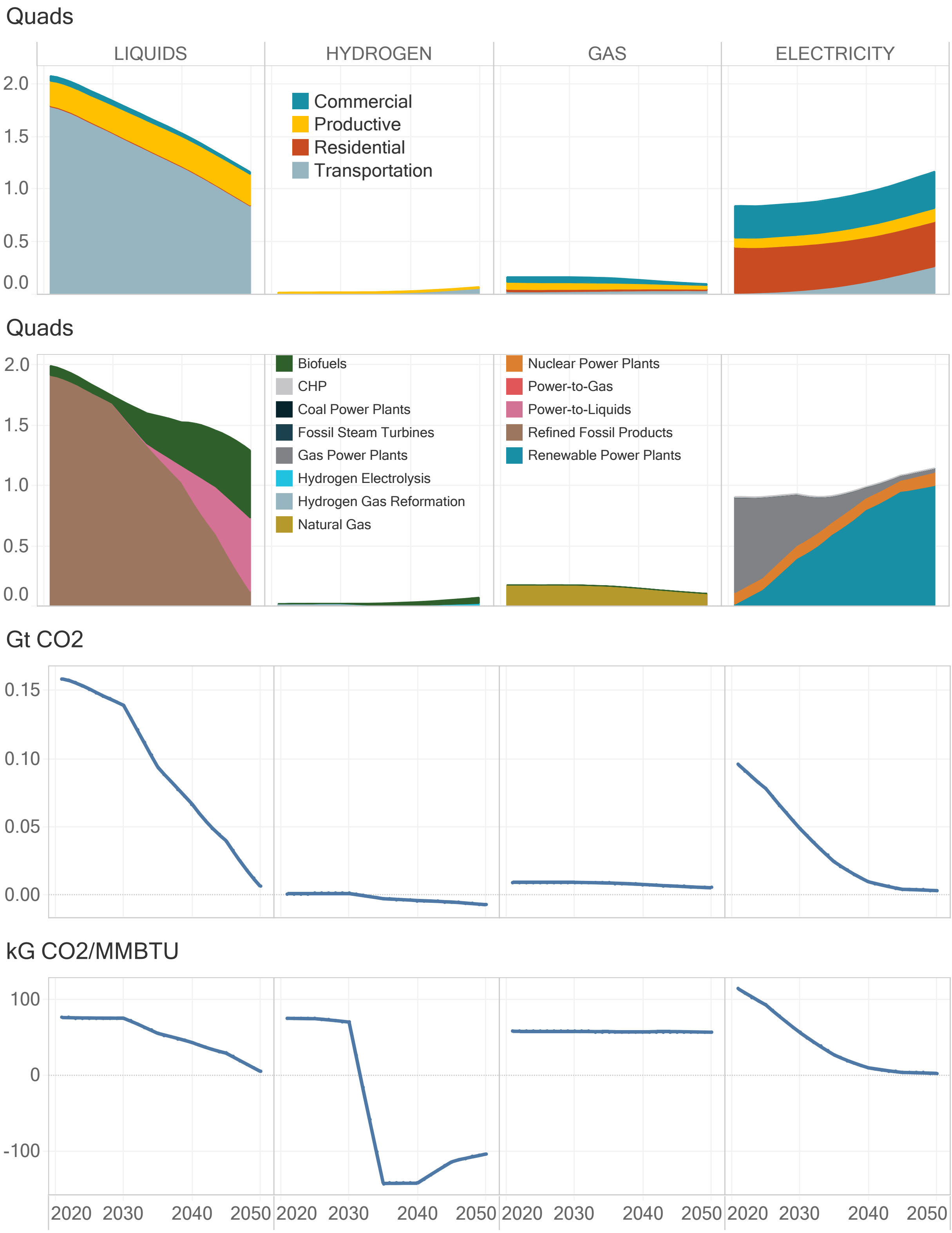


Figure 45 Components of emissions reductions in the No New Regional TX scenario - Florida

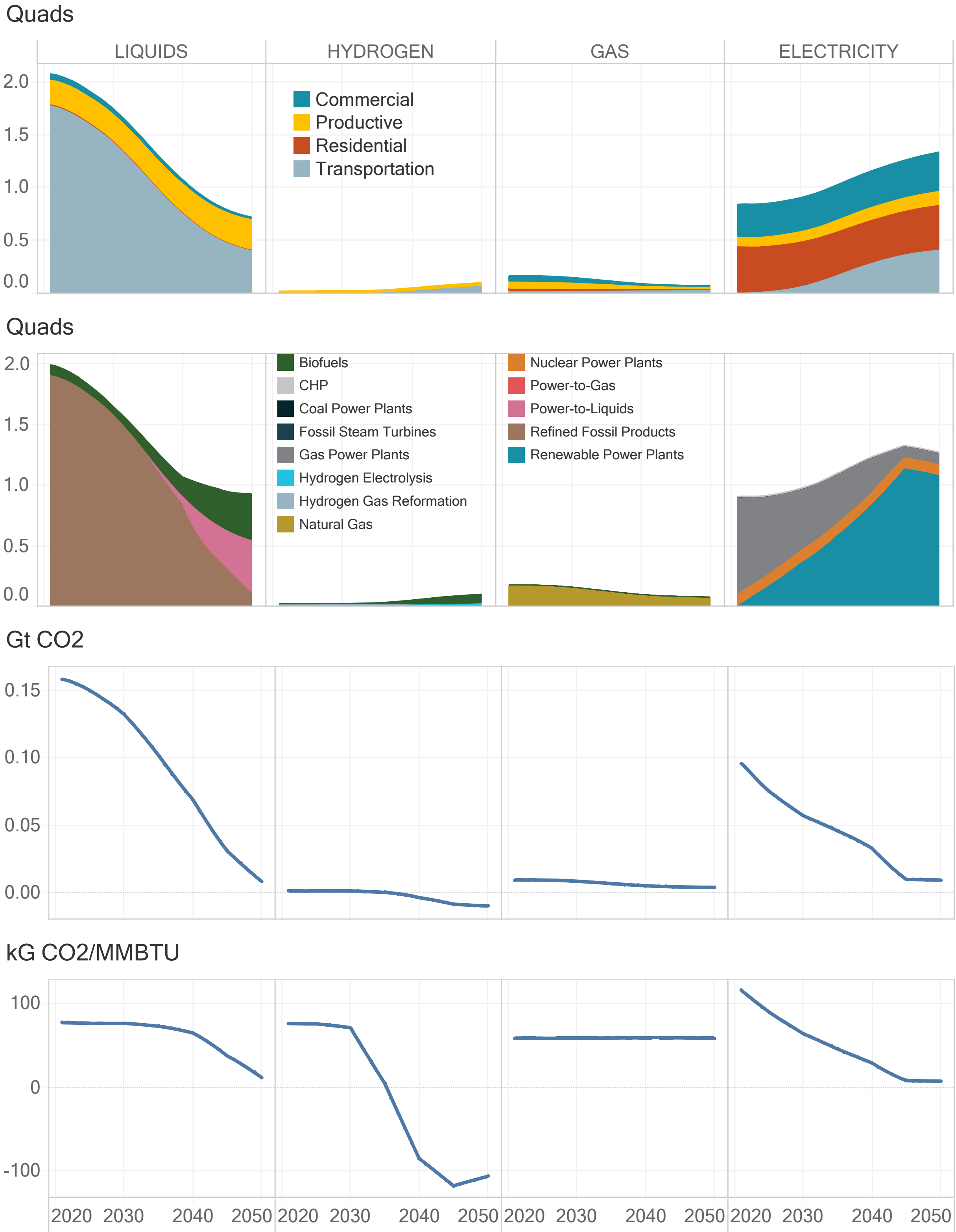
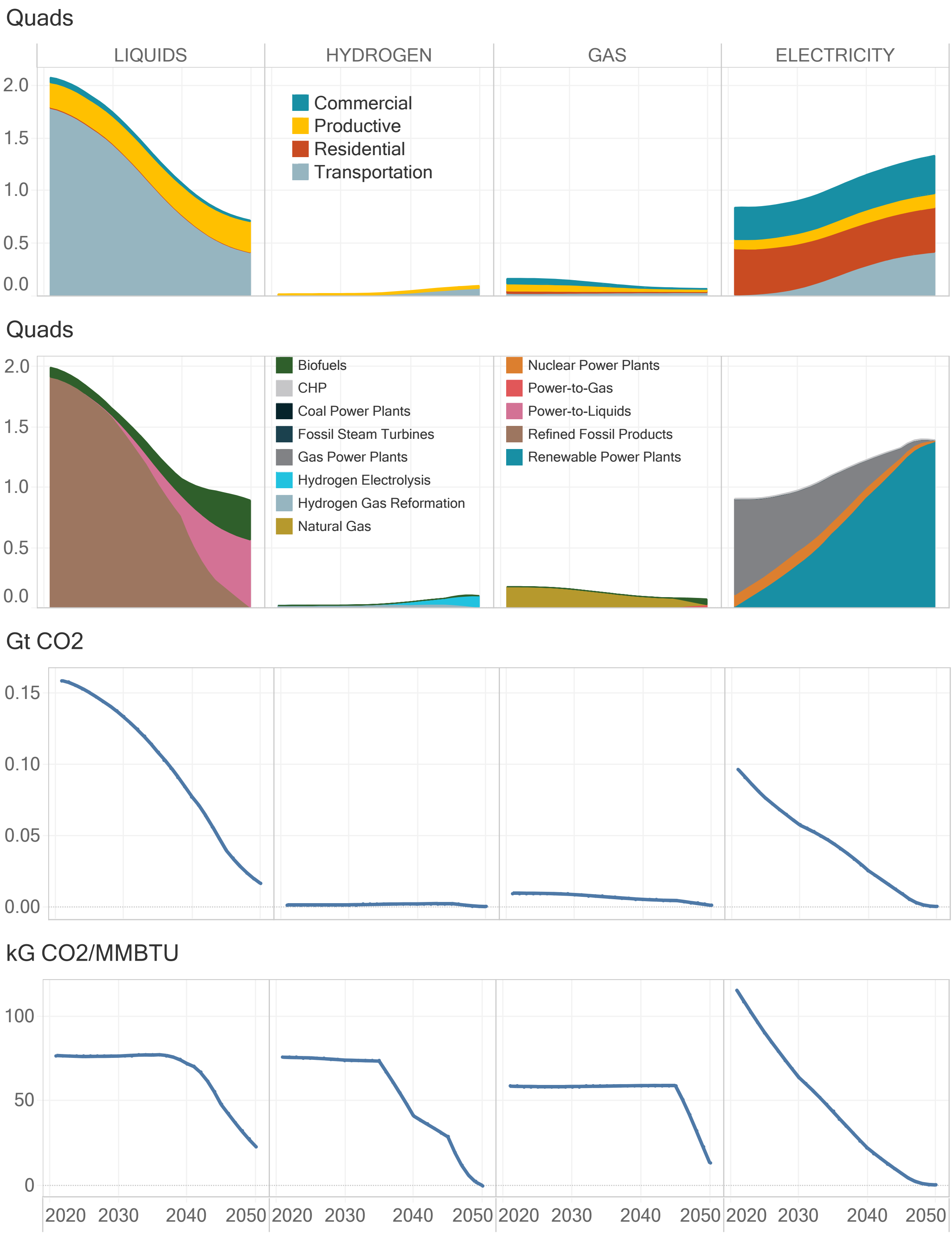


Figure 46 Components of emissions reductions in the 100% Renewable Primary scenario - Florida



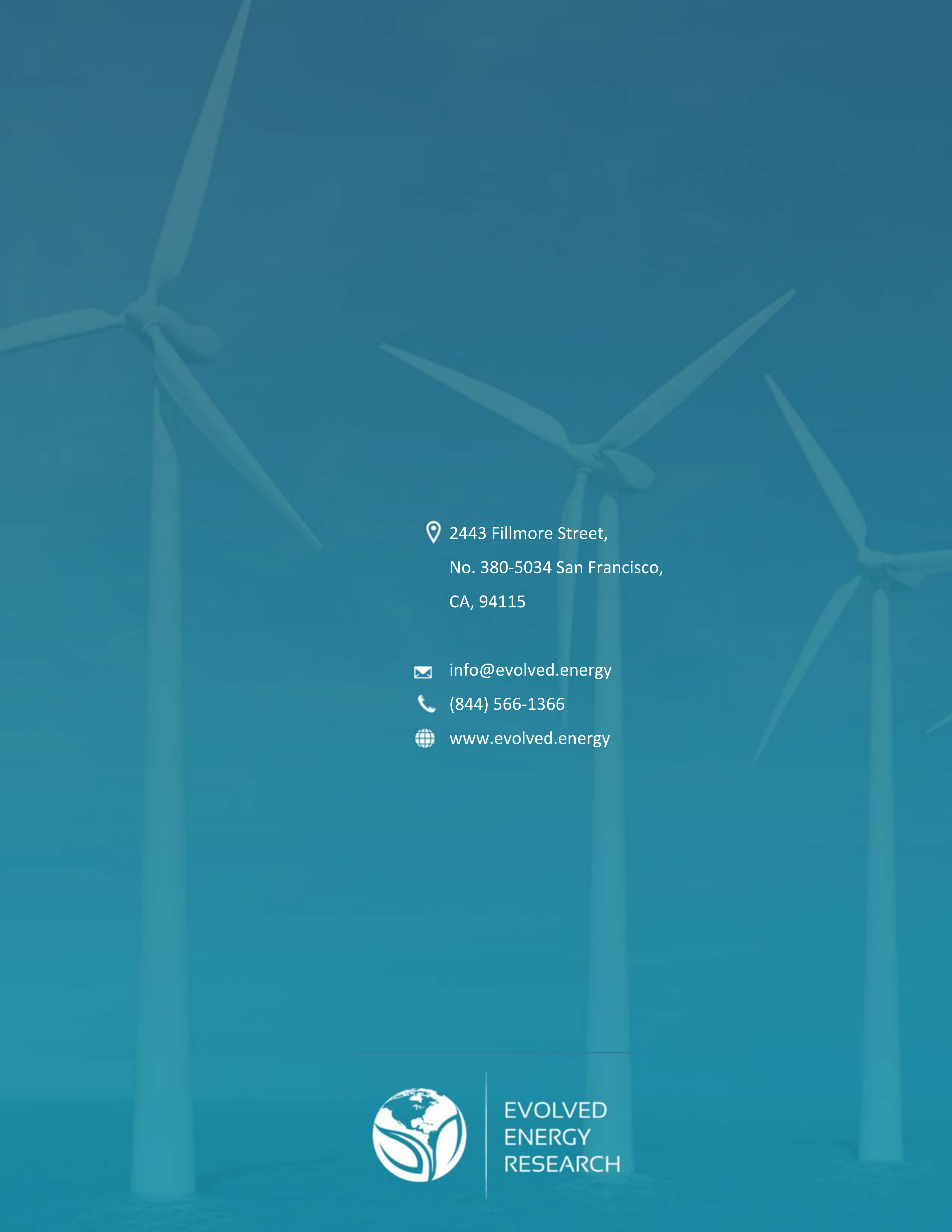


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Exhibit 3

Zero Air Pollution and Zero Carbon From All Energy Without Blackouts at Low Cost in Florida

By Mark Z. Jacobson, Stanford University, April 24, 2021

This infographic summarizes results from simulations that demonstrate the ability of Florida to match all-purpose energy demand with wind-water-solar (WWS) supply, storage, and demand response continuously every 30 seconds for the years 2050-2051. All-purpose energy is energy for electricity, transportation, buildings, and industry. Results are shown for Florida in isolation and for Florida interconnected with the Southeastern Electric Reliability Council (SERC) grid (AL, AR, FL, GA, IL, KY, LA, MS, MO, NC, SC, TN, and VA). The ideal transition timeline is 100% WWS by 2035; however, the results here are shown for 2050-2051, after additional population growth has occurred.

WWS electricity-generating technologies include onshore and offshore wind, solar photovoltaics (PV) on rooftops and in power plants, concentrated solar power (CSP), geothermal, hydro, tidal, and wave power. WWS direct heat-sources include geothermal and solar. WWS storage includes electricity, heat, cold, and hydrogen storage. WWS equipment includes electric and hydrogen fuel cell vehicles, heat pumps, induction cooktops, arc furnaces, induction furnaces, resistance furnaces, lawnmowers, etc. No fossil fuels, nuclear bioenergy, or carbon capture is included.

The results are derived from the LOADMATCH grid model using 2050 U.S. state-specific business-as-usual (BAU) and wind-water-solar (WWS) all-sector load data projected from 2018 EIA state load data. The model also uses 30-second resolution WWS supply plus building heating/cooling load data from the GATOR-GCMOM weather-prediction model. The models and results are described, respectively, in the following publications:

Jacobson, M.Z. (2021) On the correlation between building heat demand and wind energy supply and how it helps to avoid blackouts, Smart Energy, 1, 100009, doi:10.1016/j.segy.2021.100009, http://web.stanford.edu/group/efmh/jacobson/Articles/Others/21-Wind-Heat.pdf

Jacobson, M.Z., A.-K. von Krauland, S.J. Coughlin, F.C. Palmer, and M.M. Smith (2021), Zero air pollution and zero carbon from all energy at low cost and without blackouts in variable weather throughout the U.S. with 100% wind-water-solar (WWS) and storage, in review.

Main results. Transitioning Florida to 100% WWS for all energy purposes…

- **Keeps the grid stable 100% of the time. This is helped by the fact that, during cold storms, winds are stronger (Figure 1) and wind/solar are complementary in nature;**
- **Creates 356,000 more long-term, full-time jobs than lost when Florida's grid is interconnected with the SERC grid and 393,000 when its grid is isolated;**
- **Saves 2,840 lives from air pollution per year in 2050 in Florida;**
- **Eliminates 283 million tonnes-CO_2e per year in 2050 in Florida;**
- **Reduces 2050 all-purpose, end-use energy requirements by 52.8%;**
- **Reduces 2050 annual energy costs by 52.5% (from \$97.0 to \$46.1 b/y) when interconnected and 55.6% (from \$102.4 to \$45.4 b/y) when isolated;**
- **Reduces annual energy, health, plus climate costs by 84.2% (from \$292 to \$46.1 b/y) when interconnected and 84.7% (from \$298 to \$45.4 b/y) when isolated;**
- **Costs ~\$515 b upfront when interconnected and \$472 b when isolated. Upfront costs are paid back through energy sales. Costs are for WWS electricity, heat, and H_2 generation; electricity, heat, cold, and H_2 storage; heat pumps for district heating; all-distance transmission; and distribution;**
- **Requires 1.04% of Florida land for footprint, 0.91% for spacing when interconnected; 1.37% and 0.53% when isolated.**

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Table 1. Reduced End-Use Demand (Load) Upon a Transition From BAU to WWS

1st row: 2018 annually-averaged end-use load (GW) and percentage of the load by sector. 2nd row: estimated 2050 total annually-averaged end-use load (GW) and percentage of the total load by sector if conventional fossil-fuel, nuclear, and biofuel use continues to 2050 under a BAU trajectory. 3rd row: estimated 2050 total end-use load (GW) and percent of total load by sector if 100% of BAU end-use all-purpose delivered load in 2050 is instead provided by WWS. Column (i) shows the percent reductions in total 2050 BAU load due to switching from BAU to WWS, including the effects of (f) energy use reduction due to the higher work to energy ratio of electricity over combustion, (g) eliminating energy use for the upstream mining, transporting, and/or refining of coal, oil, gas, biofuels, bioenergy, and uranium, and (h) policy-driven increases in end-use efficiency beyond those in the BAU case. Column (j) is the ratio of electricity load (=all energy load) in the 2050 WWS case to the electricity load in the 2050 BAU case. Whereas Column (j) shows that electricity consumption increases in the WWS versus BAU cases, Column (i) shows that all energy decreases. The end-use loads are the same whether Florida's grid is isolated versus interconnected within the SERC region.

Scenario	(a) Total annual average end-use load (GW)	(b) Residential percent of total end-use load	(c) Commercial per-cent of total end-use load	(d) Industry per-cent of total end-use load	(e) Transport per-cent of total end-use load	(f) Percent change end-use load w/WWS due to higher work: energy ratio	(g) Percent change end-use load w/WWS due to eliminating upstream	(h) Percent change end-use load w/WWS due to efficiency beyond BAU	(i) Overall percent change in end-use load with WWS	(j) WWS :BAU electricity load
BAU 2018	97.3	16.9	15.5	12.3	55.4					
BAU 2050	103.8	18.8	17.7	16.0	47.4					
WWS 2050	49.0	29.8	24.1	19.8	26.3	-38.65	-5.36	-8.76	-52.77	1.38

Table 2. 2050 WWS End-Use Demand by Sector

2050 annual average end-use electric plus heat load (GW) by sector and region after energy in all sectors has been converted to WWS. Instantaneous loads can be higher or lower than annual average loads. Values for each region equal the sum over all state values from Table 1. The end-use loads are the same whether Florida's grid is isolated versus interconnected within the SERC region.

State/region	Total	Residential	Commercial	Transport	Industrial
Florida	49.0	14.63	11.80	9.71	12.91

Table 3. WWS End-Use Demand by Load Type

Annual average WWS all-sector inflexible and flexible loads (GW) for 2050 by region. "Total load" is the sum of "inflexible load" and "flexible load." "Flexible load" is the sum of "cold load subject to storage," "low-temperature heat load subject to storage," "load for H_2" production, compression, and storage (accounting for leaks as well), and "all other loads subject to demand response (DR)." Annual average loads are distributed in time at 30-s resolution, as described in the text. Instantaneous loads, either flexible or inflexible, can be much higher or lower than annual average loads. Also shown is the annual hydrogen mass needed in each region, estimated as the H_2 load multiplied by 8,760 hr/yr and divided by 59.01 kWh/kg-H_2. The end-use loads are the same whether Florida's grid is isolated versus interconnected within the SERC region.

State/region	Total end-use load (GW)	Inflexible load (GW)	Flexible load (GW)	Cold load subject to storage (GW)	Low-temperature heat load subject to storage (GW)	Load subject to DR	Load for H_2 (GW)	H_2 needed (Tg-H_2/yr)
Florida	49.0	25.3	23.8	1.66	2.91	5.62	13.6	0.83

Table 4. Nameplate Capacities Needed by 2050 and Installed as of 2019/2020

Final (from LOADMATCH) 2050 total (existing plus new) nameplate capacity (GW) of WWS generators needed to match power demand with supply, storage, and demand response continuously during 2050-2051. Two cases are shown: one when Florida is isolated from the SERC region (2050-Iso). The second is when Florida is interconnected within the SERC region (2050-Int). Also provided are nameplate capacities already installed as of 2019 or 2020 end. Nameplate capacity equals the maximum possible instantaneous discharge rate.

Year	Onshore wind	Offshore wind	Residential rooftop PV	Comm/govt rooftop PV	Utility PV	CSP with storage	Geothermal-electricity	Hydro power	Wave	Tidal	Solar thermal	Geothermal heat
2019/20	0	0	0.40	0.08	2.07	0.08	0	0.04	0	0	0	0
2050-Iso	10.46	58.71	34.79	27.26	158.6	0.13	0	0.04	0.53	0.11	0	0
2050-Int	17.93	95.41	54.94	32.71	120.3	0.065	0	0.04	0.53	0.11	0	0

Table 5. Capacity Factors of WWS Generators

Simulation-averaged 2050-2051 capacity factors (percent of nameplate capacity produced as electricity before transmission, distribution or maintenance losses). The mean capacity factors in this table equal the simulation-averaged power supplied by each generator in each region (Table 6) divided by the nameplate capacity of each generator in each region (Table 4).

Scenario	Onshore wind	Offshore wind	Rooftop PV	Utility PV	CSP with storage	Geothermal electricity	Hydropower	Wave	Tidal	Solar thermal	Geothermal heat
Florida isolated	0.199	0.193	0.212	0.235	0.81	0	0.545	0.297	0.247	0	0

Capacity factors of offshore and onshore wind turbines account for array losses (extraction of kinetic energy by turbines). The symbol “--“ indicates no installation of the technology. Rooftop PV panels are fixed-tilt at the optimal tilt angle of the country they reside in; utility PV panels are half fixed optimal tilt and half single-axis horizontal tracking.

Table 6. Percent of Load Met by Different WWS Generators

Projected simulation-averaged 2050-2051 all-sector WWS energy supply before transmission and distribution losses, storage losses, or shedding losses, in Florida, and percent of supply met by each generator, based on LOADMATCH simulations. Simulation-average power supply (GW) equals the simulation total energy supply (GWh/yr) divided by the number of hours of simulation. The percentages for each region add to 100%. Multiply each percentage by the 2050 total supply to obtain the GW supply by each generator. Divide the GW supply from each generator by its capacity factor (Table 5) to obtain the 2050 nameplate capacity of each generator needed to meet the supply (Table 4).

Scenario	Total WWS supply (GW)	Onshore wind (%)	Offshore wind (%)	Roof PV (%)	Utility PV (%)	CSP with storage (%)	Geothermal electricity (%)	Hydropower (%)	Wave (%)	Tidal (%)	Solar thermal heat (%)	Geothermal heat (%)
Florida isolated	64.1	3.25	17.65	20.53	58.09	0.16	0	0.04	0.25	0.042	0	0

Table 7. Characteristics of Storage Resulting in Matching Demand With 100% WWS Supply

Maximum charge rates, discharge rate, storage capacity, and hours of storage at the maximum discharge rate of all electricity, cold and heat storage needed for supply + storage to match demand in Florida when its grid isolated from the outside world.

Storage type	Max charge rate (GW)	Max discharge rate (GW)	Max storage capacity (TWh)	Max storage time at max discharge rate (hr)
PHS	0.10	0.10	0.0014	14
CSP-elec.	0.13	0.13	--	--
CSP-PCM	0.21	--	0.0029	22.6
Batteries	262	262	1.048	4
Hydropower	0.023	0.044	0.202	4,591
CW-STES	0.67	0.67	0.009	8
ICE	1.00	1.00	0.014	14
HW-STES	21.59	21.59	0.17	8
UTES-heat	0	21.59	10.36	480
UTES-elec.	21.59	--	--	--

Same as above, but the for the SERC region

Storage type	Max charge rate (GW)	Max discharge rate (GW)	Max storage capacity (TWh)	Max storage time at max discharge rate (hr)
PHS	10.81	10.81	0.151	14
CSP-elec.	0.065	0.065	--	--
CSP-PCM	0.10	--	0.0015	22.6
Batteries	1370	1370	5.48	4
Hydropower	6.88	15.07	60.29	4,001
CW-STES	0.94	0.94	0.013	8
ICE	1.41	1.41	0.020	14
HW-STES	59.04	59.04	0.47	8
UTES-heat	0	59.04	28.34	480
UTES-elec.	59.04	--	--	--

PHS=pumped hydropower storage; PCM=Phase-change materials; CSP=concentrated solar power; CW-STES=Chilled-water sensible heat thermal energy storage; HW-STES=Hot water sensible heat thermal energy storage; and UTES=Underground thermal energy storage (either boreholes, water pits, or aquifers). The peak energy storage capacity equals the maximum discharge rate multiplied by the maximum number of hours of storage at the maximum discharge rate.

Pumped hydro storage is estimate as the existing (in 2020) nameplate capacity plus the nameplate capacity of pending licenses and of preliminary permits by state (in 2020) (FERC, 2021). If a region has no existing or pending pumped hydro, a minimum of 100 MW is imposed to account for the addition of pumped hydro between 2021 and 2050.

Heat captured in a working fluid by a CSP solar collector can either be used immediately to produce electricity by evaporating water and running it through a steam turbine connected to a generator, stored in a phase-change material, or both. The maximum direct CSP electricity production rate (CSP-elec) equals the maximum electricity discharge rate, which equals the nameplate capacity of the generator. The maximum charge rate of CSP phase-change material storage (CSP-PCM) is set to 1.612 multiplied by the maximum electricity discharge rate, which allows more energy to be collected than discharged directly as electricity. Thus, since the high-temperature working fluid in the CSP plant can be used to produce electricity and charge storage at the same time, the maximum overall electricity production plus storage charge rate of energy is 2.612 multiplied by the maximum discharge rate. This ratio is also the ratio of the mirror size with storage versus without storage. This ratio can be up to 3.2 in existing CSP plants. The maximum energy storage capacity equals the maximum electricity discharge rate multiplied by the maximum number of hours of storage at full discharge, set to 22.6 hours, or 1.612 multiplied by the 14 hours required for CSP storage to charge when charging at its maximum rate.

Hydropower's maximum discharge rate in 2050 is its 2019 nameplate capacity. Hydropower can be recharged only naturally by rainfall and runoff, and its annual-average recharge rate approximately equals its 2019 annual energy output (TWh/yr) divided by the number of hours per year. Hydro is recharged each time step at this recharge rate. The maximum hydropower energy storage capacity available in all reservoirs is also assumed to equal hydro's 2019 annual energy output. Whereas the present table gives hydro's maximum storage capacity, its output from storage during a given time step is limited by the smallest among three factors: the current energy available in the reservoir, the peak hydro discharge rate multiplied by the time step, and the energy required.

The CW-STES peak discharge rate is set equal to 40% of the annual average cold load (for air conditioning and refrigeration) subject to storage. The ICE storage discharge rate is set to 60% of the same annual average cold load subject to storage. The peak charge rate is set equal to the peak discharge rate.

The HW-STES peak discharge rate is set equal to the maximum instantaneous heat load subject to storage during any 30-second period of the two-year simulation. The values have been converted to electricity assuming the electricity produces heat for heat pumps with a coefficient of performance of 4. Because they are based on maximum rather than the annual average loads, they are higher than the annual-average low-temperature heat loads subject to storage in Table 3. The peak charge rate is set equal to the peak discharge rate.

UTES heat stored in underground soil (borehole storage) or water (water pit or aquifer storage) can be charged with either solar or geothermal heat or excess electricity (assuming the electricity produces heat with an electric heat pump at a coefficient of performance of 4). The maximum charge rate of heat (converted to equivalent electricity) to UTES storage (UTES-heat) is set to the nameplate capacity of solar thermal collectors divided by the coefficient of performance of a heat pump=4). When no solar thermal collectors are used, such as in all simulations here, the maximum charge rate for UTES-heat is zero, and UTES is charged only with excess grid electricity running heat pumps. The maximum charge rate of UTES storage using excess grid electricity (UTES-elec.) is set equal to the maximum instantaneous heat load subject to storage during any 30-second period of the two-year simulation. The maximum UTES heat discharge rate is set equal to the maximum instantaneous heat load subject to storage. The maximum charge rate, discharge rate, and capacity of UTES storage are all in units of equivalent electricity that would give heat at a coefficient of performance of 4.

Figure 1. Keeping the Electric Grid Stable With 100% WWS + Storage + Demand Response
2050-2051 hourly time series showing the matching of all-energy demand with supply and storage in Florida when its grid is isolated from the outside world. First row: modeled time-dependent total WWS power generation versus load plus losses plus changes in storage plus shedding for the full two-year simulation period. Second row: same as first row, but for a window of 100 days during the simulation. Third row: a breakdown of WWS power generation by source during the window. Fourth row: a breakdown of inflexible load; flexible electric, heat, and cold load; flexible hydrogen load; losses in and out of storage; transmission and distribution losses; changes in storage; and shedding. Fifth row: A breakdown of solar PV+CSP electricity production, onshore plus offshore wind electricity production, building total cold load, and building total heat load (as used in LOADMATCH), summed over each region; Sixth row: correlation plots of building heat load versus wind power output and wind power output versus solar power output, obtained from all hourly data during the simulation. Correlations are very strong for R=0.8-1 (R^2=0.64-1); strong for R=0.6-0.8 (R^2=0.36-0.64); moderate for R=0.4-0.6 (R^2=0.16-0.36); weak for 0.2-0.4 (R^2=0.04-0.16); and very weak for 0-0.2 (R^2=0-0.04) (Evans, 1996). The model was run at 30-s resolution. Results are shown hourly, so units are energy output (TWh) per hour increment, thus also in units of power (TW) averaged over the hour. No load loss occurred during any 30-s interval. Raw GATOR-GCMOM results for solar, wind, heat load, and cold load were provided and fed into LOADMATCH at 30-s time increments. LOADMATCH modified the magnitudes, but not time series, of GATOR-GCMOM results, as described in the main text.

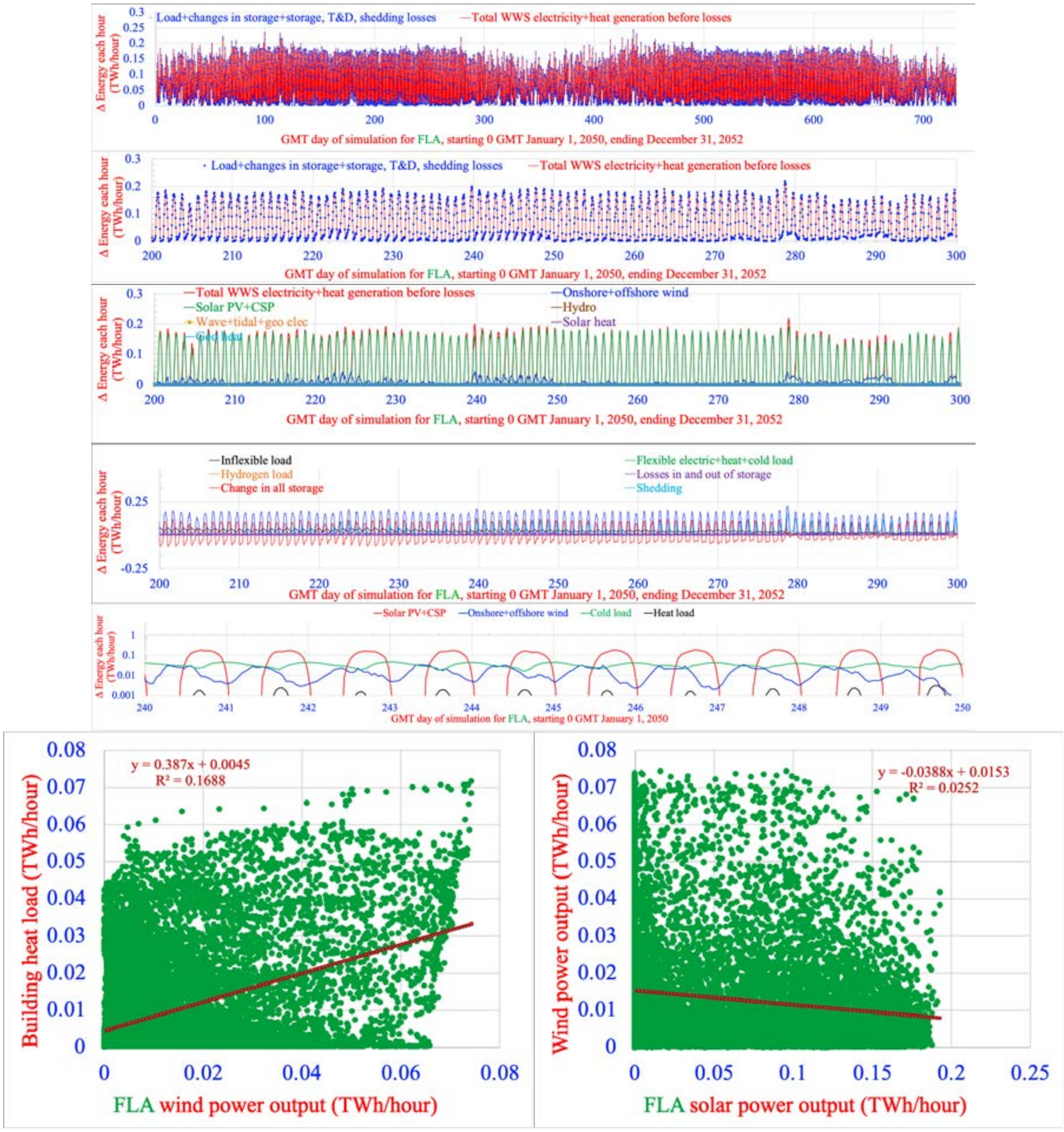

Table 8. Summary of Energy Budget Resulting in Grid Stability

Budget of simulation-averaged end-use power demand met, energy lost, WWS energy supplied, and changes in storage, during the 2-year (17,507.4875 hour) simulations. All units are GW averaged over the simulation and are derived from the data in Table 9 by dividing values from the table in units of TWh per simulation by the number of hours of simulation. TD&M losses are transmission, distribution, and maintenance losses. Wind turbine array losses are already accounted for in the "WWS supply before losses" numbers," since wind supply values come from GATOR-GCMOM, which accounts for such losses. Results are shown for Florida when its grid is isolated and for the SERC region as a whole, within which Florida is interconnected.

Scenario	(a) Annual average end-use load (GW)	(b) TD&M losses (GW)	(c) Storage losses (GW)	(d) Shedding losses (GW)	(e) End-use load+ losses =a+b+ c+d (GW)	(f) WWS supply before losses (GW)	(g) Changes in storage (GW)	(h) Supply+ changes in storage =f+g (GW)
Florida isolated	49.04	4.02	3.02	8.33	64.41	64.12	0.29	64.41
SERC region	378.8	37.73	15.05	180.2	611.7	610.5	1.25	611.7

Table 9. Details of Energy Budget Resulting in Grid Stability

Budget of simulation-total end-use energy demand met, energy lost, WWS energy supplied, and changes in storage, during the 2-year (17,507.4875 hour) simulations. All units are TWh over the simulation. Divide by the number of hours of simulation to obtain simulation-averaged power values, which are provided in Table 8 for key parameters. Results are shown for Florida when its grid is isolated and for the SERC region as a whole, within which Florida is interconnected.

	Florida isolated	SERC region
A1. Total end use demand	**859**	**6,631**
Electricity for electricity inflexible demand	463	3,454
Electricity for electricity, heat, cold storage + DR	297	2,637
Electricity for H_2 direct use + H_2 storage	98	540
A2. Total end use demand	**859**	**6,631**
Electricity for direct use, electricity storage, + H_2	803	6,378
Low-T heat load met by heat storage	51	246
Cold load met by cold storage	4.56	7.26
A3. Total end use demand	**859**	**6,631**
Electricity for direct use, electricity storage, DR	680	5,782
Electricity for H_2 direct use + H_2 storage	98	540
Electricity + heat for heat subject to storage	51	269
Electricity for cold load subject to storage	29.11	41.12
B. Total losses	**269**	**4,078**
Transmission, distribution, downtime losses	70	661
Losses CSP storage	0.01	0.01
Losses PHS storage	0.0000	0.0077
Losses battery storage	28.88	158.1
Losses CW-STES + ICE storage	0.82	1.3
Losses HW-STES storage	5.59	28.7
Losses UTES storage	17.51	75.4
Losses from shedding	145.9	3,154
Net end-use demand plus losses (A1 + B)	***1,127.7***	***10,709***
C. Total WWS supply before T&D losses	**1,123**	**10,687**
Onshore + offshore wind electricity	235	2,956
Rooftop + utility PV+ CSP electricity	884	7,589
Hydropower electricity	0.4	123.8

Wave electricity	2.78	16.90
Geothermal electricity	0	0
Tidal electricity	0.469	2.016
Solar heat	0	0
Geothermal heat	0	0
D. Net taken from (+) or added to (-) storage	**5.0525**	**21.8576**
CSP storage	0.0015	0.0007
PHS storage	-0.0001	-0.0151
Battery storage	-0.0636	-0.3131
CW-STES+ICE storage	-0.0022	-0.0031
HW-STES storage	0.1189	0.3435
UTES storage	3.2758	22.5206
H_2 storage	1.7223	-0.6759
Energy supplied plus taken from storage (C+D)	***1,127.7***	***10,709***

End-use demands in A1, A2, A3 should be identical. Generated electricity is shed when it exceeds the sum of electricity demand, cold storage capacity, heat storage capacity, and H_2 storage capacity.

Onshore and offshore wind turbines in GATOR-GCMOM, used to calculate wind power output for use in LOADMATCH, are assumed to be Senvion (formerly Repower) 5 MW turbines with 126-m diameter blades, 100 m hub heights, a cut-in wind speed of 3.5 m/s, and a cut-out wind speed of 30 m/s.

Rooftop PV panels in GATOR-GCMOM were modeled as fixed-tilt panels at the optimal tilt angle of the country they resided in; utility PV panels were modeled as half fixed optimal tilt and half single-axis horizontal tracking. All panels were assumed to have a nameplate capacity of 390 W and a panel area of 1.629668 m^2, which gives a 2050 panel efficiency (Watts of power output per Watt of solar radiation incident on the panel) of 23.9%, which is an increase from the 2015 value of 20.1%.

Each CSP plant before storage is assumed to have the mirror and land characteristics of the Ivanpah solar plant, which has 646,457 m^2 of mirrors and 2.17 km^2 of land per 100 MW nameplate capacity and a CSP efficiency (fraction of incident solar radiation that is converted to electricity) of 15.796%, calculated as the product of the reflection efficiency of 55% and the steam plant efficiency of 28.72%. The efficiency of the CSP hot fluid collection (energy in fluid divided by incident radiation) is 34%.

Table 10. Breakdown of Energy Costs Required to Keep Grid Stable

Summary of 2050 WWS mean capital costs of new electricity plus heat generators; electricity, heat, cold, and hydrogen storage (including heat pumps to supply district heating and cooling), and all-distance transmission/distribution ($ trillion in 2020 USD) and mean levelized private costs of energy (LCOE) (USD ¢/kWh-all-energy or ¢/kWh-electricity-replacing-BAU-electricity) averaged over each simulation. Also shown is the energy consumed per year in each case and the resulting aggregate annual energy cost. Results are shown for Florida when its grid is isolated from the outside world and for the SERC region as a whole, within which Florida is interconnected.

	Florida isolated	SERC region
Capital cost new generators only ($trillion)	0.348	3.351
Cap cost new generators + storage ($trillion)	**0.472**	**3.897**
Components of total LCOE (¢/kWh-all-energy)		
Short-dist. transmission	1.050	1.050
Long-distance transmission	0.000	0.042
Distribution	2.375	2.375
Electricity generators	4.898	6.037
Additional hydro turbines	0	0
Solar thermal collectors	0	0
LI battery storage	1.244	0.842
CSP-PCM + PHS storage	0.001	0.000
CW-STES + ICE storage	0.020	0.004
HW-STES storage	0.028	0.010
UTES storage	0.221	0.078
Heat pumps for filling district heating/cooling	0.122	0.043
H_2 production/compression/storage	0.616	0.252
Total LCOE (¢/kWh-all-energy)	**10.57**	**10.733**
LCOE (¢/kWh-replacing BAU electricity)	9.587	10.346
GW annual avg. end-use demand (Table 1)	49.0	378.8
TWh/y end-use demand (GW x 8,760 h/y)	430	3,318
Annual energy cost ($billion/yr)	**45.4**	**356.1**

The LCOEs are derived from capital costs, annual O&M, and end-of-life decommissioning costs that vary by technology (and that are a function of lifetime and a social discount rate for an intergenerational project of 2.0 (1-3)%, all divided by the total annualized end-use demand met, given in the present table.

Capital cost of generators-storage-H_2-HVDC ($trillion) is the capital cost of new electricity and heat generators; electricity, heat, cold, and hydrogen storage; hydrogen electrolyzers and compressors; and long-distance (HVDC) transmission.

Since the total end-use load includes heat, cold, hydrogen, and electricity loads (all energy), the "electricity generator" cost, for example, is a cost per unit all energy rather than per unit electricity alone. The 'Total LCOE' gives the overall cost of energy, and the 'Electricity LCOE' gives the cost of energy for the electricity portion of load replacing BAU electricity end use. It is the total LCOE less the costs for UTES and HW-STES storage, H_2, and less the portion of long-distance transmission associated with H_2.

Short-distance transmission costs are $0.0105 (0.01-0.011)/kWh.

Distribution costs are $0.02375 (0.023-0.0245)/kWh.

Long-distance transmission costs are $0.0089 (0.0042-0.010)/kWh (in USD 2020), which assumes 1,500 to 2,000 km HVDC lines, a capacity factor usage of the lines of ~50% and a capital cost of ~$400 (300-460)/MWtr-km.

Table 11. Energy, Health, and Climate Costs of WWS Versus BAU

2050 annual-average end-use (a) BAU load and (b) WWS load; (c) percent difference between WWS and BAU load; (d) present value of the mean total capital cost for new WWS electricity, heat, cold, and hydrogen generation and storage and all-distance transmission and distribution; mean levelized private costs of all (e) BAU and (f) WWS energy (¢/kWh-all-energy-sectors, averaged between today and 2050); (g) mean WWS private (equals social) energy cost per year, (h) mean BAU private energy cost per year, (i) mean BAU health cost per year, (j) mean BAU climate cost per year, (k) BAU total social cost per year; (l) percent difference between WWS and BAU private energy cost; and (m) percent difference between WWS and BAU social energy cost. All costs are in 2020 USD. H=8760 hours per year. Results are shown both for Florida when its grid is isolated and for when its grid is interconnected within the SERC region.

Scenario	(a)[1] 2050 BAU Annual avg. end-use load (GW)	(b)[1] 2050 WWS Annual avg. end-use load (GW)	(c) 2050 WWS minus BAU load = (b-a)/a (%)	(d)[2] WWS mean total cap-ital cost ($tril 2020)	(e)[3] BAU mean private energy cost ¢/kWh-all energy	(f)[4] WWS mean private energy cost ¢/kWh-all energy	(g)[5] WWS mean annual all-energy private and social cost = bfH $bil/	(h)[5] BAU mean annual all-energy private cost = aeH $bil/y	(i)[6] BAU mean annual BAU health cost $bil/y	(j)[7] BAU mean annual climate cost ($bil/y)	(k) BAU mean annual BAU total social cost =h+i+j $bil/y	(l) WWS minus BAU private energy cost = (g-h)/h (%)	(m) WWS minus BAU social energy cost = (g-k)/k (%)
FL isolated	103.8	49.0	-52.8	0.472	11.26	10.57	45.4	102.4	37.4	157.9	298	-55.6	-84.7
FL interconnected	103.8	49.0	-52.8	0.515	10.67	10.73	46.1	97.0	37.4	157.9	292	-52.5	-84.2

[1] From Table 1.

[2] Capital cost of generators-storage-H_2-HVDC ($trillion) is the capital cost of new electricity and heat generators; electricity, heat, cold, and hydrogen storage; hydrogen electrolyzers and compressors; and long-distance (HVDC) transmission.

[3] This is the BAU electricity-sector cost of energy per unit energy. It is assumed to equal the BAU all-energy cost of energy per unit energy.

[4] The WWS cost per unit energy is for all energy, which is almost all electricity (plus a small amount of direct heat)

[5] The annual private cost of WWS or BAU energy equals the cost per unit energy from Column (f) or (g), respectively, multiplied by the energy consumed per year, which equals the end-use load from Column (b) or (a), respectively, multiplied by 8,760 hours per year.

[6] The 2050 annual BAU health cost equals the number of total air pollution mortalities per year in 2050 from Table 12, Column (a), multiplied by 90% (the estimated percent of total air pollution mortalities that are due to energy) and by a statistical cost of life of $11.56 ($7.21-$17.03) million/mortality (2020 USD) and a multiplier of 1.15 for morbidity and another multiplier of 1.1 for non-health impacts (Jacobson et al., 2019).

[7] The 2050 annual BAU climate cost equals the 2050 CO_2e emissions from Table 12, Column (b), multiplied by the social cost of carbon in 2050 of $548 ($315-$1,188)/metric tonne-$CO_2$ (in 2020 USD), which is updated from values in Jacobson et al. (2019), which were in 2013 USD.

Table 12. Air Pollution Mortalities, Carbon Dioxide Emissions, and Associated Costs

Florida (a) estimated air pollution mortalities per year in 2050-2051 due to anthropogenic sources (90% of which are energy); (b) carbon-equivalent emissions (CO_2e) in the BAU case; (c) cost per tonne-CO_2e of eliminating CO_2e with WWS; (d) BAU energy cost per tonne-CO_2e emitted; (e) BAU health cost per tonne-CO_2e emitted; (f) BAU climate cost per tonne-CO_2e emitted; (g) BAU total social cost per tonne-CO_2e emitted; (h) BAU health cost per unit all-BAU-energy produced; and (i) BAU climate cost per unit-all-BAU-energy produced. Results are shown both for when Florida's grid is isolated and for when it is interconnected within the SERC region.

Scenario	(a)[1] 2050 (Deaths/ y)	(b)[2] 2050 BAU CO_2e (Mtonne/ y)	(c)[3] 2050 WWS ($/ tonne-$CO_2e$-elim-inated)	(d)[4] 2050 BAU energy cost ($/ tonne-$CO_2e$-emitted)	(e)[4] 2050 BAU health cost ($/ tonne-$CO_2e$-emitted)	(f)[4] 2050 BAU climate cost ($/ tonne-$CO_2e$-emitted)	(g)[4] 2050 BAU social cost = d+e+f ($/ tonne-$CO_2e$-emitted)	(h)[5] 2050 BAU health cost (¢/kWh)	(i)[5] 2050 BAU climate cost (¢/kWh)
Florida isolated	2,839	283	160.6	362	132.2	558	1,053	4.11	17.4
Florida interconnected	2,839	283	163.0	343	132.2	558	1,034	4.11	17.4

[1] 2050 state mortalities due to air pollution are scaled from 2010-12 state values from Jacobson et al. (2015) using the ratio of the total 2050 air pollution mortalities for the U.S. from Jacobson et al. (2019) 53,199/yr (36,394/yr-73,614/yr) to the total 2010-12 number of deaths across the U.S. from Jacobson et al. (2015) 62,381/yr (19,363/yr-115,723/yr).

[2] CO_2e=CO_2-equivalent emissions. This accounts for the emissions of CO_2 plus the emissions of other greenhouse gases multiplied by their global warming potentials.

[3] Calculated as the WWS private energy and total social cost from Table 11, Column (g) divided by the CO_2e emissions from Column (b) of the present table.

[4] Columns (d)-(g) are calculated as the BAU private energy, health, climate, and total social costs from Table 11, Columns (h)-(k), respectively, each divided by the CO_2e emissions from Column (b) of the present table.

[5] Columns (h)-(i) are calculated as the BAU health and climate costs from Table 11, Columns (i)-(j), respectively, each divided by the BAU end-use load from Table 11, Column (a) and by 8760 hours per year.

Table 13. Land Areas Needed

Footprint areas for *new* utility PV farms, CSP plants, solar thermal plants for heat, geothermal plants for electricity and heat, and hydropower plants and spacing areas for new onshore wind turbines. Results are shown both for when Florida's grid is isolated and for when it is interconnected within the SERC region.

Scenario	State or region land area (km^2)	Footprint Area (km^2)	Spacing area (km^2)	Footprint area as percentage of state or region land area (%)	Spacing area as a percentage of state or region land area (%)
Florida isolated	139,670	1,914	742	1.37	0.53
Florida interconnected	139,670	1,446	1,273	1.04	0.91

Spacing areas are areas between wind turbines needed to avoid interference of the wake of one turbine with the next. Such spacing area can be used for multiple purposes, including farmland, rangeland, open space, or utility PV. Footprint areas are the physical land areas, water surface areas, or sea floor surface areas removed from use for any other purpose by an energy technology. Rooftop PV is not included in the footprint calculation because it does not take up new land. Conventional hydro new footprint is zero because no new dams are proposed as part of these roadmaps. Offshore wind, wave, and tidal are not included because they don't take up new land. Areas are given both as an absolute area and as a percentage of the state or regional land area, which excludes inland or coastal water bodies. For comparison, the total area and land area of Earth are 510.1 and 144.6 million km^2, respectively.

Table 14. Changes in the Employment

Estimated long-term, full-time jobs created and lost due to transitioning from BAU energy to WWS across all energy sectors when Florida's grid is isolated versus when it is interconnected within the SERC region. The job creation accounts for new jobs in the electricity, heat, cold, and hydrogen generation, storage, and transmission (including HVDC transmission) industries. It also accounts for the building of heat pumps to supply district heating and cooling. However it does not account for changes in jobs in the production of electric appliances, vehicles, and machines or in increasing building energy efficiency. Construction jobs are for new WWS devices only. Operation jobs are for new and existing devices. The losses are due to eliminating jobs for mining, transporting, processing, and using fossil fuels, biofuels, and uranium. Fossil-fuel jobs due to non-energy uses of petroleum, such as lubricants, asphalt, petrochemical feedstock, and petroleum coke, are retained. For transportation sectors, the jobs lost are those due to transporting fossil fuels (e.g., through truck, train, barge, ship, or pipeline); the jobs not lost are those for transporting other goods. The table does not account for jobs lost in the manufacture of combustion appliances, including automobiles, ships, or industrial machines.

Scenario	Construction jobs produced	Operation jobs produced	Total jobs produced	Jobs lost	Net change in jobs
Florida isolated	198,321	240,438	438,759	46,249	392,510
Florida interconnected	204,276	198,310	402,586	46,249	356,337

Exhibit 4

EXPERT REPORT
OF
DR. HAROLD R. WANLESS

Professor of Geological Sciences
University of Miami

Kelsey Cascadia Rose Juliana; Xiuhtezcatl Tonatiuh M.,
through his Guardian Tamara Roske-Martinez; et al.,
Plaintiffs,

v.

The United States of America; Donald Trump,
in his official capacity as President of the United States; et al.,
Defendants.

IN THE UNITED STATES DISTRICT COURT
DISTRICT OF OREGON

(Case No.: 6:15-cv-01517-TC)

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TABLE OF ACRONYMS AND ABBREVIATIONS

C:	Celsius
CCATF:	Miami-Dade County Climate Change Advisory Task Force
CO_2:	carbon dioxide
EPA:	United States Environmental Protection Agency
F:	Fahrenheit
ft:	feet
GMSL:	global mean sea level
IPCC:	Intergovernmental Panel on Climate Change
LiDAR:	Light Detection and Ranging
m:	meters
NAO:	North Atlantic Oscillation
NOAA:	National Oceanic and Atmospheric Administration
ppm:	parts per million
SFWMD:	South Florida Water Management District
SLR:	sea level rise
USGCRP:	United States Global Change Research Program

INTRODUCTION

I, Harold Rogers Wanless, have been retained by Plaintiffs in the above-captioned matter to provide expert testimony regarding how human-caused CO_2 emissions are causing sea level rise, which results in some of the injuries and constitutional violations alleged in the Complaint in this case. I discuss the paleoclimate record and fluctuations in sea level rise, and how human-caused climate change, ocean warming, and polar ice melt are accelerating sea level rise. I also describe the very real harms the Plaintiffs face associated with sea level rise, particularly as young people. I have also been asked to opine on the urgency of stopping additional greenhouse gas emissions in order to arrest the even more significant consequences of sea level rise. To render my opinions in this report, I have relied upon my extensive qualifications and 46 years of experience in the fields of geology, marine geology, and the paleo-sea level record. I have also reviewed a number of documents identified at the end of this report.

The opinions expressed in this report are my own and are based on the data and facts available to me at the time of writing. All opinions expressed herein are to a reasonable degree of scientific certainty and historical accuracy, unless otherwise specifically stated. Should additional relevant or pertinent information become available, I reserve the right to supplement the discussion and findings in this expert report in this action.

This report contains my opinions, conclusions and the reasons therefore. My professional and educational experience is summarized in my curriculum vitae attached to this declaration as **Exhibit A**. My curriculum vitae also contains a list of publications I authored within the last ten years and more. I have not provided testimony within the preceding four years as an expert at trial or by deposition. My report contains citations to all documents that I have used or considered in forming my opinions, listed in **Exhibit B**.

In preparing my expert report and testifying at trial, I am deferring my expert witness fees charged to the Plaintiffs given the financial circumstances of these young Plaintiffs. If a party seeks discovery under Federal Rule 26(b), I will charge my reasonable fee of $250 per hour for the time spent in addressing that party's discovery.

EXECUTIVE SUMMARY

Geologic evidence reveals that, following the last ice age 18,000 years ago, sea level rose over 128 meters (420 feet), to near its present level, but it did not do so slowly and steadily. Rather it rose in a series of rapid 1m to 10m "pulses" over a short timeframe of just a century or so, each in response to a pulse of rapid disintegration of some ice sheet sector. This is also how ice melt and sea level rise will occur in the future, and means that anthropogenic warming and loss of glacial ice is having and will have grave implications for the future of coastal cities and people around the world.

The geologic evidence for repeated rapid pulses of sea level rise during the past 18,000 years can only be explained by repeated pulses of disintegration of ice sheet sectors. This occurred throughout the rapid and slower phases of increasing global temperatures in response to naturally increasing CO_2 levels from 180 to 280 ppm over that 18,000 years.

Since the beginning of the industrial revolution, the burning of fossil fuels has very rapidly increased atmospheric CO_2 levels another 125 ppm. We now have global air temperatures at almost 1°C warmer than at the beginning of the Industrial Revolution and an ocean that has absorbed over 93 percent of the atmospheric heat produced by buildup of these anthropogenic greenhouse gases. This warmed ocean and atmosphere is now accelerating melt of the Ice Sheets of Greenland and Antarctica.

Ice melt acceleration and associated sea level rise is occurring faster than any of the climate models predict, including those used by the Intergovernmental Panel on Climate Change (IPCC) for sea level rise projections, because the models have not included, and still do not include, many of the numerous accelerating feedbacks in ice melt anticipated by the paleo record and that are now being observed in real time. These accelerating feedbacks that are accelerating ice melt and sea level rise are the real time display of the onset of a new pulse of rapid sea level rise. This pulse of rise has been triggered by the atmospheric and ocean warming resulting from the extremely rapid buildup of CO_2 in the atmosphere from our burning of fossil fuels.

Sea level rise impacts are exacerbated by increasingly intense storms that bring storm surges and heavy rains, worsening the flooding that stems from sea level rise alone. Although the precise timing and landfall of an individual storm event cannot be specifically attributed to human-induced global warming, scientists can now calculate that powerful storms are more likely and made worse from the additional heat and water vapor in the atmosphere and heat in the oceans due to the increasing concentration of atmospheric CO_2. In addition, storm surges are acting at higher sea levels. Simply put, warmer ocean temperatures provide more energy to fuel storms. Increasingly destructive storms and rainfall events are not off in the future, they are here now.

For Plaintiffs like Levi, who lives on a low-lying barrier reef island off of the southeastern seaboard, sea level rise and storm surges will make his home uninhabitable within decades, and eventually inundate it permanently with seawater.

QUALIFICATIONS

I am a Professor in the Department of Geological Sciences where I was also Chair for the previous 19 years and was Cooper Fellow of the College of Arts and Sciences at the University of Miami from 2010 to 2013. My office is located in Coral Gables, Florida. I am a Registered Professional Geologist in the State of Florida #985.

My father, Dr. Harold Rollin Wanless, was a sedimentary geologist who extensively studied the rocks of Paleozoic Pennsylvania Period and was one of the first to publish on the cyclical nature of sedimentation during Pennsylvanian Period resulting from sea level rises and falls in response to repetitive glaciations. As a child, I grew up immersed in the history of the “rocks” of the Pennsylvanian Period and the ancient stories they told of dramatic and repetitive fluctuations of sea level on scales from hundreds to millions of years. Those early beginnings led me to my own deep study of geology and the paleo-sea level record, and ultimately human-induced climate change and resulting modern-day sea level rise.

I received an A.B. degree in Geology from Princeton University in 1964; a M.S. degree in Marine Geology and Geophysics from the University of Miami in 1967; and a Ph.D. degree in Earth and

Planetary Sciences from the John Hopkins University in 1973. My Master's Thesis was on the Holocene sediments that have accumulated in the Biscayne Bay region over the past 7,000 years and the character and role of sea level rise and storm and biological processes in defining the nature of these sediments. During my time as a Master's student, I worked for my Advisor, Dr. A. Conrad Neumann, on developing a sea level curve for south Florida, the Bahamas and Bermuda using core boring samples from freshwater peat deposits that formed close to sea level elevation. My Ph.D. dissertation was on the Paleozoic Cambrian strata in the Grand Canyon, Arizona, where small-scale sedimentary cyclic sequences were deposited in response to natural cycles of sea level fluctuation operating a half billion years ago.

Since 1971, I have had 46 years of experience as a geologist and marine geologist on the faculty at the University of Miami. My research specialty is coastal and shallow marine sedimentology, modern and ancient, with a focus on documenting and understanding the role of sea level dynamics and storm processes in creating and modifying coastal and shallow marine environments. Much of my research, and that of my students, has focused on determining the fine-scale sea level history over the past 7,000 years and the associated response of coastal and shallow marine environments. This research has focused on the South Florida-Bahamas-Caicos region. Our research has been funded from a variety of sources, including the National Science Foundation, the Department of the Interior (National Park Service), the Department of Commerce (Sea Grant and National Oceanic and Atmospheric Administration), Miami-Dade County Department of Environmental Resource Management, petroleum companies (including Exxon, for whom I received research funding through much of the 1980s), and development companies. I have been publishing on past sea level trends in the juried literature since 1976 and have been projecting future trends since 1982 (Wanless, 1976; Wanless, 1982; Wanless and Parkinson, 1989; Dominguez and Wanless, 1991; Wanless, Parkinson, and Tedesco, 1994; Science Committee, 2008; Technical Ad Hoc Work Group, 2011 and 2015).

Since 1981, I have been using our knowledge of past environments to look to the future. My students and I have been documenting the changes in south Florida coastal environments in response to both accelerated sea level rise occurring since 1930 and major (category 4 and 5) hurricanes. Through this research, we have studied the coastal and low wetland environments bordering Biscayne Bay, Florida Bay, southwest Florida from Cape Sable to Everglades City, and the 10,000 islands. We focus our research on coral and oyster reefs, coastal lagoons and estuaries, coastal sandy beaches and barrier islands, saline mangrove wetlands, low-lying freshwater wetlands near the coast, as well as the adjacent fresh-water Everglades and low-lying upland. To put it simply, the scientific study of islands, mangroves, sand, mud, reefs, and rocks gives us a clear window into historic sea level rise and, combined with other scientific tools, allows us to better project sea level rise into the future.

As polar ice sheet melt has significantly accelerated on both Greenland and Antarctica since about the 1990s, I have been active in working with other scientists, communities, Miami-Dade County, the State of Florida and Federal agencies in using new research data from myself and others to project future sea level rise both globally and regionally and to determine the impact it will have on low-lying coastal environments, coastal communities, agriculture, and industry. This includes an evaluation of the changing anthropogenic effects on coastal and shallow marine environments with rising sea level (Science Committee, 2008; Technical Ad Hoc Work Group, 2011 and 2015).

I was an active member of, and invited speaker at, the Miami-Dade County Climate Change Advisory Task Force (CCATF), comprised of 25 members, appointed by the Commissioners, Mayor, and County Manager. Throughout its existence, I served as the Chair of CCATF's Science Committee and drafted their reports. From 2006–2011, the CCATF served as an advisory board to the Board of County Commissioners and was charged with identifying potential future climate change impacts to Miami-Dade County, while providing recommendations regarding realistic and necessary mitigation and adaptation measures to respond to climate change.

Miami-Dade County has officially recognized and relied upon my expertise and peer-reviewed research on climate change and sea level rise as evidenced through County review and adoption of CCATF recommendations, which was based in part upon my peer-reviewed research, as well my position as the Chair of CCATF's Science Committee.

In 2010, the Southeast Florida Regional Planning Council initiated efforts to create a four county "Regional Compact," an agreed-upon statement of climate change and anticipated sea level rise. I was part of the committees that used the peer-reviewed scientific literature and our expertise to write reports on anticipated sea level rise for the Compact. These reports are incorporated into the overall "Regional Compact" Documents (Technical Ad Hoc Work Group, 2011 and 2015).

The South Florida Water Management District ("SFWMD") has previously relied upon and cited to my peer-reviewed research in assessing sea level rise implications for South Florida. (SFWMD, "*Preliminary Estimate of Impacts of Sea Level Rise on The Regional Water Resources of Southeastern Florida*;" SFWMD, "*Estimated Impacts of Sea Level Rise on Florida's East Coast.*")

U.S. Army Corps of Engineers personnel acknowledged and cited to my research regarding sea level rise in a presentation entitled "Climate Change Concerns for Everglades Restoration Planning," which was presented at the Planning Community of Practice Conference 2008.

I have twice been an invited speaker to the State of Florida legislature to present evidence for anticipated sea level rise and implications to South Florida coastal environments and the Everglades (2007). I have been an invited speaker to the Council on Environmental Quality at the White House, addressing sea level rise and the urgent need to shift the Mississippi River outlet back onto the continental shelf to help save the Mississippi River Delta (2009).

I am familiar with the findings of the U.S. Global Change Research Program ("USGCRP") and the 2014 Report entitled "Global Climate Change Impacts in the United States: A State of Knowledge Report from the U.S. Global Change Research Program" as well as the 2017 USGCRP National Climate Assessment. I am also familiar with the broad body of scientific literature on climate change and sea level rise.

EXPERT OPINION

I. The Paleoclimate Record and Fluctuations in Sea Level Rise

Earth has different orbital cycles that affect global temperatures. One of the three Milankovitch Cycles is a ~100,000 year cycle of Earth's eccentricity, or the shape of its orbit around the sun, which fluctuates between a more circular to a more oval orbit. This cycle, which affects polar cooling and warming is primarily responsible for driving Earth in and out of glacial periods over the past million years. A second cycle, obliquity, is how the Earth's axis is tilted toward the sun, which varies between 21.5 and 24.5 degrees every ~40,000 years. The third, precession, are ~19,000 and ~21,000 year cycles, which changes the wobble of the Earth as it moves around the sun and determines whether the poles are tilted towards the sun or are sideways to the sun when closest in the orbit. **Figure 1** below depicts these cycles.

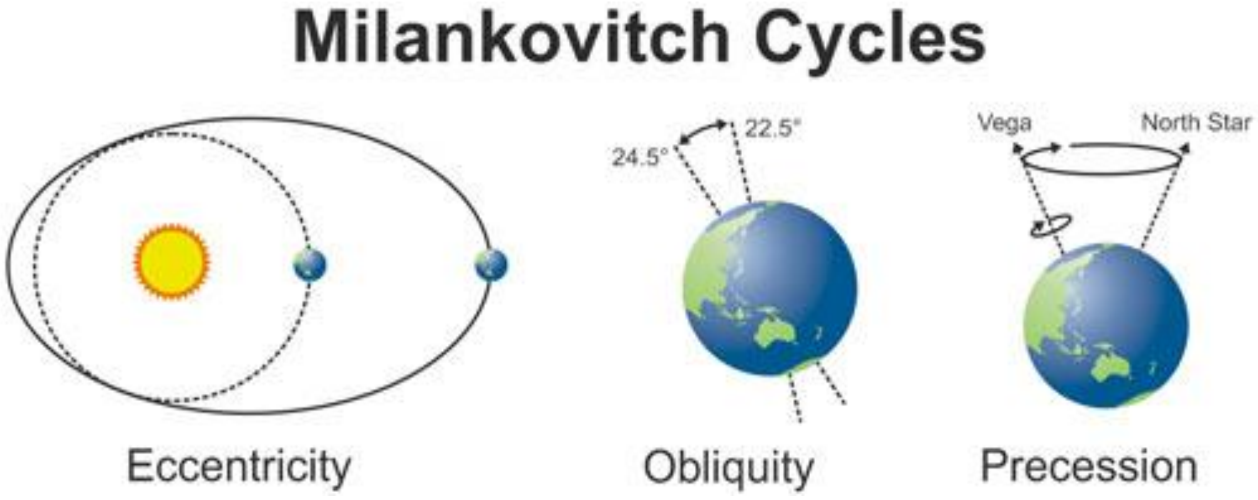


Figure 1. The Earth's orbital cycles that affect global temperatures.

These natural cycles of how Earth presents herself to the Sun result in slight differences in illumination and warming/cooling which trigger slight changes in productivity and surficial rock and soil weathering, which in turn result in changes in CO_2 and warming. By studying historic CO_2 levels through ice cores and deep ocean sampling, the scientific community has established with high confidence the close correlation between atmospheric CO_2 levels and temperature change across geologic time.

During the most recent period of the Holocene (past 12,000 years) when human civilization developed, Earth's optimum presentation to the sun occurred about 6,500 years ago, which was the warmest period of the Holocene before human-caused climate change began occurring. During that time, atmospheric CO_2 levels were ~280 ppm. As the Earth's orbit moved away from the optimum presentation, a natural, slow and slight cooling would have naturally occurred, and has been clearly documented for the 1,000 years prior to the beginning of the industrial revolution (Mann, 1994). This natural cooling has since become overshadowed by increasing human-caused greenhouse gas emissions, predominantly CO_2. Since about 1950, human inputs of CO_2 have become the primary and dominating control of climate (Mann et al., 1995).

In contrast to the Holocene, 120,000 years ago during the warmest interglacial period, known as the Eemian, atmospheric CO_2 levels were at 280–300 ppm, temperatures were only slightly warmer than today and sea level rise was 26 feet higher than it is today (because of greater ice melt from both Greenland and Antarctica than today). As shown in **Figure 2** below, the fluctuations of CO_2 from between 280–180 ppm for hundreds of thousands of years (green line) moves in parallel with the warming and cooling of Earth's atmospheric temperature (red line) and with the cyclic rise and fall of sea level (blue line) of about 100 meters (330 feet).

These 'geologically rapid' changes in climate typically occur over thousands of years. However, since the industrial revolution, human burning of fossil fuels has caused CO_2 to shoot up from 280 ppm to over 410 ppm, which is a 40% increase over preindustrial levels, and more than double the 100 ppm increase from the natural glacial to interglacial level which resulted in 100 meters (330 feet) of sea level rise. This human-driven increase has happened in a very short period of time as compared to earlier natural shifts. Based on our understanding about how increases in CO_2 drive atmospheric and oceanic warming, which in turn cause ocean expansion and polar ice melt, leading to global sea level rise, the results will be dire for humanity at current CO_2 levels, and even worse if we continue to inject even more CO_2 into the system. The last time CO_2 levels were above 400 ppm, global sea level was some 21–27 meters (70–90 feet) higher. This was over one million years ago.

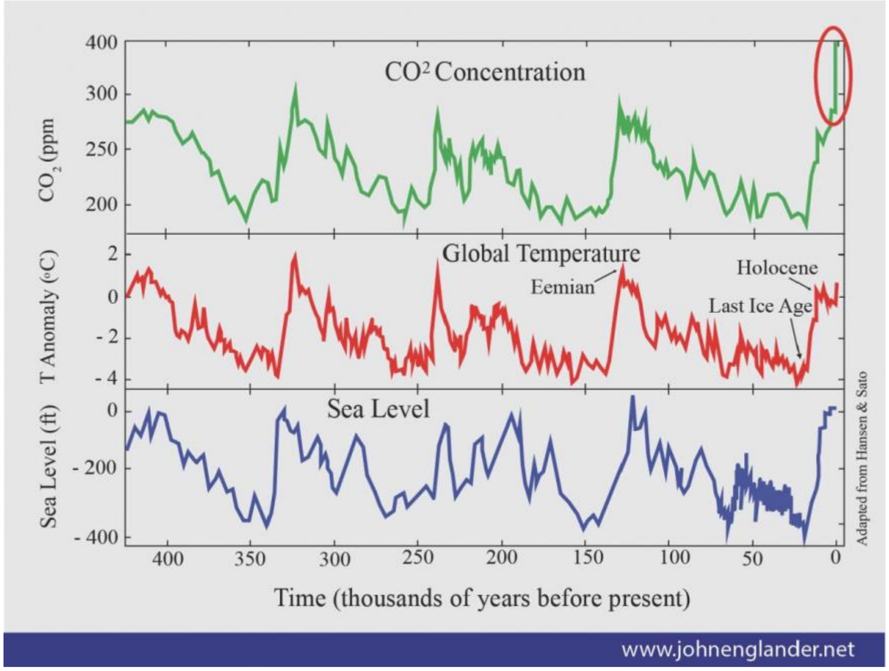


Figure 2. Graphs of 400,000 years of carbon dioxide, temperature change, and sea level. Adapted by Hansen for Englander (2013).

Figure 3 below shows the coastline of the southeastern United States, where Plaintiffs Jayden and Levi live, the last time CO_2 levels were above 400 ppm, well over a million years ago. At that time, sea levels were about 20 meters (70 feet) higher than they are today. As you can see, sea levels that high would result in the submersion of much of the states of Florida and Louisiana, along with a vast expanse along the Gulf Coast and Eastern Seaboard. Even a sea level rise of 6 meters, which happened during the last interglacial episode approximately 125,000 years ago, would result in the total loss of the cities of Miami, FL, New Orleans, LA, and other coastal cities throughout the United States.

The increase in carbon dioxide from 280 to 410 ppm from the burning of fossil fuels has occurred more than 100 times faster than the natural increase in carbon dioxide from 180 to 280 ppm following the last ice age. The reason we have not yet seen the significantly higher sea levels that were present the last time CO_2 levels were above 400ppm is that there is simply a short time lag between the greenhouse gas buildup in the atmosphere and the heat buildup in the atmosphere, and then the heat buildup in the shallow ocean and then the heat buildup in the deeper ocean. Each one of these processes takes more time. By the 1950s, there was enough CO_2 in the atmosphere to basically control atmospheric climate. By the 1990s, the human-induced buildup of heat transferred to the oceans was enough to begin melting both the Greenland and Antarctic Ice Sheets. As the Ice Sheets are warming through atmospheric and ocean water melt-water penetration, fracturing and softening, they are accelerating their melt. We are also dramatically speeding up the rate of heat production by global warming. As you can see by where we are on the projected sea level rise rate for the future (on **Figure 6** below), we are just beginning the acceleration of sea level rise from ice melt and this will become a dominating factor later in the century. And this is why scientists are so deeply concerned. We are at a tipping point that may well spin out of control this century. That is what happened repeatedly in the past as we warmed following the last ice age 18,000 years ago.

Figure 3. Map of the south Atlantic and Gulf coasts showing the inundation that would occur with 20 meters (70 feet) of sea level rise.

A. Sea Level Rise Pulses

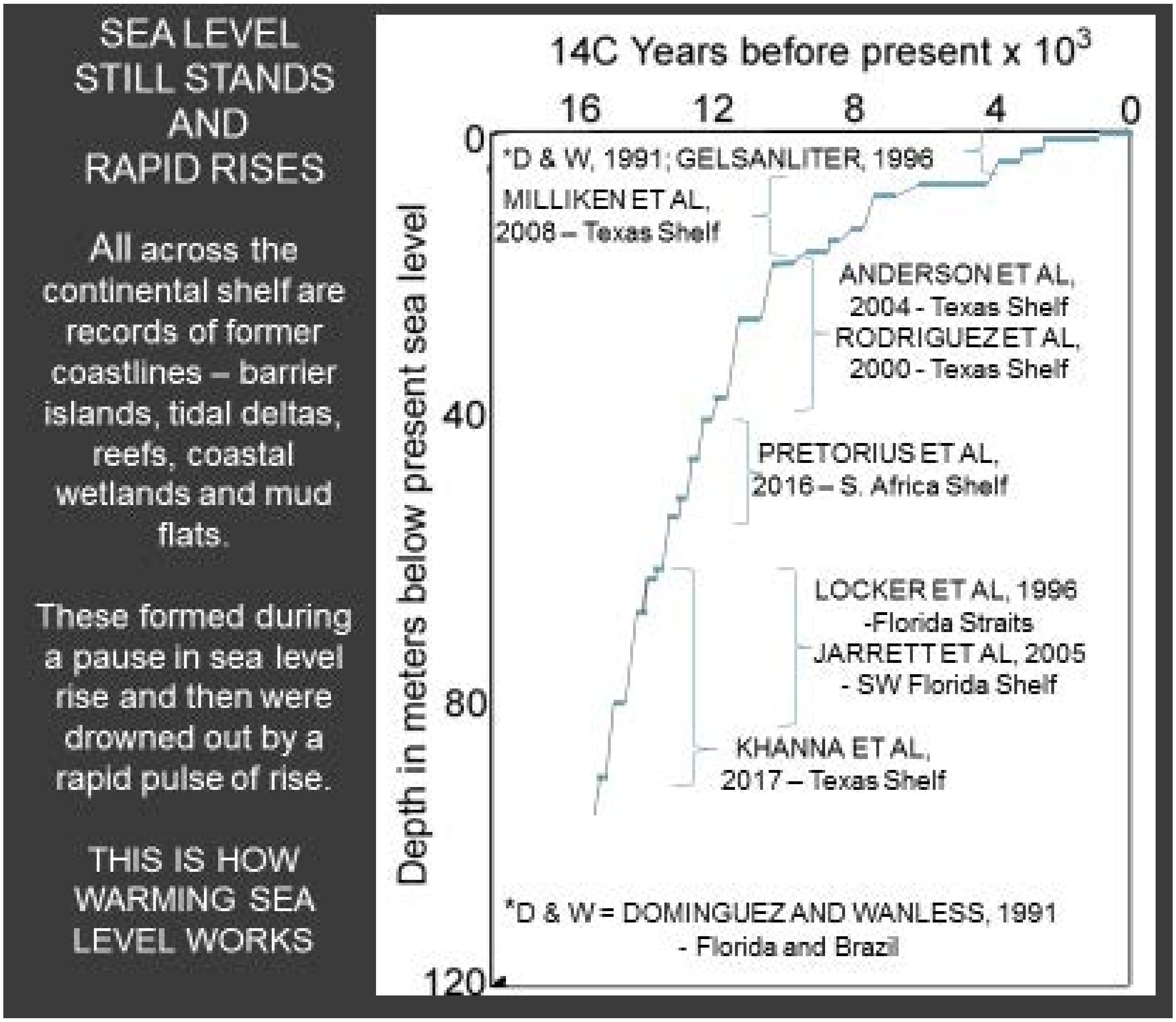
Through scientific study of the geologic record, we have shown that sea levels did not rise in a gradual linear manner in response to gradually increasing natural warming and carbon dioxide levels as we came out of the last glacial period. Global sea level rose from about -128 meters (-420 feet) 18,000 years ago to the present level as a series of rapid pulses of rise followed by pauses as warming initiated one pulse of ice sheet collapse after another. This is evidenced by drowned coastal deposits left across the continental shelves of the world. Through research and radiometric dating by myself and others of deposits from former coastal wetlands (especially red mangrove and salt marsh peats), reefal systems (coral and oyster), sandy barrier islands, intertidal encrusting and boring organisms (such as barnacles), we have understood for the past 30 years that there is a pattern of 1–10 meter (3.3–33.0 foot) sea level pulses of rapid coastal inundation followed by pauses, repeated rapid flooding and more pauses.

These pulses of sea level rise occur over relatively short periods of time (within a century or so) and are a reflection of a phase of rapid disintegration of some former ice sheet sector**.** Each pulse that has been documented to date was associated with a rather small increase in CO_2 as compared to the large and extremely rapid human-induced increase that has occurred since the beginning of the industrial revolution. When the sea rises slowly, barrier islands and coastal marshes can keep up and grow or gradually migrate landward and thus stay above sea level, and mature reefs would be able to grow upwards in response to increased subtidal space becoming available. But, if the rise is too rapid, it will simply overstep and drown the barrier island, the reef, or the coastal wetland and begin forming a new one shifted landward. All across the continental shelves of the world are old sandy barrier islands, reefs and coastal wetlands that were drowned out and left behind. If subsequent waves and currents permitted, these relict coastal deposits remain as testament. We can definitively establish that during certain periods the rises in sea level occurred very rapidly. This geologic evidence for rapid ice sheet disintegration, once destabilized, is the verification that the numerous reinforcing, accelerating feedbacks scientists are observing for recent ice sheet melt on Greenland and Antarctica is cause for deep concern. We most certainly are witnessing the onset of one of these rapid pulses of ice sheet disintegration and resulting sea level rise.

In the summer of 2013, I was able to witness the fact that accelerating ice melt is happening significantly faster than previously thought when flying about 50 miles onto the Greenland Ice Sheet following the deep channel of the Jacobshaven Icefjord in western Greenland. We reached an elevation on the Ice Sheet of over 2,000 meters (6,500 feet). It was like flying up a large, meandering, fractured, dry stream bed in the ice surface. The channel-like depression on the ice surface was some 150 m (500 feet) below the level of the ice sheet and was dramatically fractured from the accelerated ice melt from below and resulting fracture and flow. This was created by melt at the base of the ice sheet from deeply penetrating 'warmed' ocean water. As a result of the fracturing and detachment from the bottom, the forward velocity of the ice has accelerated from a couple of miles per year to over twenty. Overall, this was a spectacular, but most disturbing experience given what this means for accelerating future sea level rise.

Figure 4 below depicts the post-glacial pulses of rapid sea level rise and pauses that are well documented in the literature. These include those over the past 5,500 years that my students and I have measured in Florida and Brazil (Dominguez and Wanless, 1991; Gelsanliter, 1996;

Gelsanliter and Wanless, 1995). Others have documented earlier pulses of rapid rise, including Locker *et al*., 1996; Jarrett *et al*., 2005; Milliken *et al*., 2008; and Pretorius *et al*., 2017.



SEA LEVEL STILL STANDS AND RAPID RISES

All across the continental shelf are records of former coastlines – barrier islands, tidal deltas, reefs, coastal wetlands and mud flats.

These formed during a pause in sea level rise and were drowned out by a rapid pulse of rise.

THIS IS HOW WARMING SEA LEVEL WORKS

Figure 4. Reconstructed post glacial sea level history incorporating pulses of sea level rise following brief still-stands in which coastal barrier islands, tidal deltas, bay-head deltas, reefs, wetlands and tidal flats formed and were then drowned out. Age is in thousands of years before present. Each pulse of rise must represent a pulse of rapid ice sheet disintegration.

The reason for the pulses of sea level rise is the non-linear melting of ice superimposed on the thermal expansion of water and other lesser influences. James Hansen (2007) best describes this phenomenon as rapid ice sheet disintegration. Since 1990, we are now witnessing the onset of a new pulse of ice melt in both Greenland and Antarctica, which I discuss in greater detail below.

II. The Reality of Human-Caused Climate Change, Ocean Warming, and Accelerating Sea Level Rise.

Notwithstanding the natural long-term Milankovitch Cycles affecting Earth's temperatures and incoming solar radiation, the most significant effect on Earth's temperatures since the 1950s is from the increasing CO_2 levels in the atmosphere that result from humans burning fossil fuels. There is an extremely strong consensus with a high level of confidence among actively publishing climate scientists and strong scientific evidence that the climate is warming due to human activities, primarily the burning of fossil fuels such as coal, oil, and gas. Carbon dioxide emissions are the strongest human-induced climate forces, but other human-induced greenhouse gas emissions also contribute to climate change, including methane and nitrous oxide. At the beginning of the industrial revolution global CO_2 levels were ~280 ppm. They are currently above 410 ppm and increasing at greater than 3 ppm per year.

As depicted in **Figure 2** above, for the past 400,000 years, CO_2 fluctuated between 180 ppm and 280 ppm, and in concert sea level went down and up 100 meters or more. These natural changes in CO_2, temperature, and sea level occurred over thousands of years. For the first time in the paleo-record, CO_2 levels have risen by more than 125 ppm and within only 150 years. This is more than double the 180–280 ppm post-glacial CO_2 increase which drove the entire series of pulses that totaled 120 meters of sea level rise in response to warming and ice melt. There is no historical precedent for this rapidity of change that we can find in the paleo-record. The unprecedented rate and degree of human-caused CO_2 increase and warming should serve as a warning. The Earth will now respond in unprecedented, dire, and most certainly rapid ways.

Referring to the late 18th century as the beginning of the HyperAnthropocene, when the improved steam engine initiated the industrial revolution (Hills, 1993) and the exponential growth in fossil fuel combustion, Hansen et al. explain that three-quarters of human-caused warming since 1850 (~1°C) has occurred since 1975 (Hansen et al., 2016). When I was born in 1942, there were less than two billion people on the planet, and many countries were not at all industrialized. Now we have over 7.5 billion people, and also many large countries are rapidly industrializing.

The global-mean temperature has increased by more than 1.8°F (1°C) over the past century, and is projected to warm by a total of 3.6–4.8°F/2–4.8°C over the next century depending upon future emissions of greenhouse gases (IPCC, 2014).

A. Thermal Expansion of the Ocean

Very importantly, nearly all the excess atmospheric heat produced by the greenhouse gasses from burning fossil fuels has transferred to the oceans. Approximately 93.4% of the excess energy (heat) human pollution has forced on the planet has been absorbed by the oceans, with much of it penetrating to 1,000 meters or more in depth. This heat transfer is rapidly accelerating as people burn more and more fossil fuels. Over half of this excess heat from human-induced global warming has transferred to the ocean since 1997. **Figure 5** shows the distribution of global-warming energy accumulation (heat) relative to 1971 and from 1971–2010.

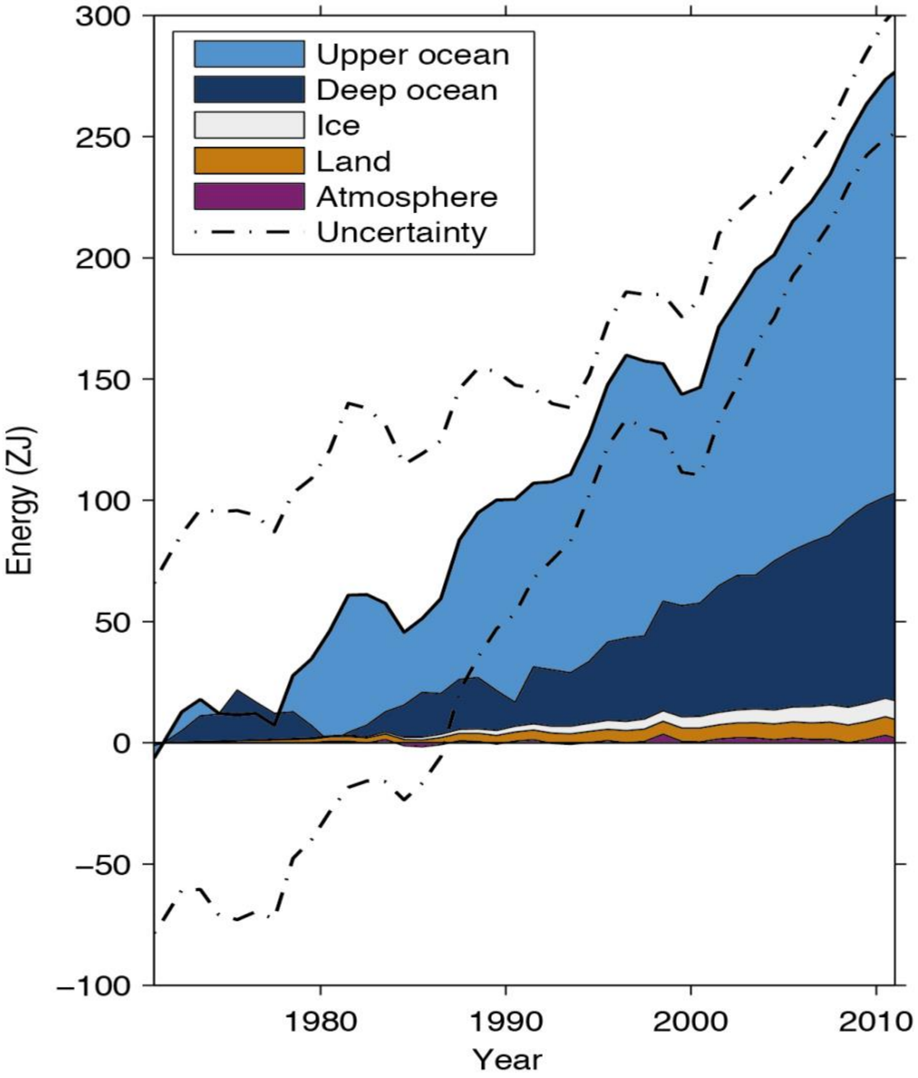


Figure 5. Plot shows the distribution of global-warming energy accumulation (heat) relative to 1971 and from 1971 to 2011 (IPCC, 2014). Half of the human-produced global warming heat has entered the ocean since 1997.

In high school physics, children are taught that water has great capacity to take in, hold, and use heat. Atmospheric warming will continue for some 30 years after we stop putting more greenhouse gasses into the atmosphere. But that warmed atmosphere will continue warming the ocean for centuries, and the accumulating heat in the oceans will persist for millennia.

The temperature of the ocean is significant for sea level rise because the density of seawater largely depends upon temperature. Because warmer water is less dense than colder water, the volume of the ocean increases even if it stays at a constant mass. Thus, thermal expansion of the ocean is one of the major contributors to sea level change. Scientists have predicted that "[i]f the upper 1,000 meters of some portion of the ocean were to warm by 1 degree Celsius, then the sea level would increase by about 50 centimeters [1.67 feet]."[1] Ocean temperature measurements have shown that the warming of the upper ocean has contributed about 30 percent of the total sea level rise between 1971 and 2010. Ice melt from mountain glaciers, Greenland, and Antarctica accounts for most of the remaining rise.

The CO_2 addition to the atmosphere has a several thousand-year residence time and is not consumed as it warms the atmosphere and ocean. Due to that large thermal inertia, the climate will continue to warm over the next half-century, even if a reduction in fossil fuel emissions and stabilization of CO_2 concentrations occurred today, and the warmed ocean will continue to melt polar ice for centuries. Put simply, the climate has warmed and future warming is unavoidable. However, how much more climate-forcing we put into the system through CO_2 and other greenhouse gas emissions this year and in the years to follow, and how much carbon we sequester from the atmosphere through improved land management practices and active sequestration, will dictate how much additional warming will occur and whether the impacts of climate change are survivable for much of humanity and many other species living on the planet.

Global warming from the atmospheric influx of CO_2 and other greenhouse gasses leads to a number of changes in climate beyond simply an increase in ocean and land-surface temperatures. These include, but are not limited to: increased frequency and intensity of heavy rainfall events and floods, increased sea level, more intense hurricanes, higher atmospheric and oceanic temperatures, ocean acidification, loss of coastal wetlands, and destabilization of permafrost in the arctic and of methane hydrates frozen in the sediments in the Arctic Ocean bottom.

B. Sea Level Rise Projections

Global mean sea level (GMSL) has risen about 20–23 cm (8–9 inches) since the industrial revolution and 8 of those centimeters (3 inches) have occurred between 1993 and 2009 (Church and White, 2011; Hay et al., 2015; Nerem et al., 2010). Even these relatively small increases have had substantial effect on low-lying areas, like we have seen in south Florida and Louisiana. The question now is not whether the seas will continue to rise, but by how much and by when.

In 2017, the National Oceanic and Atmospheric Administration (NOAA) published the most recent United States Government sea level rise projections, once again confirming that sea level rise is a certain impact of climate change (*Global Sea Level Rise Scenarios for the United States; National Climate Assessment* (NOAA, January, 2017)). NOAA's projections, which included acceleration of ice melt from Greenland and Antarctica, included a range between 1.5–2.5 m (5–8.2 ft.) global mean sea level rise (GMSL) for 2100 (**Figure 6**). However, for certain coastlines across the U.S., the high ranges could be .3–1.0 m (1–3.3 ft.) higher than the GMSL, thereby increasing projections upwards by .3–1.0 m (1–3.3 feet). NOAA's 2017 projections are higher than the projections NOAA made just five years ago in its 2012 assessment. NOAA's 2017 projections are also higher than the conservative IPCC projections for the 4th and 5th reports. The reason for this is that the IPCC is required to use only jury refereed published articles (usually published 3–4 years after the research). The IPCC cuts off use of literature 2–3 years before report

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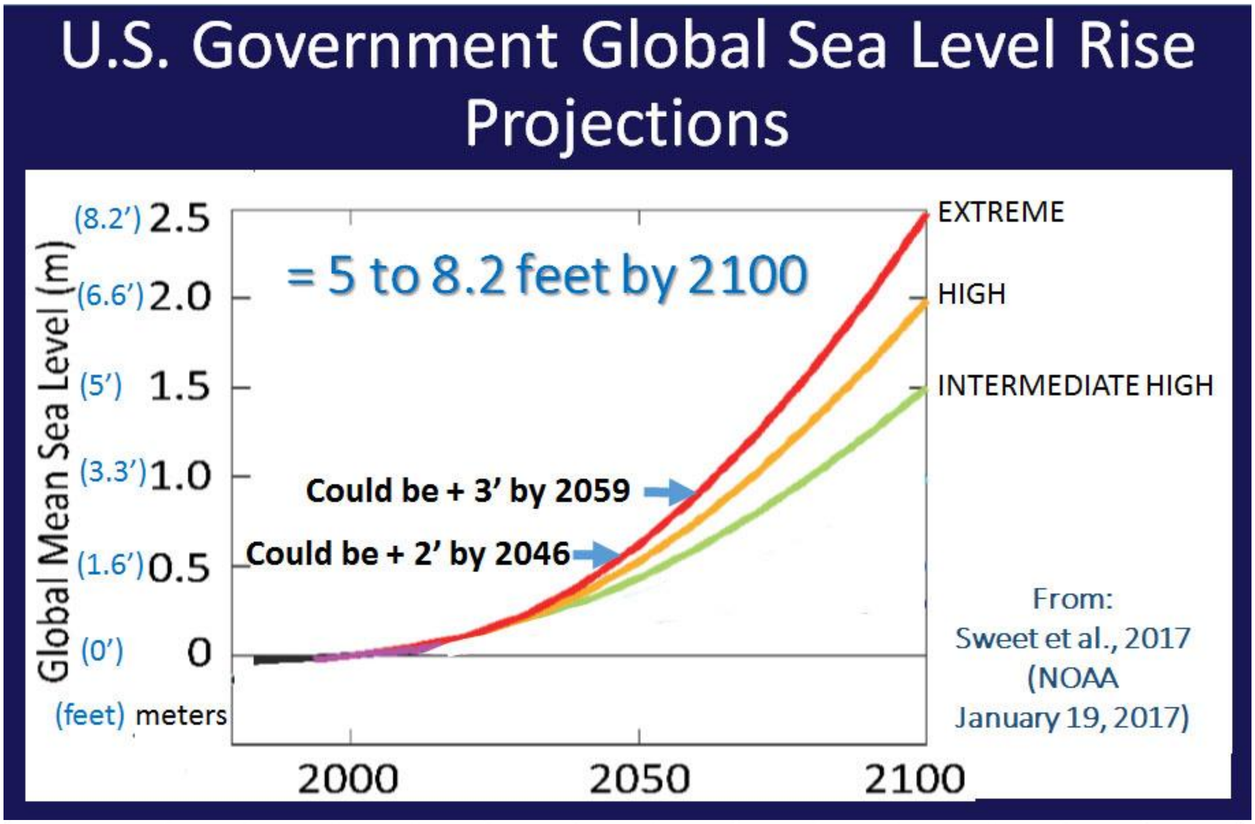
[1] Hine, C., et al., Sea Level Rise in Florida, Science, Impacts, and Options, Univ. of Fla. Press (2016) at 41.

publication because of the need for gaining scientific consensus and public review. The sea level working group has been dominated by modelers who do not see beyond their numerical models (which cannot yet incorporate many of the accelerating ice-melt feedbacks being observed), and there is governmental political pressure on some scientists to go low on sea level projections, and the consensus agreed upon will be by definition very conservative. For all the above reasons, the IPCC has put out unreasonably low sea level rise projections in their 4th and 5th reports (2007 and 2013). NOAA's and most other projections conclude that sea level rise will continue to rise and to accelerate even more after 2100. If, for example, sea level has risen 1.5 m (5 feet) by 2100, it will be rising at a rate of 30 centimeters (one foot) per decade—and accelerating.



GMSL Scenario (meters)	2010	2020	2030	2040	2050	2060	2070	2080	2090	2100	2120	2150	2200
Low	0.03	0.06	0.09	0.13	0.16	0.19	0.22	0.25	0.28	0.30	0.34	0.37	0.39
Intermediate-Low	0.04	0.08	0.13	0.18	0.24	0.29	0.35	0.4	0.45	0.50	0.60	0.73	0.95
Intermediate	0.04	0.10	0.16	0.25	0.34	0.45	0.57	0.71	0.85	1.0	1.3	1.8	2.8
Intermediate-High	0.05	0.10	0.19	0.30	0.44	0.60	0.79	1.0	1.2	1.5	2.0	3.1	5.1
High	0.05	0.11	0.21	0.36	0.54	0.77	1.0	1.3	1.7	2.0	2.8	4.3	7.5
Extreme	0.04	0.11	0.24	0.41	0.63	0.90	1.2	1.6	2.0	2.5	3.6	5.5	9.7

Figure 6. Top: 2017 NOAA projections for sea level rise which include accelerating ice melt from ice sheet disintegration and a warming, expanding ocean (Modified from Sweet et al,

2017). Bottom: Global Mean Sea Level rise scenario heights for 19-year averages centered on decade through 2200. From Sweet *et al.*, 2017. Low, Intermediate Low and Intermediate are unrealistically low projections because they do not incorporate significant acceleration in polar ice melt.

Using NOAA's higher projections, which as discussed below are conservative, the time at which each foot of sea level rise will be reached can be anticipated by using their 'Intermediate High,' 'High,' and 'Extreme' scenarios. The Intermediate High scenario projects sea level rise incorporating a warming ocean and 'limited ice sheet loss' and some ice melt acceleration. The 'Intermediate Low' scenario only incorporates sea level rise from ocean warming, minor ice melt but no ice melt acceleration. The 'Lowest' scenario is a linear projection based on historical sea level rates derived from tide gauge measurements beginning in 1900. Neither the Lowest nor the Intermediate Low scenarios are valid scenarios to use for the future. They both fail to reproduce the observed sea level rise over the past two decades because of significant acceleration from already occurring observed ice melt.

Under NOAA's 2017 projected scenarios, there could be 60 cm (2 feet) of sea level rise by 2046 and 90 cm (3 feet) by 2059. A 2–3 foot rise of sea level will make nearly all of the barrier islands of the world uninhabitable, result in inundation of a major portion of the world's deltas, and make low-lying coastal zones like south Florida and Louisiana increasingly challenging communities in which to maintain infrastructure and welfare and to assure protection of life and property during extreme rainfall events and hurricanes.

NOAA reports that even 0.9 m (3 feet) of sea level rise would permanently inundate 2 million American's homes and communities. Two meters (6.6 feet) of sea level rise would put 6 million U.S. homes underwater (Hauer et al., 2016).

While NOAA's projection of up to 2.5 m (8.2 feet) of sea level rise by 2100 is representative of sea level projections typically made in the scientific literature based on current modeling, including the current rate of accelerated melting in the poles, it does not address other very plausible high-risk scenarios.

Importantly, sea level rise is now accelerating due primarily to the rapid loss of ice on Greenland and Antarctica. This acceleration is occurring faster than any of the climate models predict, because the models currently do not include many of the numerous accelerating feedbacks in ice melt that are now being observed and that the paleo-record documents the reality of. Although not yet in the models, these accelerating feedbacks for ice melt are a reflection of the fact that ice, when destabilized, disintegrates very rapidly resulting in significant pulses of sea level rise such as are documented throughout the past. The historic record of sea level rise clearly establishes that sea level rises in pulses. Our scientific understanding of the historic rapid pulses in sea level rise as ice sheets disintegrate is not incorporated in any U.S. government models, including NOAA's 2017 model, or any of the modeling summarized by the IPCC, the governmental body reporting on the consensus science of climate change. NOAA confirms "the GMSL exceedance probabilities for the scenarios may underestimate future rates of ice melt due to effects such as Antarctic ice sheet instability." (NOAA, 2017).

Dr. James Hansen and co-authors published a peer-reviewed paper in 2016 that attempted to take into account the rapid disintegration of ice sheets that the models have not accounted for and are not yet able to provide for in a numerical model. They used a combination of climate modeling, paleoclimate analyses, and modern observations to incorporate climate feedback processes in an effort to explain the more rapid paleoclimate changes to sea levels. Hansen *et al.* explain the broad scientific understanding that during the late-Eemian, sea level reached +6–9 m (+20–30 feet), due in substantial part from melting in Antarctica at a time when Earth was only slightly warmer than today (Dutton et al., 2015; Hansen et al., 2016). Hansen *et al.* ultimately conclude that while precise predictions of sea level rise are not possible given the uncertainties around how quickly the ice sheets will disintegrate, the authors state with a high degree of confidence that multi-meter sea level rise would become practically unavoidable, probably within 50–150 years, if current emission trends continue.

Table 1 below summarizes the observed accelerating feedbacks that are speeding up ice sheet melt on Greenland and Antarctica. Most of these are not in the modeled projections of sea level rise, and necessitate consideration that the reality will be much faster than even NOAA’s most recent 2.5 meter (8.2 feet) “Extreme” projection. These accelerating feedbacks that we are now observing are the witness to the reality of a new, probably significant and rapid, pulse of ice sheet disintegration and sea level rise.

From Atmospheric Warming (mostly Greenland at Present)

1. Lowering surface elevation with melt putting surface in warmer climate belt.
2. Surface melt lakes and ponds adsorb more heat than white ice.
3. Dark dirt and soot from within ice concentrates on melting surface adsorbing more heat.
4. Surface melt water pours down moulins (melt sinkholes) to base of ice sheet lifting and detaching ice from rock substrate causing increased lateral movement and ice fracturing.
5. Resulting fracturing lets melt water into ice sheet warming interior ice making it softer and flowier (Bell et al, 2014).
6. Fracturing greatly accelerates overall melt rate as it warms throughout the ice sheet (Scambos et al., 2009).
7. Lake drainage sets up bottom flow causing tensile shock fracturing of ice and then cascading lake drainage (Christoffersen et al., 2018). This large volume of water can accelerate basal ice flow.
8. Melt water is increasing portion of the basal ice sheet that is thawed and flowier (MacGregor et al., 2016). Heat from Earth interior also plays a role in some areas.
9. Increased melt of floating Arctic pack ice creates more open water, adsorbing more heat to warm Greenland's atmosphere and adjacent ocean waters.
10. Cryoconite holes in melting ice sheet surface accelerate surface melt (Fountain et al., 2004).
11. Thick summer surface melt forms thick slush on surface that works downward melting and softening ice.
12. Surface warming has eliminated ability of firn to refreeze meltwater over much of ice sheet, accelerating meltwater production and release (Noel et al., 2017).

From Ocean Warming (Greenland and Antarctica)

13. Intensive intrusion of dense warm ocean water through glacial outlets deep beneath ice sheets causing rapid and irreversible warming (much like estuarine circulation) (Hansen et al., 2016; Kusahara and Hasumi, 2014).
14. Weight of ice produces retrograde slopes (deepening inward) making melting easier and easier inland.
15. Ice, once detached from bottom, can thin by bottom melt and by dynamic thinning (collapse along fractures much like a rack of books splaying out across a table).
16. Inward calving produces higher and higher cliffs which are very unstable above 90 meters height (DeConto and Pollard, 2016; Rignot, 2015). This can result in runaway ice cliff collapse.
17. Surface meltwater can dramatically accelerate ice fracturing of ice cliffs (called hydrofracturing) promoting rapid ice shelf collapse and breakup (Tollefson, 2016; Kopp et al., 2017b*)*.
18. Breakup of floating Ice Shelves (like Larsen A, B, and C) removes the resisting pressure on grounded glaciers and ice sheets and the upstream ice greatly accelerate its velocity of flow to the sea, accelerating sea level rise (Reese et al., 2018).

Table 1. Observed Acceleration of Ice Sheet Melt from Atmospheric Warming (mostly Greenland at Present).

Most importantly, Kopp *et al.* (2017) strongly state that "current sea-level observations cannot exclude future extreme outcomes," especially because of hydrofracturing and ice cliff collapse effects that they project to become increasingly important as the century progresses (see also DeConto and Pollard, 2016). These processes, combined with the retrograde bathymetry inward beneath the ice sheet (Rignot, 2015), provide the opportunity and strong likelihood of runaway ice sheet collapse as the century progresses.

In my expert opinion, based on the historic record, the rapid pulses, and current rates of sea level rise acceleration, I project a 4.6 to 9.1-meter (15 to 30-foot) rise in sea level by 2100 if current trends continue, with ever greater rises and acceleration in subsequent centuries until such time as we dramatically reduce the levels of CO_2 in the atmosphere and take steps to cool the upper portion of the ocean. I am not alone in this conclusion. One of the world's eminent glaciologists, Dr. Eric Rignot, predicts that an increase in global temperatures to 1.5–2°C over pre-industrial levels, will commit the planet to sea level rise of six to nine meters, which could occur in the next 100–200 years. In addition, James Hansen has projected 5–10 meters (16–

33 feet) this century (Hansen et al., 2016). Thus, only NOAA's extreme sea level rise scenario presents anything close to approximating the real risk we face with sea level rise.

C. Accelerated Sea Level Rise

Although Florida has been subjected to basically the global rise in sea level in the past, there are two features which indicate that Florida's sea level rise is accelerating and will be significantly greater than the future global average sea level rise. First, as Greenland and Antarctica ice melt is accelerating, the gravitational attraction of that decreasing ice mass is weakening the pull of water towards these ice masses. Hsu and Velicogna (2017) estimate that this redistribution of gravitational attraction is resulting in Florida's sea level rise being 52 percent greater than the global average.

Second, it is forecast that the speed of the Florida Current and Gulf Stream will decrease through the century as less water is drawn north around Greenland to replace water that has sunk to form the deep water of the ocean conveyer belt. This Florida Current/Gulf Stream slowdown is predicted in Atlantic Ocean circulation models (Kirtman et al., 2012), and has been documented in recent observations (Park and Sweet, 2015; Rahmstorf et al., 2015). The north-flowing Florida Current is pulled to the right by the Coriolis Force of Effect, a force related to the spin of the Earth. In the northern hemisphere, the Coriolis Force acts to turn a moving water current to the right and creates a slope of the water surface, higher on the right or east side of the Florida Current. Slowdown of the Florida Current and Gulf Stream lessens the effect of the Coriolis Force on the slope of the ocean resulting in an immediate rise of water level on the western (Florida) side of the current. Presently, ocean levels are about 1 meter (3.3 feet) higher at Bimini, Bahamas, than at Miami because of the strong northward flow of the Florida Current. Because of the anticipated slowdown of the Florida Current, the Southeast Florida Regional Planning Council's "Regional Compact" has recommended adding 15 percent to future global sea level rise to account for the anticipated decreasing velocity of the Florida Current and Gulf Stream (Technical Ad Hoc Work Group, 2015).

Valle-Levinson *et al.* (2017) studying the causes for times of accelerated relative sea level rise along the Atlantic Coast through "tide gauge records reveal comparable short-lived, rapid SLR accelerations (hot spots) that have occurred repeatedly over ~1500 km stretches of the coastline during the past 95 years, with variable latitudinal position." They conclude that North Atlantic Oscillation determines the latitudinal position of these SLR hot spots, while a cumulative El Niño index is associated with their timing. The North Atlantic Oscillation (NAO) is caused by fluctuations in the difference of atmospheric pressure at sea level between the Icelandic low pressure center and the Azores high pressure center. The NAO affects the strength of the westerly winds of the North Atlantic and thus influences the speed of the Gulf Stream. The El Niños influence the strength of the easterly trade winds and thus the speed of the surface currents moving westerly across the tropical Atlantic. This control of North Atlantic circulation and current speeds and eddies in the currents affects sea level along the Atlantic coast. In the past decade, portions of the coast from Miami north to Cape Hatteras have had 5- to 10-year periods of greatly accelerated sea level rise—at rates of 9 to 20 mm per year (0.35 to 0.79 inches per year) (Wdowinski et al., 2016; and Valle-Levinson et al., 2017). These were three or more times the global average and have been, fortunately, just oscillations, though it is a view of things to come.

Just a 60- to 90-cm (2- to 3-foot) rise of sea level will make nearly all the barrier islands of the world uninhabitable, begin the inundation of a major portion of the world's deltas, and make low-lying coastal zones like Louisiana and southeast Florida increasingly challenging communities in which to maintain infrastructure and assure protection of life and property during hurricanes and other extreme events. Importantly, when governments project several feet of sea level rise by the end of the century, that rise will not be some new fixed end point of sea level at equilibrium. It represents an acceleration of sea level rise because of the ongoing accelerating ice melt. If, for example, we have 1.5 meters (5 feet) of sea level rise at the end of the century, sea level will be rising at a foot per decade and accelerating. That will make maintaining coastal infrastructure, such as port facilities, extremely difficult logistically and financially.

III. Sea Level Rise in Southern Florida and Its Barrier Islands

While climate change will be felt globally, the low-lying and heavily-populated coastline of south and central Florida, including its barrier islands, makes it extremely vulnerable to the effects of climate change, particularly sea level rise, amplified by storm surges. Hurricane storm surges will make low-lying south Florida an increasingly risky place to live. The maps in **Figure 7** below show the increased extent and depth of the category 5 Hurricane Andrew (1992) storm with a further three feet of sea level rise. Nearly the entire southern two-thirds of Miami-Dade County will be affected by a deep, powerful, violent onshore storm surge and the seaward barrier islands will be dangerously swept by a strong surge.

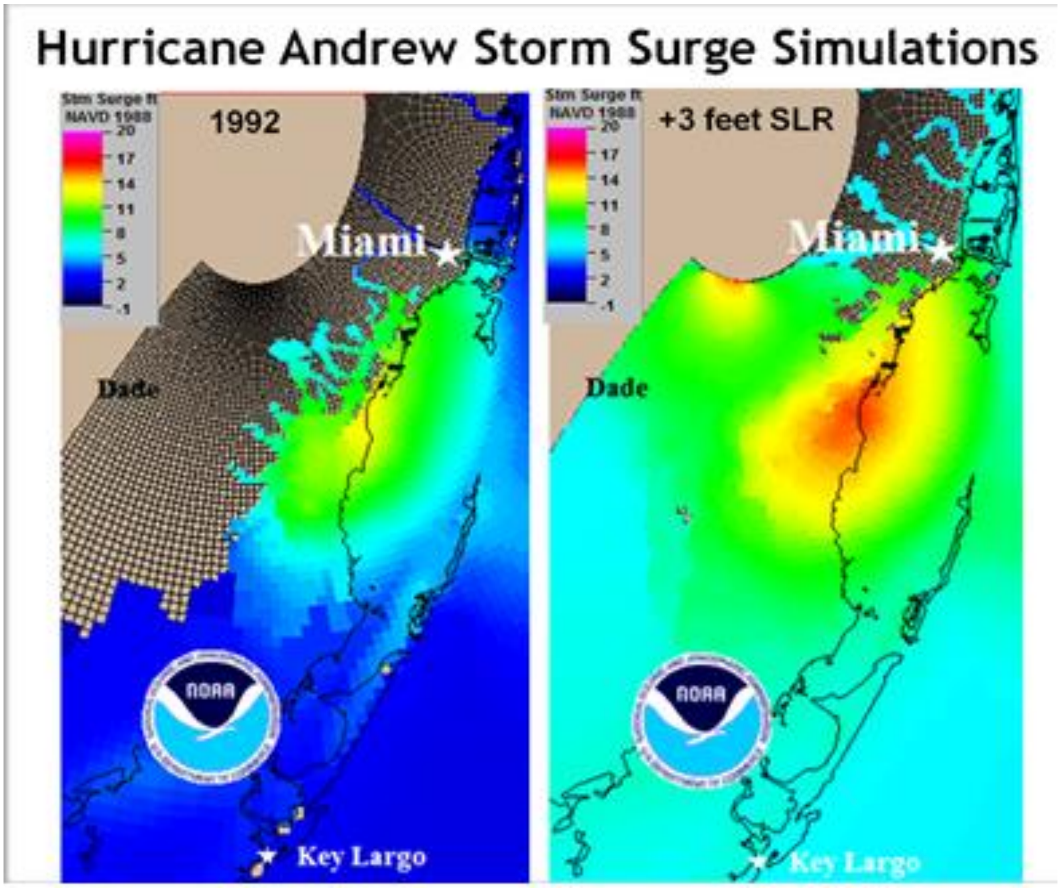


Figure 7. Left: Storm surge of category 5 Hurricane Andrew in 1992. Right: Same Hurricane Andrew storm surge with 90 cm (3 feet) of sea level rise. (Provided by Dr. Brian Soden, University of Miami).

South Florida is not significantly sinking or rising so sea level change in south Florida basically follows the global sea level change, with some potential for enhanced rises. South Florida's sea level has risen about 30 cm (12 inches) since 1930 and is currently increasing at a rate of about 3.5 cm (1.3 inches) per decade; a rate that is approximately 10 times faster than what occurred naturally over the past 2,400 years. If the current trend were to continue at the same linear rate of 1 inch per decade, the oceans along South Florida's coast would rise another 12.5 cm (5 inches) by 2060 and 25 cm (10 inches) by the end of the century. As discussed above, these scenarios are highly improbable and vastly underestimate potential sea level rise given the non-linearity we are observing and that is predicted of ice melt and resulting sea level rise.

In January 2008, the Science Committee (of which I was Chair) of the Miami-Dade Climate Change Advisory Task Force issued a projection of future sea level rise for south Florida, stating:

> With what is happening in the Arctic and Greenland, many respected scientists now see a likely sea level rise of **at least** 1.5 feet in the coming 50 years and a total of **at least** 3-5 feet [90-150 cm] by the end of the century, possibly significantly more. Spring high tides would be at +6 to +8 feet [1.8-2.4 m].

> This does not take into account the possibility of a catastrophically rapid melt of land-bound ice from Greenland, and it makes no assumptions about Antarctica. (MDC-CCATF, 2008).

Since issuing this statement, evidence for dramatically accelerating ice sheet melting has increased on both Greenland and Antarctica, again not accounted for in the modeling or in NOAA's latest sea level rise predictions. (Van den Broeke et al., 2009; Velicogna, 2009; Kerr, 2009; Jiang et al., 2010; Rignot et al., 2016, 2017).

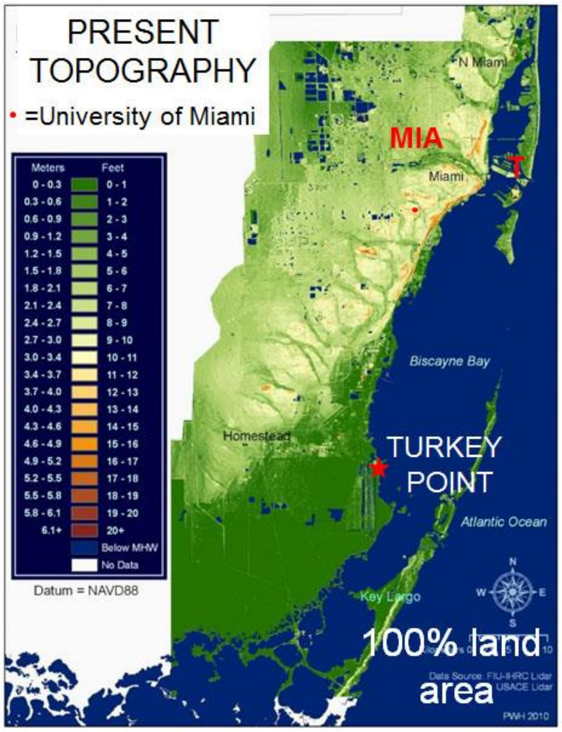
Miami is particularly at risk to the environmental impacts of sea level rise as acknowledged in the 2014 USGCRP Third National Climate Assessment:

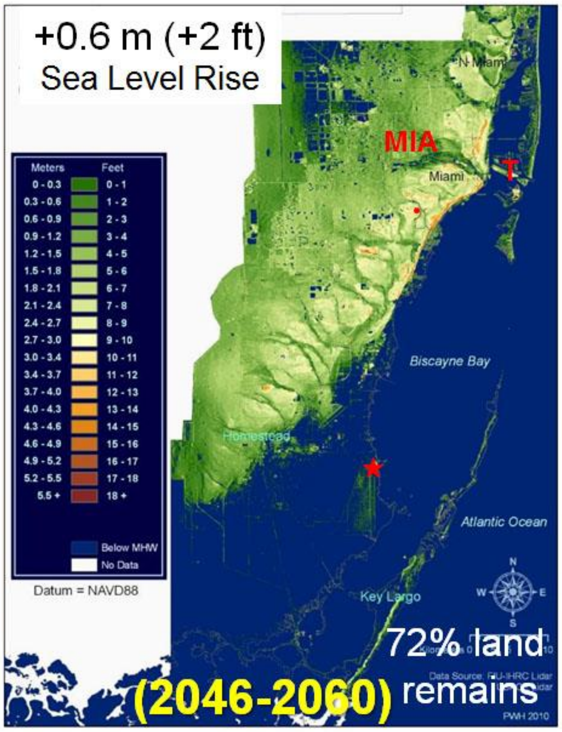
> Large numbers of cities, roads, railways, ports, airports, oil and gas facilities, and water supplies are at low elevations and potentially vulnerable to the impacts of sea level rise. New Orleans (with roughly half of its population living below sea level), Miami, Tampa, Charleston, and Virginia Beach are among those most at risk. (Strauss et al., 2012).

Even during the summer and fall of 2017, residents in some areas such as Miami Beach, Key Biscayne, and the Bayshore Drive section of Miami experienced repetitive, serious seawater flooding their streets.

Nearly all climate and sea level assessments agree that ice melt and sea level rise is and will be accelerating well into the next century. This means that coastal cities will not be adjusting to a fixed higher sea level at the end of the century, but one that *continues to rise at an accelerating rate*. Long-term adaptation to sea level rise in low-lying areas of the United States is not realistic under current rates of warming.

Using LiDAR (Light Detection and Ranging) high-resolution elevation mapping from a plane with ground-truthing, the late Peter Harlem and I mapped Miami-Dade County to show the progressive inundation of Miami-Dade County based on U.S. government projections. These are depicted below in **Figure 8**. These LiDAR maps represent mean high tide and do not include king tide or storm surge inundation, which will be substantial. They clearly illustrate the complete and irreversible loss of land and property expected this century. With NOAA's 'Highest' sea level rise scenario (again, which is conservative), we would see 60 cm (2 feet) of sea level rise by 2046, 90 cm (3 feet) by 2059, 1.2 m (4 feet) by 2069, 180 cm (6 feet) by 2084, 2.4 m (8 feet) by 2098, and 3.0 m (10 feet) by 2110.


PRESENT TOPOGRAPHY
• =University of Miami
Meters Feet
0 - 0.3 0 - 1
0.3 - 0.6 1 - 2
0.6 - 0.9 2 - 3
0.9 - 1.2 3 - 4
1.2 - 1.5 4 - 5
1.5 - 1.8 5 - 6
1.8 - 2.1 6 - 7
2.1 - 2.4 7 - 8
2.4 - 2.7 8 - 9
2.7 - 3.0 9 - 10
3.0 - 3.4 10 - 11
3.4 - 3.7 11 - 12
3.7 - 4.0 12 - 13
4.0 - 4.3 13 - 14
4.3 - 4.6 14 - 15
4.6 - 4.9 15 - 16
4.9 - 5.2 16 - 17
5.2 - 5.5 17 - 18
5.5 - 5.8 18 - 19
5.8 - 6.1 19 - 20
6.1+ 20+
Below MHW
No Data
Datum = NAVD88
N Miami
MIA
T
Miami
Biscayne Bay
Homestead
TURKEY POINT
Atlantic Ocean
Key Largo
N W E S
100% land area
Data Source: FIU-IHRC Lidar USACE Lidar
PWH 2010


+0.6 m (+2 ft) Sea Level Rise
Meters Feet
0 - 0.3 0 - 1
0.3 - 0.6 1 - 2
0.6 - 0.9 2 - 3
0.9 - 1.2 3 - 4
1.2 - 1.5 4 - 5
1.5 - 1.8 5 - 6
1.8 - 2.1 6 - 7
2.1 - 2.4 7 - 8
2.4 - 2.7 8 - 9
2.7 - 3.0 9 - 10
3.0 - 3.4 10 - 11
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3.7 - 4.0 12 - 13
4.0 - 4.3 13 - 14
4.3 - 4.6 14 - 15
4.6 - 4.9 15 - 16
4.9 - 5.2 16 - 17
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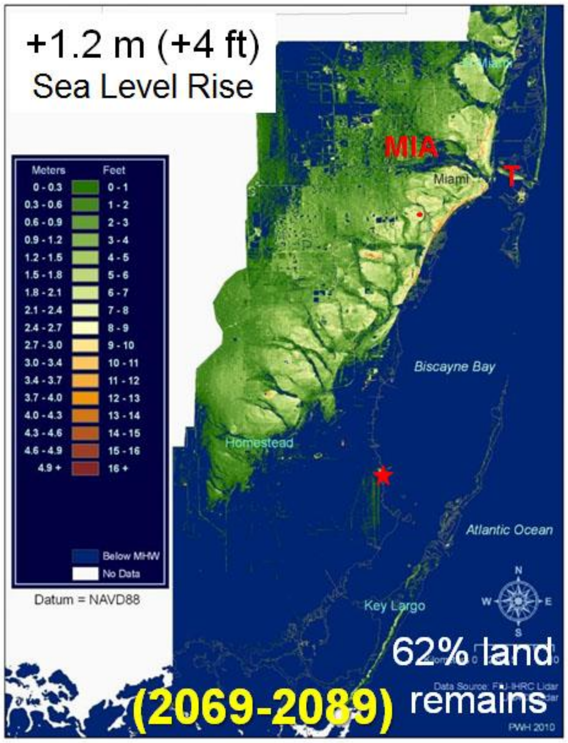
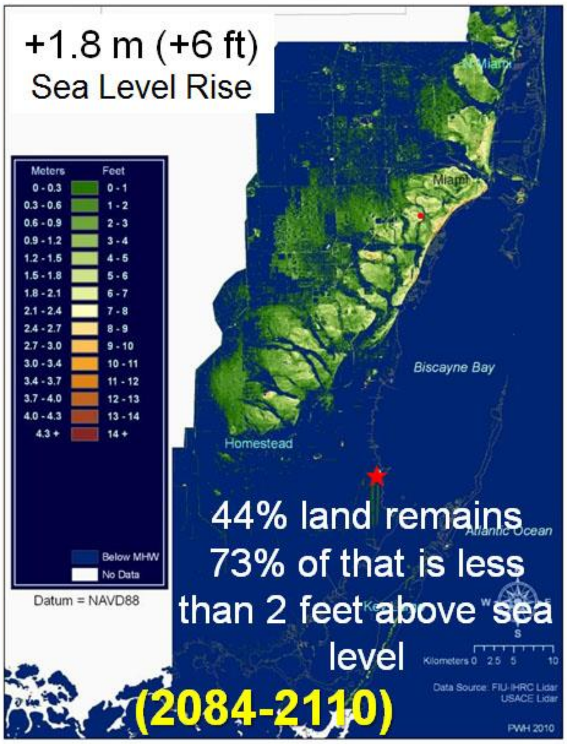
5.5+ 18+
Below MHW
No Data
Datum = NAVD88
N Miami
MIA
T
Miami
Biscayne Bay
Homestead
Atlantic Ocean
Key Largo
N W E S
72% land remains
(2046-2060)
Data Source: FIU-IHRC Lidar
PWH 2010


+1.2 m (+4 ft) Sea Level Rise
Meters Feet
0 - 0.3 0 - 1
0.3 - 0.6 1 - 2
0.6 - 0.9 2 - 3
0.9 - 1.2 3 - 4
1.2 - 1.5 4 - 5
1.5 - 1.8 5 - 6
1.8 - 2.1 6 - 7
2.1 - 2.4 7 - 8
2.4 - 2.7 8 - 9
2.7 - 3.0 9 - 10
3.0 - 3.4 10 - 11
3.4 - 3.7 11 - 12
3.7 - 4.0 12 - 13
4.0 - 4.3 13 - 14
4.3 - 4.6 14 - 15
4.6 - 4.9 15 - 16
4.9+ 16+
Below MHW
No Data
Datum = NAVD88
Miami
MIA
T
Miami
Biscayne Bay
Homestead
Atlantic Ocean
Key Largo
N W E S
62% land remains
(2069-2089)
Data Source: FIU-IHRC Lidar
PWH 2010


+1.8 m (+6 ft) Sea Level Rise
Meters Feet
0 - 0.3 0 - 1
0.3 - 0.6 1 - 2
0.6 - 0.9 2 - 3
0.9 - 1.2 3 - 4
1.2 - 1.5 4 - 5
1.5 - 1.8 5 - 6
1.8 - 2.1 6 - 7
2.1 - 2.4 7 - 8
2.4 - 2.7 8 - 9
2.7 - 3.0 9 - 10
3.0 - 3.4 10 - 11
3.4 - 3.7 11 - 12
3.7 - 4.0 12 - 13
4.0 - 4.3 13 - 14
4.3+ 14+
Below MHW
No Data
Datum = NAVD88
N Miami
Miami
Biscayne Bay
Homestead
Atlantic Ocean
44% land remains
73% of that is less than 2 feet above sea level
Kilometers 0 2.5 5 10
(2084-2110)
Data Source: FIU-IHRC Lidar USACE Lidar
PWH 2010

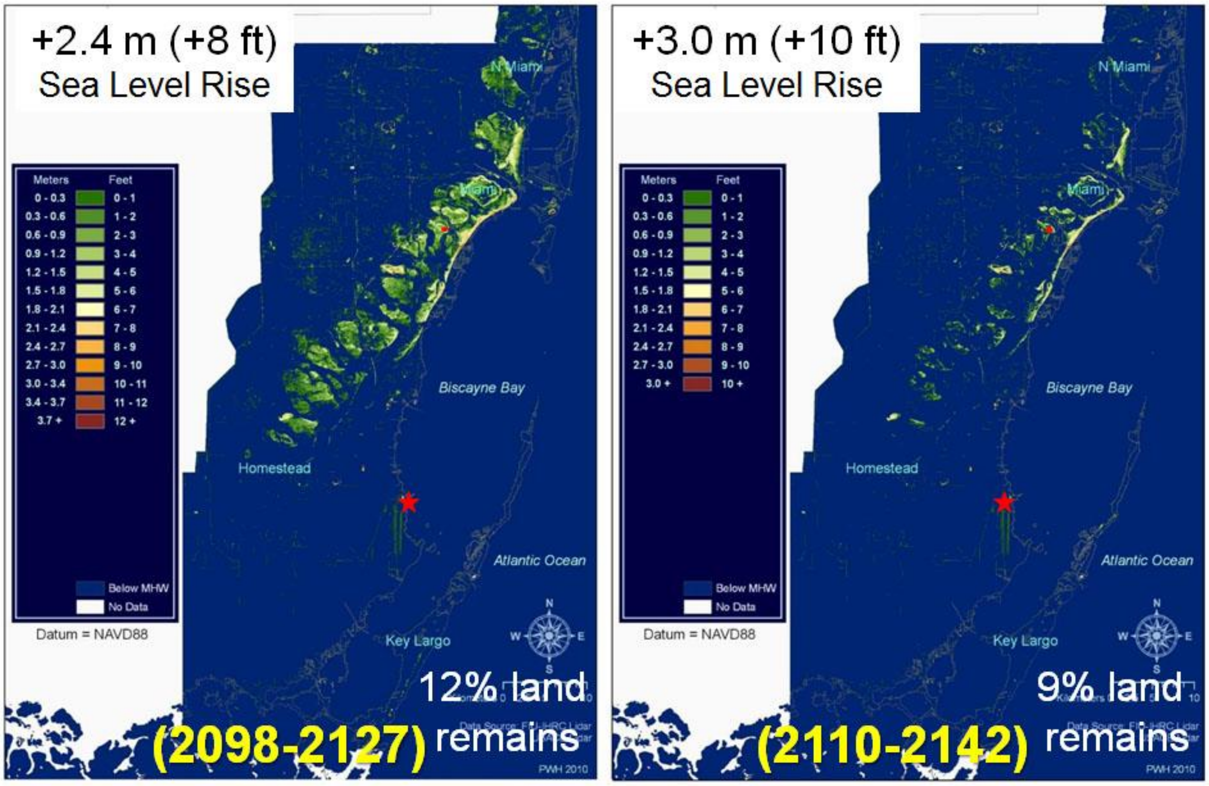


Figure 8. LiDAR elevation maps of Miami-Dade County showing areas above mean high water at present and with 0.6 m (2 feet), 1.2 m (4 feet), 1.8 m (6 feet), 2.4 m (8 feet) and 3 m (10 feet) of further sea level rise. Possible timing of these inundation levels is indicated using those U.S. Government projections that incorporate significant acceleration in polar ice melt. Maps were created by the late Dr. Peter Harlem of Florida International University using LiDAR data flown by the State of Florida. MIA= Miami International Airport; T = new tunnel to shipping/cruise port; star = Turkey Point Nuclear Power Plant.

Sandy barrier islands along tectonically passive margins, such as southeast Florida, are on a gently sloping continental shelf setting and tend to shift dramatically landward with rising sea level. In this setting, a one-foot rise in sea level will commonly result in a landward migration of a barrier island of 500 to 2,000 feet. This occurs as sand overwashes the island or is swept through inlets or to the offshore during storms.

Rising sea level will significantly change the coastal environments, interactions of land and water (including salinity), base-level elevations, tidal current patterns and strengths, and storm surge patterns and strengths. With even a two-foot rise in sea level, saltwater will intrude into Florida's southern and southeastern aquifers. For instance, saltwater intrusion is already affecting the Biscayne Aquifer, and this will become a rapidly increasing problem (Heimlich et al., 2009), diminishing and then eliminating sources of freshwater (Science Committee, 2008; Heimlich et al., 2009).

In addition to harming private and public property, rising sea level will also harm the viability of infrastructure like wastewater treatment facilities, nuclear power plants, roads, and landfills, which will become vulnerable to disruption or destruction by storms, potentially leading to vast contamination of lands and waters as other pollutants are released. There is no planning in southern Florida for cleaning the land before inundation even though many of the waste disposal sites, sewage treatment plants, industrial sites, nuclear power plant, and superfund sites are in low-lying coastal zones. For example, with only 45 to 90 cm (1.5 to 3 feet) of further sea level rise, the Central Sewage Treatment Plant and the adjacent abandoned unlined dump of Virginia Key, Florida will be all that is left of the ocean-facing sandy barrier island. Those pollutant-filled facilities will be exposed to the full force of the oceans tides, waves and storm surges. For those areas on septic tank systems, increasingly frequent sunny day flooding will flood neighborhoods and roads with fecal pollution.

Southeastern Florida and its barrier islands will experience at least two feet of sea level rise in the next 30–50 years. This rise, combined with king tides and storm effects, will eliminate the habitability of most of Florida's barrier islands. Sweet *et al*. (2018) have taken the future frequency of high-tide floods that an area will experience for the different U.S. Government sea level rise projections (Sweet, 2017). They based 'flood' as 'when water levels exceed about 0.5 m, 0.8 m and 1.17 m above a height slightly higher (3–4%) than the local tide range," because that is when they found "minor, moderate and major flooding will occur" (Sweet et al., 2018). **Figure 9** below shows the projected future flooding frequency for those levels for New York City, Miami, and San Francisco.

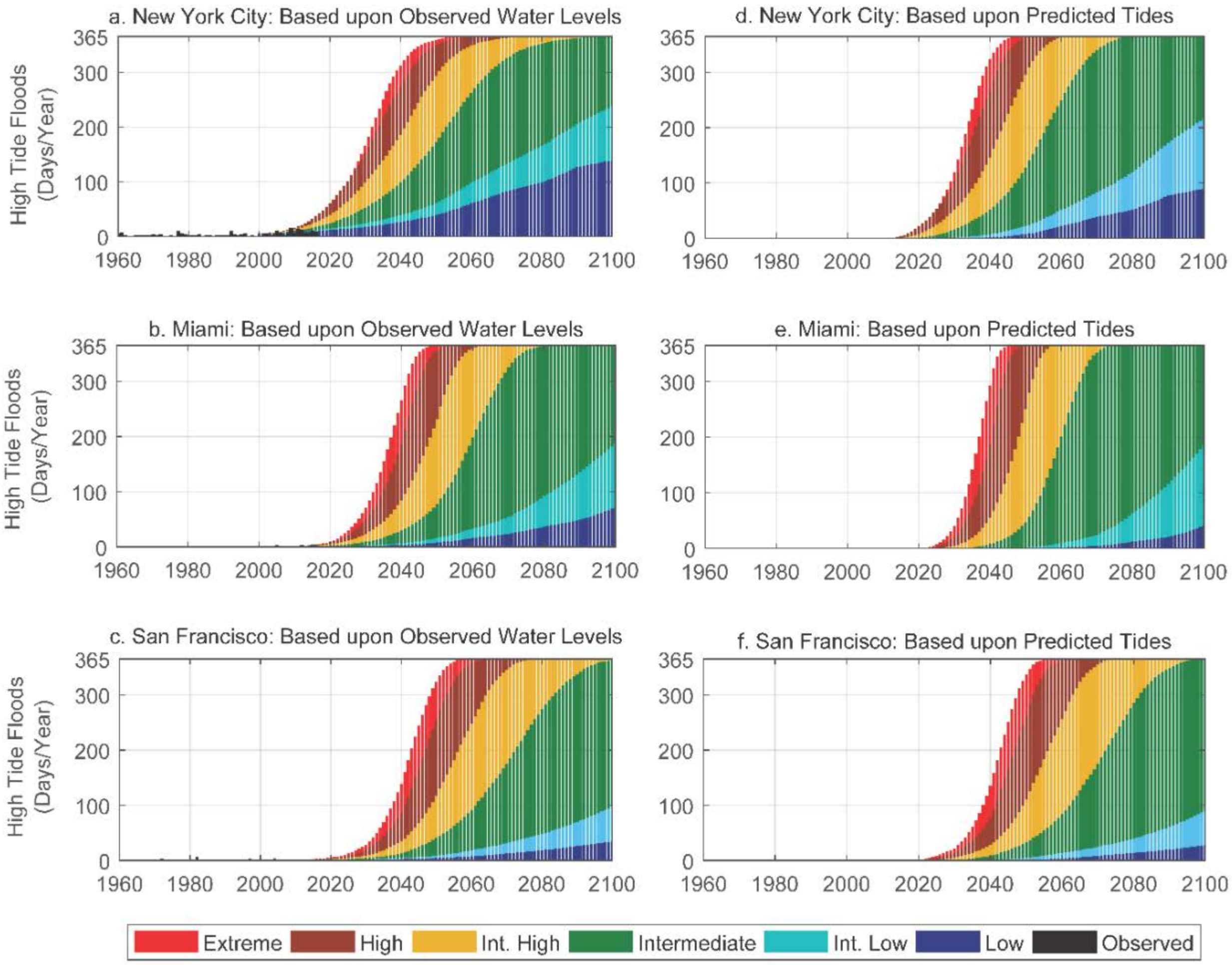


Figure 9. Projected annual frequencies of high tide flooding in response to scenarios of global sea level rise (Sweet et al., 2017) estimated at NOAA tide gauges in a) New York City (The Battery), b) Miami (Virginia Key), Florida and c) San Francisco, California considering observed patterns (combined tidal and nontidal water level components) and d), e) and f) at the same locations but assuming predicted tide forcing only. Derived high tide flood levels are 0.56m, 0.53 m and 0.57 m, respectively.

Plaintiff Levi lives in Satellite Beach on a southeastern Florida barrier island, much of which is less than 6 feet above sea level. Levi's home is at 0.9 m (3 feet) above sea level. His island is already facing sea level rise and increased inundation during storms. At 90 cm (3 feet) of sea level rise, Levi's home will be in the sea. That is likely to happen between 2065 and 2083. But long before 3 feet of sea level rise, Levi and his family will have been forced out because of increasing frequency and depth of flooding and infrastructure failure in their home and community from sunny day flood events (king tides and heavy rainfalls) and storm surges from tropical storms and hurricanes.

A. 2017 Hurricane Season and Sea Level Rise

As described above, human-induced climate change can also cause more intense hurricanes. In September 2017, we experienced this firsthand when the state of Florida was hit by Hurricane Irma as a huge category 1 to 4 storm that blanketed the state in wind damage and in heavy rains and storm surges, which caused significant flooding, even where it only reached category 1 intensity (Miami). In addition, two other hurricanes (Harvey and Maria) reached category 5 status and caused catastrophic damage in Texas, Puerto Rico (a U.S. territory) and elsewhere throughout the Caribbean.

Although the timing and landfall of storm events like these hurricanes cannot be specifically attributed to human-induced global warming, there are a number of trends predicted from global warming that contributed to the 2017 hurricane season's impacts on the United States and its territories. First, a warmer ocean fueled three category 4–5 hurricanes. Irma in particular was an unusually large storm as a category 5 storm and when it diminished in intensity, it spread out to become a spatially huge storm (much like a spinning figure skater spreading her arms). Second, the warmed ocean has a thicker warm layer than in the past, and this was especially true in the southern Gulf of Mexico where the thick warmed ocean fueled intense rain for days in and around Houston alongside Hurricane Harvey. In the past, turbulence in the upper ocean as a hurricane passed brought up cooler water from below thereby weakening the hurricane. Third, as global warming shifted the summer Jet Stream further north than in the past, its strong influence on picking up and moving on hurricanes was diminished, and hurricanes Harvey and Irma lingered on their north and northeastern passage resulting in prolonged intense rainfall (Harvey) and prolonged coastal erosion (Irma on the Atlantic Coast). Normally, as a hurricane approaches the Jet Stream, it is pulled in and swept eastward and northward. And fourth, because of the relative 30 to 75 cm (1 to 2.5) feet of relative sea level rise that the Atlantic and Gulf coasts have experienced in the past century, storm surges were more severe since they could reach higher, further inland and with more velocity than in the past without this sea level rise.

IV. Sea Level Rise and Loss of Infrastructure

As a resident of South Florida, it is truly amazing to me to watch the very aggressive building boom underway, on beaches and barrier islands, throughout downtown and in the low western areas bordering the Everglades. Even with the current, likely underestimated, projections of sea level rise by the end of the century in NOAA, 2017, it is beyond sobering to consider the risk in the present investments and safety that young people, including Plaintiffs, face.

With a further 60 cm (2 feet) of rise (possibly before 2046) most of the barrier islands (of South Florida and the world) will be abandoned and the people relocated; at the same time low places like Sweetwater and Hialeah bordering the Everglades will become more and more frequently flooded and difficult places to live, as illustrated by Hurricane Irma in September 2017. We are on a path towards losing our freshwater resources, living in a community with a failing and disconnected infrastructure, and facing increasing risk from catastrophic storm surges and from hurricanes and flooding from extreme rainfall events.

Based on what we know about sea level rise, governments should be aggressively and transparently planning for young people's future, working with elevation and infrastructure maps to determine the timing, costs and economic feasibility for maintaining a functional infrastructure, a viable insurance industry, and human health and safety. In South Florida, there are already areas that will be unlivable and properties that will be unsellable within a 30-year mortgage cycle.

On January 30, 2015, then-President Barack Obama issued Executive Order 13690, establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input. This order was designed to improve the Nation's resilience to current and future flood risks, which "are anticipated to increase over time due to the effects of climate change and other threats." The sea level rise scenarios and tools set forth in the 2017 NOAA Technical Report, Global and Regional Sea Level Rise Scenarios for the United States (NOAA, 2017), referenced above, were "intended to serve as a starting point for on-the-ground coastal preparedness planning and risk management processes," including compliance with Executive Order 13690. NOAA recognized:

> In this context, there is a clear need – and a clear call from states and coastal communities (White House, 2014) – to support preparedness planning with consistent, accessible, authoritative and more locally appropriate knowledge, data, information, and tools about future changes in sea level and associated coastal risks.

I agree with that statement and have been involved in this kind of work with local governments in South Florida for the past decade, including the 4-County Compact on climate change in Southeast Florida. The lack of current federal government support for sea level rise adaptation and preparedness planning is notable. For example, on August 15, 2017, President Trump revoked Executive Order 13690. In addition, the federal Flood Insurance Rate Maps established by the Federal Emergency Management Agency to help determine the cost of the National Flood Insurance Program flood insurance rates are based on past patterns of flooding.[2] Present and future sea level rise is not factored into the Flood Insurance Rate Maps and thus the maps do not accurately communicate the risk to residents who live in coastal areas.

Nonetheless, as I explain above, no amount of preparedness or adaptation planning will make people like Levi safe from the rising seas and increasingly dangerous storm events if mitigation through urgent emission reductions is not planned for and carried out by Defendants. We cannot adapt our way out of increasingly warm oceans and the planet's ice that will melt.

V. The Loss of Coastal Wetlands

Both Florida and Louisiana are losing vast amounts of wetland because of accelerating sea level rise and poor management. In Louisiana, through the last century, a continuous line of levees was built essentially to the outlet far out on the edge of the continental shelf. This prevented both sediment and freshwater from building and maintaining the Delta. Louisiana has lost more than

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[2] National Research Council, Tying Flood Insurance to Flood Risk for Low-Lying Structures in the Floodplain (2015); FEMA Technical Mapping Advisory Council Annual Report (Dec. 2016).

5,000 square kilometers of wetlands over the past century (Jankowski et al., 2017) and will lose another 10,000 to 13,500 square kilometers by the end of this century because of subsidence and sea level rise (Blum and Roberts, 2009). Blum and Roberts (2009) conclude that, because of upstream dams, there is no longer enough sediment coming down the Mississippi River to significantly offset this loss. Nearly all of the Mississippi River Delta is less than 1.5 meters (5 feet) above sea level and extremely vulnerable to the coming accelerating sea level rise as depicted in **Figure 10**, below.

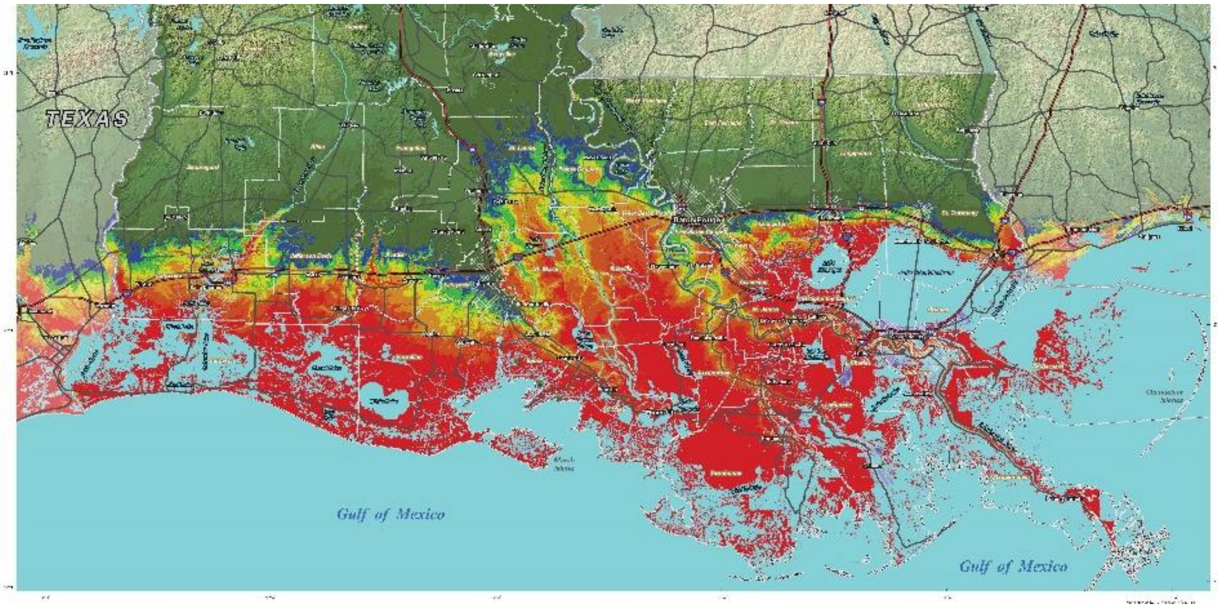

Figure 10. Low lying areas associated with the Mississippi River Delta. Red areas are less than five feet elevation; dark orange is 5 to 10 feet. The large gaps in the delta plain (G) are areas largely lost since World War II as increased blockage by levees forced deterioration. NO is New Orleans. Chenier Plain is a coast of sand beach ridges, mud and wetlands built by the western drift of sediment eroded from the main Delta and then washed to shore. Digital Elevation Data map by the U.S. Geological Survey (Kosovitch, 2008).

A part of Louisiana's wetland and coastal barrier island loss is because of subsidence brought on primarily because of the withdrawal of oil, gas, and water. Current relative sea level rise is a rate of about 12 mm per year (Jankowski, 2017) of which 3.5 mm per year is global sea level rise and 8.5 mm per year is land subsidence. That is an overall rate of relative sea level rise of 1.2 m (4 feet) per century of which 36 cm (1.2 feet) per century is global and 86 cm (2.8 feet) per century is from subsidence. Basically, no coastal sandy barrier island or coastal wetland can persist with that rate of relative sea level rise. Already the U.S. Government has had to remove 35 place names from the Louisiana Coastal Charts because they no longer exist as a result of relative sea level rise and erosion.[3] Florida is also rapidly losing coastal wetlands through a combination of rising sea levels, storm surge damage and saline intrusion.

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[3] NOAA, Office of Coast Survey, Historical Geographic Place Names Removed from NOAA Charts (updated Aug. 4, 2014), at

VI. The Unprecedented Urgency of Reducing Greenhouse Gas Emissions

The U.S. government has long known that burning fossil fuels would cause global warming and ultimately sea level rise. In 1983, I attended my first meetings with EPA where they were discussing accelerating sea level rise. I have been speaking about the threat of accelerating sea level rise since 1981 and became certain by the mid-1990s that human burning of fossil fuels was the cause.

The last time in the geologic record that atmospheric CO_2 was at present levels, the seas were 21–27 meters (70–90 feet) higher (Miller et al., 2012; Dutton at al., 2015). Several recent papers, including one from the National Science Foundation, have pointed out that we now have greenhouse gas levels sufficient to cause a 21-meter (70-foot) sea level rise (Miller et al., 2012) and be sufficient to affect or displace 70 percent of the world's population (National Science Foundation, 2012).

In my expert opinion we need to return from over 400 ppm to 350 ppm as recommended by Hansen et al. (2008) and then towards 300–325 ppm to prevent further ocean warming and eventually attempt to return to the levels of the Holocene. Even if we do that, the immense heat that is now in the ocean is only very, very slowly going to revert back to the atmosphere. It's going to stay in the oceans for centuries continuing to expand the ocean and melt polar ice. And this is why we so urgently need to stop burning fossil fuels, aggressively sequester more carbon into our lands and forests, and actively reduce carbon dioxide levels in the atmosphere.

We are headed to catastrophic sea level rise a lot faster than we have anticipated. If we act now, we may not be able to save Naples, Miami, our sandy barrier islands, the Mississippi Delta coast, and other low-lying regions. But if we do not act now, we have no chance to protect Plaintiff Levi's barrier island, and we will also be heading towards losing Orlando, Baton Rouge and many other places presently above any officially projected sea level rise.

As the ocean warms, we are also causing the release of huge amounts of methane and CO_2 from permafrost and methane hydrates from the Arctic tundra and Arctic Ocean floor. This stands to become a runaway warming contributor to catastrophic warming later this century unless we rapidly stop forcing atmospheric warming. This will very significantly affect sea level rise in the future.

Already, our local governments in southern Florida must plan for 1.5–2.4 meters (5–8 feet) of sea level rise by century's end according to the U.S. Government projections. Although I consider 4.6–9.1 m (15–30 feet) by century's end to be more likely, 1.5–2.5 m (5–8.2 feet) will be enough to basically eliminate habitation of south Florida's barrier islands and low mainland areas.

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https://historicalcharts.noaa.gov/pdfs/HistoricalPlacenames_Louisiana.pdf; Meredith Westington, NOAA, Office of Coast Survey, *Geographic Names Disappear from Charts, But Not from History*, at https://noaacoastsurvey.wordpress.com/2014/03/21/geographic-names-disappear-from-charts/ ("Some of these places have appeared on NOAA's nautical charts of Louisiana since the 1800s, so their removal raises concerns about a loss of cultural identity on the landscape.").

At times, the hard facts of science do not convey the grave danger we face, particularly when the consequences of invisible CO_2 pollution are locked in long before we physically see them. I express the urgency in this way: As we continue burning fossil fuels today, tomorrow, next month and into next year, a significant portion of the resulting CO_2 pollution is going to remain in the atmosphere for 4,000 years. Every ton of fossil fuels the U.S. government grants private companies permission to extract, when burned, adds more heat and energy to the oceans, and our oceans will hold that heat for hundreds to thousands of years, leading to more and more ice melt.

For hundreds of thousands of years, CO_2 has fluctuated up and down about 100 ppm, between 180–280 ppm, during which time sea level has been going up and down by about 100 meters in response. In the flash of time since the industrial revolution, we have tipped the CO_2 scale over 410 ppm, an increase of 130 ppm, and that rapidly warming atmosphere has already heated the ocean enough to initiate rapid melting of the ice on both Greenland and Antarctica and to initiate destabilization of the Arctic Pack Ice, permafrost, and methane hydrates. It is important to note that the natural 100 ppm rise, from 180 to 280 ppm, occurred over about a 12,000 year period. The human induced CO_2 increase of 130 ppm, from 280 to 410 ppm, has occurred in the last 120 years. This is a rate about 100 times faster than the natural geologically very rapid rate of climate change. Note that, although the industrial revolution began in the 1700s, it was not until the 20th century that burning of fossil fuels had a significant impact on climate. In 1900, only about 500 metric tons of carbon were introduced into the atmosphere by burning fossil fuels per year. By 1950, this had increased to about 1,800 metric tons per year, and by the year 2000 humans were introducing over 6,600 metric tons of carbon per year—a 13-fold increase. Progressive global industrialization and population growth have turned burning fossil fuels from a small influence to an overwhelming control on climate.

To stay at this high level for long or to further increase atmospheric CO_2 levels will wreak havoc on our oceans, our coastal lands within 100 feet of sea level, our arid areas, human civilization, and the productivity and diversity of life on earth.

Dr. Hansen et al., concluded their 2016 paper, "Ice melt, sea level rise and superstorms: evidence from paleoclimate data, climate modeling, and modern observations that 2°C global warming could be dangerous," by saying:

> We understand that in a system that is out of equilibrium, a system in which the equilibrium is difficult to restore rapidly, a system in which major components such as the ocean and ice sheets have great inertia but are beginning to change, the existence of such amplifying feedbacks presents a situation of great concern. There is a significant possibility, a real danger, that we will hand young people and future generations a climate system that is practically out of their control. We conclude that the message our climate science delivers to society, policymakers, and the public alike is this: we have a global emergency. Fossil fuel CO_2 emissions should be reduced as rapidly as practical.
>
> Social disruption and economic consequences of such large sea level rise, and the attendant increases in storms and climate extremes, could be devastating (Hansen, 2016).

Along similar lines, NOAA concludes that a strategy for decisions and planning processes where *long-term* risk management is paramount is to:

> Define a scientifically plausible upper-bound (which might be thought of as a worst-case or extreme scenario) as the amount of sea level rise that, while low probability, cannot be ruled out over the time horizon being considered. Use this upper-bound scenario as a guide for overall system risk and long-term adaptation strategies (NOAA, 2017, p. 34).

Given all of the above, it is my opinion, stated to a reasonable degree of scientific certainty, that these Plaintiffs face ongoing long-term harm, and any delay in massive reductions of greenhouse gas emissions will only increase the very dangerous situation they already face. For Plaintiff Levi, it may very well be too late to save his barrier island from the rising seas over the course of the century, but to have any reasonable possibility of avoiding irreversible harm to his home island and State, we must aggressively work to limit any additional warming of the oceans and slow the risk of rising ocean levels.

In my expert opinion, we are in the danger zone in southern Florida, and any delay in a judicial remedy for Plaintiff Levi poses clear and irreversible harm to his interests and his future. However, it is not just Plaintiff Levi and his island that are at risk. All of the children of the barrier islands, deltas, and low-lying coastal zone of the Atlantic and Gulf coasts are at risk of inheriting a life of migration further inland. And even on soft-cliffed shorelines, such as are found in portions of California, Oregon, Washington and Hawaii, very significant coastal erosion will occur as ocean waves and currents attack these weak cliffs at a higher level.

In closing, I am sometimes asked by adults about how I give hope to young people given the dire projections for their future. I tell them "I hope *you* are listening." It does a disservice to young people for adults in positions of power and governmental leadership to sugarcoat or deny the very real irreversible harms that are already occurring and are now committed to because of warming already realized. Without transparent and honest planning to urgently mitigate climate change, we are betraying young people and all citizens. We cannot have government disregard for this or have planning regarding our citizen's survivability behind closed doors. The purpose of government is not to do business with and for the coal, oil and gas industry and others who benefit in the short-term by ignoring this serious problem, to the detriment of the broad public interest and certainly the public interest in protecting our children. The public interest is fundamentally harmed by ongoing fossil fuel combustion, which urgently needs reparation.

CONCLUSION

As a geologist and marine geologist with 46 years of experience, and with over 100 peer reviewed publications, largely concerning sea level rise and coastal environmental evolution, it is my expert opinion that young people, including the Plaintiffs, are experiencing sea level rise from already occurring observed and measured ocean warming and polar ice sheet melt. This sea level rise is happening faster than the climate models predict because the models do not include many of the numerous accelerating feedbacks in ice melt that are now being observed consistent with the paleo-record. If we continue to inject even more CO_2 into the atmosphere, the results will be even more dire for these Plaintiffs and future generations. The fact of the matter is that we have warmed the atmospheric and oceanic climate and future atmospheric warming is unavoidable for some 30 years after we stop putting further greenhouse gases into the atmosphere. However, how much more climate forcing humans put into the system through CO_2 and other greenhouse gas emissions in the near-term, and how much carbon we sequester, will dictate the severity of the warming and whether these young Plaintiffs and future generations can thrive, or even survive.

The need to move quickly to stop using the burning fossil fuels as our primary energy source is in large part because, through scientific study of the geologic record, we have learned that sea levels did not rise in a sluggish, gradual linear manner in response to gradually increasing natural warming and carbon dioxide levels as we came out of the last glacial period. Rather, global sea level rose to the present level as a series of rapid pulses of rise, followed by pauses as warming initiated one pulse of ice sheet collapse after another. These historical pulses of sea level rise each caused a 1- to 10-meter rise over a relatively short period of time (within a century or so) and each reflects the rapid disintegration of some ice sheet sector.

We are most likely witnessing the onset of one of these rapid pulses of sea level rise, this time in response to human-induced CO_2 build up and warming. Through the 20th Century, atmospheric warming progressively warmed the oceans causing their expansion, and this was the reason for an initial increase in the rate of global sea level rise to some 2.3 mm/year, a rate some 8 times that of the past 2,000 years. Then in the 1990s, these warmed ocean waters initiated ice sheet melt of Greenland and Antarctica, and this is dramatically accelerating. Current models only incorporate a few of the 15 or so accelerating feedbacks that have been documented to be accelerating polar ice melt. It is these accelerating feedbacks, which are the current visual display of the nature of pulses of ice melt and resulting sea level rise that characterized the paleo-sea level record in the 18,000 years following the past ice age. All of the accelerating feedbacks recently documented are features of ice melt that are anticipated to maintain ice melt acceleration and sea level rise acceleration through this century and beyond.

For the first time in Earth's climate record, human-induced climate change has caused CO_2 levels to rise more than 125 ppm in a period of only 150 years, some 100 times faster than the increase following the last ice age. This pace and extent of CO_2 increase and associated warming is unprecedented and should serve as an emergency warning that the Earth will now respond in dire ways, including very significant sea level rise above and beyond what has already been experienced. The last time CO_2 levels were above 400 ppm, over one million years ago, sea level was some 21–27 m (70-90 feet) higher than today (Miller et al., 2012; Dutton at al., 2015). That is where we are headed.

Specifically, I project near certainty of a sea level rise of 1.5–2.5 m (4.1 to 8.2 feet) by 2100 and a strong likelihood that this could be 4.5–9 m (15–30 feet) by 2100 if current trends continue, with ever greater rises and acceleration in subsequent centuries until such time as we aggressively begin to dramatically reduce the levels of CO_2 in the atmosphere and take steps to cool the upper portion of the world's ocean. This amount of sea level rise, combined with other factors, such as hurricane storm surges, would make many parts of the coastal United States uninhabitable. Given the pulses of sea level rise documented in the paleo climate record, this amount of future sea level rise is likely to occur in a relatively short timeframe, making adaptation difficult or impossible.

To protect these Plaintiffs and future generations from the serious and significant harms associated with sea level rise, I recommend that the Federal Defendants be ordered to drastically reduce greenhouse gas emissions and initiative massive carbon sequestration efforts. The prescription set forth by Hansen, et al. in 2013 and 2016, i.e. achieving atmospheric CO_2 concentrations of at most 350 ppm before 2100, should be required. Our children and theirs and future civilization deserve much better than we are presently doing.

Signed this 4th day of April, 2018 in Miami, Florida.

Dr. Harold R. Wanless

Exhibit 5

Joint Statement on "Human Rights and Climate Change"

Committee on the Elimination of Discrimination Against Women

Committee on Economic, Social and Cultural Rights

Committee on the Protection of the Rights
of All Migrant Workers and Members of their Families

Committee on the Rights of the Child

Committee on the Rights of Persons
with Disabilities

16 September 2019

1. The Committee on the Elimination of Discrimination against Women, the Committee on Economic, Social and Cultural Rights, the Committee on the Protection of the Rights of All Migrant Workers and Members of their Families, the Committee on the Rights of the Child, and the Committee on the Rights of Persons with Disabilities (together 'the Committees') welcome the convening of the Climate Action Summit by the UN Secretary General in September 2019, to mobilize plans and actions to enhance the ambition of emissions reduction. We urge all States to take into consideration their human rights obligations as they review their climate commitments.
2. The Committees welcome also the work of the international scientific community to further understand the implications of climate change and the solutions that could contribute to avoiding the most dangerous impacts of climate change. The Committees welcome in particular the report released in 2018 by the Intergovernmental Panel on Climate Change (IPCC) concerning global warming of 1.5°C[i].
3. This report confirms that climate change poses significant risks to the enjoyment of the human rights protected by the International Convention on the Elimination of all Forms of Discrimination Against Women, the International Covenant on Economic, Social and Cultural Rights, the International Convention on the Protection of the Rights of All Migrant Workers and Members of Their Families, the Convention on the Rights of the Child, and the International Convention on the Rights of Persons with Disabilities. The adverse impacts identified in the report, threaten, among others, the right to life, the right to adequate food, the right to adequate housing, the right to health, the right to water and cultural rights. These negative impacts are also illustrated in the damage suffered by the ecosystems which in turn affect the enjoyment of human rights[ii]. The risk of harm is particularly high for those segments of the population

already marginalised or in vulnerable situations or that, due to discrimination and pre-existing inequalities, have limited access to decision-making or resources, such as women, children, persons with disabilities, indigenous peoples and persons living in rural areas[iii]. Children are particularly at heightened risk of harm to their health, due to the immaturity of their body systems[iv].

4. As reflected in CEDAW General Recommendation 37 (GR), climate change and disasters affect women and men, girls and boys differently, with many women and girls facing disproportionate risks and impacts on their health, safety and livelihoods. Situations of crisis exacerbate pre-existing gender inequalities and also compound intersecting forms of discrimination that affect disadvantaged groups of women and girls, particularly those with disabilities, to a different degree or in different ways than men or other women. The GR further recognises that climate change and disasters, including pandemics, influence the prevalence, distribution and severity of new and re-emerging diseases. The susceptibility of women and girls to disease is heightened as a result of inequalities in access to food, nutrition and health care as well as social expectations that women and girls will act as primary care-givers for children, the elderly and the sick.
5. Such adverse impacts on human rights are already occurring at 1°C of warming and every additional increase in temperatures will further undermine the realization of rights. The IPCC report makes it clear that to avoid the risk of irreversible and large-scale systemic impacts, urgent and decisive climate action is required.
6. The IPCC report further highlights that adequate action to mitigate climate change would have significant social, environmental and economic benefits. It also warns of the risk of social and environmental damage resulting from poorly designed climate measures, thereby highlighting the importance for human rights norms to be applied at every stage of the decision-making process of climate policies.
7. As emphasized in the Statement of the Committee on Economic, Social and Cultural Rights on Climate Change and the International Covenant on Economic, Social and Cultural Rights (2018), human rights mechanisms have an important role to play in ensuring that States avoid taking measures that could accelerate climate change, and that they dedicate the maximum available resources to the adoption of measures aimed at mitigating climate change. It is to be welcomed that national judiciary and human rights institutions are increasingly engaged in ensuring that States comply with their duties under existing human rights instruments to combat climate change.

Agency and Climate Action

1. Women, children and other persons such as persons with disabilities, should not be seen only as victims or in terms of vulnerability. They should be recognised as agents of change and essential partners in the local, national and international efforts to tackle climate change[v]. The Committees emphasise that States must guarantee their human right to participate[vi] in climate policy-making, and further, that given the scale and complexity of the climate challenge, States must ensure an inclusive multi-stakeholder approach, which harnesses the ideas, energy and ingenuity of all stakeholders.
2. The Committees welcome international cooperation to tackle climate change under the auspices of the UN Framework Convention on Climate Change and the Paris Agreement, as well as the national commitments and contributions made by all individual States to mitigate climate change. We welcome also the mobilisations by civil society and, in particular, by women, children and youth, urging governments to take more ambitious climate action. However, the Committees note with great concern that States' current commitments under the Paris Agreement are insufficient to limit global warming to 1.5°C[vii] and that many States are not on track to meet their commitments. Consequently, States are exposing their populations and future generations to the significant threats to human rights associated with greater temperature increases.

States' Human Rights Obligations

1. Under the International Convention on the Elimination of all Forms of Discrimination Against Women, the International Covenant on Economic, Social and Cultural Rights, the International Convention on the Protection of the Rights of All Migrant Workers and Members of Their Families, the International Convention on the Rights of the Child, and the International Convention on the Rights of Persons with Disabilities, State parties have obligations, including extra-territorial obligations, to respect, protect and fulfil all human rights of all peoples[viii]. Failure to take measures to prevent foreseeable human rights harm caused by climate change, or to regulate activities contributing to such harm, could constitute a violation of States' human rights obligations[ix].
2. In order for States to comply with their human rights obligations, and to realize the objectives of the Paris Agreement, they must adopt and implement policies aimed at reducing emissions, which reflect the highest possible ambition, foster climate resilience and ensure that public and private investments are consistent with a pathway towards low carbon emissions and climate resilient development[x].
3. In relation to efforts to reduce emissions, States parties should effectively contribute to phasing out fossils fuels, promoting renewable energy and addressing emissions from the land sector, including by combating deforestation[xi]. Additionally, States must regulate private actors,

including by holding them accountable for harm they generate both domestically and extraterritorially[xii]. States should also discontinue financial incentives or investments in activities and infrastructure which are not consistent with low greenhouse gas emissions pathways, whether undertaken by public or private actors as a mitigation measure to prevent further damage and risk.

4. When reducing emissions and adapting to climate impacts, States must seek to address all forms of discrimination and inequality, including advancing substantive gender equality, protecting the rights of indigenous peoples and of persons with disabilities, and taking into consideration the best interests of the child.
5. Migrant workers and members of their families are forced to migrate because their States of origin cannot ensure the enjoyment of adequate living conditions, due to the increase in hydrometeorological disasters, evacuations of areas at high risk of disasters, environmental degradation and slow-moving disasters, the disappearance of small island states due to rising sea levels, and even the occurrence of conflicts over access to resources. Migration is a normal human adaptation strategy in the face of the effects of climate change and natural disasters, as well as the only option for entire communities and has to be addressed by the United Nations and the States as a new cause of emerging migration and internal displacement.
6. In that regard, States must address the effects of climate change, environmental degradation and natural disasters as drivers of migration and ensure that such factors do not hinder the enjoyment of the human rights of migrants and their families. In addition, States should offer complementary protection mechanisms and temporary protection or stay arrangements for migrant workers displaced across international borders in the context of climate change or disasters and who cannot return to their countries.
7. In the design and implementation of climate policies, States must also respect, protect and fulfil the rights of all, including by mandating human rights due diligence and ensuring access to education, awareness raising, environmental information and public participation in decision-making. In particular, States have the responsibility to protect and defend effectively the rights of environmental human rights defenders, including women, indigenous and child environmental defenders.

International Co-operation

1. As part of international assistance and co-operation towards the realization of human rights, high-income States should also support adaptation and mitigation efforts in developing countries, by facilitating transfers of green technologies, and by contributing to financing climate

mitigation and adaptation. In addition, States must co-operate in good faith in the establishment of global responses addressing climate-related loss and damage suffered by the most vulnerable countries, paying particular attention to safeguarding the rights of those who are at particular risk of climate harm and addressing the devastating impact, including on women, children, persons with disabilties and indigenous peoples.

The role of the Committees

1. In their future work, the Committees shall continue to keep under review the impacts of climate change and climate induced disasters on the rights holders protected under their respective treaties and provide guidance to States on how they can meet their obligations under these instruments, in relation to mitigation and adaptation to climate change.

[i] https://www.ipcc.ch/sr15/

[ii] Report of the Special Rapporteur on the issue of human rights obligations relating to the enjoyment of a safe, clean, healthy and sustainable environment concerning the human rights obligations relating to the conservation and sustainable use of biological diversity, UN Doc. A/HRC/34/49.

[iii] Analytical study on the relationship between climate change and the full and effective enjoyment of the rights of the child - Report of the Office of the United Nations High Commissioner for Human Rights, UN Doc. A/HRC/35/13

[iv] Stanley, F. & Farrant, B., 'Climate Change and Children's Health: A Commentary' (2015), 2, 412-423; http://pediatrics.aappublications.org/content/136/5/992?rss=1&cited-by=yes&legid=pediatrics%3Bpeds.2015-3232v1

[v] CEDAW General Recommendation #37, paras 7-8.

[vi] CEDAW General Recommendation #37, paras 32-36; ICEDAW articles 7, 8 & 14; ICRC article 12; UDHR article 21; ICCPR article 25 ; ICRPD articles 4(3), 29, 33(3).

[vii] https://www.ipcc.ch/sr15/

[viii] Articles 55 and 56 of the United Nations Charter; Committee on Economic, Social and Cultural Rights Concluding Observations on Australia (2017), paras 11 & 12; CESCR Concluding Observations on Argentina (2018), para 13 & 14; CESCR General Comment #24 (E/C.12/GC/24), paras 26-28; Committee on the Rights of the Child Concluding Observations on Norway (2018), para 27; CRC

Concluding Observations on Japan (2019), para 37; Committee on the Elimination of Discrimination Against Women General Recommendation #37 'on the gender-related dimensions of disaster risk reduction in the context of climate change' (CEDAW/C/GC/37), paras 43-46; CEDAW Concluding Observations on Australia (2018), paras 29-30; CEDAW Concluding Observations on Norway (2017), paras 14-15.

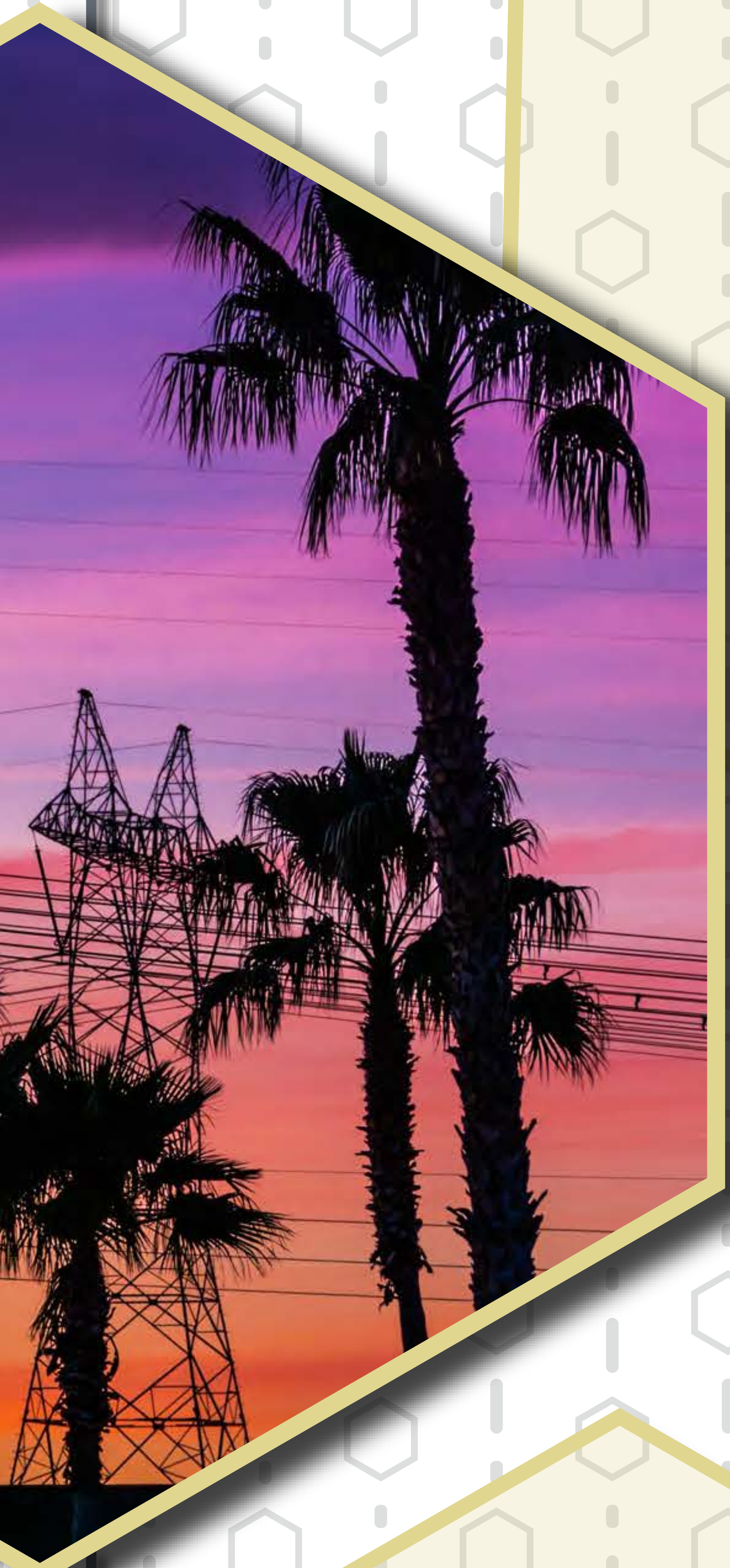
[ix] CRC Concluding Observations on Spain (2018), para 36; CRC Concluding Observations on the UK (2016), para 68; Statement of the CESCR on Climate Change and the International Covenant on Economic, Social and Cultural Rights, 8 October 2018; CESCR Concluding Observations on Australia (2017); CEDAW General Recommendation #37 (CEDAW/C/GC/37), para 14; CEDAW Concluding Observations on Norway (2017).

[x] Article 2.1 of the Paris Agreement

[xi] CEDAW General Recommendation #37; CEDAW Concluding Observations on Australia (2018); CRC Concluding Observations on Niger (2018); CESCR Concluding Observations on Argentina (2018); CESCR Statement on Climate Change and the ICESCR (2018).

[xii] CESCR Statement on Climate Change and the ICESCR (2018); CEDAW General Recommendation #37; CEDAW Concluding Observations on Fiji; CRC Concluding Observations on Spain (2018).

Exhibit 6



UNREALIZED POTENTIAL:

EXPANDING ENERGY EFFICIENCY OPPORTUNITIES FOR UTILITY CUSTOMERS IN FLORIDA

BY DAN YORK
AND CHARLOTTE COHN

ACEEE WHITE PAPER
JANUARY 2021

ACEEE
American Council for an Energy-Efficient Economy

Contents

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Acknowledgments

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Key Takeaways

- Energy efficiency (EE) is a critical industry in Florida, providing steady income and much-needed energy and cost savings to residents and businesses across the state.
- Florida's utility EE performance lags behind that of other states in the Southeast region and nationwide, largely because Florida's efficiency policies and practices do not follow those that are widely accepted and in place in other states.
- Goal-setting is a crucial step in achieving savings through EE. Florida utilities have proposed lower and lower EE savings goals each year over the past decade, with several utilities proposing a meaningless savings target of zero.
- The use of the ratepayer impact measure (RIM) test to evaluate EE program performance has led to systematic undervaluing of EE's cost effectiveness. No other state uses the RIM as its primary cost-effectiveness test.
- Accounting for program free-ridership with a two-year payback screen is also out of standard practice. This approach unduly restrains program measures and ignores some of EE's benefits.
- Florida's utility business model discourages utilities from making investments in EE.
- Florida's current utility program offerings leave out several important customer sectors, including small businesses and low-income multifamily housing.
- If Florida's Public Service Commission (PSC) adjusts its policies, and if the state's utilities broaden their program options, EE can promote economic growth, revive a struggling industry, and deliver cost savings and health benefits to millions of Floridians.

Florida's Energy Efficiency Performance

Energy efficiency (EE) is a proven utility energy resource that can save customers money, promote economic development, and contribute to meeting clean energy goals. It is also the biggest energy jobs sector in the United States, and it has been steadily growing in Florida to reach a total workforce of 127,000 in 2019 (E4TheFuture 2020). These local jobs provide stability and economic benefits while also delivering cost and energy savings to the customers and communities that need them the most. The COVID-19 pandemic, however, has had major repercussions for those valuable jobs, resulting in a net loss of more than 18,000 of Florida's efficiency jobs and wiping away all growth in that sector from the past three years.

The performance of Florida's utility EE programs greatly lags that of utilities in the Southeast and across the nation. In ACEEE's 2020 *State Energy Efficiency Scorecard,* Florida ranked 27th in the nation, falling from its 2019 ranking of 24th. This mid-range ranking is due largely to Florida's statewide building codes and state government initiatives to advance EE. In contrast to these favorable statewide EE policies, Florida falters in terms of its utility EE policies and programs. In fact, nearly every other state in the Southeast region outperforms Florida for investing in EE programs that provide opportunities for customers to save energy and money.

Electric utilities can play a critical role in delivering EE programs to Florida's families and businesses. However, utilities require the support of state regulators to apply commonly accepted practices to develop and implement cost-effective EE programs. The Florida Energy Efficiency and Conservation Act (FEECA) calls on participating utilities to set energy savings goals every five years. In recent years, however, plans for EE programs have shrunk to almost nothing as utilities set their savings goals at zero, largely due to restrictive screening practices.

Florida's screening practices are out of alignment with those of other states in the region and nationwide and have led to an undervaluing of EE by Florida's electric investor-owned utilities (IOUs). The result is that Florida's utility customers are deprived of EE services and incentives to reduce their energy costs; this is particularly true for households that face disproportionately high energy burdens.[1] Analysis of the EE potential for other Southeast states, such as North Carolina, highlights how EE programs can deliver economy-wide benefits, which are especially critical in the wake of the economic recession due to COVID-19 (Gold et al. 2020). These EE programs can also lower utility system costs, improve reliability, and reduce carbon emissions and other air pollution, resulting in benefits for all customers (Relf, York, and Kushler 2018).

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[1] *Energy burden* is the share of total household income that goes toward energy costs, which includes electricity and fuels such as natural gas, propane, or heating oil.

UNDERPERFORMANCE OF UTILITY ENERGY EFFICIENCY PROGRAMS

Florida shows significant room for improvement in EE, particularly in its utility sector. The state's utilities are underperforming in relation to other utilities in the Southeast region and nationwide in terms of EE outcomes.

The 2020 *Utility Energy Efficiency Scorecard* (Relf et al. 2020) scores the largest 52 electric IOUs nationwide based on metrics relating to EE performance, program diversity, and enabling infrastructure and policies. Three of Florida's electric IOUs are included in these rankings: Duke Energy Florida (Duke FL), Florida Power & Light (FP&L), and Tampa Electric Company (TECO). These three utilities were some of the lowest performing among electric IOUs nationwide. Of the 52 utilities evaluated, TECO ranked 46th, Duke FL 48th, and FP&L 51st. In addition to those utilities, four other Florida utilities are required to submit demand-side management (DSM) plans under FEECA: Gulf Power, Florida Public Utilities Company (FPU), Orlando Utilities Company, and Jacksonville Electric Association (JEA).

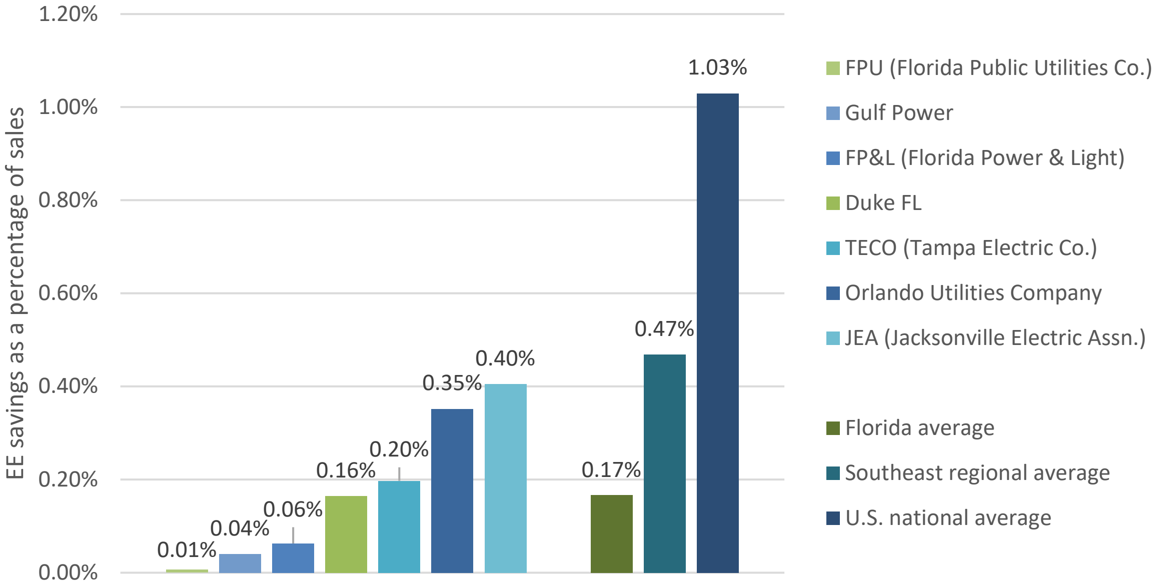

Figure 1. Energy efficiency savings as a percentage of sales—Florida utilities vs. regional and national averages. Averages are weighted based on GWh sales. *Sources*: FPL, Duke FL, TECO, and regional average data are from the ACEEE *Utility Scorecard* (Relf et al. 2020); all other utilities data are from EIA 2020.

Figure 1 compares Florida utility performance to average performance among utilities in the Southeast and nationwide. Using efficiency savings as a percentage of total sales allows for comparison of EE program performance regardless of sales volume. We can thus compare smaller utilities such as TECO, with 19,000 GWh in annual sales in 2019, to much larger utilities such as FP&L, which at 110,000 GWh is the state's largest electric IOU by volume. Overall, Florida utility performance is substantially lower than that of other regional utilities and less than a quarter of the national average.

Florida utilities' low energy savings are correlated with low spending levels on EE programs. Figure 2 shows spending as a percentage of total revenue for the seven FEECA utilities in 2019. None of Florida's electric IOUs invested more than 0.80% of their total annual revenue into EE. By contrast, the average spending on EE in the Southeast region was 1.64% of revenue, whereas the national average was even higher at 2.58%.

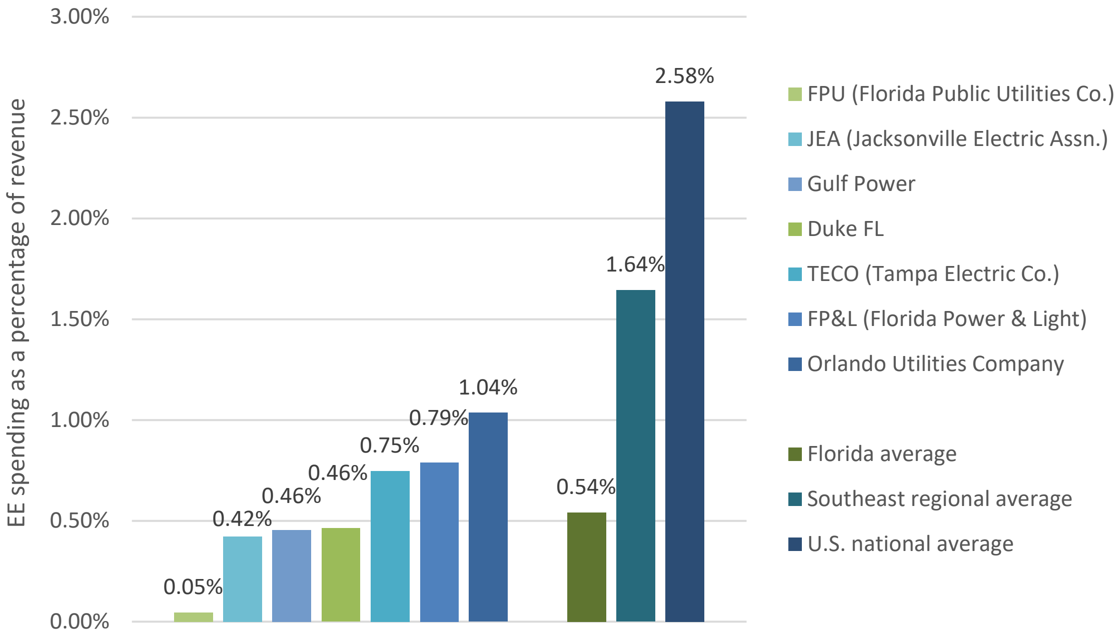

Figure 2. Energy efficiency spending as a percentage of revenue. *Sources:* FP&L, Duke FL, TECO, regional, and national average data are from the ACEEE *Utility Scorecard* (Relf et al. 2020); other utilities data are from EIA 2020.

After peaking at nearly 600,000 MWh saved in 2012, Florida's annual savings from efficiency have declined. As figure 3 shows, current (2020–2029) utility goals are far below the 2012 peak level. For the next 10 years, FEECA utilities have proposed an annual target of 59,402 MWh in energy savings from electric efficiency programs, which is only 41% of achieved savings in 2017. Further, three FEECA utilities set electricity savings goals of zero during the last goal-setting cycle, based on the claim that no programs can pass an unduly restrictive cost-effectiveness test. That test—the ratepayer impact measure (RIM)—is not used as a primary test for program cost effectiveness in any state other than Florida. We discuss the RIM and the impacts of its application later in this paper. In any case, setting ambitious goals is an important first step toward achieving significant savings. Without increasing their targets, Florida utilities will likely continue to lag in this critical area.

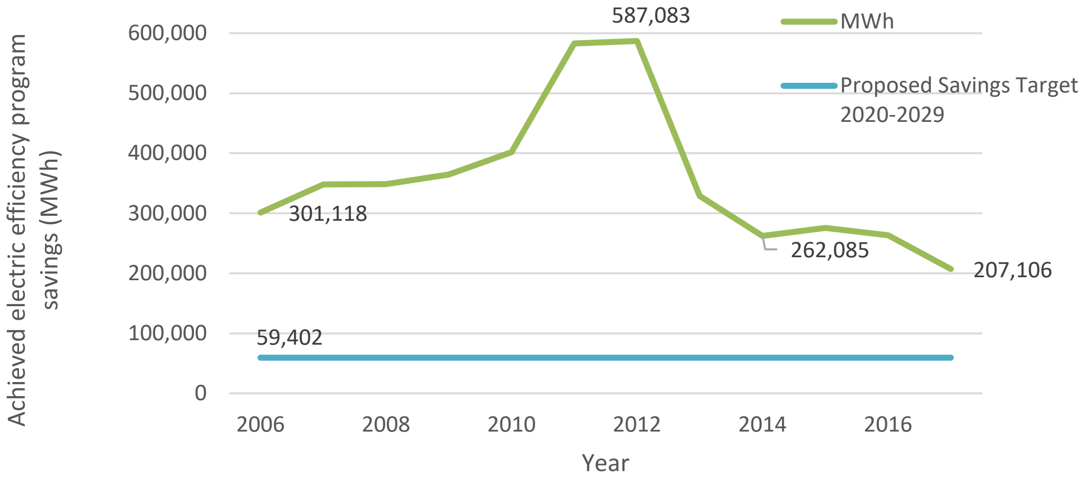

Figure 3. Total energy savings from utility EE in Florida for 2006–2017. ***Source:*** **annual ACEEE** ***State Scorecard*** **series.**

As figure 4 shows, Florida electric IOU program offerings reflect a lack of diversity in the types of customers and end uses served. Florida utilities offer fewer types of programs on average than other utilities in the region and the nation.[2] As a result, customers lack access to programs, services, and incentives to help them better manage their energy costs and realize other benefits that increased EE can provide, such as improved workplace productivity and health. This is especially important for economically disadvantaged households with high energy burdens, as well as for small businesses that are under stress due to COVID-19. Duke FL is the only electric IOU that offers any type of small business program. FP&L lacks many programs that are commonly offered by other utilities in the region, including incentives for multifamily housing efficiency, a sector that frequently overlaps with low-income and other marginalized groups. These sectors often struggle to adopt efficiency without external incentives, but they represent a significant opportunity for energy and cost savings. FP&L has not offered any new DSM programs in its portfolio since 2005 (FPL 2020).

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[2] A list of program types and descriptions can be found in the 2020 *Utility Energy Efficiency Scorecard* under Category 2: Energy Efficiency Programs. See www.aceee.org/research-report/u2004.

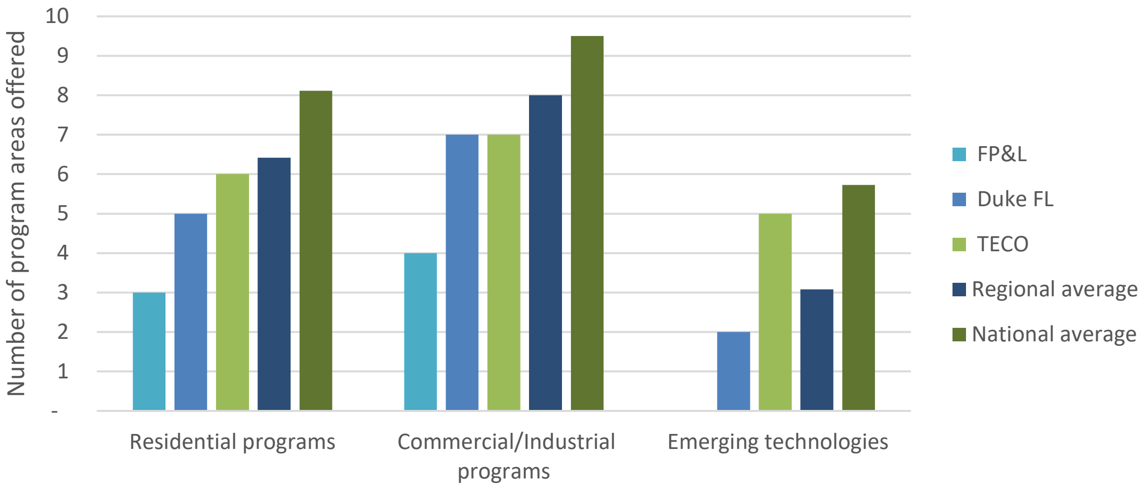

Figure 4. Energy efficiency programs offered by Florida utilities. *Source:* ACEEE *Utility Scorecard* (Relf et al. 2020).

REDUCING ENERGY BURDENS FOR FLORIDA'S MOST VULNERABLE POPULATIONS

Florida's utilities are required to offer specific income-qualified EE programs, but there is no mandated level of spending and savings.[3] The Public Service Commission (PSC) directed the FEECA utilities to educate and assist low-income customers on EE opportunities.[4] The need among low-income households is great. For example, 23% of homes in Miami and 21% of homes in Tampa are considered *energy burdened*—that is, they spend more than 6% of their income on energy costs. Of these households, 12% are *severely energy burdened*, spending more than 10% of their income on energy costs. Average burdens increase when combined with other disadvantaged demographics, including Black, Latino, and older (65+) adult households (Drehobl, Ross, and Ayala 2020).

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[3] Under Florida Statute, Section 366.82.

[4] Order PSC-14-0696-FOF-EU, issued in 2014 and reaffirmed in November 2019 with Order No. PSC-2019-0509-FOF-EG.

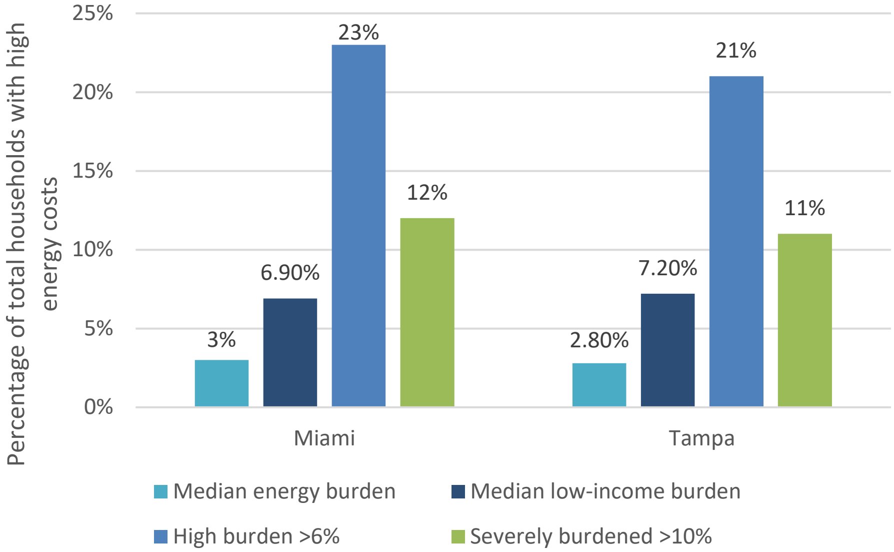

Figure 5. Energy burdens in Miami and Tampa, FL. *Source*: ACEEE (Drehobl, Ross, and Ayala 2020).

A variety of programs can effectively target and reduce household energy burdens. Low-income weatherization programs can reduce household energy use by 25% or more (Drehobl, Ross, and Ayala 2020). The National Renewable Energy Laboratory (NREL 2017) estimates that the average Florida single-family household can reduce its energy use by 23% through cost-effective efficiency improvements, particularly in HVAC, water heating, and lighting. Utilities are some of the best-situated entities to deliver these services to these households due to their existing relationship with customers and access to energy usage and bill data. Florida's electric IOUs are currently not achieving this potential due to their underinvestment in EE and the resulting lack of available customer programs, services, and incentives.

To ensure that low-income customers are receiving the full benefits of EE programs, some states set a minimum threshold for utility spending on programs for low-income customers or require that the sector achieve a minimum level of energy savings. States that have taken these steps include New Jersey and Virginia, both of which have recently passed comprehensive EE reforms that include targets for utilities to reach more low-income customers with specialized programs (Berg et al 2020).

Regulatory Barriers to Customer Energy Efficiency Programs

Florida utilities' low rankings and poor performance in comparison to other electric IOUs' energy savings and program offerings are largely due to systemic barriers within the state's regulatory environment. Stakeholders have identified three Florida regulatory practices that are out of standard practice for funding, developing, and implementing EE programs: (1) unambitious and ineffective goal-setting for energy savings, (2) use of the RIM test to evaluate cost effectiveness and screen customer programs, and (3) a minimum two-year payback requirement for customer incentives for EE measures. We now examine and discuss how Florida's practices in these areas unduly restrict the funding and provision of utility EE programs for its residents and businesses.

SETTING GOALS FOR ENERGY EFFICIENCY SAVINGS

Establishing significant, measurable, and achievable goals for utilities is a critical regulatory tool for delivering widespread energy savings. Quantitative analysis by the Brattle Group and ACEEE demonstrates that such EE resource standards are the policy most closely correlated with higher energy savings (Sergici and Irwin 2019; Molina and Kushler 2015). In 2019, the Florida PSC rejected proposals of 0% savings targets from three electric IOUs for 2020–2029. Instead, the PSC opted to continue with goals that were established in the 2014 goal-setting proceeding, which are 13% of 2010–2019 targets (Florida PSC 2020). These low savings targets reflect EE's undervaluation and the resulting underperformance of Florida's programs compared to other states. Further, these goals have no savings targets or thresholds for low-income Florida residents. Without reform, Florida's electric IOUs will likely continue to propose minimal spending and ignore program offerings and potential areas that can deliver long-term value and savings.

The importance of goal setting is illustrated by recent policies enacted in Virginia and Arkansas. Virginia passed comprehensive legislative and regulatory reforms in 2020 that set multiyear energy savings targets for utilities, with specific measures to support low-income customers (Berg et al. 2020). These reforms have made the state a new leader in the Southeast in terms of EE, DSM, and clean energy policy. In Arkansas, the Public Service Commission ordered higher EE goals (1.2% savings) than electric utilities had proposed (1.0%) in the review proceeding for three-year program plans based on the estimated EE potential (Arkansas PSC 2018).

COST-EFFECTIVENESS TESTING

As we noted earlier, Florida is the only state to still rely primarily on the RIM test, which measures cost effectiveness only through EE's impact on consumer rates rather than accounting for its complete costs and benefits in relation to customer bills and the utility system.[5] Other states have moved away from the RIM in recent years, recognizing that it does not appropriately value EE as a resource. Until recently, for example, Virginia was the only other state to rely on the RIM as its primary cost-effectiveness test. In 2018, the Virginia General Assembly adopted new rules that reduced its reliance on the test, requiring regulators to approve programs that passed other cost-effectiveness tests even if they did not pass the RIM test.

States have widely rejected the RIM test as a primary test for decision-making about the cost effectiveness of utility EE programs for several reasons.

First, the RIM test does not really measure the cost effectiveness of an EE program. Rather, it indicates the distribution of already-sunk utility system costs. That is, it treats lost sales revenue as a cost, yet those lost revenues address costs that have already been incurred

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[5] A more thorough understanding of how a given program affects consumer costs would need to include three factors: (1) a RIM test, (2) a bill impact analysis to measure the extent to which customer bills might be lowered if they install energy efficiency measures, and (3) a participation analysis to estimate the portion of customers that are receiving such benefits (Neme 2019). Relying on the RIM test alone will not result in the lowest costs to consumers.

elsewhere in the system, which typically reflect the utility's existing fixed costs. They are not actually a cost of delivering the EE program. For this reason, the RIM test does not reveal whether a program is cost effective in terms of reducing total future costs below what they would be absent the program.

Second, the RIM test can produce perverse outcomes. The more energy a program saves, the worse it will do on the RIM test, because the test treats the lost sales revenue as a cost. A simple exercise can demonstrate why the RIM test is an unacceptable device for measuring economic efficiency. Assume a utility with the following typical conditions:

- An average retail rate of 9 cents
- An avoided cost of additional supply of 6 cents
- An EE program that saves electricity at a cost of 2 cents per kWh

Under the RIM test, the benefits of 6 cents would be compared to the program costs of 2 cents plus the costs of the 9 cents of lost revenue; the program therefore would be judged to be cost ineffective, even though saving electricity in this case costs one-third of the cost of acquiring additional electricity. So, even if the EE program is free, it would fail the RIM.

Third, it is both inconsistent and unfair to apply the RIM test to EE programs when it is not applied to supply-side investments such as new power plants or new distribution system infrastructure. By definition, these supply-side investments would all fail the RIM test because they would result in some rate increase over current rates.

All other states with utility EE programs rely on other tests—such as total resource cost or program administrator/utility cost tests—to estimate cost effectiveness and screen potential programs. Dropping reliance on the RIM and using tests commonly employed by other states would increase the cost-effective EE potential in Florida. This, in turn, would enable Florida utilities to expand their portfolios and offer more programs and eligible measures to their customers.

In addition to applying industry-standard cost-effectiveness tests that align with best practices, it is also important that Florida account for the full set of benefits that result from EE programs. While the primary benefit of efficiency from the utility's standpoint is avoided energy (kWh) and capacity (kW) costs, EE programs offer additional benefits to program participants and society in general. These benefits range from improved productivity and comfort in homes and businesses to better indoor air quality, reduced air and water emissions due to avoided generation, improved home and property values due to increased efficiency, job creation, public health improvements, and economic growth. Accounting for some or all of these non-energy benefits of efficiency in cost-effectiveness tests will result in a more complete valuation for EE programs overall.

TWO-YEAR PAYBACK SCREEN

Florida utilities apply a two-year payback screen to eliminate efficiency measures that have a financial payback of two years or less, based on the assumption that customers will adopt such measures on their own. These customers are known as *free riders*—that is, customers who will adopt certain efficiency measures without receiving incentives or other program services. This treatment of free ridership is unique; most other states instead use well-established analytical techniques, such as surveys and other types of market research (NESP 2020), to estimate free-ridership.

Florida's payback screen blocks low-cost, easily implemented EE measures and discourages low-income participation and investment in EE (because low-income households can often afford only such rapid payback measures). By assuming that consumers will inevitably and independently adopt all programs with less than a two-year payback, the Florida PSC fails to recognize the informational, economic, and motivational barriers that might be keeping consumers from embracing new EE technologies.

UTILITY BUSINESS MODEL

Florida's existing utility business model discourages utilities from investing in EE by treating all energy savings as lost utility revenue. This does not need to be the case, as there are statutory and regulatory tools that better align EE and utility business models. Three primary types of regulatory tools exist to enable utility investment in EE:

- **Program direct-cost recovery.** Utilities traditionally make a profit by investing in infrastructure and recovering those costs—plus a return on investment—through rates charged to their customers. This is the method Florida utilities currently use to earn a return on their efficiency spending. However, because EE reduces kWh sales, the returns on EE investments are lower than other types of utility investments.
- **Decoupling mechanisms.** By decoupling utility revenues from kWh sales, regulators can eliminate the lost revenue issue and remove the disincentive to invest in efficiency under the current business model. Although decoupling addresses a major barrier, utilities may need additional incentives or mandates to properly scale up EE investments.
- **Performance incentives.** By tying utility profits to desired outcomes, regulators can create an environment that encourages utilities to invest in programs that deliver energy savings and other results. A performance incentive can make up for lost revenue, even without decoupling revenues from sales, by increasing the utility's rate of return on programs that achieve certain targets for energy savings or other types of goals.

Florida utilities are allowed to request decoupling or a lost revenue adjustment.[6] However, they have yet to do so, and Florida regulators have not developed mechanisms for utilities to earn a financial incentive for investing in EE. A first step to improving the utility business model would be to develop a performance incentive for EE programs. Such incentives are most effective when awarded according to achievement of specific program goals, typically for total energy savings, but they may also be aligned with other outcome-related targets such as low-income energy savings or job creation. Other states in the region, such as North Carolina, have adopted outcome-based performance incentive mechanisms. The state's two largest utilities, Duke Energy Progress and Duke Energy Carolinas, have more well-rounded EE program portfolios than Duke Energy Florida, and they are achieving close to

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[6] Under Florida Statute § 366.82.8 and 366.82.9

1% annual energy savings as a percentage of sales as of 2019 (Gold et al. 2020). This savings level is possible in Florida as well, so long as the utilities are working within a structure that better aligns utility profits with socially and economically desirable results.

Recommendations

Effective utility EE programs rely on a standard set of policies. By adopting more representative cost-effectiveness testing protocols, eliminating the unnecessary two-year payback screen, and focusing on delivering a broader variety of programs—including targeted programs for low-income customers—Florida's regulators can enable greater energy savings for the state's households, businesses, and industries. Expanded EE programs would not only directly benefit customers by reducing their energy costs, they would benefit Florida's economy and environment as well. Utilities can also partner with leaders from cities and local governments to deliver targeted EE solutions as a means to reduce costs and achieve clean energy objectives. State agencies can coordinate and support such efforts.

To realize a much greater share of Florida's EE potential, state regulators should change the rulemaking process to realign policies and practices. The following changes to rulemaking and program development would break down existing regulatory barriers and create new opportunities for realizing EE's many benefits:

- Set strong energy savings targets for utilities.
- Include specific requirements for delivery of comprehensive programs to low-income and other underserved customer categories, such as small businesses.
- End reliance on the RIM as the primary screen for EE cost effectiveness. For this FEECA cycle, we recommend that the Florida PSC evaluate proposed programs using the utility cost test results presented by utility proposals.
- Eliminate the two-year payback screen to increase the programs and EE measures available to customers. Doing so will expand opportunities for customers to benefit from EE.

Enacting changes to Florida's screening of EE measures and programs to align with common practices is a much-needed fundamental reform. To achieve its EE potential, Florida needs a full and fair accounting of the benefits and costs of implementing programs. Our recommendations above are for near-term changes that can be enacted during the present FEECA rulemaking proceeding. For future cycles, we recommend that the Florida PSC facilitate a robust stakeholder process to improve cost-effectiveness testing methodologies and inputs to utility potential studies. We suggest that such a proceeding follow the principles and practices in *The National Standard Practice Manual for Distributed Energy Resources* (NESP 2020). This industry guidebook provides a set of economically sound, politically neutral procedures and concepts for evaluating the cost effectiveness of EE and other distributed energy programs and technologies. Different tests measure different priorities, and Florida regulators, utilities, and stakeholders should evaluate which testing method will align with the desired outcomes and industry best practices.

The historically poor performance of Florida's electric IOUs in the area of EE programs has deprived customers of opportunities to reduce their energy costs and realize other benefits that result from such improvements. EE programs also reduce overall utility system costs, support job growth and economic development, and reduce carbon emissions. Compared to other regional and national utilities, Florida's utilities stand out for this poor performance. Effectively addressing restrictive regulatory practices would eliminate fundamental barriers to investing in and providing cost-effective EE programs for Florida's electric utility customers.

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Exhibit 7

THE 2020 STATE ENERGY EFFICIENCY SCORECARD

Weston Berg, Shruti Vaidyanathan, Ben Jennings, Emma Cooper, Chris Perry, Marianne DiMascio, and Jack Singletary

RESEARCH REPORT
DECEMBER 2020

ACEEE
American Council for an Energy-Efficient Economy

Contents

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Executive Summary

KEY FINDINGS

This report ranks U.S. states on their policy and program efforts to save energy and pursue efficiency as a cost-effective, critical tool for slashing emissions and meeting state clean energy goals.

In a year dramatically impacted by a global pandemic and associated recession, efforts to advance clean energy goals struggled to maintain momentum amid the loss of 400,000 energy efficiency jobs by the summer and disruptions to countless lives. Despite these challenges, some states continued to successfully prioritize energy efficiency as an important resource to help reduce household and business energy bills, create jobs, and reduce emissions.

First place goes to California, which sets the pace in saving energy on multiple fronts with adoption of net-zero energy building codes, stringent vehicle emissions standards, and industry-leading appliance standards. Growing efforts to decarbonize the state's building sector are a cornerstone of its pursuit of a 100% clean energy future. California continues to serve as a leader and standard-setter for the country in fighting climate change. More than a dozen states have adopted California's low-emissions vehicle regulations, and nine states have adopted its zero-emission vehicle program.

Rounding out the top 10 are Massachusetts at #2, followed by Vermont (#3), Rhode Island (#4), New York (#5), Maryland (#6), Connecticut (#7), the District of Columbia (#8), and a tie between Minnesota, and Oregon (#9).

Regional leaders included Massachusetts (#2) in the Northeast, Minnesota (#9) in the Midwest, California (#1) in the West, Colorado (#11) in the Southwest, and Virginia (#25) in the South.

This year's most improved state was Nevada. Last year the governor also signed AB54, adopting federal standards into state law in order to protect against federal efforts to roll back energy-saving light bulb standards. Additionally, the state has adopted the 2018 International Energy Conservation Code (IECC) for residential and commercial buildings, and in June Nevada's environmental agency announced plans to adopt California's vehicle emission standards and Zero-Emission Vehicle (ZEV) mandate.

Other states to watch include Virginia and New Jersey. They are the most recent additions to the list of now 27 states that have adopted a utility-sector energy efficiency resource standard. Stakeholders in both states continue to select and design programs to scale up efficiency offerings to meet the new standards.

Iowa fell the farthest in the rankings, an outcome of 2018 legislation that capped demand-side investment at a low level and enabled customers to opt out of paying for programs, leading to a steep decline in electric and gas savings in 2019.

Savings from ratepayer-funded electric efficiency programs remained fairly level compared with last year's results, totaling approximately 26.9 million megawatt-hours. These savings are equivalent to about 0.70% of total retail electricity sales in the United States in 2019, enough to power almost 2.6 million homes for a year.

Buildings efficiency advocates celebrated the release of the 2021 International Energy Conservation Code (IECC), the most significant advancement in model code efficiency in almost a decade. The code represents a major victory for a broad coalition of stakeholders and International Code Council voting members, including cities and states. The resulting 10% estimated improvement in efficiency will offer U.S. states and cities a great opportunity to save money and reduce GHG emissions from buildings.

The *State Energy Efficiency Scorecard*, now in its 14th edition, ranks states on their policy and program efforts over the past year.[1] It assesses performance, documents best practices, and recognizes leading efficiency strategies deployed in the service of state climate goals. These efficiency policies offer a vital strategy for states to reduce their greenhouse gas (GHG) footprints in a massive way. ACEEE analyses have determined that the United States can slash its projected energy use approximately 50% by 2050 through a suite of energy efficiency measures including zero-energy homes, building retrofits, industrial energy efficiency, and vehicle fuel economy.[2]

Figure ES1 shows the states' rankings, divided into five tiers for ease of comparison. Later in this section, table ES1 provides details of each state's scores.

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[1] The report considers programs and policies adopted as of July 2020. However, scores for some performance-based categories, such as those in Chapter 2 (utility programs), were determined by the latest available data from 2019 program years.

[2] S. Nadel. *Pathway to Cutting Energy Use and Carbon Emissions in Half*. Washington, DC: ACEEE, 2016); S. Nadel, and L. Unger. *Halfway There: Energy Efficiency Can Cut Energy Use and Greenhouse Gas Emissions in Half by 2050*. (Washington, DC: ACEEE, 2019).

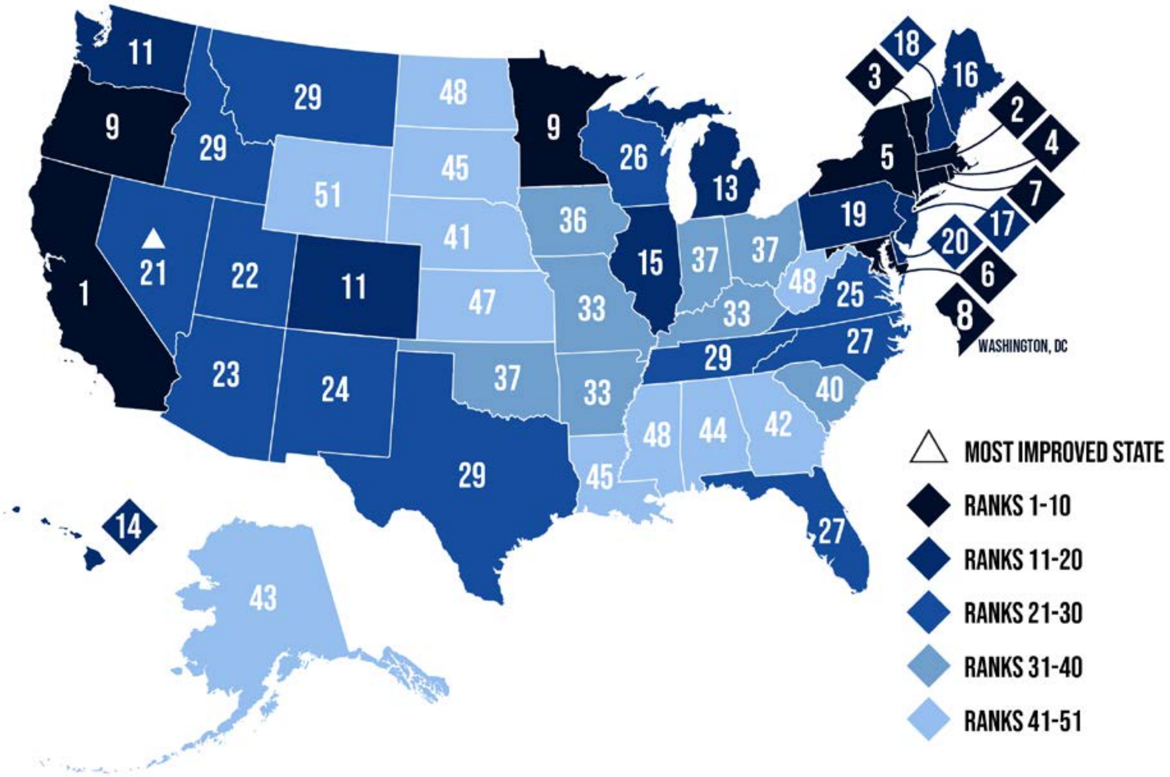

Figure ES1. *2020 State Scorecard* rankings

Following a vibrant 2019 that saw numerous states and utilities adopt ambitious climate goals, clean energy struggled somewhat to maintain a place on the policy agenda in 2020. Governments at all levels had to abruptly shift their focus to mitigate the health and economic impacts of a deadly global pandemic, and by the summer of 2020, COVID-19 had forced more than 600,000 in the clean energy sector out of work, with energy efficiency contractors among those hit hardest, representing about 70% of the total.[3] As states and legislators scrambled to redirect resources and contain both a health and an economic crisis, momentum slowed on many efforts to advance energy-saving policies.

Yet in spite of these challenges, several states celebrated some very promising policy achievements this year, laying the foundations to greatly scale up efficiency programs and slash emissions. These states included Virginia and New Jersey, which have joined 25 other states that have adopted a robust energy efficiency resource standard for their utility power sectors. Major efficiency and climate bills were also in play in Illinois, Maryland, Colorado, and Minnesota; while these stalled amid the pandemic, they are likely to remain on the table

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[3] Jordan, P. 2020. *Memorandum: Clean Energy Employment Initial Impacts from the COVID-19 Economic Crisis, April 2020*. Wrentham, MA: BW Research Partnership. e2.org/wp-content/uploads/2020/05/Clean-Energy-Jobs-April-COVID-19-Memo-FINAL.pdf.

as advocates and stakeholders continue to champion efficiency's role in meeting carbon goals.

It is also important to recognize that 2020 was a momentous year for buildings sector efficiency, following the release of the 2021 International Conservation Energy Code (IECC). The new codes, which require at least a 10% improvement in efficiency beyond the previous codes, were also a major achievement for the broad coalition of organizations and stakeholders that worked more than a year on education and outreach. These efforts helped spur state and local governments to make their voices heard by voting on and adopting the new codes. The 2021 IECC notably includes a new optional appendix enabling zero-energy performance. Local governments also overwhelmingly voted to include provisions for electric vehicle and electric appliance readiness as well as increased water heater efficiency, though these were unfortunately removed by the ICC Board of Directors upon appeal.

In addition, a growing number of states are embracing California's low- and zero-emission vehicle rules in an effort to maintain momentum on vehicle efficiency at a time when current federal leadership has sought to roll back national vehicle emissions standards. Since late 2019, Minnesota, New Mexico, and Nevada have all indicated plans to adopt these rules—joining more than a dozen others that have already done so—in a growing coalition of states committed to reducing transportation-driven emissions.

State-driven appliance standards also remained extremely important against the backdrop of federal rollback efforts. By establishing minimum efficiency thresholds for common home and office products like lighting, electronic devices, and plumbing fixtures, these state standards have been critical to helping consumers save on utility bills and spurring adoption of stronger national standards. Since our last report, California, New York, and Oregon have each advanced new standards, and Massachusetts, New Jersey, and DC have filed proposed bills still under consideration.

POLICY AREAS

The *Scorecard* compares states across five policy areas:[4]

- Utility and public benefits programs and policies
- Transportation policies
- Building energy efficiency policies
- State government–led initiatives around energy efficiency
- Appliance and equipment standards

Table ES1 provides examples of states that have adopted best-practice policies in each area. For more information about leading states, refer to the *Scorecard* chapter corresponding to the relevant policy area.

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[4] The 2020 *State Scorecard* removes our discussion of combined heat and power (CHP) policies. We continue to count savings from CHP in our utility program scoring metrics (Chapter 2).

Table ES1. States adopting best-practice policies

Area	States	Achievements
Utility and public benefits	Rhode Island, Massachusetts, Maryland, Vermont	All have adopted robust energy efficiency resource standards and continue to post electric utility savings above 2% of retail sales, the highest levels in the nation.
Transportation	California, District of Columbia, Massachusetts, Maryland, Oregon, Vermont, Washington	Each of these jurisdictions has adopted California's vehicle emissions standards as well as its Zero-Emission Vehicle (ZEV) program, and each has adopted goals to reduce vehicle miles traveled or transportation-related GHGs.
Building energy efficiency	California, Delaware, Illinois, Oregon, Maryland, Massachusetts, Nebraska, Nevada, New Jersey, New Mexico, New York, Oregon, Washington, Vermont	These states have strengthened efficiency standards for new construction by adopting building energy codes aligned with the 2018 IECC, ASHRAE 90.1-2016, or stronger, in addition to devoting resources to maintaining code compliance.
State government initiatives	California, Connecticut, Delaware, Massachusetts, Rhode Island, Vermont	These states led this year in offering loan and grant programs to spur energy savings, setting efficiency standards for public buildings and fleets, and investing proceeds from carbon pricing policies in efficiency programs.
Appliance/equipment standards	California, Colorado, Nevada, Washington, Vermont, Hawaii, New York	Each of these states passed appliance standards since 2019 that are expected to save consumers hundreds of millions of dollars on utility bills.

SCORES

Table ES2 presents state scores in the five policy areas and their total scores.

Table ES2. State scores in the *2020 State Scorecard*

Rank	State	Utility and public benefits programs & policies (20 pts.)	Trans-portation policies (12 pts.)	Building energy efficiency policies (9 pts.)	State government initiatives (6 pts.)	Appliance efficiency standards (3 pts.)	**TOTAL SCORE (50 pts.)**	Change in rank from 2019	Change in score from 2019
1	California	16	10.5	7.5	6	3	43	1	–0.5
2	Massachusetts	19.5	10	7	6	0	42.5	–1	–2
3	Vermont	17.5	8.5	6	6	2	40	0	-0.5
4	Rhode Island	19.5	8	6	6	0	39.5	–1	–1
5	New York	13.5	10.5	6.5	5.5	0.5	36.5	0	–0.5
6	Maryland	13.5	9.5	6	5.5	0	34.5	1	0
7	Connecticut	12.5	8.5	6.5	6	0	33.5	–1	–3
8	District of Columbia	9.5	11	8.5	4	0	33	3	4
9	Minnesota	13	7	6.5	5.5	0	32	–1	–0.5
9	Oregon	11	8.5	7	5.5	0	32	0	0
11	Colorado	9.5	7.5	6	5.5	2	30.5	3	3.5
11	Washington	7.5	8.5	7.5	5	2	30.5	–1	–1
13	Michigan	13	5.5	6.5	3.5	0	28.5	0	0
14	Hawaii	11	6	7	2.5	1.5	28	2	2.5
15	Illinois	12	5	6	4	0	27	–4	–2
16	Maine	9	7.5	4.5	5.5	0	26.5	–1	0.5
17	New Jersey	8.5	7	6.5	3	0	25	0	1
18	New Hampshire	10	3.5	5.5	5.5	0	24.5	2	3.5
19	Pennsylvania	4	6.5	6.5	5	0	22	–1	–1.5
20	Delaware	3.5	6.5	5.5	6	0	21.5	1	1
21	Nevada	5	4	6.5	4.5	1	21	5	5.5
22	Utah	6.5	4.5	6	3.5	0	20.5	0	1
23	Arizona	8.5	5	4.5	2	0	20	–4	–1.5
24	New Mexico	6.5	3.5	4.5	4	0	18.5	9	4.5
25	Virginia	1.5	6	5.5	5	0	18	4	3
26	Wisconsin	7.5	2.5	3	4	0	17	–1	1
27	Florida	1.5	5	6	4	0	16.5	–3	0
27	North Carolina	3	4.5	5	4	0	16.5	–1	1
29	Idaho	6	1	5.5	2	0	14.5	1	0
29	Montana	3.5	2.5	5.5	3	0	14.5	7	2
29	Tennessee	1	5	3.5	5	0	14.5	1	0
29	Texas	1	3.5	6.5	3.5	0	14.5	–3	–1
33	Arkansas	7	0	3	3.5	0	13.5	0	–0.5
33	Kentucky	1.5	3	5	4	0	13.5	5	2.5
33	Missouri	2.5	3	4	4	0	13.5	–3	–1
36	Iowa	4	3.5	4	1	0	12.5	–13	–6
37	Indiana	4	3	3	1.5	0	11.5	3	1
37	Ohio	4	0.5	3.5	3.5	0	11.5	–4	–2.5
37	Oklahoma	4	3.5	1.5	2.5	0	11.5	0	–0.5
40	South Carolina	2	2.5	2.5	4	0	11	0	0.5
41	Nebraska	0.5	2	6	2	0	10.5	2	1
42	Georgia	2	1.5	4.5	2	0	10	–4	–1
43	Alaska	1	3.5	1.5	3.5	0	9.5	–3	–1
44	Alabama	0	0.5	5.5	3	0	9	–1	–0.5
45	Louisiana	0.5	3	2	2.5	0	8	3	1.5
45	South Dakota	2	2	3.5	0.5	0	8	1	1
47	Kansas	0.5	2	3.5	1	0	7	–1	0
48	Mississippi	2	0.5	0.5	2.5	0	5.5	–3	–2.5
48	North Dakota	0	2	3	0.5	0	5.5	2	0.5
48	West Virginia	–1	1	4	1.5	0	5.5	0	–1
51	Wyoming	1	0.5	0	2.5	0	4	0	–0.5

REGIONAL HIGHLIGHTS

For the first time, the *2020 State Scorecard* ranks states not only nationally but also regionally, making it possible to compare states that have shared geographies and similar climatic conditions. States can assess how their progress on energy efficiency compares to that of their neighbors. Table ES3 shows the state rankings broken down by region.

Table ES3. Regional rankings in the *2020 State Scorecard*

Regional rank	State	Utility and public benefits programs & policies (20 pts.)	Trans-portation policies (12 pts.)	Building energy efficiency policies (9 pts.)	State government initiatives (6 pts.)	Appliance efficiency standards (3 pts.)	**TOTAL SCORE (50 pts.)**	Change in national rank from 2019	Change in score from 2019
Midwest									
1	Minnesota	13	7	6.5	5.5	0	32	–1	–0.5
2	Michigan	13	5.5	6.5	3.5	0	28.5	0	0
3	Illinois	12	5	6	4	0	27	–4	–2
4	Wisconsin	7.5	2.5	3	4	0	17	–1	1
5	Missouri	2.5	3	4	4	0	13.5	–3	–1
6	Iowa	4	3.5	4	1	0	12.5	–13	–6
7	Indiana	4	3	3	1.5	0	11.5	3	1
7	Ohio	4	0.5	3.5	3.5	0	11.5	–4	–2.5
9	Nebraska	0.5	2	6	2	0	10.5	2	1
10	South Dakota	2	2	3.5	0.5	0	8	1	1
11	Kansas	0.5	2	3.5	1	0	7	–1	0
12	North Dakota	0	2	3	0.5	0	5.5	2	0.5
Northeast									
1	Massachusetts	19.5	10	7	6	0	42.5	–1	–2
2	Vermont	17.5	8.5	6	6	2	40	0	-0.5
3	Rhode Island	19.5	8	6	6	0	39.5	–1	–1
4	New York	13.5	10.5	6.5	5.5	0.5	36.5	0	-0.5
5	Maryland	13.5	9.5	6	5.5	0	34.5	1	0
6	Connecticut	12.5	8.5	6.5	6	0	33.5	–1	–3
7	District of Columbia	9.5	11	8.5	4	0	33	3	4
8	Maine	9	7.5	4.5	5.5	0	26.5	–1	0.5
9	New Jersey	8.5	7	6.5	3	0	25	0	1
10	New Hampshire	10	3.5	5.5	5.5	0	24.5	2	3.5
11	Pennsylvania	4	6.5	6.5	5	0	22	–1	–1.5
12	Delaware	3.5	6.5	5.5	6	0	21.5	1	1
South									
1	Virginia	1.5	6	5.5	5	0	18	4	3
2	Florida	1.5	5	6	4	0	16.5	-3	0
2	North Carolina	3	4.5	5	4	0	16.5	–1	1
4	Tennessee	1	5	3.5	5	0	14.5	1	0
4	Texas	1	3.5	6.5	3.5	0	14.5	–3	–1
6	Arkansas	7	0	3	3.5	0	13.5	0	–0.5
6	Kentucky	1.5	3	5	4	0	13.5	5	2.5
8	Oklahoma	4	3.5	1.5	2.5	0	11.5	0	–0.5
9	South Carolina	2	2.5	2.5	4	0	11	0	0.5
10	Georgia	2	1.5	4.5	2	0	10	–4	–1
11	Alabama	0	0.5	5.5	3	0	9	–1	–0.5
12	Louisiana	0.5	3	2	2.5	0	8	3	1.5
13	West Virginia	–1	1	4	1.5	0	5.5	0	–1
13	Mississippi	2	0.5	0.5	2.5	0	5.5	–3	–2.5
Southwest									
1	Colorado	9.5	7.5	6	5.5	2	30.5	3	3.5
2	Nevada	5	4	6.5	4.5	1	21	5	5.5

Regional rank	State	Utility and public benefits programs & policies (20 pts.)	Trans-portation policies (12 pts.)	Building energy efficiency policies (9 pts.)	State government initiatives (6 pts.)	Appliance efficiency standards (3 pts.)	**TOTAL SCORE (50 pts.)**	Change in national rank from 2019	Change in score from 2019
3	Utah	6.5	4.5	6	3.5	0	20.5	0	1
4	Arizona	8.5	5	4.5	2	0	20	–4	–1.5
5	New Mexico	6.5	3.5	4.5	4	0	18.5	9	4.5
6	Wyoming	1	0.5	0	2.5	0	4	0	–0.5
West									
1	California	16	10.5	7.5	6	3	43	1	–0.5
2	Oregon	11	8.5	7	5.5	0	32	0	0
3	Washington	7.5	8.5	7.5	5	2	30.5	–1	–1
4	Hawaii	11	6	7	2.5	1.5	28	2	2.5
5	Idaho	6	1	5.5	2	0	14.5	1	0
5	Montana	3.5	2.5	5.5	3	0	14.5	7	2
7	Alaska	1	3.5	1.5	3.5	0	9.5	–3	–1

This year's regional leaders are Minnesota (Midwest), Massachusetts (Northeast), Virginia (South), Colorado (Southwest), and California (West). In addition to these leaders, we have identified each region's "state to watch," where many promising new policy developments are emerging.

MIDWEST

Leading state: Minnesota ranked first in the region, driven by strong energy savings goals established under the state's 2007 Next Generation Energy Act. Minnesota continues to explore opportunities to advance efficiency in ways that promote building electrification and encourage adoption of electric vehicles. For example, in 2019, Governor Tim Walz called for the creation of Minnesota's Clean Car program, which would adopt California's tailpipe and ZEV standards; plans are ongoing to complete the approval process by the end of 2020.

State to watch: In Michigan, recently approved utility integrated resource plans have set Consumers Energy and DTE Energy, the state's two largest utilities, on paths to achieve savings even higher than those set in the state's statutory goals. With the recent creation of the Michigan Office of Future Mobility and the Council on Mobility and Electrification, the state is setting the stage to further vehicle electrification and sustainable transportation policies. In October 2019, the governor and the state's Public Service Commission launched a multiyear stakeholder initiative and proceeding called MI Power Grid, which will work on new technologies, pilots, and utility business models in order to optimize the transition to a clean energy grid.

NORTHEAST

Leading state: Driven by the strength of a robust policy framework under the state's 2008 Green Communities Act, Massachusetts continues to deliver nation-leading levels of utility savings alongside strong building energy codes that include provisions for solar readiness. In recent years the state has taken major steps to better align energy efficiency with its climate goals. These steps include incentives for homeowners who switch from oil and propane furnaces to electric heat pumps, measures to reduce winter and summer peak demand, and the creation of a Clean Peak Standard, which gives credits for clean energy delivered during hours of peak demand.

State to watch: New Jersey marked a critical milestone in its efforts to scale up energy efficiency and deliver on robust energy savings goals established under its 2018 Clean Energy Act. The state's Board of Public Utilities issued an order establishing a framework of programs, including five-year targets that ramp up electric and gas savings to some of the highest levels in the nation. This order also seeks to ensure that low-income customers have equitable access to energy efficiency programs by calling for specific provisions and enhanced incentives that serve their communities. These programs, planned for June of 2021, will work in parallel with Governor Phil Murphy's recently released economy-wide Energy Master Plan (EMP), which lays out a pathway to 100% clean energy by 2050.

SOUTH

Leading state: Virginia was among the top energy stories of 2020, creating its first-ever clean energy standard and becoming the first state in the Southeast with a 100% clean electricity goal. The Virginia Clean Economy Act also established an energy efficiency resource standard that sets multiyear electric savings targets for utilities and includes important measures to support low-income customers and reduce energy burdens. The governor also signed HB 981, making Virginia the first southern state to join RGGI, with proceeds going toward energy efficiency, renewable energy, and climate mitigation measures.

State to watch: Although North Carolina ranks about midway down the *Scorecard* (tied for 27th), its utilities report some of the highest levels of electric savings in the Southeast. The state is also exploring new opportunities to strengthen both its energy efficiency programs and its adoption of electric vehicles. In 2019, in partnership with the Nicholas Institute at Duke University, the state released the North Carolina Energy Efficiency Roadmap to help achieve its energy savings potential and the goals of its Clean Energy Plan.

Southwest

Leading state: Utility savings continue to climb higher in Colorado in response to the strong efficiency goals set by Xcel Energy, the state's largest utility. State policymakers have been busy advancing plans that will address statewide climate goals signed last year, which target a 90% reduction in GHGs by 2050 (HB19-1261). These efforts have included new appliance and water efficiency standards, measures to strengthen local building energy codes, and plans to scale up utility investments to promote in EV infrastructure and adoption. In September, Governor Jared Polis released a draft GHG Pollution Reduction Roadmap with near-term actions to meet the state's 2030 and 2050 climate goals.

State to watch: Arizona and its utilities have been regional leaders in energy efficiency, delivering among the strongest levels of savings in the Southwest. However, the state is at an important turning point with its utility efficiency programs: in November 2020, the Arizona Corporation Commission decided to extend and expand the state's current energy efficiency resource standard (EERS) and set a 100% carbon-free electricity standard. The final vote to adopt these new rules is expected in 2021.

WEST

Leading state: California's enduring leadership on building energy codes, vehicle emissions, and appliance standards continues to set the pace in advancing energy efficiency on a variety of fronts at the national level and among other states who model their own policies after California's example. More than a dozen states have adopted California's low-emissions vehicle regulations, and 11 other states have adopted its zero-emissions vehicle program. A September Executive Order signed by Governor Gavin Newsom called for phasing out the sale of gasoline-powered vehicles by 2035, the most ambitious clean-car policy in the United States. In addition, the state's energy code is one of the most aggressive in the country and has been a powerful vehicle for advancing energy efficiency standards for building equipment.

State to watch: Washington made headlines in 2019 by passing an ambitious slate of climate legislation, including a law requiring that 100% of the state's electricity come from clean energy sources by 2045. Electric utilities have set biennial savings targets for the past 10 years, and in 2019 the state passed legislation (HB 1257)—expected to take effect in 2022—to also develop natural gas savings targets. The state legislature passed HB 1257 in 2019, the first statewide adoption of an energy performance standard for large commercial buildings (set to take effect in 2021). In 2019 lawmakers passed HB 1444, a comprehensive set of energy and water efficiency standards, including federal appliance and light bulb standards to protect against rollbacks.

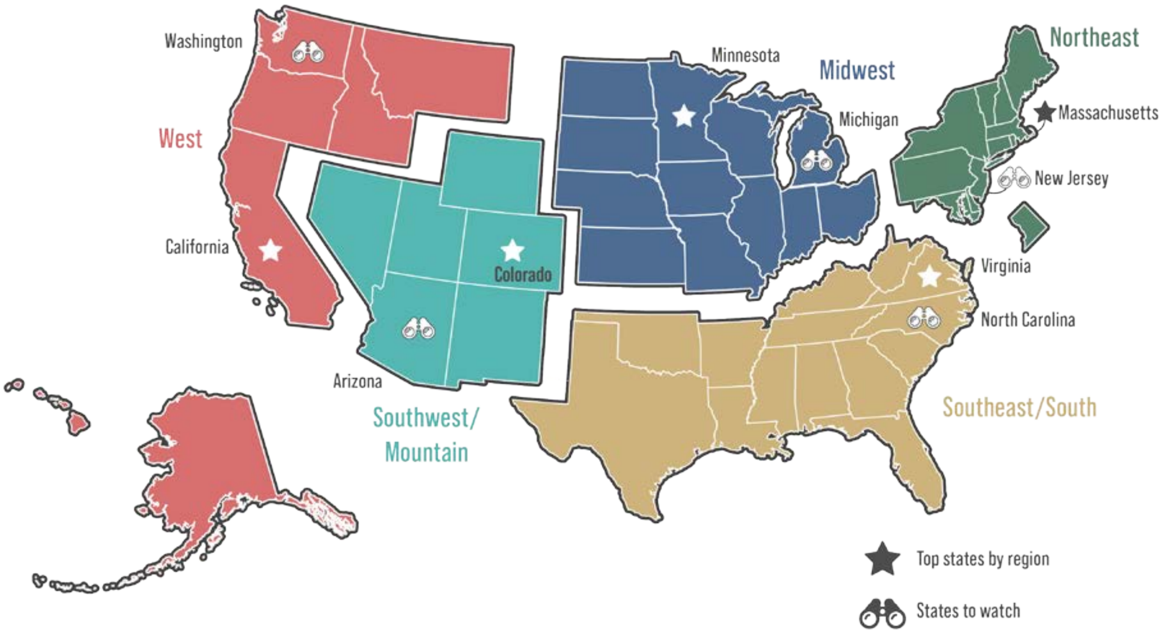

Figure ES2. *2020 State Scorecard* regional rankings

LOOKING AHEAD: EQUITY IN STATE AND UTILITY PLANNING AND PROGRAMS

An integral area of focus for ACEEE is the advancement of social equity principles in clean energy and efficiency planning, policy, and program design. Historically, energy efficiency initiatives have typically failed to adequately serve and represent marginalized groups, particularly neighborhoods whose residents are predominantly Black, Indigenous, and/or people of color, as well as low-income customers, immigrants, and people with disabilities. These individuals often face disproportionately high energy burdens, meaning they spend a larger percentage of their income on energy bills than do their counterparts.[5] Furthermore, their underrepresentation within clean energy policymaking and planning means that many of the benefits of these policies do not equitably reach all communities.

While the *State Scorecard*'s current scoring methodology considers multiple state policies to address low-income household access to and participation in energy efficiency programs, ACEEE is committed to highlighting and encouraging broader efforts to embed equity in clean energy policymaking. This year we continue to award a point for supportive low-income utility efforts in Chapter 2 (utility policies) and a half-point for policies to address equitable access to public transportation in Chapter 3 (Transportation). Still, states can do much more to ensure that policy and program outcomes are equitable. These efforts are perhaps more important now than ever as states and local communities wrestle with the impact of the COVID-19 pandemic, which has been especially devastating for communities of color. The benefits of energy efficiency, including job creation, reduced energy bills, and healthy homes, will be critical to a successful economic recovery.

In addition to increasing investments in and access to clean energy in historically underinvested low-income communities and communities of color, emerging state efforts are underway also to address equity in community engagement, decision making, and workforce development initiatives. Examples include conducting state-level needs assessments and barrier analyses and establishing internal protocols and metrics to evaluate the equity of policy outcomes. Policymakers and stakeholders can also work to address gaps in worker skills and offer trainings, job placement, and job access strategies to help bring marginalized groups into the clean energy workforce.[6]

To gather information on state efforts to better address the needs of historically overlooked customers, this year's *Scorecard* data collection effort included new questions related to equity in energy planning, decision making, and clean energy job training. While we have yet to formally integrate these data and principles within our scoring framework, we have included this information in a new section in ACEEE's State and Local Policy Database titled "Equity Metrics and Workforce Development."[7] We hope this information can serve as an important resource for policymakers, utilities, and clean energy and community advocates seeking to identify leading examples and help equitably extend the benefits of energy efficiency to all households.

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[5] A. Drehobl, L. Ross, and R. Ayala. 2020. *How High Are Household Energy Burdens? An Assessment of National and Metropolitan Energy Burdens across the U.S.* (Washington, DC: ACEEE, 2020).

[6] M. Shoemaker and D. Ribeiro. 2018. *Through the Local Government Lens: Developing the Energy Efficiency Workforce*. (Washington, DC: ACEEE, 2018); M., Shoemaker, R. Ayala, and D. York. 2020. *Expanding Opportunity through Energy Efficiency Jobs: Strategies to Ensure a More Resilient, Diverse Workforce*. (Washington, DC: ACEEE, 2020).

[7] See database.aceee.org/state/equity-workforce.

STRATEGIES FOR IMPROVING ENERGY EFFICIENCY

A variety of policy tools and program designs are available to state officials to scale up energy savings across multiple use sectors, in turn delivering immense carbon savings to help meet U.S. climate goals. These programs also provide an important opportunity to support economic recovery from COVID-19 by helping to reduce home and business energy bills, generate employment, and lessen the need for imported energy fuels. The following list highlights examples of best practices by state policymakers seeking to improve energy efficiency performance by energy utilities, in the buildings and transportation sectors, and through appliance standards. We also highlight best practices that reduce legal and market barriers to investing in energy efficiency and expand participation in programs that achieve savings.

Establish and adequately fund an energy efficiency resource standard (EERS) or similar energy savings target. EERS policies set specific energy savings targets that utilities or independent statewide program administrators must meet through customer energy efficiency programs. They serve as an enabling framework for cost-effective investment, savings, and program activity. As states address evolving priorities such as decarbonization, cost, equity, and grid value, regulators in places like Massachusetts and New York are adjusting targets to incorporate multiple goals (e.g., fuel-neutral savings) that better align efficiency programs with electrification and GHG reduction objectives.

Examples: Arkansas, Colorado, Massachusetts, Michigan, Minnesota, New Jersey, New York, Virginia

Adopt California tailpipe emissions standards and set quantitative targets for reducing vehicle miles traveled (VMT). Transportation consumes almost 30% of the total energy used in the United States and therefore offers an important opportunity to reduce carbon emissions.[8] At the state level, a comprehensive approach to transportation energy efficiency must address both individual vehicles and the entire transportation system. A variety of state-level policy options are available to improve transportation system efficiency. These include codifying targets for reducing VMT and integrating land use and transportation planning to create communities where people have access to multiple modes of travel and need not rely on owning personal vehicles. While federal fuel economy standards are expected to go a long way toward reducing fuel consumption, standards for model years 2022–2025 face an uncertain future following the April 2020 release of federal rollbacks. States that adopt California's tailpipe emissions standards will lead the way by pushing manufacturers to offer a greater variety of low- and zero-emission vehicles and accelerate the transition to EVs.

Examples: California, Colorado, Massachusetts, New York, Oregon

Ensure energy efficiency and clean energy investments and opportunities are inclusive and that benefits accrue to all customers, especially households overburdened by energy costs. Historically marginalized groups have been underserved and underrepresented in

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[8] EPA. "Sources of Greenhouse Gas Emissions," accessed May 2020. epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

clean energy planning and policymaking. States can foster equity in key decision-making processes by ensuring these efforts are inclusive and designed with all communities in mind. These include establishing internal metrics and frameworks that evaluate the degree to which policy and program outcomes are equitable, developing stakeholder processes and community assessments to better understand the needs of marginalized groups, and adopting inclusive workforce development practices to offer new economic and educational opportunities for groups often underrepresented in the energy efficiency workforce. States can also strengthen incentives and programs for income-qualified customers, and to work with utilities and regulators to recognize and value program nonenergy benefits (NEBs), such as health and economic improvements, as a means of expanding these investments. States and public utility commissions (PUCs) can also include goals specific to the low-income sector, either within an EERS or as a stand-alone minimum acceptable threshold, to ensure investments are targeted toward these customers.

Examples: California, New Jersey, Oregon, Pennsylvania, Tennessee, Washington

Adopt updated, energy-efficient building energy codes, improve code compliance, and involve efficiency program administrators in code support. Buildings use more than 40% of the total energy consumed in the United States, making them an essential target for cutting energy waste and emissions.[9] Routinely updating and strengthening building energy codes for new construction is one way to ensure a minimum level of energy efficiency for new residential and commercial buildings. Additional strategies such as energy performance standards for existing buildings, benchmarking and transparency policies, and financing tools to encourage deep retrofits are also critical for improving efficiency in the existing building stock and reducing building carbon emissions.

Examples: California, Illinois, Maryland, Nebraska, New Mexico, District of Columbia, Washington

Expand state government–led initiatives and make them visible. States can establish sustainable funding sources for energy efficiency incentive programs, invest in energy efficiency–related R&D and demonstration centers, and lead by example by incorporating energy efficiency into government operations. Integrating efficiency into their own operations empowers governments to reduce energy use in public buildings and fleets and to use energy savings performance contracts to finance energy-saving projects. States can also work with utilities and community-based organizations to promote and coordinate energy code compliance training and workforce development programs.

Examples: Alaska, Connecticut, New York

Explore and promote innovative financing mechanisms to leverage private capital and lower the up-front costs of energy efficiency measures. Although utilities in many states offer some form of on-bill financing to promote energy efficiency in homes and buildings, expanding lender and customer participation has been an ongoing challenge. States can pass legislation to increase stakeholder awareness and address legal barriers to the

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[9] U.S. Energy Information Administration. "How Much Energy Is Consumed in U.S. Buildings," June 15, 2020. eia.gov/tools/faqs/faq.php?id=86&t=1.

implementation of financing programs. A growing number of states are seeking new ways to maximize the impact of public funds and invigorate energy efficiency by attracting private capital through emerging financing models such as Property Assessed Clean Energy programs and green banks.

Examples: Colorado, Connecticut, Minnesota, Missouri, New York, Rhode Island

Adopt cost-effective efficiency standards for appliances, equipment, lighting, and plumbing products. State appliance standards are a proven policy that lowers utility bills for customers and businesses, reduces pollution, and helps spur national standards. Even when standards are not adopted at the federal level, adoption by just a few states can be enough to impact national markets. The Appliance Standards Awareness Project has recently outlined a menu of new or strengthened standards for 47 products that would reduce annual average household utility bills by more than $100 in 2030 and deliver cumulative utility bill savings of $1.1 trillion through 2050 for consumers and businesses.[10]

Examples: California, Colorado, Washington, Hawaii, Nevada, New York, Vermont

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[10] Appliance Standards Awareness Project, *A Powerful Priority: How Appliance Standards Can Help Meet U.S. Climate Goals and Save Consumers Money* (Boston: ASAP, 2020). appliance-standards.org/sites/default/files/Powerful_Priority_Report.pdf.

Chapter 1. Introduction, Methodology, and Results

Author: Weston Berg

The *State Energy Efficiency Scorecard*, now in its 14th edition, ranks states on their policy and program efforts. It assesses performance, documents best practices, and recognizes leadership. The report captures the latest policy developments and state efforts to save energy and highlights opportunities and policy tools available to governors, state legislators, and regulators.

Although prices for renewable electricity continue to decline, energy efficiency remains our nation's least-cost energy resource while delivering a variety of other benefits such as grid reliability and resilience. States reported utility spending on energy efficiency amounting to roughly $8.4 billion in 2019. Electricity savings levels remained fairly consistent with those reported last year, totaling about 26.9 million megawatt-hours (MWh), enough to power almost 2.6 million homes for a year. Many states and utilities reported efforts to grow and adapt program portfolios to look beyond lighting measures, targeting deep energy home retrofits, smart buildings, expansion of electric vehicle infrastructure, zero-energy buildings, and in some cases electrification of space and water heating.

While 2020 savings were not yet available for this report, future data will undoubtedly show the damaging impact that the COVID-19 pandemic had on programs this year, disrupting progress at all levels of policy and causing significant job losses across the clean energy industry. In the months prior to the first impacts of the pandemic, energy efficiency proved to be a strong job creator, supporting at least 2.4 million jobs across the nation. By the summer, however, the pandemic had caused the loss of 400,000 efficiency jobs and created uncertainty across the industry.

Despite these challenges, states from coast to coast made progress on energy efficiency. As regulators and program administrators worked to redirect resources to those hardest hit, work continued on a number of important clean energy bills and rulemakings, including important efficiency-related policy achievements in New Jersey, Virginia, New York, and Massachusetts. Moreover, as the nation remains mired in a global health crisis and its economic impacts, a number of states are recognizing the important role energy efficiency can play in leading the recovery by helping homeowners and businesses reduce costs, by improving living conditions, and by creating jobs, all while supporting increasingly ambitious state and local goals to reduce carbon emissions. This report seeks to capture and highlight those efforts.

The *Scorecard* is divided into seven chapters. This chapter discusses our scoring methodology (including changes made since last year), presents the overall results of our analysis, and introduces several strategies states can use to improve their energy efficiency. It also spotlights leading states, most-improved states, and policy trends underlying the rankings.

Subsequent chapters present detailed results for five major policy areas. Chapter 2 covers utility and public benefits programs and policies. Chapter 3 discusses transportation policies. Chapter 4 deals with building energy code adoption, state code compliance efforts, and building policies. Chapter 5 deals with state government initiatives, including financial incentives, lead-by-example policies, and energy efficiency–focused research and development (R&D). Chapter 6 discusses appliance and equipment efficiency standards.

The final chapter summarizes major policy highlights and setbacks occurring since the release of the last *Scorecard* and describes data limitations we encountered in our research. We also describe developing trends in energy efficiency we hope to address with new metrics in future *Scorecard*s.

SCORING

States are the testing grounds for policies and regulations. To reflect the enormous diversity of the United States, we chose metrics flexible enough to capture the range of policy and program options that states use to encourage energy efficiency. The policies and programs evaluated in the *State Scorecard* aim to reduce end-use energy consumption, set long-term commitments for energy efficiency, and establish mandatory performance codes and standards. They also help to accelerate the adoption of the most energy-efficient technologies; reduce market, regulatory, and information barriers to energy efficiency; and provide funding for efficiency programs.

We evaluated states in the five primary policy areas in which they are pursuing energy efficiency:

- Utility and public benefits programs and policies[1]
- Transportation policies
- Building energy efficiency policies
- State government–led initiatives around energy efficiency
- Appliance and equipment standards

We allocated points among the policy areas to reflect the relative magnitude of energy savings possible through the measures scored. We relied on our analysis of scholarly work and the judgment of ACEEE staff and outside experts about the impact of state policies on energy efficiency in the sectors we covered. A variety of cross-sector potential studies have informed our understanding of the energy savings available in each policy area and have led to ongoing refinements in our scoring methodology (Geller et al. 2007; Neubauer et al. 2009, 2011; Eldridge, Elliott, and Vaidyanathan 2010; Molina et al. 2011; Hayes et al. 2014).

Of the 50 total points possible, we allocated 20 points (40%) to utility and public benefits program and policy metrics, 12 points (24%) to transportation policies and programs, 9 points (18%) to building energy efficiency policies, 6 points (12%) to state-led initiatives (such as lead-by-example programs and state-sponsored incentives), and 3 points (6%) to state appliance and equipment standards.

Within each policy area, we developed a scoring methodology based on a diverse set of criteria that we detail in each policy chapter. We used these criteria to assign a score to each

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[1] A public benefits fund provides long-term funding for energy efficiency initiatives, usually through a small surcharge on electricity consumption on customers' bills.

state. The scores were informed by responses to data requests sent to state energy officials, public utility commission (PUC) staff, and experts in each policy area. To the best of our knowledge, policy information included in this report is current as of July 2020. However, some performance-based scoring categories, such as those in Chapter 2 (utility programs), are informed by the latest available data from 2019 program years.

Table 1 outlines the scoring.

Table 1. Scoring by policy area and metrics

Policy areas and metrics	Maximum score	% of total points
Utility and public benefits programs and policies	20	40%
Incremental savings from electricity efficiency programs	7	14%
Incremental savings from natural gas and fuels efficiency programs	3	6%
Spending on electricity efficiency programs	2.5	5%
Spending on natural gas efficiency programs	1.5	3%
Large-customer opt-out programs*	(–1)	NA
Energy efficiency resource standards (EERS)	3	6%
Performance incentives and fixed-cost recovery	2	4%
Support of low-income energy efficiency programs	1	2%
Transportation policies	12	24%
GHG tailpipe emissions standards	1.5	3%
Electric vehicle (EV) registrations	1	2%
EV fees	1	2%
Electric vehicle supply equipment (EVSE)	1	2%
High-efficiency vehicle consumer incentives	0.5	1%
Targets to reduce vehicle miles traveled (VMT)	1	2%
Change in VMT	1	2%
Integration of transportation and land-use planning	1	2%
Complete streets policies	0.5	1%
Transit funding	1	2%
Transit legislation	0.5	1%
Freight system efficiency goals	1	2%
Equitable transportation policies	1	2%
Building energy efficiency policies	9	18%
Level of code stringency	4	8%
Code compliance study	1	2%
Code enforcement activities	1	2%

Policy areas and metrics	Maximum score	% of total points
Energy transparency policies	1	2%
Residential energy labeling	0.5	1%
Existing buildings standards	1	2%
Zero-energy buildings	0.5	1%
State government initiatives	6	12%
Financial incentives	2.5	5%
Lead-by-example efforts in state facilities and fleets	2	4%
Carbon pricing	1.5	3%
Appliance and equipment efficiency standards	3	6%
Maximum total score	50	100%

*** We deducted points for programs and policies that are detrimental to energy efficiency.**

The *State Scorecard* is meant to reflect the current policy landscape, incorporating changes from year to year. We do not envision that the allocation of points will forever remain the same; rather, we will continue to adjust our methodology to reflect the current energy efficiency policy and program environment. Point allocations can change both within and across policy categories. This year we shifted points to both the transportation and buildings chapters to accommodate new metrics recognizing state progress on electric vehicle adoption and zero-energy buildings, as well as to credit states adopting efficiency standards for existing buildings. As part of this shift, we removed the chapter dedicated to policies addressing combined heat and power (CHP) technologies. This removal is no way intended to diminish the important carbon benefits of CHP, especially with regard to the efficient use of natural gas. We note that CHP savings reported by utility programs continue to be counted in Chapter 2 of the *Scorecard*. In the long run, CHP remains an important tool for displacing fossil fuel emissions; however, its value in reducing emissions varies by state, depending on the grid mix in each. We give further detail on these changes later in this chapter and discuss them in more depth in the relevant policy chapters.

Changes in future editions of the *Scorecard* could include further revisions to point allocations and the addition or subtraction of entire categories of scoring. In making these changes, we seek to faithfully represent states' evolving efforts to realize the potential for energy efficiency in the systems and sectors of their economies.

STATE DATA COLLECTION AND REVIEW

We rely on outreach to state-level stakeholders to verify the accuracy and comprehensiveness of the policy information that we use to score the states. As in past years, we asked each state utility commission to review statewide data for the customer-funded energy efficiency programs presented in Chapter 2. Thirty-five state commissions responded.

We also asked each state energy office to review information on transportation policies (Chapter 3), building energy codes (Chapter 4), and state government initiatives (Chapter 5).

We received responses from energy offices in 38 states. In addition, we gave state energy office and utility commission officials the opportunity to review and submit updates to the material in ACEEE's State and Local Policy Database (ACEEE 2020b).[2] We also asked them to review and provide comments on a draft version of this *Scorecard* prior to publication. We used publicly available data and responses from prior years to evaluate states that did not respond to this year's data request or requests for review.

Best-Practice Policy and Performance Metrics

The scoring framework described above is our best attempt to represent our more than 32 efficiency metrics as a quantitative score. Converting spending data, energy savings data, and policy adoption metrics spanning five policy areas into one score clearly involves some simplification. Quantitative energy savings performance metrics are confined mostly to programs run by utilities and statewide or third-party administrators using ratepayer funds. These programs are subject to strict evaluation, measurement, and verification standards. States engage in many other efforts to encourage efficiency, but such efforts are typically not evaluated with the same rigor, so it is difficult to capture comprehensive quantitative data for these programs.

Although our preference is to include metrics based on energy savings achieved in every sector, the lack of consistent ex post data makes this unrealistic. Therefore, except for utility policies, we have not scored the other policy areas on spending or reported savings attributable to a particular policy action. Instead, we have developed best-practice metrics for scoring the states. In most cases these metrics do not score outcomes directly but rather credit states that are implementing policies likely to lead to gains in energy efficiency. For example, we give credit for *potential* energy savings from improved building energy codes and appliance efficiency standards, since *actual* savings from these policies are rarely evaluated. We have also attempted to reflect outcome metrics to the extent possible; for example, electric vehicle (EV) registrations, reductions in vehicle miles traveled (VMT), and a recently introduced metric for number of publicly available electric vehicle charging stations all represent measurable results of transportation policies. We include a full discussion of the policy and performance metrics in each chapter.

AREAS BEYOND OUR SCOPE: LOCAL AND FEDERAL EFFORTS

Energy efficiency initiatives implemented by actors at the federal or local level or in the private sector (with the exception of investor-owned utilities) generally fall outside the scope of this report. It is important to note that regions, counties, and municipalities have become actively involved in developing energy efficiency programs, a positive development that reinforces state-level efficiency efforts. ACEEE's *City Clean Energy Scorecard* (Ribeiro et al. 2020) captures data on these local actions; we do not specifically track them in the *State Scorecard*. However, a few *State Scorecard* metrics do capture local-level efforts, including the adoption of building codes and land-use policies, as well as state financial incentives for local energy efficiency initiatives. We also include municipal utilities in our data set to the extent that they report energy efficiency data to the U.S. Energy Information Administration

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[2] Available at database.aceee.org.

(EIA), state PUCs, or other state and regional groups. As much as possible, however, we focus on state-level energy efficiency activities.

The *State Scorecard* has not traditionally covered private-sector investments in efficient technologies outside of customer-funded or government-sponsored energy efficiency initiatives, codes, or standards. We do recognize the need for metrics that capture the rapidly growing role of private financing mechanisms. We currently track states with active Property Assessed Clean Energy (PACE) programs, green bank financing, and loan programs offered by state agencies. However, incompleteness and variations in reporting program results have made development of a fair and transparent performance-based scoring metric a challenge. Until the reliability and completeness of savings data from these private initiatives improve, we award points for the presence of such programs but stop short of crediting levels of funding or savings. In cases in which this information was made available, we have included it in Appendix L.

THIS YEAR'S CHANGES IN SCORING METHODOLOGY

We updated our scoring methodology in several policy areas this year to reflect the changing policy landscape. Specifically, we recognize increasing efforts by states to support vehicle electrification and promote zero-energy buildings as strategies to improve efficiency and reduce emissions. We should note also that our methodology development and data collection for this report occurred in the winter and spring of 2020 as the initial impacts of the COVID-19 pandemic were still being understood. As a result, our scoring assessment does not directly address changes to efficiency policies or programs or stimulus efforts that states may have made to adapt or strengthen programs in response to the crisis.

Past *Scorecard*s have considered state EV registration rates and have awarded points to the 12 states currently administering California's Zero-Emission Vehicle (ZEV) program. This year we have added two additional EV-related scoring categories to Chapter 3 to capture policies that help accelerate the adoption of electric vehicles. One new metric tracks the number of publicly available charging stations per capita. While states can prioritize various channels and policies to increase investment in EV charging infrastructure, we hope that by using an outcome-based count of available chargers we can provide an objective assessment of state success in this area. The other new scoring category considers the stringency of EV fees assessed by states in an effort to recoup lost gasoline-tax revenues. While it makes sense for all vehicle owners to contribute to the maintenance of the roads they drive on, we deducted points for states with inordinately high surcharges that disincentivize EV uptake.

We have also updated our chapter on buildings policies, with two new metrics that credit states leading the way in targeting energy waste in existing buildings and paving the way for zero-energy buildings (ZEBs). While building energy codes address efficiency in new construction, a number of jurisdictions, particularly at the city level, have set energy performance standards to drive change in the existing building stock. In 2019 Washington State became the first to adopt such a standard at the state level as part of its Clean Buildings Act and is thus the first to earn a point in this important new *Scorecard* metric. Also, a growing number of states, through codes and other incentives, are prioritizing construction of ZEBs—buildings that produce at least as much energy as they consume—as a strategy to rapidly reduce emissions. Using data from the New Buildings Institute, our other new metric is based on the number of verified and emerging ZEBs constructed in each state. To accommodate these changes, we removed a previous metric that credited states for requiring code officials to complete energy efficiency–related training and certification.

In addition, this year we removed our chapter on CHP-supportive policies. While CHP serves an important energy-saving role, especially in industrial applications, by recovering heat that would be wasted otherwise, our decision was based on feedback from states, some of which noted that the future role of CHP as a clean energy resource has grown more complex and variable depending on local grid energy mixes. The chapter's removal will also avoid penalizing states in which higher levels of zero-emission resources make CHP less attractive as a policy priority. We note, however, that savings from CHP are already counted to some degree in Chapter 2, to the extent that they are captured in utility savings reporting.

In Chapter 6, which evaluates state government–led initiatives, we refined our carbon metric, first introduced last year to recognize states aligning energy efficiency programs with statewide climate and emissions goals. Last year's *Scorecard* credited those states supporting energy efficiency programs through proceeds from carbon pricing policies (primarily through the Regional Greenhouse Gas Initiative and California's cap-and-trade program). We have built on this with two new metrics, one crediting states that are actively tracking greenhouse gas (GHG) emissions avoided through energy efficiency programs, the other crediting those that consider the avoided carbon benefits of efficiency in assessing the cost effectiveness of utility energy savings programs. To accommodate these additions, we retired a previous metric tracking state-sponsored R&D programs with a focus on energy efficiency because most states were earning points and it was no longer a useful differentiator. However, we do continue to include this information in ACEEE's State and Local Policy Database (ACEEE 2020b).

2020 STATE ENERGY EFFICIENCY SCORECARD *RESULTS*

We present the results of the *State Scorecard* in figure 1 and describe them more fully in table 2. In this section, we also highlight some key changes in state rankings, discuss which states are making notable new commitments to energy efficiency, and provide recommendations for states wanting to increase their energy efficiency.

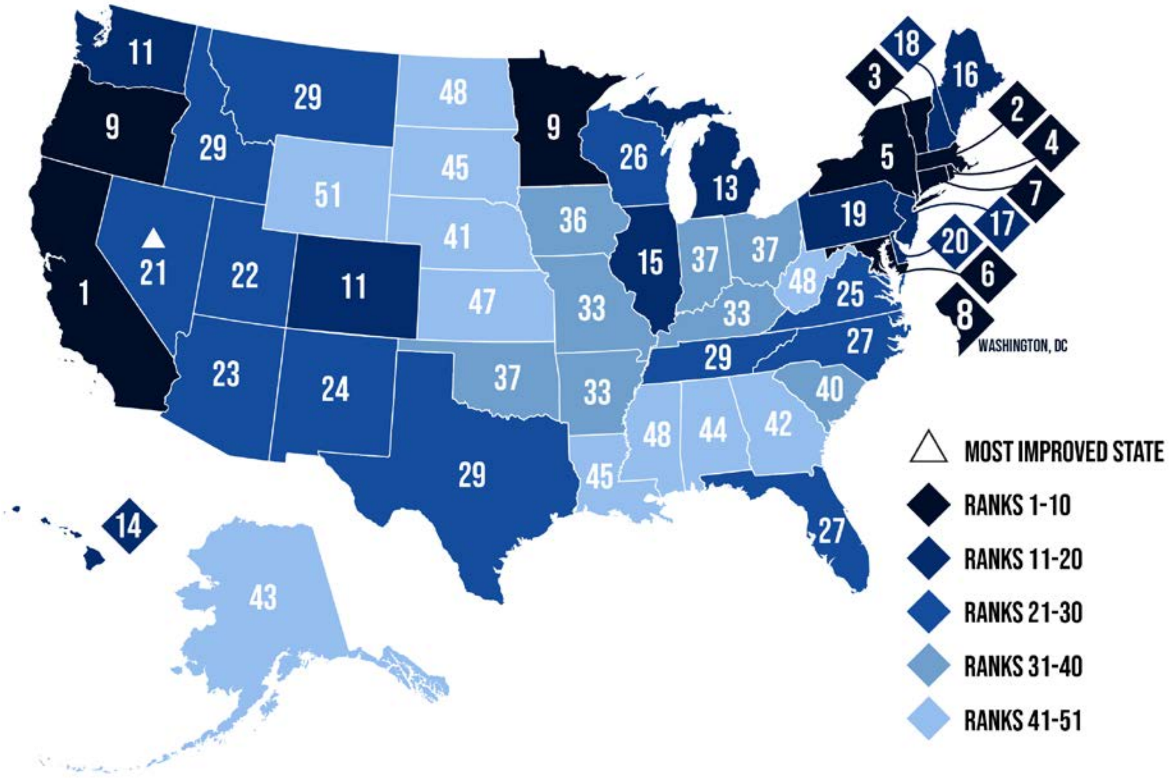

Figure 1. *2020 State Scorecard* rankings

Table 2. Summary of state scores in the *2020 State Scorecard*

Rank	State	Utility and public benefits programs & policies (20 pts.)	Trans-portation policies (12 pts.)	Building energy efficiency policies (9 pts.)	State government initiatives (6 pts.)	Appliance efficiency standards (3 pts.)	**TOTAL SCORE (50 pts.)**	Change in rank from 2019	Change in score from 2019
1	California	16	10.5	7.5	6	3	43	1	–0.5
2	Massachusetts	19.5	10	7	6	0	42.5	–1	–2
3	Vermont	17.5	8.5	6	6	2	40	0	–0.5
4	Rhode Island	19.5	8	6	6	0	39.5	–1	–1
5	New York	13.5	10.5	6.5	5.5	0.5	36.5	0	–0.5
6	Maryland	13.5	9.5	6	5.5	0	34.5	1	0
7	Connecticut	12.5	8.5	6.5	6	0	33.5	–1	–3
8	District of Columbia	9.5	11	8.5	4	0	33	3	4
9	Minnesota	13	7	6.5	5.5	0	32	–1	–0.5
9	Oregon	11	8.5	7	5.5	0	32	0	0
11	Colorado	9.5	7.5	6	5.5	2	30.5	3	3.5
11	Washington	7.5	8.5	7.5	5	2	30.5	–1	–1
13	Michigan	13	5.5	6.5	3.5	0	28.5	0	0
14	Hawaii	11	6	7	2.5	1.5	28	2	2.5
15	Illinois	12	5	6	4	0	27	–4	–2
16	Maine	9	7.5	4.5	5.5	0	26.5	–1	0.5
17	New Jersey	8.5	7	6.5	3	0	25	0	1
18	New Hampshire	10	3.5	5.5	5.5	0	24.5	2	3.5
19	Pennsylvania	4	6.5	6.5	5	0	22	–1	–1.5
20	Delaware	3.5	6.5	5.5	6	0	21.5	1	1
21	Nevada	5	4	6.5	4.5	1	21	5	5.5
22	Utah	6.5	4.5	6	3.5	0	20.5	0	1
23	Arizona	8.5	5	4.5	2	0	20	–4	–1.5
24	New Mexico	6.5	3.5	4.5	4	0	18.5	9	4.5
25	Virginia	1.5	6	5.5	5	0	18	4	3
26	Wisconsin	7.5	2.5	3	4	0	17	–1	1
27	Florida	1.5	5	6	4	0	16.5	–3	0
27	North Carolina	3	4.5	5	4	0	16.5	–1	1
29	Idaho	6	1	5.5	2	0	14.5	1	0
29	Montana	3.5	2.5	5.5	3	0	14.5	7	2
29	Tennessee	1	5	3.5	5	0	14.5	1	0
29	Texas	1	3.5	6.5	3.5	0	14.5	–3	–1
33	Arkansas	7	0	3	3.5	0	13.5	0	–0.5
33	Kentucky	1.5	3	5	4	0	13.5	5	2.5
33	Missouri	2.5	3	4	4	0	13.5	–3	–1
36	Iowa	4	3.5	4	1	0	12.5	–13	-6
37	Indiana	4	3	3	1.5	0	11.5	3	1
37	Ohio	4	0.5	3.5	3.5	0	11.5	–4	–2.5
37	Oklahoma	4	3.5	1.5	2.5	0	11.5	0	–0.5
40	South Carolina	2	2.5	2.5	4	0	11	0	0.5
41	Nebraska	0.5	2	6	2	0	10.5	2	1
42	Georgia	2	1.5	4.5	2	0	10	–4	–1
43	Alaska	1	3.5	1.5	3.5	0	9.5	–3	–1
44	Alabama	0	0.5	5.5	3	0	9	–1	–0.5
45	Louisiana	0.5	3	2	2.5	0	8	3	1.5
45	South Dakota	2	2	3.5	0.5	0	8	1	1
47	Kansas	0.5	2	3.5	1	0	7	–1	0
48	Mississippi	2	0.5	0.5	2.5	0	5.5	–3	–2.5
48	North Dakota	0	2	3	0.5	0	5.5	2	0.5
48	West Virginia	–1	1	4	1.5	0	5.5	0	–1
51	Wyoming	1	0.5	0	2.5	0	4	0	–0.5

How to Interpret Results

Although we provide individual state scores and rankings, the differences among the states are most instructive when considered in tiers of 10. Relatively few points separate states' total scores in the middle tiers: just 6.5 points in the third tier and 2.5 points in the fourth. These middle tiers also have a significant number of states tied in the rankings. For example, in the third tier, Idaho, Montana, Tennessee, and Texas are tied for 29th. Small improvements in energy efficiency will likely have a significant effect on the rankings of states in the middle tiers. Conversely, idling states will easily fall behind as other states in this large group ramp up their efficiency efforts.

The top tier exhibits more variation in scoring, stretching across an 11-point range. California, Massachusetts, and Vermont were the only states scoring 40 or more points this year. Others in the top tier are also well-established high scorers. Generally speaking, the highest-ranking states have all made broad, long-term commitments to energy efficiency, indicated by their staying power at the top of the *State Scorecard* over the past decade. However, it is important to note that retaining one's spot in the lead pack is no easy task; all of these states must embrace new, cutting-edge strategies and programs to remain at the top.

2020 Leading States

California returned to first place this year, its fifth time taking the top spot since the *Scorecard*'s inception in 2007 and a feat it last accomplished in 2016, when it tied with Massachusetts. For its part, the Bay State followed just a half-point behind to take second place. Massachusetts continues to lead on multiple fronts, including with advanced efforts to integrate efficiency with state electrification and decarbonization strategies, currently seen in only a handful of states.

California's enduring leadership on building energy codes, vehicle emissions, and appliance standards continues to set the pace in advancing energy efficiency on a variety of fronts—not just within the state's borders but at the national level. Other states have modeled their own policies after California's example, with more than a dozen states adopting its low-emissions vehicle regulations and 11 implementing its zero-emission vehicle program. Together with California, these states have created an important unified front against ongoing federal efforts to revoke states' ability to set stricter vehicle standards. California's other pivotal achievements this year included expanded investment in high-efficiency heat pump water heaters (HPWHs), along with updates to the state's building energy code to award compliance credits to builders for adoption of smart HPWHs in recognition of their unique benefits toward slashing emissions and providing demand flexibility. The state also continued to maintain progress on important appliance standards, notably expanding the scope of its strong light bulb standards last November in the face of federal efforts to reverse course on similar national standards.

Driven by the strength of a robust policy framework under the state's 2008 Green Communities Act, **Massachusetts** continues to deliver nation-leading levels of utility savings alongside comprehensive programs and policies to strengthen efficiency in the buildings and transportation sectors. Among these policies are incentives for electric vehicles and strong building energy codes based on the 2018 International Energy Conservation Code (IECC), including strengthening amendments for solar readiness. In recent years the state has taken major steps to better align energy efficiency with emissions reduction goals under its Global Warming Solutions Act. For instance, it has made policy revisions to enable strategic electrification through measures that switch homeowners from oil and propane furnaces to electric heat pumps, and it has launched incentives to reduce winter and summer peak demand. Other major policy advances this year include instituting a Clean Peak Standard, crediting clean energy delivered during hours of peak demand.

Vermont continued its now seven-year streak in the *Scorecard* top five. The state's energy efficiency resource standard is among the strongest in the nation, consistently delivering utility savings exceeding 2% of sales. Vermont is also among the states that have passed legislation (H 410) putting national appliance and light bulb standards into state law in order to protect against federal rollbacks. In addition, H 410, signed in 2018, established efficiency standards for 16 appliances not covered at the federal level, which are expected to cumulatively save consumers $210 million by 2035 and help meet the state's carbon emissions goals. The Green Mountain State has also maintained progress on buildings efficiency, adopting the 2018 IECC and ASHRAE Standard 90.1-2016 as part of an update to its residential and commercial building energy standards, which took effect this year.

Rhode Island ranks fourth this year, thanks to the success of its nation-leading utility savings targets and a mandate to procure all cost-effective energy efficiency.[3] Building decarbonization has been a growing priority for the state in recent years, with the introduction of voluntary stretch codes for construction and renovation projects in 2018 and ongoing support of zero-energy buildings. The state is also targeting energy efficiency among delivered-fuels customers, an often overlooked sector, and this year released a heating sector transformation report identifying solutions to reduce emissions through renewable fuels and a transition to electric ground source or air source heat pumps.[4] The state has also leveraged utility-led efficiency programs as a means to enhance the workforce through targeted training and recruitment opportunities, helping to increase the state's clean energy workforce by 25% since 2015. Rhode Island has also collaborated with Northeast Energy Efficiency Partnerships to increase the visibility of home energy data. In addition, the state leads by example with clear energy goals established for state agencies.

New York rounds out the top five for the second straight year. The state's utilities and energy community worked to update policies and programs to meet ambitious goals to achieve a net-zero carbon economy under the 2019 Climate Leadership and Community Protection Act (CLCPA). In January the state's Public Service Commission issued an order setting ambitious energy efficiency and building decarbonization targets in pursuit of the state goal to achieve 185 TBtus of savings by 2025. The state's efficiency goals are notable for being among the first in a next generation of fuel-neutral energy efficiency resource standards that integrate beneficial electrification and include a separate heat pump target.

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[3] "All cost-effective" requirements call on utilities to determine and invest in the maximum amount of cost-effective efficiency feasible. States use a variety of methods and assumptions for determining cost effectiveness, which will influence calculations of potential savings.

[4] Delivered fuels include fuel oil, kerosene, propane, and wood. Also referred to as "unregulated fuels," these are commonly not subject to utility energy efficiency rules, and savings associated with delivered fuels have historically not been tracked in most cases.

Also going into effect this year was NYStretch Energy Code 2020—the state's first voluntary, locally adoptable stretch code, providing savings of roughly 11% over the state's base code. Other recent achievements include the release of a new state freight plan with efficiency performance measures, as well as the signing of a bill in late 2019 strengthening efficiency standards for faucets, showerheads, and other plumbing fixtures.

States rounding out the top 10 are Maryland, Connecticut, the District of Columbia, Minnesota, and Oregon. Each has established strong policy structures, incentives, and standards to drive savings through utility programs, efficient new construction, and improved sustainability in the transportation sector.

Table 3 shows the number of years that states have been in the top 5 and top 10 spots in the *State Scorecard* rankings since their inception in 2007.

Table 3. Leading states in the *State Scorecard*, by years at the top

State	Years in top 5	Years in top 10
California	14	14
Massachusetts	13	14
Vermont	12	14
Oregon	10	14
New York	9	14
Connecticut	6	14
Rhode Island	8	13
Washington	1	13
Minnesota	0	13
Maryland	0	10
Illinois	0	2
Maine	0	2
New Jersey	0	2
District of Columbia	0	1
Wisconsin	0	1

Since the first edition of the *State Scorecard,* eight states have occupied the top 5 spots, and 14 and the District of Columbia have appeared somewhere in the top 10. California is the only state to have earned a spot among the top 5 in all 14 years, followed by Massachusetts for 13 years and Vermont for 12. New Jersey, Washington, Wisconsin, Illinois, and Maine have all placed in the top 10 in the past, but none scored high enough to rank in the top tier this year.

Changes in Results Compared with *The 2019 State Energy Efficiency Scorecard*

Overall, 20 states and the District of Columbia had higher total scores and 23 states had lower total scores this year compared with last year's *Scorecard*. Seven states had no change in score.[5] Table 4 shows point gains and losses in greater detail.

Table 4. Number of states gaining or losing points compared with 2019, by policy area

Policy category	States gaining points		No change		States losing points	
Utility and public benefits	14	27%	22	43%	15	29%
Transportation*	41	80%	3	6%	7	14%
Building energy codes	21	41%	21	41%	9	18%
State government initiatives	14	27%	21	41%	16	31%
Appliance standards	2	4%	47	92%	2	4%
Total score	21	41%	7	14%	23	45%

Percentages may not total 100 due to rounding. *Due to an adjustment to the scoring methodology that reallocated points from the discontinued CHP chapter to transportation and buildings policies, a relatively high number of states saw significant point gains in these categories.

The fact that 23 states lost points this year should not necessarily be interpreted as a sign that they are losing ground. Given the number of metrics in the *State Scorecard* and states' varying efforts, movement should be expected. The landscape for energy efficiency is in constant flux, and changes in state scores reflect a variety of factors. These include adjustments to our *Scorecard* methodology this year to reflect emerging state policies such as those supporting expansion of electric vehicle charging infrastructure, zero-energy construction, and alignment of efficiency policies with broader state decarbonization goals.

Leaving aside methodology, the number of states losing points this year does not indicate a lack of nationwide progress. On the contrary, several states, including Massachusetts, New Jersey, New Mexico, New York, and Virginia, have renewed, extended, or strengthened energy efficiency targets to help lay the groundwork for future savings. As mentioned earlier, savings from electric efficiency programs administered in 2019 totaled approximately 26.9 million MWh, equivalent to about 0.70% of total retail electricity sales in the United States. And this does not include ongoing savings from energy efficiency measures installed in earlier years that continue to save energy. Those savings amounted to more than 270 million MWh in 2019, approximately 7% of electricity consumption. More information on state scores for utility programs is included in Chapter 2.

Most-Improved States

Relative to last year, this year's most-improved state was **Nevada**. Also showing major improvement were New Mexico, Colorado, New Hampshire, the District of Columbia, and Virginia. All of these states added at least 3 points to their scores to move up in the rankings. Table 5 shows changes in points and rank compared with last year for these states.

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[5] The *State Scorecard* looks at all 50 states and the District of Columbia, which is treated as a state under DOE Program Rule 10 CFR Part 420–State Energy Program.

Table 5. Changes from 2019 for most-improved states

	Change in score	Change in rank	2020 ranking	2019 ranking
Nevada	+5.5	+5	21	26
New Mexico	+4.5	+9	24	33
District of Columbia	+4	+4	8	11
Colorado	+3.5	+3	11	14
New Hampshire	+3.5	+2	18	20
Virginia	+3	+4	25	29

Following 2017 state legislation mandating energy efficiency savings targets, **Nevada** has advanced energy efficiency on multiple policy fronts. The governor also signed AB54 last year, adopting federal standards into law in order to protect against the current presidential administration's efforts to roll back energy-saving light bulb standards. The state has adopted the 2018 IECC for residential and commercial buildings, and it works with local governments to increase adoption and compliance. In June the state's environmental agency announced plans to adopt California's vehicle emission standards and Zero-Emission Vehicle (ZEV) mandate. The state also passed legislation in 2019 setting a goal for 100% carbon-free electricity by 2050.

The **District of Columbia** maintains a diverse suite of strong energy efficiency policies that helped propel it into the *Scorecard*'s top 10 this year. In 2019 the District passed the Clean Energy DC (CEDC) Act, the most ambitious renewable portfolio standard in the nation, with a commitment to transition to 100% renewable energy by 2032. The bill also expanded building benchmarking, created energy performance standards for existing buildings, and added funding to the District's new green bank. DC is also working to produce a Transportation Electrification Roadmap per the CEDC to shift its transportation sector from traditional fossil fuels to high-efficiency zero-emission vehicles and align with the District's overarching goal of becoming carbon neutral by 2050.

New Mexico moved forward on a number of important efficiency initiatives in the wake of a pivotal 2019 in which lawmakers signed the Energy Transition Act, committing public utilities to a zero-carbon electricity goal by 2045. Utilities are also strengthening efficiency programs in response to HB-291, which set a new 2025 target to achieve savings of 5% relative to 2020 sales, raised the cap on efficiency spending, and enabled decoupling, in effect removing the disincentive for utilities to save energy. Additionally, an executive order issued by the governor last year moved the state to replace its long-outdated energy codes for new construction with the latest 2018 IECC model codes, turning the corner for buildings sector efficiency. The governor has also called for the state's adoption of stronger fuel economy standards in 2020. And 2019 legislation requires public utilities to submit electric vehicle infrastructure plans by 2021.

Colorado continues to deliver strong levels of utility energy savings in response to more ambitious efficiency goals for Xcel Energy in recent years. Last year the state took a major step forward in strengthening efficiency in new construction with the adoption of HB 19-1260. The law requires local governments to adopt and enforce, at a minimum, one of the three most recent versions of International Code Council energy codes upon updating any other building code. Colorado has also adopted strict vehicle emissions standards aligned with those of California, joining 13 other states that have already done so and helping Colorado move toward its target of cutting greenhouse gas (GHG) emissions 26% by 2025. The state also has comprehensive appliance standards, which include protection against a federal rollback of lighting standards.

In **New Hampshire**, utility-sector savings have gradually ramped up in recent years since the state established its first energy efficiency resource standard in 2016. New Hampshire is also a member of the Regional Greenhouse Gas Initiative (RGGI), the regional cap-and-trade program designed to reduce emissions, and has directed roughly half of its RGGI auction proceeds toward energy efficiency since 2009. As of November 2020, utilities have also proposed significantly higher savings goals for 2021–2023, which could be approved by state regulators in December.

In **Virginia**, the governor's signing of the Virginia Clean Economy Act (VCEA) was a major contributor to the state's 3-point improvement. The VCEA is among the top energy stories of 2020, creating the commonwealth's first clean energy standard and making it the first state in the Southeast with a 100% clean electricity goal. The VCEA also established an energy efficiency resource standard that sets multiyear electric savings targets for utilities. To support low-income customers, it includes measures to reduce energy burdens and also establishes a Percentage of Income Payment Program (PIPP), which caps the monthly electric payment of low-income participants at 6% of income for those with gas heat or 10% for those with electric heat (Virginia General Assembly 2020). The governor also signed HB 981 to make Virginia the first southern state to join RGGI, with proceeds going toward energy efficiency, renewable energy, and climate mitigation measures. As the state's utilities design and administer new customer demand-side offerings to meet VCEA goals, we anticipate the state's *Scorecard* performance will continue to improve alongside the accrual of future savings.

States Losing Ground

Twenty-one states fell in the rankings this year due to factors such as greater progress by other states and changes to the scoring methodology in several categories, including the shifting of points toward the buildings and transportation categories. This loss of ground indicates the complex relationship between changes in total score and changes in rank. Of the 23 states that lost points, 16 fell in the rankings, 6 did not change, and 1 state, California, improved to first place despite a half-point loss. The fall in rank of several states may appear incommensurate with their relatively minor loss of points relative to last year. But given the number of metrics covered in the *State Scorecard* and states' differing efforts, relative movement among the states should be expected. As mentioned earlier, the difference among states' total scores, particularly in the middle tiers of the *State Scorecard*, is small; as a result, idling states can easily fall behind in the rankings as others ramp up efforts to become more energy efficient.

Iowa lost 6 points, falling 13 positions to 36th place, the steepest point loss and fall in rankings in 2020. Previously ranked 15th as recently as 2016, the Hawkeye State felt the impact of 2018 legislation that imposes a stifling spending cap on demand-side investment and allows customers to opt out of paying for programs that fail to pass the Ratepayer Impact Measure, a cost-effectiveness test that fails to account for societal savings benefits. The result was a steep drop-off in utility-reported electric and gas savings in 2019, moving Iowa into the bottom half of the *Scorecard*.

In general, we see three trends among the states losing ground in the *State Scorecard*. First, many of those falling behind are not increasing energy savings year after year and are therefore being outpaced as other states ramp up programs to meet higher savings targets. States losing ground typically have not fully implemented changes to the utility business model that encourage utilities to take full advantage of energy efficiency as a resource, including through decoupling, performance incentives, and energy savings targets.

Second, opt-out provisions have been approved in many of the states falling behind in the *State Scorecard* rankings. These provisions allow large customers to avoid paying into energy efficiency programs, forcing other customers to subsidize them while limiting savings achieved by utilities.

Finally, a handful of states, particularly Iowa and Ohio, have passed damaging legislation that has weakened or rolled back energy efficiency programs. For example, Ohio's HB 6, signed in 2019, effectively ended the state's energy efficiency resource standard and prohibits utility cost recovery for efficiency programs. This has led to the anticipated termination of energy efficiency programs statewide by the end of 2020, with the exception of some low-income weatherization programs. Ohio fell four places in this year's rankings, from 33rd to 37th place.

STRATEGIES FOR IMPROVING ENERGY EFFICIENCY

A variety of policy tools and program designs are available to state officials to strengthen efforts to save energy across multiple use sectors. The following list highlights examples of best practices by state policymakers seeking to improve energy efficiency performance by energy utilities, in the buildings and transportation sectors, and through appliance standards. We also highlight best practices that reduce legal and market barriers to investing in energy efficiency and expand participation in programs that achieve savings.

Establish and adequately fund an energy efficiency resource standard (EERS) or similar energy savings target. EERS policies set specific energy savings targets that utilities or independent statewide program administrators must meet through customer energy efficiency programs. They serve as an enabling framework for cost-effective investment, savings, and program activity. As states address evolving priorities such as decarbonization, cost, equity, and grid value, regulators in places like Massachusetts and New York are adjusting targets to incorporate multiple goals (e.g., fuel-neutral savings) that better align efficiency programs with electrification and GHG reduction objectives.

Examples: Arkansas, Colorado, Massachusetts, Michigan, Minnesota, New Jersey, New York, Virginia

Adopt California tailpipe emissions standards and set quantitative targets for reducing VMT. Transportation consumes almost 30% of the total energy used in the United States (EPA 2020b). At the state level, a comprehensive approach to transportation energy efficiency must address both individual vehicles and the entire transportation system. A variety of state-level policy options are available to improve transportation system efficiency. These include codifying targets for reducing VMT and integrating land use and transportation planning to create sustainable communities with access to multiple modes of travel. While federal fuel economy standards are expected to go a long way toward reducing fuel consumption, standards for model years 2022–2025 face an uncertain future following the April 2020 release of federal rollbacks. States that adopt California's tailpipe emissions standards will lead the way toward clean, fuel-efficient vehicles.

Examples: California, Colorado, Massachusetts, New York, Oregon

Ensure energy efficiency and clean energy investments and opportunities are inclusive and that benefits accrue to all customers, especially households overburdened by energy costs. Historically marginalized groups have been underserved and underrepresented in clean energy planning and policymaking. States can foster equity in key decision-making processes by ensuring these efforts are inclusive and designed with all communities in mind. These include establishing internal metrics and frameworks that evaluate the degree to which policy and program outcomes are equitable, developing stakeholder processes and community assessments to better understand the needs of marginalized groups, and adopting inclusive workforce development practices to offer new economic and educational opportunities for groups often underrepresented in the energy efficiency workforce. States can also strengthen incentives and programs for income-qualified customers, and to work with utilities and regulators to recognize and value program nonenergy benefits (NEBs), such as health and economic improvements, as a means of expanding these investments. States and public utility commissions (PUCs) can also include goals specific to the low-income sector, either within an EERS or as a stand-alone minimum acceptable threshold, to ensure investments are targeted toward these customers.

Examples: California, New Jersey, Oregon, Pennsylvania, Tennessee, Washington

Adopt updated, more stringent building energy codes, improve code compliance, and involve efficiency program administrators in code support. Buildings use more than 40% of the total energy consumed in the United States, making them an essential target for energy savings. Adopting mandatory building energy codes is one way to ensure a minimum level of energy efficiency for new residential and commercial buildings. Strategies such as energy performance standards, benchmarking and transparency policies, and financing tools to encourage deep retrofits are also critical for addressing efficiency in the existing building stock.

Examples: California, Illinois, Maryland, Nebraska, New Mexico, District of Columbia, Washington

Expand state government–led initiatives and make them visible. States can establish sustainable funding sources for energy efficiency incentive programs, invest in energy efficiency–related R&D and demonstration centers, and lead by example by incorporating energy efficiency into government operations. In the latter area, they can reduce energy use in public buildings and fleets and use energy savings performance contracts (ESPCs) to finance energy-saving projects. States can also work with utilities and community-based organizations to promote and coordinate energy code compliance training and workforce development programs.

Examples: Alaska, Connecticut, New York

Explore and promote innovative financing mechanisms to leverage private capital and lower the up-front costs of energy efficiency measures. Although utilities in many states offer some form of on-bill financing program to promote energy efficiency in homes and buildings, expanding lender and customer participation has been an ongoing challenge. States can increase stakeholder awareness and pass legislation to address legal barriers to the implementation of financing programs. A growing number of states are seeking new ways to maximize the impact of public funds and invigorate energy efficiency by attracting private capital through emerging financing models such as PACE programs and green banks.

Examples: Colorado, Connecticut, Minnesota, Missouri, New York, Rhode Island

Adopt cost-effective efficiency standards for appliances, equipment, lighting, and plumbing products. State appliance standards are a proven policy that lowers utility bills for customers and businesses, reduces pollution, and helps spur national standards. Even when standards are not adopted at the federal level, adoption by just a few states can be enough to impact national markets. The Appliance Standards Awareness Project has recently outlined a menu of new or strengthened standards for 47 products that would reduce annual average household utility bills by more than $100 in 2030 and deliver cumulative utility bill savings of $1.1 trillion through 2050 for consumers and businesses.[6]

Examples: California, Colorado, Washington, Hawaii, Nevada, New York, Vermont

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[6] Appliance Standards Awareness Project, *A Powerful Priority: How Appliance Standards Can Help Meet U.S. Climate Goals and Save Consumers Money* (Boston: ASAP, 2020). appliance-standards.org/sites/default/files/Powerful_Priority_Report.pdf.

Chapter 2. Utility and Public Benefits Programs and Policies

Author: Weston Berg

INTRODUCTION

The utility sector is critical to implementing energy efficiency. Electric and natural gas utilities and independent statewide program administrators deliver a substantial share of electricity and natural gas efficiency programs in the United States.[17] These programs, funded by utility customers through utility rates and statewide public benefits funds, encourage customers to use efficient technologies and thereby reduce their energy waste. Energy efficiency is a resource—just as power plants, wind turbines, and solar panels are.

Utilities and administrators have been delivering energy efficiency programs and market transformation initiatives to customers for decades in some states, often driven by regulations from state utility commissions setting specific savings targets for residential, commercial, industrial, and income-qualified customers. And as a growing number of states have adopted increasingly ambitious clean energy goals, many are deploying energy efficiency integrated with controls as an important demand response and grid optimization resource to complement and facilitate the growing integration of renewable energy. ACEEE has also found that by scaling up energy efficiency across multiple end-use sectors, the United States can cut energy use and greenhouse gas emissions in half by 2050 (Ungar and Nadel 2019).

Utilities and administrators implement energy efficiency programs in all 50 states and the District of Columbia. Program approaches include financial incentives, such as rebates and loans; technical services, such as audits, retrofits, and training for architects, engineers, and building owners; behavioral strategies; and educational campaigns about the benefits of energy efficiency improvements. Utilities and administrators also continue to develop new and creative ways of delivering energy efficiency to their customers, including some customer segments that have been more difficult to serve, such as small businesses and multifamily housing occupants.

METHODOLOGY

For this chapter, we gathered statewide data on the following:

- Utility energy sales (electricity and natural gas) to customers in 2018 and 2019
- Utility revenues from retail energy sales in 2018 and 2019
- Number of residential natural gas customers in 2018
- Budgets for electricity and natural gas energy efficiency programs in 2019 and 2020
- Actual spending for electricity and natural gas energy efficiency programs in 2018 and 2019

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[17] Other major programs, run by state governments, are discussed in Chapter 6. In addition, the U.S. Department of Energy (DOE) Weatherization Assistance Program (WAP), started in 1976, provides weatherization services to approximately 35,000 homes every year using DOE funds. More than $200 million was dedicated annually to the program in both FY 2016 and FY 2017, though these are not considered within the *State Scorecard* given the report's state-level policy scope.

- Incremental net and gross electricity and natural gas energy efficiency program savings in 2018 and 2019[18]
- Incremental net and gross energy savings of unregulated fuels including fuel oil, kerosene, wood, and propane, where available, in 2018 and 2019
- Policies and regulations to encourage utility investment in energy efficiency
- Utility policies and programs related to large customers, including self-direct and opt-out provisions
- Policies and levels of spending related to utility investment in low-income energy efficiency programs
- Data access policies and provisions[19]

We sourced our data from information requests completed by state utility commissions and from the EIA (EIA 2020a, 2020c, 2020d). We also gathered information from regional efficiency groups.[20] We sent the data we gathered, along with last year's *State Scorecard* data, to state utility commissions and independent administrators for review. Table 6 shows overall scores for utility programs and policies. Tables 8, 10, 12, and 14 provide data on electricity and natural gas efficiency program savings and spending in the most recent years for which data were available.

SCORING AND RESULTS

This chapter reviews and ranks the states on the basis of their performance in implementing utility-sector efficiency programs and enabling policies that are evidence of a commitment to energy efficiency. The eight utility scoring metrics are

- Incremental electricity program savings as a percentage of retail sales (7 points)[21]
- Incremental natural gas and unregulated fuels program savings as a percentage of residential and commercial sales (3 points)
- Electricity program spending as a percentage of statewide electric utility revenues (2.5 points)
- Natural gas program spending per residential gas customer (1.5 points)

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[18] Gross savings are those expected from an energy efficiency program, crediting all installed efficiency measures, including those that would have been installed in the absence of the program. Net savings are those attributable to the program, typically estimated by subtracting savings from free riders (program participants who would have implemented or installed the measures without the incentive, or with a lesser incentive), and adding in estimates of savings from free drivers (program nonparticipants who implemented or installed the measures due to the program). States differ in how they define, measure, and account for free ridership and other components of the net savings calculation (Haeri and Khawaja 2012).

[19] We used this information from state responses to present best practices, not to develop scores.

[20] The six regional energy efficiency organizations (REEOs) are the Midwest Energy Efficiency Alliance (MEEA), Northeast Energy Efficiency Partnerships (NEEP), Northwest Energy Efficiency Alliance (NEEA), Southeast Energy Efficiency Alliance (SEEA), South-Central Partnership for Energy Efficiency as a Resource (SPEER), and Southwest Energy Efficiency Project (SWEEP). The REEOs work through funded partnerships with the U.S. DOE and with various stakeholders, such as utilities and advocacy groups, to provide technical assistance to states and municipalities in support of efficiency policy development, program design, and program implementation.

[21] ACEEE defines incremental savings as new savings from programs implemented in a given year. Incremental savings are distinct from cumulative savings, which are the savings in a given program year from all the measures implemented under the programs in that year and in prior years that are still saving energy.

- Opt-out provisions for large customers (–1 point)
- EERS for utilities and statewide program administrators (3 points)
- Utility business models that encourage energy efficiency, including performance incentives and revenue decoupling (2 points)
- Policies and utility funding in support of low-income energy efficiency programs (1 point)

In this category, a state could earn up to 20 points, or 40% of the 50 total points possible in the *State Scorecard*. We set this point allocation because the savings potential of utility and public benefits programs is approximately 40% of the total energy savings potential of all policy areas scored. Studies suggest that electricity programs typically achieve at least three times the primary energy savings of natural gas programs (Geller et al. 2007; Elliott et al. 2007a, 2007b; Eldridge et al. 2009). Utility-sector potential studies generally indicate significant untapped possible savings for natural gas efficiency programs (GDS 2013; Mosenthal et al. 2014; Nadel 2017; Minnesota DOC 2018). Therefore, we allocated 9.5 points to metrics for electricity programs measuring annual savings and spending and 4.5 points to metrics for natural gas and unregulated fuels programs measuring annual savings and spending. In an effort to recognize state policies and programs aimed at strengthening energy efficiency for low-income households—a sector that has historically experienced underinvestment due to policies of systemic social and economic exclusion—we introduced in the *2017 State Scorecard* a 1-point scoring category to capture these state efforts.

Hawaii consumes almost no natural gas (EIA 2019c), so it aims energy efficiency efforts at electricity only. To avoid penalizing the state for this, we awarded Hawaii points for natural gas efficiency spending, savings, and regulatory structures equivalent to the proportion of points it earned for corresponding electricity programs and policies.

We continue our practice of reporting programs' incremental energy savings (savings from measures installed in a given year) rather than their total annual energy savings (those achieved in a year from measures installed that year and in prior years) or cumulative savings. We report incremental savings in the *State Scorecard* for two reasons. First, basing our scoring on total annual savings or cumulative energy savings would involve levels of complexity that are beyond the scope of the *State Scorecard*, including identifying the start year for the cumulative series and accurately accounting for the life of energy efficiency measures and the persistence of savings. Second, the *State Scorecard* aims to provide a snapshot of states' current energy efficiency programs, and incremental savings give a clearer picture of recent efforts.

There are some other possible metrics we did not use for scoring. For instance, we did not attempt to include program cost effectiveness or level of spending per unit of energy savings. All states have cost-effectiveness requirements for energy efficiency programs (York, Cohn, and Kushler 2020). However, the wide diversity of measurement approaches across states makes comparison less than straightforward. Also, several states require program administrators to pursue all cost-effective efficiency. Although some states have prioritized low acquisition costs and encouraged maximizing the *degree* of cost effectiveness, promoting larger *amounts* of marginally cost-effective energy savings is another valid approach. We also did not adjust savings for variations in avoided costs of energy across states, as there are examples of achieving deep energy savings in both high- and low-cost states.

Note that scores are for states as a whole and therefore may not be representative of the specific efforts of each utility within a state. A single utility or a small set of utilities may do very well in terms of energy efficiency programs and associated metrics (spending and savings), but when all utilities in a state are viewed cumulatively, such efforts can be masked in the *State Scorecard* by other utilities with lower performance. For more information on the energy savings performance of individual utilities, refer to *The 2020 Utility Energy Efficiency Scorecard* (Relf, Cooper, and Gold 2020), published by ACEEE.

Table 6 lists states' overall utility scores. Explanations of each metric follow.

Table 6. Summary of state scores for utility and public benefits programs and policies

State	2019 electricity program savings (7 pts.)	2019 natural gas and fuels program savings (3 pts.)	2019 electricity EE spending (2.5 pts.)	2019 gas program spending (1.5 pts.)	2020 opt-out provision (–1 pt.)	2020–2025 energy efficiency resource standard (3 pts.)	2020 performance incentives and fixed-cost recovery (2 pts.)	2019 low-income energy efficiency programs (1 pt.)	2020 total score (20 pts.)
Massachusetts	7	2.5	2.5	1.5	0	3	2	1	19.5
Rhode Island	7	2.5	2.5	1.5	0	3	2	1	19.5
Vermont	7	1	2.5	1.5	0	2.5	2	1	17.5
California	6	3	1.5	1	0	1.5	2	1	16
Maryland	7	0.5	1.5	0.5	0	2	1	1	13.5
New York	4	1.5	1.5	1	0	2.5	2	1	13.5
Michigan	4.5	2.5	1	1	0	1.5	1.5	1	13
Minnesota	3.5	2.5	1	1	0	2	2	1	13
Connecticut	4	1	1.5	1.5	0	1.5	2	1	12.5
Illinois	5	1.5	1.5	0.5	–1	2.5	1	1	12
Hawaii	4	2	0.5	0.5	0	1	2	1	11
Oregon	3.5	1.5	1.5	1	0	1.5	1	1	11
New Hampshire	3	0.5	1	1.5	0	1.5	1.5	1	10
Colorado	3	1	1	0.5	0	2	1.5	0.5	9.5
District of Columbia	4	2	0.5	0.5	0	0	1.5	1	9.5
Maine	3.5	0.5	1	1	0	1.5	0.5	1	9
Arizona	3	1	0.5	0	0	2.5	1	0.5	8.5
New Jersey	2	0.5	0.5	1	0	2	1.5	1	8.5
Washington	3	0.5	1	0.5	0	1	1	0.5	7.5
Wisconsin	2	1.5	0.5	0.5	0	1	1	1	7.5

State	2019 electricity program savings (7 pts.)	2019 natural gas and fuels program savings (3 pts.)	2019 electricity EE spending (2.5 pts.)	2019 gas program spending (1.5 pts.)	2020 opt-out provision (–1 pt.)	2020–2025 energy efficiency resource standard (3 pts.)	2020 performance incentives and fixed-cost recovery (2 pts.)	2019 low-income energy efficiency programs (1 pt.)	2020 total score (20 pts.)
Arkansas	2	1.5	0.5	0.5	–1	1.5	1.5	0.5	7
New Mexico	1.5	0.5	0.5	0.5	0	1	1.5	1	6.5
Utah	2	2	0.5	0.5	0	0	1	0.5	6.5
Idaho	3	0	1.5	0.5	0	0	0.5	0.5	6
Nevada	2	0	0.5	0	0	1	0.5	1	5
Indiana	2	0.5	0.5	0.5	–1	0	1	0.5	4
Iowa	2	0.5	0.5	0.5	–1	1	0	0.5	4
Ohio	3	0	0.5	0	–1	0	1	0.5	4
Oklahoma	1	0.5	0.5	0.5	–1	0	1.5	1	4
Pennsylvania	2	0	0.5	0	0	0.5	0	1	4
Delaware	0.5	0.5	0.5	1	0	0	0	1	3.5
Montana	1.5	0	0.5	0.5	0	0	0	1	3.5
North Carolina	2	0	0.5	0	–1	0	1	0.5	3
Missouri	2	0	0.5	0	–1	0	0.5	0.5	2.5
Georgia	0.5	0	0	0	0	0	1	0.5	2
Mississippi	0	0.5	0	0.5	0	0	0.5	0.5	2
South Carolina	1.5	0	0.5	0	–1	0	0.5	0.5	2
South Dakota	0.5	0	0	0	0	0	1.5	0	2
Florida	0	0	0	1	0	0	0	0.5	1.5
Kentucky	0.5	0	0	0	–1	0	1.5	0.5	1.5
Virginia	0	0	0	0	–1	1	0.5	1	1.5
Alaska	0	0	0	0	0	0	0	1	1
Tennessee	0	0	0	0	0	0	0.5	0.5	1
Texas	0.5	0	0	0	–1	0	0.5	1	1
Wyoming	0.5	0	0	0	0	0	0.5	0	1
Kansas	0	0	0	0	0	0	0	0.5	0.5
Louisiana	0	0	0	0	0	0	0.5	0	0.5
Nebraska	0.5	0	0	0	0	0	0	0	0.5
Alabama	0	0	0	0	0	0	0	0	0
North Dakota	0	0	0	0	0	0	0	0	0
West Virginia	0	0	0	0	–1	0	0	0	–1

DISCUSSION

History of Utility and Public Benefits Programs and Policies

The structure and delivery of customer-funded electric energy efficiency programs have changed dramatically over the past three decades, mostly in conjunction with electric industry restructuring efforts.[22] In the 1980s and 1990s, such programs were almost exclusively the domain of utilities, but efforts in the mid-1990s to restructure and deregulate the electric utilities led numerous states to implement public benefits charges as a new source of funding for efficiency. These public benefits approaches established new structures under which utilities—or, in some states, separate efficiency utilities or other third parties—were tasked with administering and delivering energy efficiency, renewable energy, and low-income programs.[23]

Despite such public benefits programs, restructuring still resulted in a precipitous decline in funding for energy efficiency programs in the late 1990s, primarily due to regulatory uncertainty and the expected loss of cost-recovery mechanisms for those programs.[24] Generally, utilities did not see customer-funded energy efficiency programs as being compatible with competitive retail markets.

After restructuring efforts slowed in some states, utility commissions renewed their focus on energy efficiency programs. From their low point in 1998, annual investments in electricity programs had increased more than fourfold by 2010, from approximately $900 million to $3.9 billion. However, growth in efficiency investments has slowed in recent years. In 2019 total spending for electric efficiency increased about 2.9% to $6.84 billion. Adding natural gas program spending of $1.53 billion, we estimate total efficiency program spending of approximately $8.37 billion in 2019 (see figure 2), an increase of about 3.8% compared with 2018.

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[22] By *customer-funded energy efficiency programs*—also known as *ratepayer-funded energy efficiency programs*—we mean energy efficiency programs funded through charges wrapped into customer rates or appearing as some type of fee on customer utility bills. This includes both utility-administered programs and public benefits programs administered by other entities. We do not include data on separately funded low-income programs, load management programs, or energy efficiency R&D.

[23] States that have established nonutility administration of efficiency programs include Delaware, District of Columbia, Hawaii, Maine, New Jersey, New York, Oregon, Vermont, and Wisconsin.

[24] Under traditional regulatory structures, utilities do not have an economic incentive to help their customers become more energy efficient because their revenues and profits decline in line with falling energy sales resulting from energy efficiency programs. To address this disincentive, state regulators allow utilities to recover, at a minimum, the costs of running energy efficiency programs through charges on customer bills. For more on this issue, see York and Kushler (2011).

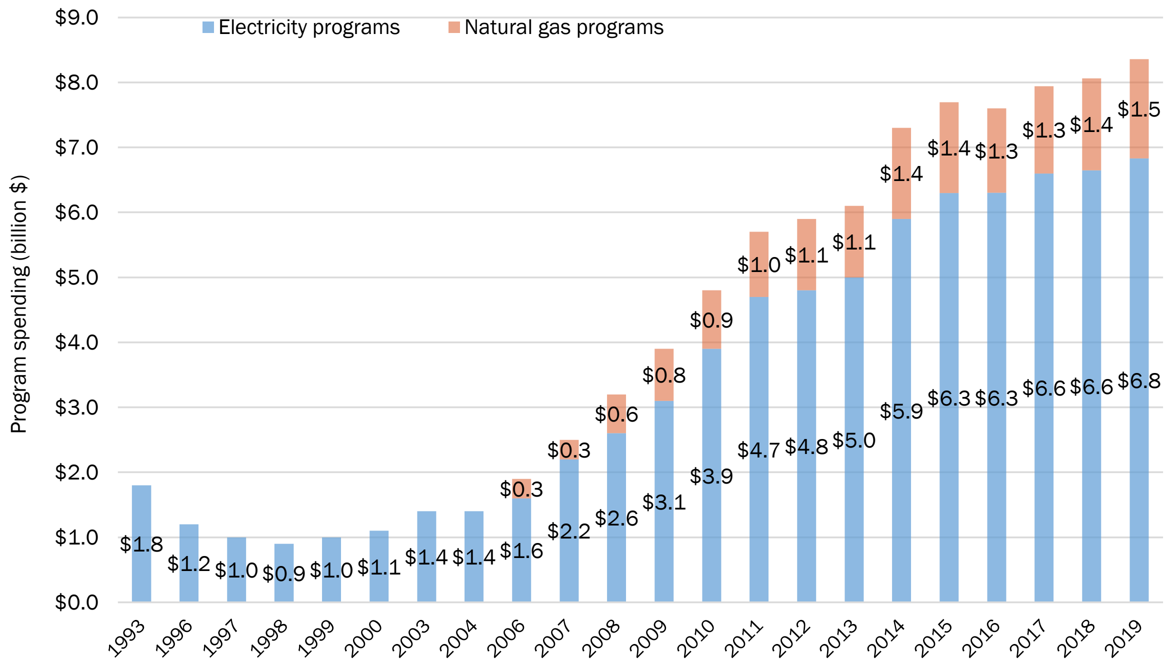

Figure 2. Annual electric and natural gas energy efficiency program spending. Natural gas spending is not available for the years 1993–2004. *Sources:* Nadel, Kubo, and Geller 2000; York and Kushler 2002, 2005; Eldridge et al. 2007, 2008, 2009; CEE 2012, 2013, 2014, 2015, 2016, 2017, 2018; Gilleo et al. 2015b; Berg et al. 2016, 2017, 2018, 2019.

Nationwide reported savings from utility and public benefits electricity programs in 2019 totaled 0.70% of sales, or 26.9 million MWh, a 0.75% decrease from 2018. However, the total annual impact of efficiency programs continues to grow, since most efficiency measures generate savings for residents and businesses for years after they are installed. As figure 3 shows, the total impact of ratepayer-funded energy efficiency programs was a savings of almost 273 million MWh in 2019: the 26.9 million MWh of incremental savings plus savings still accruing from measures implemented in prior years.[25] These large-scale savings are equivalent to approximately 7.07% of 2019 electricity consumption.

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[25] Based on annual *State Scorecard* data as cited in figure 2. Assumes an average measure life of 10 years.

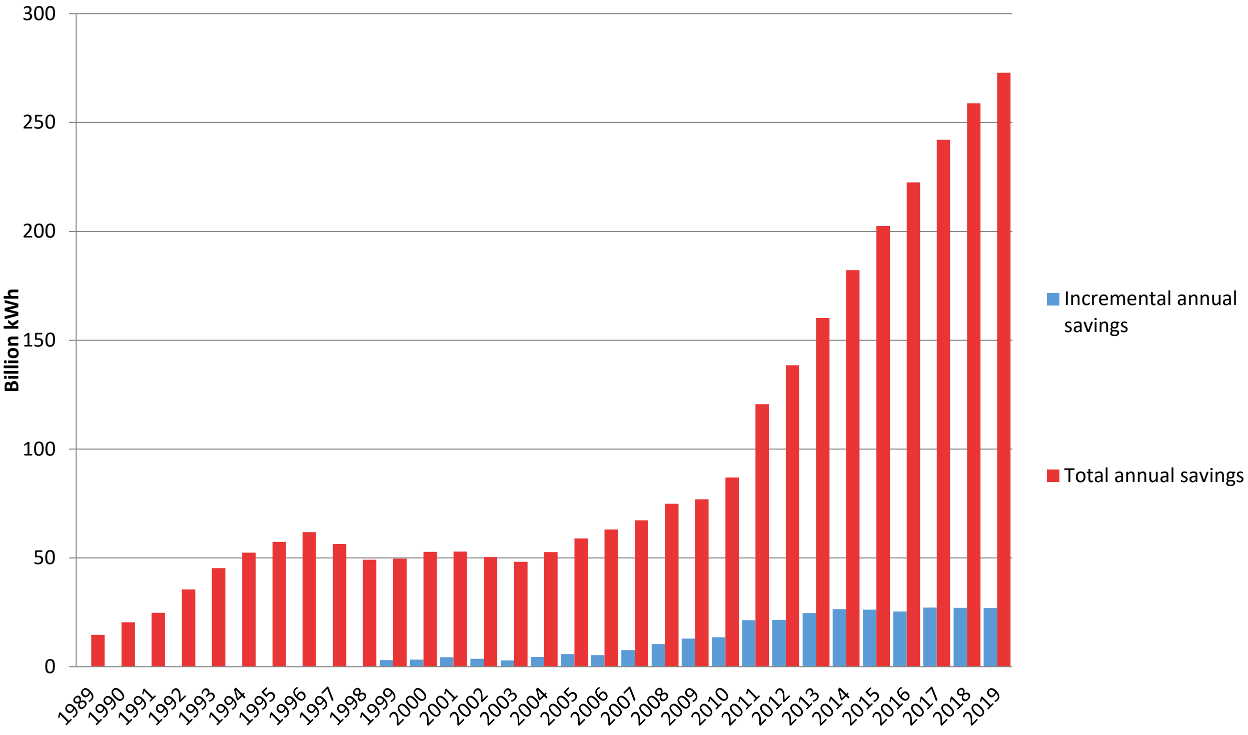

Figure 3. Electric savings from utility-sector energy efficiency programs, by year

Regional Highlights from State Utility Policies and Programs

Though COVID-19 hampered efforts in many states to enact clean energy rules and legislation, there remained numerous examples of important utility reforms advanced or achieved by lawmakers and regulators amid the pandemic.

NORTHEAST

Home to many of the *Scorecard*'s leading states, the Northeast continued to see progress in advancing efficiency in the utility sector. In New Jersey, following months of work by stakeholders, the utilities commission, and staff, the Board of Public Utilities produced an order in June setting ambitious goals to ramp up annual savings to 2.15% of electric use and 1.1% of gas use; these exceed even the respective 2% and 0.75% electric and gas goals initially called for in the state's 2018 Clean Energy Act. The order also transitions the utilities to a more central role in program delivery, establishes a performance-based recovery mechanism to encourage utilities to maximize customer savings, and strengthens stakeholder engagement processes with an added focus on equity and workforce development, all signaling a new era for efficiency in New Jersey.

In January the New York Public Service Commission also issued a major new efficiency order. It calls for the achievement of 185 TBtus of savings by 2025 per the state's Climate Leadership and Community Protection Act (CLCPA), translating to nation-leading annual goals of 3% electric savings and 1.3% natural gas savings. The order also includes a 3.6 TBtu carve-out target for savings from heat pumps, alongside a $454 million combined budget with $30 million set aside for low-to-moderate-income heat pump adoption. Shortly afterward, Con Edison announced a $1.5 billion initiative tripling efficiency investments in 2025 with a focus on heat pump deployment.

There is a growing movement among a number of states to better integrate fuel switching and electrification within efficiency portfolios, and Massachusetts continued to pursue policy designs at the leading edge of this trend. In the Bay State these efforts have been spurred in part by 2018 legislation redefining energy efficiency to include strategic electrification, aligning with the state's decarbonization goals. The current 2019–2021 efficiency plan now reflects a more holistic approach to measuring overall energy use, including an all-fuel efficiency savings metric in MMBtu with a focus on fuel switching. In March 2020, a study was completed to refine the methodology for calculating all-fuel energy savings; this will likely be further reviewed as part of the 2022–2024 planning process (Molina et al. 2020). Later in the year, the state also instituted a first-of-its-kind Clean Peak Energy Standard that provides incentives to promote the use of clean energy during periods of peak electricity demand.

MIDWEST

As across much of the United States, legislative sessions in the Midwest convened on a limited basis during 2020. While lawmakers in Illinois and Minnesota sought to advance significant clean energy bills early in the year, these efforts stalled amid competing legislative priorities, though efforts are ongoing for revival in future sessions. These included proposed bills in Minnesota that would transition the state to carbon-free electricity by 2050, raise efficiency targets, and expand efficiency portfolios to allow the inclusion of beneficial electrification and load management measures. Similarly, in Illinois, the proposed Clean Energy Jobs Act would greatly expand efficiency programs and standards across the state and set a strengthened goal of 100% renewable energy by 2050. Though the bill was not called to a vote in earlier legislative sessions, in August the governor announced plans to restart working group discussions with an eye toward potentially adopting the legislation later in the year.

Promising efforts were also underway in Michigan, where the governor and Public Service Commission launched MI Power Grid in October 2019. The multiyear stakeholder initiative will undertake work on new technologies, pilots, and utility businesses models in order to optimize the transition to a clean energy grid (State of Michigan 2019). In addition, state energy reforms passed in 2016 continue to push Michigan's regulated utilities to strengthen long-term planning, with an emphasis on clean energy and efficiency. Both major utilities, Consumers Energy and DTE, recently adopted integrated resource plans scaling up efficiency savings to 2% of annual electricity sales by 2021, far exceeding the 1% minimum statutory savings goals.

SOUTHEAST

A major victory for efficiency in the Southeast came out of Virginia this year, where lawmakers passed the Virginia Clean Economy Act. In addition to putting the state on a path to 100% clean electricity, the bill establishes the state's first-ever energy efficiency resource standard, making it one of only two states in the region, alongside Arkansas, with a mandatory EERS. Virginia's EERS stipulates that by 2025, Dominion must achieve at least 5% energy efficiency savings and that Appalachian Power Company must reach 2% savings. This translates to an average statewide incremental annual goal of 1.2% savings each year. The bill also sets up a process to strengthen the EERS after 2025, with the State Corporation Commission adjusting savings targets every three years thereafter. Importantly, utilities will have to prove they are achieving those targets before they are permitted to build new fossil fuel plants.

While state commitments to ramp up clean energy have been less of a priority across the rest of the Southeast region, some utilities, such as Dominion Energy, Duke Energy, and Southern Company, have stepped up recently to announce net-zero carbon emissions goals to be achieved by midcentury. These pledges, while a positive sign, will need to be matched by tangible long-term resource planning decisions that phase out fossil fuels and shift toward renewable sources in the very near future. In September Duke filed its integrated resource plan (IRP) for the next 15 years in the Carolinas. It shows a promising increased emphasis on efficiency as part of its pathway to net zero, although much uncertainty remains (Duke Energy 2020).

WEST

In a year of record-breaking wildfires, California's 100% zero-carbon electricity goals took on added urgency as regulators looked for ways to accelerate action. In late 2019, months after the state PUC's issuance of updated 10-year utility savings targets, the California Energy Commission released its *2019 California Energy Efficiency Action Plan*, charting progress toward statewide SB 350 goals to double efficiency by 2030 (Kenney, Bird, and Rosales 2019). While the CEC currently anticipates a shortfall in meeting ambitious 2030 targets due to a variety of factors, it also makes supplemental recommendations for increasing program participation and stimulating new market activity. These recommendations include expanding funding beyond ratepayer portfolios, strengthening collection and sharing of energy data, and better understanding and incorporating demand flexibility into building and appliance standards, to name just a few.

In Colorado, following a wave of important clean energy legislation signed in 2019—including a 90% economy-wide GHG reduction goal—the state PUC got to work on related legislated calls to reform utility distribution system planning and business models. These efforts have included an investigation into a performance-based regulation (PBR) model to potentially include performance metrics and corresponding financial incentives aligned with public benefits goals like safety, cost efficiency, and emissions reductions (Colorado Energy Office 2019). The PUC plans to submit a report on its findings and recommendations to the legislature in November 2020.

Other states pursuing new PBR frameworks to better align utility investments with state energy goals include Hawaii and Nevada. The Hawaii PUC concluded Phase 1 of its PBR proceeding in 2019 by issuing an order establishing a new utility regulatory framework; Phase 2, focusing on development of revenue adjustment mechanisms and performance incentives, is expected to produce a PUC order by the end of 2020 (Hawaii PUC 2019). Similarly, Nevada took important steps to implement SB 300, signed in 2019, which requires the utilities commission to adopt regulations enabling utilities to seek approval of alternative ratemaking plans intended to promote renewable energy, energy efficiency, and other flexible grid resources. During the summer the commission issued a series of concept papers building toward a framework for development of goals and outcomes and outlining future work to be undertaken by stakeholders (State of Nevada Public Utilities Commission 2020).

In Arizona, the state Corporation Commission (ACC) laid the groundwork this year for a new clean energy future with a 4–1 vote approving a 100% carbon-free electricity standard. It was also a pivotal year for energy efficiency, with the ACC approving a new demand-side management (DSM) plan for the Arizona Public Service Company (APS) that restores funding for a number of energy efficiency programs. In addition, the new carbon-free standard approved in November includes an important extension and expansion of the state's existing EERS—which was scheduled to expire this year—ushering in a new era of utility energy savings programs. The vote kicks off a rulemaking and hearing process and will require a final vote by the new commission next year. The coming months will be critical as the utilities and regulators determine which direction to take in the next iteration of efficiency programs.

Savings from Electricity and Natural Gas Efficiency Programs

We assess the overall performance of electricity and natural gas energy efficiency programs by the amount of energy saved. Utilities and nonutility program administrators pursue numerous strategies to achieve energy efficiency savings. Program portfolios may initially concentrate on the most cost-effective and easily accessible measure types, such as energy-efficient lighting and appliances. As utilities gain experience, as technologies mature, and as customers become aware of the benefits of energy efficiency, the number of approaches increases. Utilities estimate program energy savings, which are then subject to internal or third-party evaluation, measurement, and verification (EM&V) and are typically reported to the public utility commission on a semiannual or annual basis.

In states ramping up funding in response to aggressive EERS policies, programs typically shift focus from widget-based approaches (e.g., installing new, more efficient water heaters) to comprehensive deep-savings strategies that seek to generate greater energy efficiency savings per program participant by conducting whole-building or system retrofits. Some deep-savings approaches also draw on complementary efficiency efforts, such as utility support for full implementation of building energy codes (Nowak et al. 2011; Misuriello et al. 2012). Deep-savings approaches may also promote grid-interactive efficient buildings (GEBs) and comprehensive changes in systems and operations by including behavioral elements that empower customers.

We should note that while we consider electric and natural gas savings separately for the purposes of this report, our research has found that a handful of states—particularly those with aggressive clean energy and GHG reduction goals—have begun considering savings on a combined fuel-neutral basis. Such an approach allows states the flexibility to better account for savings from resources with competing profiles. For instance, switching homes from fossil fuel heating to electric air-source heat pumps may increase electric demand, but it will also reduce overall energy use on a total Btu basis and lower GHG emissions in regions with a relatively high penetration of renewable energy resources. This approach to accounting is still in its infancy, but as more states prioritize beneficial electrification as a decarbonization strategy, we expect to see this practice become more commonplace and will adjust our *Scorecard* methodology as appropriate.[26]

SCORES FOR INCREMENTAL SAVINGS IN 2019 FROM ELECTRIC EFFICIENCY PROGRAMS

We report 2019 statewide net energy efficiency savings as a percentage of 2018 retail electricity sales, scoring the states on a scale of 0 to 7. We relied primarily on states to provide these data. Thirty-five states and the District of Columbia completed some or all of our data request form. Where no data for 2019 were available, we used the most recent savings data obtainable, either state-reported 2018 savings from the *2019 State Scorecard* or information from the EIA (2020b).

As we have since 2015, we awarded full points to states that achieved savings of at least 2% of electricity sales. We continue to see examples of states exceeding the 2% mark. Table 7 lists the scoring for each level of savings.

Table 7. Scoring of utility and public benefits electricity savings

2019 savings as % of sales	Score
2% or greater	7
1.86–1.99%	6.5
1.72–1.85%	6
1.58–1.71%	5.5
1.44–1.57%	5
1.30–1.43%	4.5
1.16–1.29%	4
1.02–1.15%	3.5
0.88–1.01%	3
0.74–0.87%	2.5
0.60–0.73%	2
0.46–0.59%	1.5
0.32–0.45%	1
0.18–0.31%	0.5
Less than 0.18%	0

Table 8 shows state results and scores. Nationwide reported savings from utility and public benefits electricity programs in 2019 totaled 26.92 million MWh, equivalent to 0.70% of sales.

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[26] Among the states currently measuring savings on a total MMBtu basis are Massachusetts, Wisconsin, and New York, although no states have yet to abandon fuel-specific electric and natural gas goals for an exclusively fuel-neutral goal.

This is approximately 0.8% less than the 27.13 million MWh (0.73% of sales) reported last year.

Table 8. 2019 net incremental electricity savings by state

State	2019 net incremental savings (MWh)	% of 2018 retail sales	Score (7 pts.)
Rhode Island	190,159	2.51%	7
Massachusetts	1,199,409	2.25%	7
Maryland	1,327,930	2.14%	7
Vermont	117,289	2.12%	7
California†	4,447,063	1.74%	6
Illinois	2,061,135	1.44%	5
Michigan	1,474,105	1.41%	4.5
New York	1,939,971	1.29%	4
District of Columbia	139,560	1.23%	4
Connecticut	349,772	1.21%	4
Hawaii†	110,774	1.19%	4
Minnesota†	729,734	1.06%	3.5
Oregon†	523,590	1.06%	3.5
Maine†	127,786	1.03%	3.5
Washington†*	880,976	0.98%	3
Arizona†*	763,855	0.97%	3
Colorado†‡	535,056	0.95%	3
Ohio†*	1,447,594	0.95%	3
New Hampshire†*	103,111	0.93%	3
Idaho†	210,216	0.88%	3
Nevada†	277,469	0.73%	2
Pennsylvania	1,068,377	0.72%	2
Iowa†‡	360,095	0.70%	2
Utah	201,850	0.65%	2
North Carolina	890,940	0.64%	2
Wisconsin	455,118	0.64%	2
Missouri†*	515,242	0.63%	2
Arkansas	311,006	0.63%	2
Indiana†*	650,482	0.62%	2
New Jersey†	469,560	0.62%	2
New Mexico	134,209	0.56%	1.5
Montana†	82,161	0.55%	1.5
South Carolina†*	426,283	0.52%	1.5
Oklahoma*	288,417	0.45%	1
Nebraska†‡	74,428	0.24%	0.5
South Dakota†	30,359	0.24%	0.5
Georgia†	322,918	0.23%	0.5
Wyoming†	38,484	0.23%	0.5
Texas†	826,884	0.19%	0.5
Delaware	22,447	0.19%	0.5
Kentucky†*	135,912	0.18%	0.5
Mississippi	79,460	0.16%	0
West Virginia	52,221	0.16%	0
Louisiana†‡	118,281	0.13%	0
Virginia†*	133,322	0.11%	0
Florida†	251,346	0.11%	0
Tennessee	16,727	0.02%	0
North Dakota†	3,002	0.01%	0
Alabama†*	8,647	0.01%	0
Alaska†*	247	0.00%	0
Kansas†*	265	0.00%	0
U.S. total	**26,925,246**	**0.70%**	
Median	**277,469**	**0.64%**	

Savings data are from public service commission staff as listed in Appendix A, unless noted otherwise. Sales data are from EIA Form 861 (2020b).
* For states where we were unable to obtain savings data from commission staff, we relied on 2019 adjusted gross savings data from EIA-861 (2020). † At least a portion of savings were reported as gross. We adjusted the gross portion by a net-to-gross factor of 0.825 to make it comparable to net savings figures reported by other states. ‡ Includes both state-reported IOU data and some portion of EIA-reported savings for municipal utilities and co-ops.

States use different methodologies for estimating energy savings, and this can produce inequities when making comparisons (Sciortino et al. 2011). A state's EM&V process plays a key role in determining how savings are quantified. This is particularly true of a state's treatment of free ridership (savings attributed to a program that would have occurred even in the absence of the program) and spillover (savings *not* attributed to a program that would *not* have occurred without it). States report energy savings as either net or gross, with net savings accounting for free riders and free drivers, and gross savings not accounting for these.[27] The *State Scorecard* specifically focuses on net savings.

In a national survey of evaluation practices, ACEEE researchers found that, of the 42 states responding, 8 reported gross savings, 16 reported net, and 18 reported both (York, Cohn, Kushler 2020). This finding points to several important caveats regarding the electric program savings data. A number of states do not estimate or report net savings. In these cases, we applied a standard factor of 0.825 to convert gross savings to net savings (a net-to-gross ratio).[28] Doing so allows a more straightforward comparison with states that report net electricity savings. It also should be noted that different states and utilities may define net savings in different ways and adopt different calculation methods.

SCORES FOR INCREMENTAL SAVINGS IN 2019 FROM NATURAL GAS AND UNREGULATED FUELS EFFICIENCY PROGRAMS

Utilities are increasing the number and size of natural gas programs in their portfolios. However, data on savings resulting from these programs are still limited. In this category we awarded points to states that were able to track savings from their natural gas and unregulated fuels efficiency programs and realized savings of at least 0.17% of sales in the residential and commercial sectors. We relied on data from state utility commissions. Table 9 lists scoring criteria for natural gas and unregulated fuels program savings. We awarded a maximum of 3 points to states reporting savings of at least 1.00% of sales.

Consistent with the methodology we adopted in 2018 for tracking heating fuel efficiency, we combined natural gas data with data for consumption and savings associated with the most widely used unregulated fuels into a single thermal fuels energy savings metric. This approach is a consistent way to measure energy efficiency efforts and performance across states with different fuel mixes and policies. Previously, direct comparison of natural gas savings as a percentage of sales across states was complicated by the varying percentage of customers with access to natural gas, incomplete data on unregulated fuels, and varying levels of energy efficiency program funding based on regulated energy sources. These issues are most common in the Northeast, where some states have a larger share of residential and commercial customers using fuel oil and other unregulated fuels for heating.

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[27] Free drivers are utility customers who install energy efficiency measures as a result of a program but are not themselves participants in the energy efficiency program.

[28] We based the 0.825 net-to-gross factor used this year on the median net-to-gross ratio calculated from those jurisdictions that reported figures for both net and gross savings in this year's data request. These were Colorado, Connecticut, Delaware, District of Columbia, Illinois, Maryland, Missouri, Montana, Nevada, New York, North Carolina, Pennsylvania, Oklahoma, Oregon, Tennessee, Utah, West Virginia, and Wisconsin. We applied this conversion factor to all states reporting only gross savings. We determined savings to be gross on the basis of responses to our survey of public utility commissions.

To integrate unregulated fuels, we collected 2019 savings data on fuel oil, kerosene, propane, and wood from public service commissions and added these to the natural gas savings reported for each state. Similarly, we obtained consumption data by state for each fuel type from the EIA and combined this with natural gas energy sales for residential and commercial customers. We converted all energy units to MMBtus and divided savings by sales to create the common metric.

Table 9. Scoring of natural gas and unregulated fuel program savings

Savings as % of sales	Score
1.00% or greater	3
0.84–0.99%	2.5
0.67–0.83%	2.0
0.50–0.66%	1.5
0.34–0.49%	1
0.17–0.33%	0.5
Less than 0.17%	0

Table 10 shows states’ scores for natural gas and unregulated fuel program savings.[29]

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[29] As we did with electric savings, we applied a net-to-gross (NTG) factor to all states reporting only gross natural gas savings. In this case, the NTG factor was 0.846 based on states that reported figures for both net and gross natural gas savings in this year’s data request. These were Connecticut, Delaware, District of Columbia, Maryland, Massachusetts, Montana, Oklahoma, Oregon, Pennsylvania, and Wisconsin.

Table 10. State scores for 2019 natural gas and fuel efficiency program savings

State	2019 net incremental fuel savings (MMBtu)*	% of commercial and residential retail sales**	Score (3 pts.)
California	8,330,145	1.05%	3
Massachusetts†	3,364,493	0.91%	2.5
Rhode Island†	503,186	0.91%	2.5
Michigan	5,731,629	0.90%	2.5
Minnesota	2,832,660	0.84%	2.5
Utah	960,000	0.76%	2
District of Columbia	239,000	0.72%	2
Hawaii**	—	—	2
Illinois	4,330,000	0.58%	1.5
Wisconsin	1,829,486	0.55%	1.5
New York†	5,725,989	0.53%	1.5
Oregon	590,418	0.51%	1.5
Arkansas	560,000	0.50%	1.5
Arizona*	344,501	0.40%	1
Colorado	849,314	0.38%	1
Connecticut†	701,650	0.35%	1
Vermont†	195,036	0.34%	1
Maryland	686,791	0.33%	0.5
New Hampshire†*	255,487	0.30%	0.5
Maine†	297,040	0.30%	0.5
Iowa	477,761	0.28%	0.5
Oklahoma	370,000	0.27%	0.5
Delaware	98,788	0.27%	0.5
Indiana*	718,893	0.26%	0.5
Washington*	507,600	0.25%	0.5
New Jersey	1,137,484	0.24%	0.5
Mississippi	110,868	0.19%	0.5
New Mexico	150,000	0.18%	0.5
North Carolina	160,000	0.08%	0
Idaho	44,900	0.06%	0
South Dakota	22,830	0.06%	0
Florida	64,947	0.06%	0
Montana	43,708	0.06%	0
Pennsylvania	226,060	0.04%	0
Alabama	—	0.00%	0
Alaska	—	0.00%	0
Georgia	—	0.00%	0
Kansas	—	0.00%	0
Kentucky	—	0.00%	0
Louisiana	—	0.00%	0
Missouri	—	0.00%	0
Nebraska	—	0.00%	0
Nevada	—	0.00%	0
North Dakota	—	0.00%	0
Ohio	—	0.00%	0
South Carolina	—	0.00%	0
Tennessee	—	0.00%	0
Texas	—	0.00%	0
Virginia	—	0.00%	0
West Virginia	—	0.00%	0
Wyoming	—	0.00%	0
U.S. total	**42,460,661**	**0.38%**	
Median	**160,000**	**0.19%**	

Savings data were reported by contacts at public utility commissions as listed in Appendix A, unless otherwise noted. All sales data are from EIA Form 176 (EIA 2020d) and EIA's State Energy Data System (SEDS) (EIA 2019e). * States for which we did not have 2019 savings data were scored on 2018 state-reported savings. ** Hawaii uses very limited natural gas and therefore earned points commensurate with its electric efficiency savings scores. † At least a portion of natural gas savings were reported as gross; we adjusted the gross portion by a net-to-gross factor of 0.846 to make it comparable to net savings figures reported by other states. ‡ These states reported some level of unregulated fuel savings.

Electricity and Natural Gas Efficiency Program Funding

In this category, we scored states on 2019 electricity and natural gas efficiency program spending for customer-funded energy efficiency programs. These programs are funded through charges included on utility customers' bills.[30] Our data include spending by investor-owned, municipal, and cooperative utilities; public power companies or authorities; and public benefits program administrators. We did not collect data on federal grant allocations received by states through DOE's Weatherization Assistance Program. We did include revenues from the Regional Greenhouse Gas Initiative (RGGI), which contributes to customer-funded energy efficiency program portfolios of member states and to energy efficiency programs funded through AB 32 and Proposition 39 in California.[31] Where RGGI funds were channeled to energy efficiency initiatives implemented by state governments, we included them in Chapter 6, "State Government–Led Initiatives."

For states that did not provide data for 2019 spending on energy efficiency programs for electric or natural gas utilities, we used expenditure data from EIA-861 or information supplied by our state contacts in their 2018 utility data request responses.

Spending data are subject to variation across states, and this poses an ongoing challenge to our efforts to equitably score states based on a common and reliable metric. Several states report performance incentives paid to utilities or other program administrators as part of utility efficiency program spending, resulting in higher spending numbers. While most performance incentives are based on shared net benefits—viewed as an expense—the relative amounts of the incentives are in the range of 5–15% of program spending (Nowak et al. 2015). For this reason, we asked states to disaggregate program spending from these incentives. We did not credit this spending in our scoring in an effort to more accurately reflect funds directly dedicated to energy efficiency measures. As in past years, we sent spending data gathered from the above sources to state utility commissions for review. Tables 12 and 14 below report electricity and natural gas efficiency program spending, respectively.

SCORES FOR ELECTRIC PROGRAM SPENDING

States could receive up to 2.5 points for their energy efficiency spending as a percentage of 2018 electric utility revenues, with the threshold for the maximum achievable points set at 5.0% of revenues.[32] For every 1.05 percentage points less than 5%, a state's score decreased by 0.5 points. Table 11 lists the scoring bins for each spending level.

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[30] Some of these programs target unregulated fuels or are fuel-blind to household heating sources. Spending for this type of program is typically captured in our electric efficiency spending metric.

[31] AB 32 is California's GHG reduction bill that resulted in a cap-and-trade program. Proposition 39 grants significant funding to energy efficiency programs targeting schools. Both programs are subject to evaluation, measurement, and verification at least as stringent as the EM&V for utility programs.

[32] Statewide revenues are from EIA Form 861 (EIA 2020b). We measure spending as a percentage of revenues to normalize the level of energy efficiency spending. Blending utility revenues from all customer classes gives a more accurate measure of utilities' overall spending on energy efficiency than does expressing budgets per capita, which might skew the data for utilities that have a few very large customers. Statewide electric energy efficiency spending per capita is presented in Appendix B.

Table 11. Scoring of electric efficiency program spending

2019 spending as % of revenues	Score
5.00% or greater	2.5
3.95–4.99%	2
2.90–3.94%	1.5
1.85–2.89%	1
0.80–1.84%	0.5
Less than 0.80%	0

Table 12 shows state-by-state results and scores for this category.

Table 12. 2019 electric efficiency program spending by state

State	2019 elec. spending ($ million)	% of statewide elec. revenues	Score (2.5 pts.)
Rhode Island	104.1	7.58%	2.5
Vermont	55.2	6.59%	2.5
Massachusetts	620.4	6.29%	2.5
Maryland	275.6	3.84%	1.5
Oregon	161.5	3.70%	1.5
California	1516.4	3.58%	1.5
Illinois	433.8	3.17%	1.5
Idaho	61.4	3.16%	1.5
Connecticut	161.4	3.04%	1.5
New York	645.2	2.90%	1.5
Maine	45.9	2.76%	1
Washington*	190.7	2.65%	1
New Hampshire*	48.6	2.59%	1
Minnesota	157.0	2.20%	1
Michigan	250.7	2.10%	1
Colorado	108.0	1.91%	1
Utah	47.1	1.84%	0.5
Arkansas	68.0	1.76%	0.5
Iowa*	75.6	1.65%	0.5
Hawaii	42.0	1.54%	0.5
Delaware	17.9	1.44%	0.5
New Mexico	31.7	1.41%	0.5
Nevada	45.3	1.38%	0.5
Oklahoma	68.6	1.31%	0.5
Pennsylvania	197.5	1.31%	0.5
New Jersey	123.0	1.22%	0.5
Ohio*	175.0	1.15%	0.5
North Carolina	145.8	1.14%	0.5
District of Columbia	15.4	1.13%	0.5
Montana	14.4	1.09%	0.5
Indiana*	107.3	1.06%	0.5
Missouri	85.8	1.05%	0.5
Wisconsin	79.0	1.05%	0.5
Arizona*	86.2	1.01%	0.5
South Carolina*	64.0	0.81%	0.5
Wyoming	10.2	0.75%	0
Texas	196.2	0.55%	0
Florida	105.4	0.43%	0
Georgia	57.0	0.42%	0
Kentucky*	27.2	0.42%	0
Mississippi	17.1	0.37%	0
South Dakota	4.7	0.37%	0
Louisiana	24.6	0.34%	0
Virginia*	31.7	0.28%	0
West Virginia	7.6	0.26%	0
Nebraska	7.1	0.25%	0
Tennessee	19.2	0.19%	0
Alabama*	7.7	0.09%	0
North Dakota*	0.2	0.01%	0
Kansas*	0.3	0.01%	0
Alaska*	0.0	0.00%	0
U.S. total	**6,841.6**	**1.68%**	
Median	**64.0**	**1.22%**	

2018 statewide revenues are from EIA Form 861 (EIA 2020b). Spending data are from public service commission staff as listed in Appendix A.
* Where 2019 spending was not available from states, we substituted 2019 spending as reported by EIA-861 (EIA 2020d).

SCORES FOR NATURAL GAS PROGRAM SPENDING

We scored states on natural gas efficiency program spending by awarding up to 1.5 points based on 2019 program spending data gathered from a survey of state utility commissions and independent statewide administrators. To directly compare spending data among the states, we normalized spending by the number of residential natural gas customers in each state in 2018, as reported by EIA (2020e).[33] Table 13 shows scoring bins for natural gas program spending. As in last year's *State Scorecard*, states posting spending of at least $50 per customer were awarded the maximum number of points.

Table 13. Scoring of natural gas utility and public benefits spending

2019 gas spending per customer	Score
$50 or greater	1.5
$27.50–49.99	1
$5.00–27.49	0.5
Less than $5.00	0

After a significant uptick in 2014, natural gas program spending levels have remained relatively flat in recent years. In 2019, spending totaled $1.5 billion, comparable to 2018 levels. Natural gas efficiency spending remains significantly lower than spending for electricity energy efficiency programs. Table 14 shows states' scores.

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[33] We used spending per residential customer for natural gas because reliable natural gas revenue data are sparse, and use of per capita data unfairly penalizes states that offer natural gas service to only a portion of their population (such as Vermont). State data on the number of residential customers are from EIA (2020e).

Table 14. 2019 natural gas efficiency program spending by state

State	2019 gas spending ($ million)	$ per 2018 residential customer	Score (1.5 pts.)
Massachusetts	279.5	$182.35	1.5
Rhode Island	30.1	$123.59	1.5
Connecticut	44.9	$80.58	1.5
New Hampshire*	7.9	$73.20	1.5
Vermont	3.1	$66.85	1.5
Minnesota	65.7	$42.56	1
New York	177.4	$39.22	1
Oregon	28.7	$38.14	1
Maine	1.3	$37.28	1
Florida	26.7	$35.14	1
California	385.5	$34.96	1
Delaware	6.0	$33.87	1
New Jersey	89.5	$31.77	1
Michigan	96.0	$29.12	1
Arkansas	14.7	$26.51	0.5
Utah	23.6	$24.83	0.5
District of Columbia	3.8	$24.72	0.5
Washington*	27.3	$22.86	0.5
Iowa	20.1	$21.59	0.5
Illinois	75.9	$19.34	0.5
Oklahoma	16.6	$17.54	0.5
Wisconsin	20.0	$11.27	0.5
Colorado	20.0	$11.23	0.5
Idaho	4.3	$10.65	0.5
New Mexico	6.0	$10.12	0.5
Montana	2.4	$8.62	0.5
Indiana*	13.6	$7.77	0.5
Maryland	7.7	$6.67	0.5
Mississippi	2.3	$5.06	0.5
Arizona*	5.5	$4.35	0
Pennsylvania	11.4	$4.06	0
South Dakota	0.8	$4.04	0
Missouri	5.6	$3.97	0
North Carolina	2.0	$1.56	0
Nevada	1.2	$1.38	0
Alabama	0.0	$0.00	0
Alaska	0.0	$0.00	0
Georgia	0.0	$0.00	0
Hawaii**	0.0	$0.00	0.5
Kansas	0.0	$0.00	0
Kentucky	0.0	$0.00	0
Louisiana	0.0	$0.00	0
Nebraska	0.0	$0.00	0
North Dakota	0.0	$0.00	0
Ohio	0.0	$0.00	0
South Carolina	0.0	$0.00	0
Tennessee	0.0	$0.00	0
Texas	0.0	$0.00	0
Virginia	0.0	$0.00	0
West Virginia	0.0	$0.00	0
Wyoming	0.0	$0.00	0
U.S. total	**1,526.8**		
Median	**5.5**		

Spending data are from public service commission staff as listed in Appendix A, unless noted otherwise. * Where 2019 spending data were not available, we substituted 2018 spending as reported by public service commission staff. ** Hawaii was awarded points commensurate with points received for electricity spending.

Opt-Out Provisions for Large Customers

As we have since the *2014 State Scorecard*, we provide an assessment of opt-out and self-direct provisions for large customers. In many cases large customers seek to opt out of utility energy efficiency programs, asserting that they have already captured all the energy efficiency that is cost effective. However, this is seldom the case (Chittum 2011). Opt-out differs from self-direct in that customers who opt out do not have to pay into energy efficiency funds at all; self-direct allows some customers to spend their efficiency fees internally, within their own business operations. Some state policies go beyond opt-out to fully exempt customers from participating in utility energy efficiency programs. In these cases, the customers are excluded and may not opt in.

Opt-out and exemption policies have several negative consequences. Failure to include large-customer programs in an energy efficiency portfolio increases the cost of energy savings for all customers and reduces the benefits (Baatz, Relf, and Kelly 2017). In effect, allowing large customers to opt out forces other consumers to indirectly subsidize them: Those who have opted out share some of the system benefits, but only the smaller customers are paying to support energy efficiency programs. It also prevents utilities from capturing all highly cost-effective energy savings; this can contribute to higher overall system costs through the use of more expensive supply resources. While the ideal solution is for utilities to offer programs that respond to the needs of these large consumers, ACEEE's research suggests that this does not always happen (Chittum 2011). When it does not, we suggest giving these customers the option of self-directing their energy efficiency program dollars.[34] This option provides a path for including large-customer energy efficiency in the state's portfolio of savings. We provide examples of self-direct programs in Appendix C.

SCORES FOR LARGE-CUSTOMER OPT-OUT PROVISIONS

We include opt-out as a category in which states may lose rather than gain points. We subtracted 1 point for states that allow electric or natural gas customers, or both, to opt out of energy efficiency programs.[35]

We did not subtract points for self-direct programs. When implemented properly, these programs can effectively meet the needs of large customers. Self-direct programs vary from state to state, with some requiring more stringent measurement and verification of energy savings than others (Chittum 2011). In the future, we may examine these programs with a more critical eye and subtract points from states that lack strong evaluation and measurement. Table 15 shows states with opt-out programs.

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[34] Self-direct programs allow some customers, usually large industrial or commercial ones, to channel energy efficiency fees usually paid on utility bills directly into energy efficiency investments in their own facilities instead of into a broader, aggregated pool of funds. These programs should be designed to include comparable methods to verify and measure investments and energy savings. For more information, see aceee.org/sector/state-policy/toolkit/industrial-self-direct.

[35] By default, most large gas customers already are opted out because they take wholesale delivery (frequently directly from transmission) and are thus outside the purview of state government. We did not subtract points in these cases.

Table 15. States allowing large customers to opt out of energy efficiency programs

State	Opt-out description	Score
Arkansas	Under Act 253, passed in 2013, customers with more than 1 MW or 70,000 MMBtu in monthly demand may opt out. Large manufacturers that file under Act 253 do not have to offer documentation of planned or achieved savings. However, large commercial and industrial (C&I) customers not meeting the definition of manufacturing and customers that have filed under Section 11 of the state's Rules for Conservation and Energy Efficiency Programs must file an application showing how savings have been or will be achieved. More than 50 large customers have opted out, constituting a significant share of overall sales that varies by utility. In 2017, HB 1421 added state-supported higher-education institutions to the list of customers eligible to opt out.	–1
Illinois	Illinois specifically exempts large customers under recent electric savings targets passed in SB 2814. These exemptions remove an estimated 10% of ComEd's and 25% of Ameren's load from programs. The exemption weakens participation even more than an opt-out policy in that these electric utility customers cannot participate in programs even if they wish to. Under 220 ILCS 5 8-104(m) there was also a self-direct/opt-out for certain large natural gas customers. However, this sunsets in 2020 per 220 ILCS 5 8-104(n).	–1
Indiana	Opt-out applies to the five investor-owned electric utilities. Eligible customers are those that operate a single site with at least one meter constituting more than 1 MW demand for any one billing period within the previous 12 months. Documentation is not required. No evaluation is conducted. Approximately 70–80% of eligible load has opted out.	–1
Iowa	Iowa Code § 476.6(15)(a)(1)(b) allows any customer of any rate-regulated utility to request an exemption from participation in the five-year energy efficiency plan if the cumulative cost effectiveness of the combined energy efficiency and demand response plan does not pass the Ratepayer Impact Measure (RIM) test. This applies to all customers, not only large ones. Utilities must allow the exemption (opt-out) beginning in the year following the year in which the request was made. Utilities may request modifications of their energy efficiency plans due to reductions in funding resulting from customer exemptions.*	–1
Kentucky	Opt-out is statewide for the industrial rate class. Documentation is not required. Approximately 80% of eligible load has opted out, with the remaining 20% made up primarily of TVA customers.	–1
Missouri	Opt-out is statewide only for investor-owned electric utilities. Eligibility requires one account greater than 5 MW, or aggregate accounts greater than 2.5 MW and demonstration of the customer's own demand-side savings. Also, interstate pipeline pumping stations of any size are eligible to opt out. To maintain opt-out status, documentation is required for customers whose aggregate accounts are greater than 2.5 MW. The staff of the Missouri Public Service Commission perform a desk audit of all claimed savings and may perform a field audit. No additional EM&V is required.	–1
North Carolina	All industrial-class electric customers are eligible to opt out. Also, by Commission Rule R8-68 (d), large commercial-class operations with 1 million kWh of annual energy consumption are eligible to opt out. Customers electing to opt out must notify utilities that they have implemented or plan to implement energy efficiency. Opted-out load represents approximately 40–45% of industrial and large commercial load.	–1

State	Opt-out description	Score
Ohio	Ohio Senate Bill 310 (2014) allowed certain large customers to opt out of energy efficiency programs entirely if they receive service above the primary voltage level (e.g., sub-transmission and transmission rate schedules) or are a C&I with more than 45 million kWh usage per year. HB 6, signed in 2019, expanded the opt-out to include any C&I customer that uses more than 700 MWh annually or is part of a national account involving multiple facilities in one or more states. A written request is required to register as a self-assessing purchaser pursuant to section 5727.81 of the Revised Code.	–1
Oklahoma	All transportation-only gas customers are eligible to opt out. For electric utilities, all customers whose aggregate usage (which may include multiple accounts) is at least 15 million kWh annually may opt out. Some 90% of eligible customers opt out.	–1
South Carolina	Industrial, manufacturing, and retail commercial customers with at least 1 million kWh annual usage are eligible to opt out. Only self-certification is required. Approximately 50% of eligible companies opt out, representing roughly 50% of the eligible load.	–1
Texas	In Texas, for-profit customers that take electric service at the transmission level are not allowed to participate in utilities' energy efficiency programs and therefore do not contribute to them. Manufacturers that qualify for a tax exemption under Tax Code §151.317 may also apply to opt out for three years, and opt-out status can be renewed.	–1
Virginia	The Virginia Clean Economy Act (2020) replaces a previous automatic opt-out for industrial customers above 500 kW with a process enabling industrial customers using more than 1 MW to opt out after demonstrating that they are achieving energy savings through their own energy efficiency measures. The VCEA directs the commission, no later than June 30, 2021, "to adopt rules or regulations (a) establishing the process for large general service customers to apply for such an exemption, (b) establishing the administrative procedures by which eligible customers will notify the utility, and (c) defining the standard criteria that shall be satisfied by an applicant in order to notify the utility, including means of evaluation measurement and verification and confidentiality requirements."	–1
West Virginia	Opt-out is developed individually by utilities. Customers with demand of 1 MW or greater may opt out. Participants must document that they have achieved similar or equivalent savings on their own to retain opt-out status. Claims of energy and/or demand reduction are certified to utilities, with future evaluation by the Public Service Commission to take place in a later proceeding. The method has not been specified. Twenty large customers have opted out.	–1

Maine does not require large electricity customers to pay into energy efficiency programming through rates, and thus these customers are ineligible for incentives from Efficiency Maine Trust's Electric Efficiency Procurement funds. The 1-point penalty has been removed for Maine this year given that efficiency incentives for these customers are funded with Forward Capacity Market (FCM) revenues and RGGI funds. Until recently, Maine's largest natural gas customers were also exempt from contributing to the Natural Gas Efficiency Procurement. However, in the spring of 2017, the legislature amended the law codifying the inclusion of large, non-generator users.* The RIM test treats reduced energy sales as a cost, which means that the more energy a measure saves, the less cost effective it is. It is likely that the plans will not meet this impact measure, raising the possibility that many customers will opt out and thereby reduce efficiency funding by the amount they otherwise would have paid.

Energy Efficiency Resource Standards

Energy efficiency targets for utilities, often called EERS, are critical to encouraging savings over the near and long terms. States with an EERS policy in place have shown average energy efficiency spending and savings levels approximately four times as high as those in states without such a policy (ACEEE 2019). Savings from states with EERS policies in place accounted for approximately 80% of all utility savings reported across the United States in 2016 and 2017 (Gold et al. 2019). There are 27 states with EERS policies establishing specific energy savings targets that utilities and program administrators must meet through customer energy efficiency programs. This is one more than the 26 reported in the *2019 State Scorecard*, following the April 2020 signing of the Virginia Clean Economy Act, making the state the second in the Southeast—alongside Arkansas—with mandatory multiyear savings targets.

EERS policies set multiyear targets for electricity or natural gas savings, such as 1% or 2% incremental savings per year or 20% cumulative savings by 2025.[36] They differ from state to state, but each is intended to establish a sustainable, long-term role for energy efficiency in the state's overall energy portfolio. ACEEE considers a state to have an EERS if it has a policy in place that

- Sets clear, long-term (3+ years) targets for utility-sector energy savings
- Makes targets mandatory
- Includes sufficient funding for full implementation of programs necessary to meet targets

Several states mandate all cost-effective efficiency, requiring utilities and program administrators to determine and invest in the maximum amount of cost-effective efficiency feasible.[37] ACEEE considers states with such requirements to have EERS policies in place once these policies have met all the criteria listed above.

EERS policies aim explicitly for quantifiable energy savings, reinforcing the idea that energy efficiency is a utility system resource on par with supply-side resources. These standards help utility system planners more clearly anticipate and project the impact of energy efficiency programs on utility system loads and resource needs. Energy savings targets are generally set at levels that push efficiency program administrators to achieve higher savings than they otherwise would, with goals typically based on analysis of the energy efficiency savings potential in the state to ensure that the targets are realistic and achievable. EERS policies maintain strict requirements for cost effectiveness so that efficiency programs are guaranteed to provide overall benefits to customers. These standards help to ensure a long-term

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[36] *Multiyear* is defined as spanning three or more years. EERS policies may set specific targets as a percentage of sales, as specific gigawatt-hour energy savings targets without reference to sales in previous years, or as a percentage of load growth.

[37] The seven states that require all cost-effective efficiency are California, Connecticut, Maine, Massachusetts, Rhode Island, Vermont, and Washington. Connecticut sets budgets first, then achieves all cost-effective efficiency within that limit, which is a lower savings target. New Hampshire's EERS sets forth a long-term goal of achieving all cost-effective efficiency, which is anticipated to be met through planning and goal-setting in future implementation cycles.

commitment to energy efficiency as a resource, building essential customer engagement as well as the workforce and market infrastructure necessary to sustain the high savings levels.[38]

States are increasingly seeking strategies to meet GHG reduction goals, for example through grid decarbonization and the electrification of buildings and vehicles. These efforts bring opportunities to adapt EERS policies to encourage resource-specific savings while also promoting technologies that may increase grid demand but result in net reductions in emissions. Redesigning goals and establishing new targets can help meet multiple policy objectives in these cases. Examples include establishing peak demand targets and fuel-neutral goals. These remove prohibitions on fuel switching to provide more flexibility and enable energy efficiency from beneficial electrification.

SCORES FOR ENERGY EFFICIENCY RESOURCE STANDARDS

A state could earn up to 3 points for its EERS policy. As table 16 shows, we scored states according to their electricity savings targets. States could earn an additional 0.5 points if natural gas was included in their savings goals.

Some EERS policies contain cost caps that limit spending, thereby reducing the policy's effectiveness. This year, we did not subtract points for the existence of a cost cap, although we do note whether a cost cap is in place in the results below (table 17). Most of the states with these policies in place have found themselves constrained. As a result, regulators have approved lower energy savings targets. In these cases, we score states on the lower savings targets approved by regulators that take the cost cap into account, rather than on the higher legislative targets.

In an effort to distinguish states pushing the boundaries of innovation in energy efficiency with ambitious goals, in 2017 we raised the threshold for the highest number of points to energy savings targets of 2.5% of sales or greater. Multiple states have proved that long-term savings of more than 2% are feasible and cost effective.

Table 16. Scoring of energy savings targets

Electricity savings target	Score
2.5% or greater	2.5
2–2.49%	2
1.5–1.99%	1.5
1–1.49%	1
0.5–0.99%	0.5
Less than 0.5%	0

Additional consideration	Score
EERS includes natural gas	+0.5

To aid in comparing states, we estimated an average annual savings target over the period specified in the policy. For example, in a June 2020 order New Jersey's Board of Public

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[38] The ACEEE report *Next-Generation Energy Efficiency Standards* analyzed current trends in EERS implementation and found that utilities in 20 out of the 25 states examined met or exceeded their savings targets in 2017 (Gold et al. 2019).

Utilities called for electric savings targets of 1.1% beginning in 2022 and ramping up to 1.45%, 1.8%, and 2.15% in each subsequent year, translating to an average incremental savings target of 1.6% over that time span.

States with pending targets had to be on a clear path toward establishing a binding mechanism to earn points in this category. Examples of a clear path include draft decisions by commissions awaiting approval within six months and agreements among major stakeholders on targets.

Leadership, sustainable funding sources, and institutional support are required for states to achieve their long-term energy savings targets. Several states currently have (or in the past have had) EERS-like structures in place but have lacked one or more of these enabling elements and thus have undercut the achievement of their savings goals. Florida, for example, sets relatively low voluntary goals and does not earn points in this category.[39] Most states with EERS policies or other energy savings targets have met their goals and are on track to meet future goals (Gold et al. 2019).

At the same time, some states, such as Maine, have fallen short of EERS targets. We have scored these states on the basis of their policies, not on current performance, because they are losing points in other metrics such as spending and savings. We may change our scoring methodology in the future to reduce points allocated if a state does not hit savings targets.

EERS policies can vary widely with regard to the portion of statewide sales that they regulate. In several states, such as Colorado and New Mexico, an EERS may apply only to investor-owned utilities, meaning that smaller municipal utilities and electric cooperatives are exempt from meeting savings targets. While our scoring does not currently account for this variation in EERS coverage, we may revise our methodology to do so in the future. Table 17 lists scores, and Appendix D includes full policy details.

Table 17. State scores for energy efficiency resource standards

State	% of sales covered within EERS policy	Approximate average annual electric savings target for 2020–2025	Cost cap	Natural gas	Score (3 pts.)
Massachusetts	85%	2.7%		•	3
Rhode Island	99%	2.5%		•	3
Vermont	98%	2.4%		•	2.5
Arizona†	56%	2.1%		•	2.5
New York†	100%	2.0%		•	2.5
Illinois	89%	2.0%	•	•	2.5
Colorado	56%	1.7%		•	2

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[39] In 2014 Florida utilities proposed reducing electric efficiency efforts from 2010 levels by at least 80%. The Florida Public Service Commission approved this proposal.

State	% of sales covered within EERS policy	Approximate average annual electric savings target for 2020–2025	Cost cap	Natural gas	Score (3 pts.)
New Jersey	100%	1.6%		•	2
Maryland†	97%	1.6%			1.5
California†	73%	1.4%		•	1.5
New Hampshire	100%	1.3%		•	1.5
Arkansas	50%	1.2%		•	1.5
Minnesota†	97%	1.2%		•	1.5
Oregon†	61%	1.2%		•	1.5
Connecticut	93%	1.1%		•	1.5
Maine†	100%	1.0%		•	1.5
Michigan	100%	1.0%		•	1.5
Hawaii	100%	1.4%			1
Virginia	87%	1.2%			1
Nevada	88%	1.1%			1
New Mexico	69%	1.0%			1
Iowa†	75%	0.9%	•	•	1
Washington†	83%	0.9%		•	1
Wisconsin	100%	0.7%	•	•	1
Pennsylvania	96%	0.6%	•		0.5
North Carolina	100%	0.4%			0
Texas†	74%	0.2%	•		0

States with voluntary targets are not listed in this table. Targets in states with cost caps reflect the most recent approved savings levels under budget constraints. See Appendix D for details and sources.

Utility Business Model and Energy Efficiency: Earning a Return and Fixed-Cost Recovery

Under traditional regulatory structures, utilities do not have an economic incentive to promote energy efficiency. They typically have a disincentive because falling energy sales from energy efficiency programs reduce utilities' revenues and profits—an effect referred to as *lost revenues* or *lost sales*. Because utilities' earnings are usually based on the total amount of capital invested in certain asset categories—such as transmission and distribution infrastructure and power plants—and the amount of electricity sold, the financial incentives are very much tilted in favor of increased electricity sales and expanding supply-side systems.

This dynamic has led industry experts to devise ways of addressing the possible loss of earnings and profit from customer energy efficiency programs and thereby removing utilities' financial disincentive to promote energy efficiency. Three key policy approaches properly align utility incentives and remove barriers to energy efficiency. The first is to ensure that utilities can recover the direct costs associated with implementing energy efficiency programs. This is a minimum threshold requirement for utilities and related organizations to fund and offer efficiency programs; every state meets it in some form. Given the wide acceptance of program cost recovery, we do not address it in the *State Scorecard*.

The other two mechanisms are fixed-cost recovery (which comes in two general forms: full revenue decoupling and lost revenue adjustment mechanisms) and performance incentives. Revenue decoupling—the dissociation of a utility's revenues from its sales—aims to make the utility indifferent to decreases or increases in sales, removing what is known as the *throughput incentive*. Although decoupling does not necessarily make the utility more likely to promote efficiency programs, it removes or reduces the disincentive for it to do so.[40] Additional mechanisms for addressing lost revenues include modifications to customers' rates that permit utilities to collect these revenues, through either a lost-revenue adjustment mechanism (LRAM) or other ratemaking approach. LRAM allows the utility to recover lost revenues from savings resulting from energy efficiency programs while simultaneously increasing sales overall. LRAM does not eliminate the throughput incentive. ACEEE prefers the decoupling approach for addressing the throughput incentive and considers LRAM appropriate only as a short-term solution.

Performance incentives are financial incentives that reward utilities (and in some cases nonutility program administrators) for reaching or exceeding specified program goals. These may be based on achievement of energy savings targets or based on spending goals. Of the two, ACEEE recommends incentives based on achievement of energy savings targets. As table 19 shows, a number of states have enacted mechanisms that align utility incentives with energy efficiency.[41]

SCORES FOR UTILITY BUSINESS MODEL AND ENERGY EFFICIENCY

A state could earn up to 2 points in this category: up to 1 point for implementing performance incentive mechanisms and up to 1 point for implementing full revenue decoupling for its electric and natural gas utilities. We give only partial credit to LRAM policies for the reason discussed above. Table 18 describes our scoring methodology. Information about individual state decoupling policies and financial incentive mechanisms is available in ACEEE's State and Local Policy Database (ACEEE 2020b).

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[40] Straight fixed variable (SFV) rate design is sometimes considered a simple form of decoupling that collects all costs regarded as fixed in a fixed monthly charge and collects all variable costs in volumetric rates. However, SFV collects the same monthly charge (and fixed costs) for all customers within a class, regardless of customer size. ACEEE discourages the use of SFV as it is not cost-based and sends poor price signals to customers to conserve electricity. For this reason, the *Scorecard* does not recognize SFV in its scoring methodology in this section.

[41] For a detailed analysis of performance incentives, see Nowak et al. (2015). For a detailed analysis of LRAM, see Gilleo et al. (2015a).

Table 18. Scoring of utility financial incentives

Decoupling	Score
Decoupling is in place for at least one major utility for both electric and natural gas.	1
Decoupling is in place for at least one major utility, either electric *or* natural gas. There is an LRAM or ratemaking approach for recovery of lost revenues for at least one major utility for both electric and natural gas.	0.5
No decoupling policy has been implemented, although the legislature or commission may have authorized one. An LRAM or ratemaking approach for recovery of lost revenues has been established for a major utility for either electric or natural gas.	0
Performance incentives	**Score**
Performance incentives have been established for a major utility (or statewide independent administrator) for both electric and natural gas.	1
Performance incentives have been established for a major utility (or statewide independent administrator) for either electric *or* natural gas.	0.5
No incentive mechanism has been implemented, although the legislature or commission may have authorized or recommended one.	0

This year, 29 states offer a performance incentive for at least one major electric utility, and 17 states have incentives for natural gas energy efficiency programs. Some states with third-party program administrators have performance incentives for the administrator rather than for the utilities. Thirty-two states have addressed disincentives for investment in energy efficiency for electric utilities. Of these, 15 have a lost revenue adjustment mechanism and 17 have implemented decoupling, with the most recent addition to the latter being New Mexico. For natural gas utilities, 7 states have implemented an LRAM and 25 have a decoupling mechanism. Table 19 outlines these policies.

Table 19. Utility efforts to address lost revenues and financial incentives

	Decoupling or LRAM			Performance incentives			
State	Electric	Natural gas	Score (1 pt.)	Electric	Natural gas	Score (1 pt.)	Total score (2 pts.)
California	Yes	Yes	1	Yes	Yes	1	2
Connecticut	Yes	Yes	1	Yes	Yes	1	2
Hawaii [a]	Yes	—	1	Yes	—	1	2
Massachusetts	Yes	Yes	1	Yes	Yes	1	2
Minnesota	Yes	Yes	1	Yes	Yes	1	2
New York	Yes	Yes	1	Yes	Yes	1	2
Rhode Island	Yes	Yes	1	Yes	Yes	1	2

	Decoupling or LRAM			Performance incentives			
State	Electric	Natural gas	Score (1 pt.)	Electric	Natural gas	Score (1 pt.)	Total score (2 pts.)
Vermont	Yes	Yes	1	Yes	Yes	1	2
Arkansas	Yes†	Yes†	0.5	Yes	Yes	1	1.5
Colorado	Yes	Yes†	0.5	Yes	Yes	1	1.5
District of Columbia	Yes	No	0.5	Yes	Yes	1	1.5
Kentucky	Yes†	Yes†	0.5	Yes	Yes	1	1.5
Michigan	No	Yes	0.5	Yes	Yes	1	1.5
New Hampshire	Yes†	Yes*	0.5	Yes	Yes	1	1.5
New Jersey	Yes[b]	Yes	1	Yes	No	0.5	1.5
New Mexico	Yes	Yes	1	Yes	No	0.5	1.5
Oklahoma	Yes†	Yes	0.5	Yes	Yes	1	1.5
South Dakota	Yes†	Yes†	0.5	Yes	Yes	1	1.5
Arizona	Yes†	Yes*	0.5	Yes	No	0.5	1
Georgia	No	Yes	0.5	Yes	No	0.5	1
Illinois	No	Yes	0.5	Yes	No	0.5	1
Indiana	Yes†	Yes	0.5	Yes	No	0.5	1
Maryland	Yes	Yes	1	No	No	0	1
North Carolina	Yes†	Yes	0.5	Yes	No	0.5	1
Ohio	Yes*	No	0.5	No	Yes	1	1
Oregon	Yes	Yes	1	No	No	0	1
Utah	No	Yes	0.5	Yes	No	0.5	1
Washington	Yes	Yes	1	No	No	0	1
Wisconsin	No	No	0	Yes	Yes	1	1
Idaho	Yes	No	0.5	No	No	0	0.5
Louisiana	Yes†	No	0	Yes	No	0.5	0.5
Maine	Yes	No	0.5	No	No	0	0.5
Mississippi	Yes†	Yes†	0.5	No	No	0	0.5
Missouri	Yes†	No	0	Yes	No	0.5	0.5
Nevada	Yes†	Yes	0.5	No	No	0	0.5
South Carolina	Yes†	No	0	Yes	No	0.5	0.5
Tennessee	No	Yes	0.5	No	No	0	0.5
Texas	No	No	0	Yes	No	0.5	0.5
Virginia	No	Yes	0.5	No	No	0	0.5
Wyoming	No	Yes	0.5	No	No	0	0.5
Alabama	No	No	0	No	No	0	0
Alaska	No	No	0	No	No	0	0
Delaware	No	No	0	No	No	0	0
Florida	No	No	0	No	No	0	0

State	Decoupling or LRAM Electric	Natural gas	Score (1 pt.)	Performance incentives Electric	Natural gas	Score (1 pt.)	Total score (2 pts.)
Iowa	No	No	0	No	No	0	0
Kansas	Yes†	No	0	No	No	0	0
Montana	No	No	0	No	No	0	0
Nebraska	No	No	0	No	No	0	0
North Dakota	No	No	0	No	No	0	0
Pennsylvania	No	No	0	No	No	0	0
West Virginia	No	No	0	No	No	0	0

* Both decoupling and lost revenue adjustment mechanism in place. † No decoupling, but lost revenue adjustment mechanism in place. A *yes* with neither asterisk nor dagger indicates that only decoupling is in place. [a] Hawaii received full points for both gas and electric because it uses minimal amounts of natural gas. [b] New Jersey allows for LRAM or limited decoupling, through a Conservation Incentive Program (CIP), a weather-normalized, symmetrical decoupling mechanism that includes a variable margin test and a supply capacity cost reduction test (as approved for PSE&G).

Utility Low-Income Energy Efficiency Programs

Low-income communities have historically experienced policies of systemic racial discrimination, which has led to disenfranchisement from income and wealth-building opportunities, especially for Black, Indigenous, and Hispanic communities. These policies also impact housing affordability, with research finding that low-income households tend to live in less efficient housing while devoting a greater proportion of their income to utility bills than do higher-income households (Bednar, Reames, and Keoleian 2017). ACEEE research finds that low-income, Black, Native American, and Hispanic people, as well as older adults, renters, and those residing in older buildings, spent a greater proportion of their income on energy bills (Drehobl, Ross, and Ayala 2020). Nationally, 67% of low-income households spend more than 6% of their income on their energy bills, compared with 25% of all households nationally (Drehobl, Ross, and Ayala 2020).

The legacy of historic and current systemic economic and social exclusion has led to a variety of factors that exacerbate home energy burdens. Some of these factors include racial segregation, high unemployment, high poverty rates, poor housing conditions, high rates of certain health conditions, lower educational opportunity, and barriers to accessing financing and investment (Jargowsky 2015; Cashin 2004). In addition, research has found that these factors also show up in the energy sector, as lower-income households and communities of color are more likely to live in older, poorly insulated homes with older, inefficient heating systems (Cluett, Amann, and Ou 2016). In addition, people living in rental properties may lack control over heating and/or cooling systems and appliances, which makes it difficult to influence decisions that might improve the efficiency of their homes.

ACEEE research has found that low-income weatherization and energy efficiency retrofits can reduce household energy burden by 25% on average (Drehobl, Ross, and Ayala 2020). Beyond simply lowering energy bills—thereby providing families with more disposable income for other necessities beyond energy—efficiency upgrades can also improve health and comfort. In fact, in its evaluation of the Weatherization Assistance Program, DOE found that the value of nonenergy benefits greatly exceeded the value of energy savings (Tonn et al. 2014).

Efforts to improve the reach of energy efficiency programs that serve income-qualified customers face several unique barriers and challenges. A 2019 study found that 11 large investor-owned utilities across six states had distributional disparities in low-income investments, meaning that they did not spend energy efficiency dollars in proportion to the size of low-income customer populations (Reames, Stacey, and Zimmerman 2019). Additionally, a 2018 report found that only 6% of U.S. energy efficiency spending in 2015 was dedicated to low-income programs (EDF 2018). Low-income households may face prohibitive up-front costs for energy efficiency investments and therefore benefit from low-income-focused programs that address this. Another barrier for low-income customers—who are more likely to be renters—is the so-called split incentive between renters and landlords. Simply put, there is a lack of motivation for landlords to invest in efficiency upgrades when they do not themselves pay for utilities. To help overcome these challenges, regulators can play a key role in encouraging or requiring utilities to carefully consider and expand the role of income-qualified energy efficiency programs within their portfolios.

In recognition of the efforts undertaken by states to strengthen utility-led low-income energy efficiency programs, we added an additional scoring metric beginning with the *2017 State Scorecard* to highlight examples of effective policy drivers that we continue to score, including:

- The adoption of state legislation, regulations, or commission orders establishing a savings goal or minimum required level of spending on low-income energy efficiency programs
- The development of cost-effectiveness rules that account for the additional benefits that energy efficiency delivers to income-qualified customers, such as NEB quantification, adders, or exemption of these programs from cost-effectiveness testing.

States can utilize a variety of policy mechanisms to ensure that levels of investment in or savings from income-qualified energy efficiency programs meet a minimum threshold. In the case of Pennsylvania, the public utility commission has incorporated a savings target specific to low-income programs within the state's EERS. It requires each utility to obtain a minimum of 5.5% of its total consumption reduction target from the low-income sector.

In most cases, however, low-income program requirements take the form of a legislative spending set-aside, through either the creation of a separate fund that receives a minimum annual contribution from ratepayers or a requirement that utilities spend a minimum amount or percentage of their revenues on low-income programs. For example, the Future Energy Jobs Act (SB 2814) passed in Illinois in December 2016 directed ComEd and Ameren Illinois to invest $25 million and $8.35 million per year, respectively, on low-income energy efficiency measures. Similarly, in August 2016, New Hampshire's public utilities commission, in an approved settlement agreement establishing a statewide EERS, increased the minimum low-income share of the overall energy efficiency budget from 15.5% to 17%. Minnesota legislation requires municipal gas and electric utilities to spend at least 0.2% of their gross operating revenue from residential customers on income-qualified programs, and investor-owned natural gas utilities must spend 0.4% of their gross operating revenue from residential customers on such programs. In other states, such as Connecticut and Michigan, utilities are simply required to see that budgets allocated to low-income programs are proportional to the revenues they expect to collect from that sector. Descriptions of state rules and regulations establishing minimum levels of investment in low-income energy efficiency can be found in Appendix M.

Our scoring metric also recognizes public utility commissions that encourage investment in low-income energy efficiency programs by adapting cost-effectiveness screening and testing to give added consideration to the multiple important nonenergy benefits these programs produce, such as health and safety improvements. In some states, such as Illinois, Iowa, and Michigan, regulations clearly state that low-income programs are exempt from cost-effectiveness tests; in other states these exemptions may be granted in practice without being clearly stated or codified. Given the variation in policies and practices treating the cost effectiveness of income-qualified programs, some of which are established implicitly rather than explicitly within commission orders, we have tried to exercise flexibility in assigning points within this category.

Other approaches taken by program administrators to accommodate the higher costs and unique benefits of low-income programs include lowering the cost-effectiveness threshold for such programs or incorporating a percentage adder to approximate the nonenergy benefits that may otherwise be lost in a given cost–benefit calculation (as in Colorado and Vermont). In other cases, states have established methods to measure and calculate specific nonenergy benefits for inclusion in program screening. Still other states take a hybrid approach, utilizing an adder as well as incorporating NEBs that are easy to measure. Descriptions of each state's utility cost-effectiveness rules specific to low-income programs can be found in Appendix N.

SCORES FOR SUPPORT OF LOW-INCOME ENERGY EFFICIENCY PROGRAMS

In ACEEE's data request to states and utility commissions, we asked for information about the policy instruments discussed above. We also asked for specific levels of spending on low-income energy efficiency programs by states and utilities. This is distinct from funding provided by federal sources, such as DOE grant allocations for the Weatherization Assistance Program.

A state could earn up to 1 point in this category. To earn full credit, a state must have a legislative or regulatory requirement establishing minimum spending and/or savings levels for efficiency programs aimed specifically at low-income households, as well as established cost-effectiveness screening practices that accommodate or recognize the multiple nonenergy benefits of low-income energy efficiency programs. Alternatively, a state could earn full credit by demonstrating that utility spending for such programs equaled or exceeded $13 per income-qualified resident, based on the number of state residents below 200% of the federal poverty level according to the U.S. Census Bureau and Bureau of Labor Statistics.

States could earn 0.5 points if they had in place at least one of the two aforementioned policy instruments, or if they demonstrated that spending on low-income programs equaled or exceeded $6.50 per income-qualified resident.

Table 20 describes the scoring methodology.

Table 20. Scoring of support of low-income energy efficiency programs

Scoring criteria for low-income energy efficiency programs	Score
Legislative/regulatory requirements have established minimum spending or savings levels for low-income energy efficiency programs, *and* utility cost-effectiveness rules or exceptions have been established to provide flexibility for low-income programs. or Levels of spending on low-income energy efficiency equal or exceed $13 per income-qualified resident.	1
Legislative/regulatory requirements have established minimum spending or savings levels for low-income energy efficiency programs, *or* utility cost-effectiveness rules or exceptions have been established to provide flexibility for low-income programs. or Levels of spending on low-income energy efficiency are between $6.50 and $12.99 per income-qualified resident.	0.5

Table 21 shows the results of ACEEE's analysis, including levels of ratepayer-funded spending on low-income energy efficiency programs for states that provided this information through the *Scorecard* data request. These amounts are distinct from bill assistance programs and refer specifically to programs designed to improve energy efficiency through weatherization and/or energy-efficient retrofit programs that include measures such as home energy assessments, insulation, and air sealing. These amounts are also separate from federal funding, such as federal Weatherization Assistance Program (WAP) grant allocations. However, where utility or state funds have been deployed to support or supplement WAP programs or projects, we do include these in table 21.

It is important to note that states rely on a variety of funding sources to support energy efficiency measures in low-income households; these include both ratepayer dollars and government funds. For example, although Alaska reports little utility funding for low-income programs, state investment in weatherization on a per capita basis is among the highest in the nation, thanks to appropriations by the state legislature administered through the Alaska Housing Finance Corporation. In order to credit these efforts within the *State Scorecard* and avoid penalizing states that draw from diverse funding streams, any state-subsidized low-income funds reported by state energy offices in their answers to our data request have been combined with ratepayer funding for low-income programs and annotated accordingly in table 21.

Table 21. State scores for support of low-income energy efficiency programs

State	Requirements for minimum level of state or utility support of low-income programs	Special cost-effectiveness screening provisions or exceptions for low-income programs	2019 utility spending on low-income programs	2019 state spending on low-income programs per income-qualified resident[*]	Score (1 pt.)
Massachusetts	Yes[a]	Yes[d]	$130,302,412	$90.49	1
Rhode Island	No	Yes[d]	$19,829,994[†]	$75.98	1
Vermont	Yes[a]	Yes[g]	$10,300,000[†]	$72.54	1
Connecticut	Yes[abc]	Yes[e]	$31,144,990	$38.93	1
California	Yes[c]	Yes[f]	$415,883,884	$34.64	1
New Hampshire	Yes[a]	Yes[e]	$7,615,050[‡]	$32.54	1
Hawaii	No	No	$9,000,000	$30.10	1
Pennsylvania	Yes[bc]	Yes[e]	$92,176,986	$27.78	1
Illinois	Yes[a]	Yes[e]	$85,341,000	$26.95	1
Alaska	No	No	$4,700,000[†]	$23.04	1
Maryland	No	Yes[e]	$25,431,357[†]	$21.09	1
District of Columbia	Yes[a]	Yes[g]	$4,037,174[†]	$19.99	1
Montana	Yes[a]	Yes[e]	$5,298,163[†]	$16.87	1
Maine	Yes[a]	Yes[d]	$5,318,643[†]	$15.69	1
New Jersey	No	Yes[e,g]	$28,020,341	$15.29	1
Michigan	Yes[a]	Yes[e]	$37,835,679	$14.39	1
Minnesota	Yes[a]	Yes[e]	$17,732,767	$14.31	1
Oregon	Yes[a]	Yes[e]	$14,350,187	$13.09	1
Delaware	Yes[a]	Yes[d]	$2,568,774[†]	$11.62	1
New York	Yes[a]	Yes[e]	$62,757,043	$11.09	1
Oklahoma	Yes[a]	Yes[f]	$9,190,764	$7.41	1
Nevada	Yes[a]	Yes[e]	$4,719,105[†]	$5.15	1
New Mexico	Yes[a]	Yes[g]	$2,655,991	$3.15	1
Texas	Yes[a]	Yes[e]	-	-	1
Virginia	Yes[a]	Yes[e]	-	-	1
Wisconsin	Yes[a]	Yes[e]	-	-	1
Missouri	No	Yes[e]	$15,117,217	$8.91	0.5
Colorado	No	Yes[g]	$11,284,525[†]	$8.84	0.5
Iowa	No	Yes[e]	$4,595,799	$6.23	0.5

State	Requirements for minimum level of state or utility support of low-income programs	Special cost-effectiveness screening provisions or exceptions for low-income programs	2019 utility spending on low-income programs	2019 state spending on low-income programs per income-qualified resident*	Score (1 pt.)
Idaho	No	Yes[g]	$3,297,658	$6.08	0.5
Utah	No	Yes[g]	$4,093,339[†]	$5.77	0.5
Washington	No	Yes[e]	$7,500,000[†]	$4.50	0.5
Tennessee	No	Yes[e]	$9,225,752	$4.48	0.5
North Carolina	No	Yes[e]	$6,822,616	$1.97	0.5
Florida	No	Yes[e]	$7,215,685	$1.05	0.5
Georgia	No	Yes[e]	$2,959,612	$0.82	0.5
Arizona	No	Yes[e]	-	-	0.5
Arkansas	No	Yes[e]	-	-	0.5
Indiana	No	Yes[e]	-	-	0.5
Kansas	No	Yes[e]	-	-	0.5
Kentucky	No	Yes[e]	-	-	0.5
Mississippi	No	Yes[e]	-	-	0.5
Ohio	No	Yes[e]	-	-	0.5
South Carolina	No	Yes[e]	-	-	0.5
West Virginia	No	No	$712,183	$1.14	0
Nebraska	No	No	$342,784[†]	$0.72	0
Louisiana	No	No	$1,065,933	$0.63	0
Wyoming	No	No	$16,023	$0.10	0
Alabama	No	No	-	-	0
North Dakota	No	No	-	-	0
South Dakota	No	No	-	-	0

[*] 2018 low-income population based on number of residents below 200% of the federal poverty level, according to U.S. Census Bureau and Bureau of Labor Statistics 2019 Current Population Survey (CPS) Annual Social and Economic (ASEC) Supplement. [†] At least a portion of spending includes non-ratepayer/state-subsidized program funds. [‡] 2018 ratepayer funds. [a] A required level of spending on low-income energy efficiency has been established. [b] A required savings goal for low-income energy efficiency has been established. [c] A customer participation goal has been established. [d] Quantifiable low-income NEBs are included in cost–benefit calculations. [e] Low-income programs are not required to pass, or are exempted from passing, cost-effectiveness tests. [f] Cost-effectiveness threshold is lowered to accommodate low-income programs. [g] Multiplicative adder is applied to approximate low-income NEBs.

Leading and Trending States: Low-Income Energy Efficiency Programs

Virginia. The state has taken significant steps in recent years to strengthen efficiency offerings for low-income customers, including provisions in the 2018 Grid Transformation & Security Act (GTSA), which called upon the state's investor-owned utilities to greatly ramp up overall efficiency spending and established minimum funding levels for programs benefiting low-income customers. The Virginia Clean Economy Act, signed in April 2020, includes additional measures to reduce the low-income energy burden, including raising minimum funding levels from 5% to 15% for programs for low-income, elderly, or disabled individuals as well as veterans. The VCEA also establishes a percentage of income payment program (PIPP) to cap monthly electric utility payments for such ratepayers at 6% or 10% (for those with electric heat). Other environmental justice measures call for considering low-income areas, areas near fossil fuel infrastructure, and historically disadvantaged communities when planning new renewable projects, energy programs, and job training.

New York. In mid-2020, the New York State Energy Research and Development Authority (NYSERDA) and the state's investor-owned utilities (IOUs) introduced a new framework that will invest $880 million through 2025 to improve access to energy efficiency and clean energy solutions for low-to-moderate-income (LMI) households and affordable multifamily buildings. The plan will help to provide an enhanced and more coordinated and consistent approach to LMI services across the state. The framework will more than double the number of these households and buildings receiving energy efficiency services and increase the outreach, education, and community-based support programs for efficiency improvements. The initiative will also expand ongoing efforts to advance buildings electrification via research and analysis of institutional barriers for LMI communities. The plan will support the state's Climate Leadership and Community Protection Act while ensuring that its goals are reached in a just and equitable manner (New York Office of the Governor 2020).

Colorado. Xcel Energy's Low-Income Program provides a range of weatherization services and other energy efficiency measures for income-qualified customers through a multipronged approach and partnership with several nonprofit organizations. As administrator, Xcel Energy performs engineering analysis to determine cost effectiveness and approve rebates. The utility works with Energy Outreach Colorado (EOC), an independent nonprofit created by the state. EOC leverages multiple funding sources to create and expand low-income energy assistance programs. For example, Xcel and EOC developed a single-family program serving households making up to 80% of area median income to reach previously ineligible participants. Since 2009 the partnership among Xcel, EOC, and other participants has served 38,000 households, leveraged $5 million in outside funding, and saved 45 GWh and 5 million therms.

District of Columbia. The DC Council's adoption of the Clean and Affordable Energy Act of 2008 authorized the DC Sustainable Energy Utility (DCSEU) to establish a separate Energy Assistance Trust Fund (EATF). The EATF was to be used solely to fund low-income programs in the amount of $3.3 million annually. For the 2017–2021 program cycle, the low-income spending requirement was raised to 20% of expenditures ($3.9 million), with the addition of an annual low-income goal to save 46,556 MMBtus in electricity and natural gas. DCSEU's Low-Income Multifamily Custom Program, which began in October 2017, has already shown success, providing improvements to 20 properties comprising 1,770 housing units in its first year while building a strong network of key multifamily stakeholders (Samarripas and York 2019).

Massachusetts. According to Massachusetts's 2008 Green Communities Act, a minimum of 10% of electric utility budgets and 20% of gas utility budgets must serve income-qualified residents. These programs are delivered by the Low-Income Energy Affordability Network (LEAN), an association of community action agencies. LEAN coordinates administration of government- and utility-funded energy efficiency services to income-qualified customers, leveraging multiple funding sources and standardizing various program rules and eligibility requirements. LEAN also regularly hosts meetings in which utilities and nonprofit agencies discuss program and funding consistency and review potential new measures.

State policies enabling fuel switching and beneficial electrification in buildings

The past several years have seen a surge in states setting or strengthening clean energy goals, with almost half of the states now pledging to reduce greenhouse gas emissions and more than a dozen aiming for 100% carbon-free or net-zero electricity (NRDC 2020). To meet these goals, program administrators in several states are promoting electrification of space and water heating as an important building decarbonization tool. Policies of this type enable incentives for technologies like air and ground source heat pumps to displace direct fossil fuel use and can reduce emissions by shifting end uses onto the electric grid as it grows cleaner alongside a higher penetration of renewable energy sources.

While regulators in a handful of states have taken proactive steps to create or clarify rules and guidelines surrounding fuel switching, striking a balance among policy levers addressing energy efficiency in order to reduce power sector emissions, strategic electrification is a still-emerging field. Typically state energy efficiency policies address fuel types in isolation without considering the net societal and participant benefits of fuel-switching technologies. Sometimes fuel-switching programs are expressly prohibited by state rules; in other states, uncertainty or lack of state guidance has also impeded electrification efforts.

ACEEE research has begun to track the details of the current state policy landscape as it pertains to fuel switching in order to inform efforts by regulators and program administrators to design fuel-switching programs that are beneficial—i.e., that transition from higher-cost, higher-emitting fuel sources for heating to lower-cost, lower-emitting fuel sources (ACEEE 2020c). Generally we have found that state policies fall into five categories:

- Fuel switching is addressed through guidelines or fuel-neutral goals. Note that a state in this category may have set goals but may not yet have adjusted other factors like cost-effectiveness testing and potential studies.
- Supportive policies are in in place, with additional specific guidance or rules pending.
- There is no policy, but utilities or program administrators have received approval for fuel switching or substitution programs in certain cases.
- Fuel switching or substitution is prohibited or discouraged.
- No fuel-switching or substitution policies or programs are in place.

Table 22 below captures our current classification of state fuel switching policies, or lack thereof, as of July 2020. In on our ongoing effort to align the *State Scorecard* with emerging best practices, we are exploring ways to introduce a new scoring metric that recognizes the work of leading states to harmonize energy efficiency rules with electrification in a way that maximizes their public benefit by reducing costs and meeting climate goals. As one can see, more than half of states have no relevant policy in place, while 11 explicitly prohibit or discourage fuel-switching measures. For the few leading states—mostly located in the

Northeast—more details can be found in ACEEE's April 2020 policy brief on state fuel switching rules, which we plan to update as new practices emerge.[42]

Table 22. Fuel-switching policy status by state

Policy status	West	Midwest	South	Northeast
Fuel switching is addressed through guidelines or fuel-neutral goals (5 states)	Alaska, California		Tennessee	Massachusetts, Vermont
Supportive policies are in place, with additional specific guidance or rules pending (5 states)	Colorado			Connecticut, Maine, New Jersey, New York
No policy, but utilities have received approval for fuel substitution programs in certain cases (8 states and DC)		Illinois, Michigan, Wisconsin	Alabama, Georgia	Delaware, District of Columbia, New Hampshire, Rhode Island
Fuel switching or substitution is prohibited or discouraged (11 states)	Arizona, Washington	Kansas, Minnesota, Oklahoma	Arkansas, Louisiana, South Carolina, Texas, West Virginia	Pennsylvania
No policy is in place (21 states)	Hawaii, Idaho, Montana, Nevada, New Mexico, Oregon, Utah, Wyoming	Indiana, Iowa, Missouri, Nebraska, North Dakota, Ohio, South Dakota	Florida, Kentucky, Mississippi, North Carolina, Virginia	Maryland

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[42] The brief can be found at aceee.org/policy-brief/2020/04/state-policies-and-rules-enable-beneficial-electrification-buildings-through.

Chapter 3. Transportation Policies

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INTRODUCTION

The transportation sector is the largest source of GHG emissions in the United States and accounts for approximately 28% of economy-wide GHG emissions (EPA 2020b). At the federal, state, and local levels, a comprehensive approach to transportation GHG emissions includes addressing the energy efficiency of both individual vehicles and the transportation system as a whole, particularly its interrelationship with land-use policies. Starting with the Energy Independence and Security Act of 2007, the federal government has addressed vehicle energy use through joint GHG and fuel economy standards for light- and heavy-duty vehicles. However, the federal government has recently rolled back federal light-duty standards, putting a spotlight on the role of states in maintaining progress on fuel efficiency. States and local governments continue to lead the way in creating policies for other aspects of transportation efficiency and GHG reduction.

Scores for the transportation category reflect state actions that go beyond federal policies to achieve a more energy-efficient transportation sector. These may be measures to improve the efficiency of vehicles purchased or operated in the state, policies to promote more efficient modes of transportation, or steps to integrate land-use and transportation planning in order to reduce the need to drive. To accommodate recent trends in state policy, we have added two new metrics this year that reflect action on the deployment of electric vehicles. We now score states on whether or not they have additional registration or road fees for EVs in place, and on the number of available charging locations per capita.

SCORING AND RESULTS

At the national level, the current administration's recent rollback of the light-duty fuel economy and GHG standards calls for a 1.5% nominal annual increase in fuel efficiency instead of the 4-5% improvement that would have taken effect for model year 2021–2026 vehicles. As a result, the states' role in ensuring continued progress toward high-efficiency vehicles is all the more critical.[43]

We awarded states that have adopted California's vehicle-emissions standards 1 point. Washington State is the most recent state to adopt these standards, and Nevada, New Mexico, and Minnesota have signaled their intention to adopt. Given the efficiency gains achievable through vehicle electrification, we gave states that also adopted California's light-duty Zero-Emission Vehicle (ZEV) program 0.5 points. States with more than 30 registered EVs per 100,000 people qualified for an additional 0.5 points, and those with more than 70 EVs per 100,000 earned 1 full additional point. Similarly, states with 15 public charging stations per 100,000 people earned 1 point, and those with more than eight public charging locations per 100,000 people earned 0.5 points. The only chargers we counted were non-brand-specific L2 and DCFC chargers with CHAdeMO, CCS, or J1772 compatibility that were installed and publicly

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[43] Fuel economy standards adopted for model years 2022–2025 were provisional, and both fuel economy and GHG emissions standards for these model years, as well as for MY 2021, are currently under review.

available for use as of October 25, 2020.[44] We also evaluated state fees for electric vehicles and awarded 1 point to states that have no EV fee or a fee that is less than or equal to 100% of the annual average gasoline tax revenue from the average individual driver. States where the EV fee is from 101% to 125% of gasoline tax revenues earned no points, and those with an EV fee greater than 125% of gasoline revenues lost 1 point. We awarded 0.5 points to states with consumer incentives for the purchase of high-efficiency vehicles.

States can also lead the way in improving the efficiency of transportation systems more broadly. This includes taking steps to promote the use of less energy-intensive transportation modes. States that have a dedicated revenue stream for public transit earned 0.5 points in this year's *State Scorecard*. Twenty-five states have statutes that provide sustainable funding sources for transit-related capital and/or operating expenses. For details, see Appendix H. States also received points based on the magnitude of their transit spending. Per capita spending of $100 or more received 1 point, while expenditures of $20 or more but below $100 per capita received 0.5 points.

Policies that promote compact development and ensure the accessibility of major destinations are essential to reducing transportation energy use in the long term. States with smart growth statutes earned 1 point. Twenty-three states earned points in this category. These statutes include the creation of zoning overlay districts, such as the New Hampshire RSA 9-B program, as well as various other incentives to encourage development patterns that reduce the need to drive.

States that adopted reduction targets for vehicle miles traveled (VMT) or transportation-specific GHG reduction goals statewide were also eligible for 1 point. Only nine states earned points in this category. We also calculated the percentage change in VMT per capita over a 10-year period for three time frames (2007–2016, 2008–2017, and 2009–2018) and averaged them to evaluate a given state's trend in VMT growth. We awarded 1 point to states whose average 10-year VMT per capita figure fell by 5% or more between 2016 and 2018. A reduction of 1% or more but below 5% earned 0.5 points. One state, New York, as well as the District of Columbia, earned the full point for this metric. We also awarded 0.5 points to states with complete streets statutes, which ensure adequate attention to the needs of pedestrians and cyclists in all road projects.

Regarding freight system efficiency, we changed our methodology this year so that states could earn 0.5 points if the objectives of their freight plans specifically include reducing GHG emissions or energy consumption or shifting modes to more efficient forms of freight movement. They could earn an additional 0.5 points if their freight plans included an energy intensity, GHG reduction, or mode share goal. California is the only state to earn that credit, for its freight-related GHG reduction goal.

We also evaluated state policies that encourage equitable access to efficient transportation options. States earned 0.5 points if they have policies in place to encourage inclusion of low-income housing in transit-oriented neighborhoods and an additional 0.5 points if they use

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[44] L2 and DCFC chargers are different forms of EVSE chargers. L2 chargers have a minimum voltage of 240 volts and DCFC chargers have a minimum voltage of 480 volts. CHAdeMO, CCS, and J1772 fittings were the only style of charger fitting that we considered scoring for this year's scorecard.

distance from transit facilities as a criterion for awarding federal low-income tax credits to qualifying property owners.

Table 23 shows state scores for transportation policies. ACEEE recognizes that due to variations in states' geography and urban/rural composition, some states cannot feasibly implement some of the policies mentioned in this chapter. Nevertheless, every state can make additional efforts to reduce its transportation energy use, and this chapter illustrates several approaches. Additional details on incentives for the purchase of high-efficiency vehicles, state transit funding, and transportation legislation are included in Appendixes G, H, and I.

Table 23. Transportation policies by state

State	GHG tailpipe emissions standards and ZEV program (1.5 pts.)[1]	EV registrations per 100,000 people (1 pt.)[2]	EV fees[3] (1 pt.)	EVSE[4] (1 pt.)	High-efficiency consumer incentives[5] (0.5 pts.)	VMT targets (1 pt.)[6]	Average % change in VMT per capita (1 pt.)[7]	Integration of transportation and land-use planning (1 pt.)[8]	Complete streets legislation (0.5 pt.)[9]	Transit funding (1 pt.)[10]	Dedicated transit revenue stream statutes (0.5 pts.)[11]	Freight system efficiency goals (1 pt.)[12]	Equitable access (1 pt.)[13]	Total score (12 pts.)
District of Columbia	1.5	1	1	1	0.5	1	1	1	0.5	1	0	0.5	1	11
California	1.5	1	1	1	0.5	1	0	1	0.5	0.5	0.5	1	1	10.5
New York	1.5	1	1	0.5	0.5	1	1	1	0.5	1	0.5	0.5	0.5	10.5
Massachusetts	1.5	1	1	0.5	0.5	1	0	1	0.5	1	0.5	0.5	1	10
Maryland	1.5	1	1	0.5	0	1	0	1	0.5	1	0.5	0.5	1	9.5
Connecticut	1.5	1	1	0.5	0.5	0	0	1	0.5	1	0	0.5	1	8.5
Oregon	1.5	1	1	0.5	0.5	1	0	1	0.5	0	0.5	0.5	0.5	8.5
Vermont	1.5	1	1	1	0.5	1	0.5	1	0.5	0	0	0.5	0	8.5
Washington	1.5	1	1	0.5	0.5	1	0.5	1	0.5	0	0.5	0	0.5	8.5
Rhode Island	1.5	1	1	0.5	0	0	0.5	1	0.5	0.5	0	0.5	1	8
Colorado	1.5	1	1	1	0.5	0	0.5	0	0.5	0	0.5	0.5	0.5	7.5
Maine	1.5	1	1	0.5	0.5	0	0	1	0.5	0	0.5	0.5	0.5	7.5
Minnesota	0.5	1	1	0	0	1	0.5	0	0.5	0.5	0.5	0.5	1	7
New Jersey	1.5	1	1	0	0.5	0	0	1	0.5	0.5	0	0.5	0.5	7
Delaware	1	1	1	0	0.5	0	0	1	0.5	1	0	0.5	0	6.5
Pennsylvania	1	1	1	0	0.5	0	0.5	0	0.5	1	0.5	0.5	0	6.5
Hawaii	0	1	1	1	0	0	0	1	0.5	0	0.5	0.5	0.5	6
Virginia	0	1	1	0	0.5	0	0.5	1	0.5	0.5	0.5	0	0.5	6
Michigan	0	1	1	0	0	0	0	1	0.5	0.5	0.5	0.5	0.5	5.5
Arizona	0	1	1	0	0.5	0	0.5	1	0	0	0	0.5	0.5	5

State	GHG tailpipe emissions standards and ZEV program (1.5 pts.)[1]	EV registrations per 100,000 people (1 pt.)[2]	EV fees[3] (1 pt.)	EVSE[4] (1 pt.)	High-efficiency consumer incentives[5] (0.5 pts.)	VMT targets (1 pt.)[6]	Average % change in VMT per capita (1 pt.)[7]	Integration of transportation and land-use planning (1 pt.)[8]	Complete streets legislation (0.5 pt.)[9]	Transit funding (1 pt.)[10]	Dedicated transit revenue stream statutes (0.5 pts.)[11]	Freight system efficiency goals (1 pt.)[12]	Equitable access (1 pt.)[13]	Total score (12 pts.)
Florida	0	1	1	0	0	0	0.5	0	0.5	0	0.5	0.5	1	5
Illinois	0	1	0	0	0	0	0	1	0.5	1	0.5	0.5	0.5	5
Tennessee	0	1	1	0	0	0	0	1	0.5	0	0.5	0.5	0.5	5
North Carolina	0	1	1	0	0	0	0	1	0.5	0	0.5	0.5	0	4.5
Utah	0	1	1	0.5	0.5	0	0	0	0.5	0	0.5	0.5	0	4.5
Nevada	0.5	1	1	0	0	0	0	0	0.5	0	0	0.5	0.5	4
Alaska	0	1	1	0	0	0	0.5	0	0	1	0	0	0	3.5
Iowa	0	0.5	1	0	0	0	0	1	0	0	0.5	0.5	0	3.5
New Hampshire	0	1	1	0	0	0	0	1	0	0	0	0.5	0	3.5
New Mexico	0.5	1	1	0	0	0	0	0	0	0	0	0.5	0.5	3.5
Texas	0	1	1	0	0.5	0	0	0	0.5	0	0	0.5	0	3.5
Oklahoma	0	1	1	0	0.5	0	0.5	0	0	0	0	0.5	0	3.5
Indiana	0	1	0	0	0	0	0	0	0.5	0	0.5	0.5	0.5	3
Kentucky	0	0.5	1	0	0	0	0	0	0	0	0	0.5	1	3
Louisiana	0	0.5	1	0	0.5	0	0	0	0.5	0	0	0.5	0	3
Missouri	0	1	0	0	0	0	0	0	0.5	0	0	0.5	1	3
Montana	0	1	1	0	0	0	0	0	0	0	0	0.5	0	2.5
South Carolina	0	0.5	1	0	0	0	0	0	0.5	0	0	0.5	0	2.5
Wisconsin	0	1	1	0	0	0	0	0	0	0	0	0.5	0	2.5
Kansas	0	1	0	0	0	0	0	0	0	0	0.5	0.5	0	2
Nebraska	0	0.5	1	0	0	0	0	0	0	0	0	0.5	0	2

State	GHG tailpipe emissions standards and ZEV program (1.5 pts.)[1]	EV registrations per 100,000 people (1 pt.)[2]	EV fees[3] (1 pt.)	EVSE[4] (1 pt.)	High-efficiency consumer incentives[5] (0.5 pts.)	VMT targets (1 pt.)[6]	Average % change in VMT per capita (1 pt.)[7]	Integration of transportation and land-use planning (1 pt.)[8]	Complete streets legislation (0.5 pt.)[9]	Transit funding (1 pt.)[10]	Dedicated transit revenue stream statutes (0.5 pts.)[11]	Freight system efficiency goals (1 pt.)[12]	Equitable access (1 pt.)[13]	Total score (12 pts.)
North Dakota	0	0.5	0	0	0	0	0	1	0	0	0	0.5	0	2
South Dakota	0	0.5	1	0	0	0	0.5	0	0	0	0	0	0	2
Georgia	0	1	–1	0	0	0	0	0	0.5	0	0.5	0	0.5	1.5
Idaho	0	1	0	0	0	0	0	0	0	0	0	0	0	1
West Virginia	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	1
Alabama	0	0.5	–1	0	0	0	0	0	0	0	0.5	0.5	0	0.5
Mississippi	0	0	–1	0	0	0	0.5	0	0.5	0	0	0.5	0	0.5
Ohio	0	1	–1	0	0	0	0	0	0	0	0	0.5	0	0.5
Wyoming	0	0.5	–1	0	0	0	0.5	0	0	0	0	0.5	0	0.5
Arkansas	0	0	–1	0	0	0	0	0	0	0	0.5	0.5	0	0

Sources: [1] Lutsy and Slowik 2019. [2] IHS Automotive Polk 2020; state data requests. [3] DOE 2020b. [4] DOE 2020b. [5] DOE 2020a. [6] State legislation. [7] FHWA 2020. [8] State legislation. [9] NCSC 2018. [10] AASHTO 2020. [11] State legislation. [12] State freight plans. [13] State legislation.

DISCUSSION

Tailpipe Emissions Standards and the Zero-Emission Vehicle Program

The U.S. Department of Transportation (DOT) has regulated the fuel economy of automobiles since Corporate Average Fuel Economy (CAFE) standards were adopted in 1975. States are not permitted to adopt fuel efficiency standards per se. As a longtime leader in vehicle emissions reduction, however, California has authority to set its own vehicle emissions standards, including for GHG emissions. Other states may choose to follow federal or California standards. In 2002, California passed the Pavley Bill (AB 1493), the first law in the United States to address GHG emissions from vehicles. The GHG reductions from this law were expected to be achieved largely through improved fuel efficiency, making these standards, to a large degree, energy efficiency policies. Given auto manufacturers' preference for regulatory regimes that allow them to offer identical vehicles in every state, California's program has been instrumental in prodding the federal government to continue to increase the stringency of vehicle standards, drawing new efficiency technologies into the market.

Pursuant to the *Massachusetts v. Environmental Protection Agency* court decision in 2007, the EPA began regulating vehicle GHG emissions as well. Starting with model year 2012, the EPA, DOT, and the California Air Resources Board (CARB) have had harmonized standards for fuel economy and GHG emissions. In 2010 the agencies set new GHG and fuel economy standards for model years 2012 through 2016. In 2012 the agencies extended the standards to model years 2017–2025, projecting a fleetwide GHG emissions average of 54.5 miles per gallon by 2025. The DOT standards for model years 2022–2025 were provisional, and all three agencies were to participate in a midterm review of the appropriateness of the final four years of the standards. In early 2017, EPA and CARB determined that these standards remained appropriate.

The Trump administration reopened EPA's midterm review shortly after the inauguration in 2017, and in April 2018 the EPA released a new determination that these future standards were no longer appropriate. A joint DOT and EPA rule rolling back the standards for model years 2021–2026 was finalized in April 2020. The administration also revoked California's authority to set GHG standards in the fall of 2019. As the state challenges the decision, other states' adoption and support of California's standards will be critical in maintaining California's authority and progress toward clean, fuel-efficient vehicles. California has also updated its Zero-Emission Vehicle (ZEV) program, requiring a more ambitious increase in sales of plug-in hybrid, battery electric, and fuel-cell vehicles from 2018–2025 in order to reduce GHG and criteria pollutant emissions. Manufacturers of passenger cars and light trucks (up to 8,500 pounds) must earn a certain number of ZEV credits by meeting state requirements regarding the number and type of ZEVs they must produce and deliver for sale (C2ES 2017).

Fourteen states and the District of Columbia now use California's GHG regulations: Colorado, Connecticut, Delaware, the District of Columbia, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Pennsylvania, Rhode Island, Vermont, and Washington (Lutsy and Slowik 2019). (Arizona and Florida also adopted California's standards but repealed them in 2012.) Washington is the most recent state to adopt these standards, finalizing its rule in March 2020. Nevada, New Mexico, and Minnesota are planning to adopt California's standards. Twelve of these states and the District of Columbia have adopted California's ZEV requirements as well.

Electric Vehicle and Charging Infrastructure Deployment

As more EVs become available to drivers and electric vehicles become a critical part of state strategy to address transportation GHG emissions, states can help remove the barriers to their widespread adoption. In addition to reducing the higher up-front costs of these vehicles, states can provide incentives for the construction of the required fueling infrastructure. Additionally, states can offer nonfinancial benefits—such as emissions testing exemptions—that make it more convenient to own an EV. The numbers of EV registrations and publicly available charging stations per capita in a given state are indicative of the success of a state's policies to increase the uptake of electric vehicles. Due to feedback we have received, we are considering using the number of charging ports instead of the number of charging stations in the next *State Scorecard*.

State EV Fees

Projections anticipate a steep increase in the rate of EV penetration across the country. As electric vehicle sales begin to ramp up, some states have applied additional registration fees to these vehicles. To date, 28 states have done so, including Arkansas, Connecticut, Maine, and North Dakota. Bills on the table across the country propose annual fees ranging from $25 (New Mexico) to $213 (Georgia). Judging from a review of a small sample of state bills, the primary motivation for these fees is to replace lost future gasoline tax revenues that fund road maintenance. One state, Washington, intends to use the funds for a different purpose: building out EV charging infrastructure to support increased deployment.

While it makes sense for all vehicle owners to contribute to the maintenance of the roads they drive on, there are several issues that these surcharges bring to light. First, EV fees can be at odds with state targets for EV deployment. Numerous states have tax credits in place to encourage EV sales (see Appendix G) yet also have high additional registration costs for EV drivers. These policies work against each other (Tomich 2019).

Moreover, these fees in some cases exceed what the driver of an average gasoline-fueled car pays in gas taxes. Some states' EV fees are based on inaccurate tax calculations that use high annual VMT figures and low average vehicle fuel economy. As an example, North Carolina's first EV fee was set by assuming that the average vehicle in the state is driven much more than the average gasoline vehicle in the United States at 15,000 miles a year and gets a mere 20 miles per gallon—and therefore pays more than $270 annually in gasoline taxes (Stradling 2019). Finally, EV fees in many states do not take into consideration that EV owners pay other taxes that owners of gasoline-powered vehicles do not.

In any case, there is little justification for high surcharges on advanced-technology vehicles, and such charges will disincentivize the development of technologies that reduce emissions. In fact, some EV fee proposals appear to be designed for that purpose. The American Legislative Exchange Council, which receives funding from fossil fuel interests, pushed for steep EV fees in states and campaigned against the federal EV tax credit in 2018 and 2019 (Lunetta 2018). The aim of our scoring approach for this metric is to balance the need for states to promote EV sales in what is still a relatively new market with the need for users to pay their fair share of road costs. We have scored states by comparing their EV fees with the amount of gasoline tax revenue collected for the average car. We recognize that this is not a full accounting of the fees that an EV driver might pay compared with what a driver of a conventional vehicle might pay; for instance, we know EV drivers pay state taxes on the electricity they use to charge their vehicles (albeit a very small charge compared with gasoline tax spending). Still, we think this is a simple and reasonable methodology.

Incentives for High-Efficiency Vehicles

When fuel-efficient vehicles contain new, advanced technologies, high purchase cost is a barrier to their entry into the marketplace. To encourage consumers to purchase fuel-efficient vehicles, states may offer a number of financial incentives, including tax credits, rebates, and sales tax exemptions. Several states offer tax incentives to purchasers of alternative-fuel vehicles—including those that run on compressed natural gas, ethanol, propane, or electricity—and in some cases to purchasers of hybrid vehicles (electric or hydraulic). Although alternative-fuel vehicles can provide environmental benefits by reducing pollution, they are not necessarily more fuel efficient, and in the *State Scorecard* we did not credit policies that promote their purchase. However, we did credit incentives for plug-in vehicles and hybrids, which do generally have high fuel efficiency. Given the arrival of a wide range of these vehicles in recent years, tax credits are playing an important role in spurring their adoption.

We did not give credit for the use of high-occupancy vehicle lanes and preferred parking programs for high-efficiency vehicles, as they promote increased vehicle use and consequently may not deliver net energy benefits.

Vehicle Miles Traveled (VMT) Growth and VMT Reduction Targets

Improved vehicle efficiency will not adequately address energy use and GHG emissions in the transportation sector in the long term if growth in total VMT goes unchecked. EIA predicts a 20% increase in light-duty VMT between 2018 and 2050 due to rising incomes and population growth. VMT for all vehicle types is expected to increase by 1.1% annually over the next 20 years (EIA 2019a). Reducing VMT growth is key to managing transportation energy use, and several states have taken on this challenge by setting VMT reduction targets.

Integration of Land-Use and Transportation Planning

Success in achieving VMT reduction targets requires the coordination of transportation and land-use planning. Successful strategies vary among states due to differences in their infrastructure, geography, and political environment. However, all states benefit from adopting core principles of smart growth and integrating transportation and land-use planning in order to increase transportation system efficiency. Integrated approaches include measures that encourage:

- Transit-oriented development, including mixed land use (combining jobs, stores, and housing) and good street connectivity to make neighborhoods friendly to all modes of transportation
- Areas of compact development
- Convenient modes of transportation that provide alternatives to driving

- Centers of activity where popular destinations are close together and accessible by multiple transportation modes

Complete Streets Policies

Complete streets policies focus on street connectivity and aim to create safe, easy access to roads for all pedestrians, bicyclists, motorists, and public transportation users. Such policies foster increased use of alternatives to driving and thus can contribute to reducing fuel consumption. According to the National Complete Streets Coalition, modest increases in biking and walking could save 2.4 billion gallons of fuel annually across the country (NCSC 2012). A complete streets policy directs states' transportation agencies to evaluate and incorporate complete streets principles and tasks transportation planners with ensuring that all roadway infrastructure projects allow for equitable access to and use of those roadways.

State Transit Funding

While states receive some federal funds for public transit, a significant proportion of transit funding comes from state budgets. A state's investment in public transit is a key indicator of its interest in promoting energy-efficient modes of transportation.

Dedicated Transit Revenue Streams

As states face increasingly uncertain federal funding streams and federal transportation policies that remain highway focused, many have taken the lead in finding dedicated funding sources for long-term public transit expenditures. A number of states have adopted a legislative approach to generating a sustainable stream of capital and operating funds. For instance, in 2018 Alabama established a trust fund under the Alabama Public Transportation Act to increase public transportation options in the state.

Freight

Many states have freight transportation plans in place. The federal Fixing America's Surface Transportation (FAST) Act, adopted in 2015, superseded the Moving Ahead for Progress in the 21st Century (MAP-21) Act. FAST requires states to develop short- and long-range freight plans in order to receive federal funds for freight projects. Final plans were required by December 2017. Additionally, FAST created a separate pot of money for intermodal and rail freight projects. Each state is allowed to set aside up to 10% of federally awarded funds for eligible non-highway projects (114th Congress 2015). Pursuant to FAST, states must also include multimodal strategies in their freight plans.

These plans can be strengthened by adopting concrete targets or performance measures that establish energy efficiency as a priority for goods movement. Such measures involve tracking and reporting the fuel used for freight movement in the state as a whole and encourage the use of energy efficiency as a criterion for selecting or evaluating freight projects. States can formulate these performance targets in terms of gallons of fuel per ton-mile of freight moved, for example, or grams of GHG emitted per ton-mile of freight, and targets should reflect performance across all freight modes.

Equitable Access to Transportation

As cities have sprawled and jobs have moved away from urban cores in the United States, many low-income communities have become geographically more isolated and inadequately served by affordable, efficient transportation. In such cases, personal vehicles become the only option for travel—and expenditures for vehicles, including fuel, insurance, and maintenance, can be large and unpredictable. As a result, household transportation costs as a percentage of total income are higher than average for these communities (Pew Charitable Trusts 2016).

States can use policy levers in a number of ways to ensure fair and equitable access to public transportation and newer shared-use services. Providing incentives to developers who set aside a fixed percentage of low-income housing in transit-served areas helps align housing and transportation choices. Similarly, proximity to transit services is a key measure that many states use in disbursing federal low-income tax credits to qualifying property owners, ensuring that low-income communities are served by a variety of transportation alternatives.

Chapter 4. Building Energy Efficiency Policies

Author: Chris Perry

INTRODUCTION

Buildings consume 75% of the electricity and 40% of the total energy used in the United States and account for 36% of all U.S. carbon dioxide emissions (EIA 2020c).[45] This makes buildings an essential target for energy savings. Because buildings have long life spans and retrofits are often complex or costly, encouraging building efficiency measures during design and construction is one of the most effective ways to reduce building energy consumption. Mandatory building energy codes require a minimum level of energy efficiency for new residential and commercial buildings as well as major alterations and additions. Benchmarking and transparency policies also promote efficiency by informing building owners about their energy consumption. Policies encouraging energy rating and labeling of homes can help to further transform the market by enabling prospective buyers to make informed decisions about the true long-term energy costs they would be taking on.

Building Energy Code Adoption

In 1974 Oregon adopted the first statewide energy code in the United States, followed in 1978 by California's Title 24 Building Standard. Several states (including Florida, New York, Minnesota, and Washington) followed with their own codes in the 1980s. During the 1980s and 1990s, the International Code Council® (ICC) and the regional code development organizations that preceded it developed the Model Energy Code (MEC), later renamed the International Energy Conservation Code® (IECC). Today most states use a version of the IECC for their residential buildings.

Most commercial building codes are based on ASHRAE 90.1 standards, jointly developed by ASHRAE (formerly the American Society of Heating, Refrigerating and Air-Conditioning Engineers) and the Illuminating Engineering Society (IES). The IECC commercial building code tends to adopt many of the prescriptive and performance requirements of the ASHRAE 90.1 code to ensure continuity between the two codes.

With the publication of each new edition of the IECC and ASHRAE standards, DOE issues determinations on the codes that ascertain their relative impact compared with older standards and establish, if justified, the latest iteration as the base code that all states must comply with. Within two years of the final determination, states are required to send letters either certifying their adoption, requesting an extension, or explaining their decision not to comply.[46] Some states, such as Maryland, Massachusetts, and Illinois, are required by statute to adopt the most recent version of the IECC within 12–18 months of publication.

In 2019 the ICC undertook the process of updating a number of its codes, including the 2021 residential and commercial IECC. Early in 2019, the ICC solicited proposal changes from the public, and in the summer and fall of 2019 it held hearings on these potential updates to the IECC for the 2021 version. The ICC held an online vote among its members in November

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[45] From an analysis of 2018 totals from residential, commercial, industrial, and transportation end uses.

[46] Federal statute requirements are relatively weak, which helps explain why code adoption across different states is so varied.

and released the results in December 2019. Voting results showed the ICC membership overwhelmingly supported energy-efficient updates to the code.

The residential code will include a new flexible savings mechanism. This provision will allow builders to choose energy efficiency upgrades that work best for them to reduce energy use by 5%, with improvements ranging from better insulation to more efficient air conditioners and water heaters. In addition, an optional zero-energy appendix will provide a simple pathway for leading cities and states to require much higher levels of performance than in the standard IECC. Local governments also overwhelmingly voted to include provisions for electric vehicle and electric appliance readiness as well as increased water heater efficiency, though these were unfortunately removed by the ICC Board of Directors upon appeal (ICC 2020). However, they may still be able to adopt these proposals as amendments to their state or local code.

The code is expected to be released in early 2021 and will be available for immediate adoption by cities and states. ACEEE and other advocacy groups conservatively estimate that the code will improve energy efficiency by 10% over the 2018 IECC (ACEEE 2020a). However, a DOE determination will provide a more accurate estimate.

Additionally, in October 2019, ASHRAE released its updated 90.1-2019 commercial building code. The latest version of 90.1 includes new provisions to improve envelope efficiency, reduce air leakage, increase lighting controls, and improve pump efficiency. Preliminary estimates are that the 2019 code is 5% more energy efficient than the 2016 version; however, a DOE determination will provide a more accurate estimate. Determinations are typically released one to two years following the publication of a code.

A number of states have adopted the latest available version of the residential code, the 2018 IECC, including Delaware, New Mexico, Vermont, New York, Nebraska, New Jersey, Illinois, Massachusetts, Maryland, and Nevada. Meanwhile Colorado, a home-rule state, passed HB 19-1260, requiring local jurisdictions to adopt one of the three most recent versions of the IECC. The majority of these states have adopted ASHRAE 90.1-2016 (or equivalent); however, with 90.1-2019 published at the end of 2019, some states are expected to begin reviewing and adopting this code.

Early building energy codes used a prescriptive approach, requiring compliance with a specific portfolio of building specifications and efficiency measures. However, over the past two decades, performance-based compliance options have been incorporated into codes, allowing builders flexibility to chart their own course as long as the building meets a minimum standard of modeled energy performance. For residential buildings, an additional type of performance path called the Energy Rating Index was introduced in the 2015 IECC. This path involves target scores in a range of 0 to 100, where 100 represents the 2006 IECC and 0 represents a zero-energy building. The required score differs among climate zones.

At the same time, a number of states and communities have taken steps to move toward zero-energy standards for new and existing construction. A zero-energy building (ZEB) is one that produces at least as much energy as it uses, usually measured over the course of a year. This performance is achieved through energy efficiency and renewable energy technologies.

In recent years, the concept of zero energy (ZE) has increasingly taken hold among building designers and clean energy communities, prompting a growing pursuit of ZE-related targets and certifications, such as the American Institute of Architects' 2030 Challenge, the International Living Future Institute's Living Building Challenge, LEED Zero, and DOE's Zero Energy Ready Home program. States and localities have also developed more stringent building energy codes. Examples include the District of Columbia's zero-energy building code path, Oregon's executive order that requires zero-energy-ready home equivalence by 2023 (Oregon Office of the Governor 2017), Washington State's goal for a 70% reduction in energy consumption in new residential and construction by 2030, and city- and county-led efforts in Idaho and Colorado. Beyond mandating that all new homes be superefficient, California also requires rooftop PV for new construction. For the past decade the emphasis has been on advancing zero-net-energy buildings. The state is now pivoting to code requirements for low-GHG buildings, using metrics that will focus design and construction on decarbonization and demand flexibility to integrate with California's evolving clean energy grid (CEC 2020). Other active ZE plans are in place in Vermont, Rhode Island, the District of Columbia, New York, and Massachusetts. As building energy codes are amended to deepen energy savings and move states closer to ZE goals, interest is growing regarding outcome-based codes and the importance of calculating building energy savings.[47]

Building Energy Code Compliance

Robust implementation and enforcement are necessary to ensure that states will reap the benefits of adopted codes. A support network that includes DOE, the Pacific Northwest National Laboratory (PNNL), regional energy efficiency organizations (REEOs), and a variety of other local, regional, and national stakeholder groups provides technical training, educational resources, and advocacy to help states and communities reach their compliance goals.

DOE provides many resources to guide states in code compliance. In addition to funding compliance activities through grants, the agency provides technical assistance—such as model code adoption policies, compliance software, and training modules—through its Building Energy Codes Program. DOE recently completed the third phase of its single-family residential field study, which evaluated the code compliance of more than 4,500 homes across 25 states. The study concluded that the buildings industry is generally doing a good job complying with building energy codes; however, significant savings were still being left on the table. The study also found that, in many cases, these errors could be corrected through targeted education and training programs (Williams 2019). Additionally, DOE has funded studies on low-rise multifamily and commercial building codes compliance that are currently ongoing (Landry 2019; Cheslak 2019).

REEOs work closely and collaboratively within their regions and with one another to coordinate code-related activities that support adoption and compliance. They include the Northeast Energy Efficiency Partnerships (NEEP), the Southeast Energy Efficiency Alliance (SEEA), the Midwest Energy Efficiency Alliance (MEEA), the South-Central Partnership for

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[47] While the focus of building energy codes historically has been to design energy-efficient buildings, outcome-based codes attempt to consider building operation and methods to measure ongoing energy use.

Energy Efficiency as a Resource (SPEER), the Southwest Energy Efficiency Project (SWEEP), and the Northwest Energy Efficiency Alliance (NEEA).[48] REEOs have played a vital role in helping to inform code adoption efforts, providing technical assistance, policy best practices, and analysis regarding cost effectiveness and potential energy savings of energy codes. Other pivotal REEO-led initiatives include increasing access to energy code training for builders, code officials, and architects and overseeing energy code stakeholder groups and collaboratives. The REEOs have also been key contributors to DOE's ongoing residential energy code field studies in Tennessee, Colorado, Arizona, Utah, Nevada, and many other states.

Other important stakeholders providing leadership and technical expertise on code adoption and enforcement include the National Association of State Energy Officials (NASEO) and the Responsible Energy Codes Alliance (RECA), among others.

In addition to participating in these regional and national efforts, states can take other actions to support code compliance. These include the following:

- Conducting a study—preferably every three to five years—to determine actual rates of energy code compliance, identify compliance patterns, and create protocols for measuring compliance and developing best-practice training programs
- Establishing a system, including programs and an evaluation methodology, that encourages utilities and other stakeholders to support code compliance and claim energy savings from doing so
- Offering training programs and/or adopting policies establishing minimum certification requirements for code enforcement officials, in order to increase the number and effectiveness of contractors and officials who implement codes and monitor and evaluate compliance. These programs and policies are most effective when based on data collected in compliance field studies. It is worth noting that professionals' participation in state-specific licensing, certification, and continuing education credit programs has been shown to be higher than their participation in national programs.

Utilities can promote compliance with state and local building codes in a number of ways. Many utilities across the country offer energy efficiency programs that target new construction. A handful of jurisdictions with EERS policies, including California, Massachusetts, Rhode Island, the District of Columbia, New York, and Arizona, have established programs that allow utilities to claim savings for code enhancement activities both for adoption and for compliance. Utilities can fund and administer training and certification programs, assist local jurisdictions with implementing tools that streamline enforcement, provide funding for purchasing diagnostic equipment, and help with compliance evaluation. For instance, Ameren Missouri offers a robust Residential Energy Code Support program for home builders, code officials, and other professionals. Utilities also can combine code compliance efforts with initiatives to improve energy efficiency beyond code requirements. To encourage utilities to participate, prudent regulatory

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[48] These organizations cover all states except California, Hawaii, and Alaska.

mechanisms, such as program cost recovery or shared savings policies, must be in place to compensate them for their efforts.

Building Energy Use Transparency, Energy Performance Standards, and Home Energy Labeling

A significant challenge to improving efficiency in the housing sector has been a relatively low level of awareness and understanding among home buyers of the energy costs and energy-saving features of homes on the market. While miles-per-gallon stickers and Energy Guide labels have become dependable fixtures of the vehicle and home appliance markets, a lack of transparent energy use information has historically plagued the housing sector. Market signals are insufficient to direct consumers to the most efficient homes, leading to uninformed purchasing decisions and saddling home buyers with higher long-term costs than they had anticipated. This critical information gap has far-reaching ramifications that include not just bloated utility bills, but also the undervaluation of efficiency services, a concealment of vital knowledge about a home's maintenance and repair needs, and an excessive energy burden that may cause homeowners to forgo other important purchases.

Efficiency advocates and government agencies at all levels have worked to devise residential energy labeling programs and policies that inform home buyers and real estate stakeholders about a home's energy performance. Given differences in priorities among regions and stakeholders, a diverse patchwork of ratings with varying metrics and areas of focus has arisen to meet the challenge. Examples include:

- *Residential Energy Services Network (RESNET) Home Energy Rating System (HERS).*[49] Considered the industry standard, the HERS rating is required for a home to qualify for ENERGY STAR® certification, DOE Zero Energy Ready Home certification, and many energy efficiency programs that target new construction (Cluett and Amann 2013). ANSI/RESNET/ICC Standard 301-2014, known as the Energy Rating Index, is based on the HERS rating system; it is formally referenced as its own compliance path in the 2015, 2018, and 2021 IECC. The HERS allows builders flexibility in meeting code requirements and provides home sellers an opportunity to demonstrate the added energy-saving value of the home by including the score in real estate listings.
- *DOE Home Energy Score (HES).* Launched in 2012, HES has been used primarily for existing homes. HES rates homes on a 1–10 scale, with 10 being the most efficient, and provides guidance on recommended upgrades and how the upgrades will improve the home's score. The score has been incorporated into voluntary labeling initiatives in states including Alabama, Colorado, Connecticut, Massachusetts, and Oregon.[50] Starting in 2018, HES became mandatory in Portland, Oregon, at the time a property is listed for sale, with scores posted to the Multiple Listing Service.
- *Minneapolis Home Energy Score*. Minneapolis developed its own 0-to-100 rating covering a home's attic and wall insulation, heating system, and windows to meet

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[49] RESNET is a national not-for-profit standard-setting membership organization accredited by the American National Standards Institute (ANSI) as a standards development organization.

[50] Many communities are also considering incorporating HES into their climate action plans as a way to spur retrofits.

its mandatory disclosure ordinance. Energy disclosure reports are now required on homes at the time of sale (Hudson 2020).

To help consumers navigate the varied and sometimes confusing landscape of residential energy labeling protocols, a number of state energy offices have partnered with organizations like NASEO and NEEP to strengthen the regional consistency of energy rating practices. These efforts include:

- *Energy Metrics to Promote Residential Energy Scorecards in States (EMPRESS).* An initiative led by state energy offices and supported by DOE and private partners, EMPRESS aims to coordinate and harmonize the software platforms for DOE's HES and RESNET's HERS ratings as well as to foster voluntary use of residential energy data by real estate market stakeholders and others (NASEO 2020). States involved in EMPRESS include Rhode Island, Massachusetts, Missouri, Arkansas, and Oregon.
- *Home Energy Labeling Information eXchange (HELIX).* Led by NEEP and supported by DOE, the six New England states and New York have together developed a database to help bridge the energy information gap between home sellers and the market. The system auto-populates real estate listings with verified independent home energy information from home energy labels, such as HES and HERS, solar PV data, and other available energy data (NEEP 2019). As of 2019, HELIX was available for all states to use as a policy management tool and to connect to local branches of the Multiple Listing Service.
- *Home Energy Information Accelerator.* One of 13 Better Buildings Accelerators launched by DOE since 2013, the Home Energy Information Accelerator is a collaboration among national, regional, state, and local leaders aimed at expanding the availability and use of reliable home energy information in residential real estate transactions, such as through listing services and other reports. Other goals include providing data standards and technical assistance.

Mandates for residential home energy labeling are more common in local jurisdictions than at the state level. However, voluntary state programs in Connecticut, Massachusetts, and Vermont have found success through a variety of policy levers, such as piggybacking labels onto existing energy efficiency programs. This can help increase exposure to consumers and build a case for more widespread implementation through demonstration of the increased market value associated with improved energy transparency (Faesy et al. 2014). By convening stakeholders and real estate interests to share perspectives, challenges, and opportunities through a consistent governance structure, states can help craft a successful labeling program that integrates with regional listing services and has the support of both home buyers and home sellers.

On the commercial side, a growing number of jurisdictions, including more than 25 cities, have established building energy benchmarking and transparency laws (IMT 2020). These require property owners, builders, or sellers to compile information about their buildings' energy use or energy efficiency characteristics and report these data to a central database and/or to prospective buyers at the time of sale. This information can then be used to evaluate building energy use patterns and identify energy efficiency opportunities. Several studies have demonstrated that benchmarking and transparency policies can be associated with a 3–8% reduction in energy consumption or energy use intensity (EPA 2012; Mims et al. 2017).[51] Energy use transparency requirements are a fairly recent policy innovation. Commercial transparency policies are uncommon at the state level, with only California, Washington, the District of Columbia, and New Jersey requiring energy use disclosure upon sale or lease. Local governments are more likely to pursue these policies, but state governments can also use them to incentivize building stock upgrades.

Additionally, cities and a few states are starting to require Building Energy Performance Standards (BEPS). These standards, typically based on commercial buildings' energy use intensity (EUI), help to capture the ongoing energy consumption of existing buildings. This can help ensure that buildings are being operated efficiently, and if not, can identify adjustments and investments to improve energy performance. While these requirements are more prevalent in cities (e.g., New York City; Boulder, Colorado; and St. Louis), both Washington, DC, and Washington State have set BEPS requirements to be met starting in 2026 (Nadel and Hinge 2020).

Cities, states, and other jurisdictions are increasingly supplementing energy consumption metrics with carbon and GHG emissions metrics. For instance, New York City recently passed the landmark Climate Mobilization Act, which requires buildings of more than 25,000 square feet to cut their carbon emissions by 40% from 2005 levels by 2030 and by more than 80% by 2050. This bill includes sizable fines for failure to meet the requirements (New York City Council 2019).

GHG reduction goals go hand in hand with energy efficiency. As more jurisdictions start considering these new metrics, ACEEE intends to investigate the best methods for incorporating them into the *State Scorecard*.

METHODOLOGY

Our review of state building energy code stringency is based predominantly on publicly available information, such as that provided by the DOE Building Energy Codes Program, New Buildings Institute (NBI), RECA, and the national network of REEOs. It draws as well on the expert knowledge of individuals who are active in state building energy code policy and evaluation. We also relied on primary data collection to verify publicly available data, particularly for very recent or forthcoming code adoptions. We distributed a data request to energy offices and knowledgeable officials in each state, soliciting information on their efforts to measure and enforce code compliance.

While model codes are determined at the national level, states often amend these codes during the adoption process, thereby affecting the EUI of buildings constructed to that code. To more accurately capture the energy savings impact of these amendments, ACEEE worked with NBI to score building energy code stringency according to the modeled EUI of

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[51] A study by the EPA showed that benchmarking energy use led to a 7% decrease in consumption across a sample of more than 35,000 buildings (EPA 2012). A Lawrence Berkeley National Laboratory (LBNL) review of state and local benchmarking and transparency studies found that most of the research indicated a 3–8% reduction in gross energy consumption or energy use intensity over a two- to four-year period of building and transparency policy implementation. The LBNL review, however, suggested that additional research be conducted to confirm energy impacts and determine causal relationships (Mims et al. 2017).

each code as measured by NBI's Zero Energy Performance Index (zEPI). A zEPI score of zero indicates a zero-energy building.[52]

SCORING AND RESULTS

States earned credit for residential and commercial building energy codes on the basis of two measures: the stringency of the codes and the level of activity to support code compliance. We also awarded points for efforts to improve the transparency of building energy use. This included awarding points for benchmarking and energy use transparency laws. Further, we continued to use a metric introduced in 2018 that tracks the number of home energy labels distributed annually as a percentage of new home construction, based on information received through our annual data request and from publicly available data from RESNET. We awarded points as follows:

- Code stringency
    - Residential energy code (2 points)
    - Commercial energy code (2 points)
- Code compliance
    - Compliance study (1 point)
    - Other compliance activities (1 point)
- Building energy use transparency
    - Residential and/or commercial benchmarking/transparency policies (1 point)
    - Existing building performance standards (1 point)
    - Zero-energy buildings (0.5 points)
    - Energy rating and labeling of homes (0.5 points)

As in past *Scorecards*, states could earn a maximum of 4 points for stringency. We also added metrics to recognize progress in two emerging areas: the adoption of building energy performance standards for existing buildings (so far only Washington State and the District of Columbia) and efforts to advance construction of ZEBs, which we measured using data on verified and emerging ZEBs from the New Buildings Institute. To accommodate these changes, we removed a previous metric that credited states for requiring code officials to complete energy efficiency–related training and certification.

Table 24 lists states' overall building energy code scores. Explanations of each metric follow.

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[52] The zEPI system is based on a scale presented in a paper by Charles Eley, an energy efficiency advocate and New Buildings Institute fellow. The scale establishes zero-net energy as the absolute goal and enables the measurement of a building's progress toward zero-net energy performance, as opposed to the traditional percentage-better-than-code metric. To learn more about this scale, see Eley (2009). To learn more about the zEPI methodology, see newbuildings.org/code_policy/zepi/.

Table 24. State scores for building energy efficiency policies

State	Residential code stringency (2 pts.)	Commercial code stringency (2 pts.)	Compliance study (1 pt.)	Additional compliance activities (1 pt.)	Benchmarking and transparency (1 pt.)	Energy rating and labeling of homes (0.5 pts.)	Existing building standards (1 pt.)	Zero-energy buildings (0.5 pts.)	Total score (9 pts.)
District of Columbia	2	2	1	1	1	0	1	0.5	8.5
California	2	2	1	1	1	0	0	0.5	7.5
Washington	2	2	1	1	0.5	0	1	0	7.5
Hawaii	2	2	1	1	0.5	0	0	0.5	7
Massachusetts	2	2	1	1	0	0.5	0	0.5	7
Oregon	2	2	1	1	0	0.5	0	0.5	7
Connecticut	2	2	1	1	0	0.5	0	0	6.5
Michigan	2	2	1	1	0	0.5	0	0	6.5
Minnesota	2	2	1	1	0	0.5	0	0	6.5
Nevada	2	2	1	0.5	0	0.5	0	0.5	6.5
New Jersey	1.5	2	1	1	0.5	0.5	0	0	6.5
New York	2	2	1	1	0.5	0	0	0	6.5
Pennsylvania	2	2	1	1	0	0.5	0	0	6.5
Texas	2	2	1	1	0	0.5	0	0	6.5
Colorado	1.5	1.5	1	1	0	0.5	0	0.5	6
Florida	1.5	2	1	1	0	0.5	0	0	6
Illinois	2	2	1	1	0	0	0	0	6
Maryland	2	2	1	0.5	0	0.5	0	0	6
Nebraska	2	2	1	1	0	0	0	0	6
Rhode Island	1.5	2	1	1	0	0.5	0	0	6

State	Residential code stringency (2 pts.)	Commercial code stringency (2 pts.)	Compliance study (1 pt.)	Additional compliance activities (1 pt.)	Benchmarking and transparency (1 pt.)	Energy rating and labeling of homes (0.5 pts.)	Existing building standards (1 pt.)	Zero-energy buildings (0.5 pts.)	Total score (9 pts.)
Utah	1.5	2	1	1	0	0	0	0.5	6
Vermont	2	2	1	0.5	0	0	0	0.5	6
Alabama	1.5	2	1	1	0	0	0	0	5.5
Delaware	2	2	0	1	0	0.5	0	0	5.5
Idaho	1.5	2	1	1	0	0	0	0	5.5
Montana	2	1.5	1	1	0	0	0	0	5.5
New Hampshire	1.5	2	0	1	0	0.5	0	0.5	5.5
Virginia	1.5	2	1	0.5	0	0.5	0	0	5.5
Kentucky	1	1.5	1	0.5	0	0.5	0	0.5	5
North Carolina	1.5	2	1	0	0	0.5	0	0	5
Arizona	1	1	1	0.5	0	0.5	0	0.5	4.5
Georgia	1.5	2	1	0	0	0	0	0	4.5
Maine	1	1	0.5	1	0.5	0	0	0.5	4.5
New Mexico	2	2	0	0	0	0.5	0	0	4.5
Iowa	2	1.5	0	0	0	0.5	0	0	4
Missouri	1	1	1	1	0	0	0	0	4
West Virginia	1	2	1	0	0	0	0	0	4
Kansas	1	1	0	0.5	0.5	0.5	0	0	3.5
Ohio	1.5	1.5	0	0	0	0.5	0	0	3.5
South Dakota	1.5	1.5	0	0	0.5	0	0	0	3.5
Tennessee	1	1.5	1	0	0	0	0	0	3.5

State	Residential code stringency (2 pts.)	Commercial code stringency (2 pts.)	Compliance study (1 pt.)	Additional compliance activities (1 pt.)	Benchmarking and transparency (1 pt.)	Energy rating and labeling of homes (0.5 pts.)	Existing building standards (1 pt.)	Zero-energy buildings (0.5 pts.)	Total score (9 pts.)
Arkansas	1	1	1	0	0	0	0	0	3
Indiana	1.5	1	0	0	0	0.5	0	0	3
North Dakota	1.5	1.5	0	0	0	0	0	0	3
Wisconsin	1	2	0	0	0	0	0	0	3
South Carolina	1	1	0	0	0	0.5	0	0	2.5
Louisiana	1	1	0	0	0	0	0	0	2
Alaska	1	0	0	0	0.5	0	0	0	1.5
Oklahoma	1	0	0	0	0	0.5	0	0	1.5
Mississippi	0	0	0	0.5	0	0	0	0	0.5
Wyoming	0	0	0	0	0	0	0	0	0

Sources: Stringency scores are derived from data request responses (Appendix A), New Buildings Institute analysis of PNNL data, and discussions with code experts as of August 2020. Compliance and enforcement scores are based on information gathered in surveys of state building energy code contacts. See the ACEEE State and Local Policy Database for more information on state codes and compliance (ACEEE 2020b).

DISCUSSION

Stringency

We assigned each state 0 to 2 points for residential building energy codes and another 0 to 2 points for commercial building energy codes, with 2 being assigned to those with the lowest (i.e., most efficient) scores as measured by NBI's zEPI scale. We grouped the zEPI code impact scores into awarded point values generally according to their alignment with similar corresponding model codes.[53] For detailed information on building code stringency in each state, visit ACEEE's State and Local Policy Database. The zEPI Jurisdictional Score uses data from PNNL, calculating expected energy use intensity in kBtus per square foot by accounting for building type and distribution and regional climate zones for each state.[54] The zEPI scale sets the zero value at zero energy consumption, with a baseline roughly equivalent to the average building in the year 2000. Minor credits are awarded for stretch code adoption in local jurisdictions, which has the effect of improving the overall performance level of mandatory energy code adoptions within a state base.

Table 25 summarizes our scoring methodology for code stringency. Lower zEPI scores indicate lower projected energy use intensity owing to more stringent building energy codes. Residential zEPI scores between 49.1 and 57.2 earned the maximum of 2 points; these generally correspond with states that have adopted codes aligned with the 2015 or 2018 IECC. Scores between 57.3 and 66.0 earned 1.5 points, generally reflecting states that have adopted the 2012 IECC. Scores between 66.1 and 73.0 earned 1 point and align roughly with those states that have adopted codes matching the 2009 IECC. We applied a similar approach to point distributions for commercial buildings. However, state-specific amendments strengthening or weakening certain sections of a code—such as adjusting the number of air changes allowed per hour, or altering the amount of insulation required—can positively or negatively impact a state's zEPI value, and in turn its score.

Some home-rule states that have no mandatory state code and adopt building energy codes at the local level lacked sufficient data to allow calculation of a zEPI value.[55] These states could still earn points if they demonstrated a significant percentage of local adoption of a particular code, though the score assigned is a half-point less compared to that awarded for statewide adoption of a given code. Within Arizona, for example, more than 60% of new construction occurs in jurisdictions that have enacted the 2012 IECC or better, according to

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[53] We have not developed a quantitative method for comparing the interstate impact of jurisdictional code adoptions in home-rule states, in part because of a lack of consistent data across states. We recognize that our methodology is imperfect, and we do not intend to dismiss this local progress by assigning a lower score to these states.

[54] PNNL conducts state-level technical analysis based on a methodology established by DOE. PNNL reviews state energy codes based on the IECC and Standard 90.1, including any significant amendments. This helps states understand how their codes compare with the national model codes and provides a portrait of national code adoption. A quantitative analysis is performed to assess the energy savings impacts within a given state. The calculated EUI of buildings constructed to a particular state code is compared with the energy use of the model energy code. This comparison allows a categorization of each state, with categories based on recent editions of the model codes.

[55] Home-rule decentralizes power, allowing localities to exercise certain prerogatives of governance within their own administrative area. See database.aceee.org for more information on building codes in home-rule states.

SWEEP. For detailed information on building code stringency in each state, visit ACEEE's State and Local Policy Database.

Table 25. Scoring of state residential and commercial building energy code stringency

Residential zEPI score	Score (2 pts.)	Commercial zEPI score	Score (2 pts.)
49.1–57.2	2	48.0–55.7	2
57.3–66.0 or adoption of 2015/2018 IECC in major jurisdictions	1.5	55.8–65.6 or adoption of 2015/2018 IECC or ASHRAE 90.1-2013/2016 in major jurisdictions	1.5
66.1–73.0 or adoption of 2012 IECC in major jurisdictions	1	65.7–70.0 or adoption of 2012 IECC or ASHRAE 90.1-2010 in major jurisdictions	1
Adoption of 2009 IECC or equivalent in major jurisdictions	0.5	Adoption of 2009 IECC or ASHRAE 90.1-2007 in major jurisdictions	0.5

Table 26 shows state-by-state scores for this category. We should note that some states have adopted more efficient codes in recent months, too late to have new zEPI scores calculated in time for *Scorecard* publication. We note these states with an asterisk and award them points based on the anticipated zEPI score generally corresponding with the adopted title code.

Table 26. State scores for code stringency

State	zEPI score	Score	Residential code	State	zEPI score	Score	Commercial code
CA	Custom	2	*2019 Building Energy Efficiency Standards**	CA	Custom	2	*2019 Building Energy Efficiency Standards**
DC		2	*2015 IECC**	DC		2	*2015 IECC and ASHRAE 90.1 2013**
DE		2	*2018 IECC**	DE		2	*2018 IECC and ASHRAE 90.1 2016**
NE		2	*2018 IECC**	NE		2	*2018 IECC and 90.1-2016*
NM		2	*IECC 2018 with amendments**	NM		2	*2018 IECC and 90.1-2016^**
VT		2	*2018 IECC**	VT		2	*2018 IECC and ASHRAE 90.1 2016**
WA	Custom	2	*2018 WA State Energy Code (exceeds 2018 IECC)**	WA	Custom	2	*2015 WA State Energy Code (ASHRAE 90.1-2016)**
MN	49.1	2	IECC 2012 with amendments	NJ	48.0	2	90.1-2016
NY	49.7	2	IECC 2018 with amendments	MA	48.0	2	2015 IECC and 90.1-2013^
MA	49.8	2	IECC 2015 with amendments	IL	49.3	2	2018 IECC and 90.1-2016
MI	50.3	2	IECC 2015 with amendments	MD	49.5	2	2018 IECC and 90.1-2016
MD	52.6	2	IECC 2018 with amendments	PA	49.5	2	2015 IECC and 90.1-2013
NV	53.6	2	IECC 2018 with amendments	MI	49.5	2	2015 IECC and 90.1.2013^
CT	53.7	2	IECC 2015 with amendments	NY	50.2	2	2018 IECC and 90.1-2016^
IA	54.2	2	IECC 2012 with amendments	CT	50.3	2	2015 IECC and 90.1-2013
MT	54.4	2	IECC 2012 with amendments	NH	50.7	2	2015 IECC and 90.1-2013
IL	54.4	2	IECC 2018 with amendments	TX	51.0	2	2015 IECC and 90.1-2013
OR	55.0	2	IECC 2018 with amendments	AL	51.5	2	90.1-2013
PA	56.8	2	IECC 2015 with amendments	GA	51.8	2	2015 IECC and 90.1-2013^
TX	57.1	2	IECC 2015	OR	51.8	2	90.1-2016
AL	57.5	1.5	IECC 2015 with amendments	UT	51.8	2	2018 IECC and 90.1-2016
IN	58.6	1.5	IECC 2018 with amendments	ID	52.5	2	2015 IECC and 90.1-2013
GA	58.7	1.5	IECC 2015 with amendments	FL	52.5	2	2015 IECC and 90.1-2013^
OH	59.7	1.5	IECC 2018 with amendments	MN	52.5	2	2018 IECC and 90.1-2016^
NC	60.0	1.5	IECC 2015 with amendments	RI	52.5	2	2015 IECC^
NJ	60.9	1.5	IECC 2018 with amendments	VA	52.5	2	2015 IECC and 90.1-2013
VA	61.0	1.5	IECC 2015 with amendments	WI	52.5	2	2015 IECC and 90.1-2013^
NH	61.8	1.5	IECC 2015 with amendments	NV	53.0	2	Significant local adoption of 2018 IECC
FL	62.6	1.5	IECC 2015 with amendments	WV	54.5	2	90.1-2010
ID	63.3	1.5	IECC 2012 with amendments	NC	54.8	2	2015 IECC and 90.1-2013^
UT	63.6	1.5	IECC 2015 with amendments	KY	60.8	1.5	2012 IECC and 90.1-2010
RI	65.8	1.5	IECC 2015 with amendments	IA	61.2	1.5	2012 IECC and 90.1-2010
ME	66.4	1	IECC 2009	OH	63.0	1.5	2012 IECC and 90.1-2010
WI	66.5	1	IECC 2009 with amendments	MT	64.2	1.5	2012 IECC and 90.1-2010
OK	66.8	1	IECC 2009 with amendments	IN	69.0	1	90.1-2007
KY	67.4	1	IECC 2009	ME	69.0	1	2009 IECC and 90.1-2007
WV	67.9	1	IECC 2009	LA	69.4	1	90.1-2007
SC	68.6	1	IECC 2009	AR	69.8	1	2009 IECC and 90.1-2007
LA	68.9	1	IECC 2009	SC	69.8	1	2009 IECC and 90.1-2007
AR	72.3	1	IECC 2009 with amendments	OK	79.1	0	2006 IECC and 90.1-2004
HI	Home Rule	2	2015 IECC	HI	Home Rule	2	2015 IECC
CO	Home Rule	1.5	Significant adoption of 2015/2018 IECC	CO	Home Rule	1.5	Significant local adoption of 2012/2015 IECC
ND	Home Rule	1.5	Significant local adoption of 2015 IECC	ND	Home Rule	1.5	Significant local adoption of 2015 IECC
SD	Home Rule	1.5	Significant local adoption of 2015 IECC	SD	Home Rule	1.5	Significant local adoption of 2015 IECC
AK		1	Most new construction follows 2012 IECC	TN		1.5	Significant local adoption of 2012/2015 IECC
AZ	Home Rule	1	Significant local adoption of 2012 IECC	AZ	Home Rule	1	Significant local adoption of the 2012 IECC
KS	Home Rule	1	Significant adoption of 2009/2012 IECC	KS	Home Rule	1	Significant adoption of 2009/2012 IECC
MO	Home Rule	1	Significant adoption of 2009/2012 IECC	MO	Home Rule	1	Significant adoption of 2009/2012 IECC
TN		1	Significant adoption of 2009 IECC or above	AK		0	No mandatory code
MS	Home Rule	0	None statewide	MS		0	None statewide
WY	Home Rule	0	No mandatory code	WY	Home Rule	0	Significant adoption of IECC 2006 or equivalent

* These states have signed or passed legislation requiring compliance with a new iteration of codes effective by October 1, 2020, but zEPI calculations had not yet been made available when this *Scorecard* was being prepared. We award these states full credit commensurate with the average zEPI score of states that enforce a similar title code. ^ When an amendment's impact on energy efficiency could be quantified using DOE Prototype Building Models, this was captured in the analysis.

Some states regularly adopt the latest iterations of the IECC and ASHRAE 90.1 code standards as they are determined. However, other states have recently considered statutory or regulatory requirements to extend code adoption cycles. States unable to adopt the latest building energy codes will miss out on significant energy savings opportunities. ACEEE considered removing points from states with extended code adoption cycles, but most states do not actually update building codes every three years (Athalye et al. 2016). We therefore decided not to penalize those with extended cycles.

The *2019 State Scorecard* highlighted a variety of states that had recently updated to the 2018 IECC, including Nebraska, Ohio, Maryland, Illinois, and Massachusetts. Since then, a number of states have joined them in adopting the new codes, including Delaware, New Mexico, Vermont, New York, and New Jersey. While 10 states lack mandatory statewide energy codes for new residential and/or commercial construction (Alaska, Arizona, Colorado, Kansas, Mississippi, Missouri, Nevada, North Dakota, South Dakota, and Wyoming), some of these home-rule states are nonetheless showing high rates of adoption at the jurisdictional level. We awarded points to these states accordingly.

Compliance

It is difficult to score states in this area because consistent data on actual compliance rates are lacking, and other compliance metrics are largely qualitative. Still, we continue to seek ways to score states in a manner that reflects tangible improvements in energy savings.

In 2015 we updated our scoring methodology to award more credit to states that had completed compliance studies in recent years. The reasoning was that, as the 2017 deadline under the American Recovery and Reinvestment Act (ARRA) approached for states to demonstrate 90% compliance with 2009 IECC and ASHRAE 90.1-2007 codes, compliance rates should reflect a state's code enforcement efforts. Although we have used the same methodology this year, ACEEE will continue to revisit this metric to determine how it might be improved to equitably score states on the basis of actual levels of compliance reported. For more information on state compliance efforts, visit ACEEE's State and Local Policy Database (ACEEE 2020b).

Table 27 shows our scoring methodology for assessing state compliance studies.

Table 27. Scoring of state efforts to assess compliance

Compliance study	Score (1 pt.)
Compliance study has been completed in the past five years, follows standardized protocols, and includes a statistically significant sample.	1
Compliance study has been completed in the past five years but does not follow standardized protocols or is not statistically significant.	0.5
No compliance study has been completed in the past five years.	0

Table 28 shows our scoring methodology for additional activities to improve and enforce energy code compliance. A state could earn 0.5 points for each compliance strategy it engaged in during the past year, up to a total of 1 point.

Table 28. Scoring of efforts to improve and enforce code compliance

Additional metrics for state compliance efforts	Score (1 pt.)
Stakeholder advisory group or compliance collaborative	0.5
Utility involvement	0.5

Several states have completed compliance studies demonstrating 90% or higher compliance rates for residential and/or commercial buildings. It could well be argued that states demonstrating compliance rates approaching 100% should receive full credit within the above metrics regardless of whether they engage in additional strategies to enforce compliance. However, we believe the current methodology is valid in the near term for several reasons. First, while we plan to award more points in the future to states on the basis of their compliance studies' results, we also want to recognize the enormous value in a state's maintaining a robust policy framework. Such a framework can support ongoing efforts to provide training and education to staff, actively monitor code changes, and make up-to-date information available to stakeholders through strong coordination. Second, we want to avoid inadvertently penalizing states with lower compliance rates under newer or more stringent codes; this would work against the *Scorecard*'s goal of rewarding states operating at the leading edge of energy efficiency.

As we look ahead to future *Scorecards*, we plan to address these important methodological questions as well as others—including how best to compare the results of compliance studies conducted using differing methodologies (e.g., prescriptive versus performance-based) and how to update our data request accordingly.

Table 29 shows how states scored for each compliance metric. Details on state activities in these areas are given in the ACEEE State and Local Policy Database (ACEEE 2020b).

Table 29. State scores for energy code compliance efforts

State	Compliance study (1 pt.)	Stakeholder group (0.5 pts.)	Utility involvement (0.5 pts.)	Total score (2 pts.)
California	●	●	●	2
Connecticut	●	●	●	2
Massachusetts	●	●	●	2
Oregon	●	●	●	2
Pennsylvania	●	●	●	2
Texas	●	●	●	2
Alabama	●	●	●	2
Colorado	●	●	●	2
District of Columbia	●	●	●	2
Florida	●	●	●	2
Hawaii	●	●	●	2
Idaho	●	●	●	2
Illinois	●	●	●	2
Michigan	●	●	●	2
Minnesota	●	●	●	2
Missouri	●	●	●	2
Montana	●	●	●	2
Nebraska	●	●	●	2
New Jersey	●	●	●	2
New York	●	●	●	2
Rhode Island	●	●	●	2
Utah	●	●	●	2
Washington	●	●	●	2
Vermont	●		●	1.5
Kentucky	●	●		1.5
Maryland	●	●		1.5
Virginia	●	●		1.5
Arizona	●		●	1
Arkansas	●			1
Delaware		●	●	1
Georgia	●			1
Nevada	●	●		1
New Hampshire		●	●	1
North Carolina	●			1
Tennessee	●			1

State	Compliance study (1 pt.)	Stakeholder group (0.5 pts.)	Utility involvement (0.5 pts.)	Total score (2 pts.)
West Virginia	●			1
Kansas		●		0.5
Maine	○			0.5
Mississippi		●		0.5
Alaska				0
Indiana				0
Iowa				0
Louisiana				0
New Mexico				0
North Dakota				0
Ohio				0
Oklahoma				0
South Carolina				0
South Dakota				0
Wisconsin				0
Wyoming				0

An unfilled circle indicates a state receiving half credit for compliance studies, meaning that the compliance study either does not follow the PNNL methodology or does not use a significant sample size. Data are from state responses to data requests (see Appendix A). See State and Local Policy Database (ACEEE 2020c) for more details on each activity.

While 13 states scored zero, according to our survey results, almost every state in the country makes some effort to support code compliance, whether a statewide code is mandatory or not, usually by sponsoring or supporting training resources for local code officials. Nearly every state that responded uses at least one of the strategies for boosting compliance discussed above, and a growing number use many or all of them. For states that did not respond or provided partial responses to this year's survey, we referred to last year's data to complement information in some cases. States that received zero points for compliance are those that did not respond to our survey or could not report compliance activities.

Benchmarking and Energy Transparency Requirements

States with mandatory energy use benchmarking and transparency laws received 0.5 points for a policy covering either commercial or residential buildings. States with those policies in place for some or all of their commercial *and* residential buildings received 1 point. Table 30 presents states' disclosure policies.

Table 30. State benchmarking and energy transparency policies

State	Disclosure type	Building energy use transparency requirements	Score (1 pt.)
California	Commercial, residential multifamily	AB 1103 required nonresidential building owners or operators to benchmark their buildings' energy use with ENERGY STAR Portfolio Manager and to disclose this information to buyers, lenders, and lessees. AB 802 replaces this legislation and expands the requirement to any building with five or more active utility accounts, including residential multifamily buildings.	1
District of Columbia	Commercial, residential multifamily	The Clean and Affordable Energy Act of 2008 requires privately owned commercial buildings to be benchmarked annually using ENERGY STAR Portfolio Manager. Results are publicly available in the BuildSmart DC database. The Clean Energy DC Omnibus Amendment Act of 2018 lowered the building floor area threshold and set new requirements for third-party verification every three years.	1
Alaska	Residential	Alaska statute AS.34.70.101 requires the release of utility data for residential buildings at the time of sale.	0.5
Hawaii	Residential	§508D-10.5 requires residential property owners to disclose energy efficiency consumer information at the time of sale or lease.	0.5
Kansas	Residential	HB 2036 requires builders or sellers of new residential single-family homes or multifamily buildings of four units or fewer to disclose information regarding the energy efficiency of the structure to prospective buyers prior to the signing of a purchase contract.	0.5
Maine	Residential rental	HP 1468 requires the disclosure of an energy efficiency checklist upon request by tenant or lessee and allows for the release of audit information on residential rental properties, both at the time of rental.	0.5
New Jersey	Commercial	AB A3723 (2018) establishes that within five years of enactment, the owner or operator of any commercial building larger than 25,000 square feet must benchmark energy and water use with the ENERGY STAR Portfolio Manager tool.	0.5
New York	Residential	Since 1981, the Truth in Heating law has required the release of residential buildings' utility data upon request by prospective purchasers at the time of sale.	0.5
South Dakota	Residential	SB 64 (2009) established certain energy efficiency disclosure requirements for new residential buildings at the time of sale.	0.5
Washington	Commercial	SB 5854 (2009–10) requires owners of nonresidential buildings larger than 10,000 square feet and qualifying public agency buildings to benchmark their buildings' energy use with ENERGY STAR Portfolio Manager and to disclose this information to buyers, lenders, and lessees.	0.5

Policy information is based on responses to data requests from state energy offices.

Several states have taken the lead in requiring benchmarking and energy use transparency. The most recent is New Jersey, which passed significant renewable energy legislation in

2018 that included requirements for the owners of commercial buildings larger than 25,000 square feet to benchmark energy and water use using the ENERGY STAR Portfolio Manager tool. The District of Columbia and California are the only jurisdictions we surveyed that have such requirements for both the commercial and residential multifamily sectors. As benchmarking and energy use transparency policies become more common, more states will probably expand their scope to target more buildings across both markets. However, local jurisdictions are more likely to pursue these policies. Most recently, Kansas City and St. Louis, Missouri; Portland, Oregon; and Reno, Nevada, adopted benchmarking ordinances.[56]

Residential Energy Labeling

Last year we added a new 0.5-point metric to recognize state efforts to make visible the energy consumption and efficiency of homes through issuance or support of residential energy labeling initiatives. While the benchmarking metric is based on the existence of a state policy, the labeling metric is a quantitative measure of how many homes are rated. As mentioned, a variety of energy rating protocols exists, with some state-specific labels having been uniquely adapted from DOE's Home Energy Score. In order to compare states, we used publicly available 2019 RESNET HERS ratings figures as a foundational data set and supplemented it with additional state-provided labeling records gathered through ACEEE's data request to state energy offices (RESNET 2020). We then calculated the number of ratings issued as a percentage of total building permits for residential and multifamily new construction as reported by the U.S. Census Bureau. We awarded 0.5 points to states in which this percentage was equal to or higher than the median of all states. Table 31 shows the results of this analysis.

Table 31. Residential energy labeling efforts (2019)

State	Home energy ratings issued*	New residential and multifamily building permits†	Home energy ratings as % of new construction	Score (0.5 pts.)‡
Oregon[1]	11,018	22,037	50.00%	0.5
Massachusetts	8,348	17,365	48.07%	0.5
Maryland	8,658	18,491	46.82%	0.5
Indiana	10,294	22,309	46.14%	0.5
Arizona	20,298	46,580	43.58%	0.5
New Mexico	2,082	5,020	41.47%	0.5
Colorado	14,385	38,633	37.24%	0.5
Nevada	7,398	20,143	36.73%	0.5
Oklahoma	4,446	12,152	36.59%	0.5
Ohio	7,609	23,047	33.02%	0.5
Rhode Island	455	1,400	32.50%	0.5

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[56] For more information on how municipalities are encouraging building energy disclosure, see Ribeiro et al. (2015) and Cluett and Amann (2013).

State	Home energy ratings issued*	New residential and multifamily building permits†	Home energy ratings as % of new construction	Score (0.5 pts.)‡
Iowa	3,378	11,870	28.46%	0.5
Delaware	1,766	6,539	27.01%	0.5
South Carolina	9,412	36,034	26.12%	0.5
Minnesota	7,287	28,586	25.49%	0.5
North Carolina	16,849	71,307	23.63%	0.5
Texas	45,096	209,895	21.49%	0.5
Virginia	6,947	32,418	21.43%	0.5
Kansas	1,520	7,961	19.09%	0.5
Connecticut	1,105	5,854	18.88%	0.5
Michigan	3,665	20,600	17.79%	0.5
Pennsylvania	4,164	23,539	17.69%	0.5
Kentucky	2,005	11,811	16.98%	0.5
New Hampshire	742	4,743	15.64%	0.5
New Jersey	4,990	36,505	13.67%	0.5
Florida	21,090	154,302	13.67%	0.5
Alabama	2,331	17,748	13.13%	0
Idaho	2,121	17,716	11.97%	0
Georgia	5,988	53,823	11.13%	0
Illinois	2,275	20,524	11.08%	0
New York	4,474	45,219	9.89%	0
District of Columbia	528	5,945	8.88%	0
Wisconsin	1,466	17,480	8.39%	0
Utah	2,386	28,779	8.29%	0
Nebraska	581	8,025	7.24%	0
Vermont	126	1,801	7.00%	0
Wyoming	115	1,708	6.73%	0
Arkansas	591	12,723	4.65%	0
Hawaii	189	4,093	4.62%	0
Tennessee	1,840	41,361	4.45%	0
West Virginia	126	3,010	4.19%	0
Missouri[2]	583	17,460	3.34%	0
South Dakota	96	4,415	2.17%	0
Washington	902	48,424	1.86%	0

State	Home energy ratings issued*	New residential and multifamily building permits†	Home energy ratings as % of new construction	Score (0.5 pts.)‡
Louisiana	170	15,793	1.08%	0
California	848	110,197	0.77%	0
Maine	6	4,760	0.13%	0
Mississippi	3	6,952	0.04%	0
Montana	2	4,776	0.04%	0
Alaska[3]	0	1,680	0.00%	0
North Dakota	0	2,495	0.00%	0

* 2019 RESNET HERS ratings unless otherwise noted. † 2019 U.S. Census Bureau Building Permits Survey (Census Bureau 2020). ‡ Scores of 0.5 were awarded to states in which the number of ratings issued as a percentage of new construction was equal to or greater than the median, or 13.67%. [1] 7,800 Oregon Home Energy Scores supported by a state program and based on DOE's Home Energy Score; 3,045 Energy Trust of Oregon's Energy Performance Scores (EPS). EPS is a utility new homes program that evaluates homes built above code and offers incentives based on percentage above code as it is built. [2] Missouri Home Energy Certification takes into consideration both the HERS Index and the HES. A total of 3,247 Gold Certificates have been issued through the program. A home must achieve an 8 or greater on the HES, or a HERS Index score of 65 or lower to qualify. Figures for 2019 were not available. [3] AkWarm, the state-approved energy rating software, is used to model home energy requirements. More than 10,622 new homes have been constructed that meet or beat the applicable Alaska Building Energy Efficiency Standard. Figures for 2019 were not available.

Standards for Existing Buildings

Looking to the future, by 2050 roughly half of the nation's building stock will be buildings that are already standing today (Nadel 2019). While state policies often focus on improving new construction, states are also beginning to seek out ways to reduce energy consumption and carbon emissions in their stock of existing buildings. This is an important area of focus given that a building may be around for 30, 40, 50, or more years.

The two current examples of existing building standards are in the District of Columbia and Washington State. DC and Washington are both in the process of enacting requirements for commercial buildings 50,000 square feet and above to meet minimum performance standards. The standards require buildings to meet a minimum threshold—energy use intensity in Washington state and ENERGY STAR score (which is based on EUI) in DC. Both standards permit alternative compliance pathways for buildings unable to meet these thresholds, allowing them to show that they are taking sufficient steps to reduce energy consumption. Table 32 gives further details.

Table 32. Existing building standards

State	Existing building standard type	Requirements	Score (1 pt.)
District of Columbia	Commercial	The District's December 2018 Clean Energy DC Omnibus Act includes a provision to create Building Energy Performance Standards (BEPS). BEPS will require all existing buildings over 50,000 square feet to meet an energy efficiency threshold or to improve its performance by 2026. The threshold is based on an ENERGY STAR score. Alternative pathways will be available for buildings unable to meet the threshold.	1
Washington	Commercial	The state's 2019 House Bill 1257, Clean Buildings for Washington Act, set requirements for commercial buildings to meet performance targets. The Department of Commerce determines the targets using energy use intensity as a metric. Buildings over 50,000 square feet are required to comply, starting in 2026 with the largest buildings. An additional compliance pathway is available for buildings unable to meet the EUI, provided they have conducted an energy audit and invested in improvements.	1

Zero-Energy Building Deployment

Examples of zero-energy buildings, which generate at least as much energy as they consume (averaged out annually), keep increasing in number each year. With the growing interest in zero-energy and zero-carbon building design, we have included a new metric to account for states' commitment to developing zero-energy buildings.

The New Buildings Institute tracks verified and emerging zero-energy building projects throughout the United States. [57] For this metric, we considered verified zero energy buildings and, to a lesser degree, emerging zero-energy buildings. We then normalized the total by each state by gross domestic product, so as not to favor large states with greater ability to build ZEBs.

Our scoring results show Vermont to be the highest rated with our metric: With its relatively small economy, it has four verified zero-energy buildings and five emerging ones. By sheer numbers alone, California earns the top spot, with 50 verified ZEBs and 236 in the emerging category. Although having the largest economy of any state counterbalances these high numbers, California still ranked third on our list, showing that it has a disproportionately high number of zero-energy buildings. We awarded 0.5 points to states that achieved a ZEB per GDP ratio of 20 or above, which accounts for roughly a third of the states, as shown in Table 33.

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[57] Emerging projects are those that have not yet achieved zero-energy status, or those for which NBI does not have data to verify zero-energy performance (NBI 2020).

Table 33. Zero-energy buildings per GDP

State	Verified ZEBs	Emerging ZEBs	State GDP (trillion dollars)	ZEBs per GDP*	Score (0.5 points)
Vermont	4	6	0.030	232.0	0.5
Oregon	5	26	0.234	77.0	0.5
Hawaii	3	5	0.083	65.9	0.5
California	50	236	2.893	58.1	0.5
District of Columbia		9	0.138	32.6	0.5
Maine	1	2	0.061	32.5	0.5
Massachusetts	7	21	0.547	32.0	0.5
Nevada	2	6	0.156	32.0	0.5
Colorado	2	17	0.365	28.8	0.5
Arizona	1	18	0.350	28.6	0.5
Utah	2	6	0.183	27.3	0.5
Kentucky	3	4	0.194	25.8	0.5
New Hampshire		4	0.079	25.4	0.5
Montana		2	0.048	21.0	0.5
North Dakota		2	0.050	20.0	0.5
Washington	7	9	0.580	19.8	0
Iowa	2	3	0.179	19.5	0
Connecticut	3	4	0.263	19.0	0
Mississippi	1	2	0.106	18.9	0
Arkansas	1	2	0.121	16.6	0
South Carolina		7	0.225	15.6	0
Wyoming		1	0.033	15.0	0
Virginia	4	7	0.520	14.4	0
Delaware	1		0.072	14.0	0
Maryland	2	7	0.399	13.8	0
Minnesota	1	7	0.348	12.9	0
Idaho	1		0.077	12.9	0
Wisconsin	1	6	0.314	12.7	0
Pennsylvania	5	8	0.724	12.4	0
Florida	7	10	1.027	11.7	0
North Carolina	4	4	0.547	11.0	0
Alaska		1	0.046	11.0	0
New Mexico		2	0.093	10.7	0

State	Verified ZEBs	Emerging ZEBs	State GDP (trillion dollars)	ZEBs per GDP*	Score (0.5 points)
Indiana	2	3	0.344	10.2	0
New York	4	24	1.588	10.1	0
Rhode Island		1	0.056	8.9	0
Nebraska		2	0.120	8.4	0
Ohio	3	4	0.626	8.0	0
West Virginia		1	0.068	7.4	0
Missouri	1	2	0.299	6.7	0
Michigan	1	4	0.475	6.3	0
Kansas		2	0.161	6.2	0
Illinois		10	0.807	6.2	0
Tennessee		4	0.333	6.0	0
Texas	3	13	1.628	5.8	0
Georgia		5	0.581	4.3	0
New Jersey	1	2	0.574	3.5	0
Alabama		1	0.210	2.4	0
Louisiana		1	0.224	2.2	0
Oklahoma			0.173	0.0	0
South Dakota			0.051	0.0	0

*Verified zero-energy buildings are given a weight of 1, while emerging zero-energy buildings are given a weight of 0.5.
Sources: NBI 2019; BEA 2020.

Chapter 5. State Government–Led Initiatives

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INTRODUCTION

State legislatures and governors can advance energy efficiency policies and programs that affect the utilities, transportation, and buildings sectors discussed in previous chapters. They can also do more. In this chapter, we focus on energy efficiency initiatives that are designed, funded, and implemented by state entities, including energy offices, economic development agencies, and general services agencies.

We focus on three initiatives commonly undertaken by state governments: financial incentive programs for consumers, businesses, and industry; lead-by-example policies and programs to improve the energy efficiency of public facilities and fleets; and carbon pricing. This year we removed one category, R&D for energy efficiency technologies and practices, since the vast majority of states administer or support some form of R&D program. However, we continue to collect and post this information on ACEEE's State and Local Policy Database.[58] In lieu of scoring R&D, we expanded our scoring metric for carbon pricing policies that help advance investments in efficiency, as discussed further below.

SCORING AND RESULTS

States could earn up to 6 points in this policy area for the following:

- Financial incentives offered by state agencies (2.5 points)
- Lead-by-example policies (2 points)
- Carbon pricing policy (1.5 points)

Table 34 presents the overall results of scoring on state initiatives.

Table 34. Summary of scores for government-led initiatives

State	Financial incentives (2.5 pts.)	Lead by example (2 pts.)	Carbon pricing policy (1.5 pts.)	Total score (6 pts.)
California	2.5	2	1.5	6
Connecticut	2.5	2	1.5	6
Delaware	2.5	2	1.5	6
Massachusetts	2.5	2	1.5	6
Rhode Island	2.5	2	1.5	6
Vermont	2.5	2	1.5	6
Colorado	2.5	2	1	5.5
Maine	2.5	1.5	1.5	5.5

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[58] See database.aceee.org.

State	Financial incentives (2.5 pts.)	Lead by example (2 pts.)	Carbon pricing policy (1.5 pts.)	Total score (6 pts.)
Maryland	2.5	2	1	5.5
Minnesota	2.5	2	1	5.5
New Hampshire	2.5	2	1	5.5
New York	2.5	1.5	1.5	5.5
Oregon	2.5	2	1	5.5
Pennsylvania	2.5	2	0.5	5
Tennessee	2.5	2	0.5	5
Virginia	2.5	1.5	1	5
Washington	2.5	2	0.5	5
Nevada	2.5	1	1	4.5
District of Columbia	1.5	1.5	1	4
Florida	2.5	1.5	0	4
Illinois	1.5	2	0.5	4
Kentucky	2.5	1.5	0	4
Missouri	2.5	1.5	0	4
New Mexico	1.5	2	0.5	4
North Carolina	1.5	2	0.5	4
South Carolina	2.5	1.5	0	4
Wisconsin	1.5	1.5	1	4
Alaska	2.5	1	0	3.5
Arkansas	2	1.5	0	3.5
Michigan	2.5	1	0	3.5
Ohio	2.5	1	0	3.5
Texas	1.5	2	0	3.5
Utah	1.5	2	0	3.5
Alabama	1.5	1.5	0	3
Montana	1.5	1.5	0	3
New Jersey	0	2	1	3
Hawaii	0.5	1.5	0.5	2.5
Louisiana	1	1.5	0	2.5
Mississippi	1.5	1	0	2.5
Oklahoma	0.5	1.5	0.5	2.5
Wyoming	2	0.5	0	2.5

State	Financial incentives (2.5 pts.)	Lead by example (2 pts.)	Carbon pricing policy (1.5 pts.)	Total score (6 pts.)
Arizona	1	1	0	2
Georgia	0.5	1.5	0	2
Idaho	1.5	0.5	0	2
Nebraska	1.5	0.5	0	2
Indiana	1	0.5	0	1.5
West Virginia	1.5	0	0	1.5
Iowa	0.5	0.5	0	1
Kansas	0	1	0	1
North Dakota	0.5	0	0	0.5
South Dakota	0	0.5	0	0.5

DISCUSSION

Financial Incentives

While utilities offer ratepayer-funded energy efficiency programs, many states also provide financial incentives to spur the adoption of technologies and practices in homes and businesses. These incentives can be administered by various state agencies but are most often coordinated by state energy offices. Incentives can take many forms: rebates, loans, grants, or bonds for energy efficiency improvements; income tax credits and deductions for individuals or businesses; and sales tax exemptions or reductions for eligible products. Financial incentives can lower the up-front cost and shorten the payback period for energy efficiency upgrades, shrinking two barriers for consumers and businesses seeking to make cost-effective efficiency investments. Incentives also raise consumer awareness of eligible products, encouraging manufacturers and retailers to market these products more actively and to continue to innovate. As economies of scale improve, prices of energy-efficient products fall, enabling the products to eventually compete in the marketplace without the incentives.

SCORES FOR FINANCIAL INCENTIVES

Information regarding state incentives for energy efficiency improvements was gathered through our survey of state energy officials and our review of the Database of State Incentives for Renewables and Efficiency (DSIRE 2020).

We did not give points in this category for utilities' customer-funded financial incentive programs, which are covered in Chapter 2. Here we included state appropriations or bonds, oil overcharge revenues, auction proceeds from the RGGI or California's cap-and-trade program, other non-customer sources, and tax incentives. While state and customer funding sometimes overlap—for example, where state incentives are funded through a system benefits charge—we designed this category to capture energy efficiency initiatives not already captured in Chapter 2.

We also recognized growing state efforts to leverage private dollars for energy efficiency programs by awarding points for loans offered by green banks with active energy efficiency programs, and giving credit for PACE financing programs enabled by state legislation. From 2009 to 2019, energy efficiency projects accounted for 49% of commercial PACE funding (PACENation 2020a). State legislatures pass and amend legislation enabling residential or commercial PACE, and localities or private program administrators typically run the programs, depending on the jurisdiction.[59] Sometimes states play a more prominent role in PACE coordination by administering a statewide program or offering guidance to PACE providers (Fazeli 2016). Because programs are usually locally administered, we did not give extra credit for multiple active PACE programs. We indicate in table 35 whether state PACE activity is in the residential or commercial market or both. We discuss other energy efficiency financing efforts in more detail at the end of this chapter.

States earned up to 2.5 points for major financial incentive programs that encourage the purchase of energy-efficient products.[60] We judged these programs on their relative strength, customer reach, and impact. Incentive programs generally received 0.5 points each, but several states have major incentive programs that we deemed worth 1 point each; these include Arizona, Connecticut, Idaho, Nebraska, Nevada, New York, Texas, Washington, and Wisconsin. States that have at least one active PACE program were awarded 0.5 points. Table 35 shows our scoring of state financial incentives.

It should be noted that the number of financial incentive programs a state implements may not fully reflect the robustness of its efforts. Accordingly, this year we attempted to collect additional information from state energy offices regarding state budgets for financial incentives, program participation rates, verified savings from incentives, and leveraging of private capital. These data are presented in Appendix L.

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[59] Currently, 37 states plus Washington, DC, authorize PACE (PACENation 2020b). While most states' PACE activity is in the commercial market, residential PACE is currently offered in California, Florida, and Missouri.

[60] Energy-efficient products include any product or process that reduces energy consumption. While renewable energy technologies such as solar hot-water heating may reduce energy consumption, they are often rolled into larger programs that focus on renewable energy rather than energy efficiency. ACEEE would like to credit states for renewable energy technologies that reduce energy consumption, but they are often difficult to distinguish from broader renewable energy incentives that fall outside the scope of the *State Scorecard*. As a result, they are not credited at this time.

Table 35. State scores for major financial incentive programs

State	Major state financial incentives for energy efficiency	Score (2.5 pts.)
Alaska	Five loan programs; one grant program	2.5
California	California Infrastructure and Economic Development Bank–led bond program for public buildings; three grants; two revolving loans for public buildings; one loan loss reserve for small businesses; one rebate program; one tax incentive for advanced transportation technologies; commercial and residential PACE financing	2.5
Colorado	Loan loss reserve program; school loan program; Residential Energy Upgrade (RENU) Loan program; Agricultural Energy Efficiency Program; statewide commercial PACE financing	2.5
Connecticut	Connecticut Green Bank–led programs including three loans, three financing options for multifamily and low-to-moderate-income residential projects, commercial PACE financing; one loan for multifamily housing properties; two loans for multifamily and low-income residential projects	2.5
Delaware	Three loan programs; three grant programs; two rebate programs	2.5
Florida	Efficiency and Renewable Improvements in Commercial Aquaculture (ERICA); Rural Community Energy Efficiency Grant Program (RCEE); Renewable Energy and Energy-Efficient Technologies (REET) Grant Matching Program; RESTORE Act; commercial and residential PACE financing	2.5
Kentucky	Grants, loans, and bonds for farms, schools, and local governments; Kentucky Green Bank–funded loan for state government; sales tax exemption for energy-efficient products; commercial PACE financing	2.5
Maine	Residential rebate and incentive; consumer products incentive; commercial and industrial incentive; heat pump incentive; weatherization program	2.5
Maryland	Loans and grant programs for agricultural, residential, multifamily, commercial, and industrial sectors; Smart Energy Communities program; loans for state agencies; commercial PACE financing	2.5
Massachusetts	Alternative Energy and Energy Conservation Patent Exemption (personal and corporate); one bond; several grants	2.5
Michigan	Three loans; two rebates; several grants; commercial PACE financing	2.5
Minnesota	Four loans; three revolving loans; one loan loss reserve; commercial PACE financing	2.5
Missouri	One loan program; one loan loss reserve; one revolving loan; one personal tax deduction; commercial and residential PACE financing	2.5
Nevada	Property tax abatement for green buildings; Home Energy Retrofit Opportunities for Seniors (HEROS); loans for state employees; commercial PACE financing	2.5
New Hampshire	Four revolving loan funds; one grant; commercial PACE financing	2.5
New York	Green Jobs–Green NY Program; loan, grant, financing, rebate, and incentive programs; Energy Conservation Improvements Property Tax Exemption; NY Green Bank; commercial PACE financing	2.5

State	Major state financial incentives for energy efficiency	Score (2.5 pts.)
Ohio	Two loans; one grant program; property tax exemption for energy-efficient projects; commercial PACE financing	2.5
Oregon	Three grant programs; one rebate; commercial PACE financing	2.5
Pennsylvania	Alternative Energy Investment Fund; Sustainable Energy Finance Program; several grant and loan programs; commercial PACE financing	2.5
Rhode Island	Rhode Island Infrastructure Bank–led programs, including one revolving loan program and commercial PACE financing; two grants; two rebates	2.5
South Carolina	Tax credits and sales tax cap for new energy-efficient manufactured homes; two loan programs; mini-grants	2.5
Tennessee	Energy Efficient Schools Initiative (loans and grants); two grant programs; one loan program	2.5
Vermont	Three Sustainable Energy Loan Fund programs; Energy Loan Guarantee Program; Weatherization Trust Fund; Heat Saver Loan	2.5
Virginia	Energy Leasing Program for state-owned facilities; Clean Energy Manufacturing Incentive Grant Program; one loan program; personal tax incentive; financing for innovative energy technologies; commercial PACE financing	2.5
Washington	Major grant program for energy efficiency in public facilities and local communities; several loans and grants	2.5
Arkansas	Three loans; commercial PACE financing	2
Wyoming	Three grant programs; one loan program	2
Alabama	Alabama SAVES revolving loan program; AlabamaWISE Home Energy Program (loans); EE Retrofit program	1.5
District of Columbia	Green Light Grant Program; commercial PACE financing; DC Green Bank	1.5
Idaho	Income tax deduction for energy efficiency improvements; one major low-interest loan program; Government Leading by Example (GLBE) program for public buildings in rural cities and counties	1.5
Illinois	Renewable Energy and Energy Efficiency Project Financing; Green Energy Loan program; commercial PACE financing	1.5
Mississippi	One loan program; one public sector lease program for energy-efficient equipment; one private-sector grant for industrial energy efficiency	1.5
Montana	Energy conservation installation tax credit; tax deduction for energy-conserving investment; Alternative Energy Revolving Loan Program	1.5
Nebraska	Major loan program (Dollar and Energy Saving Loans); commercial PACE financing	1.5
New Mexico	Sustainable Building Tax Credit (corporate and personal); bond program	1.5
North Carolina	One loan program; one cost savings program; PACE financing	1.5
Texas	Major loan program (Texas LoanSTAR); commercial PACE financing	1.5

State	Major state financial incentives for energy efficiency	Score (2.5 pts.)
Utah	Two loan programs for state-owned buildings and schools; commercial PACE financing	1.5
West Virginia	West Virginia Division of Energy and WVU College of Engineering partnership; EE West Virginia; one revolving loan fund	1.5
Wisconsin	Major loan program (Clean Energy Manufacturing Revolving Loan Fund); commercial PACE financing	1.5
Arizona	Property tax exemption for energy-efficient building components and CHP	1
Indiana	Tax credit for purchase and installation of residential insulation; Green Project Reserve revolving loan fund	1
Louisiana	Home Energy Loan Program (HELP); Energy Fund Loan Program	1
Georgia	One grant program	0.5
Hawaii	Green Energy Market Securitization (GEMS) financing program	0.5
Iowa	Energy Bank Revolving Loan Program	0.5
North Dakota	Energy Conservation Grant	0.5
Oklahoma	Commercial PACE financing	0.5
Kansas	None	0
New Jersey	None	0
South Dakota	None	0

GREEN BANKS

States are increasingly leveraging private capital alongside public dollars to incentivize energy efficiency. One way of doing this is through green banks, which can overcome barriers faced by consumers and lenders in financing energy efficiency and renewable energy projects. While we do not currently give credit solely for the establishment of a green bank, we recognize the important contribution they make to incentivizing energy efficiency.[61] These financing institutions offer public dollars and leverage private funds to unleash new investment, reduce costs, and increase consumer demand in the clean energy sector. In addition, green banks often provide technical assistance to clean energy projects across sectors to help consumers understand available funding streams and to simplify the process of purchasing efficiency technologies (CGC 2015).

Because most state green banks are in the early planning stages and have yet to reach full scale, there is a lack of data on their performance (Gilleo, Stickles, and Kramer 2016). To more accurately assess the impacts of financing programs offered by green banks, policymakers and program administrators should collect data—and standardize data collection efforts—on the following metrics:

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[61] While we credit evaluated savings from financing programs (including on-bill financing programs) in the utilities chapter, in this chapter we recognize financing programs like green banks that leverage additional, non-ratepayer state resources.

- *Energy savings.* Independently evaluated energy savings achieved as a result of green bank investments
- *Leverage.* The ratio of private loan capital deployed and public or ratepayer funds used
- *Market penetration.* In particular, whether financing is available to low-income, multifamily, and other underserved markets
- *Coordination with utility programs.* The extent to which green banks and utilities coordinate program offerings

Leading and Trending States: Financial Incentives

Maine. Deployed statewide in October 2019 through Maine's Community Action Agency (CAA) network, MaineHousing's Heat Pump Program pays for the cost and installation of a heat pump for eligible Maine homeowners. As of the end of May 2020, the state's CAAs reported that 1,098 households had expressed an interest in or were on wait lists for heat pumps. So far, CAAs have managed the installation of 175 heat pumps at a cost of $563,321.

Hawaii. On April 8, 2019, Hawaii Governor David Ige formally announced the Green Energy Money $aver (GEM$) on-bill financing program, a statewide initiative to make clean energy more affordable for homes and small businesses. The culmination of more than seven years of work by Hawaiian authorities, the program provides easy-access financing for cost-effective rooftop solar panels and other renewable distributed energy systems, as well as energy efficiency upgrades. The GEM$ On-Bill Program is available to about 95% of Hawaii's population. In addition to rooftop solar, eligible projects include solar hot-water heaters, heat pump water heaters, and energy efficiency measures. Projects must be designed to reduce energy bills by at least 10% after accounting for repayment of the clean energy investment.

New Hampshire. The Clean Energy Fund invests in energy efficiency and renewable energy projects that reduce costs for New Hampshire businesses, nonprofits, and municipalities; help address New Hampshire's energy challenges in a fiscally and environmentally responsible manner; lower the state's contribution to global climate impacts; and reduce barriers for equitable access to clean energy benefits. Capitalized at more than $10 million, the fund merges four individual revolving loan funds dedicated to financing energy efficiency improvements and clean/renewable energy initiatives into a single program and application process, providing low-interest loans along with energy technical assistance and project funding guidance. Funding for the program comes from a combination of federal and state sources as well as the Community Development Finance Authority's own funds.

New York. The NY Green Bank (NYGB) was established in 2013 as a state-sponsored specialty financing entity housed within the New York State Energy and Development Authority (NYSERDA). NYGB combines funds from ratepayers and RGGI to leverage private clean energy capital. In 2020 NYGB reported that $117.5 million of capital had been committed in the fourth quarter of 2019, making 2019 its best-performing year to date with $276.1 million allocated. The total NYGB portfolio stands at more than $909 million, encouraging up to $2.4 billion in clean energy investments. NYGB's recent energy efficiency projects include financing the new construction of Saranac Waterfront Lodge, the first LEED-certified hotel in Adirondack Park, and providing a term loan to Ecosave, an energy services company, to support at least five energy efficiency or distributed generation projects. NYGB's investments have driven between 10 million and 18 million metric tons of gross lifetime GHG reductions, equivalent to removing up to 183,599 cars from the road for the next 23 years. These efforts support the state's goal of reducing GHGs 85% by 2050 (NYSERDA 2020).

Lead by Example

State governments can advance energy-efficient technologies and practices in the marketplace by adopting policies and programs to save energy in public sector buildings and fleets, a practice commonly referred to as *lead by example*. In the current environment of fiscal austerity, lead-by-example policies and programs are a proven strategy for improving the operational efficiency and economic performance of states' assets. Lead-by-example initiatives also reduce the negative environmental and health impacts of high energy use and promote energy efficiency to the broader public.[62]

States can show leadership in energy efficiency policy through the development of state energy plans, and in fact most states have them.[63] Governors can issue executive orders or form planning committees to evaluate state energy needs, goals, and opportunities.[64] Sometimes legislatures initiate the process. These actions help establish a statewide vision for energy use. We do not award points solely for the existence of a state energy plan, but we do consider the formal executive orders and policies that execute energy efficiency initiatives included in such plans.

SCORES FOR LEAD BY EXAMPLE

States could earn up to 2 points in this category: 0.5 points each for energy savings targets in new and existing state buildings, benchmarking requirements for public facilities, energy savings performance contract (ESPC) activities, and fleet fuel efficiency mandates. We based our review of states' lead-by-example initiatives on our survey of state energy officials as well as independent research.

State building requirements. Many states have adopted policies and comprehensive programs to reduce energy use in state buildings. State governments operate numerous facilities, including office buildings, public schools, colleges, and universities, the energy costs of which can account for as much as 10% of a typical government's annual operating budget. In addition, the energy consumed by a state's facilities can account for as much as 90% of its GHG emissions (DOE 2008). Only a handful of states have not yet implemented an energy efficiency policy for public facilities. Mandatory energy savings targets for new and existing state government facilities are the most widely adopted state measures. These requirements encourage states to invest in the construction of new, efficient buildings and retrofit projects, lowering energy bills and promoting economic development in the energy services and construction sectors.

To earn credit, energy savings targets must commit state government facilities to a specific energy reduction goal over a distinct time period. We also gave 0.5 points to states that

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[62] Energy efficiency limits harmful pollutants by reducing the need to burn fossil fuels to generate electricity. ACEEE and Physicians for Social Responsibility explore this connection in a joint fact sheet at aceee.org/fact-sheet/ee-and-health.

[63] See naseo.org/stateenergyplans.

[64] See ACEEE's *Energy Efficiency Toolkit for Governors* (2019) for more information: aceee.org/topic-brief/governors-ee-toolkit.

require state buildings to exceed the statewide energy code or meet a green building criterion like Leadership in Energy and Environmental Design (LEED) certification.

Benchmarking requirements for public buildings. Proper building energy management is a critical element of successful energy efficiency initiatives in the public sector. Benchmarking energy use in public sector buildings through tailored tools or widely available tools such as ENERGY STAR Portfolio Manager ensures a comprehensive set of energy consumption data that can be used to drive cost-effective energy efficiency investments.[65] Comparing building energy performance across agencies can also help prioritize energy efficiency projects.

Through benchmarking policies, states and cities require all buildings of a certain size or type to undergo a regular energy audit or have their energy performance tracked. We awarded 0.5 points for energy benchmarking policies and large-scale benchmarking programs for public sector facilities.

Efficient fleets. In addition to lead-by-example initiatives in state government buildings, many states enact policies encouraging or requiring efficient vehicle fleets to reduce fuel costs and hedge against rising fuel prices. Collectively, state governments own approximately 500,000 vehicles, with a median fleet size of about 3,500. Operation and maintenance costs for these fleets every year exceed $2.5 billion nationwide, ranging from $7 million to $250 million per state (NCFSA 2007). In response to these costs, states may adopt an efficiency standard specifically for state vehicle fleets that reduces fuel consumption and GHG emissions.

For this category, states received credit only if the plan or policy for increasing the efficiency of its fleet contains a specific, mandatory requirement. For example, states could qualify for 0.5 points if fleet policies specify fuel economy improvements that exceed existing CAFE standards. Other policies that earned 0.5 points include binding goals to reduce petroleum use by a certain amount over a given time frame, meaningful GHG reduction targets for fleets, and procurement requirements for hybrid-electric or all-electric vehicles. However, state adoption of such targets does not guarantee they will be achieved; we will continue to seek data on state progress toward meeting these goals and may revisit this metric in the future with an eye toward measured achievement of targets. We did not credit requirements for procuring alternative-fuel vehicles because such vehicles may not result in improved fuel economy.

Energy savings performance contracting policies and programs. If state governments have the necessary support, leadership, and tools in place, they can help projects overcome information and cost barriers by financing energy improvements through ESPCs. The state may enter into an ESPC with an energy services company (ESCO), paying for these services

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[65] Some states have their own databases of public building energy use that integrate with the ENERGY STAR Portfolio Manager. For example, Maryland's EnergyCAP database compiles the energy use (based on utility bills) of all public buildings in the state and enables comparison of buildings occupied by various state agencies.

with money saved on lower energy bills from energy conservation measures. A designated state agency may serve as the lead contact for implementing the contract.[66]

We based scores for ESPC activities on support, leadership, and tools. To promote performance contracting, states must provide an enabling framework (support) and guidance and resources (leadership and tools) to get projects underway. We awarded a state 0.5 points if it satisfied at least two of the three criteria. Table 36 describes qualifying actions.

Table 36. Scoring of ESPC policies and programs

Criterion	Qualifying action
Support	The state explicitly promotes the use of ESPCs to improve the energy efficiency of public buildings through statutory requirements, recommendations, or explicit preferences for ESPC use; executive orders that promote or require ESPCs; and/or financial incentives for agencies seeking to use ESPCs.
Leadership	A state program directly coordinates ESPCs, or a specific state agency serves as lead contact for implementing ESPCs.
Tools	The state offers documents that streamline and standardize the ESPC process, including a list of prequalified service companies, model contracts, and/or a manual that lays out the procedures required for state agencies to utilize ESPCs.

States must satisfy at least two of the three criteria above to receive credit.

Table 37 presents states' overall scores for lead-by-example efforts.

Table 37. State scores for lead-by-example initiatives

State	New and existing state building requirements	Benchmarking requirements for public buildings	Efficient fleets	ESPC policy and programs	Score (2 pts.)
California	•	•	•	•	2
Colorado	•	•	•	•	2
Connecticut	•	•	•	•	2
Delaware	•	•	•	•	2
Illinois	•	•	•	•	2
Maryland	•	•	•	•	2
Massachusetts	•	•	•	•	2
Minnesota	•	•	•	•	2
New Hampshire	•	•	•	•	2

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[66] For a full discussion of ESPCs, the ESCO market, and actual implementation trends, see Stuart et al. (2016). For additional best practices in state and local establishment and implementation of ESPC programs, see DOE's ESPC Toolkit (betterbuildingssolutioncenter.energy.gov/energy-savings-performance-contracting-espc-toolkit) and its guidelines for state ESPC program development (betterbuildingssolutioncenter.energy.gov/sites/default/files/attachments/ESPC-Program_Guidelines_Final.pdf).

State	New and existing state building requirements	Benchmarking requirements for public buildings	Efficient fleets	ESPC policy and programs	Score (2 pts.)
New Jersey	•	•	•	•	2
New Mexico	•	•	•	•	2
North Carolina	•	•	•	•	2
Oregon	•	•	•	•	2
Pennsylvania	•	•	•	•	2
Rhode Island	•	•	•	•	2
Tennessee	•	•	•	•	2
Texas	•	•	•	•	2
Utah	•	•	•	•	2
Vermont	•	•	•	•	2
Washington	•	•	•	•	2
Alabama		•	•	•	1.5
Arkansas	•	•		•	1.5
District of Columbia	•	•	•		1.5
Florida		•	•	•	1.5
Georgia	•	•		•	1.5
Hawaii		•	•	•	1.5
Kentucky	•	•		•	1.5
Louisiana	•		•	•	1.5
Maine	•		•	•	1.5
Missouri	•		•	•	1.5
Montana	•	•		•	1.5
New York	•	•		•	1.5
Oklahoma	•	•		•	1.5
South Carolina	•	•		•	1.5
Virginia	•	•		•	1.5
Wisconsin	•		•	•	1.5
Alaska	•	•			1
Arizona	•			•	1
Kansas	•			•	1
Michigan		•		•	1
Mississippi		•	•		1
Nevada		•		•	1

State	New and existing state building requirements	Benchmarking requirements for public buildings	Efficient fleets	ESPC policy and programs	Score (2 pts.)
Ohio		•		•	1
Idaho				•	0.5
Indiana	•				0.5
Iowa		•			0.5
Nebraska		•			0.5
South Dakota		•			0.5
Wyoming				•	0.5
North Dakota					0
West Virginia					0

Leading and Trending States: Lead-by-Example Initiatives

New Mexico. In 2019, Governor Michelle Lujan Grisham signed Executive Order 2019-003, which commits the state to the 2015 Paris Agreement goals and to the U.S. Climate Alliance. The order also creates a New Mexico Climate Change Task Force that will work toward a statewide climate strategy. In particular, the task force will aim to reduce light-duty vehicle emissions, set emissions limits through a market-based program, adopt new building codes, identify transmission corridors to transport renewable energy, and strengthen the state's renewable portfolio and energy efficiency standards. Further, state agencies are now required to incorporate climate mitigation and adaptation strategies into their programs and implement policies to further reduce GHGs.

Connecticut. Signed by Governor Ned Lamont in 2019, Executive Order No. 1 calls for reducing energy consumption and GHG emissions from state government operations. Focusing on state buildings, a steering committee will work on onsite heating and cooling, electricity, clean energy, vehicles, waste management, water use, and product procurement to help the state achieve its GHG emissions, waste disposal, and water consumption goals. The committee will also consider how to meet a net-zero emissions target for 2050.

Oregon. Executive Order 20-04, signed by Governor Kate Brown in 2020, establishes a plan for meeting the state's climate goals by directing state agencies to put new measures into effect to lower the state's greenhouse gas emissions. The order directs the Environmental Quality Commission and Department of Environmental Quality to amend Oregon's Clean Fuel Standards to meet GHG emissions reduction goals per unit of fuel energy. Additionally, the order requires the Department of Consumer and Business Services Building Codes Division to establish energy efficiency goals for new residential and commercial construction. The Department of Administrative Services is also directed to develop a statewide electric vehicle procurement policy for state agencies. Altogether, the order aims for the state of Oregon to reduce GHG emissions by at least 45% below 1990 levels by 2035 and at least 80% below 1990 levels by 2050 (Oregon Office of the Governor 2020).

Nevada. In 2019, Governor Steve Sisolak signed Executive Order 2019-22, which directs the administration to collaborate with public, private, and tribal partners to accelerate the state's action on meeting its bold climate goals. The order directs state agencies to assess viable policies and regulatory strategies to meet greenhouse gas reduction requirements. Moreover, the order prioritizes building energy codes to increase residential and commercial energy efficiency to achieve emissions reductions. The bill also mandates each state agency to develop priority lists for building energy efficiency projects to be shared with the administration. The administration will investigate financing opportunities for these projects, as indicated by the order (Nevada Office of the Governor 2019).

Carbon Pricing

Recent years have seen a surge in actions to strengthen GHG and renewable generation goals, including the 2019 enactment of 100% clean energy targets in five states (Nevada, New Mexico, Washington, New York, and Maine). Accordingly, last year we introduced a new metric on state carbon pricing policies that have helped support and advance efficiency programs. These policies aim to put a price on carbon, the idea being that if emitting GHGs increases costs, then the market will find a way to reduce emissions at the lowest possible expense (Nadel and Kubes 2019). Two main types of pricing are generally used: a carbon tax and a cap-and-trade system. A carbon tax is a fee charged for each unit of CO_2 (typically a tonne) that is emitted. A cap-and-trade system sets a limit on the total amount of CO_2 that can be emitted and divides this total into emissions allowances. It then distributes these allowances among GHG-emitting companies, creating a market in which the certificates can be bought and sold.

Energy efficiency plays an important role in the successful implementation of carbon pricing policies. When the funds collected from these policies are invested in efficiency, they reduce energy use, energy bills, and energy-related emissions. That can help achieve net economic benefits and cushion the effect of a carbon pricing program on energy costs (Nadel and Kubes 2019). For example, RGGI has dedicated to energy efficiency about 58% of the funds it has raised from cap-and-trade activity (RGGI 2018). That has resulted in decreased emissions, lower customer bills, lower wholesale power prices, new jobs, and a strengthened local economy (Hibbard et al. 2018).

This year we added two new sub-metrics. The first scores whether states or utilities track avoided greenhouse gas emissions achieved through energy efficiency programs, and the second scores whether utilities include avoided costs from emissions reductions in their cost-effectiveness screening. Both of these metrics are important in calculating impacts of efficiency programs and determining ways to increase their success.

SCORES FOR CARBON PRICING

States could earn up to 1.5 points in this category: 0.5 points for having either a carbon tax or a cap-and-trade policy in place; 0.5 points for tracking avoided greenhouse gas emissions achieved through energy efficiency programs; and 0.5 points for including avoided greenhouse gas emissions within benefit–cost testing calculations. Table 38 highlights the total scores for these metrics.

Table 38. State scores for carbon pricing metrics

State	Carbon pricing policy	GHG emissions tracking	Cost-effectiveness test inclusion	Score (1.5 pts.)
California	•	•	•	1.5
Connecticut	•	•	•	1.5
Delaware	•	•	•	1.5
Maine	•	•	•	1.5
Massachusetts	•	•	•	1.5
New York	•	•	•	1.5

State	Carbon pricing policy	GHG emissions tracking	Cost-effectiveness test inclusion	Score (1.5 pts.)
Rhode Island	•	•	•	1.5
Vermont	•	•	•	1.5
Colorado		•	•	1
District of Columbia		•	•	1
Maryland	•	•		1
Minnesota		•	•	1
Nevada		•	•	1
New Hampshire	•	•		1
New Jersey	•	•		1
Oregon		•	•	1
Virginia	•	•		1
Wisconsin		•	•	1
Hawaii		•		0.5
Illinois			•	0.5
New Mexico		•		0.5
North Carolina		•		0.5
Oklahoma		•		0.5
Pennsylvania		•		0.5
Tennessee		•		0.5
Washington			•	0.5
Alabama				0
Alaska				0
Arizona				0
Arkansas				0
Florida				0
Georgia				0
Idaho				0
Indiana				0
Iowa				0
Kansas				0
Kentucky				0
Louisiana				0
Michigan				0
Mississippi				0

State	Carbon pricing policy	GHG emissions tracking	Cost-effectiveness test inclusion	Score (1.5 pts.)
Missouri				0
Montana				0
Nebraska				0
North Dakota				0
Ohio				0
South Carolina				0
South Dakota				0
Texas				0
Utah				0
West Virginia				0
Wyoming				0

Table 39 lists state and utility efforts to track avoided emissions resulting from efficiency programs as described in responses to the *2020 State Scorecard* data request to state energy officials and utility regulators.

Table 39. State and utility responses on avoided emissions tracking

State	Response on GHG tracking
California	The California Air Resources Board, California Public Utilities Commission, and California Energy Commission all track avoided GHG emissions achieved through energy efficiency programs.
Colorado	Colorado reports GHG emissions reductions as a result of energy efficiency programs in its DSM annual report.
Delaware	Avoided GHG emissions are reported to RGGI for all programs funded by RGGI proceeds. In keeping with the state's EM&V regulations, program administrators file reports with the Energy Efficiency Advisory Council on energy impact information for each program; these data are used to calculate avoided greenhouse gas emissions achieved through the programs.
District of Columbia	The DC Sustainable Energy Utility tracks avoided GHG emissions associated with electric and natural gas efficiency programs, assigning a general CO_2 amount associated with each kWh and MMBtu avoided.
Hawaii	Hawaii Energy tracks GHG emissions (pre-PY19) and set targets for PY19-PY21.
Maine	The Efficiency Maine Trust reports on GHG emissions achieved through RGGI-funded energy efficiency programs through the annual "Investment of RGGI Proceeds" report to RGGI, Inc. and the RGGI Annual Report to the Maine State Legislature.

State	Response on GHG tracking
Maryland	Maryland's Greenhouse Gas Reduction Act requires the development of a GHG reduction plan and established a Maryland Climate Change Commission to help with the development of the plan. For this effort, GHG reductions are tracked economy wide, thus reflecting the results of energy efficiency and renewable energy efforts, as well as nonenergy benefits. Some reports by the EmPOWER utilities include information about GHG reductions resulting from energy efficiency programs, but reporting is not required.
Massachusetts	Most of the state's efficiency programs track avoided emissions. Some state programs (e.g., grants for training and market development) do not track avoided emissions because they address overcoming market barriers at various stages of the energy efficiency life-cycle rather than achieving direct savings.
Minnesota	The Department of Commerce publishes an annual report on the energy savings and estimated carbon dioxide reductions achieved by energy conservation improvement programs for the two most recent years for which data are available.
Nevada	Nevada reports GHG emissions reductions as a result of energy efficiency programs in its DSM annual report.
New Hampshire	The utilities typically quantify the amount of GHG reductions in their plans and quarterly updates.
New Jersey	The state requires that utilities filing energy efficiency and peak demand programs for the next generation of energy efficiency programming in New Jersey include emissions savings as a part of the minimum filing requirements. Emissions savings must be tracked and reported and will be evaluated through the evaluation, measurement, and verification process. The state will also track and report GHG emissions, among other metrics.
New Mexico	The state tracks emissions reductions for all of its programs and reports them as part of the ACEEE data request.
New York	NYSERDA and the utilities track and report avoided GHG emissions through energy efficiency programs, and results are publicly available through the Clean Energy Dashboard.
North Carolina	The NC Division of Air Quality produces an annual report that quantifies reductions in GHG from avoided generation due to energy efficiency and other non-emitting power sources that receive credits under the NC Renewable Energy and Energy Efficiency Portfolio Standard.
Oklahoma	Both Public Service Company of Oklahoma and Oklahoma Gas and Electric track avoided greenhouse gas emissions, specifically tons of CO_2e emissions savings.
Oregon	The state tracks avoided GHGs from many energy efficiency programs but does not publish the information. The state tracks and publishes GHG data of electric utilities to assist customers in understanding the impact of their electricity use. Energy Trust tracks avoided carbon emissions within its service territory.
Pennsylvania	A centralized greenhouse gas emissions tracking system does not exist for all the programs with state funding since some of the programs are housed in other agencies. However, the Pennsylvania Energy Programs Office does track emissions through its various programs. The state's Climate Action Plan and Greenhouse Gas Inventory, as required by PA Act 70 of 2008, tracks statewide emissions trends.

State	Response on GHG tracking
Rhode Island	The utility tracks avoided greenhouse gas emissions and reports that as part of its annual energy efficiency programs. Specifically, the utility projects values in its annual planning process and reports on the actuals in its year-end reports. In addition, GHG reductions from the state's EE programs are included in the statewide GHG inventories.
Tennessee	The state's Office of Energy Programs estimates CO_2 emissions avoided by state-led energy efficiency programs, including EmPower Tennessee, Energy Efficient Schools Initiative, and Pathway Energy Efficiency and Renewable Energy Loan Program.
Vermont	The state tracks avoided emissions for its energy efficiency programs as well as for Renewable Energy Standard Tier 3 programs. The information is included in the energy efficiency utility and distribution utility Tier 3 annual reports.
Virginia	The Department of Mines, Minerals, and Energy provides data on energy efficiency program savings to the Department of Environmental Quality, which tracks total GHG emissions and emissions reduction initiatives through CDP (formerly Carbon Disclosure Project).
Wisconsin	Focus on Energy tracks carbon dioxide reductions achieved through energy efficiency programs.

Leading and Trending States: Carbon Pricing Policies

Virginia. In early March 2020, a bill called the Virginia Clean Economy Act was signed by Governor Ralph Northam. The legislation encourages the state to implement a carbon dioxide cap-and-trade program that applies to electric generation facilities and complies with the Regional Greenhouse Gas Initiative (RGGI). The act also requires the Virginia Corporation Commission to receive a report from the Air Pollution Control Board before approval of “any investor-owned utility to own, operate, or construct any electric generating unit that emits carbon as a by-product of combusting fuel to generate electricity.” It also mandates the commission and utilities to account for the social cost of carbon when assessing the need for new electric generating facilities (Virginia General Assembly 2020).

New Jersey. In June 2019 the New Jersey Department of Environmental Protection approved two rules that authorized the state to rejoin the Regional Greenhouse Gas Initiative. One of them, the Carbon Dioxide Trading rule, established a carbon dioxide cap for the state's electricity generation sector at 18 million tons in 2020. New Jersey's carbon dioxide budget will decrease 30% by 2030. The state rejoined RGGI after being withdrawn by former governor Chris Christie in 2012. New Jersey's move to rejoin RGGI is an important step for the state to meet its goal of 100% clean energy by 2050 (New Jersey Office of the Governor 2019).

Pennsylvania. In November 2019 Governor Tom Wolf signed Executive Order 2019-07, which directed the Pennsylvania Department of Environmental Protection (DEP) to enter the Regional Greenhouse Gas Initiative. The order requires the DEP to develop a proposed rulemaking package to mitigate carbon dioxide emissions from electric power generators and to present the package to the Pennsylvania Environmental Quality Board. The proposed rulemaking must incorporate thorough public outreach to ensure the program results in decreased GHG emissions, increased economic productivity, and reduced costs for the consumer. The DEP is also directed to work with PJM, the regional transmission organization, to ensure the integration of this program results in competitive economic dispatch and reduced emissions discharge (Pennsylvania Office of the Governor 2019).

Energy Efficiency Programs for Low-Income Households

As discussed in Chapter 2, low-income households often face a disproportionate energy burden that can be alleviated by energy efficiency (Drehobl and Ross 2016). Reducing energy burdens for low-income households not only keeps money in these families' pockets but also improves their quality of life by creating healthier homes and neighborhoods. These efforts can help states address other priorities such as reduced emissions, economic development, and improved public health.

Energy efficiency programs for low-income households are often supported by a diverse array of funding streams that may include federal, state, or ratepayer dollars. They can be administered by utilities, state government, community action agencies, or other organizations. In Chapter 2 we specifically highlighted utility- and ratepayer-funded income-qualified programs, although in practice these often use other resources as well, since nonutility weatherization funding can be used to leverage ratepayer funds, and vice versa.

State energy offices, state housing agencies, and partner agencies have many options for investing in energy efficiency in under-resourced communities. These options include:

- Designing energy efficiency programs or incentives specifically for low-income households and investing state resources alongside federal and ratepayer dollars;
- Leveraging existing Weatherization Assistance Program delivery channels to expand energy efficiency offerings to program participants;
- Providing technical assistance and financial resources to public housing authorities as they work with ESCOs to improve their properties;
- Encouraging agencies and organizations allocating federal grants to income-qualified recipients, such as the Low-Income Housing Tax Credit, to prioritize energy efficiency in their allocation process.

States can also address low-income equity and workforce development needs through state energy plans and electrification strategies. As states move toward policies and programs to meet more ambitious GHG reduction targets by switching end uses to electricity, there is also an interest in making sure these fuel-switching efforts are in fact beneficial—i.e., that they save customers money and reduce environmental impacts. It is also important that electrification strategies be inclusive of low-income households, which may face unique barriers such as high up-front costs or lack of access to new electric technologies and appliances. Meanwhile, equitable workforce development extends benefits from these programs to underserved community members while achieving a strong, capable workforce that can impact the scale and quality of implementation (Shoemaker and Ribeiro 2018). Opportunities include:

- **Offering enhanced fuel-switching incentives for low-income customers.** The Colorado WAP is running a pilot program to install air source heat pumps, which will support building electrification for homeowners, both now through direct install and in the future once its impacts are better understood. In Maine, low-income customers qualify for a higher heat pump rebate under the Affordable Heat Initiative than the standard Home Energy Savings Program rebate (Efficiency Maine Trust 2020).
- **Developing equity-related metrics and reporting frameworks.** The Oregon PUC applies annual "diversity, equity, and inclusion" performance metrics to Energy Trust, including items such as "Complete 1,000 projects with trade allies that are minority-owned businesses" and "Implement a rural-focused workshop." These metrics are revisited every year.
- **Establishing stakeholder processes to better understand low-income sector needs.** Iowa's Energy Workforce Consortium brings industry experts, state agencies, and community colleges together to discuss and collaborate on the changing workforce and the needs of the energy industry.
- **Working with state and local colleges to provide training and technical resources, incentives for LMI communities and displaced workers, and incentives for using certain labor standards.** New Mexico's 2019 Energy Transition Act creates three new funds to provide transition assistance to tribal communities, displaced workers, and communities affected by coal plant closures. The state of Washington's Clean Energy Transformation Act includes incentives for workforce development in the form of a tax credit for using certain labor standards.

Through ongoing research and outreach, ACEEE is working to help states and utilities identify the challenges and opportunities in delivering energy efficiency to the low-income market. For more information and examples of supportive policies, please visit ACEEE's State and Local Policy Database.[67]

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[67] See database.aceee.org/state/equity-workforce.

Chapter 6. Appliance and Equipment Efficiency Standards

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INTRODUCTION

The year 2020 looked to be a very promising one for state appliance standards until the COVID-19 pandemic forced many state legislatures to adjourn or to operate on a limited basis. Though some legislatures reconvened, most restricted their work to COVID- or budget-related bills, leaving other legislation to die. Nonetheless, there were successes during the past 12 months. New York Governor Andrew Cuomo signed an appliance standards bill in December 2019, the California Energy Commission adopted several new standards, and Oregon Governor Kate Brown signed an executive order directing the state's Department of Energy to establish standards for 10 products by September 1, 2020. Of the 10 states that filed appliance standards bills, those in Massachusetts, New Jersey, and the District of Columbia are still under consideration.

State-level actions on appliance standards have taken on added urgency in recent years, given federal efforts to chip away at the national appliance standards program. Beyond missing legal deadlines for the review of 28 product standards, the current federal leadership has also rolled back light bulb standards that would have saved billions of dollars for consumers and businesses and finalized changes to the federal program to make it harder to update any existing standards. Amid these reversals, as well as ongoing systemic threats to the economy posed by climate change and COVID-19, state-level policies like appliance standards are critical to reduce energy use, save consumers money, and cut climate-changing emissions.

The power of appliance standards is in the numbers. Every day we use appliances, equipment, and lighting in our homes, offices, and public buildings. Even when the energy consumption of a particular device seems small, the extra energy consumed by less-efficient products collectively adds up to a substantial amount. However, persistent market barriers inhibit sales of more efficient models to consumers. Appliance efficiency standards overcome these barriers by initiating change at the manufacturer level, requiring appliance makers to meet minimum efficiency criteria for all products and thereby removing the most inefficient products from the market.

States have historically led the way in establishing standards for appliances and other equipment. In 1976 California became the first state to introduce appliance standards. Many others, including New York and Massachusetts, soon followed. Congress established the first national standards—based on standards previously adopted by California and several other states—in 1987 when it passed the National Appliance Energy Conservation Act. Congress enacted additional national standards in 1988, 1992, 2005, and 2007, generally basing them on existing state standards. The federal laws have typically set initial standards for specific products and required DOE to periodically review and, if warranted, strengthen them. More than 60 products are now subject to national efficiency standards. Most directly relate to energy use, although several address water efficiency.

Existing national standards saved the average U.S. household about $500 a year on utility bills in 2015, or about 16% of average annual utility bill spending. Businesses saved a total of $23 billion in utility bills that year, or about 8% of total business spending on electricity and natural gas. Total household and business utility bill savings reached $80 billion in 2015. Annual savings will increase to nearly $150 billion by 2030 as new national standards kick in and the effects of existing ones grow (deLaski and Mauer 2017).

Federal preemption generally prevents states from setting their own standards for federally regulated products. States that wish to implement their own standards after federal preemption generally must apply for a waiver; however, states remain free to set standards for any products that are not subject to national standards. State standards can generate significant energy and water savings and set precedents for adopting new national standards.

States have responded to the federal government's inaction and its efforts to weaken the national standards program. In 2020 lawmakers in 10 states (Arizona, Connecticut, Hawaii, Illinois, Maine, Massachusetts, Oregon, Pennsylvania, Rhode Island, and Vermont) and the District of Columbia pursued standards based on recommendations from the ASAP and ACEEE report *States Go First* (Mauer, deLaski, and DiMascio 2017) and its 2020 update.[68] The efficiency levels for products in the state legislation are based on California standards and ENERGY STAR and WaterSense specifications. Some states added legislative provisions to protect against the rollback of light bulb and other federal standards, and others added language to adopt standards for non-preempted bulbs.

During the period covered by this year's *Scorecard*, New York adopted standards for faucets, showerheads, toilets, urinals, and drinking fountains. The California Energy Commission (CEC) adopted new standards for replacement pool pump motors and spray sprinkler bodies and broadened the scope of general-service lamp standards. Oregon completed a rulemaking on August 28, 2020, establishing new efficiency standards for nine products and updating standards for two others. The standards require legislative approval before they go into effect.

In addition to the above, since 2017, four states (Colorado, Hawaii, Vermont, and Washington) have adopted appliance standards packages varying from 5 products in Hawaii to 18 products in Vermont. The products include computers and monitors, faucets, showerheads, commercial dishwashers, and portable air conditioners. Washington also adopted a design standard for electric storage water heaters that would enable utility programs to manage water heating loads.

States also adopted provisions to protect against the rollback of federal appliance standards (Colorado, Hawaii, Vermont, and Washington) and federal light bulb standards (Colorado, Nevada, Vermont, and Washington). Finally, Hawaii, Nevada, New York, and Washington adopted standards for water-saving products such as faucets, showerheads, toilets, and urinals, joining a handful of drought-prone states (California, Colorado, Georgia, and Texas) that have done so over the past decade. The faucet and showerhead standards will also save energy by reducing hot-water consumption.

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[68] The report recommends a package of standards that states can adopt and analyzes potential energy, water, and utility bill savings and emissions reductions.

SCORING AND RESULTS

States could earn up to 2.5 points for savings from state-specific appliance standards that are not currently preempted by federal standards; they could earn another 0.5 points for adopting existing federal standards.[69] This scoring system credits states for adopting new standards that substitute for or expand on existing federal standards.

We credited standards only if the compliance date (not the adoption date) for at least one state with an equivalent standard was within the past five calendar years or is slated for the future. This acknowledges the important role early adopters play in paving the way for other states. For example, California adopted efficiency standards for faucets in 2015, followed by Vermont in 2018 and Colorado, Hawaii, New York, and Washington in 2019 (with compliance required in 2020 and 2021). California and the above states will continue to get credit for faucet standards until at least 2026 (five years after the last compliance date)—or even longer should additional states adopt the faucet standards. Televisions dropped off the list this year since the last compliance date was six years ago, in 2014.

We calculated scores for the adoption of state standards on the basis of cumulative per capita savings (measured in million Btus) through 2035. We used a floating start date that aligns with each state's product compliance date. For example, standards for commercial dishwashers took effect in Vermont in 2020. Our savings analysis for that product in Vermont covers the period from 2020 to 2035. Colorado and Washington adopted standards for commercial dishwashers that will take effect in 2021, and so for those states the analysis period begins in 2021.

Our savings estimates were based on the approach used by ASAP and ACEEE in previous analyses of savings from appliance standards (Mauer, deLaski, and DiMascio 2017). We used estimates of annual shipments, per-unit energy savings, and average product lifetimes based on the best available data. To estimate state-by-state shipments, we allocated national shipments to individual states on the basis of population. We also accounted for the portion of sales that had already met the standard level at the time the first state standard was established for a given product.

We normalized the savings estimates using the population of each state in order to rank states according to per-capita energy savings. We scored in 0.5-point increments up to a maximum of 2.5 points.

Table 40 shows the scoring breakdown for state standards.

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[69] In 2018 and 2019, states could earn 0.5 points for adopting either federal appliance standards or federal light bulbs standards in case federal standards were rolled back. However, in 2019 the Trump administration did roll back and narrow the scope of the light bulb standards. Therefore, in 2020, instead of awarding a flat 0.5 points for adopting non-preempted light bulb standards, we estimated the savings from the standards.

Table 40. Scoring of savings from state appliance standards

Energy savings through 2035 (MMBtus/capita)	Score
35 or more	2.5
25–34.99	2
15–24.99	1.5
5–14.99	1
0.1–4.99	0.5
No energy savings	0

Other consideration	Score
Adoption of existing federal standards	+0.5

Table 41 shows the scoring results, with points allocated for the adoption of both state-specific and federal standards.

Table 41. Scoring for appliance efficiency standards

State	Energy savings from state standards through 2035 (MMBtus/capita)	Year most recent state standards were adopted	Score for adoption of state standards	Score for adoption of federal standards	Total score (3 pts.)
California	41.3	2020	2.5	0.5	3.0
Colorado	19.3	2019	1.5	0.5	2.0
Washington	19.3	2019	1.5	0.5	2.0
Vermont	17.6	2019	1.5	0.5	2.0
Hawaii	14.0	2019	1	0.5	1.5
Nevada	8.9	2019	1	-	1.0
New York	4.4	2019	0.5	-	0.5

California topped the scoring in this metric again this year, earning the maximum of 3.0 points on savings from 11 products, including recent standards for pool pump replacement motors, and for the adoption of federal standards. New York made the list this year for its adoption of plumbing product standards for faucets and showerheads.

Leading and Trending States: Appliance and Equipment Efficiency Standards

California. Just months after the U.S. Department of Energy narrowed the scope of light bulbs subject to federal standards, the California Energy Commission (CEC) broadened the scope of the state's light bulbs standards to address those bulbs no longer covered under federal standards. (Federal legislation adopted in 2007 exempted California from federal preemption on general-service light bulb standards.) CEC also adopted standards for replacement pool pump motors and spray sprinkler bodies. The commission is currently conducting rulemakings for hearth products, irrigation controllers, certain linear fluorescent lamps, and commercial and industrial fans.

New York. In December 2019, Governor Andrew Cuomo signed Assembly Bill A2286, updating water efficiency standards for faucets, showerheads, toilets, urinals, and drinking fountains to EPA's WaterSense levels. The law makes New York the eighth state to adopt updated plumbing standards. It expects to reduce water use by 3.7 billion gallons in 2025, growing threefold to 11.3 billion gallons by 2035, equivalent to the annual water consumption of 160,000 New York households.

Oregon. In March 2020, Governor Kate Brown signed Executive Order 20-04, directing the Oregon Department of Energy to "establish and update energy efficiency standards for products at least to levels equivalent to the most stringent standards among West Coast jurisdictions." The order specifies 10 products for which standards have been adopted by other states and opens the door for more product standards to be added. The rulemaking, completed on August 28, 2020, includes a performance standard for grid-connected water heaters and efficiency standards for computers; commercial dishwashers, fryers, and steamers; high-CRI fluorescent lamps; showerheads; faucets; portable electric spas; residential ventilating fans; and water coolers. The standards require legislative approval.

Chapter 7. Conclusions

The impact of the COVID-19 pandemic on states' economies forced many clean energy plans to be put on hold for much of the year. While some states still managed to advance significant energy efficiency reforms, others faced stay-at-home orders and drastically altered utility operations, leaving energy efficiency contractors unable to access homes and businesses. These upheavals led to the loss of hundreds of thousands of clean energy jobs and stalled some significant legislative efforts (BW Partnership 2020).

Although the slowdown impacted all clean energy sectors, including the renewable energy and clean vehicles industries, the largest impacts were in energy efficiency, especially residential programs, which suspended at-home visits and weatherization services and experienced other drop-offs in customer participation. While some utilities mitigated the pandemic's impact by shifting resources toward programs like virtual home energy audits and improvements to building exteriors and vacant buildings, much uncertainty remains regarding long-term effects on the industry. Many state and local leaders tried to learn from the crisis and emerge with new tools for resiliency and efficiency, such as by increasing opportunities for remote work and adding and expanding spaces for biking and walking.

AMID CRISIS, STATES PLANT SEEDS FOR FUTURE PROGRESS

Despite these challenges, several states kicked off 2020 with a series of strong policy achievements before COVID-19 disrupted their legislative calendars. This progress came on the heels of a banner 2019, in which five states (Maine, Nevada, New Mexico, New York, and Washington), in addition to Washington, DC, and Puerto Rico, enacted 100% clean energy targets.[70]

In March Virginia joined them by enacting the state's Clean Economy Act, becoming the eighth state nationwide and first in the Southeast with a 100% clean energy goal, as well as only the second in the region with a binding energy efficiency resource standard for investor-owned utilities. The bill, which sets a 100% clean energy goal, requires that by 2025 Dominion and Appalachian Power achieve electric savings equivalent to 5% and 2% of sales, respectively. These targets, which roughly equate to the 15th-highest statewide goal among those with an EERS, would avoid more than 7 million metric tons of greenhouse gas emissions over four years and would further reduce emissions well into the future as installed measures continue to save energy.

New Jersey also marked a critical milestone in its efforts to scale up energy efficiency and deliver on robust energy savings goals established under its 2018 Clean Energy Act. Following many months of work by officials and stakeholders, the state's Board of Public Utilities issued an order establishing a framework of programs, including five-year savings targets that ramp up to 2.15% of electric use and 1.1% of natural gas use, among the highest in the nation. It also calls for specific provisions and enhanced incentives for low-income customers to ensure equitable access to programs for these communities. These programs,

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[70] Prior to 2019, only California and Hawaii had committed to 100% clean energy goals.

planned for June 2021, will work in parallel with Governor Phil Murphy's recently released economy-wide Energy Master Plan, which lays out a pathway to 100% clean energy by 2050.

New York is also working toward ambitious climate goals and released important regulatory reforms this year. A January order established strong 3% electric savings targets for 2025, including robust targets for heat pumps and low-to-moderate-income programs. These efforts to dramatically scale up efficiency are an important part of achieving the mission of the 2019 Climate Leadership and Community Protection Act, which calls for net-zero carbon emissions by 2050.[71]

Meanwhile, a number of other states, such as Maryland, Nevada, and New Mexico, also reported growing levels of utility-sector savings. These states' efforts to scale up programs to meet efficiency targets are yielding positive results.

EFFICIENCY ADVOCATES WIN BIG ON NATIONAL MODEL ENERGY CODES

This year also delivered major improvements for efficiency in new construction with the release of the 2021 International Energy Conservation Code (IECC) that establishes minimum building energy performance standards. Following more than a year of work by a broad coalition of organizations, ICC voting members—including many cities and states—approved a code update to yield an estimated 10% or greater efficiency improvement in residential and commercial buildings.

Following a decade that saw very few efficiency improvements in the IECC, the new codes are an important achievement for advocates and consumers, securing improvements in lighting efficiency and first-time provisions for water heating equipment. The 2021 IECC also includes two new optional appendices to provide states and cities pathways to incorporate zero-energy performance requirements into their codes through a mix of aggressive yet achievable levels of energy efficiency and renewable energy like rooftop solar panels. This suite of additions represents a significant step forward toward decarbonizing the building sector. While there was also widespread support for provisions requiring electric vehicle and electric appliance readiness as well as increased water heater efficiency, these were ultimately removed by the ICC Board of Directors upon appeal as it was determined these changes were outside the current scope and intent of the IECC's energy provisions.

In addition, close to a dozen states and DC made significant progress towards strengthening efficiency standards for new construction at the state-level. These include many states in which the 2018 IECC has gone into effect in recent months, including Minnesota, New Jersey, New Mexico, New York, Vermont, and Delaware. The new 2021 IECC will offer these states and others further opportunity to ensure that new buildings lock-in low energy costs for generations of future residents.

STATES LEAD ON VEHICLE EMISSIONS AND ELECTRIFICATION

With the federal government moving to roll back Clean Car Standards, many states have taken vehicle efficiency into their purview by advancing tailpipe emissions regulations and

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[71] See blog.aee.net/one-giant-leap-for-energy-efficiency-in-new-york.

accelerating the adoption of electric vehicles through incentives and charging infrastructure. More than a dozen states have followed California's lead by adopting the Golden State's vehicle emissions standards, and 12 states have adopted its zero-emission vehicle program. The number is set to continue to grow following announcements in late 2019 and 2020 by governors in Minnesota, New Mexico, and Nevada that their states will also adopt these standards.

States are increasingly prioritizing electric vehicles and the charging infrastructure needed to serve them. Most states have taken some level of action to support EV deployment, from customer incentives to planning to regulatory reforms. Examples include New Jersey's passage of S-2252, an ambitious law intended to meet the governor's commitment to have 330,000 electric cars on the state's roads by 2025; this law also authorizes an incentive program for both light-duty electric vehicles and at-home electric charging infrastructure. The bill calls for the electrification of the state's light-duty vehicle fleet by 2035 and moves NJ Transit toward zero-emission bus purchases by 2032 (New Jersey Office of the Governor 2020).

In February the California Public Utilities Commission released its draft Transportation Electrification Framework that would call on utilities to develop 10-year plans to expand electrification infrastructure throughout the state, including plans for managing increased grid load. The new process would help accelerate the state's progress toward its goals for 250,000 electric vehicle chargers along with 1.5 million ZEVs on California roads by 2025, and 5 million ZEVs by 2030.

Utah passed multiple important pieces of legislation to move ahead on vehicle electrification, including HB 259, which calls on the state transportation agency to develop a statewide plan for an electric vehicle charging network, including additional funding to address areas served by rural electric cooperatives. HB 396, also passed this year, authorizes Rocky Mountain Power to collect $50 million toward the buildout of its EV charging infrastructure, with additional provisions allowing the utility to update rate designs for EV charging customers (Utah Clean Energy 2020).

Other states and major utilities also continued to roll out electrification plans of their own in 2020, including Pacific Power in Oregon and Xcel Energy in Colorado. In addition, a number of states, such as Connecticut, Virginia, Missouri, and Wisconsin, continue to conduct EV needs assessments and evaluate the appropriate roles for utilities and private entities in building EV infrastructure (NCCETC 2020).

DATA LIMITATIONS

The scoring framework used in this report is our best attempt to represent a variety of efficiency metrics as a quantitative score. Any effort to convert state spending data, energy savings data, and adoption of best-practice policies across five policy areas into one state energy efficiency score has obvious limitations. One of the most pronounced constraints is access to recent, reliable data on the results of energy efficiency. Because many states capture relatively little data on energy efficiency policy efforts, often under varying reporting protocols, we used a best-practices approach to score some policy areas. However, the actual, measurable success of these codes in reducing energy consumption is unclear without a way to verify implementation. As data become more readily available, we will continue to explore ways to incorporate a more quantitative assessment of compliance in future *Scorecard*s.

We face similar difficulty in scoring state-backed financing and incentive programs for energy efficiency investments. Though many states have seemingly robust programs aimed at residential and commercial consumers, not all are able to relay information on program budgets or the energy savings resulting from such initiatives. As a result, we can offer only a qualitative analysis of these programs. This lack of quantitative data is growing more pronounced as many states begin pouring financial resources into green banks. Without comparable results on dollars spent and rigorously evaluated energy savings, it is impossible to assess these programs with the same scrutiny that we bring to bear on utility programs.

POTENTIAL NEW METRICS

Looking ahead, we have described relevant potential future metrics or revisions to existing metrics in several chapters of this year's *State Scorecard*. While we believe our data collection and scoring methodology are comprehensive, there is always room for modifications. As the energy efficiency market continues to evolve and data become more available, we will continue to adjust each chapter's scoring metrics. Here we present some additional metrics that currently fall outside the scope of our report but nonetheless indicate important efficiency pathways.

In response to policy trends and feedback from subject matter experts, this year we added several new scoring categories intended to capture emerging state efforts around EV grid integration and building decarbonization. These include scoring that considers statewide numbers of publicly available charging stations, as well as zero-energy building projects. The goal of these metrics is to provide an approximate outcome-based assessment of the relative success of ongoing policy efforts.

As more states develop and undertake electrification plans in support of ever-strengthening clean energy goals, we plan to continue to develop the *Scorecard* to consider the role of efficiency programs in promoting the switch from fossil fuels to technologies powered by clean electricity. For example, as previewed in Chapter 2, ACEEE research has begun to track the status of current state policies and utility efficiency programs enabling fuel switching, particularly in cases where it is beneficial, enabling transitions from higher-cost, higher-emission fuel sources for heating to lower-cost, lower-emitting fuel sources. While the current utility policy landscape in this emerging field is complex and fragmented, our goal is to use the *Scorecard* to highlight the work of leading states to harmonize energy efficiency rules with electrification and accelerate the transition to a carbon-free future in a way that maximizes public benefits.

Finally, another important area of focus for ACEEE is the advancement of social equity principles in clean energy and efficiency policy and program design to ensure that the economic, health, and safety benefits of energy efficiency and clean energy reach all communities. Energy efficiency initiatives have typically not been adequately extended to marginalized and historically disadvantaged groups, nor to rural and low-income areas, where energy burdens are disproportionately high. While the *Scorecard* currently addresses low-income household access to programs to a limited extent in several chapters, ACEEE plans to use the report in the future to call greater attention to broader efforts to embed equity in community engagement, decision making, and workforce development. Through our annual data collection this year, we sought information on these types of efforts, including needs assessments, barrier analyses, job training, and the adoption of internal protocols and metrics to evaluate the equity of policy outcomes. While we have yet to formally integrate these data and principles into our scoring framework, we hope to do so in the future. Meanwhile, we have included this information on our State and Local Policy Database as a resource for communities, policymakers, and utilities to help track emerging best practices.[72]

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[72] See database.aceee.org/state/equity-workforce.

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Appendix A. Respondents to Utility and State Energy Office Data Requests

State	Primary state energy office data request respondent	Primary public utility commission data request respondent
Alabama	Maureen Neighbors, Director, and Susan Fleeman, Energy Division, Alabama Department of Economic and Community Affairs	—
Alaska	Jimmy Ord, Energy Program Information Manager, Alaska Housing Finance Corp.	—
Arizona	—	—
Arkansas	—	Jane Carpenter, Rate Case Analyst, Arkansas Public Service Commission
Bonneville Power Administration	—	Adam Morse, Bonneville Power Administration
California	Bill Pennington, Deputy Division Chief, Efficiency and Renewable Energy Division, California Energy Commission	Amanda Jordan Christenson, Energy Efficiency Analyst, California Public Utilities Commission
Colorado	Andrew Sand, Deputy Director, Colorado Energy Office	—
Connecticut	Michele Melley, Associate Research Analyst, Connecticut Department of Energy and Environmental Protection	Michele Melley, Associate Research Analyst, Connecticut Department of Energy and Environmental Protection
Delaware	Jessica Quinn, Renewable Energy Planner, Delaware Division of Energy & Climate	Jessica Quinn, Renewable Energy Planner, Delaware Division of Energy & Climate
District of Columbia	Ben Plotzker, EM&V Project Manager, Vermont Energy Investment Corporation	Ben Plotzker, EM&V Project Manager, Vermont Energy Investment Corporation
Florida	April Groover Combs, Senior Management Analyst, Office of Energy, Florida Department of Agriculture and Consumer Services	Michael Barrett, Economic Supervisor, Conservation, Florida Public Service Commission
Georgia	Kristofer Anderson, Senior Program Manager, Georgia Environmental Finance Authority	Jamie Barber, Director, Energy Efficiency and Renewable Energy Unit, Georgia Public Service Commission
Hawaii	Gail Suzuki-Jones, Energy Efficiency & Renewable Energy Program Manager, Hawaii State Energy Office	Ashley Norman, Utility Analyst, Hawaii Public Utilities Commission
Idaho	Katie Pegan, Policy Analyst, Idaho Governor's Office of Energy and Mineral Resources	—
Illinois	—	David Brightwell, Economist, Illinois Commerce Commission
Indiana	—	—
Iowa	Shelly Peterson, Program Manager, Iowa Economic Development Authority	Donald Tormey, Iowa Utilities Board
Kansas	—	—

State	Primary state energy office data request respondent	Primary public utility commission data request respondent
Kentucky	—	—
Louisiana	—	Kathryn Bowman Louisiana Public Service Commission
Maine	Dan Burgess, Director, and Melissa Winne, Energy Policy Analyst, Governor's Energy Office	Jack Riordan, Strategic Initiatives, Efficiency Maine
Maryland	Jenn Gallicchio, Assistant Director of Energy Programs, Maryland Energy Administration	—
Massachusetts	Lyn Huckabee, Residential Energy Efficiency Program Coordinator, Massachusetts Department of Energy Resources	Lyn Huckabee, Residential Energy Efficiency Program Coordinator, Massachusetts Department of Energy Resources
Michigan	Julie Staveland, SEP Specialist, Michigan Energy Office	Fawzon Tiwana, Economic Analyst, Michigan Public Service Commission
Minnesota	Anthony Fryer, Conservation Improvement Program Coordinator, Minnesota Department of Commerce	Anthony Fryer, Conservation Improvement Program Coordinator, Minnesota Department of Commerce
Mississippi	Ethan Cartwright, Energy Efficiency Program Manager, Mississippi Development Authority	Vicki Munn, Electric, Gas & Communications Division, Mississippi Public Utilities Staff
Missouri	Cherylyn Kelley, Energy Policy Analyst, Missouri Department of Economic Development	Brad Fortson, Manager, Energy Resources Department, Missouri Public Service Commission
Montana	Kyla Maki, Montana Department of Environmental Quality	Robin Arnold, Policy Analyst, Montana Public Service Commission
Nebraska	Joe Francis, Associate Director, Nebraska Department of Environment and Energy	Marc Shkolnick, Manager of Energy Services, Lincoln Electric System
Nevada	Robin Yochum, Energy Program Manager, Nevada Governor's Office of Energy	Cristina Zuniga, Economist, Nevada Public Utility Commission
New Hampshire	Alexis LaBrie, Energy Analyst, New Hampshire Office of Strategic Initiatives	—
New Jersey	Kelly Mooij, Deputy Director, New Jersey Board of Public Utilities	Kelly Mooij, Deputy Director, New Jersey Board of Public Utilities
New Mexico	Harold Trujillo, Bureau Chief, Energy Technology and Engineering, New Mexico Energy Office	John Reynolds, New Mexico Public Regulation Commission
New York	Robert Bergen, New York State Energy Research and Development Authority (NYSERDA)	Robert Bergen, New York State Energy Research and Development Authority (NYSERDA)
North Carolina	Russell Duncan, Energy Assurance Manager, North Carolina Department of Environmental Quality	Jack Floyd, Engineer, Electric Division, Public Staff, North Carolina Utilities Commission

State	Primary state energy office data request respondent	Primary public utility commission data request respondent
North Dakota	Bruce Hagen, Weatherization Program Manager, North Dakota Department of Commerce	—
Ohio	Deborah Ohler, Staff Engineer, Division of Industrial Compliance, Ohio Department of Commerce	—
Oklahoma	Katie DeMuth, Energy Policy Advisor and Legislative Affairs Director, Office of the Secretary of Energy and Environment	Kathy Champion, Regulatory Analyst, Oklahoma Corporation Commission
Oregon	Warren Cook, Manager, Energy Efficiency and Conservation, Oregon Department of Energy	Warren Cook, Manager, Energy Efficiency and Conservation, Oregon Department of Energy; Michael Freels, Energy Analyst, Oregon Department of Energy
Pennsylvania	Libby Dodson, Energy Program Specialist, Department of Environmental Protection	Joseph Sherrick, Supervisor, Policy and Planning, Pennsylvania Public Utility Commission
Rhode Island	Nathan Cleveland, Energy Efficiency Policy and Program Manager, Rhode Island Office of Energy Resources	—
South Carolina	—	Jocelyn Boyd, Chief Clerk, South Carolina Public Service Commission
South Dakota	—	Darren Kearney, Utility Analyst, South Dakota Public Utilities Commission
Tennessee	Shauna Basques, Office of Energy Programs, Tennessee Department of Environment and Conservation	Erik Franey, Specialist, Commercial Energy Solutions, Tennessee Valley Authority
Texas	Erik Funkhouser, Program Contract Manager, State Energy Conservation Office	—
Utah	Brooke Tucker, Deputy Director, Governor's Office of Energy Development	Carol Revelt, Executive Staff Director, Utah Public Service Commission
Vermont	Kelly Launder, Assistant Director, and Barry Murphy, Energy Efficiency Program Specialist, Vermont Public Service Department	Kelly Launder, Assistant Director, and Barry Murphy, Energy Efficiency Program Specialist, Vermont Public Service Department
Virginia	Barbara Simcoe, State Energy Program Manager, Virginia Division of Energy, Department of Mines, Minerals, and Energy	—
Washington	Emily Salzberg, Managing Director, Building Standards and Performance, Washington State Department of Commerce Karin Landsberg, Senior Policy Specialist, Washington State Department of Transportation	—
West Virginia	Tiffany Bailey, Energy Development Specialist, West Virginia Division of Energy	Karen Hall, Public Information Specialist, Public Service Commission of West Virginia

State	Primary state energy office data request respondent	Primary public utility commission data request respondent
Wisconsin	—	Jolene Sheil, Focus on Energy Performance Manager, Public Service Commission of Wisconsin
Wyoming	Sarah Young Director, Public Affairs & Communications Wyoming Energy Authority	—

Appendix B. Electric Efficiency Program Spending per Capita

State	2019 electric efficiency spending ($ million)	$ per capita
Rhode Island	104.1	98.24
Massachusetts	620.4	90.02
Vermont	55.2	88.46
Maryland	275.6	45.58
Connecticut	161.4	45.28
California	1516.4	38.38
Oregon	161.5	38.28
New Hampshire	48.6	35.74
Idaho	61.4	34.37
Illinois	433.8	34.23
Maine	45.9	34.12
New York	645.2	33.17
Hawaii	42.0	29.66
Minnesota	157.0	27.84
Michigan	250.7	25.10
Washington	190.7	25.05
Iowa	75.6	23.95
Arkansas	68.0	22.52
District of Columbia	15.4	21.79
Colorado	108.0	18.75
Delaware	17.9	18.41
Wyoming	10.2	17.66
Oklahoma	68.6	17.34
Pennsylvania	197.5	15.43
Indiana	101.8	15.12
New Mexico	31.7	15.12
Ohio	175.0	14.97
Nevada	45.3	14.71
Utah	47.1	14.69
Missouri	85.8	13.98
North Carolina	145.8	13.90
New Jersey	123.0	13.85
Wisconsin	79.0	13.57
Montana	14.4	13.44
South Carolina	64.0	12.43
Arizona	82.4	11.32
Texas	196.2	6.77
Kentucky	27.2	6.09
Mississippi	17.1	5.74
Georgia	57.0	5.37
South Dakota	4.7	5.31
Louisiana	24.6	5.29
Florida	105.4	4.91
West Virginia	7.6	4.24
Virginia	31.7	3.72
Nebraska	7.1	3.65
Tennessee	19.2	2.81
Alabama	7.7	1.57
North Dakota	0.2	0.20
Kansas	0.3	0.11
Alaska	0.0	0.03
U.S. total	**6,832.4**	
Median	**64.0**	**15.12**

Appendix C. Large-Customer Self-Direct Programs by State

State	Availability	Description
Arizona	Customers of Arizona Public Service Company (APS), Tucson Electric Power Company (TEP), and Salt River Project (SRP)	APS: Large customers using at least 40 million kWh per calendar year can elect to self-direct energy efficiency funds. Customers must notify APS each year if they wish to participate, after which 85% of the customer's demand-side management contribution will be reserved for future energy efficiency projects. Projects must be completed within two years. Self-direct funds are paid once per year, once the project is completed and verified by APS. TEP: To be eligible for self-direct, a customer must use a minimum of 35 million kWh per calendar year. SRP: SRP makes self-direct available only to very large customers using more than 240 million kWh per year. For all utilities, a portion of the funds that customers would have otherwise contributed to energy efficiency is retained to cover self-direct program administration, management, and evaluation costs.
Colorado	Customers of Xcel Energy and Black Hills	Xcel: The self-direct program is available to commercial and industrial (C&I) electric customers who have an aggregated peak load of at least 2 MW in any single month and an aggregated annual energy consumption of at least 10 GWh. Self-direct program customers cannot participate in other conservation products offered by the company. Rebates are paid based on actual savings from a project, up to $525 per customer kW or $0.10 per kWh. Rebates are given for either peak demand or energy savings, but not both, and are limited to 50% of the incremental cost of the project. Xcel uses raw monitoring results and engineering calculations to demonstrate actual energy and demand savings. Black Hills: To participate in the C&I self-direct program, customers must have an aggregated peak load greater than 1 MW in any single month and aggregated annual energy usage of 5,000 MWh. Rebates and savings are calculated on a case-by-case basis, with rebate values calculated as either 50% of the incremental cost of the project or $0.30 per kWh savings, whichever is lower.
Idaho	Customers of Idaho Power	Idaho Power offers its largest customers an option to self-direct the 4% energy efficiency rider that appears on all customers' bills. Customers have three years to complete projects, with 100% of the funds available to fund up to 100% of project costs. Self-direct projects are subject to the same criteria as projects in other efficiency programs.
Illinois	Statewide	Electric customers with greater than 10 MW of demand in any 30-minute period are exempt from programs. A self-direct option is available statewide for natural gas customers who meet the following criteria: annual natural gas usage in the aggregate of 4 million therms or more within the service territory of the affected gas utility, or with aggregate usage of 8 million therms or more in the state and using natural gas as feedstock to the extent such annual feedstock usage is greater than 60% of the customer's total annual usage of natural gas. Qualified natural gas customers put money into an account of their own that amounts to the lesser of 2% of the customer's cost of natural gas or $150,000. The funds are required to be used for energy efficiency projects. No evaluation is required.

State	Availability	Description
Michigan	Statewide	Self-direct is available statewide. Customers must have had an annual peak demand in the preceding year of at least 1 megawatt in the aggregate at all sites. Customers may use the amount of funds that would otherwise have been paid to the utility provider for energy efficiency programs. They must, however, submit the portion of the EE funds that would have been collected and used for low-income programs to their utility provider. They then calculate the energy savings achieved and provide it to their utility provider. In 2018, there were 15 customers self-directing.
Minnesota	Statewide	Minnesota offers a self-direct option, with a full exemption from assigned cost-recovery mechanism (CRM) fees, to customers with 20 MW average electric demand or 500,000 Mcf of gas consumption. Customers must also show that they are making "reasonable" efforts to identify or implement energy efficiency and that they are subject to competitive pressures that make it helpful for them to be exempted from the CRM fees. Participating customers must submit new reports every five years to maintain exempt status. The utility is not involved in self-direct program administration; the state Department of Commerce manages self-direct accounts and is the arbiter of whether a company qualifies for self-direct and is satisfying its obligations.
Montana	Statewide (all regulated public utilities)	Self-direct is available statewide in regulated utility service territory. About 90% of the population is served by NorthWestern Energy. NorthWestern Energy allows customers with demand larger than 1 MW to channel their cost-recovery mechanism (CRM) funds to an escrow account that repays them on a quarterly basis for completed self-direct projects. The annual maximum contribution is $500,000, and companies have two years to use their funds before they are returned to the larger pool of CRM revenues. NorthWestern administers the funds but provides no measurement or verification. Self-direct customers file annual reports with the Montana Department of Revenue. The department publishes these reports, and a public "challenge" process is provided for as the only scrutiny or review. About 60 customers use self-direct, approximately 89% of eligible large customers.
New Jersey	Statewide	A Societal Benefits Credit (SBC) program, with elements of a self-direct program, allows commercial and industrial ratepayers to establish a credit against their SBC contributions. No company has implemented an SBC program to date. The credit would be equal to one-half of the costs incurred for the purchase and installation of Clean Energy Program–supported energy efficiency products and services in the preceding calendar year, and up to 50% of the SBC contributions for a given year, per utility account. The Large Energy Users Program is designed to promote self-investment in energy efficiency and combined heat and power projects with incentives of up to $4 million for eligible projects in the state's largest commercial and industrial facilities.

State	Availability	Description
New Mexico	Statewide in the territories of three investor-owned utilities	Eligible customers must have electricity consumption greater than 7,000 MWh per year. Participants can receive credit for up to 70% of the annual energy efficiency rider. Self-direct customers provide their own engineering analysis and must meet the same total resource cost test as all the other industrial and commercial offerings. The customer must demonstrate to the reasonable satisfaction of the utility that its expenditures are cost effective. Eligible expenditures must have a simple payback period of more than one year but less than seven years.
New York	Statewide (all six electric utilities)	In an order issued February 26, 2015 (REV Order), the commission required staff to work with the utilities and large industrial customers to develop Self-Direct Program Guidelines to be filed by August 3, 2015. The order also required electric utilities to implement a self-direct program in accordance with the Self-Direct Program Guidelines no later than January 1, 2017. The Self-Direct Program is available to all individual customers with a 36-month average demand of 2 MW or greater. It is also available to customers with an aggregated 36-month average demand of 4 MW or greater, as long as one or more of the accounts being aggregated by the customer has at least a 36-month average demand of 1 MW. To be eligible to participate in the upcoming three-year cycle, current participants in the Self-Direct Program must have accessed 100% of any funds rolled over from the previous cycle, at least 45% of the funds from their ESA by September 30 of the third year of the current cycle, and have achieved savings at or below the dollar per MWh to which the participant committed at the time of enrollment. The initial three-year cycle for the Self-Direct programs ran from 2017 through 2019. Enrollment in the Self-Direct programs was generally minimal and, therefore, in a March 2018 order, the commission allowed each utility to determine whether to continue to offer its large energy-user customers a self-direct program.

State	Availability	Description
Oregon	Customers of Portland General Electric, PacifiCorp, and select customers of Emerald People's Utility District	Senate Bill 1149 directed Oregon's two largest utilities, Portland General Electric and Pacific Power, to collect a public purpose charge from their customers to fund energy conservation and renewable projects in the state. However, large electric consumer sites that used more than 8,760,000 kWh in the prior year may be eligible for the Large Electric Consumer Public Purpose Program, also known as the Self-Direct Program, which allows them to self-direct the conservation and renewable portions of their public purpose charge rather than pay the utility directly. The Oregon Department of Energy (ODOE) reviews applications and approves sites that meet eligibility criteria to become self-direct consumers. Sites then spend their own funds to build pre-certified projects. Once the project is complete, they submit an application for credit to ODOE. ODOE reviews and approves the eligible project costs, which include a small fee paid to ODOE for program administration. Certified project costs are then added to the conservation or renewable credit balance, and the credits do not expire. Each month when a site has a conservation and renewable credit balance, they can offset the monthly conservation and renewable portion of the public purpose charge, meaning they do not pay the utility that portion of the PPC. The available credit balance is reduced by the monthly conservation and renewable offset amount. Two former Pacific Power sites in Emerald People's Utility District (EPUD—a COU utility—territory participates in a self-direction program, but no COUs including EPUD are subject to public purpose charge requirements. Portland General Electric and Pacific Power cover approximately 80% of the electric customers in Oregon. Participants in the three participating programs have their proposed projects technically reviewed by the Oregon Department of Energy. This includes a technical review of claimed savings. A sampling of projects is reviewed for actual performance. Eighty sites, or roughly one-third of eligible sites, currently self-direct energy efficiency funds, accounting for about one-third of eligible load. Total savings for 2019 was 1,634,309 kWh.

State	Availability	Description
Vermont	Statewide for electric and natural gas customers	For electric energy efficiency, there are three self-direct options available statewide: Self-Managed Energy Efficiency Program (SMEEP), Customer Credit Program (CCP), and Energy Savings Accounts (ESA). SMEEP is also available for the two eligible gas customers. The SMEEP options require prospective participants or their successors to have contributed $1.5 million to the Energy Efficiency Fund in 2008 or 2017 through the Efficiency Charge added on their electric bills to meet the requirements. Currently there are two customers in the program. Additionally, an eligible customer must commit to investing a minimum of $3 million over a three-year program cycle. For SMEEP electric, an eligible customer must demonstrate that it has a comprehensive energy management program with annual objectives or demonstrate that it has achieved certification of ISO standard 14001. They then provide a report to the PUC detailing the measures undertaken, estimated savings and related costs. These reports are then reviewed and approved by the PUC. In addition, the Vermont PUC has established an option for eligible Vermont business customers to self-administer energy efficiency through the use of an Energy Savings Account (ESA) or the Customer Credit Program. These funds are still paid into the VEEUF and disbursed to the participants upon completion of an eligible energy efficiency measure. The ESA option allows Vermont businesses that pay an Energy Efficiency Charge (EEC) in excess of $5,000 total per year (or an average $5,000 total per year over three years) to use a portion of their EEC to support energy efficiency projects in their facilities. The ESA is run through the Efficiency Vermont program and related savings are reported and verified through the Savings Verification mechanism. For CCP, eligible customers must be ISO 14001-certified and meet several conditions similar to Energy Star for industrial facilities. For natural gas energy efficiency, eligible only for transmission and industrial electric and natural gas ratepayers. A pilot program has been developed to allow customers selected through a competitive process to be able to self-direct a large portion of the funds collected through the electric EEC paid by that customer to both electric and thermal energy efficiency projects. This pilot is capped at $2 million annually.
Washington	All utilities may develop self-direct options for industrial and commercial customers, but of the IOUs, only Puget Sound Energy has developed a self-direct program	Puget Sound Energy's self-direct program is available only to industrial or commercial customers on electric rate-specific rate schedules. The self-direct program operates on a four-year cycle comprising two phases: noncompetitive and competitive. During the noncompetitive phase, customers have exclusive access to their energy efficiency funds, which are collected over the four-year period. When this phase ends, any unused funds are pooled together and competitively bid on by the members of the self-direct program. Customers receive payment in the form of a check once their project is complete and verified. Participating customers do not receive any rate relief when they complete energy efficiency investments. The utility pre- and post-verifies 100% of the projects, including a review and revision of savings calculations to determine incentive levels. The program is included in the third-party evaluation cycle like any other utility conservation program.

State	Availability	Description
Wisconsin	Statewide	A self-direct option is open to customers that meet the definition of a large energy customer according to the 2005 Wisconsin Act 141. Under the self-direct option, a true-up at the end of the year returns contributions to participating customers for use on energy efficiency projects. Evaluation is required under Public Service Commission Administrative Code 137, with evaluation plans reviewed by that commission. This option has been available since 2008, but no customers have participated to date.

Appendix D. State Energy Efficiency Resource Standards

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Arizona 2010 Regulatory Electric and nat. gas IOUs, co-ops (~56%)	Electric: Incremental savings targets began at 1.25% of sales in 2011, ramping up to 2.5% in 2016–20 for cumulative annual electricity savings of 22% of retail sales, 2% of which may come from peak demand reductions. Natural gas: ~0.6% annual savings (for cumulative savings of 6% by 2020). Co-ops must meet 75% of targets.	2.1% (standard terminates in 2020)	Binding	Docket No. RE-00000C-09-0427, Decision 71436 Docket No. RE-00000C-09-0427, Decision 71819 Docket No. RG-00000B-09-0428, Decision 71855	2.5
Arkansas 2018 Regulatory Electric and nat. gas IOUs (~50%)	Electric: Incremental targets for PY 2020–22 of 1.2% of 2018 retail sales for electric IOUs. Natural gas: Annual incremental reduction target of 0.50% for 2020–22 for natural gas IOUs.	1.2% (net)	Opt-out	Order No. 17, Docket No. 08-144-U Order No. 1, Docket No. 13-002-U Order No. 7, Docket No. 13-002-U Order No. 31, Docket No. 13-002-U Order No. 43, Docket No.13-002-U	1.5
California 2004, 2009, and 2015 Legislative Electric and nat. gas IOUs (~73%)	While SB 350, signed in 2015, called on state agencies and utilities to double cumulative efficiency savings achieved by 2030, work to develop specific utility targets is ongoing. Electric: Average incremental savings targets of about 1.3% of retail electricity sales from 2020–25. Natural gas: Incremental savings targets average 0.5% from incentive and codes and standards programs for natural gas from 2020–25. Utilities must pursue all cost-effective efficiency resources.	1.6% (gross) 1.3% (net)	Binding	CPUC Decision 15-10-028 CPUC Decision 17-09-025 CPUC Decision 19-08-034 AB 995 SB 350 (10/7/15) AB 802 (10/8/15)	1.5

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Colorado 2007 and 2017 Legislative Electric and nat. gas IOUs (~56%)	Electric: For 2015–18, PSCo was required to achieve incremental savings of at least 400 GWh per year; starting in 2019, this was increased to 500 GWh, or roughly 1.7% of sales. HB 17-1227 extends programs and calls for 5% energy savings by 2028 compared with 2018. Natural gas: Savings targets commensurate with spending targets (at least 0.5% of prior year's revenue).	1.7%	Binding	Colorado Revised Statutes 40-3.2-101, et seq.; Docket No. 13A-0686EG Dec. C14-0731 HB17-1227 Proceeding no. 17A-04262EG: Settlement Agreement (2/26/18) Dec. C18-0417 approving settlement agreement in proceeding 17A-0462EG	2.0
Connecticut 2007 and 2013 Legislative Electric and nat. gas IOUs (~93%)	Electric: Average incremental savings of 1.11% of sales from 2019 through 2021. Natural gas: Average incremental savings of 0.59% per year from 2019 through 2021. Utilities must pursue all cost-effective efficiency resources.	1.1%	Binding	Public Act No. 07-242 Public Act No. 13-298 2019–21 Electric and Natural Gas Conservation and Load Management Plan	1.5
Hawaii 2004 and 2009 Legislative Electric Statewide goal (100%)	In 2009, transitioned away from a combined RPS-EERS to a stand-alone Energy Efficiency Portfolio Standard (EEPS) goal to reduce electricity consumption by 4,300 GWh by 2030 (equal to ~30% of forecast electricity sales, or 1.4% annual savings).	1.4%	Binding	HRS §269-91, 92, 96 HI PUC Order, Docket No. 2010-0037	1.0
Illinois 2007 and 2016 Legislative Electric and nat. gas utilities with more than 100,000 customers, Illinois DCEO (~89%)	Electric: Incremental savings targets vary by utility, averaging 1.77% of sales from 2018 to 2021, 2.08% from 2022 to 2025, and 2.05% from 2026 to 2030. SB 2814 also sets a rate cap of 4%, allowing targets to be adjusted downward should utilities reach spending limits. Natural gas: 8.5% cumulative savings by 2020 (0.2% incremental savings in 2011, ramping up to 1.5% in 2019).	2.0%	Cost cap	S.B. 1918 (2009) Public Act 96-0033 § 220 ILCS 5/8-103 S.B. 2814 (2015) Public Act 99-0906 Illinois Energy Efficiency Stakeholder Advisory Group	2.5

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Iowa 2009 and 2018 Legislative Electric and nat. gas IOUs (75%)	Requirements for utility submission of energy efficiency goals to the Iowa Utilities Board (IUB) are outlined in Iowa Code § 476.6(13). Incremental savings targets vary by utility and have been reduced significantly by a 2% cost cap for electric energy efficiency under Iowa Code § 476.6(15)(c)(2) (1.5% cap for natural gas). Current gross savings targets average 0.9% of electric sales and 0.2% for natural gas according to five-year utility plans (2019–23). Iowa Code § 476.6(13) requires municipal utilities and rural cooperatives to offer energy efficiency savings programs, but their plans are not reviewed or approved by the IUB.	0.9%	Binding	Senate Bill 2386 Docket EEP-2012-0001 SF 2311 (2018) Iowa Code chapter 1135, § 476.6	1.0
Maine 2009 Legislative Electric and nat. gas Efficiency Maine (100%)	Electric: Incremental gross savings targets of ~1.25% per year for 2020–2022 or roughly 1% net savings. Natural gas: Incremental savings of ~0.1% per year for 2020–2022. Efficiency Maine operates under an all cost-effective mandate.	1.25% (gross) 1.0% (net)	Opt-out	Efficiency Maine Triennial Plan (2014–16) Efficiency Maine Triennial Plan (2017–19) Efficiency Maine Triennial Plan (2020–22) HP 1128 – LD 1559	2.5
Maryland 2008 and 2015 Legislative Electric IOUs (97%)	Electricity use reduction goal of 15% per capita by 2015 (10% by utilities, 5% achieved independently); 15% reduction in per capita peak demand by 2015 compared with 2007. After 2015, targets vary by utility, ramping up by 0.2% per year to reach 2% incremental savings.	2.0% (gross) 1.6% (net)	Binding	Maryland Public Utility Companies Code § 7-211 Maryland PSC Docket Nos. 9153–9157 Order No. 87082	1.5

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Massachusetts 2009 Legislative Electric and nat. gas IOUs, co-ops, munis, Cape Light Compact (85%)	Electric: Net annual savings of 3.45 million MWh (not including fuel switching) for 2019–21, equivalent to savings of about 2.7% of retail sales per year. Natural gas: Savings goals of 1.25% of retail sales. Net annual savings of 95.89 MMTherms for 2019–21. Additional goal of 261.9 million net lifetime MMBtu for 2019–21. All cost-effective efficiency requirement.	2.7%	Binding	M.G.L. ch. 25, § 21; D.P.U. 18-110 through D.P.U. 18-119 (MA Joint Statewide Three-Year Energy Efficiency Plan for 2019 through 2021.)	3.0
Michigan 2008 and 2016 Legislative Electric and nat. gas Statewide goal (100%)	Electric: 1.0% incremental savings. Natural gas: Incremental savings of 0.75%. Targets carry forward in perpetuity for most utilities but end in 2021 for non-rate-regulated utilities (approximately 10% of state electric load).	1.0%	Binding	Act 295 (2008) S.B. 438 (2016)	1.5
Minnesota 2007 Legislative Electric and nat. gas IOUs, co-ops with more than 5,000 customers, and munis with more than 1,000 customers (~97%)	Electric: 1.5% incremental savings in 2010 and each year thereafter. Senate File 1456 signed in May 2017 exempts some rural utilities from meeting energy efficiency requirements through the Conservation Improvement Program (CIP). Natural gas: 0.75% incremental savings per year in 2010–12; 1% incremental savings in 2013 and each year thereafter.	1.5% (net) 1.2% (gross)	Binding	Minn. Stat. § 216B.241 SF 1456	1.5

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Nevada 2005 and 2009 Legislative Electric IOUs (88%)	20% of retail electricity sales to be met by renewables and energy efficiency by 2015, and 25% by 2025. Energy efficiency may meet a quarter of the standard through 2014 but is phased out of the RPS by 2025. SB 150, signed June 2017, directed the Nevada Public Utilities Commission to set new savings goals for NV Energy. The utility's 2018 Joint IRP Demand Side Plan established statewide goals of 1.18% in 2019, 1.14% in 2020, and 1.14% in 2021.	1.1%	Binding	NRS 704.7801 et seq.; Docket: 17-08023 – Investigation and rulemaking to implement Senate Bill 150 (2017) Docket No. 18-06003	1
New Hampshire 2016 Regulatory Electric and nat. gas Statewide goal (100%)	Electric: 0.8% incremental savings in 2018, ramping up to 1% in 2019 and 1.3% in 2020. Natural gas: 0.7% in 2018, 0.75% in 2019, and 0.8% in 2020.	1.3%	Binding	NH PUC Order No. 25932, Docket DE 15-137	1.5
New Jersey 2018 Legislative Electric and nat. gas Statewide goal (100%)	Electric: Under 2018 legislation A3723/S2314, utilities must achieve 2% of electric savings (as a percentage of average annual usage from the prior three years) within five years. Natural gas: Must achieve 0.75% of natural gas usage (as a percentage of average annual usage from the prior three years) within five years.	1.6%	Binding	A3723/S2314 (2018)	2
New Mexico 2008 and 2013 Legislative Electric IOUs (69%)	The state's three public utilities must achieve 5% savings of 2020 retail sales by 2025. HB 291 (2019) directs the Public Regulation Commission to set additional targets through 2030.	1.0%	Binding	NM Stat. § 62-17-1 et seq. HB 291	1

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
New York 2008, 2016, 2018, and 2020 Regulatory Electric and nat. gas Statewide goal (100%)	An April 2018 NYSERDA white paper called for 185 TBtus of cumulative annual site energy savings under the 2025 energy use forecast, as well as an electric site savings sub-target of 3% of IOU sales in 2025. A December 2018 PSC Order adopting the 3% electric goal calls for utilities to propose detailed targets. Natural gas goals ramp up to 1.3% by 2025. In January 2020, the PSC authorized annual incremental utility-specific budgets and savings targets for electric, gas, and heat pump portfolios.	2.0%	Binding	NY PSC Order Authorizing the Clean Energy Fund Framework Energy Efficiency Metrics and Target Options Report (November 2016) New Efficiency: New York (2018) NY PSC Case 18-M-0084	2.5
North Carolina 2007 Legislative Electric Statewide goal (100%)	Renewable Energy and Energy Efficiency Portfolio Standard (REPS) requires renewable generation and/or energy savings of 6% by 2015, 10% by 2018, and 12.5% by 2021 and thereafter. Energy efficiency is capped at 25% of target, increasing to 40% in 2021 and thereafter. REPS for electric cooperatives and munis requires renewable generation and/or energy savings of 3% by 2012, 6% by 2014, and 10% by 2018.	Combined RPS/EERS	Opt-out	NC Gen. Stat. § 62-133.8 04 NCAC 11 R08-64, et seq.	0
Oregon 2010 Regulatory Electric and nat. gas Energy Trust of Oregon (~61%)	Electric: Incremental targets average ~1.3% of sales annually for the period 2020–2021. Natural gas: ~0.5% of sales annually for 2020–2021	1.3% (gross) 1.2% (net)	Binding	Energy Trust of Oregon 2020 Annual Budget and 2020–2021 Action Plan Grant Agreement between Energy Trust of Oregon and OR PUC	1.5
Pennsylvania 2004 and 2008 Legislative Electric Utilities with more than 100,000 customers (96%)	Varying targets have been set for IOUs amounting to yearly statewide incremental savings of 0.6% for 2021–2026. EERS includes peak demand targets. Energy efficiency measures may not exceed an established cost cap.	0.6%	Cost cap	66 Pa. C.S. § 2806.1 Act 129 Phase IV Program Implementation Order (6/18/2020): Docket No. M-2020-3015228.	0.5

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Rhode Island 2006 Legislative Electric and nat. gas IOUs, munis (~99%)	Electric: Average incremental savings of 2.5% for 2018–20. EERS includes demand response targets. Natural gas: Incremental savings of 0.97% for 2018–20. Utilities must acquire all cost-effective energy efficiency.	2.5%	Binding	RIGL § 39-1-27.7 Docket No. 4443 National Grid's 2018–20 Energy Efficiency and System Reliability Procurement Plan	3.0
Texas 1999 and 2007 Legislative Electric IOUs (74%)	20% incremental load growth in 2011 (equivalent to ~0.10% annual savings); 25% in 2012, and 30% in 2013 and onward. Peak demand reduction targets of 0.4% compared with previous year. Energy efficiency measures may not exceed an established cost cap.	0.2%	Cost cap, opt-out	SB 7 HB 3693 Substantive Rule § 25.181 SB 1125	0
Vermont 2000 Legislative Electric Efficiency Vermont, Burlington Electric (98%)	Electric: Annual incremental savings totaling 357,400 MWh over 2018–20, or approximately 2.4% of annual sales. EERS includes demand response targets. Natural gas: Three-year annual incremental savings of 192,599 Mcf spanning 2018–20 or 0.5% of sales. Energy efficiency utilities must set budgets at a level that would realize all cost-effective energy efficiency.	2.4%	Binding	30 V.S.A. § 209; Efficiency Vermont Triennial Plan 2018–20 Order Re: Quantifiable Performance Indicator Targets for Vermont Gas Systems (12/23/15) EEU-2016-03: PUC Order on 10/12/17 re: Performance Targets	2.5
Virginia 2020 Legislative Electric IOUs (87%)	The 2020 Virginia Clean Economy Act requires Dominion Energy to achieve 5% energy savings by 2025 relative to a 2019 baseline. ApCo must achieve 2% by 2025, relative to a 2019 baseline. Statewide these goals translate to average incremental annual savings of approximately 1.2% over four years.	1.2%	Binding	Virginia Clean Economy Act	1.0

State Year(s) enacted Authority Applicability (% sales affected)	Description	Average incremental electric savings target per year (2020–2025)	Stringency	Reference	Score
Washington 2006 Legislative Electric IOUs, co-ops, munis (83%)	Biennial and 10-year goals vary by utility. Law requires savings targets to be based on the Northwest Power Plan, which targets acquiring 1,400 average MW by 2021, 3,000 aMW by 2026, and 4,300 aMW by 2035. Electric: Targets average ~0.94% incremental electricity savings per year. Natural gas: HB 1257 (2019) establishes a natural gas conservation standard requiring each gas company to acquire all conservation measures that are available and cost effective. Each company must set an acquisition target every two years, with initial targets taking effect by 2022. All cost-effective conservation requirement.	0.9%	Binding	Ballot Initiative I-937 Energy Independence Act, ch. 19.285.040 WAC 480-109-100 WAC 194-37 Seventh Northwest Power Plan (adopted 2/10/16) Washington Department of Commerce 2019 Biennial Report	1.0
Wisconsin 2011 Legislative Electric and nat. gas Statewide goal (100%)	Four-year goal for 2019–22 of 224,666,366 total net life-cycle MMBtus (combined electric and natural gas). Energy efficiency measures may not exceed an established cost cap. Electric: Minimum electric net life-cycle savings target of 22,832 GWh for 2019–22 or 1,840 GWh first-year savings across 2019–22. This translates to roughly 0.6–0.7% of sales per year in 2019–22. Natural gas: Focus on Energy targets minimum net life-cycle natural gas savings goal of 1,243 MMTherms for measures implemented in 2019–22, or 95.9 MMTherms of first-year savings, equating to approximately 0.6% savings as a percentage of sales on a net basis.	0.7%	Cost cap	2005 Wisconsin Act 141 Order, Docket 5-FE-100: Focus on Energy Revised Goals and Renewable Loan Fund (10/15) PSCW Memorandum, Docket 5-FE-101 (5/18) PSCW Decision, Docket 5-FE-101 (6/18)	1.0

Appendix E: State Electric Vehicle (EV) Fees

State	EV fee	Average gasoline tax collected for gasoline vehicles	Ratio of EV fee to gas tax revenues
Alabama	$200	$80.03	2.50
Alaska	-	$27.81	-
Arizona	-	$75.09	-
Arkansas	$200	$87.16	2.29
California	$100	$181.33	0.55
Colorado	$50	$89.30	0.56
Connecticut	-	$103.95	-
Delaware	-	$113.50	-
District of Columbia	-	$101.99	-
Florida	-	$79.03	-
Georgia	$213	$124.17	1.71
Hawaii	$50	$72.70	0.69
Idaho	$140	$132.31	1.06
Illinois	$100	$81.25	1.23
Indiana	$150	$122.98	1.22
Iowa	$65	$133.20	0.49
Kansas	$100	$99.29	1.01
Kentucky	-	$122.77	-
Louisiana	-	$92.08	-
Maine	-	$136.76	-
Maryland	-	$154.75	-
Massachusetts	-	$105.05	-
Michigan	$100	$122.75	0.81
Minnesota	$75	$137.04	0.55
Mississippi	$150	$83.57	1.79
Missouri	$75	$74.50	1.01
Montana	-	$113.00	-
Nebraska	$75	$137.91	0.54
Nevada	-	$103.83	-
New Hampshire	-	$110.18	-
New Jersey	-	$166.78	-

State	EV fee	Average gasoline tax collected for gasoline vehicles	Ratio of EV fee to gas tax revenues
New Mexico	-	$71.77	-
New York	-	$106.44	-
North Carolina	$130	$159.46	0.82
North Dakota	$120	$96.54	1.24
Ohio	$200	$124.03	1.61
Oklahoma	-	$85.44	-
Oregon	$110	$115.59	0.95
Pennsylvania	-	$249.58	-
Rhode Island	-	$152.38	-
South Carolina	$60	$81.60	0.74
South Dakota	-	$125.11	-
Tennessee	$100	$111.02	0.90
Texas	-	$96.13	-
Utah	$90	$111.64	0.81
Vermont	-	$134.98	-
Virginia	$64	$70.75	0.90
Washington	$150	$190.66	0.79
West Virginia	$200	$169.78	1.18
Wisconsin	$100	$142.37	0.70
Wyoming	$200	$101.06	1.98

Source: Atlas Public Policy 2020

Appendix F: Public EV Charging Stations

State	Number of public EV charging stations	2019 population	Stations per 100,000 people
Vermont	217	623,989	34.78
District of Columbia	147	705,749	20.83
Hawaii	273	1,415,872	19.28
California	6,177	39,512,223	15.63
Colorado	899	5,758,736	15.61
Oregon	606	4,217,737	14.37
Washington	1,008	7,614,893	13.24
Massachusetts	860	6,892,503	12.48
Rhode Island	129	1,059,361	12.18
Maryland	709	6,045,680	11.73
Maine	154	1,344,212	11.46
Utah	361	3,205,958	11.26
Connecticut	340	3,565,287	9.54
New York	1,605	19,453,561	8.25
Georgia	847	10,617,423	7.98
Virginia	610	8,535,519	7.15
New Hampshire	94	1,359,711	6.91
Kansas	200	2,913,314	6.87
Nevada	208	3,080,156	6.75
Missouri	410	6,137,428	6.68
Florida	1,346	21,477,737	6.27
Wyoming	36	578,759	6.22
North Carolina	642	10,488,084	6.12
Arizona	444	7,278,717	6.10
Tennessee	400	6,829,174	5.86
Minnesota	321	5,639,632	5.69
Delaware	53	973,764	5.44
Oklahoma	212	3,956,971	5.36
Illinois	612	12,671,821	4.83
Pennsylvania	592	12,801,989	4.62
Nebraska	89	1,934,408	4.60
Iowa	138	3,155,070	4.37

State	Number of public EV charging stations	2019 population	Stations per 100,000 people
Ohio	511	11,689,100	4.37
South Carolina	223	5,148,714	4.33
New Jersey	376	8,882,190	4.23
Texas	1,227	28,995,881	4.23
Michigan	411	9,986,857	4.12
Wisconsin	222	5,822,434	3.81
North Dakota	29	762,062	3.81
New Mexico	77	2,096,829	3.67
Idaho	63	1,787,065	3.53
Montana	37	1,068,778	3.46
West Virginia	61	1,792,147	3.40
Kentucky	138	4,467,673	3.09
South Dakota	27	884,659	3.05
Alaska	22	731,545	3.01
Indiana	190	6,732,219	2.82
Arkansas	84	3,017,804	2.78
Alabama	135	4,903,185	2.75
Mississippi	69	2,976,149	2.32
Louisiana	94	4,648,794	2.02

Appendix G. Tax Incentives for High-Efficiency Vehicles

State	Tax incentive
Arizona	Electric vehicle (EV) owners in Arizona pay a significantly reduced vehicle license tax—$4 for every $100 in assessed value—as part of the state's Reduced Alternative Fuel Vehicle License Tax program.
California	AB 118 targets medium- and heavy-duty trucks in a voucher program that aims to reduce the up-front incremental cost of purchasing a hybrid vehicle. Vouchers for up to $117,000 are available, depending on vehicle specifications, and are issued directly to fleets that purchase hybrid trucks for use within the state. California also offers rebates of up to $5,000 for light-duty zero-emission EVs and plug-in hybrid EVs on a first-come, first-served basis.
Colorado	In 2019 the Colorado legislature approved HB 1159, a bill that extends the state's alternative fuel vehicle tax credits through 2025. It sets a flat $5,000 credit, through 2019, for the purchase of a light-duty electric vehicle and makes the credit assignable to a car dealer or finance company, effectively turning the credit into a point-of-sale incentive. The tax credit declines to $4,000 for vehicles purchased in 2020, $2,500 for vehicles purchased in 2021 and 2022, and $2,000 for vehicles purchased in 2023–2025. Higher incentives are available for light-, medium-, and heavy-duty trucks.
Connecticut	Connecticut's Hydrogen and Electric Automobile Purchase Rebate Program provides as much as $3,000 for the incremental cost of the purchase of a hydrogen fuel cell electric vehicle, an all-electric vehicle, or a plug-in hybrid EV. Rebates are calculated on the basis of battery capacity. Vehicles with a battery capacity of 18 kWh or more earn $3,000, while those with capacities between 7 kWh and 18 kWh earn $1,500. Vehicles with batteries smaller than 7 kWh are eligible for a rebate of $750.
Delaware	As part of the Delaware Clean Transportation Incentive Program, the following rebates are available: • $3,500 for battery EVs under $60,000 MSRP • $1,500 for plug-in hybrid EVs and EVs with gasoline range extenders under $60,000 MSRP • $1,000 for battery and plug-in hybrid EVs over $60,000 MSRP
District of Columbia	The District of Columbia offers a reduced registration fee and a vehicle excise tax exemption for owners of all vehicles with an EPA-estimated city fuel economy of at least 40 miles per gallon.
Louisiana	Louisiana offers an income tax credit equivalent to 50% of the incremental cost of purchasing an EV under the state's alternative-fuel vehicle tax credit program. Alternatively, taxpayers may claim the lesser of 10% of the total cost of the vehicle or $3,000.
Maine	Maine is preparing to offer a $2,000 rebate for qualified electric vehicles, a $1,000 rebate for plug-in hybrids, and an enhanced rebate for low-income individuals, using monies from the Volkswagen Settlement Fund.
Massachusetts	The Massachusetts Offers Rebates for EVs (MOR-EV) program offers rebates of up to $2,500 to customers purchasing plug-in EVs.
New Jersey	All zero-emission vehicles in New Jersey are exempt from state sales and use taxes. In addition, vehicles that have an EPA fuel economy rating of less than 19 mpg or cost $45,000 or more in sales or lease price are subject to a fuel-inefficient vehicle fee.

State	Tax incentive
New York	Pursuant to legislation passed in April 2016, NYSERDA developed a rebate program for zero-emission vehicles that launched in March 2017. Rebates of up to $2,000 per vehicle are available for battery EVs, plug-in hybrid EVs, and fuel cell vehicles. New York also started the New York Truck Voucher Incentive Program, in 2014. Vouchers of up to $60,000 are available for the purchase of hybrid and all-electric class 3–8 trucks.
Oklahoma	Oklahoma offers income tax credits of up to $50,000 for the purchase of electric vehicles. Credit amounts are determined by the gross vehicle weight rating of the vehicle.
Oregon	The Oregon Clean Vehicle Rebate Program offers rebates of $1,500–2,500 toward the purchase of a new hybrid or battery electric vehicle, depending on battery capacity. Rebates of $2,500 are available to low- and moderate-income households for the purchase of new and used EVs. All eligible vehicles must have a base MSRP of less than $50,000.
Pennsylvania	The Alternative Fuels Incentive Grant Program offers rebates to assist eligible residents in purchasing new alternative fuel vehicles. Qualified electric vehicles earn a rebate of $1,750.
Texas	Electric vehicles weighing 8,500 pounds or less and purchased after September 1, 2013, are eligible for a $2,500 rebate.
Utah	Until December 2020, taxpayers are eligible for tax credits for the purchase of qualifying electric heavy-duty vehicles. Vehicles purchased in 2019 were eligible for an $18,000 tax credit. The tax credit amount has been gradually reduced from $25,000 in 2017 to $15,000 by 2020.
Virginia	The Virginia Department of Mines, Minerals and Energy, in collaboration with the Virginia Department of Transportation, offers up to $10,000 to state agencies and local governments for the incremental cost of new or converted alternative fuel vehicles.
Washington	Tax credits are available to businesses that purchase new alternative fuel commercial vehicles. Businesses may claim up to $250,000 or credits for 25 vehicles per year through January 1, 2021. HB 2042, passed in March 2019, also extends tax credits for light-duty passenger vehicles.

Source: DOE 2020a

Appendix H. State Transit Funding

State	FY 2018 funding	2018 population*	Per capita transit expenditure
Massachusetts	$2,105,381,276	6,882,635	$305.90
New York	$5,222,193,300	19,530,351	$267.39
Alaska	$181,178,229	735,139	$246.45
Connecticut	$651,477,883	3,571,520	$182.41
Illinois	$2,302,779,973	12,723,071	$180.99
Maryland	$1,032,129,469	6,035,802	$171.00
Pennsylvania	$1,689,999,183	12,800,922	$132.02
District of Columbia	$564,610,302	5,000,000	$112.92
Delaware	$102,177,731	965,479	$105.83
Minnesota	$493,700,000	5,606,249	$88.06
California	$2,635,079,270	39,461,588	$66.78
Rhode Island	$58,441,037	1,058,287	$55.22
Virginia	$454,232,979	8,501,286	$53.43
New Jersey	$389,474,344	8,886,025	$43.83
Michigan	$307,190,392	9,984,072	$30.77
Wisconsin	$113,487,500	5,807,406	$19.54
Florida	$375,809,491	21,244,317	$17.69
Washington	$106,996,000	7,523,869	$14.22
Vermont	$7,955,199	624,358	$12.74
Indiana	$65,288,653	6,695,497	$9.75
North Carolina	$93,943,490	10,381,615	$9.05
Tennessee	$56,040,141	6,771,631	$8.28
Oregon	$29,158,082	4,181,886	$6.97
Iowa	$15,932,516	3,148,618	$5.06
North Dakota	$3,831,141	758,080	$5.05
Kansas	$11,000,000	2,911,359	$3.78
Nebraska	$6,297,705	1,925,614	$3.27
Wyoming	$1,718,187	577,601	$2.97
New Mexico	$5,700,000	2,092,741	$2.72
Colorado	$15,000,000	5,691,287	$2.64
Arizona	$11,652,906	7,158,024	$1.63
Georgia	$16,000,744	10,511,131	$1.52
Oklahoma	$5,750,000	3,940,235	$1.46

West Virginia	$2,262,989	1,804,291	$1.25
Texas	$34,991,068	28,628,666	$1.22
South Carolina	$6,000,000	5,084,156	$1.18
Arkansas	$3,526,664	3,009,733	$1.17
Maine	$1,540,322	1,339,057	$1.15
South Dakota	$1,000,000	878,698	$1.14
Louisiana	$4,955,000	4,659,690	$1.06
New Hampshire	$1,353,603	1,353,465	$1.00
Montana	$825,000	1,060,665	$0.78
Ohio	$6,500,000	11,676,341	$0.56
Mississippi	$1,600,000	2,981,020	$0.54
Kentucky	$1,845,949	4,461,153	$0.41
Missouri	$1,710,875	6,121,623	$0.28
Idaho	$312,000	1,750,536	$0.18
Alabama	$0	4,887,681	$0.00
Hawaii	$0	1,420,593	$0.00
Nevada	$0	3,027,341	$0.00

* Population figures represent total area served by transit system. *Source:* AASHTO 2019.

Appendix I. State Transit Legislation

State	Description	Source
Alabama	Alabama Act 2018-161 requires the Alabama Department of Economic and Community Affairs to create, oversee, and administer the Alabama Public Transportation Trust Fund, establishing a path to increase public transportation options in the state.	legiscan.com/AL/bill/SB85/2018
Arkansas	Passed in 2001, Arkansas Act 949 established the Arkansas Public Transit Fund, which directs monies from rental vehicle taxes toward public transit expenditures.	www.arkleg.state.ar.us/assembly/2001/R/Acts/Act949.pdf
California	California's Transportation Development Act provides two sources of funding for public transit: the Location Transportation Fund (LTF) and the State Transit Assistance (STA) Fund. The general sales tax collected in each county is used to fund each county's LTF. STA funds are appropriated by the legislature to the state controller's office. The statute requires that 50% of STA funds be allocated according to population and 50% be allocated according to operator revenues from the prior fiscal year.	www.dot.ca.gov/hq/MassTrans/State-TDA.html
Colorado	In 2018 Colorado adopted SB1, which significantly expands state funding for transit. SB1 creates a new multimodal options fund dedicated to public transit and bicycle and pedestrian infrastructure and operations.	leg.colorado.gov/bills/sb18-001
Florida	House Bill 1271 allows municipalities in Florida with a regional transportation system to levy a tax, subject to voter approval, that can be used as a funding stream for transit development and maintenance.	www.myfloridahouse.gov/sections/Bills/billsdetail.aspx?BillId=44036
Georgia	The Transportation Investment Act, enacted in 2010, allows municipalities to pass a sales tax for the express purpose of financing transit development and expansion.	gsfic.georgia.gov/transportation-investment-act
Hawaii	Section HRS 46-16.8 of the Hawaii Revised Statutes allows municipalities to add a county surcharge to state tax; the surcharge is then funneled toward mass transit projects.	www.capitol.hawaii.gov/hrscurrent/Vol02_Ch0046-0115/HRS0046/HRS_0046-0016_0008.htm
Illinois	House Bill 289 allocates $2.5 billion for the creation and maintenance of mass transit facilities from the issuance of state bonds.	legiscan.com/gaits/text/70761

State	Description	Source
Indiana	House Bill 1011 specifies that a county or city council may elect to provide revenue to a public transportation corporation from the distributive share of county adjusted gross income taxes, county option income taxes, or county economic development income taxes. An additional county economic development income tax no higher than 0.3% may also be imposed to pay the county's contribution to the funding of the metropolitan transit district. Only six counties within the state may take advantage of this legislation.	legiscan.com/IN/text/HB1011/id/673339
Iowa	The Iowa State Transit Assistance Program devotes 4% of the fees for new registration collected on sales of motor vehicle and accessory equipment to support public transportation.	www.iowadot.gov/transit/funding.html
Kansas	Transportation Works for Kansas legislation, adopted in 2010, provides financing for a multimodal development program in communities with immediate transportation needs.	votesmart.org/bill/11412/30514/transportation-works-for-kansas-program%20%28T-Works%20for%20Kansas%20Program%29
Maine	The Maine Legislature created a dedicated revenue stream for multimodal transportation in 2012. The Multimodal Transportation Fund uses sales tax revenues derived from vehicle rentals. Funds must be used for purchasing, operating, maintaining, improving, repairing, constructing, and managing the assets of non-road forms of transportation.	www.mainelegislature.org/legis/statutes/23/title23sec4210-B.html
Maryland	In 2018 Maryland passed the Maryland Metro/Transit Funding Act. Maryland's Transportation Trust Fund must provide at least $167 million in revenues to the Washington Suburban Transit District through an annual grant that will be used to pay capital costs of the Washington Metropolitan Area Transit Authority. In addition, the legislation requires that at least $29.1 million of the revenue from the Transportation Trust Fund be provided for capital needs of the Maryland Transit Administration (MTA) in fiscal years 2020, 2021, and 2022. The legislation further requires that those appropriations for the MTA be increased by at least 4.4% over the previous year, starting with the fiscal year 2019 budget.	mgaleg.maryland.gov/2018RS/chapters_noln/Ch_352_hb0372E.pdf; see Transportation Article §3–216.and §7–205
Massachusetts	Section 35T of Massachusetts general law establishes the Massachusetts Bay Transportation Authority State and Local Contribution Fund. This account is funded by revenues from a 1% sales tax.	malegislature.gov/Laws/GeneralLaws/PartI/TitleII/Chapter10/Section35t
Michigan	The Michigan Comprehensive Transportation Fund funnels both vehicle registration revenues and auto-related sales tax revenues toward public transportation and targeted transit demand management programs.	www.legislature.mi.gov/(S(hlkm5k45i240utf2mb0odtzt))/mileg.aspx?page=getObject&objectName=mcl-247-660b

State	Description	Source
Minnesota	House File 2700, adopted in 2010, is an omnibus bonding and capital improvement bill that provides $43.5 million for transit maintenance and construction. The bill also prioritized bonding authorization so that appropriations for transit construction for fiscal years 2011 and 2012 would amount to $200 million.	wdoc.house.leg.state.mn.us/leg/LS86/CEH2700.1.pdf
New York	In 2010 New York adopted Assembly Bill 8180, which increased certain registration and renewal fees to fund public transit. It also created the Metropolitan Transit Authority financial assistance fund to support subway, bus, and rail.	www.ncsl.org/issues-research/transport/major-state-transportation-legislation-2010.aspx#N
North Carolina	In 2009 North Carolina passed House Bill 148, which called for the establishment of a congestion relief and intermodal transportation fund.	www.ncleg.net/sessions/2009/bills/house/pdf/h148v2.pdf
Oregon	Oregon has a Lieu of State Payroll Tax Program that provides a direct, ongoing revenue stream for transit districts that can demonstrate equal local matching revenues from state agency employers in their service areas.	www.oregonlegislature.gov/citizen_engagement/Reports/2008PublicTransit.pdf
Pennsylvania	Act 44 of House Bill 1590, passed in 2007, allows counties to impose a sales tax on liquor or an excise tax on rental vehicles to fund the development of county transit systems.	www.legis.state.pa.us/WU01/LI/LI/US/HTM/2007/0/0044..HTM
Tennessee	Senate Bill 1471, passed in 2009, calls for the creation of a regional transportation authority in major municipalities. It allows these authorities to set up dedicated funding streams for mass transit either by law or through voter referendum.	state.tn.us/sos/acts/106/pub/pc0362.pdf
Utah	Utah's comprehensive transportation funding bill, passed in 2015, allows counties to implement a 0.25% local sales tax to fund locally identified transportation needs. Of all revenues collected using this mechanism, 40% must be awarded to the county transit agency.	le.utah.gov/~2015/bills/static/HB0362.html
Virginia	House Bill 2313, adopted in 2013, created the Commonwealth Mass Transit Fund, which receives approximately 15% of revenues collected from the implementation of a 1.5% sales and use tax for transportation expenditures.	lis.virginia.gov/cgi-bin/legp604.exe?131+ful+CHAP0766
Washington	In 2015 SB 5987, the Connecting Washington Package, was passed, allocating $16 billion toward transportation connectivity, maintenance, and development projects.	apps.leg.wa.gov/documents/billdocs/2011-12/Pdf/Bills/Session%20Laws/House/2660.SL.pdf
West Virginia	In 2013 the West Virginia Commuter Rail Access Act (Senate Bill 03) established a special fund in the state treasury to pay track access fees accrued by commuter rail services operating within the state's borders. The funds can be rolled over from year to year and are administered by the West Virginia State Rail Authority.	www.legis.state.wv.us/Bill_Status/bills_text.cfm?billdoc=SB103%20SUB1%20ENR.htm&yr=2013&sesstype=RS&i=103

Appendix J. State Progress toward Public Building Energy Benchmarking

State	Percentage benchmarked/Progress status
California	100% of state-owned, executive branch facilities, benchmarked since 2013
Connecticut	42% of state buildings, 100% of the Connecticut Technical High School system, 100% of several K–12 school districts, 100% of Connecticut Community Colleges
Delaware	80%
District of Columbia	Nearly 99% of government-owned floor area
Florida	20% of state-owned or leased facilities with more than 5,000 square feet of air-conditioned space
Hawaii	More than 29 million square feet of public facilities
Iowa	80,2 million square feet benchmarked; 1,572 sites and 2,148 buildings benchmarked in the Iowa B3 Benchmarking Program
Kentucky	801 buildings, representing more than 16 million square feet of facilities
Maryland	100% of state facilities
Massachusetts	100% of about 80 million square feet of state-owned facilities
Michigan	88% of state-owned facilities
Minnesota	More than 7,500 public buildings with more than 300 million square feet, representing 22 state agencies, 410 cities, 55 counties, 60 higher-education campuses, and 214 school districts
Mississippi	95% of agencies covered by the energy and cost data reporting requirements under the Mississippi Energy Sustainability and Development Act of 2013
Missouri	Approximately 50% of square footage managed by the Office of Administration and the Department of Corrections
Montana	63.6%
Nevada	86% of total state building square footage
New Hampshire	95% of state-owned building square footage
New Mexico	Approximately 20%
North Carolina	100% of state-owned buildings and community college buildings
Oregon	100% of state-owned and occupied buildings greater than 5,000 square feet
Rhode Island	100% of all state, municipal, and public-school square footage
South Carolina	100% of state-owned buildings
Tennessee	100% of state-owned and -managed facilities
Utah	75% of buildings managed by the Division of Facilities Construction and Management
Vermont	70% of the state-owned and -operated building space that the ENERGY STAR® Portfolio Manager is capable of benchmarking
Washington	55% of state agency square footage, 30% of college square footage, 17% of university square footage

Not all states with benchmarking requirements provided the percentage of buildings benchmarked. All states listed above, except Missouri, require benchmarking in public facilities. Missouri has a voluntary program.

Appendix K. State Energy Savings Performance Contracting: Investments and Savings

State	2019 investments ($ million)	2019 incremental electricity savings for all active ESCO projects	2019 annual savings from active projects
California	$14	6 million kWh	57 million kWh
Colorado	$28.7	23,203,131 kWh	
Maryland		$3,206,939 in savings once commissioning occurs	1,209,328 MMBtus
Massachusetts	$20.8		
Montana	$7.2	3,066,183 kWh	3,340,534 kWh (2017, 2018, and 2019)
New Mexico	$12.4	39,638,521 kWh	115,472,641 kWh
North Carolina	$22.9		$2,000,451 in guaranteed savings
Pennsylvania	$5.8	3,218,886 kWh	5,145,593 kWh
Utah	$4.6		3,830,885 kWh (expected)
Virginia	$53.5	1,100,000 kWh	18,200,000 kWh
Washington	$38.9	10,307,113 kWh	477,383,938 kWh

We excluded ESPC program budgets and projected energy and cost savings from states in order to focus on investments and cost and energy savings already achieved. This table includes only data that were provided by states in response to our data request.

Appendix L. Total Energy and Cost Savings from State Financial Incentives

State	Title	Program administrator	Program-level energy savings	Program-level monetary savings	Estimated avoided CO_2 emissions
Alabama	AlabamaSAVES Revolving Loan Program	State Energy Office	1,000,000 kWh (construction on project in 2020)	$50,000 (construction on project in 2020)	
Alabama	Energy Efficient Retrofit Program	State Energy Office	694,000 kWh (FY 19 annual savings)	$100,502 (FY 19 annual savings)	491 metric tons
California	Energy Conservation Assistance Act	California Energy Commission		$1,053,808 (CY 2019)	
California	Energy Conservation Assistance Act—Education Subaccount	California Energy Commission		$1,628,677 (CY 2019)	
California	Property Assessed Clean Energy (PACE) Loss Reserve Program	California Alternative Energy and Advanced Transportation Financing Authority	1.1 billion kWh per year (estimated, based on PACE financings enrolled as of October 2019)		
Colorado	Agricultural Energy Efficiency Program	Colorado Energy Office	2.6 million kWh (estimated) to date		
Colorado	Energy Savings for Schools	Colorado Energy Office	3.5 million kWh (estimated) to date		
Colorado	C-PACE: Colorado Commercial Property Assessed Clean Energy	Sustainable Real Estate Solutions	54.5 million kBtus annually (projected)	$29.5 million (projected) to date	
Delaware	Energy Efficiency Investment Fund Rebates	Department of Natural Resources and Environmental Control	12,505,366 (2019 net savings)		7,479.55 tons
Delaware	Energize Delaware Farm Program	Sustainable Energy Utility	747,094 (2019 net savings)		853.2 tons
Delaware	State Revolving Loan Fund	Department of Natural Resources and Environmental Control	343,103 (2019 net savings)		278.85 tons

State	Title	Program administrator	Program-level energy savings	Program-level monetary savings	Estimated avoided CO_2 emissions
Iowa	Energy Bank Revolving Loan Program	Iowa Area Development Group	127,593 kWh (2019)	$10,207 (2019)	97 tons (2019)
Maine	Efficiency Maine Consumer Products Program	Efficiency Maine Trust	67,811.3 MMBtus (FY 2019)	$777,061	
Maine	Efficiency Maine Home Energy Savings Program	Efficiency Maine Trust	1,327,410 MMBtus (FY 2019)	$11,187,676	
Maine	Efficiency Maine Low-Income Initiatives	Efficiency Maine Trust	485,606 MMBtus (FY 2019)	$6,289,344	
Maine	Efficiency Maine C&I Prescriptive Program	Efficiency Maine Trust	946,449 MMBtus (FY 2019)	$9,165,825	
Maine	Efficiency Maine C&I Custom Program	Efficiency Maine Trust	1,780,153 MMBtus (FY 2019)	$9,354,773	
Maryland	Be SMART Home Efficiency Loan Program	Maryland Department of Housing and Community Development	Anticipated energy savings of 126,551 kWh/year (FY 2020)	Anticipated monetary savings of $28,593 (FY 2020)	
Massachusetts	Home Energy Market Value Performance Program (Home MVP)	Department of Energy Resources	4,578,063/year as of May 2020		1,799.8 metric tons/year as of May 2020
Massachusetts	Rapid LED Streetlight Conversion Grant Program	Metropolitan Area Planning Council	33,917 kWh		10,122 metric tons as of June 2020
Montana	Alternative Energy Revolving Loan Program	Montana Department of Environmental Quality	499,653 kWh	$54,444	649,549 pounds (2020)
Nebraska	Dollar and Energy Savings Loans	Nebraska Department of Environment and Energy		$1,154,980 (2019)	
New Mexico	Sustainable Building Tax Credit (personal)	State Energy Office	16,776,195 source energy for 2019	$845,962 from 2019 projects	3,347 tons
New York	Low-Rise Residential New Construction Program	NYSERDA	98,000 kWh/most recent year		

State	Title	Program administrator	Program-level energy savings	Program-level monetary savings	Estimated avoided CO_2 emissions
North Dakota	Energy Conservation Grant	Department of Commerce		Estimated $269,110 (July 2019 to June 2020)	
Oregon	Industrial Self-Direct of Public Purpose Funds	Oregon Department of Energy	1,634,309 kWh (2019)	$103,578 (2019)	599.8 $MTCO_2e$ (2019)
Rhode Island	Pascoag Utility District Energy Efficiency Program	Office of Energy Resources, Pascoag Utility District	262,000 kWh	$24,906	53.60 short tons in 2020
Tennessee	Energy Efficient Schools Initiative—Loans	Energy Efficient Schools Initiative	15,037,512 kWh (FY 2019)	$28 million	10,632 metric tons per year
Tennessee	Pathway Energy Efficiency and Renewable Energy Loan Program	Pathway Lending	14,603,160 kWh from 2019 loans	Average estimated annual energy savings of $37,365 per program participant for program year 2019	10,325 metric tons per year

Appendix M. State Efficiency Spending and Savings Targets for Low-Income Customers

State	Spending/savings requirements for low-income energy efficiency programs
California	California Public Utilities Code Section 382(e) set a goal to provide low-income energy efficiency measures to 100% of eligible and willing customers by 2020. A. 14-11-007 (2016) strengthened the goal and updated interpretation of the “willing and feasible to participate” factor.
Connecticut	Utilities are required to allocate their limited-income budget in parity with the revenues expected to be collected from that sector. Public Act 11-80, Section 33, establishes a goal of weatherizing 80% of homes. This goal is not specific to low-income customers, but activity in the low-income program helps the companies achieve this goal. Also, as part of the performance management incentive (PMI) calculation, the utilities are required to spend at least 95% of their low-income budget. Electric, natural gas, oil, and propane savings metrics also fall under the low-income program attached to the PMI calculation.
Delaware	Delaware established legislative energy savings targets in 2009 with the adoption of SB 106. The legislation set up a Sustainable Energy Trust Fund to collect charges assessed by energy providers in service of energy savings goals. SB 106 specifies that 20% of assessments be provided to the Weatherization Assistance Program. The Delaware Weatherization Assistance Program has an annual goal of completing 400 homes. Electric utility restructuring legislation passed in 1999 specified that Delmarva Power and Light (DPL) collect 0.095 mills per kWh (approximately $800,000 annually) from customers to be forwarded to the Department of Health and Social Services, Division of State Service Centers, to be used to fund low-income fuel assistance and weatherization programs. To make low-income energy efficiency programs more accessible, a Guidance Document was drafted in 2016 as part of the merger settlement approved by the PSC between Exelon and Delmarva Power and Light to allocate $4 million of the funds toward low-income customer energy efficiency programs. This Guidance Document applies to DPL customers, and funds are available to support organizations delivering energy efficiency programs to low-income ratepayers. Organizations that receive grants to run low-income energy efficiency programs will increase energy efficiency measures for low-income Delaware households, increase statewide electric and gas savings, engage and inform low-income households about the benefits of energy efficiency, develop a community-based approach to address energy efficiency issues in low-income housing by mobilizing public and private-sector resources, and ensure to the greatest extent feasible that job training, employment, and contracting generated by this grant will be directed to low-income persons. All settlement-funded low-income programs must be officially recommended by the Energy Efficiency Advisory Council (EEAC) and approved by the PSC.
District of Columbia	The Clean and Affordable Energy Act (CAEA) of 2008 established a separate Energy Assistance Trust Fund to support: “(1) the existing low-income programs in the amount of $3.3 million annually; and (2) the Residential Aid Discount subsidy in the amount of $3 million annually.” For the 2017–21 program cycle the low-income spending requirement was adjusted to 20% of expenditures.

State	Spending/savings requirements for low-income energy efficiency programs
Illinois	In December 2016, the Illinois State Legislature passed the Future Energy Jobs Bill (SB 2814). The legislation directs utilities to implement low-income energy efficiency measures of no less than $25 million per year for electric utilities that serve more than 3 million retail customers in the state (ComEd), and no less than $8.35 million per year for electric utilities that serve fewer than 3 million but more than 500,000 retail customers in the state (Ameren).
Maine	LD-1559, passed in June 2013, states that Efficiency Maine Trust shall "target at least 10% of funds for electricity conservation collected under subsection 4 or 4-A or $2,600,000, whichever is greater, to programs for low-income residential consumers, as defined by the board by rule."
Massachusetts	In the late 1990s, Massachusetts restructuring law established a low-income conservation fund through a 0.25 mills per kWh charge on every electric customer's bill. A conservation charge on natural gas customers' bills has funded natural gas low-income energy efficiency programs. In 2010 the program received additional funding through the 2008 Green Communities Act, which required that 10% of electric utility program funds and 20% of gas program funds be spent on comprehensive low-income energy efficiency and education programs. The legislation further directed that these programs be implemented through the low-income weatherization assistance program (WAP) and fuel assistance program network with the objective of standardizing implementation among all utilities. In addition to the WAP-coordinated programs that directly serve low-income clients, the utilities fund the Low-Income Multifamily Retrofit Program, which provides cost-effective energy efficiency improvements to multifamily buildings, including those owned by nonprofit and public housing authorities. The program is aimed at one- to four-unit residential buildings where at least 50% of the units are occupied by low-income residents earning at or below 60% of area median income. Eligible projects involve efficiency upgrades for buildings with currently high energy consumption, specifically for space heating, hot water, air sealing, and insulation of building envelopes, lighting, and appliances.
Michigan	SB 438, approved in December 2016, extended the state's 1% annual energy savings requirement for utilities through 2021. The bill does not specify a minimum required level of spending or savings for low-income energy efficiency programs, other than to direct that distribution customers' funding responsibilities for low-income residential programs be proportionate to the distribution customers' funding of the total energy optimization (EO) program: "The established funding level for low-income residential programs shall be provided from each customer rate class in proportion to that customer rate class's funding of the provider's total energy optimization programs."
Minnesota	Municipal gas and all electric utilities must spend at least 0.2% of their gross operating revenue from residential customers on low-income programs. Legislation in 2013 raised the minimum low-income spending requirement for gas IOUs from 0.2% to 0.4% of their most recent three-year average gross operating revenue from residential customers.

State	Spending/savings requirements for low-income energy efficiency programs
Montana	SB 150, passed in 2015, made changes to the state's system benefit fund, increasing a public utility's minimum funding level for low-income energy and weatherization assistance from 17% to 50% of the public utility's annual electric universal systems benefits level. A cooperative utility's minimum annual funding requirement for low-income energy assistance remains at 17% of its annual USB funding level. SB 150 also clarified that eligible projects can be located on tribal reservations.
Nevada	In July 2001 Nevada passed AB 661, which created the Nevada Fund for Energy Assistance and Conservation (FEAC) through a universal energy charge (UEC) assessed on retail customers of the state's regulated electric and gas utilities. Nevada's Energy Assistance Code specifies the UEC is 3.30 mills per therm of natural gas and 0.39 mills per kWh of electricity purchased by these customers. NRS 702.270 requires that 25% of the money in the FEAC be distributed to the Nevada Housing Division for programs of energy conservation, weatherization, and energy efficiency for eligible households. In June 2017, SB 150 was signed into law. It directs the Public Utilities Commission to establish annual energy savings goals for NV Energy and requires utilities to set aside 5% of efficiency program budgets for low-income customers.
New Hampshire	In August 2016 the New Hampshire Public Utilities Commission approved a settlement agreement establishing a statewide energy efficiency resource standard. The agreement provides for an increase in the minimum low-income share of the overall energy efficiency budget from 15.5% to 17%.
New Mexico	The state's energy efficiency targets, established in 2005 within the Efficient Use of Energy Act, were amended in 2019 with the passage of HB 291. The legislation calls for a 5% reduction of energy consumption as a percentage of 2020 sales by 2025 and also directs that no less than 5% of the amount received by the public utility for program costs shall be specifically directed to energy efficiency programs for low-income customers.
New York	In December 2018, the PSC ordered the development of a Statewide LMI Portfolio, to include ratepayer funded initiatives administered by NYSERDA and the utilities. The Order also required that a minimum of 20% of any additional energy efficiency investments through the utilities be directed to the LMI market segment. In January 2020, the PSC authorized utility specific LMI budgets, totaling a minimum of $289 million through 2025. Combined with the NYSERDA ratepayer funded LMI budget, the LMI Portfolio will include at least $650 million of new investments in LMI energy efficiency through 2025.
Oklahoma	Under OAC 165:35-41-4, all electric utilities under rate regulation of the Oklahoma Corporation Commission must propose, at least once every three years—and be responsible for the administration and implementation of—a demand portfolio of energy efficiency and demand response programs within their service territories. The regulations specify that demand portfolios must address programs for low-income and hard-to-reach customers "to assure proportionate Demand Programs are deployed in these customer groups despite higher barriers to energy efficiency investments."

State	Spending/savings requirements for low-income energy efficiency programs
Oregon	Senate Bill 1149, requiring electric industry restructuring for the state's largest investor-owned utilities, was signed into law in July 1999. The law established an annual expenditure by the utilities of 3% of their revenues to fund "Public Purposes," including energy efficiency, development of new renewable energy, and low-income weatherization. Per the legislation, 13% of the public purpose charge would be allocated to low-income weatherization through the Energy Conservation Helping Oregonians program.
Pennsylvania	In June 2015, the Pennsylvania Public Utility Commission issued an implementation order for Phase III of the Energy Efficiency and Conservation Program, setting five-year cumulative targets of 5.1 million MWh, equivalent to about 0.77% incremental savings, per year through 2020. The order also requires each utility to obtain a minimum of 5.5% of their total consumption reduction target from the low-income sector.
Texas	As amended by SB 1434 in June 2011, Substantive Rule § 25.181 states that "each utility shall ensure that annual expenditures for the targeted low-income energy efficiency program are not less than 10% of the utility's energy efficiency budget for the program year."
Vermont	Efficiency Vermont (EVT), the state's energy efficiency utility established in 1999, is funded through a systems benefits charge on all utility customers' bills. Most of the costs of the electric efficiency measures implemented by EVT and the community-based weatherization agencies are paid for by EVT, with any remaining balances covered by the federal Weatherization Assistance Program (WAP). Other funding for WAP comes from the state's Weatherization Trust Fund, which was created in 1990 through legislative enactment of a gross-receipts tax of 0.5% on all non-transportation fuels sold in the state. As specified by Vermont law, 50% of the net proceeds from the sale of carbon credits through the Regional Greenhouse Gas Initiative are deposited into a fuel efficiency fund to provide energy efficiency services to residential consumers who have incomes of no more than 80% of the state median income.
Virginia	The 2018 Grid Modernization and Security Act (SB966) required that at least 5% of energy efficiency programs benefit low-income, elderly, and disabled individuals. The 2020 Virginia Clean Economy Act increased this target to 15%.
Wisconsin	The Reliability 2000 Law, passed in 1999, created a program for awarding grants to provide assistance to low-income households for weatherization and other energy conservation services, payment of energy bills, and the early identification and prevention of energy crises. The law specifies that 47% of total low-income funds must be dedicated to weatherization. The legislation required the Department of Administration to collect $24 million for low-income public benefits services the first year and to calculate a low-income need target in subsequent years. This low-income need target is based on the estimated number of low-income families (households at or below 150% of the poverty level) multiplied by the estimated need per eligible household.

Appendix N. Cost-Effectiveness Rules for Utility Low-Income Efficiency Programs

State	Special cost-effectiveness provisions for low-income energy efficiency programs
Arizona	Since 2011 Arizona Administrative Code Title 14, Chapter 2, Article 24 (R14-2-2412) has directed that "an affected utility's low-income customer program portfolio shall be cost effective, but costs attributable to necessary health and safety measures shall not be used in the calculation."
Arkansas	Arkansas does not require program-level cost effectiveness for low-income programs.
California	California applies the Energy Savings Assistance Program Cost Effectiveness test (ESACET) and the Total Resource Cost (TRC) test to the low-income program. These tests incorporate nonenergy benefits and are used for informational purposes only, with no set minimum threshold for cost effectiveness.
Colorado	Decision No. C08-0560 directs the Colorado Public Service Commission to pursue all cost-effective low-income demand-side management (DSM) programs, "but to not forgo DSM programs simply because they do not pass a 1.0 TRC test." It also directs that, in applying the TRC to low-income DSM programs, "the benefits included in the calculation shall be increased by 20%, to reflect the higher level of nonenergy benefits that are likely to accrue from DSM services to low-income customers." This was increased to 50% for low-income measures and products in April 2018 under Decision No. C18-0417. To avoid unintended impacts to calculations of benefits pursuant to performance incentives, the decision also allows utilities to exclude these costs in these determinations: "To address this concern we find that the costs and benefits associated with any low-income DSM program that is approved and has a TRC below 1.0 may be excluded from the calculation of net economic benefits. Further, the energy and demand savings may be applied toward the calculation of overall energy and demand savings, for purposes of determining progress toward annual goals."
Connecticut	Connecticut has established formal rules and procedures for evaluation, which are stated in Public Act 11-80 and Evaluation Rules and Roadmap. The Program Administrator test has been the primary cost-effectiveness test in Connecticut. However, the TRC test is the primary test for the Home Energy Solutions Limited-Income program. Connecticut regulators have repeatedly approved non-cost-effective low-income programs.
Delaware	The Evaluation, Measurement, and Verification Committee in 2016 recommended specific net-energy impacts or net-energy benefits for low-income programs. These include weatherization-reduced arrearages and participant health and safety benefits. Specific values were also applied to the net-energy benefits and are locked in for three years. These net-energy benefits were unanimously recognized and approved by the EEAC.
District of Columbia	While no specific rules are in place for low-income programs per se, programs that are not cost effective may be included in the DC Sustainable Energy Utility's portfolio as long as the overall portfolio is cost effective based on the Societal Cost test. A 10% adder is applied to program benefits to account for additional nonenergy benefits including comfort, noise reduction, aesthetics, health and safety, ease of selling/leasing the home or building, improved occupant productivity, fewer work absences due to reduced illnesses, ability to stay in one's home and avoid moves, and macroeconomic benefits.

State	Special cost-effectiveness provisions for low-income energy efficiency programs
Florida	Applying program-level cost-effectiveness tests to low-income energy efficiency programs is not required by the energy efficiency statutes in Florida.
Idaho	In April 2013 the PUC largely adopted its staff's recommendations from an October 2012 report regarding methodology for evaluating low-income weatherization assistance programs (LIWAP) and the criteria for increased funding (Order No. 32788, Case No. GNR-E-12-01). In this order, the PUC determined that a utility may "include a 10% conservation preference adder for their low-income weatherization programs," but that if the utility believes the adder would make its cost-effectiveness calculations inconsistent, then the company need not use the adder. The PUC encouraged the utilities to include nonenergy benefits of low-income weatherization assistance programs (LIWAPs) when calculating cost effectiveness but declined to construct a "specific cost-effectiveness test for low-income programs at this time." Instead, the PUC said it would continue reviewing LIWAPs on a case-by-case basis.
Illinois	Section 8-103B (Energy Efficiency and Demand-Response Measures) of SB 2814 excludes low-income energy efficiency measures from the need to satisfy the TRC test.
Indiana	Under Senate Bill 412 and Indiana Code 8-1-8.5-10(h), an electricity supplier may submit its energy efficiency plan to the commission for a determination of the overall reasonableness of the plan either as part of a general basic rate proceeding or as an independent proceeding. A petition submitted may include a home energy efficiency assistance program for qualified customers of the electricity supplier whether or not the program is cost effective.
Iowa	According to IAC 199–35.5(4)(c)(3), "Low-income and tree-planting programs shall not be tested for cost effectiveness, unless the utility wishes to present the results of cost-effectiveness tests for informational purposes."
Kansas	Low-income programs are not required to pass strict benefit–cost analysis so long as they are found to be in the public interest and supported by a reasonable budget.
Kentucky	Requirements for low-income programming are similar to those governing other programmatic offerings, and these were established by precedent in a 1997 proceeding surrounding the approval of LG&E's DSM program portfolio. The rules for benefit–cost tests are stated in Case No. 1997-083. These benefit–cost tests are required for total program-level screening, with exceptions for low-income programs, pilots, and new technologies. The commission also found in Case No. 97-083 that "If [a] filing fails any of the traditional [cost-effectiveness] tests, LG&E and its Collaborative may submit additional documentation to justify the need for the program."
Maine	Maine has not had specific cost-effectiveness guidelines in place for low-income programs. However, the cost-effectiveness test for all programs provides for consideration of nonenergy benefits including "reduced operations and maintenance costs, job training opportunities and workforce development, general economic development and environmental benefits, to the extent that such benefits can be accurately and reasonably quantified and attributed to the program or project."

State	Special cost-effectiveness provisions for low-income energy efficiency programs
Maryland	In Order No. 87082 the PUC required cost-effectiveness screening for limited-income programs but indicated the programs may still be implemented without satisfying the test, stating: “We accept the recommendation of the Coalition that, while cost-effectiveness screening of the limited income sub-portfolio shall be required in the same manner as with respect to the other EmPOWER sub-portfolios, the results of the limited-income sub-portfolio screening shall serve as a point of comparison to other jurisdictions and past programmatic performance rather than as the basis for precluding certain limited-income program offerings.”
Massachusetts	Massachusetts relies on the TRC test as its primary test for DSM programs but specifically calculates additional benefits from low-income programs in its benefit–cost ratio. DPU 08-50-B specifies that an energy efficiency plan must include calculations of non-electric benefits, specifically those related to: “(A) reduced costs for operation and maintenance associated with efficient equipment or practices; (B) the value of longer equipment replacement cycles and/or productivity improvements associated with efficient equipment; (C) reduced environmental and safety costs, such as those for changes in a waste stream or disposal of lamp ballasts or ozone-depleting chemicals; and (D) all benefits associated with providing energy efficiency services to Low-Income Customers.” In 2010, in its 2010–12 Three-Year Plan Order, the Massachusetts Department of Public Utilities (DPU) ordered the program administrators to conduct a more thorough analysis of nonenergy impacts through evaluation studies. The DPU, with few exceptions, approved these studies. A study for the Massachusetts program administrators, conducted by NMR Group, incorporates findings from a review of the nonenergy impacts literature to quantify nonenergy benefits, including those for low-income programs.
Michigan	Sec. 71 (4)(g) of SB 438 appears to exempt low-income programs from demonstrating cost effectiveness. To demonstrate that the provider’s energy waste reduction programs, excluding program offerings to low-income residential customers, will collectively be cost effective, SB 438 states: “An energy waste reduction plan shall . . . demonstrate that the provider’s energy waste reduction programs, excluding program offerings to low-income residential customers, will collectively be cost effective.”
Minnesota	The rules for benefit–cost tests are stated in MN Statutes 261B.241 and Rule 7690.0550. The benefit–cost tests are required for portfolio, total program, and customer project-level screening with exceptions for low-income programs. Subd 7(e) of 216B.241 directs that “costs and benefits associated with any approved low-income gas or electric conservation improvement program that is not cost effective when considering the costs and benefits to the utility may, at the discretion of the utility, be excluded from the calculation of net economic benefits for purposes of calculating the financial incentive to the utility. The energy and demand savings may, at the discretion of the utility, be applied toward the calculation of overall portfolio energy and demand savings for purposes of determining progress toward annual goals and in the financial incentive mechanism.”
Mississippi	Mississippi does not require program-level cost effectiveness for low-income programs.

State	Special cost-effectiveness provisions for low-income energy efficiency programs
Montana	Montana specifies the TRC as its primary test for decision making. The benefit–cost tests are required for the individual measure level for program screening, but there are exceptions for low-income programs, pilots, and new technologies.
Nevada	Nevada Housing Division for programs of energy conservation, weatherization, and energy efficiency for eligible households does not require a cost–benefit analysis. Legislation in 2017 established that low-income programs do not have to pass cost-effectiveness screening as long as the portfolio of all DSM programs passes. Also, a nonenergy benefits adder of 25% is applied to low-income programs. Regular programs receive a 10% adder. Depending on the percentage of low-income participation in a program, the nonenergy benefits adder is adjusted using a weighted average formula.
New Hampshire	With respect to nonenergy benefits for low-income programs, as noted in Order No. 23,574, both low-income programs and educational programs could still be approved by the commission even if they do not surpass a 1.0 benefit–cost ratio given their additional hard-to-quantify benefits.
New Jersey	Implementation of a low-income energy efficiency program is required by New Jersey statute N.J.S.A. 48:3-61. In 2020 the Board of Public Utilities approved the New Jersey Cost Test, which includes a 10% adder for low-income benefits.
New Mexico	The Utility Cost test (UCT) is conducted in New Mexico and is considered the primary test for decision making and evaluating program cost effectiveness. HB 267 directs that "In developing this test for energy efficiency and load management programs directed to low-income customers, the commission shall either quantify or assign a reasonable value to reductions in working capital, reduced collection costs, lower bad-debt expense, improved customer service effectiveness and other appropriate factors as utility system economic benefits." It was later codified in New Mexico Administrative Code that "In developing the Utility Cost test for energy efficiency and load management measures and programs directed to low-income customers, unless otherwise quantified in a commission proceeding, the public utility shall assume that 20% of the calculated energy savings is the reasonable value of reductions in working capital, reduced collection costs, lower bad-debt expense, improved customer service, effectiveness, and other appropriate factors qualifying as utility system economic benefits" [17.7.2.9 NMAC–Rp. 17.7.2.9 NMAC, 1-1-15].
New York	New York screens programs at the measure level and requires each to have a TRC score of at least 1.0, with some exceptions. It appears that New York's TRC test does not explicitly address nonenergy benefits of low-income programs. However, the New York Public Service Commission (PSC) has generally recognized and considered low-income-specific benefits in deciding on funding for utility low-income programs. For example, in a 2010 order, the commission approved a low-income program with a TRC ratio of 0.91, finding that "As a general principle, all customers should have reasonable opportunities to participate in and benefit from Energy Efficiency Portfolio Standard (EEPS) programs. It is also important that supplemental funding be provided to address gas efficiency measures in this program."
North Carolina	North Carolina's low-income programs are generally not required to meet cost-effectiveness thresholds in order for utilities to provide energy efficiency programs to a sector of the population that would likely not otherwise participate in energy efficiency.

State	Special cost-effectiveness provisions for low-income energy efficiency programs
Oklahoma	Oklahoma Administrative Code (OAC) 165:35-41-4 directs that demand programs targeted to low-income or hard-to-reach customers may have lower threshold cost-effectiveness results than other efficiency programs.
Oregon	The rules for benefit–cost tests are stated in Docket UM 551, Order 94-590, which lays out a number of situations in which the PUC may make exceptions to the standard societal test calculation. Order 15-200, signed June 23, 2015, concerns Idaho Power Company's request for cost-effectiveness exceptions to its DSM programs. The commission adopted the recommendation of staff that cost-effectiveness requirements in Order 95-590 do not apply to low-income weatherization programs, such as the Weatherization Assistance for Qualified Customers Program.
Pennsylvania	In Order M-2015-2468992, the PUC specifies 2016 Total Resource Cost test requirements. Pennsylvania relies on the TRC test and considers it to be its primary cost-effectiveness test. A benefit–cost test is required for portfolio-level screening. The commission requires that the electric distribution companies provide benefit and cost data for both low-income and non-low-income residential program savings in their annual reports and that TRC tests be applied to all low-income programs and all residential programs. However, the commission does not require a separate PA TRC test calculation for the low-income sector.
South Carolina	South Carolina does not require program-level cost effectiveness for low-income programs.
Texas	In an order adopted September 28, 2012, the commission directed that low-income programs would not be required to meet the cost-effectiveness standard in Substantive Rule § 25.181, but rather would only need to meet standards required by the savings-to-investment ratio (SIR) methodology. All measures with an SIR of 1.0 or greater qualify for installation. The SIR is the ratio of the present value of a customer's estimated lifetime electricity cost savings from energy efficiency measures to the present value of the installation costs, inclusive of any incidental repairs, of those energy efficiency measures.
Utah	The rules for benefit–cost tests are stated in Docket No. 09-035-27. Utah uses the TRC test, Utility Cost test (UCT), Participant Cost test (PCT), and Ratepayer Impact Measure (RIM). Approval of individual DSM programs or portfolios of programs should be based on an overall determination that the program or portfolio is in the public interest after consideration of all four tests and the passage of the threshold test, the UCT. Utah also utilizes the PacifiCorp TRC (PTRC) test, which follows the Northwest convention of adding 10% to the avoided costs to account for unquantified environmental and transmission and distribution impacts.
Vermont	Vermont specifies the Societal Cost test to be its primary test for decision making. A 15% adjustment is applied to the cost-effectiveness screening tool for low-income customer programs.
Virginia	Virginia does not require program-level cost effectiveness for low-income programs.

State	Special cost-effectiveness provisions for low-income energy efficiency programs
Washington	Per WAC 480-109-100, low-income weatherization is not included in the portfolio or sector-level cost-effectiveness analysis. Companies may implement low-income programs that have a TRC ratio of 0.67 or above. The rules for benefit–cost tests are directed by the Energy Independence Act of 2006, codified in Chapter 194-37 WAC, which specifies that the TRC test include all nonenergy impacts that a resource or measure may provide that can be quantified and monetized. Washington also applies an additional 10% benefit to account for non-quantifiable externalities, consistent with the Northwest Power Act. In Docket UE-131723, signed March 12, 2015, the commission revised the rule language to allow, rather than require, utilities to pursue low-income conservation that is cost effective consistent with the procedures of the Weatherization Manual finding that "in recognition that low-income conservation programs have significant nonenergy benefits, we find it appropriate for utilities to maintain robust low-income conservation offerings despite the unique barriers these programs face."
Wisconsin	Administrative code requires programs for residential and nonresidential program portfolios to each pass portfolio-level cost effectiveness. One of the established reasons for setting portfolio-level testing rather than program- or measure-level testing is to provide more flexibility for low-income programs.