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# Technical Potential for Electric Energy and Peak Demand Savings in Florida

## FINAL REPORT

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# Executive Summary

In anticipation of the current round of goal-setting for demand-side management (DSM) programs, the seven Florida utilities subject to the Florida Energy Efficiency and Conservation Act (FEECA) formed a collaborative to conduct an assessment of the technical potential for energy and peak demand savings from energy efficiency (EE), demand response (DR), and customer-scale photovoltaic (PV) in their respective service territories. This technical potential study will in turn serve as the foundation for estimating economic and achievable potential for each FEECA utility, the latter of which will provide direct input into each utility's proposed DSM goals for 2010-2019.

## ES.1 Key Caveats

Since the focus of this study is to estimate technical potential, it is important to note several key caveats to interpreting and evaluating technical potential estimates. First, it should be understood that technical potential is a theoretical construct that represents the upper bound of EE, DR, and PV potential from a technical feasibility sense, *regardless of cost or acceptability to customers*. Specifically, technical potential does not account for other important real-world constraints such as product availability, contractor/vendor capacity, cost-effectiveness, or customer preferences. In this way, technical potential *does not* reflect the amount of EE, DR, or PV potential that is achievable through voluntary, utility programs and should not be evaluated as such. Additionally, it should be noted that the technical potential analyses conducted in this study do not attempt to quantify or account for interactions between EE, DR, and PV measures. As such, the technical potential estimates for EE, PV, and DR are not strictly additive, since efficiency improvements and rooftop PV generation reduce the baseline peak demand available to be reduced in DR programs. Such interactions will be addressed in the economic and achievable potential forecasting phases of this study.

## ES.2 Technical Potential for Energy Efficiency

To estimate technical potential for EE, this study used a bottom-up approach where costs and savings were assessed at the measure level in order to form a true bottom-up estimate of potential that captures important differences in energy efficiency opportunities, impacts, costs, and benefits across end uses, building types, and market segments. Based on this approach, the total technical potential for electric energy savings in the service territories of the seven FEECA utilities is estimated to be approximately 58,616 GWh which equates to 34% of current baseline annual electricity consumption. The total technical potential for summer peak demand savings is estimated to be 14,375 MW or 42% of current baseline summer system peak demand. Finally, the total technical potential for winter peak demand savings is estimated to be 8,883 MW or 28% of current baseline winter system peak demand. As Table ES-1 shows below, efficiency opportunities in the residential sector account for well over half of total technical potential for electric energy savings and more than 70% of total technical potential for summer and winter peak demand savings in the FEECA utilities.

**Table ES-1: Summary of the Technical Potential Results for Energy Efficiency Sector**

| **Sector:** | **Annual Energy** | | | **Summer System Peak** | | | **Winter System Peak** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Baseline** | **Technical** | | **Baseline** | **Technical** | | **Baseline** | **Technical** | |
| | **(GWh)** | **(GWh)** | ***(%)*** | **(MW)** | **(MW)** | ***(%)*** | **(MW)** | **(MW)** | ***(%)*** |
| Residential | 94,745 | 36,584 | *38.6%* | 22,263 | 10,032 | *45.1%* | 22,728 | 6,461 | *28.4%* |
| Commercial | 65,051 | 19,924 | *30.6%* | 9,840 | 4,079 | *41.5%* | 7,490 | 2,206 | *29.5%* |
| Industrial | 11,877 | 2,108 | *17.7%* | 1,721 | 265 | *12.8%* | 1,289 | 217 | *17.5%* |
| **Total** | **171,672** | **58,616** | ***34.1%*** | **33,825** | **14,375** | ***42.5%*** | **31,506** | **8,883** | ***28.2%*** |

The technical potential results for energy efficiency reflect several unique aspects of Florida’s customer base and the corresponding energy efficiency opportunities considered for analysis. First, the residential sector in Florida is nearly all-electric, with currently very little natural gas use. This aspect of Florida’s residential customer base drives much of the winter system peak demand and corresponding technical potential for winter peak demand savings. This aspect also explains why total technical potential for energy and peak demand savings is largely concentrated in the residential sector. Second, while the relative share of potential savings from HVAC measures primarily reflects the relative share of HVAC loads, the results presented for HVAC measures also reflect the larger number of HVAC measures considered in the analysis compared to measures affecting other end uses. This slight bias towards HVAC measures in the final measure list was a direct result of the availability of previous independent and utility-sponsored research that supported a larger number of HVAC measures compared to other end use measures. Finally, it should be understood that the technical potential results for energy efficiency include savings estimates for several advanced technologies that are likely to face significant near-term constraints in market availability and distributor/contractor capacity. These advanced technologies include SEER 19 central air conditioners, SEER 17 air-source heat pumps, geothermal heat pumps, heat pump water heaters, hybrid desiccant-DX systems, and PV-powered pool pumps.

## ES.3 Technical Potential for Demand Response

To estimate technical potential for DR, this study used a bottom-up, engineering-based approach that allowed for explicit accounting of the end-use peak loads and DR-enabling technologies that are most relevant to reducing customer load in response to DR events and/or incentives. In this analysis, three key factors were used to determine DR technical potential – the availability of communication networks, the availability and end-use demand reduction capabilities of advanced DR-enabling technologies, and the availability of dynamic pricing tariffs. Because of the emerging nature of advanced DR technologies, dynamic tariffs, and advanced communications networks, Itron developed an assumption-driven approach in order to develop the DR measure data required to estimate technical potential. The final input values for each factor were developed from a combination of utility estimates, data from the literature, and evaluations of current DR programs in Florida. To account for the uncertainty embedded in these input values, particularly the availability of dynamic pricing tariffs across various customer segments, Itron developed "high" and "low" scenarios of DR technical potential.

Table ES-2 shows the estimated DR technical potential by sector, season, scenario, DR-enabling technology, and tariff, presented in both absolute figures and as a percentage of baseline system peak demand. Note that the peak savings estimates are designed to be incremental to the existing DR resource such that only customers that are not currently enrolled in any existing DR program were considered eligible for the DR programs modeled in this analysis. In addition to the existing DR resource of 2,681 MW, the technical potential estimated from new DR programs ranges from 4,856 MW (high scenario) to 3,644 MW (low scenario). Total incremental DR technical potential ranges from 11% to 15% of current baseline peak demand across the summer and winter peak seasons and the high and low scenarios modeled in this analysis. The majority of the DR technical potential is available from residential customers and ranges from 66% to 90% across the two scenarios and the two peak seasons.

The size of the estimated DR technical potential resource presented here is highly dependent on the assumed penetration of dynamic pricing tariffs. Air conditioner (A/C) cycling and A/C shedding technologies are likely to be used only in combination with a flat rate, whereas strategies such as smart thermostats and in-home displays are likely to be used only with a dynamic pricing tariff. Additionally, the end-use load reductions from A/C shedding (100%) are substantially higher than that from smart thermostats (~36%) and in-home displays (~36%). This dynamic results in higher levels of DR technical potential when lower penetration of dynamic pricing tariffs is assumed.

## Table ES-2: Summary of the DR Technical Potential for Demand Response by Sector, Technology, and Scenario

| **Sector:** | **DR-enabling technology and tariff:** | **Summer System Peak** | | | | | **Winter System Peak** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Baseline** | **Technical Potential** | | | | **Baseline** | **Technical Potential** | | | |
| | | | **High** | | **Low** | | | **High** | | **Low** | |
| | | **(MW)** | **(MW)** | **(%)** | **(MW** | **(%)** | **(MW)** | **(MW)** | **(%)** | **(MW)** | **(%)** |
| **Residential** | A/C Cycling Switch w/ flat rate | | 601 | 2.7% | 860 | 3.9% | | 436 | 1.9% | 785 | 3.5% |
| | A/C Shedding Switch w/flat rate | | 798 | 3.6% | 1,346 | 6.0% | | 1,079 | 4.7% | 1,942 | 8.5% |
| | Smart Thermostats for A/C w/ CPP | | 1,015 | 4.6% | 203 | 0.9% | | 1,284 | 5.6% | 257 | 1.1% |
| | On-Off Switching via low-power wireless networks for water heating | | 245 | 1.1% | 49 | 0.2% | | 939 | 4.1% | 188 | 0.8% |
| | On-Off Switching via low-power wireless networks for pool systems | | 202 | 0.9% | 40 | 0.2% | | 55 | 0.2% | 0 | 0.0% |
| | In-home displays and pre-set control strategies w/CPP | | 312 | 1.4% | 62 | 0.3% | | 425 | 1.9% | 85 | 0.4% |
| | Total Residential | 22,263 | 3,173 | 14.3% | 2,561 | 11.5% | 22,728 | 4,218 | 18.6% | 3,268 | 14.4% |
| **Commercial** | Automated control strategies w/CPP | | 616 | 6.3% | 187 | 1.9% | | 355 | 4.7% | 108 | 1.4% |
| | Direct load control system | | 887 | 9.0% | 887 | 9.0% | | 251 | 3.4% | 251 | 3.4% |
| | Total Commercial | 9,840 | 1,503 | 15.3% | 1,074 | 10.9% | 7,490 | 606 | 8.1% | 359 | 4.8% |
| **Industrial** | Automated control strategies w/CPP | | 43 | 1.6% | 13 | 0.5% | | 22 | 1.0% | 7 | 0.3% |
| | Direct load control system | | 61 | 2.3% | 61 | 2.3% | | 9 | 0.4% | 9 | 0.4% |
| | Total Industrial | 2,686 | 104 | 3.9% | 74 | 2.8% | 2,109 | 31 | 1.5% | 16 | 0.8% |
| **TOTAL** | | **34,790** | **4,779** | **13.7%** | **3,709** | **10.7%** | **32,327** | **4,856** | **15.0%** | **3,644** | **11.3%** |

## ES.4 Technical Potential for Solar Photovoltaic Systems

The analytic methodology for estimating the technical potential of PV systems consisted of first estimating the total roof area suitable for siting PV systems and then translating this roof area into estimates of annual electricity generation and power output coincident with the system summer and winter peaks. Table3 summarizes annual energy and system coincident peak demand impacts by sector and building type and benchmarks these impacts relative to current baseline energy consumption and peak demand in the seven FEECA utilities. As the table shows, the total estimated technical potential of the PV systems considered in this study is 69,449 GWh of annual electricity generation, 25,614 MW of summer system peak capacity, and 4,115 MW of winter system peak capacity. Over half of total electricity generation and system peak capacity is derived from residential rooftop PV systems, 75% of which are from rooftop systems on single-family residential homes. Relative to current baseline electricity consumption and system coincident peak demand in the residential and commercial sectors of the FEECA utilities, the total estimated technical potential for PV is equivalent to 43% of annual electricity consumption, 80% of summer system peak demand, and 14% of winter system peak demand.

In this study, one of most significant assumptions is that the PV arrays eligible to be installed on residential and commercial rooftops and shading structures in commercial parking lots are based on crystalline silicon PV material rather than amorphous silicon PV material. If amorphous silicon PV material had been assumed, the technical potential results would be significantly lower. However, the assumption of 100% crystalline PV is consistent with the concept and definition of technical potential used in the EE and DR analyses, i.e. a theoretical upper bound of the potential PV resource. Another key sensitivity in the PV analysis is the timing of summer and winter system peak demand. PV power production is particularly dynamic during the times of system peak in Florida. Depending on the exact hour of future system peak demand, the level of potential PV generation could vary significantly. The winter system peak illustrates this point particularly well. During the hour from 8-9am, the sun is very low in the sky and PV systems tilted to the east are likely to not contribute any generation at the time of peak. If for some reason the winter peak occurred an hour earlier the historic winter peak, generation might be 100% less than the results of this study indicate. Summertime peak generation is subject to similar sensitivities. During the period during which summer peaks are likely to occur, the position of the sun in the sky is changing quite rapidly. If the summer peak occurred one hour later from 4-5pm, the peak generation would be approximately 15-20% less.

## Table ES-3: Summary of PV Technical Potential Results by Sector and Building Type

| | | **Annual Energy** | | | **Summer System Peak (3-4pm EDT)** | | | **Winter System Peak (8-9am EST)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sector:** | **Building Type:** | Baseline | Technical Potential | | Baseline | Technical Potential | | Baseline | Technical Potential | |
| | | (GWh) | (GWh) | *(%)* | (MW) | (MW) | *(%)* | (MW) | (MW) | *(%)* |
| **Residential** | Single-family | 64,668 | 32,627 | 50% | 15,253 | 11,840 | 78% | 15,930 | 2,156 | 14% |
| | Multi-family | 23,955 | 8,210 | 34% | 5,451 | 2,979 | 55% | 5,029 | 543 | 11% |
| | Mobile Homes | 6,122 | 2,268 | 37% | 1,560 | 823 | 53% | 1,769 | 150 | 8% |
| | **Total** | **94,745** | **43,105** | **45%** | **22,263** | **15,643** | **70%** | **22,728** | **2,849** | **13%** |
| **Commercial** | College | 2,307 | 1,122 | 49% | 2,487 | 425 | 17% | 1,653 | 54 | 3% |
| | School | 3,705 | 1,791 | 48% | 1,703 | 678 | 40% | 777 | 86 | 11% |
| | Hospital | 2,966 | 564 | 19% | 1,383 | 214 | 15% | 593 | 27 | 5% |
| | Other Health | 2,709 | 575 | 21% | 608 | 218 | 36% | 412 | 28 | 7% |
| | Lodging | 5,769 | 2,431 | 42% | 494 | 920 | 186% | 500 | 117 | 23% |
| | Restaurant | 11,412 | 1,712 | 15% | 325 | 648 | 199% | 220 | 82 | 37% |
| | Grocery | 4,627 | 489 | 11% | 396 | 185 | 47% | 282 | 23 | 8% |
| | Retail | 7,952 | 3,127 | 39% | 542 | 1,183 | 218% | 428 | 150 | 35% |
| | Warehouse | 3,745 | 5,462 | 146% | 481 | 2,067 | 430% | 566 | 263 | 46% |
| | Office | 14,387 | 6,218 | 43% | 748 | 2,354 | 315% | 540 | 299 | 55% |
| | Other | 5,471 | 2,852 | 52% | 672 | 1,080 | 161% | 1,519 | 137 | 9% |
| | **Total** | **65,051** | **26,344** | **40%** | **9,840** | **9,972** | **101%** | **7,490** | **1,266** | **17%** |
| **Total** | | **159,795** | **69,449** | **43%** | **32,103** | **25,614** | **80%** | **30,218** | **4,115** | **14%** |

# 1

# Introduction

Under the terms of the Florida Energy Efficiency and Conservation Act (FEECA), all Florida utilities with annual electric sales over 2,000 GWh are required to pursue cost-effective demand-side management (DSM) programs. In total, the following seven utilities are currently subject to FEECA requirements:

- Florida Power & Light (FPL)
- Progress Energy Florida (PEF)
- Gulf Power Company (Gulf)
- Tampa Electric Company (TECO)
- JEA
- Orlando Utilities Commission (OUC)
- Florida Public Utilities Company (FPU)

The Florida Public Service Commission (PSC) is responsible for setting numeric goals for DSM programs for each utility subject to FEECA. These numeric goals establish annual savings targets over a 10-year period and are revised every five years. The current savings goals were established by the PSC in August 2004 and run through 2014. In June 2008, the PSC established dockets 080407-EG through 080413-EG to review and revise the numeric DSM goals for 2010-2019.

In anticipation of the current round of DSM goal setting, the seven FEECA utilities formed a collaborative (the Florida Collaborative) to conduct an assessment of the technical potential for energy and peak demand savings from energy efficiency, demand response, and customer-scale renewable energy in their respective service territories. Additionally, the FEECA utilities also invited the Southern Alliance for Clean Energy (SACE) and the Natural Resources Defense Council (NRDC) to participate in the study collaborative as project advisors. The members of the collaborative developed a request for proposals (RFP) that was issued on March 21, 2008. Vendor responses were then evaluated by the collaborative. Based upon these evaluations, the study collaborative selected the Itron/KEMA team to conduct the technical potential study.

As defined in the RFP, the primary objective of this study is to assess the technical potential for reducing (avoiding) electricity use and peak demand by implementing a wide range of end-use energy efficiency and demand response measures, as well as customer-scale solar photovoltaic and solar thermal installations, in the service territories of the seven FEECA utilities. This technical potential study will in turn serve as the foundation for estimating economic and achievable potential for each FEECA utility, the latter of which will provide direct input into each utility's proposed DSM goals for 2010-2019.

The remainder of this report is organized as follows:

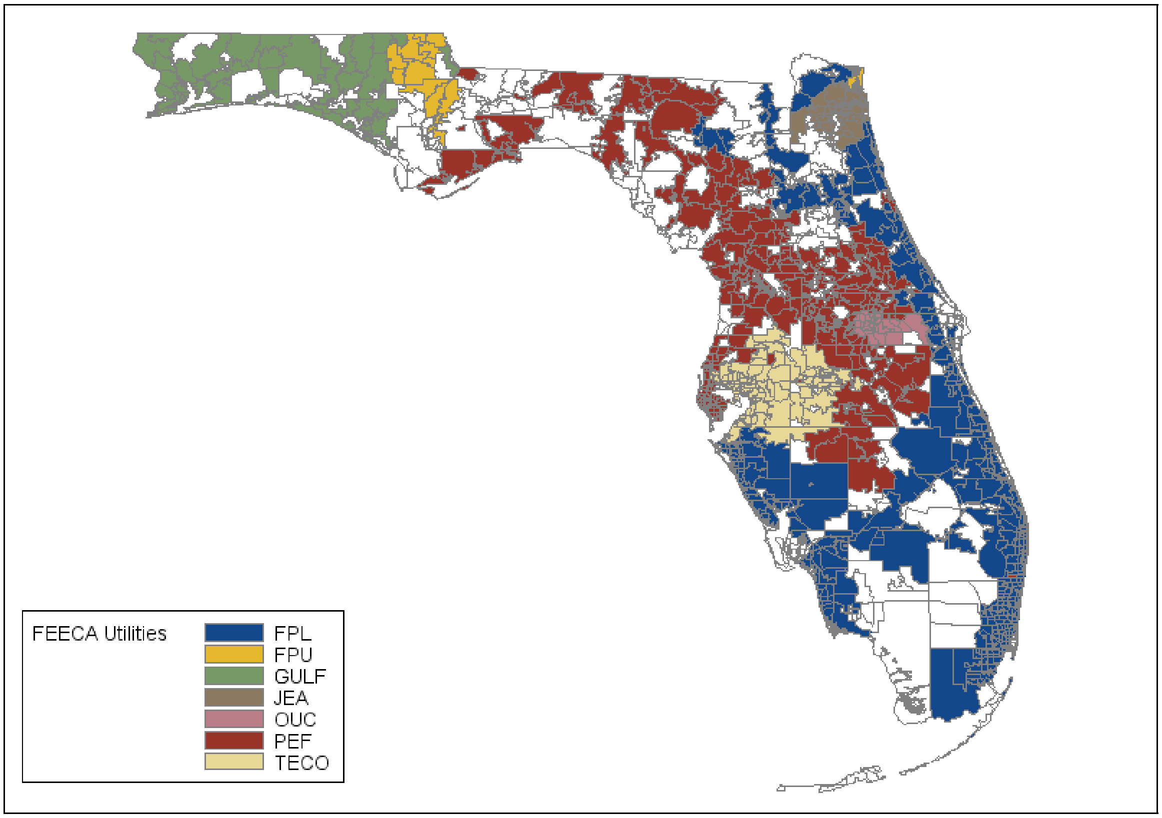
- **Chapter 2** describes the analytic scope of the study
- **Chapter 3** presents the concepts, methodology, input data, and results of the technical potential analysis for energy efficiency
- **Chapter 4** presents the concepts, methodology, input data, and results of the technical potential analysis for demand response
- **Chapter 5** presents the concepts, methodology, input data, and results of the technical potential analysis for customer-scale solar PV
- **Chapter 6** provides a comprehensive list of key data sources and references
- **Appendix A** provides brief descriptions for each energy efficiency measure analyzed in this study

# 2

# Study Scope

This study provides estimates of energy and peak demand savings opportunities available to electric customers of the seven FEECA utilities. As Figure 2-1 shows, the service territories of the seven FEECA utilities encompass nearly the entirety of the state of Florida. Indeed, when taken together, these seven utilities account for over 85% of total annual electric sales in the state of Florida in 2007 (~190 TWh/yr).

**Figure 2-1: The Service Territories of the FEECA Utilities by Zip Code**



The scope of this study includes the assessment of the potential energy and peak demand savings from energy efficiency (EE), demand response (DR), and customer-scale solar PV and solar thermal opportunities currently available to customers in the residential, commercial, and industrial sectors. It should be noted, however, these technical potential analyses do not attempt to quantify interactions between EE, DR, and PV measures. As such, the technical potential estimates for EE, PV, and DR are not strictly additive, since efficiency improvements and rooftop PV generation reduce the baseline peak demand available to be reduced in DR programs. Such interactions will be addressed in the economic and achievable potential forecasting phases of this study.

It should also be noted that energy and peak savings opportunities in a few end-use sectors were specifically excluded from this study. These sectors were agriculture, transportation, communications and utilities (TCU), construction, and outdoor/street lighting. In the agriculture and TCU sectors, there is a lack of comprehensive primary research on both end-use baselines and energy/peak savings opportunities that would allow development of reliable technical potential estimates. In the case of the construction sector, end-use electric loads are temporary by nature and often ill-suited as targets for utility-administered resource acquisition programs. In the case of outdoor and street lighting, these markets are already saturated with efficient equipment (e.g. LED traffic signals and metal halide or high-pressure sodium lamps) in most regions of the country (USDOE, 2004). More importantly for traffic signals, the Energy Star product specification (based on LED performance levels) was subsumed by revised federal efficiency standards which require all new traffic signals to meet LED-equivalent performance criteria.[1]

As Figure 2-2 shows, the in-scope sectors accounted for nearly 90% of total annual electric sales in the FEECA utilities in 2007, while the out-of-scope sectors accounted for just over 10% of total sales.

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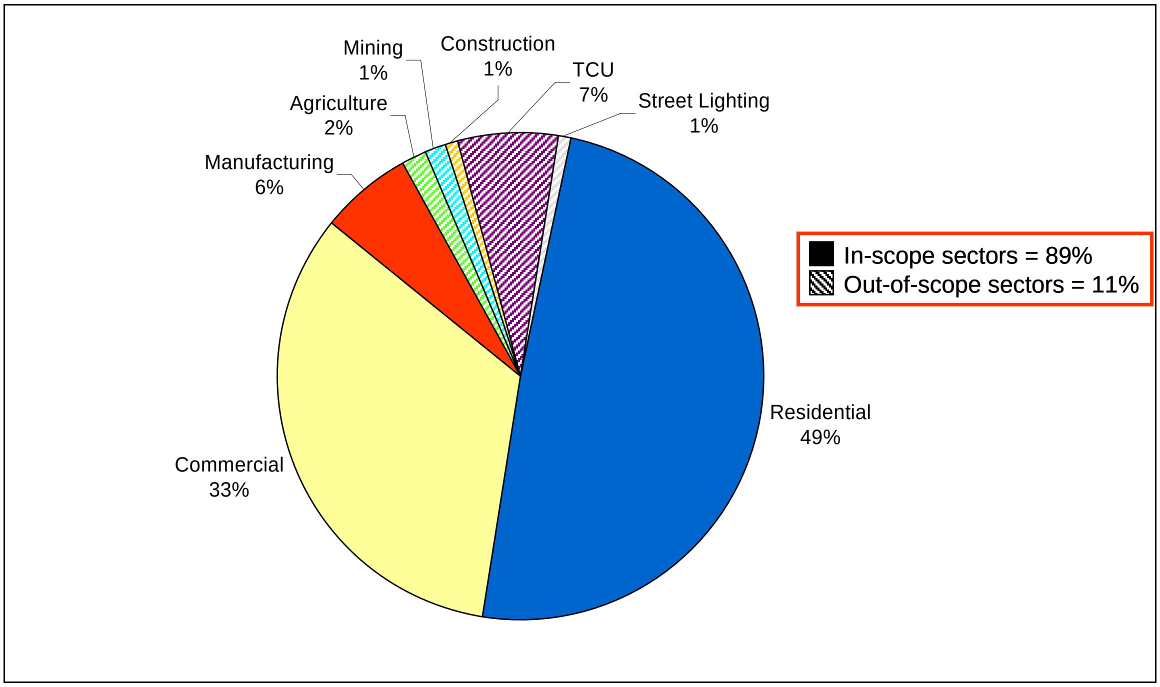
[1] See final rulemaking published in USDOE Federal Register Notice, October 18, 2005: http://www1.eere.energy.gov/buildings/appliance_standards/pdfs/technical_amendment_101805.pdf

**Figure 2-2: 2007 Electric Sales in the FEECA Utilities by End-use Sector**



# 3

# Technical Potential for Energy and Peak Demand Savings from Energy Efficiency

In this chapter, we first provide an overview of the concepts and methodology used to estimate energy efficiency potential. We then describe the data sources and methods used to develop comprehensive, end-use baselines. Finally, we present and analyze the resulting energy efficiency potential estimates and delineate key analytic caveats.

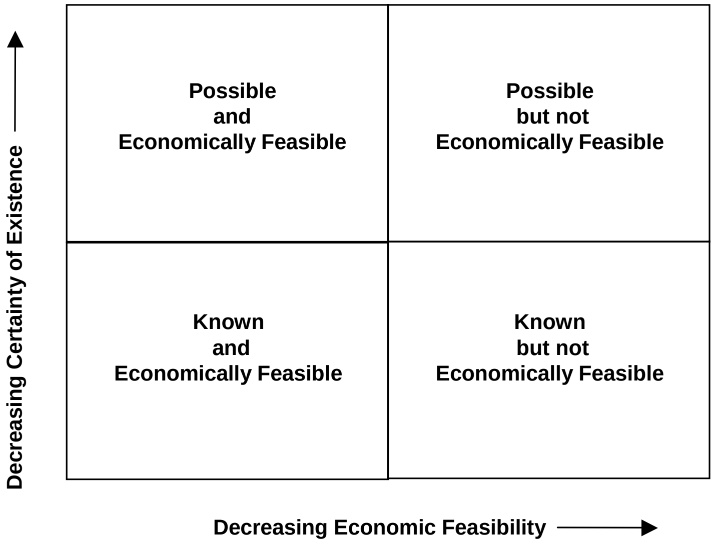
## 3.1 Characterizing the Energy Efficiency Resource

Energy efficiency has been characterized for some time now as an alternative to energy supply options such as conventional power plants that produce electricity from fossil or nuclear fuels. In the early 1980s, researchers developed and popularized the use of conservation supply curves to characterize the potential costs and benefits of energy conservation and efficiency. Under this framework, technologies or practices that reduced energy use through efficiency were characterized as “liberating ‘supply’ for other energy demands” and could therefore be thought of as a resource and plotted on an energy supply curve. The energy-efficiency resource paradigm argued simply that the more energy efficiency, or “nega-watts” produced, the fewer new plants needed to meet end users’ power demands.

Energy-efficiency potential studies were popular throughout the utility industry from the late 1980s through the mid-1990s. This period coincided with the advent of what was called least-cost or integrated resource planning (IRP). Energy-efficiency potential studies became one of the primary means of characterizing the resource availability and value of energy efficiency within the overall resource planning process.

Like any resource, there are a number of ways in which the energy-efficiency resource can be estimated and characterized. Definitions of energy-efficiency potential are similar to definitions of potential developed for finite fossil fuel resources like coal, oil, and natural gas. For example, fossil fuel resources are typically characterized along two primary dimensions: the degree of geologic certainty with which resources may be found and the likelihood that extraction of the resource will be economic. This relationship is shown conceptually in Figure 3-1.

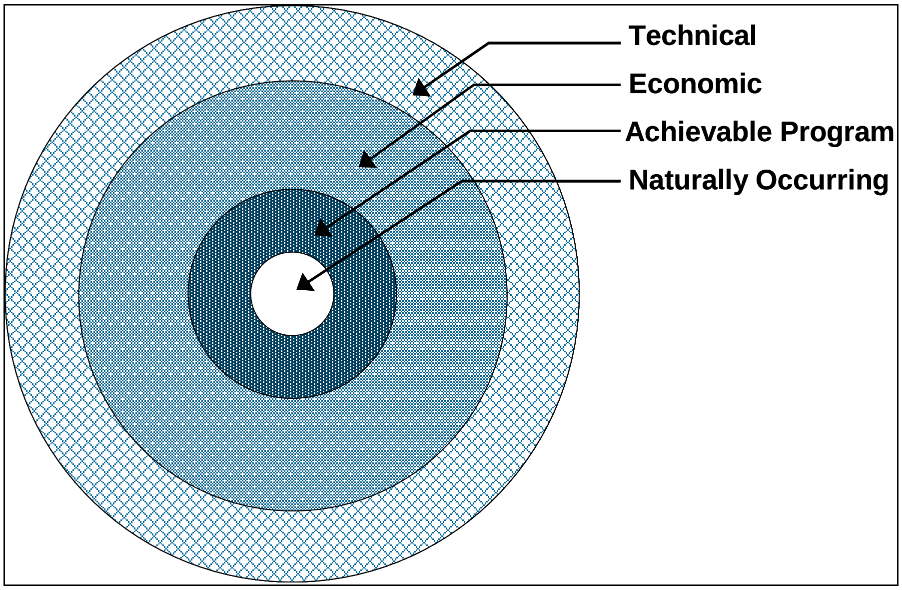
**Figure 3-1: Conceptual Framework for Estimates of Fossil Fuel Resources**



Somewhat analogously, this energy-efficiency potential study defines several different *types* of energy-efficiency *potential*, namely: technical, economic, achievable, program, and naturally occurring. These potentials are shown conceptually in Figure 3-2 and described below.

**Technical potential** is defined in this study as the complete penetration of all measures analyzed in applications where they were deemed technically feasible from an engineering perspective. **Economic potential** refers to the technical potential of those energy conservation measures that are cost-effective when compared to supply-side alternatives. **Achievable program potential** refers to the amount of savings that would occur in response to specific utility program funding and measure incentive levels. Savings associated with program potential are savings that are projected beyond those that would occur naturally in the absence of any utility programs. In this sense, **naturally occurring potential** refers to the amount of savings estimated to occur as a result of normal market forces, that is, in the absence of any utility programs.

**Figure 3-2: Conceptual Relationship Among Definitions of Energy Efficiency Potential**



The focus of this study is to produce estimates of technical potential that will then form the basis for estimates of economic and achievable potential in a follow-on study. In this respect, it is important to note several key caveats to interpreting and evaluating technical potential estimates. First, it should be understood that technical potential is a theoretical construct that represents the upper bound of energy efficiency potential from a technical feasibility sense, *regardless of cost or acceptability to customers*. Specifically, feasibility limits measure installation to opportunities where installation is feasible from an engineering perspective and physically practical with respect to constraints such as available space, noise considerations, and lighting level requirements, among other things. However, technical potential does not account for other important real-world constraints such as product availability, contractor/vendor capacity, cost-effectiveness, or customer preferences. In this way, technical potential *does not* reflect the amount of energy efficiency potential that is achievable through voluntary, utility programs and should not be evaluated as such.

## 3.2 Energy Efficiency Forecasting Methodology

Our method for estimating energy efficiency potential is a bottom-up approach, utilizing DSM ASSYST, KEMA’s MS-Excel-based DSM potential model for energy efficiency. In this approach, costs and savings are assessed at the measure level in order to form a true bottom-up estimate of potential that captures important differences in energy efficiency opportunities, impacts, costs, and benefits across end uses, building types, and market segments. The results of this bottom-up analysis can then be analyzed along a wide range of dimensions, including: 1) time (in terms of annual or cumulative costs and savings), 2) utility service territory, 3) building or business type, 4) building vintage, 5) end use, and 6) individual efficiency measure.

In the remainder of this section, we provide a detailed description of the bottom-up approach used to forecast technical potential in this study.

### 3.2.1 Core Equation

In its most basic form, total technical potential is developed from estimates of the technical potential of individual measures as they are applied to discrete market segments (commercial building types, residential dwelling types, etc). The core equation used to calculate the technical potential for energy savings from each individual efficiency measure is shown below (using a commercial measure example).

$$\begin{matrix}\text{Technical}\\\text{Potential}\\\text{(GWh)}\end{matrix} = \overbrace{\left(\begin{matrix}\text{Units of}\\\text{Consumption}\\(10e6\ \text{ft}^2)\end{matrix}\right)\left(\begin{matrix}\text{End-use Tech}\\\text{Saturation}\\(\%)\end{matrix}\right)\left(\begin{matrix}\text{Base Tech}\\\text{EUI}\\(\text{kWh/ft}^2)\end{matrix}\right)}^{\textit{Baseline Data}}\ \overbrace{\left(1-\begin{matrix}\text{Measure}\\\text{Saturation}\\(\%)\end{matrix}\right)\left(\begin{matrix}\text{Measure}\\\text{Feasibility}\\(\%)\end{matrix}\right)\left(\begin{matrix}\text{Measure}\\\text{Impacts}\\(\%)\end{matrix}\right)}^{\textit{Measure Data}}$$

As the equation shows, technical potential is estimated by interacting “baseline data” that describe current, end-use energy consumption in a given market segment with “measure data” that describe the energy savings impacts, feasibility, and current saturation of a given measure in a given market segment.

The key types of data used to develop baseline end-use energy consumption are:

- **Units of consumption –** this variable quantifies the total square feet of floor area (in the commercial analysis) or total number of dwellings (in the residential analysis) for a given market segment (e.g. office buildings in commercial or single-family dwellings in residential).

- **Base technology end-use intensity (EUI) –** this variable quantifies the annual energy used per square foot for each base-case end-use technology in each market segment. This is the consumption of the energy-using equipment that the efficient technology replaces or effects. For example, if the efficient measure were a CFL, the base EUI would be the annual kWh per square foot of an equivalent incandescent lamp. For the residential analysis, annual unit energy consumption (UECs) or energy used per dwelling, are substituted for EUIs.

- **End-use technology saturation –** this variable quantifies the fraction of the floor space (or dwelling units) in which a given base-case end-use technology is currently installed. In commercial lighting, for example, this would be the percentage of floor space lit by incandescent bulbs (in the case of a CFL analysis) or the percentage of floor space lit by linear fluorescent lamps (in the case of a premium T8 analysis).

The key types of data used to describe energy efficiency measures are:

- **Measure saturation –** this variable is the fraction of applicable floor space (or dwelling units) that has already been converted to the efficient measure. One minus the measure saturation thus provides an estimate of the size of remaining eligible market for any given measure.
- **Measure feasibility –** this variable is the fraction of the applicable floor space (or dwelling units) where it is technically feasible for conversion to the efficient technology from an engineering perspective.
- **Measure impacts –** this variable is the percentage reduction in annual energy consumption that results from application of the efficient technology.

Estimates of the technical potential for peak demand savings (as opposed to annual energy savings) are calculated analogously simply by adding peak-to-energy ratios to the equation above. These peak-to-energy ratios are derived from end-use load shape data and translate annual end-use energy consumption (kWh) to demand (kW) at the time of system coincident peak load.

By treating measures independently, their relative cost-effectiveness is analyzed without making assumptions about the order or combinations in which they might be implemented in customer premises. However, total technical potential across measures cannot be accurately estimated by simply summing the individual measure potentials directly, since some savings would be double-counted. For example, the savings from a measure that reduces heat gain into a building, such as window film, are partially dependent on other measures that effect the efficiency of the system being used to cool the building, such as a high-efficiency chiller – the more efficient the chiller, the less energy saved from the application of the window film.

In the second step of the DSM ASSYST modeling framework, total cumulative technical potential is estimated using a supply curve approach. This method, which we describe in the next subsection, minimizes the double-counting problem.

### *3.2.2 Use of Supply Curves*

Energy efficiency supply curves consist of two axes – one that captures the levelized cost per unit of savings (e.g., $/kWh saved) and the other that shows the amount of savings that could be achieved at each level of cost. These curves are built up by sorting individual measures (and their technical potential savings) on a least-cost basis.

The critical aspect of supply curves is that total potential savings from any given measure are calculated incrementally with respect to measures that precede them. This incremental accounting of measure costs and savings takes into account interactive effects between multiple measures applied to the same end use, such as those described above in the case of efficient chillers and window film measures.

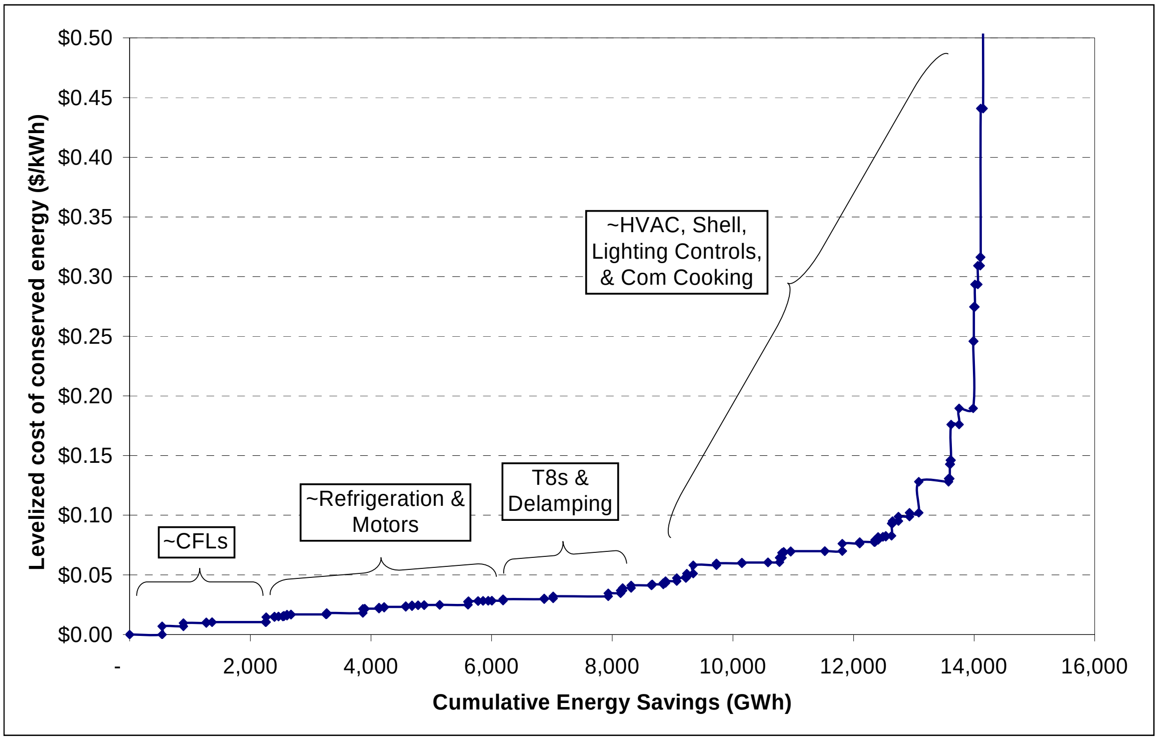
Table 3-1 shows a simplified numeric example of a supply curve calculation for several energy efficiency measures applied to commercial lighting for a hypothetical population of buildings. Measures are first sorted by cost – from least to most expensive – reflecting the assumption that measures are adopted and installed in a least-cost order. The basis for the cost sorting can be a measure-level cost-effectiveness test or the levelized cost of the measure per unit of energy or demand reduced. For this study, the Florida Collaborative chose to use the participant cost test as the basis for the least-cost ordering. Next, the base-case energy consumption of the end-use system being effected by the first efficiency measure is adjusted for the expected energy savings from that measure. For subsequent measures that effect the same end use, the expected energy savings are then re-estimated to account for the adjusted energy consumption baseline. In the example shown below, the occupancy sensor measure would save more per installation if it was applied to the base-case T12 lamp and magnetic ballast combination. However, because the T8 lamp-electronic ballast combination is more cost-effective, it is applied first, reducing the energy savings potential for the occupancy sensor. Thus, in a typical energy efficiency supply curve, the base-case end-use consumption is reduced with each unit of energy efficiency that is acquired. Notice that in Table 3-1 the total end-use GWh consumption is recalculated after each measure is implemented, thus reducing the base energy available to be saved by the next measure.

**Table 3-1: Sample Technical Potential Supply Curve Calculation for Commercial Lighting (Note: Data are illustrative only)**

| Measure | Total End Use Consumption of Population (GWh) | Applicable, Not Complete and Feasible (1000s of $ft^2$) | Average $kWh/ft^2$ of population | Energy Savings (%) | Energy Savings (GWh) | Participant B-C Ratio |
|---|---|---|---|---|---|---|
| Base Case: T12 lamps with Magnetic Ballast | 425 | 100,000 | 4.3 | N/A | N/A | N/A |
| 1. T8 w. Elec. Ballast | 425 | 100,000 | 4.3 | 21% | 89 | 3.2 |
| 2. Occupancy Sensors | 336 | 40,000 | 3.4 | 10% | 13 | 1.4 |
| 3. Perimeter Dimming | 322 | 10,000 | 3.2 | 45% | 14 | 0.5 |
| With all measures | 309 |  | 3.1 | 27% | 116 |  |

This least-cost ordering and accounting of interactive effects between measures is performed for all of the base-case technologies, market segments, and measure combinations in the scope of the study. The results are then summed to produce the technical energy efficiency potential for the entire sector. Supply curves typically, but not always, end up reflecting diminishing returns as shown in Figure 3-3, i.e. costs increase rapidly and savings decrease significantly at the end of the curve.

**Figure 3-3: Example of Technical Potential Supply Curve for the Commercial Sector (Note: Data are illustrative only)**



## 3.3 Development of Bottom-up, End-use Baselines

As implied in the previous discussion, the first step in estimating technical potential in this study involved constructing a bottom-up characterization of current energy use and peak demand at the end-use and technology level in the particular market segments of interest, e.g., existing single-family homes, office buildings, grocery stores, or metal fabrication facilities. The specific market segments and end uses defined for this study are summarized in Table 3-2 below.

**Table 3-2: Summary of Analysis Segmentation Used in this Study**

| Segment Name | Segment Definition | | |
|---|---|---|---|
| **Sector** | • Residential | • Commercial | • Industrial |
| **Building type** | • Single-family dwelling<br>• Multi-family dwelling<br>• Mobile Home | • College<br>• Food Store<br>• Hospital<br>• Other Health Care<br>• Office<br>• Lodging<br>• Restaurant<br>• Retail<br>• School<br>• Warehouse<br>• Miscellaneous | • Food Processing<br>• Textiles<br>• Lumber<br>• Paper-Pulp<br>• Printing<br>• Chemicals<br>• Petroleum<br>• Rubber-Plastics<br>• Stone-Clay-Glass<br>• Primary Metals<br>• Fab Metals<br>• Ind Machinery<br>• Electronics<br>• Transp Equipment<br>• Instruments<br>• Miscellaneous |
| **Building Vintage** | • Existing construction<br>• New construction | • Existing construction<br>• New construction | • Existing construction |
| **End Use** | • HVAC<br>• Lighting<br>• Water Heating<br>• Refrigerator<br>• Freezer<br>• Clothes Dryer<br>• Clothes Washer<br>• Dishwasher<br>• Pool Pump<br>• TV/VCR/DVD/STB/PC<br>• Other Plug Loads | • Space Cooling<br>• Ventilation<br>• Water Heating<br>• Commercial Cooking<br>• Refrigeration<br>• Exterior Lighting<br>• Interior Lighting<br>• Office Equipment<br>• Miscellaneous | • Process Heating<br>• Process Cooling<br>• Pumps<br>• Fans<br>• Compressed Air<br>• Process Drives<br>• Lighting<br>• HVAC<br>• Refrigeration<br>• Other |

For each of the end uses and market segments defined above, the key data necessary to establish the bottom-up modeling baselines are: 1) population estimates of the number of customers, number of households, total square footage of built space, and/or kWh sales; 2) end-use technology saturations (e.g., the share of the market with a certain technology installed), 3) end-use technology densities (e.g., the average number of technology units installed per household or per square foot of floor area), 4) end-use energy intensities (e.g., per household or per square foot of floor area), and 5) end-use load shapes (e.g. distribution of energy use over time of the day and season). Residential baseline analyses also require data on the number of households by building type (e.g., single-family detached homes vs. multi-family buildings) in order to scale and calibrate residential end-use estimates to total residential sales and peak demand. Similarly, commercial baseline analyses requires data on commercial floor space by building type (e.g., offices, retail stores, hospitals, or schools) in order to scale and calibrate commercial end-use estimates to total commercial sales and peak demand. Table 3-3 provides a summary of the key types of baseline data required for bottom-up potential studies.

**Table 3-3: Summary of Key Baseline Data Required for Potential Studies**

| Data Type | Units |
|---|---|
| Units of consumption | ▪ Number of households or kWh sale (residential)<br>▪ Square feet of floor space or kWh sales (commercial)<br>▪ kWh sales (industrial) |
| End-use technology saturation | ▪ Share of households with technology installed (residential)<br>▪ Share of floor space with technology installed (commercial)<br>▪ Share of load with technology installed (industrial) |
| End-use technology density | ▪ Cost units per consumption unit (e.g., lamps/home, tons cooling/square foot, motor horsepower/kWh) |
| End-use energy intensity | ▪ Annual kWh/household (residential)<br>▪ Annual kWh/square foot (commercial)<br>▪ kWh load (industrial) |
| End-use load shapes | ▪ Distribution of end-use energy consumption across times of the day, days of the week, and season |

In addition to the end-use baseline data described above, the other key data required for developing defensible, bottom-up baselines are data on actual total sales and system peak demand by customer class. These “top-down” data serve as controls totals in order to ensure that all of the bottom-up end-use energy and peak demand estimates correctly sum to actual sales and observed system peak demand. Indeed, the process of reconciling the bottom-up end-use energy and peak demand estimates with actual sales and system peak demand is critical to minimizing systematic bias embedded in technical potential assessment.

In the remainder of this section, we present and describe the data sources and methods used to develop residential, commercial, and industrial end-use baselines for this study and then summarize the resulting energy consumption and peak demand baselines by end use and market segment.

### *3.3.1 Residential Baseline Data Development*

For the residential baseline analysis, each FEECA utility provided two key datasets that served as important benchmarks for the development of residential end-use baselines. First, the FEECA utilities provided counts of residential customers by type (i.e. single-family, multi-family, or mobile home) based on information extracted from their respective Customer Information Systems (CIS) databases. Second, the FEECA utilities also provided billing data on actual residential electricity sales for calendar year 2007. This billing data served as control totals to help reconcile the bottom-up baseline estimates with actual total residential sales.

Data on end-use equipment saturations and technology densities were developed primarily from the results of the 2006 Home Energy Survey (HES). The 2006 HES consisted of just over 1,200 on-site surveys of residential homes conducted in six of the seven FEECA utilities.[2] Itron obtained the utility-specific survey results from the FPSC staff (via Progress Energy). It should be noted that outside of FPL's HES, the sample sizes from the other utilities were not large enough to produce statistically significant results by utility and building type. Itron thus aggregated the utility-specific results to produce population-weighted statewide averages by building type[3] and applied these values to utilities that did not have alternative sources of baseline saturation data (Progress, TECO, OUC, and FPU). Additionally, Gulf and JEA provided Itron with results of recent internal saturation surveys with sufficient sample sizes to support utility-specific saturation estimates for those two utilities. It should be noted that the results of the internal saturation surveys conducted by Gulf and JEA were broadly consistent with the statewide results of the 2006 HES, with the key exception of significant shares of gas space heating reported in Gulf's service territory (i.e. ~20%) compared to nearly all-electric space heating in the rest of the FEECA utilities.

Data on baseline end-use UECs (kWh/household) were derived from a variety of sources. For HVAC and water heating, baseline UECs were derived from previous Itron analyses of in-situ heating, cooling, and water heating loads conducted in support of previous FPL program impact evaluations. These analyses provided separate estimates of HVAC and water heating UECs by FPL climate zone, building type, and base technology. These FPL-specific estimates also formed the basis for the HVAC and water heating estimates developed for the other six utilities, but Itron made two important adjustments. First, space heating loads were adjusted (in the form of a scalar) to account for significant differences in the average heating degree-days in the northern and central climate zones in FPL's service territory and the average heating-degree days in the north and central climate zones of the other FEECA utilities. Second, water heating loads were adjusted (again in the form of a scalar) to account for significant differences in average inlet water temperatures in FPL's service territory

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[2] FPU was not required to participate in the 2006 HES.

[3] Itron developed weights using utility-specific shares of the 6-utility residential customer counts.

(often around 80° F) and the other FEECA utilities using weather station data on average ground water temperature differences.

Baseline UECs for lighting and appliances were derived from a variety of FL-specific sources. In the case of lighting, refrigerators, and freezers, Itron leveraged UEC estimates developed by the Florida Solar Energy Center (FSEC) that resulted from an end-use monitoring study of approximately 200 homes recently conducted for Progress Energy (Parker et al, 2000a). For clothes washers, clothes dryers, and dishwashers, Itron leveraged the Florida-specific estimates from the 2001 Residential Energy Consumption Survey (RECS) conducted by the Energy Information Administration (US Department of Energy, 2004).

For home electronics, Itron developed baseline UEC estimates for televisions, DVD players, VCRs, set-top boxes, and personal computers based on the results of the most recent national and regional studies on residential plug loads. Specifically, Itron leveraged the results of a comprehensive national assessment of energy consumption from consumer electronics recently conducted for the USDOE (Roth and McKenney, 2007) and field measurements of residential plug loads in 75 California homes recently conducted for the California Energy Commission (Porter et al, 2006).

### 3.3.2 Commercial Baseline Data Development

For the commercial baseline analysis, each FEECA utility again provided billing data on actual electricity sales to commercial customers in calendar year 2007 which served as control totals to help reconcile the bottom-up baseline estimates with actual total commercial sales. Itron also requested customer-level Standard Industrial Classification (SIC) information from utility billing/CIS databases in order to map total annual sales to the following 11 commercial building types defined for this study: Offices, Restaurants, Retail Stores, Grocery Stores, Schools, Colleges, Hospitals, Other Health Care, Hotels, Warehouses, and Miscellaneous Commercial.[4]

For four of the seven FEECA utilities, however, comprehensive SIC data for commercial customers was not readily available. For customers with missing SIC data, Itron used data

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[4] Military bases are mostly classified as Public Administration establishments and are thus considered Office buildings in this study. Two notable exceptions are sites that manufacture military goods (which are considered as part of the industrial sector) and military hospitals (which are grouped with other public and private hospitals).

from US Census Bureau and the EIA's 2003 Commercial Building Energy Consumption Survey (CBECS) to estimate utility-specific distributions of sales across building types. Specifically, Itron combined Census data on the number of full-time equivalent (FTE) staff by business type by zip code with CBECS estimates of the average annual electricity consumption per FTE staff by business type for the South Atlantic census region.[5] Interacting these estimates then provided utility-specific estimates of distribution of commercial kWh sales by building type.

Data on baseline end-use EUIs (kWh/ft2), equipment saturations, and end-use load shapes were derived primarily from a previous survey of commercial customers conducted for FPL by Regional Economic Research (now a part of Itron) in 1997. That study consisted of 1,157 on-site surveys of commercial and industrial (C&I) customers in FPL's service territory and produced estimates of average equipment saturations, densities, and capacities as well as average building characteristics for 16 commercial building types and 7 industrial facility types. These data were also fed into DOE-2 building energy simulations in order to generate hourly demand profiles by end-use, which were then weighted and scaled to the population level for each building type. Given the vintage of these baseline data, Itron supplemented these data, where possible, with recent data from ongoing Itron evaluations of FPL's C&I programs and recent C&I market assessments in California.

It should be noted that robust baseline equipment and energy efficiency measure saturation data by commercial building type are the two types of input data that are often not readily available for specific utility service territories, and consequently tend to be the most uncertain inputs in potential studies. While this study was able to leverage FPL's previous commercial survey to help minimize this type of baseline uncertainty, the FEECA utilities recognized the need for updated commercial baseline data and included a base task of conducting 600-point on-site survey of commercial facilities in the service territories of FPL, Progress Energy, and Gulf Power. The development, testing, and implementation of this data collection task is being administered by KEMA (subcontractor to Itron for this study). The principle data being collected as part of this effort include building characteristics, baseline end-use equipment saturations, densities, and capacities, and current saturation of key energy efficiency measures. At the time of this report, the final survey results and project report were still being prepared by KEMA and could not be integrated into the current analysis. However, the results of the survey will be used to update the commercial baseline and technical potential analyses within the scope of the economic and achievable potential forecasting phases of this study.

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[5] The US Census data is available at the 6-digit NAICS level, while the CBECS data is available at the 4-digit SIC level.

### *3.3.3 Industrial Baseline Data Development*

For the industrial baseline analysis, each FEECA utility again provided billing data on actual electricity sales to industrial customers in calendar year 2007 which served as control totals to help reconcile the bottom-up baseline estimates with actual total industrial sales. As in the commercial baseline analysis, Itron also requested customer-level Standard Industrial Classification (SIC) information from utility billing/CIS databases in order to map total annual sales to the 16 industrial subsectors defined for this study.

In order to develop industrial end-use estimates, KEMA (who conducted the industrial analysis as a subcontractor to Itron) leveraged subsector-specific end-use share estimates derived from the Energy Information Administration's 2002 Manufacturing Energy Consumption Survey (MECS). The 2002 MECS developed end-use consumption estimates for the manufacturing sector at the national level, broken out by primary industry types. KEMA translated these MECS data into end-use share estimates for each industry and combined those end-use shares with the total annual sales data provided by each utility to estimate subsector-specific end-use loads for each FL utility. The industrial motors end use was further broken down by application (pumps, fans, compressed air, other) using information from the USDOE's Motors Assessment Study (XENERGY, 1998). In that study, a survey of over 200 industrial facilities was conducted and analyzed to provide estimates of motor consumption and energy efficiency opportunities by industry and motor application type.

Finally, KEMA used data from utility rate load research and customer-level interval data provided by the FEECA utilities to develop subsector-specific load profiles.

### *3.3.4 Baseline results*

Below, we present the key results of our baseline analyses of annual electricity sales and system peak demand the residential, commercial, and industrial sectors in the FEECA utilities and highlight the key characteristics of Florida's customer base relevant to the assessment of electric energy efficiency potential.

Figure 3-4 shows the distribution of total, in-scope 2007 electricity sales by utility.[6] As the Figure shows, the two utilities with the largest service territories – FPL and Progress Energy – account for the vast majority of total annual sales across the FEECA utilities, with FPL

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[6] See Section 2 for a complete discussion of the end-use demand sectors that were excluded from the study scope.

accounting for just over half of total annual sales and Progress Energy accounting for approximately 20%, with the other five FEECA utilities collectively accounting for the remaining 25% of total sales.

Figure 3-5, Figure 3-6, and Figure 3-7 show the distribution of total, in-scope sales and total summer and winter system peak demand by end-use sector. Note that summer system peak demand in Florida historically occurs in the late afternoon (3-5pm), whereas winter system peak demand historically occurs in the early morning (7-9am). As these Figures show, residential customers were responsible for the largest share of total annual electricity consumption, accounting for more than half of total annual electricity sales across the FEECA utilities. Residential customers were responsible for an even larger share of system peak demand, accounting for 66% of summer system peak demand and over 70% of winter system peak demand. Commercial customers are responsible for the next largest share of annual electricity consumption and peak demand, accounting for approximately 38% of total annual electricity sales, 29% of summer system peak demand, and 24% of winter system peak demand. Industrial customers account for only 7% of total annual electricity sales and even smaller shares of summer and winter system peak demand (5% and 4%, respectively).

**Figure 3-4: Estimated Breakdown of Total Annual Sales (Excluding losses) by Utility (171,672 GWh)**

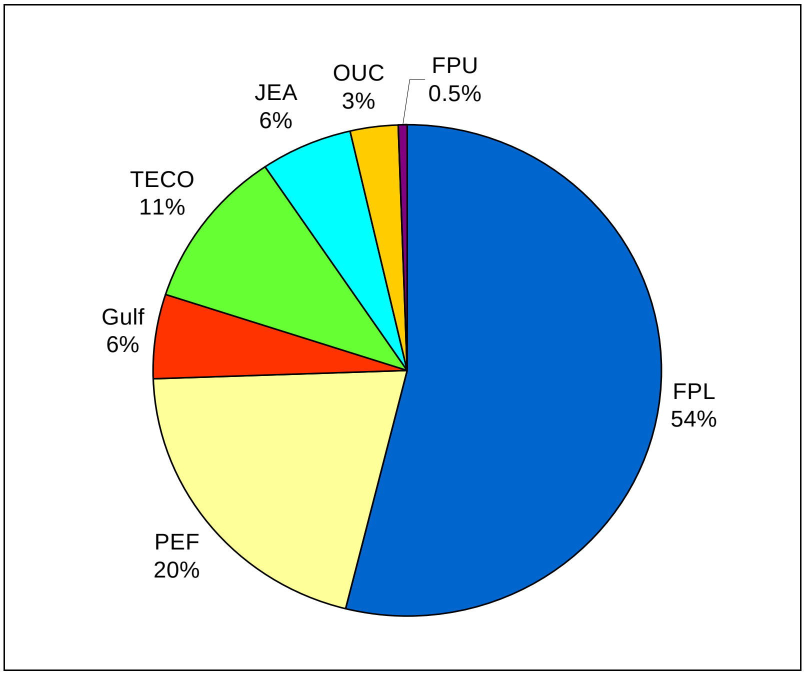


**Figure 3-5: Estimated Breakdown of Total Annual Electricity Sales (Excluding losses) by Sector**

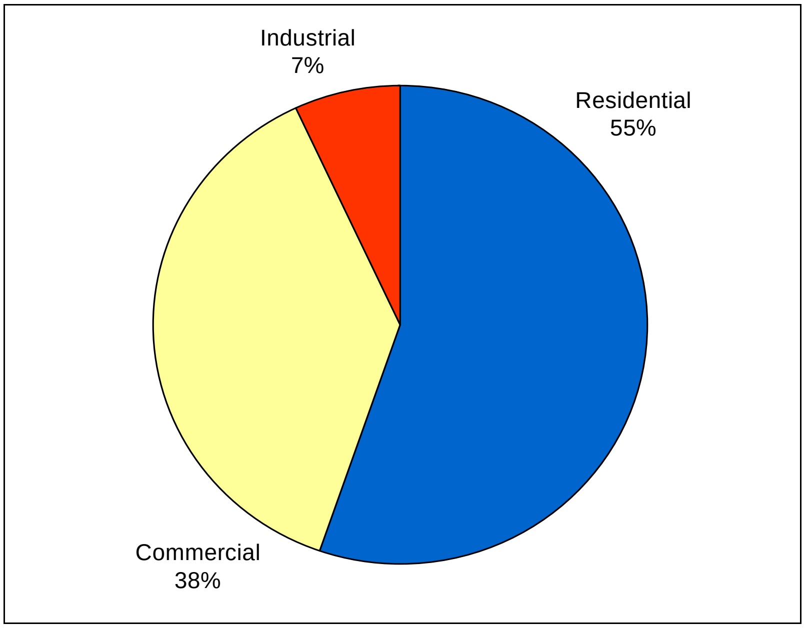


**Figure 3-6: Estimated Breakdown of Total Summer System Coincident Peak Demand (Excluding losses) by Sector (33,825 MW)**

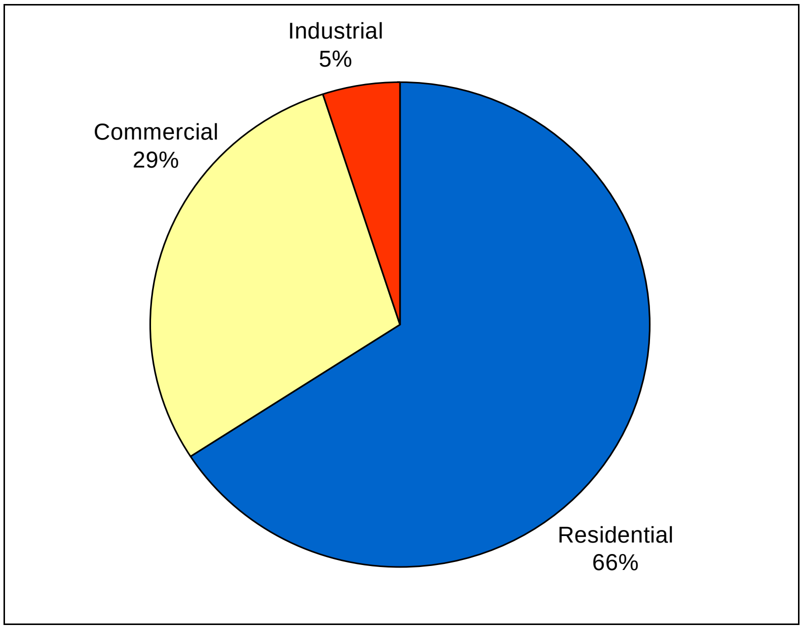


**Figure 3-7: Estimated Breakdown of Total Winter System Coincident Peak Demand (Excluding losses) by Sector (31,506 MW)**

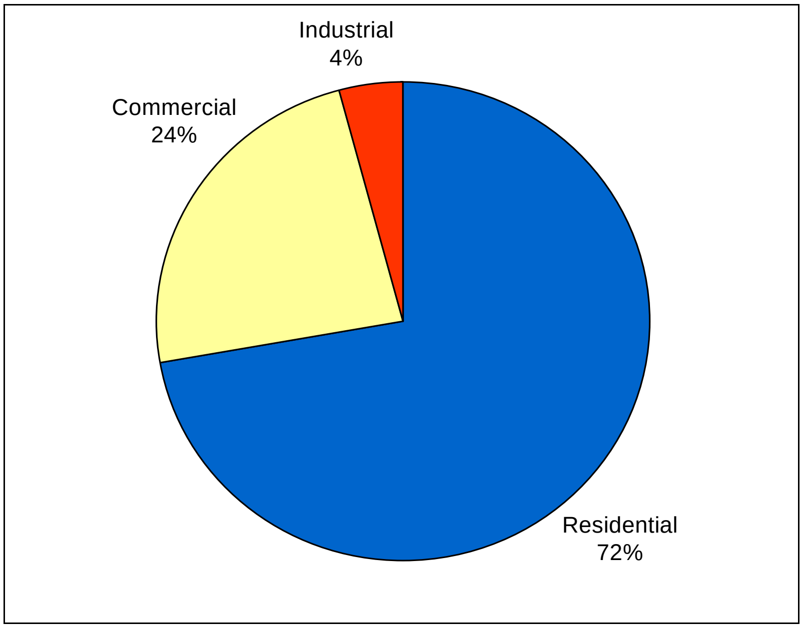


Figure 3-8 shows the breakdown of total annual electricity sales by building type in the residential sector. As the Figure shows, single-family detached homes account for more than two-thirds of total electricity consumption in the residential sector, with multi-family homes (including single-family attached homes) and mobile homes accounting for 25% and 6%, respectively, of total residential consumption. These shares of total electricity consumption largely reflect the relative number of single-family, multi-family, and mobile homes in the service territories of the FEECA utilities.

**Figure 3-8: Estimated Breakdown of Total Annual Residential Electricity Sales (Excluding losses) by Building Type (94,745 GWh)**

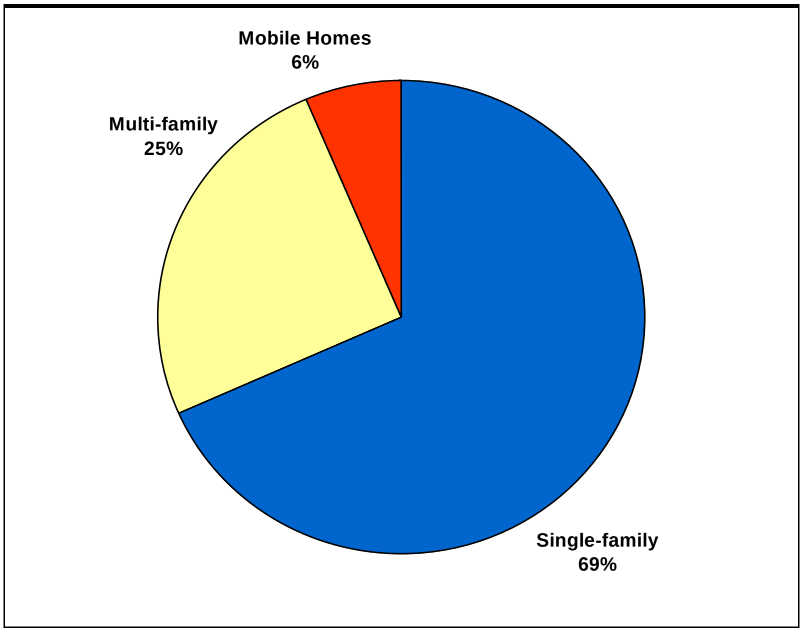
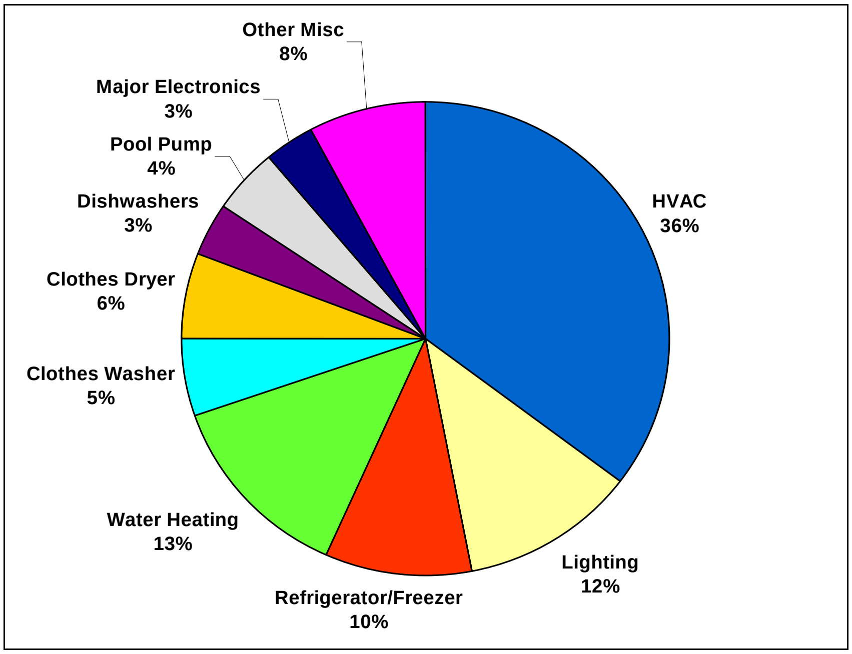


Figure 3-9, Figure 3-10, and Figure 3-11 show the breakdown of total annual residential electricity sales, summer system peak demand, and winter system peak demand by end use. As Figure 3-10 shows, heating, ventilation, and air-conditioning (HVAC) account for just over a third of residential electricity consumption, followed by water heating (13%), lighting (11%), and refrigerator-freezers (10%). The remaining third of residential consumption is split fairly evenly among other major appliances (clothes washers, clothes dryers, and dishwashers), major electronics (televisions, set-top boxes, DVD players, VCRs, and personal computers), and other miscellaneous plug loads.

**Figure 3-9: Estimated Breakdown of Total Annual Residential Electricity Sales (Excluding losses) by End Use (94,745 GWh)**



While annual electricity consumption is fairly distributed across residential end uses, both summer and winter peak demand is dominated by HVAC. As Figure 3-10 and Figure 3-11 show, HVAC accounts for more than two-thirds of summer and winter peak in the residential sector. During the summer peak, residential HVAC load is driven by central air-conditioners and heat pumps, whereas during winter peak, residential HVAC load is driven mostly by electric resistance heating. Outside of HVAC, the end-use contributions to system peak demand are largely similar between the summer and winter peak periods. There is one important exception to this observation, however. Water heating accounts for only 5% of residential load during the summer system peak period but accounts for 13% of residential load during the winter system peak load.

**Figure 3-10: Estimated Breakdown of Total Residential Summer Peak Demand (Excluding losses) by End Use (22,263 MW)**

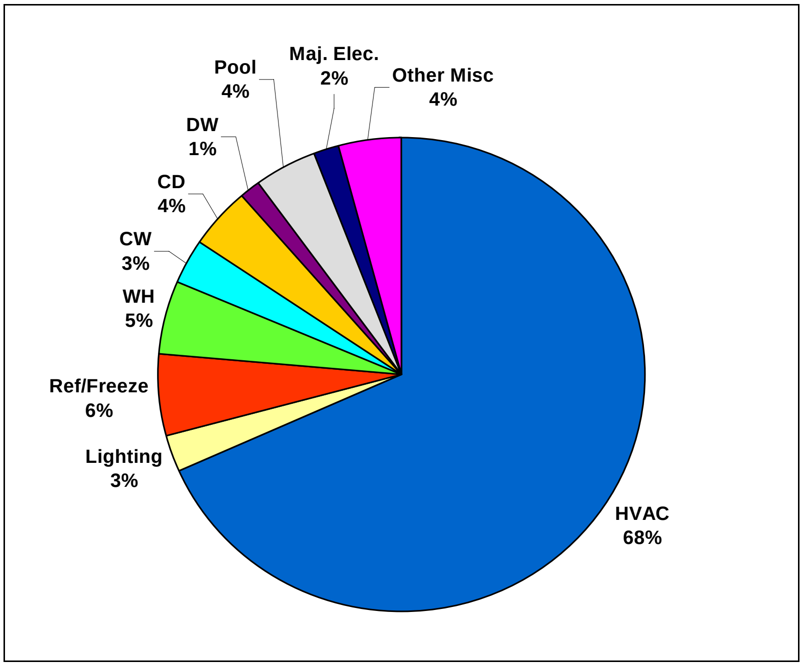


**Figure 3-11: Estimated Breakdown of Total Residential Winter Peak Demand (Excluding losses) by End Use (22,728 MW)**

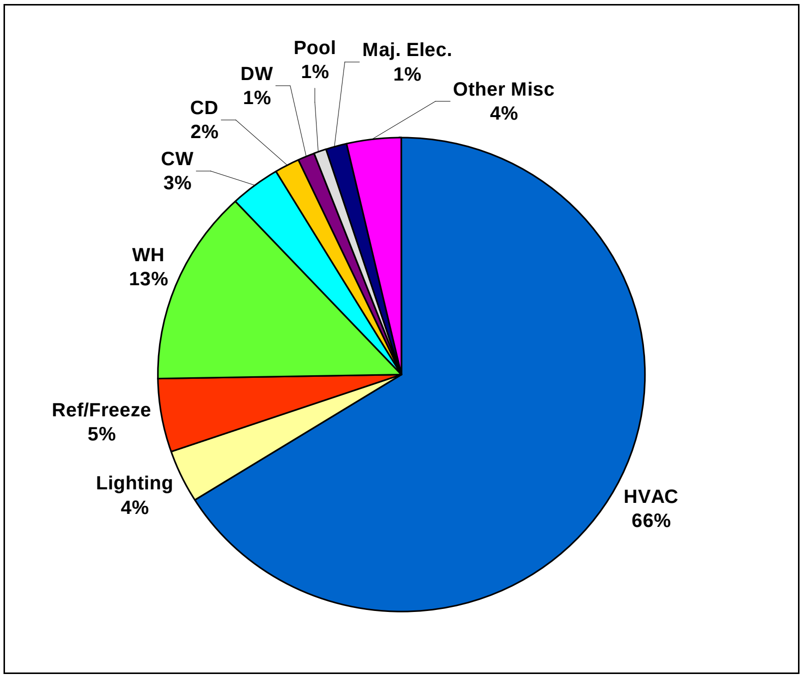


Figure 3-12 shows the breakdown of total annual electricity sales by building type in the commercial sector. As the Figure shows, office buildings and restaurants account for the largest shares of commercial electricity consumption (21% and 18%, respectively). Overall, however, total commercial electricity sales are fairly well distributed across the 11 building types defined for this study. Although the intensity of electricity use (in kWh per square foot of floor space) can differ significantly across commercial building types, the distribution of total commercial sales mostly reflects the estimated distribution of commercial floor stock across building types.

**Figure 3-12: Estimated Breakdown of Total Annual Commercial Electricity Sales (Excluding losses) by Building Type (65,051 GWh)**

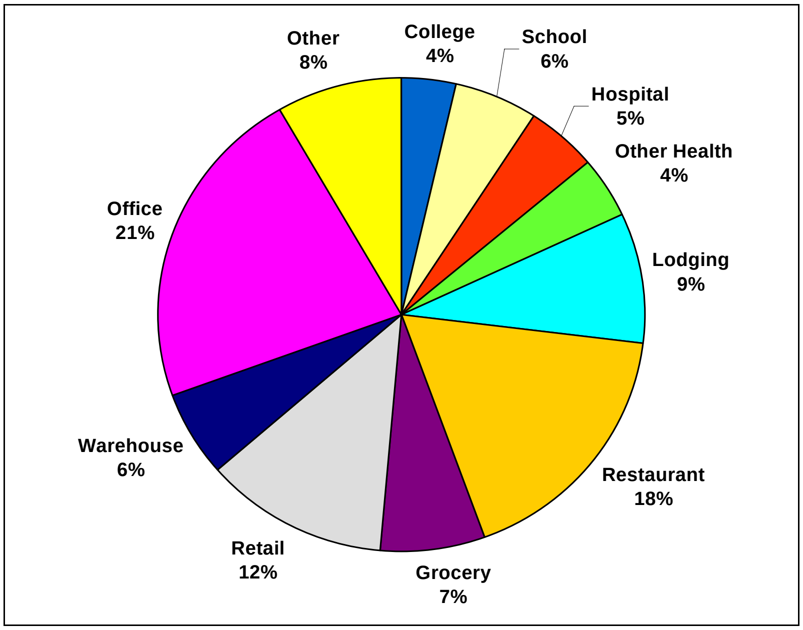


Figure 3-13, Figure 3-14, and Figure 3-15 show the breakdown of total annual commercial electricity sales, summer system peak demand, and winter system peak demand by end use. As Figure 3-13 shows, indoor lighting and space cooling account for the largest shares of total commercial electricity consumption (26% and 27%, respectively). At summer system peak, these end-use shares are mostly similar with the key exception that space cooling accounts for a significantly larger share of summer commercial peak demand (36%) compared to annual commercial consumption. At winter system peak, however, space cooling accounts for only 4% of peak demand from the commercial sector, and electric space heating (which accounts for the vast majority of winter peak demand in the 'miscellaneous' end-use category) accounts for nearly a third of commercial peak demand. It should also be noted that while overall commercial refrigeration loads are relatively small, these loads are the dominant loads within the Grocery and Restaurant segments.

**Figure 3-13: Estimated Breakdown of Total Annual Commercial Electricity Sales (Excluding losses) by End Use (65,051 GWh)**

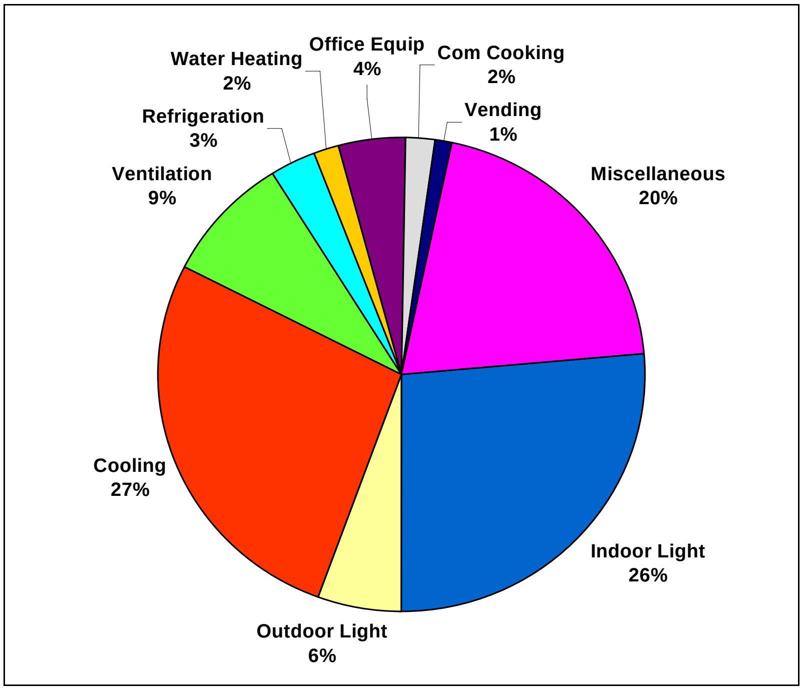


**Figure 3-14: Estimated Breakdown of Total Commercial Summer Peak Demand (Excluding losses) by End Use (9,840 MW)**

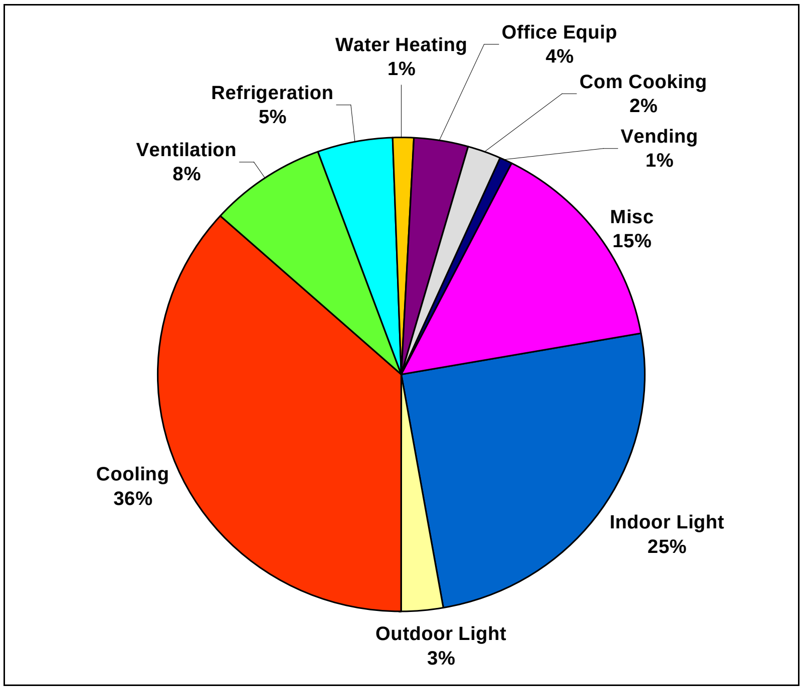


**Figure 3-15: Estimated Breakdown of Total Commercial Winter Peak Demand (Excluding losses) by End Use (7,490 MW)**

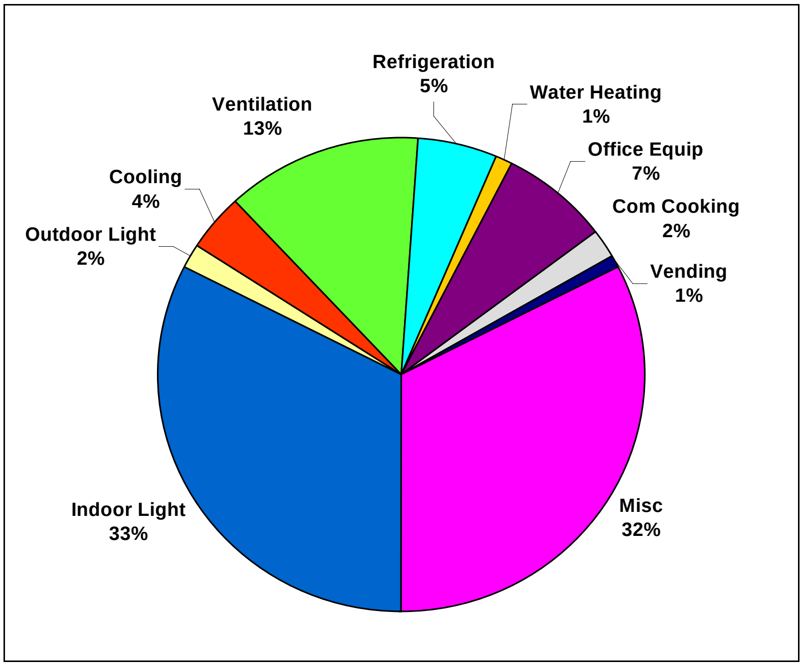
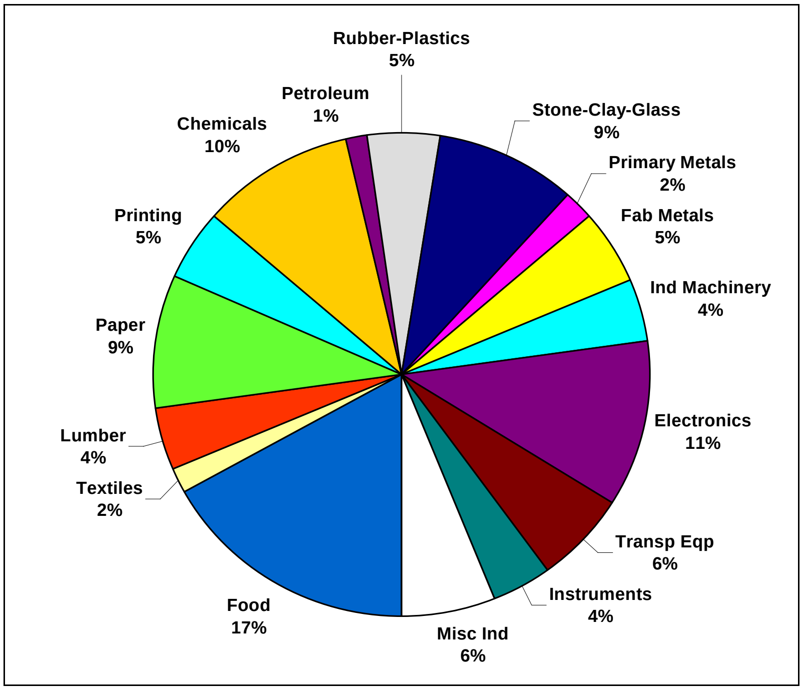


Figure 3-16 shows the breakdown of total annual electricity sales by subsector in the industrial sector. As the Figure shows, food processing accounts for the largest share of industrial electricity consumption (17%). Overall, however, total industrial electricity sales are fairly well distributed across the 16 subsectors defined for this study.

Figure 3-17, Figure 3-18, and Figure 3-19 show the breakdown of total annual industrial electricity sales, summer system peak demand, and winter system peak demand by end use. As Figure 3-17 shows, process drives and pumps account for the largest shares of total commercial electricity consumption (20% and 14%, respectively). At summer system peak, Figure 3-18 shows that the end-use shares of total load are similar with the key exception that HVAC accounts for a significantly larger share of summer industrial peak demand compared to annual industrial consumption (17% compared to 12%). At winter system peak, however, Figure 3-19 shows that HVAC accounts for only 4% of coincident peak demand in the industrial sector. The relative stability of the energy and peak demand contributions from other industrial end uses largely reflects the relatively flat load profiles of process-related industrial end uses compared to the more dynamic load profiles of weather-sensitive and occupancy-driven end uses in the residential and commercial sectors.

## Figure 3-16: Estimated Breakdown of Total Annual Industrial Electricity Sales (Excluding losses) by Subsector (11,877 GWh)



## Figure 3-17: Estimated Breakdown of Total Annual Industrial Electricity Sales (Excluding losses) by End Use (11,877 GWh)

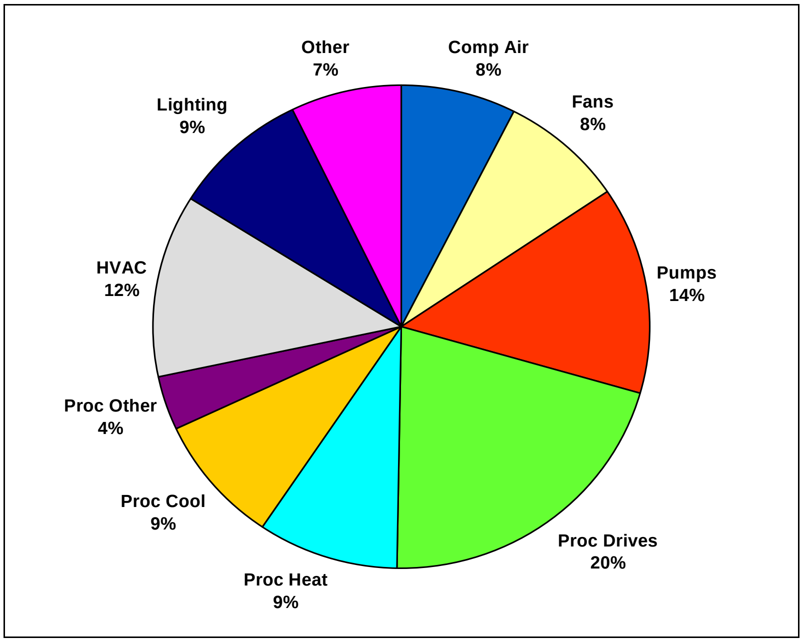


**Figure 3-18: Estimated Breakdown of Total Industrial Summer Peak Demand (Excluding losses) by End Use (1,721 MW)**

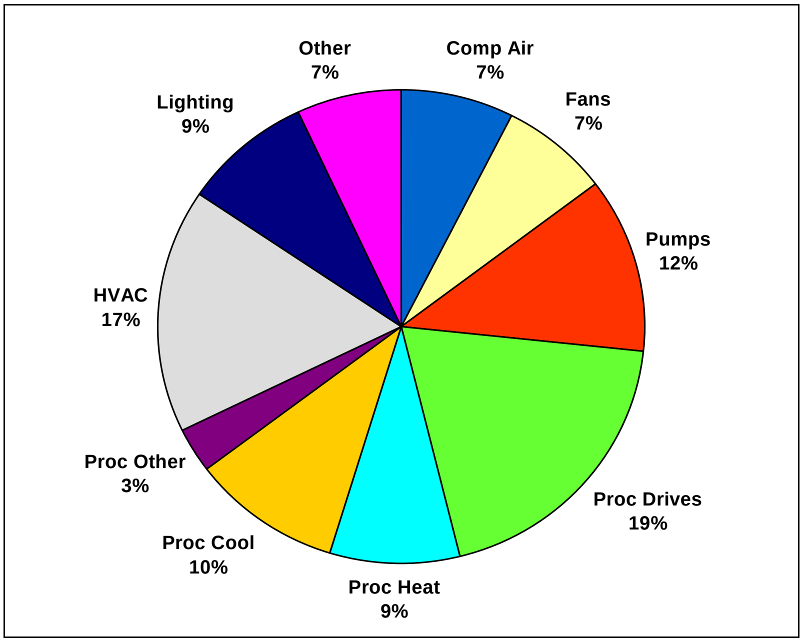
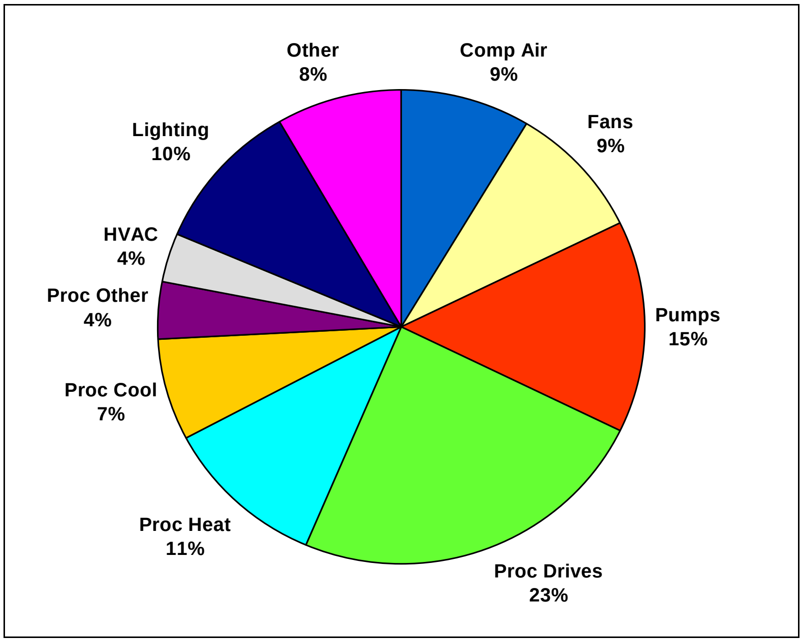


**Figure 3-19: Estimated Breakdown of Total Industrial Winter Peak Demand (Excluding Losses) by End Use (1,298 MW)**



## 3.4 Development of Energy Efficiency Measure Data

Along with baseline data on current energy use, the other key input data required in order to estimate technical potential are data that describe the energy efficiency measures being considered in the analysis. In this section, we describe the specific types of measure data collected for this study, the process used to determine the scope of the measures analyzed, and the key data sources used to develop the final measure data set.

The key measure data required to estimate technical potential are measure costs, measure savings, measure feasibility, and measure saturation. The definitions and units of each of these key measure data are summarized in Table 3-4 and described in more detail below.

**Table 3-4: Summary of Key Measure Data Required to Estimate Technical Potential**

| Data Type | Units |
|---|---|
| Measure costs | ▪ $/cost unit (e.g. per lamp, per ton of cooling capacity, per square foot of insulation) |
| Measure savings | ▪ Savings relative to base case technology at equivalent level of service |
| Measure saturation | ▪ % of households with measure installed (residential)<br>▪ % of floor space with measure installed (commercial)<br>▪ % of load with measure installed (industrial) |
| Measure feasibility | ▪ % of eligible households where measure is technically and practically feasible (residential)<br>▪ % of eligible floor space where measure is technically and practically feasible (commercial)<br>▪ % of eligible load where measure is technically and practically feasible (industrial) |

Measure costs are expressed as either full costs or incremental costs, depending on whether the measure is a retrofit (full cost, including any labor costs associated with installation) or replace-on-burnout measure (incremental first cost, relative to standard efficiency replacement, excluding any labor costs associated with installation). In Itron’s approach, we also normalize measure costs to specific “cost units” in order to allow reasonable scaling of measure costs across segments that have different technology densities and equipment capacities (e.g. $/ton of cooling capacity). Measure savings are expressed as percentage savings relative to the base technology (in terms of kWh or kW). Measure saturation is defined as the share of total consumption units (e.g. households or commercial floor space) where a given measure is already installed. Measure feasibility is typically defined as the share of households, commercial floor space, or industrial load where a given measure is technically and practically feasible. Examples of barriers that limit measure feasibility include color requirements that limit the use CFLs as replacements for incandescent lamps and the use of constant volume HVAC systems that limit the use of variable frequency drives with fan motors. Together, these two variables serve to avoid gross overestimates of efficiency potential by explicitly taking into account practical and technical barriers to particular measures and limiting the analysis to the share of the market where given efficiency measures have not yet been installed.

### *3.4.1 Development of Final Measure Scope*

The first step in developing measure data for application in technical potential studies is to determine scope of the energy efficiency analysis by defining the specific list of measures to be considered. For this study, development of the final measure scope was an iterative process that began with the minimum list of measures defined by the FEECA utilities in Appendix A of the original Request for Proposals. Building on this minimum list, Itron then proposed additional measures that had been recently analyzed in previous potential studies conducted in other jurisdictions. Itron also proposed additional measures from knowledge of existing DSM programs administered by FPL. Similarly, the other FEECA utilities proposed additional measures based on their own current program offerings, and SACE/NRDC proposed additional measures based on reviews of the current technology research literature, pilot programs in other jurisdictions, and trade literature.

It should be noted that, in general, the scope of measures proposed for consideration in the study was limited to measures that are currently available in the Florida market for which independently-verified cost and savings data are available. In this sense, non-commercialized “emerging” technologies were specifically excluded from the study.

Once the master list of proposed measures was compiled, Itron conducted an initial assessment of data availability and measure-specific modeling issues associated with “new” measures, i.e. measures that Itron had not previously analyzed in past studies. The FEECA utilities and SACE/NRDC then submitted written responses to Itron’s data assessment. These pieces formed the basis for a series of conference calls designed to either reach consensus among the study collaborative or determine further actions items required to finalize the data assessment. As a result of these conference calls, several individual FEECA utilities provided measure data from internal R&D and SACE/NRDC provided research briefs for selected measures.

The final list of the energy efficiency measures considered in this study is shown in Appendix A. In total, the study considered 257 unique measures, including 61 residential measures, 78 commercial measures, and 118 industrial measures. Importantly, the final measure list included 25 “new” measures in the residential sector and 24 “new” measures in the commercial sector. While the final measure list was constrained to measures that are commercially available in the Florida market, the final list included some measures that are likely to face significant supply constraints in near term, e.g. SEER 19 central air conditioners (CAC), hybrid desiccant-direct expansion (DX) cooling systems, solar water heating, heat pump water heaters. The final measure list also included some end-use specific renewable energy measures, e.g. solar water heating and PV-powered pool pumps. These renewable measures were included in the EE analysis (rather than the PV analysis described later in Chapter 5) because they effect end-use specific loads, rather than whole building loads, and can therefore be treated the same as EE measures in the DSM ASSYST modeling framework.

One notable exclusion from the final measure list for the technical potential study was refrigerator/freezer recycling. This exclusion was based on the difficulty in comparing and benchmarking theoretical savings from recycling measures to efficiency measures. Since recycling programs play important roles in many current utility program portfolios across the U.S., however, estimated savings from recycling measures will be included in the achievable potential forecasts in the next phase of this project.

For each of the efficiency measures on the final measure list, Itron then developed corresponding measure cost, savings, and current saturation data from a variety of sources. To the extent possible, Itron leveraged Florida-specific data sources. The remainder of this section describes the key data sources used to develop the final inputs used for the residential, commercial, and industrial measures analyzed in this study. The full set of measure data used in this study is shown in Appendix B.

### 3.4.2 Residential Measure Data

For residential measure cost data, Itron leveraged a variety of Florida-specific, regional, and national data sources. For the majority of measures effecting weather-sensitive end uses, Itron leveraged measure cost data from FPL program tracking data and previous FPL program evaluations conducted by Itron. In the case of radiant barriers, Itron specifically leveraged measure cost estimates developed by the Florida Solar Energy Center (FSEC) based on a pilot study conducted for Progress Energy (Parker et al, 2001). For insulation, advanced windows, lighting, and appliance measures, Itron leveraged the measure cost estimates available from the Database for Energy Efficient Resources (DEER) (CPUC, 2001; CPUC, 2005, CPUC, 2008).[7] For ENERGY STAR home electronics measures, Itron used the

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[7] The DEER database is a multi-year data development effort funded jointly by the California Public Utilities Commission and the California Energy Commission and contains average cost and energy savings data for over 250 energy efficiency measures currently available in the California market.

measure costs estimates embedded in the ENERGY STAR calculators developed by the US Environmental Protection Agency (EPA). Finally, for window tinting measures, Itron leveraged measure cost estimates contained in the *Energy Data Sourcebook for the U.S. Residential Sector* developed by Lawrence Berkeley National Laboratory (LBNL) (Wenzel et al, 1997).

For residential measure savings data, Itron also leveraged a variety of Florida-specific, regional, and national data sources, as well as engineering-based calculations. For the majority of measure effecting weather-sensitive end uses, Itron again leveraged measure savings estimates developed in previous FPL program evaluations and program R&D conducted by Itron for FPL. In the case of radiant barriers, sealed attics, and advanced windows, Itron leveraged measure savings estimates developed by FSEC (Parker et al, 2000b; Parker et al, 2001; Anello et al, 2001). To develop savings estimates from window screen measures, Itron conducted measure impact simulations using the RESFEN model developed by LBNL.[8] For high-efficiency lighting, water heating, clothes washer, and dishwasher measures, Itron used engineering calculations based on assumed differences in fixture wattages, energy factors, and modified energy factors to estimate average measure savings. For ENERGY STAR refrigerators and freezers, Itron used ENERGY STAR product specifications as the basis for measure savings estimates. Finally, for ENERGY STAR home electronics, Itron used ENERGY STAR product specifications regarding maximum standby and active power levels in combination with national averages of usage patterns and active/standby/off power mode draws developed by TIAX LLC for the USDOE (Roth and McKenney, 2007).

For current residential measure saturation, Itron was able to leverage largely Florida-specific data sources, primarily FPL's 2006 HES survey which contained the necessary detail to estimate the current market saturation of a variety of key residential measures, including high-SEER air conditioners and heat pumps, reflective roofs, ceiling and wall insulation, CFLs, and solar water heaters. For high-efficiency refrigerators, freezers, clothes washers, and dishwashers, Itron leveraged statewide estimates of current market saturation available from the 2005 RECS (USDOE, 2008). Finally, for Energy Star home electronics measures, Itron used current market saturation estimates developed by TIAX based on market tracking data from the USEPA (Roth and McKenney, 2007).

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[8] RESFEN is publically available at: http://windows.lbl.gov/software/resfen/resfen.html and allows city-specific savings impacts to be estimated for a variety of fenestration measures in residential buildings.

### 3.4.3 Commercial Measure Data

For commercial measure cost data, Itron leveraged many of the same sources used to develop residential measure costs. For high-efficiency lighting, space cooling, refrigeration, and water heating equipment, Itron primarily leveraged the measure cost estimates available from the DEER database. These DEER cost estimates were supplemented with program-based cost estimates for occupancy sensors, high-efficiency chillers, and high-efficiency packaged rooftop DX systems from Progress Energy and program-based cost estimates for building shell measures from FPL. FPL also provided cost estimates derived from recent FPL-sponsored field tests of hybrid dessicant-DX cooling systems, occupancy sensors for hotel room HVAC, and variable speed exhaust and make-up air fan controls. For ENERGY STAR office equipment measures, Itron used the measure costs estimates embedded in the ENERGY STAR calculators developed by the USEPA.

For commercial measure savings data, Itron again leveraged many of the same sources used to develop residential measure savings, including Florida-specific, regional, and national data sources, as well as engineering-based calculations. For the building shell and ventilation measures, Itron leveraged measure savings estimates developed in previous FPL program evaluations and program R&D conducted by Itron for FPL. In the case of commercial cool roofs, Itron leveraged measure savings estimates developed by FSEC (Parker et al, 1997). For HVAC and lighting control and maintenance measures, Itron leveraged measure savings estimates available from the DEER database. For high-efficiency lighting, water heating, packaged air conditioners, and packaged heat pump measures, Itron used engineering calculations based on assumed differences in fixture wattages, energy factors, and EER ratings to estimate average measure savings. Finally, for ENERGY STAR office equipment, Itron used ENERGY STAR product specifications as the basis for measure savings estimates.

For commercial measure saturations, there are currently no comprehensive sources of Florida-specific estimates analogous to the 2006 HES or the 2005 RECS for residential measures. Indeed, development of measure saturation estimates in Florida's commercial sector is one of the primary objectives of the commercial on-site surveys being conducted by KEMA for the FEECA utilities. For the purposes of the current study, Itron developed assumptions, where necessary, based on Itron's experience evaluating FPL's programs over the past 10 years, experience with particular measures in other jurisdictions, and professional judgment. Once KEMA's project report and analysis of the survey results are finalized, Itron will update the corresponding measure saturation inputs used in this study. It is important to keep in mind, however, that for measures that are relatively new to the Florida market (e.g. geothermal heat pumps, occupancy sensors for PTACs, electronic ballasts for HID lamps) and/or are known to face significant market barriers in Florida or nationwide (e.g. heat pump water heaters), it is highly unlikely that any primary data on current market penetration will differ significantly from our current assumptions.

### 3.4.4 Industrial Measure Data

For the industrial measures, Itron developed measure cost, savings, and current saturation data based on previous and on-going assessments of industrial energy efficiency potential in California. In 2001, KEMA developed an industrial energy-efficiency market characterization study that relied on numerous secondary sources to characterize baseline energy use and energy efficiency opportunities in the industrial sector (XENERGY, 2001a). Subsequent to this effort, KEMA developed an industrial energy-efficiency market assessment as a component of an overall California energy efficiency potential study prepared for the Energy Foundation (XENERGY, 2002). Finally, products from these two studies were combined with a series of industrial efficiency case studies conducted by LBNL to develop a more detailed industrial energy efficiency assessment for the California investor-owned utilities (Itron, 2006). This latest statewide assessment provides industrial energy efficiency potential estimates by industry type and key end uses. This body of work serves as the primary input into the industrial potential assessment conducted for the FEECA utilities.

### 3.4.5 Economic Data

The other key economic inputs required in this study were current and forecasted retail electricity rates, utility discount rates, customer discount rates, and inflation rates. For retail electricity rates, each of the FEECA utilities submitted current average retail electricity rates for residential, commercial, and industrial customers in $/kWh terms, as well as 30-year forecasts of those retail rates. For utility discount rates, each of the FEECA utilities also submitted discount rates consistent with the assumptions used in their respective system planning forecasts. For all sectors and all utilities, Itron used a customer discount rate of 15%/yr and a general inflation rate of 2%/yr.

## 3.5 Energy and Peak Demand Savings Results

In this section, we present the results of Itron's assessment of the technical potential for energy and demand savings from energy efficiency measures in the seven FEECA utilities. First we summarize the technical potential results for the residential sector, followed by those for the commercial and industrial sectors. For each sector, we present technical potential for energy savings and system peak demand savings (both summer and winter) by building type and end use. We also highlight key results for particular end uses and measures and present the final energy efficiency supply curves developed for each sector.

All of the results presented below are aggregated across the seven FEECA utilities. The detailed, utility-specific results (and inputs) are provided in Appendices B, C, and D of the individual, utility-specific project reports (forthcoming). It is worth noting, however, that the utility-specific results do not vary greatly from the statewide results shown below in terms of the relative shares of technical potential by sector, building type, and end use or the relative level of technical potential (in percentage terms) compared to current baseline energy consumption and peak demand. Where differences do exist, they largely reflect differences in the size and structure of each utility's customer base rather than differences in the nature of energy efficiency opportunities or measure cost-effectiveness across utilities.

### *3.5.1 Residential Sector Results*

The total technical potential for energy savings in the residential sector of the FEECA utilities is estimated to be 36,584 GWh, which equates to 39% of current baseline residential electricity consumption. As Figure 3-20 shows below, technically feasible energy efficiency opportunities in single-family detached homes account for just over 70% of the total technical potential for residential energy savings, while opportunities in multi-family homes and mobile homes account for 23% and 6%, respectively. This distribution of the total technical potential for residential energy savings largely reflects the distribution of baseline electricity consumption across residential building types. In this sense, the relative amount of technically feasible energy savings available in single-family, multi-family, and mobile homes were found to be largely similar on a per-home basis.

**Figure 3-20: Estimated Breakdown of Total Technical Potential for Residential Energy Savings by Building Type (36,584 GWh)**

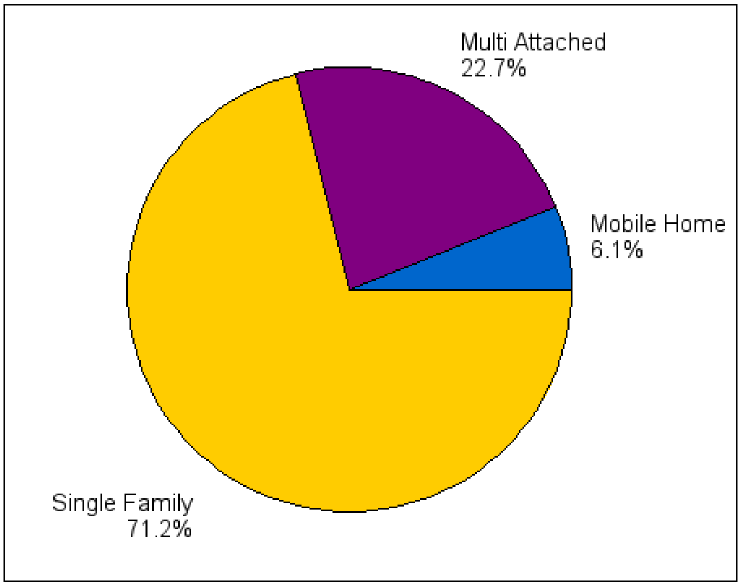
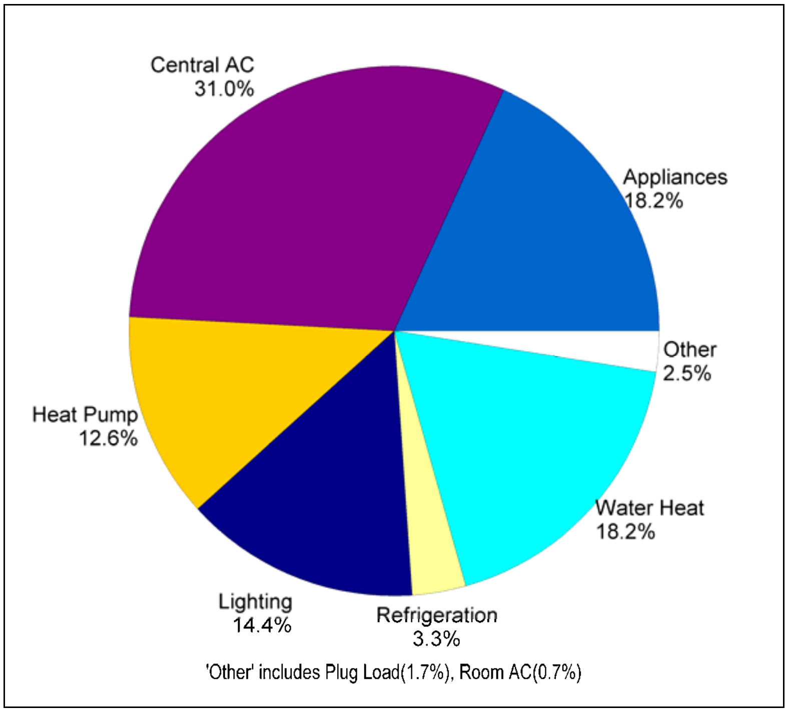


Figure 3-21 shows the breakdown of the total technical potential for energy savings in the residential sector by end use. As the Figure shows, nearly half of the total technical potential for residential energy savings is derived from measures effecting central HVAC systems, while measure effecting major appliances (clothes washers, dishwashers, and clothes dryers), water heating, and lighting account for roughly equal shares of the other half of total technical potential. Measures effecting room air conditioner systems, pool pumps, refrigerators, and major home electronics (televisions, set-top boxes, VCRs, DVD players, and home office equipment) account for less than 6% of total technical potential for residential energy savings.

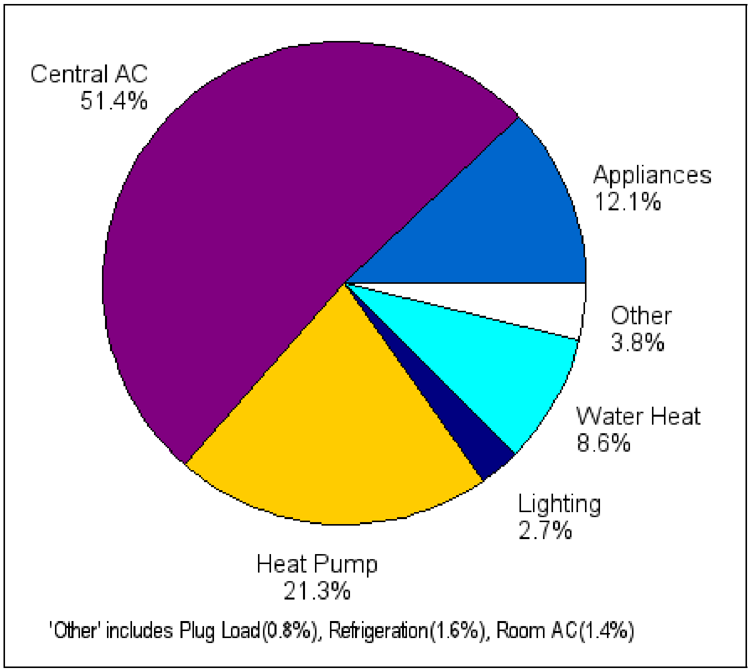
The key measures driving the technical potential results for central HVAC include high-SEER central air conditioners and heat pumps, system maintenance and optimization measures, duct repair, and building shell measures. In water heating, the key measures driving technical potential include heat pump water heaters, solar water heaters, AC heat recovery systems, water heater blankets, and measures to reduce hot water consumption (low-flow showerheads and faucet aerators). In contrast to these end uses where total technical potential reflects the combined potential savings from a wide variety of measures, it should be noted that total technical potential in residential lighting almost entirely reflects the potential energy savings from a single measure – integral ballast CFL lamps.

**Figure 3-21: Estimated Breakdown of Total Technical Potential for Residential Energy Savings by End Use (36,584 GWh)**



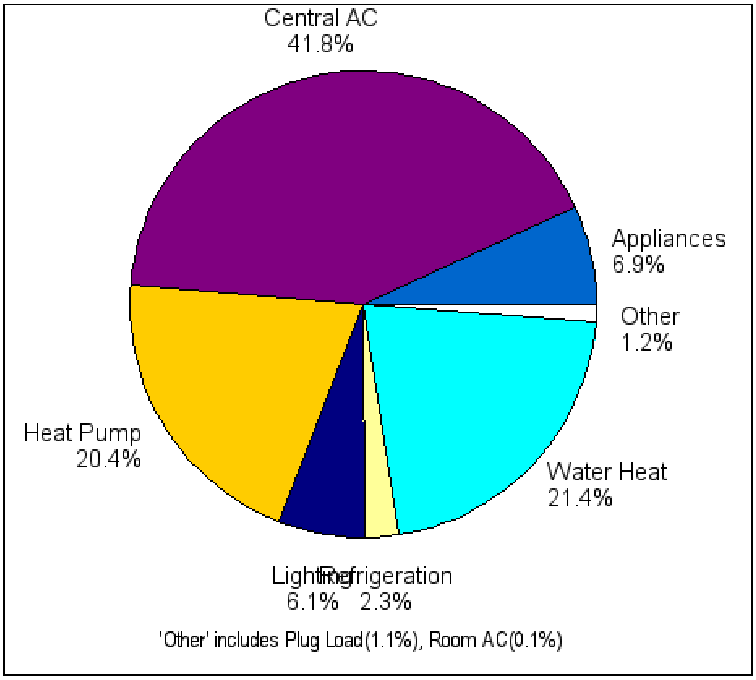
From a summer peak demand perspective, the total technical potential for system peak demand savings in the residential sector is estimated to be 10,032 MW, which equates to 45% of current baseline summer system peak demand. Figure 3-22 shows the breakdown of summer peak demand savings potential in the residential sector by end use. As the Figure shows, while central HVAC measures account for less than half of total energy savings potential, these measures account for nearly three-fourths of total summer peak demand savings potential in the residential sector. This result reflects the high coincidence of residential air conditioning loads with the summer system peak demand compared to other residential loads. Measure effecting residential HVAC therefore account for a proportionally larger share of total summer peak savings potential. In contrast, residential lighting loads have very low coincidence with summer system peak demand, and CFL measures therefore account for only a small share of total residential summer peak demand savings potential.

**Figure 3-22: Estimated Breakdown of Total Technical Potential for Residential Summer System Peak Demand Savings by End Use (10,032 MW)**



From a winter peak demand perspective, the total technical potential for system peak demand savings in the residential sector is estimated to be approximately 6,461 MW, which equates to 28% of current baseline winter system peak demand. Figure 3-23 shows the breakdown of winter peak demand savings potential in the residential sector by end use. As the Figure shows, central HVAC measures again account for the majority of total winter peak savings potential (largely from high-SEER heat pumps and insulation measures), with water heating measures accounting for more than 20%. These results again reflect the high coincidence of residential space heating and water heating loads with the winter system peak demand, which usually occurs in the early morning hours (7-9am).

**Figure 3-23: Estimated Breakdown of Total Technical Potential for Residential Winter System Peak Demand Savings by End Use (6,461 MW)**

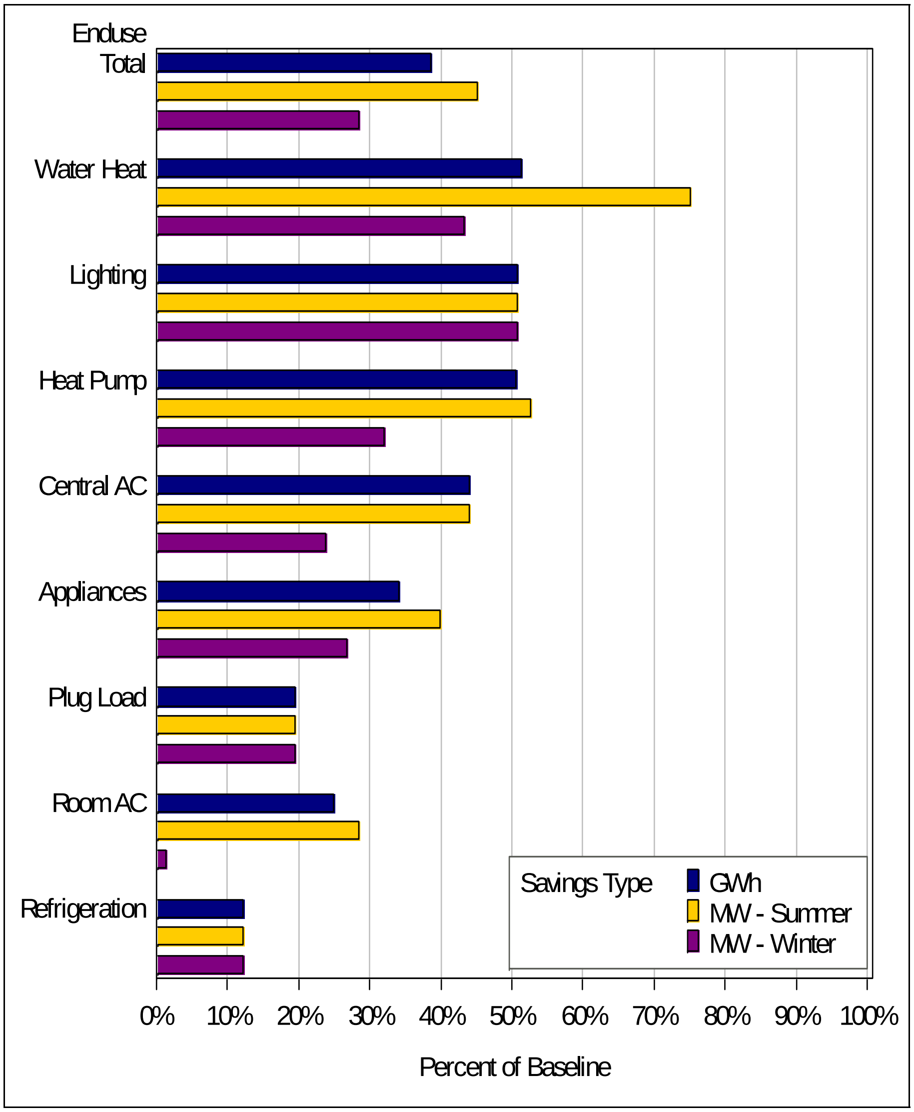


In the preceding figures, technical potential was displayed across end uses relative to total technical potential in the residential sector. Figure 3-24 again presents technical potential for energy and peak demand savings by end use, but this time relative to baseline energy consumption and peak demand for each respective end use in order to illustrate the relative size of potential end-use savings estimated in our residential analysis.

As the Figure shows, water heating displays the largest relative potential reduction in end-use baseline consumption and summer peak demand among residential end uses. This result largely reflects the potential savings from solar water heaters, which are highest during the summer peak period when conditions are sunny and outdoor temperatures are high. However, as noted earlier, because the coincidence between the summer system peak period and the demand for residential water heating is relatively low, these large potential summer peak demand savings reductions from solar water heaters in percentage terms translate to comparatively small system peak demand savings in kW terms.

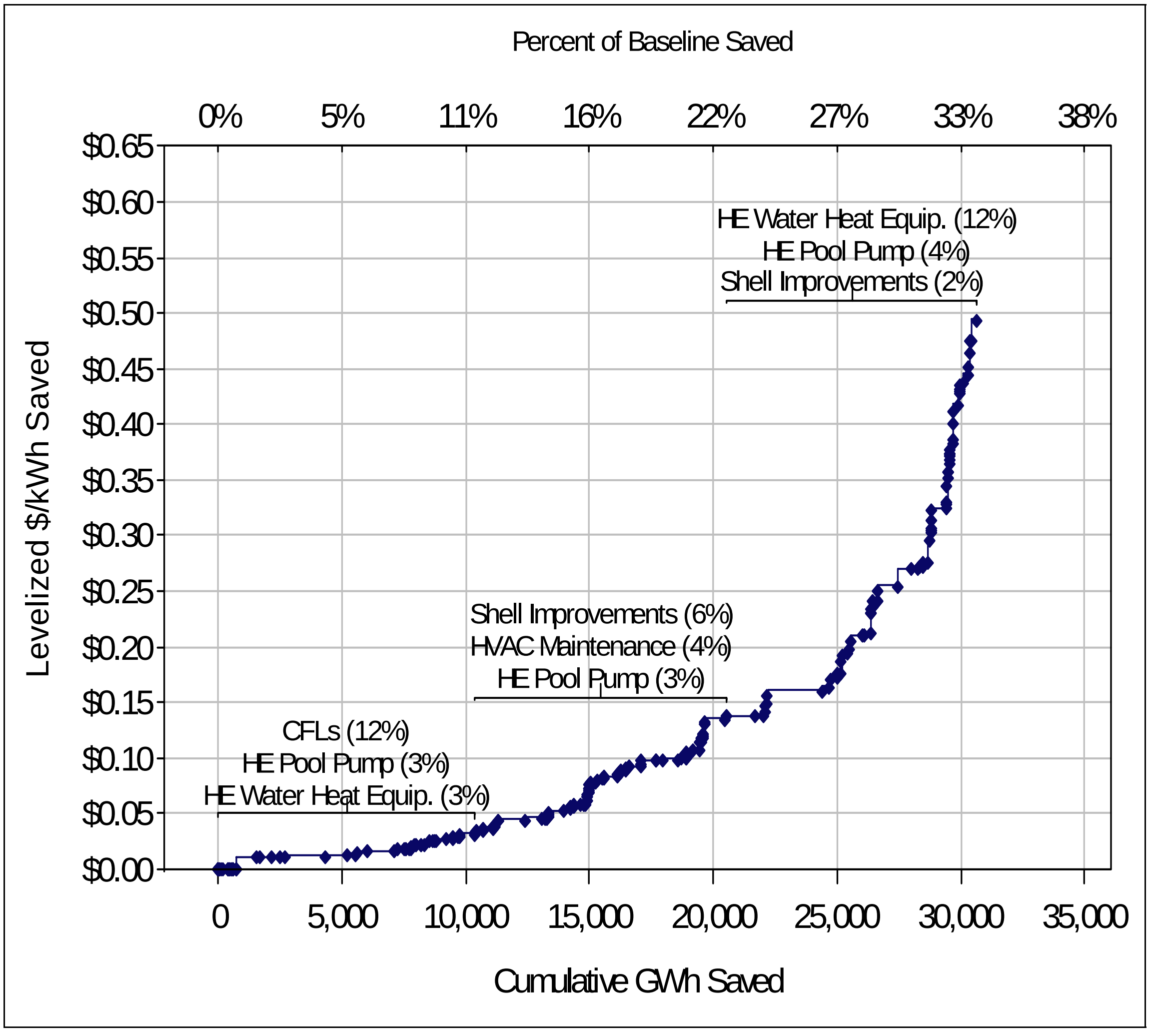
For central air conditioner and heat pump systems, potential reductions in baseline consumption and summer peak demand are similar. This result reflects the fact that annual space conditioning loads in Florida are driven largely by the long summer cooling season, with only a very short winter heating season. Note that the relative winter peak demand reduction potential in central HVAC systems is significantly lower in comparison, reflecting the fact that some of the HVAC measure analyzed only effect space cooling loads (e.g. high-SEER air conditioners) and that some HVAC measures targeting space cooling loads actually produce small space heating penalties during the heating season (e.g. window film and window treatments). In the case of lighting, the relative reductions in annual consumption, summer peak demand, and winter peak demand are virtually identical, reflecting the constant performance (i.e. the relative delivered savings) of CFL and T8 lamps, regardless of the time of day or season. The same dynamic is true in residential refrigeration, where ENERGY STAR refrigerators deliver the same relative savings regardless of the time of day or season.

**Figure 3-24: Total Technical Potential for End-use Energy and Peak Demand Savings in the Residential Sector Compared to Baseline Energy Consumption and Peak Demand**



Finally, Figure 3-25 shows the marginal costs of residential energy efficiency measures and their relative contributions to total technical potential in the form of a supply curve. From a levelized cost perspective (i.e. $/kWh saved), the Figure shows that CFLs are among the least expensive measures analyzed in this study from a levelized cost perspective (i.e. $/kWh saved) and alone account for 12% of total technical potential in the residential sector. The detailed marginal cost and savings data embedded in this Figure are shown for each measure in Appendix D in each of the utility-specific project reports (forthcoming).

**Figure 3-25: Residential Energy Efficiency Supply Curve**



It is important to recognize that cost-effectiveness, as defined by the Total Resource Cost (TRC) test or the Ratepayer Impact Measure (RIM) test, cannot be determined exclusively from these supply curves because the value of both energy and demand savings must be integrated when comparing to supply-side alternatives.

### *3.5.2 Commercial Sector Results*

The total technical potential for energy savings in the commercial sector of the FEECA utilities is estimated to be approximately 19,924 GWh, which equates to 31% of current baseline commercial electricity consumption. As Figure 3-26 shows below, technically feasible energy efficiency opportunities in office buildings account for roughly 25% of the total technical potential for commercial energy savings, with the remaining potential fairly well distributed across the other 10 commercial building types analyzed. As was the case in the residential analysis, this distribution of the total technical potential for commercial energy savings largely reflects the distribution of baseline electricity consumption across commercial building types.

**Figure 3-26: Estimated Breakdown of Total Technical Potential for Commercial Energy Savings by Building Type (19,924 GWh)**

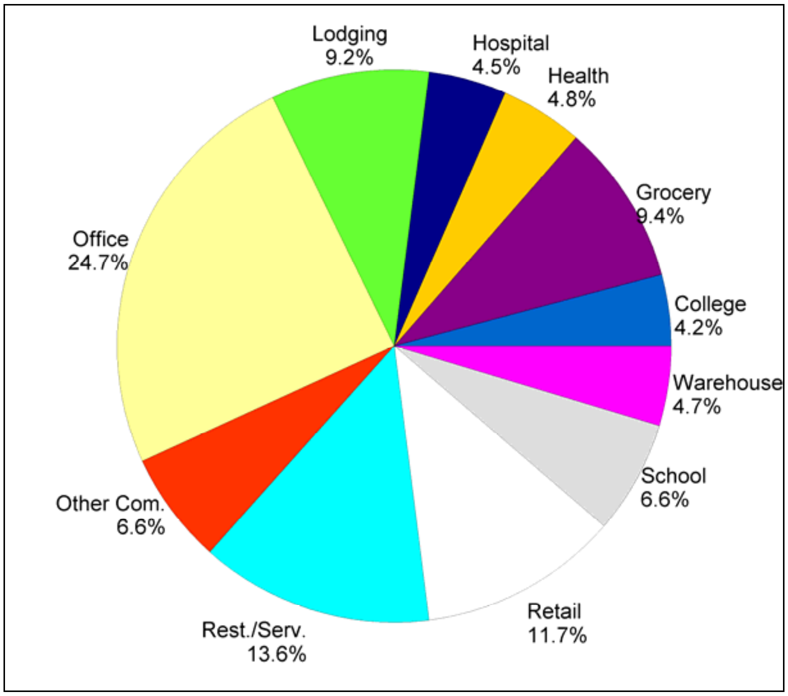
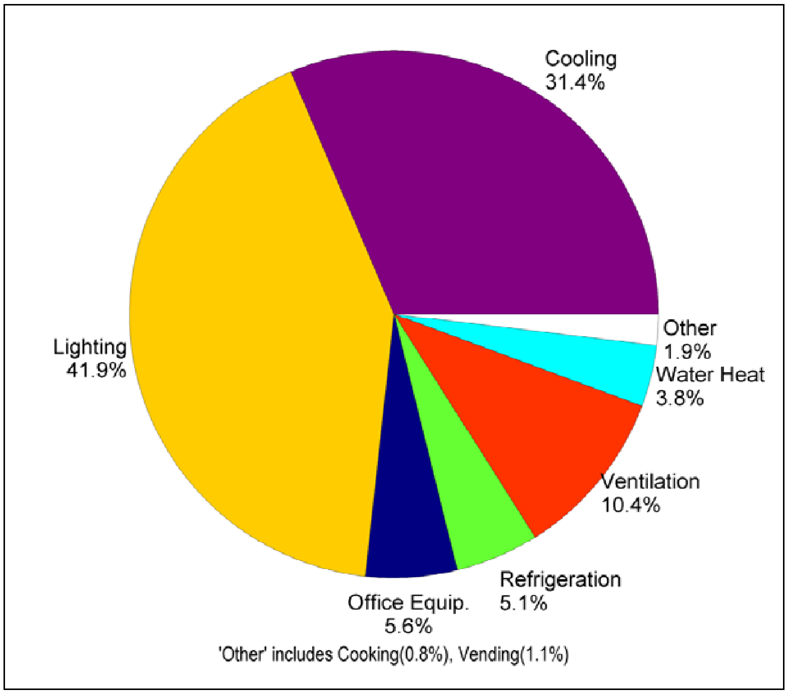


Figure 3-27 shows the breakdown of the total technical potential for energy savings in the commercial sector by end use. As the Figure shows, more than 40% of the total technical potential for commercial energy savings is derived from measures effecting commercial lighting systems, while measures effecting space cooling systems account for roughly a third of total technical potential. Measures effecting ventilation, water heating, commercial refrigeration, office equipment, cooking, and vending account for the remaining shares of total technical potential for commercial energy savings. It should be noted that refrigeration loads in the commercial sector are largely concentrated in three particular commercial building types – grocery stores, restaurants, and refrigerated warehouses. Thus, potential savings from refrigeration measures dominate total technical potential savings within those particular segments.

The key measures driving the technical potential results for lighting include CFLs, premium T8 lamps, electronic ballasts, occupancy sensors, and high-bay T5 lamps. In space cooling, the key measures driving technical potential include high-efficiency chillers and packaged

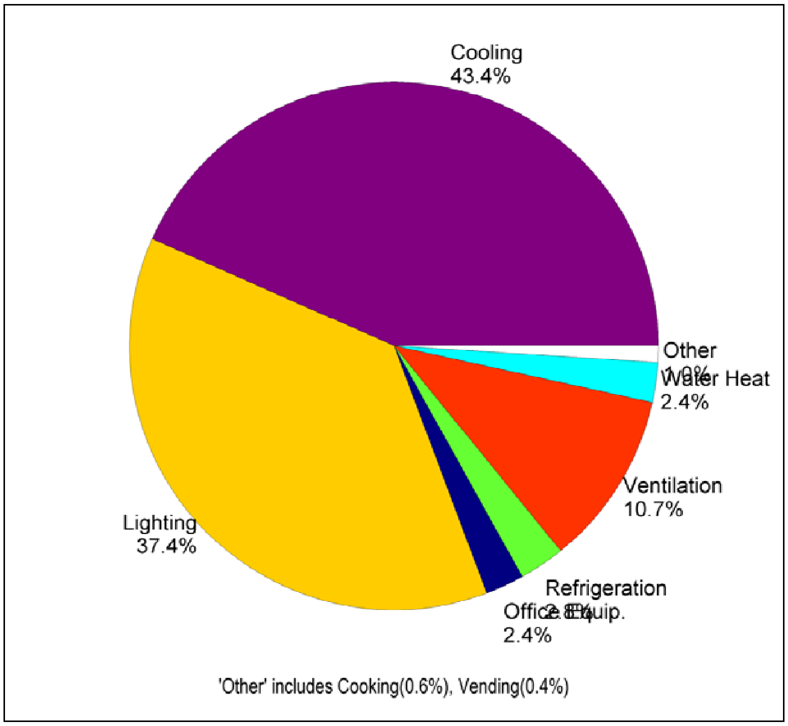
DX systems, hybrid desiccant-DX systems, duct sealing, and cool roofs. In ventilation, just over half of technical potential savings are derived from two particular measures – variable-speed drive controls and electronically-commutated motors.

**Figure 3-27: Estimated Breakdown of Total Technical Potential for Commercial Energy Savings by End Use (19,924 GWh)**



From a summer peak demand perspective, the total technical potential for system peak demand savings in the commercial sector is estimated to be approximately 4,079 MW, which equates to 41% of current baseline summer system peak demand. Figure 3-28 shows the breakdown of summer peak demand savings potential in the commercial sector by end use. As the Figure shows, the end-use shares of summer peak savings potential are largely similar to the end-use shares of annual energy savings potential, with measures effecting lighting and space cooling accounting for over 80% of total technical potential. As is the case in the residential sector, space cooling measures account for a higher relative share of potential summer peak demand savings compared to potential annual energy savings due to high coincidence of space cooling loads with system summer peak period. In contrast to the residential sector, however, several other commercial end-uses also have relatively high coincidence with the summer system peak period (e.g. ventilation, interior lighting, and water heating), which helps to explain why the distribution of potential summer peak savings is generally similar to the distribution of potential annual energy savings in the commercial sector.

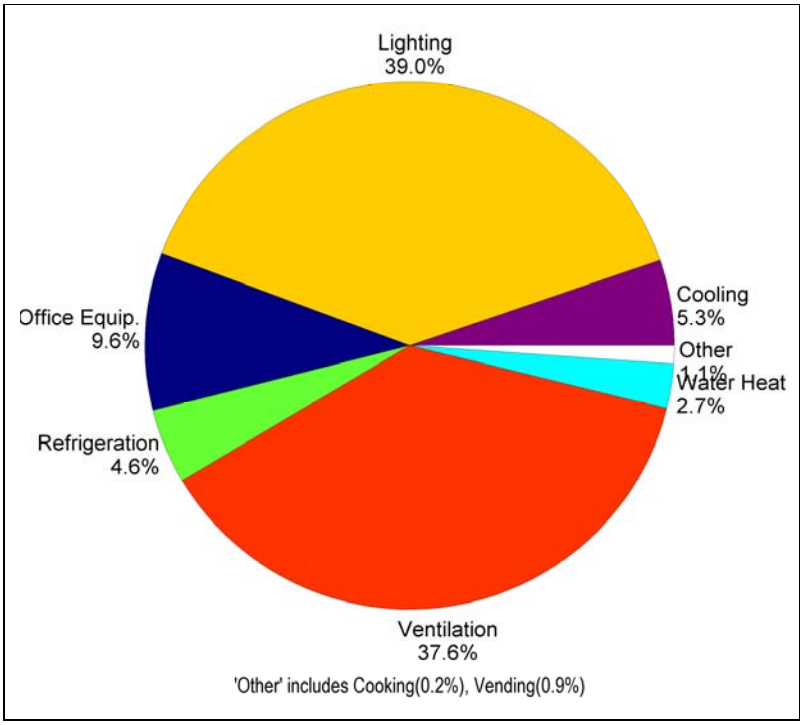
**Figure 3-28: Estimated Breakdown of Total Technical Potential for Commercial Summer System Peak Demand Savings by End Use (4,079 MW)**



'Other' includes Cooking(0.6%), Vending(0.4%)

From a winter peak demand perspective, the total technical potential for system peak demand savings in the commercial sector is estimated to be approximately 2,206 MW, or 30% of current baseline winter system peak demand. Figure 3-29 shows the breakdown of winter peak demand savings potential in the commercial sector by end use. As the Figure shows, lighting measures again account for a large share of total peak savings potential. However, in contrast to the summer peak savings and annual energy savings results, measures effecting space cooling account for only a small share of total winter peak savings potential while measure effecting ventilation account for more than a third of the total. These results again largely reflect the relative coincidence of commercial end-use loads with winter system peak demand, which typically occurs in the morning hours when space cooling loads are relatively low.

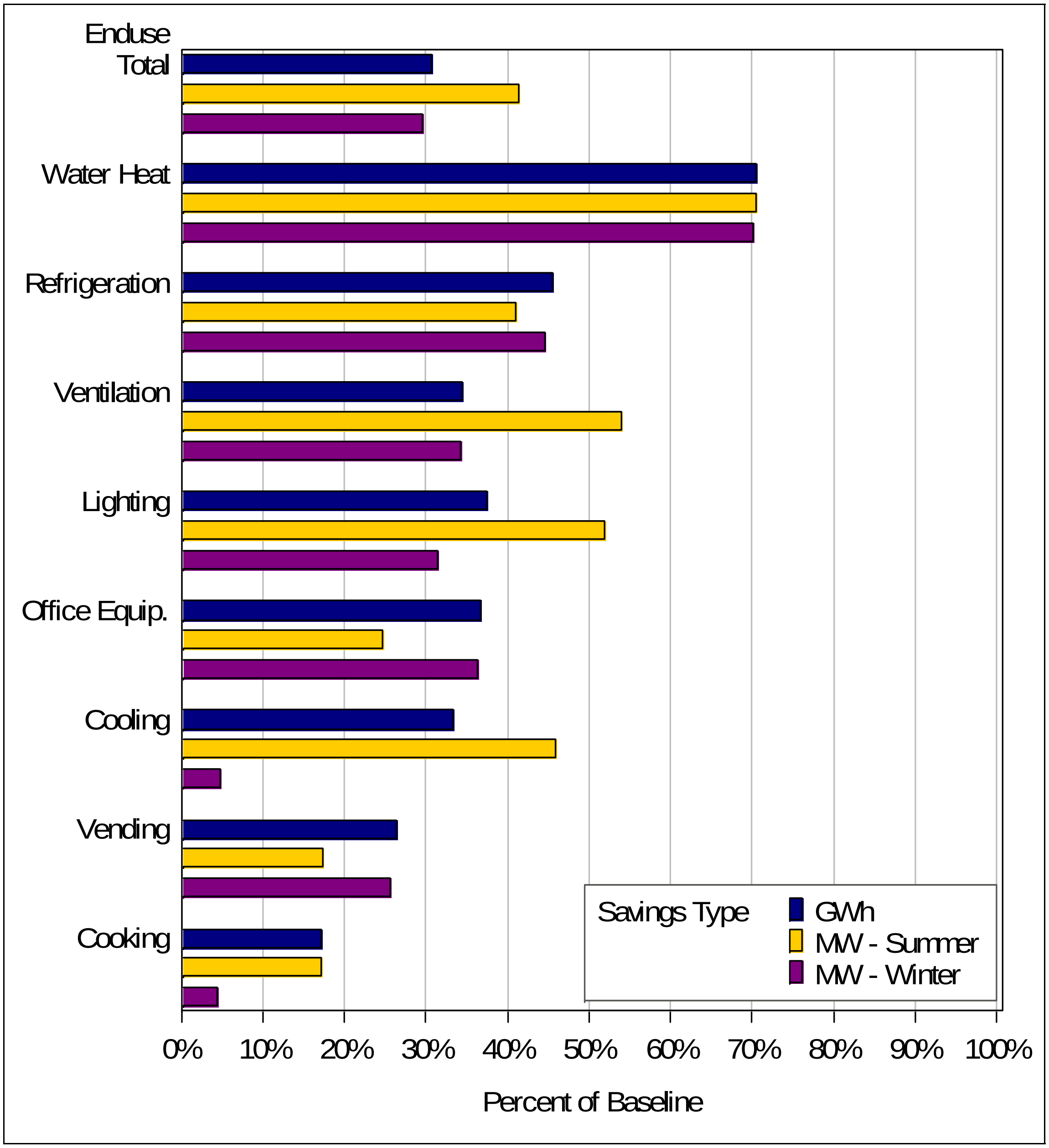
**Figure 3-29: Estimated Breakdown of Total Technical Potential for Commercial Winter System Peak Demand Savings by End Use (2,206 MW)**



In the preceding figures, technical potential was displayed across end uses relative to total technical potential in the commercial sector. Figure 3-30 again presents technical potential for energy and peak demand savings by end use, but this time relative to baseline energy consumption and peak demand for each respective end use in order to illustrate the relative size of potential end-use savings estimated in our commercial analysis.

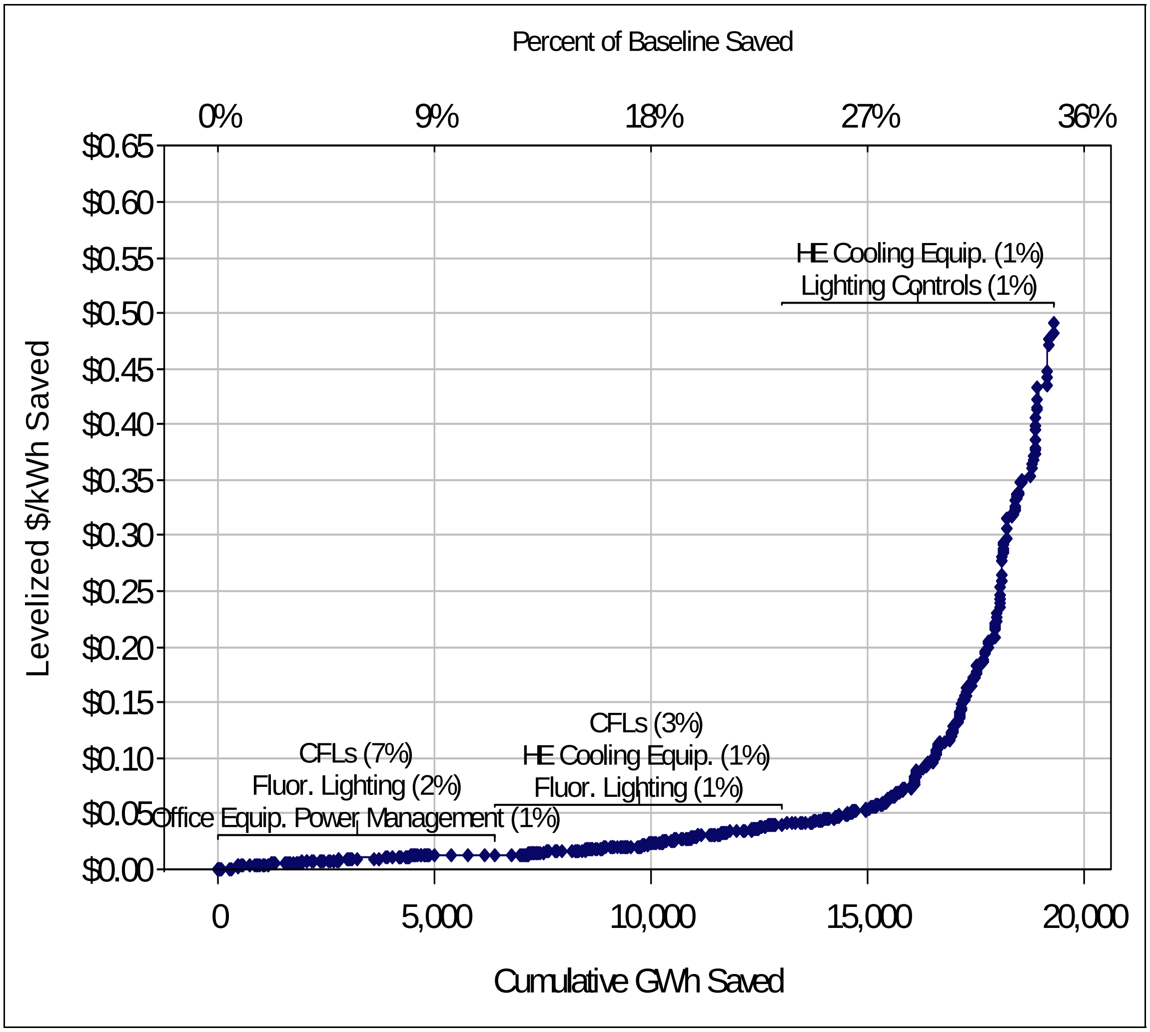
As the Figure shows, even though measure effecting water heating only contribute small shares of total technical potential energy and peak demand savings in the commercial sector, these measures produce the largest potential reduction in end-use baseline consumption and peak demand, driven principally by the potential associated with heat pump water heaters and heat recovery units. In contrast, Figure 3-30 shows that while measures effecting lighting and space cooling account for the largest shares of total technical potential savings, these measures produce more modest relative reductions in respective end-use baseline consumption and peak demand compared to the water heating measures analyzed for this study.

**Figure 3-30: Total Technical Potential for End-use Energy and Peak Demand Savings in the Commercial Sector Compared to Baseline Energy Consumption and Peak Demand**



Finally, Figure 3-31 shows the marginal costs of commercial energy efficiency measures and their relative contributions to total technical potential in the form of a supply curve. From a levelized cost perspective (i.e. $/kWh saved), the Figure shows that CFLs and premium T8 lamps with electronic ballasts are among the least expensive measures analyzed in this study from a levelized cost perspective (i.e. $/kWh saved) and together account for roughly 25% of total technical potential in the commercial sector. The detailed marginal cost and savings data embedded in this Figure are shown for each measure in Appendix D in each of the utility-specific project reports (forthcoming).

**Figure 3-31: Commercial Energy Efficiency Supply Curve**



Again it is important to recognize that cost-effectiveness, as defined by the Total Resource Cost (TRC) test or the Ratepayer Impact Measure (RIM) test, cannot be determined exclusively from these supply curves because the value of both energy and demand savings must be integrated when comparing to supply-side alternatives.

### *3.5.3 Industrial Sector Results*

The total technical potential for energy savings in the industrial sector of the FEECA utilities is estimated to be approximately 2,108 GWh, which equates to 18% of current baseline industrial electricity consumption. As Figure 3-32 shows below, technically feasible energy efficiency opportunities in the food processing sector account for 18% of the total technical potential for industrial energy savings, with the remaining potential fairly well distributed across the other 15 industrial sectors analyzed. As was the case in the residential and commercial analyses, this distribution of the total technical potential for industrial energy savings largely reflects the distribution of baseline electricity consumption across industrial subsectors.

**Figure 3-32: Estimated Breakdown of Total Technical Potential for Industrial Energy Savings by Subsector (2,108 GWh)**

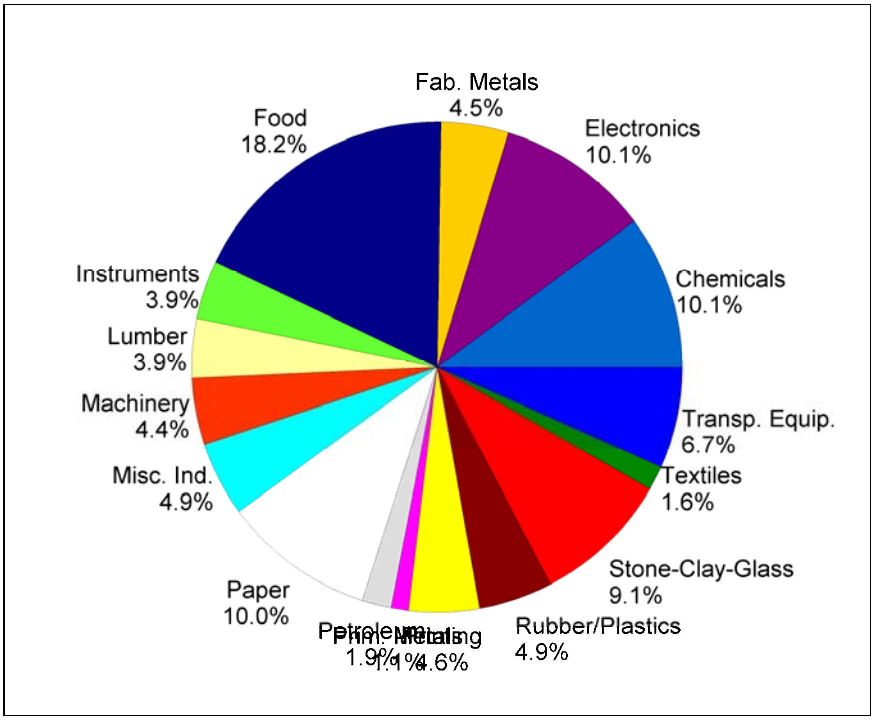
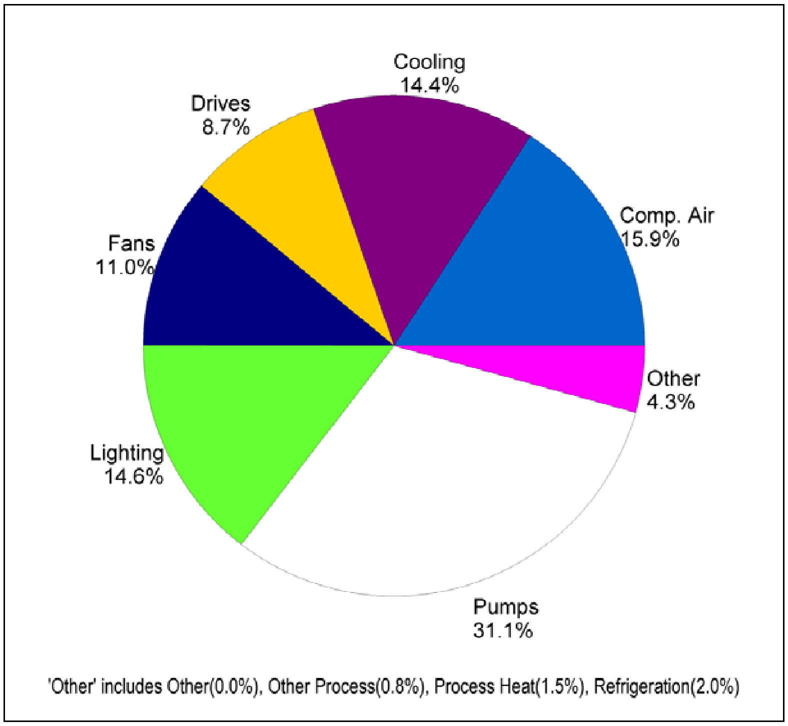


Figure 3-33 shows the breakdown of the total technical potential for energy savings in the industrial sector by end use. As the Figure shows, more than 30% of the total technical potential for industrial energy savings is derived from measures effecting industrial pumping systems, while measures effecting lighting, space cooling, and compressed air systems each account for roughly 15% of total technical potential. Measures effecting fans and drive systems account for slightly smaller but still significant shares of total industrial technical potential, while measures effecting process heat, other process loads, and refrigeration account for the remaining 4% of total technical potential.

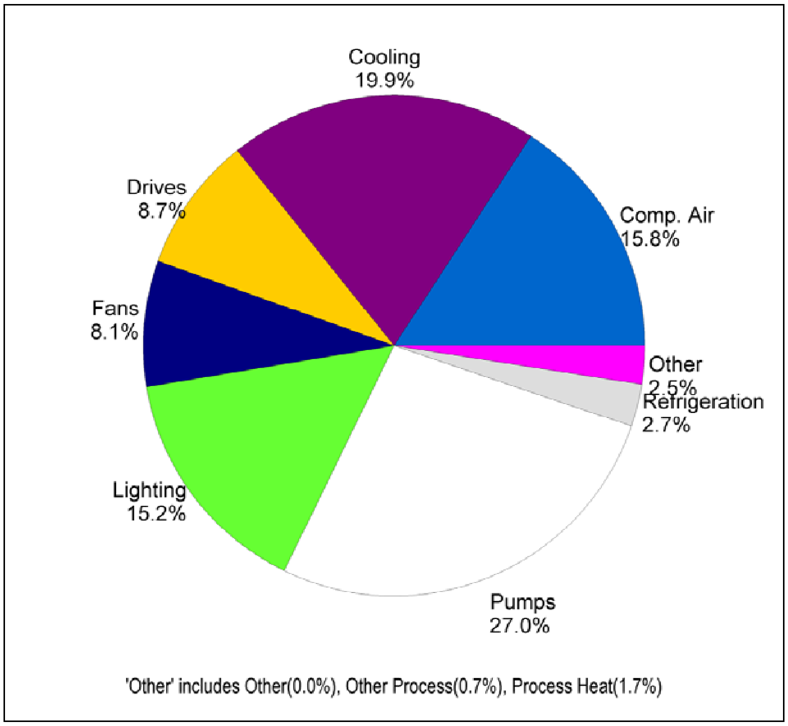
The key measures driving the technical potential results for industrial pumps include pump controls, adjustable-speed drives for pump motors, and pump system optimization measures. In lighting and space cooling, the key measures driving technical potential in the industrial sector are largely the same as those in the commercial sector – i.e. CFLs, premium T8 lamps, electronic ballasts, occupancy sensors, and high-bay T5 lamps in lighting and high-efficiency chillers, packaged DX systems, and hybrid desiccant-DX systems in space cooling. In compressed air and industrial fan systems, the key measures that drive technical potential are adjustable-speed drives, system controls, system optimization measures, and operation and maintenance (O&M) measures.

**Figure 3-33: Estimated Breakdown of Total Technical Potential for Industrial Energy Savings by End Use (2,108 GWh)**



From a summer peak demand perspective, the total technical potential for system peak demand savings in the industrial sector is estimated to be 265 MW or 13% of current baseline summer system peak demand. Figure 3-34 shows the breakdown of summer peak demand savings potential in the industrial sector by end use. As the Figure shows, the end-use shares of summer peak savings potential are largely similar to the end-use shares of annual energy savings potential, with the exception that measure effecting lighting and space cooling account for slightly larger shares of potential summer peak demand savings compared to annual energy savings. In the industrial sector, this result reflects the relatively high coincidence of space cooling and interior lighting loads with the system summer peak period and the comparatively flat nature of most other industrial end-use loads which are driven principally by batch process scheduling and operations rather than occupancy or weather.

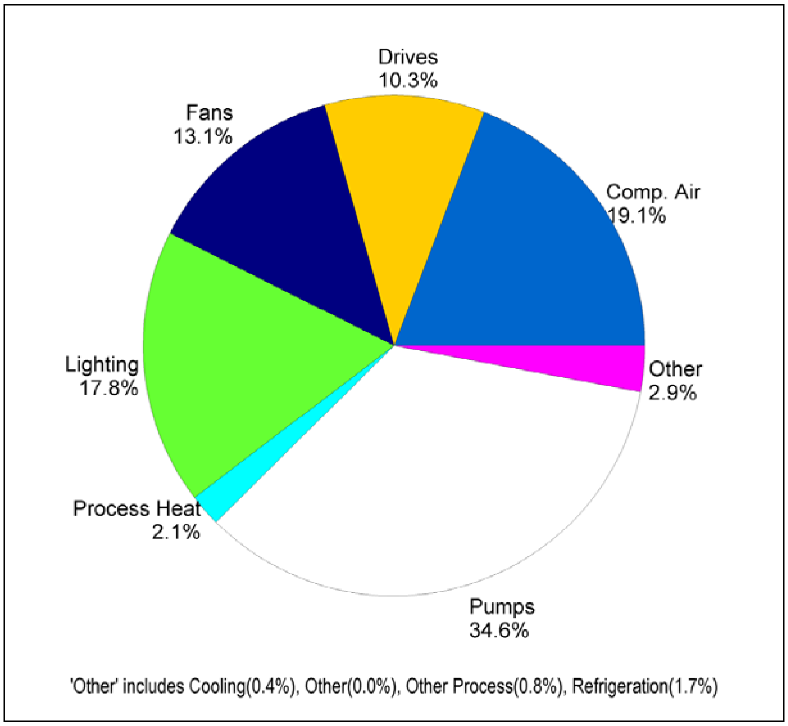
**Figure 3-34: Estimated Breakdown of Total Technical Potential for Industrial Summer System Peak Demand Savings by End Use (265 MW)**



'Other' includes Other(0.0%), Other Process(0.7%), Process Heat(1.7%)

From a winter peak demand perspective, the total technical potential for system peak demand savings in the industrial sector is estimated to be 217 MW or 17% of current baseline winter system peak demand. Figure 3-35 shows the breakdown of winter peak demand savings potential in the industrial sector by end use. As the Figure shows, pumping, lighting, and compressed air measures again account for the largest shares of total peak savings potential. However, in contrast to the summer peak savings and annual energy savings results, measures effecting space cooling account for an insignificant share of total winter peak savings potential. These results again largely reflect the comparatively flat nature of most industrial end-use loads in combination with the low coincidence between industrial space cooling loads and the winter system peak period, which typically occurs in the morning hours.

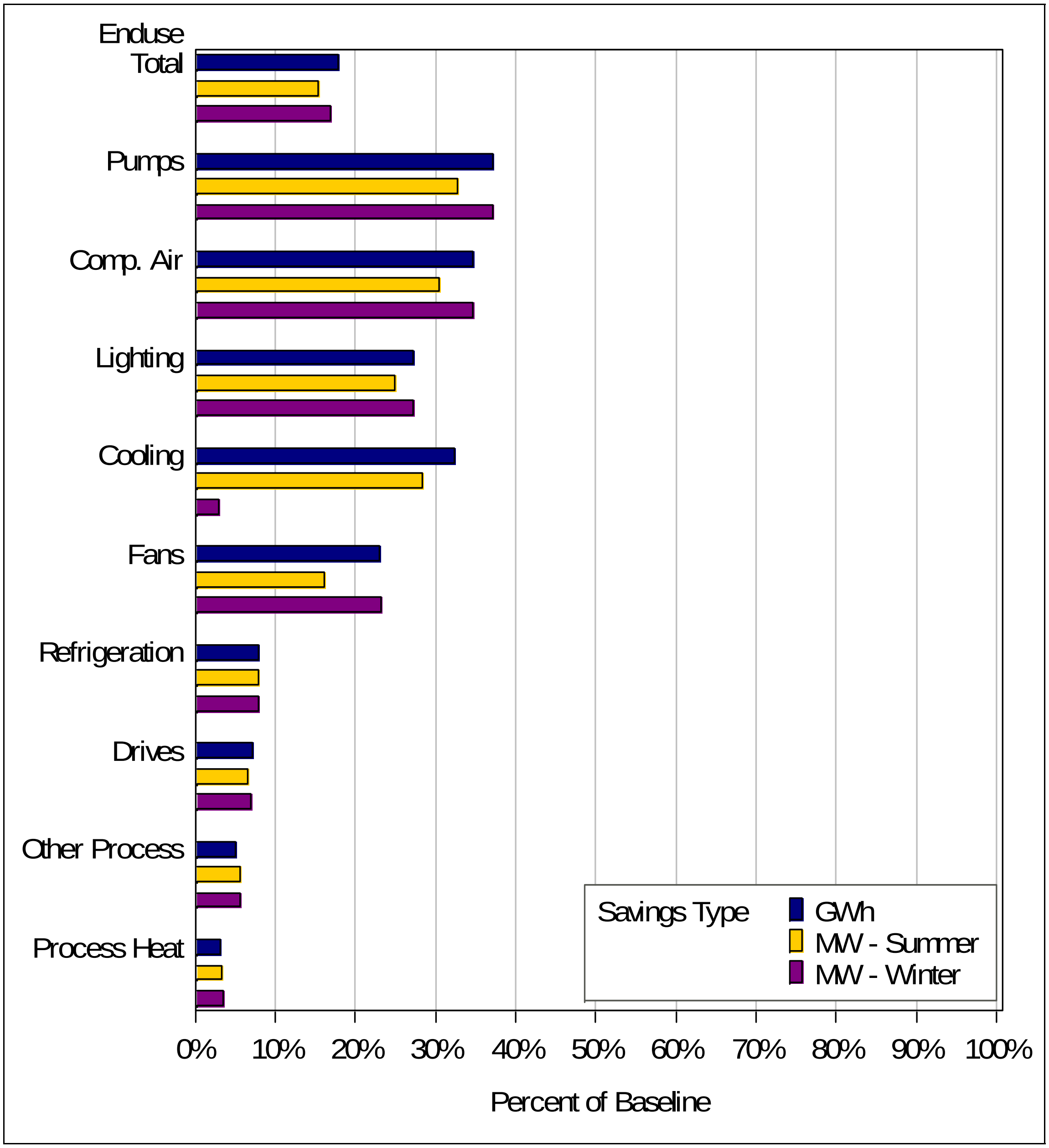
**Figure 3-35: Estimated Breakdown of Total Technical Potential for Industrial Winter System Peak Demand Savings by End Use (217 MW)**



In the preceding figures, technical potential was displayed across end uses relative to total technical potential in the industrial sector. Figure 3-36 again presents technical potential for energy and peak demand savings by end use, but this time relative to baseline energy consumption and peak demand for each respective end use in order to illustrate the relative size of potential end-use savings estimated in our industrial analysis.

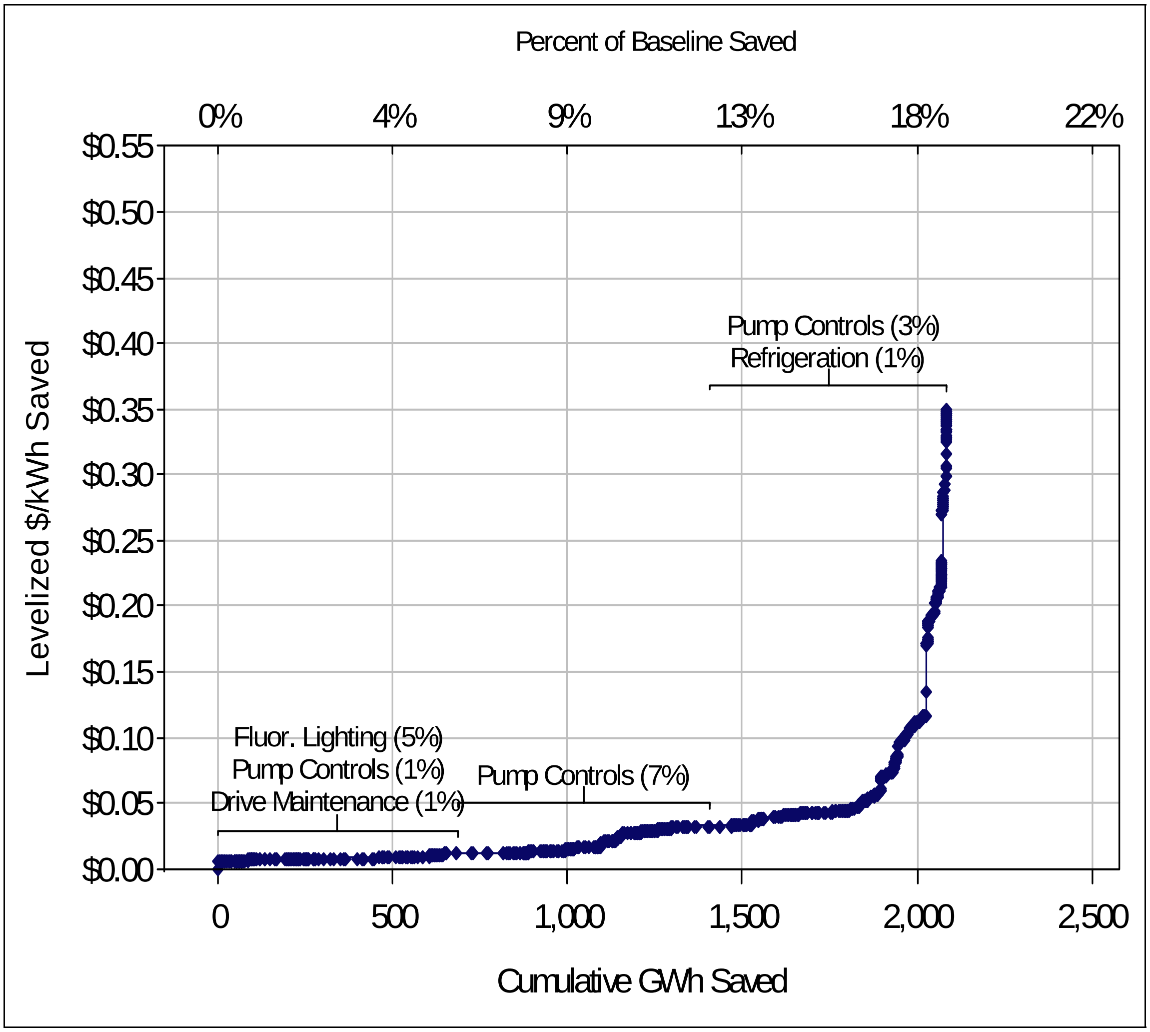
In contrast to the analogous results in the residential and commercial analyses, Figure 3-36 shows that the largest potential reductions in end-use baseline consumption and peak demand occur in the end uses that also contribute to the majority of total technical potential in the industrial sector, i.e. pumping, compressed air systems, lighting, and space cooling systems.

**Figure 3-36: Total Technical Potential for End-use Energy and Peak Demand Savings in the Industrial Sector Compared to Baseline Energy Consumption and Peak Demand**



Finally, Figure 3-37 shows the marginal costs of industrial energy efficiency measures and their relative contributions to total technical potential in the form of a supply curve. From a levelized cost perspective (i.e. $/kWh saved), the Figure shows that premium T8 lamps and pump controls are among the least expensive measures analyzed in this study, and together account for roughly 20% of total technical potential in the industrial sector. The detailed marginal cost and savings data embedded in this Figure are shown for each measure in Appendix D in each of the utility-specific project reports (forthcoming).

**Figure 3-37: Industrial Energy Efficiency Supply Curve**



Again it is important to recognize that cost-effectiveness, as defined by the Total Resource Cost (TRC) test or the Ratepayer Impact Measure (RIM) test, cannot be determined exclusively from these supply curves because the value of both energy and demand savings must be integrated when comparing to supply-side alternatives.

### *3.5.4 Aggregate Results*

Across all the end-use demand sectors analyzed in this study, the total technical potential for electric energy savings in the service territories of the seven FEECA utilities is estimated to be approximately 58,616 GWh which equates to 34% of current baseline annual electricity consumption. The total technical potential for summer peak demand savings is estimated to be 14,375 MW or 42% of current baseline summer system peak demand. Finally, the total technical potential for winter peak demand savings is estimated to be 8,883 MW or 28% of current baseline winter system peak demand. As Table 3-5 shows below, energy efficiency opportunities in the residential sector account for well over half of total technical potential for electric energy savings and more than 70% of total technical potential for summer and winter peak demand savings in the FEECA utilities.

**Table 3-5: Summary of the Technical Potential Results for the FEECA Utilities**

| | **Annual Energy** | | | **Summer System Peak** | | | **Winter System Peak** | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Baseline** | **Technical Potential** | | **Baseline** | **Technical Potential** | | **Baseline** | **Technical Potential** | |
| | **(GWh)** | **(GWh)** | ***(%)*** | **(MW)** | **(MW)** | ***(%)*** | **(MW)** | **(MW)** | ***(%)*** |
| Residential | 94,745 | 36,584 | *38.6%* | 22,263 | 10,032 | *45.1%* | 22,728 | 6,461 | *28.4%* |
| Commercial | 65,051 | 19,924 | *30.6%* | 9,840 | 4,079 | *41.5%* | 7,490 | 2,206 | *29.5%* |
| Industrial | 11,877 | 2,108 | *17.7%* | 1,721 | 265 | *12.8%* | 1,289 | 217 | *17.5%* |
| **Total** | **171,672** | **58,616** | ***34.1%*** | **33,825** | **14,375** | ***42.5%*** | **31,506** | **8,883** | ***28.2%*** |

When interpreting the aggregate results of any bottom-up potential study, it is important to understand that the overall results are largely a reflection of the baseline end-use assumptions and the scope and characteristics of the specific energy efficiency measures analyzed. The same is true for this study, in that the results presented above reflect several unique aspects of Florida's customer base and the corresponding energy efficiency opportunities considered for analysis.

First, the residential sector in Florida is nearly all-electric, with currently very little natural gas use. The sole exception is Gulf Power's service territory where approximately 20% of homes use natural gas for space heating and water heating. This aspect of Florida's residential customer base drives much of the winter system peak demand and corresponding technical potential for winter peak demand savings. This aspect also explains why total technical potential for energy and peak demand savings is largely concentrated in the residential sector.

Second, while the relative share of potential savings from HVAC measures primarily reflects the relative share of HVAC loads, the results presented for HVAC measures also reflect the larger number of HVAC measures considered in the analysis compared to measures effecting other end uses. This slight bias towards HVAC measures in the final measure list was a direct result of the availability of previous independent and utility-sponsored research that supported a larger number of HVAC measures compared to other end use measures.

Third, it is important to understand that the fairly aggressive technical potential estimates for both electric energy savings and summer peak demand savings very much reflect the wide scope of the measures considered for this study. Specifically, it should be understood that the results include savings estimates for several advanced technologies that are likely to face significant near-term constraints in market availability and distributor/contractor capacity. These advanced technologies include SEER 19 central air conditioners, SEER 17 air-source heat pumps, geothermal heat pumps, heat pump water heaters, hybrid-desiccant DX systems, and PV-powered pool pumps.

### *3.5.5 Uncertainty in EE Potential Forecasts*

In addition to understanding the unique aspects of Florida's customer base and the energy efficiency measures analyzed in this study, it is also important to understand the uncertainty associated with the technical potential savings estimates presented above. While quantitative assessments of uncertainty were beyond the scope of this study, we present a brief discussion of the nature of uncertainty in energy efficiency potential forecasts and provide qualitative assessment of the relative amount of uncertainty embedded in this study's results based on our assessment of the quality of the baseline and measure data developed for this project.

There are two principal classes of uncertainty underlying the technical potential results presented above and any assessment of technical potential. The first area is uncertainty associated with estimates of the current characteristics of end-use electricity consumption and energy efficiency measure data (hereafter, "current market" uncertainty). The second area concerns estimates of the future potential for energy efficiency, which is effected by the uncertainty in the first area, as well as uncertainty in future energy prices, electric load forecasts, and changes in market and energy efficiency measure characteristics over time (hereafter, "forecast" uncertainty). While there is considerable overlap in the underlying data associated with both types of uncertainty, it is useful to separate these classes of uncertainty for two reasons. First, this study attempts to reduce the effects of the two types of uncertainty through different approaches. Second, although both types of uncertainty could be reduced through further research, the types of research necessary are significantly different across the two classes.

With respect to the first class of uncertainty noted above – current market uncertainty – readers and users of this study should recognize that estimates of energy efficiency potential involve a process of modeling the substitution of energy efficiency equipment and systems in place of existing energy equipment and systems. As such, this process starts with estimates of current equipment characteristics and energy use by end use and market segment. These data typically are provided as inputs to energy efficiency potential studies and are, in the best of cases, developed from up-to-date and statistically accurate studies that involve detailed collection of technology market shares and comprehensive modeling of end-use consumption and peak demand. When these data are absent, outdated, or inaccurate, the uncertainty in estimates of current equipment shares and associated consumption and peak demand directly impact estimates of energy efficiency potential because energy efficiency potential varies by equipment type and market segment. For this study, Itron was able to leverage considerable research previously conducted by the FEECA utilities to quantify and understand end-use energy consumption and peak demand. In this sense, there is considerably less uncertainty in the baseline end-use consumption and peak demand data compared to many recent bottom-up potential studies conducted by Itron.

Energy efficiency measure data are the second type of data associated with current market uncertainty. Examples of energy efficiency measure data include the current incremental costs and savings of energy efficiency measures, the useful lives of those measures, their current market saturation levels, and estimates of the fraction of the market for which energy efficiency equipment and systems could substitute for existing equipment and systems. Fortunately, considerable data on the costs and savings associated with energy efficiency measures were available for this study. This is attributable to the considerable number and quality of energy savings measurement and evaluation studies that have been conducted in Florida, both by the FEECA utilities themselves and by third parties such as Itron and FSEC. Nonetheless, uncertainties exist to varying degrees in estimates of costs and savings by individual technology. In general, new measures (e.g., those on the market for two years or less) have somewhat greater uncertainty in costs and savings than measures that have been on the market for longer periods (e.g., 3 years or more). The most significant uncertainty in the measure-level data is also in the area of measure saturation. Measure-level saturation data typically come from the same types of sources discussed above for baseline equipment consumption and saturation data.

With regard to forecasting uncertainty, it should be somewhat obvious that forecasts of energy efficiency potential end electricity demand are also effected by current market uncertainty. In any forecasting process, one wants to begin with as accurate an assessment of current conditions as possible; errors in estimates of current conditions are otherwise carried forward and exacerbated. However, even with perfect data on current market conditions, forecasts are subject to their own uncertainties by their very nature.

For this study, the key areas of forecast uncertainty are:

- future end-use consumption levels and equipment shares;
- future incremental costs and savings for measures on the market today;
- future incremental costs and savings for measures not on the market today but likely to be available over the ten-year forecast period (no such measures are included in this study);
- future benefit-cost ratios for energy efficiency measures, which, in addition to uncertainty in future measure costs and savings, are a function of uncertainty in:
  - future energy and capacity prices, both retail and wholesale, including those associated with constrained areas,
  - the future value of any environmental externalities, and
  - the future level of the discount rate used in financial analyses of efficiency measures

# 4

# Technical Potential for Peak Demand Savings from Demand Response

In this chapter, we provide an overview of demand response (DR) concepts, program typology, and the various approaches that can be used to estimate DR potential. We then describe the specific approach and key assumptions used in this study. Finally, we present our estimates for technical potential from DR programs in the seven FEECA utilities by customer class (i.e. residential, commercial, and industrial) and season (i.e. summer and winter). The estimates presented here are based on what could be done from a technical feasibility perspective with respect to installing DR-enabling equipment and communications infrastructure to reduce peak load, as opposed to what might be best to do optimally from an economic or operations perspective. Estimates for economic and achievable levels of DR will be developed in the next phase of this project.

## 4.1 Characterizing the Demand Response Resource

The U.S. Department of Energy (DOE) and Federal Energy Regulatory Commission (FERC) have defined DR as "changes in electric usage by end-use customers from their normal consumption patterns in response to changes in the price of electricity over time, or to incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized" (FERC, 2008). In this section we provide an overview of the typology of DSM resources and their key characteristics and a discussion of the two commonly used methodologies for estimating DR potential.

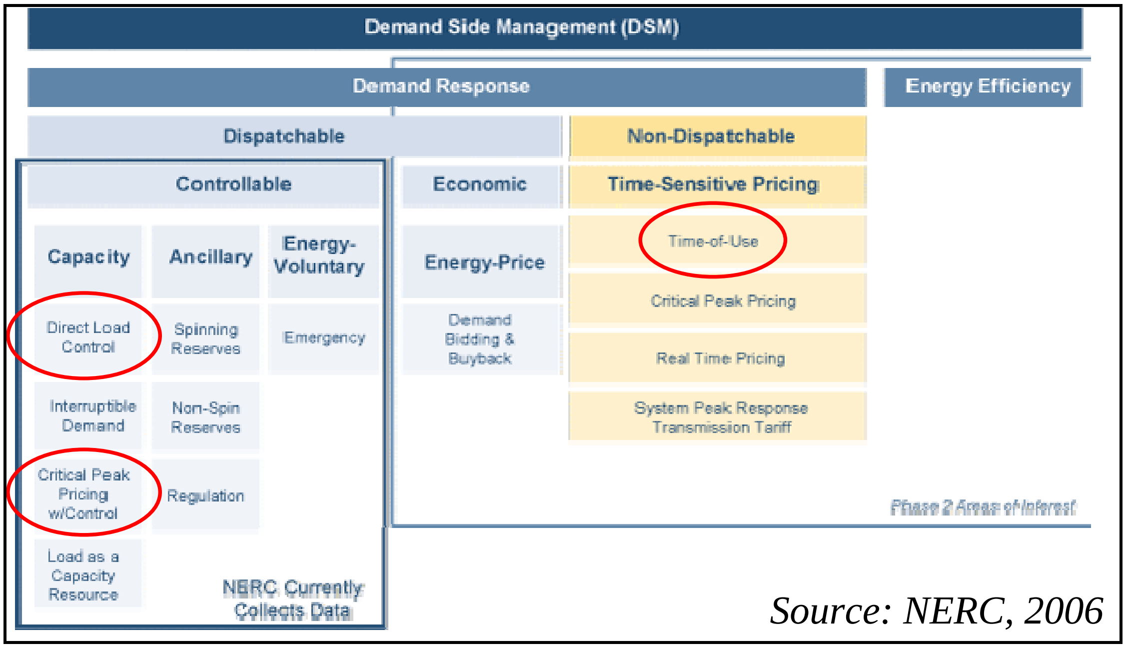
### *4.1.1 DR Program Typology*

The North American Electric Reliability Corporation (NERC) has developed a typology of various DSM resources (see Figure 4-1). There are two main types of DSM resources – energy efficiency (EE) and DR. DR resources can be further classified in two categories – dispatchable and non-dispatchable. Dispatchable resources refer to those resources that can be deployed during a DR event triggered by the load-serving entity (LSE) or the system operator. In contrast, the use of non-dispatchable resources is based purely on the customer's decision with no input from the LSE or system operator.

Based on the discussions with stakeholders in the Florida study collaborative, three types of DR programs were considered for this analysis – direct load control (DLC), critical peak pricing (CPP) with control, and time-of-use (TOU) tariffs. DLC programs are defined as a demand response activity in which the program sponsor remotely shuts down or cycles a customer's electrical equipment (e.g. air conditioner or water heater) on short notice. TOU tariffs typically establish two or more periods within a day that reflect hours when the system load is higher (peak) or lower (off-peak), and charge a higher rate during peak hours. Some TOU tariffs may also have a third period with a "shoulder period" rate. A CPP tariff specifies a very high price for electricity use only when needed to manage critical peak problems such as system contingencies or when the LSE faces extremely high prices or cost of energy. Unlike TOU tariffs where the peak/off-peak periods and prices are in place every day of the year (or season), the critical peak events can occur on any day of the year (or season) as needed by the LSE.

One utility in Florida also offers real time pricing (RTP) tariff to its large customers. An RTP tariff consists of retail electricity prices that vary at least hourly during the day, directly reflecting the underlying cost of electricity. CPP and RTP tariffs are referred to as "dynamic" pricing tariffs given their uncertain (price levels and/or timing) nature.

**Figure 4-1: DSM Resource Typology**[9]



Source: NERC, 2006

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[9] http://www.nerc.com/page.php?cid=4|53|56

### 4.1.2 Difference Between Energy Efficiency and Demand Response

There are several key differences between EE and DR even though both are defined as DSM resources. These key differences manifest themselves in three specific dimensions of EE and DR interventions: 1) the nature of customer participation, 2) the nature of costs and benefits, and 3) the predictability of costs and benefits.[10] We provide more detailed description of each of these key differences below:

- **Nature of customer participation.** Fundamentally, DR consists of a two-step process where the customer has to decide whether to enroll in the DR program and, after enrolling, whether to reduce load in response to specific events, price signals, and/or incentives. In contrast, EE is a one-step process where the customer needs to make just one decision, whether to invest in more efficient technology and/or processes.

- **Nature of cost and benefits.** The costs and benefits of participating in DR programs and reducing load in response to specific events and/or incentives depend substantially on customer behavior. The opportunity costs and energy service tradeoffs can vary greatly depending on what the specific customer DR strategy is. In contrast, energy service levels are assumed to be constant for EE interventions, and therefore the costs and benefits of EE measures are relatively constant in nature assuming past consumption patterns continue going forward.

- **Predictability of costs and benefits.** In some types of DR programs, customer response may vary from event to event. Consequently, the stream of costs and benefits is inherently difficult to predict. In comparison, the first costs and the stream of benefits from EE measures are relatively predictable since they largely depend on equipment characteristics and known consumption patterns.

### 4.1.3 Approaches for Estimating DR Potential

Two approaches – “engineering” and “economic” – have been used for estimating the DR potential. The “engineering” approach relies on a bottom-up engineering accounting of DR potential by customer end-use and DR-enabling technology. It is analogous to the approach used for estimating EE potential and is readily applicable to utility-controlled DR resources (e.g. DLC). One potential drawback of the “engineering” approach is that the analysis does not explicitly model the customer’s behavior and focuses on the end-uses and DR-enabling technologies.[11] For example, a customer may reduce lighting during one event and reduce

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[10] For detailed description, see Goldman et al. (2007).

[11] It should be noted that customer behavior is a factor in most of Florida’s DLC programs only as far as making the decision to participate and the choice of the level of cycling. In these programs, once the customer has made the decision to participate and agreed to a specific level of cycling customer behavior is not a factor in modeling the technical potential.

HVAC load for another event despite no change in the availability of DR-enabling technology between the two events. Consequently, the load reduction achieved may differ substantially between the two events.

Given the differences in EE and DR resources, especially, for customer-controlled DR resources (e.g. CPP) – the “economic” approach may provide more useful estimates of DR potential. The “economic” approach relies on empirical modeling of the customer’s behavior in response to economic signals (e.g. dynamic prices, and incentives). The “economic” approach consists of estimating price elasticities from the consumption data of customers exposed to varying prices or incentives. The price elasticities are then used for developing load impact curves (i.e. load reductions expected at various price/incentive levels).[12] One potential drawback of the “economic” approach is that the analysis does not explicitly include end-use and DR-enabling technology information about the customer and focuses on the customer’s overall consumption. However, customer surveys have suggested that level of load reduction achieved is, typically, correlated with the consumption of a subset of end-uses instead of the overall consumption.

Since we are focusing only on the technical potential from DR programs in this analysis, the “engineering” approach was used because it allows for explicit accounting of end-uses and DR-enabling technologies that are most relevant to reducing load in response to events and/or incentives.

Developing technical potential estimates for DR programs requires making judgments about the fraction of buildings that are likely to be integrated into new communications networks, (ranging from simple one-way paging to advanced communications networks) the rate choices available to these customers, and the advanced DR technologies likely to be available to each customer class. In this analysis, the availability of communication networks, advanced DR technologies, and dynamic pricing tariffs is driven by technical feasibility of deployment over a 10-year period without consideration of policy or economic factors.

The choice of communication technology decides how a DR event and/or price information is sent from the LSE/system operator to the customers. Three alternative communication technologies were considered – one-way, two-way, and advanced metering infrastructure (AMI). One-way technology relies on utility sending a signal to customer (or device on customer premises) that triggers a load reduction. There is no communication from customer

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[12] The economic analysis approach is described in detail in Goldman et al. (2007). This methodology has been used routinely for evaluating CPP-type programs in many parts of the U.S. and various examples are discussed in detail in Faruqui and Sanem (2008).

to back to the LSE. For two-way technology, the communication goes both ways between LSE and the customers. However, there is no link to a smart meter. AMI is defined by FERC as a "metering system that records customer consumption (and possibly other parameters) hourly or more frequently and provides for daily or more frequent transmittal of measurements over a communication network to a central collection point".[13]

DR-enabling technologies considered in this analysis include switches for cycling or shedding space cooling/heating, smart thermostats of space cooling/heating, and automated control strategies for various end-uses. Cycling switches are a well-known technology that has been used by many utilities across the U.S. for the past three decades. Smart thermostat is a relatively new technology where the household thermostat can be programmed by the customer to raise or reduce the set-point automatically based on the signal received from the LSE. Automated control strategies have been developed recently and consist of link to a customer facility's energy management control systems (EMCS) with external utility-generated price or emergency signals. The signals initiate pre-programmed, customer-defined strategies to shift, reduce or shed loads for brief periods of time.

Three types of rate structures were considered in this analysis - flat rate, TOU, and CPP. In previous sections, the definitions for TOU and CPP tariffs have been provided.

The peak savings estimates for DR technical potential presented here are incremental to the existing DR resources – in other words, it is assumed that customers enrolled in existing DR programs will continue on those programs and only customers that are not currently enrolled in any existing DR program are eligible for the DR programs modeled in this analysis.

Strategies used by customers for responding to events and/or prices can include foregoing consumption or shifting consumption from event (or peak period) to off-peak period or a combination of the two. Some DR programs may allow the customer to respond to events and/or prices by shifting their consumption from the grid to an onsite generator. For this study, this strategy of using onsite generators was excluded from the analysis of DR technical potential. This decision was based primarily on the difficulty in meaningfully bounding the technical feasibility of using onsite generators as a DR strategy across large segments of the residential, commercial, and industrial sectors without introducing significant uncertainty to the analysis.

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[13] FERC (2008).

## 4.2 Methodology and Assumptions

In this section we describe the approach used for developing the DR technical potential in this analysis, the key assumptions about DR measure data, and a brief description of the various DR-enabling technologies and the relevant tariff designs.

The core equation used for estimating DR technical potential is:

$$\begin{array}{c}\text{Technical}\\ \text{Potential=}\\ \text{(MW)}\end{array}\ \overbrace{\left(\begin{array}{c}\text{Units of}\\ \text{Consumption}\\ \text{(Households)}\end{array}\right)\left(\begin{array}{c}\text{End-use Tech}\\ \text{Saturation}\\ \text{(\%)}\end{array}\right)\left(\begin{array}{c}\text{Base Tech}\\ \text{EUI}\\ \text{(kW per}\\ \text{Household)}\end{array}\right)}^{\textit{Baseline Data}}\overbrace{\left(\begin{array}{c}\text{Communication}\\ \text{Network}\\ \text{(\%)}\end{array}\right)\left(\begin{array}{c}\text{Tariff}\\ \\ \text{(\%)}\end{array}\right)\left(\begin{array}{c}\text{DR}\\ \text{Technology}\\ \text{(\%)}\end{array}\right)\left(\begin{array}{c}\text{Demand}\\ \text{Reduction}\\ \text{(\%)}\end{array}\right)}^{\textit{DR Measure Data}}$$

This equation is analogous to the equation used for estimation the EE technical potential. The baseline data used for estimating DR technical potential is the same as that used for estimating the EE technical potential. As such, it should be understood that the technical potential estimates for EE and DR are not strictly additive, since efficiency improvements reduce the baseline peak demand available to be reduced in DR programs. Such interactions will be addressed in the economic and achievable potential forecasting phases of this study. For details about the data sources and development of the end-use baseline data see Section 3.3.

In the previous section, we described the three key factors that determine the DR technical potential – the availability of communication networks, advanced DR technologies, and dynamic pricing tariffs. In order to estimate technical potential, therefore, it is necessary to develop estimates for each of these factors for each DR program analyzed. For DR programs and strategies beyond traditional DLC programs, however, comprehensive data to support such estimates was not readily available for this study, largely due to the relative newness of advanced DR technologies, dynamic tariffs, and advanced communications networks. Additionally, the scope of this study did not support primary data development for advanced DR measures. As such, Itron developed an assumption-driven approach in order to develop the DR measure data required to estimate technical potential. In this approach, Itron developed an initial set of straw-man values for each factor that were then presented to all members of the Florida study collaborative. Based on feedback, the final parameter values for each factor were then developed and carried forward in Itron's forecast. The analysis results were then presented to the Florida collaborative and other stakeholders, and Itron incorporated these comments in the results shown in this chapter. The final set of key assumptions are presented and described in more detail below.

In terms of the availability of AMI, all seven FEECA utilities indicated that it was technically feasible for 100% of the customers in their service territories to be on AMI networks by 2019 (the last year of the 10-year forecast period). From this perspective, utilities would then, in theory, have the ability to administer any type of dynamic pricing tariff to all of its customers.[14]

Access to DR-enabling technology depends on several factors such as promotion, awareness, technical assistance, and others. Table 4-1 and Table 4-2 show the default values of DR control technology penetration for DR-relevant end-uses developed for the residential and commercial and industrial (C&I) customer classes, respectively. The actual parameter values used in the utility-specific analyses vary by a small amount from the parameter values shown in Table 4-1 and Table 4-2, reflecting utility-specific preferences. Note that for industrial customers, it was assumed that only HVAC, lighting, and other non-process end-uses are available for demand response. Each of the DR control technologies analyzed in this study is described in more detail below.

In a traditional DLC program, LSEs or system operators can remotely control switches on A/C and space heating end-uses on residential customer premises “cycle” or completely shut-down the appliance for short periods of time. These types of devices have been available for several years.

In contrast to a manual thermostat where the customer has to manually change the set-point to change the space cooling/heating load, the smart (or programmable) thermostat allows the customer to program the thermostat (similar to programming a VCR to record TV shows automatically at pre-set times) to change set-points automatically in response to a signal from the LSE/system operator and/or prices. The smart thermostat has the capability to receive and process the signal from the LSE and/or prices. Various models of smart thermostats with varying capabilities are available in the market today.

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[14] It is important to note that this assumption is not equivalent to the statement that all FEECA utilities will have 100% of their customers on AMI by 2019, but rather that it is technically feasible to have full-scale AMI networks deployed by 2019 in each of their respective territories.

### Table 4-1: Assumed Availability of DR Control Technology for Residential Customers by End Use in 2019

| End use | DR Control Technology | Percent of Eligible Customers with Access to DR Control Technology |
|---|---|---|
| **A/C (in summer) and Space heating (in winter)**[15] | Switch – Cycling Program | 20% |
| | Switch – Shedding Program | 10% |
| | Smart Thermostats | 50% |
| | In home display with peak threshold warning system and pre-set control strategies | 10% |
| **Water heating** | On-Off Switching via low-power wireless communication technology | 60% |
| | In home display with peak threshold warning system and pre-set control strategies | 10% |
| **Pool Systems** | On-Off Switching via low-power wireless communication technology | 10% |
| | In home display with peak threshold warning system and pre-set control strategies | 10% |
| **Other Household Loads** | In home display with peak threshold warning system and pre-set control strategies | 10% |

In-home displays that communicate emergency signals from LSEs to customers and can be programmed to control various household appliances such as A/C, space heaters, pool pumps, and others are relatively new technology. Similar to a smart thermostat, the in-home displays have the capability to receive and process signals from the LSE and/or prices. Unlike the smart thermostat that controls only the heating and cooling appliances, the in-home displays are capable of communicating with several appliances.

Various technologies are available today that enable reliable, cost-effective, low-power, wirelessly networked, monitoring, and control products. These technologies allow communication between the advanced electricity meters and specific end-uses such as water heaters and pool pumps. For example, a signal communicated to the customer's meter is relayed via the wireless technology to a device on the water heater that can then switch on or off the water heater in response to the signal.

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[15] Note that some but not all of these DR-control technologies control both cooling and heating equipment.

**Table 4-2: Assumed Availability of DR Control Technology for Commercial and Industrial (C&I) Customers by End Use in 2019**

| End use | DR Control Technology | Percent of Eligible Customers with Access to DR Control Technology |
|---|---|---|
| HVAC | Automated control strategies | 60% |
| | Direct load control system | 30% |
| Lighting | Automated control strategies | 60% |
| Other | Automated control strategies | 60% |

Automated control strategies for C&I customers are designed to link facility energy management control systems (EMCS) with LSE signals and/or prices. The signals and/or prices initiate pre-programmed, customer-defined strategies to shift, reduce or shed loads for brief periods of time. The Demand Response Research Center at LBNL has developed and demonstrated automated control strategies for several types of C&I facilities in recent years.[16]

Direct load control systems for C&I customers are similar to A/C and space heating cycling systems used for residential customers. These systems have typically, targeted the HVAC end-use at C&I facilities and in some cases may also target other end-uses.

The DR technical potential estimates by DR technology are additive and exclusive. For example, it is assumed that customers with A/C load will have access to only one applicable DR-enabling technology – cycling/shedding switch or smart thermostat or in-home display. Similarly for commercial and industrial customers, we assume that the customer has either an automated control strategy or a direct load control system.

In Table 4-3, we present the assumed applicability of each DR-enabling technology with various types of tariffs. For example, smart thermostats are applicable only with dynamic pricing tariffs while A/C cycling switches are applicable mainly with a flat rate.[17] Although customer decisions about choice of DR-enabling technology and tariff are dependent on each other at least to some extent – for the sake of estimating the technical potential we treat them as independent decisions.

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[16] http://drrc.lbl.gov/drrc-5.html

[17] One utility noted that the customer can choose to either enroll in a direct load control type program on a flat rate OR be on a time-varying tariff but not both.

### Table 4-3: Assumptions About Combinations of DR Control Technologies and Tariffs in 2019

| DR Control Technology | Compatible Tariffs |
|---|---|
| ***Residential:*** | |
| A/C Cycling | Flat rate |
| A/C Shedding | Flat rate |
| Smart Thermostats for A/C | CPP/TOU |
| On-Off Switching via low-power wireless communication technology for water heating and pool systems | CPP/TOU |
| In-home displays and pre-set control strategies | CPP/TOU |
| ***Commercial/Industrial:*** | |
| Automated control strategies | CPP/TOU |
| Direct load control system | Flat rate and CPP/TOU |

At this point, most of the customers of all seven utilities are on flat rates. A few utilities have small portions of their customers on TOU, CPP, and RTP rates. In order to examine the effect of dynamic pricing tariffs on DR potential, we developed two scenarios – high and low – with respect to the availability of CPP tariffs – see Table 4-4. Five utilities indicated that the two main pricing tariffs that are likely to exist are CPP/TOU and flat rate. The two scenarios serve as bounds for this analysis and do not represent the likely market penetration of CPP tariffs.

### Table 4-4: Scenarios for Penetration of Dynamic Pricing Tariffs by Customer Class in 2019

| Sector | CPP Penetration | Flat Rate Penetration | Total |
|---|---|---|---|
| ***Low penetration of dynamic pricing tariffs*** | | | |
| Residential | 10% | 90% | 100% |
| C&I | 10% | 90% | 100% |
| ***High penetration of dynamic pricing tariffs*** | | | |
| Residential | 50% | 50% | 100% |
| C&I | 35% | 65% | 100% |

Finally, the estimated average percent reduction in peak demand from each type of DR-enabling technology is shown in Table 4-5 and Table 4-6 and for residential and C&I

customers, respectively. The peak reduction estimates for AC cycling and shedding programs were derived from recent evaluations of DLC programs in Florida. For the other DR control technologies, Itron developed peak load reduction estimates from the available literature, primarily Faruqui and Sanem (2008).

### Table 4-5: Average Percent Reduction in Residential Peak Demand Due to DR-Enabling Technology By End Use

| End Use | DR Control Technology | Average Percent Reduction in End-use Peak Demand |
|---|---|---|
| A/C (in summer) and Space heating (in winter)[18] | Switch – Cycling Program | 31% |
| | Switch – Shedding Program | 100% |
| | Smart Thermostats | 36% |
| | In home display with peak threshold warning system and pre-set control strategies | 36% |
| Water heating | On-Off Switching via low-power wireless communication technology | 90% |
| | In home display with peak threshold warning system and pre-set control strategies | 36% |
| Pool Systems | On-Off Switching via low-power wireless communication technology | 90% |
| | In home display with peak threshold warning system and pre-set control strategies | 36% |
| Other Household Loads | In home display with peak threshold warning system and pre-set control strategies | 36% |

### Table 4-6: Average Percent Reduction in Commercial/Industrial Peak Demand Due to DR-Enabling Technology by End Use

| End Use | DR Control Technology | Average Percent Reduction in End-use Peak Demand |
|---|---|---|
| HVAC | Automated control strategies | 34% |
| | Direct load control system | 60% |
| Lighting | Automated control strategies | 34% |
| Other | Automated control strategies | 34% |

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[18] Note that some but not all of these DR-control technologies control both cooling and heating equipment.

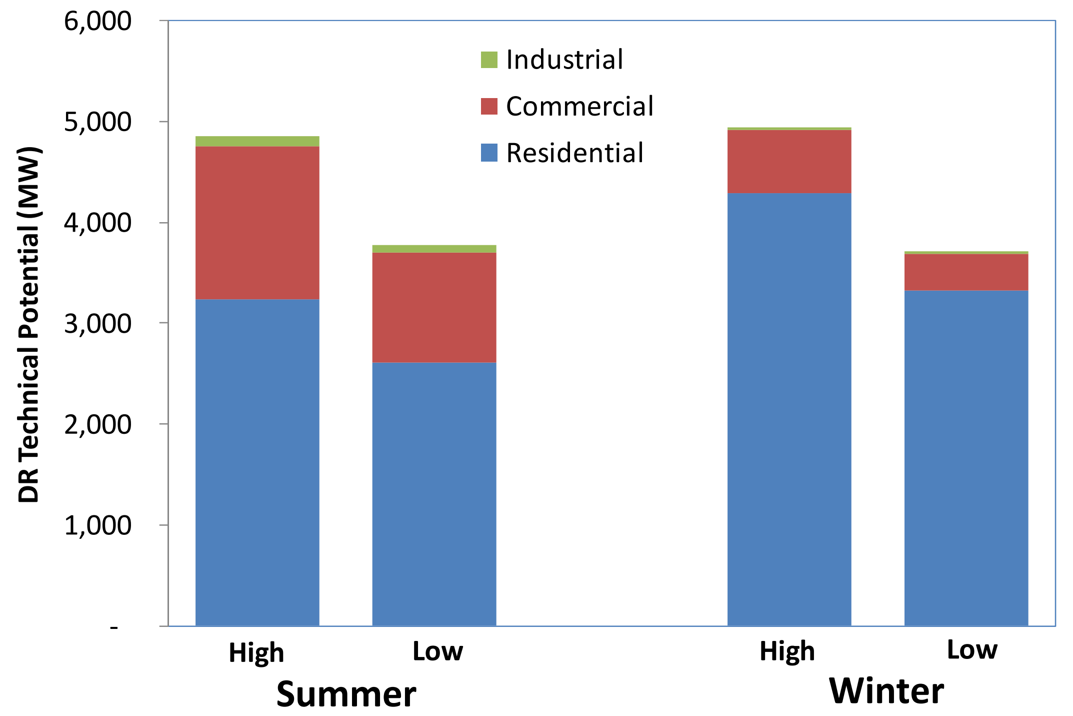
The assumptions presented above describe a subset of scenarios that could be observed in reality. There are potentially large uncertainties associated with the predicted customer behavior or response to different types of program design, and levels of tariff (both structure and level) that can lead to wide range in actual load reductions from event to event. For example, Faruqui and Sanem (2008) compared 17 residential pricing programs across the U.S. and estimated that amount of load reduction from customers with enabling technologies and subject to TOU or CPP rate varies from 27 % to 44%.

## 4.3 Peak Demand Savings Results

In this section we provide the results of the analysis at an aggregate level. The DR technical potential is presented by customer class, season, scenario, and type of DR-enabling technology. We also provide a comparison of the forecasted DR technical potential with the actual 2007 system peak demand and the existing DR resources in the FEECA utilities.

As Figure 4-1 and Figure 4-2 shows, the total estimated DR technical potential incremental to the existing DR resource in the FEECA utilities ranges from 4,779 MW in the high scenario to 3,709 MW in the low scenario for summer peak season and 4,856-3,644 MW for winter peak season. This incremental DR resource compares to 2,681 MW of existing DR resource reported by the FEECA utilities. The residential sector accounts for approximately two-thirds of the total DR technical potential during summer under the “high” scenario. This trend is even more pronounced during winter and under the “low” scenario where residential sector accounts for ~90% of the incremental resource. Relative to baseline system peak demand in 2007, the total incremental DR technical potential for the FEECA utilities ranges from 10.7% to 13.7% in summer and from 11.3% to 15% in winter. The existing DR resource is equivalent to 7.7% of 2007 summer system peak demand.

**Figure 4-2: DR Technical Potential by Customer Class and Scenario**

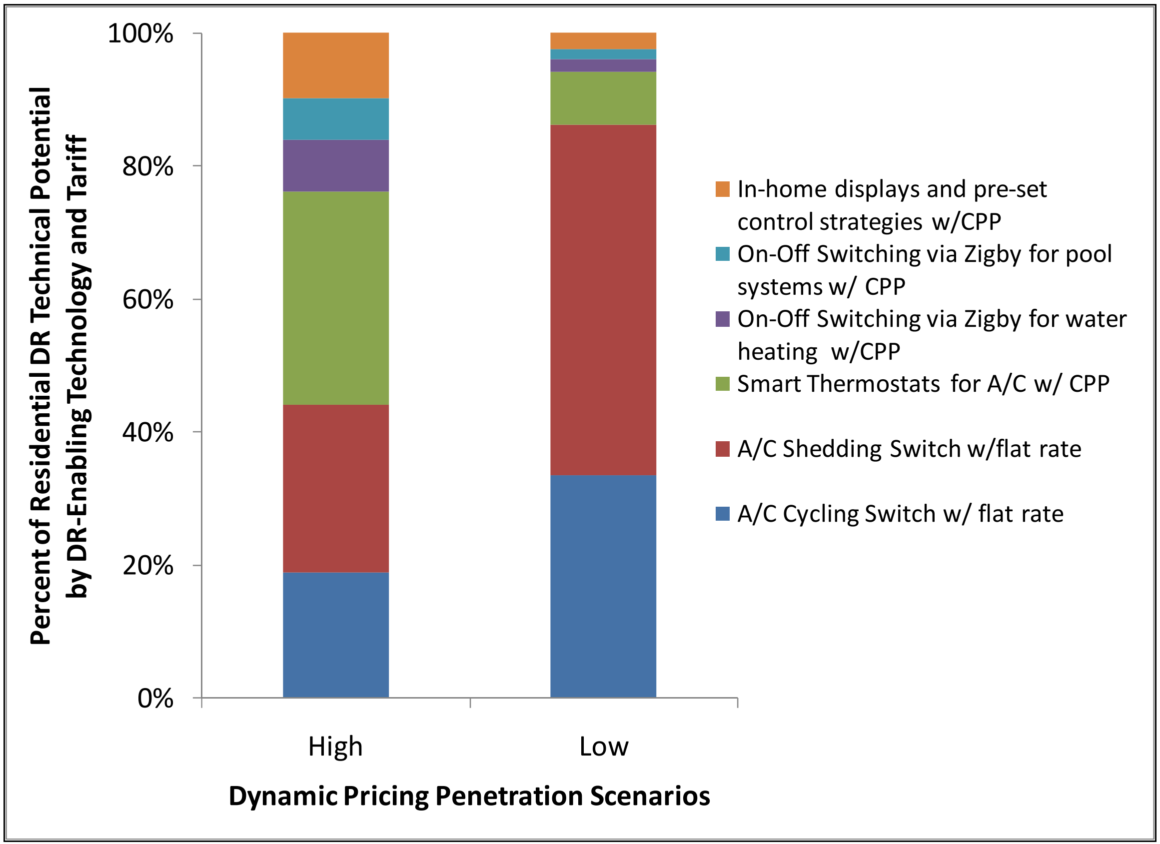


| | Summer High | Summer Low | Winter High | Winter Low |
|---|---|---|---|---|
| **DR Technical Potential as % of Peak Demand** | **13.7%** | **10.7%** | **15%** | **11.3%** |

Figure 4-3 illustrates the relative contribution of the various DR control technologies/tariff combinations analyzed to the total DR technical potential estimated for the residential sector (for summer peak savings). Note that the high and low values shown in the Figure primarily reflect the range of assumed penetration rates of dynamic pricing tariffs presented in Table 4-4. Low penetration of dynamic pricing tariffs implies that a higher proportion of customers are on flat rates. Consequently, the technical potential associated with two DR-enabling technologies – A/C cycling switches and A/C shedding switches in combination with flat rates– will be larger for the "low" scenario as compared with the "high" scenario.

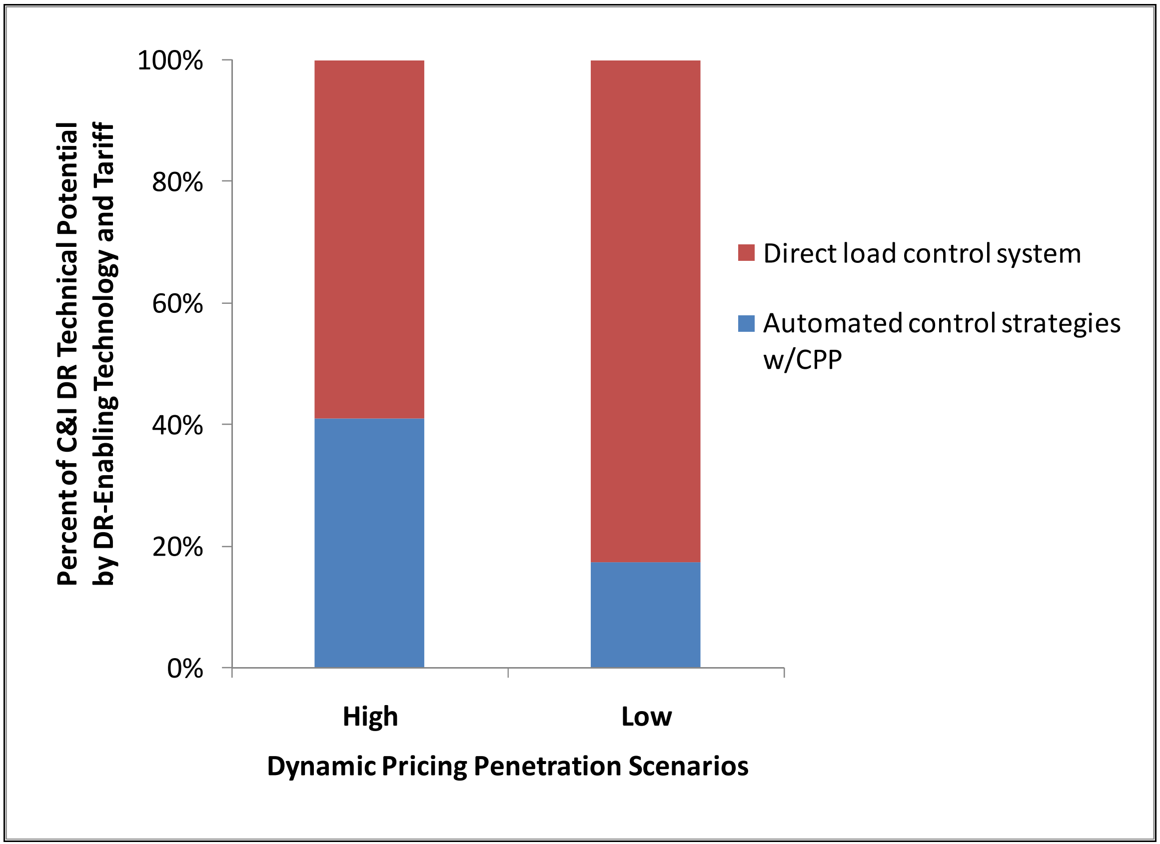
Figure 4-3 also shows that smart thermostats account for 32% of the resource under the high scenario with A/C cycling and A/C shedding together accounting for 44%. In contrast, under the low scenario A/C cycling and A/C shedding account for 86% of the total resource.

**Figure 4-3: Composition of DR Technical Potential for Residential Customers by Control Technology and Tariff in the "High" and "Low" Scenarios (Summer Peak Savings)**



In case of C&I customers, Figure 4-4 shows that the Direct Load Control systems account for a majority of the resource under both the high and low scenarios – 59% and 83%, respectively. The reason DLC systems dominate under both scenarios is because they can be used under both flat rate and dynamic pricing tariffs while automated control systems work only with dynamic pricing tariffs. Further, the load reduction potential from DLC systems is higher than automated control systems.

**Figure 4-4: Composition of DR Technical Potential for C&I Customers by Control Technology and Tariff in the "High" and "Low" Scenarios (Summer Peak Savings)**



## 4.4 Summary

In addition to the existing DR resource of 2,681 MW, the technical potential estimated from new DR programs ranges from 4,856 MW (high scenario) to 3,644 MW (low scenario).[19] Table 4-7 shows the estimated incremental DR technical potential by sector, season, scenario, DR-enabling technology, and tariff, presented in both absolute figures and as a percentage of baseline system peak demand. Total incremental DR technical potential ranges from 11% to 15% of current baseline peak demand across the summer and winter peak seasons and the two scenarios modeled in this analysis. The majority of the DR technical potential is available from residential customers and ranges from 66% to 90% across the two scenarios and the two seasons.

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[19] Again, the peak savings estimates for DR technical potential presented here are designed to be incremental to the existing DR resources. It is assumed that customers enrolled in existing DR programs will continue on those programs and only customers that are not currently enrolled in any existing DR program are eligible for the DR programs modeled in this analysis. It should also be noted that the use of onsite generation by C&I customers as a DR strategy was not modeled in this analysis.

The size of the estimated DR technical potential resource presented here is highly dependent on the assumed penetration of dynamic pricing tariffs. Both A/C cycling and A/C shedding technologies are likely to be used only in combination with a flat rate as opposed to smart thermostats and in-home displays that are likely to be used only with a dynamic pricing tariff. The technical potential for load reduction from A/C shedding (100%) is substantially higher than that from smart thermostats (~36%) and in-home displays (~36%). Therefore low penetration of dynamic pricing tariffs leads to higher levels of DR technical potential.

### Table 4-7: DR Technical Potential by Sector, DR-Enabling Technology/Tariff, and Scenario

| **Sector** | **DR-Enabling Technology and Tariff** | **Summer System Peak** | | | | | **Winter System Peak** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Baseline | Technical Potential | | | | Baseline | Technical Potential | | | |
| | | | High | | Low | | | High | | Low | |
| | | (MW) | (MW) | (%) | (MW) | (%) | (MW) | (MW) | (%) | (MW) | (%) |
| **Residential** | A/C Cycling Switch w/ flat rate | | 601 | 2.7% | 860 | 3.9% | | 436 | 1.9% | 785 | 3.5% |
| | A/C Shedding Switch w/flat rate | | 798 | 3.6% | 1,346 | 6.0% | | 1,079 | 4.7% | 1,942 | 8.5% |
| | Smart Thermostats for A/C w/ CPP | | 1,015 | 4.6% | 203 | 0.9% | | 1,284 | 5.6% | 257 | 1.1% |
| | On-Off Switching via low-power wireless networks for water heating w/CPP | | 245 | 1.1% | 49 | 0.2% | | 939 | 4.1% | 188 | 0.8% |
| | On-Off Switching via low-power wireless networks for pool systems w/ CPP | | 202 | 0.9% | 40 | 0.2% | | 55 | 0.2% | 0 | 0.0% |
| | In-home displays and pre-set control strategies w/CPP | | 312 | 1.4% | 62 | 0.3% | | 425 | 1.9% | 85 | 0.4% |
| | Total Residential | 22,263 | 3,173 | 14.3% | 2,561 | 11.5% | 22,728 | 4,218 | 18.6% | 3,268 | 14.4% |
| **Commercial** | Automated control strategies w/CPP | | 616 | 6.3% | 187 | 1.9% | | 355 | 4.7% | 108 | 1.4% |
| | Direct load control system | | 887 | 9.0% | 887 | 9.0% | | 251 | 3.4% | 251 | 3.4% |
| | Total Commercial | 9,840 | 1,503 | 15.3% | 1,074 | 10.9% | 7,490 | 606 | 8.1% | 359 | 4.8% |
| **Industrial** | Automated control strategies w/CPP | | 43 | 1.6% | 13 | 0.5% | | 22 | 1.0% | 7 | 0.3% |
| | Direct load control system | | 61 | 2.3% | 61 | 2.3% | | 9 | 0.4% | 9 | 0.4% |
| | Total Industrial | 2,686 | 104 | 3.9% | 74 | 2.8% | 2,109 | 31 | 1.5% | 16 | 0.8% |
| **TOTAL** | | **34,790** | **4,779** | **13.7%** | **3,709** | **10.7%** | **32,327** | **4,856** | **15.0%** | **3,644** | **11.3%** |

# 5

# Technical Potential for Energy and Peak Demand Savings from Solar PV

In this section, estimates for technical potential from solar photovoltaics (PV) are presented for all seven FEECA utilities by customer class (i.e. residential and commercial) and season (i.e. summer and winter). The estimates presented here are based on what could be done from a technical feasibility perspective with respect to installing PV in select applications, as opposed to what might be best to do optimally from an economic or operations perspective. Applications covered by this study include rooftop PV in the residential and commercial sectors, and parking lot PV in the commercial sector. Estimates for economic and achievable levels of PV potential will be developed in the next phase of this project.

In this chapter we provide an overview of the PV resource, a description of the methodology used for estimating PV potential, key assumptions, and results for the technical potential of PV for all seven FEECA utilities. Alternating current (AC) power and energy units are used throughout this chapter.

## 5.1 Characterizing the Solar PV Resource

Several key parameters can be used to characterize the design of PV solar electric systems. For this study one important design parameter is PV material type. This, and several other key design parameters, are identified and discussed below.

- **Photovoltaic Material Type**. When PV systems are placed on buildings, the total available surface area becomes a constraint to system capacity. The several types of PV material commercially available today exhibit varying levels of power output per unit of area. This analysis was based on crystalline silicon PV material. If amorphous silicon was assumed in lieu of crystalline silicon then initial capacity estimates would be approximately 60 percent of those estimated for crystalline PV. A mix of amorphous silicon and crystalline silicon would yield an intermediate result. This approach was used because selection of material type is largely an economic decision. The influence of project costs on economic potential will be addressed in the second phase of this project. Thus, the PV material selected for this technical potential analysis results in the maximum amount of PV potential based on the various types of materials available.

- **Energy Storage**. It is possible to incorporate energy storage into PV systems. Addition of energy storage, typically in the form of batteries, opens up the possibility of de-coupling system output from solar irradiance patterns. Currently the frequency of energy storage is higher in the residential sector than the commercial sector. Overall the frequency of energy storage is very low currently. Therefore for this analysis it was assumed that there was no energy storage.
- **Tracking**. When PV arrays are mounted on single- or dual-axis tracking devices their energy output per unit of installed capacity can be increased. However, addition of tracking capability increases system complexity, weight, and maintenance requirements. For this analysis PV arrays are assumed to be fixed, not tracking.
- **Design**. This technical potential study includes houses on a wide variety of orientations. In most cases, PV system power output or energy production could be maximized by mounting the arrays on racks designed to optimize orientation, rather than simply mounting them parallel with the roof surface. Some customers deem complex mounting structures undesirable however, citing aesthetic, cost, and other concerns. Arrays not mounted parallel to roof decks also are more susceptible to wind damage in the hurricane-prone service territory of Florida. Similar considerations pertain to PV systems installed on commercial buildings. For this analysis, PV arrays are assumed to be mounted parallel with roof surfaces.[20]
- **Urban Hosts**. In the urban environment residential and commercial buildings are the most obvious host site for PV arrays. Other host sites, particularly shading structures in commercial parking lots, are also likely candidates for PV systems. For this analysis, PV arrays are assumed to be installed on residential and commercial buildings, and in parking lots of commercial buildings.
- **On versus Off Grid**. PV systems are capable of operating separately from the grid. This analysis addresses only the technical potential of grid-tied PV systems deployed by customers of the FEECA utilities. PV operating separately from the grid cannot directly reduce grid peak load or energy usage from the grid.

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[20] One consequence of this simplifying assumption is loss of information that might be developed regarding the cost-effectiveness variability exhibited by PV systems with different configurations. Due to schedule and budget constraints it was not possible to develop and retain large quantities of information concerning PV system designs that are not expected to account for large portions of the markets examined. For example, it is possible to install tracking PV systems on building rooftops however this is uncommon and therefore this prototype was not included in the technical potential study.

In Section 3.1 key terms underlying potential studies were defined and discussed. That discussion focused on technical potential of energy efficiency resources, however, the same concepts and definitions apply to the PV technical potential analysis covered below.

## 5.2 PV Technical Potential Analysis Methodology

This assessment of PV technical potential covers PV installed in the commercial and residential sectors. The analytic methodology consists of first estimating total roof area suitable for siting PV systems and then translating this roof area into estimates of annual electricity generation and power output coincident with the electric system summer and winter peaks. For commercial buildings the total roof area also is used to estimate parking lot area over which parking shade structures might hold PV systems.

### *5.2.1 Core Equation*

The form of the PV core equation is similar, but not identical, to that of the EE and DR core equations. The core equation used for estimating PV technical potential is:

$$\begin{array}{c}\text{Technical}\\\text{Potential}\\\text{(GWh)}\end{array} = \overbrace{\left(\begin{array}{c}\text{Floor space}\\\text{(10e6ft}^2\text{)}\end{array}\right)\left(\begin{array}{c}\text{Roof space}\\\text{Ratio}\\\text{(\%)}\end{array}\right)}^{\textit{Baseline Data}}\overbrace{\left(1-\begin{array}{c}\text{Measure}\\\text{Saturation}\\\text{(\%)}\end{array}\right)\left(\begin{array}{c}\text{Measure}\\\text{Feasibility}\\\text{(\%)}\end{array}\right)\left(\begin{array}{c}\text{Measure}\\\text{Size}\\\text{(kW/ft}^2\text{)}\end{array}\right)\left(\begin{array}{c}\text{Measure}\\\text{Impacts}\\\text{(kWh/kW)}\end{array}\right)}^{\textit{Measure Data}}$$

Because PV potential is not correlated with baseline energy consumption but rather the non-energy physical characteristics of buildings and facilities, the “baseline data” for PV potential analysis is available roof space.[21] The key types of data used to develop baseline estimates of available roof space are:

- **Floor space** – this variable quantifies the total square feet of floor area for a given market segment (e.g., office buildings in commercial or single-family dwellings in residential).
- **Roof space ratio** – this variable quantifies the amount of roof space corresponding to each unit of floor space. This factor accounts for the fact that in all sectors and for all building types covered by the analysis the average number of floors exceeds one.[22] A

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[21] Similarly, one variable that appears in the core equation for EE potential but not in the core equation for PV potential is end-use technology saturation, since all houses have a roof, whereas – for example – only a portion of houses are equipped with central air conditioners.

[22] This is true even for mobile homes as one case of a unit placed atop another structure increases the average number of floors above one.

similar ratio applies to parking lots for commercial buildings that would hold PV systems atop parking shade structures. The area of parking lots for commercial buildings is correlated with building floor space since larger buildings require larger parking areas.

The key types of data used to describe the PV measure are:

- **Measure saturation** – this variable is the fraction of applicable roof space, including parking shade structure roof space that has already been equipped with PV. One minus the measure saturation thus provides an estimate of the size of remaining eligible market for PV.
- **Measure feasibility** – this variable is the fraction of the applicable roof space where it is technically feasible for installation of PV from an engineering perspective.
- **Measure size** – this variable quantifies the nominal, rated system size of installed PV system capacity.
- **Measure impacts** – this variable quantifies the actual electricity generation per unit of installed PV system capacity.

Estimates of the technical potential for peak generation (as opposed to annual energy generation) are calculated by adjusting the units of the measure impacts term to be a ratio of kW output at the time of system coincident peak to the nominal, rated PV system size. The peak impact factors are derived from PV hourly generation profile data that are then used to estimate PV power output at the time of system coincident peak load. Note that it is not necessary to use supply curve modeling in the PV technical potential assessment because whereas EE measures are subject to substantial interactive effects, the PV measures are not.

## 5.3 Development of Roof Space Baselines

Technical potential of solar PV in the urban environment is closely tied to total square footage of buildings. To maintain consistency with the EE and DR analyses the PV technical potential analysis utilized the housing counts and commercial floor space baseline data described in Chapter 3. Total roof space area is less than total building area because the average number of floors per building exceeds one. The methods used to estimate roof space area available for siting PV systems on residential buildings, commercial buildings, and parking lots based on residential housing counts and commercial floor space are described below.

**Residential Buildings**: Baseline housing unit counts developed for the EE analysis are the foundation of the residential PV technical potential analysis. These counts were translated into housing square footage estimates using the per-dwelling floor space factors presented in Table 5-1, which were derived from the results of FPL's 2006 Home Energy Survey.

**Table 5-1: Residential Floor Space per Dwelling**

| Dwelling Type | Floor Space ($ft^2$/dwelling) |
|---|---|
| Single Family | 2,067 |
| Multi Family | 1,198 |
| Mobile Home | 1,102 |

Data from the Energy Information Administration's 1997 Residential Energy Consumption Survey were used to calculate roof area to floor space factors in order to translate residential floor space values into baseline roof space values. The analysis incorporated information concerning the total number of housing units of various size categories, types (i.e., single family, multi-family), and configurations (i.e., floors). To calculate roof area a gable style roof design with a 20 degree slope roof and one foot overhangs was assumed. The assumed ratio of gross residential roof space to floor space was 0.88.

**Commercial Buildings**: As with the residential analysis, the commercial baseline analysis centers on estimating the total roof square footage available for siting photovoltaic systems. Baseline commercial square footage estimates developed for the EE analysis serve as the foundation of the commercial baseline developed for the PV technical potential analysis.

Nationwide data from the Energy Information Administration's 2003 Commercial Buildings Energy Consumption Survey were used to estimate the distribution of number of floors for the building floor space for each of several building size categories. The resulting distributions, which were based on national data, were then used in combination with total floor space data to estimate a "Roof Area Factor" that relates total roof area to total floor space. The value of the Roof Area Factor calculated in this manner is 0.62. That is, on average, there are 0.62 square feet of roof area associated with each square foot of commercial floor area. Total commercial roof area in the FEECA utilities was thus calculated as the product of the Roof Area Factor and an estimate of the total floor space of commercial buildings in Florida in 2007. The assumed ratio of gross commercial roof space to floor space was 0.62.

**Parking Lots**: The number of parking spaces is related to total commercial building square footage. Depending on building use, the number of parking spaces per 1,000 square feet of building area is typically 3 to 5, which corresponds to 200 to 333 square feet of building area per parking spot. For this analysis a conservative value of 400 square feet of building area per parking spot was assumed.

The International Parking Institute estimates that the ratio of off-street spaces to on-street is roughly two to one. More than 60 percent of paid off-street parking is in surface lots, with the remaining 40 percent in garages. This proportion was assumed to hold for all parking spots in Florida when calculating the total number of off-street, surface parking spots associated with commercial buildings in Florida in 2007.

Table 5-2 summarizes the baseline values for residential and commercial roof area and parking areas developed for this study by building type.

**Table 5-2: Summary of Floor, Roof, and Parking Space Estimates**

| Sector | Building Type | Building Counts | Floor Area (000,000 ft2) | Gross Roof Area (000,000 ft$^2$) | Gross Parking Area (000,000 ft2) |
|---|---|---|---|---|---|
| Residential | Single-family | 4,162,964 | 8,605 | 7,572 | (na) |
| | Multi-family | 2,339,073 | 2,802 | 1,906 | (na) |
| | Mobile Homes | 542,754 | 598 | 526 | (na) |
| | Total | 7,044,792 | 12,005 | 10,004 | (na) |
| Commercial | College | (na) | 164 | 101 | 63 |
| | School | (na) | 261 | 162 | 100 |
| | Hospital | (na) | 82 | 51 | 31 |
| | Other Health | (na) | 84 | 52 | 32 |
| | Lodging | (na) | 354 | 220 | 136 |
| | Restaurant | (na) | 250 | 155 | 95 |
| | Grocery | (na) | 71 | 44 | 27 |
| | Retail | (na) | 456 | 283 | 174 |
| | Warehouse | (na) | 796 | 494 | 305 |
| | Office | (na) | 906 | 562 | 347 |
| | Other | (na) | 416 | 258 | 159 |
| | Total | (na) | 3,841 | 2,381 | 1,469 |
| Total | | | 15,846 | 12,385 | 1,469 |

## 5.4 Development of PV Measure Data

The key measure data required to estimate technical potential are summarized in Table 5-3 and described in more detail below.

### Table 5-3: Summary of Key Measure Data for PV Technical Potential

| Data Type | Units |
|---|---|
| Measure saturation | % of floor space with measure installed |
| Measure feasibility | % of eligible roof space where measure is technically and practically feasible |
| Measure size | the nominal, rated size of the quantity of PV that the baseline areas could practically accommodate (kW/ft$^2$) |
| Measure impacts | After accounting for weather, the annual electricity generation (kWh/kW) and coincident peak electricity generation (kW/kW) |

### *5.4.1 Measure Saturation - PV*

Measure saturation refers to the portion of baseline area already equipped with PV and therefore excluded from estimates of the technical potential for installation of additional PV. Current saturation levels for PV are so low that for purposes of this study they are considered negligible. As quantities of installed PV increase in the future, this parameter will become more important for PV potential analyses.

### *5.4.2 Measure Feasibility - PV*

It is not technically and practically feasible to install PV on all the eligible roof space and parking lot area discussed in the previous section. Factors such as shading, obstructions, and orientation preclude installation of PV on a portion of the baseline area. Measure feasibility diminution factors for residential, commercial, and parking lot PV are discussed below.

**Residential**: Roof design features and shading from objects (e.g., trees) other than the roof may interfere with siting of residential PV. Roof orientation is another factor influencing PV siting and performance. For example, for homes situated on an east-west axis, the portion of the roof facing north is not well suited for PV. The following assumptions were used to estimate total usable residential roof area available for siting PV systems.

- Homes are oriented randomly on four axes: E-W, N-S, NW-SE, NE-SW,
- Homes oriented on E-W, NW-SE, NE-SW axes are candidates for PV only on roof surface with a south-facing component and not on roof surface with a north-facing component,
- Homes oriented a N-S axis are candidates for PV on both east-facing and west-facing roof surfaces,
- Roof slopes are 20 degrees,

- Roof design features eliminate one-third of roof area (e.g., skylights, chimneys, vents),
- Shading from objects (e.g., trees, other buildings) other than the roof eliminate 15 percent of otherwise usable roof area, and
- Other factors (e.g., structural limitations) eliminate 10 percent of the remaining, otherwise usable total roof area.

The shading factor accounts for effects of shading caused by buildings and other obstructions that cannot be removed. This factor does not include effects of existing trees that could be trimmed or replaced with trees that shade windows and walls instead of the roof surface.

**Commercial Buildings**: Roof features (e.g., vents, skylights, pipe, duct, HVAC equipment, skirting) commonly found on commercial buildings may interfere with PV siting. The following assumptions were used to estimate total usable commercial roof area available for siting of PV systems.

- Roofs are flat (PV array is flat-mounted so array tilt is 0 degrees)
- Roof features eliminate one-third of roof area
- Shading from objects (e.g., trees, other buildings) other than the roof eliminate 15 percent of remaining, otherwise usable total roof area
- Other factors (e.g., structural limitations) eliminate 10 percent of the remaining, otherwise usable total roof area.

**Commercial Parking Lots:** For this analysis it was assumed that one-half of off-street parking spots could have structures built over them that could be topped with flat-mounted PV systems. These structures also would serve to shade parked vehicles. An allowance of 20 percent of the resulting area was excluded to allow for required electrical equipment and access to the arrays, so the net parking area percentage was 40 percent.

Table 5-4 summarizes the final measure feasibility factors developed for this study for residential and commercial roof space.

**Table 5-4: Summary of Measure Feasibility Factors**

| | Net Feasible Space | |
|---|---|---|
| Sector | Net roof area (%) | Net parking area (%) |
| Residential | 26% | (na) |
| Commercial | 41% | 40% |

### 5.4.3 Measure Size - PV

For the PV technical potential analysis PV measure size is an important intermediary result because it describes the amount of physical hardware corresponding to the annual energy generation and peak generation results. Later, for the economic and achievable potential analyses, this quantity serves as the basis of PV system cost estimates. The translation of total square feet of usable roof area into PV system capacity entailed two steps.

First, the total DC Standard Test Conditions (STC) module capacity that could be placed on the usable roof area was estimated.[23] Review of manufacturers' product data suggests that crystalline silicon modules typically produce approximately 12 Watts DC (STC) per square foot of module area. It was assumed that every square foot of usable roof area could be covered with a square foot of PV module since the usable area already accounted for area unavailable due to space needed for wiring raceways, access to roof, etc. Total DC (STC) module capacity was thus calculated as the product of the total usable roof area and this per-unit-area module capacity value.

Second, the impacts of DC to AC conversion losses and actual operating temperatures were taken into account. As a first-order approximation, an adjustment factor equal to 94 percent can be used for DC-to-AC conversion efficiency, and an adjustment factor equal to 90 percent for conversion from STC to PV USA Test Conditions (PTC).[24] Consequently, the estimate of measure size is equal to the product of DC (STC) module capacity and 0.85. In the discussions that follow, PV system capacity values conforming to this basis are referred

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[23] STC refers to Standard Test Conditions commonly utilized by manufacturers of PV cells and modules. STC comprises 1,000 W/m$^2$ irradiance and cell temperature equal to 25˚C. When actually operating in the field, cell temperatures coincident with 1,000 W/m$^2$ irradiance levels often exceed 25˚C, which may result in observed power output falling short of manufacturer nameplate ratings.

[24] PTC refers to one commonly-used weather basis for PV system size ratings. Developed by the Photovoltaics for Utility Scale Applications (PVUSA) national public-private partnership, PVUSA Test Conditions (PTC) weather comprises 1,000 W/m$^2$ plane-of-array irradiance, 20˚C ambient temperature, and wind speed equal to 1 m/s. Cell temperatures coincident with PTC weather conditions vary from system to system depending on a variety of factors and can be estimated using experimental or theoretical methods.

to as “nominal” system sizes and are denoted symbolically as “$kW_n$”.[25] Table 5-5 lists the total potential installed capacities by sector in units of nominal Megawatts.

**Table 5-5: Summary of Installed Capacities**

| Sector | Installed Capacity (MW) |
|---|---|
| Residential | 25,898 |
| Commercial | 15,828 |

### 5.4.4 Measure Impacts - PV

The preceding section examined the physical quantity of PV that could be installed in terms of $kW_n$. While this is an important measure of technical potential, ultimately what is of greatest concern is the ability of that hardware to actually generate electricity. Estimation of annual generation and coincident peak generation was accomplished by first producing hourly models of PV performance and then using these data to develop information about measure impacts.

#### ***Hourly PV System Generation Profiles***

To account for actual performance, typical meteorological year (TMY) weather data were used in combination with a standard solar radiation model (Duffie & Beckman, 1991) to calculate hourly estimates of plane-of-array solar radiation. The U.S. Department of Energy's National Renewable Energy Laboratory has sponsored development of a National Solar Radiation Database. This database has been used to create “TMY2” weather data as hourly, typical-year weather data files for 239 locations throughout the United States. While seven of these locations are in Florida, typical meteorological year ambient temperature and solar radiation data for Tampa were used in this analysis. Tampa was chosen as it was centrally located and its annual average solar resource is within 6 percent of the solar resources corresponding to the other six locations of Daytona Beach, Key West, Miami, West Palm Beach, Jacksonville, and Tallahassee. Beam and diffuse solar radiation data were used in calculations of plane-of-array solar radiation, while ambient temperature was used in the calculation of PV system performance adjustment factors.

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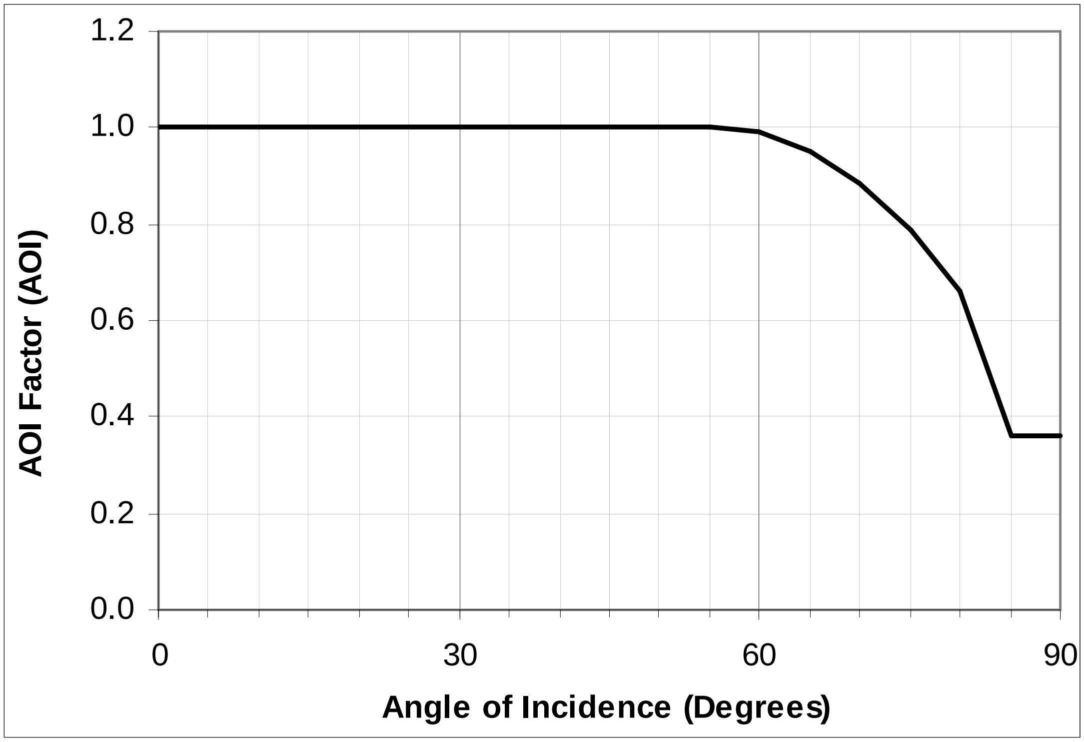
[25] The PV system size basis defined here is consistent with approaches taken by administrators of large PV programs in the United States and therefore facilitates seamless utilization of PV system cost and performance data from secondary sources. It is important to note, however, that other bases are also in use (e.g., the basis of PV system size values entered into the popular online PV performance tool *PVWatts* is different). Care must be taken when comparing certain PV system performance parameters (e.g., annual energy production per unit of PV system capacity) if they are based on different system size bases.

Results of the solar geometry calculations were adjusted to incorporate angle-of-incidence effects that influence photovoltaic system performance. PV module power output may be sensitive not only to geometric "cosine" effects[26] that influence the intensity of beam radiation striking the module surface, but also to other angle of incidence (AOI) effects related to reflectivity or other factors. Sandia National Laboratories has studied these other angle of incidence effects and published results in terms of an AOI factor that summarizes the influence of angle of incidence on PV power output. Data presented in that Sandia report (King, 2002) were used to fit a curve relating AOI factor to angle of incidence, where the angle of incidence is the angle between the beam radiation on a surface and the normal to that surface. The result is depicted graphically in Figure 5-1.

**Figure 5-1: Angle of Incidence Factor**



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[26] The term 'geometric cosine effect' refers to a relationship between the intensity of beam radiation striking PV modules (and hence their power output) and the angle between that beam radiation and a line perpendicular to the PV module surface (i.e., angle of incidence). As the incidence angle increases above zero degrees (where the cosine is equal to 1), the intensity of beam radiation varies as the cosine of the angle of incidence.

Adjusted plane-of-array solar radiation results were used in PV module temperature and PV system power output calculations. The AOI factor from Figure 5-1 was applied to the beam component of solar radiation only.

The estimate of total effective solar radiation on the tilted plane of the array was calculated as:

$$I_e = \left(I_b \times AOI + I_d + I_r\right)$$

where:

$I_e$ = Total effective solar radiation on the tilted plane of the array
$I_b$ = Beam solar radiation on the tilted plane of the array
$AOI$ = Angle-of-Incidence Factor
$I_d$ = Diffuse solar radiation on the tilted plane of the array
$I_r$ = Reflected solar radiation on the tilted plane of the array

Next, for each hour, an initial estimate of power output was calculated for a PV system sized to produce 1.0 kW under PTC conditions. The initial estimate of power output accounted for the actual, effective solar radiation during the hour, but did not account for temperature effects. The initial estimate of power output was calculated as:

$$PV_i = \frac{I_e}{I_{PTC}} \times kW_n \times LOSS$$

where:

$PV_i$ = Initial estimate of PV system power output
$I_{PTC}$ = Total solar radiation on the tilted plane of the array for PTC conditions (i.e., 1,000 W/m$^2$)
$kW_n$ = One nominal unit of system capacity (kW)
$LOSS$ = Dimensionless loss factor (0.92) used to account for the combined effects of initial light-induced degradation, d.c. cabling, diodes and connections, mismatch, transformers, a.c. wiring, and soiling.

The actual module temperature for each hour was estimated by adjusting from the PTC module temperature depending on ambient temperature and plane-of-array solar radiation, based on the following assumptions:

- Power is produced only when solar radiation exceeds 30 W/m2,

- Module temperature is 48.5°C at PTC conditions (i.e., 20°C ambient, 1,000 W/m$^2$),
- A drop from 1,000 to 900 W/m$^2$ yields a drop in module temperature of 3.4°C,
- An increase in ambient temperature from 20°C to 37.8°C yields an increase in module temperature of 20.2°C,
- PV module temperature is never less than ambient temperature,
- 1°C increase in crystalline module temperature yields a 0.5 percent power output decrease, and

The final estimate of PV system power output was calculated as:

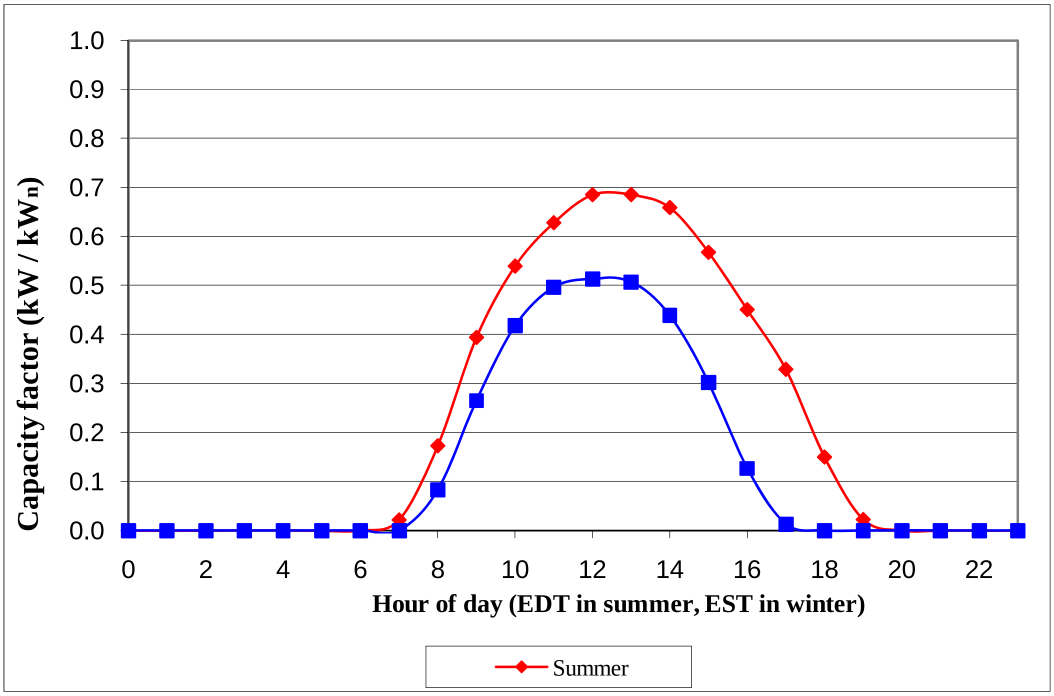
$$PV = PV_i \times (1 + TEMP)$$

Where:

$PV$ = Final estimate of PV system power output
$TEMP$ = Power output factor accounting for module temperature effects

Representative results of the hourly PV system performance modeling are illustrated in Figure 5-2. The basis for these capacity factors is estimated kWh per kW$_n$. The values plotted are hourly average commercial PV system capacity factors for summer (June-August) and winter (December-February). PV system performance coincident with summer and winter electric system peak conditions is discussed in the next section.

**Figure 5-2: Average Hourly Capacity Factors on Summer and Winter Days**



## *Summer and Winter Peak Generation*

Winter system peak in the FEECA utilities generally occurs in the morning (8-9am EST). This type of peak typically reflects high electric resistance heating load caused by low ambient temperature. While ambient temperature does affect PV system power output to some extent, solar radiation is much more influential. The magnitude of PV system peak impacts depends on sky conditions on the types of cold mornings likely to coincide with the electric system peak. Ambient temperatures could be very low in part due to clear skies. However, it could also be the case that stormy (i.e., cloudy) conditions are responsible for very low ambient conditions. The cause of the low ambient temperatures will have a direct bearing on PV system performance coincident with the winter peak.

To better understand the weather conditions typically coincident with winter peak, TMY2 weather data were reviewed. During the winter months of December through February, ambient temperatures during the hour from 8-9am EST ranged from 36-74˚F. These ambient temperature data are summarized in Table 5-6 along with global horizontal solar radiation data.

### Table 5-6: Summary of Typical Weather during Winter: 8-9am (n=90)

| Summary Statistic | Ambient Temperature (˚F) | Global Horizontal Radiation[27] (W/m$^2$) | Direct Normal Radiation[28] (W/m$^2$) |
|---|---|---|---|
| Range | 36.0 – 73.9 | 47 - 248 | 0 - 740 |
| Average | 57.8 | 142 | 292 |

The data in the table summarize wintertime weather during the hour from 8-9am. To estimate technical potential it is necessary to examine solar radiation data on the very coldest days when heating loads are highest. Data for those days, presented in Table 5-7, show us that on the coldest mornings it is common for the weather to be sunnier than average. Given the variability exhibited by these data, for purposes of estimating technical potential at 8-9am on a winter peak-like day a solar resource of 151 W/m$^2$ global horizontal radiation (GHR) and 443 W/m$^2$ direct normal radiation (DNR) is deemed both reasonable and somewhat conservative. These factors along with an assumed ambient temperature of 39.9˚F were used as inputs into Itron's model of overall PV system performance for arrays mounted at various tilts and facing in various directions known as azimuths.

### Table 5-7: Typical Weather on Winter Peak-like Days: 8-9am

| Ambient Temperature (˚F) | Global Horizontal Radiation (W/m$^2$) | Direct Normal Radiation (W/m$^2$) |
|---|---|---|
| 36.0 | 188 | 686 |
| 37.0 | 217 | 652 |
| 39.0 | 190 | 668 |
| 39.9 | 151 | 443 |
| 41.0 | 147 | 106 |

Hourly PV generation profile data for winter peak weather conditions at 8-9am estimated from Itron's PV performance model are listed in Table 5-8. The results for tilted (i.e., residential) systems exhibit variability depending on the direction the PV system is facing. The output of the tilted residential systems facing SE towards the rising sun is greatest (0.18), while no output is anticipated at this early morning hour for PV systems facing west away

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[27] Global horizontal radiation is the total amount of direct and diffuse solar radiation incident on a horizontal surface.

[28] Direct normal radiation is the amount of solar radiation received within a 5.7˚ field of view centered on the sun.

from the sun at that hour of day. The output of the commercial systems is very low as the sun is still low in the eastern sky and there is very little direct normal radiation on a flat-mounted array.

### Table 5-8: Normalized PV System Performance – Winter Peak Hour

| Azimuth | Tilt | Winter Peak Factor ($kW/kW_n$) |
|---|---|---|
| (na) | 0 | 0.08 |
| East | 20 | 0.17 |
| SE | 20 | 0.18 |
| S | 20 | 0.13 |
| SW | 20 | 0.05 |
| W | 20 | 0.00 |

Winter peak factors for the flat-mounted commercial and tilted residential sectors are presented in Table 5-9. The value for the residential sector is an average of the PV performance results for the tilted PV systems at the five different azimuths. The value for the commercial sector is based solely on the PV performance results for horizontal PV systems. Winter peak technical potential for PV is calculated as the product of these factors and the estimates of total installed PV capacity.

### Table 5-9: Winter Peak Generation Factors for PV

| Sector | Winter Peak Factor ($kW/kW_n$) |
|---|---|
| Commercial | 0.08 |
| Residential | 0.11 |

In summer the electric system peak generally occurs in the afternoon (3-4pm EDT). This type of peak typically reflects high air conditioning load caused by a combination of high ambient temperature, high humidity, and high solar radiation. The magnitude of PV system peak impacts depends on the types of hot afternoons likely to coincide with a summer peak. To help better understand the weather conditions typically coincident with summer peak, TMY2 weather data were reviewed. During the summer months of June through August ambient temperatures during the hour from 3-4pm EDT ranged from 73-96˚F. These ambient temperature data are summarized in Table 5-10 along with relative humidity and solar radiation data.

### Table 5-10: Summary of Typical Weather During Summer: 3-4pm EDT (n=92)

| Summary Statistic | Ambient Temperature (˚F) | Relative Humidity (%) | Global Horizontal Radiation (W/m$^2$) | Direct Normal Radiation (W/m$^2$) |
|---|---|---|---|---|
| Range | 73.0 – 96.1 | 35 - 90 | 191 - 856 | 0 - 844 |
| Average | 88.1 | 60 | 623 | 356 |

The data in the table summarize summertime weather during the hour from 3-4pm. To estimate technical potential it is necessary to examine solar radiation data on the days corresponding to the highest cooling loads. Data for those days, presented in Table 5-11, show us that on the hottest days it is common for the DNR values to reflect presence of some degree of cloud cover. Given the variability exhibited by these data, for purposes of estimating technical potential a solar resource of 716 W/m$^2$ GHR and 343 W/m$^2$ DNR is deemed both reasonable and somewhat conservative. These factors along with an assumed ambient temperature of 96.1˚F were used as inputs into Itron's model of overall PV system performance for arrays mounted at various tilts and various azimuths.

### Table 5-11: Typical Weather on Summer Peak-like Days: 3-4pm EDT

| Ambient Temperature (˚F) | Relative Humidity (%) | Global Horizontal Radiation (W/m$^2$) | Direct Normal Radiation (W/m$^2$) |
|---|---|---|---|
| 96.1 | 45 | 716 | 343 |
| 93.9 | 49 | 599 | 156 |
| 93.6 | 55 | 596 | 195 |
| 93.6 | 50 | 807 | 623 |
| 93.0 | 54 | 729 | 483 |

Hourly PV generation profile data for summer peak weather conditions at 3-4pm estimated from Itron's PV performance model are listed in Table 5-12. The results for tilted (i.e., residential) systems exhibit variability depending on the azimuth. The output of residential systems facing W is greatest (0.66) as the sun is in the western sky at that hour of day.

### Table 5-12: Normalized PV System Performance – Summer Peak Hour

| Azimuth | Tilt (Degrees) | Summer Peak Factor ($kW/kW_n$) |
|---|---|---|
| (na) | 0 | 0.63 |
| East | 20 | 0.54 |
| SE | 20 | 0.56 |
| S | 20 | 0.61 |
| SW | 20 | 0.65 |
| West | 20 | 0.66 |

Summer peak factors for the commercial and residential sectors are presented in Table 5-13. The value for the residential sector is an average of the PV performance results for the tilted PV systems at the five different azimuths. The value for the commercial sector is based solely on the PV performance results for horizontal PV systems. Summer peak technical potential for PV is calculated as the product of these factors and the estimates of total installed PV capacity.

### Table 5-13: Summer Peak Generation Factors for PV

| Sector | Summer Peak Factor ($kW/kW_n$) |
|---|---|
| Commercial | 0.63 |
| Residential | 0.60 |

### ***Annual Energy Generation***

The PV generation profiles underlying the assessment of coincident winter and summer peak generation are also used for assessment of annual energy generation. Simply summing the hourly values for the several configurations considered yields the annual energy generation results presented in Table 5-14.

### Table 5-14: Normalized PV System Performance – Annual Generation

| Azimuth | Tilt | Annual Generation Factor (kWh/Year/kW$_n$) | Annual Generation Capacity Factor (%) |
|---|---|---|---|
| (na) | 0 | 1,622 | 19 |
| East | 20 | 1,555 | 18 |
| SE | 20 | 1,680 | 19 |
| S | 20 | 1,726 | 20 |
| SW | 20 | 1,656 | 19 |
| W | 20 | 1,521 | 17 |

Annual energy generation capacity factors for the commercial and residential sectors are presented in Table 5-15. The value for the commercial sector is based solely on the PV performance results for horizontal PV systems. Annual energy generation technical potential for PV is calculated as the product of these factors and the estimates of total installed PV capacity.

### Table 5-15: Annual Energy Generation Factors for PV

| Sector | Annual Generation Capacity Factor (%) |
|---|---|
| Commercial | 19 |
| Residential | 19 |

## 5.5 Annual Energy and Coincident Peak Generation Results

In this section we provide the aggregate results of the PV technical potential analysis for the FEECA utilities, highlight key results, and discuss key uncertainties in the analysis.

Table 5-16 summarizes annual energy and summer and winter peak hour demand impacts by sector and building type and benchmarks these impacts relative to current baseline energy consumption and peak demand in the seven FEECA utilities. As the table shows, the total estimated technical potential of the PV systems considered in this study is 69,449 GWh of annual electricity generation, 25,614 MW of summer system peak capacity, and 4,115 MW of winter system peak capacity. Over half of total electricity generation and system peak capacity is derived from residential rooftop PV systems, 75% of which are from rooftop systems on single-family residential homes. Relative to current baseline electricity consumption and system coincident peak demand in the residential and commercial sectors of the FEECA utilities, the total estimated technical potential for PV is equivalent to 43% of annual electricity consumption, 80% of summer system peak demand, and 14% of winter system peak demand.

These estimates of PV technical potential results represent a substantial portion of current electrical energy consumption and peak demand in Florida. Due to the nature of this type of study, however, the results are subject to uncertainty and are sensitive to certain key assumptions. In this study, one of most significant assumptions is that the PV arrays eligible to be installed on residential and commercial rooftop and commercial parking lot shading structures are based on crystalline PV material. As discussed earlier in Section 5.1, the results would have been significantly lower if amorphous silicon PV material had been assumed. Specification of 100% crystalline PV is consistent with the definition of technical potential first outlined in Section 3.1 of this report, i.e. a theoretical upper bound of the potential PV resource. Another key sensitivity and source of uncertainty in this analysis is the timing of summer and winter system peak demand. PV power production is particularly dynamic during the times of system peak in Florida. Depending on the exact hour of future system peak demand, the level of potential PV generation could vary significantly. The winter system peak illustrates this point particularly well. During the hour from 8-9am, the sun is very low in the sky and PV systems tilted to the east are likely to not contribute any generation at the time of peak. If for some reason the winter peak occurred an hour earlier the historic winter peak, generation might be 100% less than the results of this study indicate. Summertime peak generation is subject to similar sensitivities. During the period during which summer peaks are likely to occur, the position of the sun in the sky is changing quite rapidly. If the summer peak occurred one hour later from 4-5pm, the peak generation would be approximately 15-20% less.

## Table 5-16: Summary of PV Technical Potential Results by Sector and Building Type[29]

| **Sector:** | **Building Type:** | **Annual Energy** | | | **Summer System Peak** | | | **Winter System Peak** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Baseline | Technical Potential | | Baseline | Technical Potential | | Baseline | Technical Potential | |
| | | (GWh) | (GWh) | *(%)* | (MW) | (MW) | *(%)* | (MW) | (MW) | *(%)* |
| Residential | Single-family | 64,668 | 32,627 | 50% | 15,253 | 11,840 | 78% | 15,930 | 2,156 | 14% |
| | Multi-family | 23,955 | 8,210 | 34% | 5,451 | 2,979 | 55% | 5,029 | 543 | 11% |
| | Mobile Homes | 6,122 | 2,268 | 37% | 1,560 | 823 | 53% | 1,769 | 150 | 8% |
| | Total | 94,745 | 43,105 | 45% | 22,263 | 15,643 | 70% | 22,728 | 2,849 | 13% |
| Commercial | College | 2,307 | 1,122 | 49% | 2,487 | 425 | 17% | 1,653 | 54 | 3% |
| | School | 3,705 | 1,791 | 48% | 1,703 | 678 | 40% | 777 | 86 | 11% |
| | Hospital | 2,966 | 564 | 19% | 1,383 | 214 | 15% | 593 | 27 | 5% |
| | Other Health | 2,709 | 575 | 21% | 608 | 218 | 36% | 412 | 28 | 7% |
| | Lodging | 5,769 | 2,431 | 42% | 494 | 920 | 186% | 500 | 117 | 23% |
| | Restaurant | 11,412 | 1,712 | 15% | 325 | 648 | 199% | 220 | 82 | 37% |
| | Grocery | 4,627 | 489 | 11% | 396 | 185 | 47% | 282 | 23 | 8% |
| | Retail | 7,952 | 3,127 | 39% | 542 | 1,183 | 218% | 428 | 150 | 35% |
| | Warehouse | 3,745 | 5,462 | 146% | 481 | 2,067 | 430% | 566 | 263 | 46% |
| | Office | 14,387 | 6,218 | 43% | 748 | 2,354 | 315% | 540 | 299 | 55% |
| | Other | 5,471 | 2,852 | 52% | 672 | 1,080 | 161% | 1,519 | 137 | 9% |
| | Total | 65,051 | 26,344 | 40% | 9,840 | 9,972 | 101% | 7,490 | 1,266 | 17% |
| **Total** | | **159,795** | **69,449** | **43%** | **32,103** | **25,614** | **80%** | **30,218** | **4,115** | **14%** |

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[29] The results shown in this table are highly sensitive to two key assumptions: 1) the assumption of 100% crystalline PV material systems and 2) the assumed timing of both winter and summer system peaks. If amorphous silicon PV systems were assumed to have a significant market share, the technical potential estimates would be lower. If actual summer or winter peak occur an hour earlier or later than assumed for purposes of this study, the system coincident peak capacity estimates would vary according to the generation profiles shown in Figure 5-2. In this respect, caution is required when applying the system peak capacity results shown above in other contexts (e.g., utility-specific seasonal peaks, feeder-level seasonal peaks).

In addition to these key sensitivities, it should also be noted care should be taken in using PV winter and summer peak factors in assessing the value of PV to address peak demand. As indicated earlier, timing of system peak influences the ability of PV systems to address overall system peak. Studies on the California electricity system have indicated that PV may have a significant influence in addressing peak demand at distribution feeders. Hourly distribution feeder load is dependent on a number of factors including makeup of the electricity customers served by the distribution system. In distribution feeders where peak loading typically occurs in the early afternoon, PV systems can have a greater impact on "unloading" of the distribution feeder. In addition, because the total loading of a distribution feeder is significantly lower than the entire utility system load, emerging technologies such as PV can show a relatively greater absolute impact than if assessed at the overall system level.

Similarly, PV technical potential should be evaluated in light of the locational aspects of the distribution system. Not all distribution feeders have the same hourly loading. In some instances, locating high concentration of PV generation (e.g., commensurate with new home developments employing PV systems) may have an adverse affect if the local distribution feeder has peak loading in the late afternoon. Conversely, high concentrations of PV in urban centers served by distribution feeders that exhibit high mid-morning or early afternoon peak loading may demonstrate high distribution system benefits. Generally, some degree of power flow modeling is needed to identify how best to address the locational aspects of distributed generation resources such as PV systems.

Finally, it is worth re-emphasizing that the percent savings estimates presented in Table 5-16 above are relative to current baseline energy consumption and peak demand. As such, these percent savings estimates of PV technical potential are not strictly additive with the percent savings results from the EE and DR technical potential analyses presented earlier. Changes to total electrical energy consumption and peak demand due to EE and DR impacts would change the basis against which PV potential savings are normalized.

# 6

# Key Measure Data Sources and References

**Residential efficiency measure data sources:**

Anello, M, D Parker, J Sherwin, and K Richards, 2001. Measured Impact of Advanced Windows on Cooling Energy Use. FSEC-PF-364-01.

California Public Utilities Commission, 2001. *Database for Energy Efficient Resources – 2001 Update*. Available at: http://energy.ca.gov/deer/index.html

California Public Utilities Commission, 2004. *Database for Energy Efficient Resources – Version 2.01*. Available at: http://energy.ca.gov/deer/index.html

California Public Utilities Commission, 2008. *Database for Energy Efficient Resources – 2008*. Interim results from ongoing project not yet publicly available.

Roth, K and K McKenney, 2007. *Energy Consumption by Consumer Electronics in U.S. Residences*. Prepared for the Consumer Electronics Association by TIAX LLC. TIAX report #D5525. Available at: http://www.ce.org/pdf/energy%20consumption%20by%20ce%20in%20u.s.%20residences%20(january%202007).pdf

Parker, D, M Anello, S Kalaghchy, and J Klongerbo, 2000a. FPC Residential Monitoring Project: Assessment of Direct Load Control and Analysis of Winter Performance. Prepared for Florida Power Corporation. FSEC-CR-1112-99.

Parker, D, J Sonne, and J Sherwin, 2000b. Comparative Evaluation of the Impact of Roofing Systems on Residential Cooling Energy Demand in Florida. FSEC-CR-1220-00.

Parker, D, J Sherwin, and M Anello, 2001. FPC Residential Monitoring Project: New Technology Development – Radiant Barrier Pilot Project. FSEC-CR-1231-01.

Porter, S, L Moorefield, and P May-Ostendorp, 2006. *Energy Use of Plug Load Devices in California Homes: Field Research Report.* Prepared for the California Energy Commission by Ecos Consulting. Available at: http://www.efficientproducts.org/reports/plugload/Plug_Loads_CA_Field_Research_Report_Ecos_2006.pdf

U.S. Department of Energy, 2004. 2001 Residential Energy Consumption Survey. Available at: http://www.eia.doe.gov/emeu/recs/contents.html

U.S. Department of Energy, 2008. 2005 Residential Energy Consumption Survey. Available at: http://www.eia.doe.gov/emeu/recs/contents.html

Wenzel, T, J Koomey, G Rosenquist, M Sanchez, and J Hanford, 1997. Energy Data Sourcebook for the U.S. Residential Sector. LBNL-40297. Available at: http://enduse.lbl.gov/Info/LBNL-40297.pdf

**Commercial efficiency measure data sources:**

California Public Utilities Commission, 2001. *Database for Energy Efficient Resources – 2001 Update*. Available at: http://energy.ca.gov/deer/index.html

California Public Utilities Commission, 2004. *Database for Energy Efficient Resources – Version 2.01*. Available at: http://energy.ca.gov/deer/index.html

California Public Utilities Commission, 2008. *Database for Energy Efficient Resources – 2008*. Interim results from ongoing project not yet publicly available.

Parker, D, J Sonne, and J Sherwin, 1997. Demonstration of Cooling Savings of Light Colored Roof Surfacing in Florida Commercial Buildings: Retail Strip Mall. FSEC-CR-964-97.

Regional Economic Research, 1996. Commercial and Industrial Sector End-Use Study. Prepared for Florida Power and Light Company.

Roth, K, F Goldstein, and J Kleinman, 2002. Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings Volume I: Energy Consumption Baseline. Prepared for the USDOE Office of Building Technology State and Community Programs. Arthur D. Little Reference No. 72895-00.

U.S. Department of Energy, 2004. Draft Technical Support Document - Energy Efficiency Program for Commercial and Industrial Equipment: High-Intensity Discharge Lamps, Analysis of Potential Savings. Available at: http://www1.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/hid_energy_savings_report.pdf

U.S. Department of Energy, 2008. 2003 Commercial Building Energy Consumption Survey. Available at: http://www.eia.doe.gov/emeu/cbecs/contents.html

**Industrial efficiency measure data sources:**

Alliance to Save Energy. 2000. *Steam Digest 2000*. Prepared for U.S. Department of Energy, Office of Industrial Technologies. Washington, DC. http://www.oit.doe.gov/bestpractices/steam/pdfs/digest2k.pdf

Aspen Systems Corporation. 2003. *Nonresidential Market Share Tracking Study*. Prepared for the California Energy Commission. December.

Aspen Systems. 2003. *The Compressed Air Systems Market Assessment and Baseline Study for New England*. Rockville, MD: Aspen Systems Corporation.

Caffal, C. 1995. *Energy Management in Industry*. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), The Netherlands. Analyses series 17, December.

Canadian Industry Program for Energy Conservation and Canadian Foundry Association. 2003. *Guide to Energy Efficiency Opportunities in Canadian Foundries*. Ottawa, ON.

Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). 1997. *Process Heating in the Low and Medium Temperature Ranges* (Caddet Analysis report 22), International Energy Agency/CADDET, Sittard, The Netherlands.

Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). 1997. *Saving Energy with Efficient Compressed Air Systems*. Maxi Brochure 06.

Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET). 2001. *Saving Energy with Daylighting Systems*. Maxi Brochure 14.

Compressed Air Challenge (CAC). 2002. *Guidelines for Selecting a Compressed Air System Service Provider and Levels of Analysis of Compressed Air Systems*. Available at http://www.compressedairchallenge.org.

Compressed Air Challenge (CAC). 2001. *Assessment of the Market for Compressed Air Efficiency Services*, prepared by XENERGY Inc. for Oak Ridge National Laboratory and Lawrence Berkeley National Laboratory and USDOE Compressed Air Challenge.

Council of Forest Industries. 1996. *Energy Efficiency Opportunities in the Solid Wood Industries*. Vancouver, BC: Carrol-Hatch Ltd.

De Beer, J.G., van Wees, M.T., Worrell, E., and Blok, K., 1994. ICARUS-3: *The Potential of Energy Efficiency Improvement in the Netherlands up to 2000 and 2015*. Utrecht, The Netherlands: Utrecht University.

Einstein, D., Worrell, E., Khrushch, M. 2001. "Steam systems in industry: Energy use and energy efficiency improvement potentials." Lawrence Berkeley National Laboratory. LBNL-49081.

Elliot, N. R. of the American Council for an Energy Efficient Economy (ACEEE). 1994. *Electricity Consumption and the Potential for Electric Energy Savings in the Manufacturing Sector*. Washington, D.C.

Energy Information Administration, 2007. *Manufacturing Energy Consumption Survey 2002*. Washington, DC: Energy Information Administration, US Department of Energy.

Galitsky C., Martin N., Worrell E., Lehman B. 2003. *Energy Efficiency Improvement and Cost Saving Opportunities for Breweries: An Energy Star Guide for Energy and Plant Managers*. Lawrence Berkeley National Laboratory. Report LBNL-50934.

Galitsky C., Worrell E., Ruth M. 2003. *Energy Efficiency Improvement and Cost Saving Opportunities for the Corn Wet Milling Industry: An ENERGY STAR Guide for Energy and Plant Managers.* Lawrence Berkeley National Laboratory. Report LBNL-52307.

Galitsky, C. and E. Worrell. 2003. *Energy Efficiency Improvement and Cost Saving Opportunities for the Vehicle Assembly Industry - A Guide for Energy and Plant Managers*. Berkeley, CA: Lawrence Berkeley National Laboratory. Report LBNL-50939.

Galitsky, C. and Worrell, E. 2004. *Profile of the Chemical Industry in California*. Prepared for the California Energy Commission. Berkeley, CA: Lawrence Berkeley National Laboratory. Report LBNL-55668.

Hydraulic Institute and Europump. 2001. *Pump Life Cycle Costs: A Guide to LCC Analysis for Pumping Systems*. Parsippany, NJ.

Hydraulic Institute. 2002. Website, http://www.pumps.org/

Industrial Assessment Center (IAC). Industrial Assessment Center Database. http://oipea-www.rutgers.edu/site_docs/dbase.html.

Infomil, 1996. *Information Plastic Processing Industry*, The Hague, The Netherlands (in Dutch)

Infomil, 1997. *Information for Bread and Bread-and Pastry-Bakeries for Energy Use in Environmental Permitting*. The Hague, The Netherlands: Infomil (in Dutch)

Ingersoll Rand. 2001. *Air Solutions Group-Compressed Air Systems Energy Reduction Basics*. http://www.air.ingersoll-rand.com/NEW/pedwards.htm

Interlaboratory Working Group on Energy-Efficiency and Clean Energy Technologies, 2000. *Scenarios for a Clean Energy Future*. Oak Ridge, TN: Oak Ridge National Laboratory and Berkeley, CA: Lawrence Berkeley National Laboratory.

Itron, Inc. 2006. *California Energy Efficiency Potential Study*. Prepared for the Pacific Gas & Electric Company. May 24. Available at: http://www.calmac.org/.

Jallouk, P., and C.D. Liles. 1998. *Industrial Electric Motor Drive Systems*. Centre for the Analysis and Dissemination of Demonstrated Energy Technologies (CADDET), Sittard, The Netherlands.

Lawrence Berkeley National Laboratory (LBNL) and Resource Dynamics Corporation. 1998. *Improving Compressed Air System Performance, a Sourcebook for Industry*. Prepared for the U.S. Department of Energy, Motor Challenge Program.

Lawrence Berkeley National Laboratory (LBNL), Resource Dynamics Corporation and the Hydraulic Institute. 1999. *Improving Pumping System Performance: A Sourcebook for Industry*. Prepared for the U.S. Department of Energy Motor Challenge Program.

Ledyard, T., L. Barbagallo and E. Lionberger. 1999. *Commercial and Industrial O&M Market Segment Baseline Study (Final Report)*. Middletown, CT: RLW Analytics.

Martin N., Anglani N., Einstein D., Khrushch M., Worrell E., Price LK. 2000. *Opportunities to Improve Energy Efficiency and Reduce Greenhouse Gas Emissions in the U.S. Pulp and Paper Industry*. Lawrence Berkeley National Laboratory. Report LBNL-46141.

Martin, N., E. Worrell, M. Ruth, L. Price, R.N. Elliott, A.M. Shipley, J. Thorne. 2000. *Emerging Energy-Efficient Industrial Technologies*. Lawrence Berkeley National Laboratory/American Council for an Energy-Efficient Economy, Berkeley, CA/Washington, DC. Report LBNL-46990.

Martin, N., N. Anglani, D. Einstein, M. Khrushch, E. Worrell, L.K. Price. 2000. "Opportunities to Improve Energy Efficiency and Reduce Greenhouse Gas Emissions in the U.S. Pulp and Paper Industry," Berkeley, CA: Lawrence Berkeley National Laboratory. Report LBNL-46141.

Mercer, A.C. 1994. *Learning from Experiences with Industrial Drying Technologies.* Sittard, The Netherlands: CADDET.

Michaelson, D. A. and F. T. Sparrow. 1995. “Energy Efficiency in the Metals Fabrication Industries”. In: ACEEE 1995 Summer Study on Energy Efficiency in Industry, Partnerships, Productivity, and the Environment, conference proceedings, New York. Vol. 1: 135-137.

Nadel, S., N. Elliott, M. Shepard, S. Greenberg, G. Katz and A.T. de Almeida. 2002. *Energy-Efficient Motor Systems: A Handbook on Technology, Program and Policy Opportunities (2nd Edition)*, Washington, DC: ACEEE

National Dairy Council of Canada. 1997. *Guide to Energy-Efficiency Opportunities in the Dairy Processing Industry*. Mississauga, ON, Canada.

Natural Resources Canada, The Council of Forest Industries, Canadian Industry Program for Energy Conservation. 1996. *Energy Efficiency Opportunities in the Solid Wood Industries*. Vancouver, BC.

Paprican. 1999. *Energy Cost Reduction in the Pulp and Paper Industry*, Pointe Claire, Quebec, Canada: Paprican.

Radgen, P. and E. Blaustein (eds.). 2001. Compressed Air Systems in the European Union, Energy, Emissions, Savings Potential and Policy Actions. Germany.

Tutterow, V. 1999. *Energy Efficiency in Pumping Systems: Experience and Trends in the Pulp and Paper Industry*. American Council for an Energy Efficient Economy (ACEEE).

Tutterow, V., D. Casada and A. McKane. 2000. "Profiting from your Pumping System." Proceedings of the Pump Users Expo 2000. Louisville, KY: Pumps & Systems Magazine and Randall Publishing Company. September.

U.S. Census Bureau. 1997. *1997 Economic Census: Comparative Statistics for California 1987 SIC Basis: Manufacturing*. http://www.census.gov/epcd/ec97sic/E97SCAD.HTM

U.S. Department of Energy. 2003. Office of Industrial Technologies, Energy Efficiency and Renewable Energy. Industries of the Future Program for Metal Casting. Information available at: http://www.oit.doe.gov/metalcast/

U.S. Department of Energy. 2004. Industrial Assessment Centers (IAC) Database. http://iac.rutgers.edu/database/

U.S. Department of Energy. 2004. *Improving Process Heating System Performance: A Sourcebook for Industry*. Industrial Technologies Program. Washington, DC. http://www.oit.doe.gov/bestpractices/pdfs/proc_heat_sourcebook.pdf

U.S. Department of Energy. 2004. *Improving Steam System Performance: A Sourcebook for Industry*. Industrial Technologies Program. Washington, DC. http://www.nrel.gov/docs/fy05osti/35682.pdf

Worrell, E. and Galitsky, C. 2003. *Energy Efficiency Improvement Opportunities for Cement Making - An ENERGY STAR Guide for Energy and Plant Managers*. Berkeley, CA: Lawrence Berkeley National Laboratory, (LBNL 54036).

Worrell E., Martin N., Price LK. 1999. *Energy Efficiency and Carbon Dioxide Emissions Reduction Opportunities in the U.S. Iron and Steel Sector*. Lawrence Berkeley National Laboratory. Report LBNL-41724.

Worrell, E. and Galitsky, C. 2004. *Profile of the Petroleum Refining Industry in California* Prepared for the California Energy Commission. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-55450).

Worrell, E. and Galitsky, C. *Energy Efficiency Improvement and Cost Saving Opportunities for Petroleum Refineries: An Energy Star Guide for Energy and Plant Managers*, Lawrence Berkeley National Laboratory, Berkeley, CA (forthcoming).

Worrell, E., Dian Phylipsen, Dan Einstein, Nathan Martin. 2000. *Energy Use and Energy Intensity of the U.S. Chemical Industry*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-44314).

Worrell, Ernst, Nathan Martin, Norma Anglani, Dan Einstein, Marta Khrushch, Lynn Price. 2001. "Opportunities to Improve Energy Efficiency in the U.S. Pulp and Paper Industry," Proceedings Paper Machine Technology, February 7-8, Lanaken, Belgium.

XENERGY. 1998. *United States Industrial Electric Motor Systems Market Opportunities Assessment*. Prepared for the U.S. Department of Energy's Office of Industrial Technology and Oak Ridge National Laboratory. Burlington, MA. December.

XENERGY. 2001a. *California Industrial Energy Efficiency Market Characterization Study*. Prepared for PG&E. December.

XENERGY. 2001b. *Motorup Evaluation and Market Assessment.* Prepared for Motorup Working Group. Burlington, MA.

XENERGY. 2002. *California's Secret Energy Surplus: The Potential for Energy Efficiency*. Prepared for the Energy Foundation. September.

**Demand response measure data sources:**

Faruqui, Ahmad and Sanem Sergici, 2008. *The Power of Experimentation: New Evidence on Residential Demand Response*. May 11. Available at: http://www.brattle.com/_documents/uploadlibrary/upload683.pdf

Goldman, Charles, Nicole Hopper, Ranjit Bharvirkar, Bernie Neenan, and Peter Cappers, 2007. *Estimating Large-Customer Demand Response Market Potential: Integrating Price and Customer Behavior*. Berkeley, CA: Lawrence Berkeley National Laboratory (LBNL-63347). June 1. Available at: http://repositories.cdlib.org/lbnl/LBNL-63347/

FERC, 2008. *Assessment of Demand Response and Advanced Metering: Staff Report*, December. Available at: http://www.ferc.gov/legal/staff-reports/12-08-demand-response.pdf

**Solar photovoltaic measure data sources:**

Duffie, J. and Beckman, W. 1991. *Solar Engineering of Thermal Processes*. New York: John Wiley & Sons.

King, David, William Boyson, Jay Kratochvil. 2002. *Analysis of Factors Influencing the Annual Energy Production of Photovoltaic Systems.* Proceedings Paper IEEE 29th Photovoltaic Specialists Conference, May 19-24, New Orleans, LA.

# Appendix A

## Energy Efficiency Measure Descriptions

## A.1 Residential Measures

This subsection provides brief descriptions of the residential measures included in this study.

### *A.1.1 HVAC equipment*

**Central Air Conditioner and Heat Pumps Upgrades**: Air conditioner and heat pump equipment include a compressor, an air-cooled or evaporatively-cooled condenser (located outdoors), an expansion valve, and an evaporator coil (located in the supply air duct near the supply fan). Cooling efficiencies vary based on the quality of the materials used, the size of equipment, the condenser type, and the configuration of the system. Central air conditioners and heat pumps may be of the unitary variety (all components housed in a factory-built assembly) or be a split system (an outdoor condenser section and an indoor evaporator section connected by refrigerant lines and with the compressor at either the outdoor or indoor location). Efficient air conditioner and heat pump measures involve the upgrade of a standard efficiency unit (13 SEER) to a higher efficiency unit (15, 17, or 19 SEER). Note that upgrading from central air conditioners with electric resistance space heating to efficient central heat pumps provides additional heating savings that result from an increase in the coefficient of performance from one to over three in mild heating conditions.

**Advanced Geothermal Heat Pumps (water-source, closed loop):** In contrast to more typical air-source heat pumps that transfers heat to and from the indoors and outside air, water-source geothermal heat pumps transfer heat to and from the indoors and groundwater or another nearby water source. The constant temperature of groundwater compared to outside air allows water-source heat pump systems to reach higher average efficiencies across a wider range of ambient conditions compared to air-source heat pumps. The advanced geothermal heat pump measure in this study assumes overall performance equivalent to 13 EER (roughly equivalent to 17 SEER).

**High Efficiency Room Air Conditioner**: Window (or wall) mounted room air conditioners are designed to cool individual rooms or spaces. This type of unit incorporates a complete air-cooled refrigeration and air-handling system in an individual package. Cooled air is discharged in response to thermostatic control to meet room requirements. Each unit has a self-contained, air-cooled direct expansion (DX) cooling system and associated controls. The efficient room air conditioner measure involves the upgrade of a standard efficiency unit (9 EER) to a higher efficiency unit (11 or 12 EER).

**Proper Refrigerant Charging and Air Flow**: This measure involves diagnostic and repair services for existing central air conditioners to improve their operating efficiency. Inspection and services of AC systems involves checking the refrigerant level, cleaning the blower, cleaning or replacing filters, and making sure air is flowing properly through the system.

**Outdoor AC Coil Cleaning:** This measure is another type of maintenance service measure for existing central air conditioners or heat pumps to improve their operating efficiency. Cleaning the outdoor condenser coils to remove build up improves airflow around the coils and therefore heat transfer rates.

**Indoor AC Coil Cleaning:** This measure is another type of maintenance service measure for existing central air conditioners or heat pumps to improve their operating efficiency. Similar to cleaning outdoor condenser coils, cleaning the indoor evaporator coils to remove build up improves airflow around the coils and therefore heat transfer rates. However, indoor coils tend to be less accessible compared to outdoor coils.

**Duct Repair**: An ideal duct system would be free of leaks, especially when the ducts are outside the conditioned space. Leakage in unsealed ducts varies considerably with the fabricating machinery used, the methods for assembly, installation workmanship, and age of the ductwork. To seal ducts, a wide variety of sealing methods and products exist. Care should be taken to tape or otherwise seal all joints to minimize leakage in all duct systems and the sealing material should have a projected life of 20 to 30 years. Current duct sealing methods include use of computer-controlled aerosol and pre- and post-sealing duct pressurization testing.

**HVAC proper sizing:** Optimum air conditioning performance is achieved when air conditioners or heat pumps are ran continuously. Oversized air conditioners will tend to cycle, rather than run continuously, during both typical and peak cooling periods. This more frequent cycling reduces overall operating efficiency and also results in more variable indoor humidity levels. Oversizing of air conditioners occurs at the time of purchase when equipment is selected and often reflects contractor incentives to mask future problems from duct leaks, improper flow across the coils, and improper charge.

**Electronically Commutated Motors (ECM) on Air Handlers**: Air handler models with the lowest electrical use ratings employ ECMs. ECMs, also known as brushless DC motors or variable speed blower motors, have two principal advantages over the typical permanent magnet split capacitor (PSC) blower motors found in the majority of air handlers. First, ECMs are claimed to be 20% to 30% more efficient than standard blower motors. Second, the typical ECM blower can produce a much wider range of airflow than a PSC blower, which typically has only three or four set speeds over a narrow range. Because power consumption by an air handler rises with the cube of airflow, the ability to reduce airflow when appropriate can dramatically reduce the electrical power draw by the air handler.

### *A.1.2 Building envelope*

**Reflective Roofs:** Light-colored roof materials with high reflectivity, a.k.a. reflective roofs, have been shown to significantly reduce heat gain into attic spaces (where residential duct systems are commonly located) compared to more typical dark-colored roof materials. Reductions in attic heat gain reduce radiative losses in the duct system and in turn result in significant reductions in cooling loads. Reflective roofs are typically constructed of white or light-colored tile or metal.

**Radiant Barriers:** This measure consists of a layer of aluminum foil fastened to roof decking or roof trusses to block radiant heat transfer between the hot roof surface and the attic below. As with reflective roofs, the resulting reductions in attic heat gain reduce radiative losses in the duct system and in turn result in reductions in cooling loads.

**Sealed Attics:** This measure is another strategy to reduce attic heat gain. In this approach, the attic space is completely sealed using spray foam insulation applied to the underside of the roof decking. This approach not only seals the attic space but also insulates the attic space at the roof decking rather than at ceiling surface. This effectively brings the duct system into the conditioned space of the house, resulting in reduced attic temperatures and reduced radiative losses in the duct system, as well as reduced humidity and infiltration.

**Window Film**: This measure involves application of a dark-colored film to the existing windows of a home. The film lowers the shading coefficient of a window, reducing the amount of solar heat gain of a building, and thus decreasing the cooling load for that building.

**Window Tinting:** This measure involves increasing the shading coefficient of new windows through the use of tinted glass instead of clear glass. Window tints are typically achieved through a thin application of bronze on the clear glass surface at the time of manufacturing.

**Default Window with Sunscreen**: This measure prevents direct sunlight on window surfaces, reducing solar gain and consequent cooling requirements.

**Single Pane, Clear Windows to Double Pane, Low-E Windows**: Windows affect building energy use through conductive heat transfer (U-value), solar heat gain coefficients (SHGC), daylighting (visible light transmittance), and air leakage. The performance of a window is determined by the type of glass, the number of panes, the solar transmittance, the thickness of, and the gas type used in the gap between panes (for multi-pane windows). Low-emittance or "low-e" windows feature a thin coating that is highly reflective of long wavelength radiation (room temperature heat) and thus reduce wintertime heating requirements. Newer low-e coatings also filter incoming light to block infrared portions of the spectrum and reduce summertime air conditioning requirements. For this study, standard single pane clear windows are specified as having U-value=1.20 and SHGC=0.76. As defined by the Energy Star program, low-e windows most appropriate for hot climates are specified as having U-value=0.65 and SHGC=0.4.

**Ceiling Insulation**: Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. By inhibiting the flow of heat energy, thermal insulation can conserve energy by reducing heat loss or gain of a structure. An important characteristic of insulating materials is the thermal resistivity, or R-value. The R-value of a material is the reciprocal of the time rate of heat flow through a unit of this material in a direction perpendicular to two areas of different temperatures. In this study, we specify two efficiency measures involving ceiling insulation: adding R-19 insulation to un-insulated ceilings, and retrofitting R-19 insulated ceilings to R-38.

**Wall Insulation**: For existing construction, this measure involves adding R-13 insulation to un-insulated walls. This is usually accomplished by drilling holes into the building's siding and blowing in insulation material.

**Weatherization:** Weatherization measures include weather stripping and caulking. These measures reduce energy consumption by improving the tightness of the building shell and limiting heat gain and loss. Home installation of these measures is usually most effective at fixing easily found leaks. Professional installation of these measures sometimes includes use of blower doors and is usually much more effective than home installation methods. Measure costs for this study reflect professional weatherization.

### *A.1.3 Lighting equipment*

**Compact Fluorescent Lighting (CFLs)**: Compact fluorescent lamps are designed to replace standard incandescent lamps. They are approximately four times more efficient than incandescent light sources. Screw-in modular lamps have reusable ballasts that typically last the life of four lamps.

**Super T-8 Lamps with Electronic Ballast**: T-8 lamps are a smaller diameter fluorescent lamp than T-12 lamps. When paired with specially designed electronic ballasts, T-8 lamps provide more lumens per watt, resulting in energy savings. Electronic ballasts replace the standard core and coil technology in magnetic ballasts with solid-state components. This technology allows for more consistent control over ballast output and converts power to higher frequencies, causing the fluorescent lamps to operate more efficiently. For existing first generation T-8 systems, this measure is specified as an upgrade to efficiency levels associated with optimal Super T-8 lamp-ballast combinations on a replace-on-burnout basis.

**Photocell/timeclock controls:** Photocells can be used to automatically control outdoor lamps according daylight levels. When lights do not need to be on all night, a photocell in series with a time clock provides maximum savings and eliminates the need for manual operation and seasonal time clock adjustments.

### *A.1.4 Water heating equipment*

**High Efficiency Water Heater**: Higher efficiency water heater have greater insulation to reduce standby heat loss. For this study, efficiency of the base unit (measured as the Energy Factor) is specified as 0.92, whereas the efficiency of the high efficiency electric water heater is specified as 0.93.

**Heat Pump Water Heater:** Air-to-water heat pump water heaters extract low-grade heat from the air then transfer this heat to the water by means of an immersion coil. This is the most commonly utilized residential heat pump water heater. The air-to-water heat pump unit includes a compressor, air-to-refrigerant evaporator coil, evaporator fan, water circulating pump, refrigerant-to-water condenser coil, expansion valve, and controls. Residential heat pump water heaters replace base electric units with the same tank capacities. For this study, efficiency of the base unit (measured as the Energy Factor) is specified as 0.92, whereas the efficiency of the heat pump water heater is specified as 2.9.

**Solar Water Heater**: This measure is a heat transfer technology that uses the sun’s energy to warm water. Solar water heaters preheat water supplied to a conventional domestic hot water heating system. The energy savings for the system depend on solar radiation, air temperatures, water temperatures at the site, and the hot water use pattern. For this study, solar faction (i.e. fraction of water heating load met by the solar water heater) is specified as 70%.

**AC Heat Recovery Units:** This measure is another heat transfer strategy that uses the heat rejected during the refrigerant cycle on air conditioning units to heat water in hot water tanks.

**Water Heater Blanket (Tank Wrap)**: Much of water heater efficiency is related to the amount of insulation surrounding the tank. For low-efficiency units, placing an additional layer of insulation around the tank saves energy by reducing the amount of heat loss due to inadequate insulation.

**Low-Flow Showerhead**: Many households are still equipped with showerheads using 3+ gallons per minute. Low flow showerheads can significantly reduce water heating energy for a nominal cost. Typical low-flow showerheads use 1.0-2.5 gallons per minute compared to conventional flow rate of 3.5-6.0 gallons per minute. The reduction in shower water use can substantially lower water heating energy use since showering accounts for about one-fourth of total domestic hot water energy use.

**Pipe Wrap**: Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. By inhibiting the flow of heat energy, thermal insulation can conserve energy by reducing heat loss or gain.

**Faucet Aerators**: Water faucet aerators are threaded screens that attach to existing faucets. They reduce the volume of water coming out of faucets while introducing air into the water stream. A standard non-conserving faucet aerator has a typical flow rate of 3-5 gallons per minute. A water-saving aerator can reduce the flow to 1-2 gallons per minute. The reduction in the flow rate will lower hot water use and save energy (kitchen and bathroom sinks utilize approximately 7 percent of total domestic hot water energy use).

**Heat Trap:** Heat traps are valves or loops of pipe, which allow water to flow into the water heater tank but prevent unwanted hot-water flow out of the tank that would otherwise occur due to convection.

### A.1.5 Pool pump equipment

**High Efficiency Pool Pump and Motor**: This measure involves the replacement of a standard-efficiency motor and low volume pump with a smaller high-efficiency motor and a new high-volume pump.

**Two Speed Pool Pump**: Two speed pool pumps saves energy by reducing the energy used during ongoing pool filtering operation.

**Variable-Speed Pool Pump:** This measure saves energy much in the same way as two-speed pool pumps, with the exception that variable-speed pumps are able to further optimize pump operation and pool water flows to match the specific needs and requirements of individual owners.

### A.1.6 Appliances

**Energy Star Refrigerator**: ENERGY STAR® refrigerators must exceed the July 1, 2001 minimum federal standards for refrigerator energy consumption by at least 20 percent. An energy efficient refrigerator/freezer is designed by improving the various components of the cabinet and refrigeration system. These component improvements include cabinet insulation, compressor efficiency, evaporator fan efficiency, defrost controls, mullion heaters, oversized condenser coils, and improved door seals.

**Energy Star Freezer**: Stand-alone freezers include either upright or chest models. ENERGY STAR® freezers should exceed minimum federal standards for freezer energy consumption by 10 percent or more.

**Energy Star Dishwasher**: ENERGY STAR® labeled dishwashers must exceed minimum federal standards for dishwasher energy consumption by at least 25 percent. Efficient dishwashers save by using both improved technology for the primary wash cycle, and by using less hot water to clean. They include more effective washing action, energy efficient motors and other advanced technology such as sensors that determine the length of the wash cycle and the temperature of the water necessary to clean the dishes. For this study, efficiency of the base unit (measured as the Energy Factor) is specified as 0.46, whereas the efficiency of the ENERGY STAR® unit is specified as 0.65.

**Energy Star Clothes Washer**: A standard clothes washer uses various temperatures, water levels, and cycle durations to wash clothes depending on the clothing type and size of the laundry load. A high-efficiency vertical-axis clothes washer, which eliminates the warm rinse option and utilizes a spray technology to rinse clothes, can significantly reduce washer-related energy. Such machines also utilize a spin cycle that eliminates more water from the clothes than conventional clothes washers and are generally driven by more efficient motors. A horizontal axis clothes washer utilizes a cylinder that rotates horizontally to wash, rinse, and spin the clothes. These types of washing machines can be top loading or front loading, and utilize significantly less water (hot and cold) than the standard vertical axis machines. A vertical axis machine generally fills the tub until all of the clothes are immersed in water. In contrast, the horizontal axis machine only requires about one third of the tub to be full, since the rotation of the drum around its axis forces the clothes into the water and thus can drastically reduce the total energy use for washing. These machines are also easier on clothes and use less detergent. For this study, efficiency of the base unit (measured as the Modified Energy Factor) is specified as 1.6, and we consider three efficiency levels for ENERGY STAR® units, 1.8, 2.0, and 2.3, which correspond to the Tier 1, 2, and 3 efficiency levels, respectively, as defined by the Consortium for Energy Efficiency.

**High Efficiency Clothes Dryer**: High efficiency clothes dryers incorporate moisture sensors and prevent the frequency and magnitude of over-drying compared standard clothes dryers without moisture sensors.

**Energy Star Home Electronics (Televisions, Set-top Boxes, DVD Players, VCRs, and Personal Computers):** All ENERGY STAR® qualified home electronics have off-mode power draws of 1 watt or less. The home electronic devices spend the vast majority of their time in off-mode but often continue to draw a small “trickle charge” to maintain clock or other memory functions. Reductions in off-mode power draws can thus produce significant reductions in total energy consumption without changing on-mode power consumption characteristics. Savings from ENERGY STAR® home electronics considered in this study were estimated based on reductions in off-mode power draw from standard to ENERGY STAR® levels.

## A.2 Commercial Measures

This subsection provides brief descriptions of the commercial measures included in this study.

### *A.2.1 Lighting equipment and controls*

**Super T-8 Lamps with Electronic Ballast**: T-8 lamps are a smaller diameter fluorescent lamp than T-12 lamps. When paired with specially designed electronic ballasts, T-8 lamps provide more lumens per watt, resulting in energy savings. Electronic ballasts replace the standard core and coil technology in magnetic ballasts with solid-state components. This technology allows for more consistent control over ballast output and converts power to higher frequencies, causing the fluorescent lamps to operate more efficiently. For existing first generation T-8 systems, this measure is specified as an upgrade to efficiency levels associated with optimal Super T-8 lamp-ballast combinations on a replace-on-burnout basis.

**T-5 High-Output Lighting with Electronic Ballast**: Like T8 lamps, straight tube T5 lamps are available in nominal 2', 3', 4', and 5' lengths. Standard T-5 lamps have light output and efficiency comparable to T-8/electronic ballast systems. High output T-5 lamps have considerably higher light output: a 1-lamp high output T-5 cross-section can replace a 2-lamp T 8 cross-section. The 5/8" bulb diameter of the T-5 lamp lends itself to low profile luminaires well-suited for cove lighting and display case lighting. Its smaller scale allows for sleeker fluorescent indirect and direct/indirect pendants and shallower profile recessed troffer type luminaires. Because of variances in actual lamp lengths and a different socket design, the T-5 lamp cannot easily be retrofitted in existing T-12 and T-8 luminaires. Consequently, use the T-5 lamp to its best advantage in specially designed luminaires.

**Reflectors**: Optical reflectors are mirrored surfaces installed in fluorescent fixtures to direct light toward a specific area or work surface. By installing optical reflectors, four-lamp and three-lamp fluorescent fixtures can be reduced to two lamp fixtures and still meet the needed lighting levels.

**Pulse-Start Metal Halide Lamps**: Pulse start lamps have a greater light output than standard metal halide, provide a white light and require special ballasts and fixtures for each specific lamp. The pulse start metal halide combined with new, more efficient low current crest factor ballasts using high voltage ignitors provides higher light levels initially (20% more) and significantly more maintained light over time (40% more) than today's standard metal halide.

**Compact Fluorescent Lighting (CFLs)**: Compact fluorescent lamps are designed to replace standard incandescent lamps. They are approximately four times more efficacious than incandescent light sources. Screw-in modular lamps have reusable ballasts that typically last for four lamp lives.

**High Pressure Sodium Lamps**: In many situations, 400 watt mercury vapor lamps can be replaced by 250 watt high pressure sodium (HPS) lamps. HPS lamps are HID lighting and emit a golden-white or yellow light. The color rendition for HPS lamps is worse than for MV lamps, but the number of lumens per watt, although dependent on the size of the lamps, is much improved over MV lamps.

**Lighting Control Tune-up**: This involves various measures to optimize the customer's current lighting control systems, with measures such as: relocating/tuning occupancy sensors, relocating photocells, optimizing sweep timers, repairing lighting timers, and adjust lighting schedules.

**Occupancy Sensors**: Occupancy sensors (infrared or ultrasonic motion detection devices) turn lights on upon entry of a person into a room, and then turn the lights off from ½ minute to 20 minutes after they have left. Occupancy sensors require proper installation and calibration. Their savings depend on the mounting type.

**Continuous Dimming:** Dimming electronic ballasts can be incorporated into a daylighting strategy around the perimeter of office buildings or in areas under skylights. These systems use photocells to reduce power consumption and light output when daylight is available.

**Outdoor Lighting Controls (Photocells and Timeclocks)**: Photocells can be used to automatically control both outdoor lamps and indoor lamps adjacent to skylights and windows. When lights do not need to be on all night, a photocell in series with a time clock provides maximum savings and eliminates the need for manual operation and seasonal time clock adjustments. Time clocks enable users to turn on and off electrical equipment at specific times during the day or week.

**LED exit signs:** Exit signs that use light-emitting diodes (LEDs) as the backlighting source require significantly lower power draws compared to exit signs that use fluorescent or incandescent backlight sources (e.g. 5 W compared to 15 W and 40 W, respectively). Additionally, LED exit signs also have significantly longer service lives compared to fluorescent or incandescent exit signs (e.g. 10 years compared to 1 year and 3 months, respectively).

### *A.2.2 Space Cooling*

**Chiller Efficiency Upgrade**: Centrifugal chillers are used in building types which normally use water-based cooling systems and have cooling requirements greater than 200 tons. Centrifugal chillers reject heat through a water cooled condenser or cooling tower. In general, efficiency levels for centrifugal chillers start at 0.80 kW/ton (for older units) and may go as high as 0.4 kW/ton. This measure involves installation of a high-efficiency chiller (0.51 kW per ton) versus a standard unit (0.58 kW per ton). This measure also serves in the potential analysis as a proxy for other non-centrifugal chiller systems.

**High-Efficiency Chiller Motors:** This measure involves replacement of standard efficiency motors that power compressor systems on chillers. High-efficiency chiller motors have typically have efficiencies exceeding 90% and are typically electronically-commutated motors, which produce higher average operating efficiencies at partial loads compared to standard efficiency, brushed DC compressor motors.

**VSD – Cooling Circulation Pumps**: Variable speed drives installed on chilled water pumps can reduce energy use by varying the pump speed according to the building’s demand for cooling. There is also a reduction in piping losses associated with this measure, which can have a major impact on the heating loads and energy use for a building. Pump speeds, however, can generally only be reduced to a minimum specified rate, because chillers and the control valves may require a minimum flow rate to operate.

**VSD – Cooling Tower Fans**: Energy usage in cooling tower fans can be reduced by installing electronic variable speed drives (VSDs). VSDs are a far more efficient method of regulating speed or torque than other control mechanisms. Energy required to operate a fan motor can be reduced significantly during reduced load conditions by installing a VSD.

**Chiller Tune-up/Diagnostics**: In addition to some of the activities conducted in a DX tune-up, an optimization of the chilled water plant can include activities such as: optimizing CW/CHW setpoints, improving chiller staging, trimming pump impellers, resetting chilled water supply temperature, and staging cooling tower fan operation.

**Thermal Energy Storage:** This measure is a load-shifting strategy that is designed to reduce peak demand for air-conditioning by producing ice during off-peak hours (typically overnight) and using this ice to pre-cool chilled water during peak hours, thereby reducing the peak cooling load served by chillers. This load-shifting strategy produces significant peak demand savings benefits but can also result in overall energy consumption penalties due to the energy required to produce sufficient quantities of ice during off-peak hours.

**Packaged DX or Packaged Heat Pump System Efficiency Upgrade**: A single-package A/C or heat pump unit consists of a single package (or cabinet housing) containing a condensing unit, a compressor, and an indoor fan/coil. Packaged direct expansion (DX) units provide only air conditioning, while packaged heat pump systems provide both air conditioning during the cooling season and space heating during the winter season. An additional benefit of package units is that there is no need for field-installed refrigerant piping, thus minimizing labor costs and the possibility of contaminating the system with dirt, metal, oxides or non-condensing gases. This measure involves installation of a TIER 2 high-efficiency packaged DX or heat pump unit (EER=10.9) as compared to a base case unit with EER=10.3.

**Advanced Geothermal Heat Pumps:** In contrast to more typical air-source heat pumps that transfers heat to and from the indoors and outside air, water-source geothermal heat pumps transfer heat to and from the indoors and groundwater or another nearby water source. The fairly constant temperature of groundwater compared to outside air allows water-source heat pump systems to reach higher average efficiencies across a wider range of ambient conditions compared to air-source heat pumps. The advanced geothermal heat pump measure in this study assumes overall performance equivalent to 13 EER (roughly equivalent to 17 SEER).

**Hybrid Desiccant-DX Systems:** This measure involves the replacement of standard packaged DX systems with a new, hybrid space cooling system that combines a desiccant wheel with a chiller coil to produce more efficient humidity removal and significant energy savings in space cooling applications that require strict humidity control.

**High-Efficiency Packaged Terminal AC Units:** Packaged terminal air conditioners (PTAC) are a type of self-contained space cooling system most commonly found in hotels and are functionally similar to room air conditioners, with the key difference being that

PTAC units typically have larger capacities that room units and are mounted in through-the-wall configurations as opposed to being mounted in window frames. This measure involves the installation of a high-efficiency PTAC unit (EER=9.6) as compared to a standard efficiency unit with EER=8.3.

**DX Tune up/Advanced Diagnostics**: The assumed tune-up includes cleaning the condenser and evaporator coils, establishing optimal refrigerant levels, and purging refrigerant loops of entrained air. The qualifying relative performance range for a tune-up is between 60 and 85 percent of the rated efficiency of the unit. Includes fresh air economizer controls providing demand control ventilation and consisting of a logic module, enthalpy sensor(s), and CO2 sensors in appropriate applications.

**Energy Management System**: The term Energy Management System (EMS) refers to a complete building control system which usually can include controls for both lighting and HVAC systems. The HVAC control system may include on\off scheduling and warm-up routines. The complete lighting and HVAC control systems are generally integrated using a personal computer and control system software.

**EMS Optimization**: Energy management systems are frequently underutilized and have hundreds of minor inefficiencies throughout the system. Optimization of the existing system frequently results in substantial savings to the measures controlled by the EMS (e.g. lighting, HVAC) by minimizing waste. Improvements can include: building start-up schedule adjustments, improving integrated sequence of operations, calibration of sensors, and relocation of OA sensors.

**Occupancy Sensors (hotels):** This measure involved the installation of occupancy sensors that control the temperature settings of individual PTAC systems in hotel rooms such that PTAC loads are dramatically reduced during times that rooms are unoccupied.

**Aerosol Duct Sealing:** An ideal duct system would be free of leaks, especially when the ducts are outside the conditioned space. Leakage in unsealed ducts varies considerably with the fabricating machinery used, the methods for assembly, installation workmanship, and age of the ductwork. Advanced duct sealing methods include the use of computer-controlled aerosol applications and pre- and post-sealing duct pressurization testing.

**Duct Insulation**: Insulation material inhibits the transfer of heat through the air-supply duct. Several types of ducts and duct insulation are available, including flexible duct, pre-insulated flexible duct, duct board, duct wrap, tacked or glued rigid insulation, and water proof hard shell materials for exterior ducts. Duct insulation for existing construction involves wrapping uninsulated ducts with an R-4 insulating material.

**Cool Roof**: The color and material of a building structure surface will determine the amount of solar radiation absorbed by that surface. By using an appropriate reflective material to coat the roof, the roof will absorb less solar radiation and consequently reduce the cooling load.

**Window Film**: Reflective window film is an effective way to reduce solar energy gains, thus reducing mechanical cooling energy consumption. Windows affect building energy use through thermal heat transfer (U-value), solar heat gains (shading coefficient), daylighting (visible light transmittance), and air leakage.

**Roof/Ceiling Insulation**: Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. By inhibiting the flow of heat energy, thermal insulation can conserve energy by reducing heat loss or gain of a structure. An important characteristic of insulating materials is the thermal resistance, or R-value. The R-value of a material is the reciprocal of the time rate of heat flow through a unit of this material in a direction perpendicular to two areas of different temperatures.

### *A.2.3 Ventilation*

**Motor Efficiency Upgrade**: Premium-efficiency motors use additional copper to reduce electrical losses and better magnetic materials to reduce core losses, and are generally built to more precise tolerances. Consequently, such motors are more reliable, resulting in reduced downtime and replacement costs. Premium-efficiency motors may also carry longer manufacturer's warranties.

**Air Handler Optimization**: Optimization of a building's air-handling system is concerned principally with the proper sizing and configuration of its HVAC units. Energy savings can result from a variety of improvements, including reduced equipment loads and better functionality of existing equipment.

**VFD on Motor Installation**: Energy usage in HVAC systems can be reduced by installing electronic variable frequency drives (VFDs) on ventilation fans. VFDs are a far more efficient method of regulating speed or torque than throttling valves, inlet vanes and fan dampers. Energy required to operate a fan motor can be reduced as much as 85% during reduced load conditions by installing a VFD.

**Electronically Commutated Motors (ECM) on Air Handler Unit:** Air handler models with the lowest electrical use ratings employ ECMs. ECMs, also known as brushless DC motors or variable speed blower motors, have two principal advantages over the typical permanent magnet split capacitor (PSC) blower motors found in the majority of air handlers.

First, ECMs are claimed to be 20% to 30% more efficient than standard blower motors. Second, the typical ECM blower can produce a much wider range of airflow than a PSC blower, which typically has only three or four set speeds over a narrow range. Because power consumption by an air handler rises with the cube of airflow, the ability to reduce airflow when appropriate can dramatically reduce the electrical power draw by the air handler.

**Demand-Controlled Ventilation**: Often, usage of a building's ventilation control goes beyond what is necessary to maintain a healthy and comfortable environment. A variety of controls can save energy by limiting the use of the ventilation system to minimum amount necessary. Sensors that detect critical contaminants activate ventilations systems only when necessary. Occupancy sensors limit the operation ventilation systems to periods when the building is in use.

**Energy Recovery Ventilation:** These systems provide a controlled way of ventilating a building while minimizing energy loss. Heating energy requirements are reduced during the winter season by transferring heat from the warm inside air being exhausted to the fresh (but cold) supply air. Similarly, in the summer, the inside air being exhausted cools the warmer supply air and reduces cooling energy requirements.

**Separate Makeup Air/Exhaust Hoods:** Ventilation requirements in restaurants and grocery stores are driven both by occupancy and by the need to exhaust fumes from food preparation activities. Standard ventilation and exhaust systems operate at constant speeds that are most often matched to maximum ventilation requirements. Systems that modulate both exhaust and make-up air flow rates in response to measurements of "smoke" and temperature in the exhaust hood reduce exhaust and make-up air flow rates when full exhaust capacity is not required, and can thereby produce significant reduction in fan power and space conditioning energy use.

### *A.2.4 Refrigeration*

**Motor Efficiency Upgrade for Fans and Compressors**: In addition to saving energy, premium-efficiency motors are more reliable, resulting in reduced downtime and replacement costs.

**Strip Curtains**: Installing strip curtains on doorways to walk-in boxes and refrigerated warehouses can produce energy savings due to decreased infiltration of outside air into the refrigerated space. Although refrigerated spaces have doors, these doors are often left open, for example during product delivery and store stocking activities.

**Night Covers**: Installing film or blanket type night covers on display cases can significantly reduce the infiltration of warm ambient air into the refrigerated space. This reduction in display case loads in turn reduces the electric use of the central plant, including compressors and condensers, thus saving energy. The target market for this measure is small, independently owned grocery stores and other stores that are typically closed at night and restock their shelves during the day. The target cases are vertical displays, with a single- or double-air curtain, and tub (coffin) type cases.

**Evaporator Fan Controller for Medium Temperature Walk-Ins**: In response to the temperature setpoint being satisfied in a medium temperature walk-in cooler, evaporator fans are cycled to maintain minimum necessary air flow, which prevents ice build-up on the evaporator coils. In conventional systems, fans run constantly whether the temperature setpoint is satisfied or not.

**Variable Speed Compressor Retrofit**: A variable speed compressor is a screw or reciprocating compressor whose current is modulated by a frequency inverter. A controller senses the compressor suction pressure and modulates the current and therefore the motor speed in response to changes in this pressure. When low load conditions exist, the current to the compressor motor is decreased, decreasing the compressor work done on the refrigerant.

**Floating Head Pressure Controls**: Floating head pressure controls allow a refrigeration system to operate under lower condensing temperature and pressure settings, where compressor operation is most efficient, working against a relatively low head pressure. The condensing temperature is allowed to float below the design setpoint of, say, 95 deg. F under lower outdoor temperatures, which in-turn lowers the condensate pressure. In a conventional system a higher fixed condensing temperature setpoint is used which results in a lowered capacity for the system, requires extra power, and may overload the compressor motor. Energy savings can be realized if the refrigeration system head pressure is allowed to float during periods of low ambient temperature, when the condensing temperature can be dramatically reduced.

**Refrigeration Commissioning**: Refrigeration commissioning refers to a process whereby refrigeration systems are subject to inspection on a variety of criteria to ensure efficiency. The commissioning process can involve tests that cover a system’s controls for humidity and temperature, anti-condensation, and heat recovery, among others.

**Demand Defrost**: Defrost of a refrigeration system is critical to its efficient operation. Demand defrost uses a pressure-sensing device to activate the defrost cycle when it detects a significant drop in pressure of the air across the refrigeration coil. Because load during defrost can be three times that of normal operation, defrosting on demand only – not when an individual operator deems it necessary – can save energy by minimizing the amount of time spent on defrosting.

**Humidistat Controls**: A humidistat control is a control device to turn refrigeration display case anti-sweat heaters off when ambient relative humidity is low enough that sweating will not occur. Anti-sweat heaters evaporate moisture by heating the door rails, case frame and glass of display cases. Savings result from reducing the operating hours of the anti-sweat heaters, which without a humidistat control generally run continuously. There are various types of control strategies including cycling on a fixed schedule.

**High R-Value Glass Doors:** This measure involves the replacement of standard glass doors on refrigerated display cases with advanced glass doors that incorporate heat-reflective treated glass and/or low-conductivity gas fills between panes to produce high R-values. The greater insulation properties of the insulated glass doors reduce condensation buildup and reduce or eliminate the need for anti-sweat heaters.

**Multiplex Compressor Systems:** Multiplex refrigeration systems involve the use of multiple compressors in parallel, rather than single compressors, to serve specific refrigeration loads. Multiplex systems are designed so that compressors can be selectively selected and cycled in order to better match changes in refrigeration load dynamically and increase the overall operational efficiency of the compressors.

**Oversized Air Cooled Condenser:** The use of oversized condensers can provide additional “natural sub-cooling” of the condensed refrigerant, which results in lower-temperature refrigerant liquid in the system, lower evaporator temperatures, and reduced load on the compressor.

**Freezer/Cooler Replacement Gaskets:** Worn out freezer/cooler door gaskets can result in significant leakage and increased cooling energy consumption. Regular replacement of worn door gaskets reduces unnecessary air leaks and can lead to significant refrigeration energy savings.

**LED Display Case Lighting:** This measure involves the replacement of standard fluorescent tube lighting fixtures within medium and low-temperature display cases with LED fixtures. The higher luminous efficacy of LED lamps compared to T-8 and T-5 fluorescent lamps delivers significant energy savings and also results in lower heat gains inside refrigerator and freezer cases, which in turn reduces the effective load served by the compressor. LED fixtures also exhibit much longer service lives compared to T-8 or T-5 fixtures and very little maintenance requirements.

### *A.2.5 Water heating equipment*

**High Efficiency Water Heater**: Higher efficiency water heater have greater insulation to reduce standby heat loss. For this study, efficiency of the base unit (measured as the Energy Factor) is specified as 0.88, whereas the efficiency of the high efficiency electric water heater is specified as 0.93.

**Heat Pump Water Heater:** Air-to-water heat pump water heaters extract low-grade heat from the air then transfer this heat to the water by means of an immersion coil. This is the most commonly utilized residential heat pump water heater. The air-to-water heat pump unit includes a compressor, air-to-refrigerant evaporator coil, evaporator fan, water circulating pump, refrigerant-to-water condenser coil, expansion valve, and controls. Residential heat pump water heaters replace base electric units with the same tank capacities. For this study, efficiency of the base unit (measured as the Energy Factor) is specified as 0.88, whereas the efficiency of the heat pump water heater is specified as 2.9.

**Solar Water Heater**: Heat transfer technology that uses the sun’s energy to warm water. Solar water heaters preheat water supplied to a conventional domestic hot water heating system. The energy savings for the system depend on solar radiation, air temperatures, water temperatures at the site, and the hot water use pattern.

**Demand-Controlled Circulating Systems:** Hot water circulation systems are designed to maintain water in hot water pipes at a pre-determined temperature and prevent excess water demand (and associated water heating energy) from waiting for hot water to arrive from the water heater. Demand-controlled circulating systems provide additional savings by optimizing pumping energy requirements to only specific moments of hot water demand. This is achieved through the integration of an electronic controller on the circulation pump that is triggered by a switch engaged by the consumer at the point of hot water demand.

**Heat Recovery Units:** This measure is heat transfer strategy that uses the heat rejected during the refrigerant cycle on air conditioning units to heat water.

**Pipe Wrap**: Thermal insulation is material or combinations of materials that are used to inhibit the flow of heat energy by conductive, convective, and radiative transfer modes. By inhibiting the flow of heat energy, thermal insulation can conserve energy by reducing heat loss or gain.

**Heat Trap:** Heat traps are valves or loops of pipe, which allow water to flow into the water heater tank but prevent unwanted hot-water flow out of the tank that would otherwise occur due to convection.

### *A.2.6 Office Equipment*

**Energy Star Monitors and Copiers:** All ENERGY STAR® qualified office equipment have off-mode power draws of 1 watt or less and sleep-mode power draws of 2 watts or less. As with home electronic devices, office equipment spend the vast majority of their time in off-mode or sleep-mode but often continue to draw significant power. Reductions in off-mode and sleep-mode power draws can thus produce significant reductions in total energy consumption without changing on-mode power consumption characteristics. Savings from ENERGY STAR® office equipment considered in this study were estimated based on reductions in off-mode and sleep-mode power draw from standard to ENERGY STAR® levels.

**Power Management Enabling**: This measure can be applied to PCs, PC monitors, laser printers, and copiers. For PCs and copiers, manual enabling of the power management features is the only viable solution. For monitors, manual enabling and group enabling via network software are options.

## A.3 Industrial Measures

This subsection provides brief descriptions of the industrial measures included in this study. Cross-cutting measures that are generally applicable across industrial subsectors are presented first, followed by process-specific measures.

### *A.3.1 Cross-Cutting Measures*

**Replace motors**: This measure refers to the replacement of existing motors with high-efficiency motors. High-efficiency motors reduce energy losses through improved design, better materials, tighter tolerances, and improved manufacturing techniques. With proper installation, high-efficiency motors can run cooler than standard motors and can consequently have higher service factors, longer bearing life, longer insulation life, and less vibration.

**Adjustable speed drives (ASDs)**: Adjustable speed drives better match motor speed to load and can therefore lead to significant energy savings compared to constant speed motors. Typical energy savings associated with ASDs range from 7-60%.

**Motor practices**: This measure refers to proper motor maintenance. The purposes of motor maintenance are to prolong motor life and to foresee a motor failure. Motor maintenance measures can be categorized as either preventive or predictive. Preventive measures, whose purpose is to prevent unexpected downtime of motors, include electrical consideration, voltage imbalance minimization, motor ventilation, alignment, and lubrication, and load consideration. The purpose of predictive motor maintenance is to observe ongoing motor temperature, vibration, and other operating data to identify when it becomes necessary to overhaul or replace a motor before failure occurs. The savings associated with ongoing motor maintenance could range from 2-30% of total motor system energy use.

**Compressed air - operation and maintenance (O&M)**: Inadequate maintenance can lower compression efficiency and increase air leakage or pressure variability, as well as lead to increased operating temperatures, poor moisture control, and excessive contamination. Improved maintenance will reduce these problems and save energy. Proper maintenance includes regular motor lubrication, replacement of air lubricant separators, fan and pump inspection, and filter replacement.

**Compressed air – controls**: The objective of any control strategy is to shut off unneeded compressors or delay bringing on additional compressors until needed. Energy savings for sophisticated controls have been around 12% annually. Available controls for compressed air systems include start/stop, load/unload, throttling, multi-step, variable speed, and network controls.

**Compressed air - system optimization**: This is a general measure that refers to compressed air system improvements (besides sizing, controls, and maintenance) that allow it to perform at maximum energy efficiency. Such improvements could include reducing leaks, better load management, minimizing pressure drops throughout the system, reducing air inlet temperatures, and recovering waste compressor heat for other facility applications.

**Compressed air – sizing**: This measure refers to the proper sizing of compressors, regulators, and distribution pipes. Oversizing of compressors can result in wasted energy. By properly sizing regulators, compressed air will be saved that is otherwise wasted as excess air. Pipes must be sized correctly for optimal performance or resized to fit the current compressor system. Increasing pipe diameters typically reduces annual energy consumption by 3%.

**Pumps - operation and maintenance (O&M)**: Inadequate maintenance can lower pump system efficiency, cause pumps to wear out more quickly, and increase costs. Better maintenance will reduce these problems and also save energy. Proper pump system maintenance includes bearing inspection and repair, bearing lubrication, replacement of worn impellers, and inspection and replacement of mechanical seals.

**Pumps – controls**: The objective of pump control strategies is to shut off unneeded pumps or, alternatively, to reduce pump load until needed. In addition to energy savings, proper pump control can lead to reduced maintenance costs and increased pump life.

**Pumps – system optimization**: This is a general measure that refers to pump system improvements (besides sizing, controls, and maintenance) that allow it to perform at maximum energy efficiency. Such improvements could include pump demand reduction, high-efficiency pumps, impeller trimming, and installing multiple pumps for variable loads.

**Pumps – sizing**: Pumps that are sized inappropriately result in unnecessary losses. Where peak loads can be reduced, pump size can also be reduced. Replacing oversized pumps with pumps that are properly sized can save 15-25% of the electricity consumption of a pumping system (on average for U.S. industry).

**Fans – operation and maintenance (O&M)**: This measure refers to the improvement of general O&M practice for fans, such as tightening belts, cleaning fans, and changing filters regularly.

**Fans – controls**: The objective of fan control strategies is to shut off unneeded fans or, alternatively, to reduce fan load until needed. In addition to energy savings, proper fan control can lead to reduced maintenance costs and increased pump life.

**Fans – system optimization**: This measure refers to general strategies for optimizing fans from a systems perspective, and includes such actions as better inlet and outlet design and reduction of fan sizing, where appropriate.

**Fans – improve components**: This measure refers to the improvement of fan components, such as replacing standard v-belts with cog v-belts and upgrading to the most energy efficient motors possible.

**Replace T-12 by T-8 and electronic ballasts**: T-12 tubes consume significant amounts of electricity, and also have extremely poor efficacy, lamp life, lumen depreciation, and color rendering index. Replacing T-12 lamps with T-8 lamps (smaller diameter) approximately doubles the efficacy of the former. Electronic ballasts save 12-30% power over their magnetic predecessors; typical energy savings associated with replacing magnetic ballasts by electronic ballasts are estimated to be roughly 25%.

**Metal halides/fluorescents**: Metal halide lamps can replace mercury or fluorescent lamps with energy savings of 50%. For even further savings, high-intensity fluorescent lamps can be installed, which can yield 50% electricity savings over standard metal halide (high-intensity discharge) systems.

**Switch off/O&M**: Lighting is often left on, even when the area or room is not occupied. Sensors can be installed (see below), but savings can also be realized by training personnel to switch off lights (and other equipment) when not needed. Furthermore, adapting switching to the use pattern of the building will enable to control the lighting in those areas where it is needed (e.g. in many assembly areas a single switch controls all lighting, even when lighting would only be needed in a few zones within the assembly hall).

**Controls/sensors**: Lights can be shut off during non-working hours by automatic controls, such as occupancy sensors, which turn off lights when a space becomes unoccupied. Manual controls can also be used in addition to automatic controls to save additional energy in small areas.

**Super T-8s**: Super T-8 fluorescent systems are a further development of (standard) T-8 tubes. Super T-8s combine further improvement of the fluorescent tube (e.g. barrier coating, improved fill, enhanced phosphors) with electronic ballasts in a single system.

**HVAC management system**: An energy monitoring and control system supports the efficient operation of HVAC systems by monitoring, controlling, and tracking system energy consumption. Such systems continuously manage and optimize HVAC system energy consumption while also providing building engineers and energy managers with a valuable diagnostic tool for tracking energy consumption and identifying potential HVAC system problems

**Cooling system improvements**: The efficiency of chillers can be improved by lowering the temperature of the condenser water, thereby increasing the chilled water temperature differential. This can reduce pumping energy requirements. Another possible efficiency measure is the installation of separate high-temperature chillers for process cooling.

**Duct/pipe insulation/leakage**: Duct leakage can waste significant amounts of energy in HVAC systems. Measures for reducing duct leakage include installing duct insulation and performing regular duct inspection and maintenance, including ongoing leak detection and repair. Improved duct and pipe insulation can prevent excessive heat/cooling dissipation, thereby improving system energy efficiency.

**Cooling circulation pumps – variable speed drives (VSDs)**: Variable speed drives better match motor speed to load and can therefore lead to significant energy savings compared to constant speed drives. This measure considers the installation of VSDs on cooling circulation pumps.

**DX tune-up/advanced diagnostics**: The tune-up includes cleaning the condenser and evaporator coils, establishing optimal refrigerant levels, and purging refrigerant loops of entrained air. The qualifying relative performance range for a tune-up is between 60 and 85 percent of the rated efficiency of the unit. Includes fresh air economizer controls providing demand control ventilation and consisting of a logic module, enthalpy sensor(s), and CO2 sensors in appropriate applications.

**DX packaged system, EER=10.9, 10 tons**: A single-package A/C unit consists of a single package (or cabinet housing) containing a condensing unit, a compressor, and an indoor fan/coil. An additional benefit of package units is that there is no need for field-installed refrigerant piping, thus minimizing labor costs and the possibility of contaminating the system with dirt, metal, oxides or non-condensing gases. This measure involves installation of a TIER 2 high-efficiency unit (EER=10.9) versus a standard unit (EER=10.3.

**Window film**: Low-emittance windows are an effective strategy for improving building insulation. Low-emittance windows can lower the heat transmitted into a building and therefore increase its insulating ability. There are two types of Low-E glass, high solar transmitting (for regions with higher winter utility bills) and low solar transmitting (for regions with higher summer utility bills).

**Programmable thermostat**: A programmable thermostat allows to control temperature settings of space heating and cooling, and optimizing settings based on occupancy and use of the building. This will reduce unnecessary heating and cooling outside hours of building use. It may also help in building cooling using nighttime cooling.

**Chiller O&M/tune up**: This measure refers to the proper inspection and maintenance of chilled water systems. This can include setting correct head pressure, maintaining correct levels of refrigerant, and selecting and running appropriate compressors for part load. Energy saving can also be achieved by cleaning the condensers and evaporators to prevent scale buildup.

**Setback temperatures (weekends and off duty)**: Setting back building temperatures (i.e., turning building temperatures down in winter or up in summer) during periods of non-use, such as weekends or non-production times, can lead to significant savings in HVAC energy consumption.

**Replace v-belts**: Inventory data suggest that 4% of pumps have V-belt drives, many of which can be replaced with direct couplings to save energy. Based on assessments in several industries, the savings associated with V-belt replacement are estimated at 4%.

**ENERGY STAR transformers**: This measure refers to the replacement of existing transformers, where feasible, by the latest ENERGY STAR certified transformers. ENERGY STAR transformers ensure a high level of energy efficiency.

### A.3.2 Sector-Specific Measures

***SIC 20 : Food and kindred products***

**Efficient refrigeration – operations**: Refrigeration is an important energy user in the food industries. Operations of refrigeration systems can be improved by applying appropriate settings, opening refrigerated space as short as possible, reducing leakage by controlling doorways, making sure that refrigerated space is used optimally, optimization of defrosting cycle, as well as other small operational changes.

**Optimization refrigeration**: The refrigeration system can be optimized by improving the operation of the compressors, selecting cooling systems with high COP values, reducing losses in the coolant distribution system, improved insulation of the cooled space, variable speed drives on cooling system, and optimizing the temperature setting of the cooling system.

**Bakery – process**: Process improvements in the bakery can reduce electricity consumption through selection of energy-efficient equipment for the different processes, optimization of electric ovens, and good housekeeping (e.g. switching equipment off when not in use).

**Bakery – process (mixing)**: About 35% of electricity in bakeries is used to mix and knead the dough. When selecting equipment electricity use should be one of the considerations as energy is the largest cost on a life-cycle basis. Today, energy use is not a criterion. High-efficiency motors, speed control and other measures may reduce electricity consumption.

***SIC 23 : Apparel and other textile products***

**Drying (UV/IR)**: This measure refers to the use of direct heating methods, such as infrared dryers. Direct heating provides significant energy savings because it eliminates the inefficiency of transferring heat to air and from the air to the wet material. The energy efficiency of direct heating is about 90%.

**Membranes for wastewater**: Membrane technologies focus on separating the water from the contaminants using semi-permeable membranes and applied pressure differentials. Membrane filtration of wastewater is typically more energy efficient than evaporation methods, and can lead to significant reductions in facility freshwater intake.

**O&M/drives spinning machines**: Electric motors are the single largest electricity user in spinning mills. Optimization of motor use, proper maintenance procedures (e.g. preventative maintenance), use of new high-efficiency motors instead of re-winding, switching off equipment when not in use can help improve energy efficiency.

### ***SIC 25: Furniture and fixtures***

**Air conveying systems**: Pneumatic or air conveying systems are used to transport material (e.g. sawdust, fibers) in the lumber industry. Energy efficiency improvement is feasible by optimizing the lay-out of the systems, reducing leakages, reducing bends in the system, and improving compressor operations (see also with compressed air systems).

**Optimize drying processes**: This is a general measure, which refers to the optimization of drying systems through such actions as the use of controls, heat recovery, insulation, and good housekeeping/maintenance.

**Heat pumps – drying**: This measure refers to the recovery of low grade heat from the drying process via a heat pump, where cost effective.

### ***SIC 26: Paper and allied products***

**Gap forming paper machine**: The gap former produces a paper of equal and uniform quality at a higher rate of speed. Coupling the former with a press section rebuild or an improvement in the drying capacity increases production capacity by as much as 30%. Energy savings from gap formers come from reduced electricity consumption per ton of product produced.

**High consistency forming**: In high consistency forming, the furnish (process pulp) which enters at the forming stage has more than double the consistency (3%) than normal furnish. This measure increases forming speed, and reduces dewatering and vacuum power requirements. Application of this technology is limited to specific paper grades, especially low-basis weight grades such as tissue, toweling, and newsprint. Electricity savings are estimated at 8%.

**Optimization control PM**: Large electric motors are used to run the paper machine. Optimization of the paper machine will reduce electricity use of the drives. Improved control strategies will improve throughput, reduce breakage and downtime, improving the energy efficiency per unit of throughput. Variable speed drives may help to optimize the energy use in water pumps in the paper machine.

### ***SIC 27: Printing and publishing***

**Efficient practices printing press**: Optimizing the use of the printing press by reducing production losses, switching off of the press when not in use and other improved operational practices.

**Efficient printing press (fewer cylinders)**: New printing press designs allow the use of fewer cylinders (or rollers). This reduces the electricity use to drive the printing machine.

**Light cylinders**: Reducing the weight of the cylinders (or rollers) in the printing machine will reduce the power needed to drive the machine. Using lightweight materials for cylinders has been demonstrated in Europe.

### ***SIC 28: Chemicals and allied products***

**Clean room – controls**: Reduced recirculation air change rates, while still meeting quality control and regulatory standards can reduce energy use, optimized chilled water systems, reduction of cleanroom exhaust, and, occasionally, a cleanroom is classified at a higher cleanliness level than is necessary for its current use, and by declassifying energy can be saved.

**Clean room – new designs**: When designing a clean room, energy use should be a primary consideration. Benchmarking tools and design tools are being developed to help improve the energy efficiency of new cleanroom systems. Furthermore, in the design phase the system can be optimized for improved air filtration quality and efficiency, and the use of cooling towers in lieu of water chillers.

**Process controls (batch + site)**: This is a general measure to implement computer-based process controls, where applicable, to monitor and optimize various processes from an energy consumption perspective. In general, by monitoring key process parameters, processes can be fine tuned to minimize energy consumption while still meeting quality and productivity requirements. Control systems can also reduce the time required to perform complex tasks and can often improve product quality and consistency while optimizing process operations. This measure could include the installation of controls based on neural networks, knowledge based systems, or improved sensor technology.

**Power recovery**: Various processes run at elevated pressures, enabling the opportunity for power recovery from the pressure in the flue gas. The major application for power recovery in the petroleum refinery is the fluid catalytic cracker (FCC). However, power recovery can also be applied to hydrocrackers or other equipment operated at elevated pressures. A power recovery turbine or turbo expander is used to recover energy from the pressure. The recovered energy can be used to drive the FCC compressor or to generate power.

**Efficient desalter**: Alternative designs for desalting include multi-stage desalters and a combination of AC and DC fields. These alternative designs may lead to increased efficiency and lower energy consumption.

### *SIC 30 : Rubber and misc. plastics products*

**O&M – extruders/injection molding**: Improved operation and maintenance procedures of extruders, optimization of extruder settings, optimization of the extruder screw shape, optimization of the shape/thickness of the product, and reduction of standby time.

**Extruders/injection molding – multipump**: The use of multiple pumps and an appropriate control system allow to reduce energy use of the extruder when not working at full capacity, only using the pump(s) needed.

**Direct drive extruders**: Use of a direct drive, instead of a gearbox or belt, will reduce the losses by approximately 15% in extruders.

**Injection molding – impulse cooling**: Impulse cooling regulates the cooling water use increasing the cooling rate and reducing productivity (and downtime).

**Injection molding – direct drive**: Use of a direct drive, instead of a gearbox or belt, will reduce the losses by approximately 20% in injection molding machines.

### *SIC 32 : Stone, clay, glass, and concrete products*

**Efficient grinding**: This is a general measure that refers to efficient grinding technologies, which can include the use of high-efficiency classifiers or separators.

**Top-heating (glass)**: Most electric furnaces use electrodes in the batch to melt the raw materials into glass. Newer designs with top-mounted electrodes can improve and maintain product quality, and obtain a higher share of salable glass, which leads to lower energy intensities (energy per kg of glass produced).

**Autoclave optimization**: In various processes autoclaves are used to press materials. Multiple autoclaves are used. By synchronizing the time of the use of the individual autoclaves, energy can be reduced by re-using the output of one to operate the other autoclave.

### ***SIC 33 : Primary metal industries***

**Efficient electric melting**: Electric arc furnaces are used in the steel industry to melt scrap. Only one minimill is operating in California. Multiple options are available to reduce the electricity consumption of the furnace, e.g. foamy slag, oxy-fuel injection, improved transformers, eccentric bottom tapping (EBT), as well as scrap preheating.

**Near net shape casting**: Near net shape casting is the direct casting of the metal into very nearly the final shape, thereby eliminating other processing steps such as hot rolling, which can lead to significant energy savings.

### ***SIC 38 : Instruments and related products***

**Optimization process (M&T)**: This is a general measure for optimizing the efficiency of painting processes, via such actions as the use of process controls, proper maintenance, and reducing the airflow rates in paint booths.

**Scheduling**: Optimization of the scheduling of various pieces of equipment can reduce downtime and hence save energy. Furthermore, improved control strategies can reduce standby energy use of equipment as part of an optimized scheduling system.

**Efficient curing ovens**: Efficiency options for curing ovens include the optimization of oven insulation, the use of heat recovery techniques, and the use of direct heating methods, such as infrared heating, microwave heating, and ultraviolet heating.

**Machinery**: Many machines (e.g. metal processing) use electricity or compressed air to drive the equipment. The use of compressed air systems should be minimized and replaced by direct drive systems, because of the low efficiency of the compressed air supply. Furthermore, many machines do not use high-efficiency motors or speed controls.

### ***SIC 36 : Electrical and electronic products***

**Efficient processes (welding, etc.)**: New more power efficient welding technology is developed. For welding robots, new servo-based systems reduce energy use. See also new transformers welding (see section 1.1).

### ***SIC 39 : Misc. manufacturing industries***

**Process heating**: Induction furnaces are often used for electric process heating. Improved operation and maintenance can reduce part-load operation, downtime and tap-to-tap time. Furthermore, high-frequency induction furnaces improve energy use.