FPL.

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January 16, 2018

STAFF'S FIRST DATA REQUEST

-VIA ELECTRONIC FILING-

Ms. Carlotta Stauffer, Commission Clerk
Office of the General Counsel
Florida Public Service Commission
2540 Shumard Oak Blvd.
Tallahassee, FL 32399-0850

Re: Electric Vehicle Charging Station Study

Dear Ms. Stauffer:

Please find enclosed for filing a copy of Florida Power & Light Company's ("FPL") responses to Staff's First Data Request for the above mentioned study.

Thank you for your assistance. Please contact me should you or your staff have any questions regarding this filing.

Sincerely,

s/ William P. Cox

William P. Cox
Senior Attorney
Florida Bar No. 0093531

WPC/msw
Enclosures
cc: Shelby Whitfield, Office of Industry Development and Market Analysis

QUESTION:
How many Plug-in Hybrid Electric Vehicle (PHEV) charging stations are currently located in the utility's service territory?

a. How many charging stations are "Public Chargers," e.g. available to the general public?

b. Does this include charging available to RV parks, rest areas, and campgrounds?

c. How many are in-home, private charging stations?

d. How many charging stations are "Private," e.g. not available to the general public, excluding in-home charging?

e. How many charging stations are owned by the utility?

RESPONSE:
Please note that this set of data requests asks only about plug-in hybrid electric vehicles (PHEV) and charging stations. However, FPL's responses to all data requests reflect both battery electric vehicles (BEV) and PHEV vehicles because both are charged via the grid. The following definitions explain the differences between these types of vehicles:

- Battery Electric Vehicles (BEV) – examples: Nissan Leaf, Chevrolet Bolt, Tesla Model S. These cars are propelled solely by an electric motor. BEVs typically features a large lithium-ion battery with capacities ranging from 24-100kWh.
- PHEV – examples: Ford Fusion Energi, Chevy Volt. These EVs have internal combustion engines (ICE) with a battery that is recharged by plugging into an electric source. The high voltage battery is smaller than in a BEV and has an all-electric range of 10-60 miles. Charging speeds are slower, mainly due to the ICE taking over after battery depletion.

FPL typically breaks Electric Vehicle Supply Equipment (EVSE) into three categories as defined by the Department of Energy (DOE) PHEV Handbook[1]:

- Level 1 AC charging – 120V / up to 15amps at a rate of up to 1.8kW.
- Level 2 AC charging – 240V / up to 80amps at rates from 3.3kW-19.2kW.
- DC Fast Charging: – 480V / 3-Phase AC at rates of 50kW – 350kW.

Although there have been improvements concerning the reporting of active EVSE, accurate tracking remains challenging. EVSE site hosts are surveyed on an annual basis and new stations are added regularly, however, no accurate process concerning residential chargers is currently

[1] National Renewable Energy Laboratory. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. (n.d.). Plug-in electric vehicle handbook for consumers. P8-9. (DOE/GO-102011-3274). Retrieved from website: http://www.afdc.energy.gov/afdc/pdfs/51226.pdf

available. The most reliable source can be found on the DOE's Alternative Fuels Data Base (AFDB) website.

a. DOE reports that there are 545 (872 handles) public charging stations in FPL's service territory.

b. Yes. The DOE includes all reported charging stations including such locations.

c. Since DOE does not accurately track residential charging stations, FPL can only estimate the number based on EVs registrations in Florida. All new EVs ship with a Level 1 charging station and some owners opt to install a Level 2 charging station as well. As of Q2 2017, there were 14,013 registered EVs in FPL's service territory.

d. We estimate 100 (226 handles) non-residential private stations in FPL's service territory.

e. FPL owns 316 private charging handles and 1 public station.

QUESTION:
Please complete the table below describing the projected number of PHEV charging stations that are anticipated to be located in utility's service territory.

Number of Projected PHEV Charging Stations

	Level 1	Level 2	Level 2+	Level 3	Level 4	Total
2016						
2017						
2018						
2019						
2020						
2021						
2022						
2023						
2024						
2025						

Note: PHEV Charging Station Energy Specifications:

Level 1 - 1.1 kW, 15 amp, 110 V (< 15 amps delivered)
Restricted to at home only, overnight full charge
9 pm to 9 am, randomized start, full plug-in PHEV charge

Level 2 - 3.3 kW, 15 amp, 220 V
Restricted to home and work
Charge anytime, charge until full
Effectively two plug-in PHEV charges per day

Level 2+ 6.6 kW, 30 amp, 220 V
Unrestricted location; wherever you park
Charge anytime; charge until full
Several plug-in PHEV charges per day

Level 3 50 kW, 100 amp, ~400 V
Refueling station concept for PHEVs
Charge anytime; charge until full
Up to hundreds of charges per day

Level 4 Other, please defined

RESPONSE:
FPL does not have a forecast of EVSE growth, but the number of stations in FPL's service territory is expected to increase in the near future due to, but not limited to, the following factors: mandatory investment by Electrify America as a result of the Volkswagen (VW) Settlement; manufacturer installations to support new products (such as the Tesla Model 3); and the opportunity for Florida to spend up to 15% (or ~$24M) of VW Mitigation Trust funding on EVSE.

Please note FPL does not agree with certain aspects of the EVSE specifications provided above.

- Level 1 charging is not restricted to the times indicated or the locations specified.
- Some workplace charging programs include Level 1 charging.
- Level 2 charging rates also do not correlate to the charging location and are not limited to 3.3 kW charging rates.
- Public charging (Level 2+) is not required to charge at a 6.6 kW rate.
- Each category can provide charging at rates above or below the specified definitions.
- Level 3 (DC Fast Charging) has advanced beyond 50 kW with Tesla utilizing 120 kW superchargers. This rate is expected to increase to 350 kW in the future.

QUESTION:
Please describe the impact PHEV charging stations had on the utility's load in 2016. Please include contribution to peak demand, a typical hourly profile for load from PHEV charging stations, and a typical hourly profile for the electric system as a whole for comparison purposes,for each month of 2016.

Please provide this information for:

1. In-home charging stations.

2. Other private charging stations

3. Public charging stations.

RESPONSE:
Based on data from the Florida Department of Transportation, as of 2016 Q4, there were an estimated 12,538 PHEVs in FPL's service territory. It is estimated that PHEVs contributed 17 MW to the summer peak and 8 MW to the winter peak. The individual hourly profile for in-home charging stations, public charging stations, and other private charging stations is unknown as there is currently no feasible way to track this usage. Below is the average FPL hourly profile by month for 2016 and the estimated EV hourly profile.

Estimated Hourly Charge EV profile and Average FPL hourly Profile by Month - in MW													
	EV	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16
Hour 1	5.4	9,429	9,202	9,985	10,516	11,677	13,362	14,527	13,904	12,942	11,459	9,736	10,151
Hour 2	2.8	8,921	8,696	8,902	9,646	10,772	12,430	13,523	13,005	12,079	10,690	8,788	9,402
Hour 3	2.4	8,668	8,467	8,767	9,101	10,161	11,802	12,828	12,390	11,496	10,169	8,407	8,973
Hour 4	2.2	8,605	8,438	8,529	8,785	9,787	11,388	12,368	12,002	11,138	9,868	8,224	8,749
Hour 5	2.2	8,765	8,637	8,531	8,727	9,669	11,239	12,167	11,893	11,058	9,826	8,264	8,760
Hour 6	2.2	9,401	9,373	9,006	9,134	9,974	11,498	12,337	12,209	11,440	10,210	8,743	9,191
Hour 7	2.2	10,593	10,737	10,029	10,092	10,723	12,041	12,729	12,883	12,257	11,034	9,669	10,054
Hour 8	2.2	11,478	11,685	10,795	10,693	11,349	12,811	13,364	13,323	12,624	11,531	10,356	10,694
Hour 9	1.5	12,077	12,188	11,528	11,544	12,438	14,188	14,838	14,441	13,562	12,193	11,194	11,634
Hour 10	1.1	12,538	12,515	12,478	12,639	13,773	15,755	16,562	15,984	15,089	13,343	12,086	12,678
Hour 11	0.7	12,779	12,684	13,379	13,633	15,024	17,250	18,231	17,540	16,576	14,438	12,853	13,510
Hour 12	0.5	12,813	12,695	14,056	14,429	16,089	18,493	19,627	18,861	17,854	15,355	13,430	14,117
Hour 13	0.5	12,725	12,589	14,576	15,074	16,915	19,345	20,649	19,874	18,821	16,068	13,887	14,563
Hour 14	0.4	12,583	12,577	14,956	15,678	17,549	19,901	21,383	20,597	19,466	16,639	14,241	14,846
Hour 15	0.4	12,411	12,498	15,204	16,149	17,968	20,191	21,770	20,937	19,740	16,977	14,398	14,982
Hour 16	5.7	12,289	12,474	15,311	16,537	18,237	20,308	21,894	21,014	19,812	17,165	14,360	14,914
Hour 17	8.1	12,245	12,476	15,349	16,754	18,300	20,245	21,774	20,820	19,724	17,107	14,127	14,662
Hour 18	8.4	12,630	12,596	15,209	16,644	18,132	19,889	21,379	20,373	19,339	16,784	14,068	14,726
Hour 19	25.2	13,512	13,289	15,005	16,140	17,642	19,245	20,726	19,695	18,643	16,287	14,276	15,179
Hour 20	52.3	13,382	13,417	14,863	15,467	16,852	18,411	19,799	18,900	18,158	16,298	13,881	14,717
Hour 21	41.4	12,906	12,911	14,594	15,365	16,516	17,938	19,229	18,580	17,764	15,744	13,272	14,081
Hour 22	21.0	12,158	12,124	13,697	14,484	15,720	17,267	18,520	17,680	16,714	14,786	12,441	13,299
Hour 23	15.1	11,234	11,178	12,613	13,221	14,424	16,047	17,269	16,413	15,446	13,692	11,471	12,311
Hour 24	12.2	10,191	10,102	11,282	11,792	12,991	14,652	15,863	15,039	14,128	12,484	10,395	11,129

QUESTION:
Has the utility estimated the number of PHEVs in Florida at present, both in its service territory and statewide? If so, how many?

RESPONSE:
Yes. FPL estimates EV vehicle penetration based on registration data purchased from the Florida Department of Motor Vehicles (DMV). The most recent data available is through Q2 2017, which showed 22,125 EVs for Florida and 14,013 in FPL's service territory.

QUESTION:
Has the utility estimated the number of PHEVs that are expected to be in use in Florida through 2025?

If yes, please provide and include source of estimates and how derived.

RESPONSE:
Yes. FPL updates its EV forecast for Florida annually using the following methodology:

- FPL starts by forecasting the number of EVs expected to be in use in the United States using a number of third party resources (*i.e.*, Bloomberg New Energy Finance, ExxonMobil, British Petroleum, and International Energy Agency) and discussions with knowledgeable professionals in the automotive industry.

- FPL then takes the number of registered EVs in Florida and divides it by the number of vehicles in use nationally to derive Florida's current share of the U.S. market.

- This percentage share (historically ~3.6%) is then multiplied by FPL's national forecast to get the Florida EV forecast by year.

Florida Cumulative	
Year	Number of PHEVs
2016	20,217
2017	27,636
2018	35,539
2019	45,263
2020	60,821
2021	81,825
2022	110,181
2023	148,461
2024	207,521
2025	279,870

QUESTION:
Has the utility estimated the number of PHEVs that are expected to be in use in its service territory through 2025?

If yes, please provide and include source of estimates and how derived.

If yes, please complete the table below showing actual and projected number of PHEVs in your service territory through 2025.

RESPONSE:
Yes. FPL updates its EV forecast for its service territory annually using the following methodology:

- FPL takes the number of registered EVs in its service territory (DMV registrations) and divides it by the number of vehicles in use in Florida (DMV registrations) to derive FPL's current share of the Florida market.

- This percentage share (historically ~64%) is then multiplied by the Florida EV forecast (as described in FPL's response to Staff's First Data Request No. 5) to get the FPL EV service territory forecast by year.

FPL Cumulative	
Year	Number of PHEVs
2016	12,987
2017	17,753
2018	22,830
2019	29,076
2020	39,071
2021	52,564
2022	70,779
2023	95,370
2024	133,309
2025	179,786

QUESTION:
Explain how load management or rate design tools may mitigate the demand impacts of PHEV charging on peak demand.

RESPONSE:
Because most charging occurs at home, the most effective rate structure would likely be a residential EV-Only Time-of-Use (TOU) rate. However, there are some drawbacks/challenges to such a rate:

a. It requires separate metering or sub-metering which is an added expense for the customer and utility. Given FPL's relatively low residential rate, it would be difficult for a customer to recover their investment in a reasonable timeframe.

b. A TOU rate needs to have a sufficient on-peak to off-peak rates differential to incent moving usage to off-peak times. While it is possible that sufficiently large cost differentials may exist elsewhere in the country, such cost-based differentials do not exist on FPL's system. Therefore, to be effective, a TOU rate would have to not be cost-based.

c. A TOU rate could create a new peak if such a TOU rate was implemented and resulted in large participation.

At this time, FPL does not feel that it has a need for an EV TOU Rate. FPL already offers a residential TOU rate option which EV owners, like all residential customers, are eligible for without the added metering expense mentioned above. Additionally, workplace charging programs are becoming more common in Florida. Charging EVs in the early to mid-morning hours at a workplace instead of evening hours at home during peak demand times helps to mitigate grid impacts by shifting the load to a lower demand time.

Load control options related to EV charging are being examined by the industry. However, it is too soon to know the results. Two potential operational concerns with this approach are the implementation cost and alignment with the times when EV owners are charging. Given current forecasts of charging behavior, there may be limited numbers of EVs actually charging during FPL's peak. In addition, the question remains whether consumers will accept third-party control over their EV, charging habits, and battery impacts.

QUESTION:
Does your utility currently have or plan to offer to its customers load management programs or rate designs specifically for PHEVs?

> If yes, please describe these programs including participation and peak reduction.
>
> If not currently but plan to, when will plans designed for PHEVs be offered to your customers?

RESPONSE:
No. FPL does not currently have or have plans to offer to its customers load management programs or rate designs specifically for EVs.

QUESTION:
What type of additional policies and processes does the utility currently have in place to manage the addition of charging facilities to your system?

RESPONSE:
Planning for long-term increases in electricity demand is part of FPL's core business. FPL has included the load from EVs in its Ten-Year Site Plan forecast since 2009. Today, many of FPL's existing departments are handling EV-related issues as part of their regular duties, including Service Planning, Customer Care Center, and Load Forecasting.

One of the primary objectives of FPL's EV program is to ensure reliable service which includes the following practices and policies:

- Studying the market and actively engaging in discussions with automotive manufacturers, charging infrastructure providers, and others in the industry;

- Working closely with Tesla, Electrify America, EvGo, and others on the installation of large and small charger sites;

- Analyzing any potential EV charging impacts to the grid and taking the appropriate steps if needed to ensure being fully prepared to meet any new electrical demand created by EVs; and

- Involvement with a number of industry organizations that are performing studies and/or have influence over policies associated with EVs and EV charging.

QUESTION:
Based on the utility's experiences, what challenges do PHEVs present to utility and grid operation?

RESPONSE:
Please see Attachment No. 1, FPL's 2014 Electric Vehicle Reliability Study, provided in Staff's First Data Request No. 16 for details. In the near-term, DC Fast Charging can present challenges based on desired site location characteristics and available locational system capacity. With the future capacity capability of DC Fast Chargers expected to increase to as high as 350 kW at main road corridor locations, thoughtful and coordinated planning is necessary to ensure mutually beneficial installations for the utility and the customer served. Longer-term challenges for utilities, and the EV industry as a whole, include standards, policies, and possibly future programs related to load management, vehicle-to-grid, and vehicle-to-home.

QUESTION:
What additional generation or transmission assets will the utility require if 1 percent of vehicles in the utility's service area are replaced with PHEVs for each year through 2025?

What if the figure reaches 5 percent, 10 percent, 25 percent, or 50 percent?

What are the costs of these additional generation assets expected to be?

What effect will these additional costs have on the general body of ratepayers?

RESPONSE:
FPL interprets the question to be asking what additional generation or transmission assets the utility will require if 1 percent of vehicles in the utility's service area are replaced with EVs by 2025 compared to what is projected for EVs in the utility's current load forecast. FPL's load forecast projects that approximately 1 percent of vehicles in its service territory will be EVs by the year 2025. Therefore, FPL's forecast does not project the need for any additional generation or transmission assets through that period.

FPL does not believe that 5 percent, 10 percent, 25 percent, or 50 percent EV penetration levels are realistic within this timeframe. Therefore, FPL has not performed any analysis of such levels of EV penetration. However, FPL carefully monitors and tracks monthly sales of electric vehicles in the United States and is prepared to make revisions to its forecast if needed. If EV penetration projections change to approach these levels by 2025, additional generation and transmission could be needed to manage the load.

QUESTION:
Has the utility adjusted its load forecast to account for additional load from PHEVs?

If yes, please describe the basis for the projected load adjustment and provide resources relied upon for this adjustment.

If yes, please complete the table below summarizing the incremental projected load from PHEVs.

RESPONSE:
Yes. The contribution to net energy for load from PHEVs was derived from FPL's light duty vehicle (passenger car or "LDV") and truck and bus forecasts using an estimated kWh per vehicle. It was assumed that charging would take place 365 days per year for LDVs, 250 days per year for medium duty trucks, and 360 days per year for buses. FPL has been testing electric vehicles in both fleet and commuting applications since the early 1990s. For residential/commuting applications, experience indicates that on average LDVs can travel approximately three miles for every kWh of charge. A survey by the U.S. Department of Transportation conducted on the National Household Travel Trends in 2009 indicates that the daily average driving distance in the U.S. is approximately 36 miles (Reference: Santoso A., McGuckin, N., Nakamoto, H.Y., Gray, D., & Liss, S. U. S. Department of Transportation, Federal Highway Administration.(2011). Summary of travel trends: 2009 national household travel survey (FHWA-PL-11-022), Table 14. P28.). When this estimate is coupled with the FPL experience for electric vehicles in residential/commuting applications, it suggests the average daily charging energy required per LDV would be about 12 kWh per day (36 miles per day / 3 miles per kWh.) The kWh forecast was developed using this factor plus a similar forecast developed in 2010 for trucks and buses. Energy values are at the generator and have been adjusted for system losses.

For summer and winter peak demand, FPL estimated the most likely charging schedule for LDVs, trucks, and buses. The percent of each vehicle type charging during the summer and winter peak periods was then estimated in relation to the forecasted summer and winter peak demands. To create the summer and winter coincident peak demand impact, the estimated number of vehicles (as previously described) was multiplied by the percentage of each vehicle type charging during FPL's peak hour and multiplied by the kW per vehicle type.

	Summer MW	Winter MW	GWH
2016			5
2017	7	3	27
2018	13	7	50
2019	22	11	78
2020	35	18	123
2021	53	27	184
2022	78	39	266

2023	111	56	377
2024	162	81	548
2025	225	112	757
Notes:	Includes cars and trucks Incremental from mid-2016		

QUESTION:
Is the utility's existing electric generation system adequate to accommodate PHEV demand based on the estimated number of PHEVs expected to be in use through 2025?

Please explain.

RESPONSE:
Yes, based on FPL's 2017 Ten-Year Site Plan EV charging load forecast.

Based on the most likely projections of load currently available, the number of plug-in electric vehicles projected in FPL's service territory through 2025 will not be large enough to put any significant demand on FPL's generation system.

QUESTION:
Is the utility's existing electric transmission system adequate to accommodate the PHEV demand based on the estimated number of PHEVs expected to be in use through 2025?

Please explain.

RESPONSE:
Yes. Based on FPL's most recent EV Reliability Study (completed in 2014), since no additional generation is anticipated to be required to meet the projected 2025 EV load requirements, FPL's existing transmission system is adequate to accommodate the expected EV demand.

QUESTION:

Has the utility performed any analysis or prepared any studies examining the magnitude and nature of PHEV charging, especially regarding whether different levels (as delineated in question 2) of charging are more or less likely to occur at specific times of day?

If yes, please provide the analysis or study and describe the results.

RESPONSE:

Yes. Please see Attachment No. 1, FPL's 2014 Electric Vehicle Reliability Study, provided in FPL's response to Staff's First Data Request No. 16.

QUESTION:
Has the utility performed any analysis or prepared any studies related to the potential impacts of PHEV charging on its transmission system?

If yes, please provide the analysis or study and describe the results.

RESPONSE:
Yes. Please see Attachment No. 1, FPL's 2014 Electric Vehicle Reliability Study, attached to this response, and FPL's response to Staff's First Data Request No. 14.

EV Reliability Team

FPL Electric Vehicle Reliability Study

Final

FPL

FPL EV Reliability Study

Executive Summary

When looking at FPL's system, there does not appear to be any significant impact on power distribution or generation through 2030. The plug-in electric vehicle (PEV) adoption rate is expected to be slow, reaching only around 1 percent over the next five to ten years. It will take a large number of vehicles charging during FPL system peak to have any significant impact on generation or distribution – current forecasts indicate this is a number of years off, 2025 or later.

Smaller residential transformers are likely to be the first point where FPL's system could be impacted by PEV charging. Except at high charge rates, only a small percentage of transformers would be impacted with on-peak charging; most charging occurs during non-peak hours. Additionally, higher rates of charge like 19.2kW, only occur in limited cases.

Based on what we know of our system and what we expect from PEV charging, FPL is well situated for PEV charging.

How many PEVs that are potentially charging at a given time is dependent on a number of factors that FPL will continue to monitor. FPL began receiving quarterly updates on PEV registrations from the Florida Department of Motor Vehicles to continue to monitor this, which allows FPL to get accurate numbers on PEVs in its territory, down to the zip code level. More precise data is currently not available, other than on a voluntary basis directly from customers, and is probably not necessary at this point.

Study findings:

- There is no significant impact expected on distribution or generation – current forecasts indicate this to be the case through 2025 or later.
- The expected PEV adoption rate is near 1 percent over the next five to ten years.
- A minimum of 6.6kW Level 2 charging is likely to be more prevalent in future model years, though it is unclear what proportion of customers will charge at Level 2, and what percentage will opt to only charge at Level 1.
- Residential charging, even at higher rates, will likely have a minimal impact on power quality and reliability, at least in the near term.
- PEV charging will most likely impact smaller residential transformers (25 & 37.5kVA) first. However, most charging occurs during non-peak hours and impact may be limited to Tx that are already highly loaded, or where charging occurs during the daily peak.
- Areas with higher percent of PEVs or transformers that are near 200% loading are more likely to be impacted.

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Industry/Market Overview

Background

An electric vehicle (EV) uses one or more electric or traction motors for propulsion. PEVs or plug-in electric vehicles are electric vehicles that that use a battery for all or part of the electricity to power their electric motor and are recharged using an external power source. Recharging is achieved directly, or indirectly, from the electric grid.

EVs were first developed in early 1800s and by 1900 electric vehicles made up approximately 10 percent of all vehicle sales compared to approximately 20 percent for internal combustion (ICE) vehicles (automobile, 2012). EVs had many advantages over early 20th century gasoline counterparts; they had little vibration, smell, or noise and they didn't require crank start or gear change making them especially popular among well-healed city dwellers and women.

However, within a few years, various factors in favor of ICE vehicles had made them the propulsion of choice for motorized transportation. While sales of EVs peaked at approximately 6,000 in 1913, they now only made up approximately 1 percent of total automobile sales. There were a number of factors contributing to this reversal of fortunes including:

- Limited battery technology combined with a poor electric infrastructure severely inhibited the range of electric vehicles as the development of the interstate road system made longer range travel much more viable.
- Mass assembly of ICE vehicles significantly lowered their price.
- The development of the electric starter eliminated the need for crank-starting of ICE vehicles.
- The discovery of large reserves of oil in OK, TX, CA significantly reduced the price of gasoline.

In subsequent years, electric vehicles would occasionally pop up, but pricing and technology were never enough to give them any significant traction in the market. In 1990, the California Air Resources Board (CARB) enacted a mandate requiring the seven major auto manufacturers at that the time to produce and sell zero emissions vehicles (ZEV) in order to continue marketing their vehicles in California. A handful of EVs were developed as a result, the most popular of which was GM's EV1 (which was available strictly as a leased vehicle). (Wikipedia, 2012)

Eventually, some of these vehicles were available in Florida, leading to the development of a PEV program at FPL. However, due to a number of factors, CARB backed off of their strict mandate. No longer needing to manufacture ZEVs, and despite their popularity, auto companies discontinued production of their EVs with GM recalling all of their EV1's and crushing them. This led to the dissolution of the FPL PEV program shortly thereafter.

Now, due to a number of influences, PEVs are once again becoming available to consumers in FPL's service territory. Higher gasoline prices, improved technologies, a growing desire to reduce dependence on foreign oil, and government backing have all contributed to this resurgence and give PEVs momentum that they haven't seen since the late 1800's. Also, new regulations for corporate average fuel economy (CAFE) that will nearly double fuel economy standards by 2025 to 54.5 miles per gallon, have also helped increase momentum of PEVs.

Because of this momentum, FPL is preparing for the continued adoption of PEV's in its territory.

To prepare for continued PEV adoption, FPL has continued to assess its system readiness. FPL conducted an initial reliability analysis in 2008 and this study is a continued effort to assess system reliability as PEVs began entering FPL's territory in November 2011[1]. The number of vehicles in the territory, the type of vehicle, the size of their battery, their charge rate, where they charge, when they charge, and any harmonics/interference produced by charging will all affect how PEVs impact the grid. Because PEV market adoption is in its infancy, the magnitude of these impacts is largely unknown. Due to varying grid standards across the country, it is important for each utility to examine the potential impacts on their system. FPL is evaluating the influence of PEVs on its system to ensure that widespread adoption does not cause negative impacts on reliability for its customers.

EV Overview

EVs fall into four categories: Hybrid Electric Vehicles (HEV), Plug-In Hybrid Electric Vehicles (PHEV), Battery Electric Vehicles (BEV), and Extended Range Electric Vehicles (EREV). They can run on all battery power, or can run on a combination of gas and electric power. The battery can be charged by plugging into an external source or from an ICE. From the standpoint of reliability, FPL is only concerned with with plug-in vehicles.

Battery capacity is measured by kilowatt hours. Current battery sizes for PEVs range from 4.4kWh to 85kWh. While range depends on driving habits, driving conditions, and the efficiency of the vehicle, PEVs generally get roughly 3.4 miles per kWh.

Types of Electric Vehicles

Hybrid Electric Vehicles (HEV).

- Vehicle has dual drive-trains, both an electric motor and an internal combustion engine, which are mechanically coupled to the wheels through a transmission – also known as a parallel hybrid.
- Vehicle does not run on pure battery power or connect to the grid; battery is recharged by the ICE.
- e.g. Toyota Prius, Toyota Camry Hybrid
- Battery Size: 1.8kWh
- Range: 500+ miles (depending on gas tank size)

[1] The Tesla Roadster has been available in FPL territory since 2008, but this is a limited production vehicle with only 59 registered to FPL customers.

Plug-In Hybrid Electric Vehicles (PHEV)

- A HEV that is capable of running in all-battery mode that recharges when it is connected to the grid. Once the battery is depleted, it runs as a regular HEV.
- e.g. Toyota Prius plug-in, Ford Energi C-Max
- Battery Size: 4.4kWh
- Range: 10-20 miles on battery; 500+ miles total (depending on gas tank size)

Battery Electric Vehicles (BEV)

- A BEV has a single drive train with an electric motor powered by a battery which is charged from an external source that connects it to the grid.
- e.g. Nissan Leaf, Tesla Model S, Ford Focus Electric, Coda, BYD e6
- Battery Size: 24kWh – 85kWh
- Range: 70-100 miles (24kWh) to 250-300 miles (85kWh)

Extended Range Electric Vehicle (EREV)

- BEV with a generator or fuel cell to power the electric motor when the battery is depleted. Still has a single electric drive-train that requires connecting to the grid to recharge; the generator does not power the wheels – also known as a series hybrid.
- e.g. Chevy Volt, Fisker Karma
- Battery Size: 10.4kWh
- Range: 35-45 miles on battery; 300+ miles total (depending on gas tank size)

PEVs charge their battery from an external source, usually by plugging in directly though some are now looking into the viability of wireless charging. Charging is done directly from the grid. While off-grid charging is theoretically possible using solar/wind power or a generator, there are currently no economically feasible ways for this type of charging.

PEVs have an onboard charger that uses a rectifier circuit to transform alternating current from the electrical grid to direct current (DC) suitable for recharging the battery pack. Cost and thermal issues limit how much power the rectifier can handle, so some vehicles have the additional capability to charge DC directly to the battery via an off-board charger – known as DC fast charging. Electric Vehicle Supply Equipment (EVSE), more commonly known as a charging station, is used to connect the charger to a power source. EVSEs can vary from essentially a heavy duty extension cord with some controls to protect the vehicle to a full network connected charging station with interactive touch screens.

Most vehicles use a standard connector – the Society of Automotive Engineers (SAE) J1772 Electric Vehicle Conductive

Figure 1 SAE J1772

Charge Coupler for AC charging. Currently Tesla is an exception to this with their own propriety device, using their own coupler, though they do offer a J1772 adapter. Additionally, vehicles capable of DC fast charging currently have an additional coupler. Nissan vehicles come equipped with the CHAdeMO connection for DC charging. Going forward, the SAE has developed a standard connection based on the J1772 that will allow vehicles to use a single socket for both AC and DC charging.

Vehicles charge at different rates with varying designations for these rates. FPL recognizes the SAE charging configurations and ratings terminology when talking about charge rates. Under SAE, there are three levels for both AC and DC charging, though in practice, only AC Level 1, AC Level 2 and DC Level 2 are in general use (commonly referred to as Level 1, Level 2 and DC fast charge) (SAE Hybrid Committee, 2011).

All vehicles are capable of Level 1 and Level 2 charging. Additionally, all vehicles ship with a Level 1 EVSE. Level 1 charging uses a standard 110-120V wall outlet and charges at a rate of 1.3kW.

Level 2 charging uses 208-240V and requires installation by an electrical contractor. Level 2 charging ranges from 3.3kW to 19.2kW. In 2012, nearly all vehicles charge at a Level 2 rate of 3.3kW. However, today most vehicles starting with the 2013-2014 model year will charge at a minimum rate of 6.6kW.

DC fast charge requires three-phase AC at 208-450V and 200amps necessitating commercial/industrial service. As of early 2014, there are three DC fast charge stations in FPL's territory, courtesy of Tesla Motors. Tesla has plans to expand their charging across the U.S., including more in Florida through the end of 2015. A number of vehicle expected to be released over the next few years are expected to have this capability though.

	LEVEL 1	LEVEL 2	FAST CHARGE (DC Level2)
Current Type	Alternating Current (AC)	Alternating Current (AC)	Direct Current (DC)
Amperage (amps)	12-16 amps	Up to 80 amps	Up to 200 amps
Voltage (V)	110-120V	208-240V	208-450V DC
Kilowatts (kW)	1.2 – 1.9kW	3.3 – 19.2kW Most common: 3.3, 6.6, and 9.6kW	36 - 90kW Most common presently is 50kW
Charging time: range gained per hour	**3-5 miles per hour**	**10-60 miles per hour**	**60-80 miles per half hour**
Approximate Cost	No additional cost, or up to $1,000	$1,500 - $10,000	$20,000 or more
Suitable Locations	Home, Fleet, Workplace	Home, Fleet, Workplace, Public	Public, Major corridors

PEV Model Overview

After the demise of EVs in the early 2000's, the first highway capable serial production PEV available in FPL territory was the Tesla Roadster – a limited production all-electric sports car. The Roadster was a high-end (base price

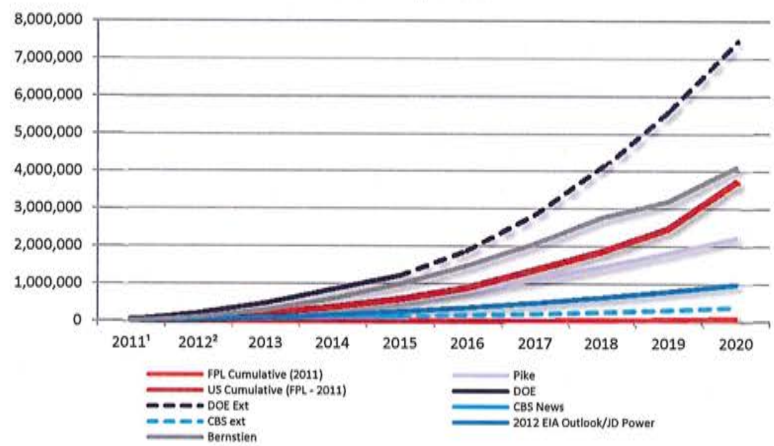
$109,000), high performance vehicle car with a 53kWh battery. Only 2,400 were produced world-wide through 2011 with 69 Roadsters registered in FPL territory (Florida DMV, August 2012).

Until November 2011, the Tesla Roadster was the only PEV available for sale in Florida. At the end of 2011, the Chevy Volt, Nissan Leaf, and Fisker Karma were made available in Florida. The Volt and Karma are EREVs while the Leaf is a BEV. In mid-2012, Tesla started delivery of a new BEV, the Model S. At the end of 2012, these were the only vehicles available in Florida. By the end of 2013, there were many more PEV models in Florida, with over 15 different types found in Florida. (Note: Some were purchased out of state and then registered in Florida like the Rav4 PEV.) The top five most prevalent vehicles in Florida at the end of 2013 were the Chevy Volt, Tesla Model S, Nissan Leaf, Ford C-Max and the Fisker Karma with more models expected to come to market in 2014.

PEV Forecast/Sales

Currently, there is a great deal of speculation as to the ultimate impact and growth of the PEV market. There are a number of factors such as production delays, gas prices, technology breakthroughs, government incentives, etc. that create uncertainty, both positive and negative, in the projected future growth of the PEV market. Because of this, estimates differ greatly ranging from limited adoption to PEVs comprising a significant portion of the US vehicle fleet.

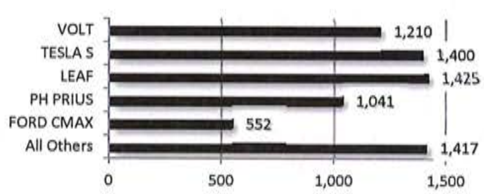
Forecast Comparisons



Since 2010, PEVs have rolled out slowly, with models being first offered in California, and select other markets including OR, WA, TN, Detroit, New York, before being rolled out to more populated markets (including FL), and finally to the rest of the country. States like California, where PEVs were first offered, have zero emission mandates (ZEV) from the Environmental Protection Agency (EPA) expediting the need for PEVs in those areas, whereas Florida does not have a similar mandate. Despite some setbacks including production delays and limited model offerings, PEV sales are gradually gaining momentum and have sold at a faster pace than when HEVs were introduced in the 1990's.

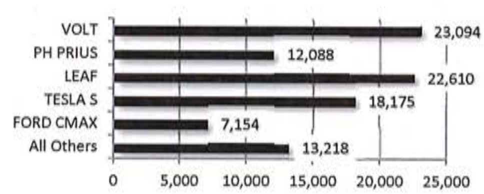
Current U.S. Monthly Sales

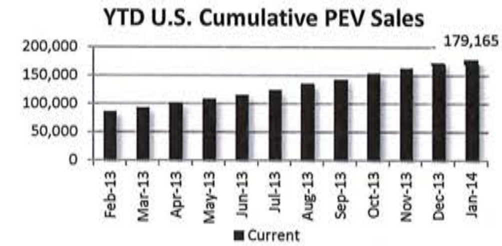
Top 5 PEVs as of Feb. 2014

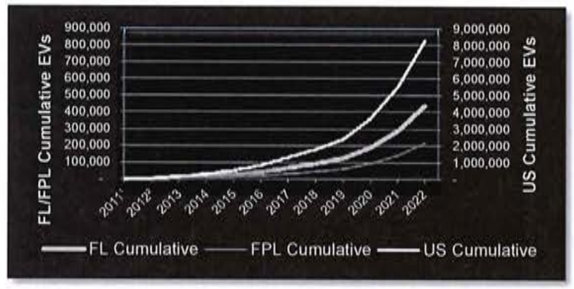


2013 Year-end U.S. Sales

Top 5 PEVs







Based on discussions with automobile manufacturers, industry experts, other forecasts and other information available, FPL is forecasting PEVs to grow slowly, but steadily over the next 20 years. Growth should be slow initially, reaching approximately 98,000 in FPL territory by 2020 (about 0.12 percent of total vehicles). Adoption is expected to pick up after 2020, reaching a little over 800,000 PEVs in FPL territory by 2030, about 9 percent of total vehicles. (See Appendix for additional information.)

In Florida, PEVs are showing up in Florida with larger concentrations in Florida's major metropolitan areas. Approximately 65 percent percent of Florida PEVs are in FPL Territory. Based on vehicle registration data received from the Department of Motor Vehicles for year-end 2013, Florida now has 3.6 percent of all PEV sales in the U. S.

As of year-end 2013, there were 6,377 PEVs registered in Florida, with 4,121 registered in FPL territory. Based on 2013 FL PEV registrations and increased U.S. sales, our forecasts predict between 8,000 and 9,000 PEVs in FPL territory by the end of 2014.

While momentum has certainly picked up for PEVs, both in Florida and across the U.S., it is still unclear how strong the momentum is or how long it will last. A number of new models are expected in the next few years, but pricing and range anxiety remain issues.

There are a number of headwinds and tailwinds impacting PEVs; how these issues play out will determine how fast PEVs grow, and whether they grow to a significant portion of the total automobile market or they remain a niche product.

HEADWINDS AND TAIL WINDS IMPACTING PEVS

Tailwinds	Headwinds
• Fuel Savings – approximately 75 to 80 percent cheaper and lower cost of ownership due to less maintenance, etc.	• Vehicle/Battery costs – Currently ~$500/kWh
• Incentives – Federal, State, Local and Dealer (Up to $7,500 federal tax incentives, HOV Lane access, Rebates, Tax Credits, Competitive Lease Deals, Dealer Incentives)	• Battery Energy Density – In addition to costs, current battery technologies require very large batteries in order to achieve significant driving range
• Volatility in gas prices - 2035 fuel expected to be $145/barrel • Desire for Energy Independence	• Limited BEV Range – Currently 70 to 100 miles for most vehicles, though the Tesla has a range of up to 250+ and other models are being introduced with ranges of over 100 miles
• Cool Factor – EVs are cutting edge technology and fun to drive	• Lack of public charging infrastructure
• Vehicle options – A number of new BEV/EREV/PHEV models are expected over the next few years	• Lack of awareness of PEVs by consumers • Recent emergence of condensed natural gas (CNG) vehicles as well as fuel cell vehicles
• 2025 CAFE Standards – Requires automobile manufacturers fleets to average 54.5mpg by model year 2025)	• Political pressures to eliminate incentives
• Rapidly improving technology – more efficient batteries, larger/lighter batteries, etc.	• Potential of significant increases in ICE fuel efficiencies

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Reliability Study

Scope

As part of FPL's ongoing and continuous commitment to provide cost-effective, reliable service to our customers, it was our desire to understand the effects that PEVs have on our system load. The primary objective of this study is to understand the impact of charging PEVs on FPL's grid.

To accomplish this, FPL looked to answer the following questions:

1) How important is it to know who has an PEV in case proactive measures are necessary?
2) When/where do people charge their vehicles?
   a) Does significant charging occur during FPL's peak hours?
   b) Does most charging, from a load standpoint, occur at customers' homes?
3) Are programs or incentives needed to promote off-peak charging?
   a) Time of use rate program?
   b) Load control?
   c) Others?
4) Are our current distribution standards sufficient to meet the demands of PEV charging?
5) Should upgrades be deemed necessary due to PEV charging, who is responsible – FPL, customer, or both?
6) Will additional generation be necessary to meet the extra PEV load?

There were two main areas of focus in this study:

- The impact, if any, on FPL's system due to the increased electricity load from PEV charging
- The impact, if any, that PEV charging has on FPL's power quality

Increased customer load can have an impact on both generation capacity and equipment (transformers, poles and wires, breakers, service drops, etc.). Vehicles charging at 3.3kW – such as the Nissan Leaf and the Chevy Volt – create an immediate demand roughly similar to that of a residential AC, electric oven, or an electric dryer. Faster charging rates create a load greater than any appliance currently seen in typical households.

The Electric Power Research Institute (EPRI) has conducted studies that indicate that most utilities will not experience any issues even with moderate adoption of PEVs (EEI Staff, November 2011). However, these studies have been mainly academic and do not necessarily take into consideration the particular components of FPL's system.

There are four factors that that help us determine the impact to utilities system and performance:

- How many vehicles are charging at a given time
- The rate at which they charge
- The time of day that they charge
- The length of time that they charge (determined by the battery size, the charge rate, and the charge state of the battery)

A significant number of PEVs charging at higher rates during peak hours could create a need for additional generation[2] while charging during off-peak hours would have very little impact on generation capacity (PNNL Staff, 2007). FPL proactively analyzed various scenarios to assess potential load profiles on electricity generation.

Beyond the generation capacity, increased loading can affect the distribution system. While some independent studies have begun to look into the effects of PEV charging in terms of feeder loading, asset overloads, and aging across a distribution system, the actual impacts are currently largely unknown (Duvall, et al., 2011). FPL conducted a high-level distribution analysis looking at a general inventory of utility circuit loading over the entire system to determine areas of possible impact.

While overall system impacts are not likely to occur until a significant number of PEVs are adopted, localized interruptions in individual components are possible. Individual transformers are one of the first points that PEV charging interacts with FPL's system. A single PEV could affect a transformer by both exceeding the transformer's capacity and shortening its life due to increased loading. Multiple PEVs charging on a single transformer becomes more likely as PEVs grow in popularity, increasing the impact potential. FPL proactively analyzed the readiness of its system components to handle significant levels of PEV adoption. PEV charging could have a negative impact on power quality if it causes adverse changes in current, voltage, etc. These impacts could be either at the EVSE location or down the line at other residences/businesses. FPL studied power quality of individual charging stations early on to understand the potential for future issues on both individual circuits and system-wide.

PEV Reliability Team

Ensuring system reliability involves a number of departments at FPL. FPL's PEV Program formed a cross-functional team made up of all relevant stakeholders in order to study PEVs impact on reliability. This team ensured that it utilized the correct expertise, that it deployed adequate resources for reliability, and that a chain of responsibility was developed. This team also provided regular status updates to management.

Members of the team came from distribution, forecasting, and the PEV department. The team was co-lead by the PEV team member and Distribution help maintain the cross-functional aspects of the team requirements while providing the resources and expertise necessary to complete the distribution aspects of the study. Once formed, the team assigned responsibilities and developed milestones to measure progress. The team will met monthly in order to ensure that it met its milestones.

Develop PEV and Load Forecast

In September 2011, FPL developed a PEV Forecast for the number of PEVs expected in its territory through 2030 to understand the potential magnitude of impacts on FPL's system. The forecast took into account forecasts from other organizations – e.g. DOE, JD Power, CAR, etc. – as well as practical considerations related to FPL's territory. FPL also developed a list of factors that could impact the forecast – up or down. FPL

[2] 500,000 vehicles charging during FPL's summer peak at a rate of just 3.3kW would require additional generation of 1.65kW.

assesses these factors annually to determine if/how the forecast needs to be modified or adjusted.

There are many variables affect the overall load due to PEV charging:

- The total number of vehicles in FPL territory
- The rate(s) that these vehicles charge
- The times that they charge
- The battery size of the vehicle
- The distance that vehicle drive between charges

FPL combined its PEV forecast with these other variables – battery size, charge rate, charge time, etc. to estimate potential hourly PEV loads, particularly during peak times. FPL joined this information with its forecasted system loads through 2030 to develop a PEV load simulation tool to analyze various potential scenarios. This simulation tool allows FPL to see the potential impacts of its PEV forecast – or various worst-case scenarios – on FPL's forecasted loads through 2030.

Update 2008 Reliability Study

In 2008, FPL completed an initial assessment of Electric Vehicles on FPL's system – Plug-In Hybrid Electric Vehicles: 2008 Assessment of Market and Potential Impacts for FPL. This report used the best information available at the time. However, now that PEVs are becoming available in the market, FPL re-evaluated the assumptions and conclusions in this report and updated this study using current information and real-world data where available.

Industry Review

FPL has held a number of discussions with other utilities, and has obtained reports, regarding PEV and power reliability. Some utilities, mainly on the West Coast, have had a number of PEVs in their territory for some time. Their experiences can provide additional insights into potential issues for FPL's system. While Florida's unique climate causes different demands on its system than much of the rest of the country, the experience of other utilities still provide useful information that helps enhance reliability. FPL has relationships with the PEV programs of many utilities and is in contact with them to understand any insights that they may have.

FPL Pilot Program

In order to gather real world data about PEVs in FPL's service territory, it started a PEV pilot program. The primary objective of the pilot program was to assess PEV impacts to the grid. This program allowed FPL to gather actual data from early PEV adopters to ensure we understand the impact of PEV charging in before there are a significant numbers of PEVs in its territory.

The pilot program consisted of giving 43 PEV owners a charging station – installed – in exchange for allowing FPL to gather detailed information about how/when they charge, their driving habits, and their electricity use. This gave FPL a controlled method of gathering data on actual impact to FPL's system. The pilot program allowed FPL to gather actual data regarding loads and power quality, and also allowed FPL to speak directly to customers to understand EV charging behaviors that could affect reliability.

The pilot included a mix of PEVs and charging stations (EVSE – electric vehicle service equipment). The mix included 23 Nissan Leafs, 20 Chevy Volts – the first two EVs available in FL. There were two Level 2 EVSE models in the pilot, the Ecotality Blink and the Clipper Creek CS40.

This mix allowed FPL to examine any potential differences between cars or types of charging stations.

- The Chevy Volt is an extended range plug-in hybrid vehicle (EREV) that has both a battery and a generator to run the electric motor with a 10.4kWh battery that charges at 3.3kW/hr.
- The Nissan Leaf is a battery electric vehicle (BEV) with a 24kWh battery that also charges at 3.3kW/hr.

Residential Charging Power Quality

Power quality, specifically as it relates to PEVs charging, needed to be fully understood. There are two types of disturbances that can affect power quality: steady-state disturbances and dynamic disturbances. Steady-state disturbances include over-voltages, under-voltages, frequency variations, repetitive voltage fluctuations, repetitive source impedance variations, conducted and radiated electromagnetic interference (EMI), and harmonics. Dynamic disturbances include voltage surges, voltage sags, voltage swells, and momentary outages (see appendix). (Staff, 10/24/1997)

Table 1-1
Electric Vehicle Charging Equipment Operational Recommendations from the PNNL

	Level 1 Charging	Level 2 Charging
POWER QUALITY PARAMETERS		
1. Total Power Factor (minimum)	95%	
2. Power Conversion Efficiency (minimum)	85%	
3. Total Harmonic Current Distortion	20% Maximum	
4. Current Distortion at Each Harmonic Frequency	IEC 555-2; IEC 1000-3-2 3/95	IEC 1000-3-4 (draft)
5. Inrush Current	28 A	56A
SUSCEPTIBILITY PARAMETERS		
1. Voltage Range	90%–110% of nominal	
2. Voltage Swell	180% of nominal for 2 cycles	
3. Voltage Surge	6 kV Minimum ANSI C62.41& C62.45	
4. Voltage Sag	Down to 80% of nominal for 2 seconds	
5. Momentary Outage	0 Volts for 12 cycles	
6. Frequency Variations	±2% of nominal	
POWER CONTROL PARAMETERS		
1. Staggered restart after power loss	Delay restart 2 minutes + 10 minute random start or ramp up.	

IWC Load Management Committee — http://www.epri.com/csg/trans/iwc/

The early hypothesis was, that given the nature of PEV charging, it would not have an adverse impact on power quality. However, to confirm this, FPL attached recorders to various locations, to assess power quality impact due to PEV charging. These recorders were located at the power shut-off panel to document the power quality. The recorders measured power quality metrics based on the Electric Vehicle Charging Equipment Operational Recommendations developed by the Electric Power Research Council's Infrastructure Working Council Load Committee listed below in

Prior to the pilot's launch, FPL installed recorders at select fleet locations with active charging stations in order to identify any patent power quality issues. Over the course of the pilot, FPL attached the recorders at residences of selected pilot participants to measure power quality metrics. The recorders were in place for approximately two weeks – about one week prior to installing the charging station until approximately one week after it passes inspection. FPL set a minimum of two recorders at each combination of charging station and vehicle (Volt and Blink, Volt and Clipper Creek, Leaf and Blink, Leaf and Clipper Creek, etc.).

As any concerns arose outside of FPL's parameters, the residence was revisited to reattach the recorder in order to verify the readings. Other residences were visited with the same PEV/EVSE configuration to test whether the power quality issue stems from PEV charging or from the home. Because the electronics are the same for each charging station and vehicle, when a power quality issue arose at one house and not another, it stems from another issue in the home rather than the PEV.

FPL entered the data for each recording in the power quality tracking spreadsheet. The power quality spreadsheet listed all of the criteria and the measurements from each recorder location. From this spreadsheet, FPL developed a summary that gives an overview of the power quality results.

Individual Transformer Loading

Along with the power quality recorders, FPL monitored the loading of the transformers at the pilot locations. This allowed FPL to understand what impact, if any, the chargers had on FPL's transformers. When feasible, FPL looked at loading at other locations, where PEV charging takes place.

FPL measured the loading of transformers by adding all of the peak loads of each residence. This gave a theoretical loading if every house hit their peak at the same time on the same day. However, the pilot was restricted to customers with AMI meters in place. Because of this, FPL was able to look at the actual loading of the transformer. This gave a more accurate look at the effect of PEV charging on each transformer as FPL looked at the theoretical loading as well as peak loads. This allowed FPL to conduct what-if analyses of adding additional charging stations or charging at different times.

Develop Pilot Load Profiles

One of the requirements of the pilot program was that the customer must have an AMI meter. This allowed FPL to look at when customers in the pilot are charging their vehicles and compare them to their survey responses. Additionally, at least half of the charging stations in the Pilot were ECOtality Blink charging stations capable of supplying charging statistics. This allowed FPL to verify the additional loads and times that PEV charging takes place. FPL used this to data to enhance the peak load simulation.

FPL pulled at least one month (or up to 12 months when able) of pre-installation, 15-minute consumption data for each Pilot participant, and each customer on the transformer. It then pulled the same data every month throughout the pilot period.

The team summarized the data to develop a charging profile of customers based on what their charging load is at a given hour. Additionally, it developed a load profile for each transformer in the pilot.

PEV Charging Signatures

A key question that this study set out to understand is whether FPL needs to know the location of PEV customers charging at home. If initial data – power quality, transformer loading, or load profile – showed any potential negative impacts to FPL's grid, it would become necessary to identify PEV customers in FPL territory in order to take prescriptive measures. Knowing where these customers are would allow FPL to take prescriptive measures in specific areas where PEVs are, rather than to take blanket measures in areas where they may not be necessary.

Level 2 PEV charging creates greater demand, for a longer duration, than most other appliances in a typical residence. Additionally, PEVs are likely to charge at particular times i.e. after people get home from work after 5 p.m. These two features create the possibility that PEV charging, unlike other appliances, would display a unique 'signature' when looking at an interval customer's load.

System Transformer Review

FPL tracks the theoretical loading of every transformer in its system. Additionally, in areas where it has installed advanced meter infrastructure (AMI) meters, FPL can look at the actual loading on transformers. Based on the increased loads on transformers measured in the pilot, combined with the system-wide transformer loading, FPL developed metrics to measure when a transformer is at risk due to PEV charging.

Additionally, based on FPL's, and other research, FPL developed metrics to identify areas that are more likely to see PEVs, as well as potential areas with more than one PEV on a transformer. FPL mapped that information along with transformers that are at risk. Where these two coincide, FPL could examine that part of its system more closely to see if it is sufficiently robust.

Transformer Simulation

While mapping at risk transformers can help FPL understand where problem areas could be, it is relatively static. It does not allow for looking at the impacts of greater PEV adoption than forecast, the impacts of various charging rates, or the impacts of different clustering on transformers. In order to examine this, FPL built a simulation similar to the load simulation that allowed it to run various what-if scenarios to stay in front of any potential impacts on FPL transformers.

System Equipment Review

While transformers are the most likely part of FPL's system that will be impacted by PEV charging, other parts could be affected as more vehicles are charging. Significant PEV charging could impact fuses, lines, switches, reclosers, regulators, etc., in terms of feeder loading, asset overloads, and aging across a distribution system. FPL built additional simulations to look at the potential impacts on FPL equipment of various charging scenarios and will allow it to identify potential areas of concern.

Meter Test Center Analysis

While the pilot provided real world information, the FPL meter testing facility was used to further evaluate the impact of PEV charging. The test facility provided a controlled environment that allowed specific testing of PEV power quality, load, charge rates, charge times, etc. This allowed FPL to validate what it sees in the pilot data, or to investigate more, issues that come up.

System Review

System Load

PEVs represent a potentially significant new demand on FPL's generation. If enough PEVs are charging during FPL's peak periods, additional generation could be required to meet the additional demand. FPL's load forecasts have begun considering PEV demand as part of its long term planning. Additionally, the team developed a load simulation tool to evaluate various scenarios that could impact load requirements. –See Appendix. Estimating how many vehicles are plugged in at a given time, at what rate they are charging, and how long they are charging are keys to understanding any load impacts.

As mentioned earlier, FPL is anticipating a slow adoption rate over the next few years, picking up by 2020 and reaching approximately 800,000 vehicles in FPL's service territory by 2030. However, not all of these vehicles will necessarily be plugged in at the same time, let alone during FPL's peak load times. Additionally, we must consider whether enough PEVs will be charging at some other time to create a new peak.

FPL's summer peak typically occurs from 4 to 5 p.m. FPL's load is within 5 percent of this peak from 1 to 4 p.m. For a PEV to impact the peak system load, it must be plugged in, and more importantly, actually charging at that time. Empirically, most PEVs will not be at home during these times, and afternoon/early evening traffic will show that most vehicles are driving and not parked during these times[3]. Additionally, the 200 National Household Travel Survey's (NHTS) Summary of Travel Trends (Santos, McGuckin, Nakamoto, Gray, & Liss, 2010) shows that the number of daily trips peaks at around 5 p.m. Further analysis by the Pacific Northwest National Labs in 2008 (Morrow, Karner, & Francfort, 2008) estimated that less than 5 percent of vehicles would be charging from 5 to 6 p.m. and less than 15 percent would be charging from 6 to 7 p.m.

Closely related to when people charge is 'where' people charge. Currently, there is very little public infrastructure in Florida meaning that presently, a majority of it is occurring at residences. Charging infrastructure is being added to Florida every year, but it is anticipated that most charging will still occur at home. Home charging is more convenient and except for free public charging, and is generally less expensive than public charging. Given that vehicles are generally parked from the evening to the morning, home charging will likely mean mainly off-peak charging.

Regardless, it is likely that at least some vehicles will be plugged in during system peak times. In anticipation of this likelihood, some utilities have instituted some form of time-of-use (TOU) pricing to encourage customers to charge during off-peak times. These TOU rates are either whole house rates or specific PEV charging rates (requiring some sort of separate metering).

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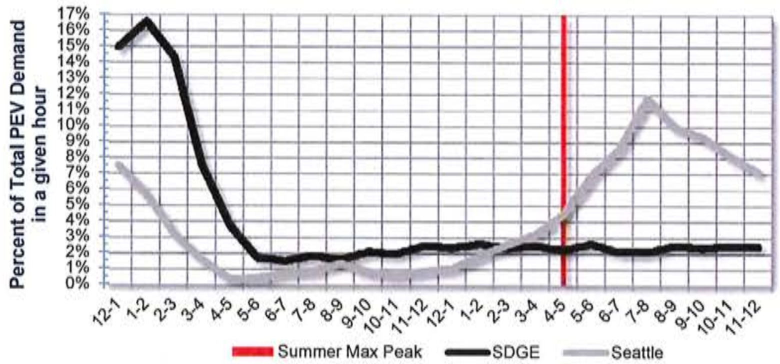
[3] As long as PEVs require a plug to charge, they cannot impact the electric grid unless they are parked. Any PEVs driving during rush hours would then not impact FPL's peak load. Theoretically, there is potential for in-road wireless charging, which would then impact the grid when people are driving rather than when they are parked. However, while there has been some discussion, and even some work done, on in-road charging, it is not financially feasible now or in the near future. No currently announced vehicle has this technology. Given the financial, technological, and logistical hurdles for this technology, it is unlikely to impact the grid for many years, if ever.

The EV Project, a joint project with the Department of Energy, ECOtality and the Idaho National Labs, has been collecting date in various cities and utilities, where PEVs have been on the road since early 2011. This data has shown that in territories where these incentives exist (e.g. San Diego Gas and Electric – SDGE), people indeed shift their charging to off peak times (The EV Project, October 23, 2012). However, this report also shows that where no incentive exists (e.g. Seattle), most charging still occurs off-peak, usually peaking around 7 to 8 p.m. Under either scenario, it is likely that most vehicles are not charging during FPL's system peak. In Seattle, only approximately 15 percent of customers are charging at 5 p.m.



Currently, nearly all PEVs on the road charge at a Level 2 rate of 3.3kW with newer vehicles charging at 6.6 kW. As such, FPL is assuming 6.6kW will be the standard Level 2 charging rate within a few years when PEVs charge at Level 2.

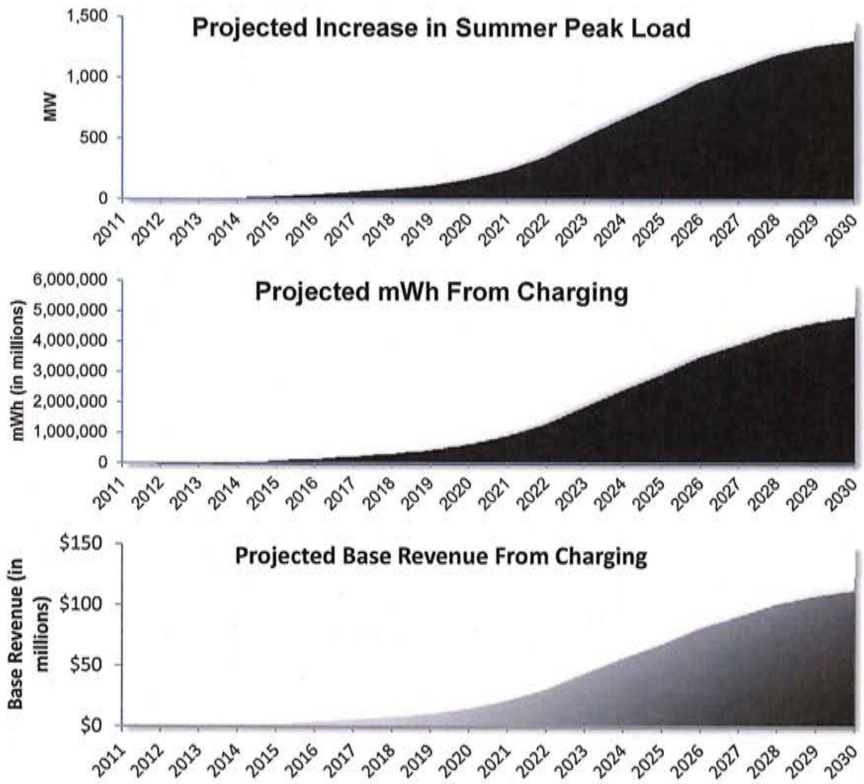
Because of its significantly shorter charging time, there is a great deal of speculation that consumers will opt for Level 2 charging at home. For example, a 24kWh Nissan Leaf battery will take about 18.5 hours to charge at 1.3kW (Level 1), but only takes around 7-8 hours at 3.3kW and about 4 hours at 6.6kW. These charge times assume a depleted battery – driving 70 to 100 miles per day.

Real world driving is usually less than that, with the 2009 NHTS showing that consumers drive approximately 36.1 miles per day on average (Santos, McGuckin, Nakamoto, Gray, & Liss, 2010). This translates into using approximately 12kWh[4] taking only about 9 hours to recharge at Level 1 – enough time for a PEV to charge overnight. Additionally, all PEVs ship with a Level 1 EVSE requiring no additional cost to the consumer, unlike Level 2 EVSEs.

These factors make Level 1 charging much more viable for many consumers. Indeed, GM has mentioned in presentations that as many as 40 to 50 percent of Volt buyers are choosing to stick with Level 1 charging, and some reports indicate 15 percent of Nissan Leaf owners are sticking with Level 1 indicating even BEV customers are starting to consider Level 1 charging. However, for planning purposes and given that the future is unknown, Level 2 charging is assumed in order to be prepared for the worst case scenario.

[4] Calculated using 3.0 miles/kWh based on FPL PEV fleet experience

Analysis by the Oakridge National Laboratory in 2008 for the Department of Energy (Hadley & Tsvetkova, 2008) estimated that some additional generation capacity (2.2GW) would be needed by 2030 during summer peak times in the Florida Reliability Coordinating Council Region if there were 3.1 million vehicles in Florida (approximately 1.55 million in FPL territory) all charging at 6.6kW beginning at 5 to 6 p.m. Developments and information since then indicate actual impacts will be far less than this worst-case scenario. FPL's 2030 base summer max peak load is expected to be 30,508MW[5]. By 2030 FPL is projecting 803,829 PEVs in its territory with 20 percent charging during peak at an average rate of 6.6kW. This would add 1,308 mW to the expected peak load, increasing it by 4.3 percent to 31,816mW. The 803,829 vehicles are expected to consume 4.88 million mWh generating $112.2 million in base revenues.[6]



[5] Forecasted Load for 2030 is 31,816mW, however, this includes 1,308mW projected from PEV vehicles and trucks.
[6] Based on 803,829 vehicles averaging 36.1 miles per day, charging 12.03 kWh/day with base revenue equal to $0.023/kWh.

Transformers

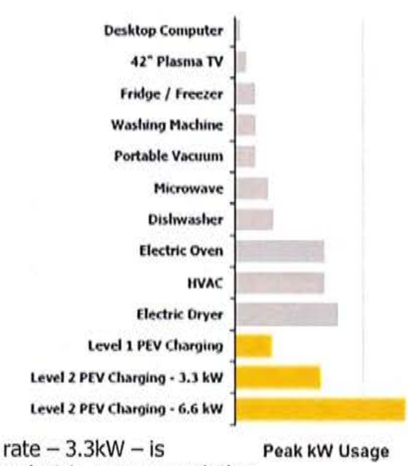
Transformers (Tx) are the first point where PEV charging will interact with FPL's system. They are also the point most sensitive to individual demand increases. As such, we focused on analyzing the impact to FPL's transformers.

While severe overloading could theoretically cause a transformer failure, the more likely scenario is increased loading decreasing the life of the transformer. Transformers have a load rating measured in kilovoltamperes (kVA). FPL's residential transformers[7] are sized at 25, 37.5[8], 50, 75, and 100kVA. Loading on a transformer is not constant, varying throughout the day as demand increases or decreases.

A transformer has no mechanical parts. It uses magnetic flux to step down higher voltages from the substation to voltages more suitable for residential use and consists of separate coil windings wrapped around a core of insulated steel laminations. As the load increases in a transformer, heat is generated due to resistance. High temperatures in a transformer will significantly reduce its life (Staff B of R, April 2005). Mineral oil is commonly used to dissipate heat and provide a medium with high dielectric strength.

Under normal operations over time, heat and contaminants cause oil degradation. As the oil degrades, the insulating paper ages and is exposed to moisture and oxygen. As the insulating paper ages, arcing, which causes a short and blowing the fuse or in rare extreme circumstances complete failure, becomes more likely.

Transformers are rated at the power output they can continuously deliver at a rated voltage and frequency, without exceeding a specified temperature rise. Because the temperature rise is at least partly due to the thermal limitations of the core, winding and insulation, the rating is based on the maximum allowable temperature of the insulation. Transformers are ideally sized so that base load does not exceed the rated size and peak load does not exceed 200 percent of the rated size.

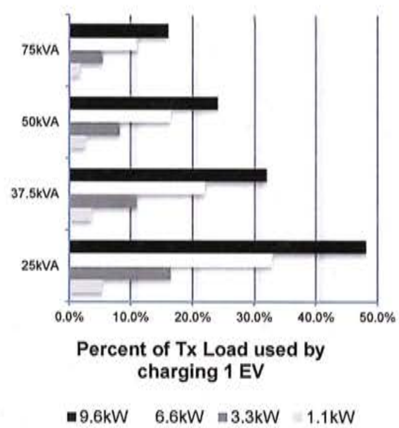


The demand from Level 1 PEV charging is similar to many typical residential appliances such as a microwave oven or a dishwasher. The lowest Level 2 charge rate – 3.3kW – is roughly equivalent to an HVAC system, an electric, oven or a clothes dryer. Currently the only demand similar to higher rates of Level 2 charging – 6.6kW to 19.2kW is instant hot water heaters. However, while the instant hot water has a demand that spikes quickly and then drops off, PEV charging remains at the higher demand until the battery's charge nears capacity.

[7] Not including areas with three-phase service or multi-family dwellings with vaults.
[8] While 37.5 kva single phase aerial transformers exist in FPL's system, they have not been purchased in over 20 years . All new transformers are 25, 50, 75 and 100 KVA.

The impact of a PEV charging on the Tx depends on the PEV charge rate, the size of the Tx, the number of customers and loading currently on the Tx, the length of time that a vehicle charges, and the number of vehicles charging on the Tx. Lower charge rates do not have as much instant impact on loading, but they maintain an elevated load for a longer time. Additionally, one vehicle charging during peak times on a heavily loaded Tx can have more impact than multiple vehicles charging off peak times.

Smaller transformers are more heavily impacted by a single EV charging. A single EV charging at 6.6kW or more creates an instant load of at least 30 percent of the capacity of a 25kVA transformer. Charging at 19.2kW creates an instant load of 24kVA – nearly the entire rated capacity of a 25kVA Tx, and 64 percent of a 37.5kVA Tx. However, larger transformers can be impacted as well if there are a number of customers on it that create heavy loads.



FPL measures the loading on its transformers based on the peak loading. Currently peak loading uses a theoretic worst case scenario based on each customer's individual peak. As AMI data became available, actual peak loads were calculated.

The potential impact on FPL's transformers will depend on how many will have their peak load increased to 200 percent or more due to the addition of a PEV charging. FPL has a small percentage of transformers whose peak loading is currently over 200 percent. These won't be significantly impacted as FPL is already evaluating them.

Based on the current rated peak loading of 25, 37.5, 50, 75, and 100kVA transformers, only 0.6 percent or 2,275 would be increased to 200 percent loading by the addition of at least 1 PEV charging at up to 9.6kW. It is important to note that nearly all of those 1,982 are 25kVA transformers. Adding as many as three PEVs charging at the same time would increase the number of transformers impacted to 79,481 or 22.4 percent of the total. Again, nearly all 70,542 of the affected transformers would be 25kVA with another 7,555 being 37.5kVA. Only 1,384 of those impacted would be 50-100kVa.

Widespread use of 19.2kW charging would have a much greater impact affecting 5.3 percent of transformers with a single vehicle charging and up to 72.5 percent of transformers with three vehicles simultaneously charging. Again, 25kVa and 37.5kVa transformers would make up the bulk of those transformers impacted. Currently though, 19.2kw residential charging is expected in only a very small percentage of cases.

Currently, the only company that has plans to offer that rate of charging is Tesla. It is an added cost option and many customers, even given the high-end nature of the vehicles, are not opting for it. Additionally, it requires 100A open in the home's electric panel. Many homes will require an expensive panel upgrade in addition to the cost of installing the Level 2 charging station.

While the addition of PEVs charging could impact some transformers, the actual impact is expected to be lower. Each transformer would need a PEV charging during that transformer's peak time to see an impact on every transformer. Information presented in this study indicates it is likely that the majority of vehicles will be charging during off-peak times. Additionally, while charging rates are expected to increase, the charge times are expected to be shorter, given the current average daily drives. As such, each PEV charging would impact loading on a transformer for two hours per day or less.

Number of Tx pushed over 200% loading by addition of EV charging at peak

EVS on Tx	Charge Rate (kW)	25kVA	37.5 kVA	50 kVA	75 kVA	100 kVA	Total	% Increase
1	1.3	-	-	-	-	-	**-**	**0.0%**
1	3.3	317	23	18	16	3	**377**	**0.1%**
1	6.6	946	83	49	25	5	**1,108**	**0.3%**
1	9.6	1,982	172	75	39	7	**2,275**	**0.6%**
1	19.2	17,311	1,117	343	78	13	**18,862**	**5.3%**
2	1.3	181	8	12	11	1	**213**	**0.1%**
2	3.3	946	83	49	25	5	**1,108**	**0.3%**
2	6.6	4,721	378	146	46	9	**5,300**	**1.5%**
2	9.6	17,311	1,117	343	78	13	**18,862**	**5.3%**
2	19.2	133,491	26,108	4,865	292	48	**164,804**	**46.4%**
3	1.3	317	23	18	16	3	**377**	**0.1%**
3	3.3	2,491	172	87	41	7	**2,798**	**0.8%**
3	6.6	20,386	1,358	387	80	15	**22,226**	**6.3%**
3	9.6	70,542	7,555	1,206	149	29	**79,481**	**22.4%**
3	19.2	147,505	54,635	53,922	1,072	134	**257,268**	**72.5%**
	Total Tx	148,011	55,942	125,591	20,427	5,092	355,063	100.0%

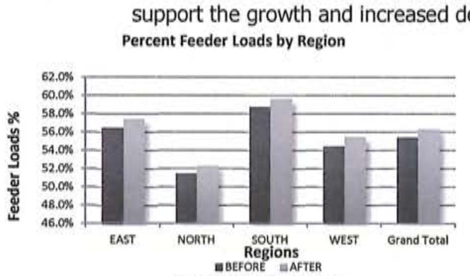
Feeder & System Loads

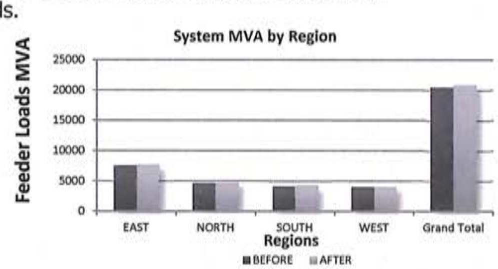
Most PEV charging analyses focused on the potential impact to generation and residential transformers. However, increased loads due to PEV charging could also impact feeder and system loads. As loads increase, feeders and substations could become overloaded. As more become overloaded, construction of new feeders and substation transformers becomes necessary.

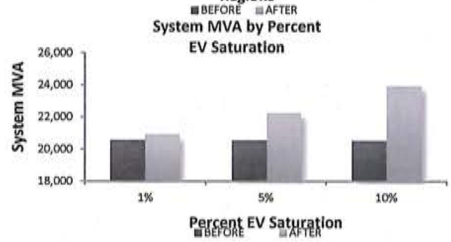
Substation transformers are similar to residential transformers and are similarly impacted by increased loads. However, they would likely be the last of distribution facilities to be impacted from load growth generated by PEV charging. Distribution feeders are rated based on the feeder breaker or conductor rating for the first run of conductor out of the substation, whichever is smaller. Normal operating conditions for feeders range between 220A-430A or 50 to 80 percent loading to allow sufficient capacity to restore customers during single contingency scenarios. Feeders operating above 100 percent of their normal rating will require additional facilities be constructed to prevent power interruptions due to overload conditions.

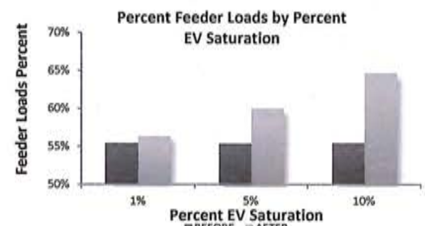
Loading on current feeders and substations transformers are unlikely to be impacted due to PEV charging[9] until PEV penetration reaches 10 percent[10], which is currently not expected until 2028 at the earliest. In the near term PEV saturation of 1 percent of all vehicles, expected around 2017-18, will likely result in minimal, if any impact to system and feeder loads. At 1 percent, feeder loads would be expected to increase by 1-2 percent and system loads would be expected to increase by 400MmVA.

Ten percent penetration would increase feeder loads by an average of 8 to 10 percent and system loads by approximately 3,400 MVA. This would overload an estimated 75 to 80 feeders and 15 to 20 substation transformers. These overloads would require construction of 20 to 25 new feeders and 4 to 6 substation transformers in order to support the growth and increased demands.









[9] Assumes an average charge rate of 6.6kW
[10] 10% penetration equals between 720,000 and 930,000 vehicles depending on the year being analyzed and passenger vehicle growth estimations

System Review Summary

Based on this study's results and current assumptions available today, PEV charging does not presently show any red flags projected onto the current state of the system. There would not appear to be any significant impact on distribution or generation through 2030. The expected PEV adoption rate is expected to be slow, reaching only around 1 percent over the next 5 to 10 years. It would take a large number of vehicles charging during FPL system peak to have any significant impact on generation or distribution. Current forecasts indicate this is a number of years off, 2025 or later.

Smaller residential transformers are likely to be the first point on FPL's system to be impacted from PEV adoption. With the exception of higher charge rates, only a small percentage of transformers would be impacted with on-peak charging; and, early indications show that most charging occurs during non-peak hours. Additionally, current assumptions are that higher rate charging at 19.2kW, will likely only occur in limited cases.

In order to validate these assumptions and ensure continued reliability for FPL customers, it was necessary to gather real world data. Because PEVs only recently have been made available on any sort of significant scale, very little actual data regarding the impact of PEV charging on the electric infrastructure exists. Some data was available from other utilities and organizations such as EPRI or the EV Project. However, given Florida, specifically FPL's unique climate and system requirements, data was gathered from willing customers as PEVs enter its territory.

Data began being complied in early 2012, and was completed in December 2013. Power quality data, individual charging data, individual AMI usage data, and transformer AMI data was pulled and analyzed for pilot customers and others who have volunteered information.

Pilot/Customer Data

Pilot Overview

The Pilot program enrolled its first customers at the end of January 2012. It enrolled its last customer in December 2012. Data was finalized at the end of 2013.

The pilot program was divided into 23 Leaf owners and 20 Volt owners. Both vehicles have a Level 2 charge rate of 3.3kW and use a standard SAE-J1772 coupler to connect. The Chevy Volt is an Extended Range Electric Vehicle. It has a 12kWh[11] battery with an approximate electric range of 30 to 40 miles. Once the battery is depleted, a gasoline powered generator kicks in to power the electric motor. In situations where particularly heavy acceleration is necessary, the gas motor can provide some power to the wheels, but under most driving conditions, there is no mechanical connection to the wheels and they are under only electric power.

The Nissan Leaf is a BEV with a 24kWh battery that charges at 3.3kW at Level 2[12]. This gives it a range of approximately 70 to 90 miles depending on driving styles and conditions. The Leaf also has DC fast-charge capability, however, that was not part of this pilot's scope.

Two types of Level 2 EVSEs were provided for the participants, a Clipper Creek CS-40 and An ECOtality Blink residential unit. The Clipper Creek CS-40 was wall-mounted and required an open 40 amp circuit breaker. It has a SAE-J1772 coupler and can charge at rates of 3.3kW-7.2kW depending on the vehicle charged. The only outputs are LEDs indicating whether the vehicles are plugged in, charging, or if there is an error during the charge. 15 CS-40s were installed.

The ECOtality Blink residential unit was also wall-mounted, has a SAE-J1772 coupler and required an open 40amp breaker for installation, and charges between 3.3kW and 7.2kW. However, unlike the CS-40, the Blink unit also has a touch screen and is a network connected.

Car owners could program charging and configure the unit via the touch screen. The network connection allowed the unit to connect with the Blink network and transmit charging data such as whether the unit is plugged in, whether it is charging, when it started and ended charging, and how many kWh were charged. It also allowed for remote access to the charger via a personal computer or a phone app. 28 Blink units were installed for the pilot.

In order to qualify for the pilot program, customers had to own a single-family home or townhouse with a garage, have an active account in good standing with FPL, and have a Wi-Fi connection so those who received Blink units could connect to the network.

[11] The Actual battery size is 16kWh, but the Volt does not make all cells available for powering the vehicle in an effort to increase the battery's life. Additionally, the battery uses an additional 2 kWh for maintenance functions, so the actual charge available for driving is about 10kWh.
[12] 2013 models will have a level 2 charge rate of 6.6kW.

Additionally, they had to have an active AMI meter and agree to let FPL monitor their usage and charging. The pilot was only open to customers in Palm Beach, Broward, and Miami-Dade counties.

Charging Data

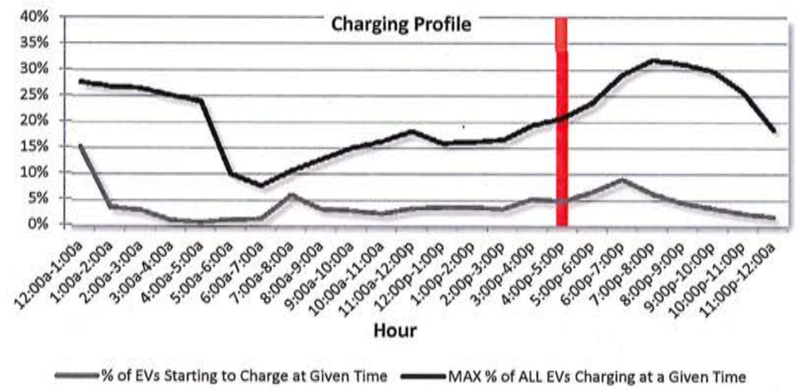
AMI data allowed us to look at the overall impact to individual customer usage. It also allowed us to roll up customer usage and see any impacts at the transformer level. However, because AMI data is only able to measure loads at the meter level, and currently is only aggregated hourly, it was not be able to directly show when people are actually charging, other than potentially increased loads when compared to a baseline.

Another limitation of AMI data at the time of this study was that it doesn't show actual demand, only usage. Demand can be inferred – usage of 6kWh had a demand of at least 6kW over the hour measured. However, it did not show demand peaks that last for less than an hour. For example, a PEV could charge at 9.6kW for half an hour and it would only show 4.8kW of usage for that hour. If the PEV charging bridged an hour, say from 4:45 to 5:15 p/m., AMI would show as little as 2.4kWh of usage. On average though, AMI data provides a good proxy for actual demand.

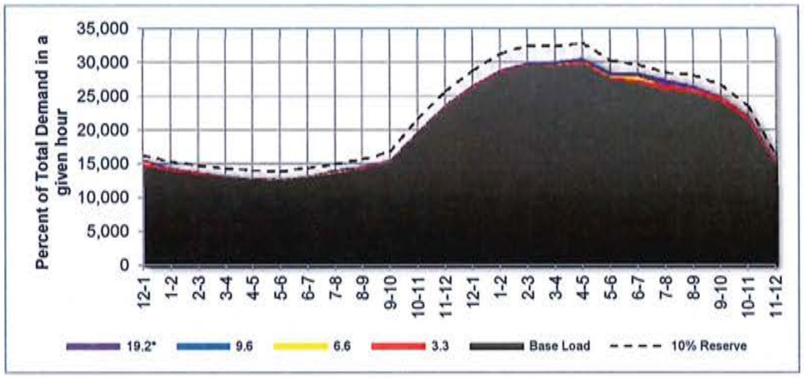
The Blink units via the Blink network allowed us to gather actual charging data, and also peak demand. They provided data on when vehicles are plugged versus when they are charging. They show what times people are charging and how much they charged.

This allowed us to build a charging profile to understand how much people are charging and when. By syncing this information with AMI data, we analyzed impacts to usage, and rolled the information up to look at impacts on the transformer. Additionally, this information was compared to the non-networked CS-40 units to help understand load impacts where we don't have access to charging data.

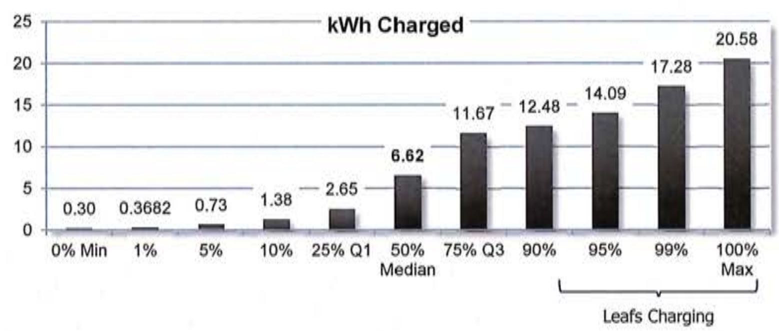
Data collected has provided some insights. Less than 20 percent of participants are charging during FPL's summer peak time of 4 to 5 p.m. The peak charge time occurs at 7 to 8 p.m. when a maximum of 32 percent of people are plugged in, agreeing, so far, with speculation and profiles in other areas suggesting that most people will not be charging during FPL peak times.



When this profile is applied to the 2030 summer maximum base load using the FPL EV forecast for 2030, there is very little impact to the peak load. This profile would see the heaviest loads as FPL's peak is tailing off. Even if all of these vehicles were charging at 19.2kW, it would only add about 2 percent to FPL's peak.



Most charging events to date are less than 6.6kWh[13]. Only about 10 percent are greater than 12.5 kWh *(roughly the capacity of the Volt and equal to about 35-40 miles of driving)*. The median charge per plug-in is 6.6kWh, which equals a charge time of approximately 2 hours at 3.3kW (1 hour at 6.6kW).



The median charge for Leafs is 7.5kWh and the median charge for Volts is 6kWh – see appendix. Both of these, so far, are less than expected as driving an average of 34 miles per day would require approximately 10kWh of charging. It is also less than the EV pilot, with the Leaf and Volt both going 28-29 miles between charges (approximately 8-8.5 kWh) and 30-40 miles total per day. It is likely that as we gather more data, and people become more comfortable with their cars, the median charge will increase as people drive further between charges.

[13] There are a number of charging events that are less than 0.3kWh, or not enough charge to drive the car one mile, so these data were not included. It appears that the battery experiences some sort of draw-down and the charging station automatically kicks on to account for it. This will be examined further in 2013 to fully understand the phenomena.

Most vehicles released in the near future will likely charge at a Level 2 rate of at least 6.6Kw, a factor that should be considered during this analysis. 6.6kW charging doubles the charge rate, but halves the charge time. This study estimated the impacts of these higher charge rates when feasible.

The average transformer for customers in this pilot is about 50kVA with about 7 customers – see Appendix. The average loading is 126 percent, but there are three transformers in the pilot loaded between 203 percent and 224 percent. Adding 3.3kW charging to the peak load would increase the number loaded over 200 percent to eight, and 6.6kW charging would increase the number to nine. These numbers are a little higher than expected given overall system loads.

Tesla Motors

A bit of a wildcard for system impacts are PEVs produced by Tesla Motors. Tesla is a Silicone Valley startup car company founded by Elon Musk, the founder of PayPal. Tesla differs from most other PEV manufacturers in that they developing their own specifications and charge rates, as a direct-to-customer model for selling vehicles.

Their first vehicle was a high-end sports car with a limited production run of 2,500 vehicles worldwide. Their second vehicle, the Model S, is a five-passenger luxury sedan that has garnered numerous awards, including the 2012 Motor Trend Car of the Year and the highest quality rating from Consumer Reports. Tesla has released a new model, a high-end crossover SUV – the Model X - at the end of 2013 and is expected to release a higher volume, lower priced vehicle, the Tesla E, towards the end of 2015. Tesla also has formed collaborations to provide components for the Mercedes A-Class E cell, the Smart ForTwo EV, the Toyota Rav4 EV, and the Freightliner Electric Van.

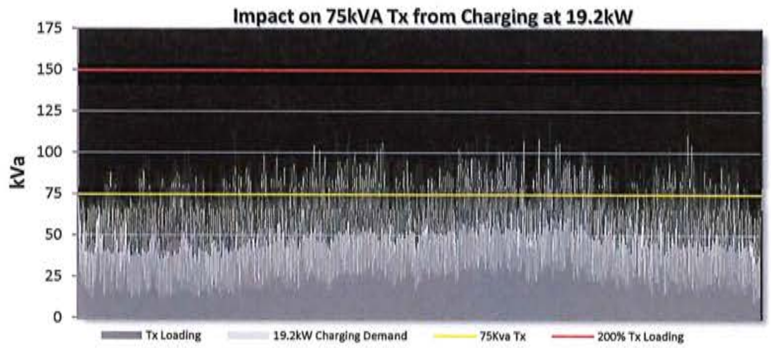
Tesla Model S

Where Tesla becomes a concern for utility reliability is in its charge rate. The Tesla Model S offers batteries ranging from 40 to 85kWh and charges at a Level 2 rate of 9.6kW. Additionally, it offers a dual-charge option that charges at 19.2kW – close to FPL's demand range.

While initial volumes are expected to be low, these rates are much greater than most typical residential loads so they are much more likely to impact FPL's system. Should Tesla have success with their higher charge rates, others could be persuaded to introduce these rates as well, which further increases the potential impact of FPLs systems. An attempt was made to include some Teslas in our pilot program. However, it was unsuccessful. We have had some Tesla customers voluntarily reach out to us, so we can begin to get a look at their AMI data.

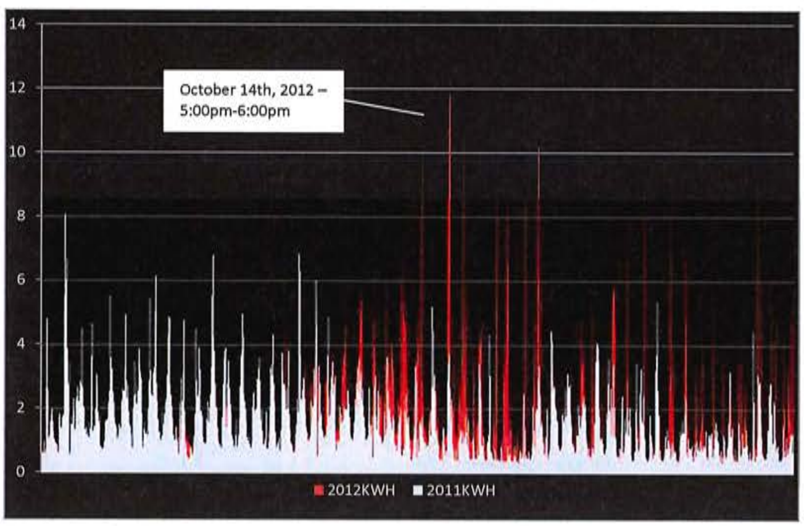
One customer notified us that he anticipated charging at 19.2kW. In order to understand the potential impacts, we pulled 12 months of hourly AMI data for all 6 customers on the transformer, and aggregated it to the transformer level. We then added 19.2kW demand for every hour to understand if there was any time in the past year that would be overloaded with the addition of this charge rate.

Over the entire year, there was no hour when charging at 19.2kW would have loaded the transformer at 200 percent. The highest was approximately 125 percent. While this is a single transformer, and there are certainly transformers on FPL's system that would be severely impacted by this charge rate, it at least demonstrated that even charging at 19.2kW won't necessarily impact a given transformer.

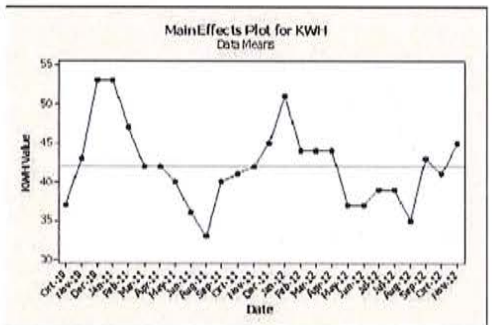


Late in 2012, we were notified of the first confirmed delivery of a Tesla Model S into FPL territory. The vehicle charged at 9.6kW, but has the capability to charge at up to 19.2kW.

It is fairly evident from the graph when he received the car and started charging at 9.6kW. There is clear jump in consumption from 5 to 6 p.m. That was the first time that his usage consistently exceeded 10kWh. Between 9/19/2011 and 10/13/2012, he had an hour where his usage exceeded 10kWh twice, on consecutive days in February 2012. He exceeded 10kWh 14 times between 10/14 & 11/11 2012 – sometimes it was consecutive hours, so it only appears as a single spike on the graph.



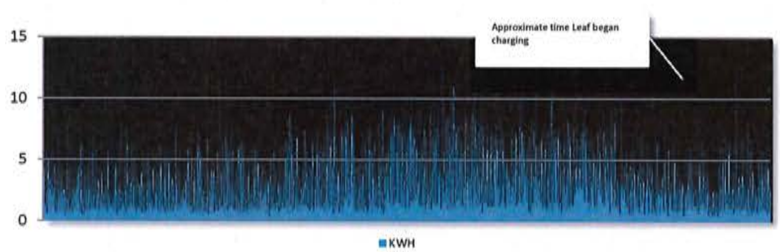
Interestingly, there is very little noticeable impact when rolled up to the transformer level. While this is a significant increase at the meter level, it is not as significant at the transformer. The transformer is 75kVA and has 10 customers on it. A cold snap, or warm period when all customers simultaneously turn on the heat or AC can easily cause a jump of 37kVA making a single increase of 12 KVA much harder to detect unless it occurs during a peak time.



Another interesting comparison is to look at a Leaf pilot participant's AMI data after they start charging at 3.3kW (chosen at random). It is much less evident when the Leaf began charging. 3.3kW is very similar to the load one would see from an AC, or a dryer, so it is much more difficult to see when it is charging from just AMI data.

Overall usage should increase by about 300kWh per month. But, it is not nearly as evident in hourly usage as is 9.6kW charging.

Leaf Pilot Paticipant 2012 KWH



Power Quality

There is very little hard data on the impact to utility power quality from PEV charging stations, but it is not expected to be a significant concern for the industry. While power quality has not been studied nearly as much as load impacts, industry consensus is that electric utilities should be readily able to incorporate smaller PEV charging stations without seeing negative impact to power quality indicators. One of the few studies published that has looked into this issue concluded that that 'harmonics from the measured commercial electric vehicle chargers are not expected to have a significant impact on low voltage networks' (Carter, Cruden, Rosco, Densley, & Nicklin, 2012). An additional study by EPRI concludes that most existing distribution systems should be able to accommodate the introduction of PEV battery charging without widespread harmonic problems." (Grady, 1997). The pilot allowed FPL to analyze any impacts to power quality in real-world charging situations.

The main concern is the potential for issues downstream. These may include overload conditions on devices that would otherwise not require replacement. The power quality team installed data recorders at various EV pilot locations. Both Clipper Creek and ECOtality units had recorders attached and the data analyzed does not indicate any power quality issues. All of the main parameters measured such as inrush current, voltage and momentaries are within FPL's limits – see below.

There is still some question on higher charging rates. Because none of the vehicles in the pilot charged any higher than 3.3kW at Level 2, there hasn't been an opportunity to monitor any higher charging rates. However, notifications are beginning to come in about Tesla customers charging at 9.6kW and 19.2kW. Additionally, the Ford Focus is now available in FPL territory, as well as Nissan Leafs charging at 6.6kW in the near future.

Name	City	Zip Code	Power Factor	Current Distortion	Voltage Range	Voltage Swell	Voltage Surge	Voltage Sag	Momentary Outage	Frequency Variation
VB03	Pompano Beach	33064	N/A	22.60%	105.00%	0.00%	0.00%	0.00%	None	None
VB02	Hollywood	33027	97.00%	23.40%	102.00%	0.00%	0.00%	0.00%	None	None
VCC02	Fort Lauderdale	33322	92.00%	15.90%	103.00%	0.00%	0.00%	0.00%	None	None
LCC01	Fort Lauderdale	33317	97.00%	19.70%	103.00%	0.00%	0.00%	0.00%	None	None
VCC06	Fort Lauderdale	33328	N/A	17.00%	105.00%	0.00%	0.00%	0.00%	None	None
LB01	Pompano Beach	33062	100.00%	8.40%	105.00%	0.00%	0.00%	0.00%	None	None
VB07	Fort Lauderdale	33322	N/A	21.90%	104.00%	0.00%	0.00%	0.00%	None	None
VB06	Hollywood	33021	N/A	73.40%	105.00%	0.00%	0.00%	0.00%	None	None
VB05	Hollywood	33025	N/A	20.90%	103.00%	0.00%	0.00%	0.00%	None	None

Pilot observations

Based on what we know of our system and what we expect from PEV charging, FPL seems to be well situated for PEVs charging on its system. However, this remains speculative at this point and we need to analyze hard data to help ensure any potential impacts are not overlooked. This current data is not raising any red flags.

There are three aspects of PEV charging that affect the impact to FPL's system: when PEVs charge, how many PEVs are charging at a given time, and their rate of charge. The pilot allowed us to gather hard data on when they charge and their rate of charge. Additionally, we will continue to review results from other utilities or groups like EPRI and the EV Project to be aware of any results that they are seeing.

How many PEVs that are potentially charging at a given time are dependent on a number of factors that FPL will continue to monitor. In 2013, FPL began receiving quarterly updates on PEV registrations from the Florida Department of Motor Vehicles.

This allows FPL to get accurate numbers on PEVs in its territory, down to the zip code level. More precise data is currently not available, other than on a voluntary basis directly from customers, and is probably not necessary at this point.

Observations:

- No significant impact is expected on distribution or generation – current forecasts indicate this to be the case through 2025 or later.
- Expected PEV adoption rate is near 1 percent over the next 5 to 10 years.
- A minimum of 6.6kW Level 2 charging is likely to be more prevalent in future model years, though it is unclear what proportion of customers will charge at Level 2, and what percentage will opt to only charge at Level 1.
- Residential charging, even at higher rates, will likely have a minimal impact on power quality and reliability, at least in the near term.
- PEV charging will most likely impact smaller residential transformers (25 & 37.5kVA) first. However, most charging will occur during non-peak hours and impact may be limited to Tx that are already highly loaded, or where charging occurs during the daily peak.
- Areas with higher percent of PEVs or transformers that are near 200 percent loading are more likely to be impacted.

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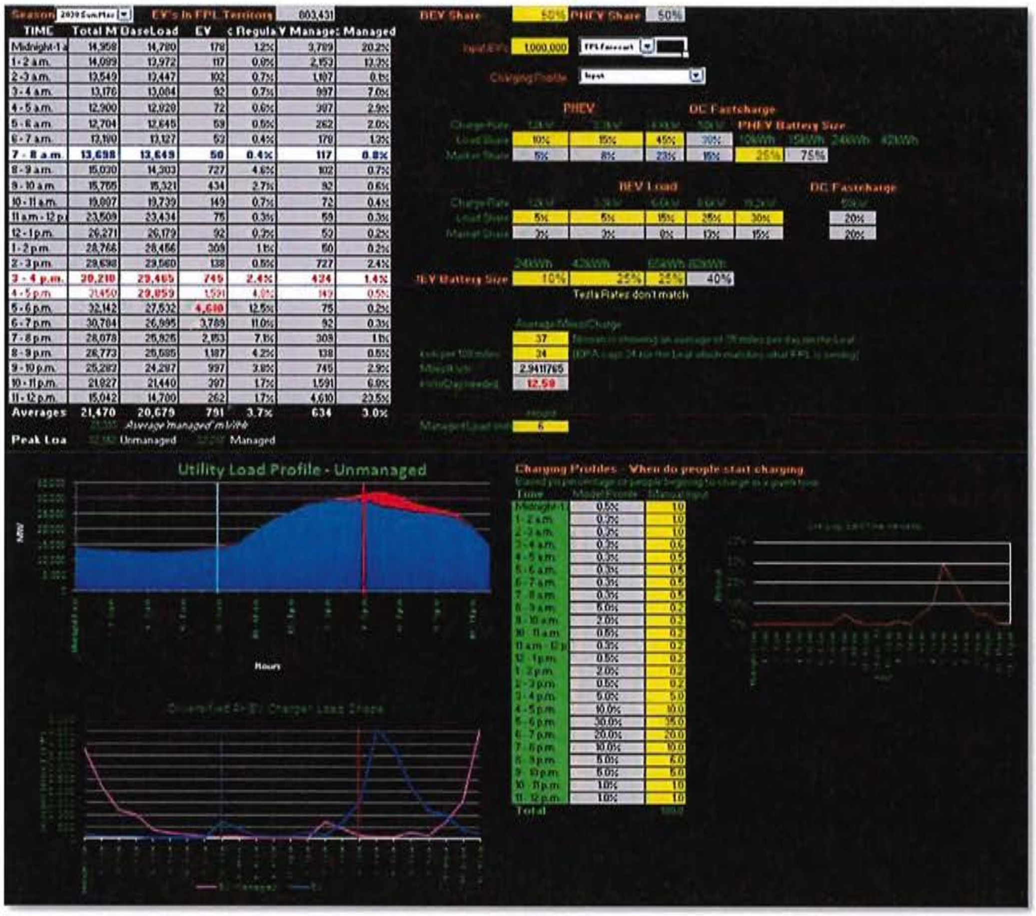
FPL

Appendix

2013 FPL Forecast

Year	US Cumulative	FL Cumulative	FPL Cumulative	Incremental MWh
2012	78,350	2,539	1,314	5,771
2013	174,569	9,172	4,586	20,142
2014	331,900	17,510	8,755	38,453
2015	552,761	29,216	14,608	64,161
2016	852,272	45,090	22,545	99,021
2017	1,331,489	70,488	35,244	154,798
2018	1,813,702	96,046	48,023	210,925
2019	2,427,489	128,576	64,288	282,364
2020	3,664,364	194,132	97,066	426,330
2021	5,519,677	292,462	146,231	642,271
2022	8,302,646	439,960	219,980	966,189
2023	12,477,099	661,206	330,603	1,452,063
2024	16,234,106	860,328	430,164	1,889,352
2025	19,490,180	1,032,900	516,450	2,268,334
2026	23,397,468	1,239,986	619,993	2,723,113
2027	25,741,841	1,364,238	682,119	2,995,980
2028	28,320,651	1,500,914	750,457	3,296,132
2029	29,738,996	1,576,086	788,043	3,461,216

Load Simulation



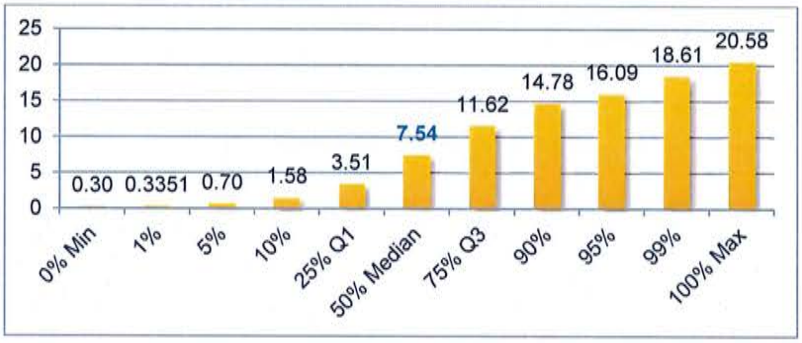
TIME	Total M	BaseLoad	EV	Regula	Manage	Managed
Midnight-1 a	14,958	14,780	178	1.2%	3,789	20.2%
1-2 a.m.	14,089	13,972	117	0.8%	2,153	12.3%
2-3 a.m.	13,549	13,447	102	0.7%	1,187	0.1%
3-4 a.m.	13,176	13,084	92	0.7%	997	7.0%
4-5 a.m.	12,900	12,828	72	0.6%	397	2.9%
5-6 a.m.	12,704	12,645	59	0.5%	262	2.0%
6-7 a.m.	13,180	13,127	53	0.4%	178	1.3%
7-8 a.m.	13,698	13,649	50	0.4%	117	0.8%
8-9 a.m.	15,030	14,303	727	4.8%	102	0.7%
9-10 a.m.	15,755	15,321	434	2.7%	92	0.6%
10-11 a.m.	19,887	19,739	149	0.7%	72	0.4%
11 a.m.-12 p	23,509	23,434	75	0.3%	59	0.3%
12-1 p.m.	26,271	26,179	92	0.3%	53	0.2%
1-2 p.m.	28,765	28,456	309	1.1%	50	0.2%
2-3 p.m.	29,698	29,560	138	0.5%	727	2.4%
3-4 p.m.	30,210	29,465	745	2.4%	434	1.4%
4-5 p.m.	31,450	29,859	1,591	4.0%	149	0.5%
5-6 p.m.	32,142	27,532	4,610	12.5%	75	0.2%
6-7 p.m.	30,784	26,995	3,789	11.0%	92	0.3%
7-8 p.m.	28,078	25,926	2,153	7.1%	309	1.1%
8-9 p.m.	26,773	25,585	1,187	4.2%	138	0.5%
9-10 p.m.	25,283	24,287	997	3.8%	745	2.9%
10-11 p.m.	21,827	21,440	397	1.7%	1,591	6.9%
11-12 p.m.	15,042	14,780	262	1.7%	4,610	23.5%
Averages	21,470	20,679	791	3.7%	634	3.0%

Average managed mWh

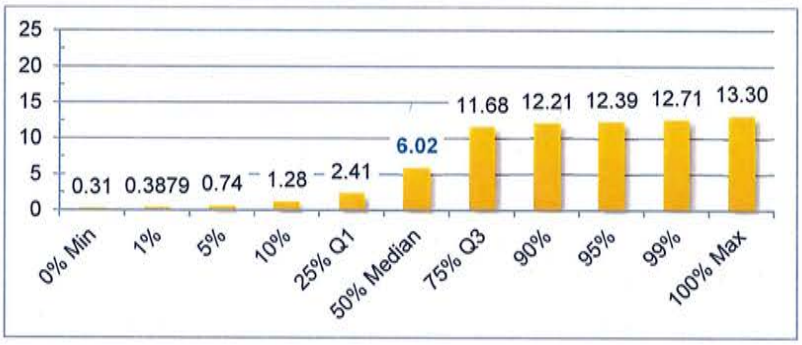
Peak Loa | Unmanaged | Managed

Time	Model Profile	Manual Input
Midnight-1	0.5%	1.0
1-2 a.m.	0.3%	1.0
2-3 a.m.	0.3%	1.0
3-4 a.m.	0.3%	0.6
4-5 a.m.	0.3%	0.5
5-6 a.m.	0.3%	0.5
6-7 a.m.	0.3%	0.5
7-8 a.m.	0.3%	0.5
8-9 a.m.	5.0%	0.2
9-10 a.m.	2.0%	0.2
10-11 a.m.	0.5%	0.2
11 a.m.-12 p	0.3%	0.2
12-1 p.m.	0.5%	0.2
1-2 p.m.	2.0%	0.2
2-3 p.m.	0.5%	0.2
3-4 p.m.	5.0%	5.0
4-5 p.m.	10.0%	10.0
5-6 p.m.	30.0%	35.0
6-7 p.m.	20.0%	20.0
7-8 p.m.	10.0%	10.0
8-9 p.m.	5.0%	6.0
9-10 p.m.	5.0%	5.0
10-11 p.m.	1.0%	1.0
11-12 p.m.	1.0%	1.0
Total		

Leaf kWh Charged



Volt kWh Charged



Pilot Participant Transformers

PILOT #	TLN #	Type SVC	TX KVA	Load KVAD	Load %	Load% @ 3.3	Load % @ 6.6	CUSTOMERS	Feeder
LB01	8-7987-3469-0-2	OH	37.5	76	203	214%	225%	9	OHELY - 02637
LB02	8-6151-2423-0-6	OH	37.5	71	189	200%	211%	8	HVILLAGE GREEN - 07433
LB03	8-6447-0474-0-0	OH	50	43	86	94%	103%	3	KENDALL - 04340
LB04	8-6874-2946-0-1	UG	75	53	71	76%	82%		DRIFTWOOD - 02038
LB05	8-6346-3872-0-9	OH	50	54	108	116%	125%	4	KENDALL -04334
LB06	6-6719-0671-0-0	OH	25	38	152	169%	185%	2	LOXAHATCHEE - 07667
LB07	8-6468-4320-0-1	UG	50	54	108	116%	125%	7	FLAMINGO - 07263
LB08	8-7194-5901-0-9	OH	25	44	176	193%	209%	3	HOLMBERG - 06463
LB09	6-7613-6519-0-9	UG	75	51	68	74%	79%	8	ABERDEEN - 08861
LB10	6-7519-5651-0-1	UG	25	56	224	241%	257%	6	JOG - 07232
LB11	8-7567-4979-0-2	OH	50	79	78	166%	175%	4	OJUS - 04932
LB12	8-7091-9333-0-9	UG	50	63	126	134%	143%	5	REMSBURG - 05864
LB14	8-7654-5067-0-1	OH	75	46	61	67%	72%	21	MIAMI BEACH - 00231
LB15	8-6252-2363-0-8	UG	50	74	148	156%	165%	9	OLYMPIA HEIGHTS -08935
LB16	8-7362-0403-0-4	OH	50	83	166	174%	183%	23	MIAMI SHORES - 03431
LCC01	8-6978-9248-0-2	UG	75	82	109	115%	120%	7	DAVIE 02533
LCC02	8-6750-7522-0-2	OH	25	48	192	209%	225%	3	UNIVERSITY 05035
LCC03	8-6443-1080-0-5	OH	50	41	82	90%	99%	3	CUTLER - 02036
LCC04	8-7198-3950-0-9	UG	75	70	93	99%	104%	9	KIMBERLY -06865
LCC05	8-6992-4543-0-3	UG	50	64	128	136%	145%	6	REMSBURG -05865
LCC06	8-6541-2855-0-1	UG	75	92	123	128%	134%	9	CUTLER - 02035
LCC07	8-6650-2873-0-7	OH	37.5	60	160	171%	182%	8	SOUTH MIAMI - 02433
VB01	8-6176-4923-0-6	UG	75	72	96	102%	107%	11	IMAGINATION 04265
VB02	8-6071-8906-0-7	UG	75	87	116	122%	127%	9	BASSCREEK 06361
VB03	8-7991-9452-0-3	OH	50	52	104	112%	121%	4	SAMPLE ROAD 01035
VB04	8-7053-3424-0-4	OH	50	43	86	94%	103%	7	GRAPELAND 02934
VB05	8-6571-7015-0-3	UG	50	59	118	126%	135%	8	HOLLYBROOK - 06163
VB06	8-7373-3835-0-0	OH	50	49	98	106%	115%	6	STIRLING - 01732
VB07	8-6781-1358-0-9	UG	100	57	57	61%	65%	5	HIATUS - 06064
VB08	8-6682-1795-0-0	UG	50	66	132	140%	149%	10	HIATUS - 06066
VB09	6-7519-3569-0-1	OH	37.5	28	75	86%	97%	2	JOG - 07232
VB10	8-5743-6059-0-1	UG	50	69	138	146%	155%	8	EUREKA - 11264
VB11	8-7782-3242-0-3	OH	25	47	188	205%	221%	6	VERENA - 00635
VB12	8-7658-7415-0-1	OH	50	102	204	212%	221%	7	40TH ST 00941
VCC01	8-7578-4132-0-9	OH	37.5	72	192	203%	214%	12	PINEHURST 00337
VCC02	8-6781-7528-0-8	UG	37.5	71	189	200%	211%	6	MOTOROLA 04064
VCC03	8-6476-4928-0-7	UG	75	71	95	100%	106%	6	IMAGINATION 04262
VCC04	8-6149-2590-0-1	OH	37.5	44	117	128%	139%	4	MILLER - 05636
VCC05	8-7780-1225-0-6	OH	75	116	155	160%	166%	24	SISTRUNK - 00144
VCC06	8-6876-9836-0-9	UG	75	74	99	104%	110%	6	TIMBERLAKE - 05236
VCC07	8-6894-7753-0-3	UG	75	60	80	86%	91%	3	REMSBURG - 05866
VCC08	8-6445-6904-0-2	OH	25	29	116	133%	149%	2	CUTLER - 02033
		Averages	52.68	62.143	126%	137%	146%	7.4	

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QUESTION:
Has the utility performed an analysis or prepared any studies related to the potential impacts of PHEV charging on its generation system?

If yes, please provide the analysis or study and describe the results.

RESPONSE:
Yes. FPL has included PHEV load in its Ten-Year Site Plan, and therefore is accounting for the associated generation need. Please see pages 35-37 of FPL's 2017 Ten-Year Site Plan.

QUESTION:
What improvements will be required for the utility's distribution network if 1 percent of existing vehicles are replaced with PHEVs for each year through 2025?

What if the figure reaches 5 percent, 10 percent, 25 percent, or 50 percent?

What will the costs of these distribution improvements be?

Does the utility believe that a Contribution in Aid of Construction would be appropriate action to off-set the costs of these improvements?

RESPONSE:
What improvements will be required for the utility's distribution network if 1 percent of existing vehicles are replaced with PHEVs for each year through 2025?

Assuming a 1 percent replacement rate, FPL does not anticipate that there will be any significant improvements needed to FPL's distribution network through 2025. Based on FPL's most recent EV Reliability Study, FPL expects that small residential transformers currently loaded to or near capacity are likely to be the first improvements that will be required due to plug-in electric vehicles.

What if the figure reaches 5 percent, 10 percent, 25 percent, or 50 percent?

FPL has not specifically studied the higher penetration levels provided in this question, as FPL has not considered them to be achievable based on current electric vehicle economics and market conditions. FPL acknowledges the impacts associated with these penetration levels would be greater than the expected/forecasted levels.

What will the costs of these distribution improvements be?

To date, FPL has not developed cost estimates for improvements due to any level of electric vehicle penetration.

Does the utility believe that a Contribution in Aid of Construction would be appropriate action to off-set the costs of these improvements?

Contribution-in-aid-of-construction (CIAC) could certainly be considered as an alternative for off-setting the costs of improvements necessitated by electric vehicles.

QUESTION:
To what extent will "clusters" of PHEVs in the same geographic area cause localized distribution problems, especially in residential areas?

> Explain how many PHEVs charging simultaneously on a single residential transformer will necessitate upgrades to the utility's distribution network.
>
> Describe the methods to minimize any additional costs for distribution upgrades.

RESPONSE:
Explain how many PHEVs charging simultaneously on a single residential transformer will necessitate upgrades to the utility's distribution network.

There is no set number of PHEVs on a single transformer that will require an upgrade to distribution facilities. Facility upgrades will likely be dictated by a combination of PHEV quantities and charging rates (3.3kW, 6.6kW, or 19.2kW), as well as the available capacity of the existing facilities serving specific locations.

As mentioned in FPL's response to Staff's First Data Request No. 18, FPL's most current EV Reliability Study, PHEV charging will most likely impact first smaller residential transformers. However, most charging occurs during non-peak hours and impact may be limited to transformers that are already highly loaded or where charging occurs during the daily peak.

Describe the methods to minimize any additional costs for distribution upgrades.

While there could be a number of potential options to minimize the cost of distribution upgrades, options would include contribution-in-aid-of-construction, charging occurring off-peak, and programs that spread EV charging out over a longer time period.

QUESTION:
What effect will quick-charge stations (Level 3 or above) have on the utility's distribution network?

Will this effect vary in urban, suburban, or rural areas? If so, how?

RESPONSE:
What effect will quick-charge stations (Level 3 or above) have on the utility's distribution network?

At this time, the broad effect of DC Fast Charging (DCFC) stations is not fully understood. There are different charge rates within the DC fast charge. The impact to the network will also depend on the location of these stations. While FPL has conducted some power quality monitoring on quick-charge stations, further studies are required to fully understand and determine the impact on the utility's distribution network. FPL is working closely with Tesla and Electrify America on the installation of DCFC stations in FPL's territory. By doing so, FPL is able to ensure that it understands the ramifications of quick charging now and in the future.

Will this effect vary in urban, suburban, or rural areas? If so, how?

As mentioned above, location could have a significant impact on the distribution network and the cost to provide the EV charging service.

QUESTION:
Has the utility performed any analysis or prepared any studies related to the potential impacts of PHEV charging on its distribution system?

If yes, please provide the analysis or study and describe the results.

RESPONSE:
Has the utility performed any analysis or prepared any studies related to the potential impacts of PHEV charging on its distribution system?

Yes. Please see FPL's response to Staff's First Data Request No. 16.

If yes, please provide the analysis or study and describe the results.

Study findings:

- There is no significant impact expected on distribution or generation – current forecasts indicate this to be the case through 2025 or later.
- The expected PHEV adoption rate is near 1 percent over the next five to ten years.
- A minimum of 6.6kW Level 2 charging is likely to be more prevalent in future model years, though it is unclear what proportion of customers will charge at Level 2, and what percentage will opt to only charge at Level 1.
- Residential charging, even at higher rates, will likely have a minimal impact on power quality and reliability, at least in the near term.
- PHEV charging will most likely impact smaller residential transformers (25 & 37.5kVA) first. However, most charging occurs during non-peak hours and impact may be limited to transformers that are already highly loaded, or where charging occurs during the daily peak.
- Areas with higher percent of PHEVs or transformers that are near 200% loading are more likely to be impacted.

QUESTION:
Is the utility's existing electric distribution system adequate to accommodate PHEV demand based on the estimated number of PHEVs expected to be in use on your system through2025?

Please explain.

RESPONSE:
Yes. Please see FPL's responses to Staff's First Data Request Nos. 18 and 21.

QUESTION:
Are you aware of any required system upgrades where PHEVs have been a contributing factor?

If so, please explain.

RESPONSE:
No. To date, there have been no required system upgrades where PHEVs have been a contributing factor.