Electric Vehicle Charging Station

Pilot Evaluation Report

May 2015

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Executive Summary

The Electric Vehicle Charging Station (EVCS) Pilot was implemented in 2013 and 2014 to help prepare for the arrival of mass market electric vehicles. The aim of the pilot was to gain understanding of:

- customer charging patterns and behaviors,
- how charging load coincides with Xcel Energy's Generation System (System) peak in Colorado,
- how technically and operationally feasible it is to interrupt vehicle charging through Demand Response (DR), and
- how vehicles may impact the distribution system.

Another key objective of the pilot was to establish technical assumptions and determine cost-effectiveness for the DR portion of the pilot in order to determine whether the pilot should be proposed as a DR program within Xcel Energy's Demand Side Management (DSM) program portfolio and offered to a larger group of customers.

Twenty Xcel Energy electric customers in Colorado were recruited to participate in the pilot through a combination of work with a third-party vendor (National Car Charging) and Xcel Energy marketing channels. Ten participants received a ChargePoint Level 2 (240 Volt) charging station and the other ten participants had a Consert load control device installed on their existing Level 2 charger. Along with the ability to keep the equipment after the conclusion of the pilot, the participants were given a $100 incentive for each year they agreed to participate in DR events. In exchange for this, Xcel Energy was able to monitor the daily usage of the charging stations, download the data, and control the charging up to twelve times per year.

Electric Vehicle Charging Patterns

When reviewing the aggregated charging data of the group of 20 pilot participants, we see that customers charge their vehicles throughout the day, but two distinct peak periods are evident. The highest peak time is around 11:00 p.m., with a secondary peak around 9:00 a.m. This secondary peak is primarily driven by about 25% of the pilot participants who charge their vehicles in the morning vs. overnight.[1]

The resulting aggregated load profile of the pilot participants has a general shape that appears to be independent of the time of year (season) and time of week (weekday or weekend). However, when each participant is looked at as an individual there is noticeable variation hour-by-hour and month-by-month in the load levels.

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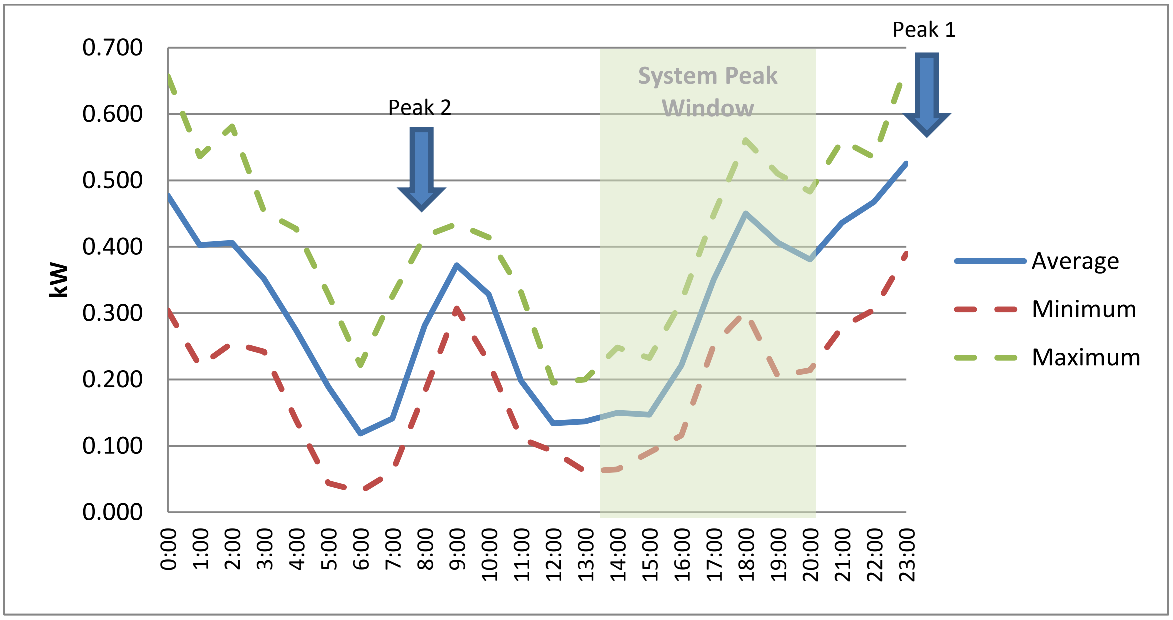
[1] The morning peak has not been a characteristic of larger data sets and may be exaggerated in the results because of the small sample size. Non-Xcel Energy EV project data sets can be referenced at www.theevproject.com/documents.php.

Figure 1: EVCS Participants: 12-Month Load Profile



System Peak Impact

Results from the evaluation of the EVCS pilot indicate that there is minimal impact to System peak, in terms of additional load/potential DR savings, even as the kilowatt (kW) savings are projected across the estimated existing population of electric vehicles in Colorado. The average potential demand reduction (kW) per vehicle on the System peak day is approximately 0.28 kW. For comparison, the average demand of a typical household refrigerator is 0.19 kW.

Along with this low System peak impact is a load factor of 19.5% which means that EV charging is not constant.

Distribution System Impacts

An internal Xcel Energy study concluded that the Company is 10+ years away from seeing any significant impact to mainline distribution feeders, substation transformers, or distribution transformers from electric vehicles. The study also concluded:

- A 5% EV penetration rate (EVs per total number of residential customers) equates to 2%-4% additional substation transformer peak load.
- Distribution feeder capacity significance starts around a 4% EV penetration rate and equates to a 2%-4% demand growth per feeder.
- At a 5% EV penetration rate across the residential customer segment, potentially 4% of the distribution transformer population serving residential customers could be overloaded if charging is aligned with peak load times.
- Distribution transformer loading will be of most concern when there are two or more EVs served off the same transformer.

Data analysis from the pilot showed that 86% of the time EVs are not charging at all and there was a wide variance in when charging took place.

Customer Comments and Feedback

Approximately half of the pilot participants owned their EV, and the other half leased them. Around half of the group expected to keep their EV for another 1-3 years and another third of the participants expected to keep their EV for less than a year.

The pilot participants were happy overall with the pilot believing that communication was at an appropriate level and 12 control events per season were reasonable. Most were either not inconvenienced, or mildly inconvenienced, by the control events and felt that a yearly incentive of $100 was sufficient.

A group of non-pilot participant EV owners was also surveyed and, along with the pilot participants, most charged their vehicle at home most of the time, with many not able to charge their vehicle at work. About half of EV drivers are using the higher voltage Level 2 (240 Volt) charger.

EV owners are an engaged group of customers and there is a high willingness to participate in future EV-related pilots with the primary motivation being no up-front equipment costs (i.e. utility pays for any incremental equipment needed to participate).

Other Key Learnings

- Controlling EV charging is technically feasible
- The pilot group had slightly lower charging peaks in summer than winter
- Customers have shown interest in an off-peak EV rate
- EV owners are also very interested in renewable energy

If System impacts become more significant there are several mitigation opportunities utilities might consider. Such opportunities could include rates that encourage off-peak EV charging or advanced load control programs that optimize customer charging needs with System costs.

Electric Vehicle Charging Station (EVCS) Pilot

Background

In 2011, Xcel Energy expected to see mass market electric vehicles (EV) delivered in Colorado starting in 2012. To better understand the impact of this market, Xcel Energy implemented an Electric Vehicle Charging Station (EVCS) Pilot. This pilot was launched via the 60-Day Notice in late 2011.

The pilot was to provide monitoring and demand response (DR) results for three years from the DR event season of 2012 through the DR event season of 2014. However, based on performance of vendor equipment during 2012, the scope was changed and recruiting participants started in Q2-2013; therefore customer equipment monitoring and controlling did not commence until August 2013.

Objectives

The main objectives of the pilot were to determine when customers are charging, the typical duration of the charge, and frequency by which the charging load is available for Demand Response. Other objectives included analyzing the demand savings, establishing technical assumptions and determining cost-effectiveness. These things, along with customer acceptance, were undertaken to determine whether an electric vehicle DR program should be offered to a wider set of customers.

Original research to be addressed by this pilot included:

- Monitoring residential and commercial[2] charging characteristics and behaviors
- Identifying if the vehicle charging overlapped with the System peak
- Distinguishing a potential strategy for controlling vehicle charging that would minimize the impact to the distribution system

Evaluation Plan

Evaluation of demand data was one of the key outcomes for the pilot. Charging data for all participants and control periods was analyzed to understand what a “typical” charging curve looks like for an average participant, the average over the population, and the average per type of vehicle. This information was used to determine the coincidence factor associated with controlling a residential EV charger. All participants were controlled and monitored via a two-way communication capable DR control device. Along with controlling load, the DR device had the capability of recording data every 15 minutes. The DR device recorded the following data: date and time, kilowatts, volts, amps, kilowatt-hours, frequency, and charging events. Data retrieval from all participants occurred on a daily basis. In order to simulate a DR event, up to twelve 4- to 6-hour duration control events during each summer peaking season were dispatched to determine peak demand (kW), charging demand (kW) curves, coincidence to System peak, and duration of charging periods.

Pilot Description

The pilot’s original design called for a direct load control switch to be installed adjacent to an EV charging station to monitor and control the customer’s vehicle charging. The switch selected for the

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[2] While commercial charging characteristics were proposed for the original pilot, the scope was scaled down to only focus on residential EV charging.

pilot was similar to devices used for the Company's Saver's Switch product, which provide direct load control on central air conditioners. However, the EV pilot switch was also slated to provide two-way communication and monitoring capabilities. Due to poor functionality, installation difficulties, and higher than anticipated costs with this approach, the pilot was redesigned at the end of 2012. The Company wanted to ensure the best experience for pilot participants and potential future program participants.

Phase 1 of the redesigned pilot was aimed at finding an existing charging system that already had load control capability, two-way communication, and load monitoring built in, so that the Company could readily start calling DR events for the 2013 control season. Simultaneously, research was done to find another switch/controller that met the requirements of the original filed pilot design. Once the new device was identified, it was added as Phase 2 of the pilot. Along with hardware installations, the pilot team decided to explore the potential for partnering with an automotive manufacturer on a software-based solution for controlling EV chargers. This was defined as Phase 3 of the pilot.

Phase 1: Test of EV Charging Stations

Phase 1 involved deployment of ten market-tested EV charging stations. Although this solution went beyond what would be deployed in an EV program, as it included a Level 2 charging station along with the controller, the units had all the capabilities desired from a load control device and were available for immediate deployment. A third-party reseller was engaged to manage the end-to-end deployment, from customer recruiting, device procurement, and post-sale support. The ChargePoint system—the selected charging station—included a robust reporting system with an appealing design and user interface. The pilot participants purchased these systems directly from the reseller at a reduced price and subsidized by Xcel Energy.

Phase 2: Test of Charge Controller on Existing Level 2 Chargers

While Phase 1 was being deployed and initial data was collected, the pilot team searched to find a load control device which provided the functionality originally desired at a price point in line with budget estimates. A suitable solution, a controller from Consert, was found and ten load control devices were deployed on existing Level 2 EV chargers as was originally envisioned for the pilot. An independent electrician was hired to manage the installation of the equipment. Unfortunately, the device was not available from the manufacturer until the second quarter of 2013, delaying customer deployment and installation.

Phase 3: Test of Onboard Vehicle Capabilities

Work in re-scoping the pilot drove to the conclusion that the ultimate load control solution for EVs may involve direct interaction with the vehicles themselves. To this end, a third phase was added to engage vehicle manufacturers and determine how Xcel Energy could leverage on-board charge control technology. The goal was to validate the ability to leverage this technology in lieu of deploying separate load control devices to control/interrupt the charging. Conversations with various manufacturers led to serious discussion with GM OnStar and a project proposal was submitted to them in July 2013.

During demand response events Xcel Energy interrupted participants' charging devices no more than 12 times per control season. For their participation, customers were given an annual credit of $100 and access to the associated data related to the vehicle charging.

To assess Phases 1 and 2 of the pilot, daily load data was tracked and recorded starting in March 2013 through December 2014 once equipment was installed and operational. Phase 3 efforts were disbanded in August 2014 due to an inability to reach a mutually acceptable agreement with OnStar.

Target Market

The primary target market for this pilot was 20 customers who currently own EVs and, in the case of the Phase 2 test, already had a Level 2 charger installed.

Participants in Phase 1 were acquired by the marketing efforts of a third-party reseller managing the end-to-end deployment. Participants were individuals who were owning/leasing EVs and in the market for a Level 2 charging station. Charging stations were provided to participants on a “first come, first served” basis.

Phase 2 participants were recruited via e-mail and direct mail targeting Public Service customers who had purchased/leased a qualifying EV according to the Electric Vehicle Information Exchange (EVIX) listings. Participation was, similar to Phase 1, available to eligible customers on a “first come, first served” basis.

Technology/Equipment

The EVCS Pilot design originally involved working with a load control device from Canon, similar to the device used for the Saver’s Switch (A/C load control) program. Upon initial deployment of the selected load control device in 2012, key issues were identified which impacted the filed budget and scope of the pilot.

- Actual costs associated with the load control devices were greater than the initial vendor quote.
- The customer experience associated with the equipment selected for the test was not at an acceptable level.
    - The device lacked an “OEM look/feel,” thus presenting a poor customer experience.
    - Charging data within the customer portal was reported in Amps. Conversion to kWh was possible, but at a notable cost to the pilot.

Due to these challenges, the pilot was re-scoped, new vendors were investigated, the new scope was tested, the budget updated, and new devices were deployed starting in 2013.

Phase 1

Phase 1 recruiting started in the second quarter of 2013 and included the installation of Level 2 (240 Volt) ChargePoint charging stations in ten participating customer’s homes. This process was managed by a local ChargePoint subcontractor. ChargePoint provided a web portal to access the 15-minute interval load data. The web portal was only available for access by Xcel Energy, not the pilot participants. Following completion of the pilot the customer was able to keep the charging station.

ChargePoint Model CT-

chargepoint

Phase 2

Phase 2 recruiting began in at the end of the 2nd quarter of 2013. This solution provides those customers currently owning a Level 2 (240 Volt) charging station with a load control device provided by the company Consert. The device was installed in the customer's home free of charge. As with Phase I, the customers received a $100 credit on their bill for participation in the pilot. Customer recruiting for this effort was managed internally by the Company. Interval load data was collected at 5-minute intervals each day and was available for download from Consert's secure FTP site the following day. The pilot participants were able to view their daily usage at the Consert web portal.

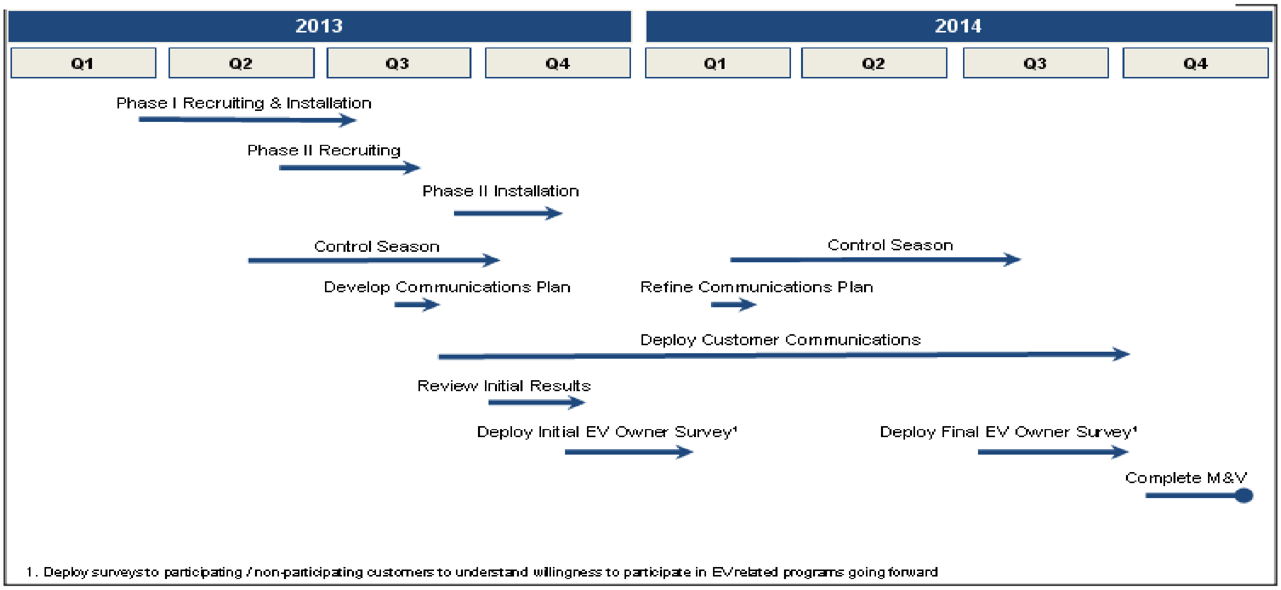
Phase 3

Phase 3 of the EVCS Pilot was designed to understand the ability to leverage OEM's onboard capabilities (e.g. General Motor's OnStar®, Nissan's CarWings™ and Ford's SYNC™) as a load control solution. Initial research determined that OnStar was the only manufacturer with the capability to support demand response related actions via telematics (at the time). Other OEM's were hesitant to engage in discussions on this.

Timeline

The following chart illustrates the planned timeline of the pilot:

Figure 2: Pilot Timeline



Data Used for Analysis

The majority of pilot analysis utilized the daily load data collected for each participant. Information from the DR events also provided insight on impact to the customer and Xcel Energy's System.

Daily Load Data

Daily load data was tracked for all participants in the pilot. The 15-minute interval load data from ChargePoint data and 5-minute interval load data from Consert was collected from March 2013 through December 2014. The data was then compiled into hourly averages by Xcel Energy's Load Analysis staff to determine the load profile and peak load impact.

Demand Response Events

In 2013, DR events were scheduled for four hours between 2:00 p.m. and 6:00 p.m. for both Phase 1 & 2 participants. Since the daily load data was indicating that most participants didn't charge their vehicles during this time, the event period was extended in 2014 to six hours (between 2:00 p.m. and 8:00 p.m.).

Originally, the DR events were meant to align with peak load days on the Xcel Energy System and only interrupt on days where the temperature was forecasted to be above 95°F (considered System peak conditions). June and July of 2014 passed with no forecasted 95°F days,[3] so in order to ensure an adequate number of test days, the temperature threshold was reduced to 90°F and DR events recommenced in August 2014.

Also of note, the Consert system would only allow 4-hour control windows. The vendor was notified of this; however, there was no plan to change this in their software. So, an attempt was made to schedule two consecutive events to cover the 2:00 – 8:00 p.m. window

The following is a summary of the DR events that were implemented in 2013 and 2014:

Phase 1: ChargePoint

In 2013, the control event periods were scheduled from 2:00 – 6:00 p.m. In 2014, the control event periods were extended an additional two hours from 2:00 – 8:00 p.m. The shaded dates on the calendar indicate ChargePoint control event days.

June 2013						
S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10 🟩	11	12 🟩	13 🟩	14	15
16	17	18	19 🟩	20	21 🟩	22
23	24	25	26	27 🟩	28	29

July 2013						
S	M	T	W	T	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16 🟩	17	18	19	20
21	22 🟩	23	24	25	26	27
28	29	30	31			

August 2013						
S	M	T	W	T	F	S
				1 🟩	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19 🟩	20	21 🟩	22	23	24
25	26	27	28 🟩	29	30	31

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[3] Control events were planned on a day-ahead weather forecast developed by in-house meteorologists using NOAA data.

August 2014						
S	M	T	W	T	F	S
					1	2
3	4	🟩 5	6	🟩 7	8	9
10	11	🟩 12	🟩 13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	🟩 28	29	30
31						

September 2014						
S	M	T	W	T	F	S
	1	2	🟩 3	4	5	6
7	8	9	10	🟩 11	12	13
14	15	16	17	18	19	20
21	22	23	24	🟩 25	🟩 26	27
28	29	30				

Phase 2: Consert

In 2013, control events were generally scheduled from 2:00 – 6:00 p.m., with the exception of 2:00 – 4:00 p.m. on 8/21/2013. In 2014, most control events were scheduled from 4:00 – 8:00 p.m. as the Consert system only allowed a maximum of 4-hour control periods. Work-arounds were used for 8/5/2014 and 9/26/2014 to attempt to cover the entire 2:00 – 8:00 p.m. time period. It was recommended to Consert that future software updates allow any length of control period. The shaded dates on the calendar indicate Consert control event days.

August 2013						
S	M	T	W	T	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	🟩 19	20	🟩 21	22	23	24
25	26	27	🟩 28	29	30	31

September 2013						
S	M	T	W	T	F	S
1	2	🟩 3	🟩 4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

October 2013						
S	M	T	W	T	F	S
		1	🟩 2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

August 2014						
S	M	T	W	T	F	S
					1	2
3	4	🟩 5	6	🟩 7	8	9
10	11	🟩 12	🟩 13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	🟩 28	29	30
31						

September 2014						
S	M	T	W	T	F	S
	1	2	🟩 3	4	5	6
7	8	9	10	🟩 11	12	13
14	15	16	17	🟩 18	19	20
21	22	23	24	🟩 25	🟩 26	27
28	29	30				

Analysis & Results

Measurement of available DR was one of the key outcomes of the pilot. Charging data for all participants was analyzed to understand what a “typical” charging curve looks like for given participants and vehicles. This was used to identify the coincidence factor associated with controlling a Level 2 residential EV charger.

All participants were controlled and monitored via a two-way communication capable DR control device. The device was capable of controlling load and recording data in 5- or 15-minute intervals. This daily interval data was collected and analyzed to determine charging demand (kW) curves, coincidence with System peak, and the duration of charging periods.

In order to understand the logistics and effects of DR on EV charging (and vice-versa), up to twelve 4- to 6-hour DR events were dispatched during two summer seasons.

Customers who participated in the pilot as well as other EV owners were surveyed about their EV use and their likelihood to participate in future EV charging related pilots. The results of those surveys are discussed in the section “Participant Feedback” section of this report.

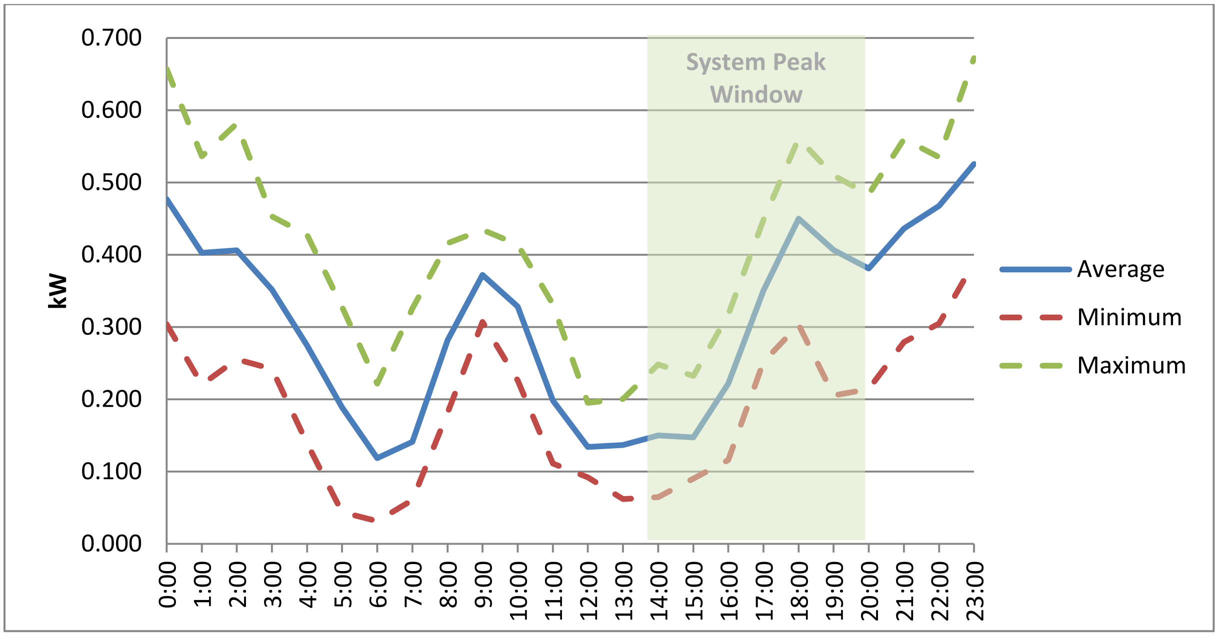
Charging Demand (kW) Curves

There are many ways the data can be presented in regards to the demand curves. The shape of the curve displayed by total average, vehicle type, month-to-month, weekday vs. weekend, etc. shows a similar trend with charging hitting peak levels generally from 10:00 p.m. to 1:00 a.m., and then a secondary peak around 10:00 a.m. The shaded area of Figures 3-7 below illustrates the typical window of time of Xcel Energy’s System peak demand (2:00 – 8:00 p.m.).

EV Charging Load Profiles – Average of All Pilot Participants

Figure 3 illustrates the average profile of the combined 20 participants in the pilot. The highest usage period is in the late night hours. Interestingly, there is a second peak usage period around 9:00 a.m. Analysis of individual usage patterns shows large diversity in charging habits month to month. Generally, most charging is done in the evening hours and approximately 20% of participants charge mid-morning. This smaller group that charges between 9:00 a.m. and noon accounts for the secondary peak we see in the average profile.

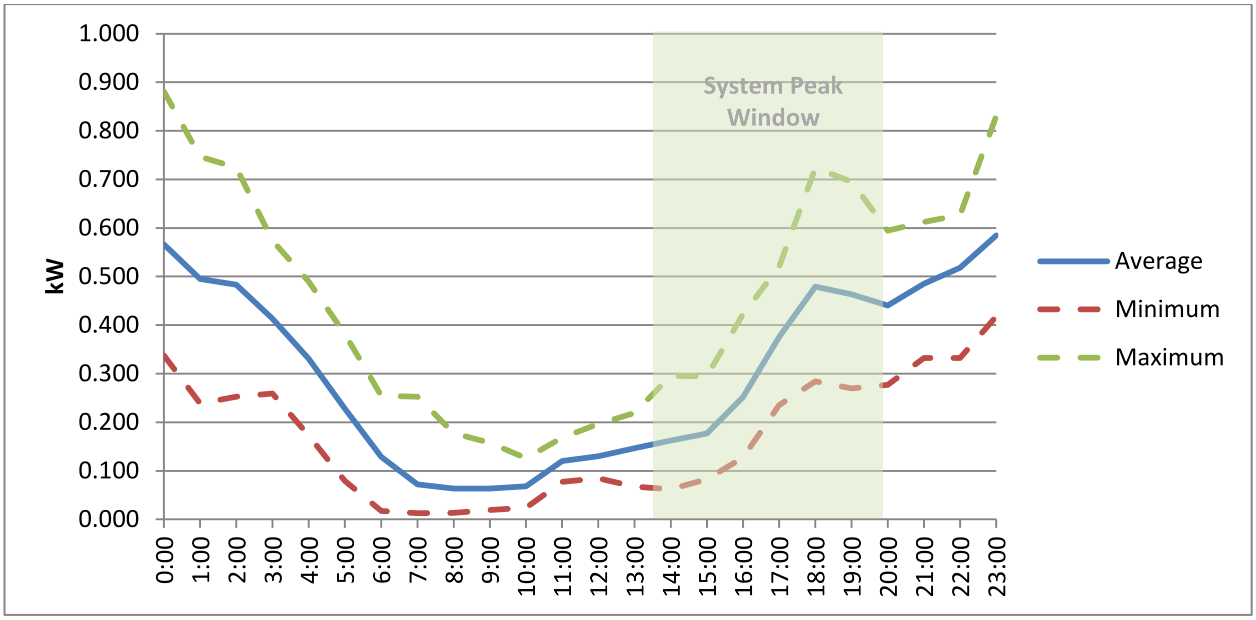
Figure 3: EVCS Pilot: Average Load Profile



EV Charging Profiles – Average of Pilot Participants without "Morning Chargers"

Since the load shape overall included a secondary peak, something that appeared to be a unique characteristic of this pilot, the data was further analyzed to determine who was doing major charging in the morning. These four participants were pulled out and the remaining participant's load shapes were included in Figure 4.

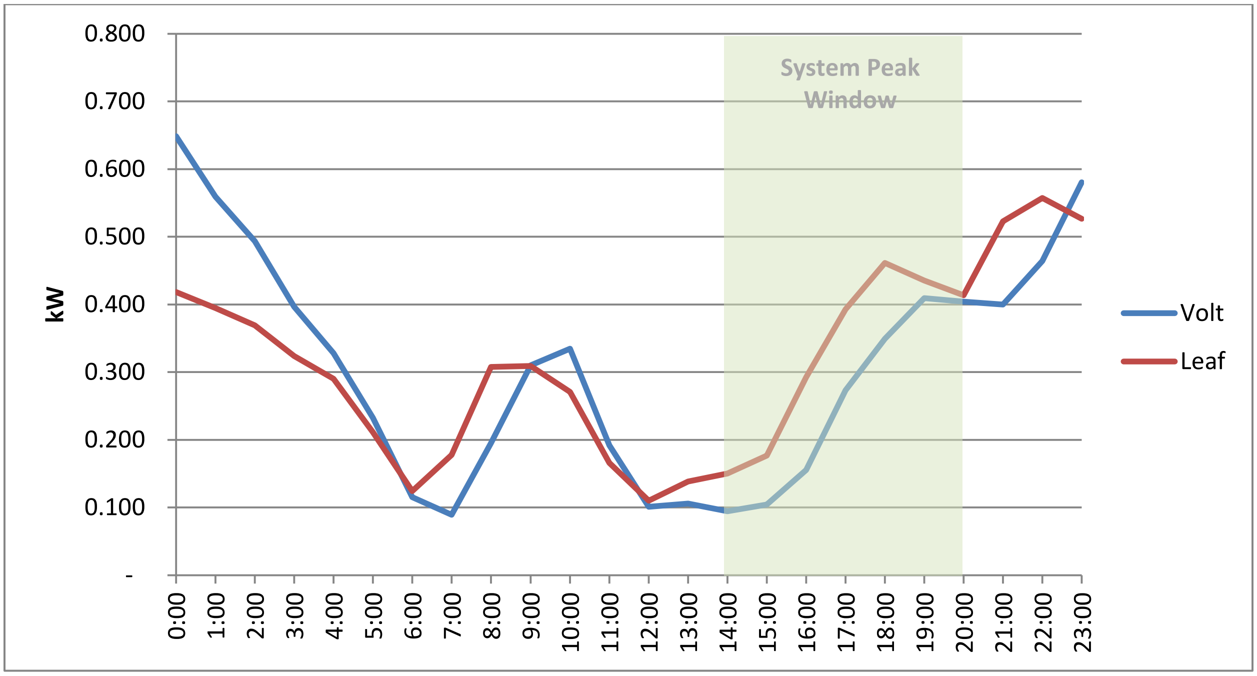
Figure 4: EVCS Pilot: Average Load Profile without "Morning Chargers"



EV Charging Profiles – Nissan Leaf vs. Chevy Volt Owners

Figure 5 illustrates charging profiles are similar between Nissan Leaf and Chevy Volt owners in the pilot. As you can see, the shapes are similar with the Volt owners charging a bit later in the day. This was not investigated further as charging profile differences between EV models was not of primary investigation for the pilot.

Figure 5: Load Profile: Leaf vs. Volt Owners



Seasonality with EV Charging

There appears to be some seasonality to the level of charging, with the lowest average load during the summer months regardless of the time of week (weekday or weekend). However, as Figure 6 illustrates, the load profile is similar across the seasons.

Figure 6: Seasonal Load Profile: Weekdays

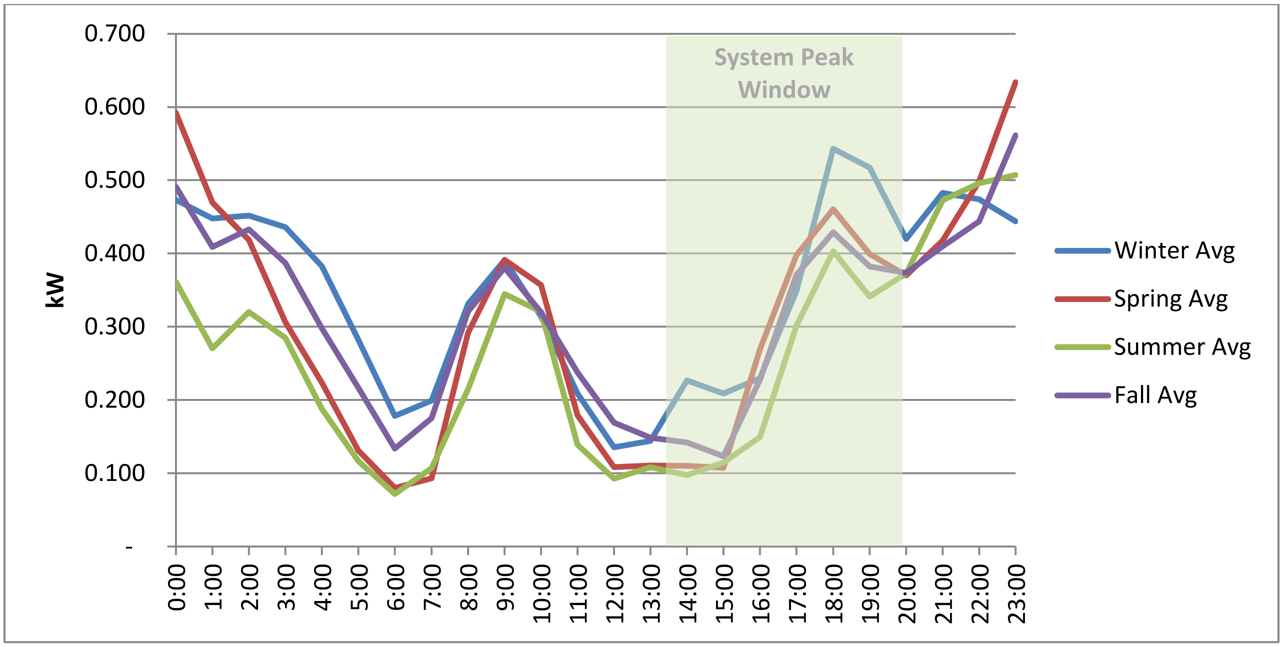
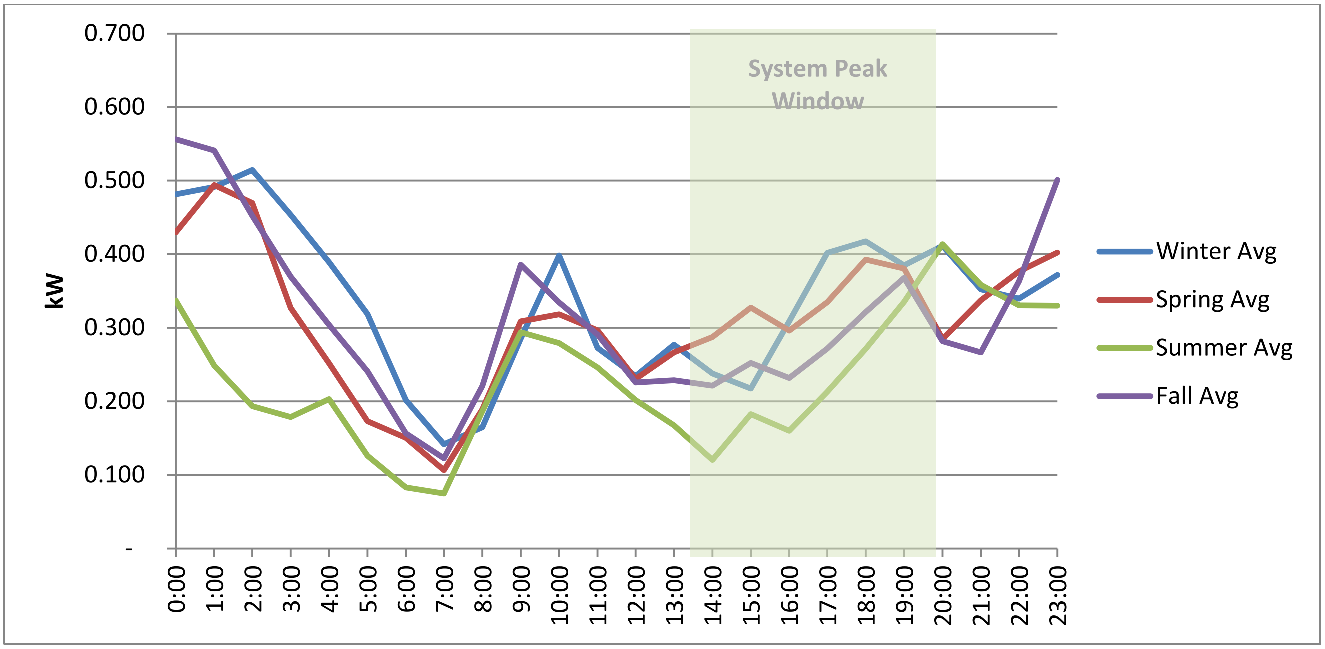


Figure 7: Seasonal Load Profile: Weekends



Coincidence with System Peak

The data from the EV pilot participants was multiplied across the "EV Class" which is defined here as the number of EV owners in Xcel Energy's Colorado service territory. The EV population at the time of this analysis was estimated to be 3,315. The peak month used for the derivation of load factor was July 2014.

Average Energy Use

The average monthly energy use of the pilot participants is shown in the table below and was extrapolated to the EV Class population to give an estimate of overall energy use of the total EV population in Colorado.

Figure 8: EVCS Average Monthly Energy Use

	Avg kWh/EV	**Avg EV Class kWh**
Oct 2013	244	809,329
Nov 2013	240	794,421
Dec 2013	244	808,014
Jan 2014	254	842,609
Feb 2014	240	795,170
Mar 2014	249	826,221
Apr 2014	220	730,100
May 2014	214	708,115
Jun 2014	176	584,583
Jul 2014	190	629,131
Aug 2014	187	619,481
Sep 2014	206	683,029
ANNUAL AVERAGE	**222**	**740,652**

Coincident Peak

The peak load of the EV Class does not appear to coincide with the Xcel Energy System peak as illustrated in Figure 10. However, even though absolute peak hour of EV charging doesn't coincide with the System peak hour, there is still a significant amount of charging occurring on peak.

It is important to note that the EV's in the pilot used Level 2 charging, which could have an electric demand requirement between 3.3 to 7.7 kW during a 3 to 8-hour charging period. The data for the pilot was analyzed on an hourly basis, so the 5 and 15-minute interval data was averaged for each hour of the day. This resulted in lower average hourly demands per vehicle as some 5 or 15-minute intervals within a 1-hour period had no charging and thus affected the average kW. See the table below for July7, 2014 between 9:00 p.m. and 11:00 p.m. For example, in Figure 9, Station 12 shows a 9:00 p.m. hourly average of 2.3 kW, when for 30 minutes it was at 3.9 kW.

Figure 9: Example of 15-minute Interval Data

Station #	1	2	3	4	5	11	12	13	14	15
9:00 PM	0.0	3.7	0.0	3.2	0.0	0.0	0.0	0.0	0.0	3.7
9:15 PM	0.0	3.7	0.0	3.4	0.0	0.0	1.3	0.0	0.0	3.7
9:30 PM	0.0	3.7	0.0	3.4	0.0	0.0	3.9	0.0	0.0	3.7
9:45 PM	0.0	3.7	0.0	3.4	0.0	0.0	3.9	0.0	0.0	3.7
AVG	**0.0**	**3.7**	**0.0**	**3.4**	**0.0**	**0.0**	**2.3**	**0.0**	**0.0**	**3.7**
10:00 PM	0.0	3.7	0.0	1.1	0.0	0.0	3.9	0.0	0.0	3.7
10:15 PM	0.0	3.7	0.0	0.0	0.0	0.0	3.9	0.0	0.0	3.7
10:30 PM	0.0	3.3	0.0	0.0	0.0	0.0	3.9	0.0	0.0	3.3
10:45 PM	0.0	0.6	0.0	0.0	0.0	0.0	3.9	0.0	0.0	1.1
AVG	**0.0**	**2.8**	**0.0**	**0.3**	**0.0**	**0.0**	**3.9**	**0.0**	**0.0**	**2.9**

Analysis of the 15-minute interval data on the Xcel Energy CO System peak day of July 7, 2014, revealed that only 5% of the pilot participants (1 out of 20) were charging at the System peak hour of 5pm.

A review of the hourly data revealed that at most only 50% of vehicles in the pilot were charging at the same time during any particular hour.

The peak charging hour for the pilot participants doesn't align with the System peak as illustrated in the following table. And at the System peak hour, 0.55 kW of load per vehicle is projected at most.

Figure 10: Hourly Peak Times and Average Loads

	EV Class peak time	***EV Class peak (kW)***	***Per Vehicle (kW)***	***SYSTEM peak time***	***EV Class (kW)***	***Per Vehicle (kW)***
Oct 2013	10/01/13 11:00 PM	4,427	1.34	10/15/13 08:00 PM	195	0.06
Nov 2013	11/09/13 04:00 AM	4,355	1.31	11/21/13 06:00 PM	610	0.18
Dec 2013	12/12/13 02:00 AM	4,362	1.32	12/05/13 06:00 PM	1,807	0.55
Jan 2014	01/17/14 07:00 PM	3,853	1.16	01/05/14 07:00 PM	274	0.08
Feb 2014	02/11/14 08:00 AM	4,365	1.32	02/05/14 07:00 PM	1,391	0.42
Mar 2014	03/05/14 06:00 PM	4,234	1.28	03/01/14 07:00 PM	1,825	0.55
Apr 2014	04/17/14 12:00 AM	4,753	1.43	04/13/14 09:00 PM	414	0.12
May 2014	05/01/14 11:00 PM	5,207	1.57	05/28/14 06:00 PM	912	0.28
Jun 2014	06/29/14 08:00 PM	4,101	1.24	06/30/14 05:00 PM	1,050	0.32
Jul 2014	07/17/14 08:00 PM	4,347	1.31	07/07/14 05:00 PM	783	0.24
Aug 2014	08/16/14 12:00 AM	4,139	1.25	08/13/14 05:00 PM	891	0.27
Sep 2014	09/06/14 11:00 AM	4,047	1.22	09/03/14 05:00 PM	827	0.25
AVERAGE		**4,349**	**1.31**		**915**	**0.28**

Potential Future Impact

In looking at what point EV load becomes impactful on the Xcel Energy electric grid, below is a graph that estimates the growth of EV's across Colorado.

Figure 11: Projected EV Growth in Colorado

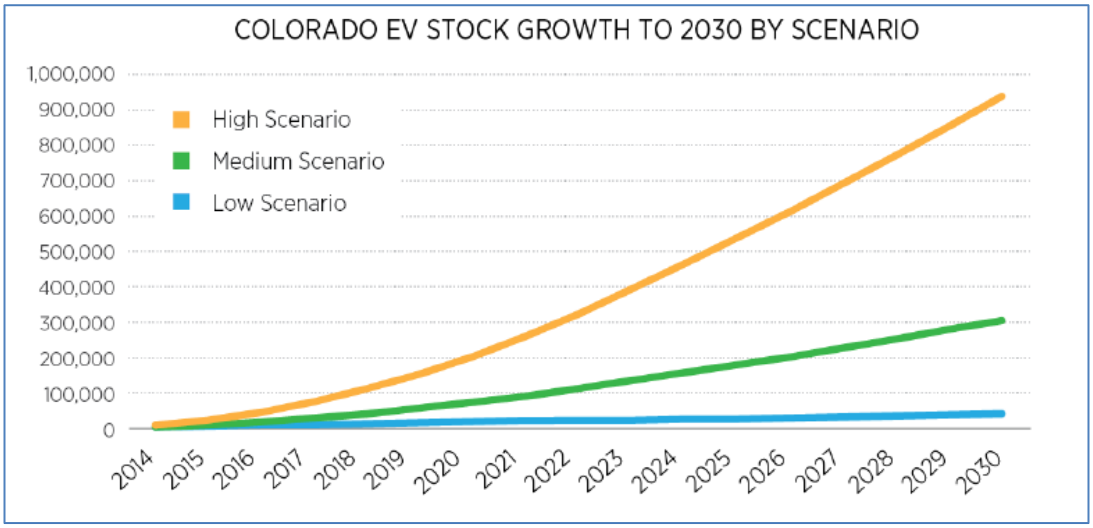


Image Source: BCS Incorporated, "*Colorado Electric Vehicle Market Implementation Study",* January 2015 Link to study

At an average monthly peak load of 1.31 kW per vehicle (average of "per vehicle" values in Table 2), by 2020 (using the High Scenario) the total average monthly peak load could be around 268 MW (1.6% of Xcel Energy's total Colorado generation capacity).

Contribution to the Coincident Peak Hour

The contribution to the monthly system peak was calculated for October 2013 through September 2014 for the EV Class (estimated 3,315 EV's in Xcel Energy's Colorado service territory).

Figure 12: EV Monthly Contribution to System Peak

	EV Class kW (3,315 EVs)	***Avg kW per Vehicle***
Oct 2013	195	0.06
Nov 2013	610	0.18
Dec 2013	1,807	0.55
Jan 2014	274	0.08
Feb 2014	1,391	0.42
Mar 2014	1,825	0.55
Apr 2014	414	0.12
May 2014	912	0.28
Jun 2014	1,050	0.32
Jul 2014	783	0.24
Aug 2014	891	0.27
Sep 2014	827	0.25

EV Charging Station Load Factors

There are several definitions of Load Factor. For purposes of this report we are focusing on two: 1) System Peak Load Factor and 2) Non-Coincident Peak (NCP) Load Factor.

System Peak Load Factor

The System Peak Load Factor is the ratio of the EV Class average demand in the system peak month to the EV Class peak demand at the system peak hour. For July 2014, this is:

$$\frac{\text{Average Demand}}{\text{Peak Demand}} = \frac{(629{,}131/744)}{783} = 1.08\ (108\%)$$

This says the average demand in July is 8% higher than at system peak hour. This is significant because it means that this load could be served by base load generation and it improves the System load factor as well.

Non-Coincident Peak Load Factor

The Non-Coincident Peak (NCP) Load Factor is the ratio of the EV Class average demand to the EV Class NCP demand. For July 2014, this is:

$$\frac{\text{Average Demand}}{\text{NCP Demand}} = \frac{(629{,}131/744)}{4{,}347} = 0.195\ (19.5\%)$$

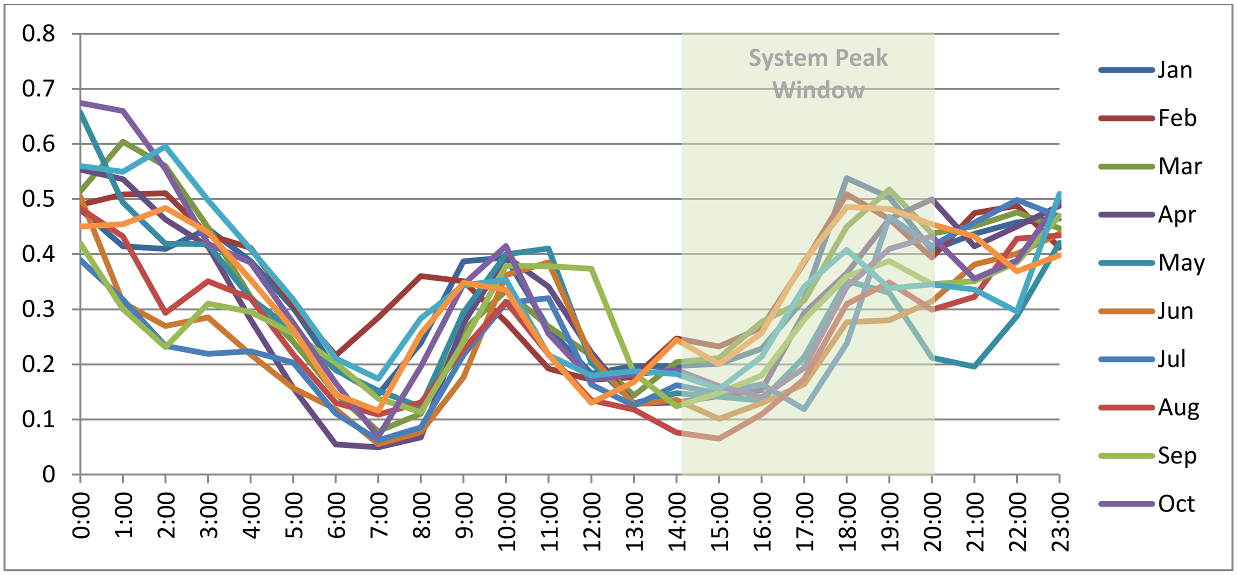
This says that if there was dedicated generation for EV charging, that generator would only be in use 19.5% of the time during July 2014.

Average Charging Profile

In order to profile the average EV charging day, the average kW across the twenty participants for each hour of each day of each month was calculated e.g. the average kW of 20 vehicles at 1am for every day in the year. This is attempting to profile the “typical day” of EV charging each month of the year.

Figure 13 illustrates the average load each hour for the twenty EV pilot participants for each month.

Figure 13: Average EV Charging Profile for Each Month

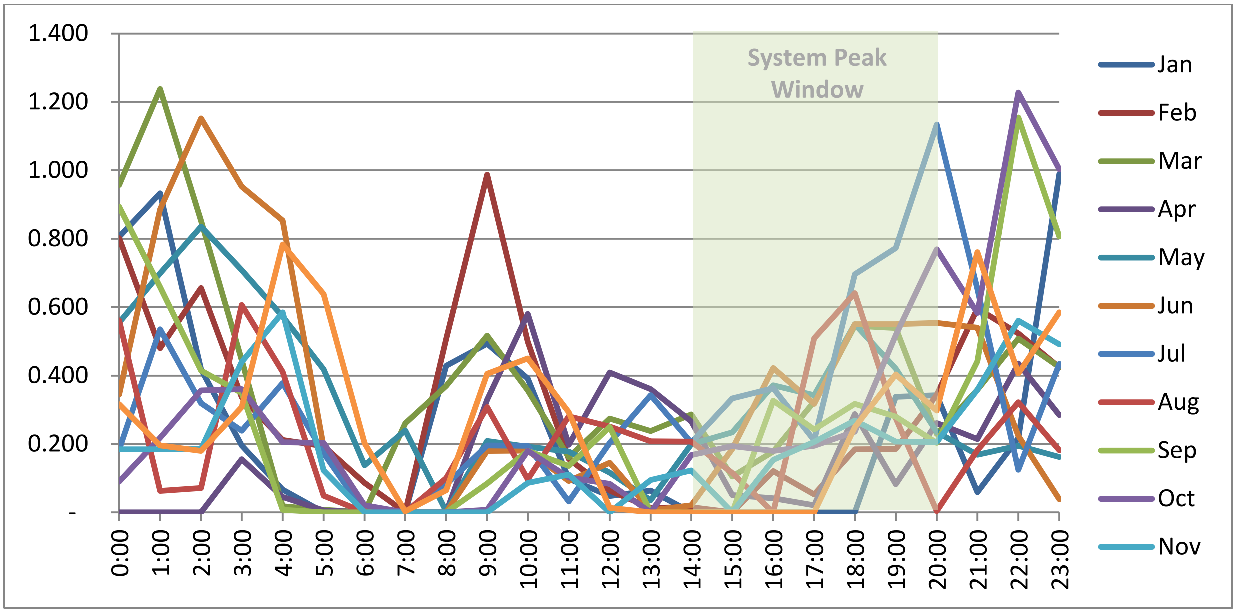


Peak Day Charging Profile

In order to profile the EV charging on System peak load days, the average kW across the twenty participants for each hour on the System peak day of each month was calculated e.g. the average kW of 20 vehicles at 1am for every day in the year. This is attempting to profile EV charging when the electric grid is at its peak load.

Figure 14 illustrates the average load each hour of the EV pilot participants on the peak day of each month. The monthly peak days between October 2013 and September 2014 are shown in Figure 10.

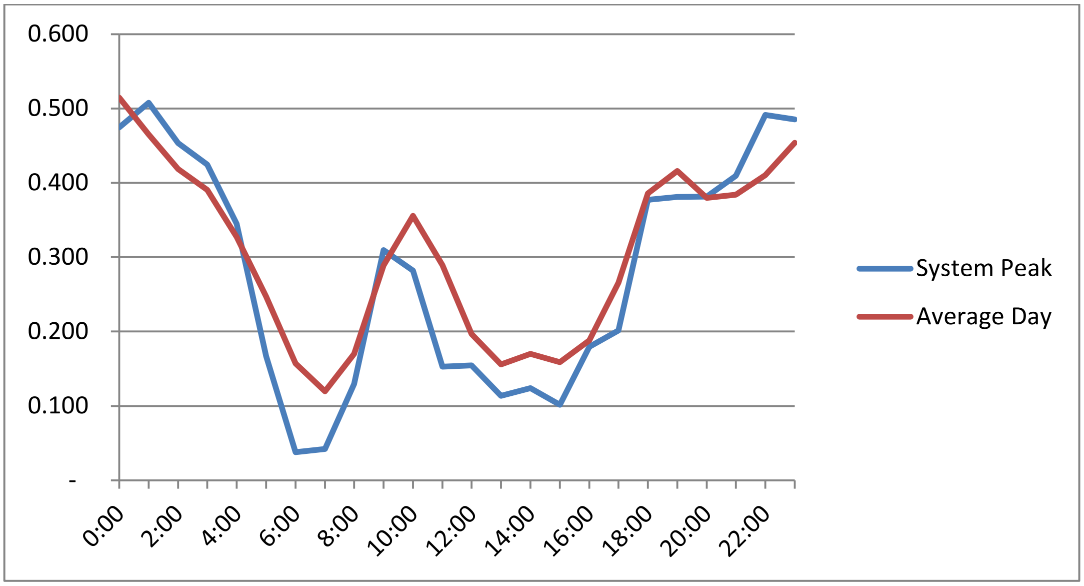
Figure 14: EV Charging Profile on Peak Day Each Month



Average Charging Profile vs. Peak Day Charging Profile

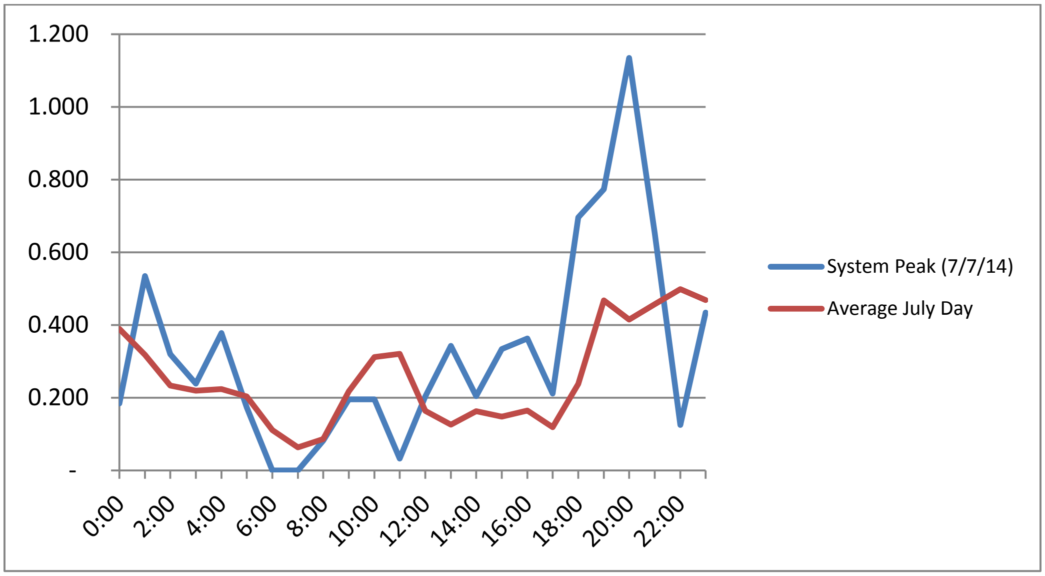
The following graph combines the two previous graphs in order to compare the Average EV charging profile over 12 months and the average EV charging profile on the System peak day for those same 12 months. This illustrates that on a system peak day, EV charging tended to be less than the average charging day in a month.

Figure 15: EVCS: Load on System Peak Day vs. Load on an Average Day



The following graph compares the profile of the average day in July with the Xcel Energy's Colorado System peak day.

Figure 16: EVCS: Average July Day vs. System Peak (7/7/14)



Charging Characteristics

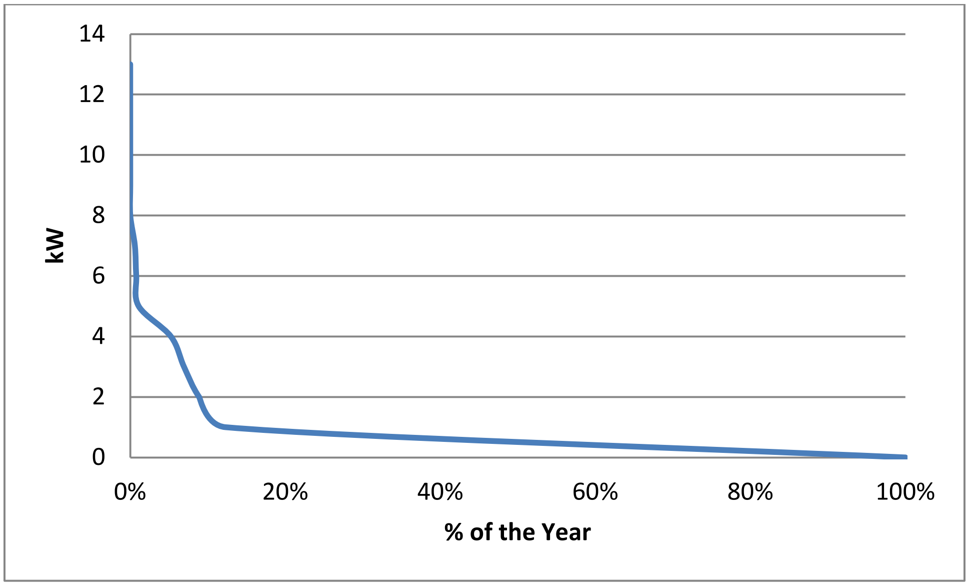
The usage data provide some information on the various charging characteristics of the pilot participants such as when are customers charging and how long charging sessions last?

- Averaged charging trends show a pattern of charging throughout the day, where most (around 87%) charging takes place during off-peak hours
- There is an interesting bump in charging around 9am, which is attributable to about 20% of the pilot participants. Most participants do their charging at night.
- More kWh are used in the winter and fall, but the load profile is the same general shape as in spring and summer
- There is an appreciable amount of load available with each vehicle while charging (63% of load readings were between 2 and 4kW per vehicle).

- Charging sessions appear to run from 1 to 4 hours on average.

What is interesting about the charging data is how much of the time there is no charging taking place. In Figure 17, the graph shows the number of readings at different kW levels for all 20 stations in the pilot between 10/1/13 and 9/30/14. Around 86% of the readings were zero with the remaining majority of readings between 1 and 5 kW. The average hourly reading was above 5 kW less than 1% of the time.

Figure 17: Load Duration Curve



Cost-effectiveness

Looking at the simple benefit-to-cost, this pilot is not cost-effective from a Modified Total Resource Cost (MTRC) and Utility Cost Test (UCT) test ratio perspective. The MTRC test ratio is 0.09 and the UCT test ratio is 0.03 (a cost-effective product has a ratio of at least 1.0). Generally, pilots are not expected to be cost-effective, but the low TRC and UCT tests illustrate the low peak demand savings opportunity with EV Demand Response.

It may be more cost-effective to manage demand through workplace charging where it is more likely to be coincident with System peak load hours.

There are other factors to consider around cost-effectiveness. For instance, there is no broadly accepted lifetime for charging equipment. The life of the equipment may end due to failure or technology obsolescence. Additionally, unlike a home, with mostly fixed assets, the EV may only be at the house for a certain time before the customer moves. Similarly, if the vehicle is leased the potential life of the equipment for that customer may be the term of the lease.

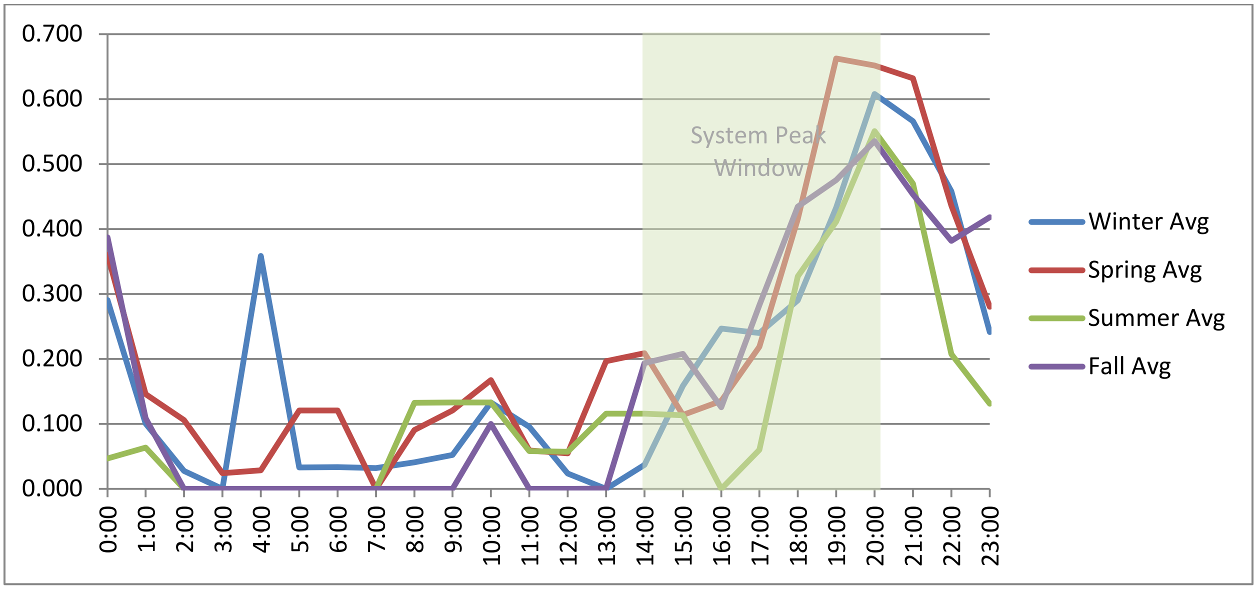
Electric Distribution System Impacts

EV Charging Profiles – Individual Stations

The Electric Distribution System is likely to be most impacted by EVs at the transformer level. Figure 18 below is an example of the load profile of one of the charging stations in the pilot, where the participant charges mainly in the evening hours and generally not in the morning. This profile is similar to other utility studies such as the "California Joint IOU Electric Vehicle Load Research Report" and "The EV Project".

The unique behaviors of individuals will likely play a role in determining how much of a concern the overloading of distribution transformers or low-voltage conditions on the distribution system really is. Many things have to align such as how many neighbors on the same transformer have EVs, the cycling of the EV charging itself, and the length of each charging cycle, coincidence of other loads, presence of rooftop solar, etc. Based on the data from the pilot, it would likely be a rare occurrence for vehicles to be charging at their maximum levels all at the same time as well as to start charging at exactly the same time.

Figure 18: Individual Station Example



Distribution System Capacity Impacts

In Q4 of 2014, Xcel Energy's Distribution Engineering Department presented a study of distribution capacity impacts of plug-in electric vehicles at the annual Minnesota Power Systems Conference (aka: MIPSYCON). The study looked at capacity concerns at the substation, feeder, and service transformer levels. The study concluded that Xcel Energy is 10+ years away from seeing any significant impact to mainline distribution feeders or substation transformers resulting from EVs.

Other key conclusions relating to the distribution system capacity impact of EVs:

- A 5% EV penetration rate (EVs per total number of residential customers) equates to 2-4% additional substation transformer peak load (worst case).
- Distribution feeder capacity significance starts around a 4% EV penetration rate and equates to a 2-4% demand growth per feeder.
- At a 5% EV penetration rate across the residential customer segment, potentially 4% of the distribution transformer population serving residential customers could be overloaded if charging is aligned with peak load times.
- Distribution transformer loading will be of most concern when there are multiple EVs served off the same transformer.

Participant Feedback

In December 2014, two surveys were completed to gather feedback from the pilot participants and general EV owners in Colorado. For the EV owners' survey, the Company reached out to an internal list of customers who had expressed interest in the Xcel Energy *Re-powering Transportation* initiative. The surveys were sent electronically through Survey Monkey. It was completely voluntary and there was no cash/gift incentive offered. Due to the power of social media, the Company received 61% of the responses from EV owners in Minnesota as information about the survey was passed on through Facebook. This data was not included in the analysis. Also, we found that there are many members on our email list that do not currently own EVs, but consider themselves "EV enthusiasts."

Pilot Participant Satisfaction Survey Summary

Eleven of the 20 pilot participants responded to the survey; Figure 21 shows overall satisfaction. Other key results include:

- 54.5% owned and 45.5% lease their EV.
- 45.5% are expecting to keep their EV from 1-3 years, 36.4% for longer than 3 years, and 18.2% for less than one year.
- 81.8% do not have access to EV charging at work.
- 82% of the participants were either somewhat or very satisfied with the pilot.

In regards to the logistics of the pilot itself, the survey participants were overwhelmingly supportive of the pilot operations; with data showing:

- A vast majority (91%) responded that 12 control events were a reasonable amount.
- 63.6% were mildly inconvenienced and 36.4% were not at all inconvenienced by the control events.
- 91% stated that they received the right amount of information of communication about the control events.
- 72.7% received the right amount of general information about the pilot. The rest felt that there was too little communication.

- 63.6% believed the $100/year incentive was an appropriate amount and 36.4% thought it wasn't enough.

Survey participants were also asked open-ended questions such as what went well with the pilot, what other comments they would like to make, etc. Some comments came back in support of a special rate for EV charging. Here are those comments:

> *"If Xcel Energy is serious about reducing electrical load during peak hours, it should ask the Colorado PUC to approve lower, off-peak electrical usage rates for residential customers. I would happily recharge my vehicle at home at night if the rates were lower at that time. Right now, Xcel Energy offers me no financial incentive to do that."*
>
> *"If Xcel Energy were to provide lower, off-peak electrical usage rates for residential customers in Colorado, this would make sense."*
>
> *"Any pilot programs that XCEL Energy could develop such as EV time of use charging and incentives toward Renewable charging of EVSE stations would be very complimentary…"*
>
> *"Time of use rates are needed to encourage EV off peak charging and maximize efficient use of the electric grid."*
>
> *"Off peak charging rate please!"*

Most pilot participants surveyed do their EV charging almost exclusively at home (8 out of 11). The other three split their time between home and work or between home and businesses they frequent. The percentage of time at public charging stations (or elsewhere) is very low. Figure 20 below shows the overall average of those surveyed.

Figure 19: Percent of Time at Various Charging Locations

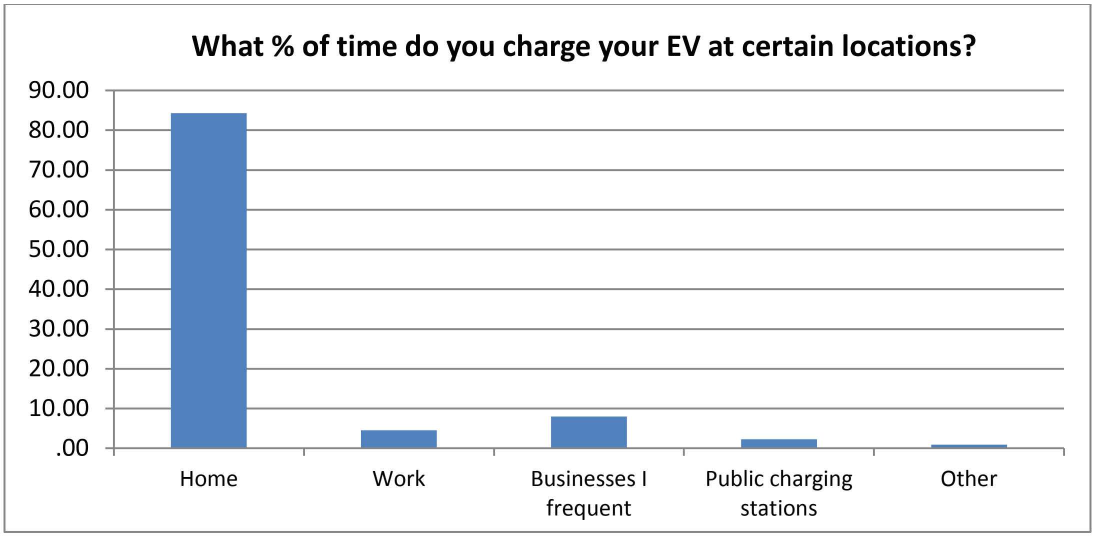
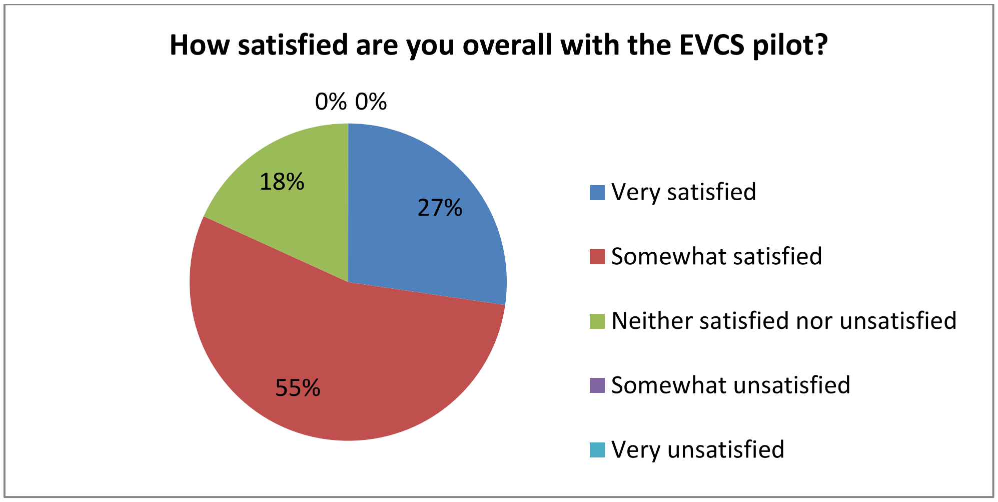


Figure 20: Overall Pilot Satisfaction

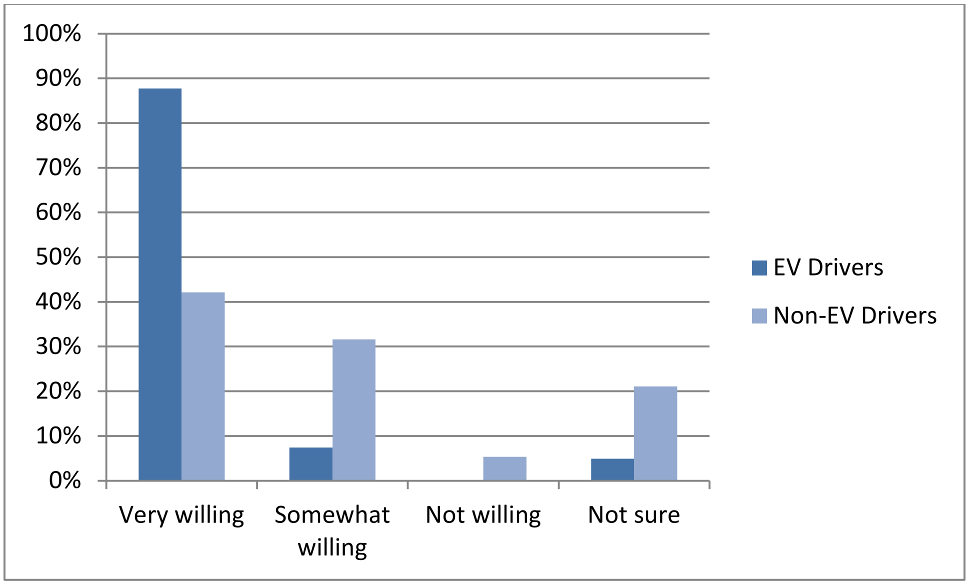


General EV Owner's Survey Summary

One of the main objectives of the survey to general EV owners was to gauge interest in participating in future utility pilots (either EV-related or not).

For future EV-related pilots, most EV drivers surveyed were very willing to participate, and most non-EV drivers were either very or somewhat willing to participate. See Figure 22 below.

Figure 21: Willingness to Participate in Future EV Pilots



Respondents (82 out of 100) wrote in reasons why they would be willing to participate, as shown in Figure 23.

Figure 22: Reasons to Participate in EV Pilots

Reason	#
Advancing Vehicle Adoption Interest	27
General interest	14
Societal interest (Altruistic)	14
Professional Interest	12
Environmental Interest	10
Innovation/Technological Interest	10
Self Interest (Mostly Financial)	3
More Charging Infrastructure Interest	2

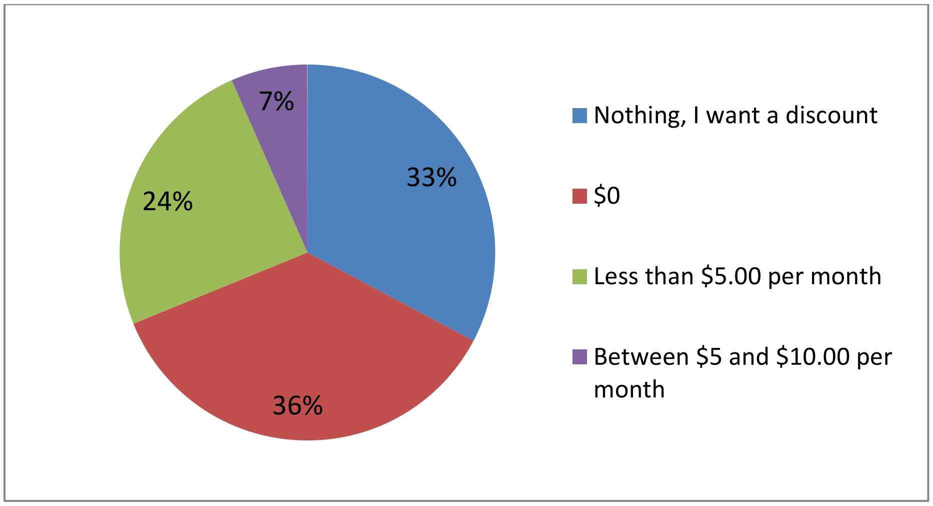
For future non-EV-related pilots, 92% of survey respondents they are either very or somewhat willing to participate in other pilots or programs to help Xcel Energy better understand customer behavior relative to electricity or natural gas consumption in general. Table 9 gives some reasons why.

Figure 23: Reasons to Participate in Other Utility Pilots

Reason	#
General interest	16
Advancing Utility Innovation Interest	11
Environmental Interest	10
Self Interest (Mostly Financial)	8
Societal interest (Altruistic)	7
Interested in EV’s Only	7
Conservation of Energy	6
Innovation/Technological Interest	5

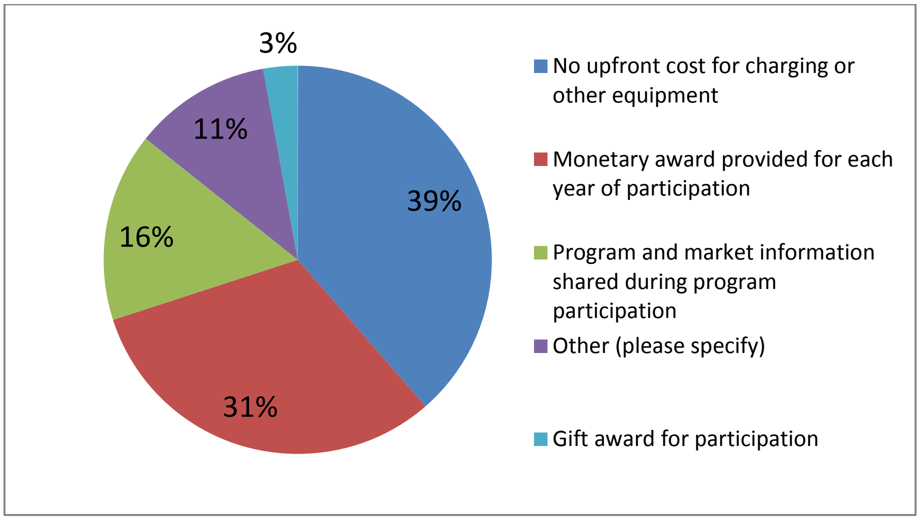
Survey participants were asked about program costs and benefits such as if they were open to pay more for an EV program that provides charging equipment that can communicate with the utility and how much they were willing to pay. Respondents were not willing to pay more than $10 per month.

Figure 24: Willingness to Pay for EV Program



Survey participants were then asked what would provide the greatest motivation to participate in such a program.

Figure 25: Motivation Factors to Participate in EV Program



Notable comments received:

- "I am glad Xcel is finally getting on board. I have been asking since Nov of 2011."
- "I'm glad to see that Xcel has finally showed some interest in EV's. When I started getting involved earlier this year there seemed to be no interest at all from Xcel. Also, information on rates for charging at various times of the day would be helpful."
- "I think that Xcel should be doing whatever they can to promote the purchase of electric vehicles and the cleanest generation sources for charging them at night."
- "I charge at home because I have solar panels on my home to offset the power consumption."
- "Typically charge overnight, or when rooftop solar is producing well."

Conclusion

The Electric Vehicle Charging Station pilot was a success in that it set out what it was intended to do:

- Understand customer charging patterns and behaviors,
- Understand how charging load coincides with Xcel Energy's system peak in Colorado,
- Show that it is technically and operationally feasible to interrupt vehicle charging through Demand Response (DR), and
- Predict how these vehicles may impact the distribution system

There is an appreciable amount of load available with each vehicle while charging (63% of readings are 2-4kW/vehicle, but vehicles are often not charging (88% of the hourly readings between 10/1/13 and 9/30/14 were zero) and generation dedicated for that load would only need to be available around 20% of the time. That reality means that there is not a lot of load available on average for DR events, and therefore not a lot of peak load savings.

EV charging does contribute to peak demand, but that contribution is not 100% coincident with System peak, and the variability in charging load can lead to high variable peak contributions from EVs (EV load at System peak hour, month by month).

It is important to note the level of sample size uncertainty inherent in the data. This could make it difficult to take away definitive conclusions about things like average charging load curves and demand response potential. At the same time, the demand response results were not cost-effective even if the most aggressive pilot results (maximum load of 20 participants) were used.

The cost of delivering the pilot as it was designed and the small amount of average peak load savings that were measured resulted in the pilot being not cost-effective. There is potential for cost-effective DR programs that leverage on-board charge control capabilities. However, because those program designs rely on customers paying for the cost of those onboard systems, the market size is unknown and could be small. Cost-effectiveness will face other challenges as we cannot count on a long useful life based on what we learned of EV ownership and what we don't know about the lifetime of the charging/control equipment.

Pilot participation and the survey results show that EV owners are a highly engaged group of customers. We might be able to design programs that take advantage of this fact, by motivating EV owners to shift load in different ways. But while feedback from the pilot was positive, these folks are the early adopters. Interest may be different for more mass-market EV drivers.

As it appears that a DR program may be difficult to be cost-effective, a next step for Xcel Energy may be to explore rate design options that can help manage load growth from EVs. Interest from the pilot participants as well as general EV owners and the cost of controlling charging directly also support exploring a rate that encourages off-peak charging. As rate design options are explored, potential for workplace charging access and load management will need to be considered.

Appendix A: EVCS Pilot Participant Satisfaction Survey

1. Do you own or lease your electric vehicle?
    - Own
    - Lease
2. How long are you likely to keep your electric vehicle?
    - 3 Years or more
    - 1 to 3 years
    - Less than 1 year
    - Other
3. How many miles do you travel in your electric vehicle per year?
    - <8,000
    - 8,000-10,000
    - 10,001-12,500
    - 12,501-15,000
    - >15,000
4. Roughly what percentage of time do you typically charge your electric vehicle at the following locations?
    - Home
    - Work
    - At businesses I frequent
    - Public charging stations
    - Other
5. Do you have access to electric vehicle charging at work?
    - Yes
    - No
    - Sometimes
6. Do you think up to 12 control events per summer is:
    - Too many
    - Too few
    - Just right
    - Don’t know
7. How inconvenienced were you during the control events?
    - Very inconvenienced
    - Mildly inconvenienced
    - Not inconvenienced at all
    - Don’t know / Don’t recall
8. How was the level of communication about the control events?
    - Too much
    - Too little
    - Just right
9. How was the level of general communication about the pilot?
    - Too much
    - Too little
    - Just right
10. What is your opinion on the monetary incentive ($100/year) for your participation?
    - Too much
    - Too little
    - Just right
11. What is your overall satisfaction with the EVCS pilot?

  - Very satisfied
  - Satisfied
  - Neutral
  - Unsatisfied
  - Very Unsatisfied
12. What do you thing went well with the pilot?
13. What could we do to improve the experience for future pilots?
14. How willing are you to participate in future electric vehicle-related pilots or programs designed to help Xcel Energy better understand the impacts electric vehicles have on customer electric consumption and the electric grid?
    - Very willing
    - Somewhat willing
    - Not willing
15. What would provide the greatest motivation to participate in such a program?
    - Monetary award provided for each year of participation
    - Gift awarded for participation
    - Program and market information shared during program participation
    - Other ___________________________
16. How willing would you be to participate in other pilots or programs to help Xcel Energy better understand customer behavior relative to electric or gas consumption in general?
    - Very willing
    - Somewhat willing
    - Not willing
17. Is there anything else you would like to share with Xcel Energy staff related to your electric vehicle experience or the EVCS pilot?

Appendix B: EVSE Participant Willingness to Participate Survey

1. Do you own or lease your electric vehicle?
    - Own
    - Lease
2. How long are you likely to keep your electric vehicle?
    - 3 Years or more
    - 1 to 3 years
    - Less than 1 year
    - Other
3. How do you typically charge your electric vehicle at home?
    - Manufacturer-provided charging station (with a common 110V outlet)
    - Level 1 charging station
    - Level 2 charging station
    - Other
4. How often do you typically charge your electric vehicle?
    - More than once per day
    - Daily
    - A couple times per week
    - Weekly
    - Less than weekly
5. How many miles do you travel in your electric vehicle per year?
    - <8,000
    - 8,000-10,000
    - 10,001-12,500
    - 12,501-15,000
    - >15,000
6. At what time of day do you typically charge your electric vehicle?
    - Daytime hours
    - Overnight
7. Roughly what percentage of time do you typically charge your electric vehicle at the following locations?
    - Home
    - Work
    - At businesses I frequent
    - Public charging stations
    - Other
8. Do you have access to electric vehicle charging at work?
    - Yes
    - No
    - Sometimes
9. How willing are you to participate in electric vehicle-related pilots or programs designed to help Xcel Energy better understand the impacts electric vehicles have on customer electric consumption and the electric grid?
    - Very willing
    - Somewhat willing
    - Not willing
10. What would provide the greatest motivation to participate in such a program?
    - Monetary award provided for each year of participation
    - Gift awarded for participation
    - Program and market information shared during program participation

    - Other
11. How willing would you be to participate in other pilots or programs to help Xcel Energy better understand customer behavior relative to electric or gas consumption in general?
    - Very willing
    - Somewhat willing
    - Not willing
12. Is there anything else you would like to share with Xcel Energy staff related to your electric vehicle experience?

Appendix C: EV Growth Forecast

Vehicle Count	**2020**	**2025**	**2030**
High	203,692	537,239	937,216
Medium	72,598	177,978	302,429
Low	17,884	24,375	38,056

(Source: Colorado EV Market implementation Report)

Energy (kWh)	**2020**	**2025**	**2030**
High	542,576,685	1,431,049,602	2,496,472,861
Medium	193,380,114	474,082,012	805,583,548
Low	47,637,813	64,927,963	101,370,198

(Vehicle count times average kWh per year per vehicle of 2663.7 kWh)

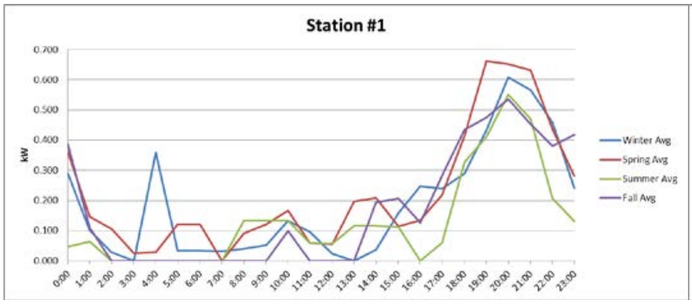
Total Demand (kW)	**2020**	**2025**	**2030**
High	267,346	705,126	1,230,096
Medium	95,285	233,596	396,938
Low	23,473	31,992	49,949

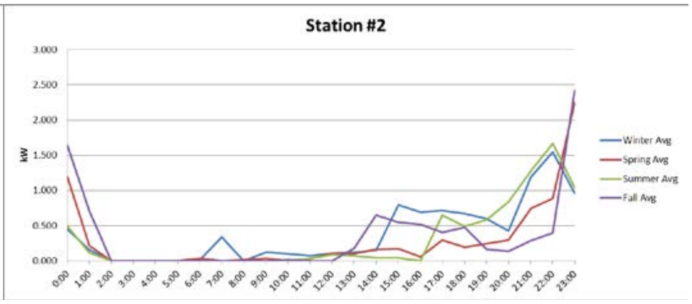
(Vehicle count times monthly kW average per vehicle of 1.31 kW)

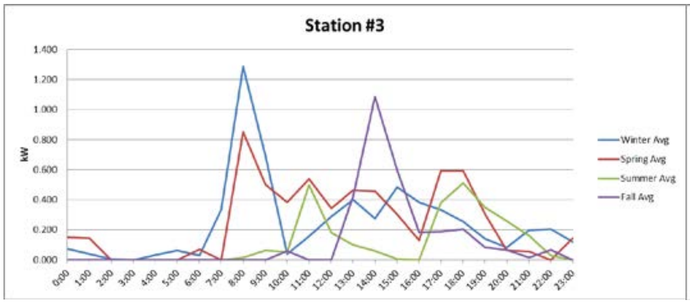
Coincidental Peak Demand (kW)	**2020**	**2025**	**2030**
High	150,112,883	395,923,723	690,690,825
Medium	53,501,831	131,162,690	222,878,115
Low	13,179,795	17,963,403	28,045,755

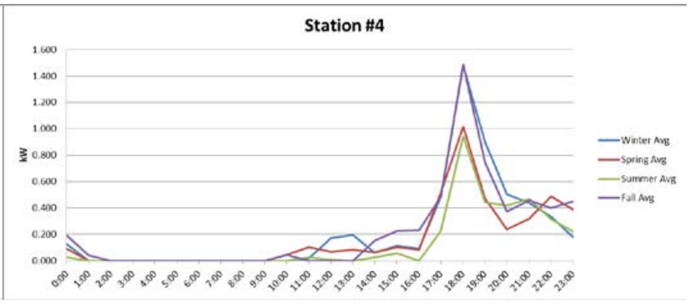
(Vehicle count times monthly kW average per vehicle of .28kW)

Appendix D: Individual Charging Station Average Daily Usage


Station #1


Station #2


Station #3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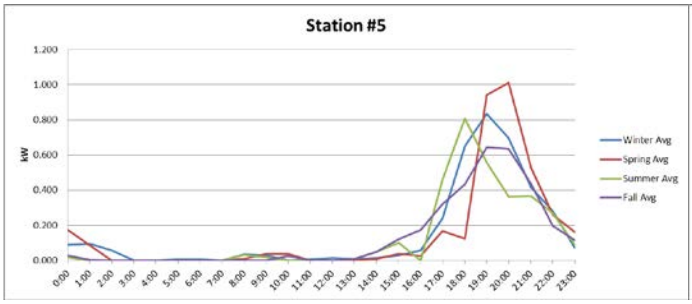
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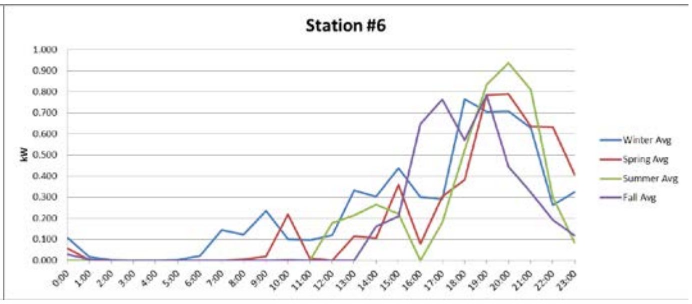
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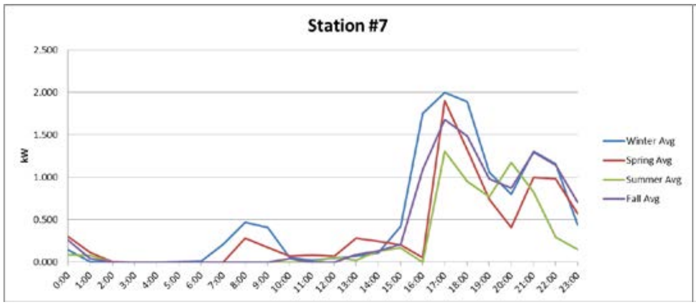
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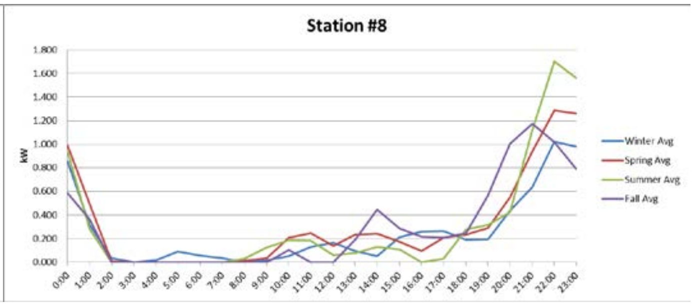
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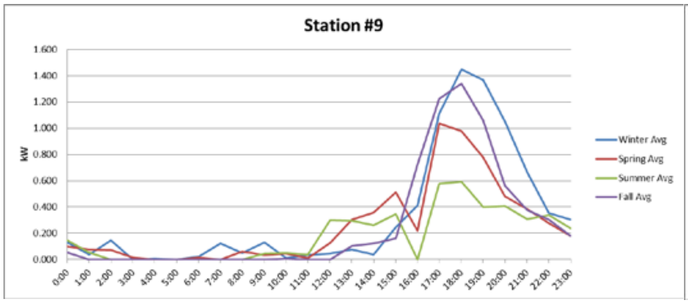
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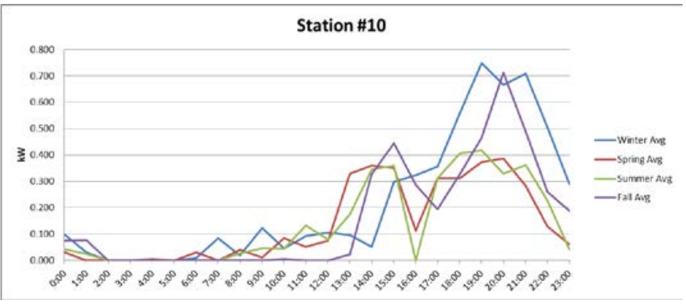
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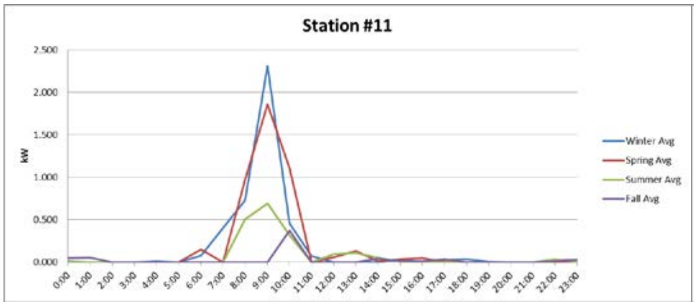
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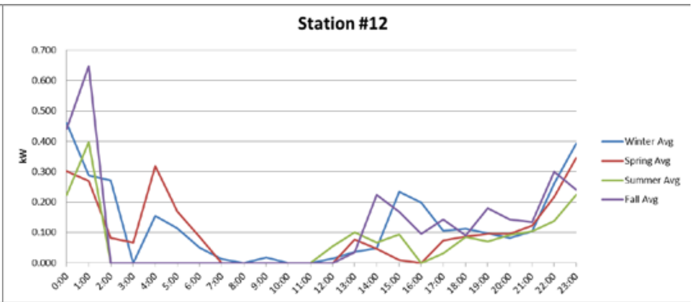
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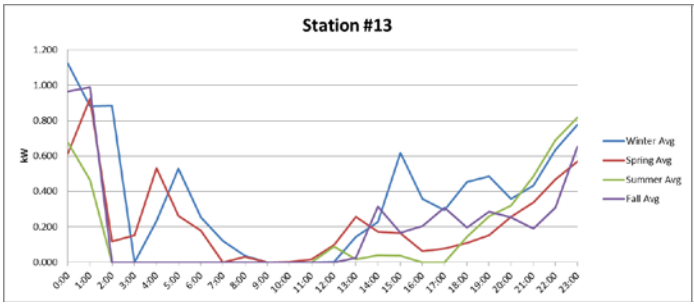
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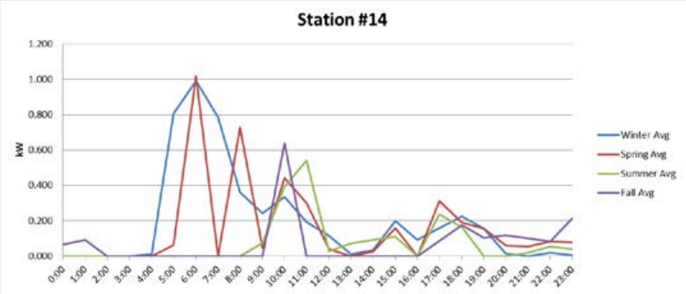
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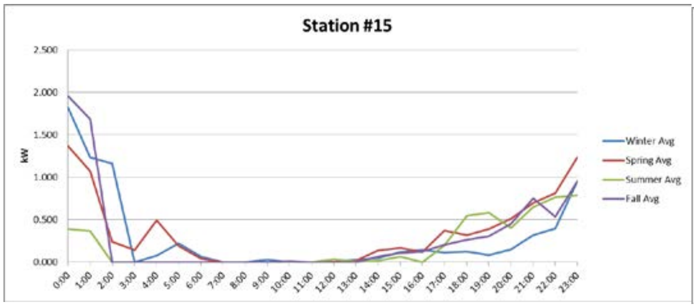
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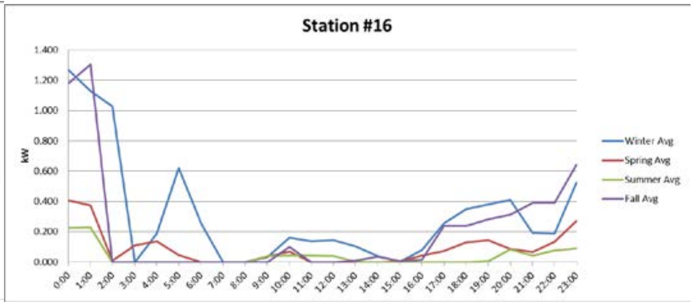
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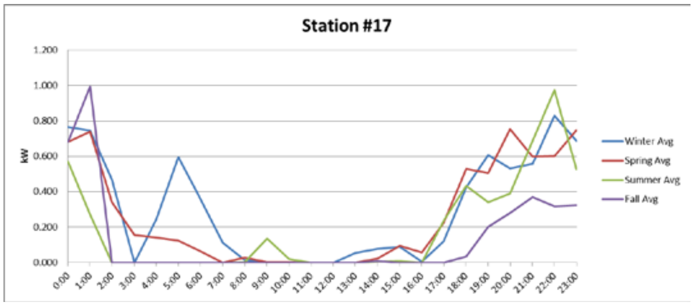
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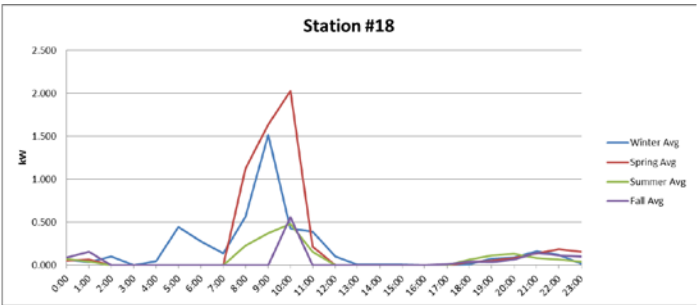
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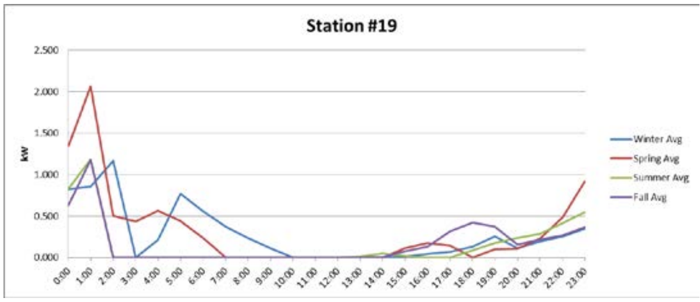
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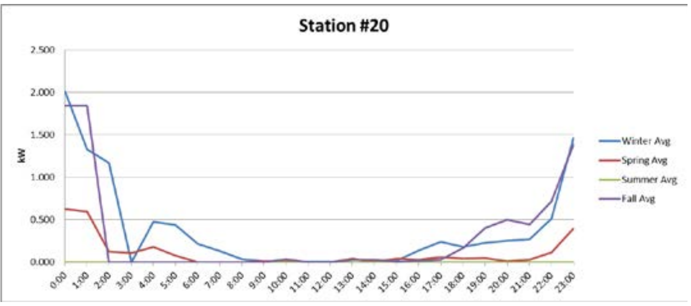
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