SWT-2016-13 NOVEMBER 2016

CONSUMER PREFERENCES FOR THE CHARGING OF PLUG-IN ELECTRIC VEHICLES

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Report No. SWT-2016-13
November 2016

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWT-2016-13		

4. Title and Subtitle	5. Report Date
Consumer Preferences for the Charging of Plug-In Electric Vehicles	November 2016
	6. Performing Organization Code: 383818

7. Author(s)	8. Performing Organization Report No.
Brandon Schoettle and Michael Sivak	SWT-2016-13

9. Performing Organization Name and Address	10. Work Unit no. (TRAIS)
The University of Michigan Sustainable Worldwide Transportation 2901 Baxter Road Ann Arbor, Michigan 48109-2150 U.S.A.	11. Contract or Grant No.

12. Sponsoring Agency Name and Address	13. Type of Report and Period Covered
The University of Michigan Sustainable Worldwide Transportation	14. Sponsoring Agency Code

15. Supplementary Notes

Information about Sustainable Worldwide Transportation is available at http://www.umich.edu/~umtriswt.

16. Abstract

The growth of the market for plug-in electric vehicles (PEVs) is expected to continue to increase in the coming years. This expected increase is due to several factors, including the need to meet more stringent future CAFE fuel economy goals for manufacturers, and the general expectation that PEVs might turn out to be an ideal vehicle embodiment (in terms of fuel source) for future self-driving or fully-autonomous vehicles.

In anticipation of more widespread adoption and use of PEVs by the general public, this study was designed to explore the factors that are important to consumers when considering charging a PEV. A survey was performed to examine consumer preferences and expectations for several charging scenarios, and the relative importance of each applicable technology or function to potential PEV users.

The following issues were explored: plug-and-charge, eVehicle roaming, optimized load management (with and without renewable energy), optimized load management for home area networks, reverse charging, and inductive (wireless) charging. Consumer preference levels and ranking of importance for different charging scenarios were compared. The alignment of consumer expectations and preferences with existing support from the current charging protocol standards were also examined. Finally, the potential effects of prior PEV experience were discussed.

17. Key Words	18. Distribution Statement
consumers, charging, electric vehicle, EV, plug-in electric vehicle, PEV, plug-in hybrid vehicle, PHEV, battery electric vehicle, BEV, ISO 15118, SEP 2.0, Smart Energy Profile	Unlimited

19. Security Classification (of this report)	20. Security Classification (of this page)	21. No. of Pages	22. Price
None	None	40	

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Introduction

In recent years, sales of plug-in electric vehicles (PEVs), or more specifically plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs), have increased. PEVs help automakers meet increasingly more stringent CAFE performance goals in the coming years (EPA/NHTSA, 2012), and help drivers to achieve significant fuel economy improvements and fuel cost savings (Schoettle and Sivak, 2016). Overall, such vehicles help reduce the amount of greenhouse gases and other emissions resulting from the use of light-duty passenger vehicles. In fact, some speculate that sales of PEVs will become even more important as attempts are made to continue reducing transportation-related emissions in both the U.S. and worldwide (Amsterdam Roundtable Foundation/McKinsey & Co., 2014; Detroit Free Press, 2016). In the U.S., 30 models of PEVs being sold currently comprise just over 1% of new vehicle sales in 2016, with PHEV sales up by 68% and BEV sales up by 16% over the previous year (Hybridcars.com, 2016). Beyond the U.S., other regions have seen even more rapid adoption of PEV technology by consumers, with sales of PHEVs and BEVs in China growing by 128% since 2015 (EV Sales, 2016b). In Norway, such vehicles have already established a strong foothold in the market, with three out of the top five vehicle models sold being PEVs and making up roughly 30% of all new vehicle sales (EV Sales, 2016a; 2016b). (Moreover, no vehicles with conventional internal combustion engines are in the top five models sold in Norway [EV Sales, 2016a].)

Furthermore, PEVs are increasingly considered to be an ideal or preferred vehicle type (i.e., fuel source) for future self-driving or fully autonomous vehicles, adding to the potential growth of PEVs in the coming years (Detroit Free Press, 2016; Slate, 2016). With the inclusion of technologies or functionality such as inductive (wireless) charging, combined with automatic vehicle identification and pre-negotiated billing rates ("plug-and-charge"), a completely self-driving vehicle would also be capable of completely self-fueling, with no human intervention required. Additionally, fully electric vehicles are easier, in general, for a computer to control compared with vehicles powered by traditional internal combustion engines (Detroit Free Press, 2016; Slate, 2016).

In anticipation of more widespread adoption and use of PEVs by the general public, it is important to understand the expectations and preferences of vehicle users and consumers at large, including both those with EV experience and those without. This study was designed to explore the factors that are important to consumers when considering charging a PEV. A survey was developed to examine consumer preferences and expectations for several charging scenarios, and the relative importance of each applicable technology or function to potential PEV users.

Method

Survey instrument

An online survey was conducted using SurveyMonkey (www.surveymonkey.com), a web-based survey company. A questionnaire was developed to examine several topics related to consumer preferences regarding charging of electric vehicles (EVs). The text of the questionnaire is included in the appendix. The survey was performed in September 2016.

Respondents

SurveyMonkey's Audience tool was used to target and recruit respondents 18 years and older from SurveyMonkey's respondent database in the U.S. Fully completed surveys were received for 542 respondents. The margin of error at the 95% confidence level for the overall results is +/- 4.2%. Demographic breakdowns for the respondents are presented in Table 1. The age and gender breakdowns are similar to the latest U.S. Census age and gender demographics. Figure 1 shows each U.S. Census region and the corresponding states.

Table 1
Demographic breakdowns for the 542 respondents.

Demographic aspect		Percent
Age group	18 to 29	21.6
	30 to 44	26.0
	45 to 59	27.7
	60 or older	24.7
Gender	Female	51.7
	Male	48.3
Income	$0 to $24,999	17.7
	$25,000 to $49,999	19.9
	$50,000 to $74,999	13.3
	$75,000 to $99,999	9.2
	$100,000 to $124,999	7.2
	$125,000 to $149,999	6.3
	$150,000 to $174,999	3.1
	$175,000 to $199,999	1.7
	$200,000 or more	7.2
	Prefer not to answer	14.4
U.S. Census region	New England	6.5
	Middle Atlantic	13.4
	South Atlantic	17.4
	North Central	20.2
	South Central	17.9
	Mountain	8.0
	Pacific	16.6

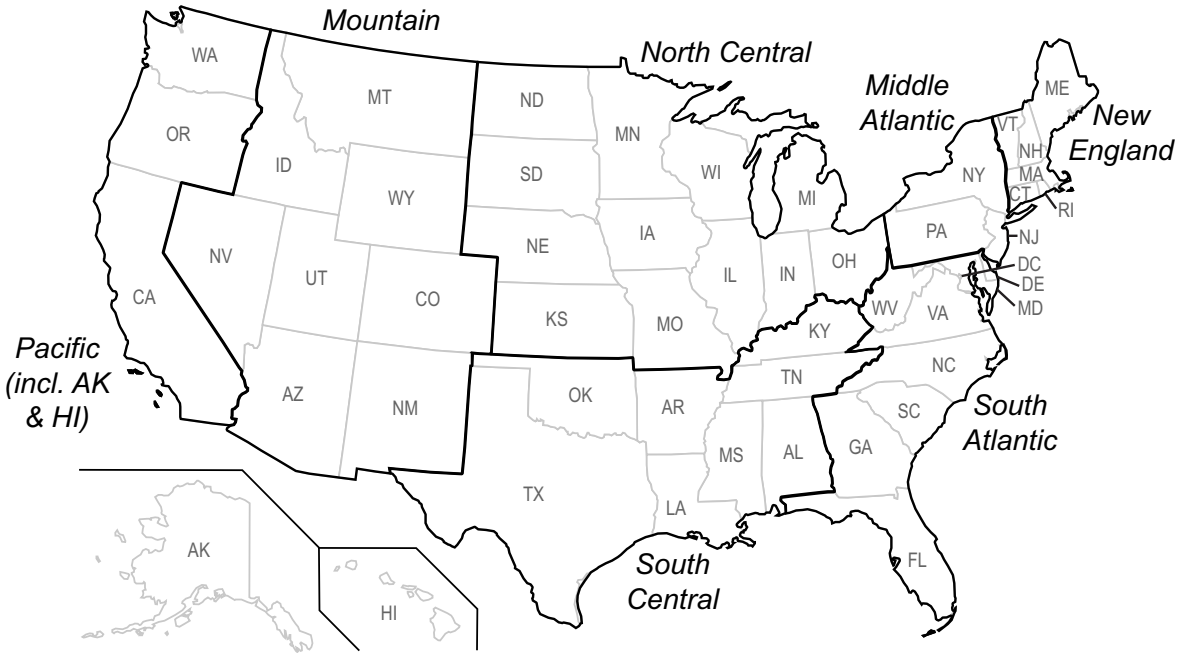

Figure 1. U.S. Census regions.

Prior PEV experience

In addition to the typical demographic groups described in Table 1, we also examined the data for trends related to those who have prior experience with PEVs (either as owners or users) versus those who do not have any prior PEV experience. Table 2 shows a breakdown of respondents by prior PEV experience.

Table 2
Breakdown of respondents by prior PEV experience.

Type	Response	N	Percent
Prior PEV experience (owner, user, or passenger)	Q2 = 1, 2, 3, 4	117	21.6
No prior PEV experience	Q2 = 5	425	78.4

Results

Vehicle ownership and usage

Respondents were asked to identify their current vehicle ownership or user status (Q1). Though a large majority (77.9%) of respondents were vehicle owners, the second most frequent response was from those who said they do not currently ride or drive in a passenger vehicle (7.8%). Figure 2 summarizes the results for all respondents, while Table 3 presents a complete summary of responses by gender, age, and income.

Vehicle ownership rates steadily increased as respondent age increased (from 63.2% for the youngest group to 88.1% for the oldest). Similarly, ownership rates also increased as household income increased (from 71.1% for the lowest income group to 87.9% for the highest). Additionally, the percentages of respondents reporting using a vehicle owned by someone else or riding as a passenger only were notably higher than average for the youngest age group and the lowest income group.

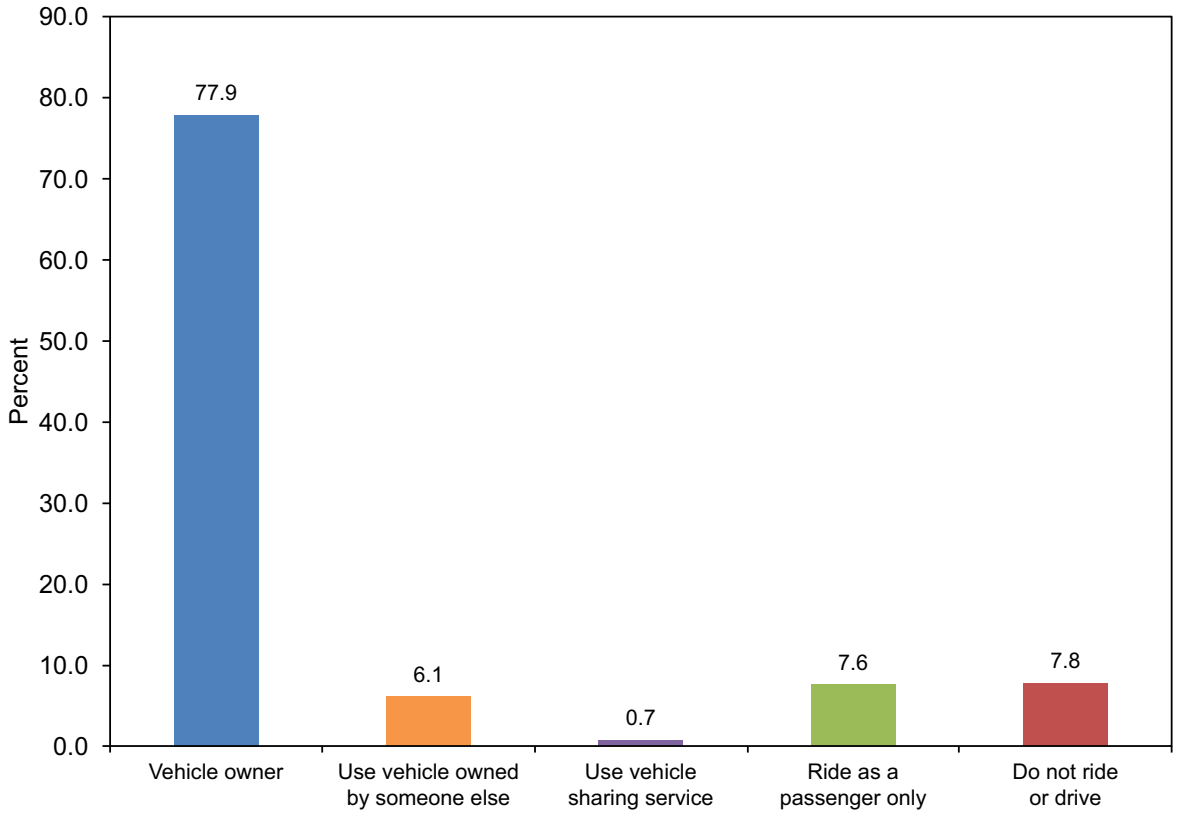

Figure 2. Summary of responses to Q1: "*Do you currently own or regularly use a passenger vehicle?*"

Table 3
Percentage of responses, by gender, age, and income, to Q1: "*Do you currently own or regularly use a passenger vehicle?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Vehicle owner	**76.8**	**79.0**	**63.2**	**72.3**	**85.3**	**88.1**	**71.1**	**81.4**	**87.9**	***77.9***
Use vehicle owned by someone else	5.7	6.5	14.5	7.1	2.7	1.5	7.8	3.1	4.0	*6.1*
Use vehicle sharing service	0.0	1.5	0.9	2.1	0.0	0.0	1.0	1.2	0.0	*0.7*
Ride as a passenger only	8.9	6.1	12.0	12.1	4.0	3.0	13.2	2.5	3.0	*7.6*
Do not ride or drive	8.6	6.9	9.4	6.4	8.0	7.5	6.9	11.8	5.1	*7.7*

Prior PEV ownership or experience

When respondents were asked about their previous experience with PEVs (Q2), most respondents (78.4%) indicated that they had no previous experience with such vehicles, while 3.9% were current or previous owners of a PEV. Figure 3 summarizes the results for all respondents, while Table 4 presents a complete summary of responses by gender, age, and income.

Female respondents were more likely than males to report having no prior experience with PEVs (82.1% versus 74.4%. respectively). Those reporting no prior experience with a PEV consistently decreased as income increased (from 84.3% for the lowest income group to 69.7% for the highest income group).

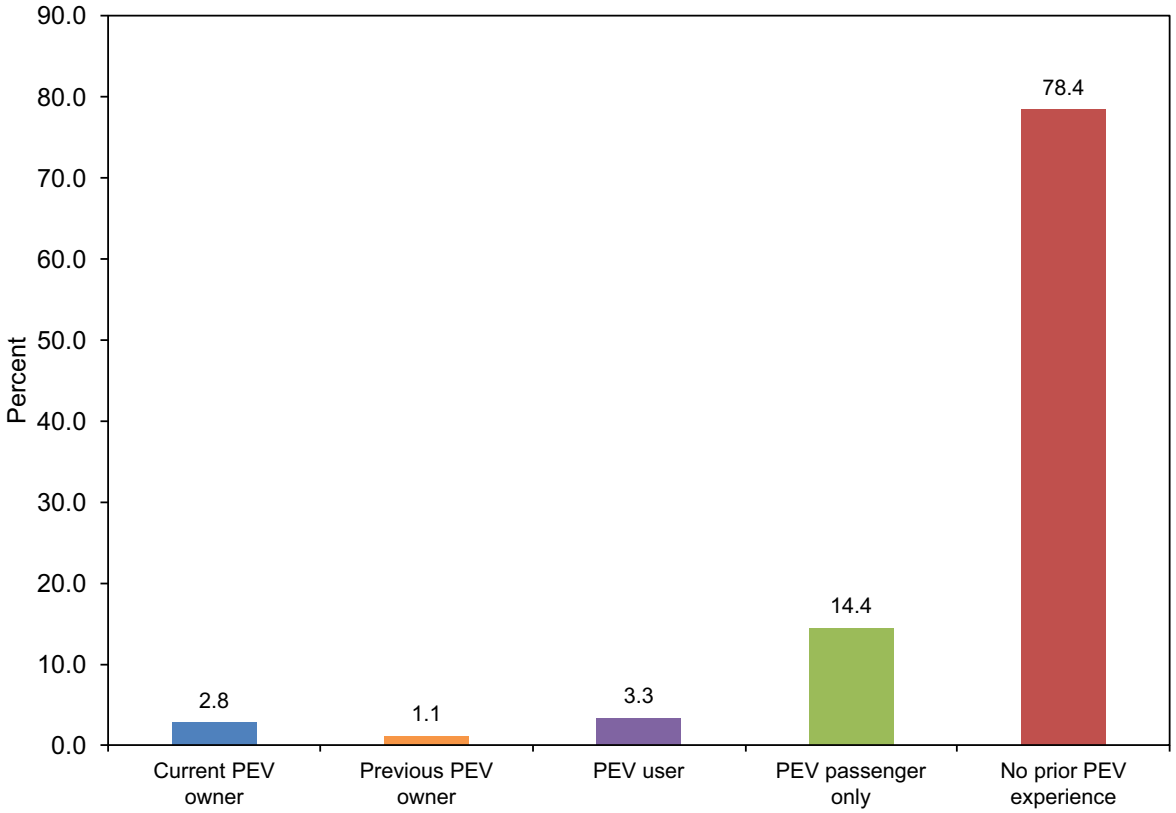

Figure 3. Summary of responses to Q2: "*Please select the ONE option that best describes your previous experience with plug-in electric vehicles (PEVs)?*"

Table 4
Percentage of responses, by gender, age, and income, to Q2: "*Please select the ONE option that best describes your previous experience with plug-in electric vehicles (PEVs)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Current PEV owners	3.6	1.9	2.6	2.1	3.3	3.0	2.9	3.1	2.0	*2.8*
Previous PEV owner	1.1	1.1	2.6	0.0	1.3	0.7	0.5	0.0	2.0	*1.1*
PEV user	1.1	5.7	4.3	5.0	2.0	2.2	2.9	3.7	4.0	*3.3*
PEV passenger only	12.1	16.8	10.3	18.4	16.7	11.2	9.3	13.0	22.2	*14.4*
No prior PEV experience	**82.1**	**74.4**	**80.3**	**74.5**	**76.7**	**82.8**	**84.3**	**80.1**	**69.7**	***78.4***

Payment authorization

When respondents were asked about how they would prefer to authorize payment *when charging a vehicle in a public parking area* (Q3), a slight preference was shown for pay-per-use payment authorization without automatic billing (53.5%) over automatic payment authorization (which includes automatic vehicle identification to allow automatic billing to a pre-existing account). (However, respondent preference was generally evenly split between the two options, and the difference falls within the margin of error for this survey.) Figure 4 summarizes the results for all respondents, while Table 5 presents a complete summary of responses by gender, age, and income. Table 6 presents a summary of responses by prior PEV experience level.

No notable gender difference was found. As age increased so did preference for pay-per-use payment authorization. The main preference of the highest income group was opposite the survey average, instead preferring automatic payment authorization (52.5%). Similarly, a slight majority (50.4%) of those with prior PEV experience preferred automatic payment.

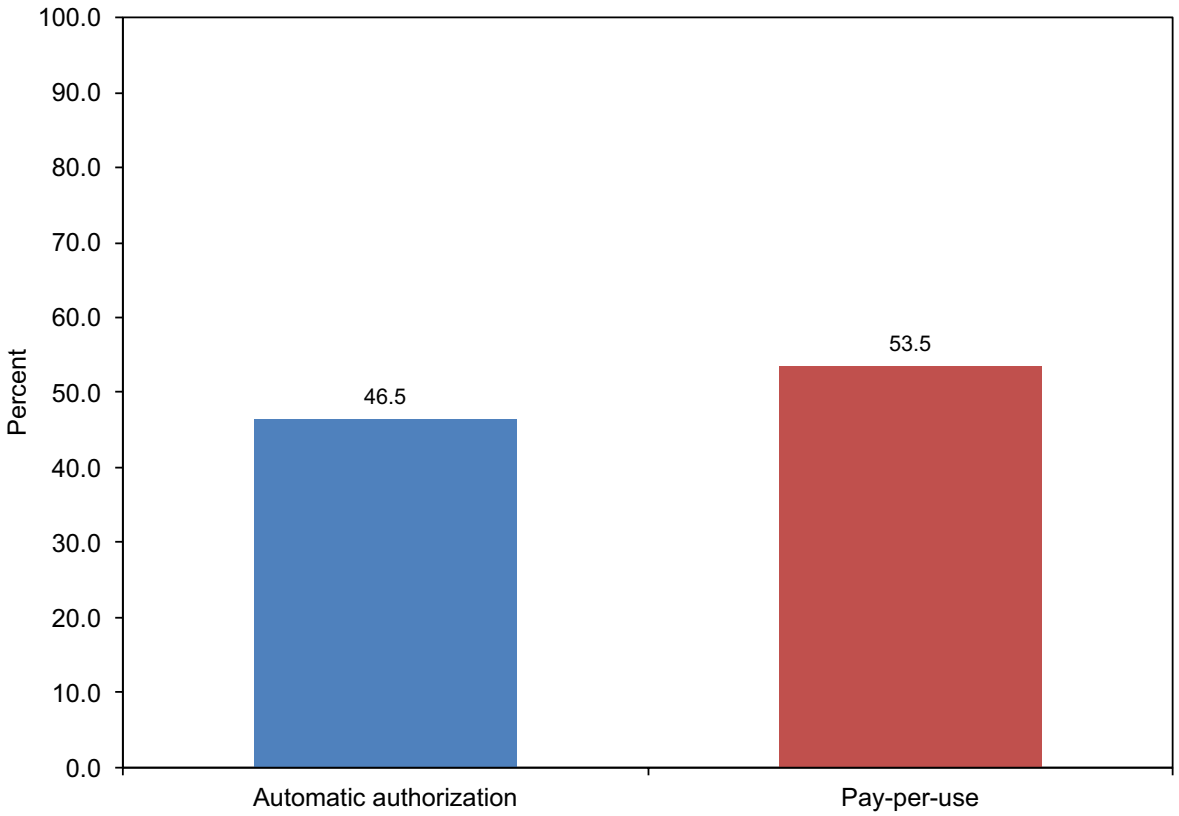

Figure 4. Summary of responses to Q3: "*If you were to park a vehicle* ***in a public parking lot, street space, or parking garage****, which of the following options would you prefer for authorizing payment if you were charging a plug-in electric vehicle (PEV)?*"

Table 5

Percentage of responses, by gender, age, and income, to Q3: "*If you were to park a vehicle **in a public parking lot, street space, or parking garage**, which of the following options would you prefer for authorizing payment if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Automatic	48.2	44.7	**50.4**	49.6	45.3	41.0	42.6	47.2	**52.5**	*46.5*
Pay-per-use	**51.8**	**55.3**	49.6	**50.4**	**54.7**	**59.0**	**57.4**	**52.8**	47.5	***53.5***

Table 6

Percentage of responses, by prior PEV experience, to Q3: "*If you were to park a vehicle **in a public parking lot, street space, or parking garage**, which of the following options would you prefer for authorizing payment if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Automatic	**50.4**	45.4	*46.5*
Pay-per-use	49.6	**54.6**	***53.5***

Setting the price for vehicle charging

When respondents were asked about how they would prefer to set the price *when charging a vehicle in a public parking area* (Q4), a slight preference was shown for pre-negotiated billing rates using a utility bill or contract (53.1%) over variable-rate billing with no contract. (However, overall respondent preference was generally evenly split between the two options, and the difference falls within the margin of error for this survey.) Figure 5 summarizes the results for all respondents, while Table 7 presents a complete summary of responses by gender, age, and income. Table 8 presents a summary of responses by prior PEV experience level.

No notable gender difference was found. Those with prior PEV experience preferred pre-negotiated billing rates (59.8%) *more* than the survey average. The main preference of the youngest respondent group and the lowest income group were opposite the survey average, instead preferring variable-rate billing with no contract (53.0% and 52.9%, respectively).

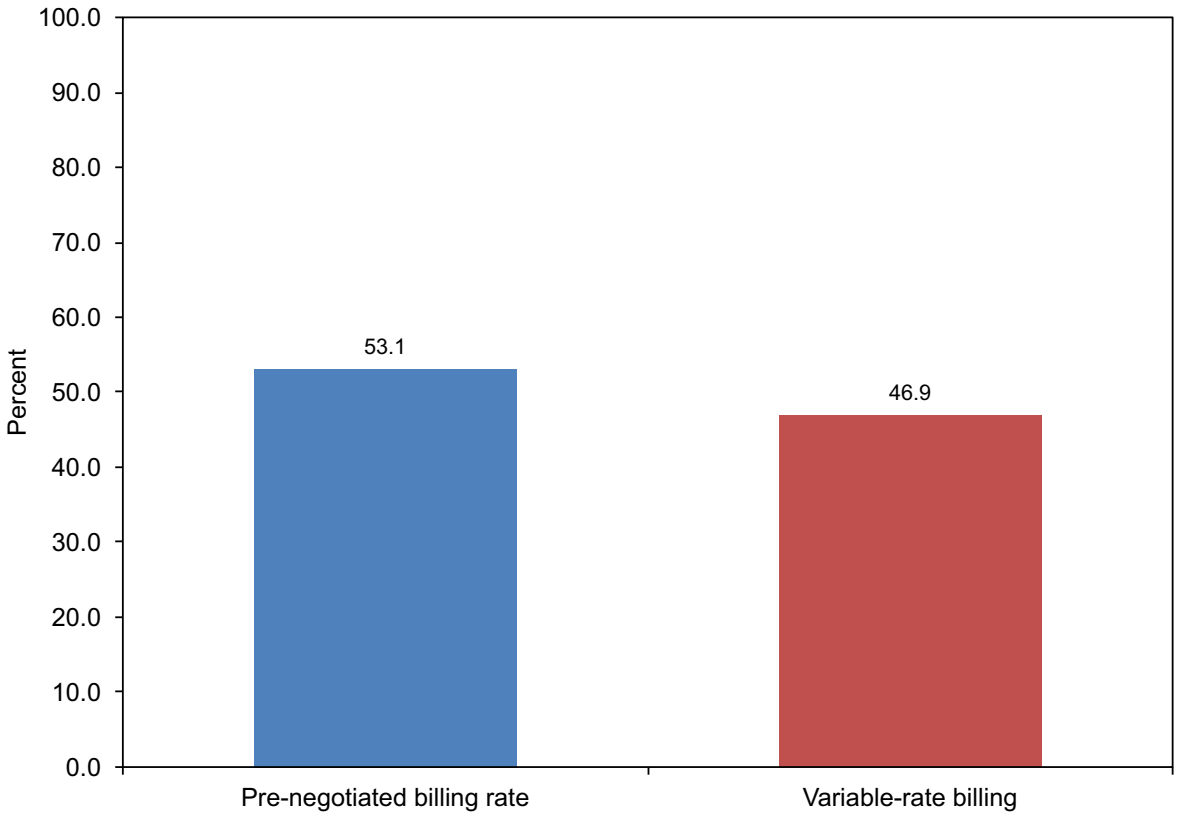

Figure 5. Summary of responses to Q4: "*If you were to park a vehicle* ***in a public parking lot, street space, or parking garage****, which of the following options would you prefer for setting the price if you were charging a plug-in electric vehicle (PEV)?*"

Table 7

Percentage of responses, by gender, age, and income, to Q4: "*If you were to park a vehicle **in a public parking lot, street space, or parking garage**, which of the following options would you prefer for setting the price if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Pre-negotiated billing rate	**54.6**	**51.5**	47.0	**53.9**	**58.0**	**52.2**	47.1	**57.8**	**59.6**	***53.1***
Variable-rate billing	45.4	48.5	**53.0**	46.1	42.0	47.8	**52.9**	42.2	40.4	*46.9*

Table 8

Percentage of responses, by prior PEV experience, to Q4: "*If you were to park a vehicle **in a public parking lot, street space, or parking garage**, which of the following options would you prefer for setting the price if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Pre-negotiated billing rate	**59.8**	**51.3**	***53.1***
Variable-rate billing	40.2	48.7	*46.9*

Managing costs and overall energy demand

When respondents were asked about how they would prefer to manage costs and overall demand *when charging a vehicle in public or at home* (Q5), they strongly preferred optimized charging (73.1%) over on-demand charging. Figure 6 summarizes the results for all respondents, while Table 9 presents a complete summary of responses by gender, age, and income. Table 10 presents a summary of responses by prior PEV experience level.

No notable trends by gender, age, or income were found. While still preferring optimized charging overall, those with prior PEV experience expressed this preference *less* (68.4%) than the survey average.

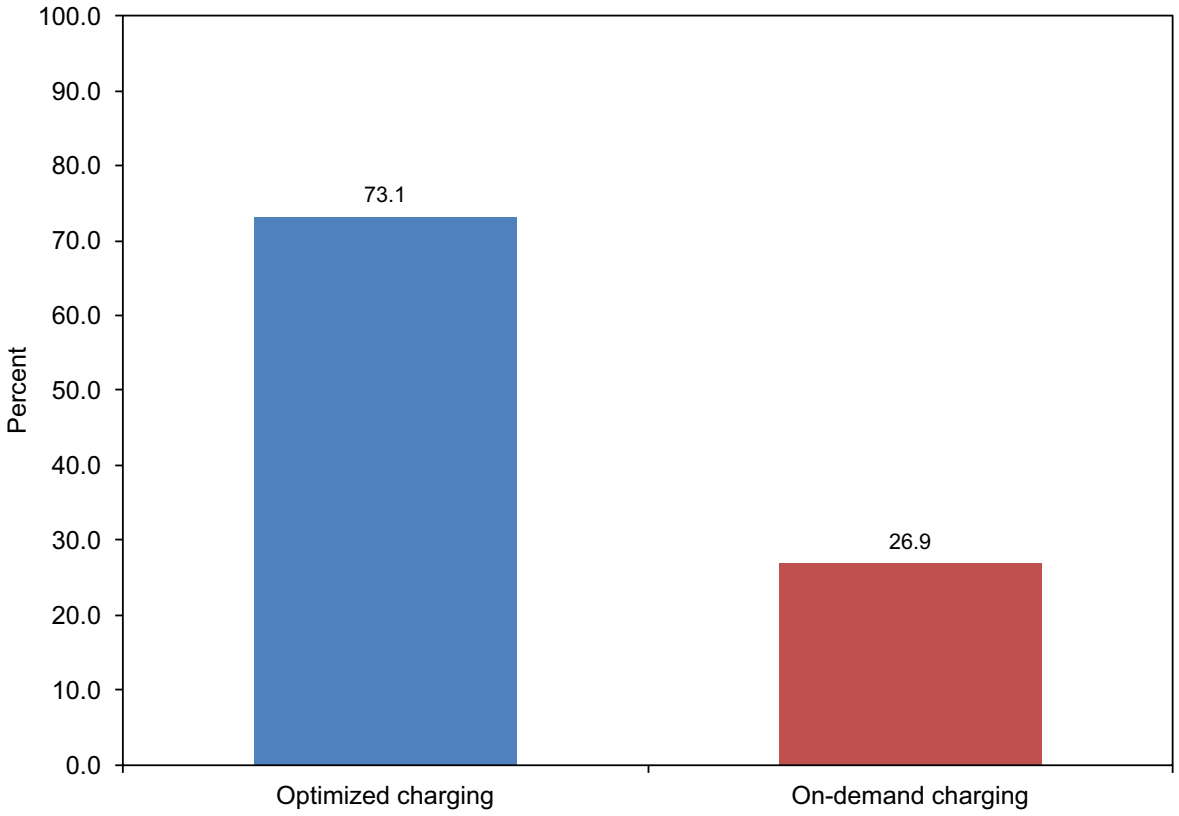

Figure 6. Summary of responses to Q5: "*If you were to park a vehicle* ***in public or at home****, which of the following options would you prefer for managing costs and overall demand if you were charging a plug-in electric vehicle (PEV)?*"

Table 9

Percentage of responses, by gender, age, and income, to Q5: "*If you were to park a vehicle **in public or at home**, which of the following options would you prefer for managing costs and overall demand if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Optimized charging	**75.4**	**70.6**	**73.5**	**70.2**	**70.7**	**78.4**	**71.6**	**79.5**	**61.6**	***73.1***
On-demand charging	24.6	29.4	26.5	29.8	29.3	21.6	28.4	20.5	38.4	*26.9*

Table 10

Percentage of responses, by prior PEV experience, to Q5: "*If you were to park a vehicle **in public or at home**, which of the following options would you prefer for managing costs and overall demand if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Optimized charging	**68.4**	**74.4**	***73.1***
On-demand charging	31.6	25.6	*26.9*

Managing costs and demand while prioritizing renewable resources

When respondents were asked about how they would prefer to manage costs, overall demand, and prioritization of renewable resources *when charging a vehicle in public or at home* (Q6), prioritizing renewable resources was strongly preferred (65.3%) over standard optimized charging. Figure 7 summarizes the results for all respondents, while Table 11 presents a complete summary of responses by gender, age, and income. Table 12 presents a summary of responses by prior PEV experience level.

A large difference was observed between genders, with females preferring the prioritization of renewable resources much more than males (77.1% vs. 52.7%). No notable trends were found by age, income, or prior PEV experience.

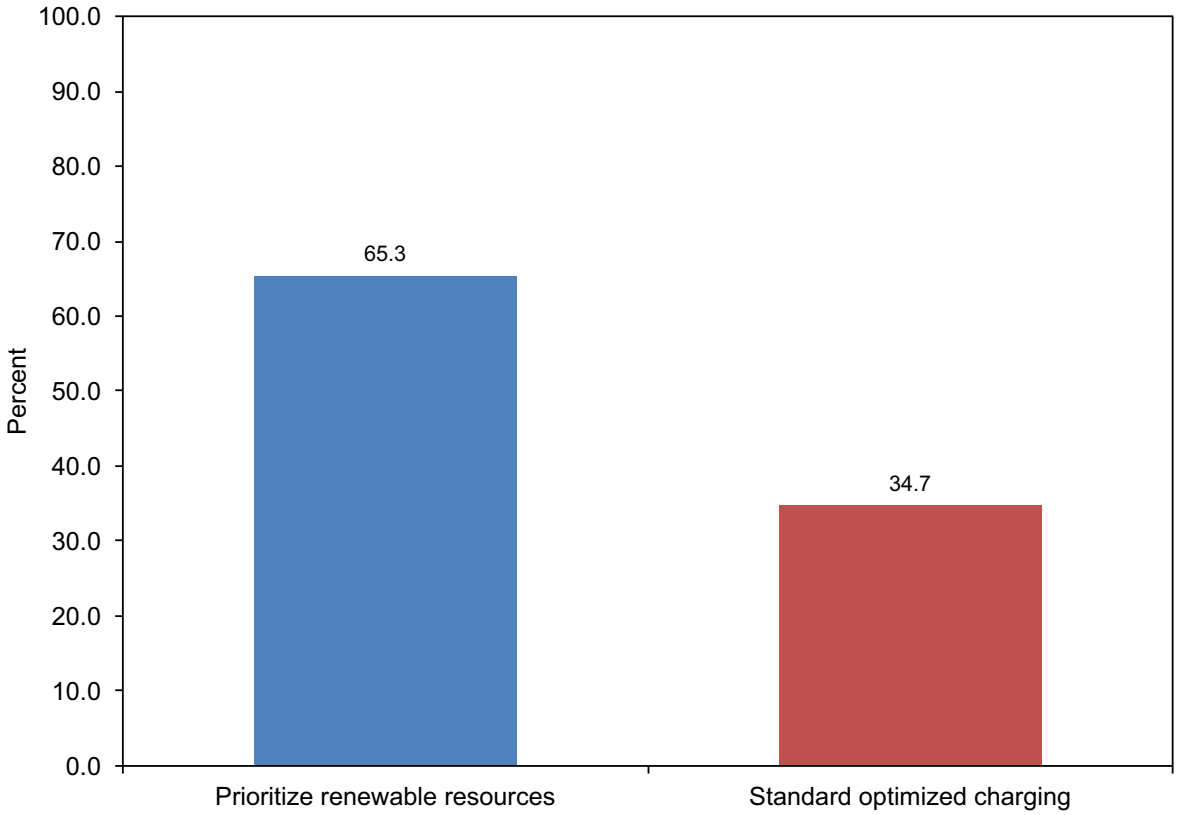

Figure 7. Summary of responses to Q6: "*If you were to park a vehicle in* ***public or at home****, which of the following options would you prefer for* ***managing costs, managing overall demand, and managing the use of renewable energy resources*** *if you were charging a plug-in electric vehicle (PEV)?*"

Table 11

Percentage of responses, by gender, age, and income, to Q6: "*If you were to park a vehicle **in public or at home**, which of the following options would you prefer for managing costs, managing overall demand, **and managing the use of renewable energy resources** if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Prioritize renewable resources	**77.1**	**52.7**	**65.0**	**68.1**	**62.7**	**65.7**	**65.7**	**65.8**	**62.6**	***65.3***
Standard optimized charging	22.9	47.3	35.0	31.9	37.3	34.3	34.3	34.2	37.4	*34.7*

Table 12

Percentage of responses, by prior PEV experience, to Q6: "*If you were to park a vehicle **in public or at home**, which of the following options would you prefer for managing costs, managing overall demand, **and managing the use of renewable energy resources** if you were charging a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Prioritize renewable resources	**67.5**	**64.7**	***65.3***
Standard optimized charging	32.5	35.3	*34.7*

Monitoring and controlling vehicle charging at home

When respondents were asked about how they would prefer to monitor and control the charging of a vehicle *at home* (Q7), respondents were nearly evenly divided, with 50.4% preferring centralized monitoring and control (which would allow the balancing of overall demand on the public electrical grid). (With overall respondent preference evenly split between the two options, the difference falls within the margin of error for this survey.) Figure 8 summarizes the results for all respondents, while Table 13 presents a complete summary of responses by gender, age, and income. Table 14 presents a summary of responses by prior PEV experience level.

The main preference of the following groups was opposite the survey average, instead preferring independent monitoring and control of charging (with the percentage preferring this option in parentheses): males (56.9%); the youngest (53.0%) and oldest (50.7%) respondent groups; the highest income group (54.5%); and those with prior PEV experience (51.3%).

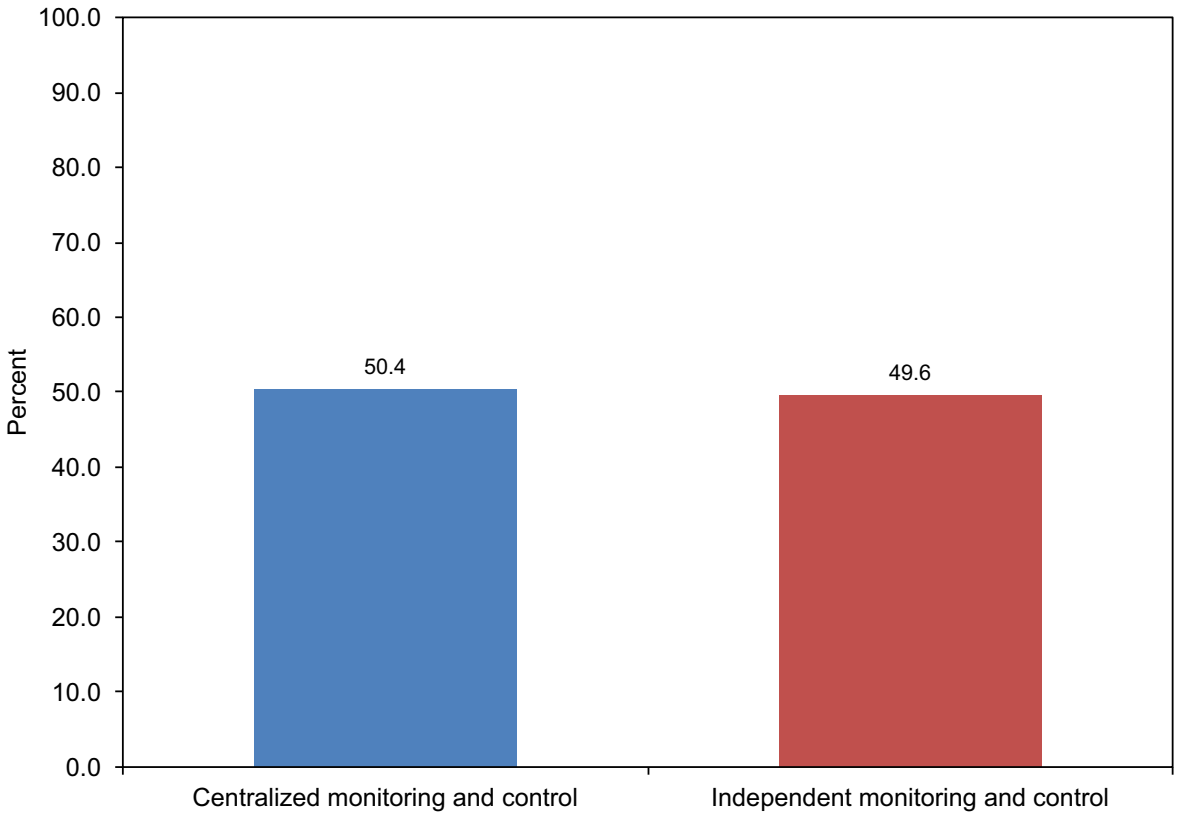

Figure 8. Summary of responses to Q7: "*If you were to park a vehicle **at home**, which of the following options would you prefer for monitoring and controlling the charging of a plug-in electric vehicle (PEV)?*"

Table 13
Percentage of responses, by gender, age, and income, to Q7: "*If you were to park a vehicle **at home**, which of the following options would you prefer for monitoring and controlling the charging of a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Centralized monitoring and control	**57.1**	43.1	47.0	**53.9**	**50.7**	49.3	**50.5**	**57.8**	45.5	***50.4***
Independent monitoring and control	42.9	**56.9**	**53.0**	46.1	49.3	**50.7**	49.5	42.2	**54.5**	*49.6*

Table 14
Percentage of responses, by prior PEV experience, to Q7: "*If you were to park a vehicle **at home**, which of the following options would you prefer for monitoring and controlling the charging of a plug-in electric vehicle (PEV)?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Centralized monitoring and control	48.7	**50.8**	***50.4***
Independent monitoring and control	**51.3**	49.2	*49.6*

PEV as a power source ("reverse charging")

When respondents were asked if they would prefer to have the ability to supply electricity back to the public electrical grid in exchange for compensation (i.e., "reverse charging") (Q8), a large majority (83.9%) preferred to have this option available. Figure 9 summarizes the results for all respondents, while Table 15 presents a complete summary of responses by gender, age, and income. Table 16 presents a summary of responses by prior PEV experience level.

Females preferred the reverse charging option (88.2%) more often than males (79.4%). No notable trends were observed by age. Preference for the reverse charging option declined as income increased, ranging from 86.3% for the lowest income group to 71.7% for the highest income group. While still preferring overall to have the reverse charging option, those with prior PEV experience were somewhat *less* likely to indicate this preference, with 78.6% saying they wanted this option.

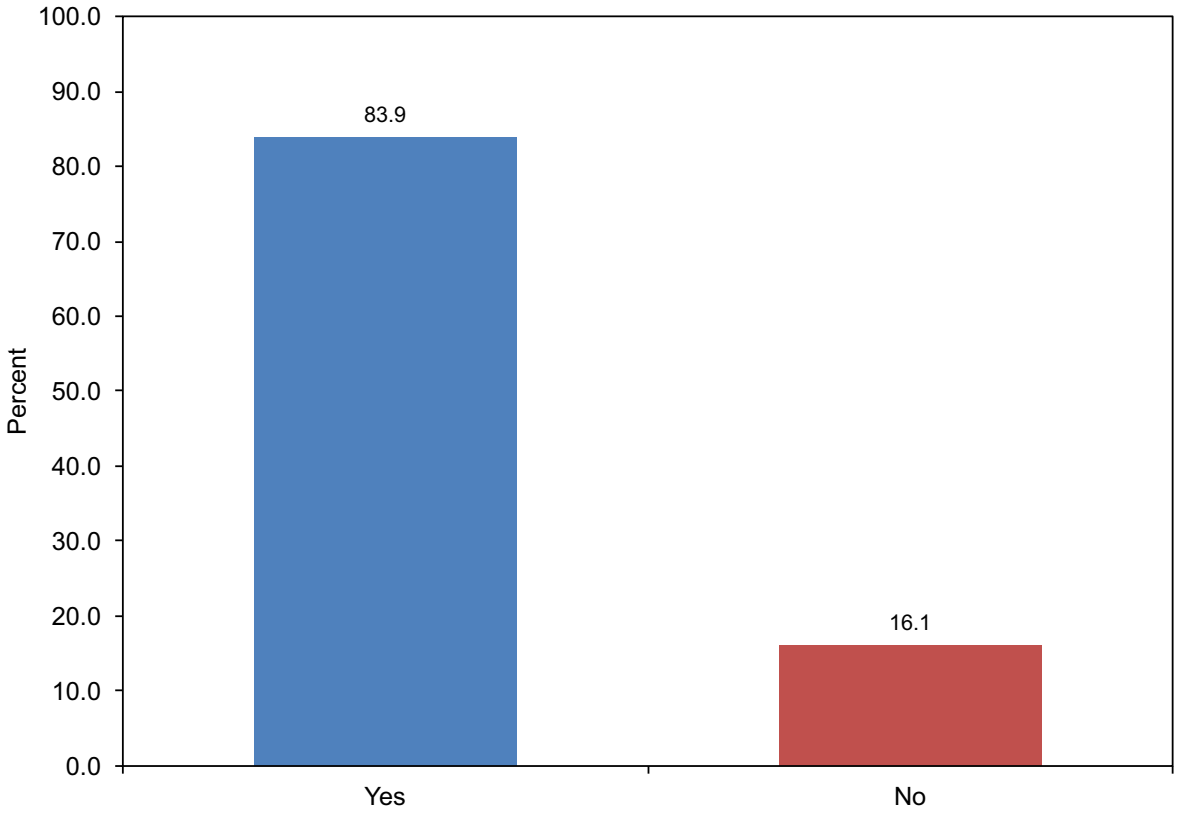

Figure 9. Summary of responses to Q8: "*If it were possible for your PEV to supply electricity back to the public electrical grid, and for you to receive compensation for returning this energy to the grid, would you prefer to have this option available when charging?*"

Table 15

Percentage of responses, by gender, age, and income, to Q8: "*If it were possible for your PEV to supply electricity back to the public electrical grid, and for you to receive compensation for returning this energy to the grid, would you prefer to have this option available when charging?*"
(The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Yes	**88.2**	**79.4**	**82.9**	**85.1**	**82.0**	**85.8**	**86.3**	**85.1**	**71.7**	***83.9***
No	11.8	20.6	17.1	14.9	18.0	14.2	13.7	14.9	28.3	*16.1*

Table 16

Percentage of responses, by prior PEV experience, to Q8: "*If it were possible for your PEV to supply electricity back to the public electrical grid, and for you to receive compensation for returning this energy to the grid, would you prefer to have this option available when charging?*"
(The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Yes	**78.6**	**85.4**	***83.9***
No	21.4	14.6	*16.1*

Inductive (wireless) charging

When respondents were asked if they would prefer to use inductive (wireless) charging or a conventional cable and plug (Q9), 52.7% said that they either strongly or somewhat preferred to use a conventional cable and plug, as opposed to 24.5% who preferred inductive charging, while 22.7% had no preference. Figure 10 summarizes the results for all respondents, while Table 17 presents a complete summary of responses by gender, age, and income. Table 18 presents a summary of responses by prior PEV experience level.

No notable trends were observed by gender. As age increased, so did preference for using a conventional cable and plug. The main preference of the youngest respondents (35.9%) and the lowest income group (26.5%) was for neither option (i.e., neutral). No notable trends were found by prior PEV experience.

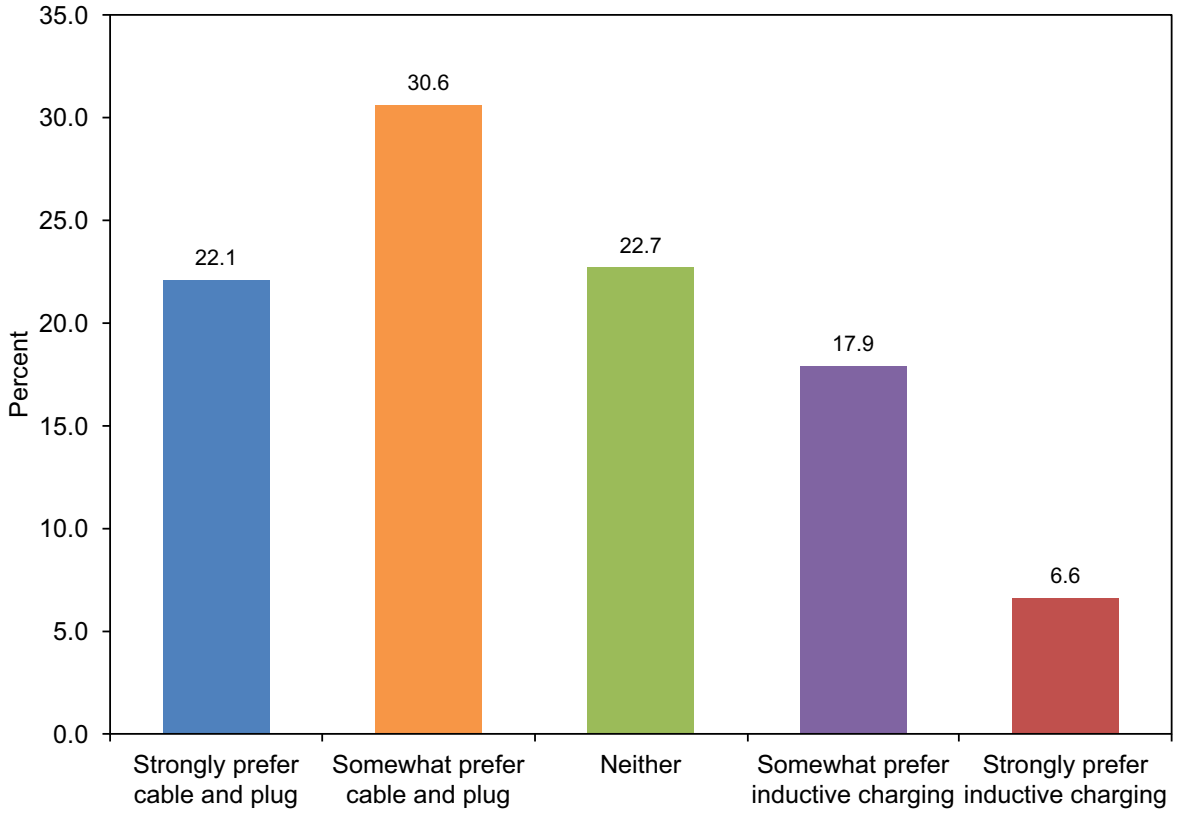

Figure 10. Summary of responses to Q9 [following a description of inductive charging technology]: "*In general, would you prefer to use the inductive charging method, or the conventional charging method that uses a cable and plug to connect to the charger?*"

Table 17

Percentage of responses, by gender, age, and income, to Q9 [following a description of inductive charging technology]: "*In general, would you prefer to use the inductive charging method, or the conventional charging method that uses a cable and plug to connect to the charger?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Strongly prefer cable and plug	21.1	23.3	19.7	19.9	25.3	23.1	23.5	19.9	18.2	*22.1*
Somewhat prefer cable and plug	**32.9**	**28.2**	22.2	**29.8**	**30.7**	**38.8**	26.0	**36.0**	**33.3**	***30.6***
Neither	21.8	23.7	**35.9**	22.7	16.0	18.7	**26.5**	18.0	22.2	*22.7*
Somewhat prefer inductive charging	17.9	17.9	16.2	20.6	19.3	14.9	18.6	18.0	19.2	*17.9*
Strongly prefer inductive charging	6.4	6.9	6.0	7.1	8.7	4.5	5.4	8.1	7.1	*6.6*

Table 18

Percentage of responses, by prior PEV experience, to Q9 [following a description of inductive charging technology] "*In general, would you prefer to use the inductive charging method, or the conventional charging method that uses a cable and plug to connect to the charger?*" (The most frequent response for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Strongly prefer cable and plug	24.8	21.4	*22.1*
Somewhat prefer cable and plug	**28.2**	**31.3**	***30.6***
Neither	16.2	24.5	*22.7*
Somewhat prefer inductive charging	23.9	16.2	*17.9*
Strongly prefer inductive charging	6.8	6.6	*6.6*

Ranking of technologies and functions

Respondents were asked to rank each of the previously presented technologies or functions in order from most important (#1) to least important (#7) to have if they owned a PEV (Q10). Overall, the top three most important technologies or functions by mean rank (in parentheses) are:

1) Optimized charging (3.2)
2) Automatic vehicle identification (3.4)
3) Pre-negotiated billing rate (3.5)

Figure 11 summarizes the results for all respondents, while Table 19 presents a complete summary of responses by gender, age, and income. Table 20 presents a summary of responses by prior PEV experience level.

No notable trends were observed by gender. While the top three preferences for each demographic group were always the same three listed above, the order of preference varied for some groups. The top (#1) preference of the youngest respondents was automatic vehicle identification (2.9); for the lowest income group it was pre-negotiated billing rates (3.4).

While inductive charging was ranked least important overall (5.0), the following groups instead indicated that reverse charging was the least important technology or function (with the mean rank in parentheses): the second oldest respondent group (4.8); the highest income group (5.1); those with prior PEV experience (4.8).

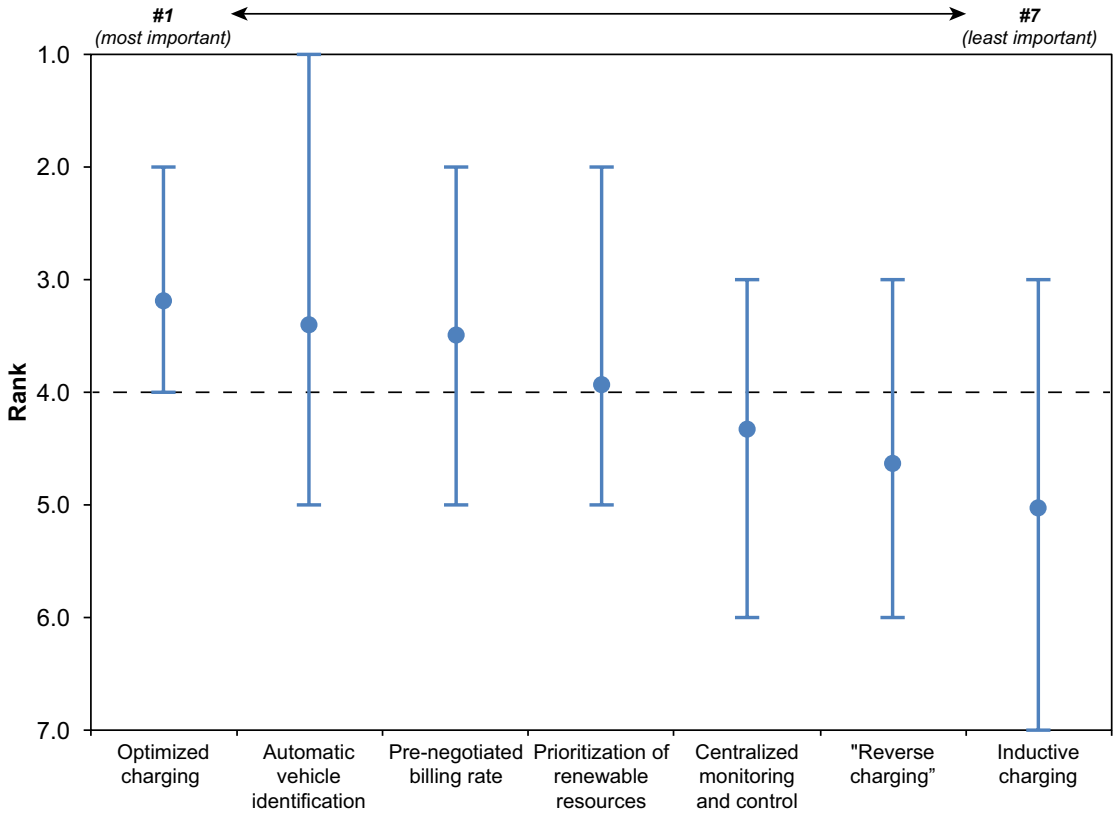

Figure 11. Summary of responses to Q10: "*Please rank the following advanced vehicle charging technologies or functions from most important (1) to least important (7) to you if you were to own or regularly use a PEV.*" The symbols mark the average rank for each technology or function, while the error bars show the span between the 25th- and 75th-percentiles. The dashed line indicates the midpoint (4.0) in the rankings.

Table 19

Percentage of responses, by gender, age, and income, to Q10: "*Please rank the following advanced vehicle charging technologies or functions from most important (1) to least important (7) to you if you were to own or regularly use a PEV.*" (The highest ranked technology or function for each demographic grouping is shown in **bold**.)

Technology or function	Gender		Age				Income			*Total*
	Female	Male	18-29	30-44	45-59	60+	$0-$49k	$50k-$124k	$125k+	
Optimized charging	**3.25**	**3.13**	3.29	**2.94**	**3.37**	**3.17**	3.41	**3.14**	**3.00**	***3.19***
Automatic vehicle identification	3.46	3.35	**2.91**	3.43	3.60	3.60	3.40	3.44	3.25	*3.41*
Pre-negotiated billing rate	3.62	3.36	3.31	3.65	3.65	3.31	**3.39**	3.57	3.50	*3.49*
Prioritizing renewable resources	3.62	4.27	3.97	4.08	3.88	3.81	3.87	3.86	4.20	*3.93*
Centralized monitoring and control	4.36	4.28	4.46	4.50	4.07	4.31	4.42	4.25	4.24	*4.32*
Reverse charging	4.48	4.78	4.73	4.55	4.76	4.48	4.48	4.52	5.13	*4.63*
Inductive charging	5.21	4.83	5.32	4.87	4.67	5.33	5.04	5.22	4.67	*5.03*

Table 20

Percentage of responses, by prior PEV experience, to Q10: "*Please rank the following advanced vehicle charging technologies or functions from most important (1) to least important (7) to you if you were to own or regularly use a PEV.*" (The highest ranked technology or function for each demographic grouping is shown in **bold**.)

Response	Prior PEV experience (owner or user)	No prior PEV experience	*Total*
Optimized charging	**3.35**	**3.15**	***3.19***
Automatic vehicle identification	3.40	3.41	*3.41*
Pre-negotiated billing rate	3.64	3.45	*3.49*
Prioritizing renewable resources	3.81	3.97	*3.93*
Centralized monitoring and control	4.38	4.31	*4.32*
Reverse charging	4.76	4.59	*4.63*
Inductive charging	4.66	5.13	*5.03*

Discussion

Consumer preferences versus relative importance for different charging scenarios

Table 21 compares consumer preference levels (the percentage of those saying they would want the technology or function instead of its alternative) with the relative importance to consumers (based on the rank order by respondents). As is evident in Table 21, a high preference level does not necessarily correspond to a high ranking. For example, plug-and-charge was preferred by less than 50% of respondents in comparison with its alternative, but was ranked as the second most important relative to the other scenarios. Conversely, reverse charging was highly preferred (83.9%), but was ranked as the second least important relative to the other scenarios.

Table 21
Comparison of charging scenarios based on consumer preference level (percentage) and relative importance (rank), sorted by rank.

Charging scenario	Consumer preference level (%)	Relative importance to consumers (rank)
Optimized to balance costs and demand (Q5): "Optimized load management"	73.1	#1
Automatic payment authorization (Q3): "Plug-and-charge"	46.5	#2
Pre-negotiated billing rate (Q4): "eVehicle roaming"	53.1	#3
Prioritizing the use of renewable resources (Q6): "Optimized load management with renewable energy"	65.3	#4
Centralized monitoring and control of home-based charging: (Q7): "Optimized load management for home area networks"	50.4	#5
Ability to use vehicle as a power source (reverse charging) in exchange for compensation (Q8): "Vehicle-to-grid (V2G) energy source"	83.9	#6
Inductive charging (Q9)	24.5	#7

Convenience versus control for consumers

In general, scenarios that enable consumers (or the PEV itself) to exercise greater control and management over vehicle charging were given a higher preference level than those that offer greater convenience. For example, the ability to supply energy back to the grid, and both scenarios that optimize load management while charging, all showed the highest overall preference levels. Conversely, scenarios enabling greater convenience, such as plug-and-charge and inductive charging, showed considerably lower preference levels (less than 50% preference for both scenarios) by respondents in this study.

Alignment of consumer expectations with supported protocols

A comparison of charging scenarios in terms of support by current protocols (i.e., ISO 15118 and SEP 2.0) and consumer expectations (based on ranking of relative importance) is presented in Table 22. A scenario is identified as being "supported" when the end user (including the PEV or the electric vehicle supply equipment [EVSE]) is capable of implementing and controlling the scenario under a specific protocol. Two of the top four most important scenarios to consumers are not currently supported by the SEP 2.0 protocol, and the remaining two scenarios are only partially supported. However, all of the top four scenarios are currently supported by the ISO 15118 protocol. Furthermore, the remaining two applicable charging scenarios in Table 22, although ranked as least important, are (or will be) at least partially supported by both protocols (EMERALD, 2016; ISO, 2013; IEEE, 2013; Voit, 2015).

In addition to the underlying charging communication protocols needing to operate properly when carrying out the required charging functions, the ability of such protocols to satisfy consumer expectations is also paramount. A system that operates correctly, yet fails to satisfy the preferences and expectations of the PEV users, may end up limiting future acceptance of such systems and PEVs in general. This might be especially applicable to consumers who may already be reluctant to adopt a relatively new technology like PEVs. Furthermore, potential future uses of PEVs to enable self-fueling of self-driving vehicles may be problematic or unfeasible without the support for scenarios such as plug-and-charge and eVehicle roaming.

Table 22
Comparison of charging scenarios, support for such scenarios by current protocols, and consumer preferences (relative importance based on rank), sorted by rank.

Charging scenario	Supported by protocol?		Relative importance to consumers (rank)
	ISO 15118	SEP 2.0	
Optimized load management (Q5)	✔	✔	#1
Plug-and-charge (Q3)	✔	✖	#2
eVehicle roaming (Q4)	✔	✖	#3
Optimized load management with renewable energy (Q6)	✔	✔	#4
Optimized load management for home area networks (Q7)	✔	✔	#5
Vehicle-to-grid (V2G) energy source (Q8)	✔*	✔	#6
Inductive charging (Q9)	n/a		#7

✔ = Fully supported ✔ = Partially supported ✖ = Not supported

✔* = Fully supported in a future revision

Effect of prior experience with PEV technology

Table 23 presents a comparison of agreements and differences in preferences between those with and without prior PEV experience. Overall, the preferences expressed by the respondents in this survey were similar for those with and without prior PEV experience. For all but two questions (Q3 and Q7), respondents of both types shared the same overall preferences (though sometimes to varying degrees). For the two questions where the opposite preference to the survey average was conveyed by those with prior PEV experience, respondents were generally evenly divided (i.e., roughly 50/50 split), and the differences were small and within the margin of error for this survey. These results indicate that general preferences for PEV charging system design and functionality are commonly shared by all vehicle users, and prior experience with PEVs has little effect on such preferences. This is especially important in light of the public's potential reluctance to adopt new technology as discussed above. However, the general agreement between both groups of prospective future PEV users in this survey indicates that designing to meet user preferences and expectations is generally not dependent upon an individual's prior level of experience with PEVs.

Table 23
A comparison of agreements and differences in preferences between those with and without prior PEV experience.

Charging scenario	Overall preference for available options with each charging scenario	
	Agreement between those with and without prior PEV experience	Difference for those with prior PEV experience
Automatic payment authorization (Q3): "Plug-and-charge"		✔
Pre-negotiated billing rate (Q4): "eVehicle roaming"	✔	
Optimized to balance costs and demand (Q5): "Optimized load management"	✔	
Prioritizing the use of renewable resources (Q6): "Optimized load management with renewable energy"	✔	
Centralized monitoring and control of home-based charging: (Q7): "Optimized load management for home area networks"		✔ (negligible difference)
Ability to use vehicle as a power source (reverse charging) in exchange for compensation (Q8): "Vehicle-to-grid (V2G) energy source"	✔	
Inductive charging (Q9)	✔	

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Appendix: Questionnaire

Electric vehicle charging use-case survey

We are conducting a survey of opinions about electric vehicle charging. Even if you have never owned or ridden in an electric vehicle, we are still interested in your opinions as a potential future user.

No previous experience with driving (or charging) electric vehicles is required.

The survey will simply ask about what you would generally expect or how you would like things to work when you think about trying to charge an electric vehicle.

In this survey, when we use the term *vehicle*, we mean any type of passenger vehicle, including cars, sport utility vehicles (SUVs), vans, minivans, and pickup trucks. However, we do not mean buses, trains, or any other form of mass public transportation.

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1) Do you currently own or regularly use a passenger vehicle?

   Please select the ONE option that best describes you:

   ☐ I use a vehicle that I own or lease (including personal company-owned vehicles)

   ☐ I use a vehicle owned or leased by someone else

   ☐ I use a vehicle sharing service (also called car sharing) such as Zipcar

   ☐ I only ride as a passenger in a vehicle and never drive

   ☐ I do not currently use a vehicle or ride as a passenger

---

2) **Plug-in electric vehicles (PEVs)** must be plugged in to an electrical outlet or an electric charging station to recharge the batteries that power the vehicle.

   PEVs can include both plug-in hybrid electric vehicles (PHEV) and all-electric vehicles (EV) (sometimes also called battery-electric vehicles [BEV]).

   Please select the ONE option that best describes your previous experience with plug-in electric vehicles (PEVs):

   ☐ I currently own/lease a PEV

   ☐ I have owned/leased a PEV in the past (but not currently)

   ☐ I have only used a PEV

   ☐ I have only been a passenger in a PEV

   ☐ I have never used or been a passenger in a PEV

(next page)

Basics of charging a PEV:

The process of plugging in a PEV to charge is very similar to plugging in any other electrical plug; it is also very similar to plugging the gasoline pump nozzle into a conventional vehicle.

The newest and most advanced systems (called inductive charging) do not even require a user to plug the vehicle in—the only requirement is that the vehicle be parked in a specially equipped parking space for this type of charging.

With intelligent charging, the user is able to tell the system when he or she plans to return and drive the vehicle again. This way, a charging schedule can be planned to ensure the vehicle is fully charged when needed while still allowing the charging system some flexibility in scheduling (to get a cheaper electricity rate, to charge other vehicles, etc.).

Non-intelligent, conventional charging simply attempts to start charging the vehicle as soon as the vehicle is plugged in.

For the remainder of the survey, please answer each question as though you were the owner or regular user of a plug-in electric vehicle (PEV).

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3) If you were to park a vehicle ***in a public parking lot, street space, or parking garage***, which of the following options would you prefer for <u>authorizing payment</u> if you were charging a plug-in electric vehicle (PEV)?

- ☐ <u>Automatic payment authorization</u>: With this method, your vehicle would automatically identify itself to the charging station. This identification would allow automatic billing to a pre-existing account.
- ☐ <u>Pay-per-use payment authorization</u>: With this method, you would provide the required identification and billing information (such as a credit card or electronic ID tag) or provide cash payment each time you attempt to charge at a charging station. This would function similarly to the way many gasoline pumps or fully-electronic public parking payment systems currently operate.

(next page)

4) If you were to park a vehicle ***in a public parking lot, street space, or parking garage***, which of the following options would you prefer for <u>setting the price</u> if you were charging a plug-in electric vehicle (PEV)?

- ☐ <u>Pre-negotiated billing rate using utility bill or contract</u>: With this method, your vehicle's unique identification would allow automatic billing to a pre-existing account, such as your monthly utility bill or a separate charging contract, with pre-negotiated pricing that would remain in effect at any charging station you choose to use whether in public or at home.
- ☐ <u>Variable-rate billing with no contract</u>: With this method, you would not have the billing rate linked to any contract or agreement for a pre-negotiated price, and would pay the rates billed at each specific charging station (either through credit card or electronic ID tag). These rates may be higher or lower than the pre-negotiated rates, and could vary based on location, time of day, etc. (Pre-negotiated pricing would still likely be available when charging at home.)

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5) If you were to park a vehicle ***in public or at home***, which of the following options would you prefer for <u>managing costs and overall demand</u> if you were charging a plug-in electric vehicle (PEV)?

- ☐ <u>Optimized charging</u>: With this method, vehicle charging would be optimized to consider factors that might affect charging costs, such as your vehicle's specific charging requirements and the demand for electricity from the public electrical grid. This would allow the charging system to negotiate with the electric utility provider to determine the best cost and time to charge based on the amount of charging required, while still guaranteeing the pre-set time of departure and balancing the overall demand for power from the public electrical grid.
- ☐ <u>On-demand charging</u>: With this method, the charging system would attempt to charge your vehicle as quickly as needed, without regard for reducing cost to you or balancing demand on the public electrical grid.

(next page)

6) If you were to park a vehicle ***in public or at home***, which of the following options would you prefer for managing costs, managing overall demand, **and managing the use of renewable energy resources** if you were charging a plug-in electric vehicle (PEV)?

- ☐ Prioritizing renewable resources: With this method, vehicle charging would be optimized to consider factors that might affect charging costs and the demand for electricity from the public electrical grid, while also maximizing the use of available renewable resources (wind, solar, etc.). The charging system would determine the lowest cost, balance overall demand for power from the public electrical grid, and allow for low (or even zero) well-to-wheels emissions whenever possible.
- ☐ Standard optimized charging: With this method, vehicle charging would be optimized to consider factors that might affect charging costs, such as your vehicle's specific charging requirements, and the overall demand for electricity from the public electrical grid, but the charging system would not attempt to maximize the use of renewable resources.

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7) If you were to park a vehicle ***at home***, which of the following options would you prefer for monitoring and controlling the charging of a plug-in electric vehicle (PEV)?

- ☐ Centralized monitoring and control: With this method, vehicle charging would be monitored and controlled by a centralized system that allows your home-based charging equipment and the electric utility provider to communicate and coordinate your charging schedule. This would enable the central system to determine the lowest cost and best schedule for you while also balancing the overall demand for power from the public electrical grid.
- ☐ Independent monitoring and control: With this method, vehicle charging would be monitored and controlled ***only*** by your home-based charging equipment. This would enable your charging system to determine the lowest cost and best schedule for you, but would ***not*** allow balancing the overall demand for power from the public electrical grid.

(next page)

8) If it were possible for your PEV to supply electricity *back* to the public electrical grid, and for you to receive compensation for returning this energy to the grid, would you prefer to have this option available when charging?

This would work just like charging a vehicle—but in reverse. The electric utility provider would pay you for energy you supplied from your vehicle's battery pack. (The charger would make sure that your vehicle is fully charged before you return to drive it based on a schedule you set at the charger or vehicle.)

- ☐ Yes
- ☐ No

---

9) Some PEVs may be able to charge simply by parking in a specially equipped parking space and would not use a cable and plug to connect to the charging system—known as inductive charging. However, this type of charging may be slower and/or less efficient than conventional charging that uses a cable and plug.

In general, would you prefer to use the inductive charging method, or the conventional charging method that uses a cable and plug to connect to the charger?

- ☐ Strongly prefer conventional cable and plug
- ☐ Somewhat prefer conventional cable and plug
- ☐ Neither
- ☐ Somewhat prefer inductive charging
- ☐ Strongly prefer inductive charging

(next page)

10) Please rank the following advanced vehicle charging technologies or functions from most important (1) to least important (7) to you if you were to own or regularly use a PEV:

Hold your mouse over each technology or function to see a more detailed description.

RANK	TECHNOLOGY / FUNCTION
	Automatic vehicle identification and payment authorization
	Pre-negotiated billing rate at any charging station you choose to use
	Optimized charging to balance your costs and overall electricity demand
	Prioritizing use of renewable resources to help reduce overall well-to-wheel emissions while balancing your costs and overall electricity demand
	Centralized monitoring and control of home-based charging systems to schedule charging for balancing your costs and overall electricity demand
	Ability to use your vehicle's battery pack as a power source to return electricity back to the grid for compensation ("reverse charging")
	Inductive charging, which only requires you to park in a specially equipped parking space and does not use a cable and plug to connect to the charging system

Thank you for taking the time to complete this survey!