Missouri Smart & Clean EV Charging

Ameren Missouri's Evaluation of Automated Emissions Reduction for Residential EV Charging

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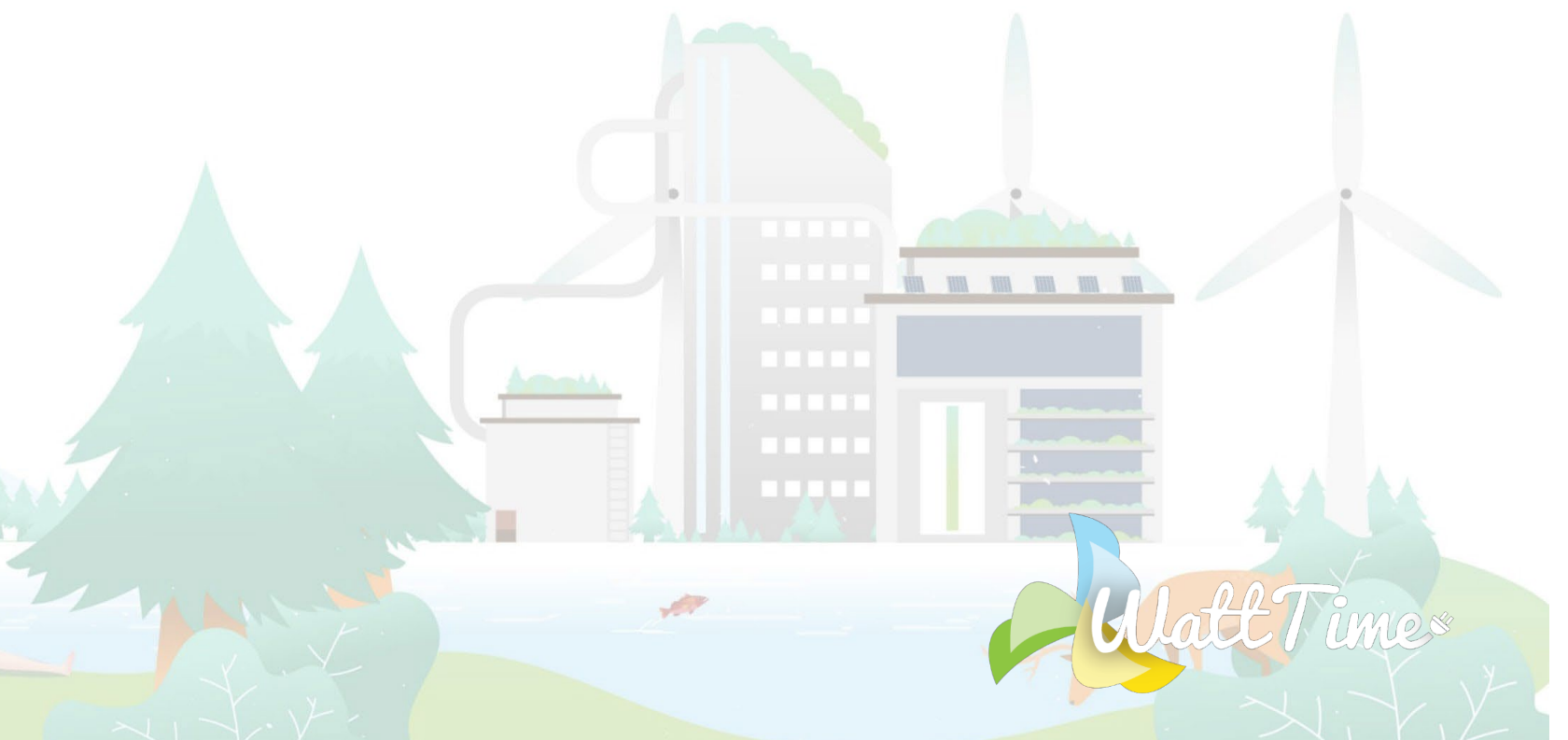

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EXECUTIVE SUMMARY

From 2020 to 2022 Ameren Missouri's Charge Ahead program has incentivized the deployment of better electric vehicle (EV) charging infrastructure for their customers to encourage EV adoption and contribute to decarbonizing the transportation sector. WattTime has assisted Ameren Missouri in evaluating the marginal greenhouse (GHG) impacts of portions of the program and has identified strategies to achieve better carbon reduction performance by enabling EV infrastructure with Automated Emissions Reduction (AER).

WattTime and Ameren Missouri have evaluated the incremental benefits that AER can provide for EV charging in the state of Missouri in a two-phase pilot program, which started in January 2020. The AER software selected for this pilot was JuiceNet Green from Enel X Way (formerly Enel X). WattTime has completed the evaluation, which tested JuiceNet Green on 53 residential EV charging stations and 4,300 charging sessions.

The key take-aways from the pilot evaluation include:

1. AER-enabled EV charging is available, functional, and practical for drivers in Missouri.
2. JuiceNet Green AER technology reduced carbon emissions by 2.6% overall during the evaluation period, a total of 1,953 pounds of CO_2.
3. Carbon reduction varied widely among users, with the best user reducing their induced carbon emissions by 15.5%.
4. Some users had trouble with the EV JuiceNet app and many did not use it at all, which negatively affected JuiceNet Green's performance. These are not issues with the AER algorithm, they are specific to Smart Charging with the EV JuiceNet app.
5. The carbon reduction opportunity is currently higher in Western MO (Southwest Power Pool) than it is in Ameren Missouri territory (MISO).

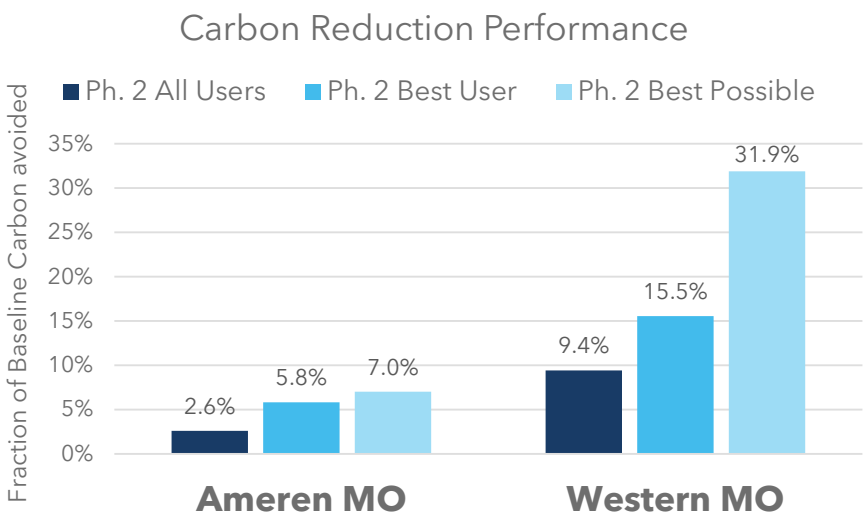

Figure 1: Due to the spread in user performance, the best performing user far outperformed the average in both regions. Western MO had larger carbon reductions due to higher variability in grid emissions.

The carbon reduction effectiveness of charging EVs with AER in Ameren Missouri territory will improve as (a) more renewables are built in and around the local grid, (b) the AER software improves, and (c) the user experience becomes more consistent and less manual. Modest

improvements in these categories are expected to bring performance in Ameren Missouri territory up to that of 2022 Western Missouri by 2025 (9.5%). If program participation is expanded to 10,000 drivers, the carbon avoidance impact is estimated at 1,810 metric tons per year.

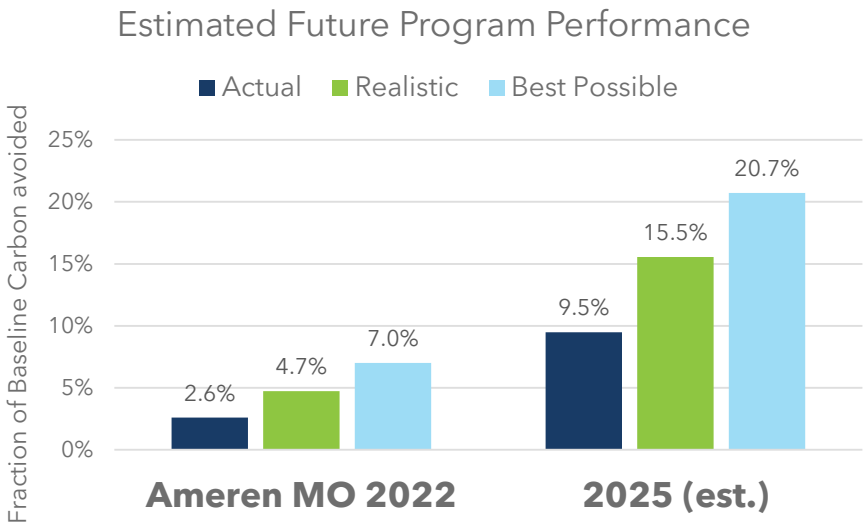

Figure 2: WattTime outlined an Ameren MO program growth scenario for the next 3 years, that included estimates of carbon reduction improvements as the grid evolves and the software improves.

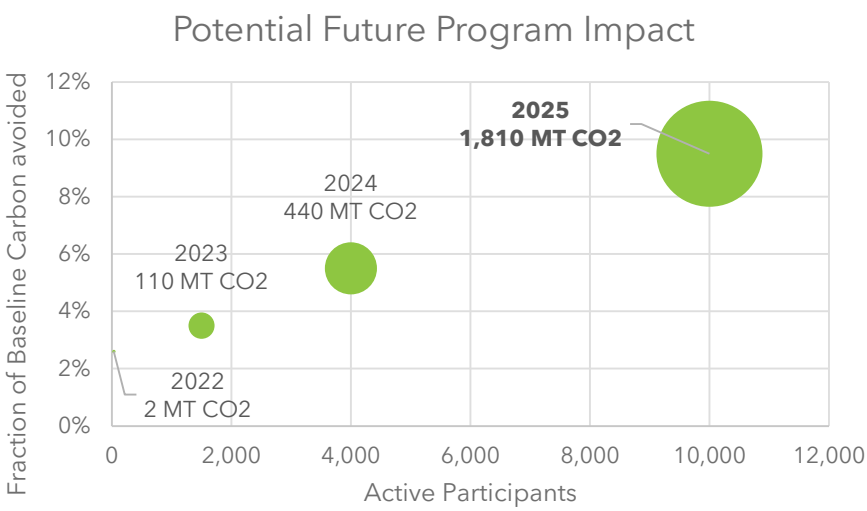

Figure 3: If expanded to 10,000 users by 2025, the program could avoid 1,810 metric tons of CO_2 per year.

If the above estimates of program impact are beneficial enough to Ameren Missouri and Missouri regulators, Ameren Missouri could expand the AER for EV charging incentive program beyond this initial evaluation, to all Ameren Missouri residential customers. Since EV adoption may be a limiting factor, to improve participation, the program could allow participation via any smart charging hardware or software capable of performing AER (currently, there are 5 companies offering AER for EV charging in the US market).

Missouri regulators and other utilities should take particular note that there is ripe opportunity for significant carbon reductions in Western Missouri (particularly in the Southwest Power Pool) from similar programs.

PROJECT BACKGROUND

1. Ameren Missouri's Charge Ahead Program

Ameren Missouri's "Charge Ahead" program – announced in 2019 – aims to accelerate the installation of EV charging stations by providing financial incentives to business customers and thereby provide more opportunity for charging electric vehicles (EVs). The Charge Ahead incentive program period is approved for three years (2020-2022), and if successful can be renewed for another two years.

One of the key benefits of EVs is the reduction of air pollution such as GHG, NOx, and particulates. During regulatory negotiations, Ameren Missouri agreed to implement a pilot to evaluate WattTime-enabled AER technology as a software solution to reduce GHG emissions as measured using WattTime's marginal emissions dataset. This allowed Ameren Missouri to explore the use of technology *to automatically charge EVs at times when the electric grid has the lowest associated emissions.*

2. Automated Emissions Reduction for Electric Vehicles

Along with the innovation of internet-connected (or "smart") devices came the ability for users to control these devices in convenient and beneficial ways. "Smart charging" for battery-powered devices means that the devices are charged at certain times that are more beneficial than others, e.g., more convenient, less expensive, or lower carbon times.

WattTime is a non-profit organization which provides data about the marginal carbon-intensity of local electric grids through an Application Programming Interface (API). WattTime provides this real-time data (and a 72-hour forecast) to smart device and software companies so that they can optimize the control of devices to use more energy when the grid is clean and less energy when it is dirty. This technology—enabled by WattTime's data, implemented by internet-of-things (IOT) companies—is called Automated Emissions Reduction (AER).

Enel X Way manufactures EV supply equipment (EVSE) hardware for charging EVs at homes and businesses, which is called the JuiceBox. Their JuiceNet software platform (a cloud service available on desktop and mobile devices) allows users to monitor and control the JuiceBox to charge their EV.

Enel X Way uses emissions data from WattTime to offer EV drivers the choice to optimize their charging to cause fewer emissions. The product is called JuiceNet Green (JNG) and it is available as an optional software add-on to any residential JuiceBox or JuiceNet-enabled EV charging station. JuiceNet Green gives EV owners a choice to power their vehicles with cleaner energy by shifting charging from times when this charging load would be served by fossil-fuel resources to times when it would be served by lower carbon or zero carbon resources, such as renewable electricity. For example, a driver can set a 7:00 AM departure time, and JNG will automatically choose the cleanest moments to charge throughout the night while making sure the car is fully charged in the morning.

3. How Enel X Way's JuiceNet Green Works

Initial setup by the driver/user

a. An EV driver buys and installs a JuiceBox EVSE or other JuiceNet enabled charger.
b. Purchase JuiceNet Green as a software add-on to their charger (or is given free or discounted access through a utility incentive program)
c. Download the EV JuiceNet mobile app (available for Apple and Android)
d. During registration in the app, enter the location of the charger (used to determine the local electricity grid region)
e. Also during registration or in the app settings, select the make and model of their EV(s)

Beginning a charging session

1. Plug in the EV
2. Open the EV JuiceNet app
3. **Check to make sure the correct EV model is selected (for drivers with more than one EV)**
4. Check EV's dashboard to see the current level of the battery
5. **Dial in the current battery level**
6. **Dial in the desired battery level**
7. **Check to make sure "Smart Charging" is selected**
8. **Drag the slider to select your departure time, i.e., the time you need to unplug the EV**

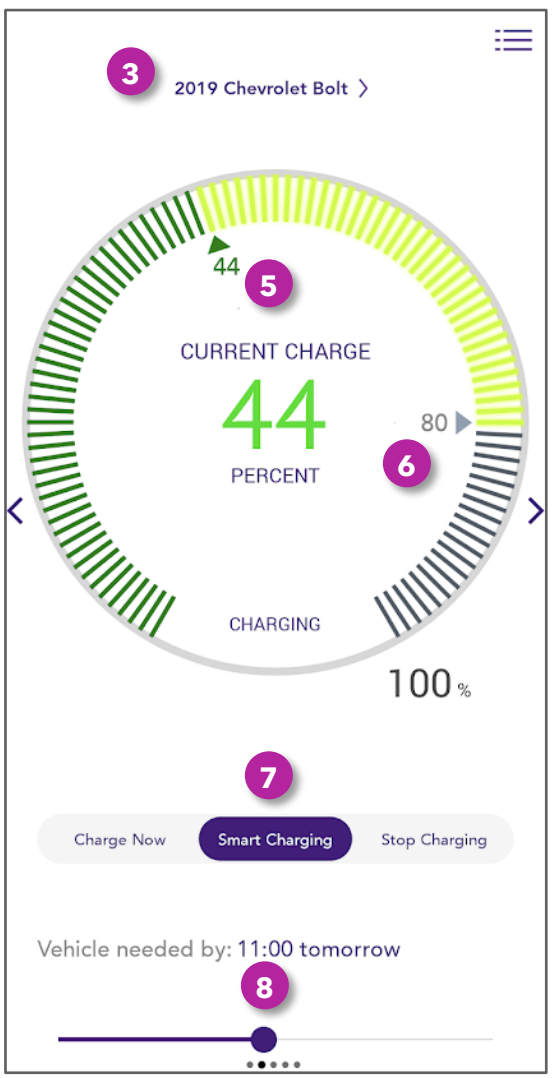

Figure 4: The user input screen of the EV JuiceNet App

During the session

i. EV JuiceNet determines the total energy needed based on the user inputs. Referencing how quickly the selected EV charges, it calculates how much charging time is needed.
ii. JNG pulls a forecast of the local grid emissions from WattTime. With the objectives of (a) charging the EV to the desired level by the departure time and (b) minimizing emissions, it creates a charging schedule.
iii. If the electricity grid is serving power from high-emissions sources, charging is automatically paused, and the user receives a notification from the app that it is waiting for cleaner electricity.
iv. When grid power becomes cleaner, charging starts automatically, and the user is notified.
v. As the session proceeds, JNG periodically updates its estimate of the battery level and re-checks the emissions forecast, then updates its charging schedule.
vi. When the desired battery level is reached, the charging stops, and the user is notified.
vii. The user has the option to choose "Charge Now" at the beginning of or during a session, which will override the JNG schedule and charge immediately from then on.

4. Ameren Missouri's AER for EV Charging Evaluation

Ameren Missouri supports reducing GHG emissions and accelerating the transition to renewable energy. When evaluating new technology to achieve this, they recognized that an AER program could give their customers an option to minimize the carbon emissions caused by their EV charging. For these reasons, Ameren Missouri decided to develop a pilot program to evaluate AER.

WattTime was contracted at no cost to Ameren Missouri to evaluate the emissions reduction benefits of AER for EV charging. The evaluation of AER was performed in two phases, with more users added in the second phase.

JuiceNet Green from Enel X Way was the first AER offering for EV charging in the marketplace and was the only available AER solution for residential EV charging during the planning for phase 1, in 2019 (as of July 2022, there are a total of 5 companies that offer AER for residential EV charging). WattTime evaluated JNG as the most mature example of AER in both phases.

Objectives of the pilot program:

1. Demonstrate that AER for EV charging is functional and practical in Missouri
2. Evaluate the ease-of-use for the end-user
3. Measure the CO_2 emissions reduction achieved by JuiceNet Green
4. Estimate the CO_2 emissions reduction potential from EV charging with AER that could be achieved by future programs

Pilot Phase 1: Ameren Missouri Employees, 10 Chargers

Key details, Phase 1:

- 10 EV chargers, 1,800 charging sessions
- Users/drivers were Ameren Missouri Employees who live in St. Louis, Missouri
- Performance evaluation period: Sept 2020 – Nov 2021 (14 months)
- Users were provided a JuiceBox free of charge, no additional incentive was paid to users

Pilot Phase 2: Missouri Smart & Clean Charging, 48 Chargers

Ameren Missouri provided funding for an incentive to expand the pilot population to gather more performance and user experience data. Enel X Way and WattTime offered the JuiceNet Green add-on and a participation incentive to all known and eligible JuiceBox owners in the state of Missouri.

Key details, Phase 2:

- 48 EV chargers, 2,500 charging sessions
- 43 active participants from the state of Missouri were evaluated
- 5 of the Ameren employees from phase 1 opted in
- Performance evaluation period: Feb – May 2022 (4 months)
- The added participants were provided a $50 Amazon gift card

EVALUATION METHODOLOGY

WattTime performed an evaluation of the JuiceNet Green pilot incentive program based on the criteria set forth by the program objectives. Functionality and performance were measured with data analysis of charging session history for pilot users. Ease-of-use was evaluated with surveys to the enrolled users about their experience.

1. Evaluation Periods

In Phase 1, WattTime evaluated the GHG emissions reduction performance during the 14 months of September 2020 through October 2021. A survey for user feedback was sent in early October 2020. The start of the Phase 1 evaluation was delayed due to the impact of Covid-19 on driving habits, which also allowed users to become acquainted with their new EV charging hardware and software. A preliminary report on Phase 1 was issued based on data through November 2020, and most of the Phase 1 participants opted in to extend their participation. The Phase 2 evaluation covered 4 months from February to May of 2022 and included users from all over Missouri. JuiceBox owners were offered $50 Amazon gift cards for Phase 2 participation.

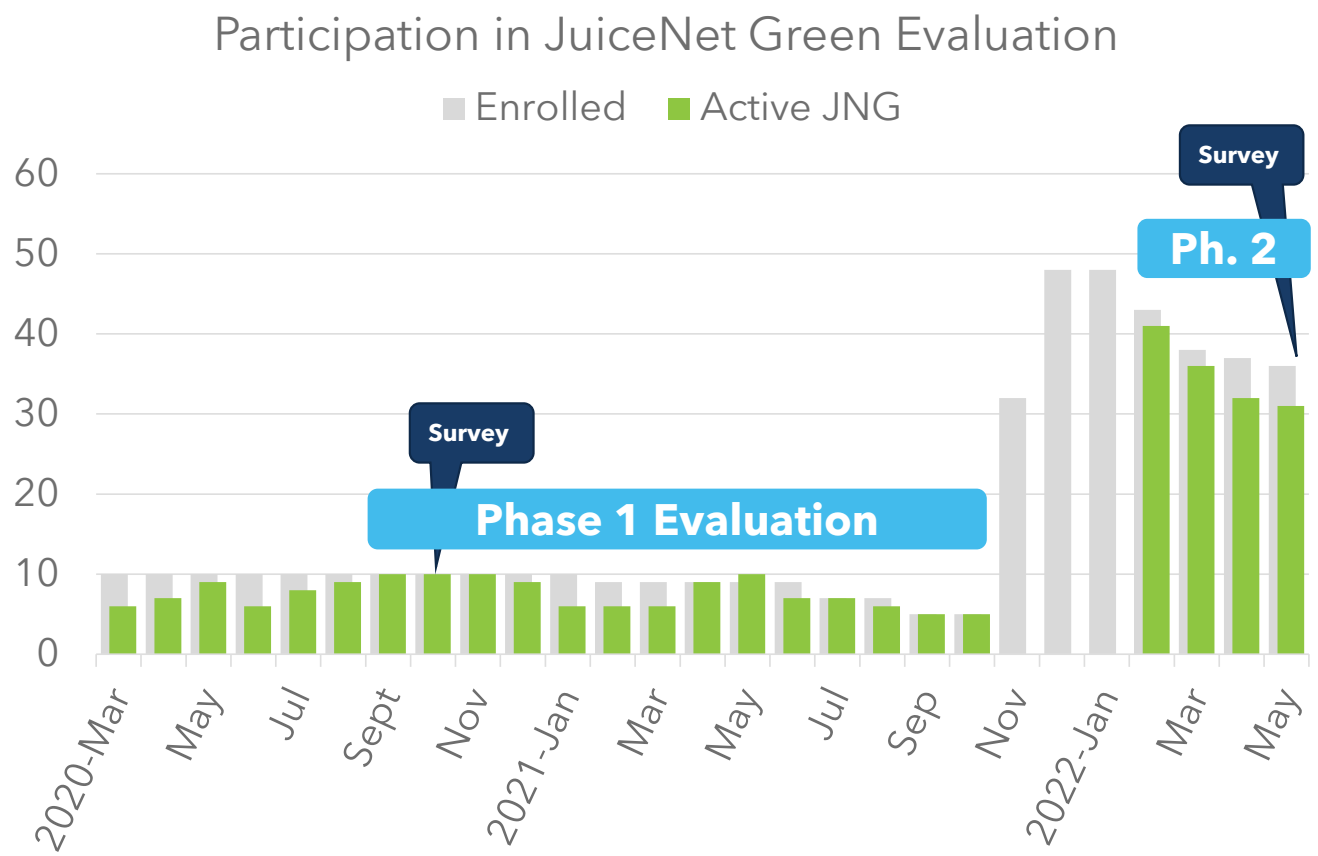

Figure 5: Shows the number of enrolled and active participants and the timing of user surveys and performance evaluation periods. In Phase 2 JuiceNet Green evaluation program expanded to JuiceBox owners anywhere in Missouri.

2. Method for Evaluating Performance

WattTime quantitatively evaluated the carbon reduction performance of JuiceNet Green as used by the EV drivers. This performance evaluation was focused on quantifying the avoided carbon impact of choosing to charge an EV using JNG, instead of charging immediately. Often it can be of interest to also quantify the carbon emissions avoided by driving an EV rather than an internal combustion engine vehicle, but that was specifically excluded from this analysis.

An uncontrolled EV charger will begin charging the vehicle immediately when plugged in and continue charging at the maximum safe charging rate until the battery is fully charged or is unplugged (sometimes referred to as "dumb charging"). For this pilot, this immediate charging behavior is considered the baseline for evaluating the emissions reduction of an EV charger that is controlled to avoid emissions.

To quantify the avoided carbon emissions of a JNG charging session, the carbon emissions induced by the actual JNG session were subtracted from that of the baseline simulation.

The avoided carbon analysis methodology is detailed in "Appendix A: Methodology."

Additionally, WattTime simulated the ex-ante "ideal" case for each charging session, in which the charging energy for a session is delivered in the exact optimal intervals, those intervals with the lowest marginal emissions rates. This allows for a comparison of ideal to baseline and actual induced emissions. This ideal case can be a helpful benchmark to show the overall opportunity for carbon reduction, though it is unachievable in practice because forecasts are not perfect.

For a more realistic benchmark, WattTime estimated an ex-ante "expected" or realistically achievable performance for each month of the evaluation. This expected performance level was estimated based on the performance of the best participants with a correction to normalize for the flexibility[1] of charging sessions. Expected performance is an approximation of the performance that could have been achieved by users if they had used JNG as intended (perform initial app setup and enter charging preferences each time they plug in). Where lower-than-expected performance occurred, WattTime investigated the various causes of performance degradation.

[1] "Flexibility" in this context is defined as the ratio of the inactive duration to the full session duration (e.g., for an 8-hour session with 2 hours of active charging, 6 hours are inactive, and the flexibility is 75%; for a different 8-hour session with 8 hours of active charging, there is 0% flexibility).

3. Method for Evaluating Ease-of-use

WattTime qualitatively evaluated the ease-of-use of JNG and the EV JuiceNet app from Enel X Way. The primary means for collecting feedback about ease-of use was via two surveys of the pilot program's participants, delivered via email, one in each phase. Additionally, some feedback was relayed to WattTime from Enel X Way regarding the reasons given by drivers who opted out of the program. In Phase 1, some informal user feedback was also given to WattTime by the Ameren Missouri project contacts, from their colleagues who were in the test group. WattTime's analyst performing this evaluation was also using JNG during most of the evaluation period, and while he was not a participant, his experience using the app helped him to better understand and interpret the feedback from the participants. This was especially useful for summarizing and aggregating the main themes of open-ended, long-form questions.

The two user surveys largely featured the same questions. A few new questions were added to the second survey, to assess the way the users were interacting with the app in more detail.

During the second survey period, to increase survey responses, participants who hadn't yet responded were offered an additional incentive ($25 Amazon gift card) to complete the survey.

Figure 6: Shows a preview of the user survey. The survey assessed the user's priorities and their experiences using the EV JuiceNet app.

EVALUATION RESULTS

1. Functionality/Practicality Evaluation

One objective of this pilot project was to evaluate whether an EV charging system can perform functions that will automatically reduce the emissions that result from charging an EV. The functionality was evaluated using questions that were key to the assessment.

Table 1: The three key questions used to evaluate functionality. All three were satisfied in this evaluation.

Is "smart charging" technology available in the marketplace?	Yes, Enel X Way and several other companies offer advanced control of EV charging over the internet
Can the GHG intensity of the grid be measured and communicated to EV device companies in real-time?	Yes, WattTime provides real-time and forecast Marginal Operating Emissions Rates for grid subregions (e.g. MISO_SAINT_LOUIS) at a 5-minute frequency, available over the internet via an API.
Can "smart charging" technology incorporate a GHG intensity signal to charge during times when grid emissions are lower (i.e. AER-enabled EV charging)?	Yes, during both Phase 1 and Phase 2 of the pilot, Enel X Way's JNG software showed the ability to start and stop a user's charging in response to the variation in marginal operating emissions intensity data provided by WattTime. An example is shown in the next section.

Enel X Way is the first company to make an AER-enabled EV charging station commercially available. The Enel X Way JuiceBox and JuiceNet combination has been available in the market for more than five years. AER capability for these products, now called JuiceNet Green, was first introduced in 2015.

Here is a list of companies currently offering AER for residential EV charging as of July 2022:

- Enel X Way
- Honda
- Flexcharging
- Optiwatt
- EV.energy

The result of this assessment was an overall confirmation that AER is functional and practical for charging EVs in Missouri.

2. Example of JuiceNet Green Reducing Carbon Emissions

JuiceNet Green reduces emissions by prioritizing charging to occur when it would cause the least emissions, the time when the local electricity grid has the lowest marginal emissions rate. When the EV is plugged in, JNG plans a strategy for the charging session in advance based on the marginal emissions forecast and any other constraints or preferences defined by the user. It then actively charges during times of low marginal emissions and disables charging during times of high emissions while ensuring a full charge is reached by the end of the session.

Figure 5 shows an example from the pilot for an overnight session that started on March 19, 2022. This user plugged in their EV just before 6:00 pm and unplugged at 8:00 am (likely with a 7:00 am departure time constraint). The EV needed 19 kWh to be fully charged before departure. WattTime simulated the baseline where the EV would charge at the maximum rate of 9.6 kW for just over 2 hours until fully charged. The actual charging energy was delivered during times that the marginal operating emissions rate (MOER) was much lower than it was during the baseline charging. Induced carbon emissions were reduced by 87% compared to the baseline.

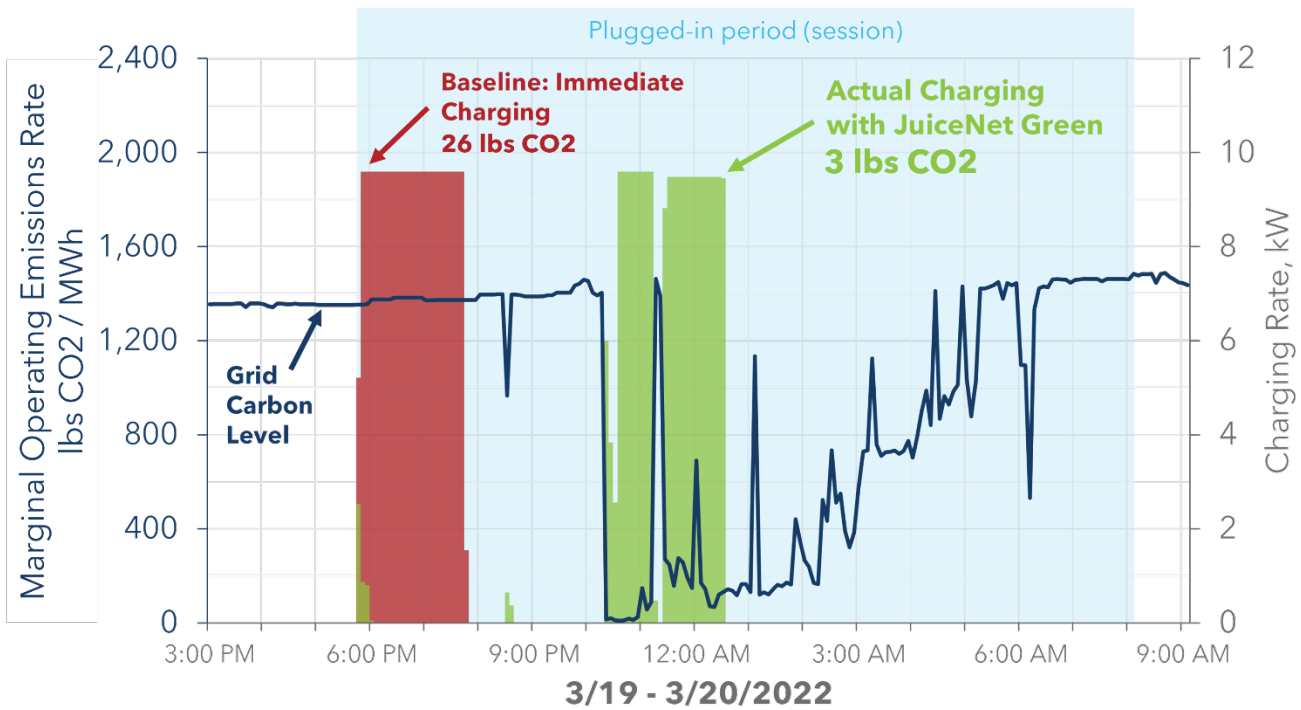

Figure 7: This charging session from the evaluation (for an EV driver in Kansas City, MO) shows JuiceNet Green choosing the cleanest times to charge the EV. The local grid's marginal emissions rate spiked around 11:15 pm and charging was paused, showing that JuiceNet Green has a fast response time to changing emissions rates within a session. Compared to a baseline where the EV charges immediately, 87% of the emissions that would have been induced were avoided.

Some additional summary figures that describe the EV charging data that was collected are included in "Appendix B: Charging Data".

3. Carbon Avoidance Evaluation Results

Overall Results, Phases 1 & 2

WattTime's analysis showed that 1,953 pounds of carbon dioxide (CO2) emissions were avoided by the active participants using JuiceNet Green during the 18 month, 2-phase evaluation period.

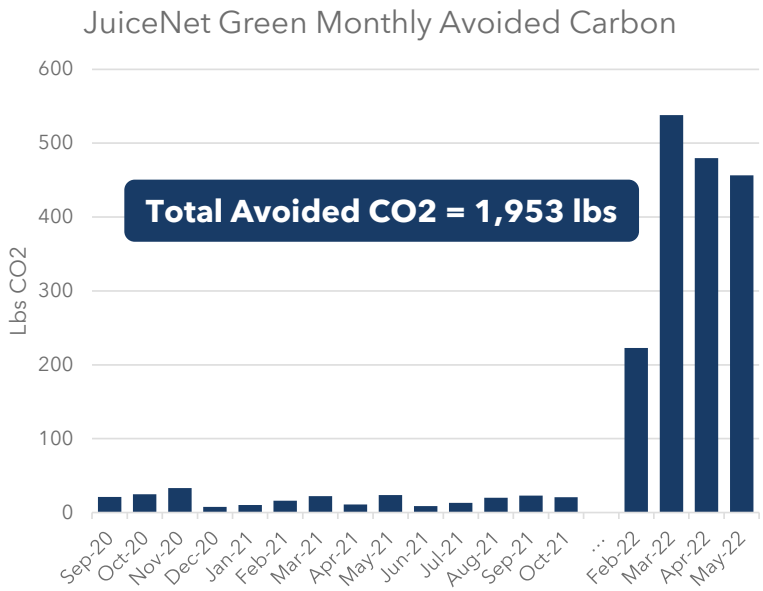

Figure 8: Avoided carbon emissions by month. Phase 2 (in 2022) had a larger population of active users, thus more carbon was avoided. The total avoided carbon was just under 1 metric ton.

WattTime compared the actual results to what was realistically achievable with JNG, and the best possible results given the parameters of each charging session and when it occurred.

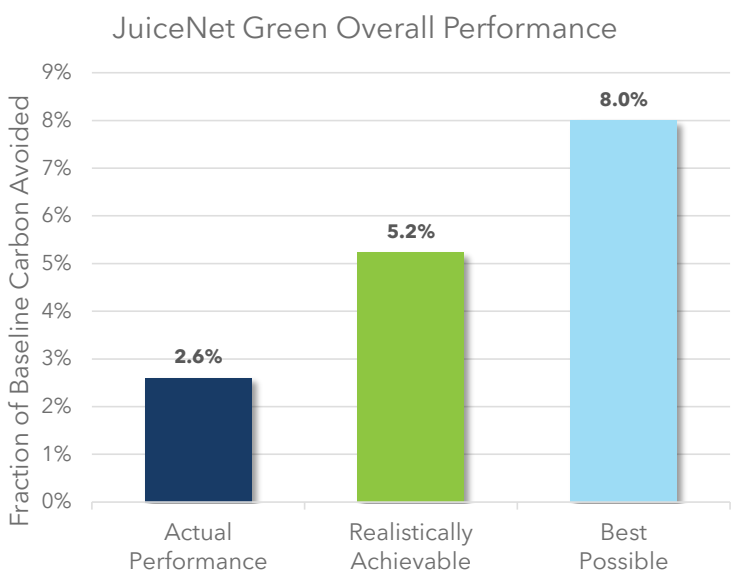

Figure 9: JuiceNet Green avoided 2.6% of the carbon emissions that would have otherwise been emitted without it (Ph1 + Ph 2). JuiceNet Green could have achieved about 5.2% under the same circumstances if all users performed like the top quartile. The best possible savings for this population would have been 8.0%.

Performance Comparison for Various Locations

In Phase 2, the population included active participants from two different ISOs that operate in Missouri. This allowed a comparison of carbon avoidance by ISO region.

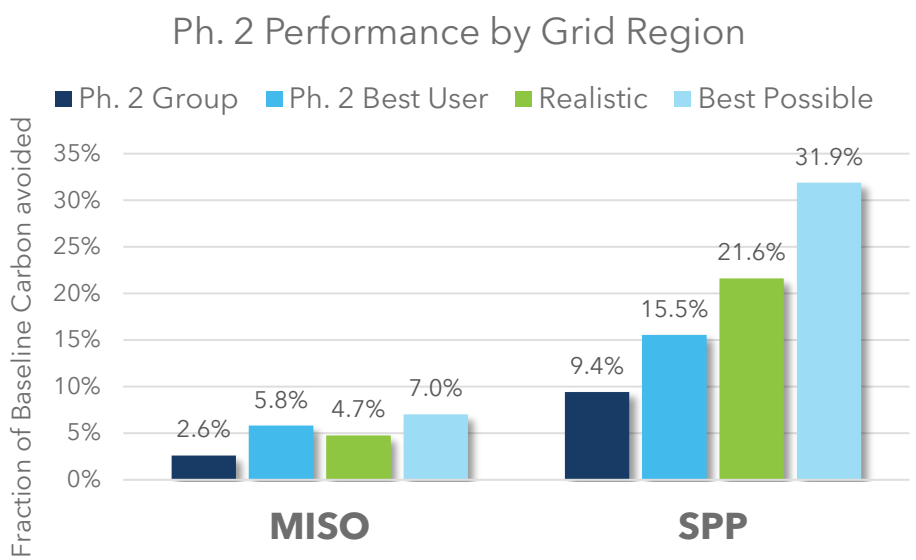

Figure 10: All MISO users were in the MISO_SAINT_LOUIS subregion, and likely inside Ameren Missouri territory. SPP grid regions (e.g. Kansas City) have much more variability in the marginal emissions rate (primarily due to a higher prevalence of wind generation curtailment), which provides a better opportunity to avoid emissions.

Range of Performance

WattTime evaluated carbon reduction performance by individual users compared to what should have been realistic, given the timing and flexibility of their charging sessions. User performance varied widely among the active participants, from 0% to over 100%. There were underperforming users in both ISO grid regions, which brought down the total performance of the group.

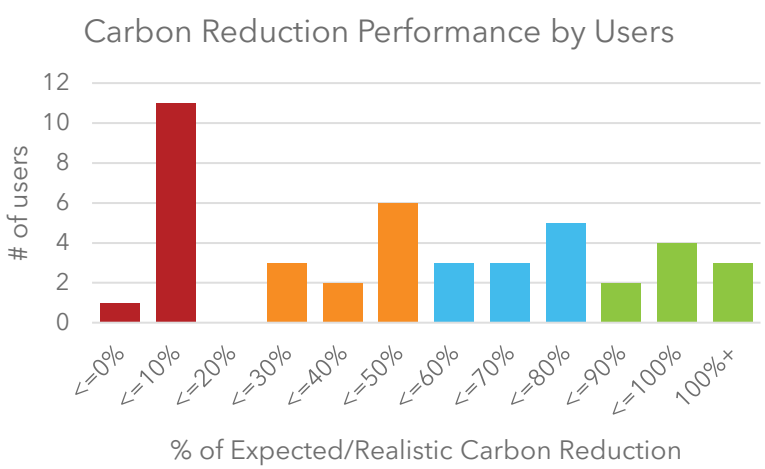

Figure 11: Roughly a quarter of users achieved less than 10% of the expected carbon reduction. Half of users performed at 20-80% of expected. The top quarter achieved more than 80% of the expected reduction.

4. User Experience Feedback

User feedback was gathered twice during the pilot using surveys sent to the participants by email. The surveys were used for multiple purposes, including (a) to evaluate the ease of use of the JuiceNet Green application, and (b) to identify areas where the user engagement or preferences affected performance.

The phase 1 survey received 10 responses from 10 active participants. The phase 2 survey received 21 responses out of 31 active participants at the time. The overall response rate by users who were sent the survey was 76%. Users who had already opted out of the program were not sent the survey, but were asked for a reason they were opting out.

Feedback from users who opted out of the program was also recorded.

Charging Priorities

Priority Ranking: 31 drivers responded to a survey question that asked them to rank their priorities for charging their EV. The question read: *"As an EV driver, what are your priorities related to charging your vehicle(s)?"* Charging cleanly was the first priority for 23% of people (quickly-32%, cheaply-39%, and fully-6%). The "fully" option was a write-in that means that the people had a preference about their EV's battery being fully charged at the end of a session.

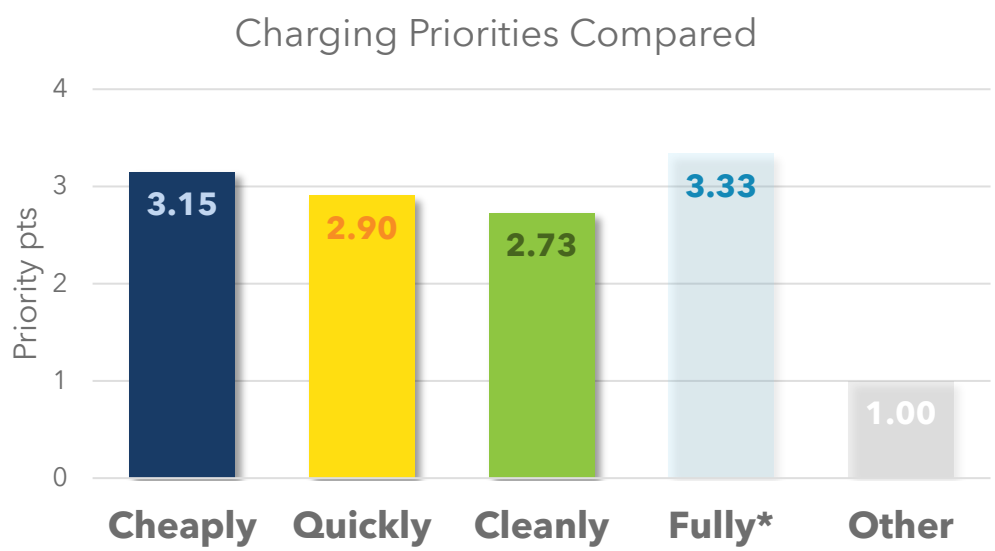

*Figure 12: Using a scale of 4 points for 1st priority, 3 points for 2nd priority, etc., participants on average were motivated most by charging cheaply and fully (*Fully was a write-in with only 3 responses).*

Use of EV JuiceNet App

Do you use the app? 31 users responded to a question that read, *"How do you set your JuiceBox charging preferences?"* Multiple choice answers included, Mobile App (Phone/Tablet), Online Dashboard (Computer), None of the Above, and Other (write-in). Answers to this question and the next were aggregated to determine whether each user was using the app when plugging in.

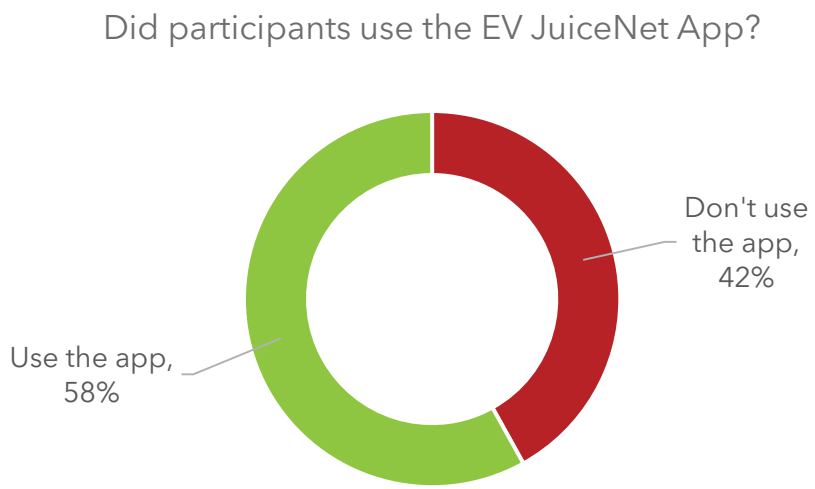

Figure 13: 42% of users didn't regularly use the app to set their charging session preferences.

App usage (how?): In the second survey, we dug deeper into how the users were using the app. 21 users responded to a question that asked about the way they set their preferences for a charging session. The question read, *"When you start a charging session, which parameters do you usually adjust in the EV JuiceNet app? (Check all that apply)"* The choices included all of the preferences that can be set in the EV JuiceNet app for a charging session (the survey included an annotated diagram of the app screen where users enter these preferences, exactly as shown in Figure 2 on page 7), and also a write-in option. The answers were tallied and categorized to gauge whether participants were using the app as intended.

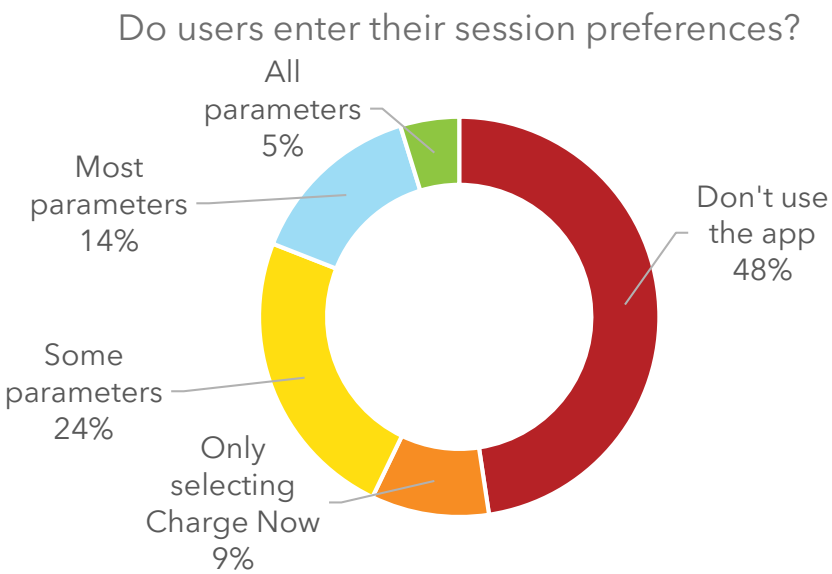

Figure 14: Only one user reports entering all of the parameters that define the charging needs for a charging session. 81% of users report using the app in a way that likely degrades JuiceNet Green performance.

Charge Now (JNG override): 31 users responded to a question that read, *"Do you ever use the "Charge Now" feature to override Smart charging?"* This is an override feature that would disable smart charging with JuiceNet Green and instead charge immediately.

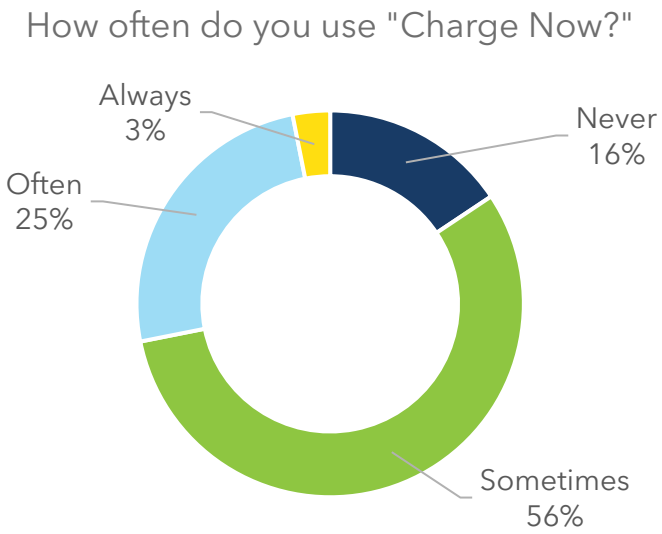

Figure 15: Most users (84%) at some point used the "Charge Now" option to disable JuiceNet Green for a session, opting out of reducing CO2. Some users reported that they used that option often or every time (28%).

Smart & Clean Incentive Program

Would you recommend it? (Yes/No): 21 users responded to a question that read, *"If your electric utility offered this incentive program more widely, and you knew other EV drivers in your area, would you recommend it to them?"* This was referring to the Missouri Smart & Clean EV Charging program.

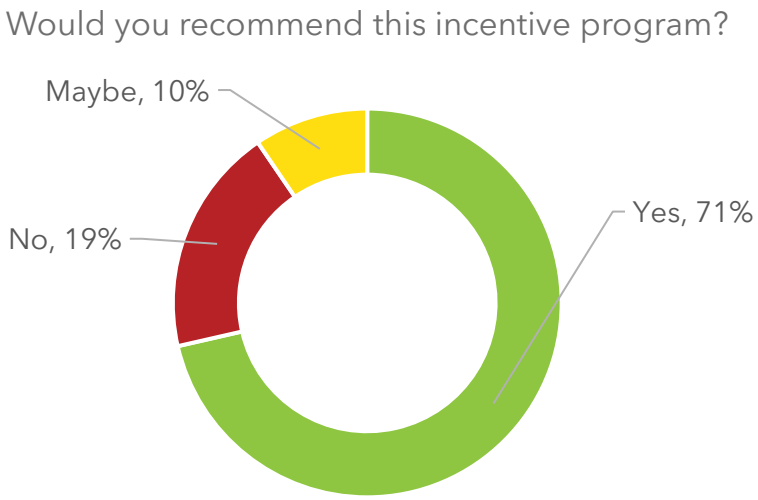

Figure 16: 71% of users would recommend this incentive program to other EV drivers. Two users responded "maybe"; one said "not using your charger" and the other said "if the parameters were more clear."

How likely are you to recommend it? 21 users responded to a question that read, *"How likely is it that you would recommend this program, if you knew/know another EV driver?"* They rated their likelihood on a scale of 1-10.

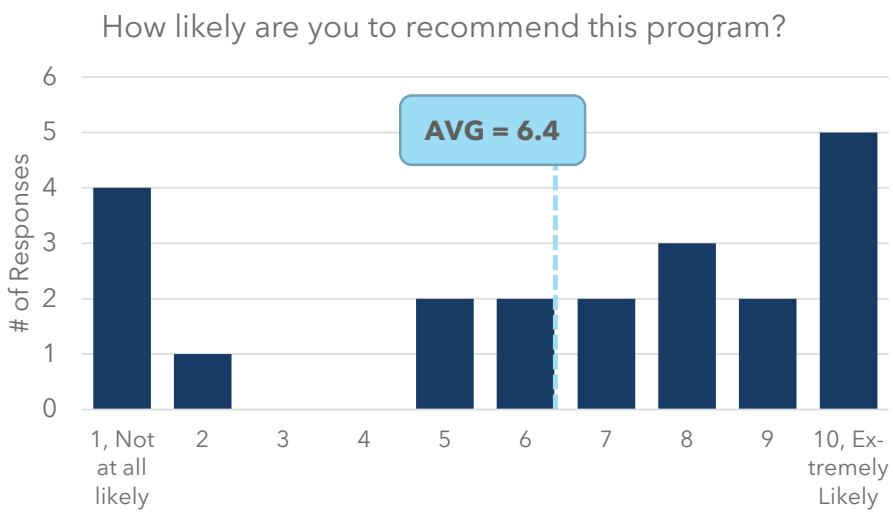

Figure 17: The average likelihood of recommending the program was 6.4 on a scale of 1-10.

Recommendation, why or why not? 18 out of 21 users responded to a follow-up question that asked, *"Can you share your primary reason for recommending or not recommending?"* Below is the full table of responses to both questions.

Table 2: Reasons given for/against recommending this incentive program.

How likely is it that you would recommend this program, if you knew/know another EV driver?	Can you share your primary reason for recommending or not recommending?
10	Good for environment
10	
10	It rarely if ever impacts my needs to let the charge when it is best for the environment.
10	Doesn't really affect my usage and helps more effectively use energy
10	I believe it fits with the reason many drivers select a EV.
9	Ease of use
9	It allows charging during non-peak gours
8	Helps the grid
8	It works best with one EV. With 2, there are logistics of delaying charging. You have to remember to switch vehicles etc.
8	most of time I have to click charge now even I set time to start
7	I had issues that my Chevy Bolt would not start charging even during a time that should be available (like after 11 pm)
7	Good program but sometimes car is not charged
6	I don't know if this is the cheapest way to charge
6	It hasn't been totally reliable. It may just be our juicebox hardware, but occaisionalyl we will get some unknown error where it didn't charge and is beeping and we have to unplug/plug back in the juicebox to get it to charge.
5	
5	
2	charger will not charge if the app crashes
1	The program limited my charging by 1/5th even when I selected charge now. That was really silly. If I don't need my car this is great. If I need to charge my car immediately this program is silly.
1	The incentive offered is trivial
1	Didn't charge when needed
1	No one cares. Most don't want to take extra steps to charge during off-peak hours.

Issues & Concerns

Common concerns: WattTime categorized all concerns mentioned in any area of the survey to show patterns in the reported issues.

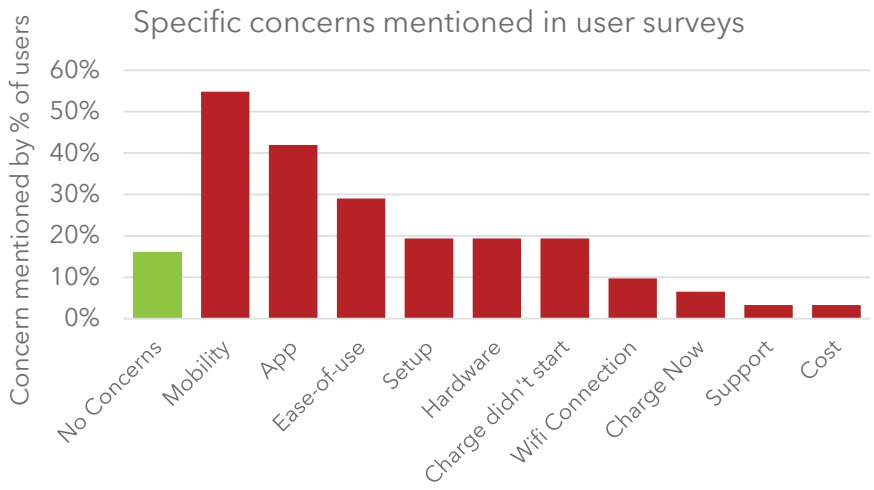

Figure 18: 16% of users reported that they had no concerns. Most underlying concerns manifested as an insufficient charge (mobility). Many users reported difficulty with the app and that their EV was not charging when they were expecting it would.

Mobility: 31 users responded to a question that read, *"Has Smart-charging ever caused your car's battery to be insufficiently charged when you leave the garage/driveway?"* WattTime categorized affected users according to their reported app usage behavior from a prior question.

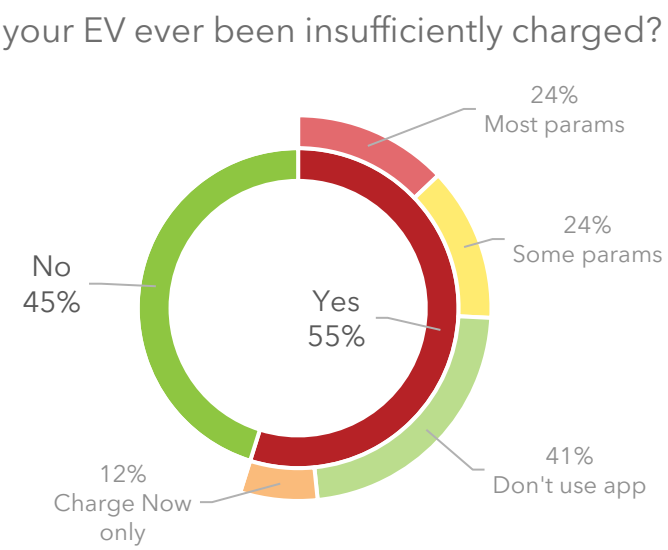

Figure 19: Just over half of users report that JuiceNet Green has affected their ability to receive a full charge by the time they unplugged. ***However, most of the affected users are either not using the app or not properly providing their session preferences. Inputting the battery level and time needed will reduce the likelihood of an insufficient charge.***

What was your main concern? 29 of 31 participants responded in free-form to this question, *"What has been your biggest issue or concern with the EV charging pilot or with JuiceNet Green?"* The full text of user responses is included in Appendix C: Additional Survey Responses.

Opt-Outs

In Phase 2, there were 43 enrollees. There were two enrollees that were no longer located in Missouri, who were deemed ineligible. There were 8 enrollees in Phase 2 that opted out before the survey was released. Enel X gathered some limited feedback from those users regarding the reason they disenrolled. The reasons given were the following (paraphrased):

- (3) "charge now" feature is not working
- (1) smart charging didn't work
- (1) battery didn't reach desired charge level
- (1) inconvenient
- (2) no reason given

10 of 10 Phase 1 users participated beyond the initial period that they opted in to, and 3 of those users remained at the end of Phase 2 (more than 2 years after their enrollment).

DISCUSSION

This two-phase evaluation was helpful to demonstrate the performance and ease-of-use of JuiceNet Green as an example of AER technology. The evaluation exposed some limitations in the current version of the EV JuiceNet app which hindered the performance of JNG, and the information that was gathered will be useful for development of Enel X Way's new app with JNG and for other implementations of AER. The evaluation also established real-world performance benchmarks for JNG and AER more broadly, in multiple regions, which helps to characterize how the overall carbon reduction opportunity is expected to change and improve over time.

1. User Experience Affects Performance

The EV JuiceNet app uses charging session parameters known at the beginning of the session to decide the best times to charge the EV (true for JuiceNet Green and any other smart charging type, e.g., time-of-use). To fully define the charging session, JuiceNet needs to know the EV model, the starting battery level, the desired battery level, and the expected unplug time. With these parameters, JuiceNet can calculate the duration of active charging that will need to occur to deliver the necessary energy to fill the battery, and with that, it knows the latest possible time that it could start charging the car to still deliver the desired battery level. If any of the parameters is missing, JuiceNet will use a default assumption. For a user that has a regular commute and only has one EV, the user can "set and forget" 3 out of the 4 session parameters: for example, they always drive a Tesla Model 3, unplug at 7:00 am, and want a 100% full battery. However, JuiceNet still needs the user to manually enter the starting battery level and if they don't, the assumption JuiceNet makes could be very different from the reality (for a Tesla Model 3, the needed charging duration could vary from less than an hour to over 7 hours, depending only on the starting level). Since Enel X Way places a high value on providing a full battery by the end of the session, their default assumption for the starting battery level tends to be intentionally conservative (low) so that ample time is reserved. This assumption can significantly, and artificially, limit the flexibility for JNG optimization, resulting in degraded carbon reduction performance.

It is difficult to get someone to change their behavior once they are accustomed to doing something a certain way. In Phase 1, the participants were given a new JuiceBox charger at the beginning of the evaluation, and instructions about how to use EV JuiceNet for JuiceNet Green; so from the start, they expected that they had to pull out their phone and enter their preferences every time they plugged in. In Phase 2, the incentive for participation was offered to EV drivers who already owned a JuiceBox; this population's prior behavior was likely that they just plugged in and didn't look at the app every time. They were given new instructions about how to use their JuiceBox, which included an extra step of pulling out their phone to enter their charging preferences. This could explain why when asked if their battery had ever been insufficiently charged, 90% of the first group said no (they tended to use the app), and 76% of the second group said yes (they tended *not* to use the app).

This limitation—requiring manual input from the user—is not inherent to AER, or even to JuiceNet Green, and could be improved in the future. In fact, the other versions of AER for EV charging in the market do not rely on the user to enter the starting battery level. For example, Honda's SmartCharge software (which runs JuiceNet Green on the back end) can access the state-of-charge (SOC) of the battery directly from the vehicle's onboard computer, which eliminates the need for the driver to enter it. Other AER software uses a 3rd party integration from Smartcar to retrieve battery SOC from the original equipment manufacturer's (OEM) app. WattTime expects

performance to be more consistent from user to user in AER implementations where the SOC is retrieved automatically.

2. Enel X Way's Upcoming App Release

Enel X Way has acknowledged the issues users have experienced with the EV JuiceNet App. The feedback gathered during this evaluation and their other programs around the country has informed the design and development of improvements to their app. WattTime invited Enel X Way to explain how they hope the updated app will address some of the concerns from users in this evaluation.

Comments from Enel X Way

Enel X Way will soon retire the EV JuiceNet app and will incorporate the control of Smart Charging (including JNG) into their other app called JuicePass. With the updated JuicePass app, the user experience has been improved in most of the critical aspects mentioned in the user evaluation.

Short Term Improvements:

- Charge Now functionality has been reworked to ensure stability of the core feature
- JuicePass for now maintains a default conservative assumption for starting battery level, in case the user doesn't provide it. The conservative value will be taken into account such that the vehicle will be fully charged at the end of the charging process. Enel X Way will continue to strongly advise users to enter all the required charging preferences into the app at the start of a session to make sure these constraints are respected when charging (EV Characteristics, Departure Time, Target SoC, Start SoC).
- JuicePass will provide the user with more helpful push notifications about:
    - Status of the charging process: the user will be able to see from the home charging screen the reason behind charging statuses (charging reason, pause reason, e.g., smart charging override). In the case of paused charging, the user will be given an estimate of when active charging will be resumed.
    - Charging needs that cannot be met within the desired departure time: user will be warned if the current charging needs cannot be met within the selected departure time. This notification has been introduced to address the issue related to EVs which were not fully charged at plug out.
- JuicePass charging session monitoring and reporting has been improved and will include a CO2 reduction estimate and will introduce charts to monitor actual station charging power, CO2 emissions rates over time.

Long Term Improvements (future version update):

- Start SoC will not be entered anymore by the user and will be directly retrieved from the EV.
- Provide an option for even more notifications based on charging needs
- Resume charging functionality: user will be able to return to Smart Charging during a session in which they had already used the Charge Now override.

3. The Future Carbon Reduction Opportunity of AER for EVs

There are multiple ways that the carbon reduction impact of a program like this could improve in the future.

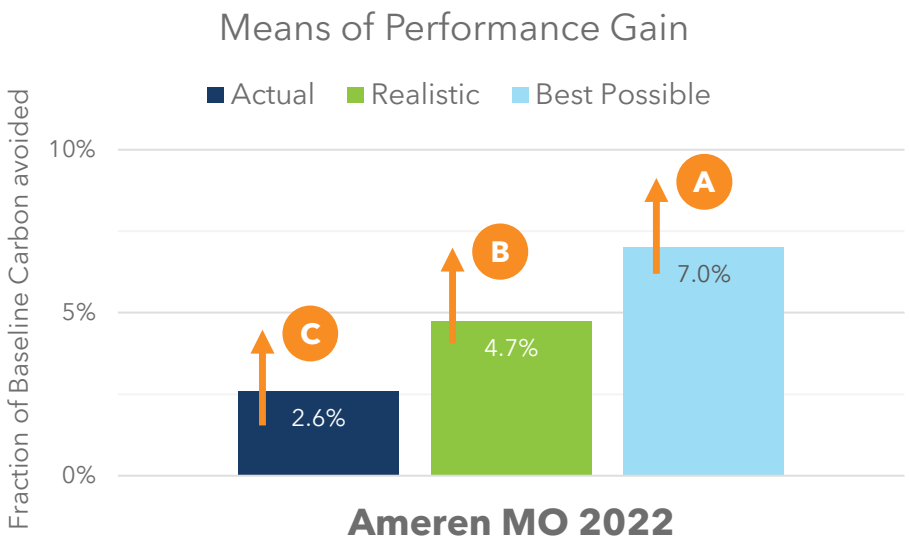

Figure 20: The overall opportunity for carbon reduction can improve as more renewables are added to grids. A user's ability to avoid as much carbon as possible depends on the AER technology and how they use it.

First (A), the overall opportunity for carbon avoidance will increase as more renewable energy is added to the grid. The majority of Ameren Missouri territory is within MISO, which currently has annual renewable generation of about 15% (compared to SPP with over 25%). The level of renewable energy penetration in MISO is projected to double to 30% by 2026[2]. When there is a higher proportion of variable renewables in a particular region, these zero carbon sources are more often a factor in the marginal emissions rate (during renewable curtailment events), and with more frequent and lower dips in the marginal emissions rate, the opportunity for carbon avoidance with AER increases.

Next (B), the gap between best and realistic performance can be narrowed; this will primarily be achieved through software updates. The JuiceNet Green software algorithm developed by Enel X Way can be improved to better optimize charging for emissions avoidance. EV charging software that uses WattTime's data for AER relies on both the real-time and forecast marginal emissions rates; as WattTime's forecast improves, JNG and other AER software will be able to make charging plans that avoid more emissions.

Also (C), the gap between actual and realistic performance can be narrowed. By definition, we know that "realistic" performance can be achieved today, since it is already achieved regularly by 25% of users or more. However, there are also users in the population that regularly underperform (less than 10% of the realistic performance). The biggest opportunity to improve overall JNG performance is by helping the lowest performers. This can be done by relying on the user's input less; if Enel X Way's smart charging became more automated and less reliant on user input, that would reduce the performance spread amongst users; the other EV charging AER software in the

[2] RIAA Summary Report, 2021 https://cdn.misoenergy.org/RIIA%20Summary%20Report520051.pdf

market is able to access the state-of-charge of the battery automatically through a vehicle OEM data integration. The lowest performers can also improve through better education about how the app works and/or better feedback shown in the app about their performance; these improvements may prevent some users from giving up on using the app altogether. Another way of improving performance in this category, would be to tie the program incentive to performance; this would reduce the rate of free-riders that join the program with no intention of using JNG even though their account has been upgraded to access the feature.

WattTime has estimated the overall performance gains that are reasonably achievable by 2025. This assumes that the MISO grid exceeds 25% renewable penetration (similar to SPP today), and that the MISO_SAINT_LOUIS grid region sees more frequent wind curtailment but still at a lower frequency than that of SPP_KC today (because MISO's renewables are more concentrated away from Missouri). The estimate of projected performance also assumes modest gains in software and program design. Counteracting performance gains, the retirement of fossil fuel generators is assumed to decrease the baseline CO2 per kWh by 5% per year.

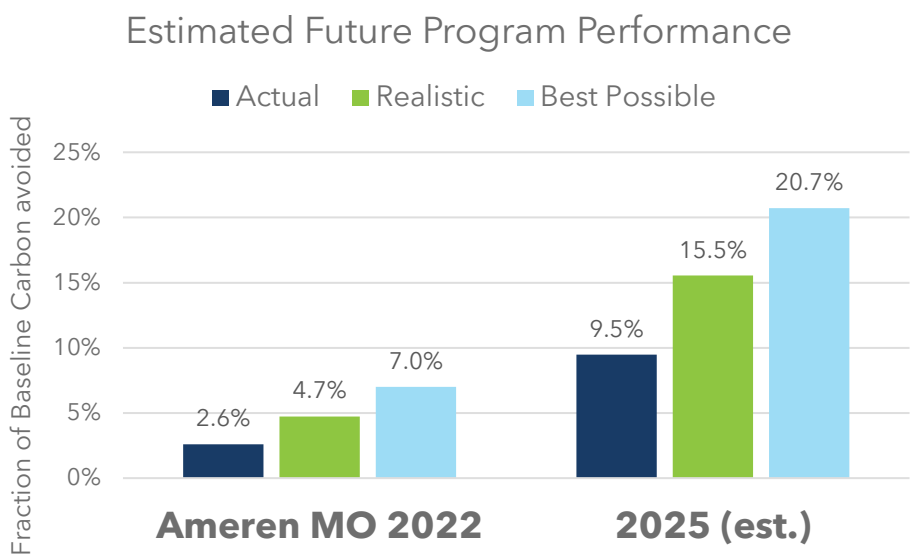

Figure 21: The ability for EV charging with AER to avoid carbon emissions in Ameren Missouri territory will increase as (a) more renewables are built in and around the local grid, (b) the AER software improves, and (c) the user experience becomes more consistent and less manual. Modest improvements in these categories lead to a three-fold improvement in performance in the next three years. This level of performance was already achieved in Western Missouri in this evaluation, so these assumptions seem reasonable if not conservative.

4. Potential Future Impact of an AER for EV Program

If Ameren Missouri expands this AER for EV charging program, the overall program impact will increase as more drivers participate and as the performance of each user increases. Program expansion will be limited by the rate of adoption of EVs in Ameren Missouri territory. The subset of Ameren Missouri ratepayers that drive an EV is expected to increase year-over-year, as EVs continue to gain market share. The rate of EV adoption and program enrollment are difficult to predict at this point, so we've made some very preliminary assumptions to show one scenario for how things could unfold in the future.

Scenario assumptions include 10,000 Miles driven per year, EV efficiency of 3 miles per kWh, and the following pro forma assumptions:

	Participants	**Carbon Avoidance**	**Carbon Avoided**
2022	32	2.6%	2 metric tons
2023	1,500	3.5%	110 metric tons
2024	4,000	5.5%	440 metric tons
2025	10,000	9.5%	1,810 metric tons

This potential future program scenario results in a total impact of 1,810 metric tons of CO_2 avoided in 2025.

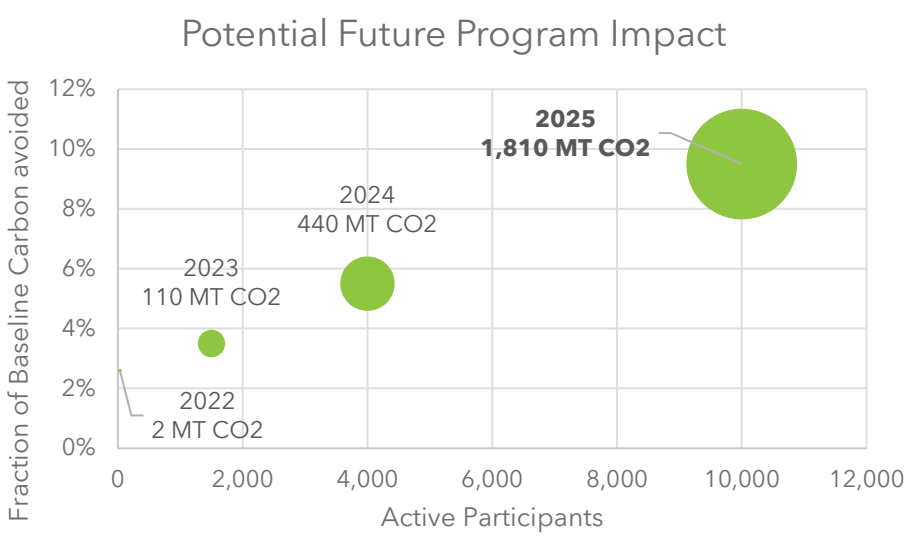

Figure 22: Each year, as the incentive program adds more users and the performance of the AER software improves, the carbon reduction impact of the program grows. One scenario's impact is shown.

CONCLUSIONS

AER-enabled EV charging is available, functional, and practical for drivers in Missouri. During this evaluation, JuiceNet Green reduced the carbon emissions caused by the participants' EV charging sessions by just under one metric ton (2.6%). In Phase 2, the carbon avoidance was shown to vary by region, with 2.6% carbon avoidance achieved in Ameren Missouri territory, and 9.4% carbon avoidance in Western Missouri. Carbon avoidance performance also varied widely among users, as some users had trouble with the EV JuiceNet app and many users did not use the app at all.

The carbon reduction effectiveness of charging EVs with AER in Ameren Missouri territory will improve as (a) more renewables are built in and around the local grid, (b) the AER software improves, and (c) the user experience becomes more consistent and less manual. Modest improvements in these categories are expected to bring performance in Ameren Missouri territory up to that of 2022 Western Missouri by 2025 (9.5%). If program participation is expanded to 10,000 drivers, the carbon avoidance impact is estimated at 1,810 metric tons per year.

Ameren Missouri could expand the AER for EV charging incentive program beyond this initial evaluation, to all Ameren Missouri residential customers. Since EV adoption may be a limiting factor, to improve participation, the program could allow participation via any smart charging hardware or software capable of performing AER (currently, there are 5 companies offering AER for residential EV charging in the US).

Missouri regulators and other utilities should take particular note that there is already significant opportunity for carbon reductions in Western Missouri (particularly in the Southwest Power Pool) from similar programs.

APPENDIX A: METHODOLOGY

Data Sources

EV charging data was gathered through the Enel X Way JuiceNet platform. Enel X Way provided raw charging session and segment event data to WattTime. WattTime was also given JuiceNet access for spot-checking.

WattTime converted session and segment event data into time-series energy (kWh) data for each charging session, at a 5-minute frequency. Segments were the active charging portions of the overall session.

WattTime used CO_2 MOER data from its historical database to define the carbon intensity of the grid for this analysis. This data is stored at a 5-minute frequency. Two versions of this data were available during the period the pilot was running, since the MOER model was updated on December 15, 2020. When the MOER model was updated from V2.1 to V3.0 the subregion granularity was improved. Some of the early preliminary analysis performed during the pilot was performed with MOER V2.1 for the MISO_IL grid region. All final analysis and results shown in this report were performed with MOER V3.0 for the MISO_SAINT_LOUIS grid region for Phase 1, and for these grid regions in phase 2: MISO_SAINT_LOUIS, SPP_KC, SPP_SPRINGFIELD.

Avoided Carbon Calculation

The avoided carbon emissions WattTime is reporting for this analysis results from the choice to use AER to charge the vehicle instead of charging in an uncontrolled, immediate manner.

WattTime simulated the immediate charging baseline behavior for each session. The baseline charging behavior was defined by a constant charge at the maximum charge rate for the car, starting when the car is plugged in, and ending when the full amount of energy is delivered. The full amount of energy was the amount that was actually delivered by the JuiceBox in the real-life session. This baseline time-series data was also calculated at a 5-minute frequency for each session.

Carbon avoided for each session is the difference in marginal carbon emissions between the baseline and actual cases.

$$CO_2\ Avoided\ [lbs] = \sum_{t=0}^{end\ of\ session} MOER_t \left[\frac{lbs\ CO_2}{kWh}\right] \times (Baseline\ Energy_t - Actual\ Energy_t)[kWh]$$

Sources of Error, Potential Methodology Improvements

The rate of charge within a segment was simplified in this analysis to equal the average charging rate of each full segment. Using raw time-series data instead of event data would allow improved fidelity of the changes in charging rate within a charging segment. This error is small for the majority of segments, and we do not expect this to significantly impact the analysis results.

Some users have multiple cars, each with a different maximum charging rate. The baseline case was defined using our best, but automated determination of which car was charging. This baseline assumption would be improved with a more certain and automated way to detect which car is plugged in. This source of uncertainty could be significant but was not present in the majority of users in this population.

Future analysis could include alternate baselines (instead of simply immediate charging). For example, if smart-charging is activated to charge based on a time-of-use electricity cost rate, that behavior could be incorporated to define an alternate baseline scenario.

APPENDIX B: CHARGING DATA

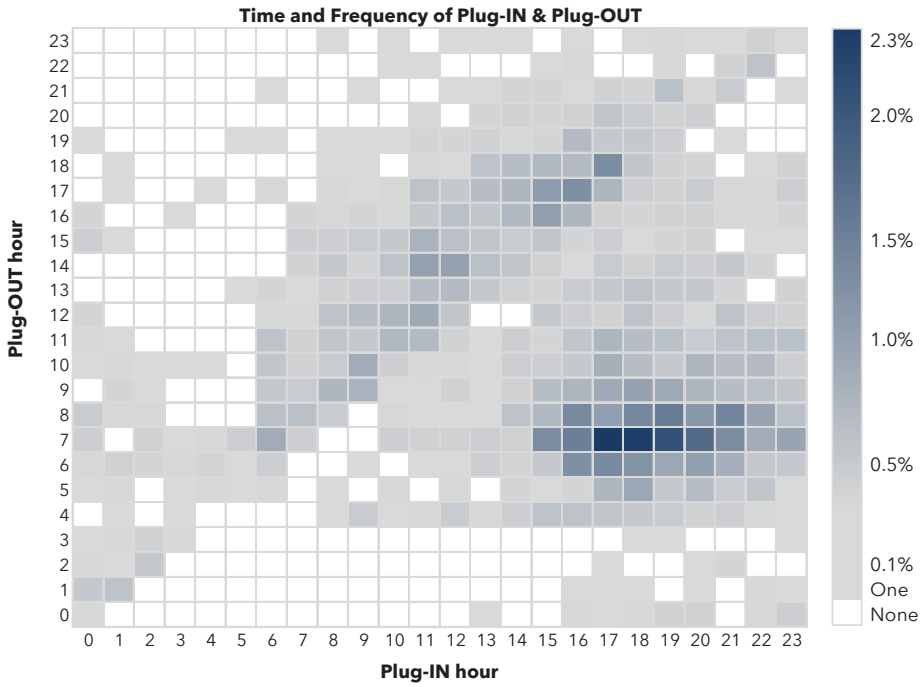

Figure 23: Phase 2 data (2,500 sessions) visualized with the Plug-IN/Plug-OUT pairs that define a session. The most frequent session type is an overnight session (the grouping in the lower right), with 5:00PM-7:00AM the most common. The diagonal band shows short daytime sessions where 0-4 hours of charging is needed.

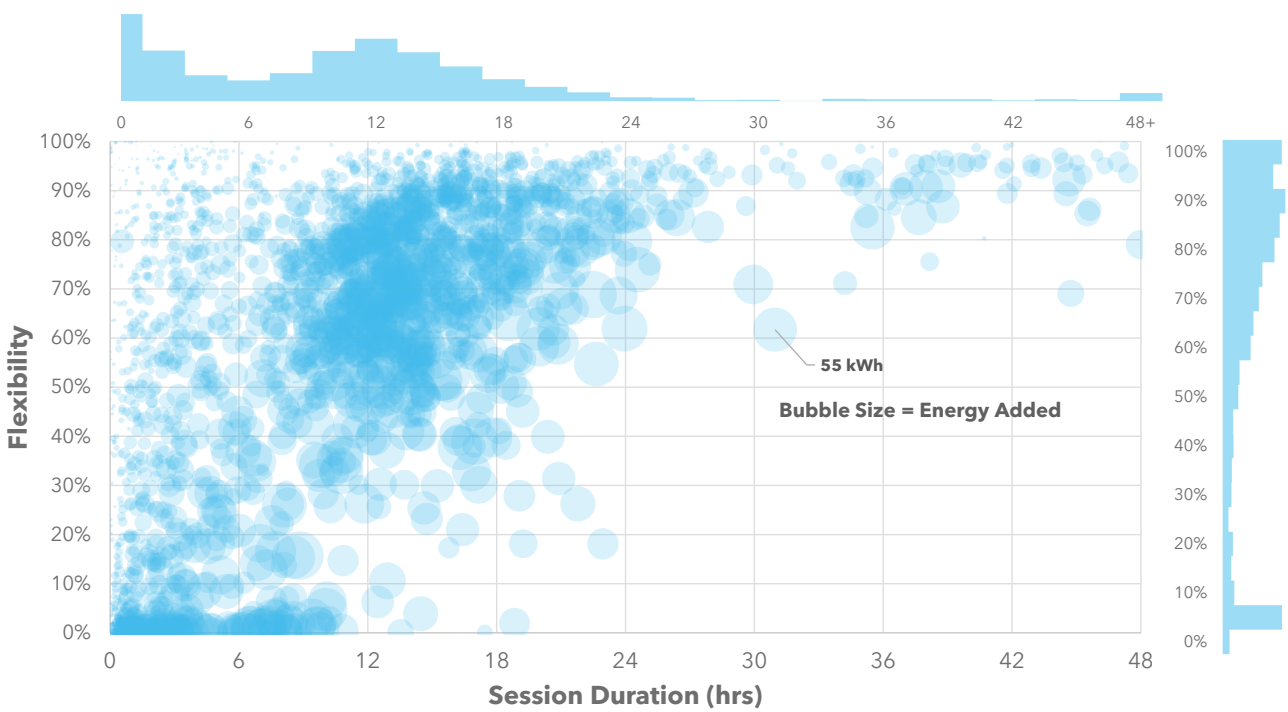

Figure 24: Ph 2 sessions averaged 12 hours with 2.7 hours of charging. 33% of sessions last 10-16 hours, 28% of sessions last under 4 hours. Longer sessions tend to have higher flexibility for shifting active charging. Average flexibility was 77% and two-thirds of sessions have more than 60% flexibility.

APPENDIX C: ADDITIONAL SURVEY RESPONSES

What has been your biggest issue or concern with the EV charging pilot or with JuiceNet Green?
The need by time hasn't always worked
The charge now functionality is worthless/
Had trouble setting it up initially but help desk was very helpful
could not override smart charging to start now, would always revert back unless completely disabled
On occasion, I did not get the charge I desired
app crashed would not reset, charger would not charge car, was at a low state of charge. Could not get any help mobile or online. Bought another charger no problems.
Is this less expensive than charging at off peak hours
When the app did not operate properly when the program first started and I had to call customer service to start charging on my call.
The mobile app stooped working early in the program and I have been forced to used the mobile website which also has some issues.
Didn't charge when needed
When our juicebox does not charge when we expect it to.
Sometimes my charge session would never start
I need my car charged more than smart charging allows.
Reliability of app
none
Not having car charge when needed
I have to switch to charge now every time I charge, no incentive program here
Having to change to "charge now." The charger stopped working
Nothing
smart charging most of time does not work
Not having enough charge on my vehicle when I forget to manually override the smart charging.
I don't get notifications on the mobile app when Smart Charging delays the charging of my vehicles.
Initial Wi-Fi setup instructions were misleading. The phone app indicated that the Wi-Fi setup was complete even though no connection was made. The first charger received was replaced but I had the same connectivity issue with the replacement.
The instructions were for an app that didn't function. Enel X was very responsive and had me using the correct app within minutes.
For me it was learning how to use the APP. I contacted the developers and through trial and error figured it out. I also had to be aware of my driving needs to override the app when i needed charging during the day.
None. Everything has been working fine.
Outside of having to replace the faulty charger once, I really do not have any concerns
None
The charger we received has been replaced by contacting Customer Service due to WIFI not functioning on the original unit. The replacement unit seems to be functioning fine and so far no concerns with WIFI connectivity.