Cleaner EV Charging

Ameren Missouri's Phase 1 Pilot Project Update

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EXECUTIVE SUMMARY

From 2020 to 2022 Ameren Missouri's Charge Ahead program is incentivizing the deployment of better electric vehicle (EV) charging infrastructure for their customers that will encourage EV adoption and contribute to decarbonizing the transportation sector. WattTime is helping Ameren Missouri evaluate the marginal GHG impacts of the overall program and identifying strategies to achieve better carbon reduction performance by enabling EV infrastructure with Automated Emissions Reduction (AER).

WattTime and Ameren Missouri are evaluating the incremental benefits that AER can provide for EV charging in the St. Louis area in a two-phase pilot program, which started in January 2020. WattTime has completed the evaluation of Phase 1, which tested AER on ten (10) residential EV charging stations. AER was tested with the JuiceNet Green software and JuiceBox EV chargers from Enel X. The evaluation resulted in positive outcomes for the four Phase 1 objectives:

1. AER-enabled EVSE is available, functional, and practical in Ameren Missouri territory
2. EV drivers can use the technology relatively easily and had no persistent complaints
3. JuiceNet Green AER technology reduced carbon emissions by 1.1%
4. Performance improvement opportunities identified during the pilot are expected to result in about 4.6% carbon savings in Phase 2 of the pilot.

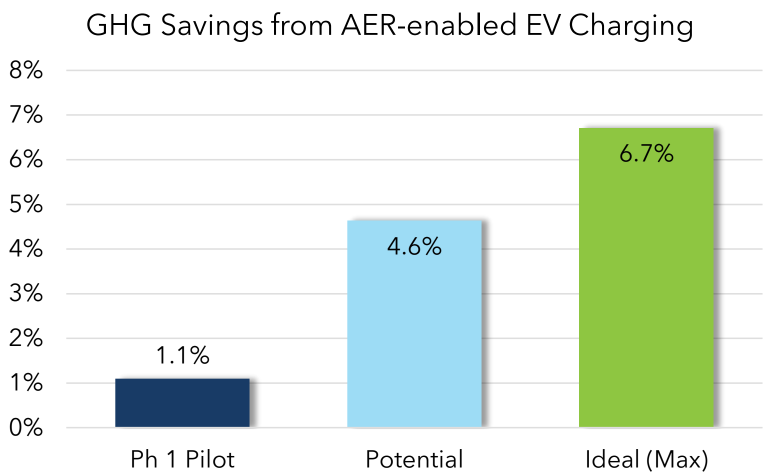

Figure 1: Comparison of actual CO_2 savings measured, potentially achievable savings, and ideal (or maximum theoretical) savings for the pilot evaluation period.

The ideal CO_2 savings, or the maximum possible, during the pilot was 6.7%, but this will not always be the upper limit. Ideal savings will increase as more renewables are added to the electricity grid in the Midcontinent Independent System Operator (MISO) region (with more renewables, carbon reductions up to 100% are achievable). As the ideal savings increases, the potential savings of 4.6% will likewise continue to increase over time.

WattTime is encouraged by the positive outcomes the Phase 1 pilot and recommends proceeding to Phase 2, which will offer AER-enabled EVSE to a wider group of Ameren Missouri customers.

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 viable and successful can be renewed for another two years.

One of the key benefits of EVs is the reduction of air pollution such as NOx and greenhouse gases (GHG). During regulatory negotiations, Ameren Missouri agreed to implement a pilot to evaluate WattTime technology as a software solution to reduce GHG emissions as measured using WattTime's marginal emissions dataset. Ameren Missouri is exploring 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 in real-time. WattTime provides this real-time data (and a 24-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 is broadly called Automated Emissions Reduction (AER).

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

Enel X uses WattTime emissions data to offer EV drivers the choice to charge their cars with lower-carbon electricity. The product is called JuiceNet Green (an example of AER) 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 where the grid is primarily served by fossil-fuel resources to times with more renewable or low-carbon electricity. For example, a driver can set a 7:00 AM departure time, and JuiceNet Green will automatically choose the cleanest moments to charge throughout the night while making sure the car is fully charged in the morning.

3. Ameren Missouri's AER for EV Charging Pilot

Ameren Missouri supports reducing GHG emissions and accelerating the transition to renewable energy and recognized that WattTime may provide an additional program option for customers interested in minimizing the carbon emissions related to their EV charging. For these reasons, Ameren Missouri decided to develop an internal pilot program to evaluate WattTime.

WattTime was contracted at no cost to Ameren Missouri to assist in the evaluation of the emissions-reduction potential from using AER to reduce the emissions from EV charging. A small-scale pilot project would be the first step to determining whether the technology could produce the desired benefits and, if so, Ameren Missouri would consider offering the technology to their customers.

Pilot Phase 1: Ameren Missouri Employees, 10 Chargers

The Enel X JuiceNet Green product was the first to offer AER for EV charging in the marketplace and was selected for Phase 1 of the pilot project. Here are the key details about Phase 1:

- 10 users (Ameren Missouri Employees who live in the St. Louis, Missouri area)
- EVSE with AER: JuiceBox with JuiceNet Green (Provided by Enel X)
- **Objectives:**
    1. Demonstrate the practicality of EV charging with AER in Ameren Missouri territory
    2. Evaluate the ease-of-use for the end-user
    3. Measure the CO_2 emissions reduction achieved by JuiceNet Green in Phase 1
    4. Estimate the CO_2 emissions reduction potential from EV charging with AER that could be achieved by future programs

Pilot Phase 2: Ameren Missouri Customers

An expanded pilot to offer EV charging with AER to an as-of-yet undetermined number of Ameren Missouri customers is tentatively planned to follow if the Phase 1 pilot validates the potential benefits.

PROJECT STATUS

1. Timeline Review

A high-level recap of the timeline to-date is shown in Figure 2. Ameren Missouri filed an extension request on January 1, 2020 with Missouri PSC to allow for a two-phase pilot of EV charging with AER to be performed. This date is the unofficial kickoff of the project and there was significant work and planning done prior. Ameren Missouri recruited ten (10) Ameren employees to participate in the Phase 1 pilot by mid-February. Enel X provided and Ameren installed JuiceBox EVSE hardware at the home of the participants in March and early April.

WattTime evaluated the GHG emissions reduction performance during the three months of September through November. A survey for user feedback was sent in early October.

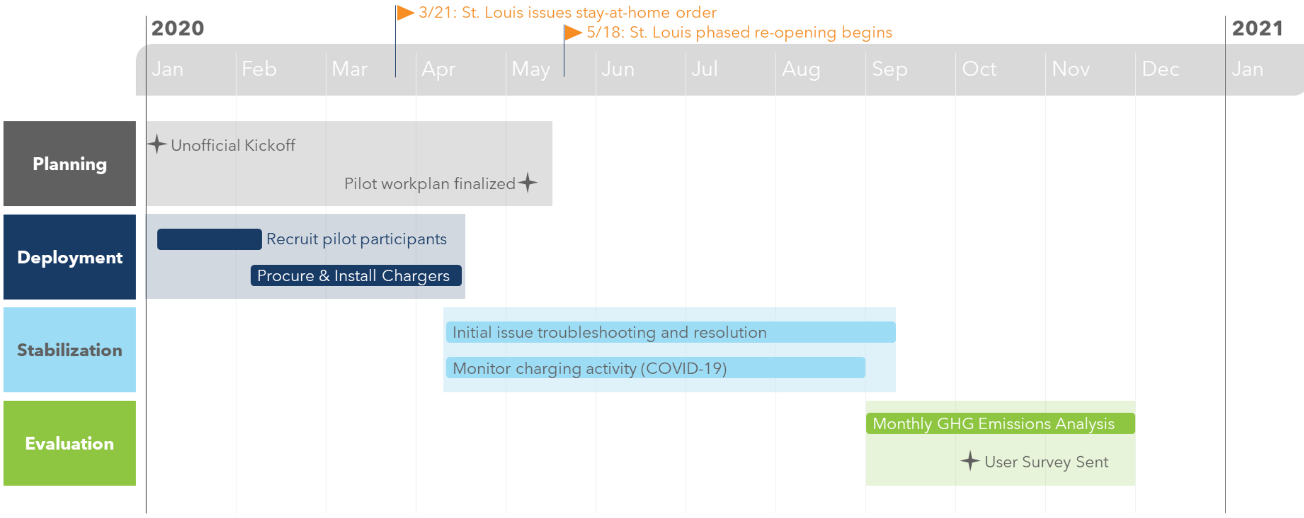

Figure 2: Phase 1 pilot project timeline

2. Monitoring Activity and Participation

By September, all ten users were online and charging activity had increased and stabilized since the start of the pandemic.

There were two primary circumstances which caused a delay to the start of the performance evaluation period. First, during the initial months of operation, four users experienced difficulty with the Wi-fi connectivity of their JuiceBox, and these four units were replaced by Enel X.

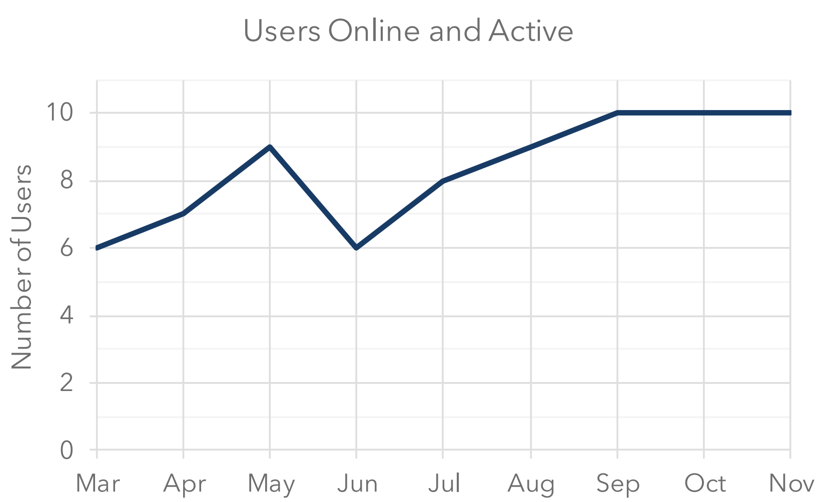

Figure 3: Monthly number of users with at least one charging session. All ten users were online and active starting in September and through November.

Second, the COVID-19 pandemic reduced the frequency and regularity of driving and charging. Driving and charging activity was limited for the first three months after the pilot started, likely due to the stay-at-home order issued in St. Louis on March 19th. Increased driving activity roughly corresponds with when the phased re-opening of St. Louis began on May 18th. The pattern of stabilized usage from June through November can be observed in the chart below, however this pattern was not obvious in the midst of this pilot period. It is still unclear how the COVID-19 pandemic has re-shaped the balance of work at offices and homes in the long-term, and how average driving patterns will be affected.

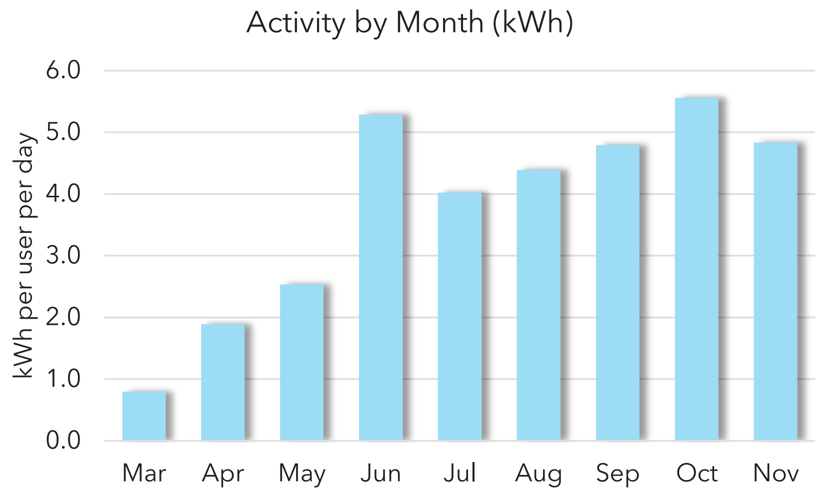

Figure 4: Activity is indicated by the amount of charging energy (kWh) per user per day. EV usage was relatively low in March through May, increased in June, then stabilize around an average of just under 5 kWh per user per day.

3. Next Steps

If Ameren Missouri is encouraged by the early results, the pilot program can be extended and/or expanded. Phase 1 of the pilot can be extended for a longer period with the same 10 users, provided the users are willing. Initial discussions indicate that Phase 1 can be relatively easily extended. If the stakeholder consensus is to proceed into Phase 2 of the pilot (to offer AER-enabled EV Charging to a broader set of Ameren Missouri customers), WattTime can again assist with planning, execution, and evaluation. Proceeding to Phase 2 is likely to take more consideration and planning as it would be a customer-facing pilot program which would likely require regulatory approval.

PHASE 1 PILOT 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 according to some key questions that drive this 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 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 the Phase 1 pilot, Enel X's JuiceNet Green has shown the ability to start and stop a user's charging in response to the variation in marginal operating emissions intensity data provided by WattTime.

Enel X is the first company to make an AER-enabled EV charging station commercially available. The Enel X 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.

WattTime evaluated whether the JuiceNet Green system would start and stop charging during a session to prioritize lower-emissions intervals over higher-emissions intervals. WattTime verified that JuiceNet Green was able to perform this function.

The technology will be practical if it is available, functional, and produces the intended results in Ameren Missouri territory. JuiceNet Green is available and functional in the Ameren Missouri territory, and the emissions reduction performance was also measured and will be described next.

2. Example of JuiceNet Green Reducing Carbon Emissions

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 unplugged. For this pilot, this immediate charging behavior is considered the baseline for evaluating the emissions reduction of an EV charger that is controlled to reduce emissions.

JuiceNet Green reduces emissions associated with EV charging by shifting charging energy into intervals when the grid has lower emissions. When the EV is plugged in, JuiceNet Green 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 enables charging during times of cleaner energy and disables charging during times of dirtier energy while ensuring a full charge is reached by the end of the session.

Figure 5 shows a real example from the pilot from September 23. This user plugged in their EV around 4:30 pm and had a 7:00 am departure time constraint. The EV needed 16 kWh to be fully charged before departure. WattTime simulated the baseline where the EV would charge at the maximum rate of 3.9 kW for about 4 hours until fully charged. The actual charging energy was delivered during times that the marginal operating emissions rate (MOER) was lower than during the baseline charging.

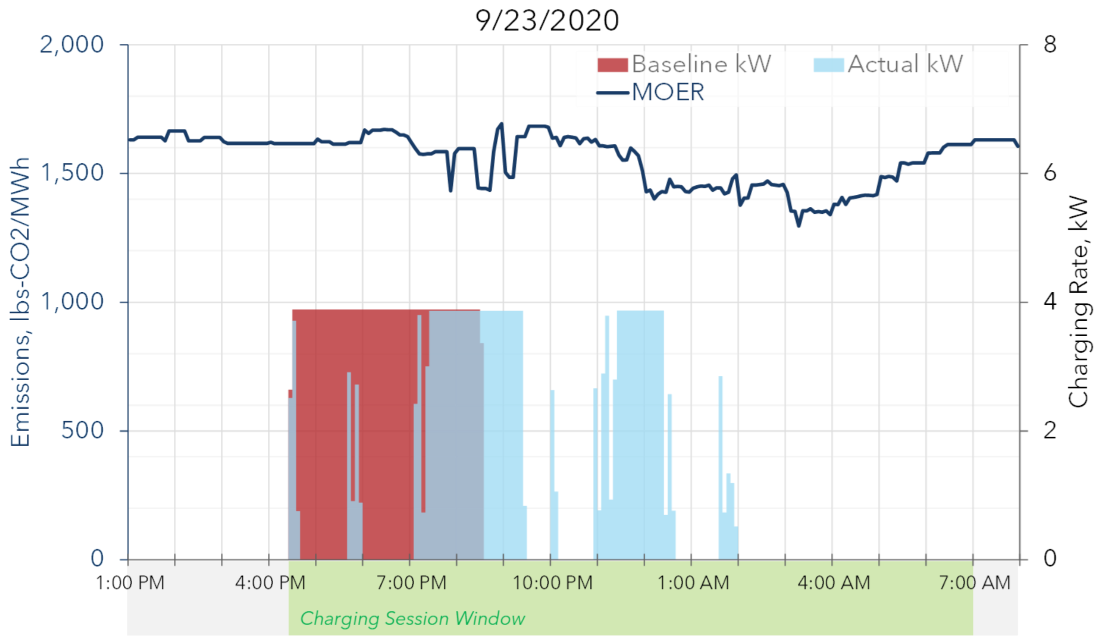

Figure 5: An example charging session from the pilot and the simulated baseline for the session. Vehicle charging occured during times with lower emissions rates, causing fewer emissions.

3. Phase 1 Pilot Results Summary

WattTime analyzed the emissions reduction performance of JuiceNet Green during the evaluation period from September 1, 2020 through November 30, 2020. The methodology for this analysis is detailed in "Appendix A: Methodology." Carbon savings varied by user from less than 1% to more than 5%, and by month. In total, 80 pounds of carbon were saved, or 1.1%, compared to the baseline simulations during this evaluation period.

Table 2: EV charging analysis summary by user during the evaluation period.

Unit ID (ending)	# of Sessions	Charging Duration per Session (hrs, avg)	Session Duration (hrs, avg)	% of Session Spent Charging	kWh Total	kWh per session	CO2 Saved (lbs)	CO2 Saved (%)
...346020625524	65	2.4	11.7	21%	687	10.6	8	0.7%
...227020625325	43	2.1	9.2	23%	449	10.4	11	1.5%
...132020625524	68	2.8	12.2	23%	741	10.9	18	1.5%
...569020625524	34	2.2	14.4	15%	273	8.0	9	2.0%
...166020625519	91	1.9	16.3	12%	518	5.7	8	0.9%
...568020625525	10	2.5	39.2	6%	113	11.3	10	5.5%
...407020627124	26	3.4	12.4	28%	513	19.7	7	0.9%
...526120628324	86	2.2	8.1	27%	779	9.1	3	0.2%
...865120628324	11	8.6	17.2	50%	322	29.3	3	0.6%
...589220621724	19	2.6	24.8	10%	182	9.6	4	1.2%
Totals	453	30.6	165.6		4,576		80	
Average by/per user	45	3.1	16.6	21%	458	12.5	8	1.5%
Average of all data		2.5	13.3	20%		10.1		1.1%

4. Analysis of Potential Future Performance

There is potential for improvement of the emissions reduction performance of JuiceNet Green. This is demonstrated using the previous example from Figure 5. The updated graph in Figure 6 shows how the charging strategy could have been improved to further reduce emissions, by aligning each charging interval with the lowest marginal emissions rates.

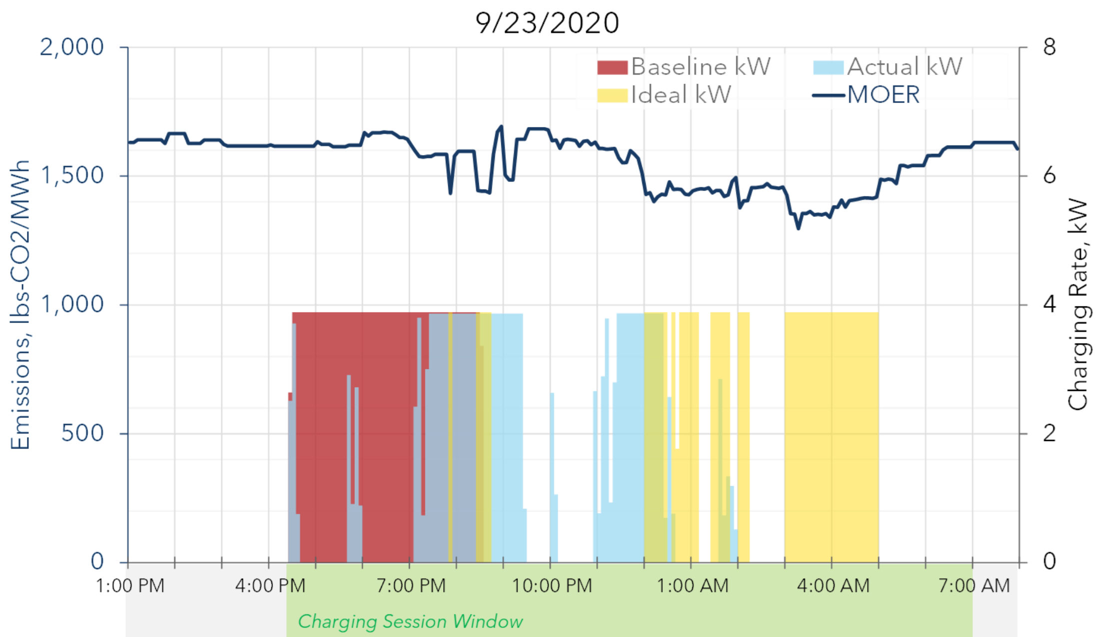

Figure 6: The ideal charging behavior is indicated, which would result in the lowest possible emissions for the charging session.

This "Ideal" performance is the best that could have been achieved for this time period when measured against this MOER signal. However, this ideal performance is not realistically achievable because it is not known in advance and would be achieved only with a perfect forecast (a forecast that perfectly ranks all intervals from cleanest to dirtiest in advance).

The potential carbon savings for a particular session—the performance that is realistically achievable—lies somewhere in between what was achieved in the pilot and the ideal performance. WattTime evaluated its forecast performance for the evaluation period and based on the average charging duration and session duration to determine the potential savings for this application as a % of ideal savings. For this application, the potential savings ranges from 66-73%. For the purposes of this report, a potential savings performance of 69% of ideal was used which corresponds to a charging session of 12 hours with 3 hours of charging.

If the WattTime forecast was used at the beginning of each session to plan the time of optimal charging and the On/Off control perfectly followed the plan, about 4.6% CO_2 savings would have been achieved during this evaluation period.

However, at the time of the pilot, the JuiceNet Green software was not yet using the latest version of the WattTime MOER forecast. WattTime believes that this represents the biggest opportunity for improving the performance of JuiceNet Green. Enel X is in the process of integrating the newest WattTime MOER forecast. When this is complete (expected early 2021), the performance is expected to improve to around 4.6% carbon savings (equivalent to 339 pounds of CO2 for this evaluation period).

Table 3: Comparison of actual, potential, and ideal CO_2 savings for the pilot evaluation period by user.

Unit ID (ending)	# of Sessions	kWh Total	CO2 Saved (lbs)	CO2 Saved (%)	Potential CO2 Savings (lbs)	Potential CO2 Savings (%)	Ideal CO2 Savings (lbs)	Ideal CO2 Savings (%)
…346020625524	65	687	8	0.7%	50	4.5%	72	6.5%
…227020625325	43	449	11	1.5%	33	4.5%	47	6.5%
…132020625524	68	741	18	1.5%	56	4.7%	81	6.8%
…569020625524	34	273	9	2.0%	22	5.0%	32	7.2%
…166020625519	91	518	8	0.9%	48	5.8%	69	8.3%
…568020625525	10	113	10	5.5%	18	10.2%	27	14.8%
…407020627124	26	513	7	0.9%	28	3.4%	41	5.0%
…526120628324	86	779	3	0.2%	51	4.1%	73	5.9%
…865120628324	11	322	3	0.6%	17	3.4%	25	4.9%
…589220621724	19	182	4	1.2%	17	5.8%	24	8.4%
Totals	453	4,576	80		339		490	
Average by/per user	45	458	8	1.5%	34	5.1%	49	7.4%
Average of all data				1.1%		4.6%		6.7%

The Effect of Charging Duration

A pattern that appeared in the data was that the savings and potential for savings was higher when a smaller portion of the total session window was needed for charging. Figure 7 shows this inverse relationship using average metrics over 3-month evaluation period for each of the ten users (along with a line of best fit using an exponential equation). This relationship should be considered when evaluating potential program opportunities (for example, short duration fast-charging may not have as much opportunity for GHG savings).

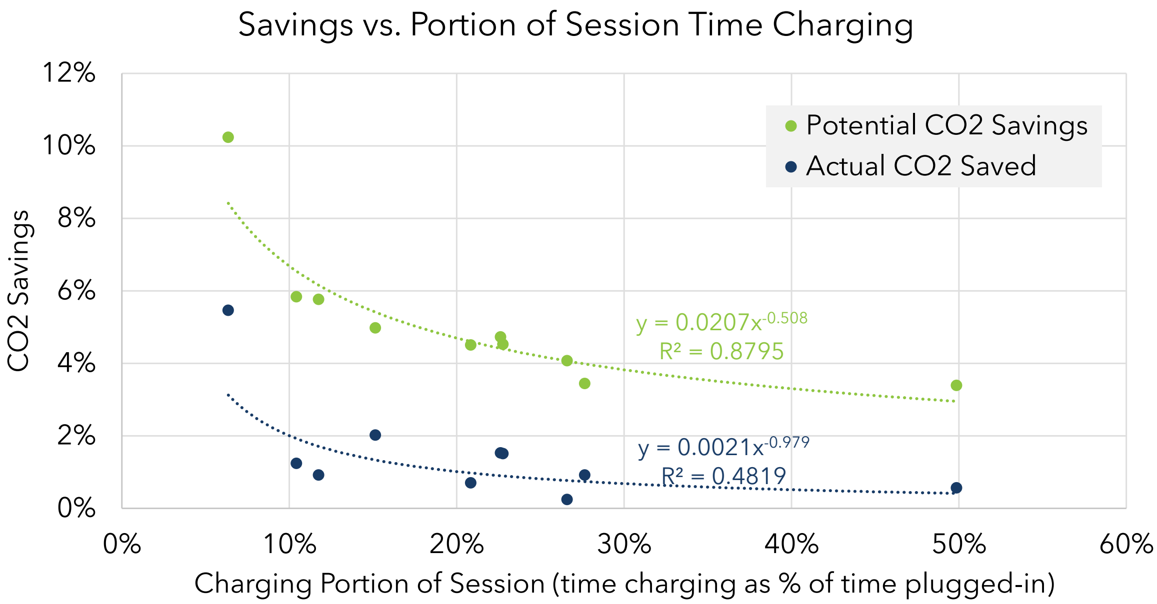

Figure 7: If less of the plugged-in window is needed for charging, the potential carbon savings increases.

USER FEEDBACK

WattTime requested feedback from the 10 Ameren employee users in the form of a survey, which was initially sent to them on October 5, 2020. All ten surveys were completed and returned by October 15, 2020.

Here are some takeaways from the survey responses:

- 100% response rate
- 90% of users prefer using the Mobile App to interact with JuiceNet
- 90% of users did not have their mobility affected by JuiceNet Green
- The priorities for this group are, in order: charging cheaply (1.6), quickly (2.0), cleanly (2.4) [These (values) are the priority averages of the group with 1 being highest]
- Even though users have the option to override the "Green" function each time they plug in, none of the users are "often" or "always" overriding this functionality.
- 40% of users had no issues or complaints and the issues other users faced had been resolved by the time the survey was completed.

Overall, the feedback was very positive. There were no major complaints left unresolved, and there had been no persistent mobility issues. Users gave good qualitative suggestions for improvements. There is no indication that these users are losing patience or would not want to continue to use JuiceNet Green. This feedback is encouraging in support of an extension of the Phase 1 pilot, and also a good sign for a positive experience for new users in the Phase 2 pilot.

DISCUSSION & RECOMMENDATIONS

The Phase 1 pilot was successful in evaluating the potential of AER-enabled EV charging technology and achieved positive outcomes for Ameren Missouri's objectives.

Phase 1 Pilot Objectives	Results
1. Demonstrate the practicality of EV charging with AER in Ameren Missouri territory	JuiceNet Green—an AER-enabled EV charging technology—is available, functional and was demonstrated to achieve emissions reduction in Ameren Missouri territory.
2. Evaluate the ease-of-use for the end-user	The pilot users of JuiceNet Green have been using the technology for 8-9 months and have no unresolved complaints. Some users had initial difficulty with the app and their feedback has been communicated to Enel X for planning of software updates.
3. Measure the CO_2 emissions reduction achieved by JuiceNet Green in Phase 1	JuiceNet Green achieved an emissions reduction of 80 pounds or 1.1% during the evaluation period compared to an immediate charging baseline.
4. Estimate the CO_2 emissions reduction potential from EV charging with AER that could be achieved by future programs	AER-enabled EV charging has the potential to achieve 4.6% carbon savings. JuiceNet Green performance should approach this level after the next software upgrade.

1. Future Carbon Reduction Performance

The ideal CO_2 savings of 6.7% will not always be the upper limit. This value represents the average optimal result for this set of users, for the charging sessions evaluated. Some users had a higher ideal savings, up to 14.8%. With a bigger sample size, the average savings will likely change, and the average may increase.

Ideal savings will also increase as more renewables are added to the electricity grid in the MISO region. 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. More variability in the MOER provides more opportunity for emissions savings from load shifting. If renewable energy becomes abundant to the point where curtailment occurs frequently, the ideal savings for some charging sessions will be 100%, as charging during times of curtailment means using renewable energy that would otherwise be thrown away.

As the ideal savings increases, the potential savings that can be achieved will also increase accordingly. The potential savings as a fraction of ideal will also increase as WattTime's forecasts are further improved.

All of these changes will continue to drive the potential carbon savings of 4.6% to increase over time.

2. Recommendations

Enel X is on the verge of a software update that WattTime expects will significantly improve the carbon savings performance of their JuiceNet Green technology. This update is estimated to be available to JuiceNet users in January 2021. WattTime recommends asking these users to extend their participation at least through April 2021. This would allow for another 3-month evaluation period (February through April). WattTime can evaluate carbon savings for the updated JuiceNet Green software during this Phase 1 pilot extension. This extension is subject to the willingness of the participants, but based on the feedback we've received, we expect a high participation rate.

In parallel, Ameren Missouri and WattTime can initiate the planning of Phase 2 of the pilot to expand the offer of AER-enabled EV charging to a wider group of Ameren Missouri customers. WattTime and Ameren Missouri can collaborate to further define how the Phase 2 pilot will be deployed and evaluated. We will need input from Enel X regarding their participation (and potentially other EVSE suppliers). The planning for Phase 2 and recruitment of users is likely to take a few months and this work can be done in parallel with the Phase 1 extension.

WattTime is supportive of both extending the Phase 1 pilot and initiating work on the Phase 2 pilot.

APPENDIX A: METHODOLOGY

Data Sources

EV charging data was gathered through the Enel X JuiceNet platform. Enel X 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 data from its Marginal Operating Emissions Rate (MOER) database to define the carbon intensity of the grid for this analysis. This data is stored at 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. The preliminary analysis performed during the pilot was performed with MOER V2.1 for the MISO_IL subregion. The Phase 1 results analysis shown in this report was performed with MOER V3.0 for the MISO_SAINT_LOUIS subregion.

Carbon Savings Calculation

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

WattTime simulated the baseline charging 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 savings for each session is the difference in marginal carbon emissions between the baseline and actual cases.

$$CO_2\ Savings\ [lbs] = \sum_{t=0}^{end\ of\ session} MOER_t \left[\frac{lbs\ CO_2}{MWh}\right] \times (Baseline\ Energy_t - \ Actual\ Energy_t)[kWh] \times \frac{1\ [MWh]}{1{,}000\ [kWh]}$$

Sources of Error, Potential Methodology Improvements

The rate of charging within a segment was simplified in this analysis to equal the average charging rate of each segment. Using raw time-series data instead of event data would allow the fidelity of the changes in 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 into the baseline definition.

APPENDIX B: ADDITIONAL DATA & RESULTS

The performance of the pilot group during the evaluation period is summarized below on a monthly basis.

Table 4: EV charging analysis summary by month during the evaluation period.

Month	# of Sessions	Charging Duration per Session (hrs, avg)	Session Duration (hrs, avg)	% of Session Spent Charging	kWh Total	kWh per session	CO2 Saved (lbs)	CO2 Saved (%)
September	150	2.3	11.6	24%	1,406	9.6	47	2.1%
October	170	2.6	13.0	22%	1,726	10.1	0	0.0%
November	133	2.5	15.7	18%	1,444	10.6	33	1.5%
Monthly Average	151	2.5	13.4	21%	1,525	10.1	27	1.2%
Total (Sept-Nov)	453				4,576		80	1.1%

Table 5: Comparison of actual CO2 savings, potential savings, and ideal savings for the pilot evaluation period by month of the evaluation period.

Month	# of Sessions	kWh Total	CO2 Saved (lbs)	CO2 Saved (%)	Potential CO2 Savings (lbs)	Potential CO2 Savings (%)	Ideal CO2 Savings (lbs)	Ideal CO2 Savings (%)
September	150	1,406	47	2.1%	121	5.3%	175	7.7%
October	170	1,726	0	0.0%	119	4.4%	172	6.4%
November	133	1,444	33	1.5%	98	4.2%	142	6.1%
Monthly Average	151	1,525	27	1.2%	113	4.7%	163	6.7%
Total (Sept-Nov)	453	4,576	80	1.1%	339	4.6%	490	6.7%