EVs@Scale

U.S. Department of Energy

EVs@Scale FUSE

Fall ‘24 Deep Dive

October 31, 2024

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

NREL/PR-5400-91860

Deep Dive Agenda (NREL Presentations)

Agenda	Title	Presenter	Time (MDT)
Introduction: EVaS MOST and FUSE Project Overview		Jesse Bennett	12:00 (10 min)
Vehicle Grid Integration	Consumer and Commercial Vehicles: Updated Smart Charge Management (SCM) Controls	Mingzhi Zhang	12:10 (22 min)
	Planning and Operations: Broad Regional Analysis Update	Manoj Kumar/ Steven Schmidt	12:32 (22 min)
	Interconnection: Uncontrolled Charging Impact Analysis	Nadia Panossian	12:54 (22 min)
Break (resume @ 1:30)			1:16 (14 min)
Vehicle Grid Integration	Knowledge Transfer and Decision Support: Grid Impact Simulations and SCM Mitigation	Shibani Ghosh/ Wenbo Wang	1:30 (22 min)
	Consumer and Commercial Vehicles: Opti-VGI SCM Management	Nithin Manne	1:52 (22 min)
Reliability/Resiliency	Reliable, Efficient Charging: Caldera Mid-route/Concentrated Charging	Andrea Mammoli/ Steven Schmidt	2:14 (22 min)
	Site Architectures: Laboratory and Field Demonstrations	Abdullah Hashmi	2:36 (22 min)
Conclusions		Jesse Bennett	2:58 (2 min)

Other Lab's presentation

EVs@Scale Laboratory Consortium

Leadership Council

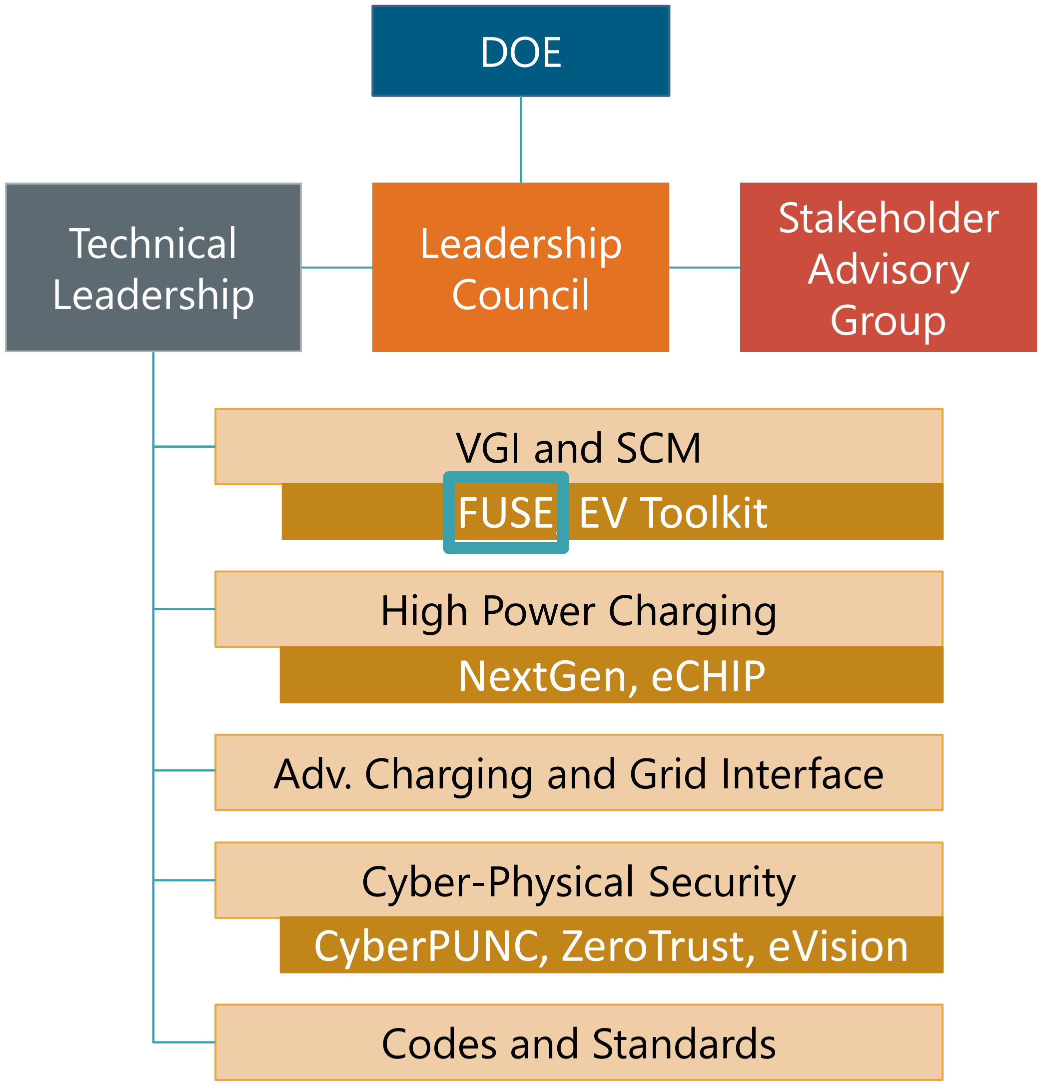
- Andrew Meintz (NREL, chair), Tim Pennington (INL, rotating co-chair), Don Stanton (ORNL), Summer Ferreira (SNL), Lori Ross (PNNL), Dan Dobrzynski (ANL), Bin Wang (LBNL)

Stakeholder Advisory Group

- Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure

Consortium Pillars and Technical Leadership

- Vehicle Grid Integration and Smart Charge Management (VGI/SCM): Jesse Bennett (NREL), Jason Harper (ANL)
- High Power Charging (HPC): John Kisacikoglu (NREL)
- Advanced Charging and Grid Interface Technologies (ACGIT): Madhu Chinthavali (ORNL)
- Cyber-Physical Security (CPS): Richard "Barney" Carlson (INL), Craig Rodine (SNL)
- Codes and Standards (CS): Ted Bohn (ANL)

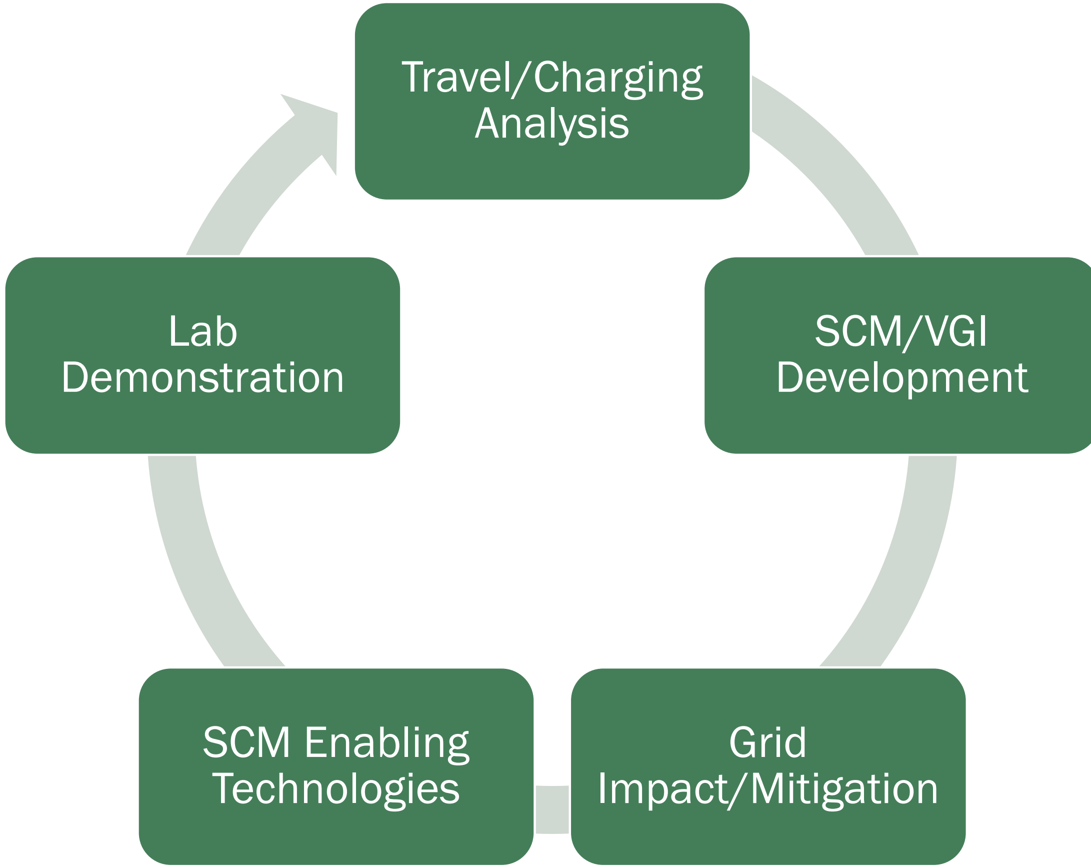


EVs@Scale FUSE - Approach and Outcomes

- This project will evaluate and demonstrate SCM and VGI approaches to reduce grid impacts from EVs@Scale as a result of the charging needs of the LD, MD, and HD on-road electrified fleet.

- **SCM/VGI Analysis**
  - Assess the potential charging demand for EVs@Scale and determine the uncontrolled charging grid impacts.
  - Develop and analyze the effectiveness of various VGI and SCM strategies at mitigating the grid impacts of charging EVs@Scale

- **SCM/VGI Demonstration**
  - Expand on existing SCM/VGI strategies to adapt to the evolving needs EVs@Scale throughout a wide range of vehicles and vocations.
  - Develop enabling technologies to demonstrate the potential for new and existing SCM and VGI in a laboratory and real-world environment.
  - Coordinate with Codes and Standards Pillar to determine the potential of existing technologies and need for future developments.



EVs@Scale MOST Framework

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MOST Framework: Mission -> Objective -> Strategy -> Tactics

Mission: The EVs@Scale Lab Consortium will advance charging technologies, systems, and infrastructure and their integration with the energy sector through joint R&D of the national laboratories with key stakeholders.

Objective

Objective	
Vehicle-Grid Integration	Achieve seamless integration and charging for EVs@Scale to enable synergistic coupling of the energy and transportation sectors.
Interoperability	Advance the connectivity, compatibility, and scalability of systems and technologies operating across the interfaces of an open, standards-based EV charging ecosystem.
Reliability and Resiliency	Improve the reliability of charging and enhance the ability of the electric grid to provide dependable power and robustly react and recover from adverse events
Cybersecurity	Advance the cyber-physical security posture across the EV charging ecosystem.

Strategies of Focus Today

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Strategies

Vehicle-Grid Integration	**Consumer and Commercial Vehicles**	**Planning & Operations**	**Interconnection**	Knowledge Transfer & Decision Support
Interoperability	Communications and Control	Codes and Standards	System Conformance	
Reliability and Resiliency	**Reliable, Efficient Charging**	Advanced High-Power Charging	**Site Architecture**	Resilient Infrastructure
Cybersecurity	Threat Scenarios & Vulnerability Assessment	Protect, Detect, Respond, & Recover	Secure Platforms & Supply Chains	

<u>Consumer and Commercial Vehicles</u>: Identify approaches to enable and leverage the effective and efficient integration of all classes of on- and off-road vehicles with the grid.

<u>Planning and Operations</u>: Identify pathways, support technology development, and advance smart charge management to effectively predict and control EV charging to mitigate potential grid impacts and reduce grid upgrades.

<u>Interconnection</u>: Identify approaches and solutions to address challenges hindering the establishment of safe, reliable, and streamlined utility interconnection processes.

<u>Knowledge Transfer and Decision Support</u>: Provide user-friendly national laboratory tools, data, and analyses to help stakeholders make vehicle-grid integration decisions.

<u>Reliable, Efficient Charging</u>: Develop new approaches to planning, design, and operations of charging equipment and sites to improve the reliability and cost of charging.

<u>Site Architecture</u> : Develop common, scalable approaches for the interaction and coordination of EV charging infrastructure with distributed energy resources, loads, and site energy management, while enabling vehicle-to-everything (V2X) charging.

FUSE Partnership Opportunities

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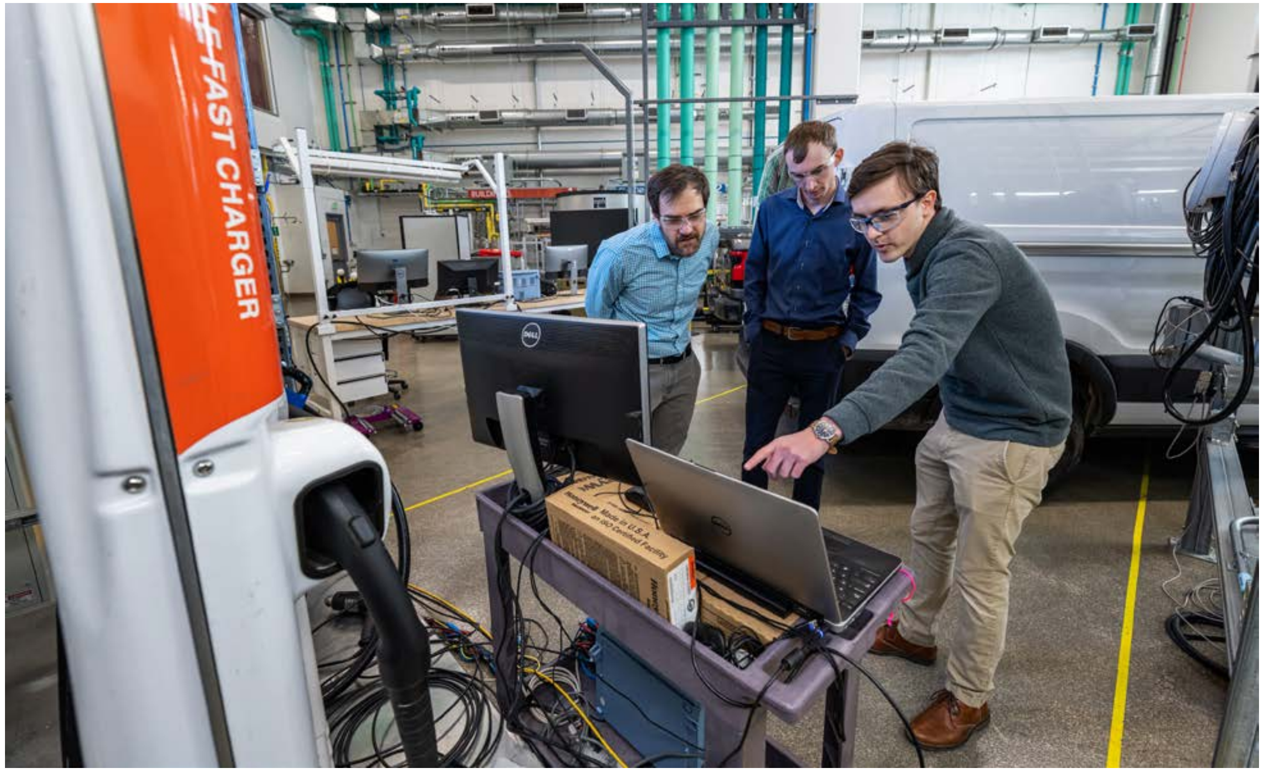
- **SCM demonstration/deployment for fleets**
  - TOU and LMP rates, DER integration, emission reduction
- **Broad regional analysis**
  - Utility and PUC Regional EV load planning (Caldera Tools)
- **Transform grid analysis into actionable outcomes**
  - Distribution planning with EVs, forecast impact areas…
- **Integrate EV loads into planning frameworks**
  - Enterprise software integration of FUSE analysis framework
- **Enabling Technology Demonstrations**
  - Field demonstrations of new SCM technologies
- **Community EV charging Plans**
  - Municipal and housing authorities, EV advocacy groups…
- **SCM Applications and Adoption**
  - Simplify SCM adoption in grid use cases, DERMS integration…



Interested in Partnering with FUSE? Contact:

FUSE Lead PI: Jesse Bennett: Jesse.Bennett@NREL.gov

ANL PI: Jason Harper: jharper@anl.gov

INL PI: Manoj Kumar: ManojKumar.CebolSundarrajan@inl.gov

Sandia PI: Andrea Mammoli: aamammo@sandia.gov

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Consumer and Commercial Vehicles: Updated Smart Charge Management (SCM) Controls

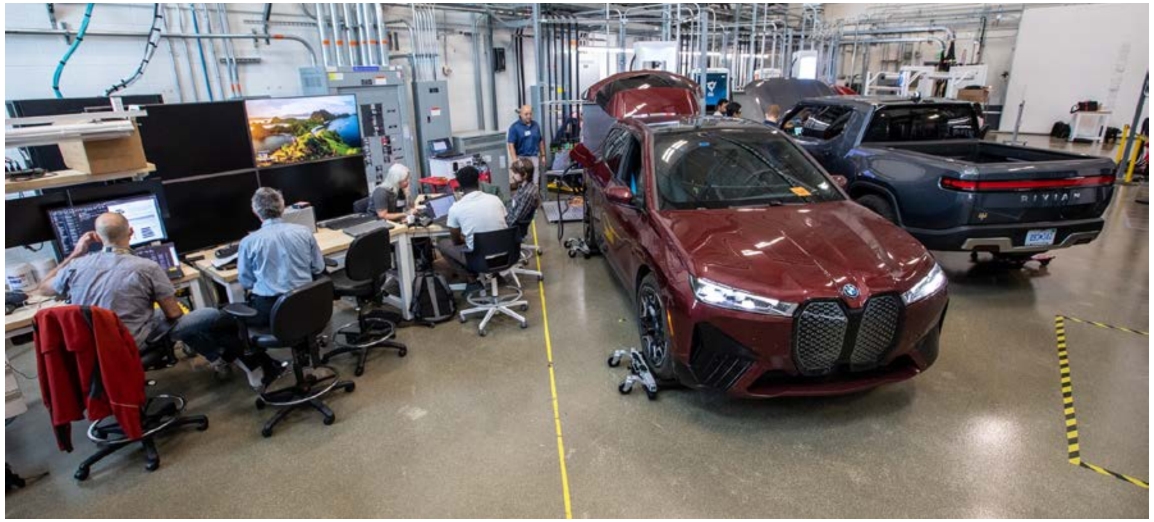
Mingzhi Zhang, NREL

October 31, 2024

EVs@Scale FUSE - Overview

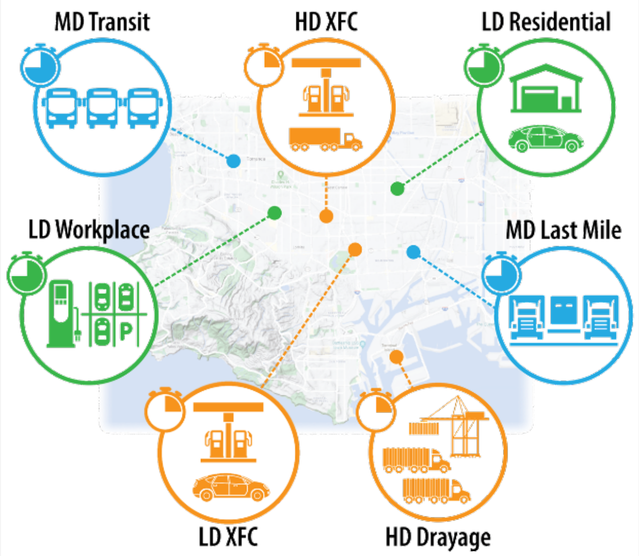
Objective:

- Develop an **adaptive ecosystem of smart charge management (SCM) and vehicle grid integration (VGI)** strategies and tools relevant to assess and reduce barriers to electrification throughout a wide geographic area and across numerous vocations

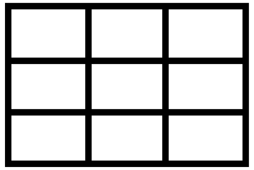


Outcomes:

- **Broadly identify limitations and gaps** in the existing VGI and SCM strategies to strategically shift PEV charging in time across a wide range of conditions
- **Develop enabling technologies** and demonstrate VGI approaches to reduce grid impacts throughout the entirety of the **LD, MD, and HD on-road electric fleet** while accounting for vehicle operational and energy requirements.
- **Determine SCM and VGI benefits** for consumers and utilities for EVs@Scale across the range of conditions (geographies and seasons) found in the US



Deep Dive Agenda: Smart Charge Management (SCM) Controls



SCM Controls Overview

SCM Control: Carbon Emission Reduction

SCM Control: Transformer Overloading Mitigation

SCM Controls: Overview

Strategy Name	Objective	Control Simulation	Grid Services
TOU Immediate	PEV driver responds to Time-of-Use incentives by charging at the beginning of TOU windows	Caldera Internal	Price Signals
TOU Random	Decentralized control randomly distributes EV charging within vehicle dwell and TOU windows	Caldera Internal	Price Signals, Capacity Deferral
Random Start	Decentralized control randomly distributes EV charging within vehicle dwell	Caldera Internal	Capacity Deferral
Centralized Control (Feeder Peak)	Centralized control shifts EV charging within vehicle dwell to minimize feeder peak	Caldera Internal	Capacity Deferral
Volt/VAR	Decentralized control provides reactive power support based on local power quality	Caldera Internal	Voltage Support
Global Voltage	Decentralized control shifts EV charging within dwell to reduce nearby grid voltage concerns	External Control	Demand Response, Voltage Support
BTM (Renewables)	Decentralized control shifts EV charging within dwell to reduce behind-the-meter peak demand	External Control	Demand Charge Mitigation, Max Renewables
Depot controls	Minimize difference between peak and mean using BTMS dispatch first, followed by EV charging dispatch	External Control	Demand Charge Mitigation
Carbon Emission Reduction (Renewable Following)	Minimize carbon emission of EV charging based on bulk grid emissions	External Control	Demand Charge Mitigation, Max Renewables
Transformer Overloading Mitigation	Decentralized coordinate EV charging under the same service transformer to avoid overloading the transformer	External Control	Transformer upgrade deferral

SCM Control: Carbon Emission Reduction

Apple's Grid Forecast for Home Energy Usage

About the Forecast

What's considered clean (or less clean) in your location is relative to the energy sources available on your grid. Throughout the day, the grid forecast highlights times when electricity is "cleaner" compared to other times.

Cleaner
During "cleaner" times, available energy sources may have lower carbon emissions. Even if you live in an area with limited sources of renewable generation, such as solar and wind, relatively cleaner energy may still be available. By shifting your electricity usage — like running appliances or charging EVs — to these cleaner times, you may be able to reduce the carbon impact of your home.

Less Clean
During "less clean" energy hours, the available energy sources powering the grid may emit more carbon into the atmosphere.

Energy consumers are becoming more and more active!

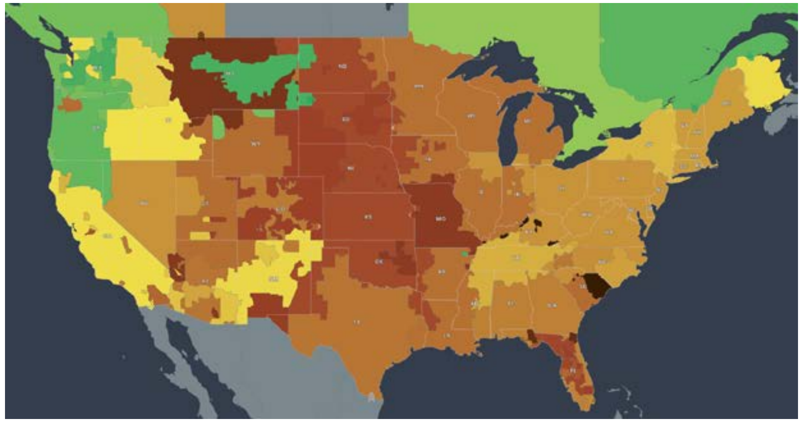
SCM Control: Carbon Emission Reduction

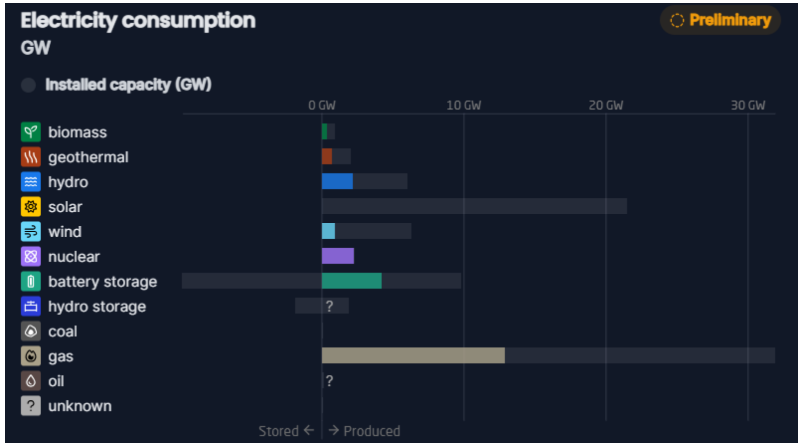
Electricity Maps: Carbon Intensity Map

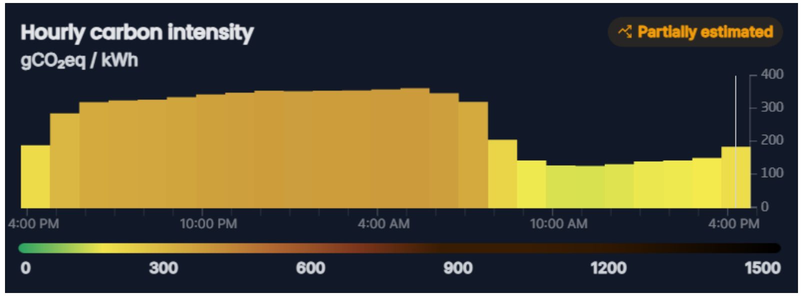
- **Dataset coverage**
  Offer hourly carbon electricity consumption and production data for over 50+ countries globally (and 200+ regions)

- **Power breakdown**
  Get insights into the production and consumption breakdown of electricity by power source (e.g. gas, solar).

- **Carbon intensity data in hourly granularity**
  Carbon intensity (in gCO2eq/kWH) of electricity consumed in a specific region, which takes into account the life-cycle emissions of electricity production.







Forecasting the emissions of the electrical grid in a specific location is a complex and challenging task with potentially massive impacts.

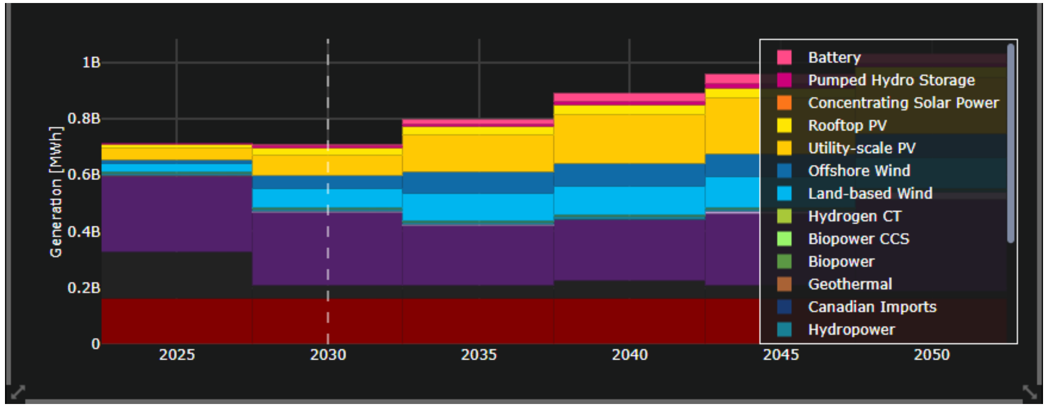
https://app.electricitymaps.com

SCM Control: Carbon Emission Reduction

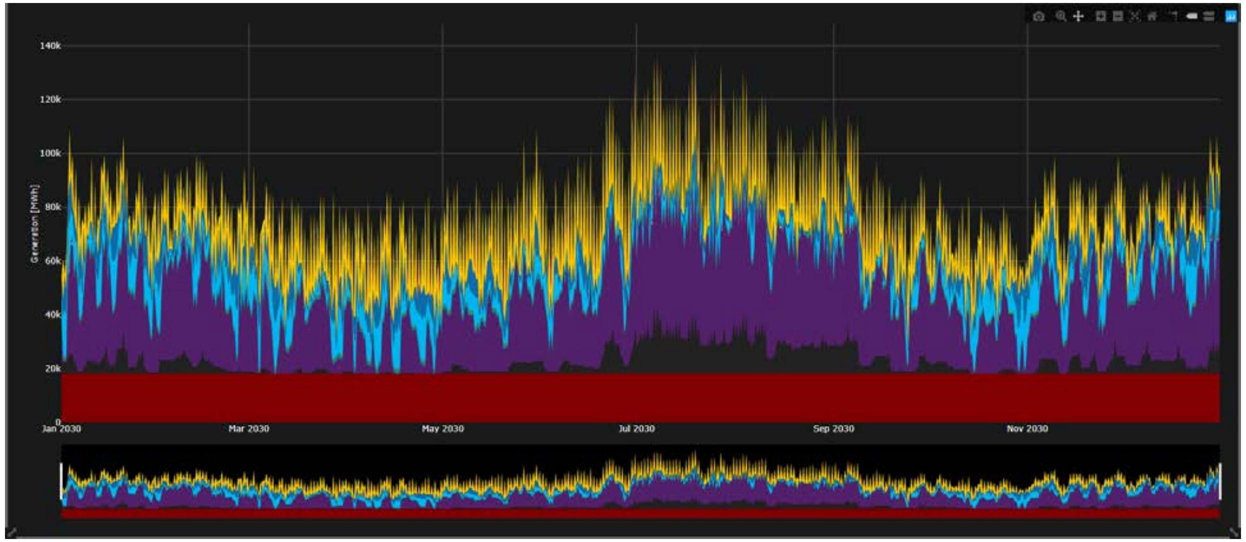
Cambium Datasets (NREL)

- Cambium is annually updated and expands on the metrics reported in NREL's Standard Scenarios—another annually released set of projections of how the U.S. electric sector could evolve across a suite of potential futures.

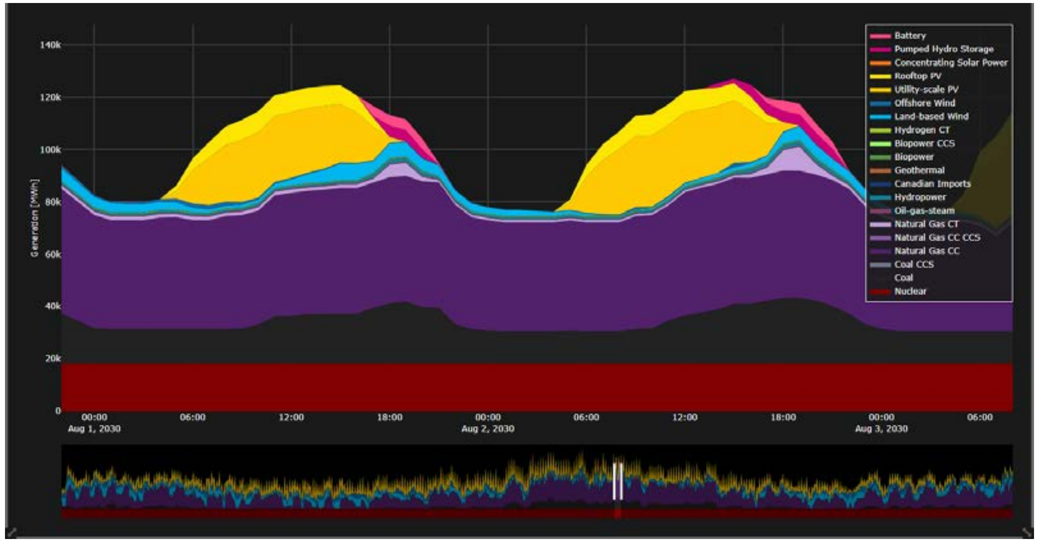
- It contain modeled hourly emission, cost, and operational data for a range of possible futures of the U.S. electricity sector through 2050, with metrics designed to be useful for forward-looking analysis and decision support.



Energy mix of PJM (Mid-case Scenario)



Annual energy mix variation of PJM (2030 Mid-case Scenario)

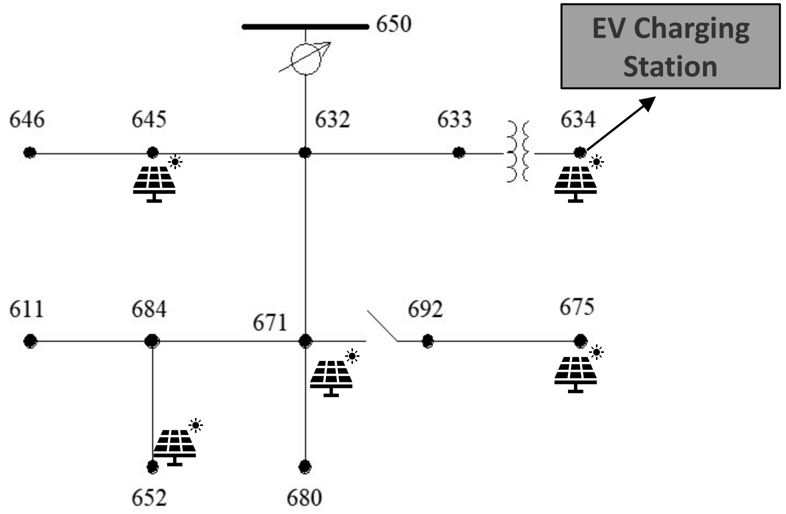


Daily energy mix variation of PJM (2030 Mid-case Scenario)

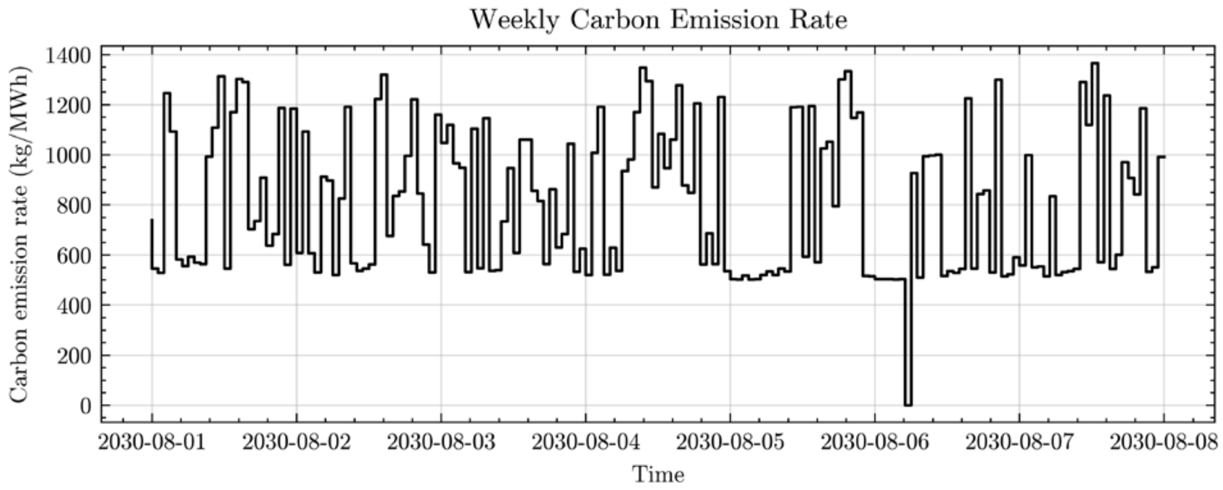
SCM Control: Carbon Emission Reduction

Case Setup: Workplace Charging Scenario

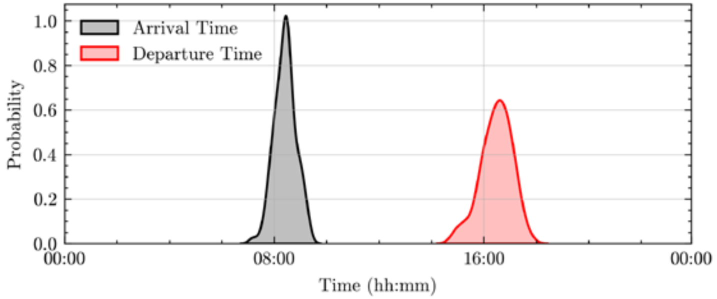
- 100 EVs with different arrival and departure time.
- Each EV has a random initial SOC (20%-60%).
- EV battery size: 60 KWh.
- Maximum charging power of EV: 9.6 KW.
- Distribution system: Modified IEEE 13 bus feeder (3-phase unbalanced system) with 1000 KW PV installment capacity.
- Carbon Emission Rate: PJM Area 2030 Mid-case Scenario (NREL Cambium Dataset)



Modified IEEE 13 bus feeder



Short-run marginal carbon emission rates



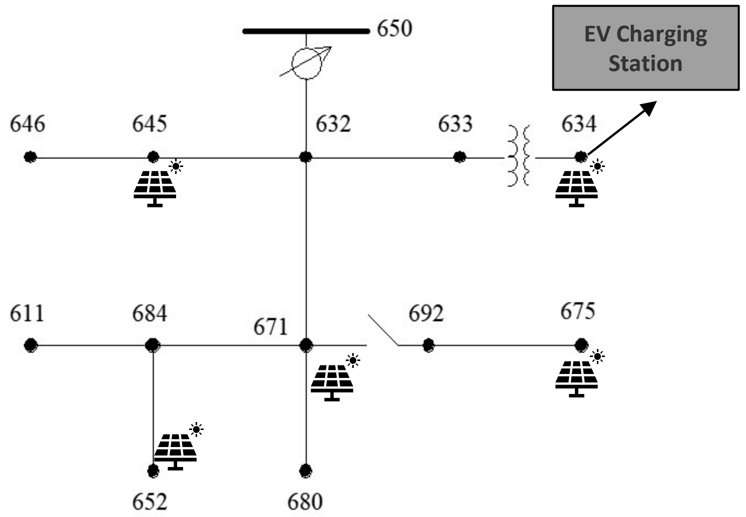
Arrival/departure distributions of EVs

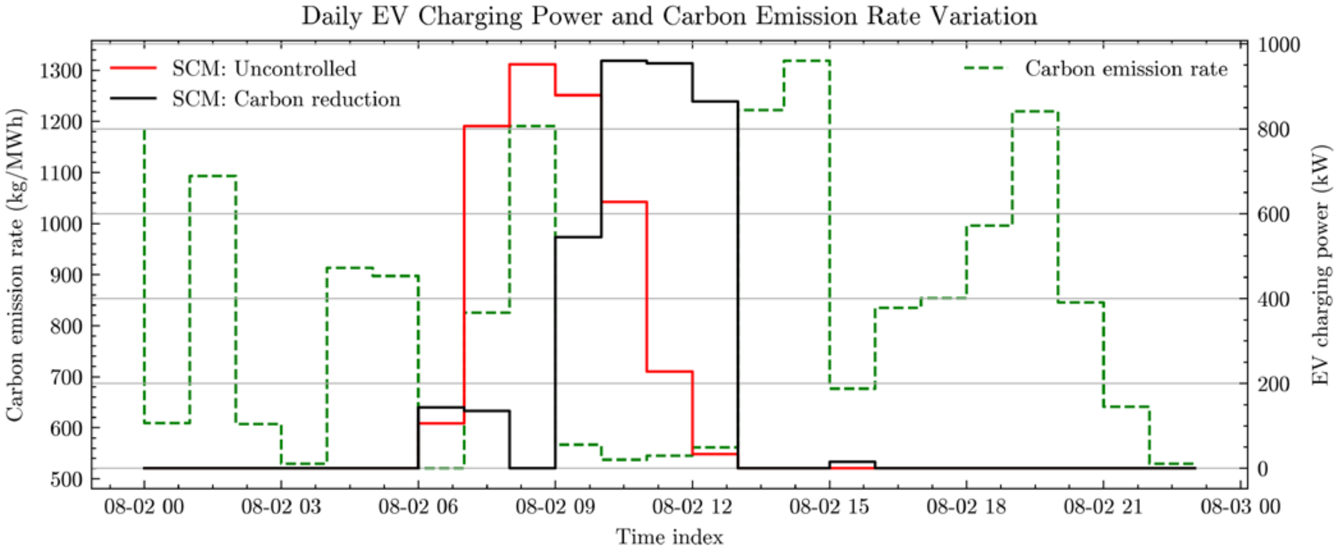
SCM Control: Carbon Emission Reduction

Daily EV Charging Station Operation Scenario:

- SCM Objectives:
  1) Meet the energy needs of EVs prior departure;
  2) Minimize the total carbon generation under the marginal carbon emission rates for the corresponding region’s load.

- Based on the hourly varied marginal carbon emission rate, the carbon reduction-based EV smart charging control method can effectively shift the EV charging loads to low-carbon emission periods, and thus effectively align EV charging loads with renewable energy generation.





Daily charging energy needs	Carbon emission (SCM: Uncontrolled)	Carbon emission (SCM: Carbon Reduction)	Reduction ratio
3.63 MWh	2832.65 kg	2028.01kg	28.4%

Adopting carbon reduction-based SCM, the EV charging station can reduce carbon emissions by 28.4% during daily operations.

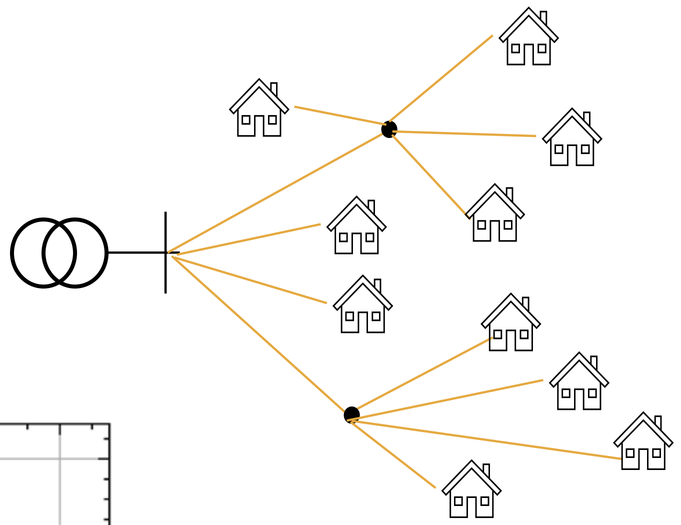
SCM Control: Transformer Overloading Mitigation

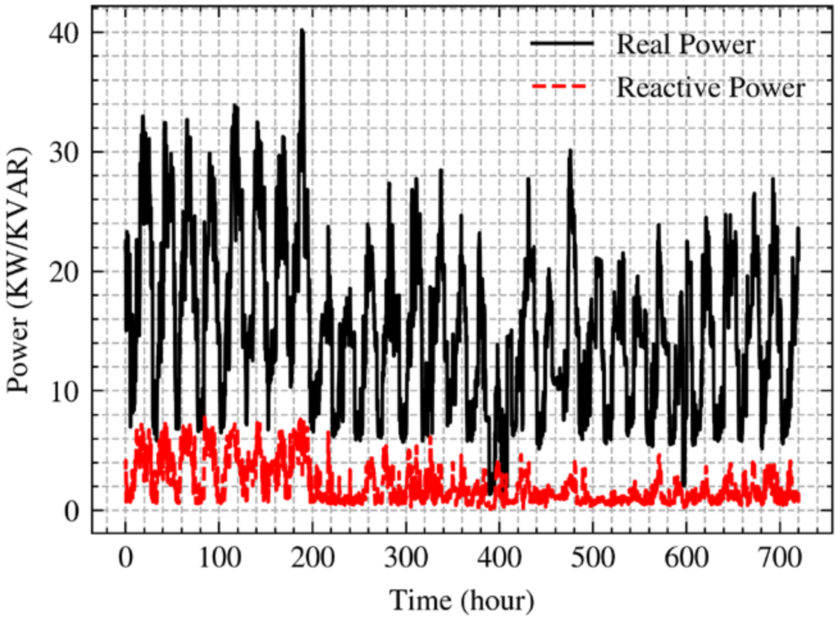
SCM Control: Transformer Overloading Mitigation

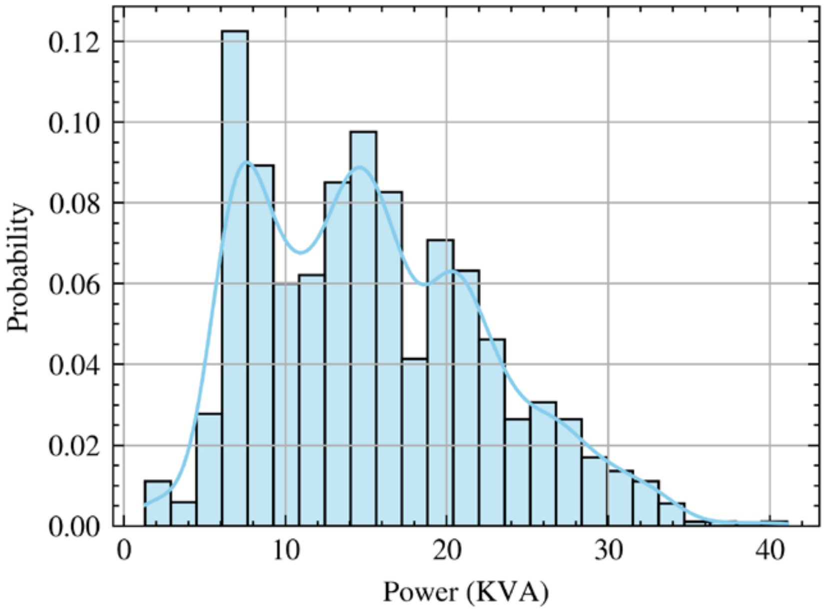
Service transformer level EV Integration Scenario:

- Service transformer: 50 KVA
- Base Load: Historical transformer loading date of September
- Customers: 10
- EV numbers: 10 (100% penetration rate),
- EV maximum charging power: 9.6KW.

1 transformer serving 10 customers





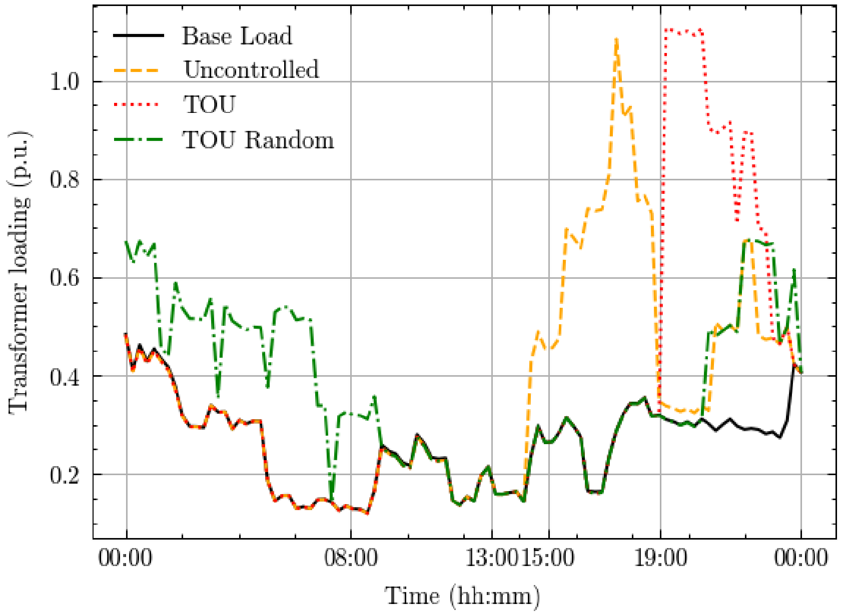


Service transformer loading conditions (base load in September)

SCM Control: Transformer Overloading Mitigation

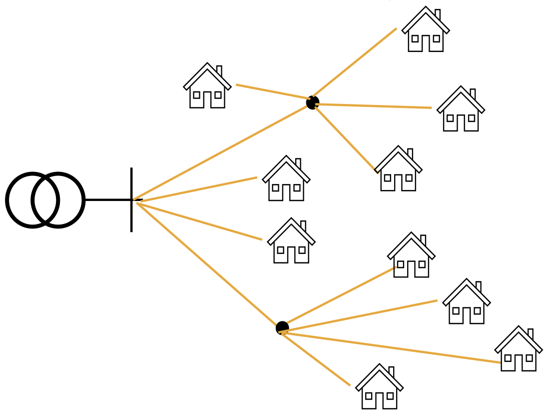
Service Transformer-level EV Integration Scenario:

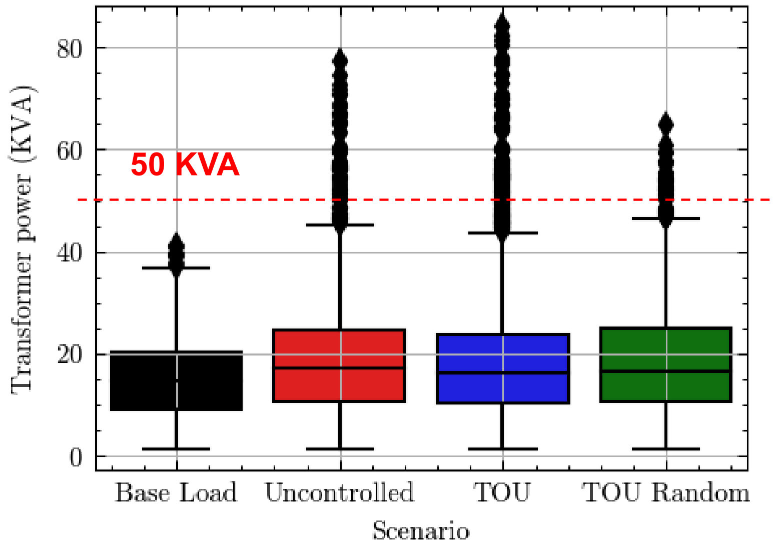
- **Uncoordinated SCM strategies**:
  1) Uncontrolled: Start charging immediately when plug-in.
  2) TOU: Start charging as soon as the TOU off-peak price starts.
  3) TOU Random: Start charging randomly during low-price periods (while still meeting energy requirements).



Daily service transformer loading

50 KVA transformer serving 10 customers



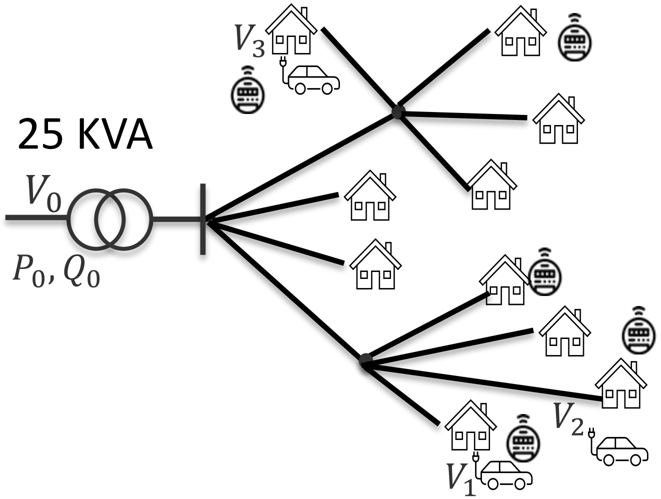


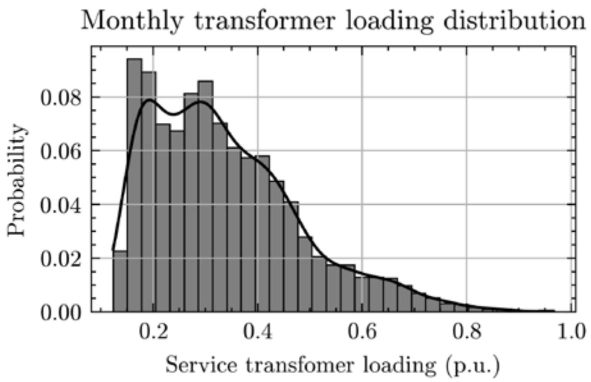
Monthly service transformer loading with EV integration

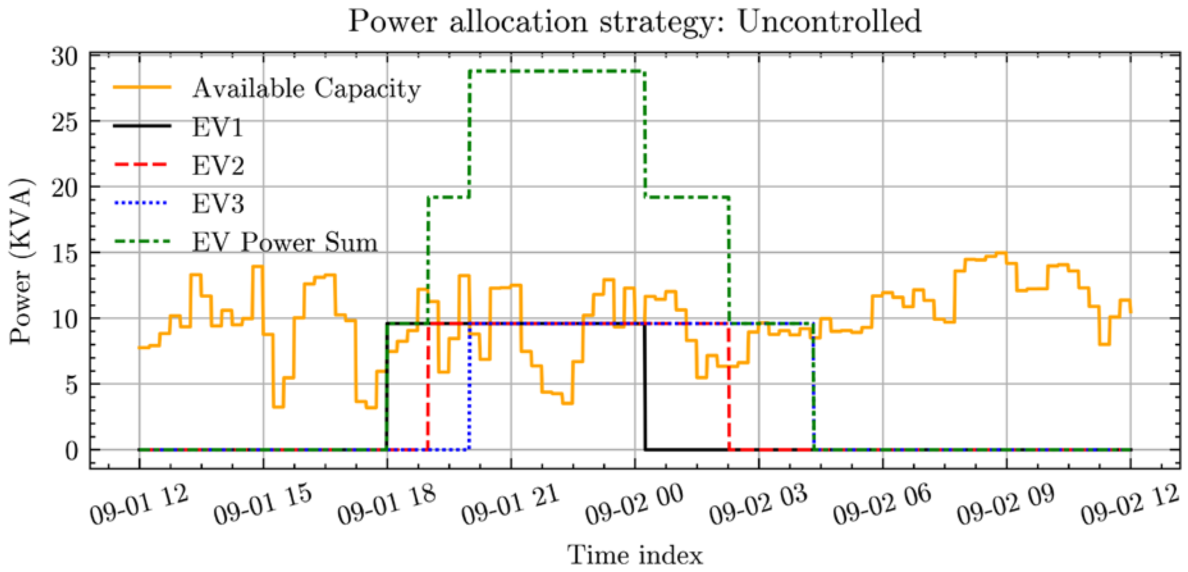
Uncontrolled charging and TOU-based EV charging control can both overload service transformer under high EV penetration ratio.

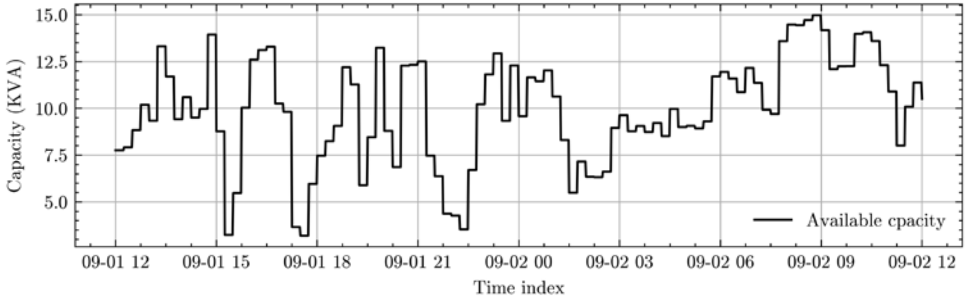
SCM Control: Transformer Overloading Mitigation

- **SCM Control Objective:**
  - Coordinate EV charging under the same service transformer to avoid overloading the transformer.
- **Case Study: Daily Coordinated EV Charging for Transformer Overloading Mitigation**
  - 25 KVA transformer, 3 EVs;
  - EV charging power: 9.6 kW;
  - Capacity available for EV charging = (25 - Base load).
- **SCM Power Allocation Strategies:**
  - Base case: Uncontrolled;
  - Equal sharing;
  - First come, first serve (FCFS).









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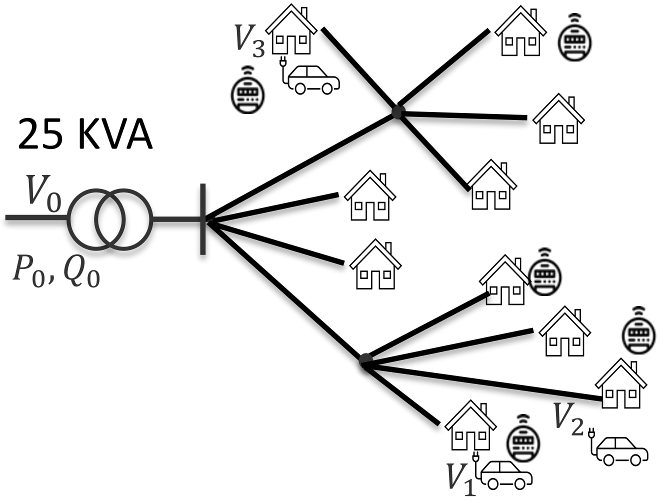
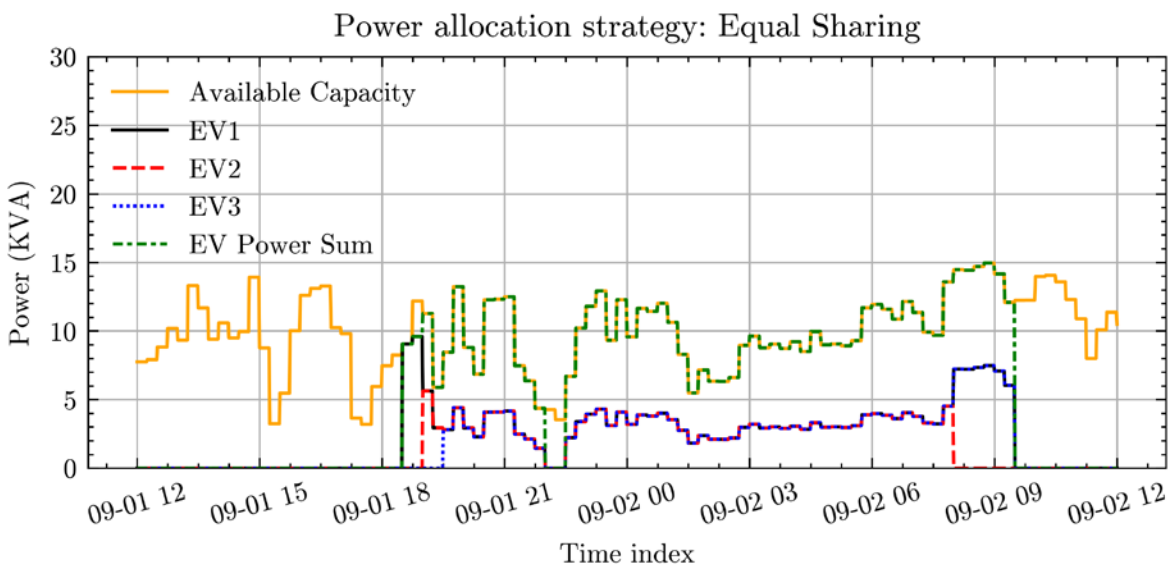
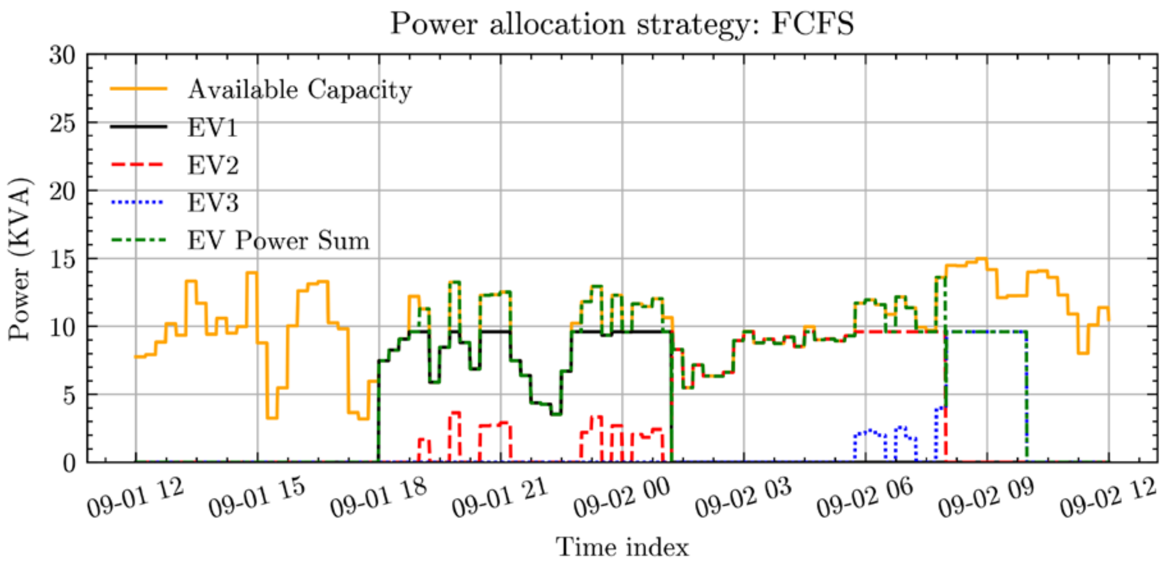
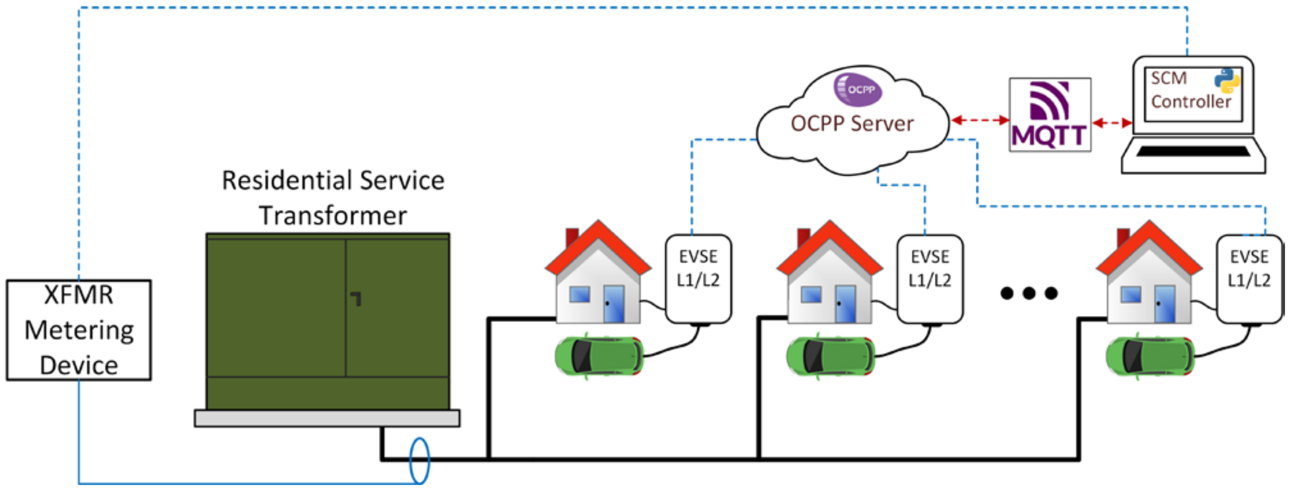
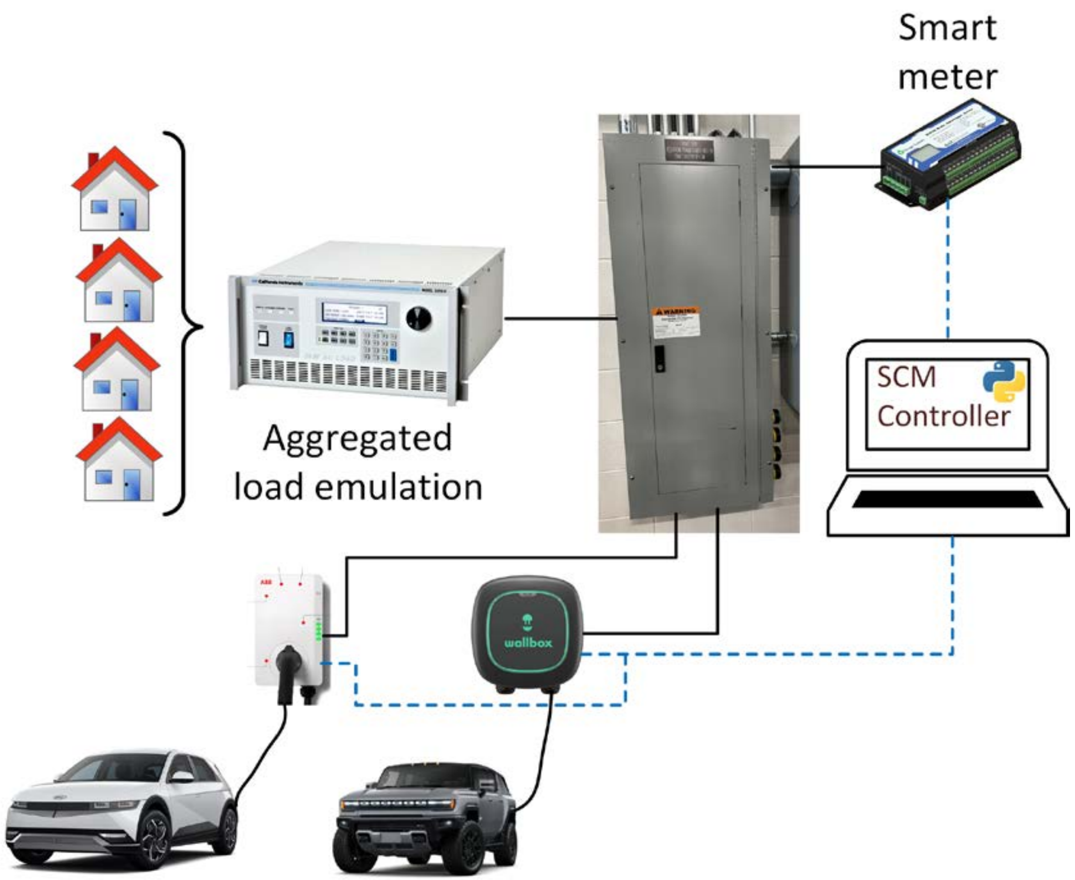






Lab Hardware Testbed for Transformer Overloading Mitigation





Residential transformer load mitigation tests

- Design, test, and evaluate performance of SCM systems to mitigate transformer overloading during simultaneous EV charging for residential customers
- During testing, residential loads are aggregated and either emulated or manually adjusted using a load bank to impose capacity constraints
- SCM-related controller challenges (step time, latency, responsiveness, comms failure, etc.) will be addressed and investigated

Conclusion and Next Steps

Conclusion:

1) Adopting carbon reduction-based SCM can significantly reduce the carbon emissions from EV charging loads by utilizing its inherent flexibility.

2) Due to its simplicity, time-of-use (TOU) is still the most dominant rate design adopted by utility companies. However, TOU-based SCMs lack coordination among different EVs connected to the same service transformer, potentially causing transformer overloading from multiple EV charging loads coinciding.

3) Capacity-constrained SCMs for transformer overloading mitigation can coordinate charging of EVs under the same service transformer, and effectively shift charging loads to low-demand periods, alleviating overloading of the service transformer from EV grid integration.

Next Steps:

- Evaluated the performance of the proposed SCMs on various distribution feeders (Dominion Energy).
- Collaborated with our utility partner to demonstrate the proposed SCM for mitigating transformer overloading in the field (Holy Cross Energy).

FUSE Partnership Opportunities

- **Fleet SCM Demonstration**
  - Reducing energy costs under TOU rates/demand charges;
  - Reducing carbon emission;
  - Avoid transformer upgrades by deploying on-site PV/ESS;
  - Adopting and leveraging dynamic price signals like Locational marginal pricing (LMP);
  - Energy market participation

- **Utility and/or PUC guidance/coordination**
  - Grid impacts for high EV integration scenario;
  - SCM evaluation and comparison at the system level, such as the transformer loading and voltage impacts.
  - Incorporate our analysis results into your planning and operational standards. For example, for a 50KVA transformer, what is the maximum number of customers it can serve based on the EV adoption forecast?
  - Field demonstration/pilot programs for SCMs.

Interested in Partnering with FUSE?

Contact FUSE PI: Jesse Bennett, NREL

Jesse.Bennett@NREL.gov

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Thank You !

Contact

FUSE PI: Jesse Bennett, NREL

Jesse.Bennett@NREL.gov

Mingzhi Zhang, NREL

Mingzhi.Zhang@nrel.gov

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Broad Regional Analysis – Evergy service territory

Manoj Sundarrajan
Steven Schmidt
Jean Chu
Timothy Pennington

Oct 31, 2024

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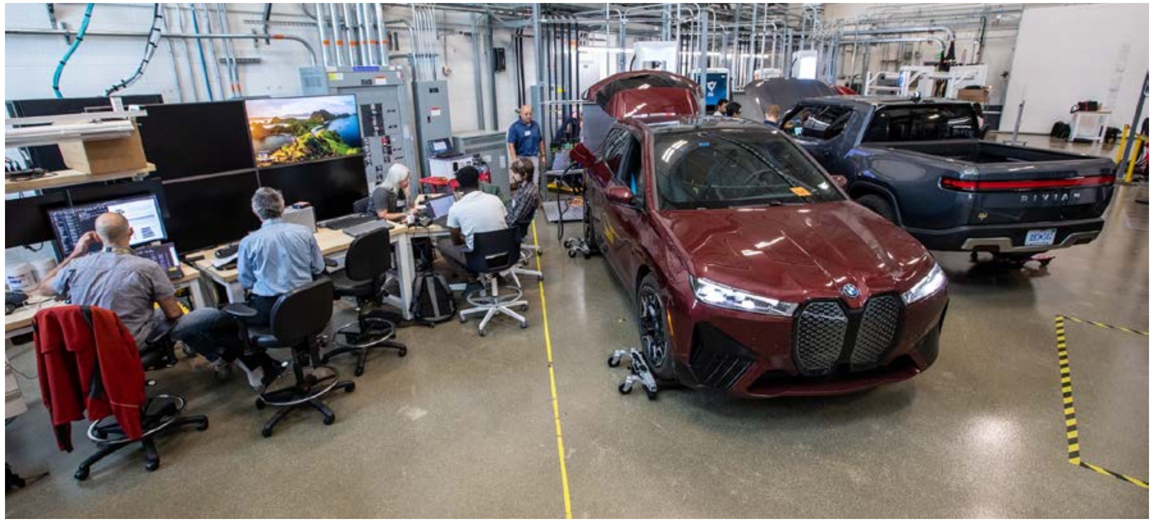
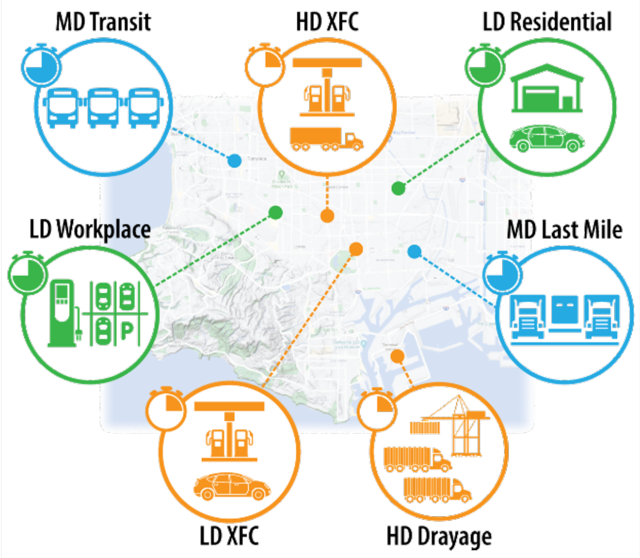
- **Determine SCM and VGI benefits for consumers and utilities for EVs@Scale across the range of conditions (geographies and seasons) found in the US**





Review

- Evaluated smart charge management strategies from RECHARGE project in El Paso electric service territory and ISNE – Vermont subregion.
  - Smart charge management strategies
    - Time of Use Immediate
    - Time of Use Random
    - Centralized Aggregator – Feeder Peak Avoidance
  - El Paso Electric Service territory
    - High Solar generation potential
    - High AC loads with demand fluctuation from night to day
  - ISNE – Vermont subregion
    - Winter peaking load
  - Take aways
    - SCM strategies were not flexible enough to respond to dynamic changes in renewables
    - A strategy that works in one scenario doesn't work in a different scenario

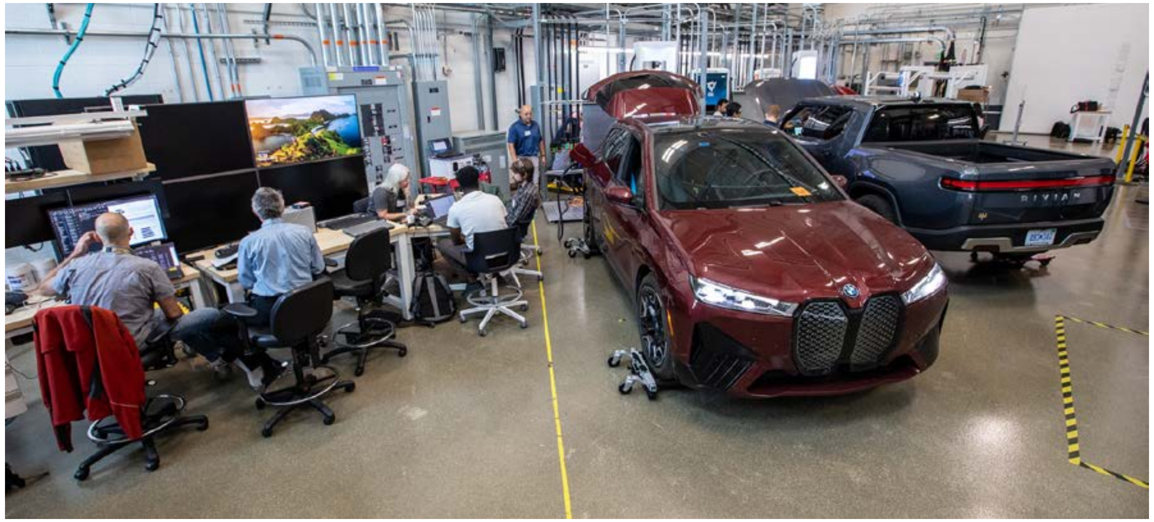
EVs@Scale FUSE - Overview

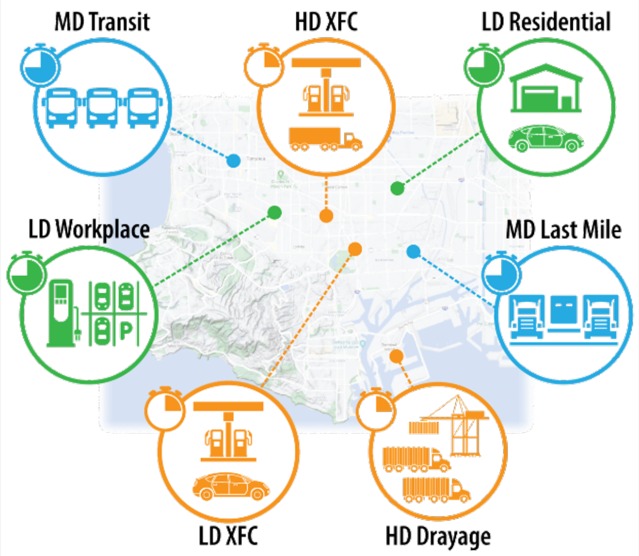
Objective:

- Develop an adaptive ecosystem of smart charge management (SCM) and vehicle grid integration (VGI) strategies and tools relevant to assess and reduce barriers to electrification throughout a wide geographic area and across numerous vocations

Outcomes:

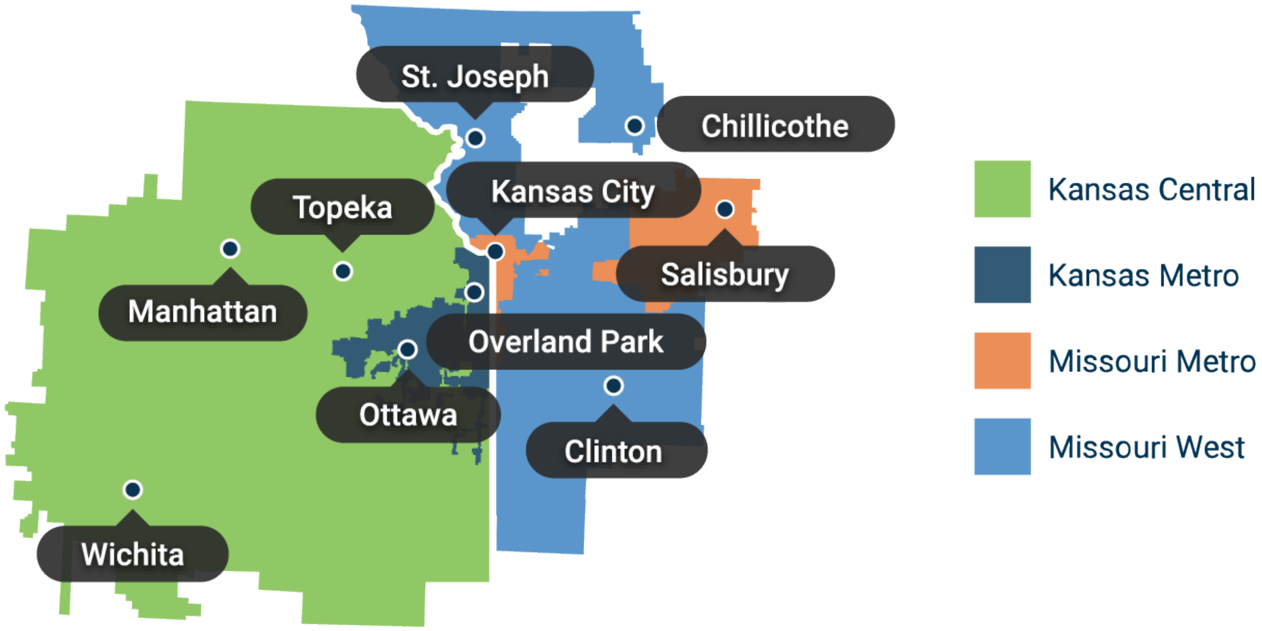
- **Broadly identify limitations and gaps** in the existing VGI and SCM strategies to strategically shift PEV charging in time across a wide range of conditions
- **Develop enabling technologies** and demonstrate VGI approaches to reduce grid impacts throughout the entirety of the **LD, MD, and HD on-road electric fleet** while accounting for vehicle operational and energy requirements.
- **Determine SCM and VGI benefits for consumers and utilities for EVs@Scale across the range of conditions (geographies and seasons) found in the US**

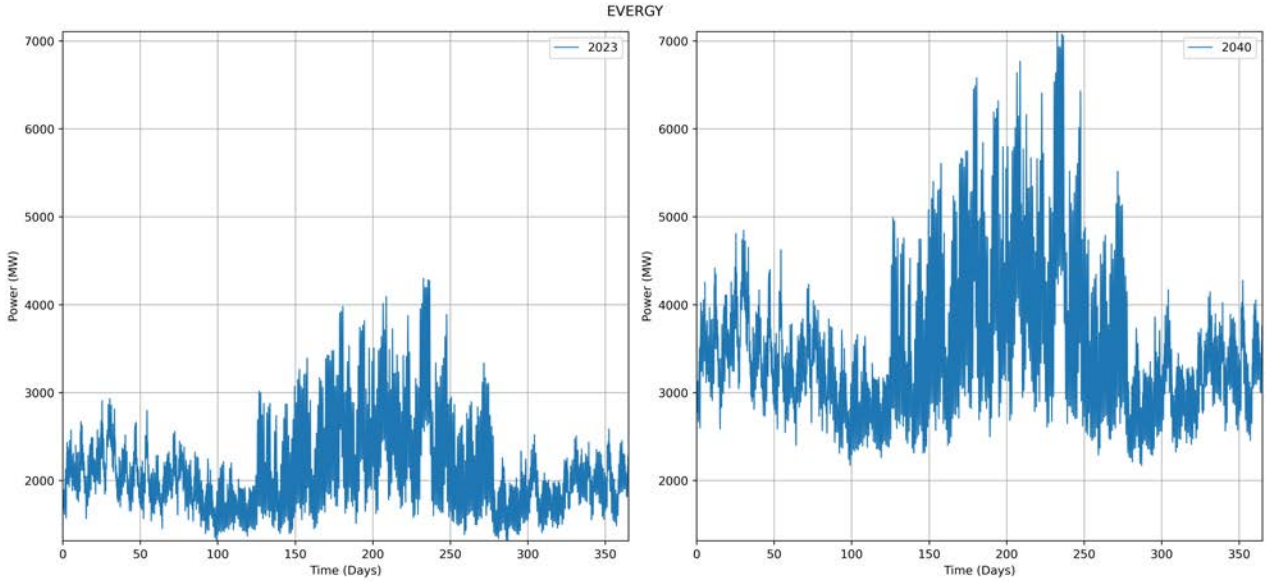




Evergy Service Territory

- Parts of Kansas and Missouri
- High Solar and Wind generation potential
- 1,875,008 LD Electric Vehicles
  - 50% EV adoption by 2040 TEMPO scenario
- 7GW peak power demand
  - 3.2% electricity demand growth rate
  - Data Source: EIA.gov
- Expected Generation Capacity
  - Nuclear: 1218 MW
  - Wind: 5270 MW
  - Solar: 3200 MW
  - Data Source: Evergy IRP report
- Charging Mix (Assumption)
  - Home L2: 40%
  - Work L2: 40%
  - Destination L2: 20%



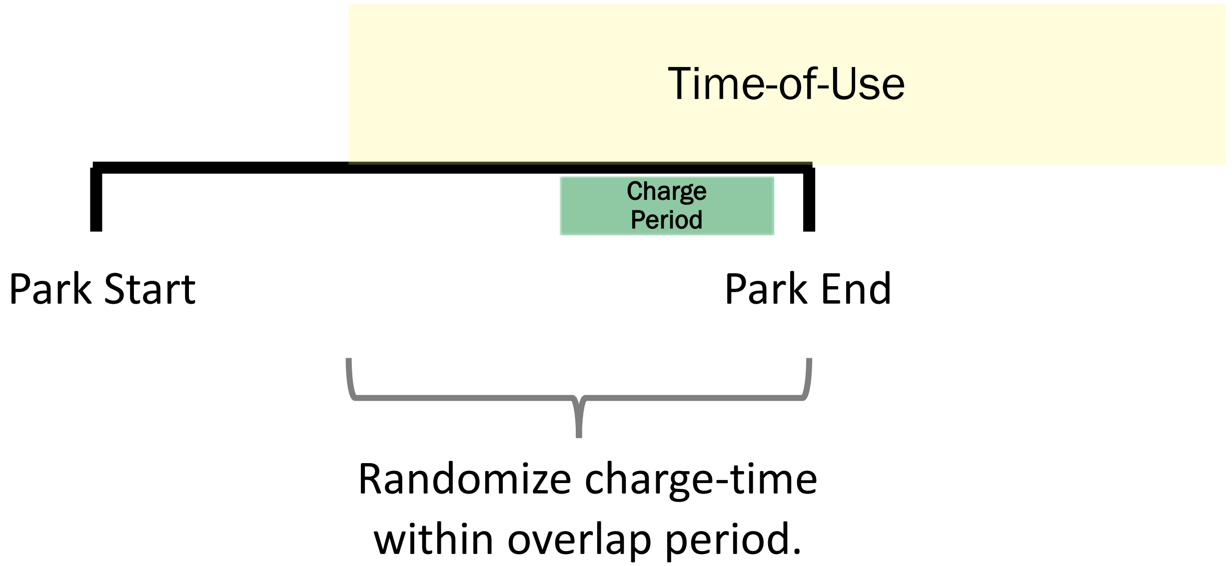


Smart Charge Management Summary

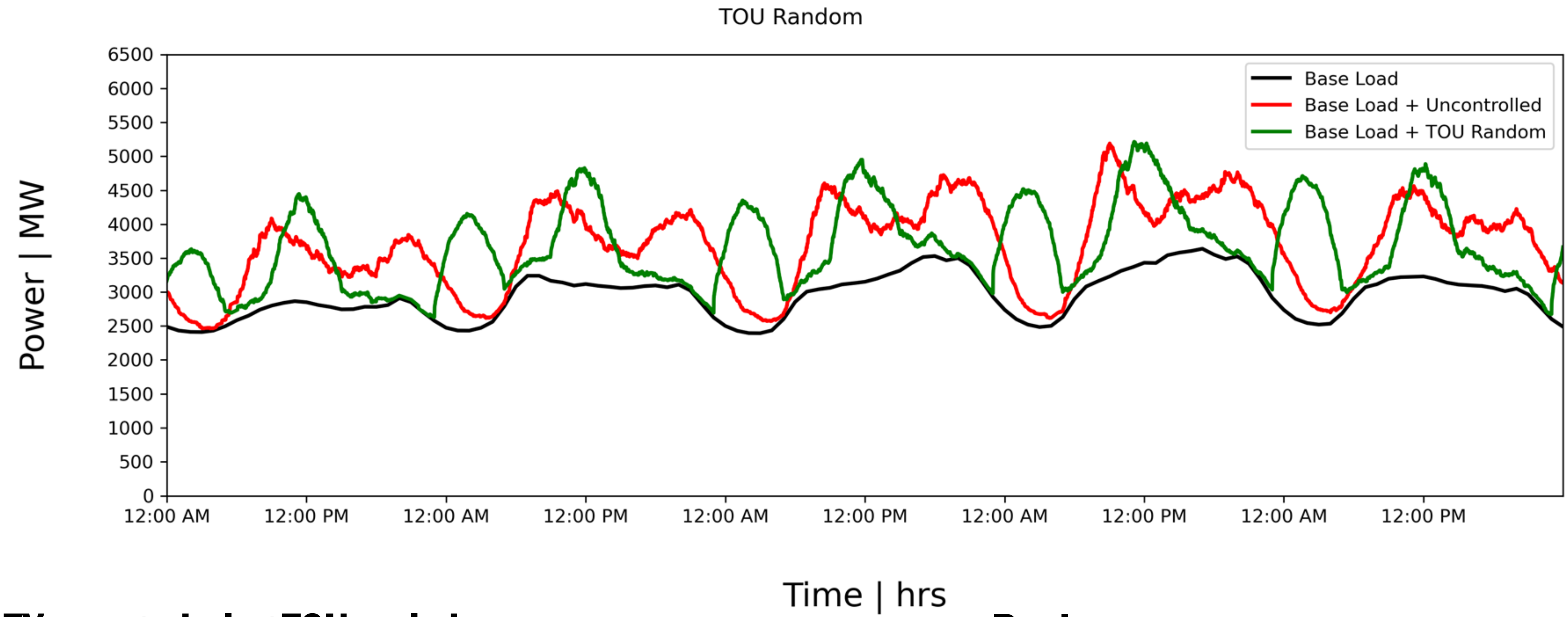
Smart Charge Management	Objective	Methodology	Metric
Vocation based Time of Use Random	Shift Energy to Off-peak	Shift EV charging during TOU window. TOU window based on charging location.	Energy Shifted
Cost-based Dynamic Decentralized	Reduce Charging Cost	Incentivize charging during least cost duration	Cost of EV Charging
Cost-based Dynamic Decentralized	Reduce Charging Cost	Incentivize charging during least cost duration with cost of charging changing based on optimized EV charging profiles.	Cost of EV Charging, Peak Power
Centralized Aggregator	Avoid charging during feeder peak	EV charging demands shared with centralized aggregator entity. The entity shapes EV charging based on demand and objective.	Peak Power
Centralized Aggregator	Maximize Renewable Energy Utilization	EV charging demands shared with centralized aggregator entity. The entity shapes EV charging based on demand and objective.	Renewable utilization
Centralized Aggregator	Flatten Fossil Fuel Utilization	EV charging demands shared with centralized aggregator entity. The entity shapes EV charging based on demand and objective.	Renewable utilization

Vocation based Time of Use Random

- **EVs prefer to randomly distribute charging in the TOU window**
- **Time of Use periods can be adjusted based on charging locations.**
  - Home charging:
    - 11 PM to 5 AM
    - Low baseload demand
  - Workplace and destination charging:
    - 9 AM to 3 PM
    - High solar generation period



Vocation based Time of Use Random



EV energy during TOU period

Uncontrolled: 39567.4 MWh

Controlled: 75078.9 MWh (+89.7%)

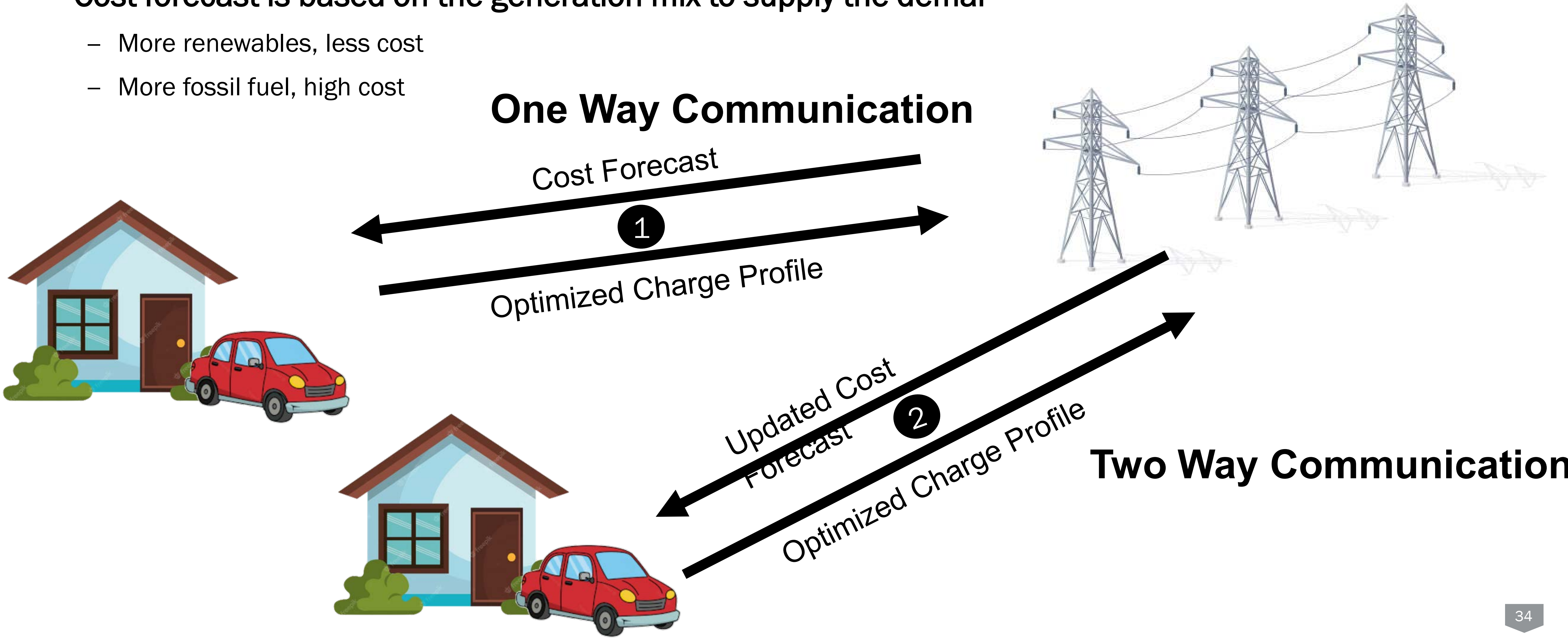
Peak power

Uncontrolled: 5187.3 MW

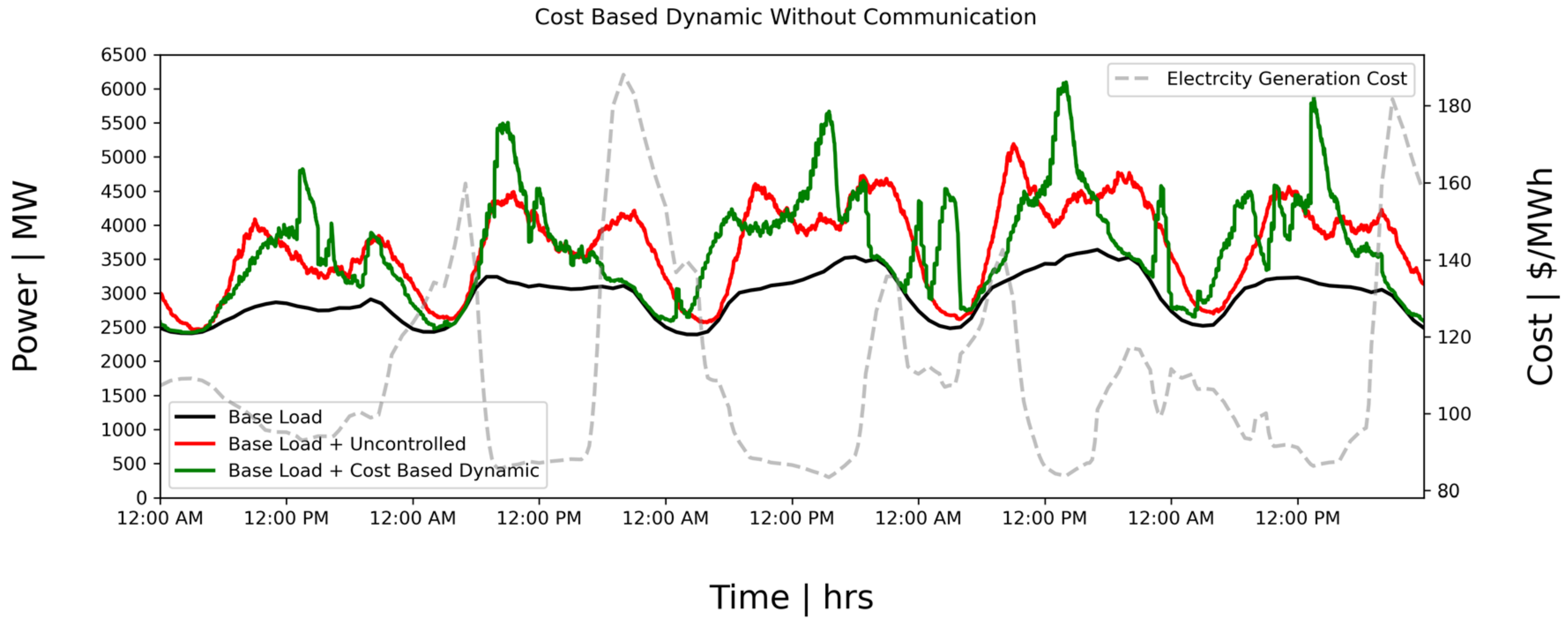
TOU Random: 5211.6 MW (+0.4%)

Cost-based dynamic decentralized

- EVs charge during lowest cost period based on cost forecast from the utility.
- Cost forecast is based on the generation mix to supply the demar
  - More renewables, less cost
  - More fossil fuel, high cost



Cost Based Dynamic – No Communication



Average Cost of Charging

Uncontrolled: $109.48/MWh

Controlled: $96.67/MWh (-11.7%)

Peak power

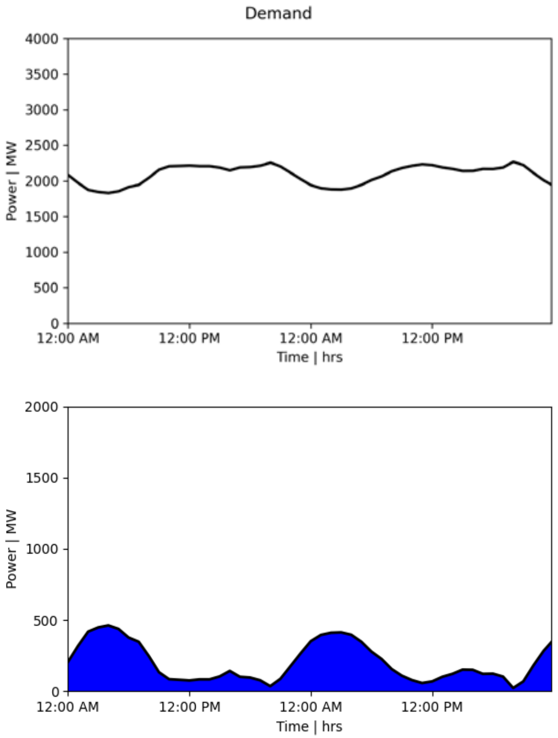
Uncontrolled: 5187.3 MW

Controlled: 6094.2 MW(+17.4%)

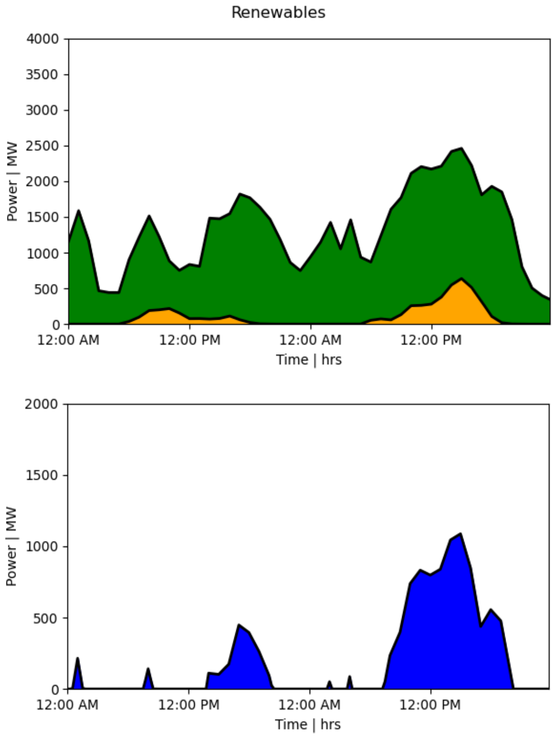
Centralized Aggregator

- **A Centralized Aggregator entity controls EV charging based on the objective function.**
- **Involves 2-way communication between EV and the aggregator.**
  - Charging needs from EV to Aggregator
  - Energy Setpoints from Aggregator to EV

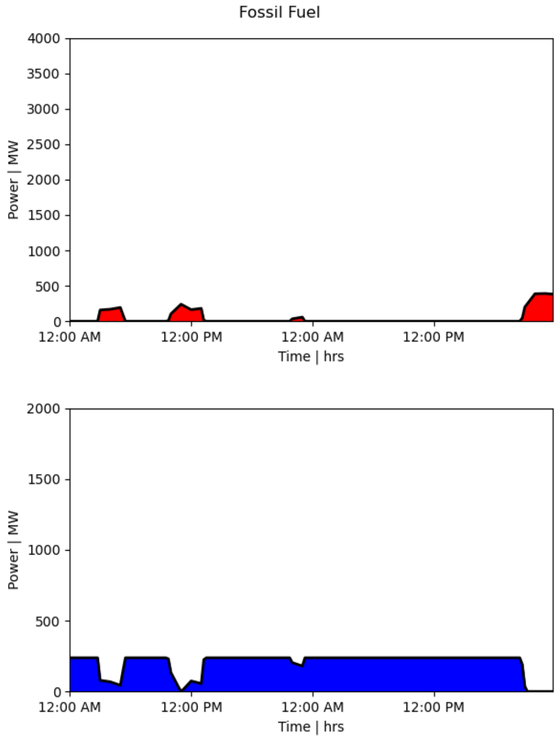
Feeder Peak Avoidance



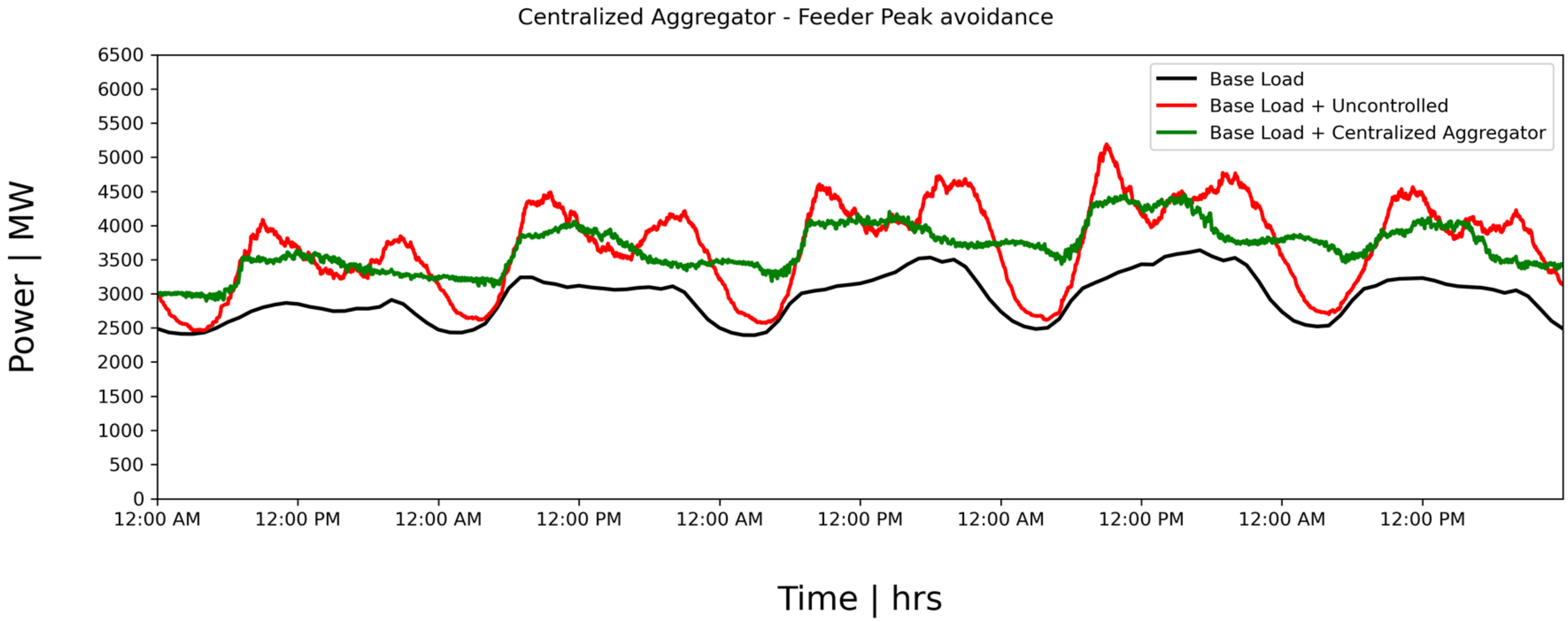
Maximize Renewables



Flatten Fossil Fuel demand



Centralized Aggregator – Feeder Peak Avoidance



Peak Power EV charging

Uncontrolled: 1956.0 MW

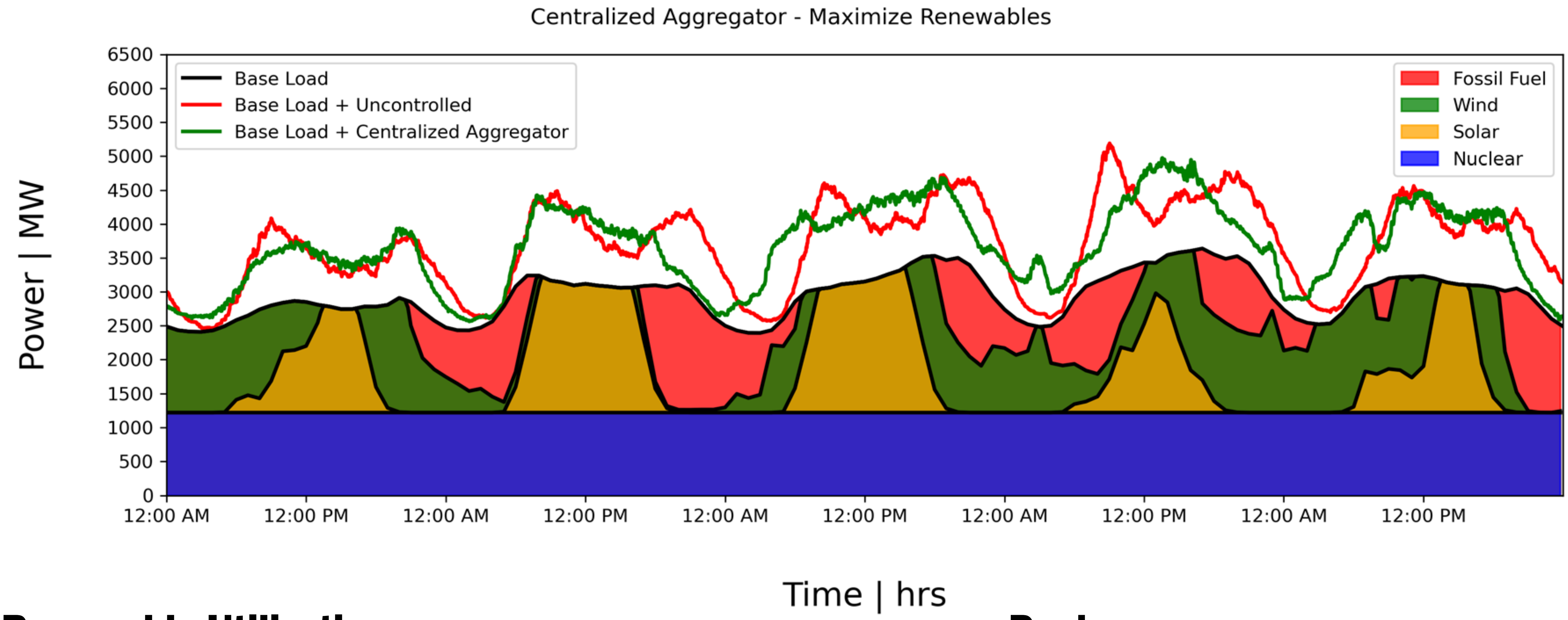
Controlled: 1296.2 MW (-33.7%)

Peak Power

Uncontrolled: 5187.31 MW

Controlled: 4452.29 MW (-14.1%)

Centralized Aggregator – Maximize Renewables



Renewable Utilization

Uncontrolled: 85.1%

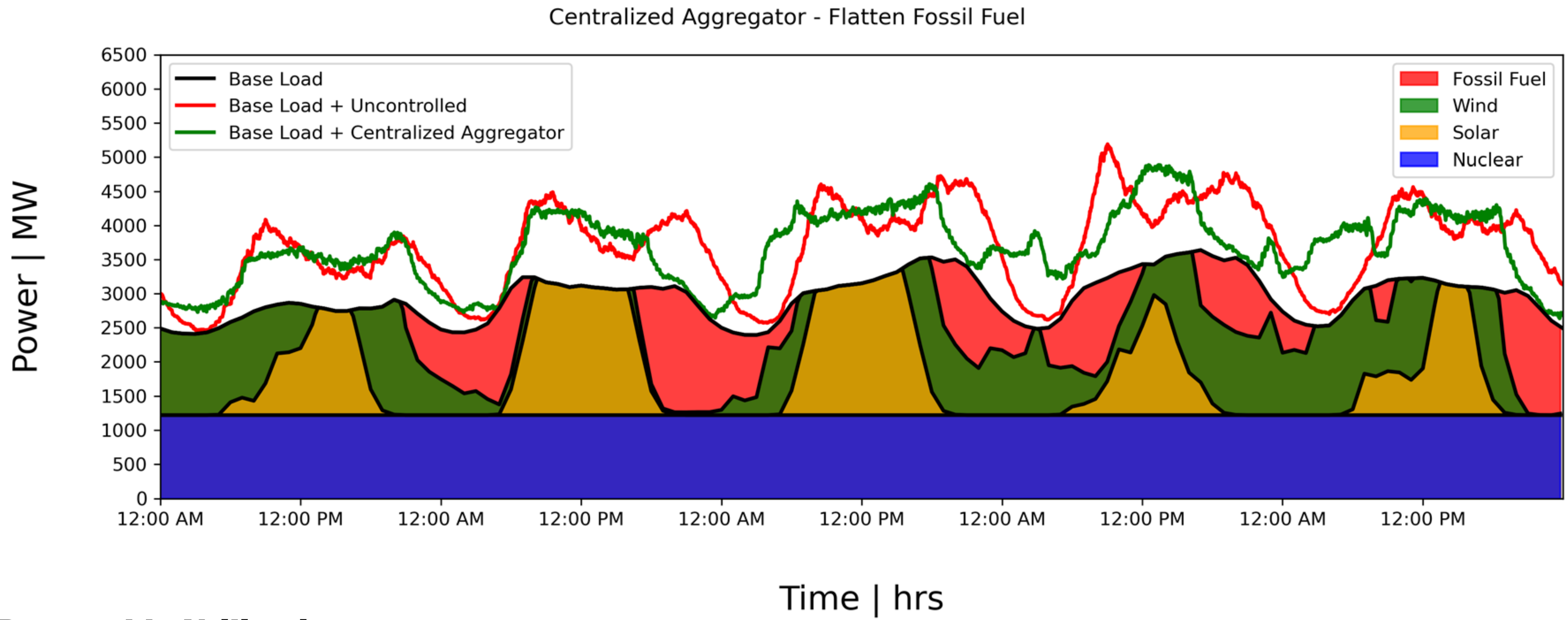
Controlled: 97.05% (+13.9%)

Peak power

Uncontrolled: 5187.3 MW

Controlled: 4971.0 MW (-4.1%)

Centralized Aggregator – Flatten Fossil Fuel Utilization



Renewable Utilization

Uncontrolled: 85.1%

Utilization Controlled: 96.79% (+13.6%)

Peak Power

Uncontrolled: 5187.31 MW

Controlled: 4883.1 MW (-5.8%)

Next Steps

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Work completed this semester:

- 48- hour weather forecast models from NOAA.
- Cost-based dynamic decentralized control.
- New objectives for centralized aggregator.
- HPC pipeline to run simulation scenarios at scale.
- Evaluation of LD L2 charging in a wind heavy region.

Next Steps:

- **Evaluation for**
  - a range of charging mix scenarios.
  - a range of SCM penetration scenarios.
  - other long dwell MD/HD vocations (School Bus, Transit, etc.)
  - SCM strategies in other regions with different generation mix, demand characteristics, transportation characteristics.

Partnership opportunities

- **Utility planning for EV charging load?**
  - SCM objective that is right for your region.
  - Build charging infrastructure where it matters for your region.
  - Other Caldera capabilities
    - Charging station demand forecasting (CalderaCast).
    - Spatial shifting of EV charging (Caldera CDM).
    - EV charging impacts on the Grid (Caldera Grid).
- **Contact:**

Manoj Kumar Cebol Sundarrajan

ManojKumar.CebolSundarrajan@INL.gov

FUSE INL PI

EVs@Scale
U.S. Department of Energy

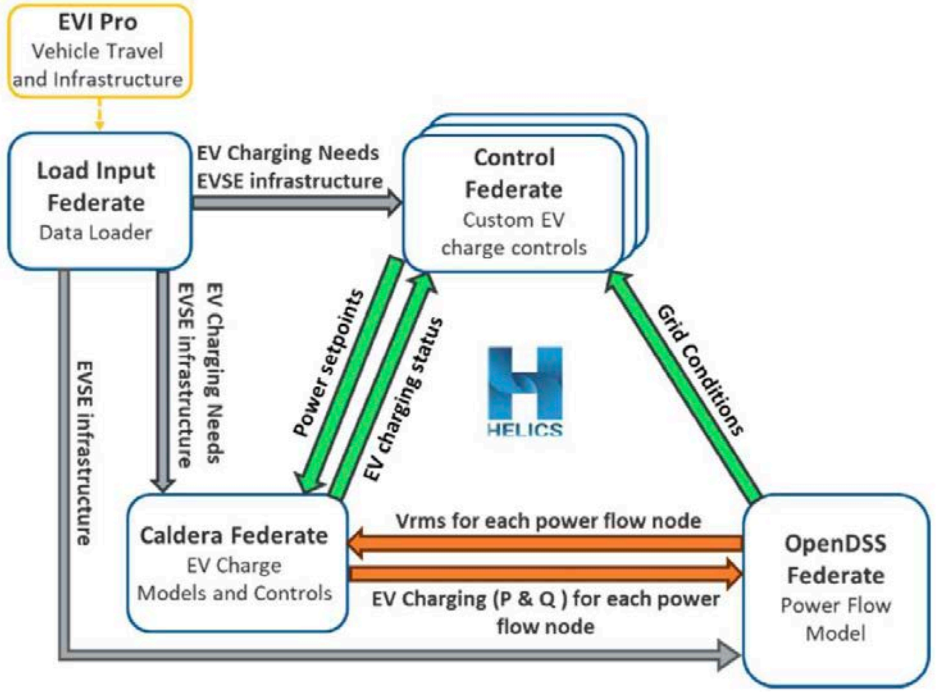
FUSE Deep Dive: Uncontrolled Charging Impact Analysis

Nadia Panossian, Priti Paudyal, Wenbo Wang
October 31, 2024

Grid Impact Assessment: Simulation Architecture

EVs@Scale
U.S. Department of Energy

- **Grid Impact Co-simulation**
  - Three day time series power flow at 5 minute intervals starting at 6 am with charging needs provided by transportation/charging team
  - Simulations performed across 57 feeder models in VA (Newport News/Richmond)
  - HELICS co-simulation coordinates multiple federates to simulate charging
    - EVI-Pro inputs from the grid team identify charging needs and dwell periods
    - Control Federate houses SCM objective functions to optimize charge sessions
    - Caldera simulates charge sessions and passes real/reactive power to OpenDSS
    - OpenDSS performs power flow analysis and determines grid impacts with different controls



- **Simulation Focus**
  - Uncontrolled – Evaluate grid impacts for all 60 feeders without SCM
  - Feeder Peak – Assess each controls ability to reduce feeder peak (TOU, Central, LMP)
  - Market/Emissions – Quantify emission reduction benefits (TOU, LMP, Emission)
  - Transformer – Determine mitigated transformer overloading (Transformer, Depot)
  - Voltage Quality – Review voltage benefits from each approach (Volt/VAR, Volt/Watt)

Uncontrolled Long Dwell Charging Impact Analysis

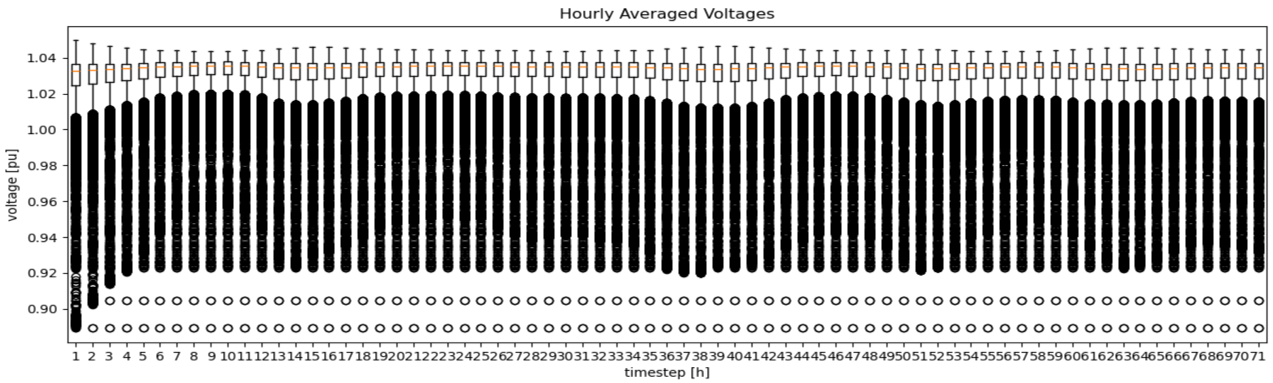
EVs@Scale U.S. Department of Energy

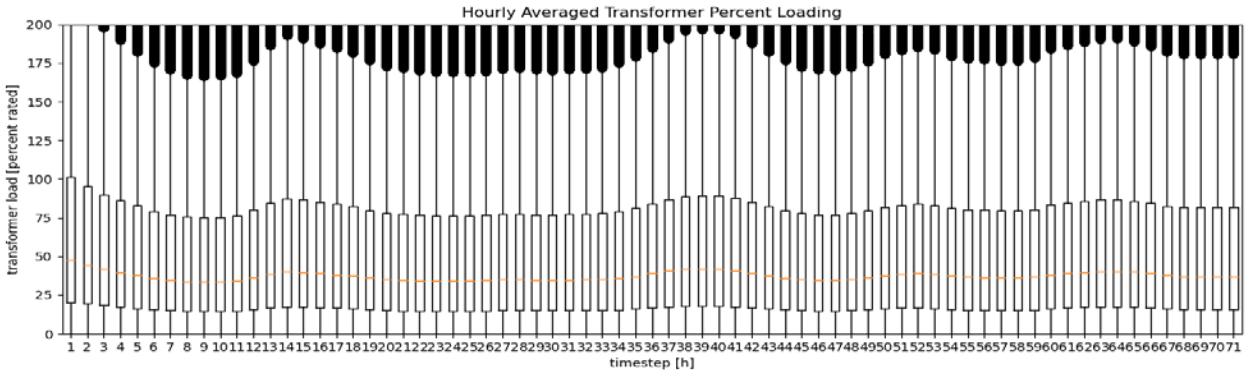
Long Dwell still creates Transformer Overloads:

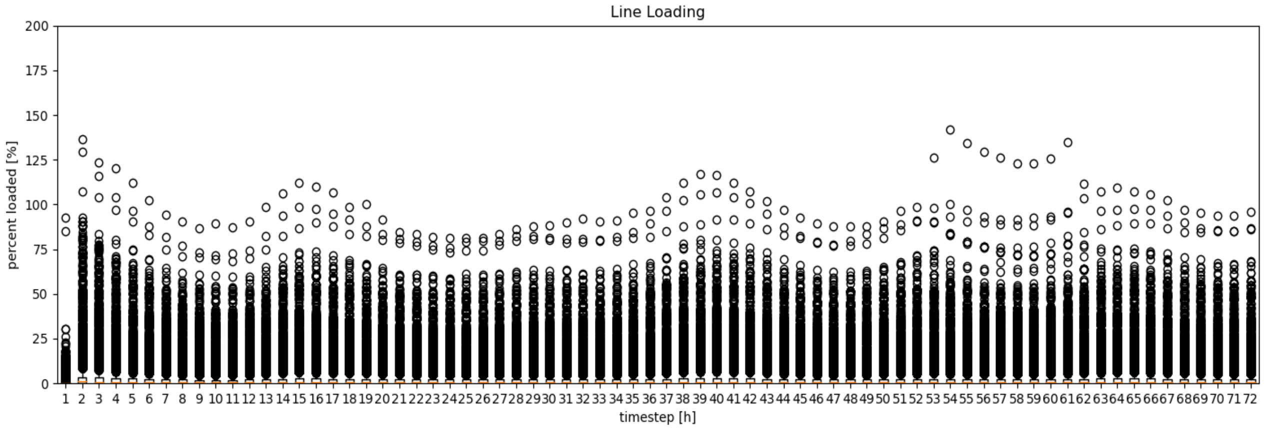
- 57 real feeders analyzed
- Few under-voltages: 0.5% below 0.95pu, 0.0074% below
- Many transformer overloads with a few 100x rated capac
- Most EV load in early afternoon to evening

Total Transformers	23,232
Transformers Overloaded	6142
Total Transformer Overload Duration	17.4%
Mean Overload Duration	7.58 hrs
Max Transformer Overload Duration	24.0 hrs

Total Lines	19,318
Lines Overloaded	10
Total Line Overload Duration	0.03%
Max Line Overload Duration	24.0 hrs

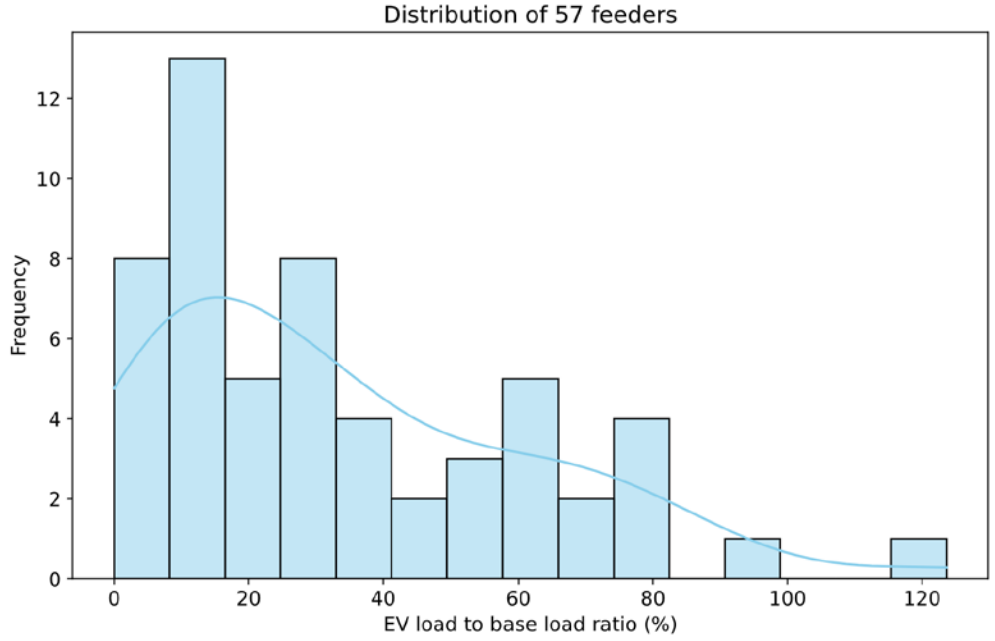


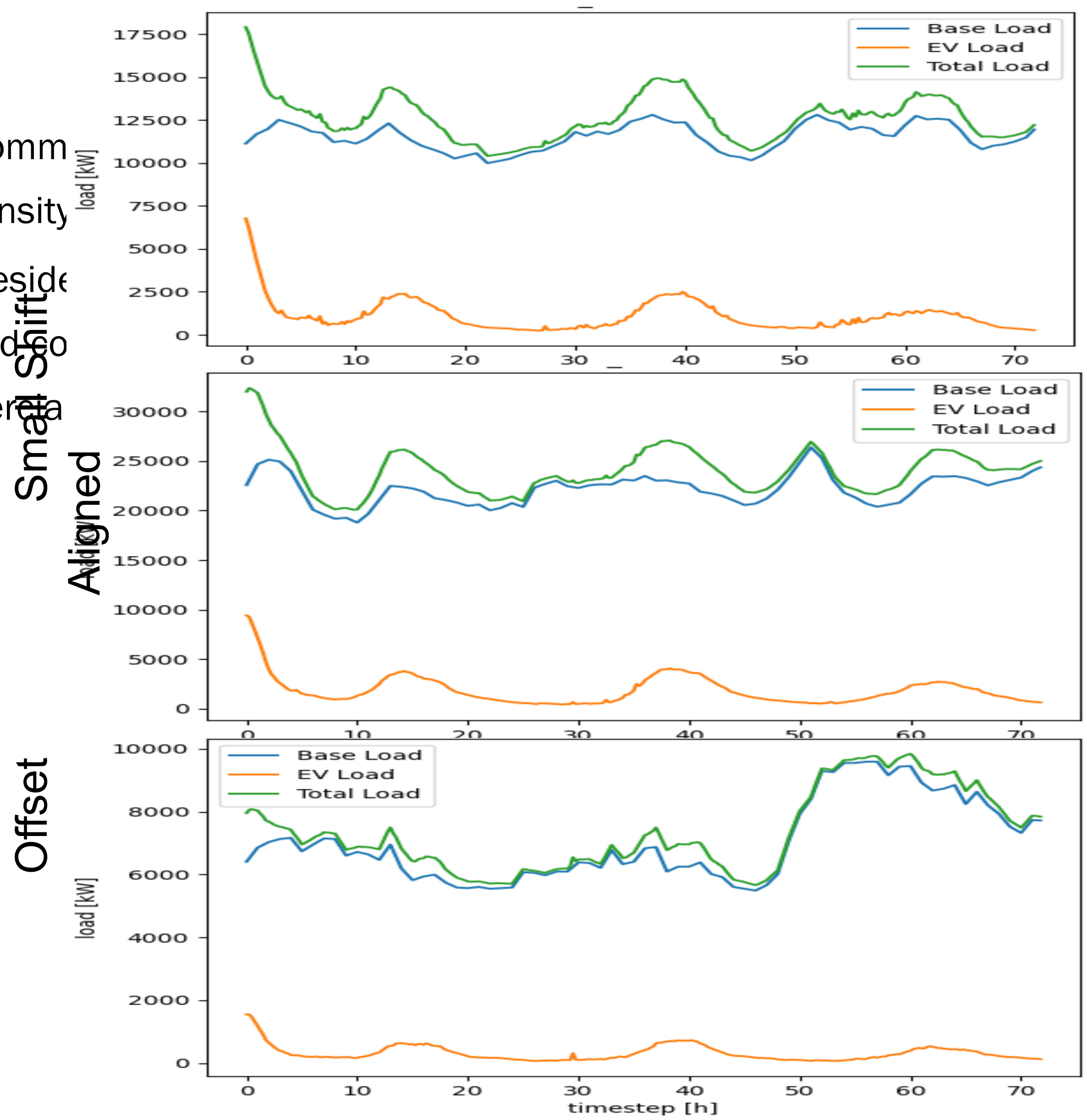




Uncontrolled Long Dwell Charging Load Shapes

- **Three main categories:**
  - Aligned with base load: mix of residential and comm
  - Small shift from base load: residential, lower density
    - Longer tail, because vehicles charge after reside
  - Offset from base load: uncommon, industrial and co
  - 3 feeders without chargers: high density commerci





Detailed Look at Single Feeder for Comparison to Controlled Cases

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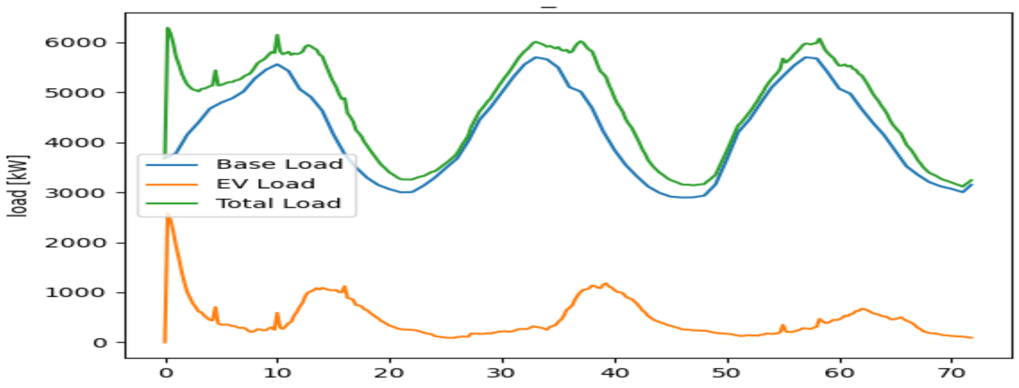
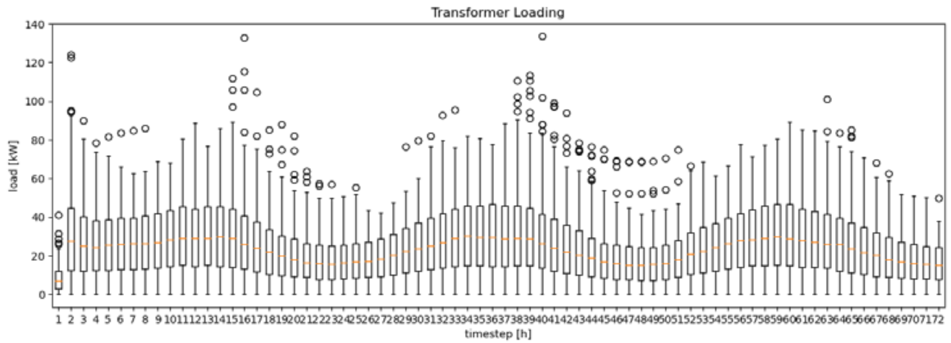
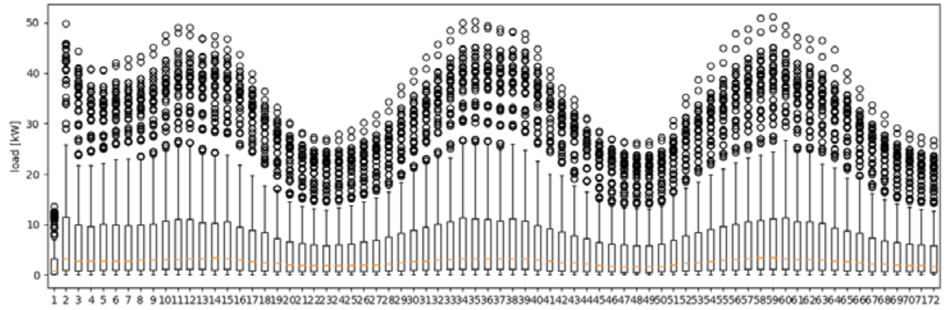
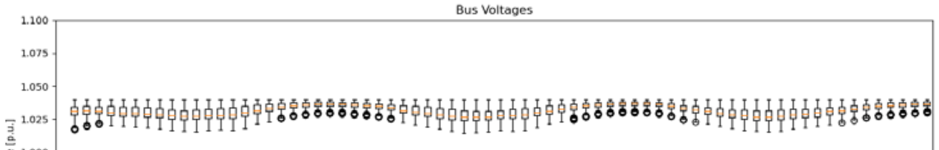
- One feeder selected for preliminary comparison to cont
- Transformer overloading coincides with net feeder overl
- Voltage is not an issue for this feeder
- Line overloading not an issue for this feeder









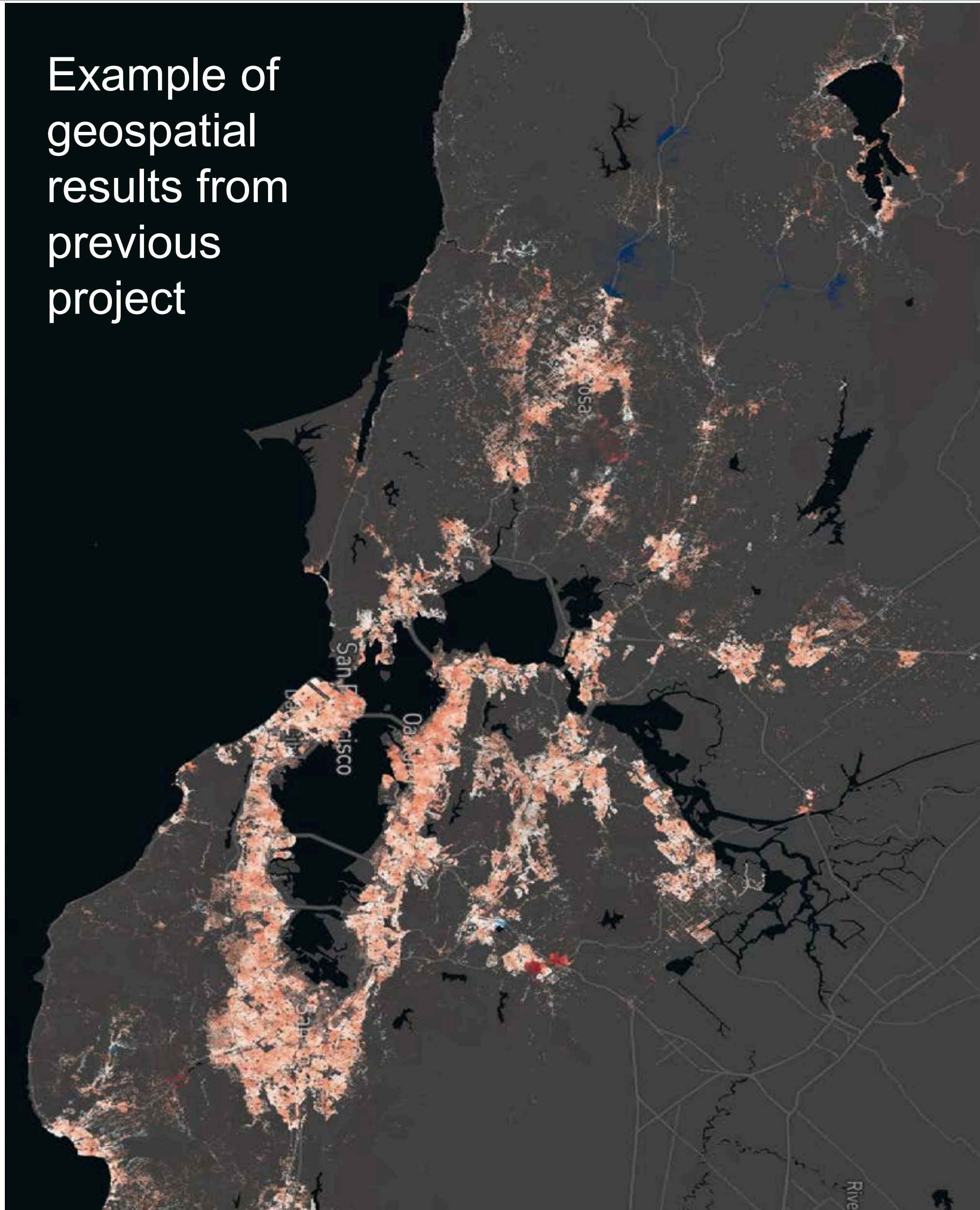
Total Transformers	356
Total Transformer Overload Duration (perc of total hours)	21.74%
Overloaded transformers	172
Total overloaded transformer hours	5571
Total Lines	**523**
Overloaded lines	0
Total overloaded line hours	0

Next Steps: Further Analysis

- **Inclusion of short-dwell:**
  - How do fast chargers change the landscape?

- **Geospatial Analysis:**
  - Are certain areas or corridors disproportionately impacted?

- **Closer investigation of most impacted feeders**
  - What are defining characteristics of feeders with the most component overloads?



Example of geospatial results from previous project

FUSE Partnership Opportunities

- **Leverage analysis into actionable items:**
  - Determine rules of thumb for distribution transformer sizing
  - Distribution planning outcomes
  - Analyze to determine factors for most impacted feeder components
  - Determine factors of most impacted regions and substations

Interested in Partnering with FUSE?

Contact FUSE PI: Jesse Bennett, NREL

Jesse.Bennett@NREL.gov

EVs @ Scale

U.S. Department of Energy

FUSE Deep Dive: Grid Impact Analysis

October 31, 2024

Outline

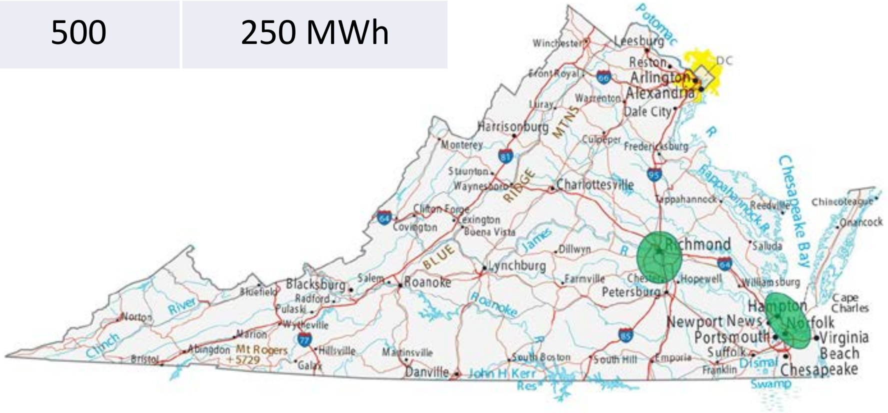
- Background - baseline assumptions
- Updated results
- Key findings and next steps
- Future collaborations ideas

Uncontrolled Impact Results: Long-Dwell Charging

EVs@Scale
U.S. Department of Energy

- **Uncontrolled Charging Baseline Assumptions**
  - LDV and MHDV long-dwell from transportation/charging
  - Newport News: 29 Feeders, Richmond 31 Feeders
  - 29 total substations
  - Customer Count: 130k (approximate)
    - Commercial (17%), Industrial (2%), Residential (81%)
- **Simulation**
  - Allocate baseload (as measured at feeder head) to each distribution transformer
  - Map each simulated charging event to nearest distribution transformer
  - Co-simulate 72 hr of charging with Caldera and OpenDSS
  - Evaluate Grid impacts including:
    - Load Profiles, equipment loading, voltage levels

	EV count	Daily energy
Passenger cars	700,000	1.50 GWh
Local freight	17,000	410 MWh
School buses	3,000	670 MWh
Transit buses	500	250 MWh



Feeder	Capacity	Peak*	Loading
Averages	28 MVA	17 MVA	61%
Lowest Capacity	9.2 MVA	6.2 MVA	67%
Highest Capacity	36 MVA	23 MVA	64%
Lowest Loading	36 MVA	10.6 MVA	29%
Highest Loading	35.9 MVA	31.7 MVA	89%

*Peak just includes Baseline loads to show peak capacity for EV charging

Grid Impact Simulation Summary

<table>
<tr><th></th><th>Objective</th><th>Feeders</th><th>LD POV</th><th>Transit Bus</th><th>School Bus</th><th>Local Freight</th></tr>
<tr><td rowspan="4">Sim1: Feeder Peak</td><td rowspan="4">Compare performance of multiple controls at reducing feeder peak with even application across all vocations</td><td rowspan="4">2 Substation Sets:
NNSS_1 X 2 feeders
RichSS_2 X 4 feeders</td><td colspan="4">Centralized Feeder Peak</td></tr>
<tr><td colspan="4">Day-ahead LMP</td></tr>
<tr><td colspan="4">Random Distribution</td></tr>
<tr><td colspan="4">TOU Immediate</td></tr>
<tr><td rowspan="3">Sim2: Bulk Generation</td><td rowspan="3">Compare performance of multiple controls with different vocation applications representing different rate distributions</td><td rowspan="3">4NN and 4Rich feeders representing a high net energy from each vocation and region</td><td>LMP</td><td colspan="2">Emissions</td><td>LMP</td></tr>
<tr><td>TOU</td><td colspan="3">LMP</td></tr>
<tr><td>TOU</td><td colspan="2">Emissions</td><td>LMP</td></tr>
<tr><td rowspan="2">Sim3: Transformer Upgrades</td><td rowspan="2">Assess different control objectives and PV/ESS deployments and their ability to mitigate upgrades</td><td rowspan="2">4NN and 4Rich feeders representing relatively high transformer overloading</td><td>Res Xfmr</td><td colspan="3">Depot</td></tr>
<tr><td>Res Xfmr (W/PV)</td><td colspan="3">Depot (W/DER)</td></tr>
<tr><td rowspan="2">Sim4: Voltage Concerns</td><td rowspan="2">Assess the benefits of voltage controls focusing on real/reactive power support</td><td rowspan="2">4NN and 4Rich feeders representing relatively high voltage concerns</td><td colspan="4">Volt/VAR</td></tr>
<tr><td colspan="4">Volt/Watt</td></tr>
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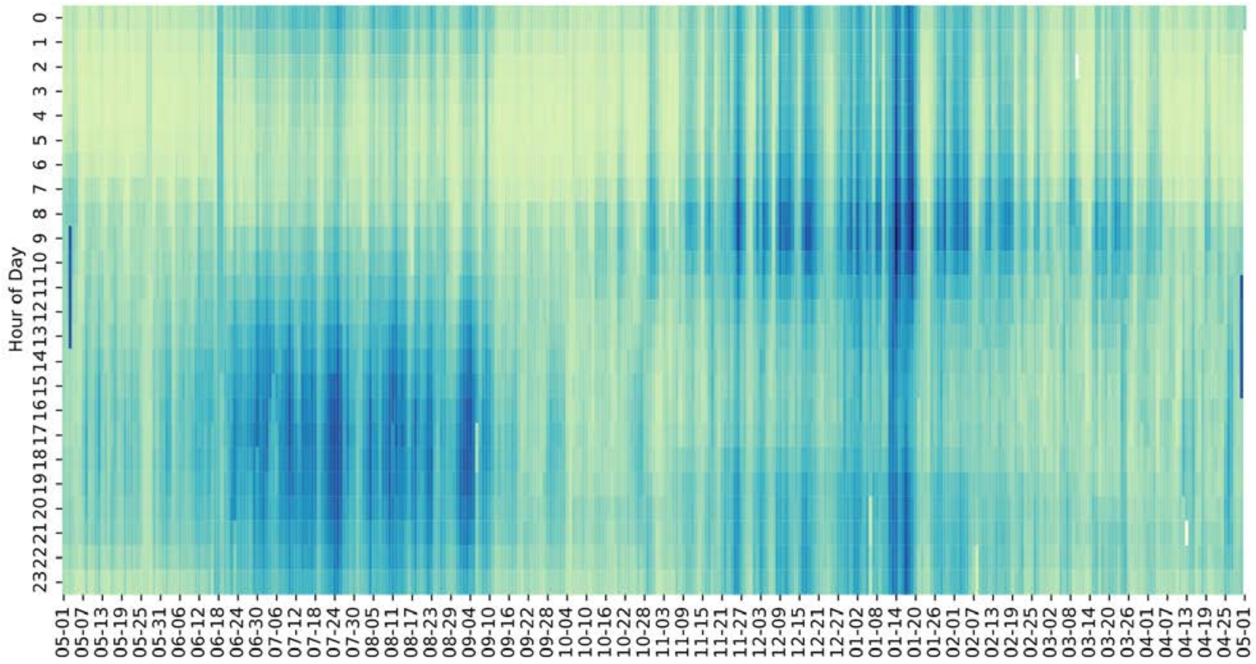
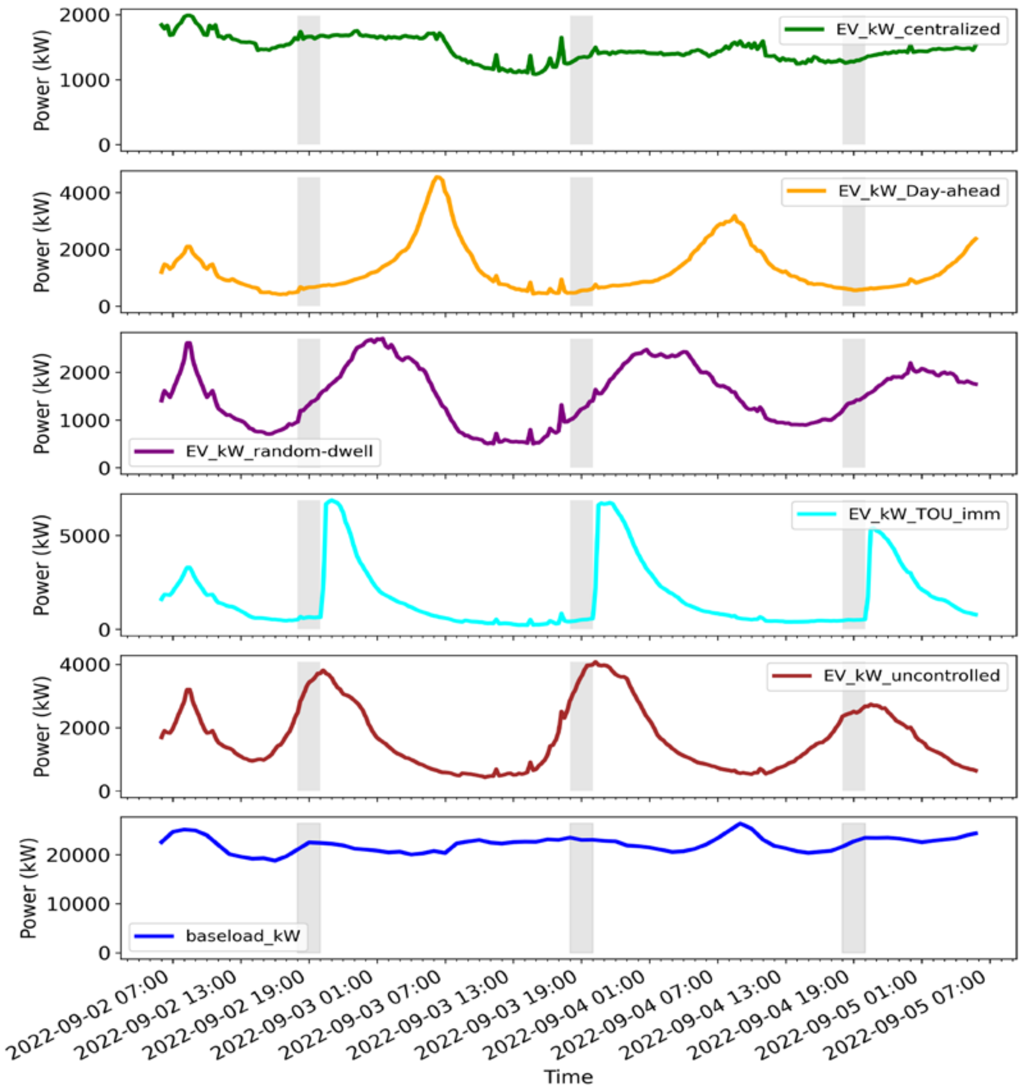
Sim 1 Results: A peek into peak shifting

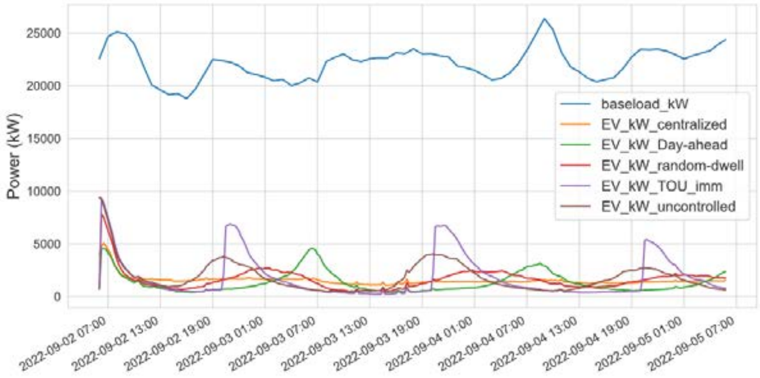
SCADA data reveals the peak happened within 5-8 pm in September

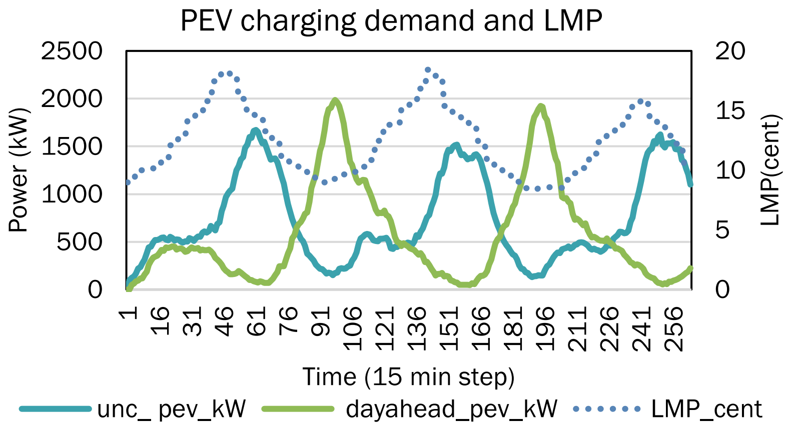


Energy shift performance

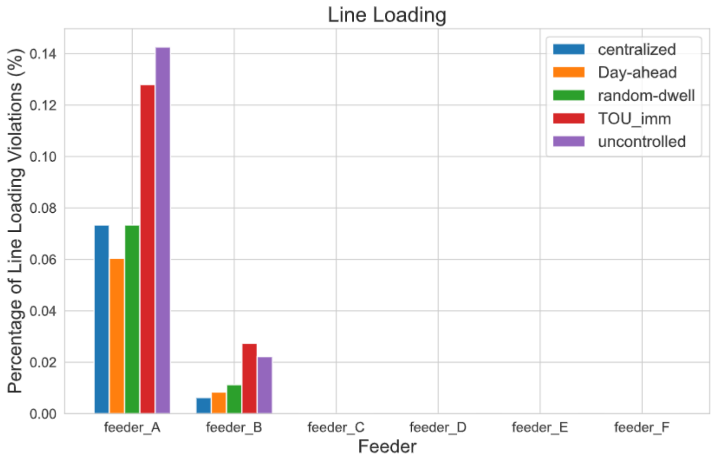


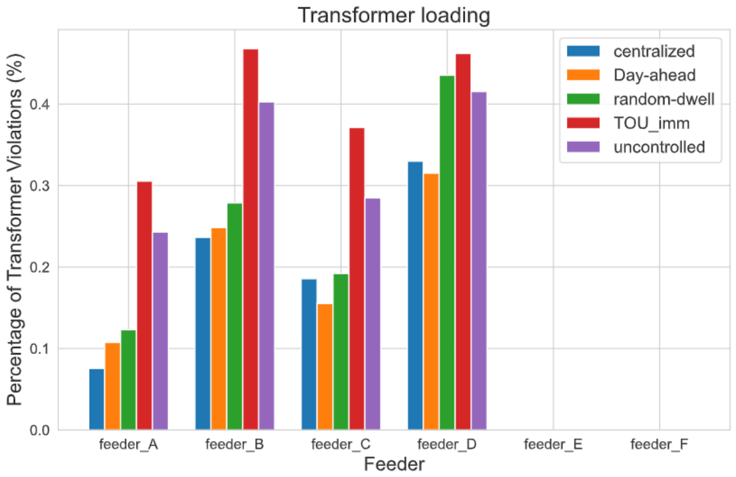
Grid Impact Assessment – Sim 1 Feeder Peak





Single feeder: left plot shows the TOU_imm induces largest timer peak; right plot shows initial results from LMP control where EV charging tracks lower LMP rates (dashed line) but does not cause significant spike.

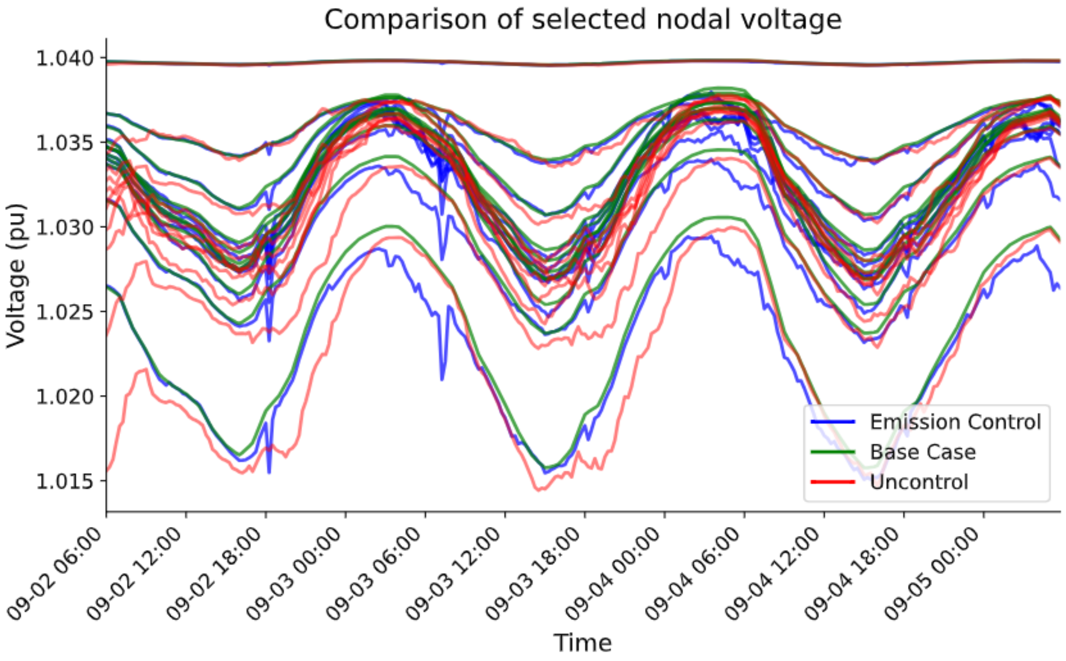


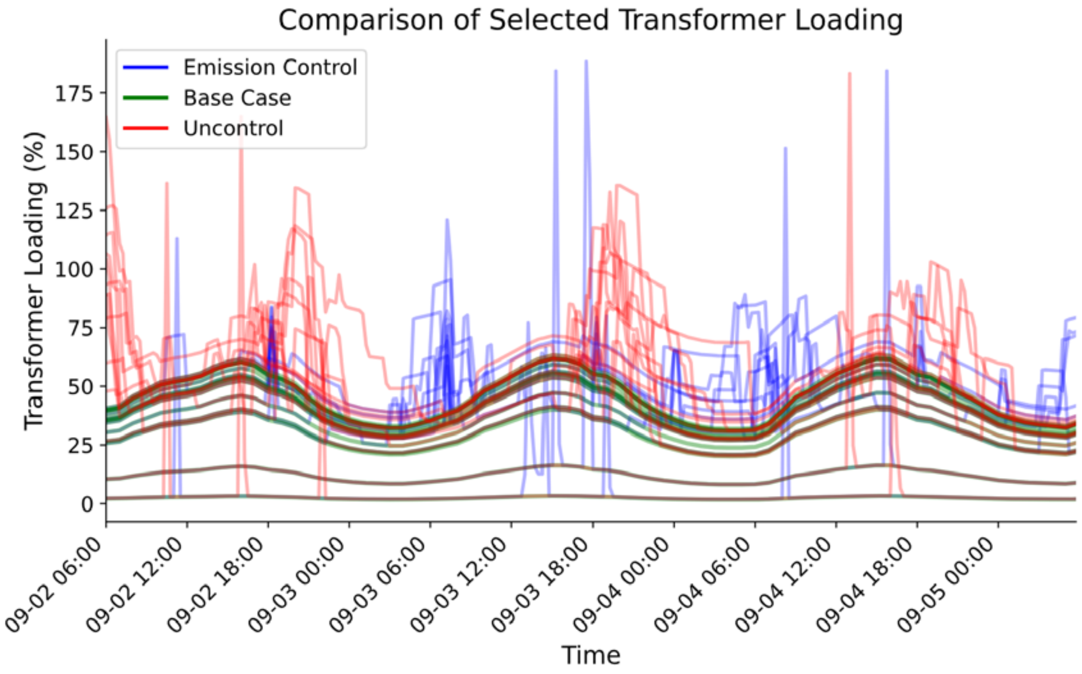


Multiple feeders: comparing control strategies using number of violations shows line and transformer loading: this plot shows the centralized control perform in reducing overloading, despite it might require communications, the day-ahead performs closest to centralized; In contrast, the TOU_imm strategy actually exacerbates the overloading problem, performing worse than the uncontrolled scenario in most cases.

Grid Impact Assessment – Sim 2, Bulk Generation

- Emission control vs. no control vs. base case (no EV)





Next Steps: Complete all simulation scenarios and summarize results statistics and metrics

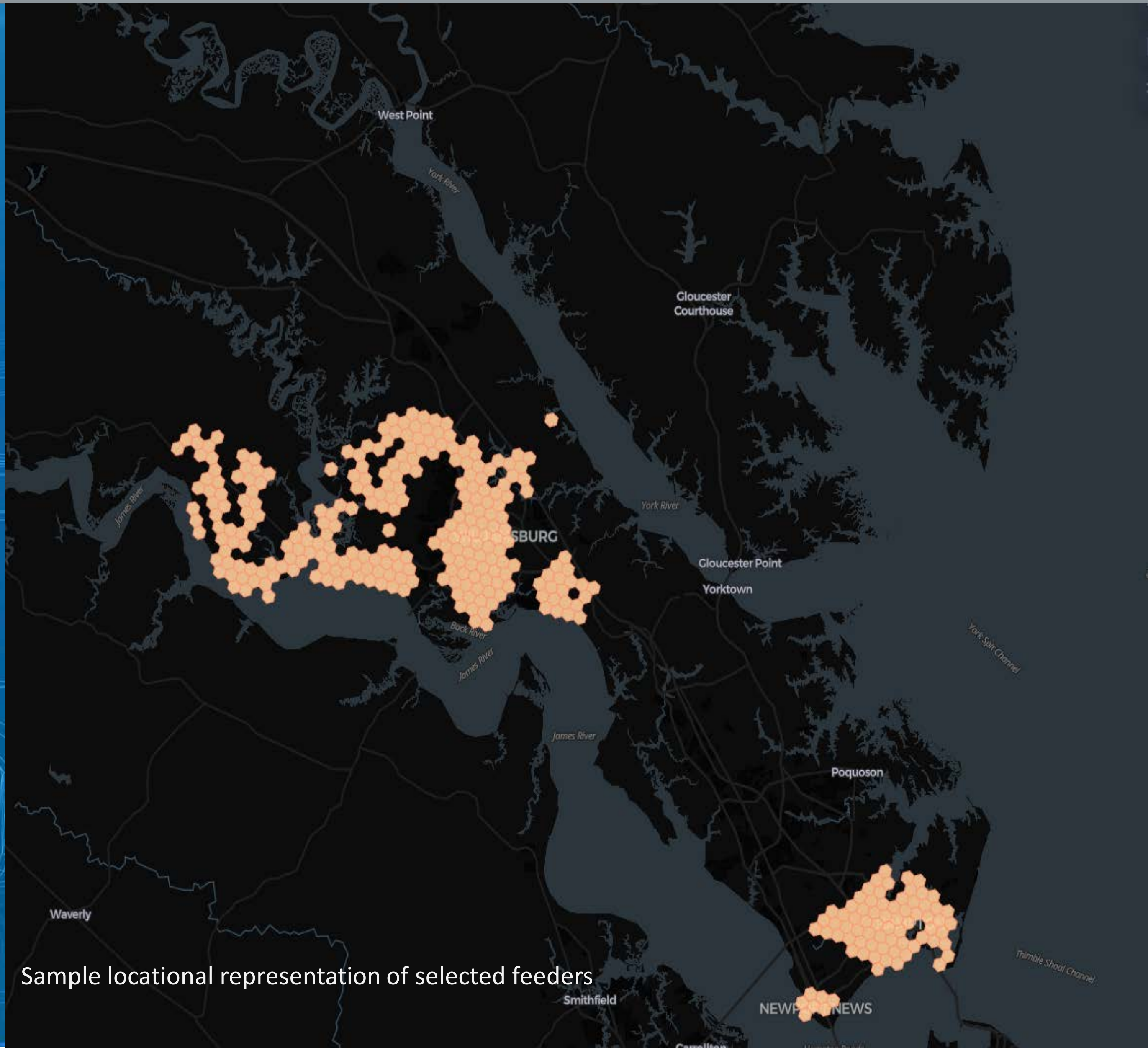
Key findings

- **Voltage issues – selected feeders are healthy so not much impact voltage-wise, could be different for other feeders or other areas**
  - Voltage issues could be more prominent with secondaries included
- **Transformer loading levels are more of a problem area compared to line loading**
  - SCM methodologies could provide relief for overloaded transformers
- **Centralized control provides the best results for selected feeders**
  - Utility discussion is needed to understand the cost-benefit perspective of implementing such control strategy
- **TOU immediate might not be the best option with EV penetration on the rise**
  - More time and location aware controls would be better

Next Steps

- **Technical metrics**
  - NREL team will continue to work on summarizing the results with effective technical metrics

- **Feeder selection**
  - For future control scenarios, diverse sets of feeders will be selected which could showcase better efficacy with implementing SCM methodologies



Sample locational representation of selected feeders

Ideas for Collaboration

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U.S. Department of Energy

Possible Avenues

- Automation of dataset curation, planning processes --> tool development
- Useful planning framework for utilities – interoperability with integrated planning and operational controls
- Discussion with enterprise software entities to utilize our open-source pipeline and formulate a plugin for utilities/engineers

EVs @ Scale
U.S. Department of Energy

Opti-VGI: Smart Charge Management

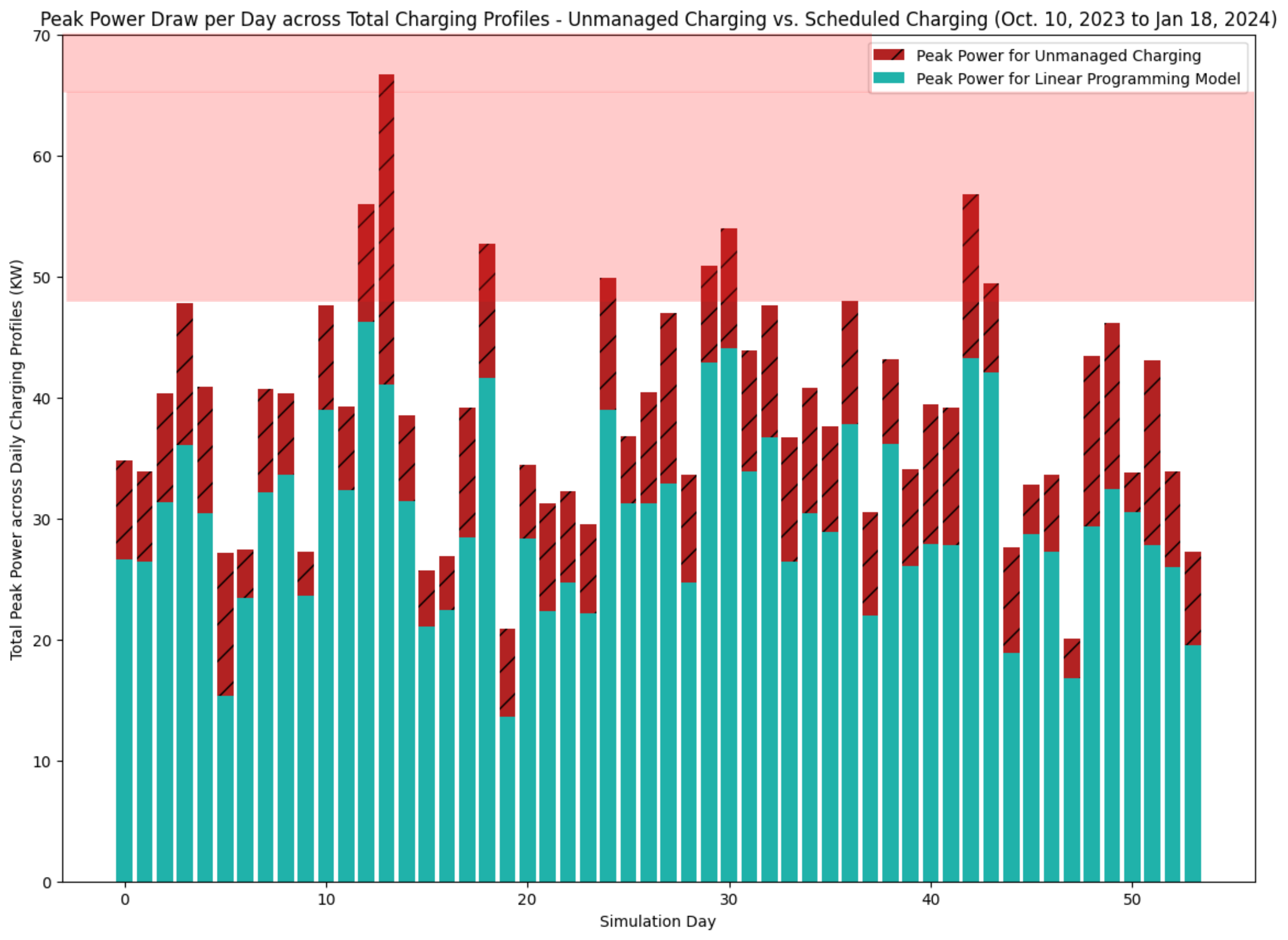
Deployment & Analysis

Nithin Manne, ANL

FUSE SCM/VGI Deep Dive
October 31, 2024

Background

- **Peak** charging loads at ANL's Bldg-300 are exceeding infrastructure capacity
  - 160 A operating limit of breaker panel
  - 40 kW (nominal) Solar Panel
- Simulations on historical charging data shows **SCM** can successfully reduce peak demand to stay within constraints
- Opportunity: Can we **leverage** the **needs** of the EV driver to **effectively** address these infrastructure limitations?

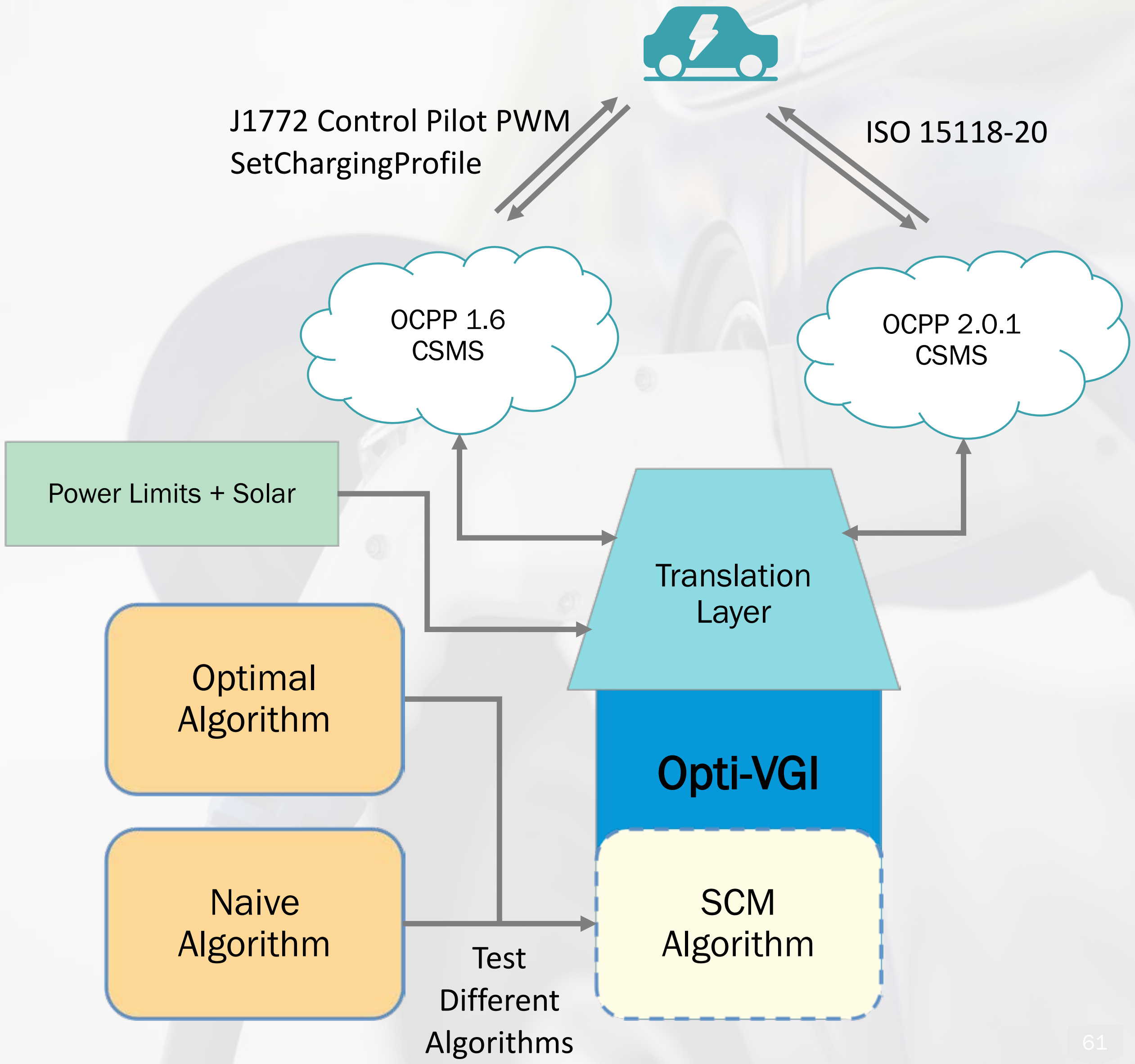


Opti-VGI (Introduction)

- **Opti-VGI** is an EV smart charging management (**SCM**) application designed to optimize electric vehicle charging based on power or pricing constraints

- This application can integrate with any
  - *OCPP 2.X* **CSMS** to accomplish ISO 15118 charge scheduling
  - *OCPP 1.6* **CSMS** to accomplish smart charging by setting J1772 PWM duty cycle

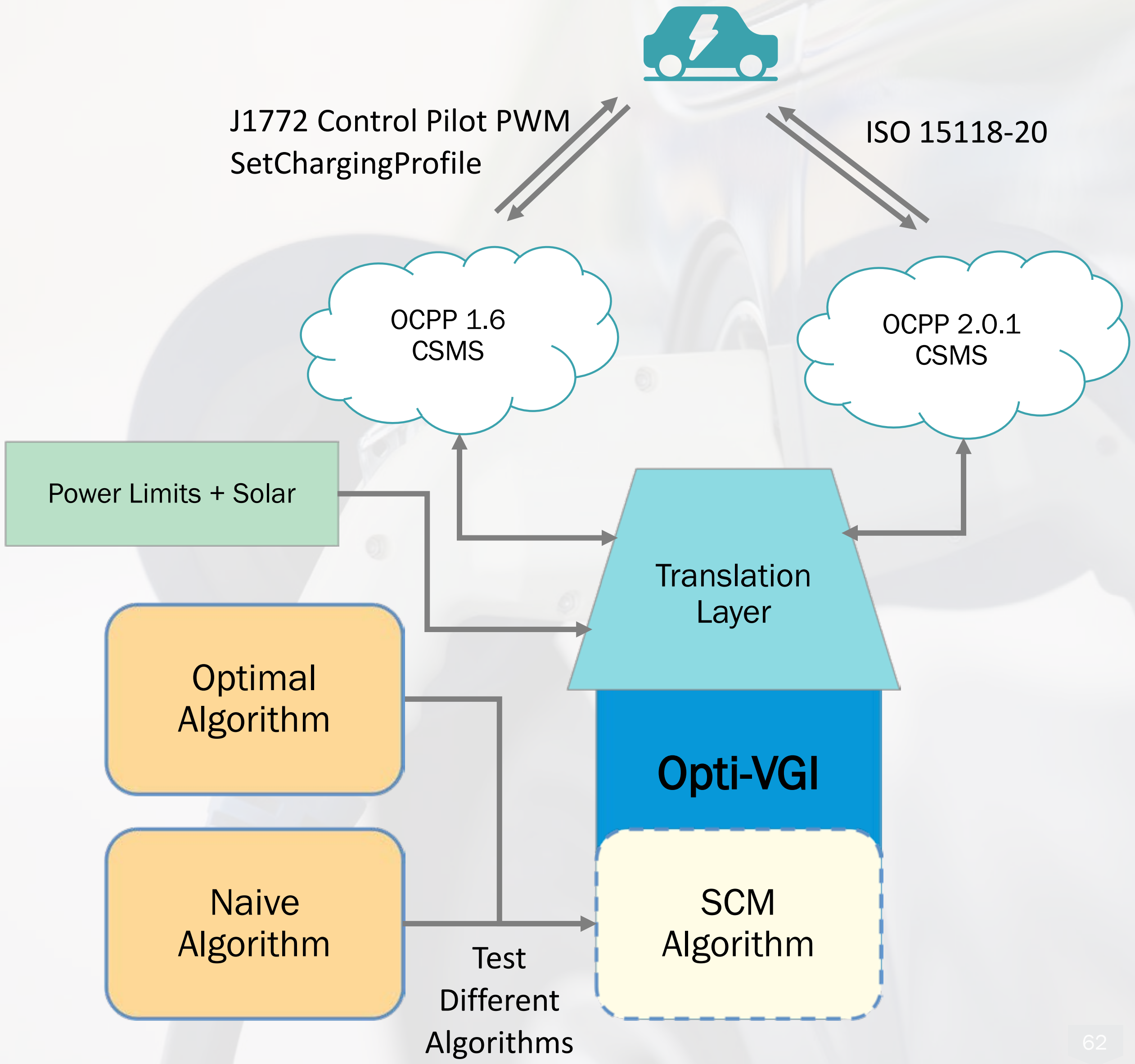
- **Opti-VGI** can be used to test different **SCM** algorithms to **evaluate** performance on real-world scenarios



Opti-VGI (Architecture)

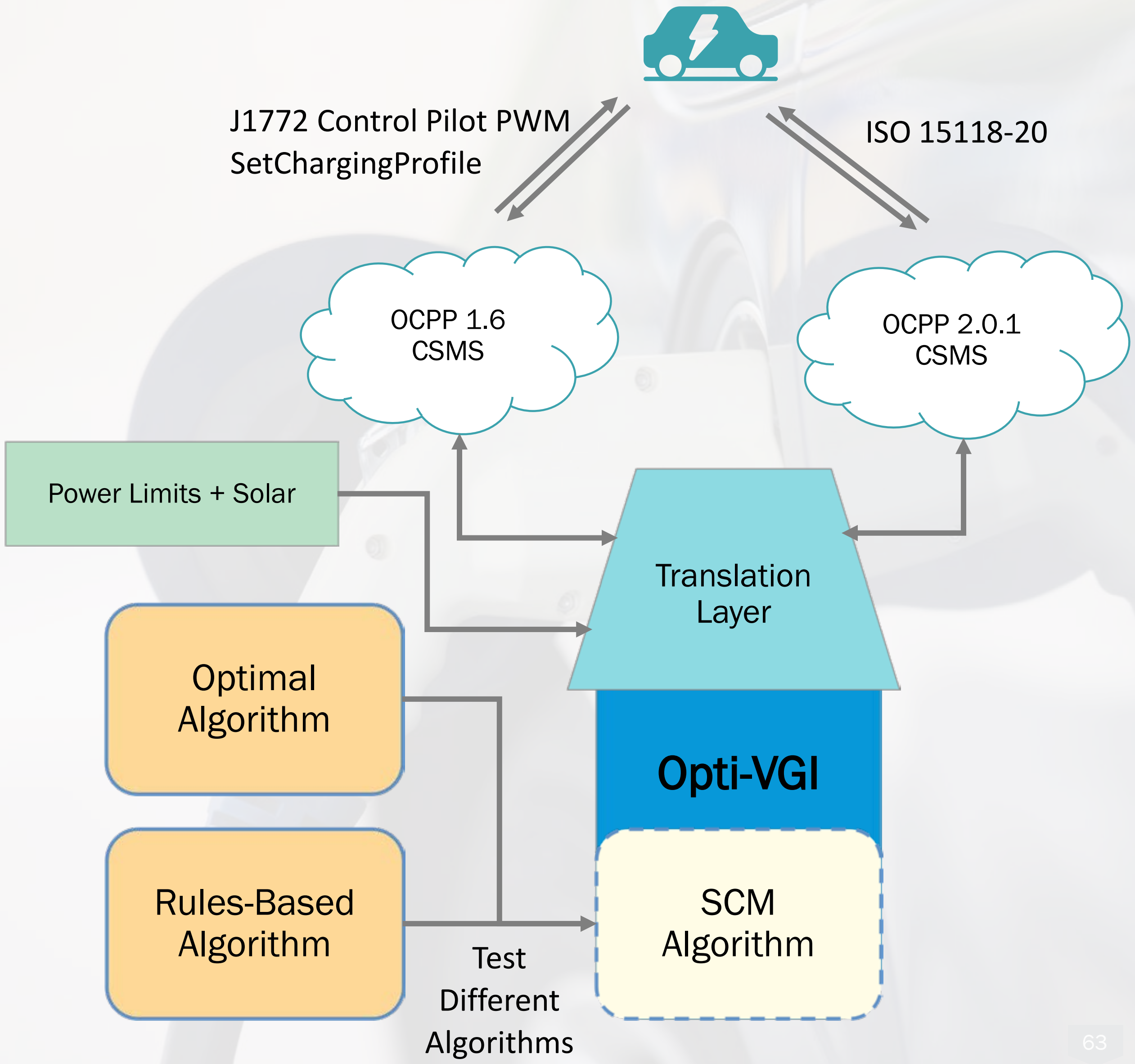
- **Modular Charge Scheduling Management (SCM) Application**
  - A modular framework that allows swapping & testing different algorithms
  - Well-defined API specification makes it easy to implement & test various **SCM** algorithms

- **Translation Layer**
  - An application that interfaces between the Charge Station Management System (**CSMS**) and the Charge Scheduling Management Algorithm
  - Describes an *API* ***specification*** that needs to be implemented to support each **CSMS**



Opti-VGI (SCM Algorithms)

- As part of our research, we designed two different algorithms for optimal **SCM**
- **Optimal Algorithm**
  - Model the constraints as an integer linear programming problem and use an optimization solver to generate most optimal charging plan
  - Pros: **Guaranteed** to be optimal based on constraints and choice of *objective* function
  - Cons: **Inconsistent** prioritizing of EVs across time causes constant **fluctuations** in charging speed for individual EVs
- **Rules-based Algorithm**
  - *Analyze* the problem scenario and **design** an algorithm to **distribute** available power to all EVs based on their needs
  - Pros: Predictable power distribution gives consistent results in a real-world application
  - Cons: Not guaranteed to be optimal when considering all **edge cases** of power distribution

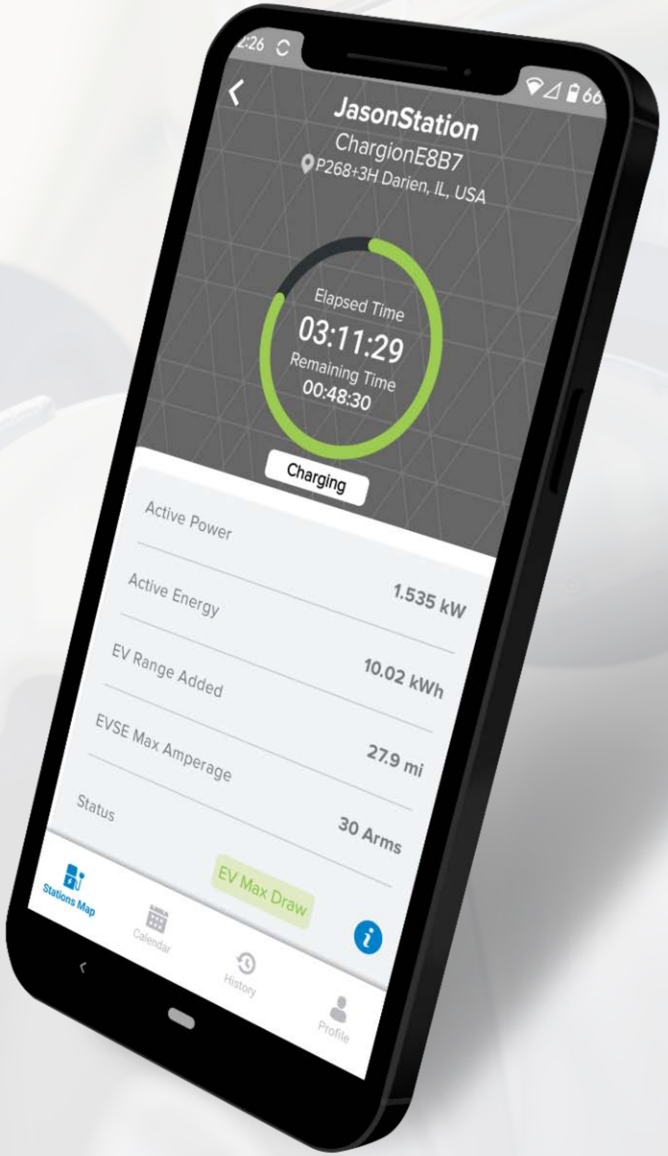


EVrez (formerly EVrest)

- **EVrez** was developed by Argonne National Laboratory to manage the EV charging program with over 35 stations
- Access to **real-world** EV charging data from over **200** drivers enrolled in the employee charging program
- **EVrez** allows drivers to reserve EV chargers by specifying
  - Charging Station / Port
  - Reservation Start Time
  - Reservation Duration
  - *Requested Miles* *

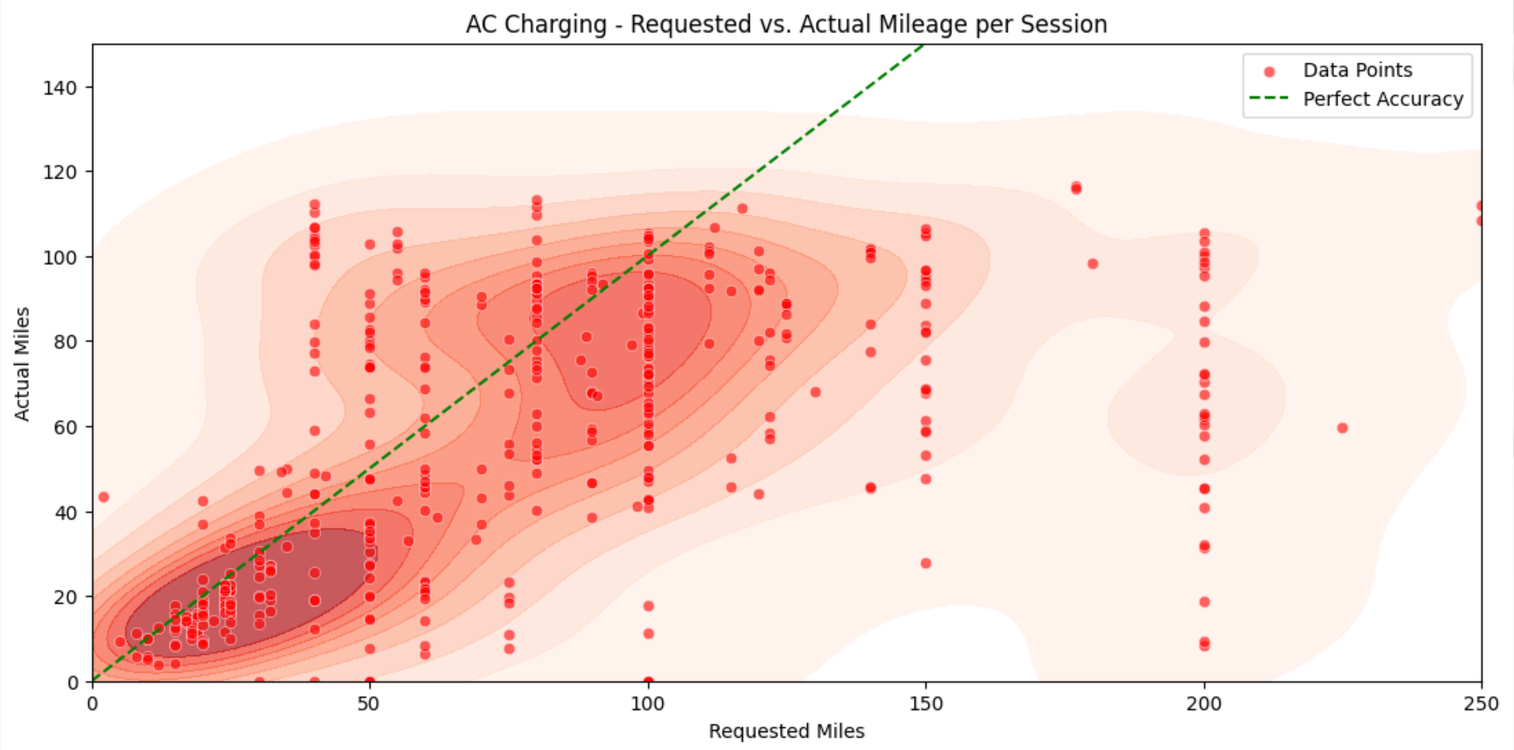
- Timeline (October 2024)

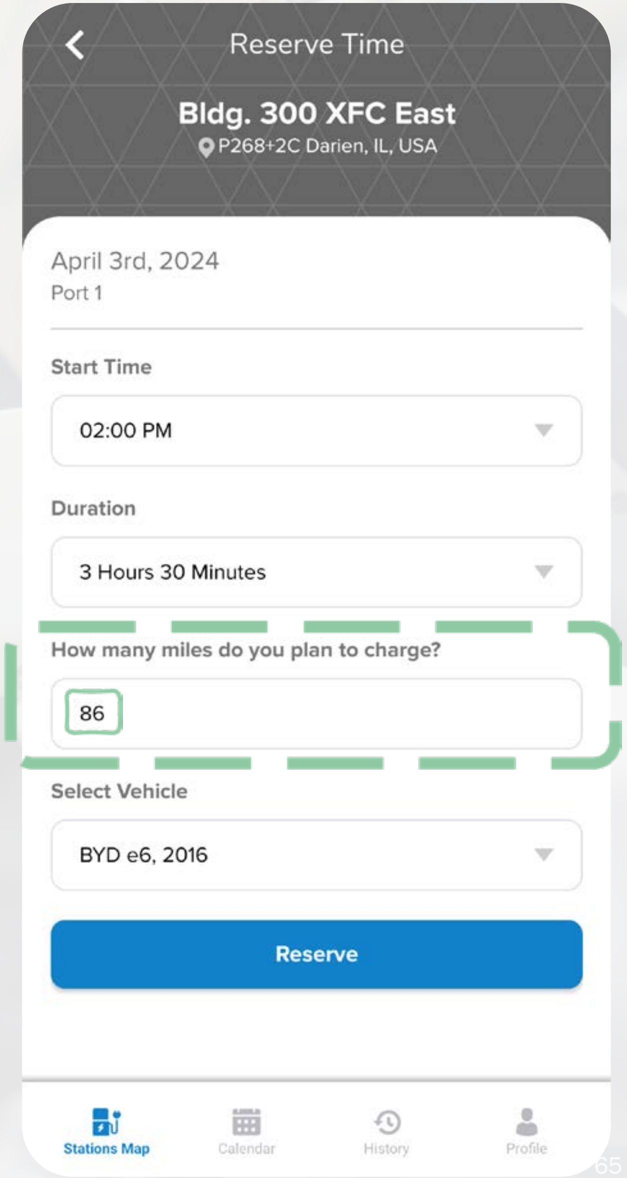
10-09-23	10-13-23	11-22-23	11-29-23	09-21-24
Opened **EVrez** Registration	6 AC Chargers at Bldg. 300 go live	9 AC Chargers at Bldg. 242/362 go live	DC Chargers at Bldg. 300 go live	19 new AC Chargers across ANL go live



EVrez (Miles Prediction using Machine Learning)

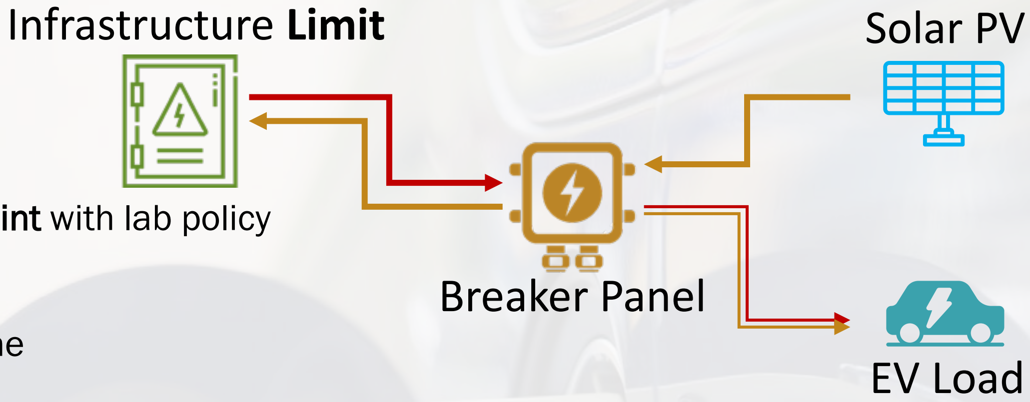
- *Requested Miles* is one of the most important input for <u>optimal</u> **SCM**
  - <u>A lot</u> of drivers indicate a <u>larger</u> value than they end up charging
- <u>Pre-populate</u> the Requested Miles field using an **ML model** trained on all user's sessions
  - Convenient for drivers to not fill an additional box
  - Better for **SCM** algorithm since miles are more accurately representative of historical data



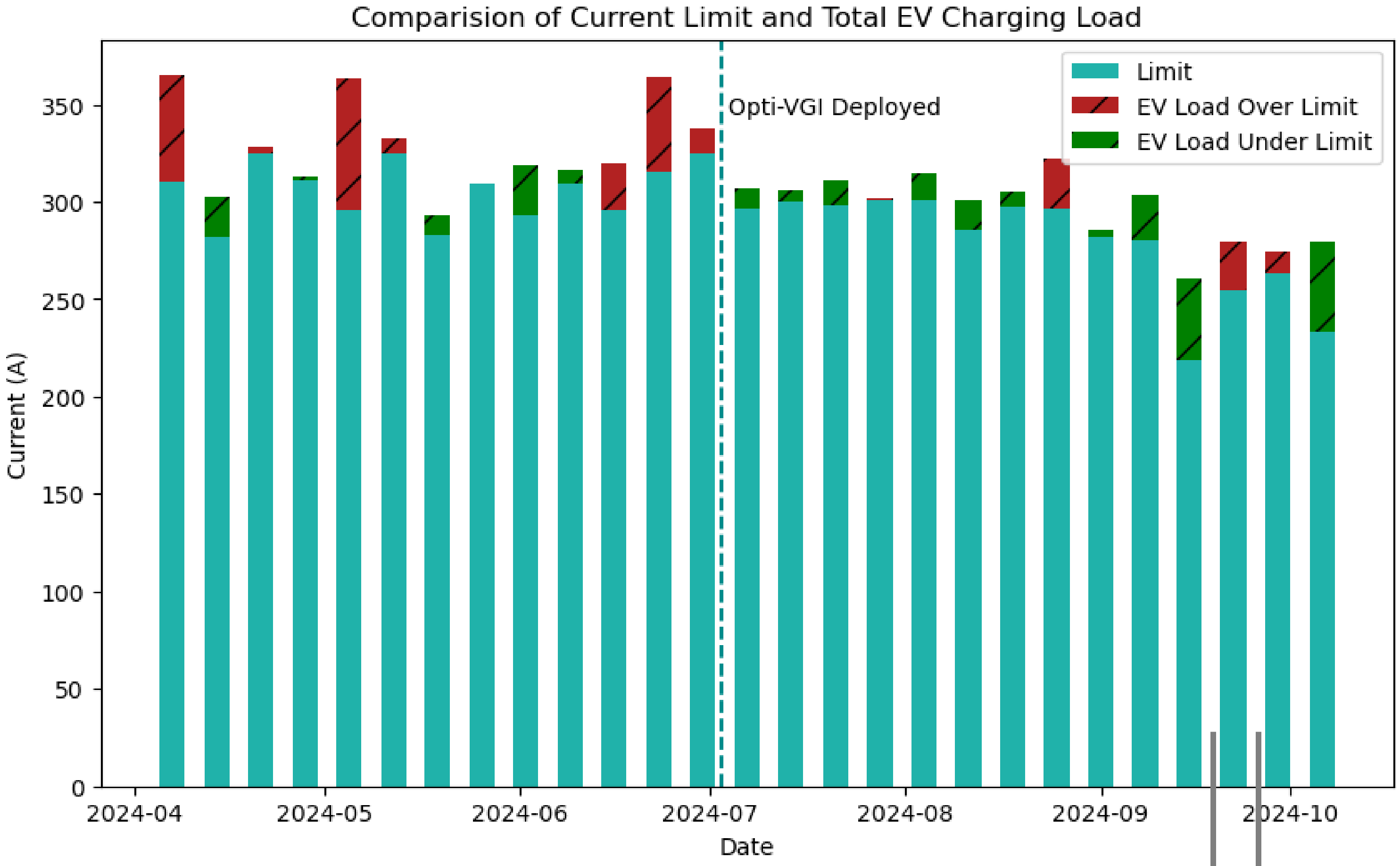


Opti-VGI (Deployment)

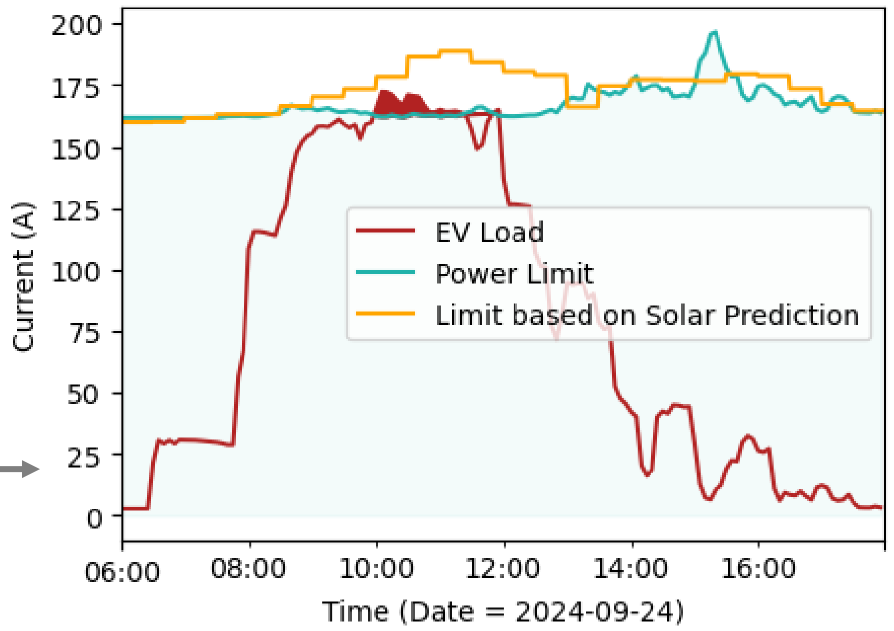
- **Opti-VGI** was deployed at Building 300 on *07/01/2024*
- Perfect testbed for deploying **SCM:**
  - Capacity constraints essentially **mandate** some form of smart charging to be **complaint** with lab policy
  - Access to **diverse real-world** data through the lab's employee charging program
  - In-line solar panels result in ***variable*** & ***dynamic*** power limit curve instead of a flat line
- How to generate this ***dynamic*** limit?
  - Use a solar irradiance **forecasting** API by '*Solcast*' to estimate solar power for next 4 hours
- **Operational Goals**
  - Meet the charging **needs** of the EV driver
  - Reduce peak charging load to stay under **160 A** at the breaker panel



Analysis (Reduction of Peak Charging Load)



- **Opti-VGI** deployment **reduced** the number of number of times usage **exceeded** capacity
- **Incorrect** solar forecasting data results in all over-load events after **Opti-VGI** deployment
  - Real-time monitoring/control needed to solve

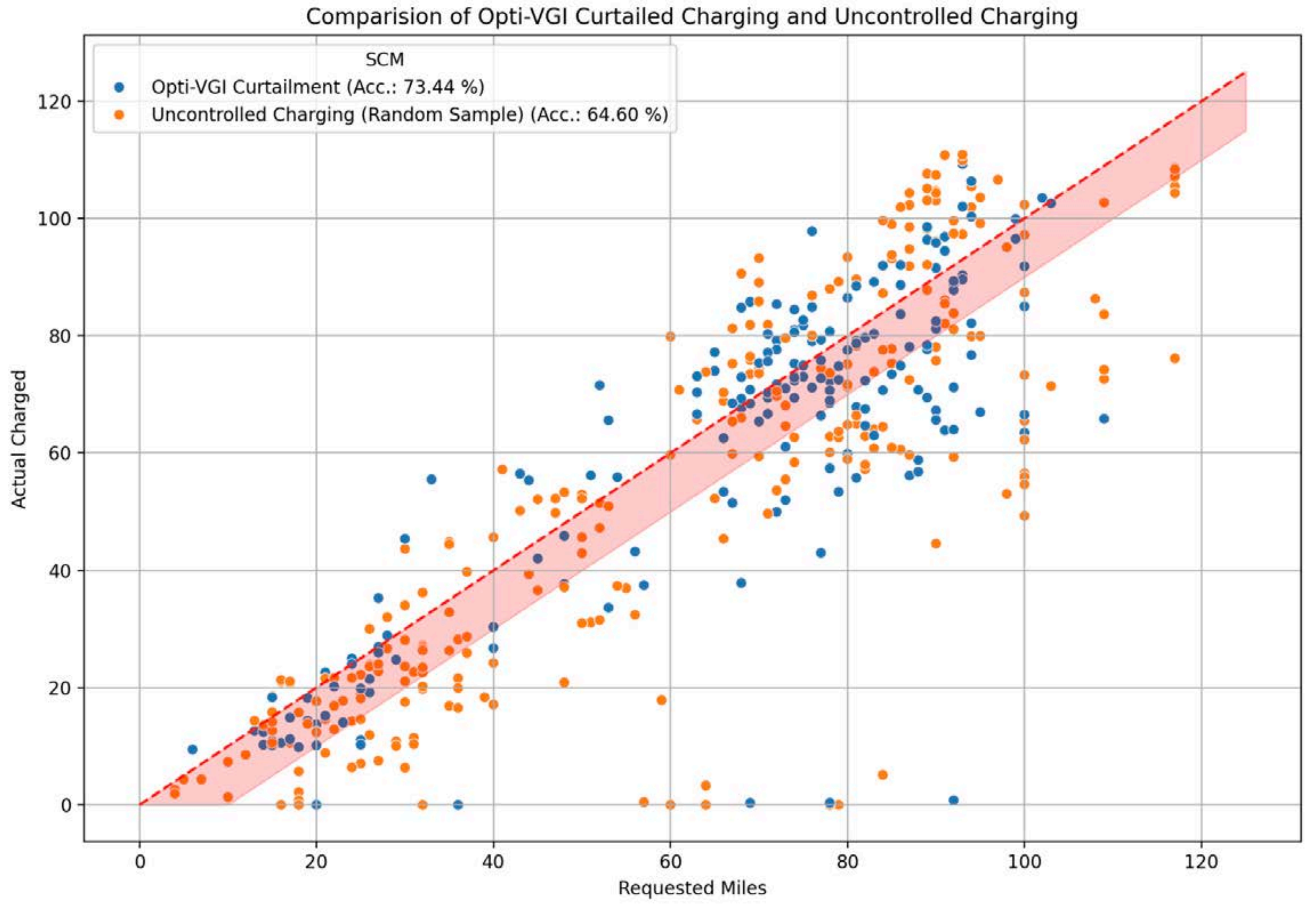


Analysis (Meet the Charging Needs of EVs)

- **Opti-VGI** generates optimal **SCM** plans, but there are still many reservations that miss their mileage target due to various reasons

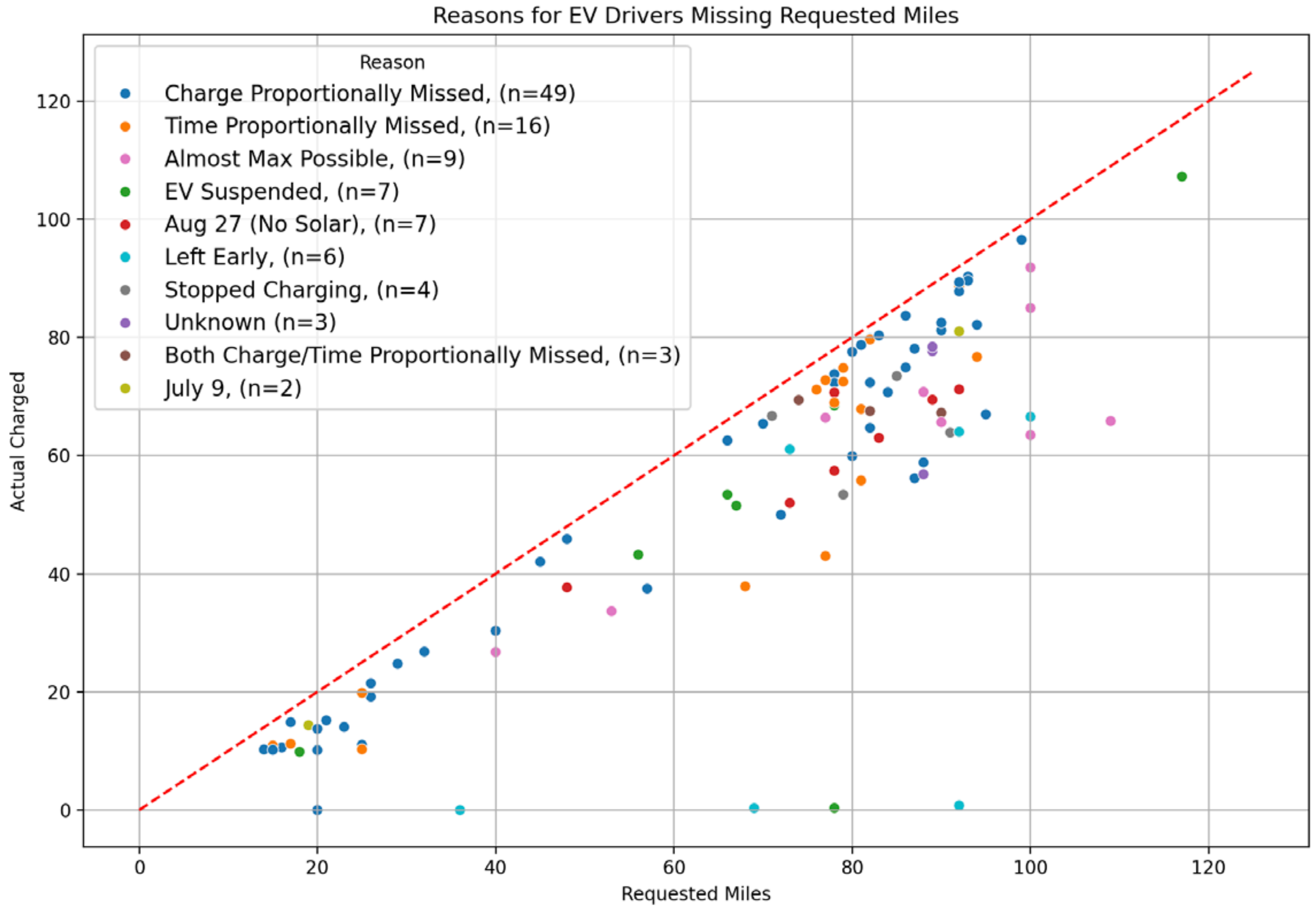
- This plot compares reservations where **curtailment** happened with reservations with uncontrolled charging

- Uncontrolled charging implies all vehicles charge at **full power** and is only possible if the load is well **under limit**



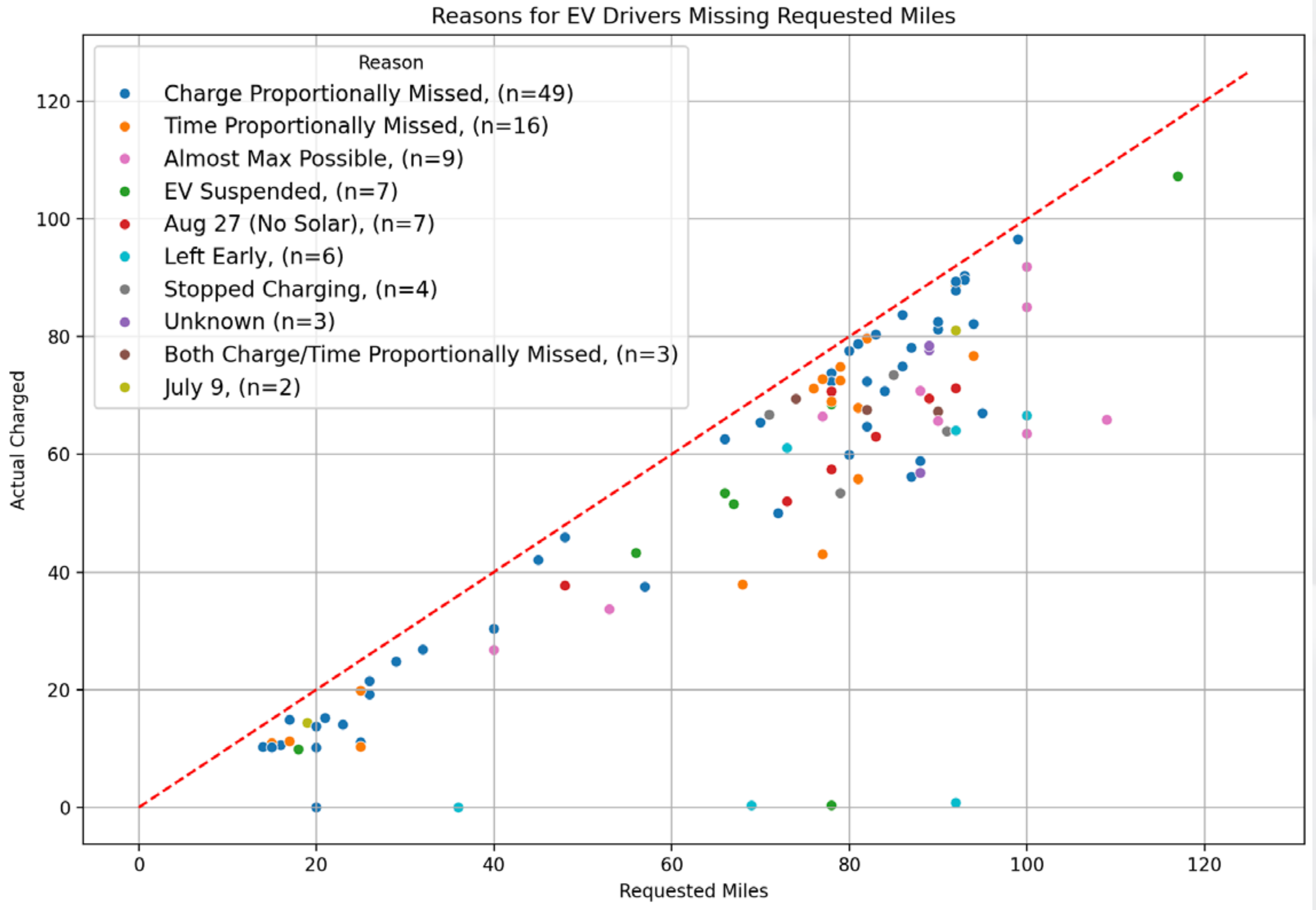
Analysis (Reasons for missing mileage targets)

- We analyzed all charging sessions that missed their requested mileage and discovered the following ***reasons***:
  - Charge Proportionally Missed (*~45%*)
    - Most EVs don't follow the current limit sent by the EVSE exactly and instead keep a **safety margin**, which means they charge **slower** than expected.
    - This means that many vehicles end up missing their requested mileage proportional to this effect
  - Time Proportionally Missed (*~15%*)
    - Sometimes EV drivers leave **before** their departure time
    - All sessions with this reason missed their request **proportional** to how early they left
  - Both Charge/Time Proportionally Missed *(~3%)*
    - Can only be explained by combining **both** effects



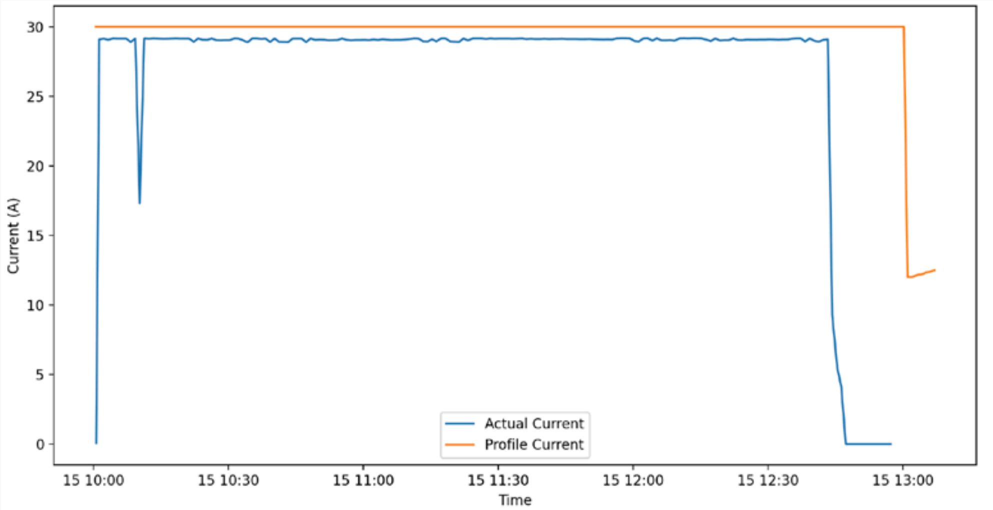
Analysis (Reasons for missing mileage targets)

- We analyzed all charging sessions that missed their requested mileage and discovered the following ***reasons***:
  - <u>Almost Max Possible</u> (*~8%*)
    - The requested miles for this reservation is equal to the **maximum possible** energy that could be dispensed to this vehicle
    - A single timestep where this EV doesn't have full power allocated to it could lead to this session not meeting its goal
  - <u>EV Suspended</u> (*~7%*) / <u>Stopped Charging</u> (*~4%*)
    - Usually indicates that battery is **full** or charging stopped due to an **error** with the onboard charger
  - <u>Left Early</u> (*~6%*)
    - The reservation ended **prematurely** since the driver stopped Charging and left
  - <u>No Solar</u> (Aug 27, July 9) (*~8%*)
    - **Unusually** low solar production on a rather busy day caused a lot of EVs miss mileage targets

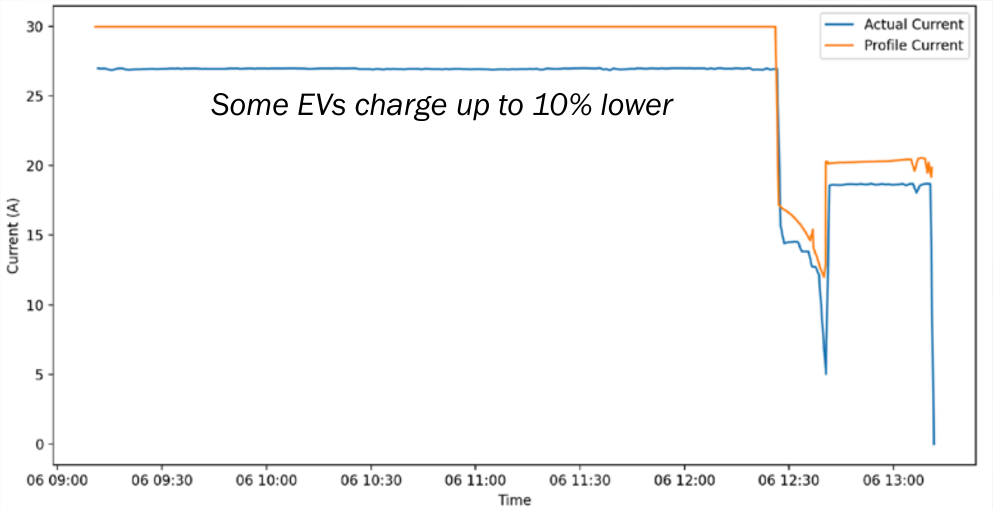


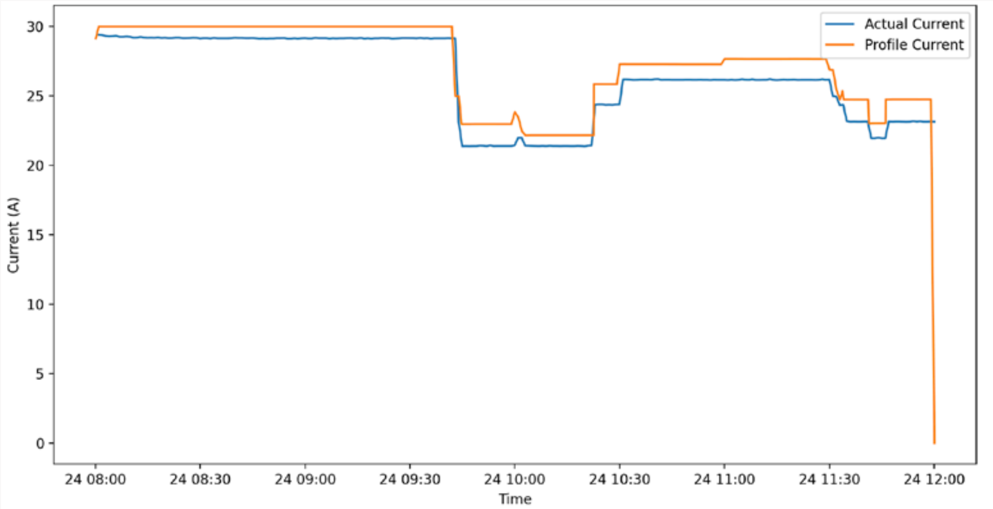
Analysis (Examples of Charging Sessions)

Time Proportionally Missed (Left Early)

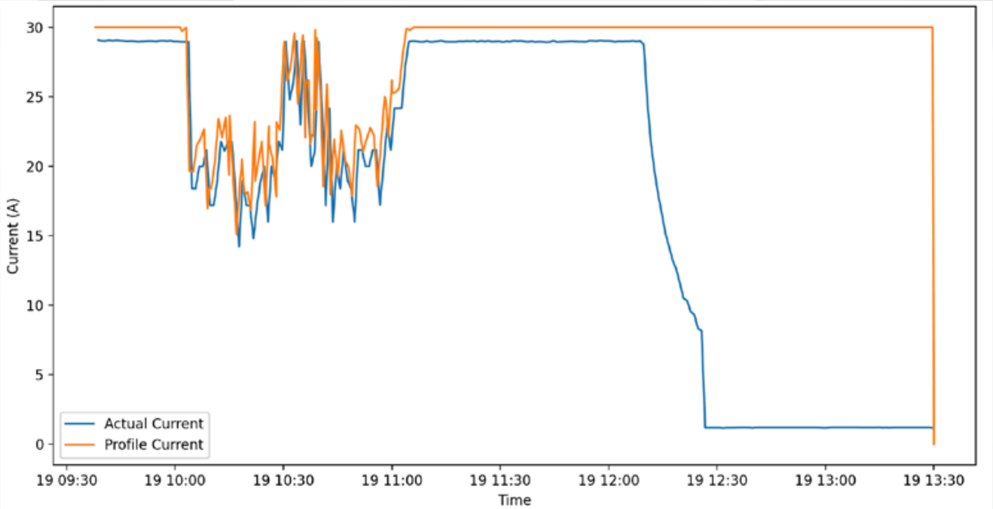


Charge Proportionally Missed





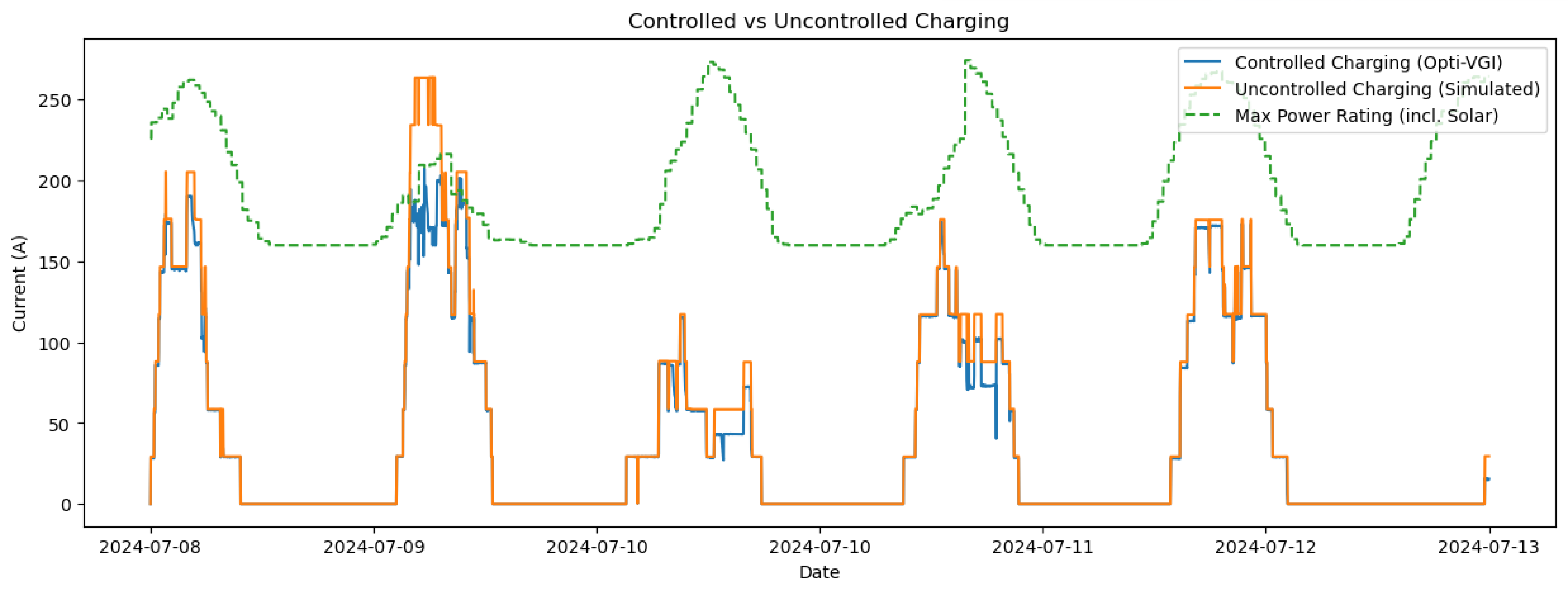
Max Possible Energy Requested



EV Stopped Charging

Analysis (Weekly Data)

- On July 9, an **unusually** *cloudy* day at Argonne National Laboratory caused solar generation to drop by almost half
- Without **Opti-VGI**, Bldg. 300 breaker panel would have **exceeded** its limit by **50 A** for more than **2 hours**
- The *side-effect* of this scenario is that a lot of vehicles were **curtailed** and did not meet their needs

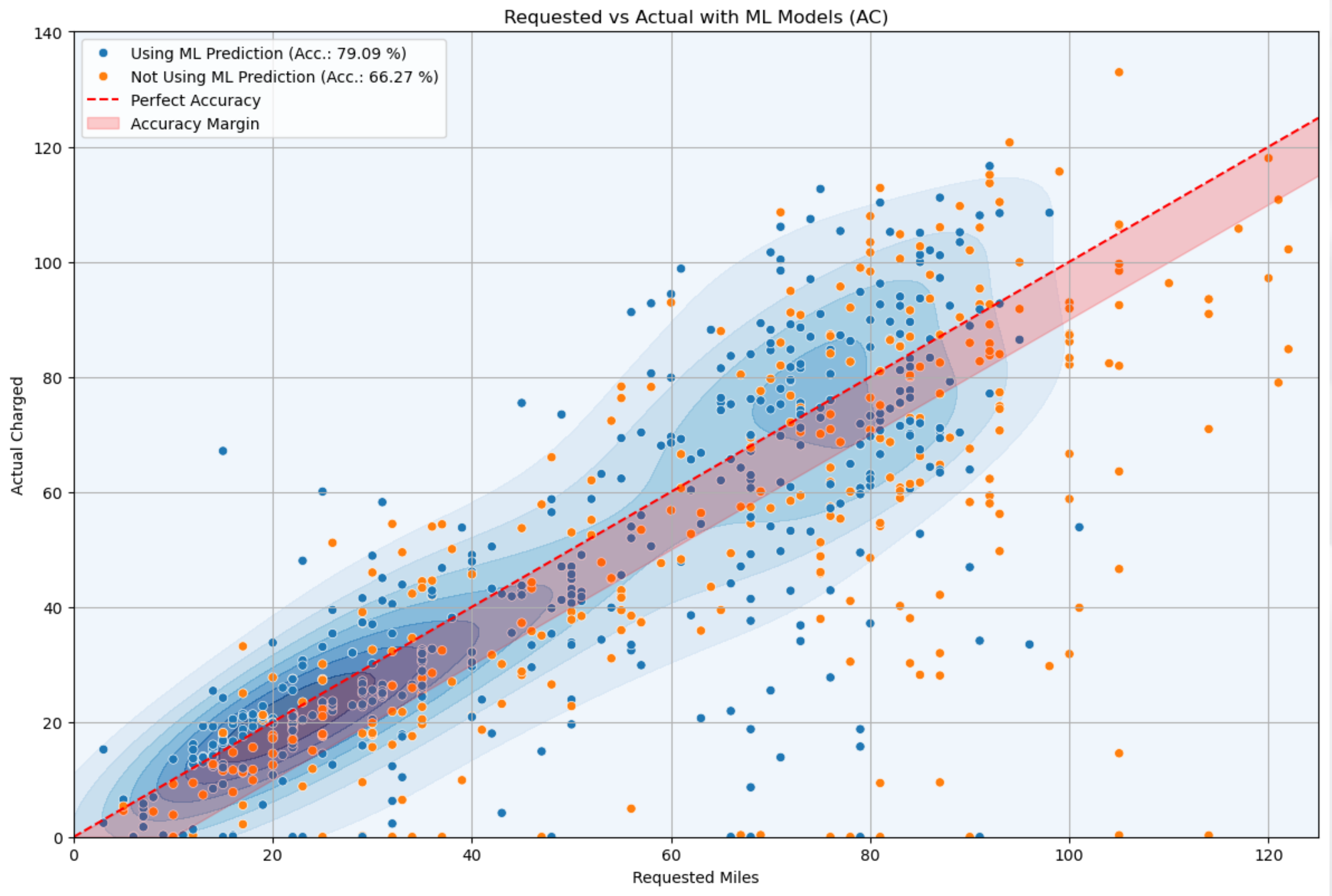


Analysis (Miles Prediction using Machine Learning)

- Increased accuracy of drivers meeting their needs when using the *ML-predicted* mileage request

- This increase in accuracy is even more prominent on the higher ranges where its easier for drivers to *over-estimate* their need

- ML model allows **Opti-VGI** to more *effectively* perform smart charging due to more realistic and historically accurate mileage requests.



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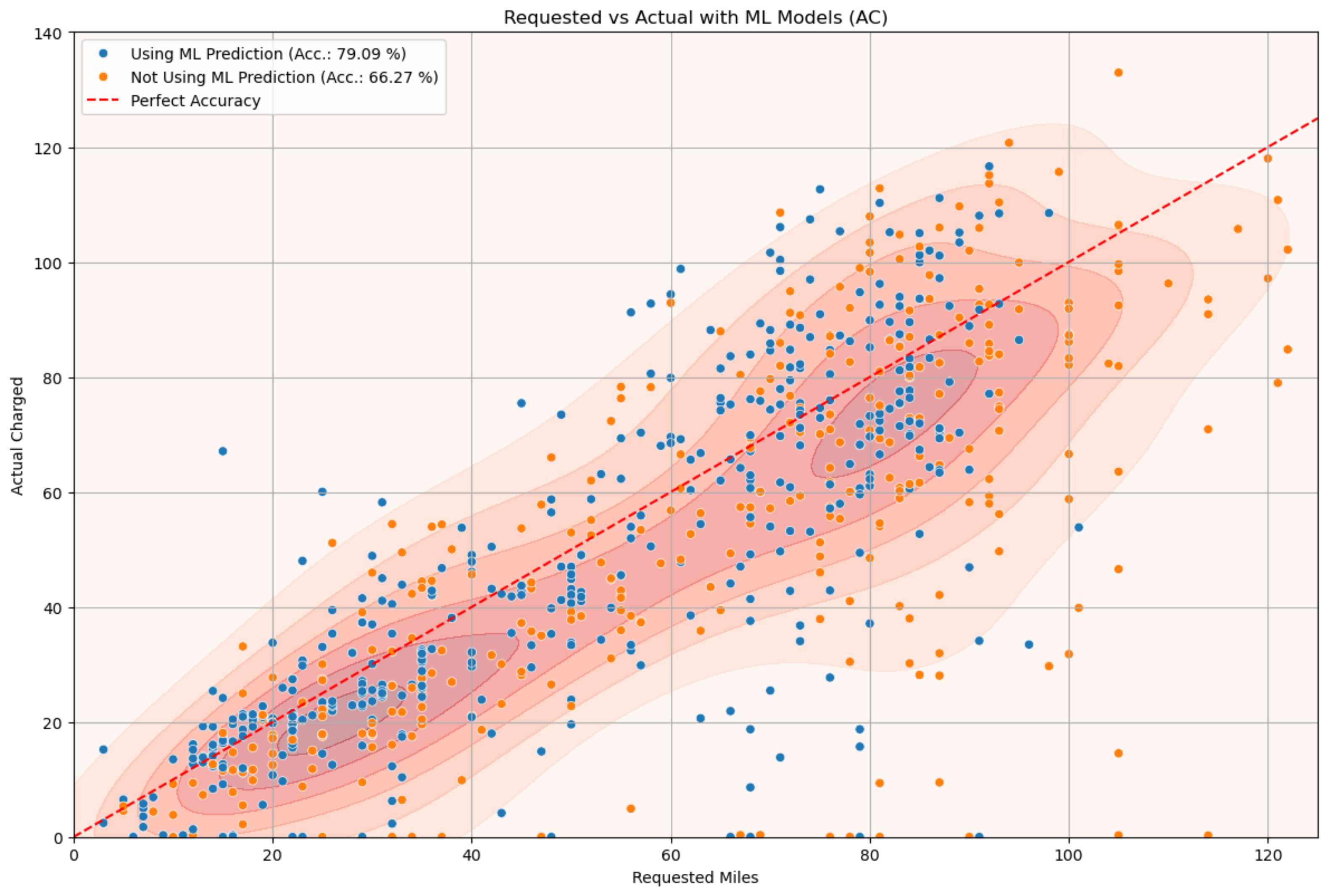

Key Observations

- Most charging sessions meet their indicated needs
  - Almost *75%* of sessions with **Opti-VGI** curtailment met their needs by departure (using a 10-mile accuracy margin)
- EVs may charge up to *10%* lower than requested
  - Almost all EVs have a built-in safety margin that causes them to draw less power than the **J1772** current limit
- Some EVs are fully charged and stop charging, which leaves a lot of available power
  - Power allocated to these EVs will be unused and could have been re-distributed
- Some EV drivers depart earlier than requested
  - Higher chance of the departing EV not meeting their needs
  - We re-allocate released energy to other vehicles immediately
- Busy days with lower available solar power causes all drivers to miss goal
  - Lower available power limit causes all EVs to be curtailed

Future Improvements

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- Use an ML model to predict **departure time** and try to generate a schedule that is more optimal based on this information
- Monitor the **actual power draw** of vehicles and compensate for vehicles drawing slightly lower power and vehicles that have completed charging
- Monitor the real-time solar generation data to quickly respond to
- **Improve** the rules-based algorithm to include any identified **corner cases**
- **Open source** Opti-VGI and **support** popular open-source CSMS (Ex: CitrineOS, MaEVe) by creating translation layers
- **Analyze** charging profiles by vehicles' make/models to determine how accurately they **follow** the duty cycle

FUSE Partnership Opportunities

- **Opti-VGI Deployment**
  - Deploy **EVrez** app and **CSMS** to manage multiple EVSEs with a reservation system for users
  - Deploy **Opti-VGI** SCM application in conjunction with **EVrez** to perform Smart Charging based on user needs
  - Deploy **Opti-VGI** without EVrez to perform Smart Charging based on Utility/Grid constraints

Interested in Partnering with FUSE?

Contact

Researcher: Nithin Manne, ANL (nmanne@anl.gov)

EVrez PI: Jason Harper, ANL (jharper@anl.gov)

FUSE PI: Jesse Bennett, NREL (Jesse.Bennett@NREL.gov)

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Thank You!

Contact

Researcher: Nithin Manne, ANL (nmanne@anl.gov)

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Quantifying the inconvenience of long-dwell public charging

Jeewon Choi, Thad Haines, Andrea Mammoli, Emily Moog, Will Vining

Fall 2024 Deep Dive Meeting

U.S. DEPARTMENT OF ENERGY | Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

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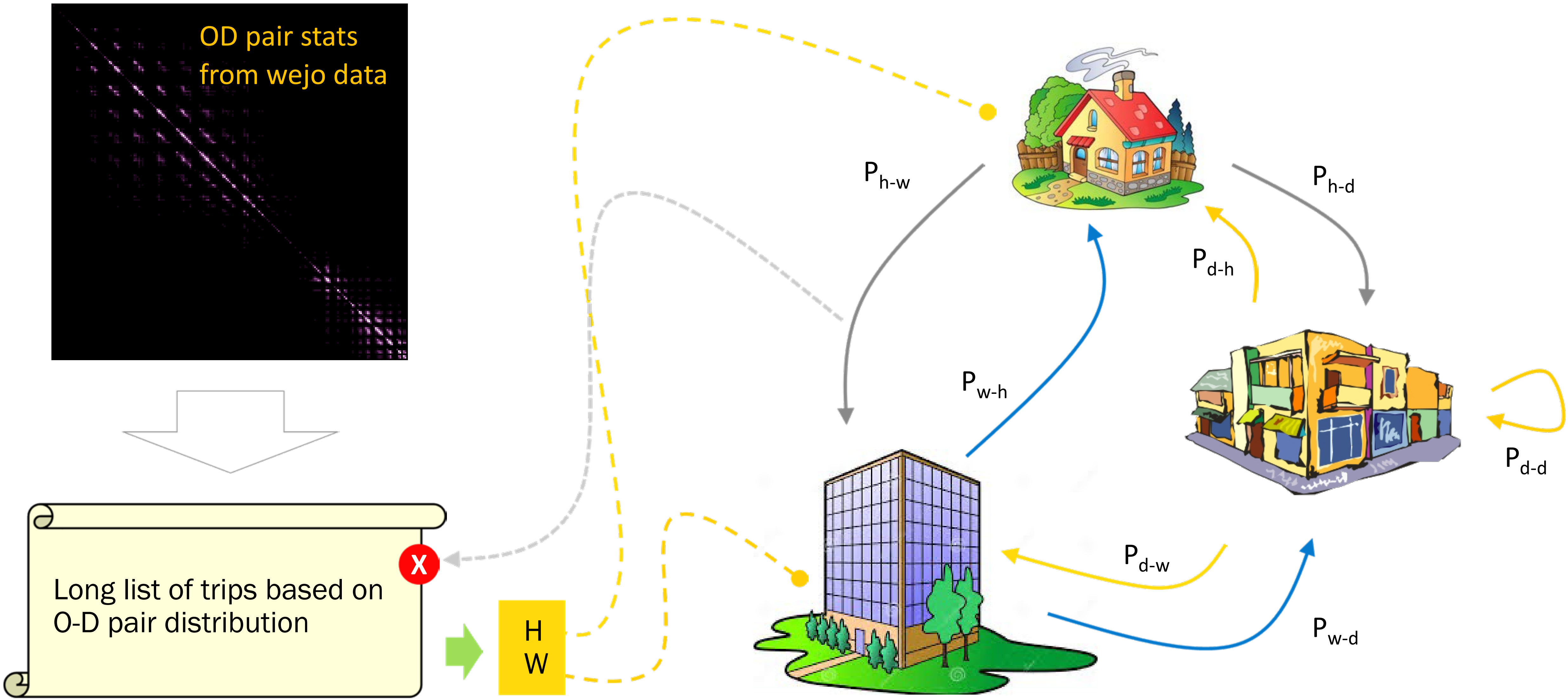
Why measure inconvenience

- **32% of consumers were considering an EV but cite a lack of charging stations in their area as the reason they wouldn't purchase.** https://thefutureeconomy.ca/op-eds/vehicle-to-grid-technology-will-boost-ev-adoption/?utm_source=Reddit&utm_medium=Social+Media&utm_campaign=Rob+Safrata
- **64% of Americans live within 2 miles of a public charging station, and those who live closest to chargers view EVs more positively** https://www.pewresearch.org/data-labs/2024/05/23/electric-vehicle-charging-infrastructure-in-the-u-s/
- **71.68% of public EV charge ports are in the top fifth of counties based on income** https://www.autoweek.com/news/industry-news/a44627107/ev-charging-access-inequality-usa/
- **Just under 10% of those living in the top 50 US cities live within a 5-minute walk from a public EV charger** https://www.emergingtechbrew.com/stories/2021/08/11/90-americans-dont-easy-access-ev-chargers
- **With home charging, BEV operational inconvenience can approach and surpass parity with ICV operational inconvenience** Rabinowitz, Aaron I., John G. Smart, Timothy C. Coburn, and Thomas H. Bradley. "Assessment of factors in the reduction of BEV operational inconvenience." *IEEE Access* 11 (2023): 30486-30497.
- **Those who cannot charge at either home or work can expect large increases in inconvenience**
- **those in highly urbanized localities experience less operational inconvenience than those in suburban or semi-rural localities** Dixon, James, Peter Bach Andersen, Keith Bell, and Chresten Træholt. "On the ease of being green: An investigation of the inconvenience of electric vehicle charging." *Applied Energy* 258 (2020): 114090.

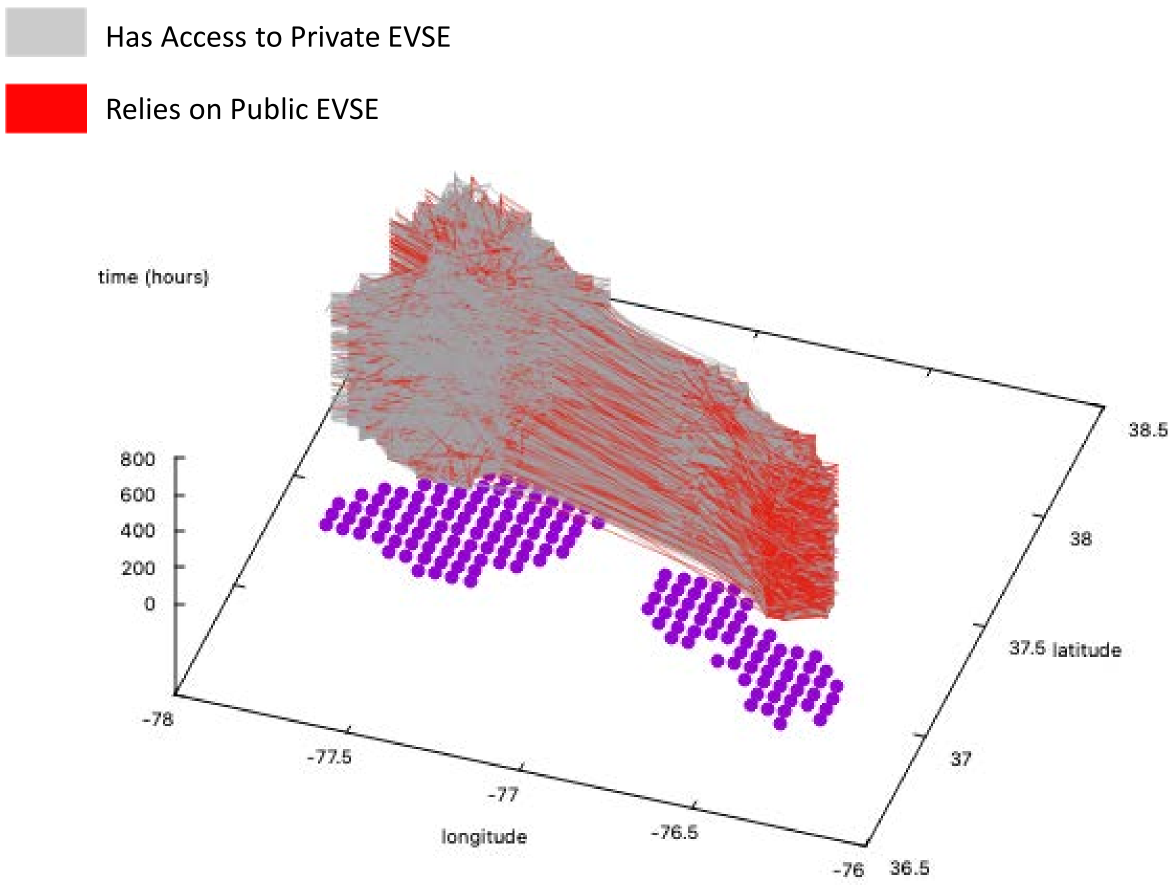
How is charging inconvenience measured?

- **In transportation literature, user inconvenience is measured in terms of a linear sum of factors associated with time spent performing certain actions:**
  - For trains: weighted sum of time spent waiting, in transit, transferring trains, overcrowding
  - Some relate time with monetary cost, for example by surveying “willingness to pay” WTP – but need to consider income
  - Actions happening outside of a desired window – e.g. early arrivals, late departures
  - Perceived inconvenience depends on the level of information about waiting times
- **Charging inconvenience occurs only during the time that a user’s actions are constrained**
  - At home, at work, en route, or at a destination (supermarkets, restaurants, gyms, etc.)
- **People prefer to charge at home, at work, then at destinations**
- **The value of time, as measured in terms of WTP, is strongly dependent on time of day and activities**

List-constrained Markov chain trip sequence generation



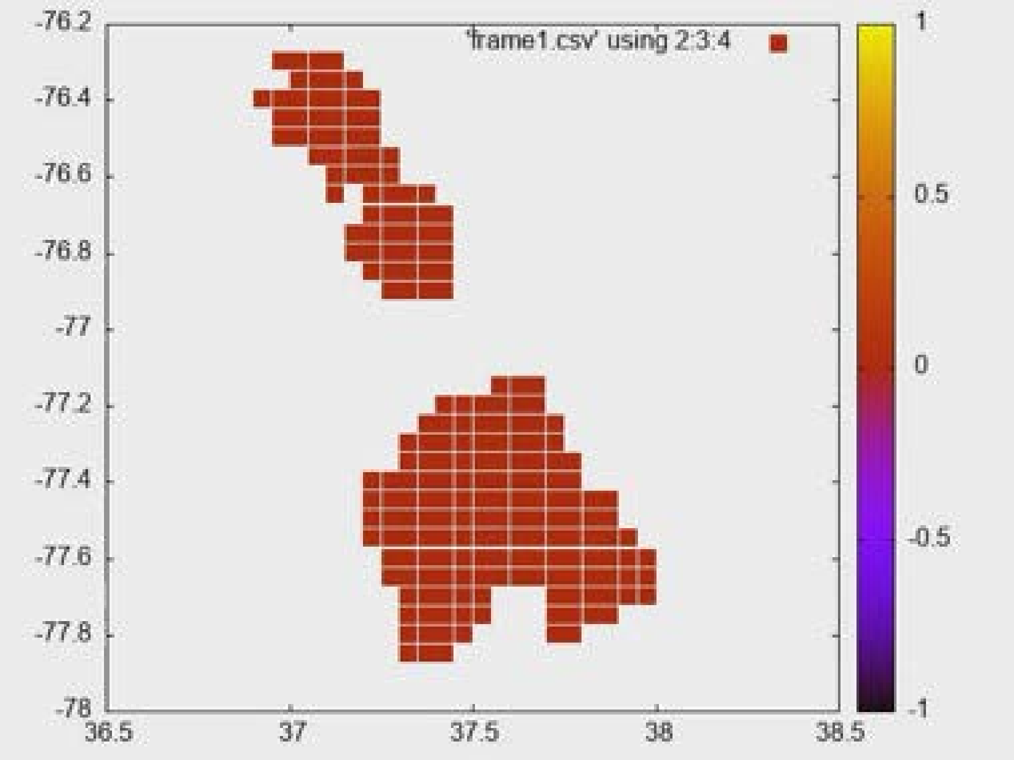
Locating charging stations where they are needed



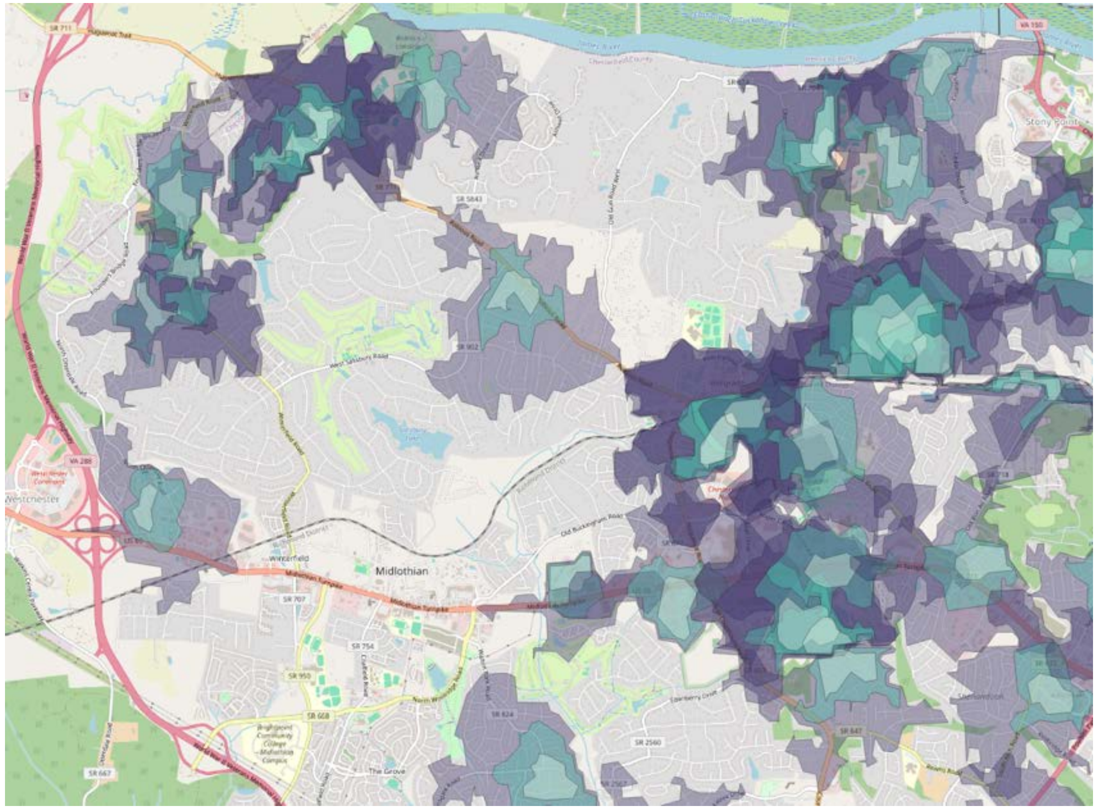
Identify itineraries for no-access customers and evaluate energy needs by territory cell

- **Given a list of itineraries:**
  - We associate fixed specific addresses to the home and work locations, and addresses to all other waypoints
  - We find the actual route driven by each agent as they travel along the itinerary
  - We calculate the energy need at all waypoints at each hour and for an entire 30-day period
  - We calculate the average power for each grid cell
  - We determine how many L2 charge ports are needed to meet the average power demand, assuming a capacity factor of 0.25 (same as for gas stations)
  - We deploy EVSE at reasonable locations accessible to vehicles.

The basics: locating charging stations within reach



Hourly transfer of power that is required by vehicles collectively traveling along trajectories



Addresses where EV drivers can access EVSE within a given walking distance, based on placement of EVSE

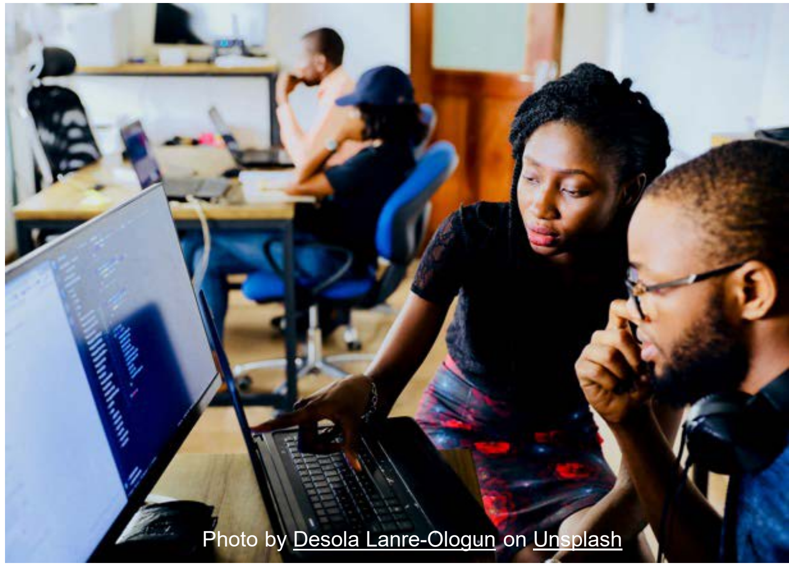
Major life activities that could be affected by charging

- **Sleep & personal care**
  - Hard to interrupt sleep – perhaps use night-time charging rules, similar to parking restrictions
- **Leisure and sports**
  - Could be high-value time
- **Work**
  - Depends on work flexibility
- **Household activities**
  - Maybe a welcome break, likely flexible
- **Eating and drinking**
  - Likely disruptive
- **Purchasing goods and services**
  - Work charging into the trip


Photo by Jamie Street on Unsplash


Photo by Sebastian Coman Photography on Unsplash


Photo by Lisa Marie Theck on Unsplash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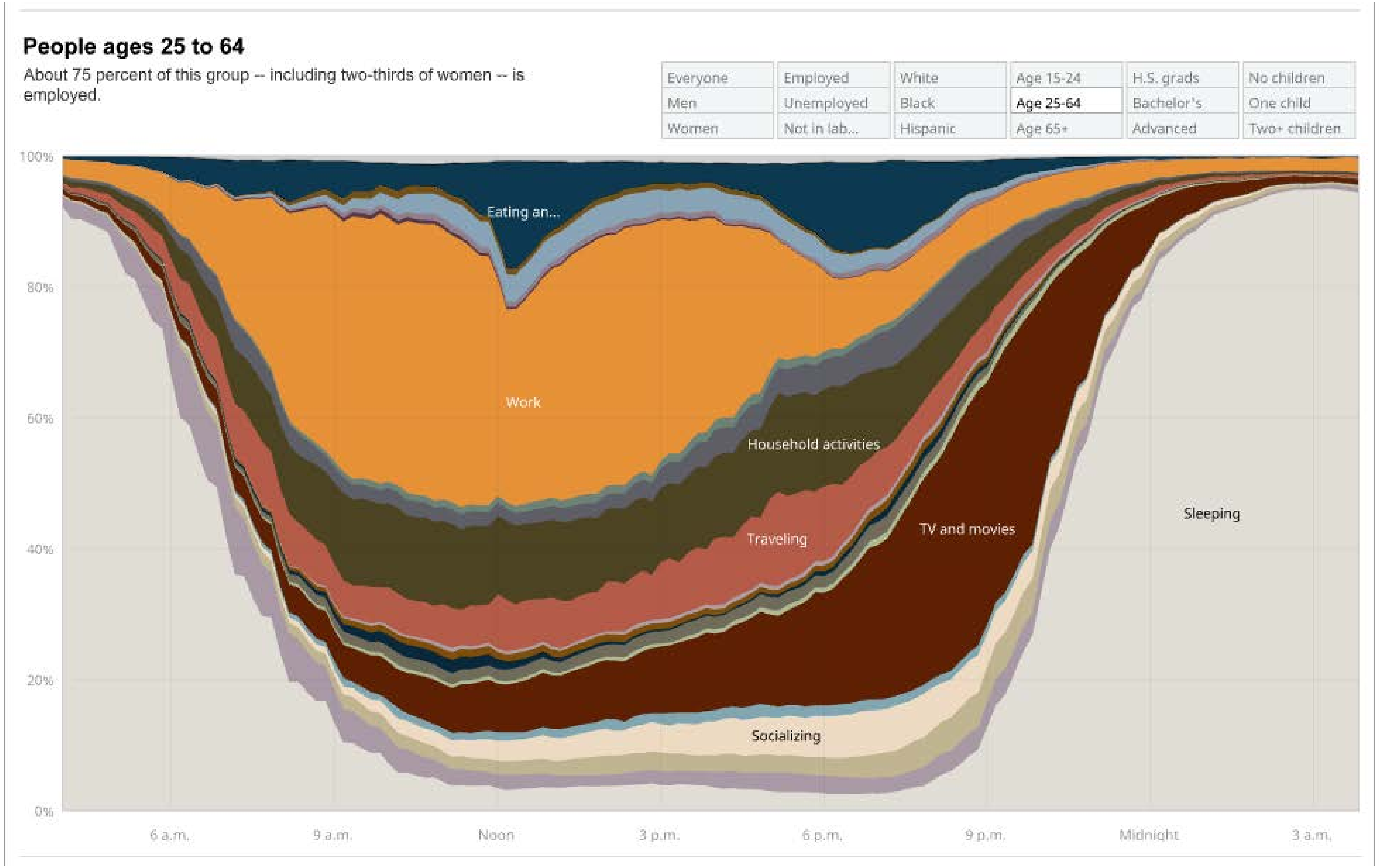
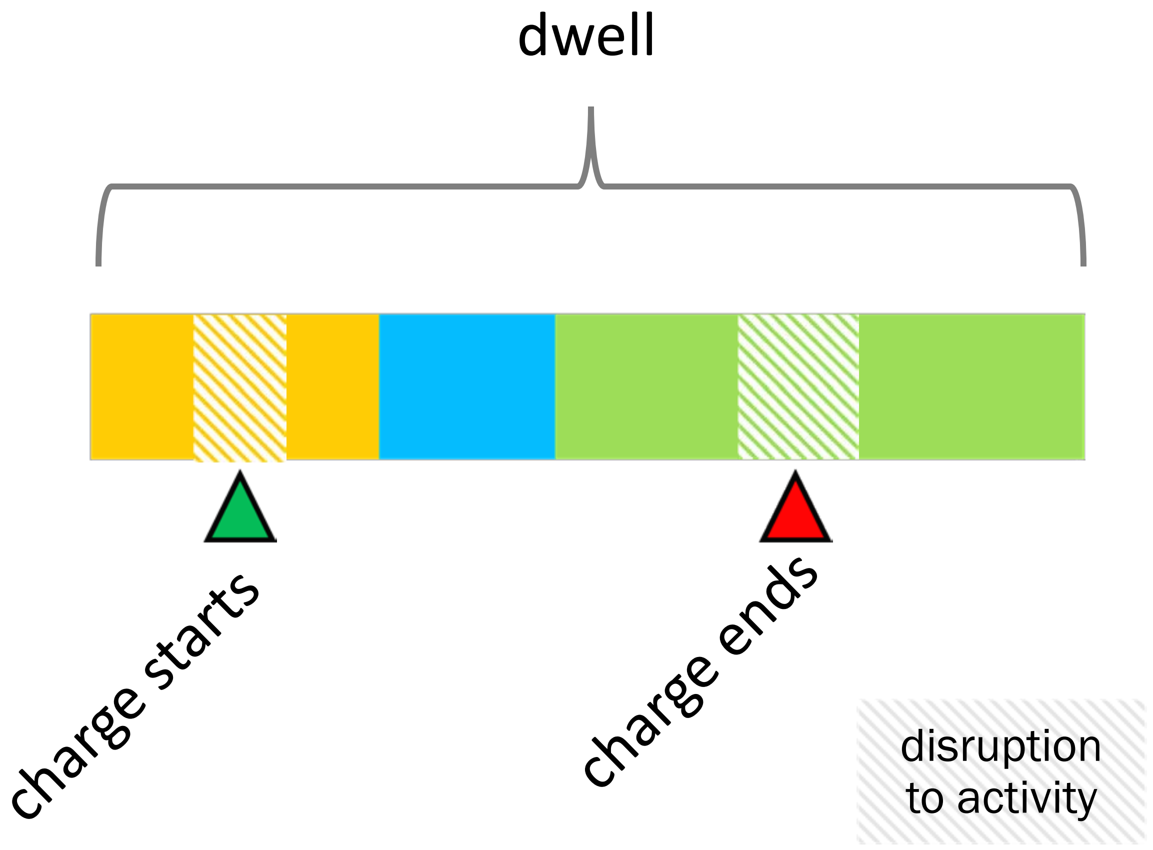
How to appropriately weigh inconvenience?



A pseudo-algorithms for evaluating an event's inconvenience

- **When charge event starts:**
  - What time is it?
  - Where is the agent?
  - Pick activity disrupted probabilistically for that agent at that time
  - Each activity has its own "inconvenience weight"
  - Evaluate activity disruption time, based on activity, distance from charger, etc.
  - Add inconvenience to tally for agent
  - Record other metadata, such as activity type, time that inconvenience was incurred, etc.
- **When charge event ends**
  - Same process as for event start



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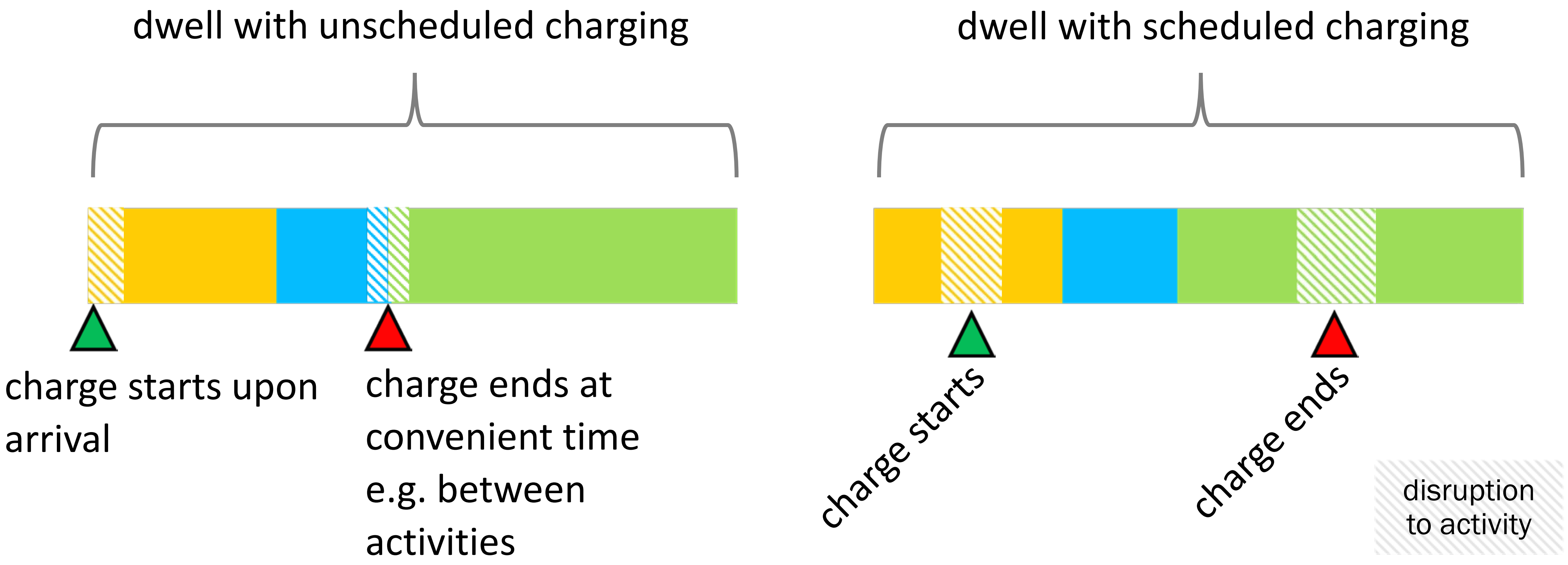
Inconvenience vs. who decides when to charge



Potential activities given location, inconvenience multipliers

Home	**weight**
– Chores	1.0
– Eating	1.5
– Wellness	4.0
– Entertainment	3.0
Work	**weight**
– Working – flex	1.5
– Working – nonflex	3.0
– Eating	1.0
Destination	**weight**
– Groceries / shopping	1.0
– Eating	1.5
– Entertainment / Socializing	3.0
– Sports / Wellness	2.0

Photo by Luke van Zyl on Unsplash

How inconvenience changes with EVSE distance and scheduling

Sandia National Laboratories

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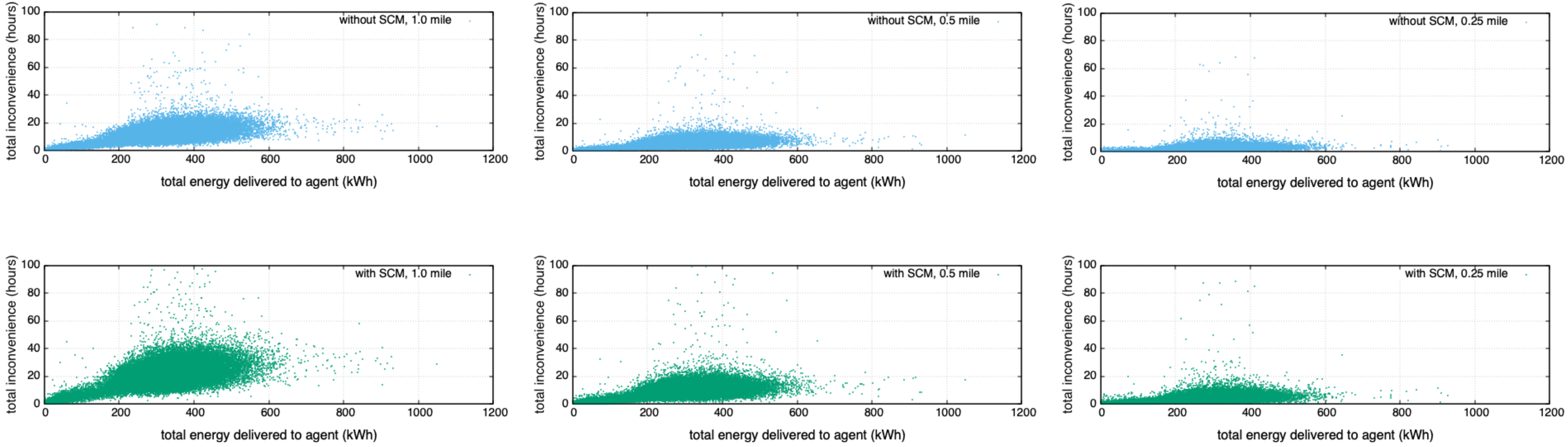

1.0 mile

First come, first served

0.5 mile

Strictly scheduled

0.25 mile

Total charging inconvenience over a 30-day period for non-access EV drivers

Outcomes of the inconvenience study

- **Charging at public infrastructure can tax people's time**
- **Scheduled charging could have a strong effect on inconvenience**
- **Availability of EVSE close to dwell locations has a strong effect on inconvenience**
- **There is room for optimization:**
  - Fine-grained location of EVSEs reflecting population density
  - Scheduling that aligns with people's activities

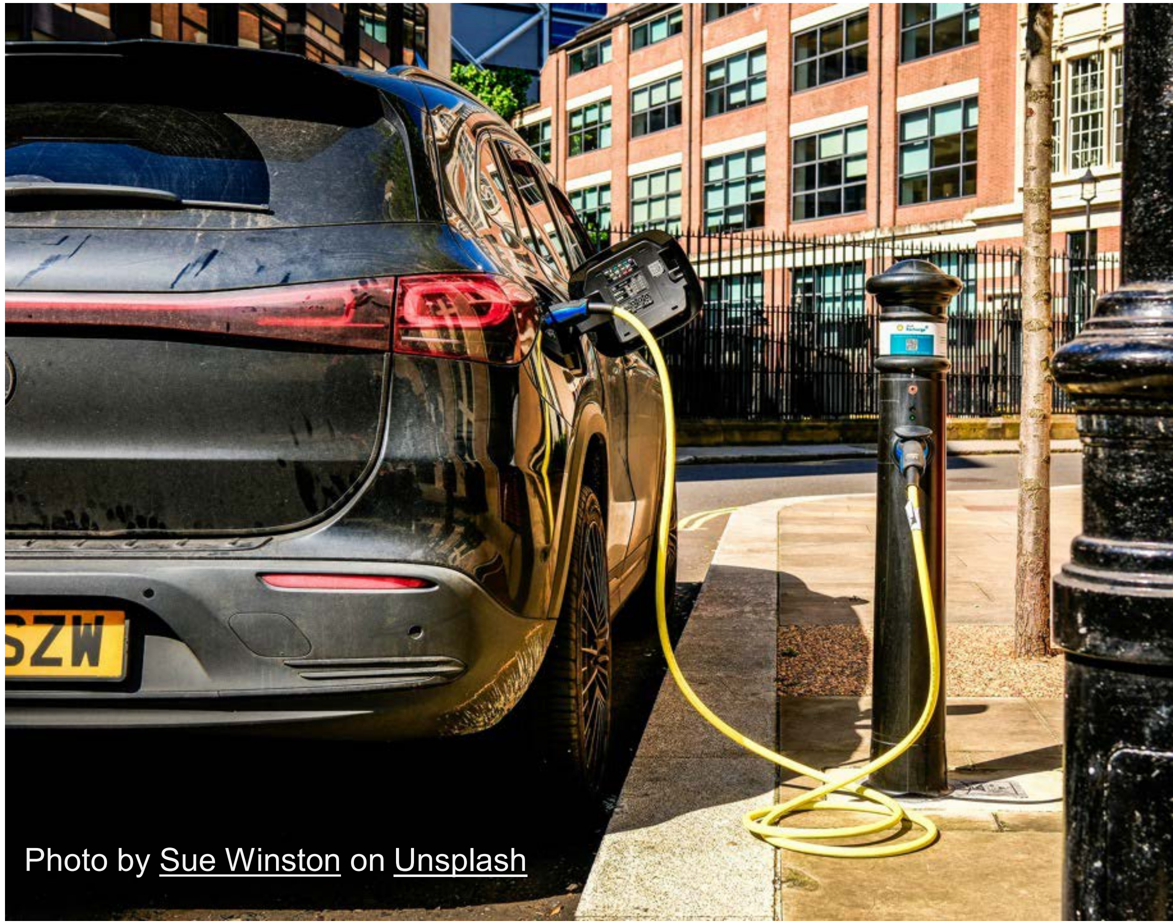

Photo by Sue Winston on Unsplash

– Municipal authorities
– EVSE providers who cater to community charging
– EV advocacy organizations
– Housing authorities

Are you interested in sharing data for analysis?

Contact: Andrea Mammoli: aamammo@sandia.gov
Steven Schmidt: steven.schmidt@inl.gov

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U.S. Department of Energy

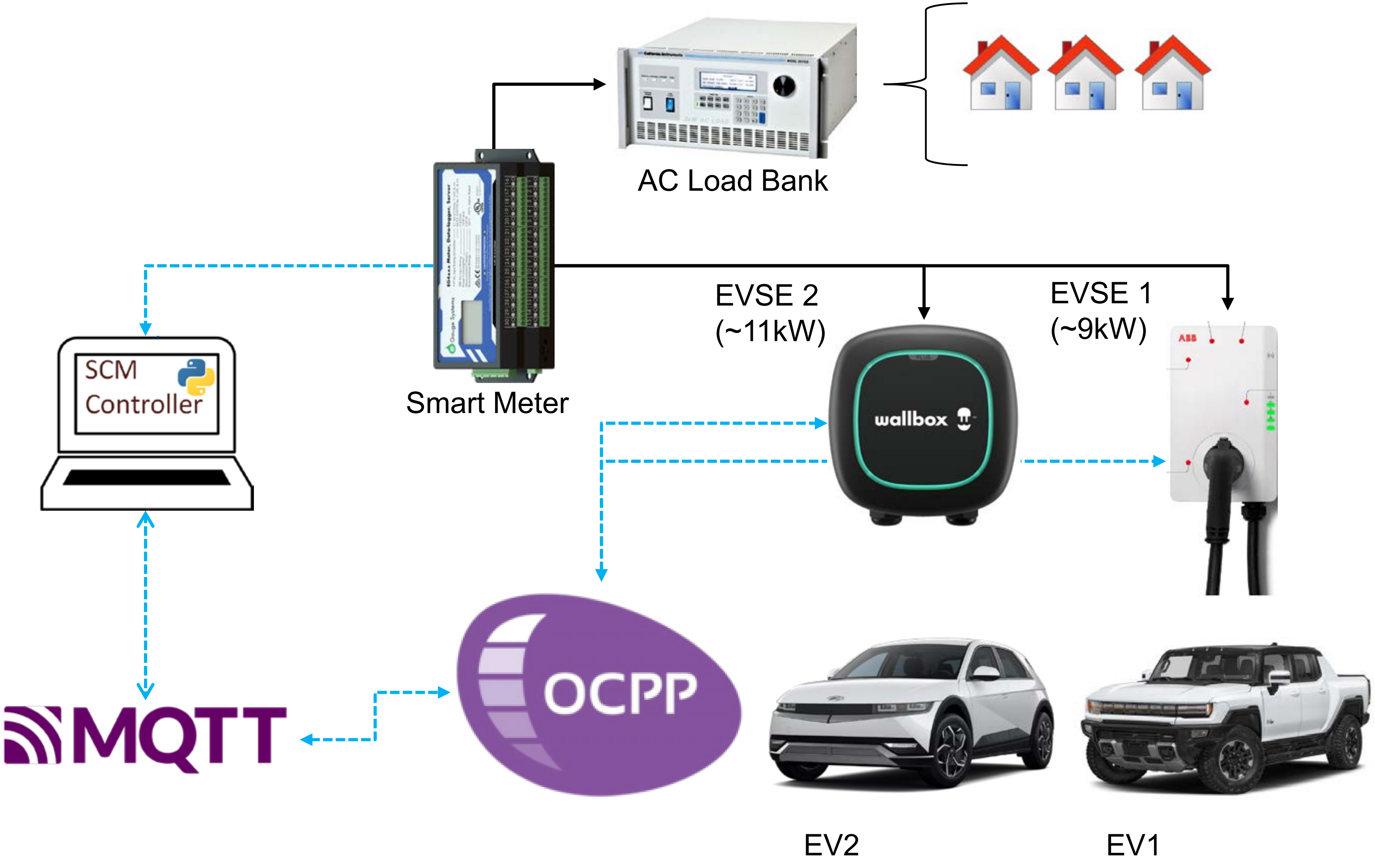
Laboratory and Field Demonstration of Smart Charge Management

Abdullah Hashmi, Emin Ucer, Nadia Panossian, Yukihiro Hatagishi

10/31/2024

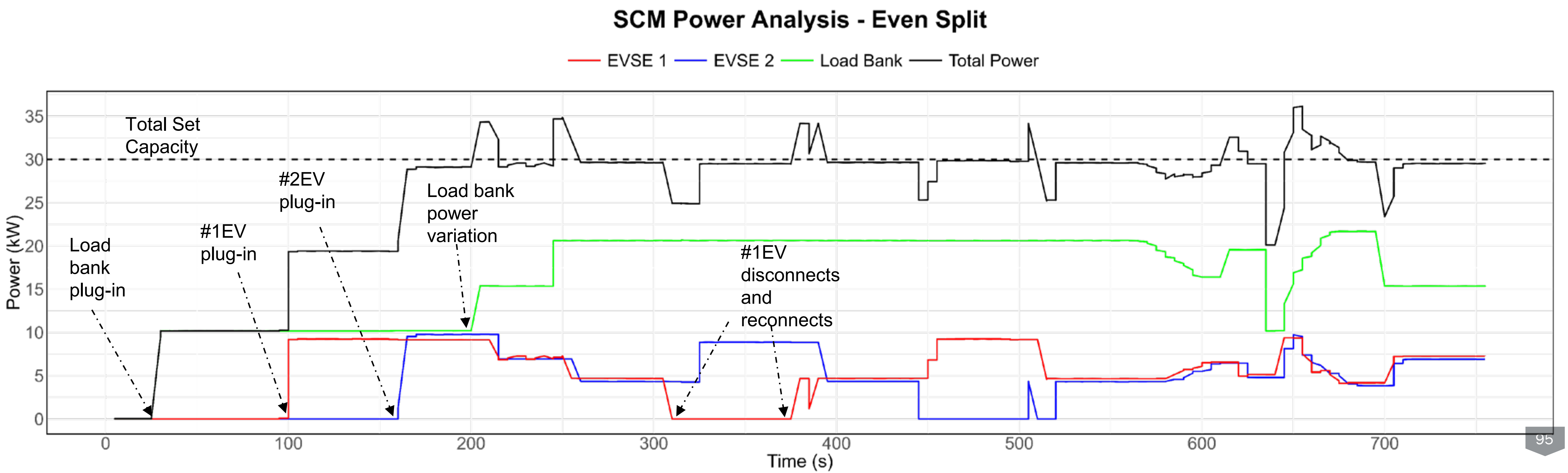
Test Objective and setup

- **Objective:** Adjust EV power allocation based on un-controllable connected loads
- AC load bank emulated building loads
- In-house developed SCM controller
- MQTT interface to communicate with EVSEs using OCPP
- Two Case Scenarios: Even Split and First Come First Serve



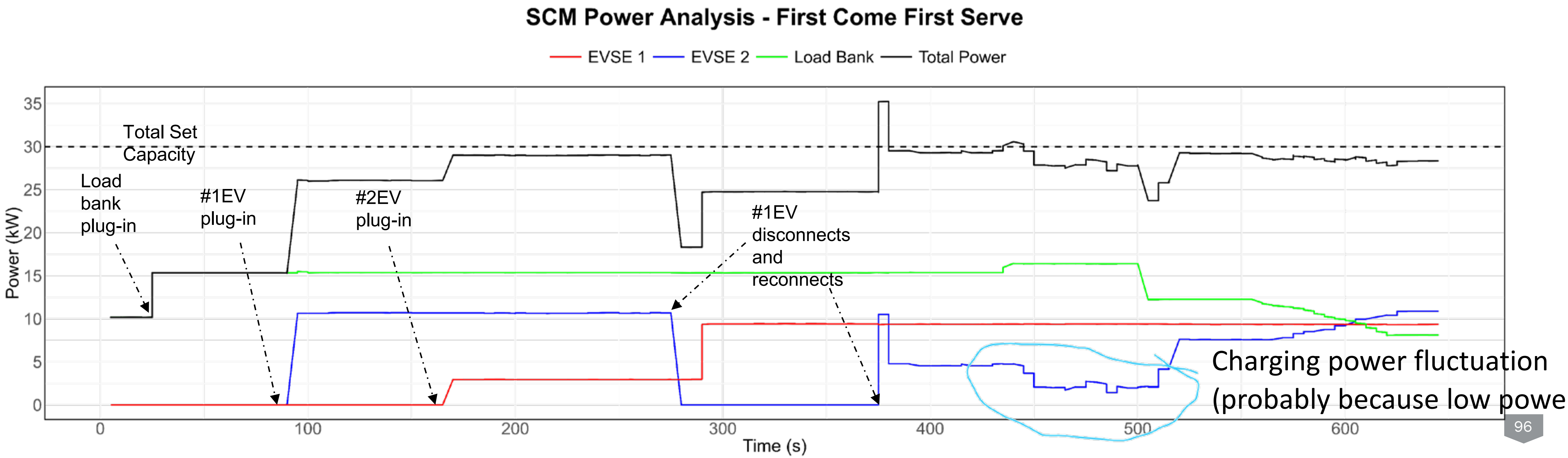
SCM Logic: Even-split

- **Even-split allocates the remaining available power equally**
- **Priority order:**
  1. “Building Loads”
  2. EVSE
- **Temporary overshoots are arising due to delays in EVSE/EVs following the set point**



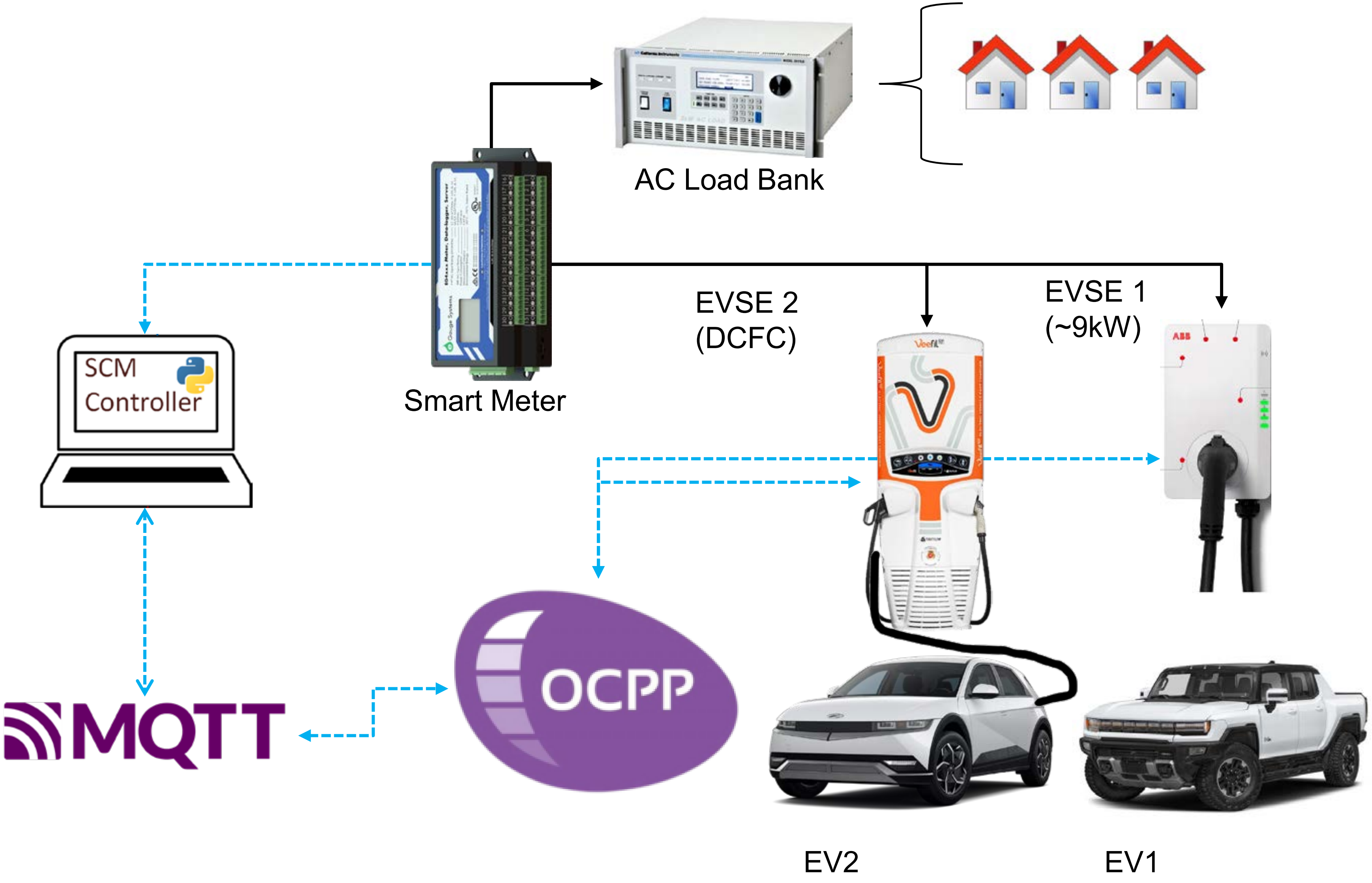
SCM Logic: 1st come 1st serve

- **Prioritizes the order in which vehicle was connected**
  - Resets the order at disconnect i.e., 2nd vehicle becomes 1st if it is the only one connected
- **Priority order:**
  1. "Building Loads"
  2. 1st EVSE
  3. 2nd EVSE...



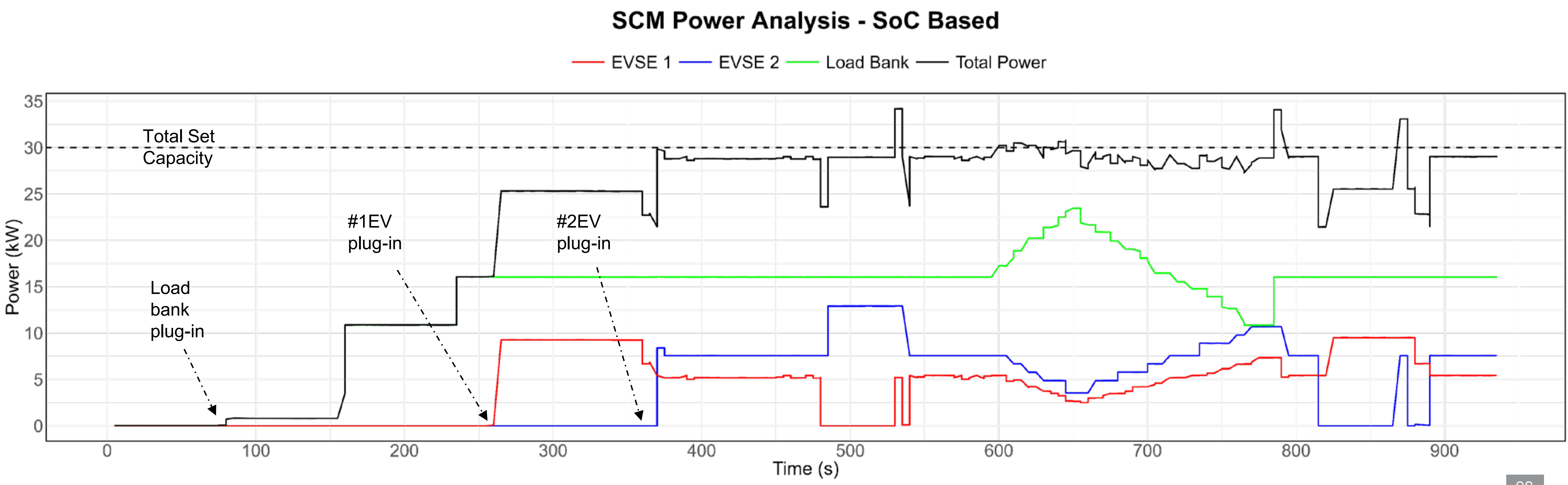
Test Objective and setup – SoC

- **Objective:** Adjust EV power allocation based on un-controllable connected loads while considering **State of Charge** of vehicle
- AC load bank emulated building loads
- In-house developed SCM controller
- MQTT interface to communicate with EVSEs using OCPP



SCM: SoC Priority

- **Read EV SoC and allocate power accordingly**
  - Assume 50% SoC for no SoC communication
- **#1EV has 50% assumed SoC and #2EV has 22% actual SoC**

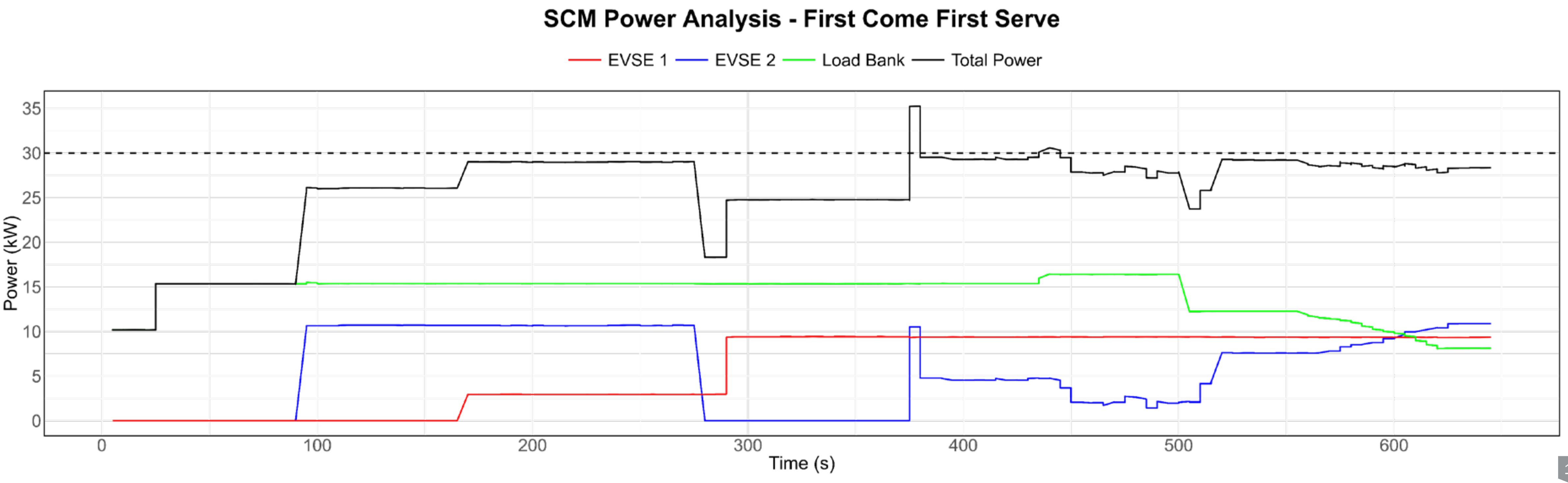


Key Lessons Learned

- **Sending power setpoints need device specific considerations:**
  - Number formatting needs be considered for appropriate communication and control across different EVSEs
  - Some EVSEs don't accept the consecutive identical setpoints
  - Some (old) EVSEs WebSocket connection is unstable. Active connection opening/closing is needed.
- **Corner use cases consideration such as re-plugging or plugging a different vehicle at the same EVSE connector**
- **Charging power fluctuations at low power**

High fluctuations at lower set power point

- **The EVSE follows the set limit**
- **Charging power fluctuation at low power setpoints ~430-490s**
- **Continuous AC programmable load variation from 550-620W**



Next Steps and partnership opportunities

- **Partnership Opportunities: Available for demonstration at your site**
- **Sandbox testing at NREL before deployment**
- **DERMS integration testing**
- **Time horizon profile deployment testing**
- **OCPP comm. disconnect response**