EVs @ Scale

U.S. Department of Energy

Flexible charging to **U**nify the grid and transportation **S**ectors for **E**Vs at scale (FUSE)

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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

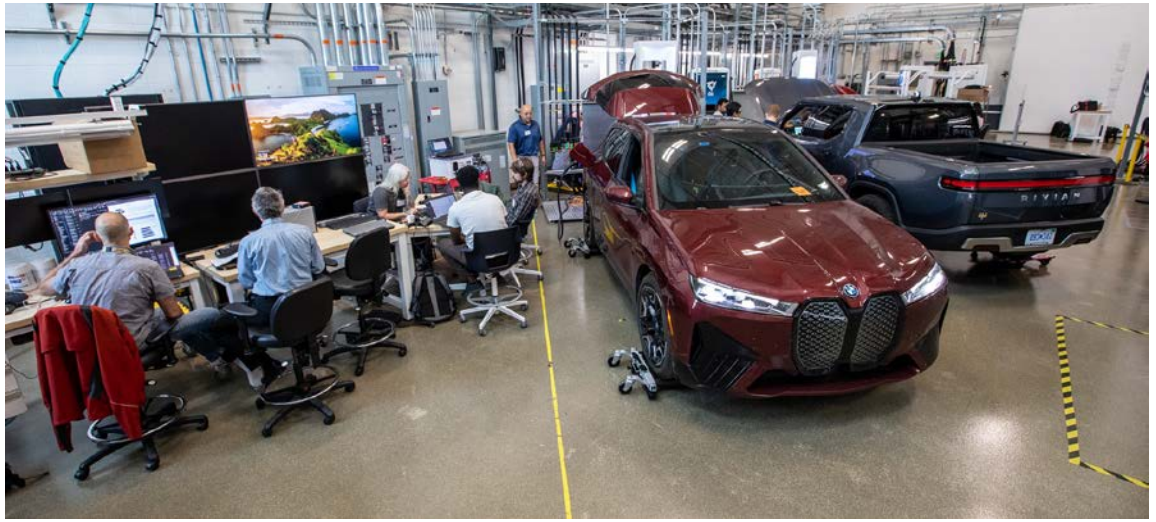

Photo by Werner Slocum, NREL

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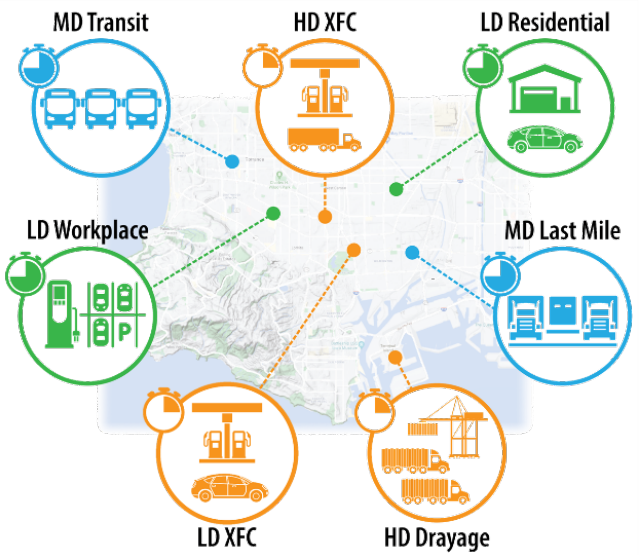

EVs@Scale FUSE - Team and Partners

Team:

- **National Renewable Energy Laboratory (NREL)**
  - Vehicle Charging, Grid Impact Analysis, SCM/VGI Development and Demonstration
- **Argonne National Laboratory (ANL)**
  - SCM/VGI Development and Demonstration
- **Idaho National Laboratory (INL)**
  - Vehicle Charging Analysis, SCM/VGI Development
- **Sandia National Laboratories (Sandia)**
  - Grid impact Analysis

Industry Partners/Data Sources:

- **Electric Distribution Utilities**
  - Dominion Energy (100+ distribution feeder models throughout VA)
- **Vehicle Travel Data**
  - Wejo (~400 million LDV trips in VA for Sept. '21 and Feb. '22)
  - GeoTab (Altitude API Access MD/HD vehicle operations)

NREL Transforming ENERGY

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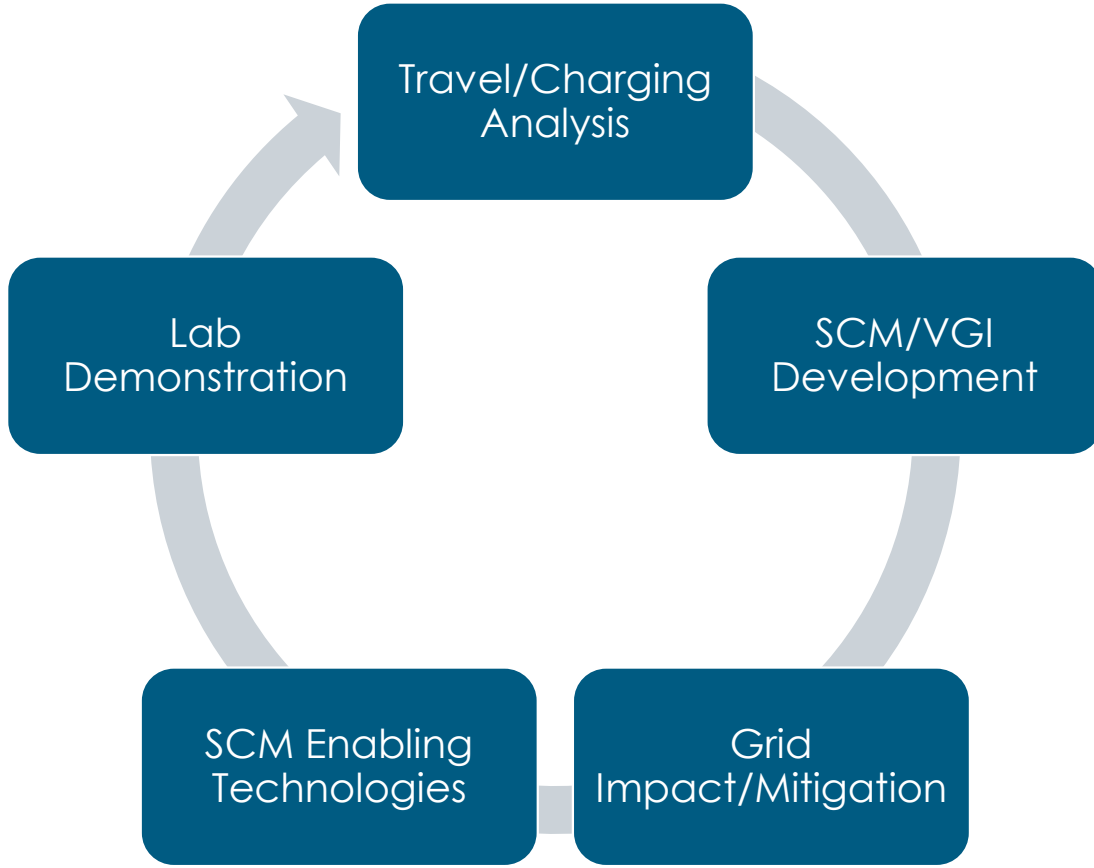
EVs@Scale FUSE - Approach and Outcomes

- **This project will analyze 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.

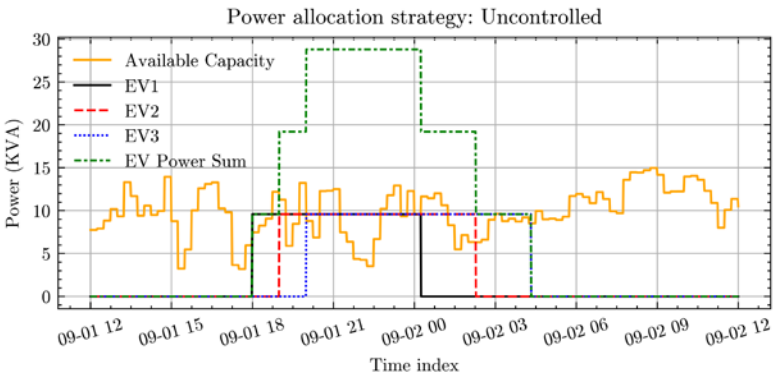


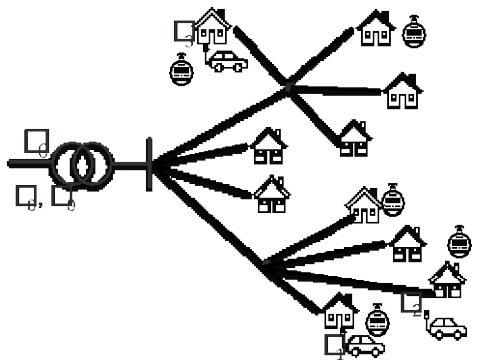
SCM Controls: New NREL Objective Functions

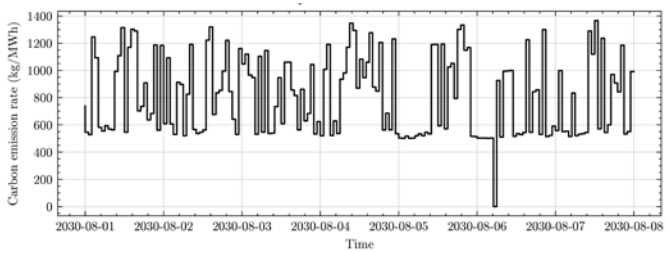
New FY24 Objective Functions

- **BTM Depot DER**
  - Mitigate transformer upgrades at large charging depots with behind-the-meter (BTM) distributed energy resources (DER) assets to limit net peak demand from grid
- **Distribution Transformer**
  - Coordinate EV charging under a single service transformer to avoid coincident peaks and overloading equipment
- **Renewables and Emissions**
  - Schedule EV charging to either coincide with renewable sources of generation or during times of low emissions
  - Emissions forecasts from NREL's Cambium 2030 mid-case

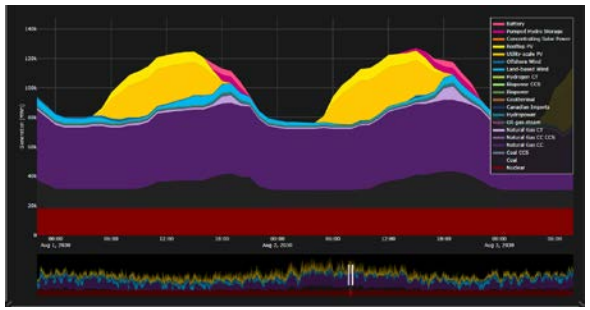
Strategy Name	Objective Function: EV Charging…
TOU Immediate	begins immediately at start of TOU within dwell
TOU Random	randomly distributed within dwell during lowest TOU
Random Start	randomly distributed within dwell
Feeder Peak Avoidance	distributed within dwell to limit feeder peak
Volt/VAR	provides reactive power support
Volt/Watt	power adjusted to support local voltage quality
Day-ahead Pricing	scheduled to minimize costs per PJM LMP
BTM Depot DER	schedule to avoid transformer upgrade with PV/ESS
Distribution Transformer	scheduled to reduce coincident charge/overloads
Renewables/Emissions	scheduled to coincide w/ renewables/low-emissions







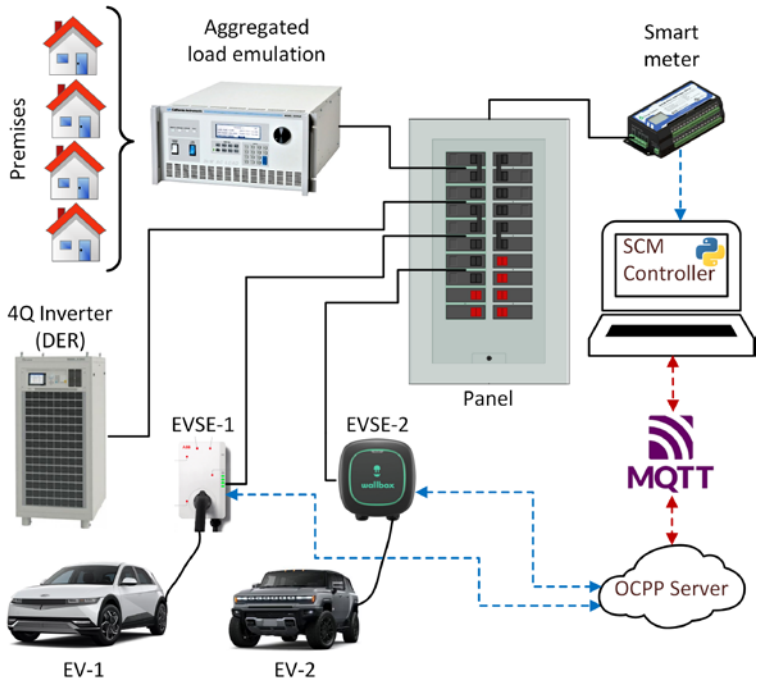
Week-long Marginal Carbon Emission Rates

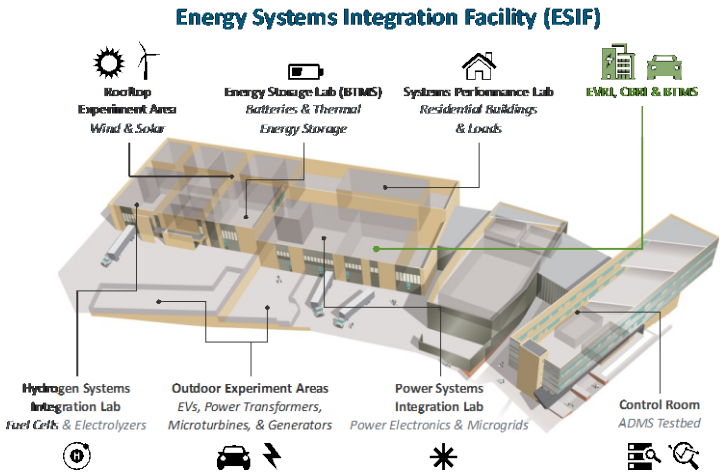


Daily Energy Mix Variation of PJM

Enabling Technology: NREL Testbed Supporting SCM Evaluation

- **SCM Testbed Verifies SCM Performance**
  - SCM controls adapted from simulation to support real-world signals and dynamic response
  - SCM controller receives OCPP signals and other necessary meter data
- **ESIF* Serves as SCM Proving Ground**
  - Transformer control is designed in preparation for field demonstration in utility environment
  - Multiple EVSE represent different houses on a single secondary bank from one transformer
- **SCM Controls Prepared for Field Demo**
  - Transformer control responds to EV connection signals, EVSE current, and home load fluctuations
  - SCM optimizes EV charging to avoid exceeding a power ceiling (mitigating transformer overloads)





Photos by Werner Slocum, NREL

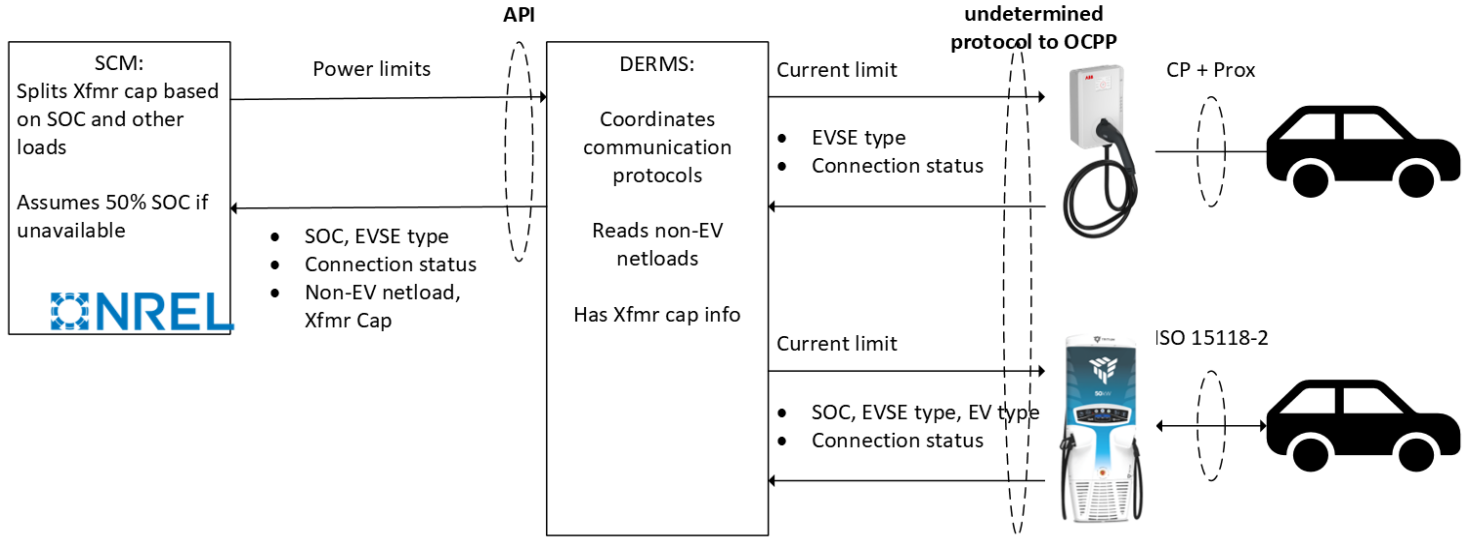
*NREL's Energy Systems Integration Facility (ESIF)

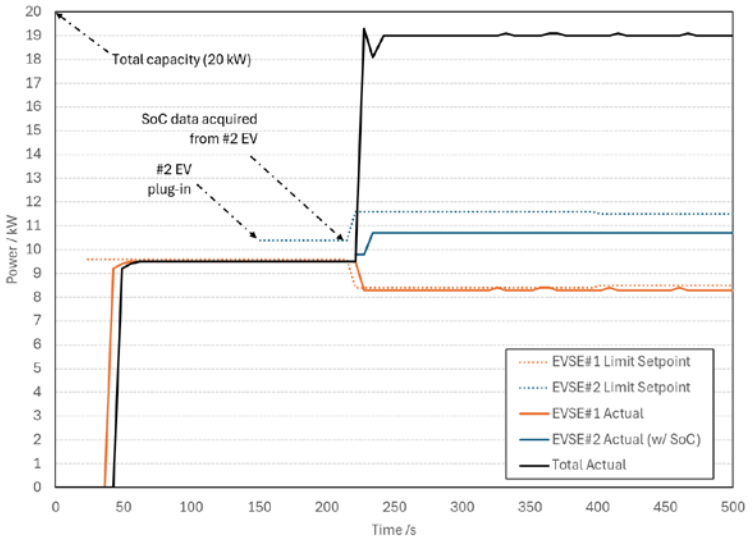
Enabling Technology: Verifying SCM Performance

- **Transformer Control Objective**
  - Establishes power ceiling (e.g transformer nameplate capacity)
  - Monitors building loads (eGauge) to determine remaining capacity for EVSE*
  - EVSE sends connection signal to SCM via OCPP to initiate charge session
  - DC EVSE may send SOC via ISO 15118-2 to inform weighted power distribution**
  - SCM optimizes all present EVSE loads within remaining transformer capacity
- **Next Steps:**
  - Dynamic building load tests
  - Field Demonstration at HCE
  - SCM developed for DERMS integration

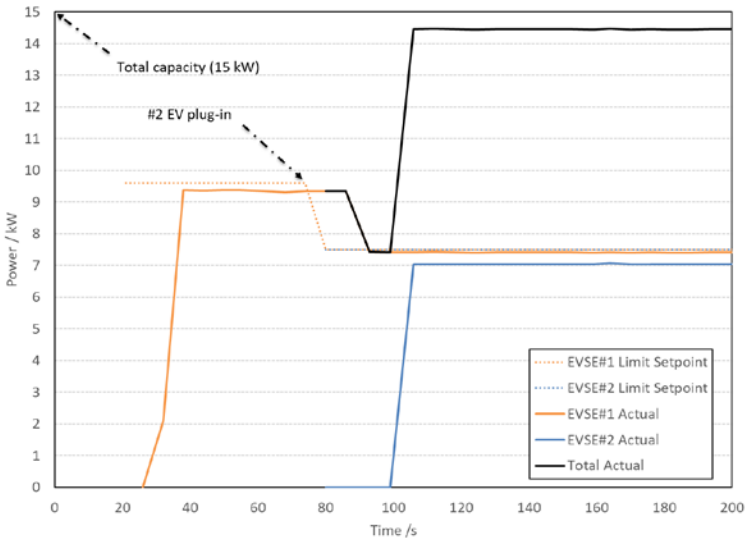
*not present in initial test results shown

**feature currently not supported in standards for AC EVSE





SCM Result With SoC



SCM Result Without SoC

Transportation and Charging Needs (NREL)

EVs@Scale U.S. Department of Energy

- **Completed work**
  - Updated EVSE access assumptions for each dwell location and vehicle class
  - Integrated concentrated charging locations into EVI-Pro results
    - Concentrated charging locations determined by Sandia analysis of low-/no-access household locations serve charging needs with less access
  - Simulated charging loads across seven categories of vehicles
    - Includes light-duty (LDV) passenger cars, and medium-heavy duty (MHDV) across multiple vocations requiring short and long dwell charging
    - Coordinated with INL to determine mid-route charging needs
  - Analyzed coincidence of charging demand for four categories of vehicle across geographic regions, times of day, and duration of load reduction

- **Outreach**
  - School bus charging study accepted for publication by *Transportation Research Record*
  - Coincidence analysis and "long-dwell" charging load modeling study presented at Transportation Symposium on Environment, Energy, and Livable Economies
  - "Long-dwell" study submitted to 2025 Transportation Research Board conference, under revision for journal submission (*Applied Energy* planned)

Modeled types of EV charging demand

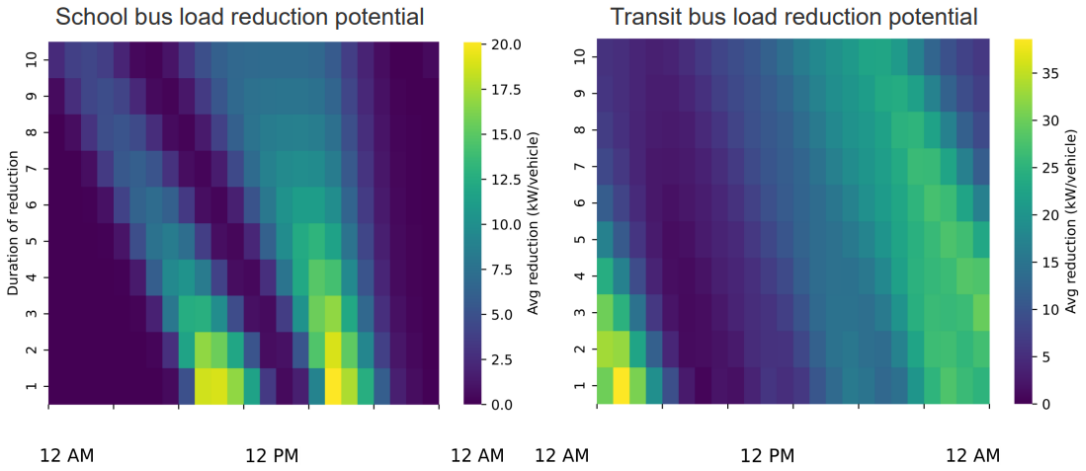
Classes	Vocation	Charging dwell types
LDV	LD passenger cars	Concentrated chargers (Sandia & NREL), XFC (INL & NREL), home, work, public (NREL)
MHDV	Local delivery	Depot
MHDV	Transit buses	Depot, terminals
MHDV	School buses	Depot
MHDV	Drayage	NREL & INL: depot, destination, mid-route XFC
MHDV	Regional freight	NREL & INL: depot, destination, mid-route XFC
MHDV	Long-haul freight	NREL & INL: depot, destination, mid-route XFC

Photo by Natasha Headland, NREL

Transportation and Charging Needs (NREL)

- **Next steps**
  - Support the use of charging load datasets to develop and test SCM strategies
  - Extend coincidence analysis to consider which types of vehicles offer value as SCM targets at various times of day for various regions
  - Apply coincidence analysis to develop simplified guidelines (e.g., load factors) to help improve EVSE interconnection practices

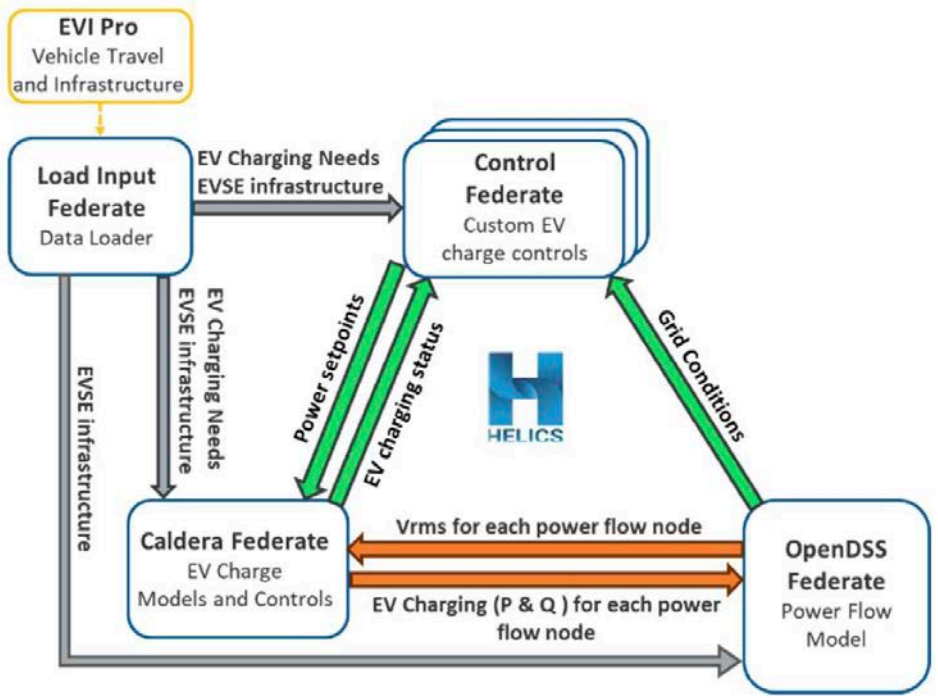
Example flexibility matrices from coincidence analysis



"Long dwell" LDV + MHDV charging loads
(Richmond, fall weekday)

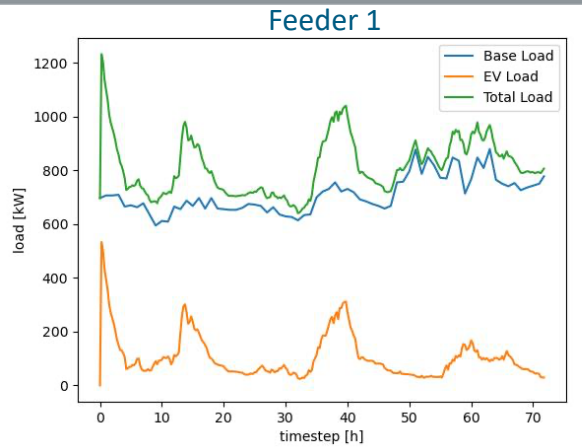
Grid Impact Assessment (NREL)

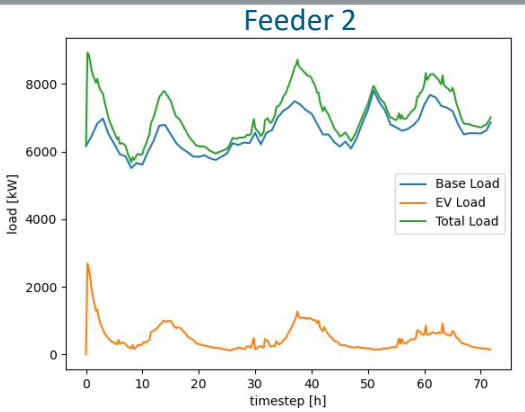
- **Grid Impact Co-simulation**
  - Three day time series power flow at 15 minute intervals with charging needs provided by transportation/charging team
  - Simulations performed across 60+ feeder models in VA (Newport News/Richmond)
  - HELICS co-simulation coordinates multiple federates to simulate 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)

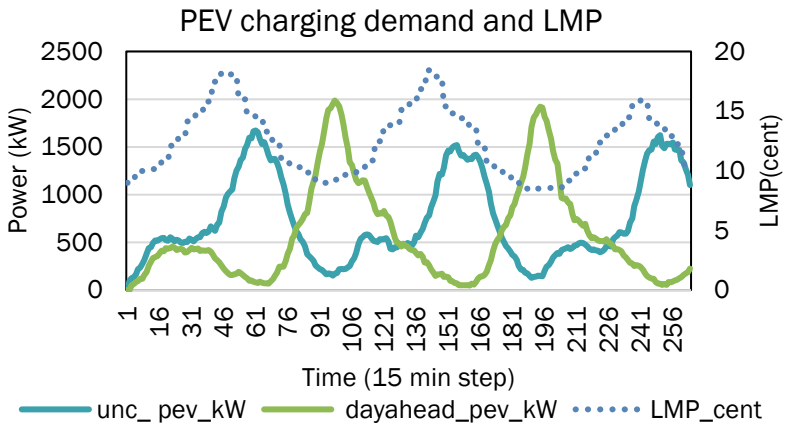


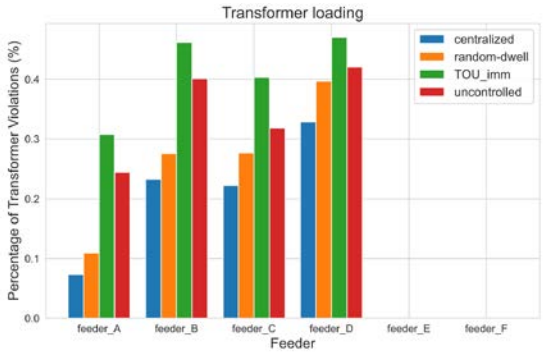
Grid Impact Assessment (NREL)

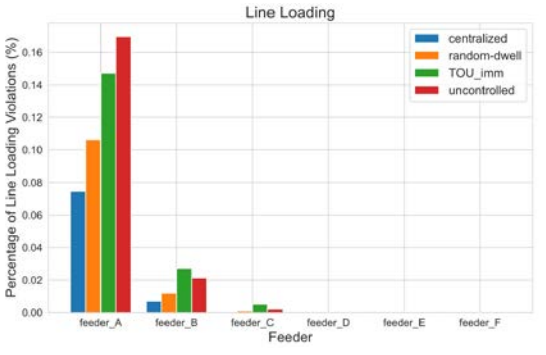
- **Grid Impact Considerations**
  - Load Profiles: Detail charging and SCM performance
  - Equipment Loading: overloaded transformers/conductors
  - Voltage: voltage drop across feeder (+/- 5%)
- **Uncontrolled Results**
  - Significant EV charging peaks have impact on feeder loads and often coincide with existing base load peaks
- **New SCM Performance – LMP Response**
  - More dynamic LMP rates distribute charging incentives
  - Distributed incentives distribute charging without a timer peak
- **Detailed Results – Equipment Loading**
  - Transformer overloading is most severe for TOU immediate
  - Line overloading may occur more due to uncontrolled charging
  - Overloading events vary across feeders and distribution transformer overloading appears to be a leading indicator











Successful Partnerships – EVs@Scale FUSE

- **Dominion Energy**
  - Dominion Energy has partnered with FUSE to provide feeder models for grid impact analysis and FUSE shares research findings specific to service area
- **Geotab**
  - FUSE acquired access to Geotab transportation data and multi-lateral NDAs protect sensitive information
- **Balancing Authorities**
  - FUSE has partnered with multiple balancing authorities to share and discuss findings and guide future transportation/charging/SCM research
- **Holy Cross Energy**
  - FUSE has partnered with Holy Cross Energy to expand their current SCM program with cutting edge SCM communication architecture and objective functions
- **Ampcontrol**
  - FUSE has partnered with Ampcontrol to assess their load management software for fleets and provide feedback

Photo by Dennis Schroeder, NREL

Photo by Natasha Headland, NREL

Typical EVs@Scale Partnerships Include:

- Mutually beneficial topic areas
- Lab research for EVs@Scale funded by DOE*
- Early access to cutting edge research and lab facilities
- NDAs to ensure sensitive information is secure
- In-kind contributions provided by Industry Partners

*Subject to change based on annual funding levels

FUSE Partnership Opportunities

- **DERMS Integration Opportunities**
  - Would you like to integrate FUSE SCM into DERMS?
- **Utility Distribution Planning**
  - How can FUSE help inform your distribution planning?
- **Fleet SCM Demonstration**
  - Do you have a fleet that could benefit from FUSE SCM?
- **Utility and/or PUC guidance/coordination**
  - Would you like to discuss research results with FUSE?

Photo by Werner Slocum, NREL

Interested in Partnering with FUSE?

Contact FUSE PI: Jesse Bennett, NREL

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Thank You

Join us for the
SCM/VGI Deep Dive

Thursday October 31st

Additional Details to Follow