OEMR Hosted: ID EV Stakeholder Webinar

September 21, 2020

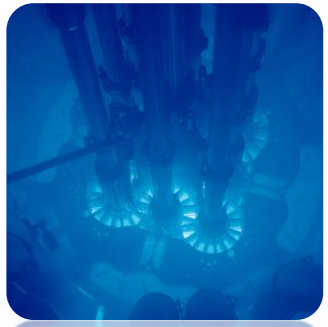
Timothy Pennington
Sr. Research Engineer

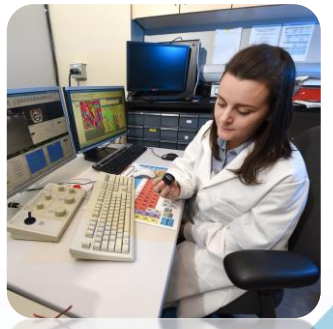
Caldera™

An Idaho National Laboratory Tool for Modeling Electric Vehicle, Grid, and Stationary Energy Storage Interactions

Idaho National Laboratory

Idaho National Laboratory





Energy & Environment S&T

- Advanced transportation
- Environmental sustainability
- Clean energy
- Advanced manufacturing
- Biomass

National & Homeland Security S&T

- Critical infrastructure protection and resiliency
- Nuclear nonproliferation
- Physical defense systems

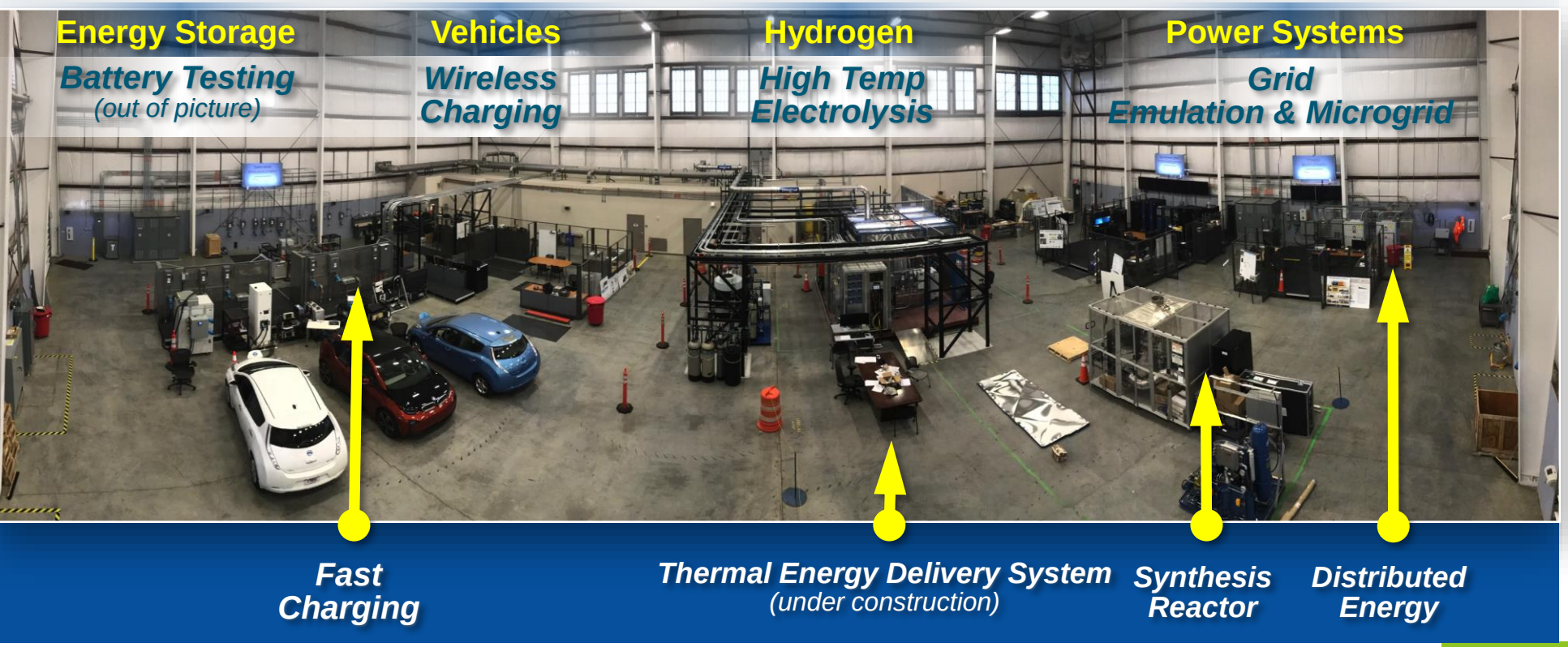
Plus three other Nuclear Energy Directorates

- 890 square miles
- 177 miles of paved roads
- 21 miles of railroad lines
- 111 miles of transmission lines
- Mass transit system

…the National Nuclear Energy Laboratory

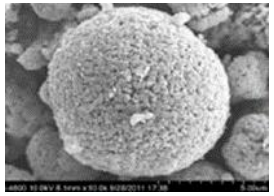
Energy Systems Laboratory

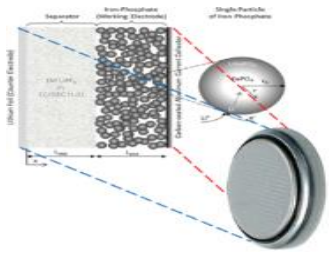
- Electric Vehicle Infrastructure Laboratory (EVIL)
- Power and Energy Real-Time Laboratory (PERL)
- Battery Testing Center (BTC)
- Microgrid Research Laboratory

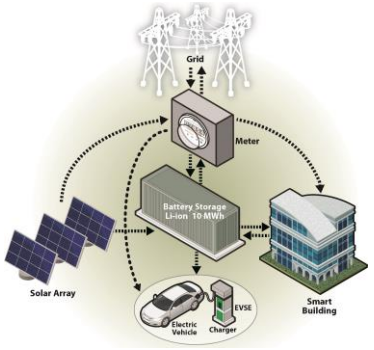


540 kW Grid Emulator Amatek

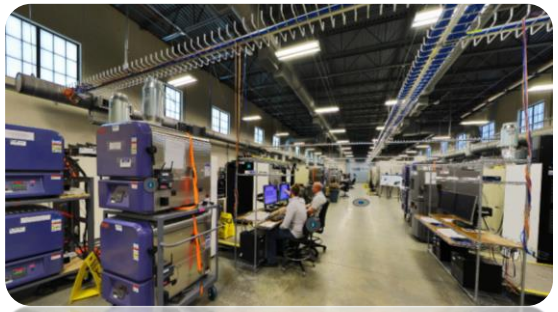
Energy Storage and Advanced Transportation Department







Molecular Material Studies ***Advanced Battery Characterization*** ***Future Electrified Mobility***



Battery Test Center (BTC)

Non-destructive Battery Evaluation Lab (NOBEL)

Electric Vehicle Infrastructure Laboratory (EVIL)

Consequence-driven Cybersecurity for XFC & WPT

- Conceptualize and assess vulnerabilities for high power EV charging infrastructure (XFC and WPT)
- Score and prioritize high consequence events (HCE)
- Evaluate Impact Severity and Cybersecurity Complexity
- Develop and evaluate mitigation strategies and solutions
- Publish mitigation strategies, solutions, and design methodologies

Idaho National Laboratory

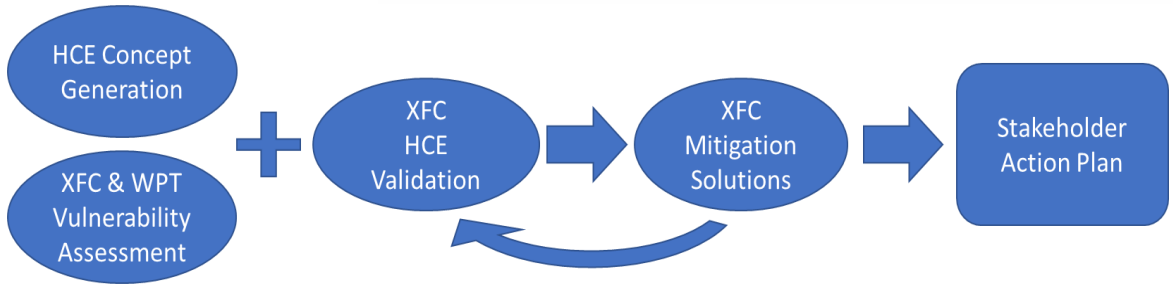
NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

ABB

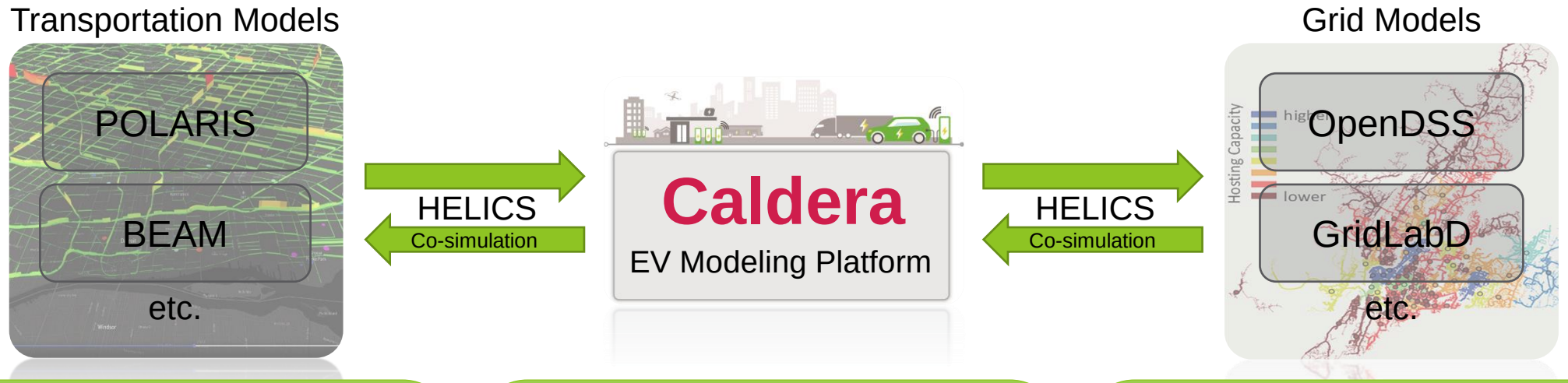
TRITIUM

electrify america



What is Caldera?

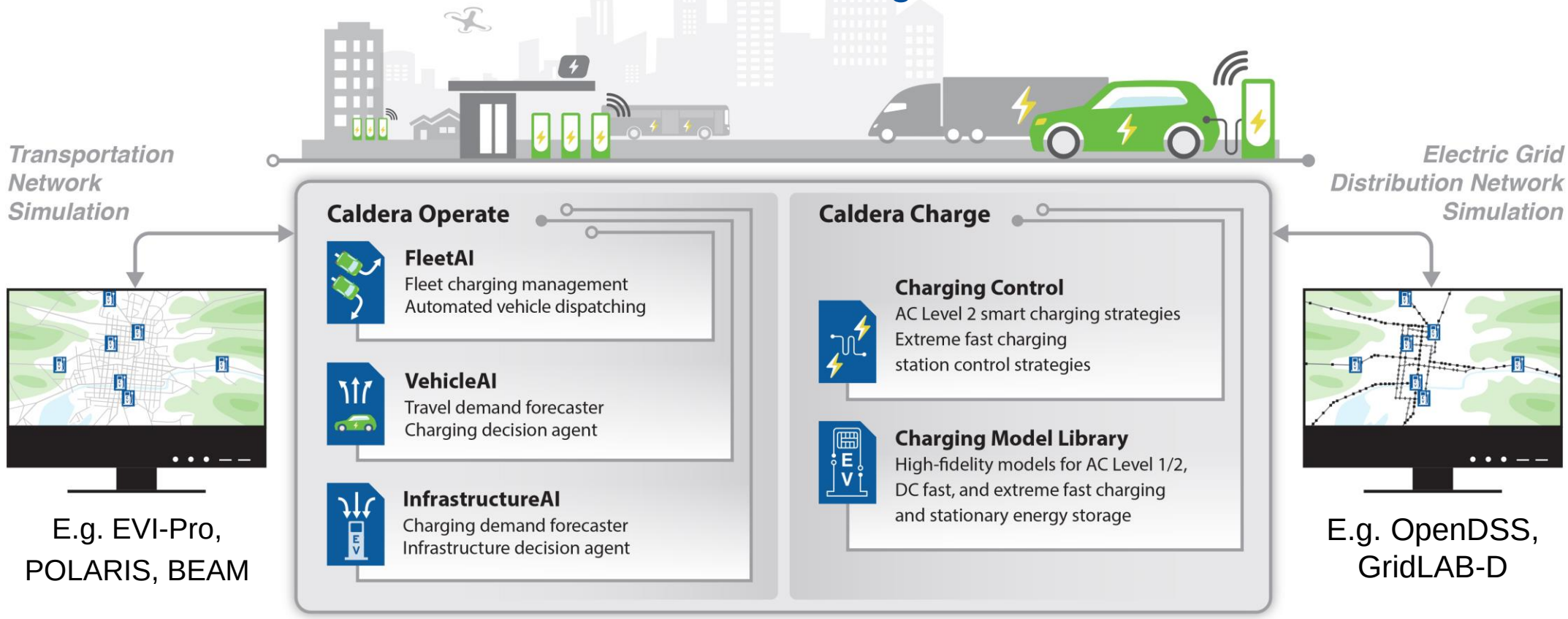
- The “Missing Link” to high quality modeling of Electric Vehicle Impacts on the Grid



Simulating mobility	Linking Transportation and Grid Tools	Simulating distribution and traditional loads
Existing tools lack understanding of: grid topology, power availability, charging cost information, detailed charge profiles	Demonstrates EV charging effects and illustrates system optimization by co-simulating both grid and driving conditions	Existing tools lack understanding of: when and where EVs will charge, detailed load profiles, effects of control strategies

Caldera

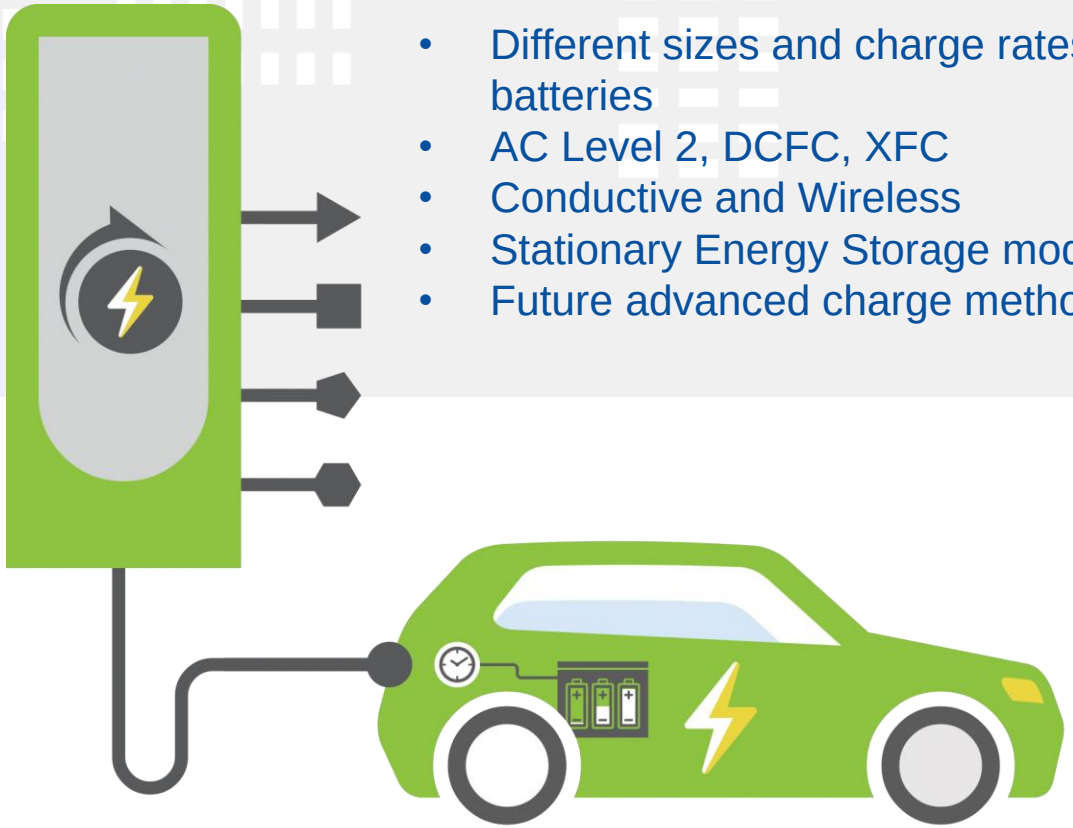
Electric Vehicle & Infrastructure Decision Management Simulation Platform



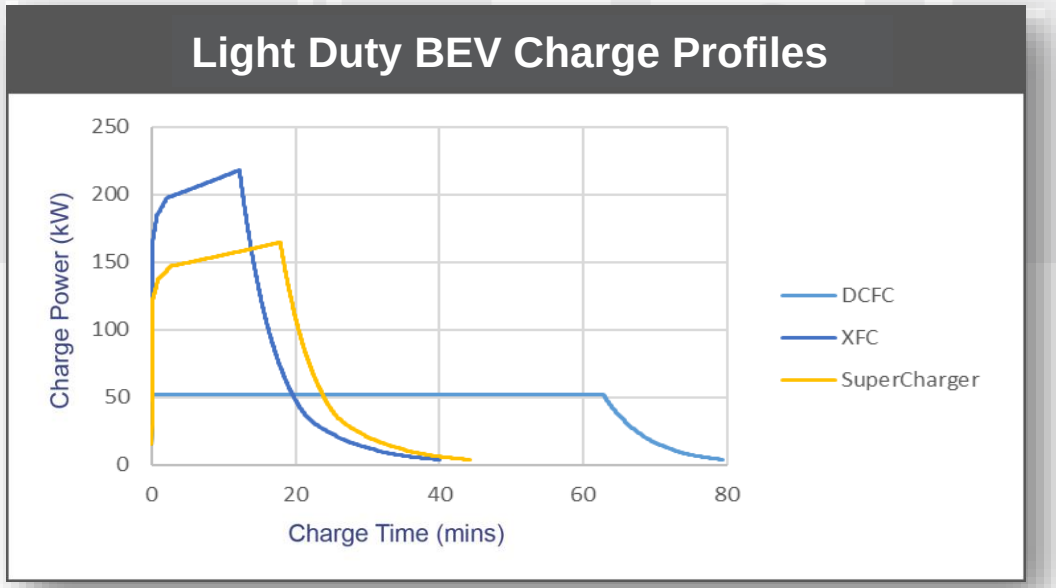
Caldera is an agent-based modeling platform for predicting detailed system impacts and demonstrating intelligent management strategies

Charging Model Library

Includes high-fidelity charging models derived from and validated against lab testing

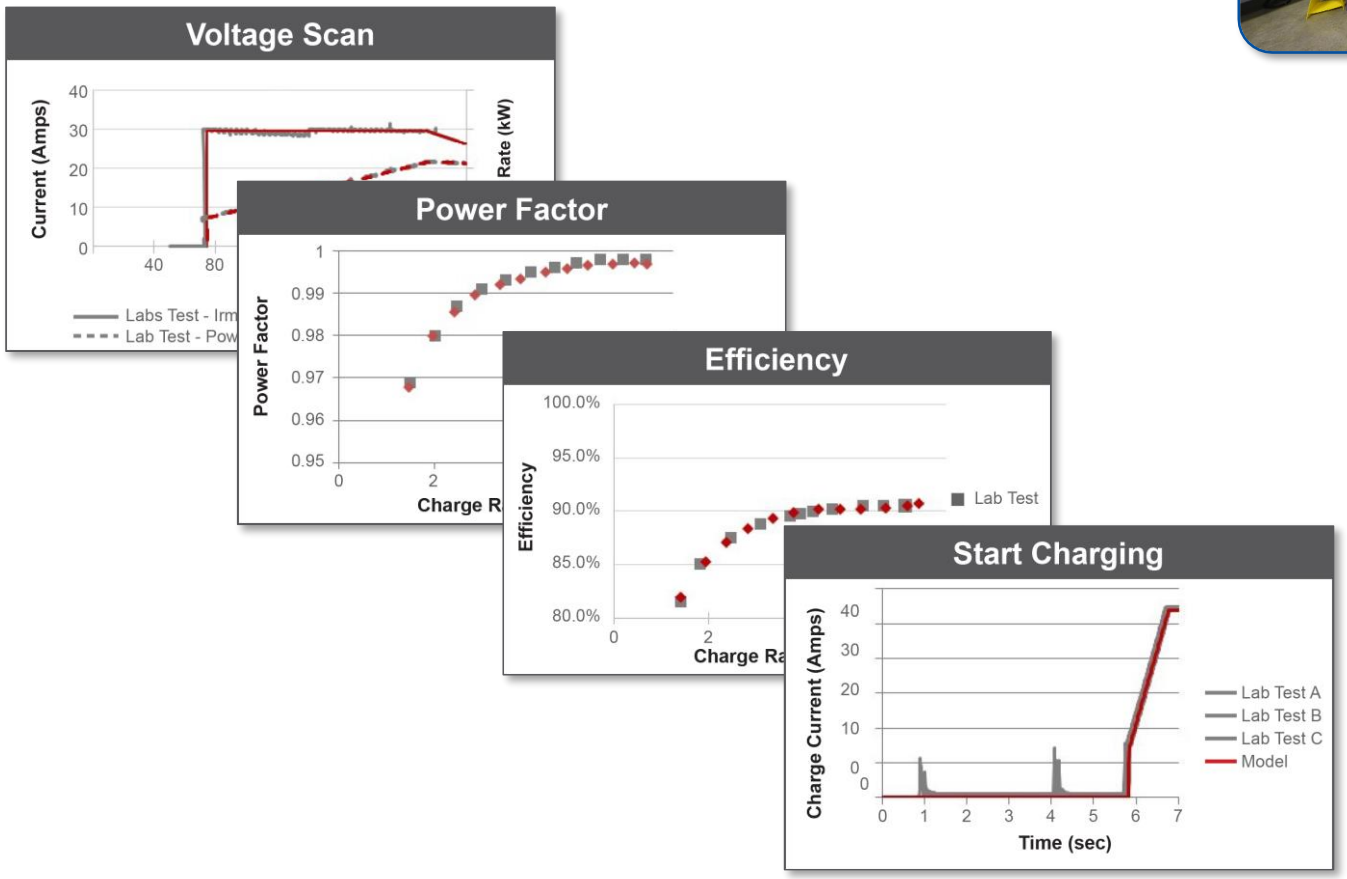


- Different sizes and charge rates of batteries
- AC Level 2, DCFC, XFC
- Conductive and Wireless
- Stationary Energy Storage models
- Future advanced charge methods



High Fidelity EV / EVSE Charging Models

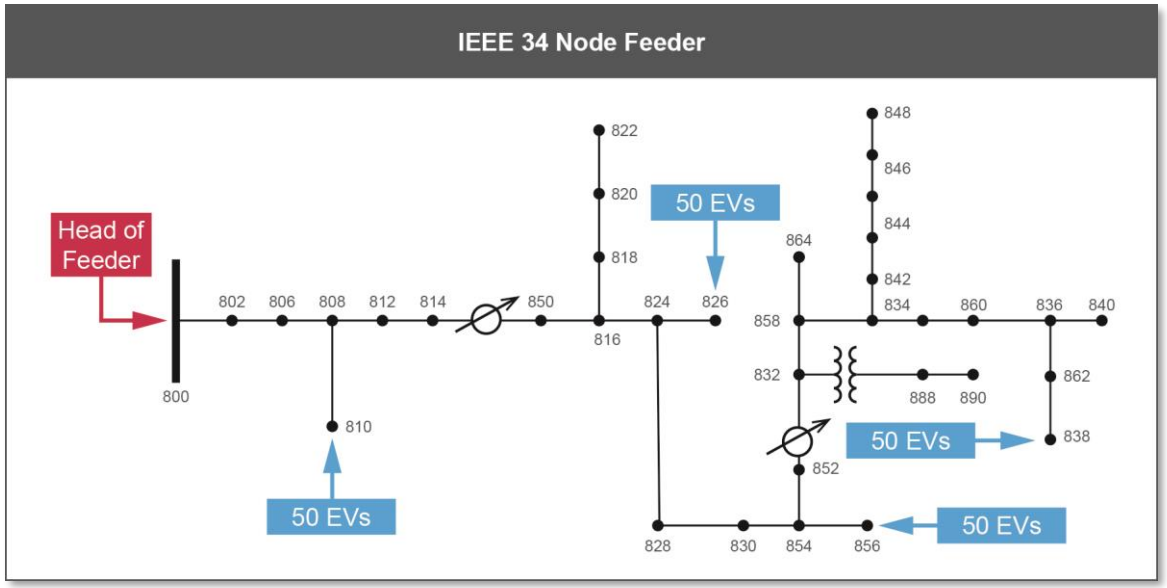
- In Caldera EVs and EVSEs are modeled **individually** using high-fidelity models. Aggregate or composite models are **not** used.
- These high-fidelity models are based on results from testing real EVs, EVSE, and batteries in the laboratory.

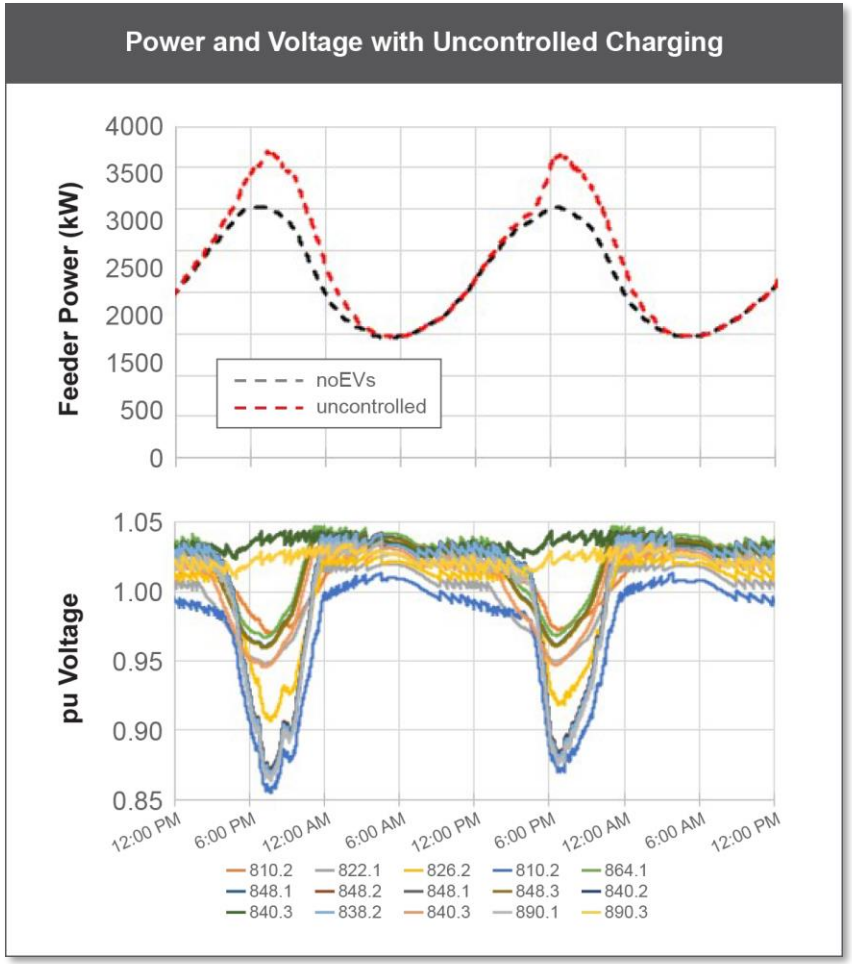


- The testing is done in INL's BTC and EVIL labs.
- Each of these graphs compares lab test results to outputs from one of INL's high fidelity EV charging models.

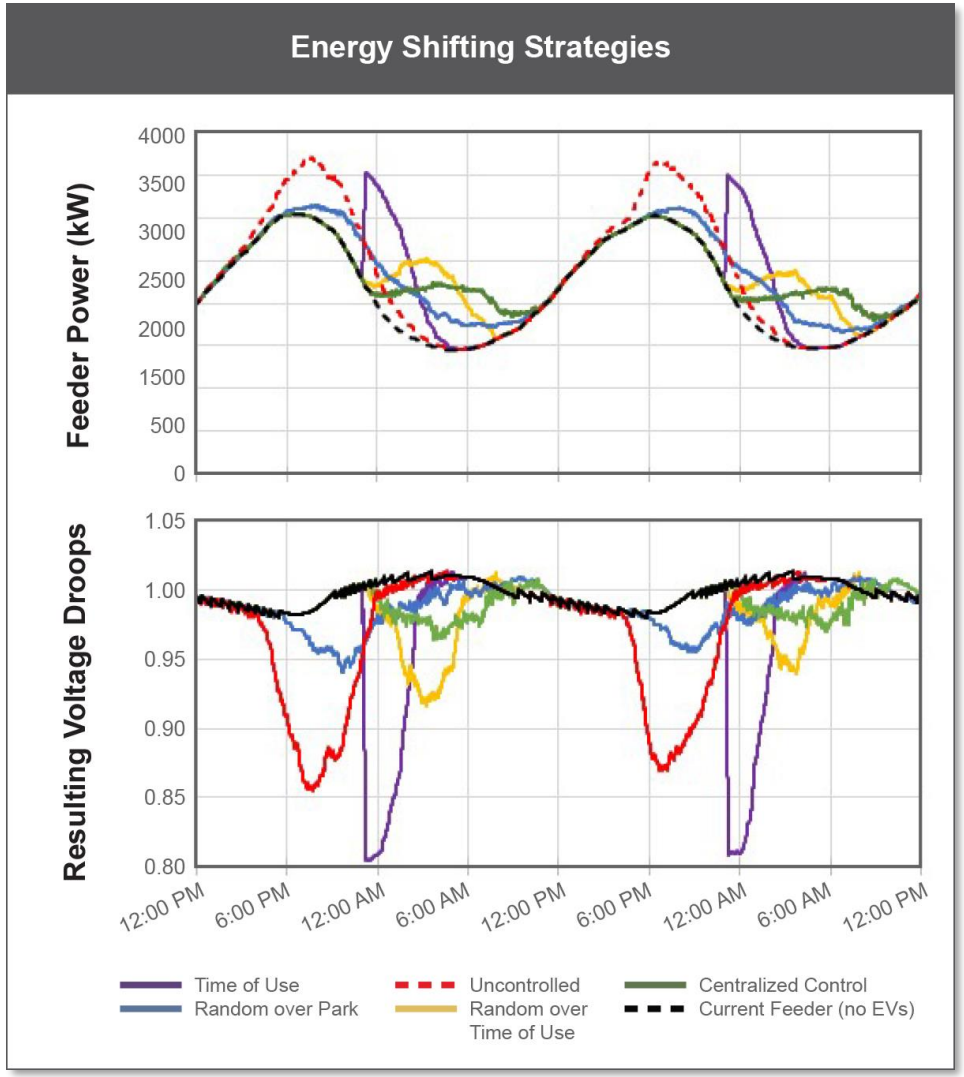
Grid Impact Demonstration Platform

- Transportation simulation determines when and where vehicles are connected to the grid
- Charging model library accurately simulates loads which are applied to the grid model and can be viewed as an aggregate impact
- **Uncontrolled charging** is demonstrated and resulting impacts on the grid such as peak feeder power and node voltage are assessed for improvement



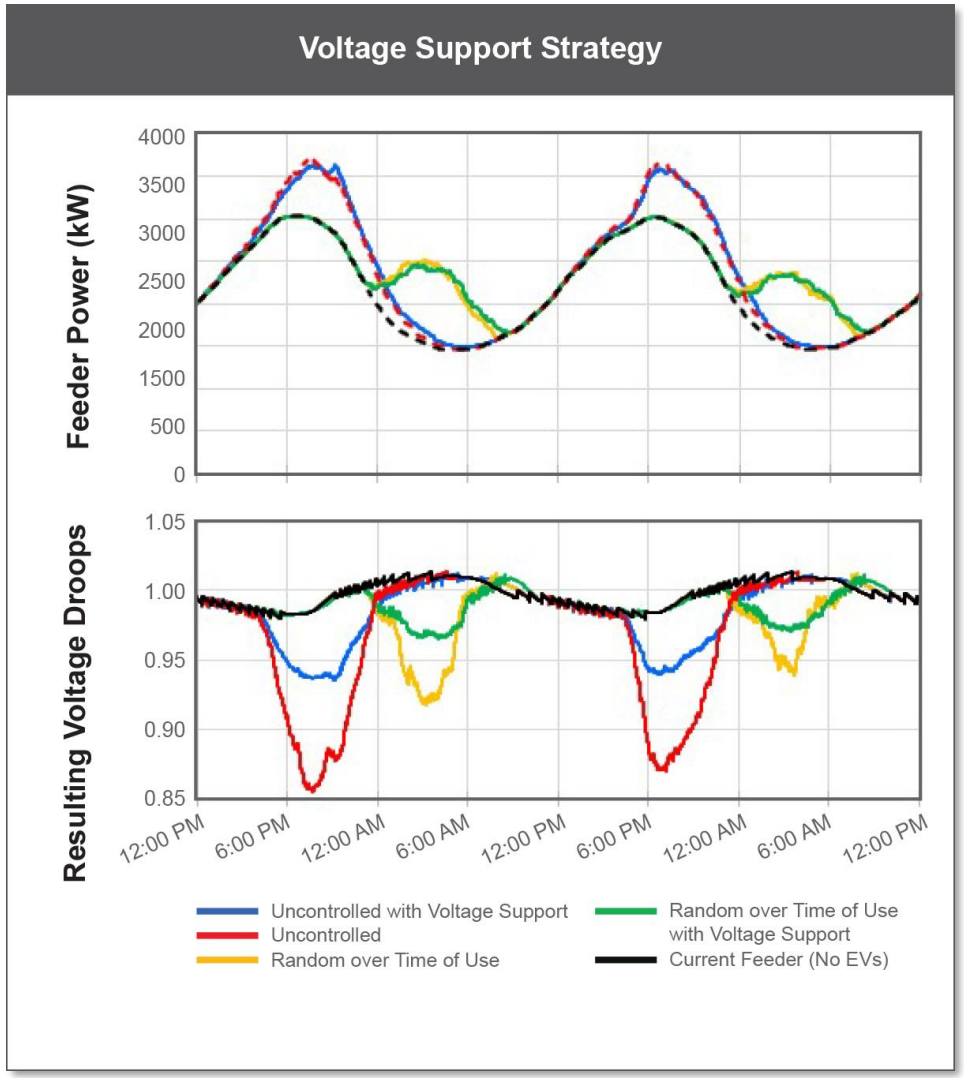


Control Strategy Demonstration Platform

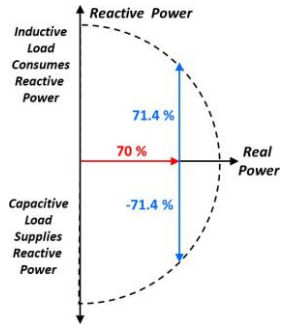


- Control Strategies are developed, tested, and compared in Caldera
- Energy shifting control strategies shown here include:
  - Centralized aggregator
  - Distributed random start
  - Time-of-Use rates (TofU)
  - Random starts during TofU
- Benefits increase with increasing EV Adoption, filling in trough can consume otherwise curtailed renewables
- Voltage may continue to be a problem

Voltage support using Reactive Power



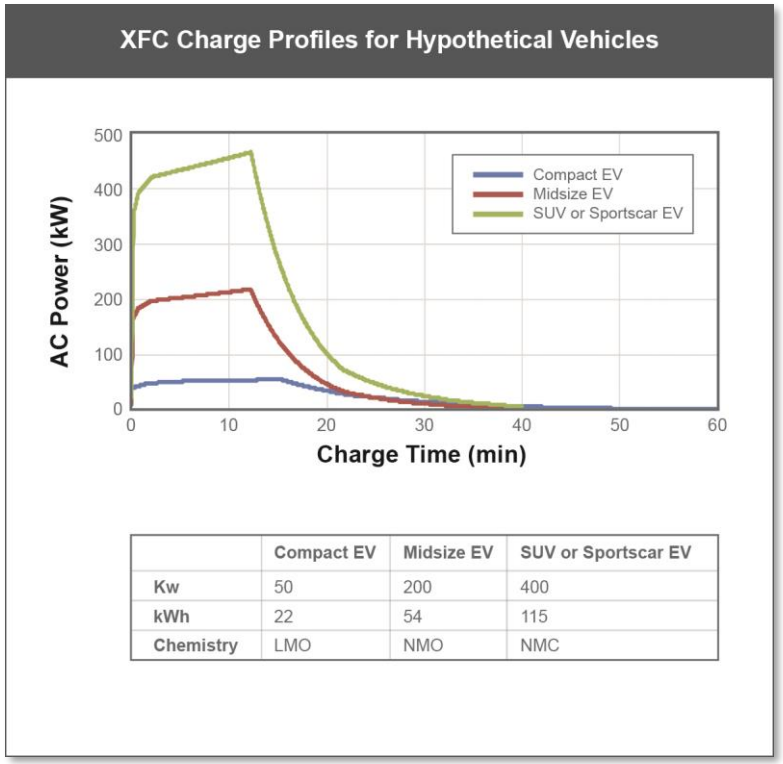
- Just as Smart Inverters are currently proliferating in the solar industry and allow solar generation to provide better support to the grid, we envision improved power electronics in EV battery charging hardware could provide reactive power and substantially lessen EV impacts on the grid; and Caldera can prove that.



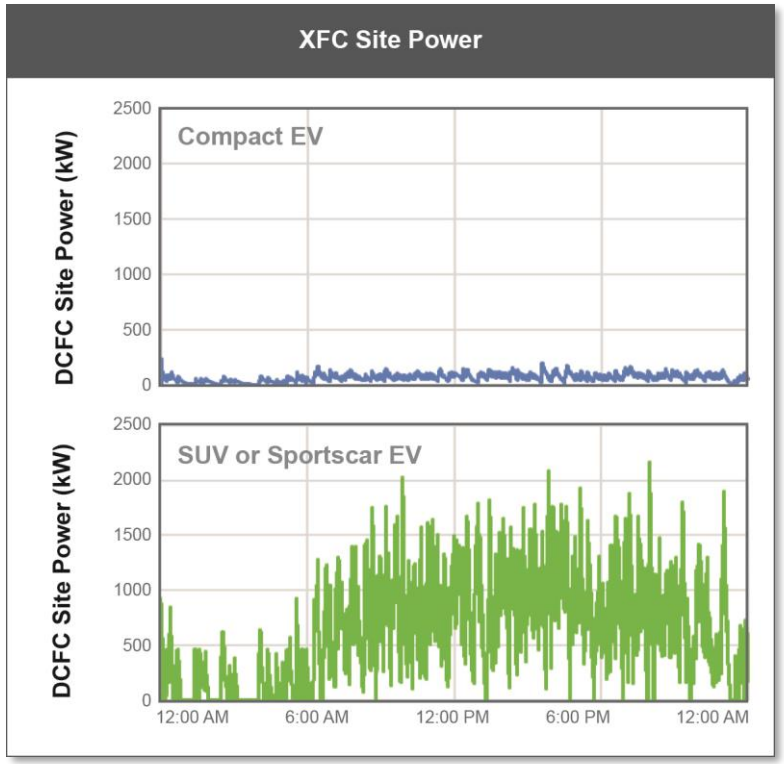
  - EVs (with smart invertors) charging at less than 100% power, or connected and not charging are able to provide reactive power to the grid.

- The results show that with the energy shifting decentralized strategy of random starts over the Time of Use rate period, the peak power is not increased, but the voltage would fall to unacceptable levels; until the Reactive Power strategy is added and it then stays above 0.95 puVA

Challenges of an XFC Station



	Compact EV	Midsize EV	SUV or Sportscar EV
Kw	50	200	400
kWh	22	54	115
Chemistry	LMO	NMO	NMC



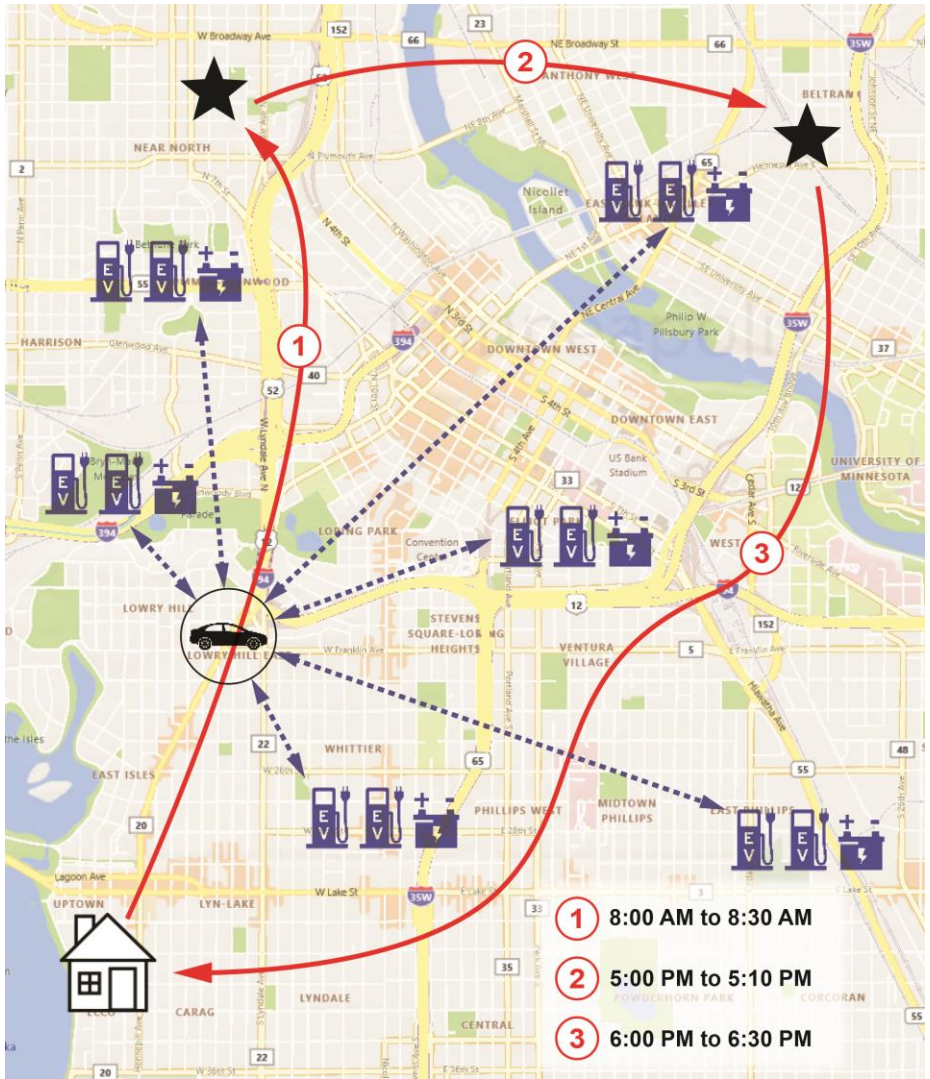
Caldera Simulation of XFC Station:

- 5 x 500 kW chargers collocated
- Vehicle use based on real-world gas station data
- Note abrupt ramping and high peaks for high charge power vehicles
- Demand charges impact the station operator. Electrify America has said “up to 80% of a station electricity bill can be demand charges.”

Stationary Energy Storage – Charging Station Site Management

- Local station controls and the presence of stationary energy storage can smooth and reduce peaks
- With lower peak loads more XFC stations can be placed on weak grid, increasing convenience for EV owners
- Stationary energy storage can mitigate demand charges, increase profits for charge network operators (CNPs)
- Caldera incorporates an accurate Stationary Energy Storage Electro-Chemical Model and site management system in the Infrastructure AI
- This is a tool for utilities and CNPs to study the benefits and aging effects of specific battery energy storage systems on their network

Smart Charge Management for Extreme Fast Charging (XFC)



In the case of XFC there is no extra dwell time for energy shifting

Instead we are studying possible grid impact mitigations by informing the EV owner about optimal charging options, and enabling reservations

The “Open Table” for EV Charging allows owners to avoid wait times and find cheaper charging options, charging station management to optimize stationary energy storage and price to avoid demand charges, and ultimately reduces impact on the grid while increasing energy sold

Assessing Specific Distribution Networks

We have simulated transportation and distribution networks in the following 3 metro areas working with the resident major utilities

Georgia Power

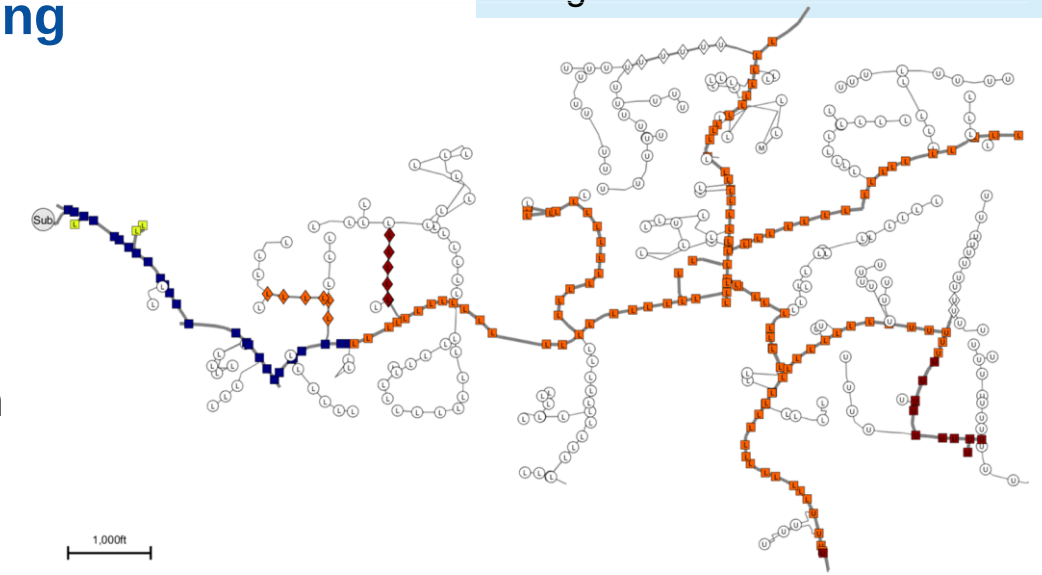
PG&E Pacific Gas and Electric Company

Xcel Energy®

We look forward to working with different regions and utilities to assess and improve their unique future with electrified transportation

Technical Accomplishments and Progress:
Task 3 - PEV Charging and Distribution System Modeling

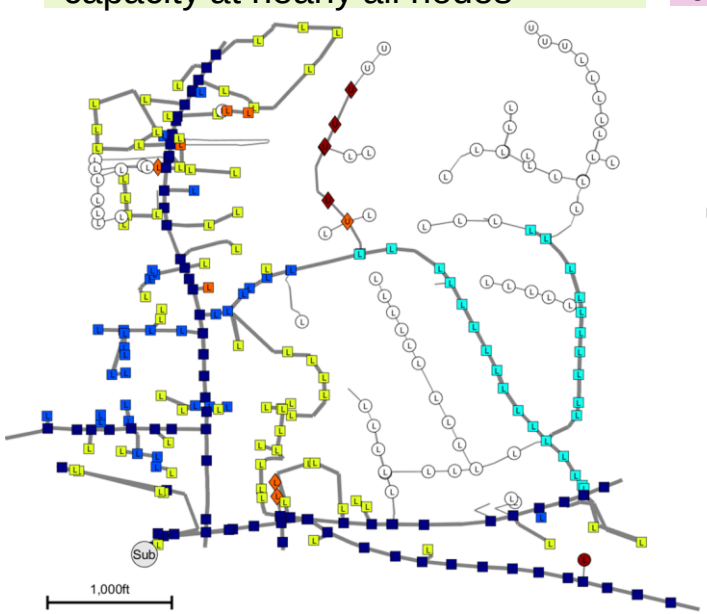
Residential feeder has capacity along main “backbone”



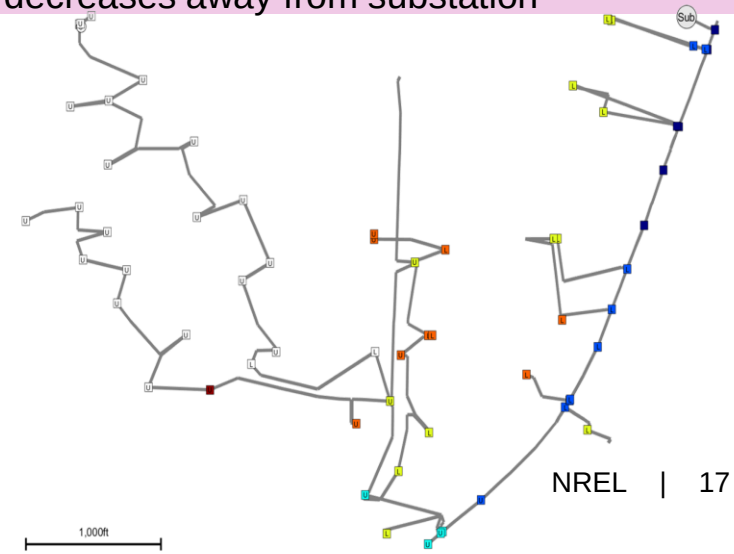
Atlanta EV Hosting Capacity

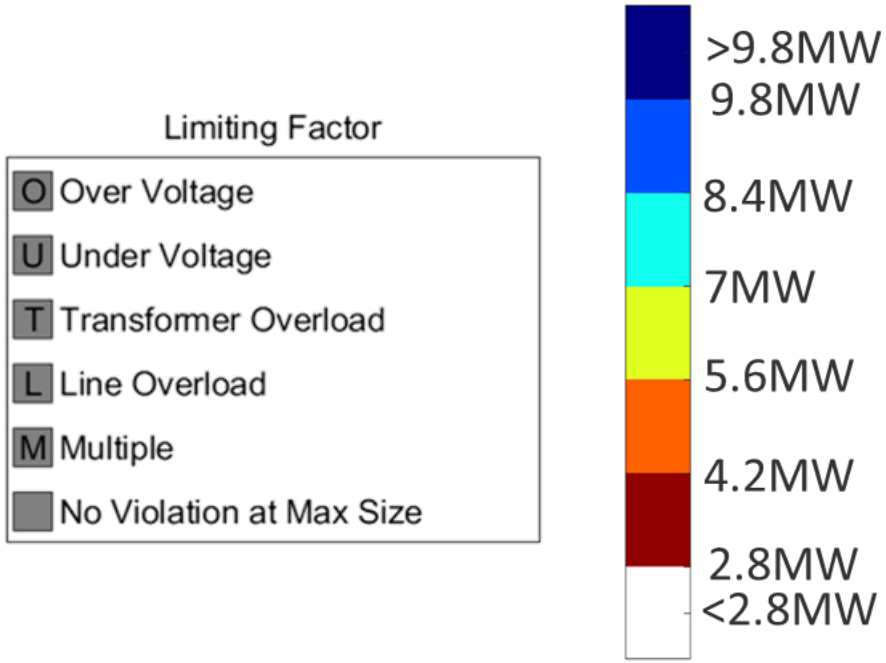
- **EV hosting capabilities vary by location on the feeder**
- Line overloads most common limiting factor, then under voltage
- Distance from substation is important: higher capacity closer to substation
- Commercial feeders tend to have the most nodes with high capacity
- Some of the study feeders would likely host future public charging infrastructure and all feeders have at least some locations capable of multiple 350kW xFC

Commercial feeder has significant capacity at nearly all nodes



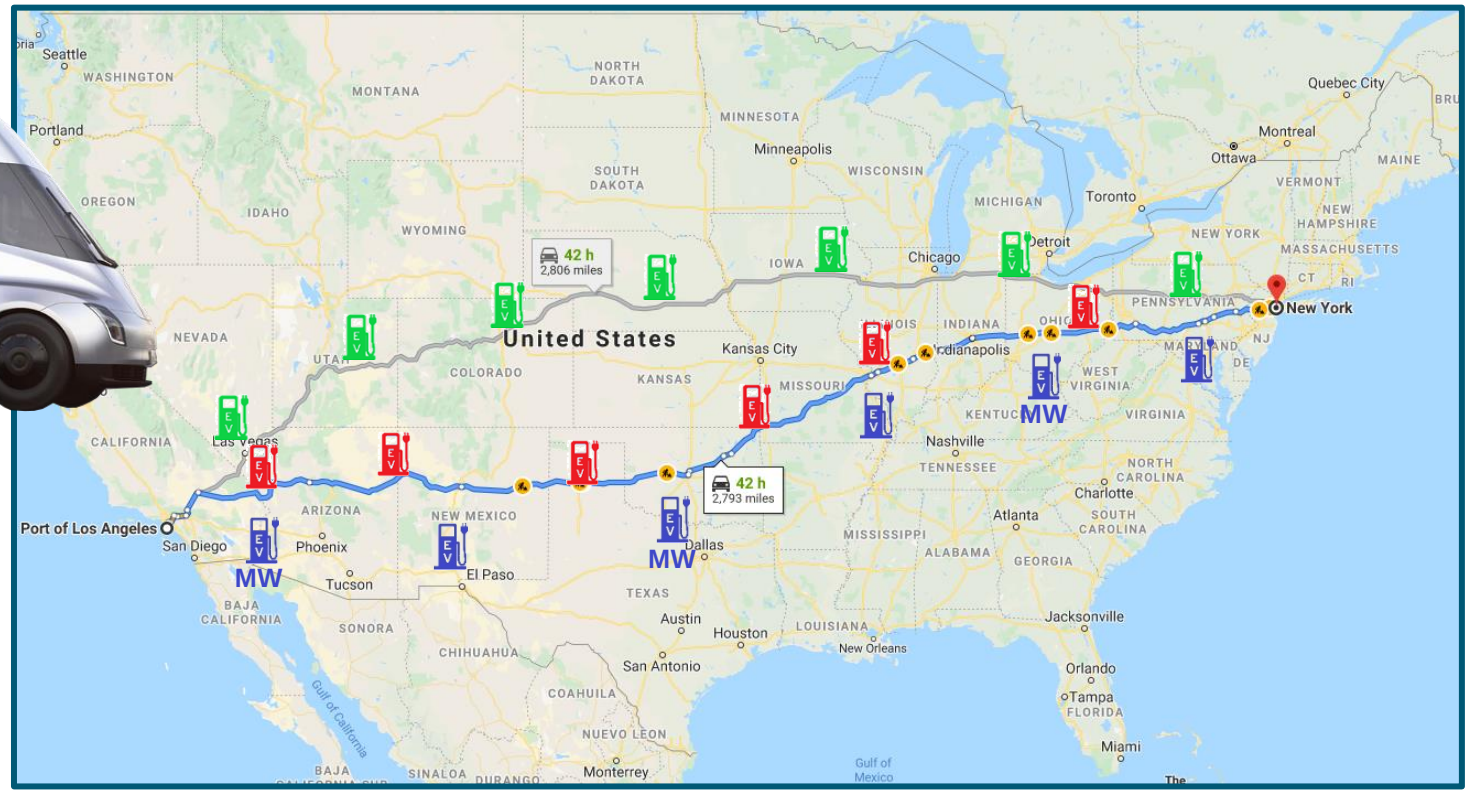
Industrial feeder capacity starts high but rapidly decreases away from substation





Future Work: Smart Charge Management for Trucks

- Caldera to guide truckers toward optimal charging decisions that minimize cost, grid impact, and maximize miles driven
- Advance communication and scheduling of 1+MW charging and onsite energy storage is necessary



- Use of lower-power, cheaper infrastructure when possible
  - Coordinate lower power chargers with “Hours Of Service” stops

Other Planned Applications for Caldera

- Distributed Energy Resource (DER) modeling on the grid
  - Caldera will be well suited to study stationary energy storage, and PEVs with L2 and XFC
  - An augment to OpenDSS's capabilities for other DERs
- Electrified Fleet Management
  - Especially MD/HD interactions with distribution centers
  - Transit Bus Fleets
  - Other local MD/HD uses such as sanitation, utility, last mile

What are you working on?
How can you use Caldera?
Where can we collaborate?

Timothy.Pennington@inl.gov

at.inl.gov