INL/CON-24-78030-Revision-0

JO Electrification TA from INL - CalderaCast

June 2024

Changing the World's Energy Future

Timothy David Pennington

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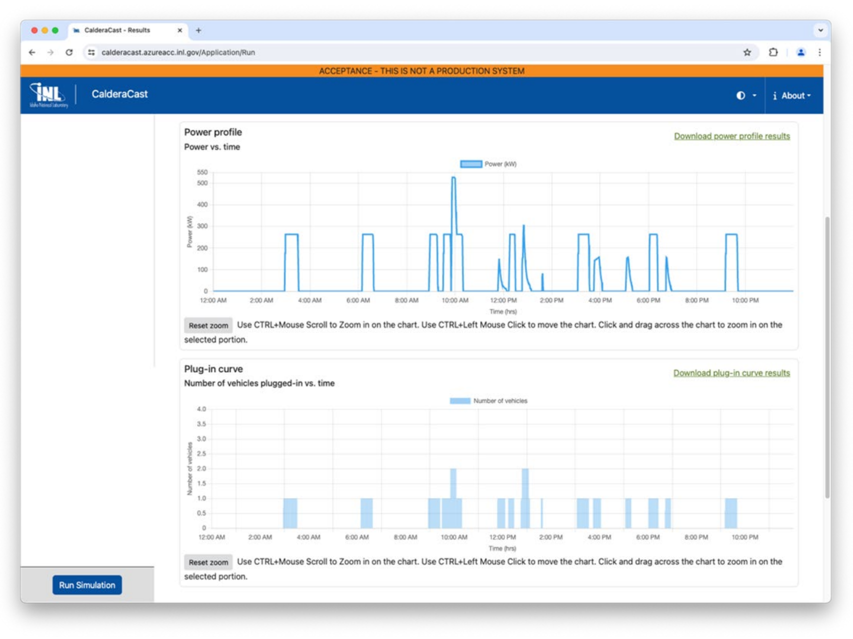
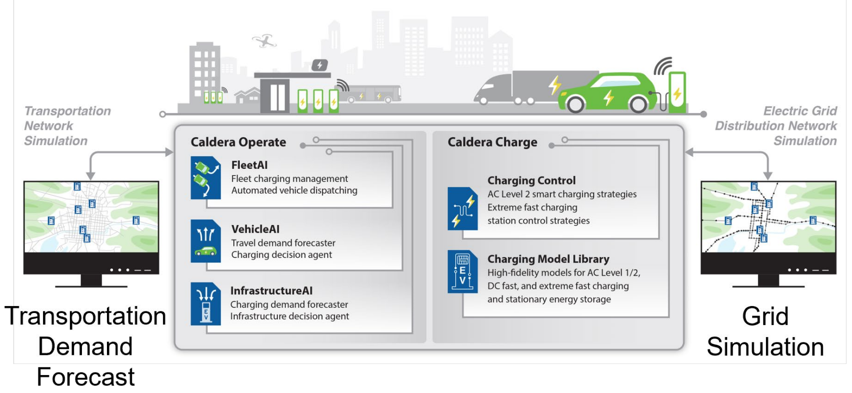


JOET009

June 6, 2024

Timothy D. Pennington
Research Group Lead



JO Electrification TA from INL - CalderaCast (JOET009)

A Public Web Tool for Forecasting Load at Public Corridor Charging Stations

"This presentation does not contain any proprietary, confidential, or otherwise restricted information."

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Idaho National Laboratory

INL/CON-24-78030

CalderaCast Overview

Objective:

- Leverage INL's Caldera simulation platform to provide a publicly available web tool for forecasting electric load at proposed Electric Vehicle Charging Stations along Alternative Fuel Corridors.
- This will allow stakeholders to independently evaluate potential vehicle demand and electric load of a station they are considering operating, funding, planning, or providing electrical grid connection for.

Timeline: (2 years)

Start Date: October 2022

End Date: September 2024

Budget: $1.4M Total for FY23 & 24

Progress: 85% Complete

Partners:

- Coordinating with PNNL on related tool development.
- Substantial stakeholder input and testing by utilities, state agencies, potential charging station operators, and related industry groups.

CalderaCast Relevance

- Electric Vehicle (EV) charging infrastructure is expanding rapidly with significant support from the National Electric Vehicle Infrastructure (NEVI) program funded by the Bipartisan Infrastructure Law (BIL).
- However; many state agencies, utilities, and potential charging station operators tasked with implementing new stations have little or no prior experience with this particular and unique type of electric load.
- Estimating the vehicle demand, and resulting electrical load is a necessary part of properly planning these stations to ensure: state usage/coverage goals, utility interconnections, and business operating plans.
- Caldera is an INL developed simulation platform previously used to research potential electric load from future EV charging. CalderaCast makes that capability available outside of the lab to users with basic information about proposed charging stations.

Approach: Caldera Background

Why Caldera?

Caldera is the “Missing Link” to understanding EV charging demand and providing solutions to satisfy energy needs

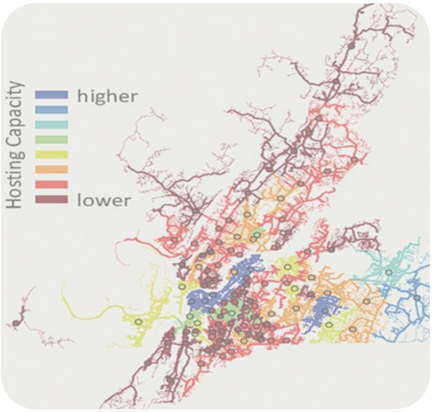
Transportation Models

HELICS
Co-simulation

Caldera
EV Modeling Platform

HELICS
Co-simulation

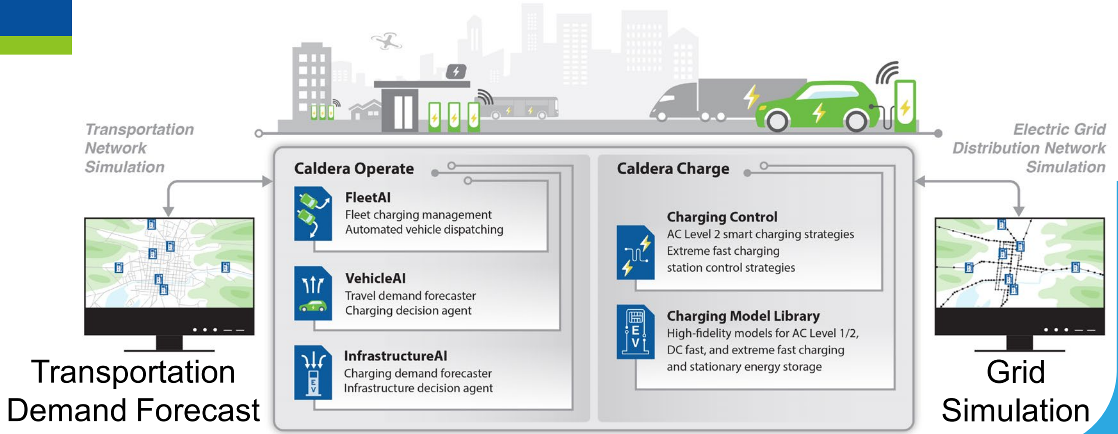
Energy System Models



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

Approach: Caldera Background

Electric Vehicle & Infrastructure Decision Management Simulation Platform



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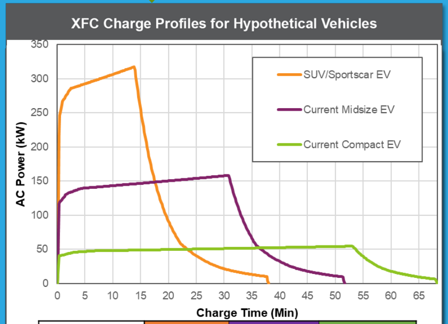
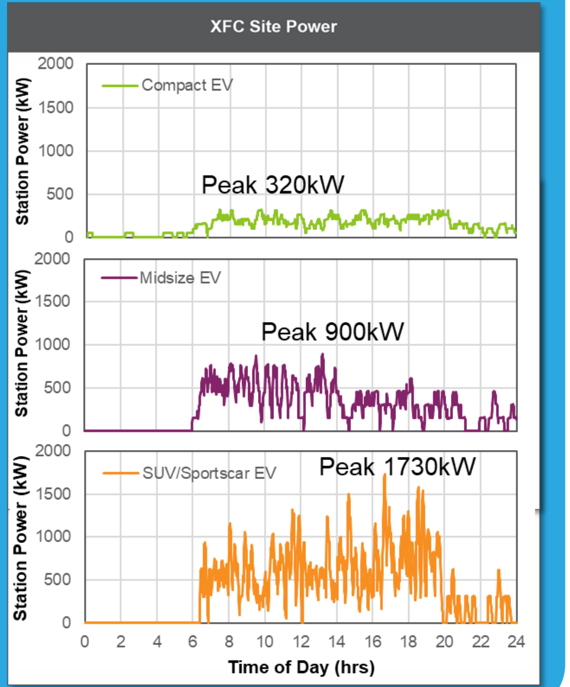


	SUV/ Sportscar EV	Current Midsize EV	Current Compact EV
Max Charge Rate (kW)	300	150	50
Vehicle Range (Miles)	250	275	150
Vehicle Resembles	Porsche Taycan	Tesla Model 3	Nissan Leaf

2



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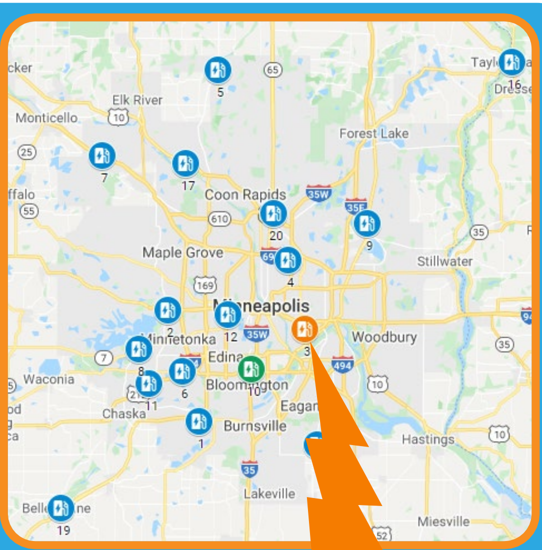
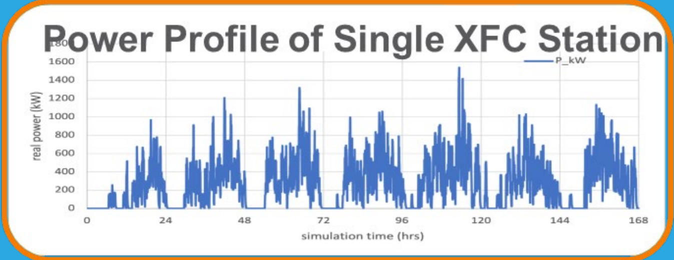
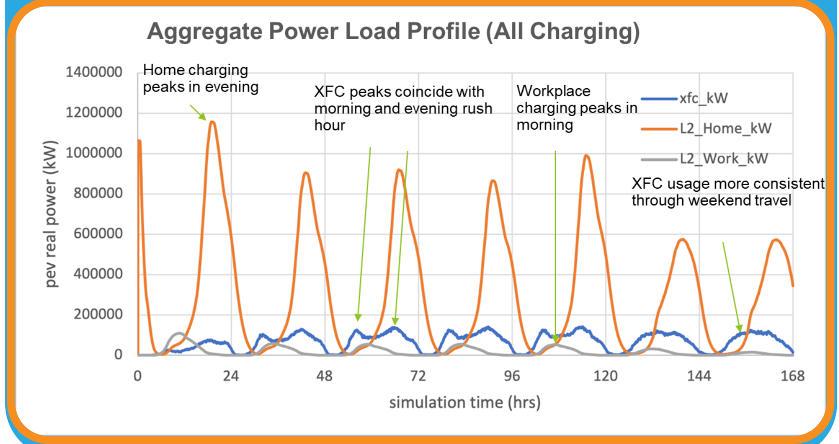




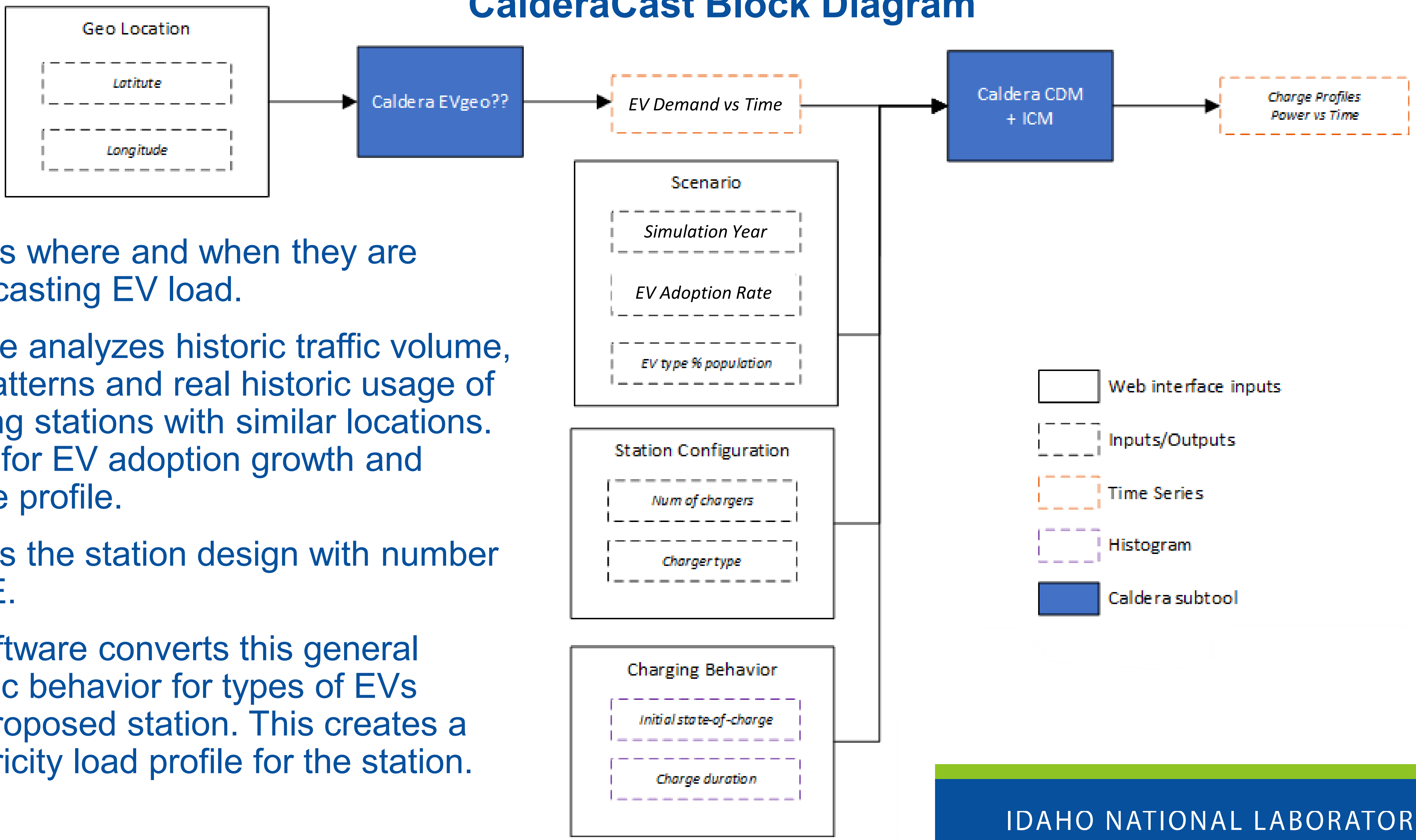


Caldera is an agent-based modeling platform for predicting detailed system impacts and demonstrating intelligent management strategies.

Approach

CalderaCast Simulation Workflow

CalderaCast Block Diagram



- The user indicates where and when they are interested in forecasting EV load.
- "EV Geo" software analyzes historic traffic volume, trends in traffic patterns and real historic usage of some EV Charging stations with similar locations. Adds forecasting for EV adoption growth and produces a usage profile.
- The user indicates the station design with number and type of EVSE.
- "Caldera Sim" software converts this general usage into specific behavior for types of EVs charging at the proposed station. This creates a high-fidelity electricity load profile for the station.

Milestones

Milestone ID	Schedule	Milestone Description	Status
M1.1	FY23 Q1	Set assumptions and locate input data sets	☑ On Time
M1.2	FY23 Q2	Complete simulation development, initiate web development	☑ On Time
M1.3	FY23 Q3	Web interface for internal review, hosting agreement in process	☑ On Time
M1.4 (Go/No-Go)	End FY23	CalderaCast ready for deployment on web, promoted to users	☐ In Process
M1.5	FY24 Q2	Improvements to CalderaCast deployed to web	☐ In Process
M1.6	End FY24	Integrate with other EV Grid Assist tools and deploy to web	☐ Future Task

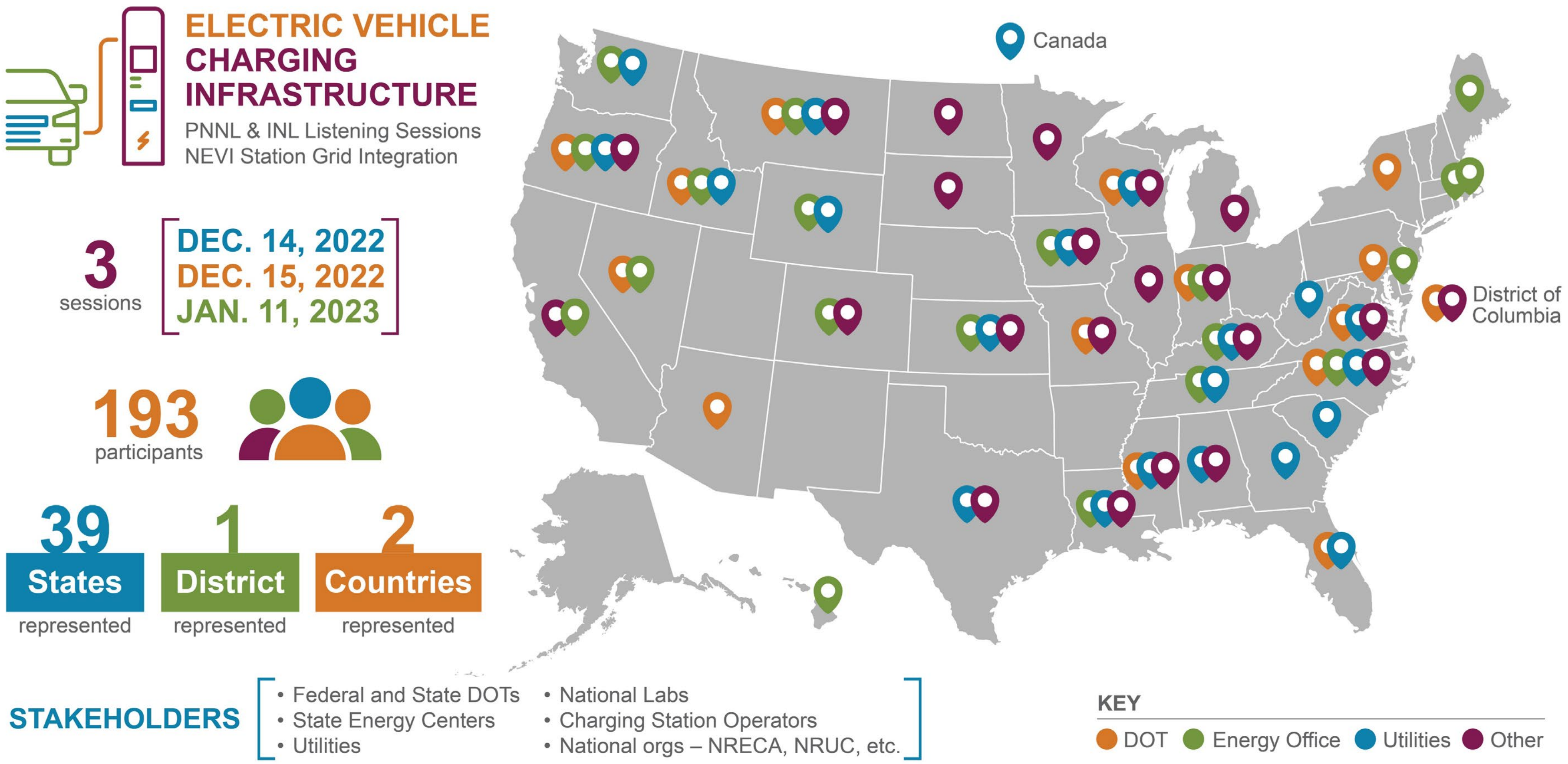
M1.4 – CalderaCast tool development was completed by the team and “beta sessions” were held with seven stakeholders by end of FY23. Feedback and subsequent review processes have necessitated changes primarily to non-simulation related aspects. As of early May 2024 the code has been “locked” and under final cybersecurity review for several months, with only non-functional changes made for approval. Communications and outreach are being planned for the expected launch.

M1.5 – While the website public release has been delayed by reviews and approvals the research team has worked on improvements to accuracy, coverage, and user experience. These improvements will be deployed soon after site release and will initiate our continuous improvement deployment process.

Technical Accomplishments

Stakeholder Outreach and Beta Volunteer Engagement

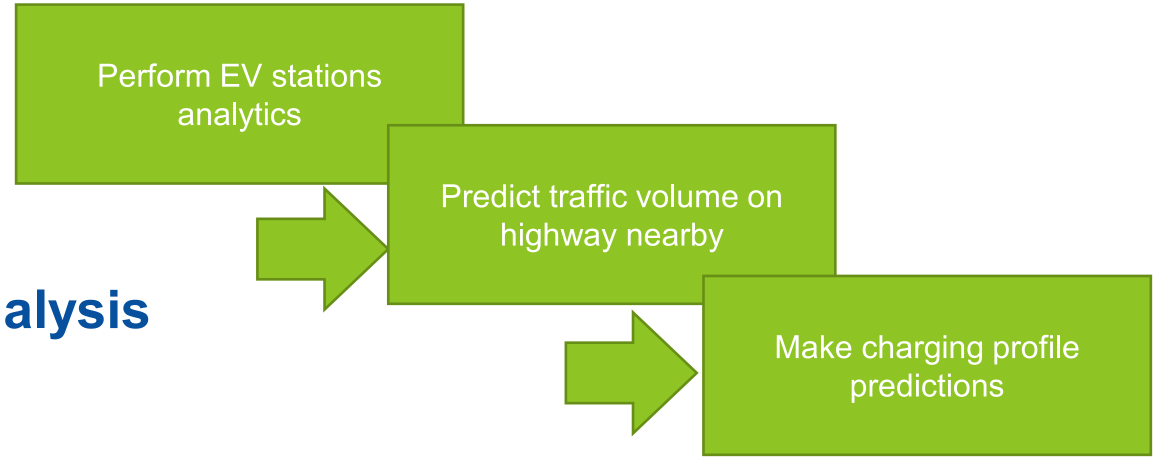
- Previously held 3 “Listening Sessions” including NEVI stakeholders
- Received very useful feedback:
  - More than half have never done EV infrastructure before
  - Majority use nameplate power rating, some use static derating, some have proprietary method
  - Interested in the “average daily peak power” as well as the range of power profiles



- Held 3 “Beta Sessions” in September
- 7 Total Stakeholder Organizations Represented
  - 5 State Agencies
  - 1 Engineering Firm
  - 1 Consumer Advocate Organization

Technical Accomplishments (cont.)

CalderaGeo
EV charging behavior platform



Perform EV stations analytics – Exploratory analysis of EV WATTS data

1. Identify stations along the highway
2. Estimate traffic volume in the nearby area
3. Model stations usage profile
4. Build correlation with location, population density and traffic

Predict traffic volume on highway nearby – Estimate traffic counts on highway segment and monitoring stations

1. Specify the location of the proposed EV charging station.
2. Identify the closest TMAS station and surrounding highway segments.
3. Provide traffic predictions

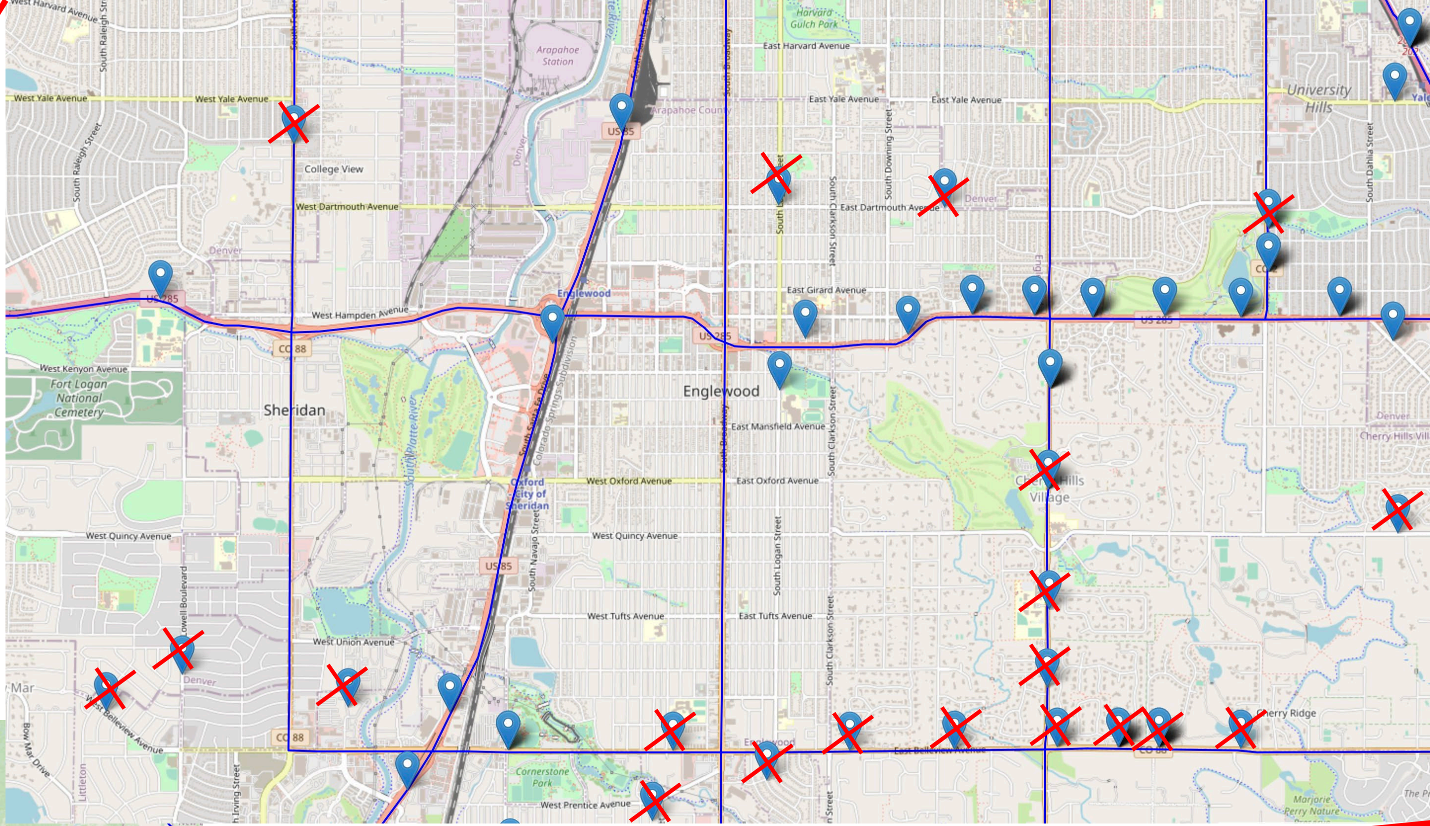
Make charging profile predictions – Predict charging profile

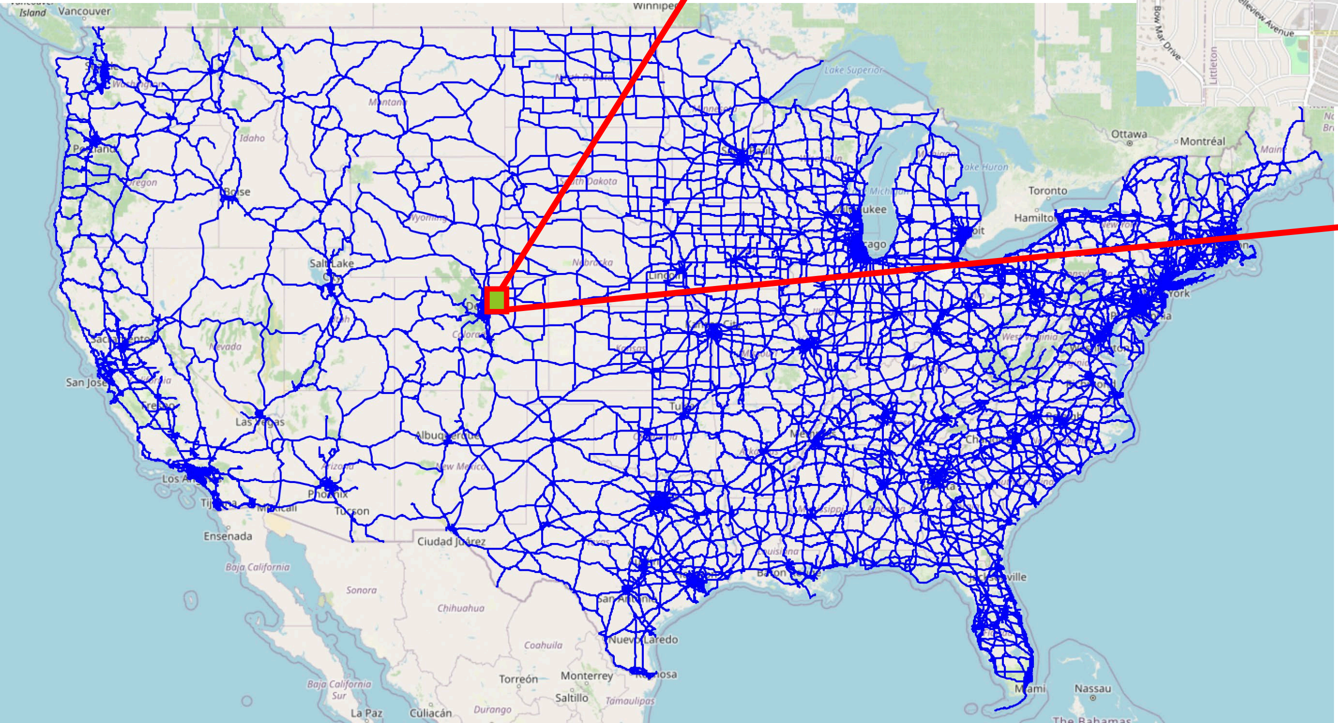
Model potential stations usage profile, considering location population density and traffic predictions made in previous steps

Technical Accomplishments (cont.)

Data sources

Main data sources are EV WATTS from Energetics, National Transportation Atlas Database from BTS, Highway Performance Monitoring System from FHWA, and Travel Monitoring Analysis System from USDOT.





EV WATTS STATIONS OF INTEREST

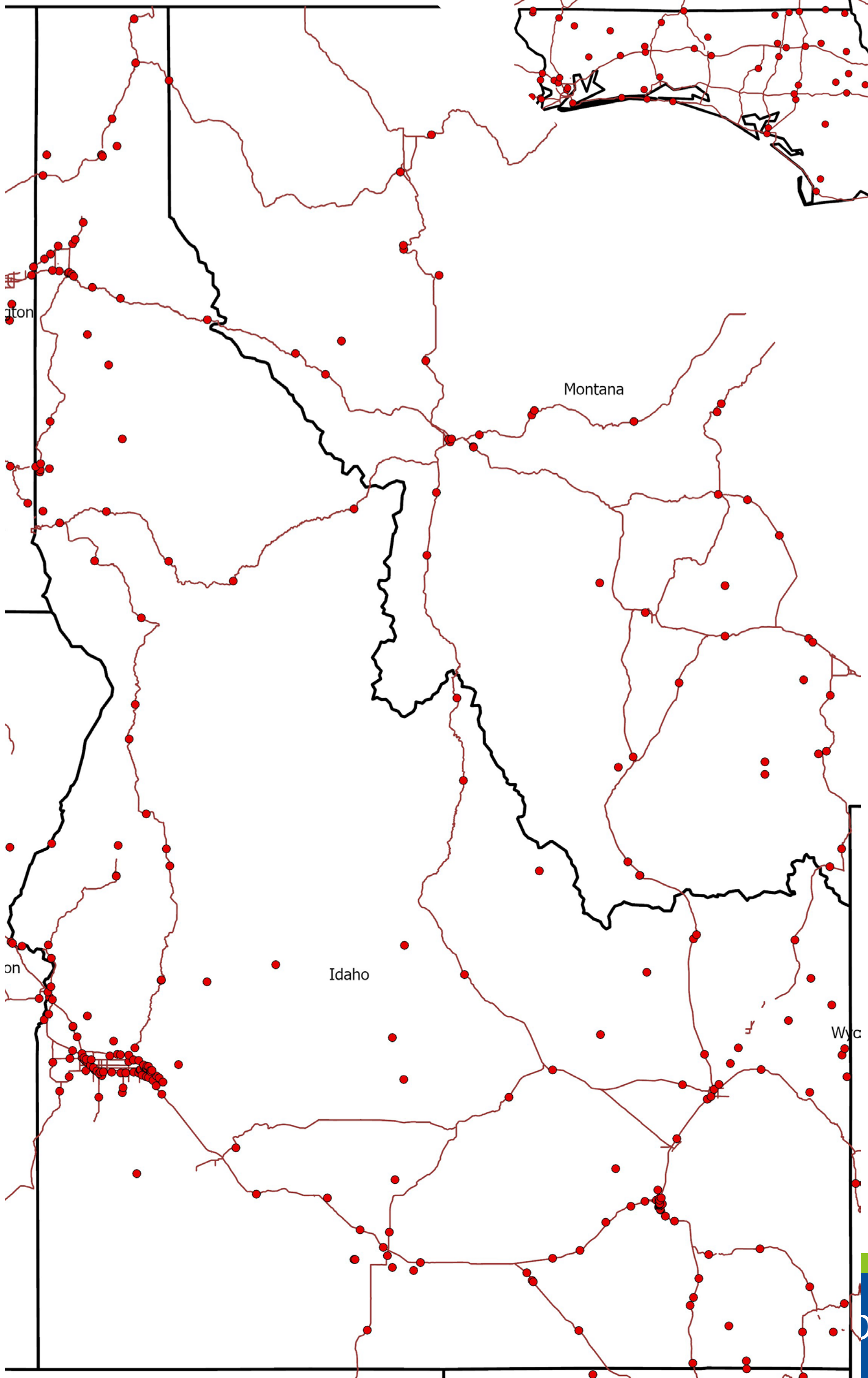
Figure on the left shows the US NHS (National highway system).
Figure on top (blowup of a location in figure on left) shows EV WATTS stations close to corridors.
Stations not close to corridors (e.g., home-based) are removed from training set for machine learning.

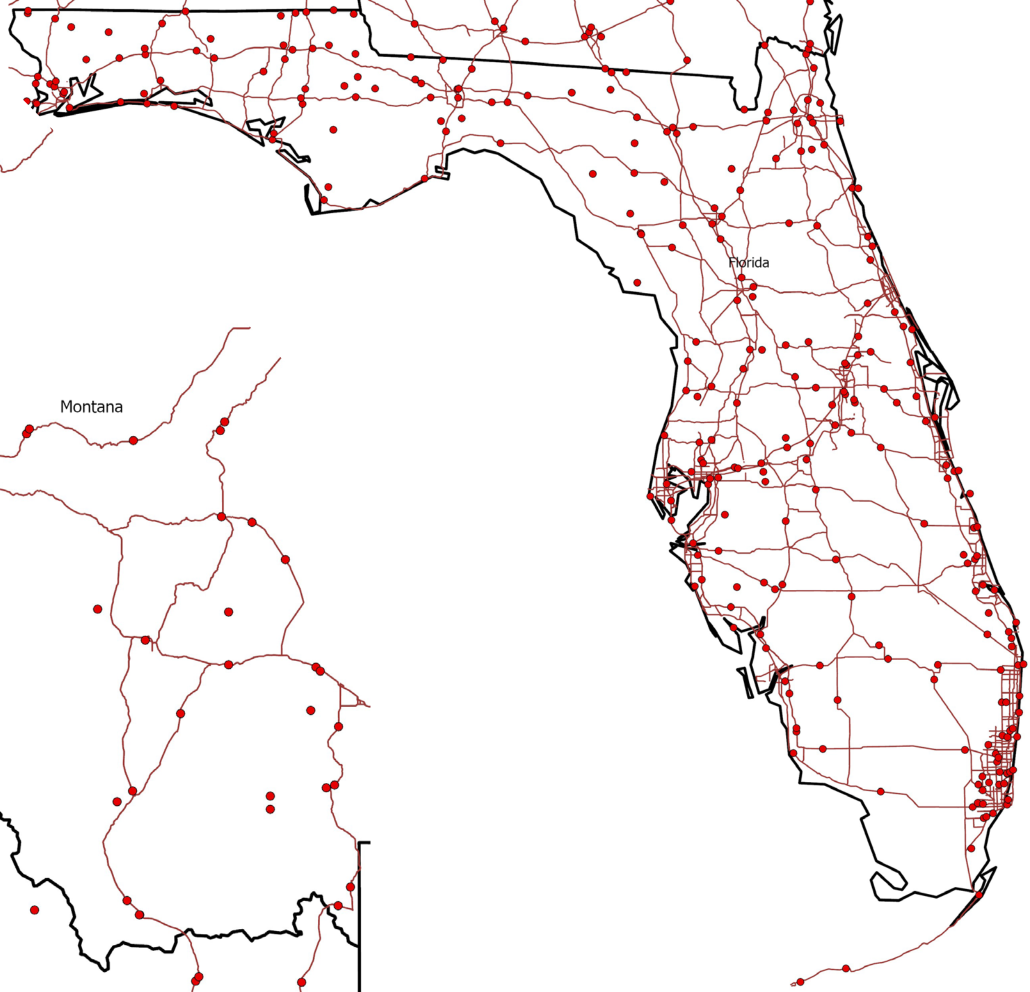
Technical Accomplishments (cont.)

Alternative Fuel Corridor Traffic Data Coverage

Travel Monitoring Analysis System (TMAS)from USDOT has good temporal resolution and national coverage.

Alignment with Alt Fuel Corridors (AFC) appears good as seen in these maps.

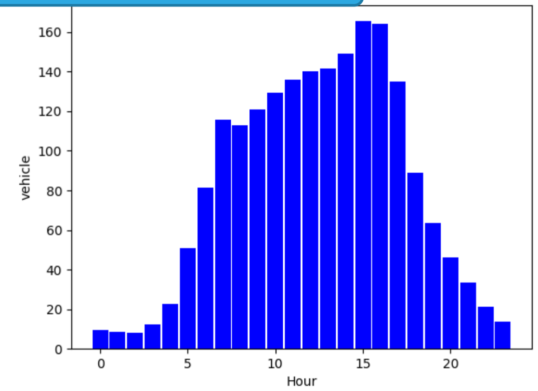


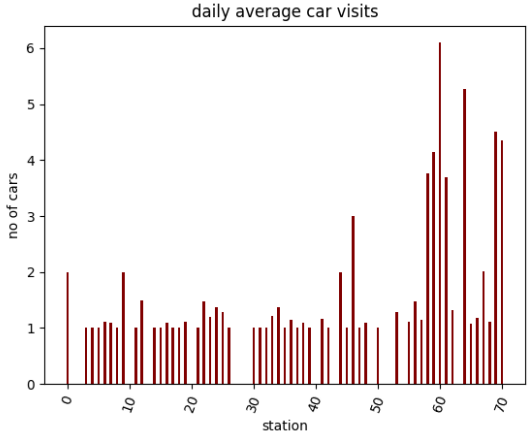


Technical Accomplishments (cont.)

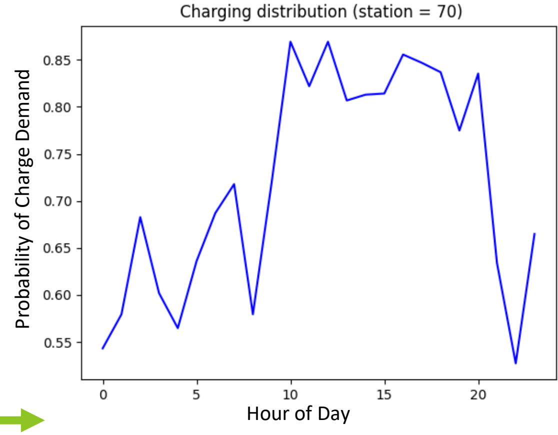
Perform EV stations analytics – Exploratory analysis of EV WATTS data

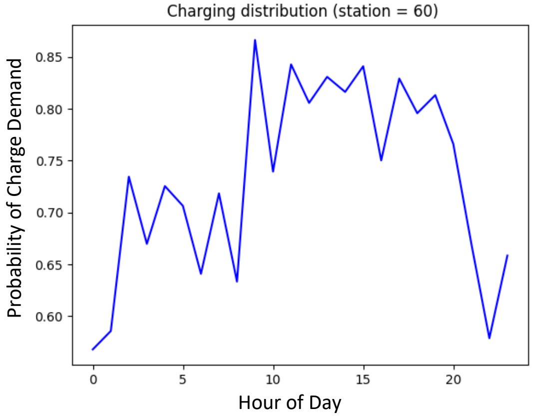
Traffic volume





Profiles vary based on location due to difference in traffic volume trends





EV station usage profile
+ Average daily charge events
+ Traffic volume on highway nearby

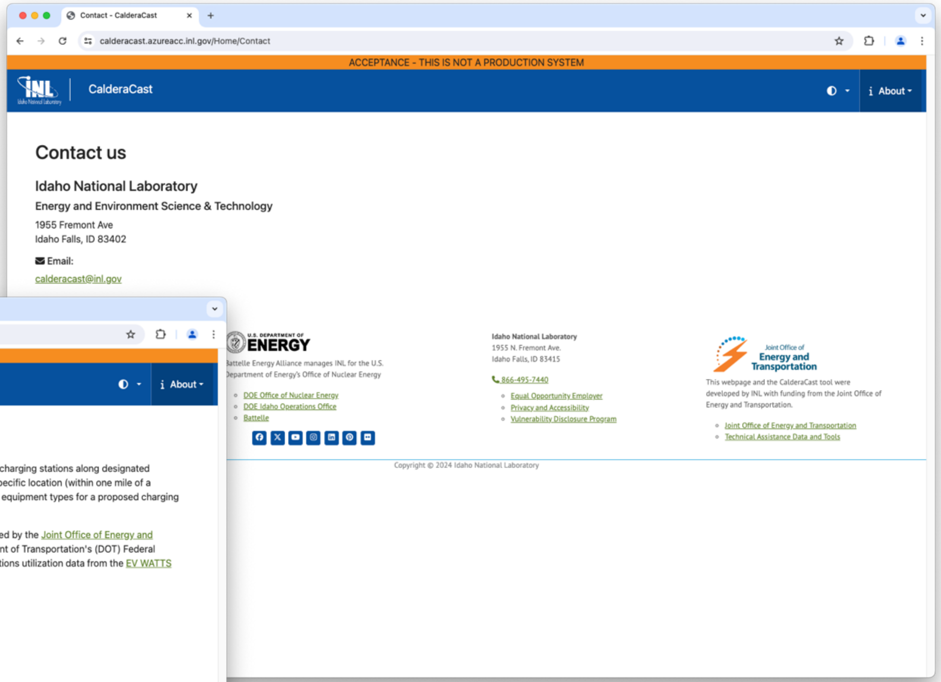
Charging Distribution
+ Binomial Distribution

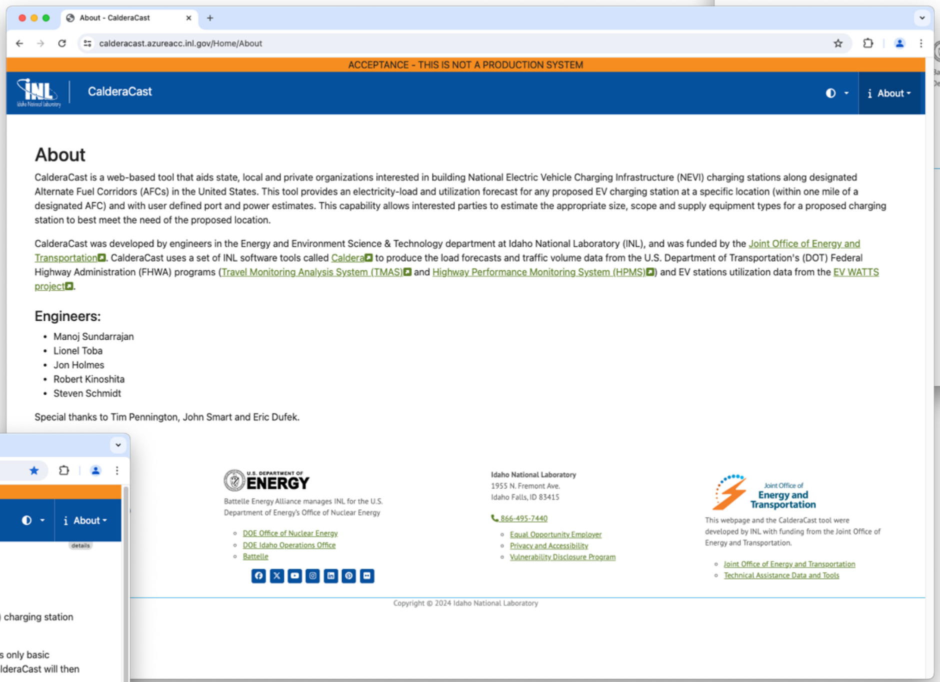
$$P_x = \binom{n}{x} p^x q^{n-x}$$

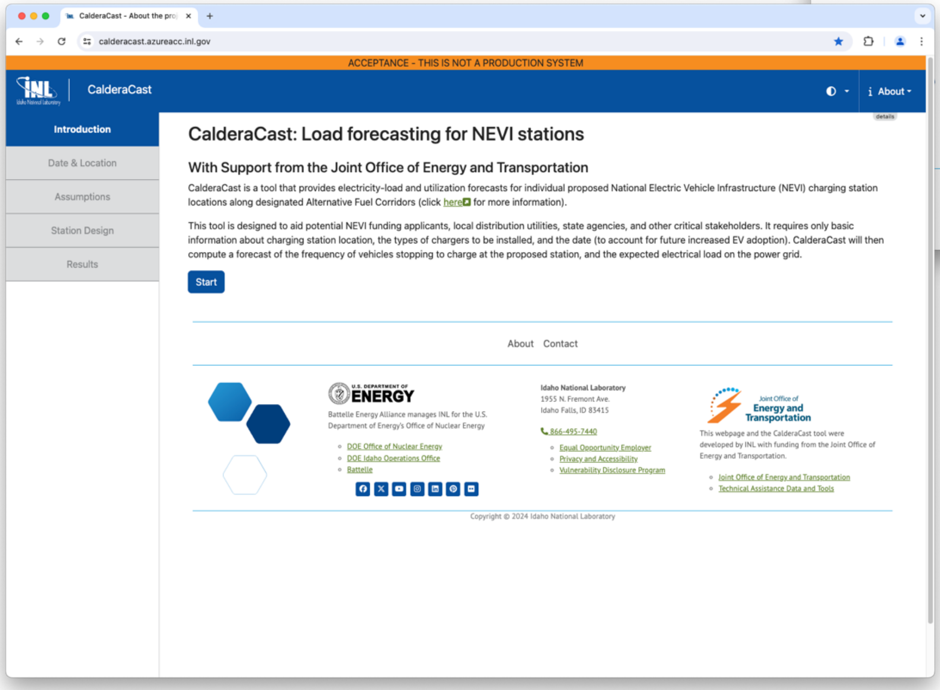
where P[X = x] is the probability of x successes (number of charge events) in n trials (traffic volume), each with a probability of p (q = 1-p)

Technical Accomplishments (cont.)
Website Development

Developing the CalderaCast website has been a crosscutting effort at INL, engaging software and web architects and developers, communications and branding experts, hosting and cybersecurity staff, all in addition to our EV, simulation, and machine learning experts.





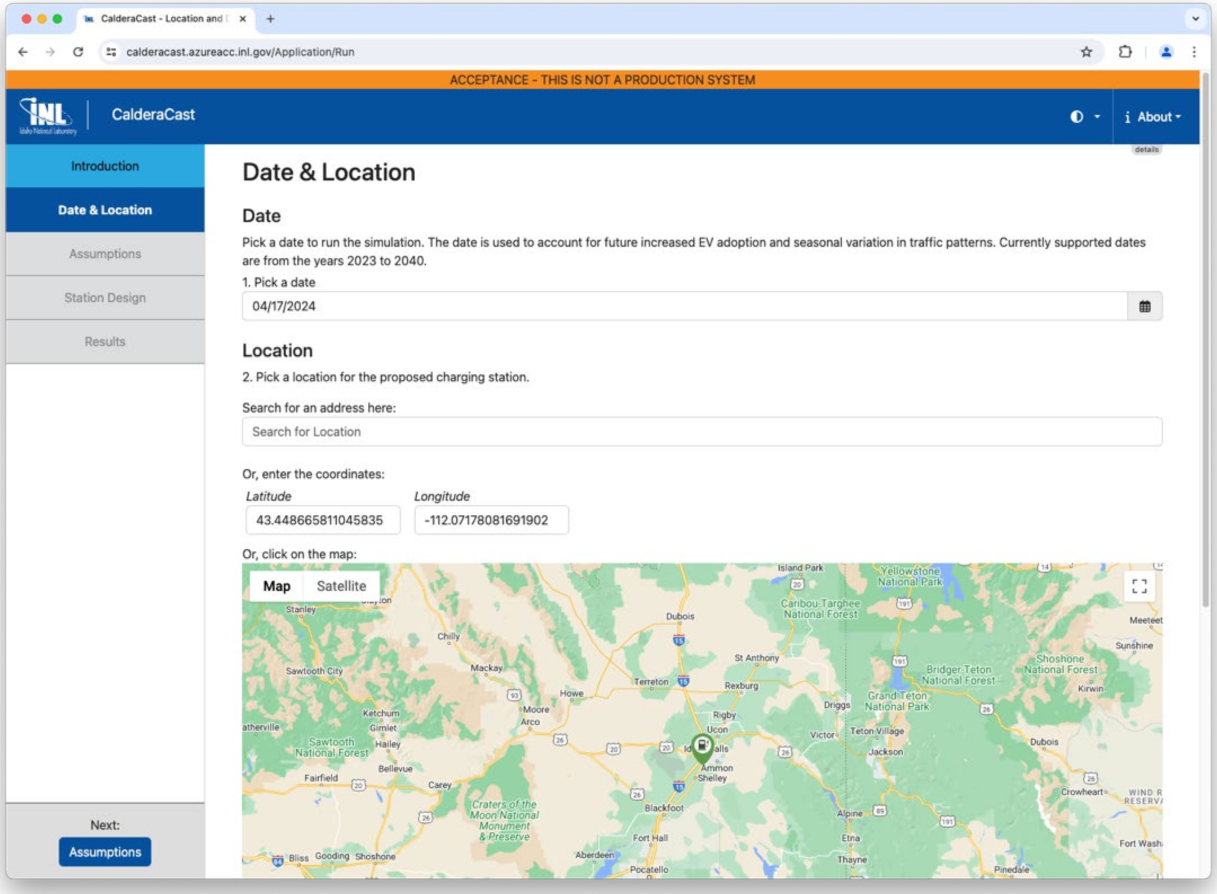


The final version of the website, shown here, matches INL, DOE, and JOET style and branding requirements.

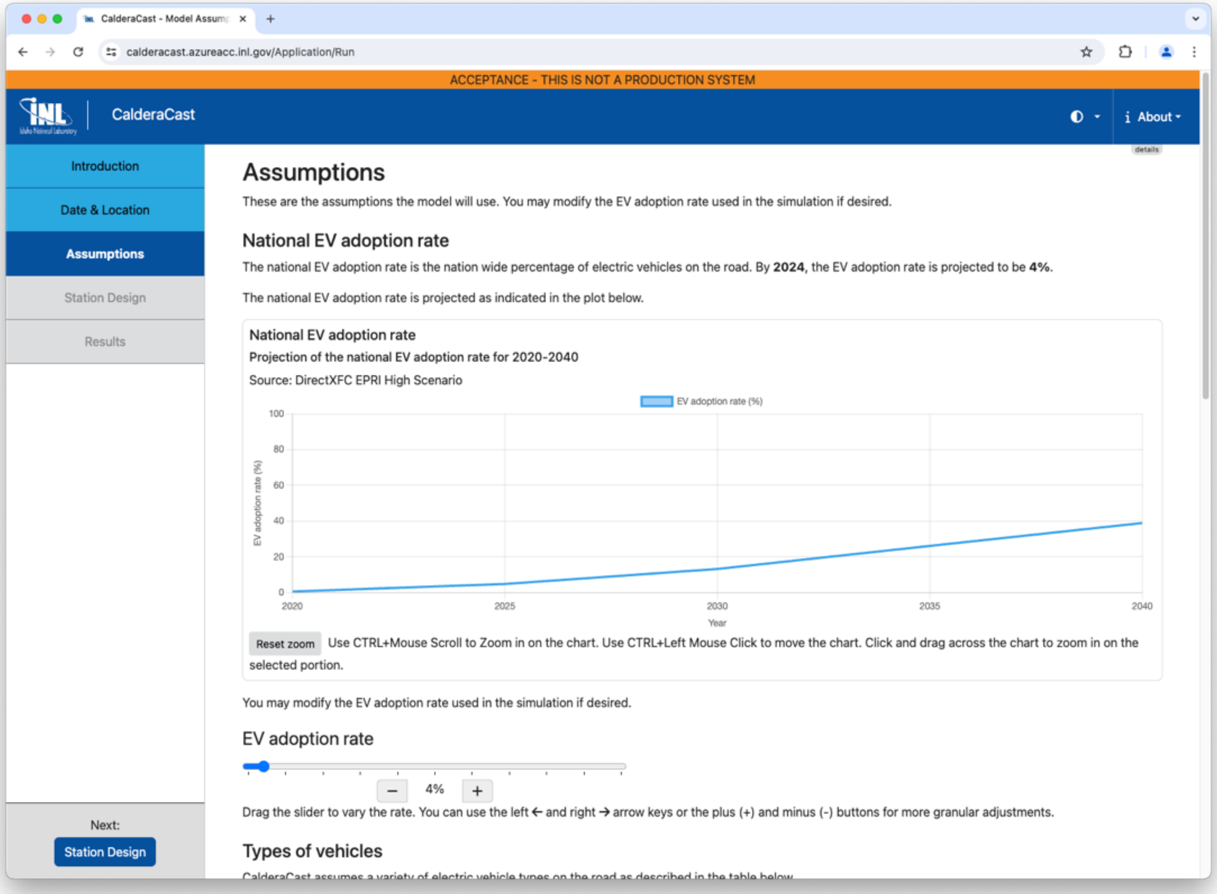
It begins with background information, an explanation of the team and support, and contact information.

Technical Accomplishments (cont.) Website Development

Once a user clicks “Start” they begin a step-by-step process in the tool, shown on the following slides

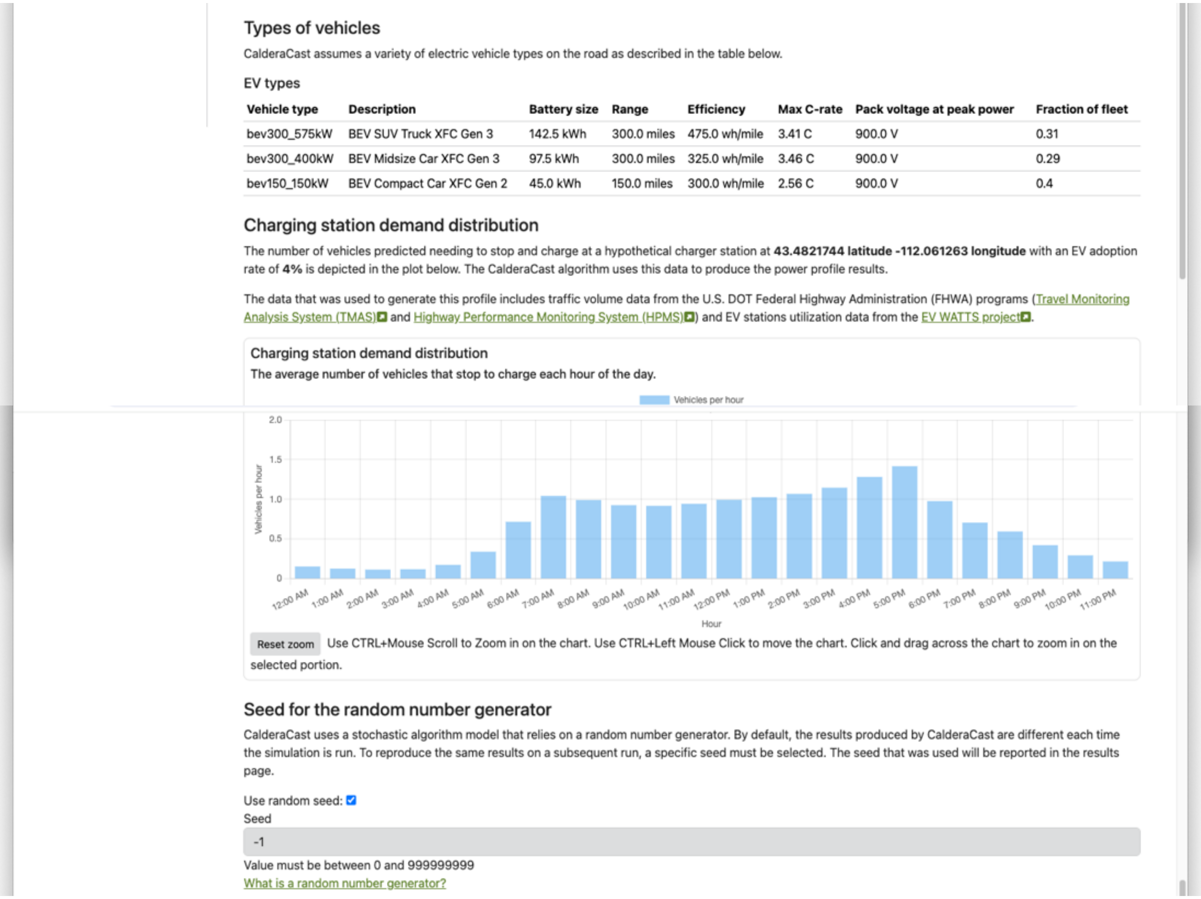


Step One prompts the user to select a date for the simulation, and then a location for the proposed charging station. The location may be entered as an address, Lat/Lon or by clicking on the map to refine the position.



Step Two shows the user assumptions that will be used in their simulation and allows them to modify those recommended settings.

Technical Accomplishments (cont.)
Website Development


Types of vehicles

CalderaCast assumes a variety of electric vehicle types on the road as described in the table below.

EV types

Vehicle type	Description	Battery size	Range	Efficiency	Max C-rate	Pack voltage at peak power	Fraction of fleet
bev300_575kW	BEV SUV Truck XFC Gen 3	142.5 kWh	300.0 miles	475.0 wh/mile	3.41 C	900.0 V	0.31
bev300_400kW	BEV Midsize Car XFC Gen 3	97.5 kWh	300.0 miles	325.0 wh/mile	3.46 C	900.0 V	0.29
bev150_150kW	BEV Compact Car XFC Gen 2	45.0 kWh	150.0 miles	300.0 wh/mile	2.56 C	900.0 V	0.4

Charging station demand distribution

The number of vehicles predicted needing to stop and charge at a hypothetical charger station at **43.4821744 latitude -112.061263 longitude** with an EV adoption rate of **4%** is depicted in the plot below. The CalderaCast algorithm uses this data to produce the power profile results.

The data that was used to generate this profile includes traffic volume data from the U.S. DOT Federal Highway Administration (FHWA) programs (Travel Monitoring Analysis System (TMAS)) and Highway Performance Monitoring System (HPMS)) and EV stations utilization data from the EV WATTS project.

Charging station demand distribution

The average number of vehicles that stop to charge each hour of the day.

Reset zoom Use CTRL+Mouse Scroll to Zoom in on the chart. Use CTRL+Left Mouse Click to move the chart. Click and drag across the chart to zoom in on the selected portion.

Seed for the random number generator

CalderaCast uses a stochastic algorithm model that relies on a random number generator. By default, the results produced by CalderaCast are different each time the simulation is run. To reproduce the same results on a subsequent run, a specific seed must be selected. The seed that was used will be reported in the results page.

Use random seed: ☑

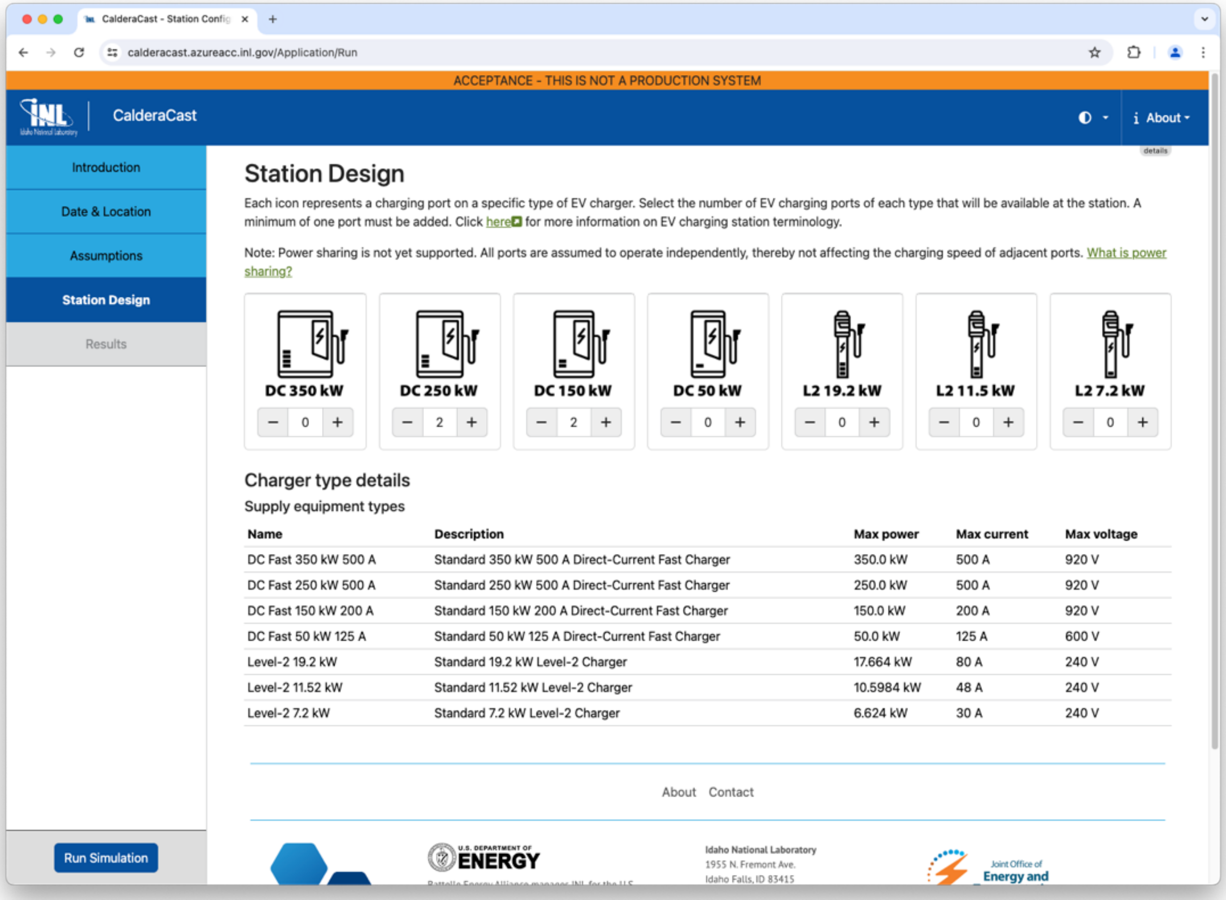
Seed

-1

Value must be between 0 and 999999999

What is a random number generator?

Input Assumptions include: EV adoption rate, Types of EVs on the road, Charging station demand distribution, and seed control for the stochastic algorithm (for reproducible results).


CalderaCast - Station Config ×

calderacast.azureacc.inl.gov/Application/Run

ACCEPTANCE - THIS IS NOT A PRODUCTION SYSTEM

INL CalderaCast i About

Introduction
Date & Location
Assumptions
Station Design
Results

Station Design

Each icon represents a charging port on a specific type of EV charger. Select the number of EV charging ports of each type that will be available at the station. A minimum of one port must be added. Click here for more information on EV charging station terminology.

Note: Power sharing is not yet supported. All ports are assumed to operate independently, thereby not affecting the charging speed of adjacent ports. What is power sharing?

DC 350 kW	DC 250 kW	DC 150 kW	DC 50 kW	L2 19.2 kW	L2 11.5 kW	L2 7.2 kW
− 0 +	− 2 +	− 2 +	− 0 +	− 0 +	− 0 +	− 0 +

Charger type details

Supply equipment types

Name	Description	Max power	Max current	Max voltage
DC Fast 350 kW 500 A	Standard 350 kW 500 A Direct-Current Fast Charger	350.0 kW	500 A	920 V
DC Fast 250 kW 500 A	Standard 250 kW 500 A Direct-Current Fast Charger	250.0 kW	500 A	920 V
DC Fast 150 kW 200 A	Standard 150 kW 200 A Direct-Current Fast Charger	150.0 kW	200 A	920 V
DC Fast 50 kW 125 A	Standard 50 kW 125 A Direct-Current Fast Charger	50.0 kW	125 A	600 V
Level-2 19.2 kW	Standard 19.2 kW Level-2 Charger	17.664 kW	80 A	240 V
Level-2 11.52 kW	Standard 11.52 kW Level-2 Charger	10.5984 kW	48 A	240 V
Level-2 7.2 kW	Standard 7.2 kW Level-2 Charger	6.624 kW	30 A	240 V

About Contact

Run Simulation

U.S. DEPARTMENT OF ENERGY

Idaho National Laboratory
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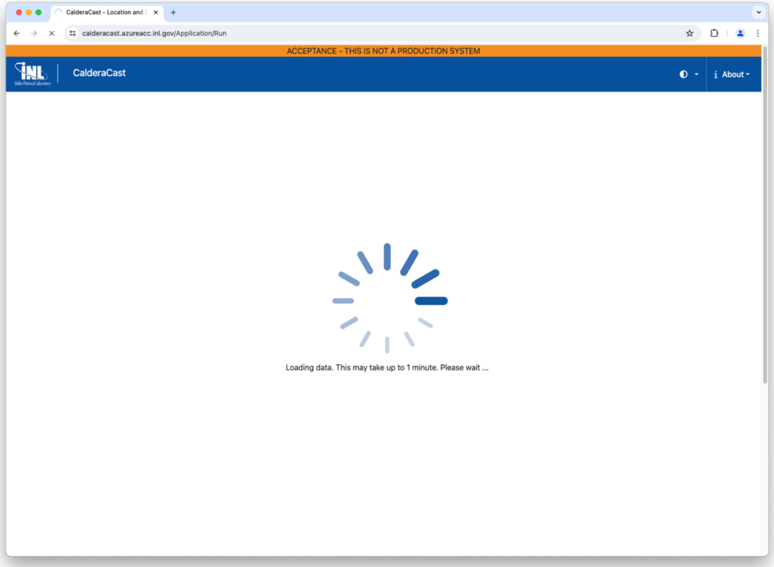
Idaho Falls, ID 83415

Joint Office of Energy and

Step Three allows the user to input the design of their proposed station include quantity and type of Electric Vehicle Supply Equipment (EVSE). In addition to fast chargers which meet CFR 680 for corridors, the tool includes 50kW and L2 style chargers which may be present at the station for increased accuracy.

Technical Accomplishments (cont.)

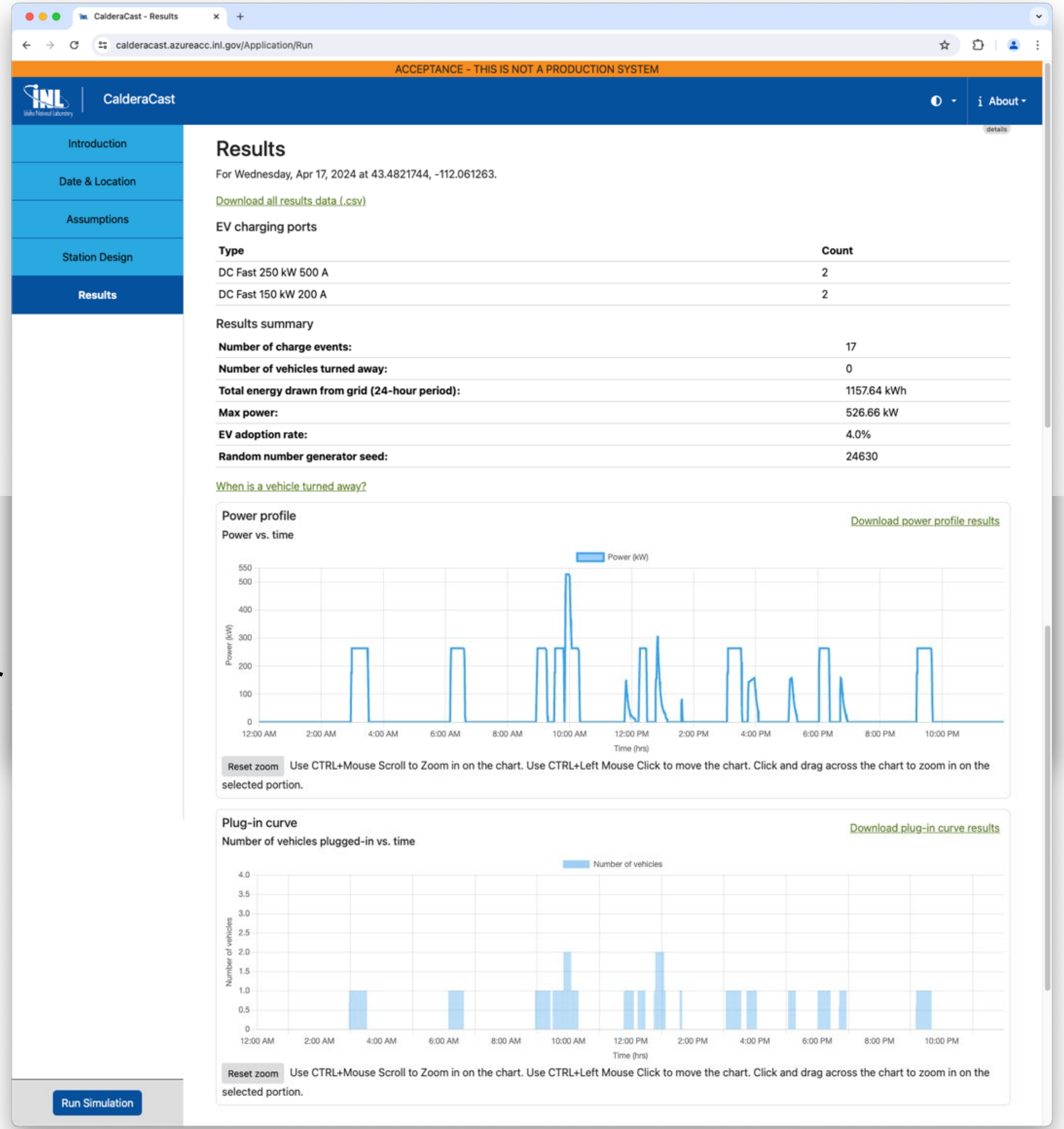
Website Development



CalderaCast consists of 3 modules: the Web Interface, EV Geo, and CalderaSim. Each can take time to process and communicate with the next, resulting in less than 60 seconds of wait time.

Results are presented in the final step in the form of a Power Profile for the station, a plot of how many EVs are connected over time, and several statistics including: Number of charge events, Number turned away, Total energy, Maximum power, and documentation of the inputs.

The plots and a full set of data may be downloaded for users own documentation.



Collaboration and Coordination

- INL partnered with the Pacific Northwest National Laboratory (PNNL) for stakeholder outreach in the needs assessment phase of both projects.
- We obtained user feedback through several “Beta Sessions” with seven likely users of the tool and worked to incorporate their suggestions into the final tool.
- Once the website is released publicly we will reengage those and other stakeholders for continual feedback and improvement.
- We also intend to collaborate further with PNNL, and other labs providing technical assistance to the JOET, to enable our complimentary tools to directly inform and benefit each other.

“Any proposed future work is subject to change based on funding levels.”

Remaining Challenges and Barriers

- INL and DOE are serious about cybersecurity and a proper review and release process. CalderaCast is in some respects a new type of product for this research institution and it is the first webtool of this type submitted for review under "Zero Trust" protocols.
- As of early May, the cybersecurity approval was still a work in progress requiring new solutions to ensure all three modules of CalderaCast operate and communicate with high security. The site is expected to launch before this presentation but is not assured.
- Providing forecast coverage for Puerto Rico is also a work in progress as the same traffic and station data is not available.

Proposed Future Research

- CalderaCast could be improved to include increasingly common station controls:
  - Power sharing between ports
  - Onsite energy storage
  - Onsite energy generation
- Assessing and including the impacts of other charging stations in proximity would improve forecasts.
- Continually increasing the volume of recent data on: station usage, traffic volume, new EV types, and EVSE capabilities - will improve performance.
- Adding coverage outside of AFCs would increase usage by more stakeholders including the Charging and Fueling Infrastructure (CFI) program.

“Any proposed future work is subject to change based on funding levels.”

CalderaCast Summary

- CalderaCast is a public webtool intended to assist NEVI stakeholders in forecasting load at proposed corridor charging stations.
- CalderaCast has built in the necessary input data to conduct stochastic estimates for nearly all possible locations of NEVI funded stations.
- Basic users only need to know the location and charging equipment at the proposed site to produce a forecast.
- Advanced users may alter assumptions and further customize their simulation.
- The tool is useful to many diverse stakeholders:
  - Funding agencies – to obtain an independent estimate of usage and cost
  - Utilities – to estimate the size and shape of unique electrical load for interconnection
  - Station operators – to forecast revenue and costs of their business plan, and evaluate multiple locations for best performance

Questions?

Idaho National Laboratory

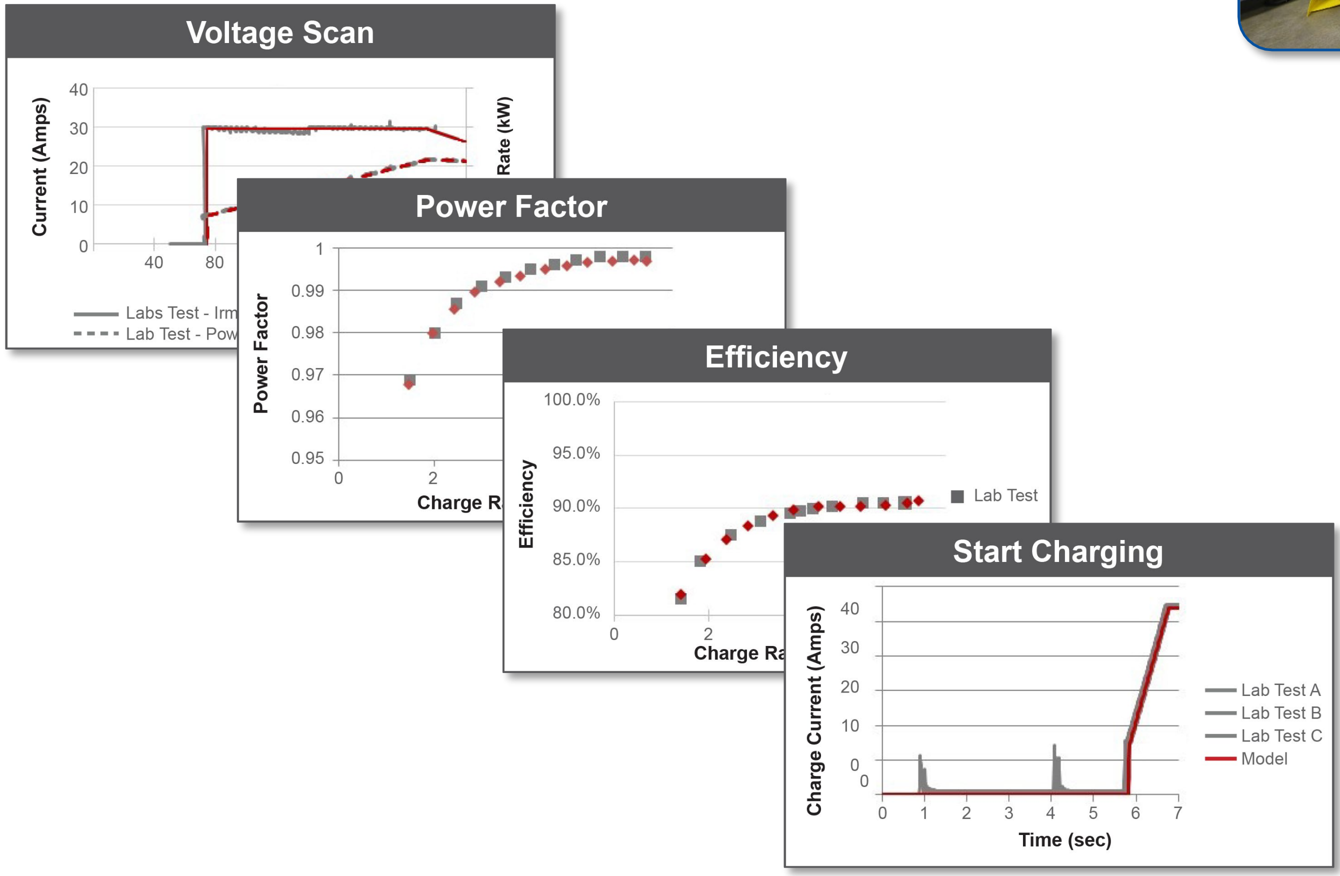
Timothy.Pennington@inl.gov

https://cet.inl.gov/caldera

Technical Backup Slides

High Fidelity EV / EVSE Charging Model library

- 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.

Perform EV stations analytics – Exploratory analysis of EV WATTS data

Correlation Modeling

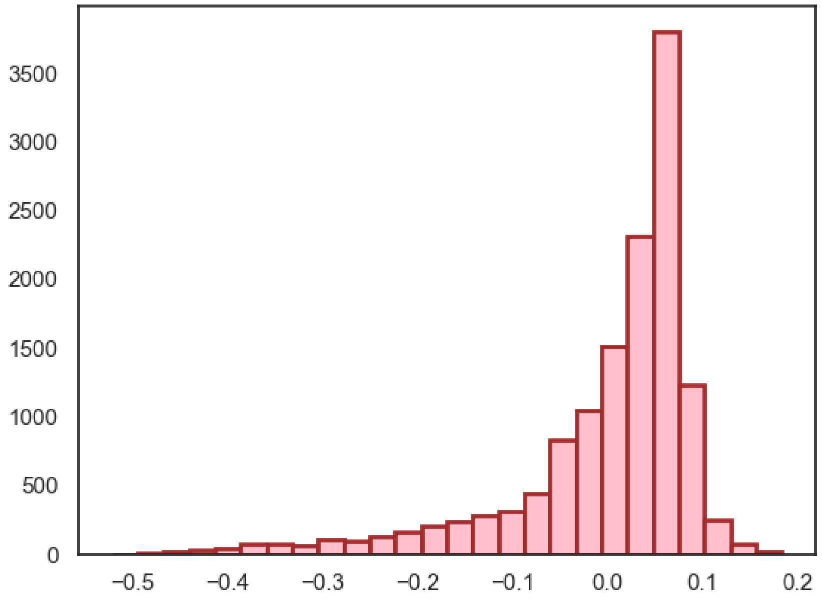
Variables

- Traffic volume
- Population
- Location

Model

Regression ML modeling

Prediction accuracy

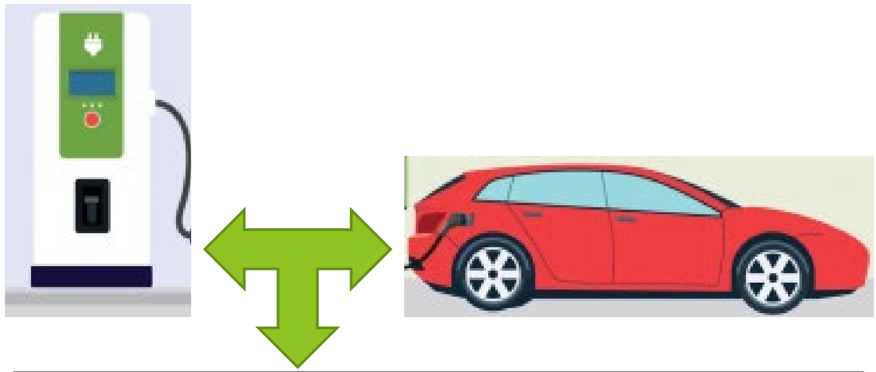


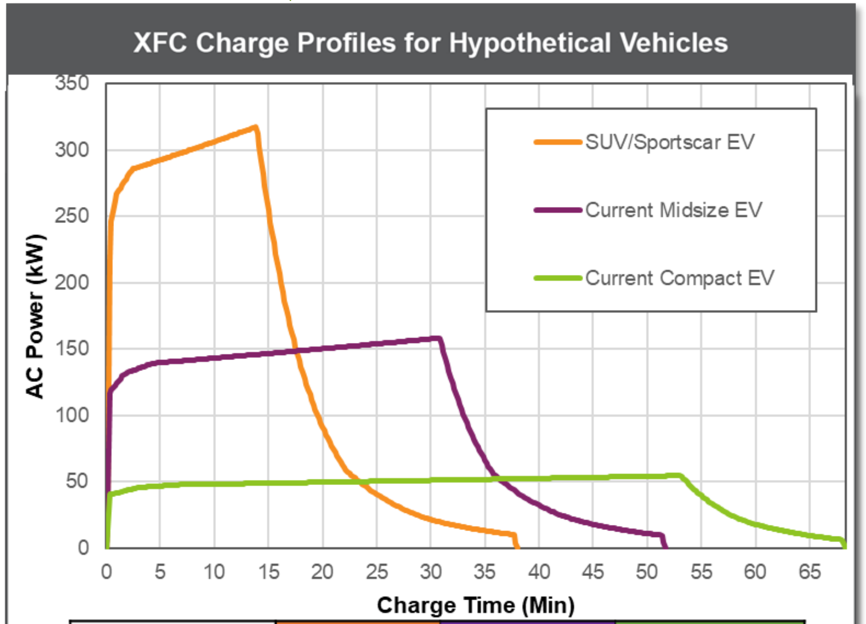
Unique Charge Profiles

- Caldera generates load profiles based on the specific vehicle and specific charger that are paired.
- For CalderaCast only models that meet NEVI minimum requirements will be used.
- Vehicle types and quantities are shown in table below.
- New charger models are being added to Caldera Library to be completed by end of April.

	Vehicle Type	EV Range (mi)	Charge Power (kW)	Driving Efficiency (Wh/mi)	Adoption Med High	2.6% 4.8%	5.4% 13.2%	9.5% 26.1%	14.7% 38.9%
	BEV				2020[2]	2025	2030	2035	2040
XFC Gen3	Sports Car	250	400	350				1%	1%
XFC Gen3	SUV/Truck	300	575	475				6%	8%
XFC Gen3	Midsize Car	300	400	325				4%	15%
XFC Gen2	SUV/Truck	250	350	475			7%	11%	10%
XFC Gen2	Midsize Car	300	300	325			4%	12%	16%
XFC Gen2	Compact Car	150	150	300			5%	6%	10%
XFC Gen1	Sports Car	250	300	350		1%	1%	1%	0%
XFC Gen1	SUV/Truck	200	150	475	7%	25%	24%	13%	9%
XFC Gen1	Midsize Car	275	150	300	32%	27%	23%	19%	10%
DCFC	Compact Car	250	75	300	4%	6%	4%	2%	
DCFC	Compact Car	150	50	300	18%	13%	7%	3%	
	PHEV				2020	2025	2030	2035	2040
AC Only	SUV/Truck	50	Do not fast charge	475	5%	8%	11%	13%	16%
AC Only	Midsize Car	50	Do not fast charge	310	14%	13%	9%	8%	5%
AC Only	Midsize Car	20	Do not fast charge	250	20%	7%	5%	2%	

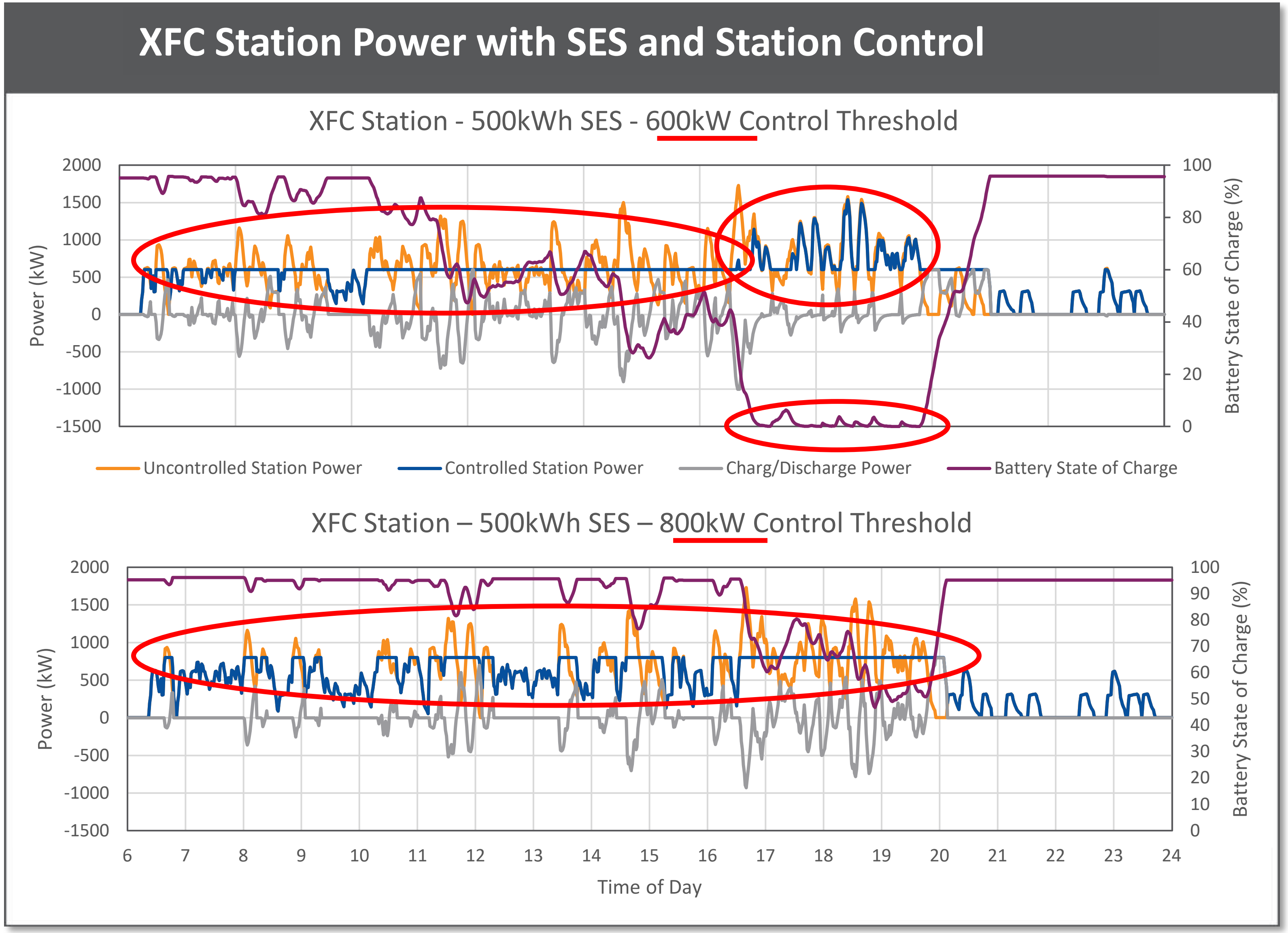
[2] E-drive: https://www.anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates





	SUV/ Sportscar EV	Current Midsize EV	Current Compact EV
Max Charge Rate (kW)	300	150	50
Vehicle Range (Miles)	250	275	150
Vehicle Resembles	Porsche Taycan	Tesla Model 3	Nissan Leaf

Simulating XFC with Energy Storage and Station Control



Results from Caldera in DirectXFC DOE Project

Battery Energy Storage System:

- 500kWh battery costs ~$500k
- Reduces 1730kW peak to 725kW
- If demand charge were $15/kW BESS saves $15,000/month
- BESS payback period = 33months

Caldera can help design and simulate other EV charging power controls.

Stakeholder Comments from “Beta Sessions”

J.H. - State Agency
"Thank you. This has been great.
Actually, this is awesome.
So thanks for taking some time to talk to this."

M.B. – State Environmental Agency
"Thank you for the presentation, this looks like a great tool."

D.F. – State Transportation Department
"This is fascinating, thank you."

C.D. - Engineering Contractor
“I will say I think this is amazing and I see a lot of value in what we're doing in NEVI planning, but also like as we get further and further down the line towards looking at where is their power and what is the power need.
And like working with our utility partners, I think this is a great tool that is not available today.
So appreciate all the work that you guys have done. I think there's a lot of value in it.
Yeah, I would like to just stop all our NEVI planning until you guys are done with these two tools."

A.W. - Public Engagement Contractor
"And I think that's a great idea, having some sort of user interface system that can help adjust and right size, capacity and demand.“

H.D. – State Working Group - Executing NEVI
This was all very informative. I appreciate the level of thought that's coming into this.
For planning purposes and for selection purposes this could be useful. I also really think it could be great for the utilities. We’ll be excited to get them involved with it.
It would be handy in six months time to have this in our back pocket when we start to look at the next round.