EVs@Scale

U.S. Department of Energy

EVs@Scale Deep Dive - SCM/VGI

Day 1: SCM/VGI Analysis

September 28, 2022

U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

NREL/PR-5400-84273

EVs@Scale SCM/VGI Deep Dive - Day 1 Agenda

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11:00 a.m. – 11:15 a.m. ET **Welcome/Introductions, FUSE Overview**
Andrew Meintz, Jesse Bennett

11:15 a.m. – 12:15 p.m. ET **Session 1: Vehicle Charging and SCM/VGI**
Zhaocai Liu, Brennan Borlaug, Mingzhi Zhang, Christian Birk Jones

12:20 p.m. – 1:20 p.m. ET **Session 2: Grid Modeling and Impact Analysis**
Shibani Ghosh, Nadia Panossian, Tim Pennington, Manoj Sundarrajan

1:20 p.m. – 2:00 p.m. ET **Wrap-up Discussion and Feedback Gathering**
All Attendees

EVs@Scale SCM/VGI Deep Dive

11:00 a.m. – 11:05 a.m. ET	**Opening Remarks**
	Lee Slezak
11:05 a.m. – 11:10 a.m. ET	**Overview of Deep Dive**
	Andrew Meintz
11:10 a.m. – 11:15 a.m. ET	**SCM/VGI Pillar Challenges and Opportunities**
	Jesse Bennett

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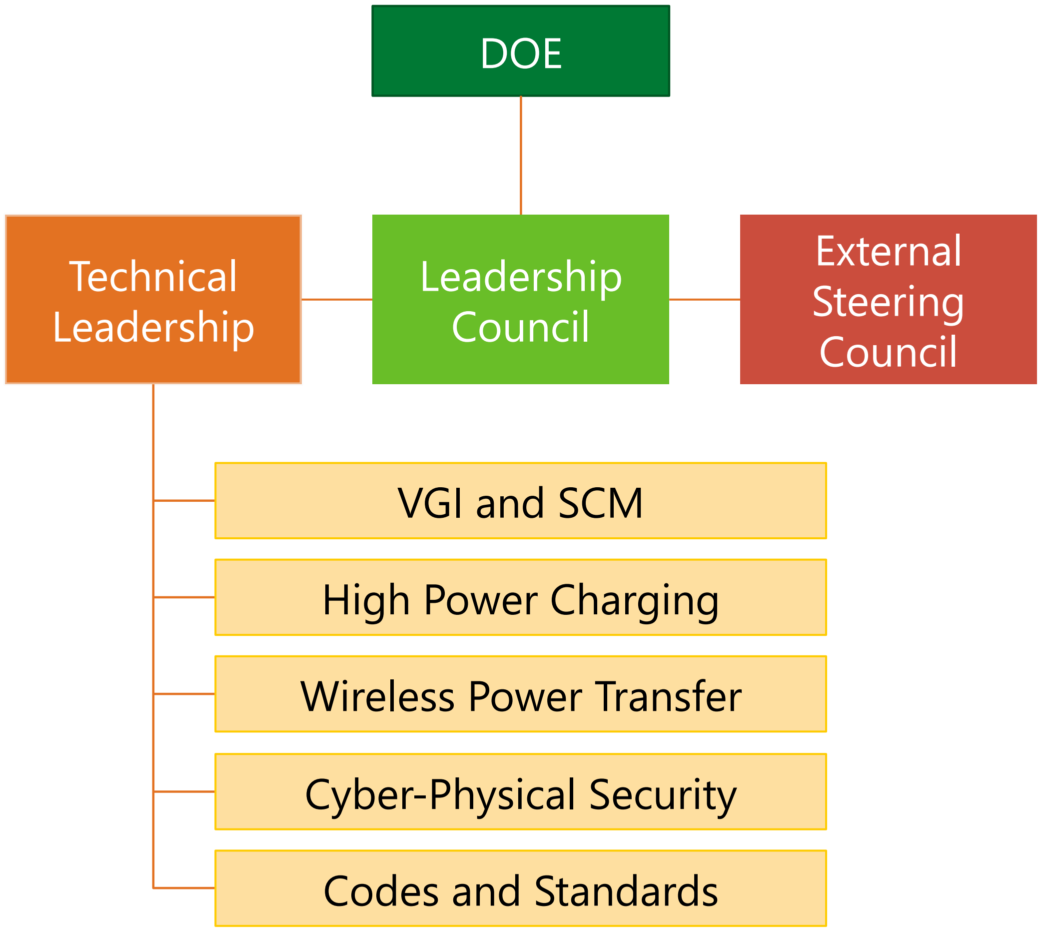
Opening Remarks

Andrew Meintz

Lee Slezak

Consortium Structure

- Leadership Council
  - Andrew Meintz (NREL, chair), Keith Hardy (ANL, rotating co-chair), David Smith (ORNL), Summer Ferreira (SNL), Rick Pratt (PNNL), Tim Pennington (INL)
- External Steering Council
  - 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)
  - Wireless Power Transfer (WPT): Veda Galigekere (ORNL)
  - Cyber-Physical Security (CPS): Richard "Barney" Carlson (INL), Jay Johnson (SNL)
  - Codes and Standards (CS): Ted Bohn (ANL)



EVs@Scale Lab Consortium Stakeholder Engagement and Outreach

BIANNUAL STAKEHOLDER MEETING

- Open Virtual Forum
- High Level Information Exchange
- Common Understanding / Direction
- Comprehensive Situational Awareness
- Long / Short Term Plans
- Long / Short Term R&D Results
- RFI and Stakeholder Feedback
- FOA Information
- Visibility

DEEP DIVE TECHNICAL MEETINGS

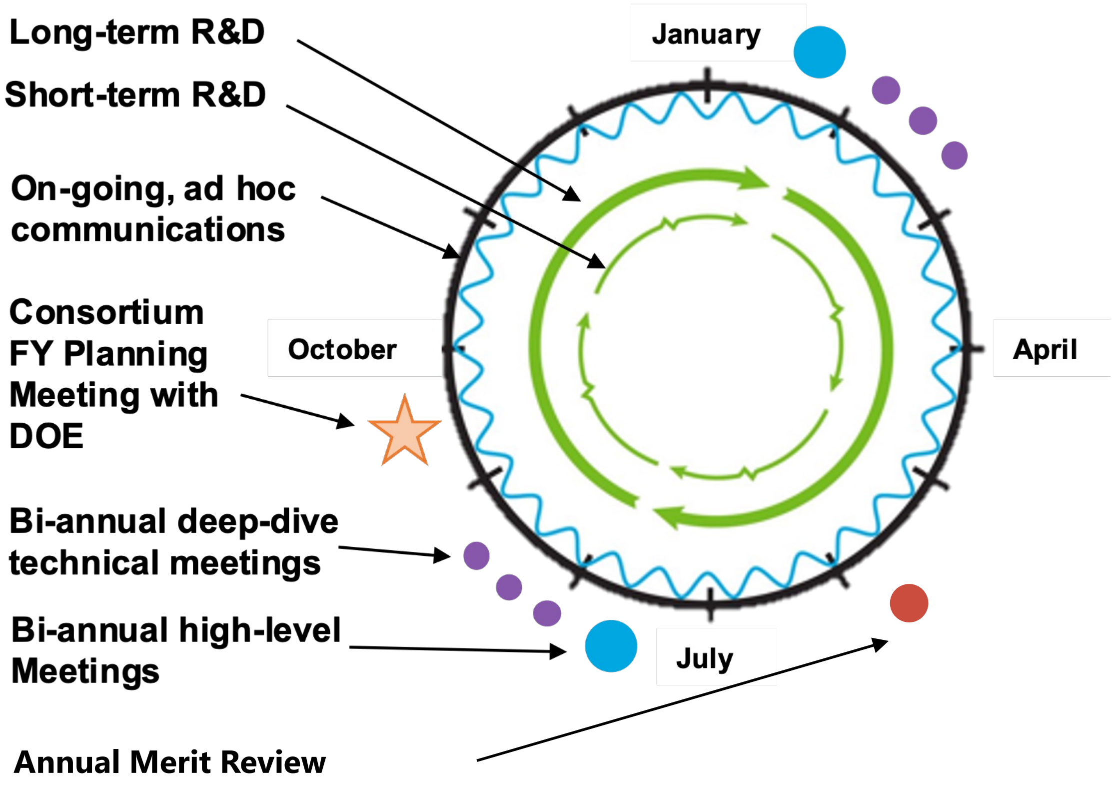
- Detailed Technical Discussions
- Project Plans and Progress
- Stakeholder Feedback
- R&D Agility
- Active Pool of Project Stakeholders
- Short Inception IABs
- Support for RFI Process
- Tech Transfer

DEDICATED ENGAGEMENT WEBSITE

- Continuous Stakeholder Engagement
- Ease of Information Exchange
- Formal and Informal Communications
- Project Updates and Review
- Enable Project Participation
- Record of Information
- Meeting Logistics

Collaboration and Coordination

- **Consortium Laboratories**
  - ANL, INL, NREL, ORNL, PNNL, SNL
- **External Steering Committee**
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
- **Direct interaction for each pillar projects**
  - Utilities, EVSE & Vehicle OEMs, CNOs, SDOs, Gov't, Infrastructure
  - Webinars / Project discussions
- **Bi-annual high-level meetings**
  - Rotation among labs with discussion on all pillars
- **Bi-annual deep-dive technical meetings**
  - VGI/SCM, HPC & WPT, and CPS with C&S incorporated into all meetings



Importance of the Deep Dives

These deep-dives are open to industry experts to help us better shape the R&D efforts for EVs@Scale.

We need your input to identify:

- Partners for our R&D efforts to help with insight, data, and other resources.
- Progress in our activities to ensure timely research is available to key stakeholders
- Priorities for R&D that accelerates the transition to EVs at Scale.

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Flexible charging to Unify the grid and transportation Sectors for EVs at scale (FUSE)

Jesse Bennett, NREL

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

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:

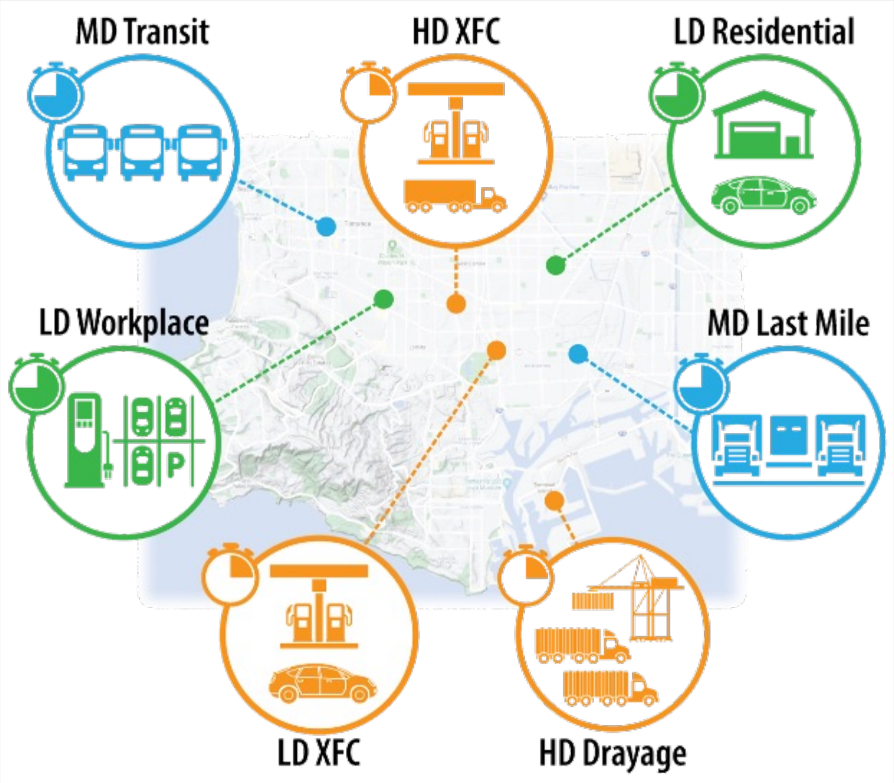
- **Electric Distribution Utilities**
  - Dominion Energy (100+ distribution feeder models throughout VA)
- **Vehicle Travel Data**
  - Wejo (~400 million trips throughout VA for Sept. ‘21 and Feb. ’22)

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.



Session 1 - Vehicle Charging Needs and SCM/VGI Controls

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11:15 a.m. – 11:45 a.m. ET **Vehicle Energy Needs**

Presentation (20 min) *Zhaocai Liu, Brennan Borlaug*

Q&A (10 min)

11:45 a.m. – 12:15 p.m. ET **SCM/VGI Development**

Presentation (20 min) *Mingzhi Zhang, Christian Birk Jones*

Q&A (10 min)

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EVs@Scale Deep Dive - SCM/VGI

Day 1: Vehicle Energy Needs

Brennan Borlaug (NREL),
Zhaocai Liu (NREL)

September 28, 2022

Year 1 Objective – Passenger EVs:

- Passenger EV charging demands are simulated for aggressive 2040 electrification scenario to understand the **energy requirements** and **smart charge management** opportunities for EVs@Scale.
- Extend previous models/approaches for synthesizing spatially resolved passenger **EV travel and charging data** to new regions (Virginia) and higher adoption levels (>50% EV penetration).

1. Trip Data Acquisition & Preprocessing

Representative LDV travel data for region(s) of study is joined with geographically determined locational characteristics obtained from multiple data sources.

2. EV Adoption Modeling

For a given analysis year (2040), assign PEVs to households by vehicle model (battery size, ECR, & max kW acceptance required for simulation).

3. Travel Itinerary Synthesis

Vehicle trips from data aggregators typically do not contain persistent vehicle identifiers enabling analysis of multi-trip travel itineraries. Thus, an approach for generating synthetic travel itineraries is leveraged.

4. EV Charging Demand Simulation

EV charging is simulated for synthetic travel itineraries considering: 1) EV adoption assumptions; 2) charging behaviors and location-specific EVSE availability; 3) home charging access assumptions.

5. EV Load Profile Generation

Charging demand for a given analysis year (2040) is assigned to specific locations (i.e., land parcels) by location type.

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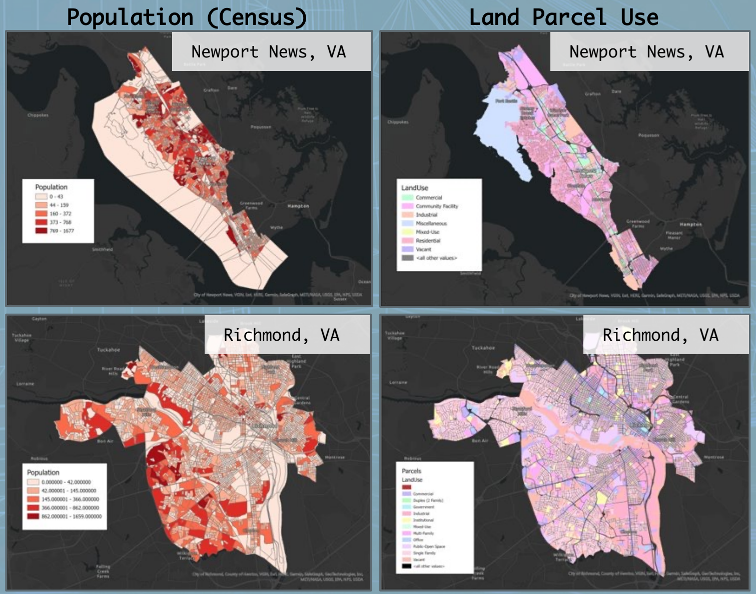
Real-World Driving Data Set:

- ❑ Vehicle trips data acquired from Wejo for two months in the state of Virginia.
  - ❖ ~3% of passenger vehicle population
  - ❖ September 2021 and February 2022
  - ❖ **Richmond, VA** and **Newport News, VA** regions selected for detailed grid modeling.
- ❑ Trip O/Ds joined to land use data to infer trip purpose.

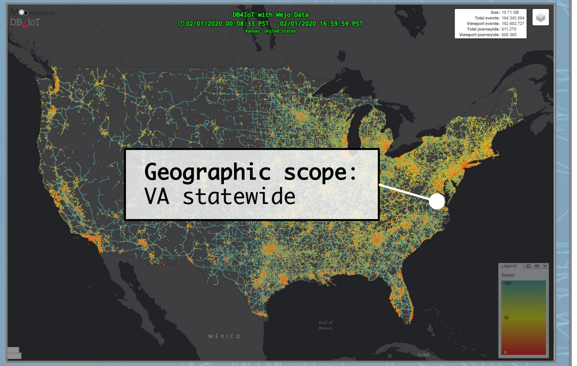
wejo

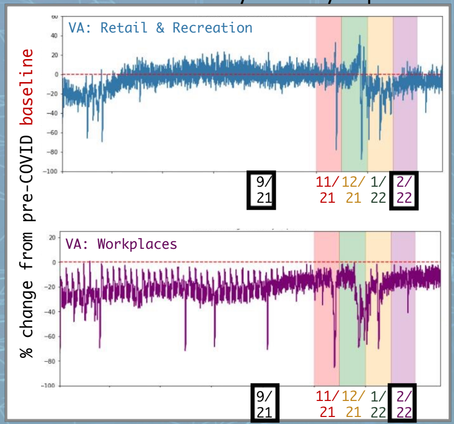
Regional Trip Data Summaries:

Region	Sep. Trips	Feb. Trips	Sep. VMT	Feb. VMT
Newport News, VA: Newport News, Hampton, York county, James City county	920k	720k	4.3M	3.3M
Richmond, VA: Richmond, Henrico county, Chesterfield county, Hanover county	1.5M	1.3M	8.9M	7.2M



Google
COVID-19 Community Mobility Reports





Temporal scope:
September 2021 (summer)
February 2022 (winter)

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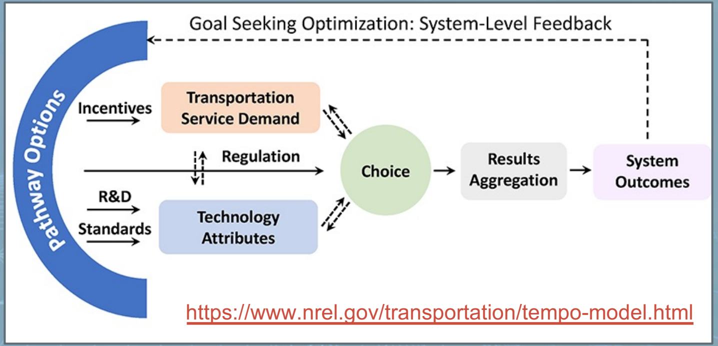
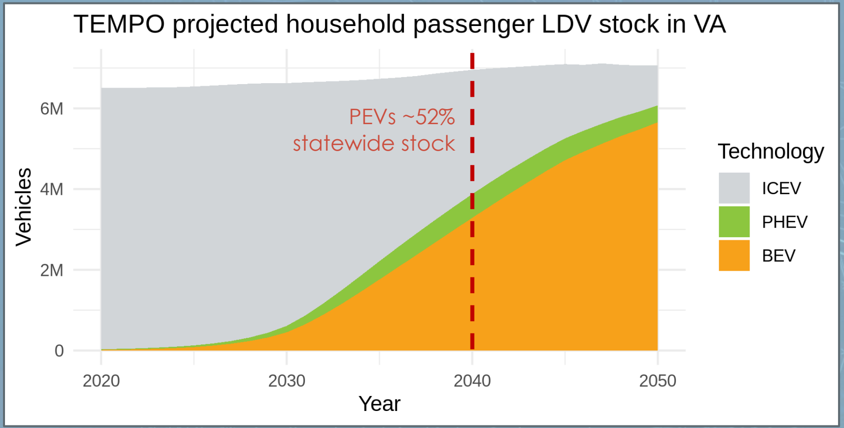
EV Adoption Modeling – NREL TEMPO Model:

TEMPO

- TEMPO is an all-inclusive transport demand model that projects **household-level vehicle ownership** and technology choices based on heterogenous consumer preferences.
- 2040 aggressive passenger EV adoption scenario assumes:
  - 50% national PEV sales by 2030
  - 100% national PEV sales by 2035
- TEMPO adoption outputs mapped to BEV/PHEV **archetype vehicles**
  - established for previous DOE projects



TEMPO Modeling Diagram



Map TEMPO PEV adoption to archetype vehicles for charging simulation

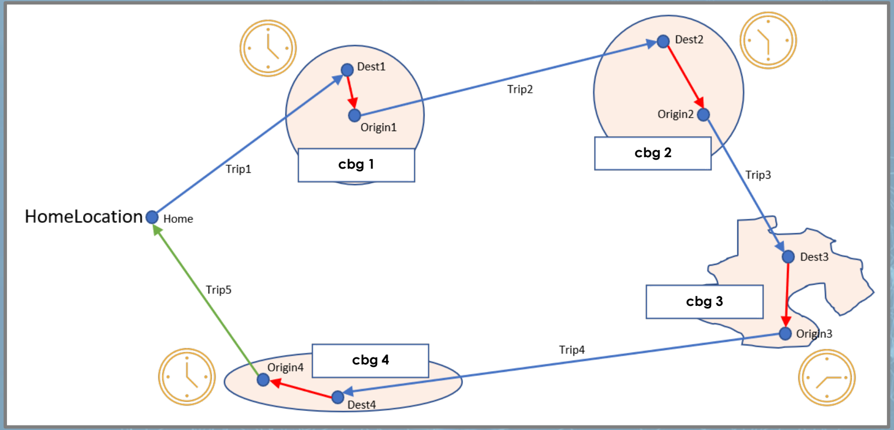
Archetype Vehicles for Simulation:

202k passenger EVs → 2040 NN fleet share; 470k passenger EVs → 2040 Rich fleet share

Veh. Gen.	Vehicle Type	EV Range (mi.)	ECR (Wh/mi.)	DC Charge Accept. (kW)	2040 NN fleet share (%)	2040 Rich fleet share (%)
Gen 3	BEV SUV/truck	300	475	575	37.5%	39.5%
	BEV midsize car	300	325	400	7.8%	6.3%
Gen 2	BEV SUV/truck	250	475	350	10.8%	13.5%
	BEV midsize car	300	325	300	3.5%	3.7%
	BEV compact car	150	300	150	19.7%	17.8%
Gen 1	BEV SUV/truck	200	475	150	1.3%	2.2%
	BEV midsize car	275	300	150	0.6%	0.7%
	PHEV SUV/truck	50	475	N/A	10.8%	9.7%
	PHEV midsize car	50	310	N/A	3.2%	2.4%
Gen 0	BEV compact car	150	300	50	0.5%	0.8%
	PHEV midsize car	20	250	N/A	4.3%	3.2%

Synthetic Vehicle Travel Itineraries:

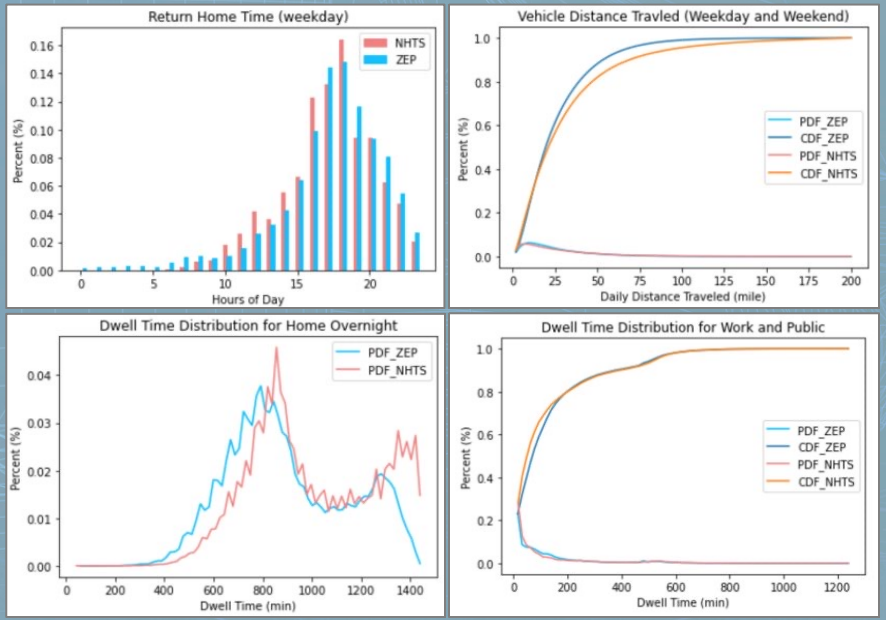
- Wejo travel data contained unlinked trips with no persistent vehicle identifier, thus a procedure for generating synthetic travel itineraries (through **trip chaining**) was leveraged.
- Locational dwell distributions (from 2017 NHTS) are used to infer vehicle dwells at each stop. Trips are chained based on **spatiotemporal alignment** of trip origins and destinations (+ dwell).
- Synthetic vehicle travel itineraries are validated against 2017 NHTS vehicle trip distributions.



Example trip chain

Validation plots:

ZEP = synth veh itineraries
NHTS = ground truth



EV Charging Simulation – NREL EVI-Pro Model:

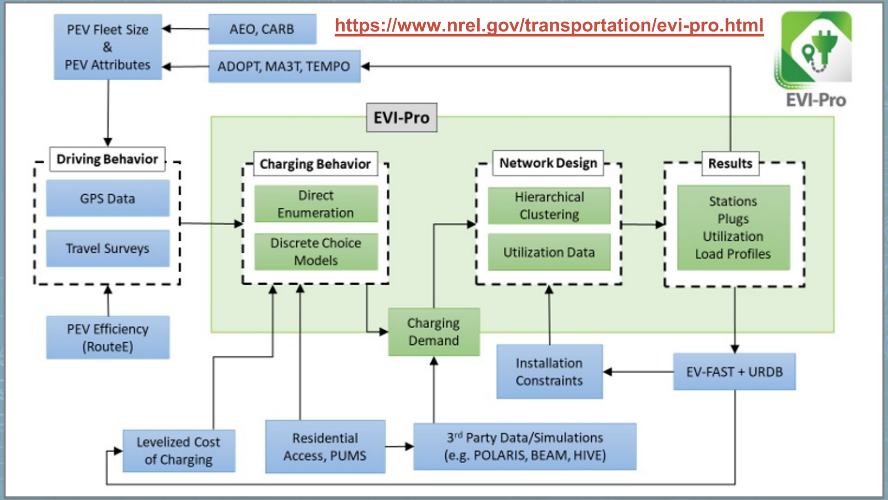
- EVI-Pro takes EV adoption and travel demand data and simulates **EV charging behaviors, energy demands, and infrastructure requirements**.
- For this study, EV drivers are assumed to **prioritize home charging**, followed by workplace and public slow charging (increased opportunities for SCM and presumably lower charging costs).
- Home charging access is derived from previous modeling, **72%** for both Newport News and Richmond regions in 2040 scenario.
- 1-week charging demands are produced for September and February in both regions of study.

EVI-Pro

EVI-Pro ordered charge preference:

Home > Work > Public L2 > Public DCFC

*drivers prefer to destination charge during long dwell periods, **maximizing opportunities for SCM**...*



EVI-Pro Modeling Diagram

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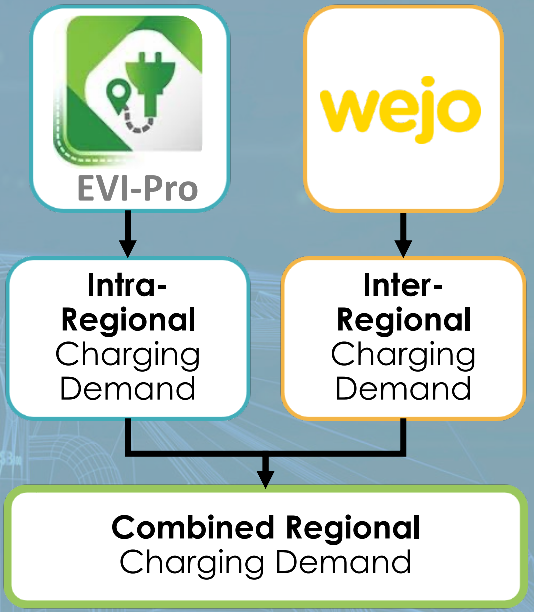
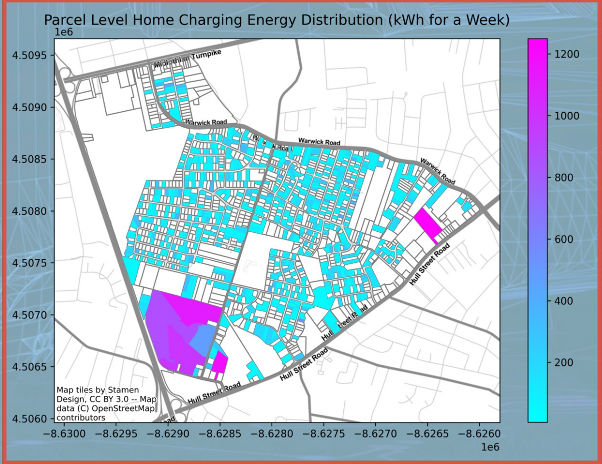
EV Load Profiles:

- EV charging demand is combined from two sources:
  - **Intra-regional charging demand** is determined from EVI-Pro simulations
  - **Inter-regional charging demand** is determined by separately simulating charging for long-distance trips (>100-mi.) that end within the region of interest.
- EV charging events are assigned spatial coordinates depending on their location type:
  - **Home charging locations** = EV adoption projections + residential land use data.
  - **Workplace charging locations** = census tract of charging demand + commercial land use data.
  - **Public charging locations** = census tract of charging demand + commercial land use data.
- EV charging events can be assigned to **individual stations** depending on EVSE type(s), station size, and port utilization assumptions.





Vehicle Energy Needs

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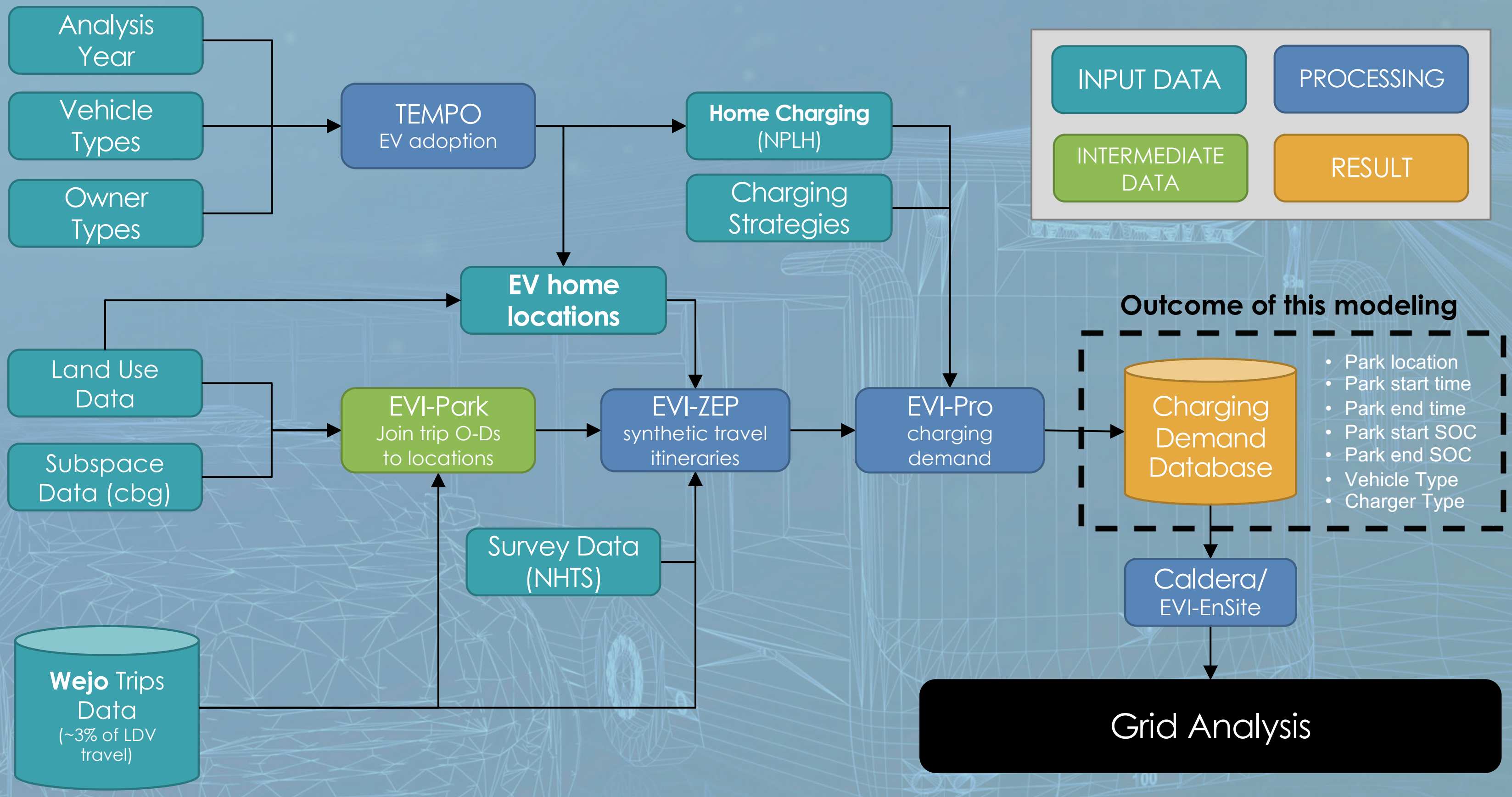
Complete Modeling Framework:



Vehicle Energy Needs

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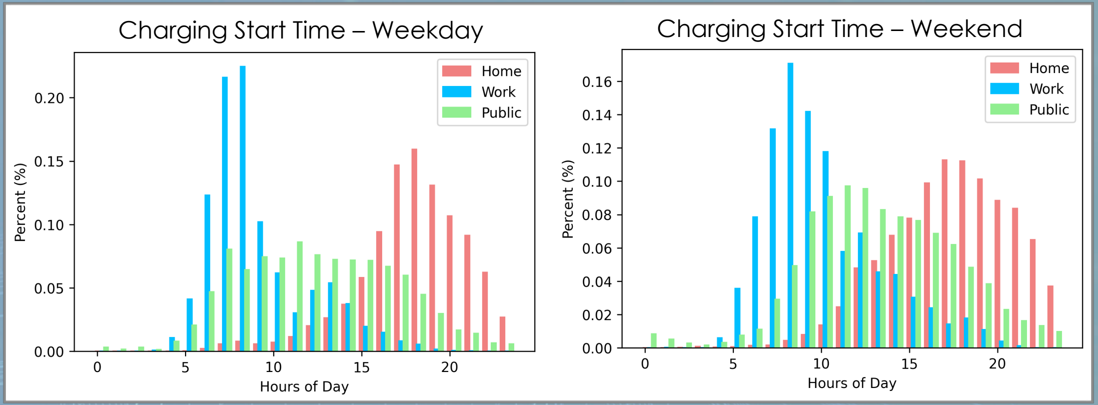
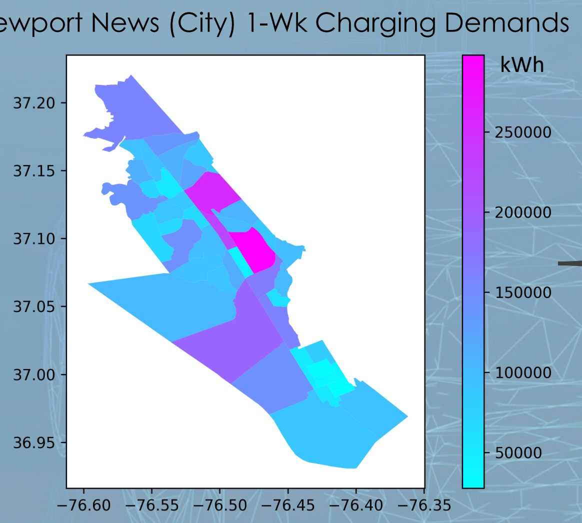
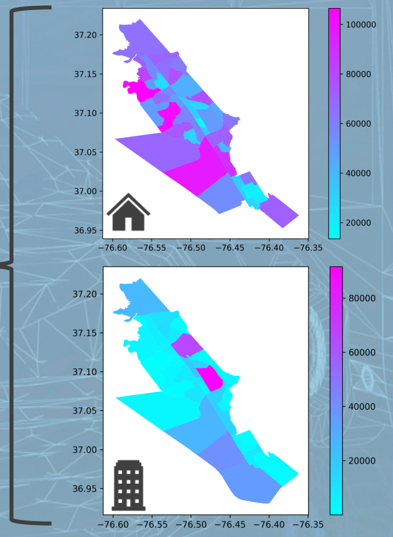
Results – Newport News, VA (Sept.):

Region	PEVs	1-wk kWh	% kWh - Location	% kWh – Flexible*
Newport News, VA: Newport News Hampton York county James City county	202,212	14,352,169	Home: 51%; Work: 9%; Public: 40%	Home: 81%; Work L2: 26%; Public L2: 13%; Public DC: 19%

**In this scenario, EVs only charge when it is required to complete travel activities (i.e., they are not plugged in to provide grid services). Home charging is preferred over work and public use cases (see slide 11). Flexible kWh were determined from charging events where <6.2 kW is required to fulfill energy demands (with 5% time buffer) for home, work L2, and public L2 and <50 kW is required to fulfill energy demands (with 5% time buffer) for public DC charging.*

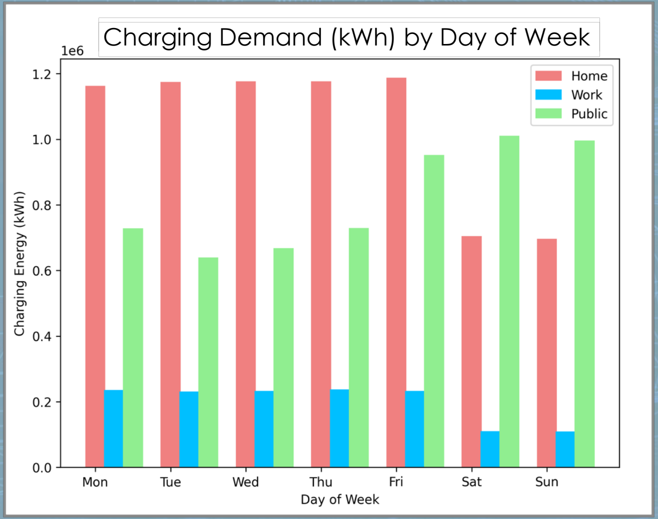






Home Charging Demands (PM peaking)

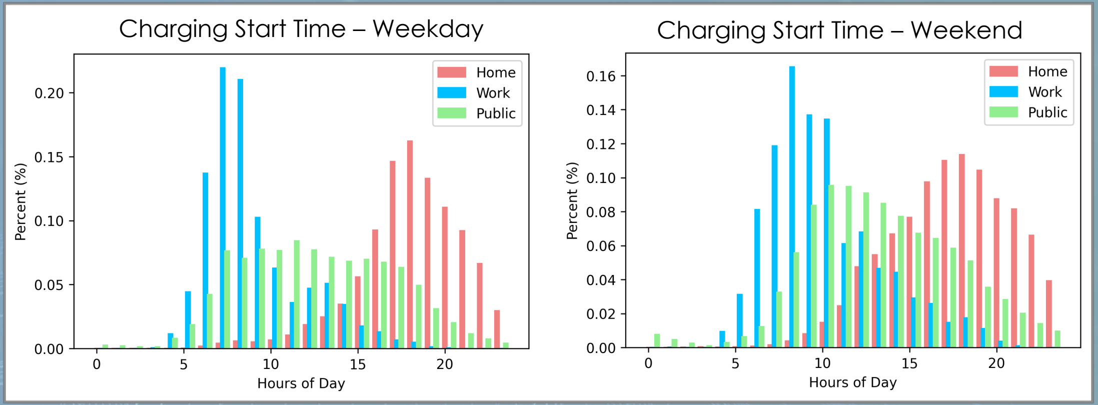
Work Charging Demands (AM peaking)

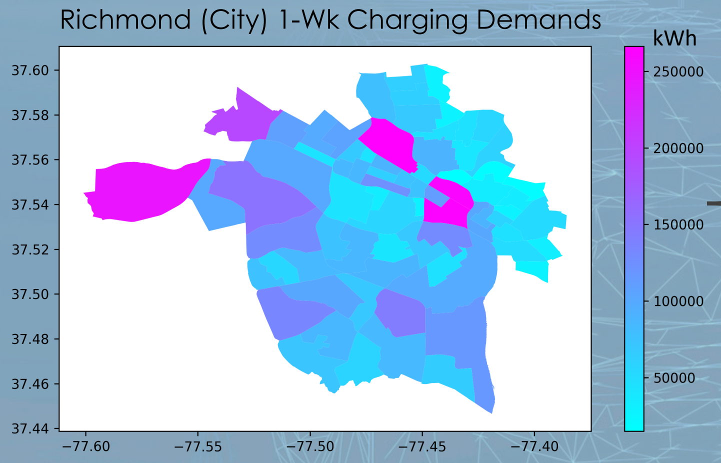


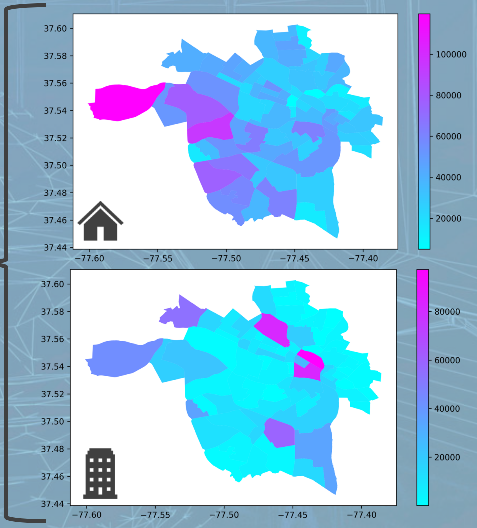
Results – Richmond, VA (Sept.):

Region	PEVs	1-wk kWh	% kWh - Location	% kWh – Flexible*
Richmond, VA: Richmond Henrico county Chesterfield county Hanover county	470,114	39,745,324	Home: 53%; Work: 9%; Public: 38%	Home: 78%; Work L2: 23%; Public L2: 12%; Public DC: 21%

**In this scenario, EVs only charge when it is required to complete travel activities (i.e., they are not plugged in to provide grid services). Home charging is preferred over work and public use cases (see slide 11). Flexible kWh were determined from charging events where <6.2 kW is required to fulfill energy demands (with 5% time buffer) for home, work L2, and public L2 and <50 kW is required to fulfill energy demands (with 5% time buffer) for public DC charging.*

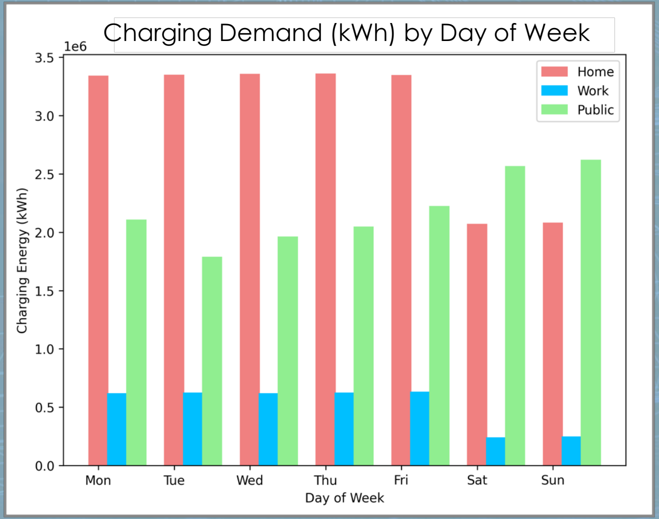






Home Charging Demands (PM peaking)

Work Charging Demands (AM peaking)



Vehicle Energy Needs

Next Steps:

- ❑ Facilitate use of passenger EV charging data sets for SCM/VGI analysis in EVs@Scale.
- ❑ Year 2 – Focus shifts to M/HD EVs, introducing several challenges:
  - ❖ Many vehicle types and **heterogenous vocational usage patterns**.
  - ❖ **Limited public or commercial data sets** capturing the full extent of M/HD operations.
  - ❖ High **uncertainty around technology adoption and timing**.
  - ❖ M/HD charging **models/approaches are less mature** than for passenger vehicles.

Recommendations are timely and appreciated!

Stakeholder Feedback

Vehicle Energy Needs Analysis

(10 minutes)

Brennan Borlaug
brennan.borlaug@nrel.gov

Zhaocai Liu
zhaocai.liu@nrel.gov

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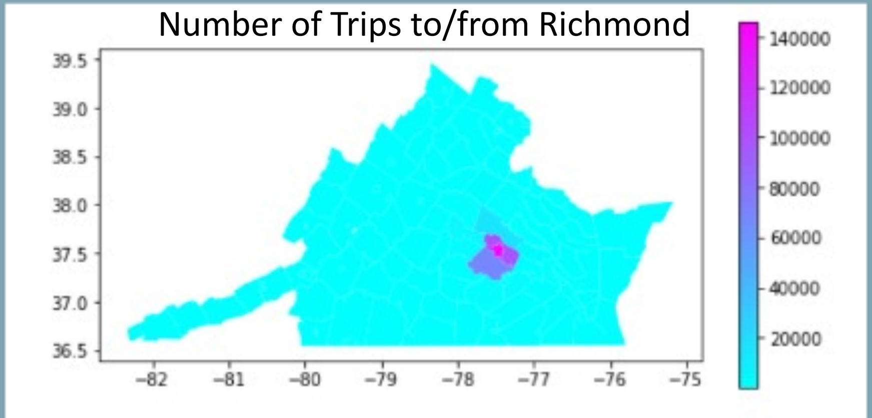
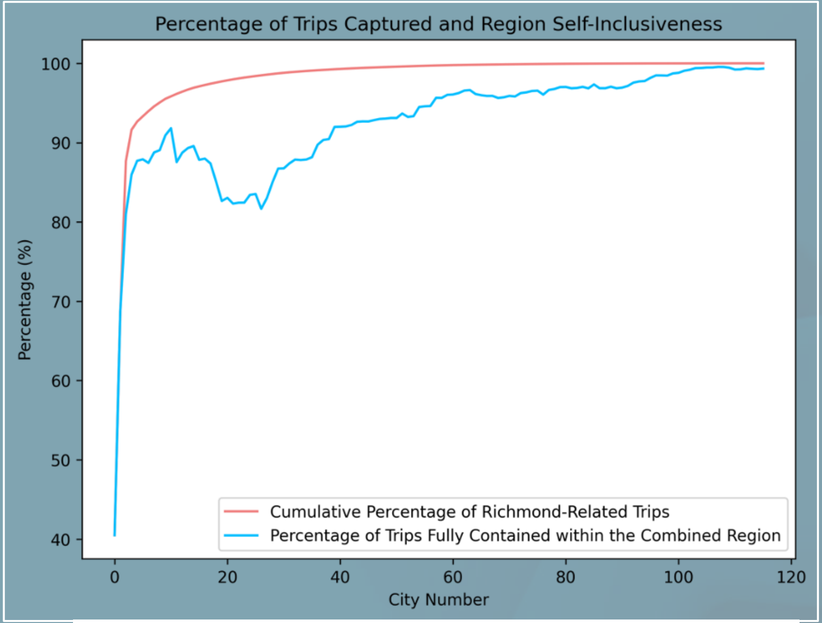
We need your input to identify:

- **Partners** for our R&D efforts to help with insight, data, and other resources.
- **Progress** in our activities to ensure timely research is available to key stakeholders
- **Priorities** for R&D that accelerates the transition to EVs at Scale.

Extra Slides: Region Selection

Key idea: only need consider cities/counties that "related to" Richmond



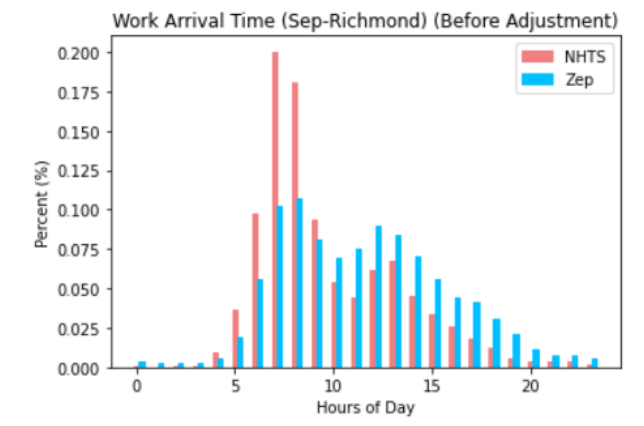


*Define **self-contained regions for simulation** based on % of travel captured in city's core county and the % of self-contained trips within the aggregated region*

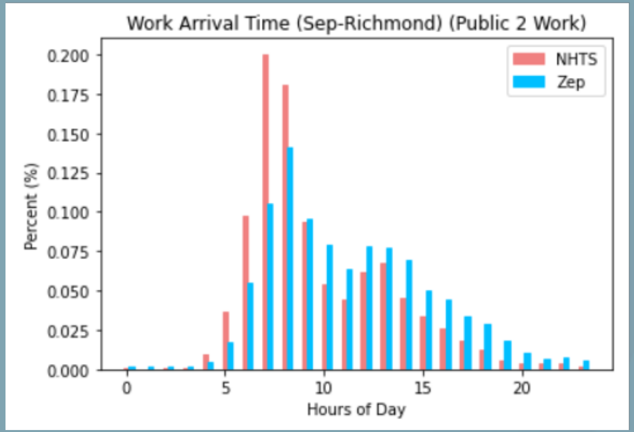
NAMELSAD	cum_percent	self inclusiveness
Richmond city	40.810081	0.40810081
Henrico County	68.472736	0.68264386
Chesterfield County	87.5951994	0.80584406
Hanover County	91.4282845	0.85328371
Goochland County	92.5436174	0.87202693
New Kent County	93.1944607	0.87201947
Powhatan County	93.7805824	0.88476212
Petersburg city	94.3485708	0.87983326

Extra Slides: Land Use Classification and Reclassification

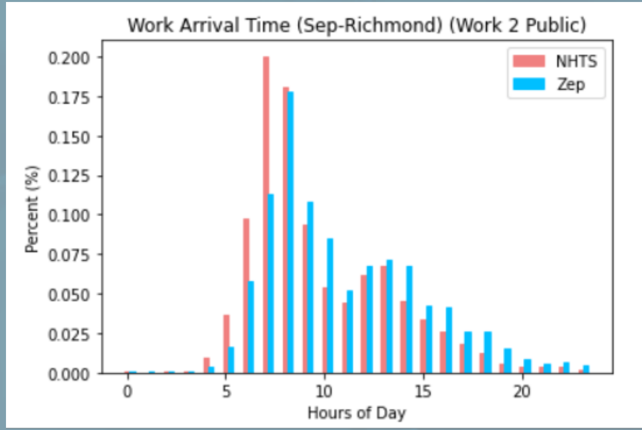
First classify land use parcels based on land use description: e.g. single family house -> residential
Then reclassify the land use based on NHTS work/public distribution



Work/Public = 21/100



Work/Public = 56/100



Work/Public = 32/100

NHTS: Work/Public = 34/100

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EVs@Scale Deep Dive - SCM/VGI

Day 1: SCM/VGI Development

Mingzhi Zhang (NREL),
Christian Birk Jones (Sandia)

September 28, 2022

SCM Market Options and Gaps

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- **SCM Availability:**
  - EVSE Vendors
    - ABB, Schneider, Siemens, Eaton, Wallbox, Enel X, ChargePoint, etc.
    - Traditional EVSE vendor has the advantage of combining hardware and software to deliver a full range of smart charging control solutions.
  - Third-party Charging Management Company:
    - ChargeLab, Ampcontrol, Driivz, VIRTA, MOEV, PowerFlex, WeaveGrid, BP Pulse (AMPLY Power), etc.
    - With the Open Charge Point Protocol (OCPP), a number of third-party startups offer cloud-based EV smart charging platforms as software as a service (SaaS).

- **SCM Gaps:**
  - Existing SCMs focus on site or household level, such as avoiding demand charges and coordinating with renewables.
  - There is a lack of interoperability between existing SCM platforms and the power system. Smart charging control is not available on a large scale with advanced functions like price-responsive smart charging, volt-var control, or V2G functionality.
  - EVs' flexibility and controllability are rarely exploited to mitigate their impacts on the power system, which is critical for EV@Scale.

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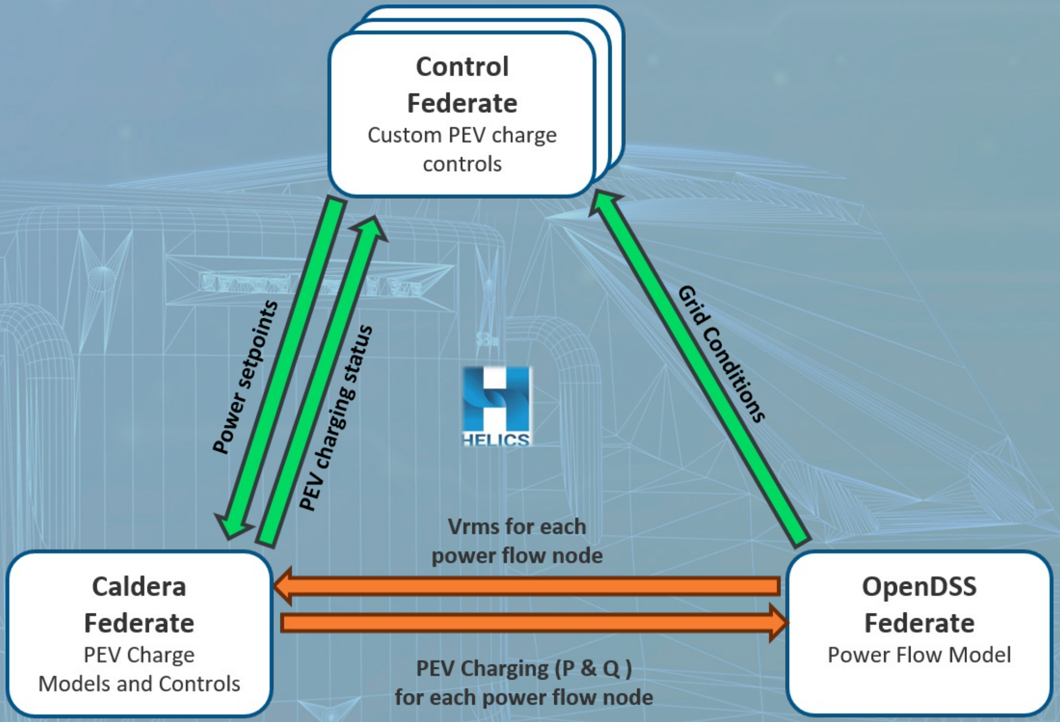
Caldera OpenDSS Co-simulation Platform

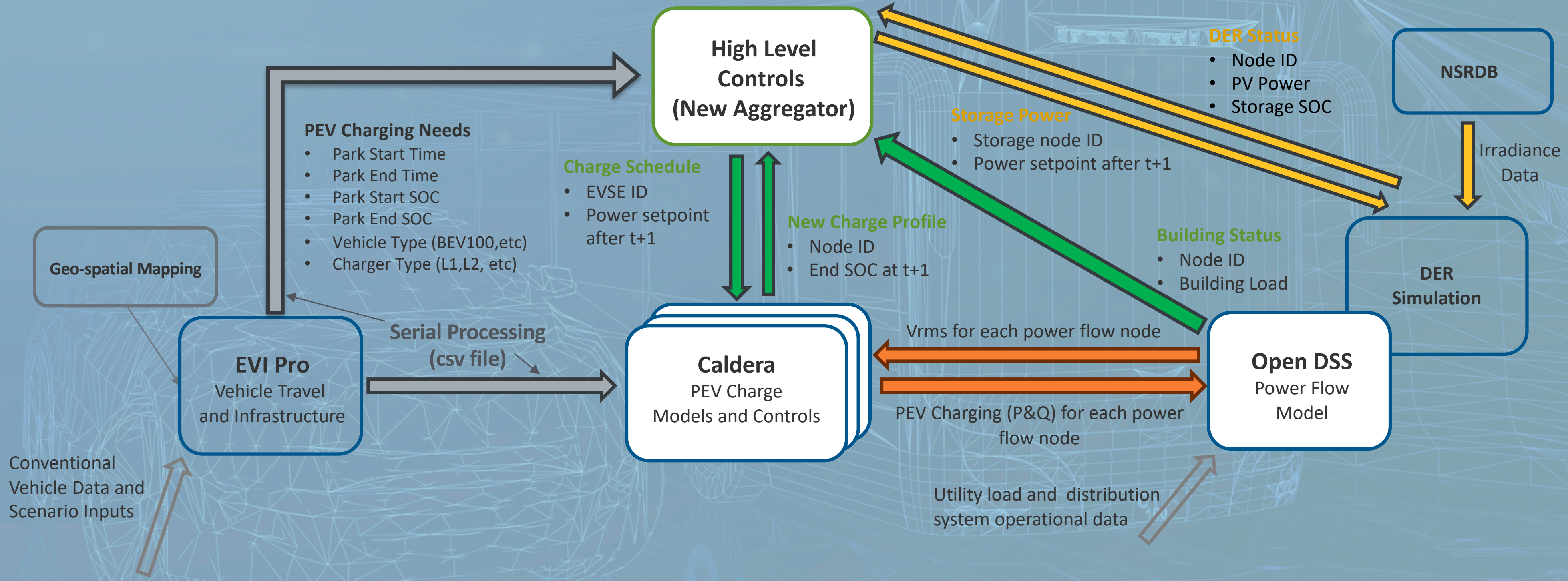
- The HELICS (Hierarchical Engine for Large scale Infrastructure Co-Simulation) co-simulation framework facilitates communication and synchronization between the federates.
- The following three entities are co-simulated in the following framework:
  - OpenDSS: Distribution system power flow calculation
  - Caldera: High-fidelity EV charging models
  - Control Module: Control the charging behaviors of EVs using Caldera or custom defined SCM strategies.
- Caldera is an EV charging infrastructure simulation platform developed by INL. Caldera is designed to study the impact of EV charging on the grid and develop strategies to manage charging.



SCM R&D Capabilities

Caldera OpenDSS Co-simulation Platform

- ❑ EVI-Pro is a tool developed by NREL to create charging demands from EVs on a large scale.
- ❑ HELICS based co-simulation platform also support DER integration scenarios, including：
  - ➢ PV generation based on NSRDB data;
  - ➢ Energy storage system (ESS) charging/discharging control;
  - ➢ Integrated with building EMS and achieve Behind-the-meter (BTM) control.

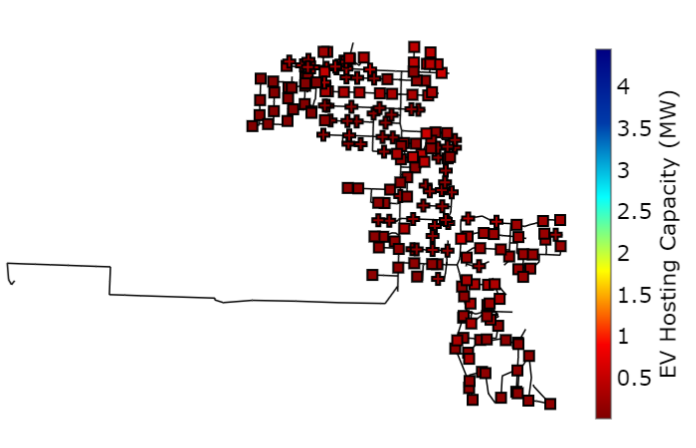


NSRDB – National Solar Radiation Database
DER – Distributed Energy Resource

Hosting Capacity Analysis

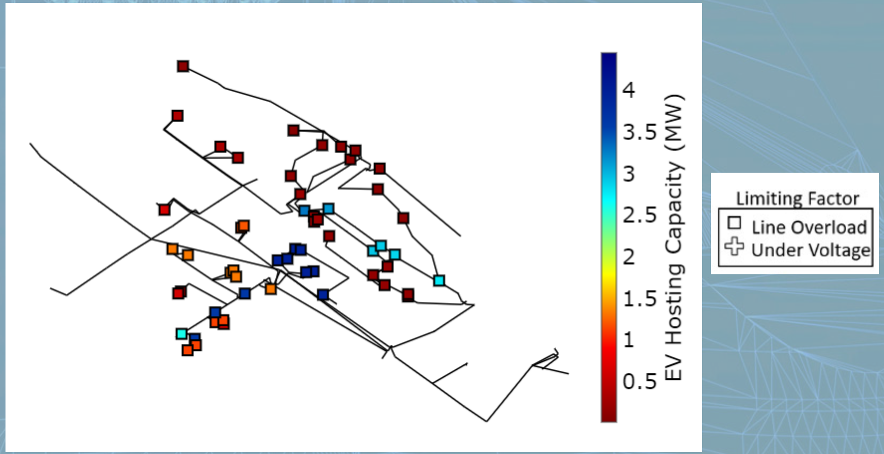
- EV hosting capabilities vary by the feeder type and the location on the feeder.
- Line overloads are the most common limiting factor, then the under-voltage issue.
- Distance from the distribution system substation is important, usually higher capacity closer to the substation.

Residential feeder



Industrial-mix feeder

Commercial and industrial feeder



SCM R&D Capabilities

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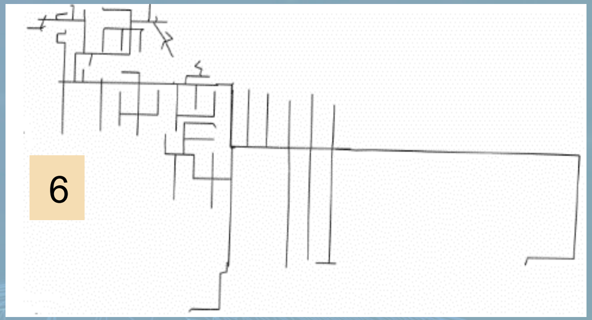
SCM Strategies Developed in RECHARGE

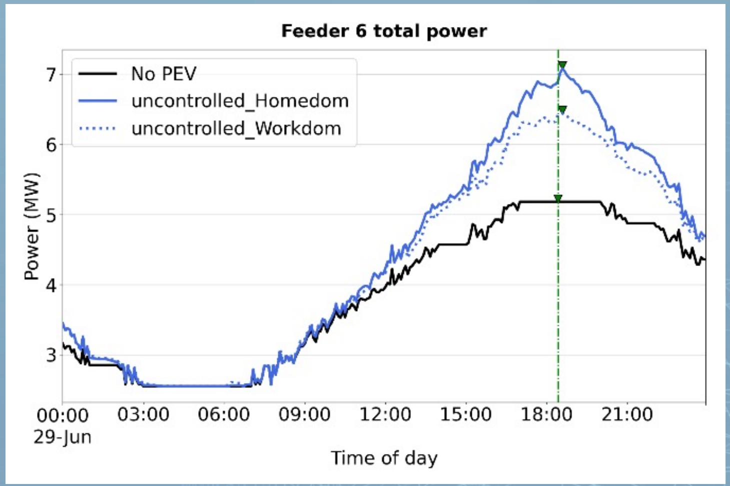
Strategy Name	Objective	Control Simulation	Grid Services
TOU Immediate	PEV driver responds to Time-of-Use incentives by charging at the beginning of TOU windows	Caldera	Price Signals
TOU Random	Decentralized control randomly distributes EV charging within vehicle dwell and TOU windows	Caldera	Price Signals, Capacity Deferral
Random Start	Decentralized control randomly distributes EV charging within vehicle dwell	Caldera	Capacity Deferral
Centralized Control (Feeder Peak)	Centralized control shifts EV charging within vehicle dwell to minimize feeder peak	Caldera	Capacity Deferral
Volt/VAR	Decentralized control provides reactive power support based on local power quality	Caldera	Voltage Support
Global Voltage	Decentralized control shifts EV charging within dwell to reduce nearby grid voltage concerns	Outside Caldera*	Demand Response, Voltage Support
BTM (Renewables)	Decentralized control shifts EV charging within dwell to reduce behind-the-meter peak demand	Outside Caldera*	Demand Charge Mitigation, Max Renewables

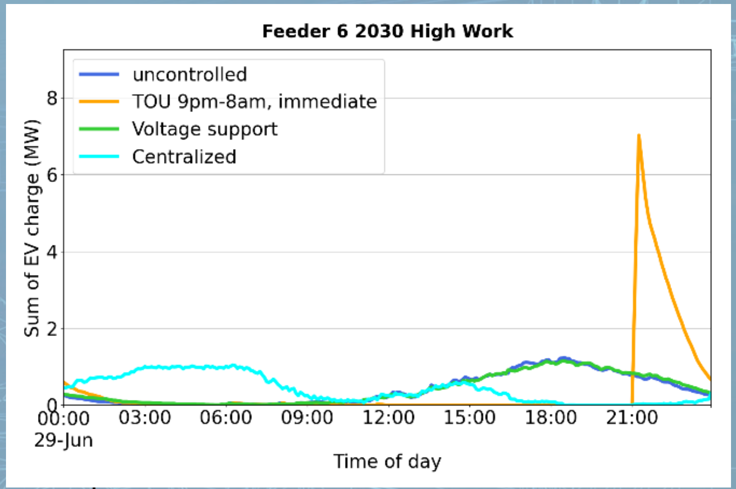
SCM R&D Capabilities

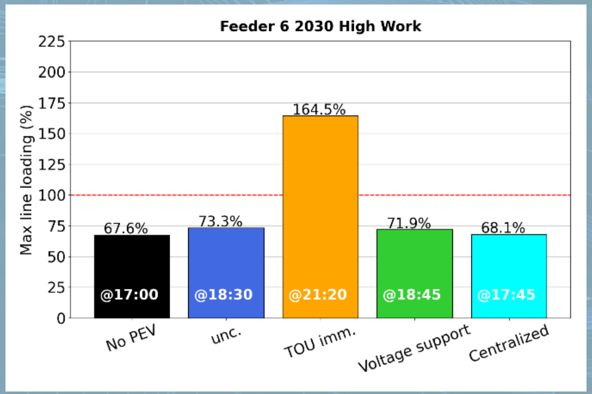
Grid Impact Analysis

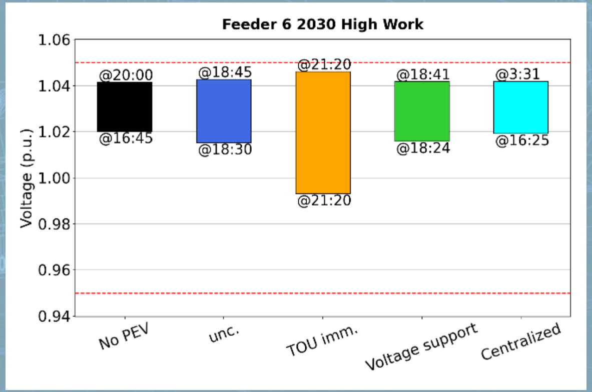
- Residential, some commercial feeder, no EV peak load 5.2 MW, no EV maximum line loading ratio 67.6%, EV adoption rate 13% (2030).
- Work charging dominant scenario: the vehicle will only charge at workplaces unless it is impossible to make it to workplaces without charging.
- Home charging dominant scenario: the vehicle will only charge at home unless it is impossible to make it home without charging.











Metric name	No EVs	2030 High Home: No Control	2030 High Home: TOU imm.	2030 High Home: Voltage support	2030 High Home: Centralized	2030 High Work: No Control	2030 High Work: TOU imm.	2030 High Work: Voltage support	2030 High Work: Centralized
Feeder peak load (MW)	5.18	7.09	14.24	6.89	5.58	6.45	12.08	6.36	5.4
Minimum voltage (pu)	1.0201	1.0138	0.9884	1.0144	1.0182	1.0152	0.9931	1.0158	1.0192
Maximum voltage (pu)	1.0415	1.0428	1.0465	1.0419	1.042	1.0427	1.0461	1.0418	1.0419
Avg. line loading change (%)	0	5.5	22.39	5.2	2.92	4.22	17.87	3.84	2.75

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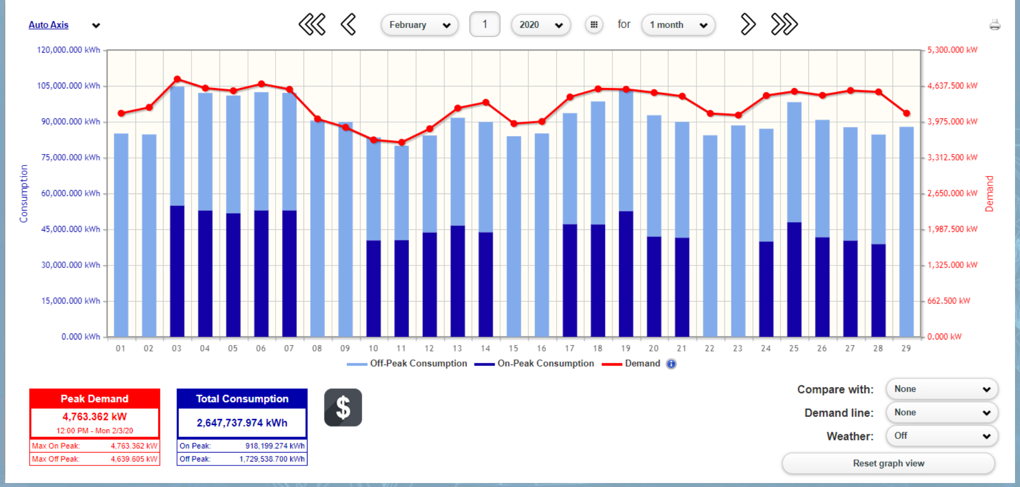
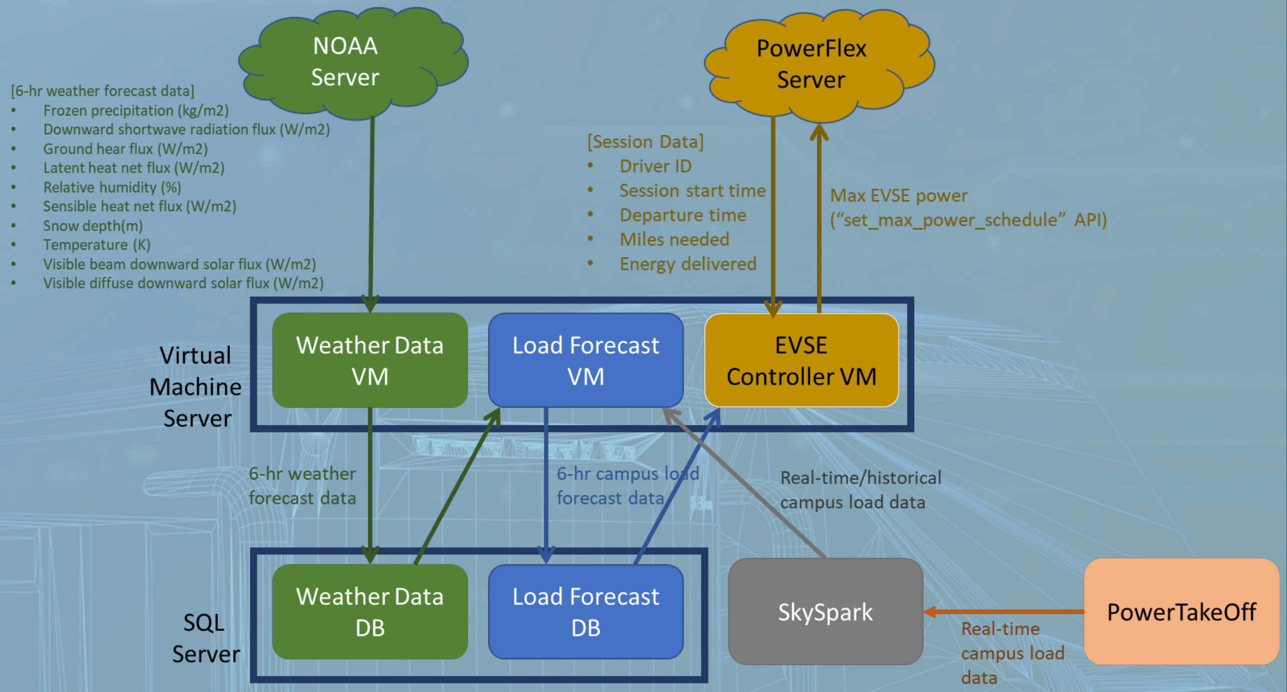
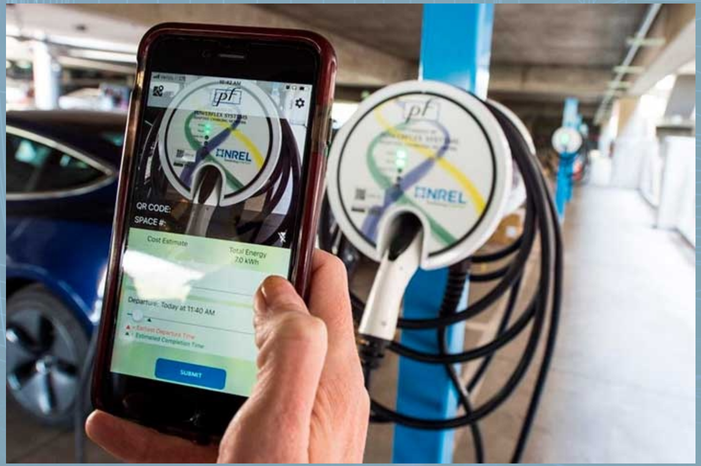
Smart Charge Management at NREL Garage

- NREL is home to more than 100 Level 2 EV charging stations by PowerFlex. The innovative charging stations feature an adaptive charging network with load-sharing and demand-management capabilities.

- Managed charging in accordance with building loads. A workplace demand-charge-management system to control EV charging stations based on aggregated building loads.







Sandia National Laboratories

C. Birk Jones, Ph.D.
email: cbjones@sandia.gov

Team Members:
Andrea Mammoli, Matthew Lave, Thad Haines, Will Vining

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Initial Task: Identify high capacity locations for concentrated EV charging throughout region(s) of study.

Electric Grid Networks

Define Electric grid capabilities to host concentrated Electric Vehicle charging stations - Level 2.

Building Characteristics

Compare the grid capabilities with the nearby building characteristics.

Transportation Network

Identify the proximity of the high power charging locations to the road network. **AND** compare locations with existing driving patterns.

Public Transportation

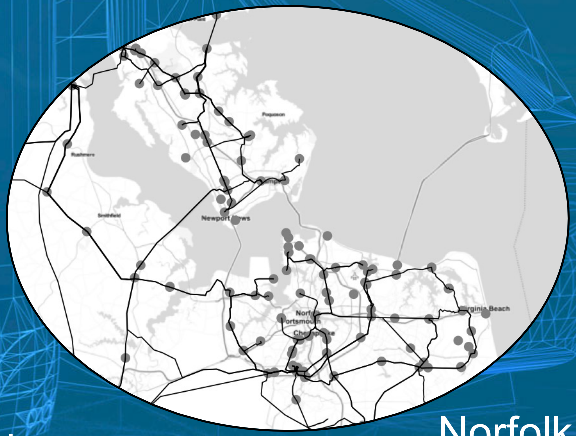
Define public transportation electrification energy consumption and charging demands.

Electric Grid Networks

Transmission Grid:

Acquired GIS of the transmission grid for the area of interest. The data is only for spatial analysis and does not include a power flow model.

Richmond



Norfolk

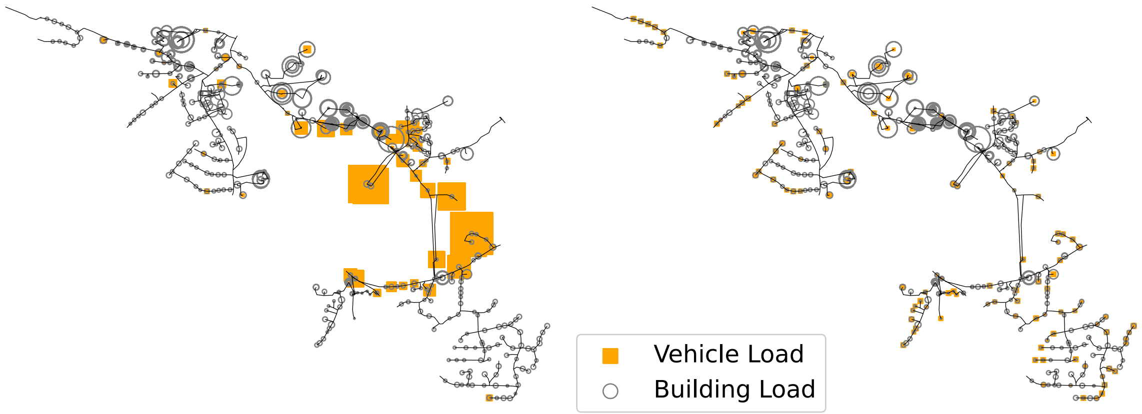
Distribution Grid Models:

Waiting for distribution models from local utility.

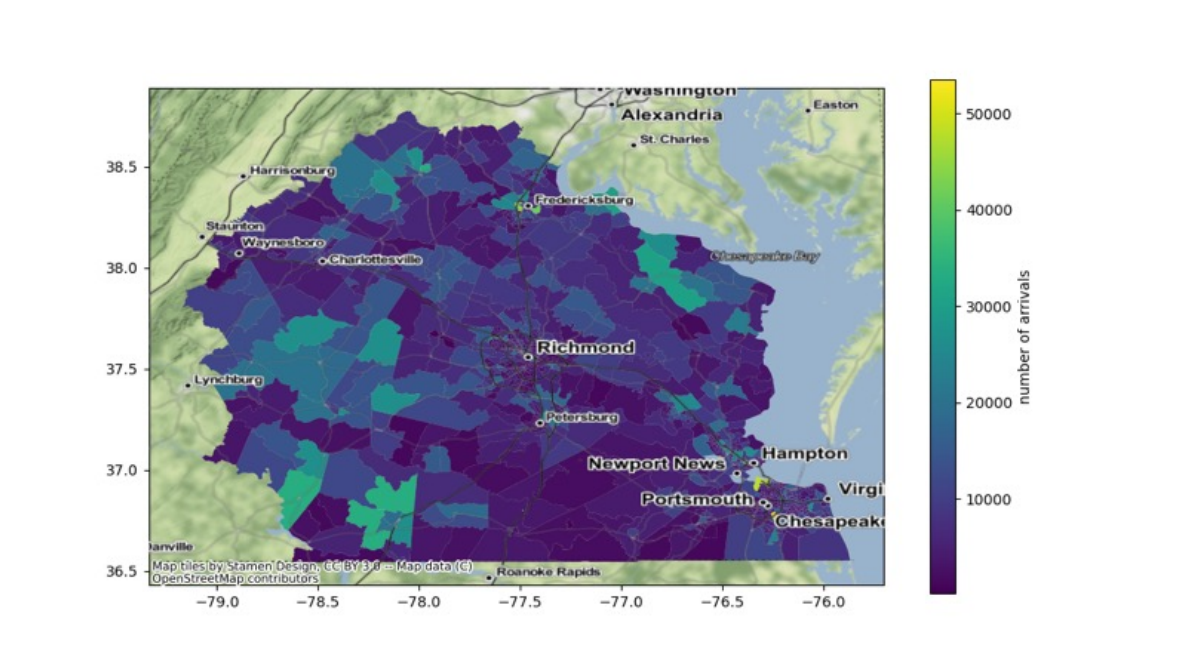
Once we have OpenDSS models, we plan to perform hosting capacity analysis to identify potential CONCENTRATED & DISTRIBUTED charging locations.

Concentrated

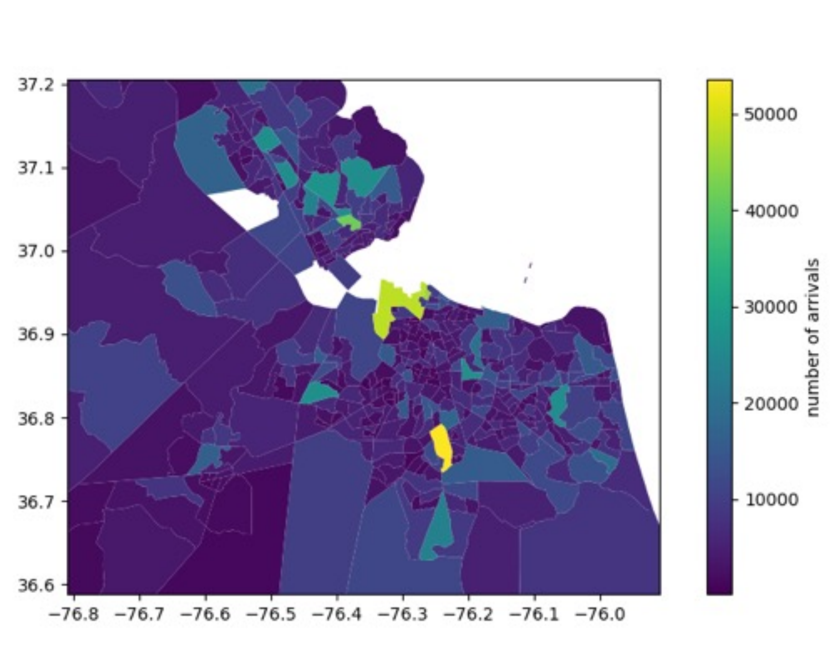
Distributed



Vehicle Behaviors to Identify Charging Locations



Heatmap of vehicle arrivals in Eastern Virginia by census tract



Zooming in on the Norfolk area show several potentially good options for centralized charging

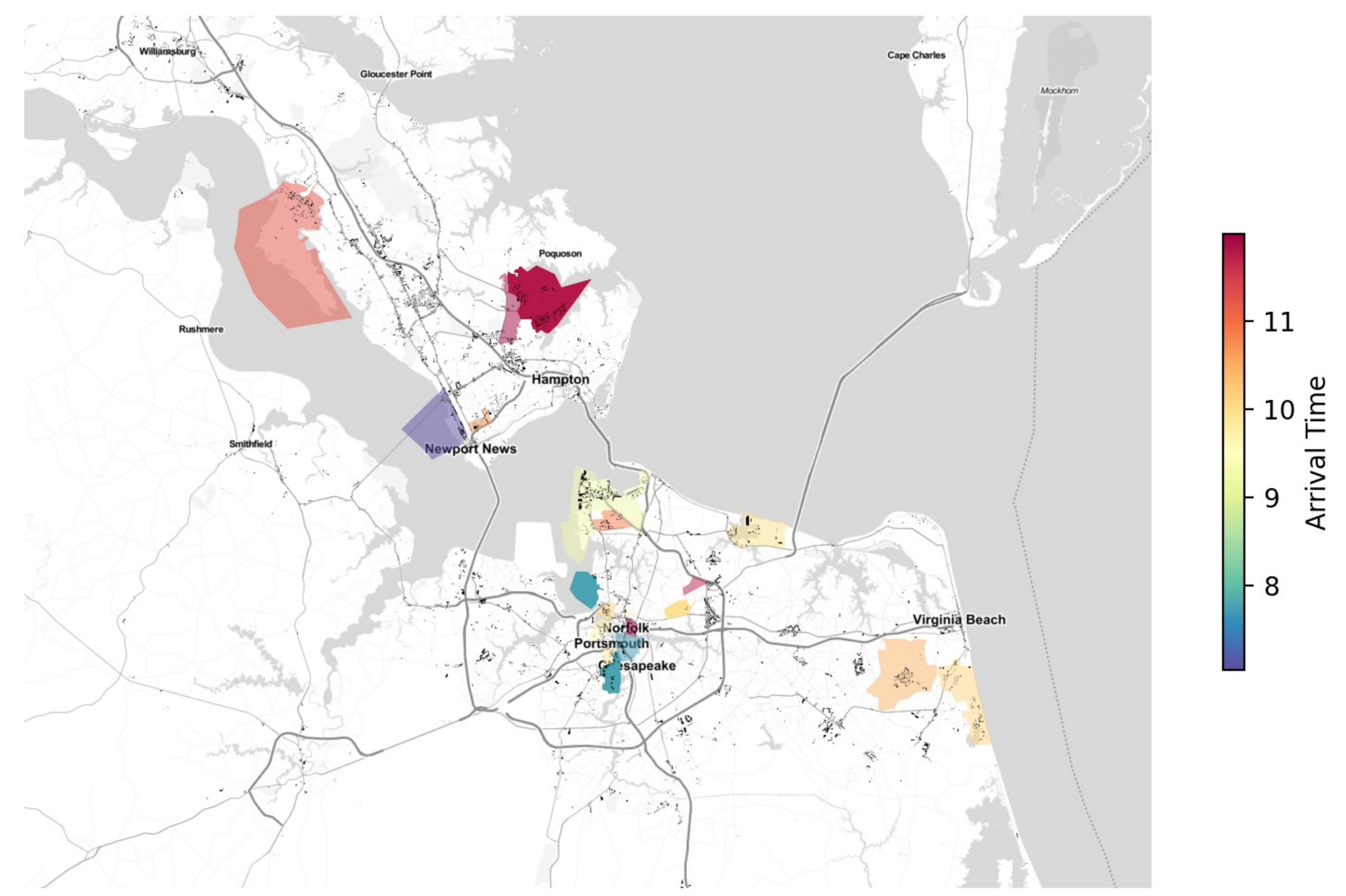
Public Charging Areas – At places of Work

Morning Arrivals:

Census tracts where drivers arrived before 12 pm

Potentially represent morning commuters destinations – places to charge while working

Morning arrivals concentrated in commercial areas and near ports



Public Charging Areas – At Housing Units

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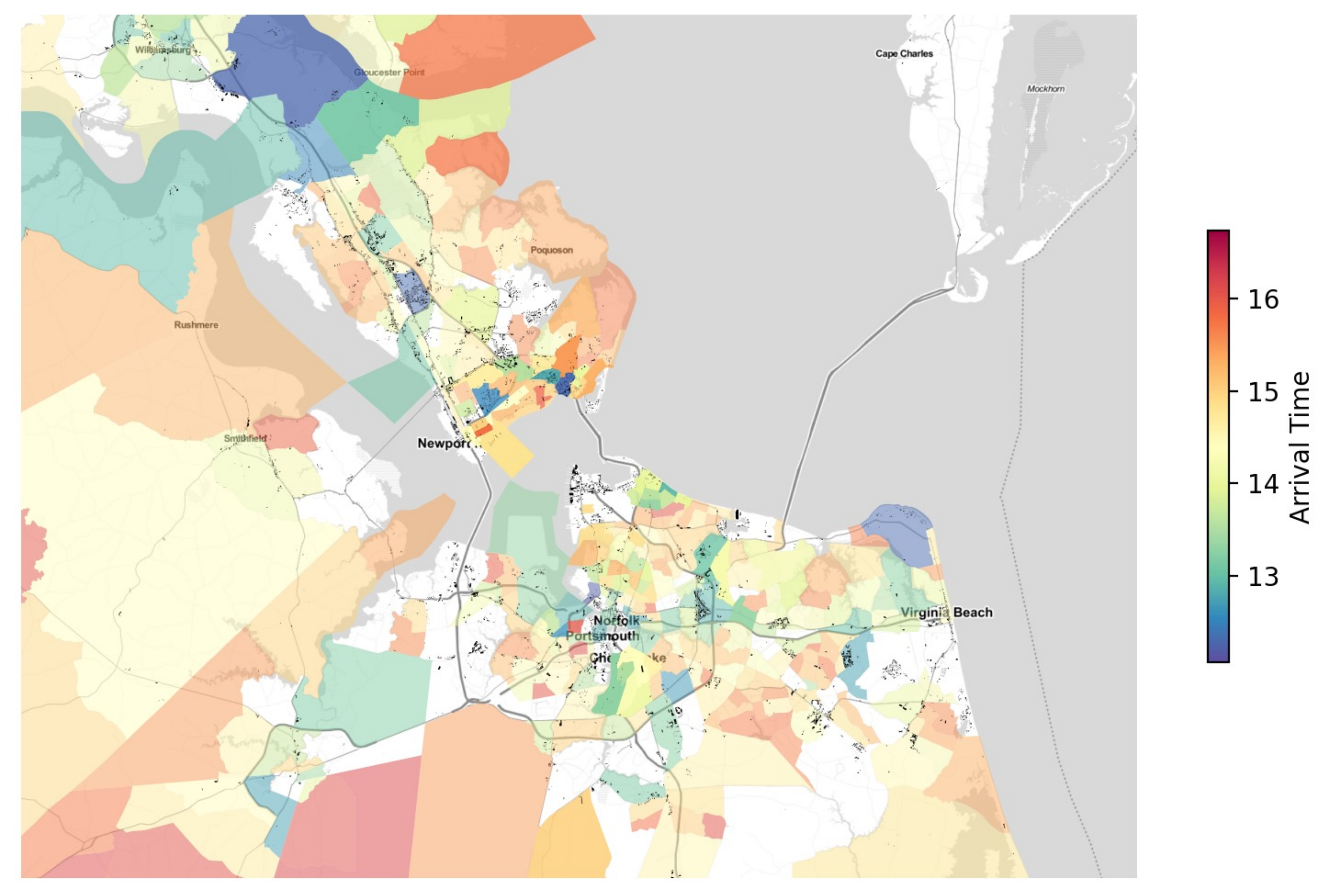
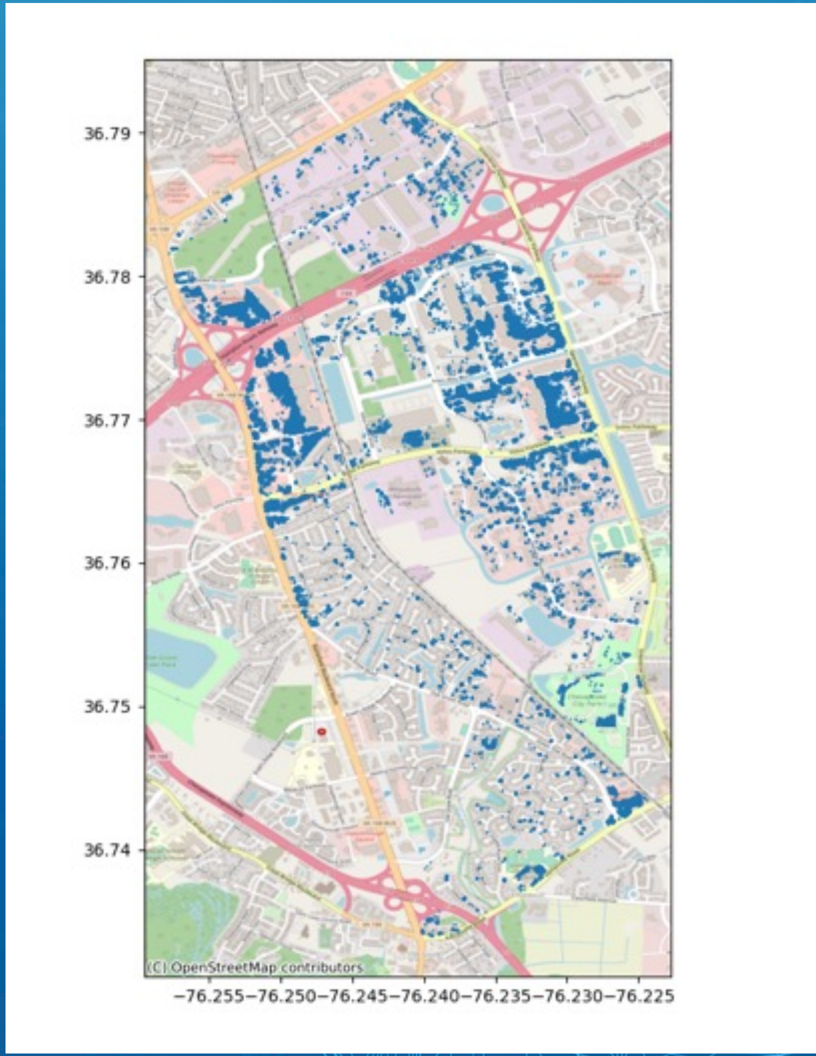
Afternoon/Evening Arrivals:

Census tracts where drivers arrived after 1 pm

Potentially represent return trips after working, shopping, or other activities – <u>places to charge at home</u>

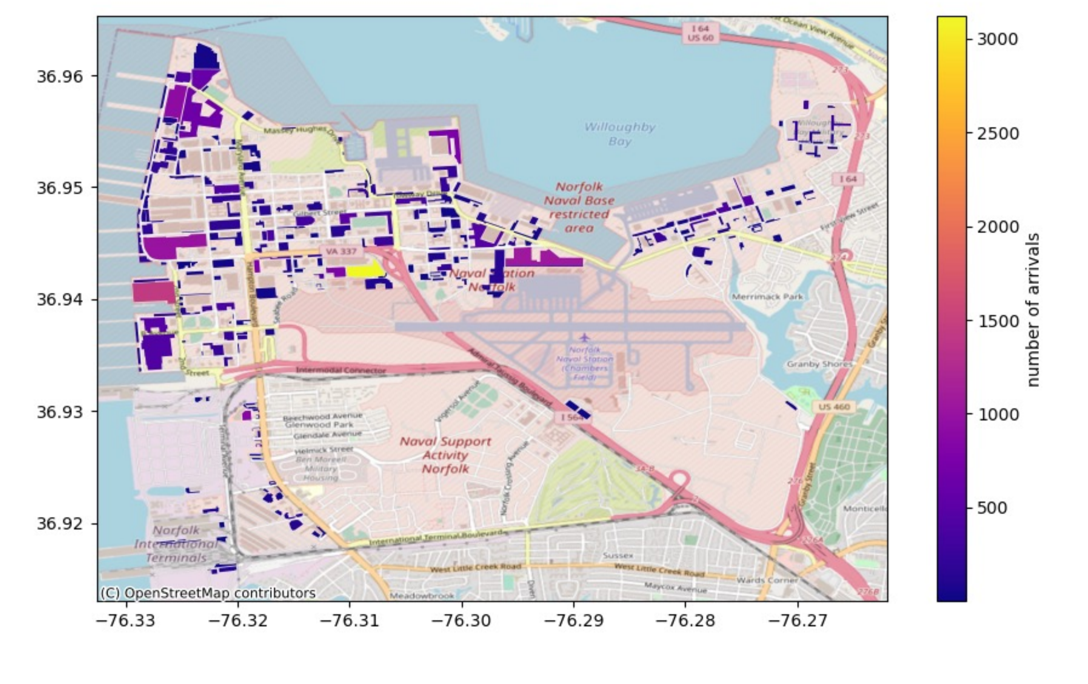


Parking Lot Locations & Vehicle Arrivals



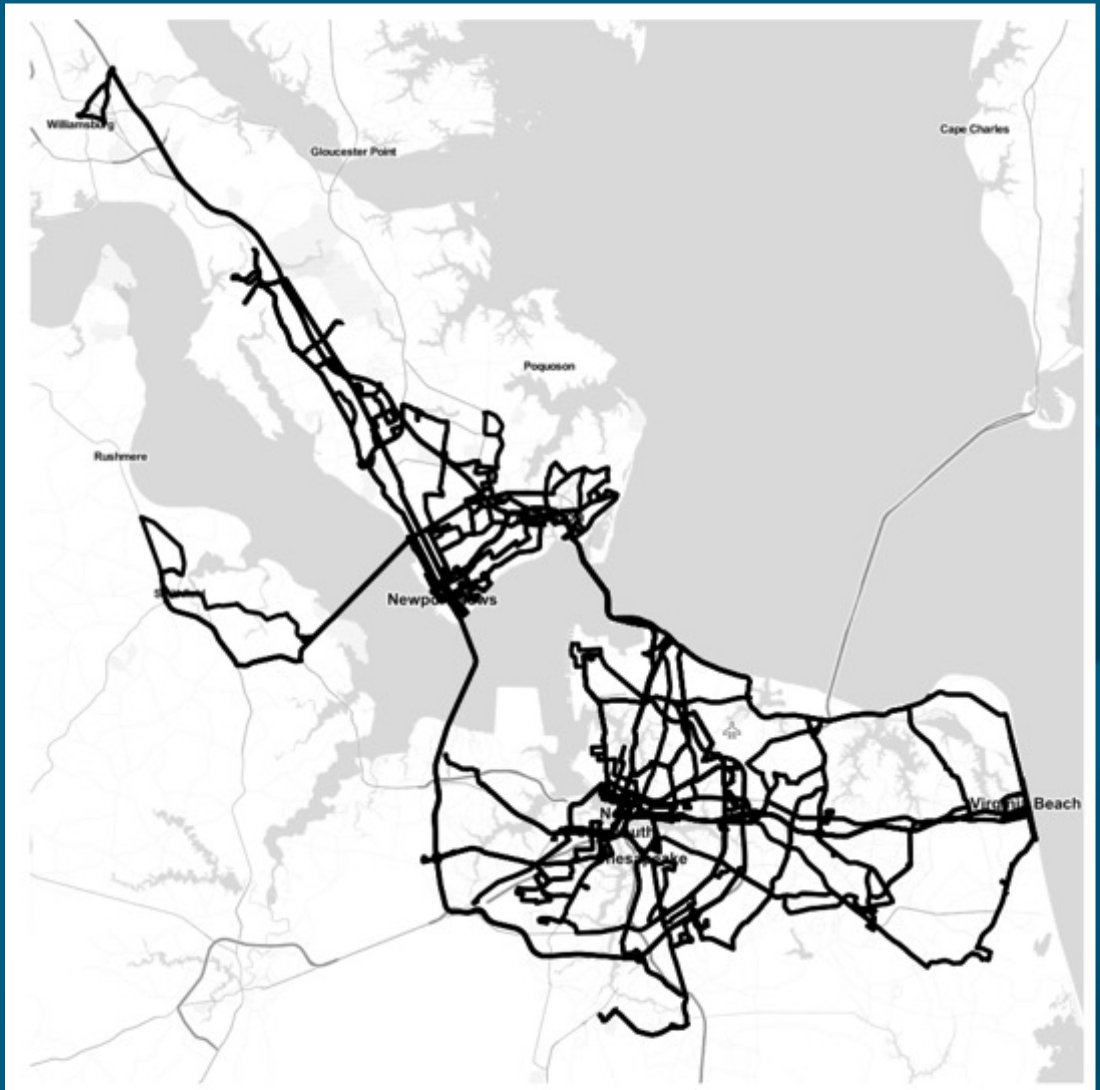
In Southern Norfolk the census tract with the most arrivals (left) contains numerous parking lots, shopping centers, gyms, offices, apartments, houses, residences, and a large park.

This tract has large numbers of arrivals on weekdays *and* weekends



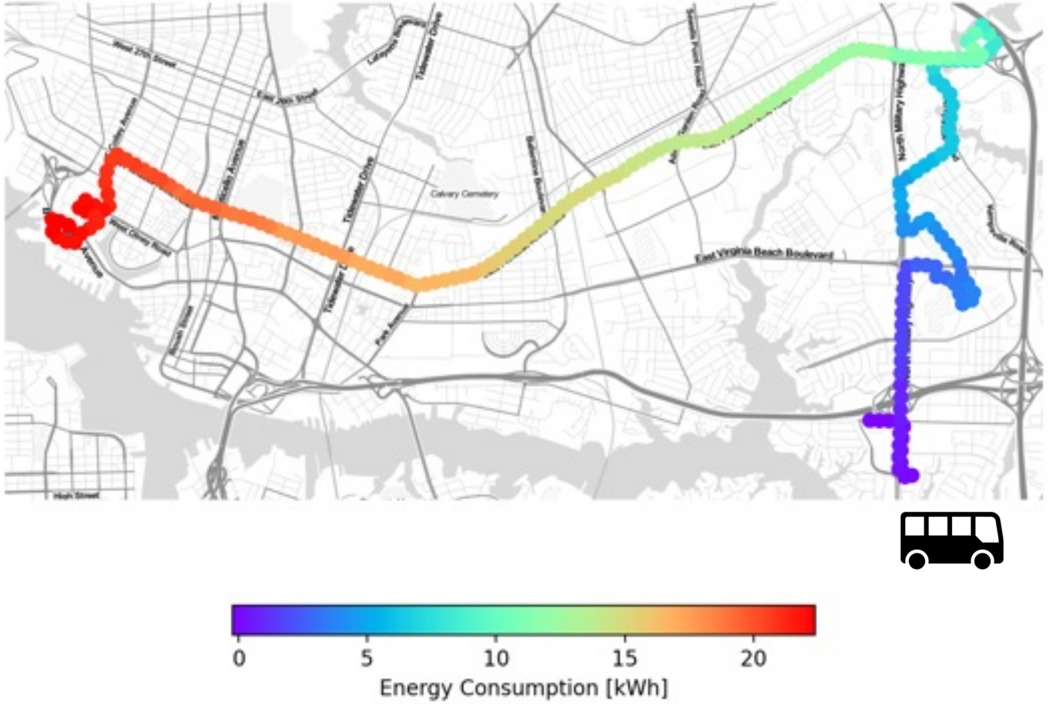
The port (left) also has a high number of arrivals, but generally only on weekdays.

Public Transportation Charging Sizes and Locations



Bus routes for Norfolk (left) and other municipalities could be used to estimate electrical energy consumption of public fleet.

For example (below), a single bus along shown route will consume about 22.3 kWh.



Stakeholder Feedback

SCM/VGI Development

(10 minutes)

Mingzhi Zhang
Mingzhi.Zhang@nrel.gov

Christian Birk Jones
cbjones@sandia.gov

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We need your input to identify:

- **Partners** for our R&D efforts to help with insight, data, and other resources.
- **Progress** in our activities to ensure timely research is available to key stakeholders
- **Priorities** for R&D that accelerates the transition to EVs at Scale.

5 minute break

Please take a 5-minute break and plan to return at 12:20 p.m. ET

Session 2 - Grid Modeling and Impact Analysis

12:20 p.m. – 12:50 p.m. ET — **Grid Modeling and Analysis**

Presentation (20 min) — *Shibani Ghosh, Nadia Panossian*

Q&A (10 min)

12:50 p.m. – 1:20 p.m. ET — **Broad SCM Assessment**

Presentation (20 min) — *Tim Pennington, Manoj Sundarrajan*

Q&A (10 min)

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EVs@Scale Deep Dive - SCM/VGI

Day 1: Grid Modeling and Analysis

Shibani Ghosh (NREL),
Nadia Panossian (NREL)

September 28, 2022

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

Grid Analysis Approach

Prototyping grid impact analysis on a utility's service territory

Selecting Regions

Gathering data, validating models, assembling tools/software

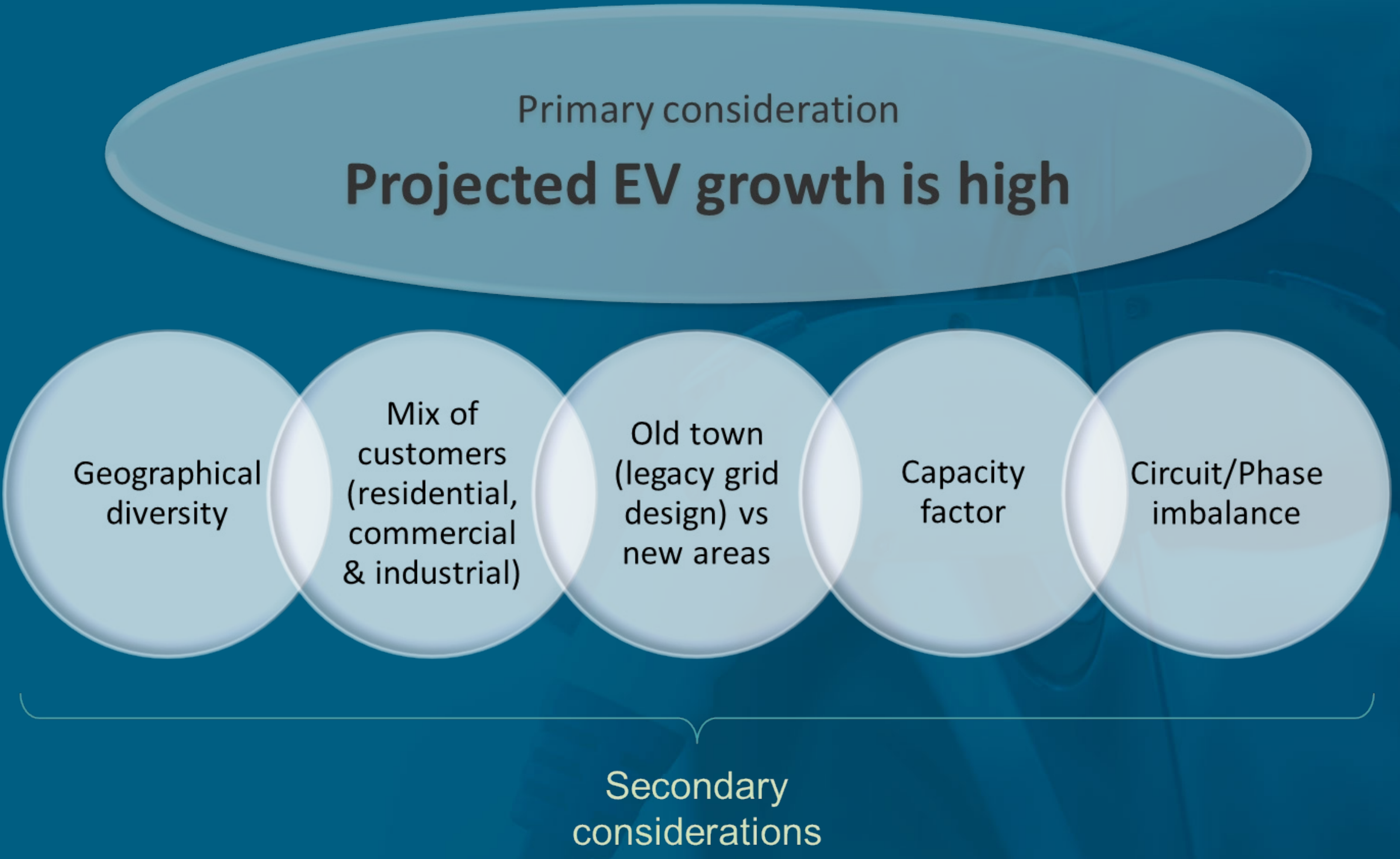
Distribution feeder(s) baseline and EV Integration Scenarios

Analyzing results and the insights the results provide

Hosting Capacity and Grid Impact Results

Selecting Regions

- Deep dive in distribution network analysis can be effective when selected substations/feeders are in focus
- Iterative process with Utility's planning, operations, data and designs teams to determine the "right" feeders



Utility Collaboration

Dominion Energy

16 states (Selected region: Virginia)

7 million customers

Headquartered in Richmond, VA

- Strongly invested in vehicle electrification
- Has a green fleet goal (2021)
  - Transform a fleet of more than 8,600 vehicles that serves millions of customers across 16 states
  - 75% of passenger vehicles, including sedans and SUVs, will be converted to electric power by 2030.
- EV charger reward program incentivizes residential customers (Level 2 EV smart chargers) to adjust their charging behavior during periods of high demand
- Smart Charging Infrastructure Pilot (SCIP) Program – rebates on qualifying charging stations, infrastructure and installation

Feeder Selection

- ~150 feeders from green clusters --> Synergi models and yearly feeder head data are ready to be shared once the 3-way NDA is signed
- NDA process has seen good progress and nearing its end
- Feeder list can be extended to include a greater number/diverse set of feeders if needed

Grid Modeling and Analysis

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Utility feeder model verification and OpenDSS charging impact assessments on the grid

1) Convert model to OpenDSS format using DiTTo
2) Evaluate model for missing elements and PV adoption within OpenDSS
3) Conduct initial distribution upgrade analysis for baseline using DISCO
4) Evaluate EV hosting capacity and placement (similar to RECHARGE methods)
5) Conduct distribution upgrade analysis with EV charging using DISCO

DiTTo

Converts distribution models from one format to another

Can convert models into OpenDSS format

DSS

Models powerflow of Distribution feeders can handle high adoption rates of feeders When wrapped with PyDSS

DISCO

Does hosting capacity and upgrade cost analysis for varying solar adoptions

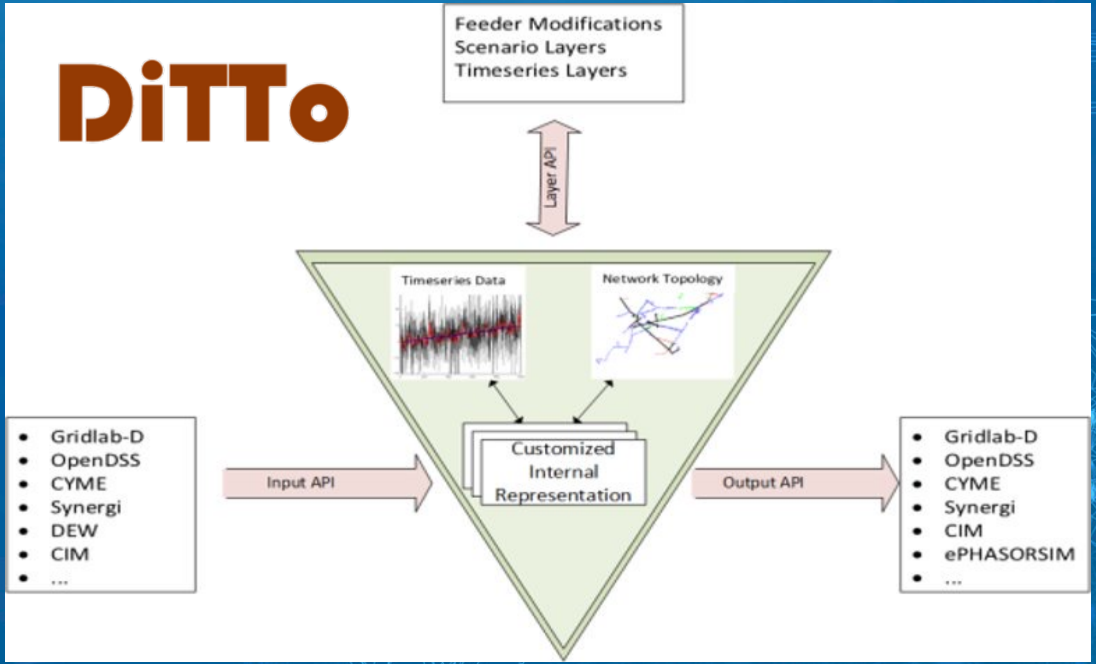
Can work with EV hosting capacity outputs From RECHARGE methods

Scalable with Jade on hpc

Utility feeder model verification and OpenDSS charging impact assessments on the grid

DISCOs Process:

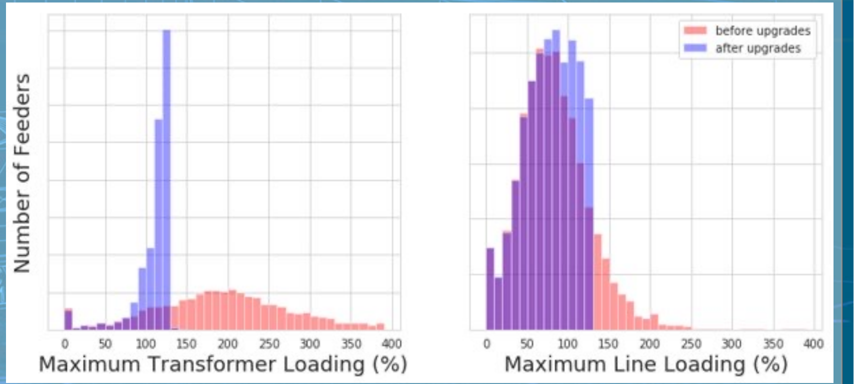
- upgrade lines and transformers to eliminate thermal overloads
- upgrade voltage regulators, capacitors, and controls to eliminate voltage excursions
- upgrade lines and transformers again to compensate for any thermal overloads that occurred after first two steps



Initial powerflow to check for missing components

DISCO

Scalable iterative powerflow and upgrades to prevent thermal and voltage violations



Stakeholder Feedback

SCM/VGI Development

(10 minutes)

Shibani Ghosh

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Nadia Panossian

Nadia.Panossian@nrel.gov

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EVs@Scale Deep Dive - SCM/VGI

Day 1: Broad Assessment of SCM

Timothy Pennington (INL),
Manoj Sundarrajan (INL)

September 28, 2022

Broad Assessment of Smart Charge Management limitations

- **Smart Charge Management strategies are developed to improve the impact of EV charging on the grid.**
- **But they must be based on the conditions of a particular grid at a particular time.**

When is the best time to charge EVs?

It depends.

Depends on what?

Which way the wind blows…

And your regions: Wind deployment, Solar deployment, Air Conditioning load, Electric Heat, Existing load shape (residential, commercial, industrial), the current season, the daily weather, and many other characteristics

Regional Characteristics

- Renewable Generation Adoption
  - Solar
  - Wind
    - Inland
    - Offshore
- Electrical Demand
  - Summer Peaking
    - High AC Loads
  - Winter Peaking
  - Small City
  - Rural Region
  - Large City
- Transportation
  - Port City with Drayage
  - Major Highway
    - In small lightly loaded region
    - Significant truck traffic

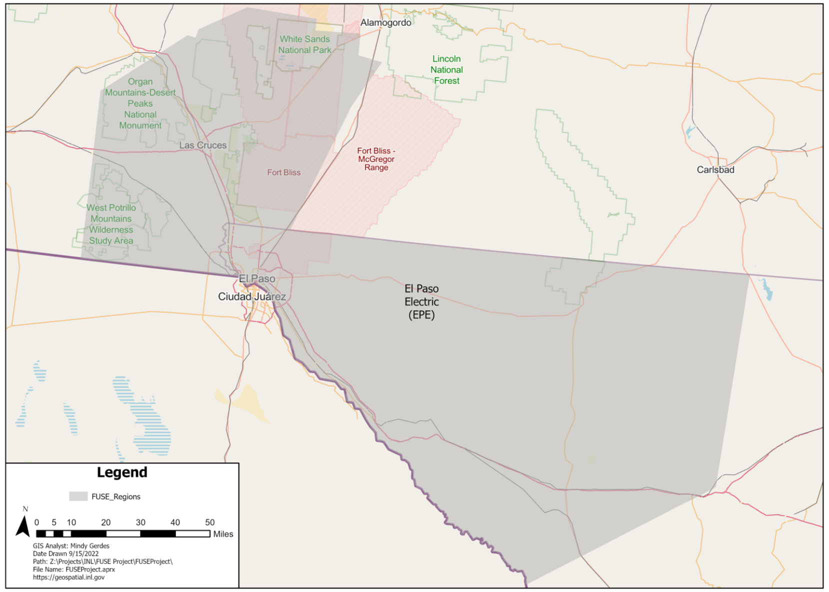




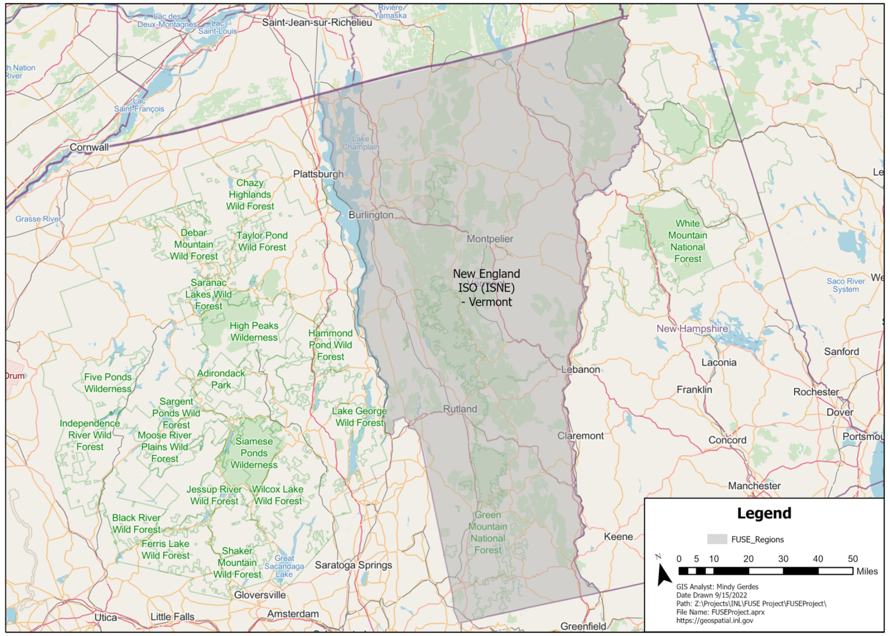
Broad Assessment Study Regions

FUSE Regions

El Paso Electric (EPE) Region



New England ISO (ISNE) - Vermont Region



Regional Characteristics Matrix

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Characteristics	ERCOT Coast	El Paso Electric (EPE)	Evergy	New England ISO (ISNE) - Vermont	Dominion Energy	Final
High Solar	X	X				X
Inland Wind	X		X			X
Offshore Wind				X	X	X
Extreme Summer Peaking		X				X
Winter Peaking				X		X
Large Metro Area	X	X				X
Rural Region				X		X
Large Seaport	X					X
Large Airport	X					X
Pass-Through Truck Traffic			X			X
International Truck Traffic		X				X

Renewable generation adoption – Green
Electrical demand – Yellow
Transportation – Blue

Broad Analysis Results – 2 Regions: 28 simulations

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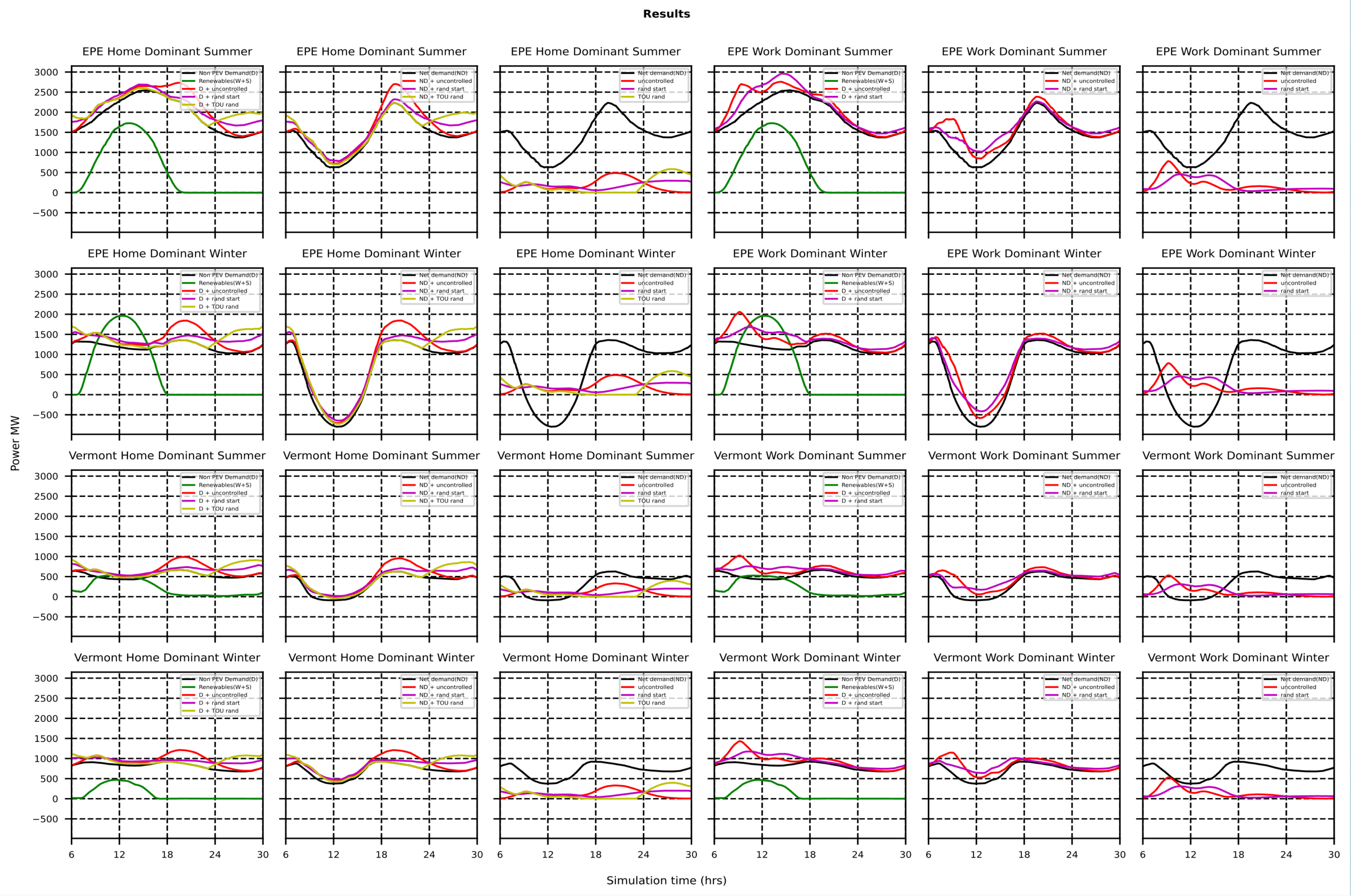
- Two Regions
  - EPE
  - ISNE-Vermont
- Two Season
  - Summer
  - Winter
- Two energy allocation scenarios
  - Home dominant (HD)
    - Home 75%, Work 25%
  - Work dominant (WD)
    - Home 25%, Work 75%
- Seven charging behaviors
  - HD Uncontrolled
  - HD Random start home work
  - HD Random start home
  - HD TOU random home
  - WD Uncontrolled
  - WD Random start home work
  - WD Random start work

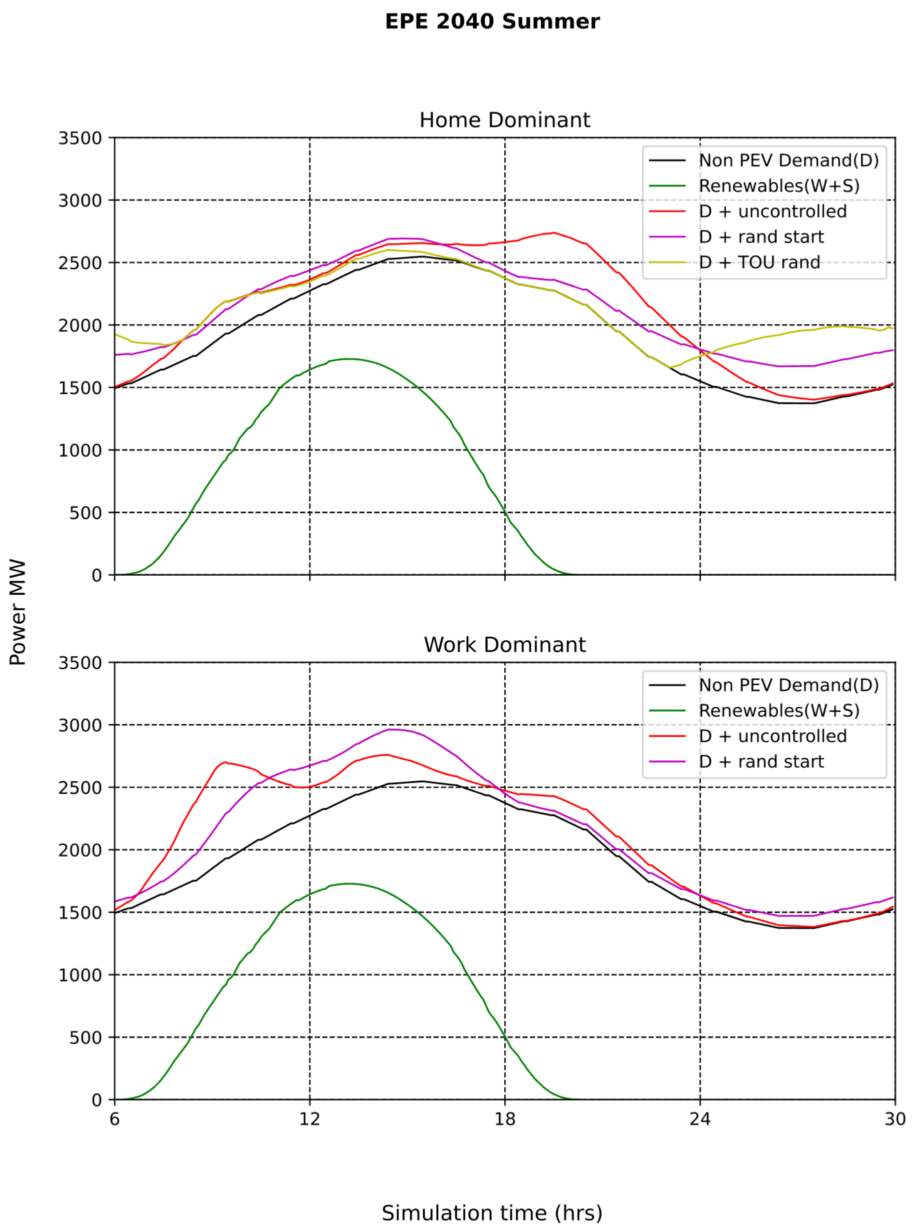


Broad Analysis Results (Continued)

- **EPE Winter**
  - Less variation in daily native demand
  - Very high solar w.r.t winter native demand, excess solar needs storage or curtailment
  - In this case, it is most desirable for EVs to charge at time of high solar
  - In home dominant scenario, most charging occurs in night
    - not useful to the grid, or for renewable integration
  - In work dominant scenario, most charging occur during the day
    - Uncontrolled peak occurs before solar peak
    - Random start did a decent job of pulling the charging towards the solar period but a purpose built strategy could do better.

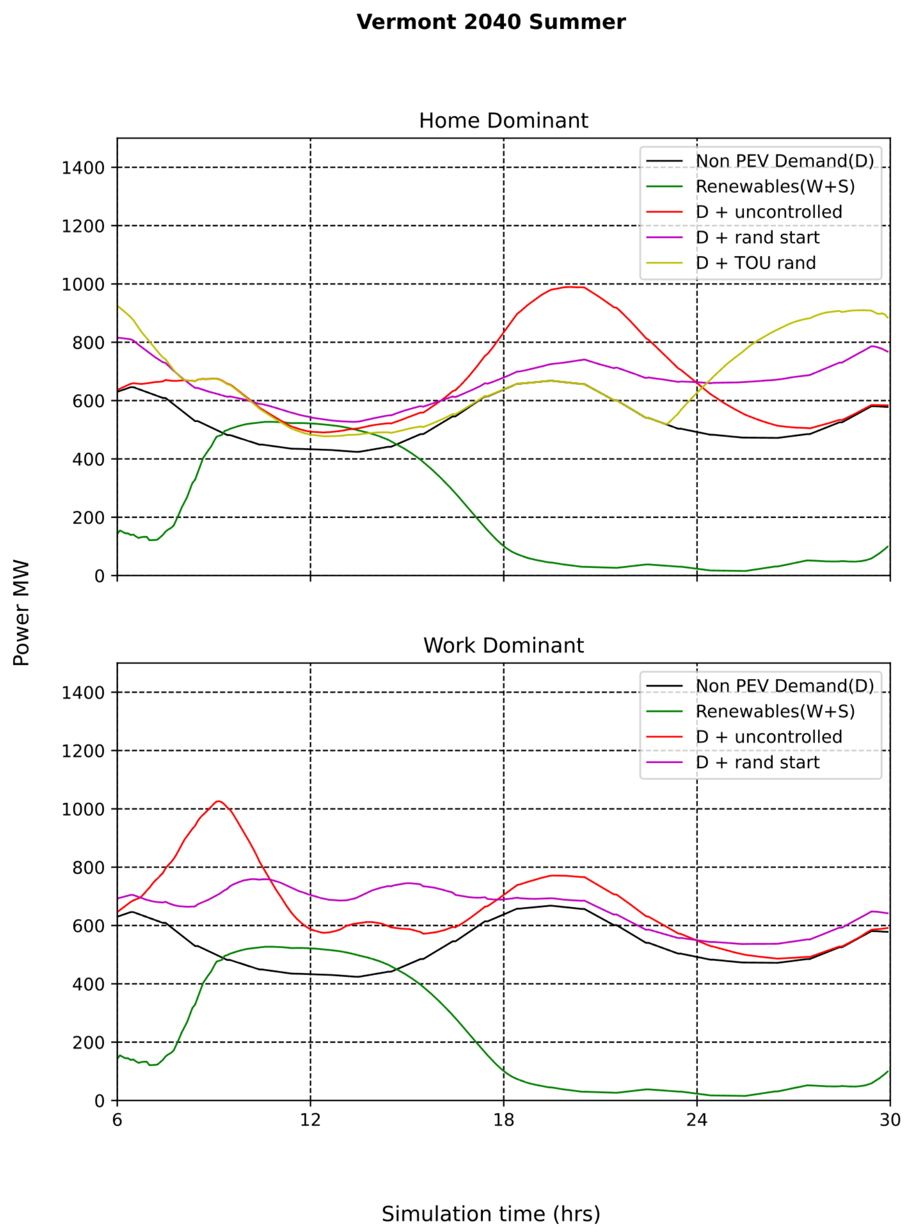
Broad Analysis Results (Continued)

- **EPE Summer**
  - Lots of daily variation due to air conditioning loads
    - Large afternoon peak in native load
  - On high solar days, shift charging to solar
    - Work dominant charging with control is the best for solar alignment.
  - On low solar days, it may be best to shift some charging to off peak period.
    - Home dominant with time of use random



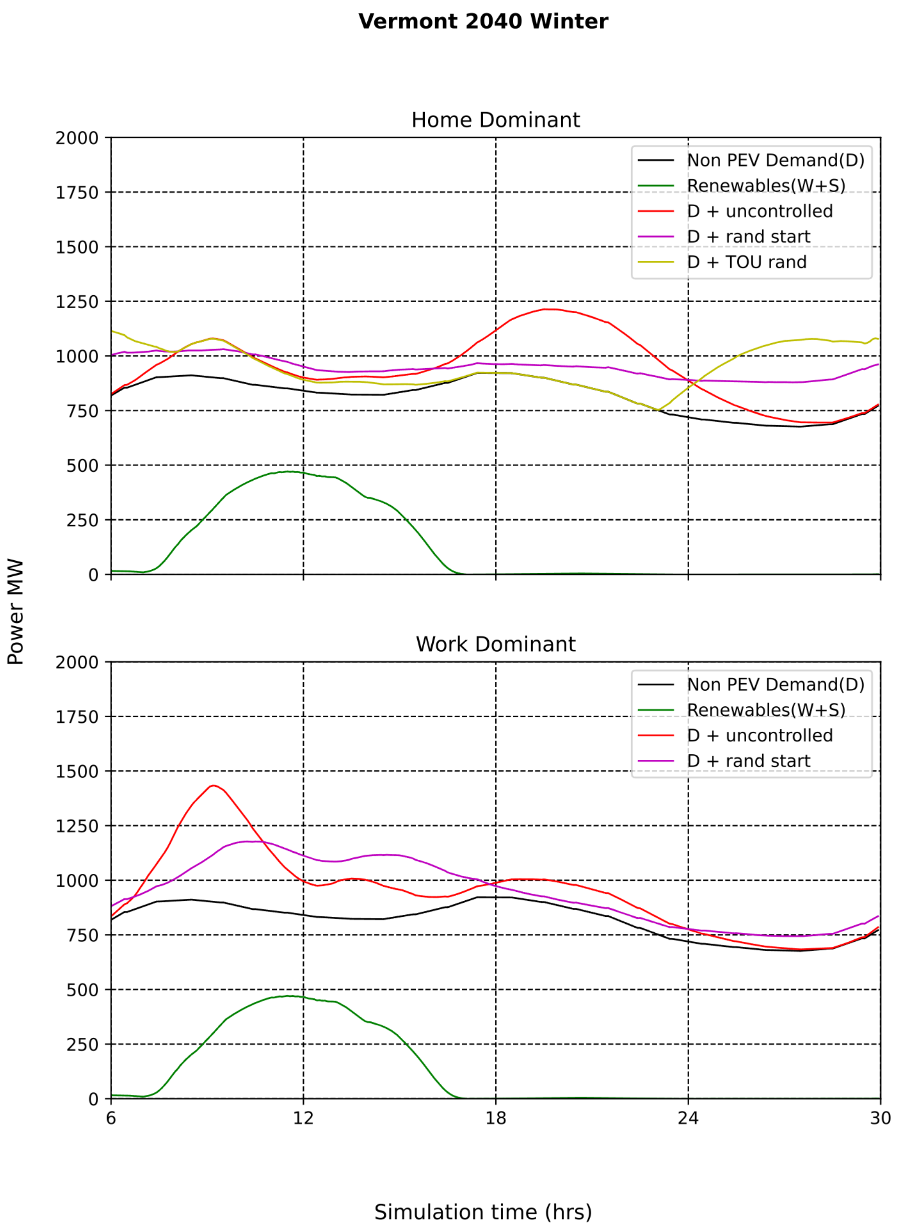
Broad Analysis Results (Continued)

- **Vermont Summer**
  - Controlled charging is much better than uncontrolled
  - Predicted solar outproduces native daytime demand
    - Aligning solar will certainly avoid the need for storage or curtailment
    - Work dominant charging with random start control best at solar objective
  - Even without solar the work dominant random start control has the lowest total peak power largely due to Vermont's particularly low daytime load



Broad Analysis Results (Continued)

- **Vermont Winter**
  - Native load is higher as a Winter Peaking region with electric heat loads
  - On high solar days it is again useful to maximize daytime charging aligned with noon peak
  - However, on low solar days, similar to EPE Summer, it may be best to use home dominant charging for nighttime charging
    - In this scenario home dominant with random start produces the most steady demand
    - Note that Time of Use random concentrates charging causing a new undesirable system peak



Broad Analysis Results (Continued)

- **Key takeaways**
  - A control that works in a particular scenario doesn't mean it'll work for all scenario
    - E.g., TOU random control that worked for EPE summer did not work in Vermont.
  - Region characteristics not only differs between different regions but also between seasons and even between days due to renewables integration.

Next Steps

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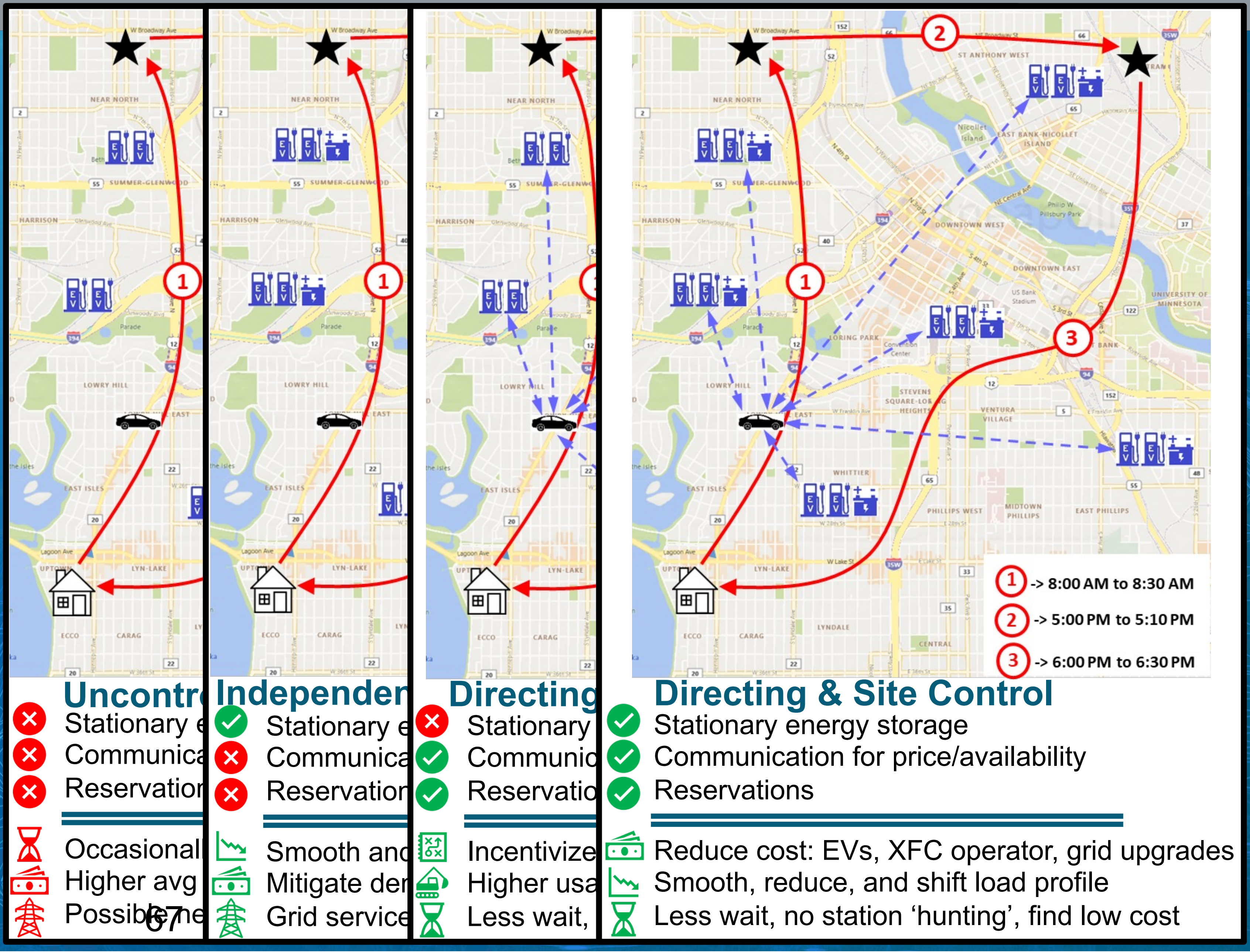
- Complete uncontrolled and existing SCM simulations for other regions
- Evaluate the unique implications of wind heavy generation
- Add public fast charging
- Add MD/HD commercial travel and interstate highway impacts on demand
- Work directly with each utility to refine generation and demand predictions
- Modify existing, and develop new control strategies to optimize each region
- Consider implications on charging infrastructure build outs

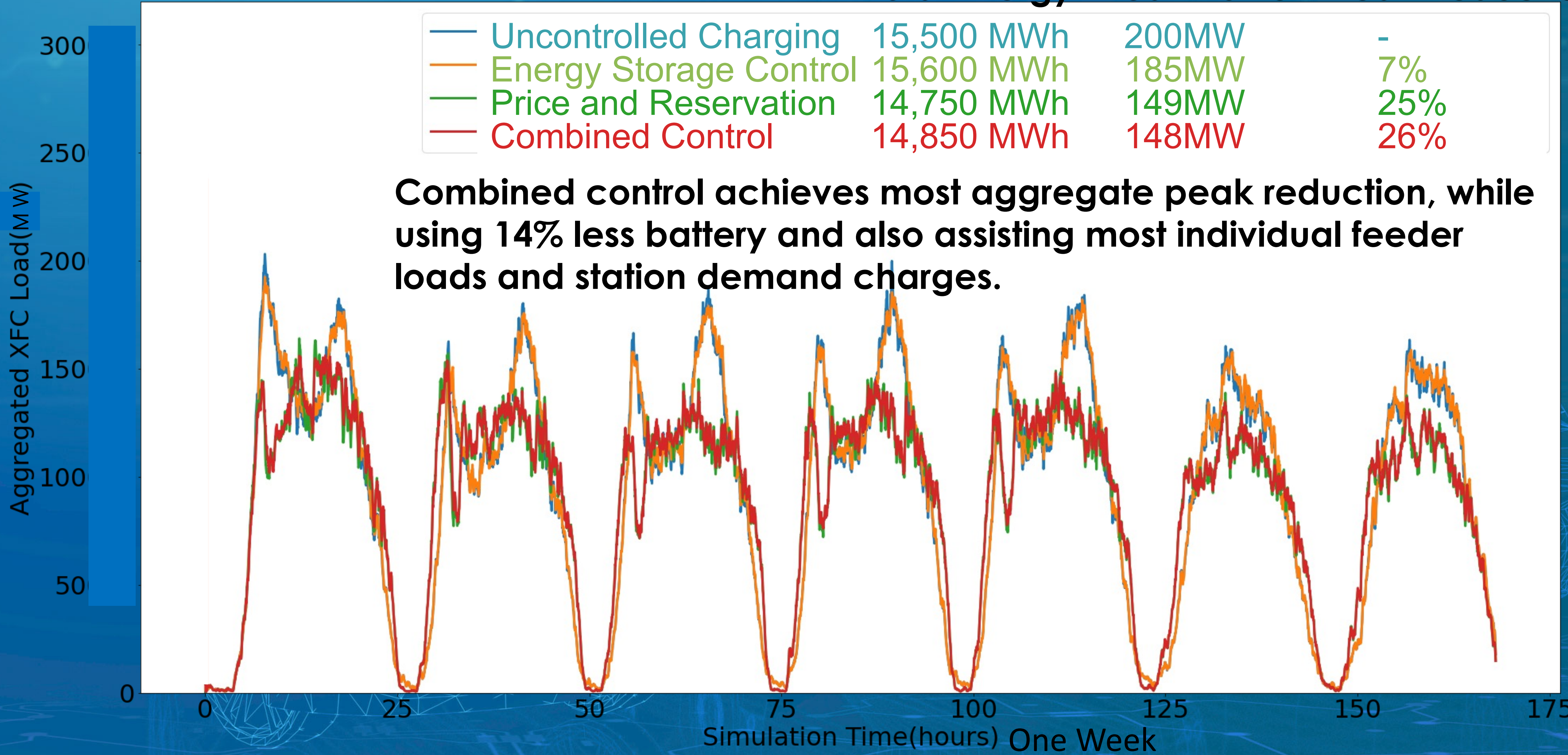
Communications and Reservations as SCM



SCM Approaches for Mitigating EV XFC Charging Load

	Total Energy	Peak Power	Peak Reduction
Uncontrolled Charging	15,500 MWh	200MW	-
Energy Storage Control	15,600 MWh	185MW	7%
Price and Reservation	14,750 MWh	149MW	25%
Combined Control	14,850 MWh	148MW	26%

Combined control achieves most aggregate peak reduction, while using 14% less battery and also assisting most individual feeder loads and station demand charges.



One Week

Stakeholder Feedback

Broad Assessment of SCM

(10 minutes)

Tim Pennington
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Manoj Sundarrajan
ManojKumar.CebolSundarrajan@inl.gov

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We need your input to identify:

- **Partners** for our R&D efforts to help with insight, data, and other resources.
- **Progress** in our activities to ensure timely research is available to key stakeholders
- **Priorities** for R&D that accelerates the transition to EVs at Scale.

Cross-cutting wrap-up discussion and feedback gathering

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1:20 p.m. – 1:25 p.m. ET	**Wrap-up** *Jesse Bennett*
1:25 p.m. – 1:35 p.m. ET	**Addressing Biannual Meeting feedback** *FUSE Team*
1:35 p.m. – 2:00 p.m. ET	**Open-mic feedback** *Attendees*

Addressing Bi-Annual Meeting Feedback

- **Explore more VGI options, in addition to SCM**
  - Sandia has shared some of their progress and plans for a concentrated charging VGI approach
- **Broaden the scope of what will be managed**
  - Concentrated charging VGI analysis will shift charging spatially, as opposed to the temporal shifting from SCM controls
  - Energy analysis in FY23 will include M/HDV charging needs
- **Review current industry offerings and expand SCM analysis to include new capabilities**
  - SCM market review was conducted to determine demonstration options for measurement and verification (Day 2 Discussion)
  - Expanded SCM SCM controls will be pursued to accommodate LDV and M/HDV needs for EVs@Scale

Open-mic Feedback

- Open discussion for all attendees to share feedback with the FUSE Team on progress and next steps

EVs @ Scale

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Thank you!