Project ID# eems068
SMART Mortar Pillar

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Demonstrate Mobility Energy Productivity Benefit of Intelligent Electric Vehicle Infrastructure Design Using Agent-Based Models

Eric Wood
National Renewable Energy Laboratory
2019 Vehicle Technologies Office Annual Merit Review
June 11, 2019

Argonne NATIONAL LABORATORY
INL Idaho National Laboratory
BERKELEY LAB
OAK RIDGE National Laboratory
NREL NATIONAL RENEWABLE ENERGY LABORATORY

OVERVIEW

Timeline

- Project start date: January 2019
- Project end date: September 2019
- Percent complete: 30% complete

Barriers

- Availability of alternative fuels and electric charging station infrastructure
- Consumer reluctance to purchase new technologies
- Maintenance of local coalition effectiveness

Budget

- Total project funding
  - DOE share: $500k
    - Includes a total of $250k to ANL and LBNL
  - Contractor share: NA

Partners

- Argonne National Laboratory (ANL)
- Lawrence Berkley National Laboratory (LBNL)
- California Energy Commission

RELEVANCE

- Emerging urban mobility options are poised to fundamentally transform modern transportation systems in ways that cannot be understood without equally complex modeling approaches. Supply of and demand for various mobility options are effectively represented using agent-based models (ABMs) at ANL (POLARIS) and LBNL (BEAM).

- Parallel with new mobility options, electricity is predicted to become a significant source of transportation fuel in existing vehicle-based modes. NREL's Electric Vehicle Infrastructure Projection Tool (EVI-Pro) model projects consumer demand for various types of charging infrastructure.

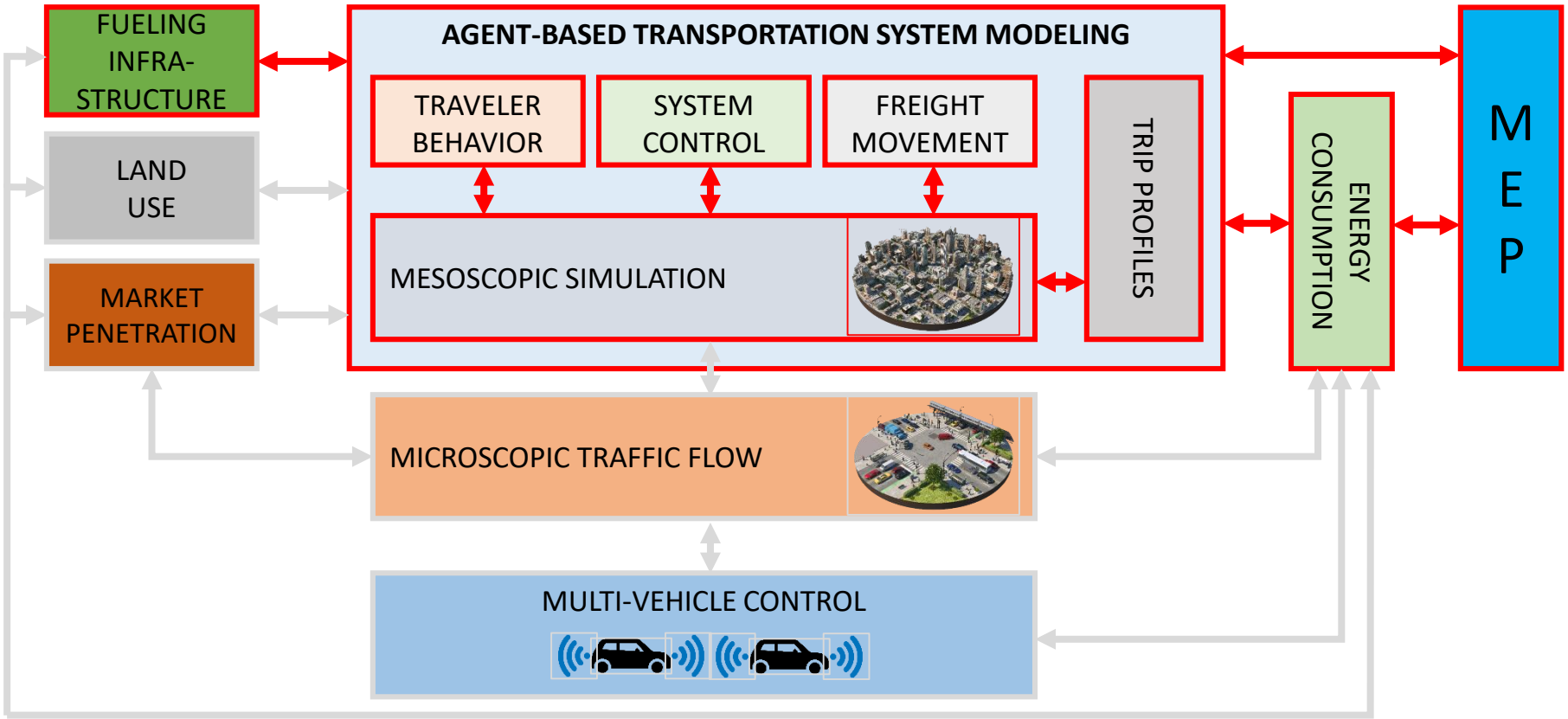
- Quantification of impacts from simultaneous introduction of new travel modes and electrification of existing ones presents a challenge to weigh the inherent tradeoffs between mobility, energy, and productivity. NREL's Mobility Energy Productivity (MEP) framework provides the necessary structured analytical approach to weight said costs and benefits.

- **This project leverages all these tools in a demonstration of the value of the SMART Modeling Workflow focused on MEP benefits of intelligent electric vehicle (EV) charging infrastructure design.**

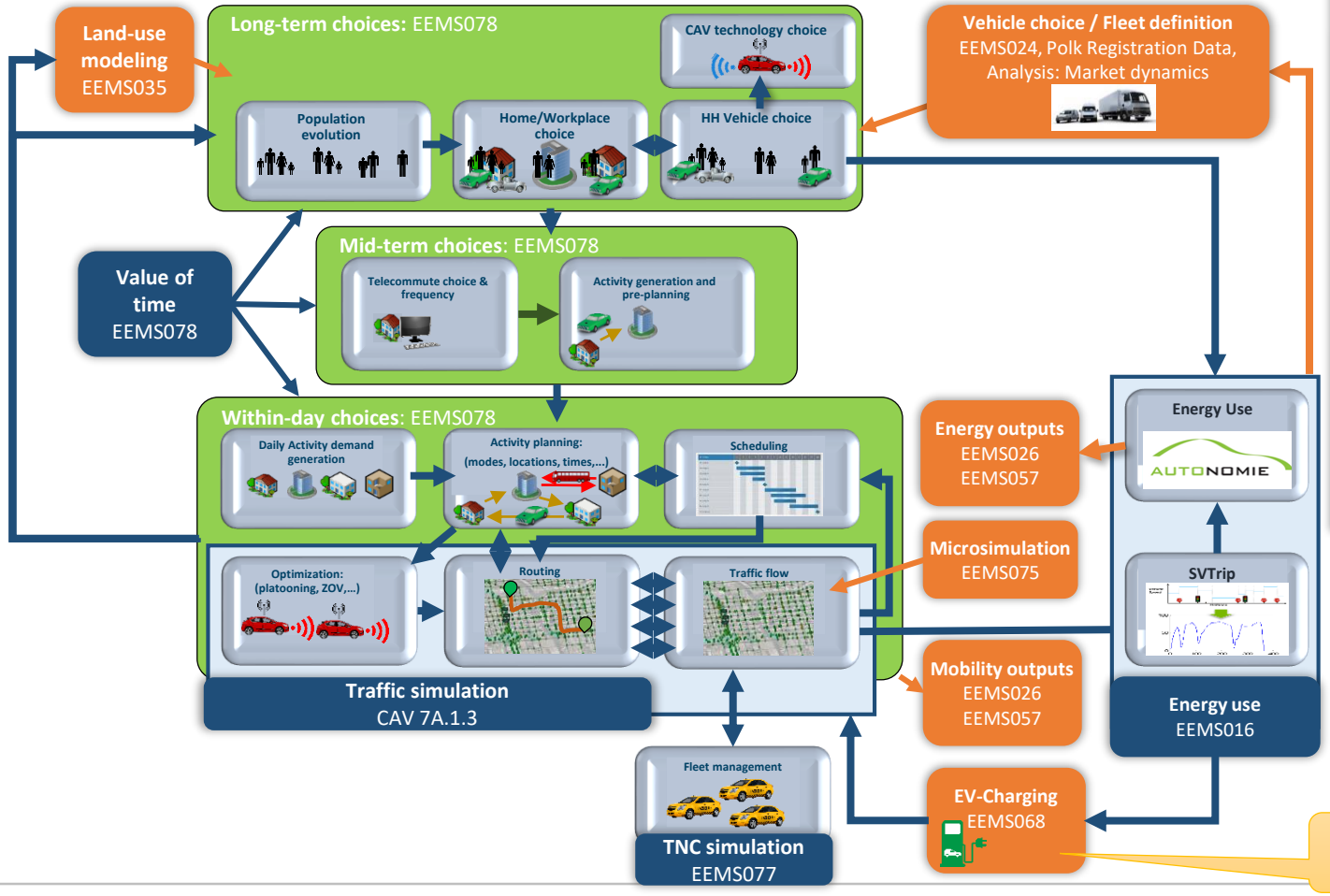
MILESTONES

Milestone Name/Description	Criteria	End Date	Type	Status
BEAM simulation results completed and delivered to NREL (LBNL)	An update presentation will be given to VTO	3/31/2019	Quarterly	Submitted
POLARIS simulation results completed and delivered to NREL (ANL)	An update presentation will be given to VTO	3/31/2019	Quarterly	Submitted
Charging infrastructure solutions simulated in EVI-Pro and delivered back to ABMs (NREL)	An update presentation will be given to VTO	6/30/2019	Quarterly	On Track
MEP benefits calculated and summarized for all mobility and infrastructure scenarios (NREL)	A draft report will be given to VTO summarizing approach and findings.	9/30/2019	Annual	On Track

END-TO-END MODELING WORKFLOW



POLARIS: AGENT-BASED ACTIVITY-TRAVEL SIMULATION MODEL SIMULATES REGIONAL MOBILITY



Polaris Highlights:

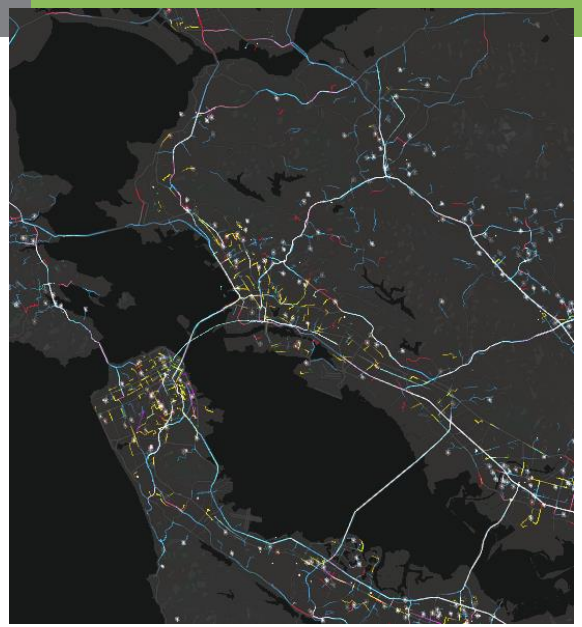
- Simulate **regional** mobility
- Provides detailed travel information by each **agent**
- Fully **integrated** demand, dynamic traffic assignment, and simulation
- Integrated with **energy** model for regional energy analysis
- **Open-source** C++ for Windows/Linux
- Supports **high-performance computing (HPC)**
- 4-8 hr for 10M agents

Inputs from:	EEMS016, EEMS023, EEMS024, EEMS035, EEMS075
Used in:	EEMS013, EEMS017, EEMS058, EEMS060, EEMS077,EEMS078
Outputs to:	EEMS026, EEMS035, EEMS057, **EEMS068**

Focus of this project

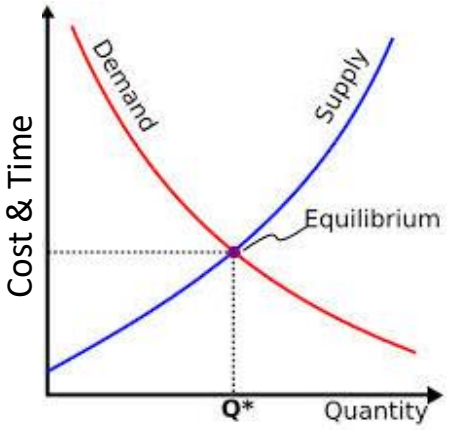
TNC: transportation network company

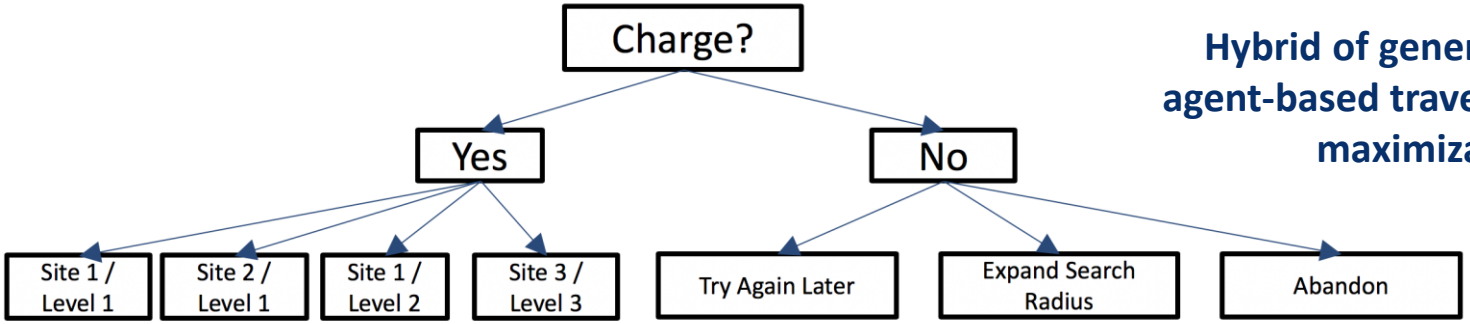
Agent-Based Modeling in San Francisco using BEAM



BEAM Model (Behavior, Energy, Autonomy, Mobility): A core capability developed for VTO's SMART Mobility Research

A virtual environment to assess energy dynamics of transportation systems with traveler mode choice and penetration of vehicle automation, sharing, & electrification





Hybrid of generalized equilibrium, agent-based travel demand, and utility maximization models

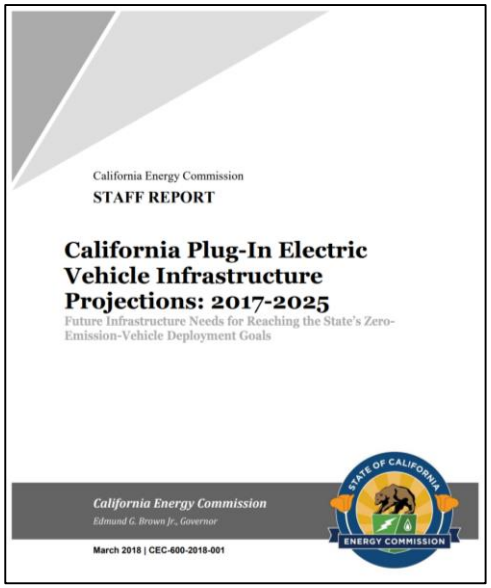
Embedded discrete choice models in an ABM where preferences for emerging technologies impact system performance

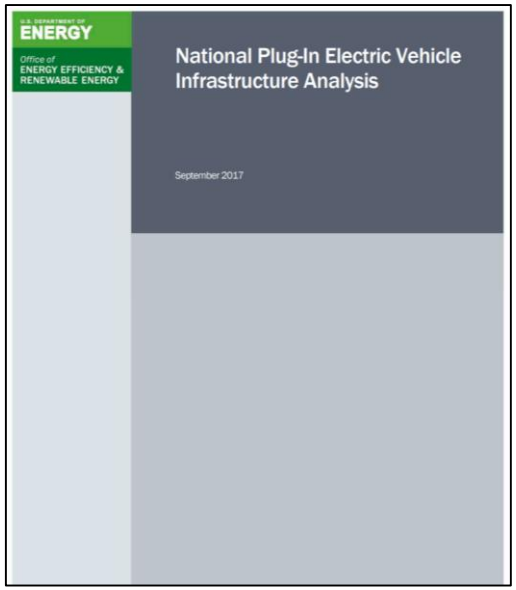
Estimating Charging Infrastructure Needs using EVI-Pro

While calculating coverage requirements is fundamentally a geographic problem, estimating consumer demand for charging infrastructure requires a more sophisticated approach.

- NREL has developed the **EVI-Pro Tool** in collaboration with the California Energy Commission to estimate consumer demand for charging infrastructure.
- EVI-Pro is a bottom-up plug-in electric vehicle (PEV) driving/charging simulator that leverages real-world travel profiles and assumes economically efficient charging behavior with the majority of charging occurring at residential locations (subject to user input).

EVI-Pro

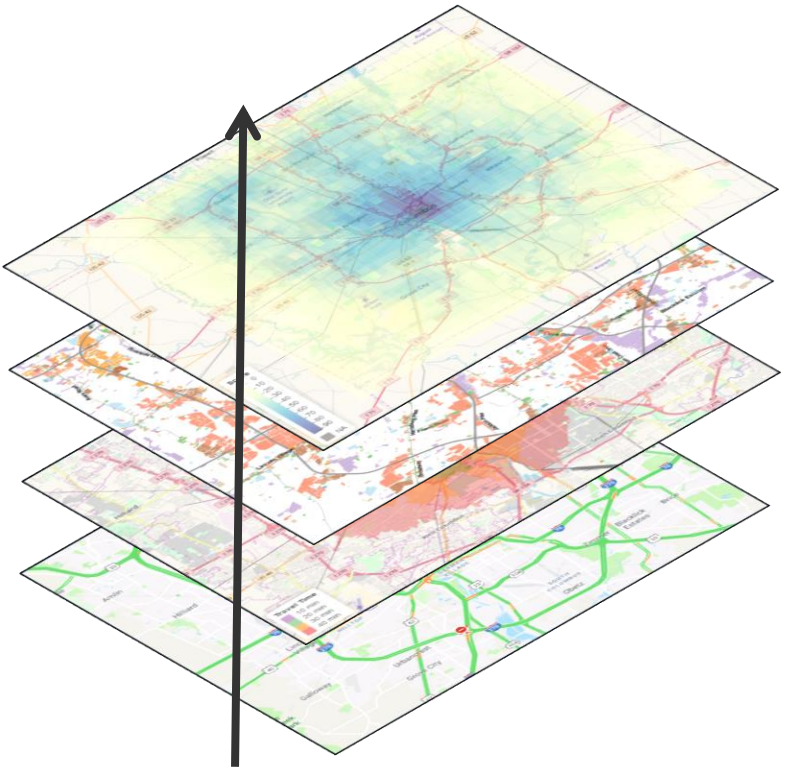




Quantifying Mobility Energy Productivity (MEP)

Mobility: The quality of a network or system to connect people to goods, services, and employment that define a high quality of life.

MEP = *F* (mobility weighted by [time, energy, cost, trip purpose])

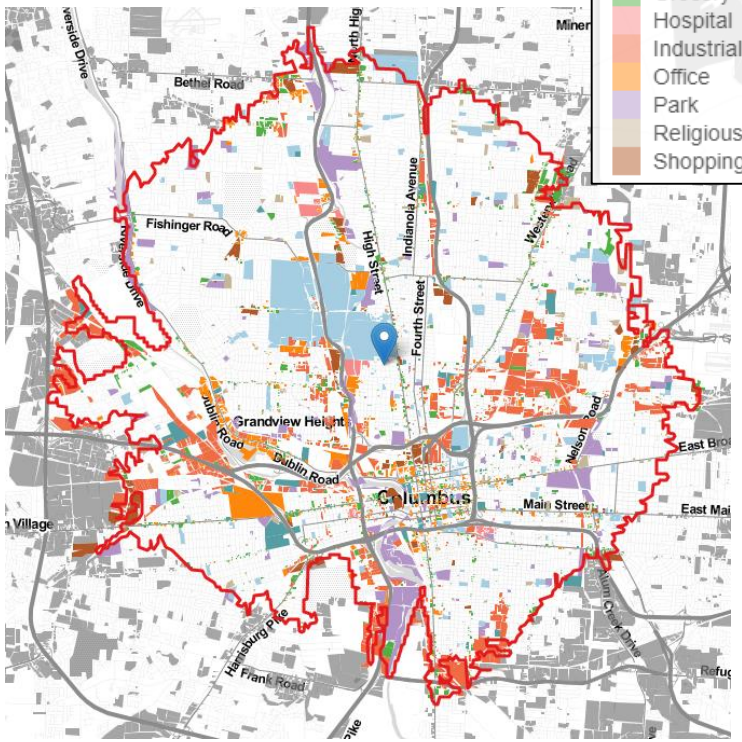


Mobility

Land use

Travel time
(various modes)

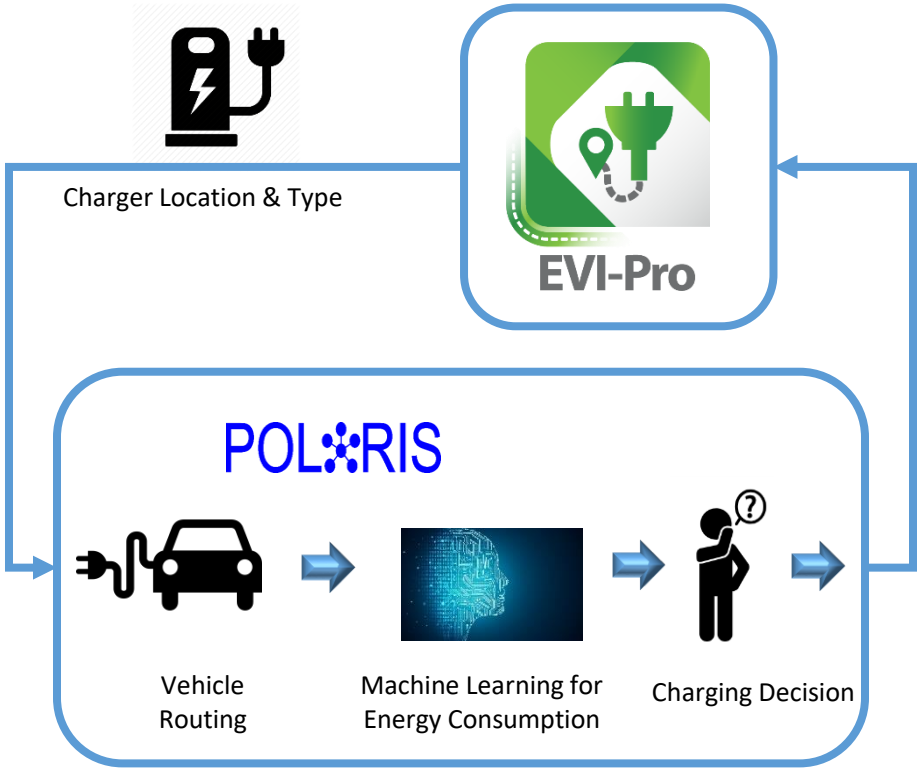
Locations

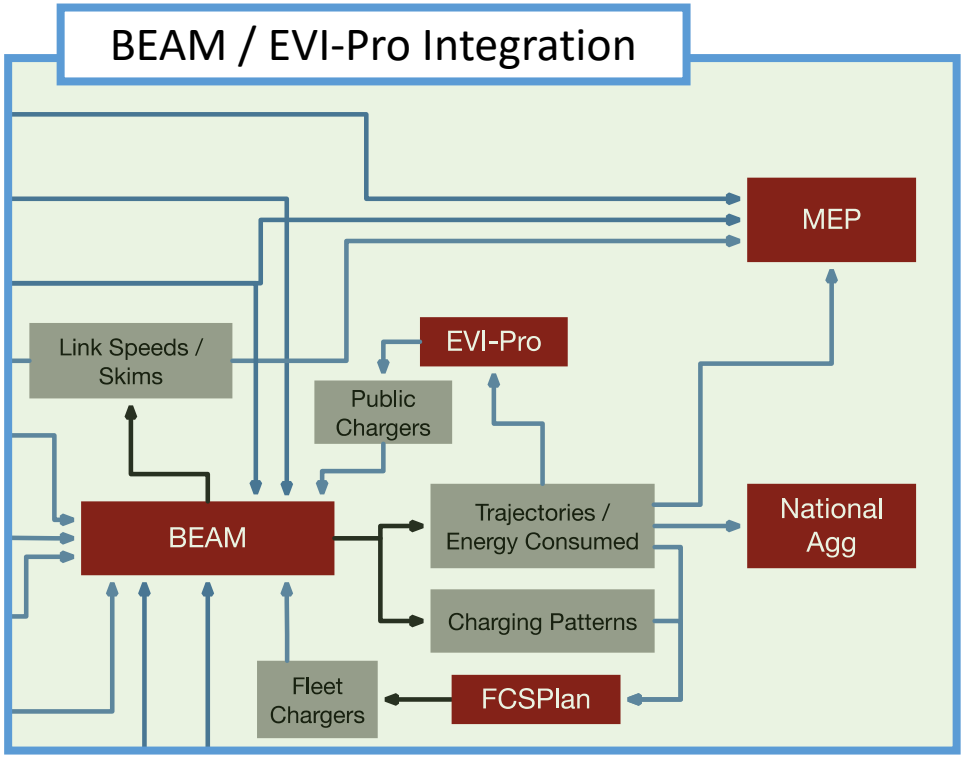


Model Integration

Functionally equivalent EVI-Pro integration pathways for POLARIS and BEAM

- Both approaches invoke unconstrained charging infrastructure simulation in an ABM
- EV demand is provided for spatial/temporal aggregation in EVI-Pro
- Constrained charging network is provided back to ABM in an iterative process





Accomplishments: Scenario Generation

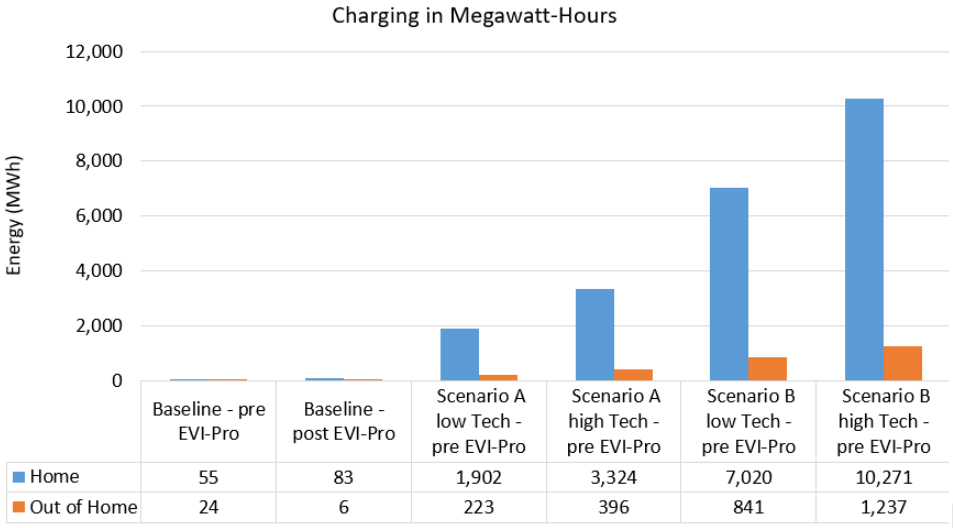
In alignment with the overall SMART Workflow, scenarios within this mortar task utilize a common set of scenarios for light-duty vehicle stock

The table shows EV stock assumptions for all scenarios, including estimates for residential charging availability as a function of PEV adoption level

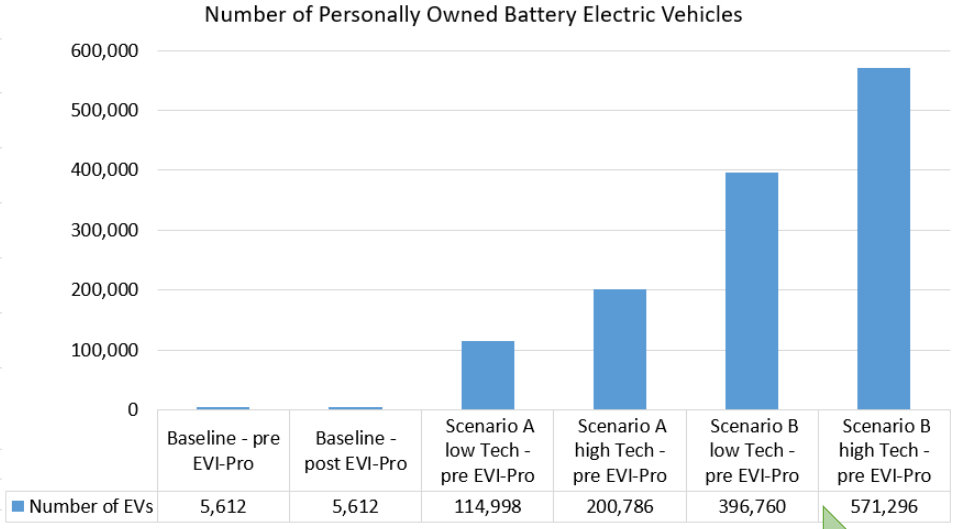
Scenario	Alias	Time Frame	VTO Tech Level	PEV Stock Share	BEV Share (% of PEVs)	% PEVs w/ Home EVSE
Baseline	Baseline	Present Day	Low Tech	0.2%	50.0%	99.0%
A: High Sharing, Low Automation	"Sharing is Caring"	Near Term	Low Tech	7.0%	57.1%	92.0%
			High Tech	12.0%	58.3%	88.0%
B: High Sharing, High Automation	"Technology Takes Over"	Long Term	Low Tech	25.5%	70.6%	80.0%
			High Tech	50.5%	77.2%	75.0%
C: Low Sharing, High Automation	"All About Me"	Long Term	Low Tech	25.5%	70.6%	80.0%
			High Tech	50.5%	77.2%	75.0%

Multiple EV charging networks are deployed within each EV adoption scenario based on EVI-Pro simulations driven by ABM unconstrained demand profile

Accomplishments: POLARIS + EVI-Pro
Aggregate Charging Metrics by Scenario

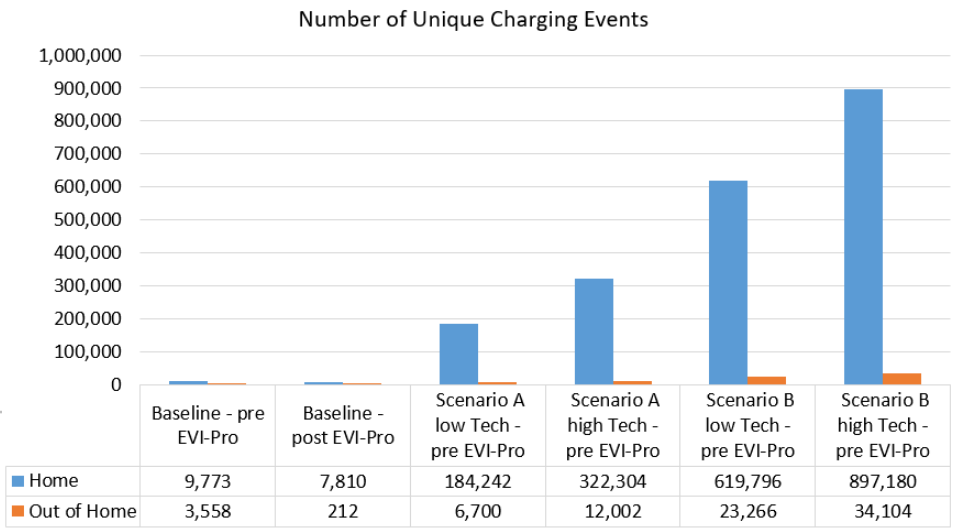


	Baseline - pre EVI-Pro	Baseline - post EVI-Pro	Scenario A low Tech - pre EVI-Pro	Scenario A high Tech - pre EVI-Pro	Scenario B low Tech - pre EVI-Pro	Scenario B high Tech - pre EVI-Pro
Home	55	83	1,902	3,324	7,020	10,271
Out of Home	24	6	223	396	841	1,237

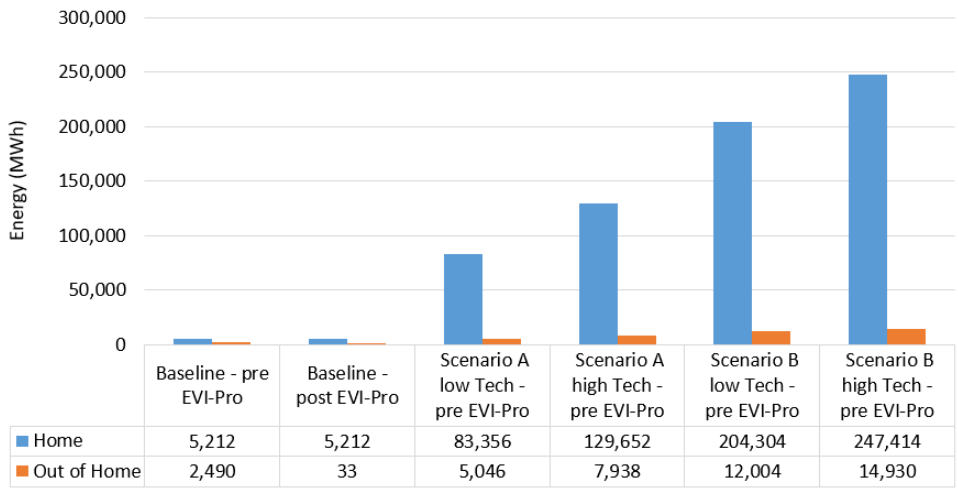


	Baseline - pre EVI-Pro	Baseline - post EVI-Pro	Scenario A low Tech - pre EVI-Pro	Scenario A high Tech - pre EVI-Pro	Scenario B low Tech - pre EVI-Pro	Scenario B high Tech - pre EVI-Pro
Number of EVs	5,612	5,612	114,998	200,786	396,760	571,296

Hypothetical Chicago Charging Networks Simulated in POLARIS w/ Increasing Numbers of EVs & Reliance on Public Charging

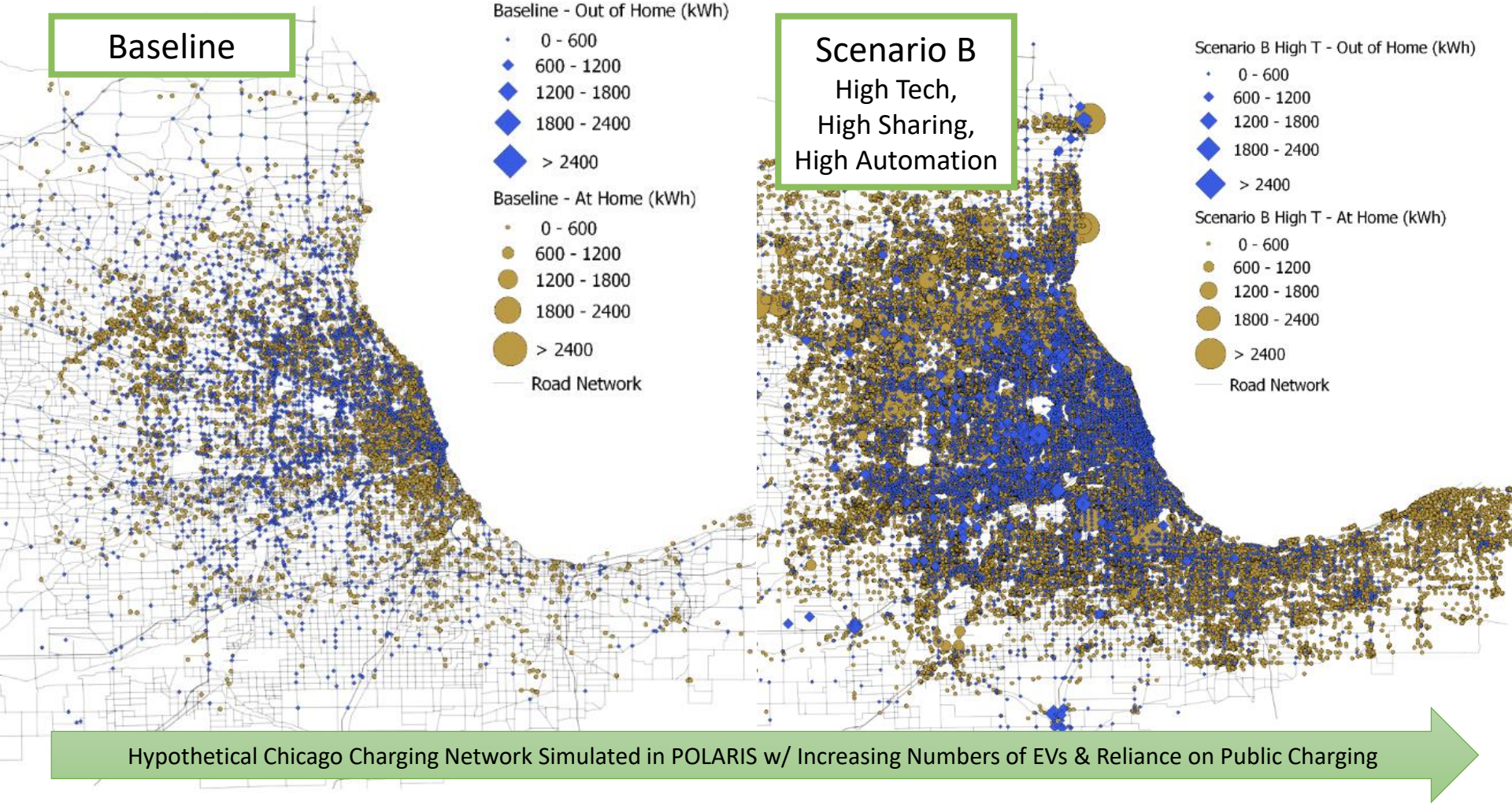


	Baseline - pre EVI-Pro	Baseline - post EVI-Pro	Scenario A low Tech - pre EVI-Pro	Scenario A high Tech - pre EVI-Pro	Scenario B low Tech - pre EVI-Pro	Scenario B high Tech - pre EVI-Pro
Home	9,773	7,810	184,242	322,304	619,796	897,180
Out of Home	3,558	212	6,700	12,002	23,266	34,104



	Baseline - pre EVI-Pro	Baseline - post EVI-Pro	Scenario A low Tech - pre EVI-Pro	Scenario A high Tech - pre EVI-Pro	Scenario B low Tech - pre EVI-Pro	Scenario B high Tech - pre EVI-Pro
Home	5,212	5,212	83,356	129,652	204,304	247,414
Out of Home	2,490	33	5,046	7,938	12,004	14,930

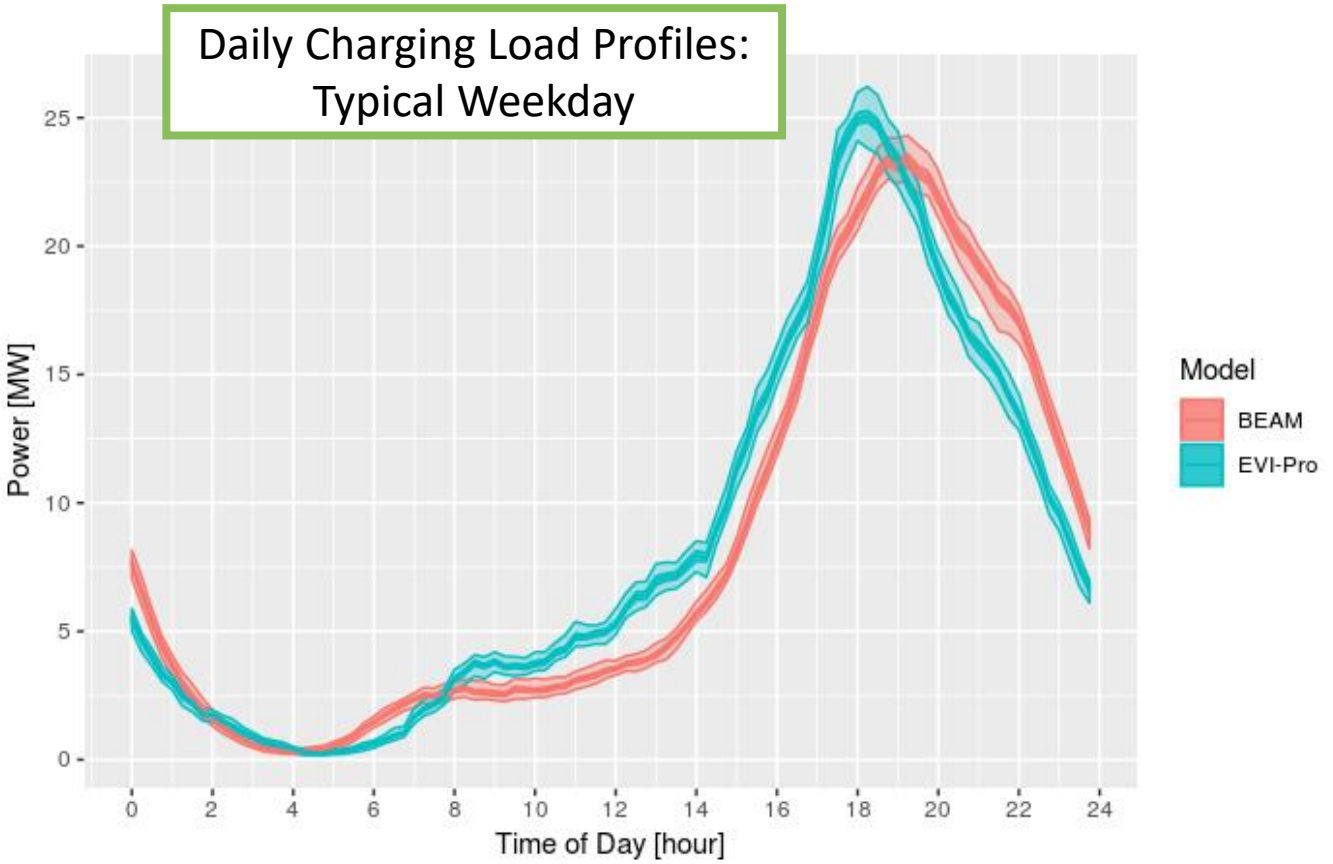
Accomplishments: POLARIS + EVI-Pro
Spatial Distribution of Charging by Type



Hypothetical Chicago Charging Network Simulated in POLARIS w/ Increasing Numbers of EVs & Reliance on Public Charging

Accomplishments: BEAM + EVI-Pro

- Charging load profiles from EVI-Pro were contrasted with the BEAM model using functionally equivalent scenarios
- A high degree of similarity in charging behavior and aggregate load profiles was observed
- Demonstrates consistency in BEAM and EVI-Pro charging behavior models (despite disparate approaches)
- LBNL and NREL are continuing to collaborate on development/refinement of charging behavior algorithms within BEAM



RESPONSES TO PREVIOUS YEAR'S REVIEWERS COMMENTS

- This is a new project funded in FY19 and was not presented at the 2018 Annual Merit Review.

COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

- This project has benefited from inter-lab collaboration between NREL, ANL, and LBNL.
- Due to the early stages of this project, no formal external collaborations have been established.
  - However, interest from a number of organizations (including automotive manufacturers, electric utilities, and state agencies) has been expressed and informal conversations are ongoing.

REMAINING CHALLENGES AND BARRIERS

- This project was originally planned for 12 months (FY19) and has since been compressed to 9 months. All three labs will need to remain diligent in communicating status and delivering results on time to ensure success by the end of FY19.

- Adoption of EVs by residents of multi-unit dwellings remains an area of uncertainty. This project is coordinating with ongoing work at NREL supported by VTO-Analysis exploring residential charging availability as a function of EV market share and multi-unit dwelling adoption.

- Scarce real-world data on charging behavior of long-range battery EVs exist. Calibration of charging behavior algorithms in BEAM, POLARIS, and EVI-Pro will need to be coordinated using common sets of assumptions and exploring uncertainty using sensitivity analysis.

PROPOSED FUTURE RESEARCH

POLARIS + EVI-Pro

COMPLETE

1. Every single vehicle, including EVs, is simulated in POLARIS.
2. EV energy consumption is modeled during the simulation using a Machine Learning (ML) model.
3. Based on the state-of-charge (SOC), EV drivers schedule and implement a charging event at a nearby station.
4. EVs also charge at home.

IN-PROGRESS

1. Using Idaho National Lab data, the initial (beginning of the day) SOC is drawn from a distribution.

BEAM + EVI-Pro

COMPLETE

1. BEAM model developed and calibrated to simulate full work flow scenarios
2. BEAM simulated assuming unrestricted battery capacity in EVs
3. Outputs delivered to NREL

IN-PROGRESS

1. EVI-Pro analysis of EV trajectories is used to site public infrastructure
2. BEAM simulated with infrastructure portfolio and EV batteries set to have restricted capacities
3. Further iteration if necessary after analysis of BEAM results

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

SUMMARY

Relevance

- Significant investments are currently being made in PEV charging infrastructure
- These investments are occurring in parallel with evolution of urban mobility

Approach

- Integrate EVI-Pro with POLARIS and BEAM to estimate infrastructure requirements and impacts on MEP

Technical Accomplishments and Progress

- POLARIS has undergone significant capability enhancements to accurately represent EV energy consumption using machine learning and represent EV charging (residential and public)
- Initial data have been exchanged between POLARIS and EVI-Pro to generate a hypothetical charging network for the work flow Baseline Scenario (additional scenarios in progress)
- BEAM/EVI-Pro charging behavior logic has been compared with a high degree of similarity (additional refinement in progress)
- BEAM has delivered WF Scenario simulation results to EVI-Pro (network design at NREL in-progress)

Collaboration

- Informal conversations underway; seeking additional collaboration/coordination

Proposed Future Research (depending on future funding)

- Additional ABM simulations and EVI-Pro network designs in-progress
- Integration of MEP calculations and sensitivity analysis of various network designs

QUESTIONS?