Project ID: EEMS012

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Modeling and Analysis of Plug-in Electric Vehicle Charging Infrastructure Supporting Shared Mobility

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U.S. Department of Energy Vehicle Technologies Office
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June 8, 2017

Argonne National Laboratory · INL Idaho National Laboratory · Berkeley Lab · Oak Ridge National Laboratory · NREL National Renewable Energy Laboratory

Project Overview

Timeline

- Project start: Oct. 2016
- Project end: Sept. 2019
- Completion: 20%

Budget

	FY17	Total
INL	$210K	$800K
ANL	$210K	$670K
NREL	$200K	$765K
ORNL	$50K	$395K

** Funding amount by lab is for this task only, not for the entire pillar*

Barriers

- Infrastructure has long been a major barrier to alternative fuel vehicle (AFV) adoption
- Need cost-effective fueling infrastructure to support energy efficient shared mobility applications
- Limited understanding on energy impacts of shared mobility applications

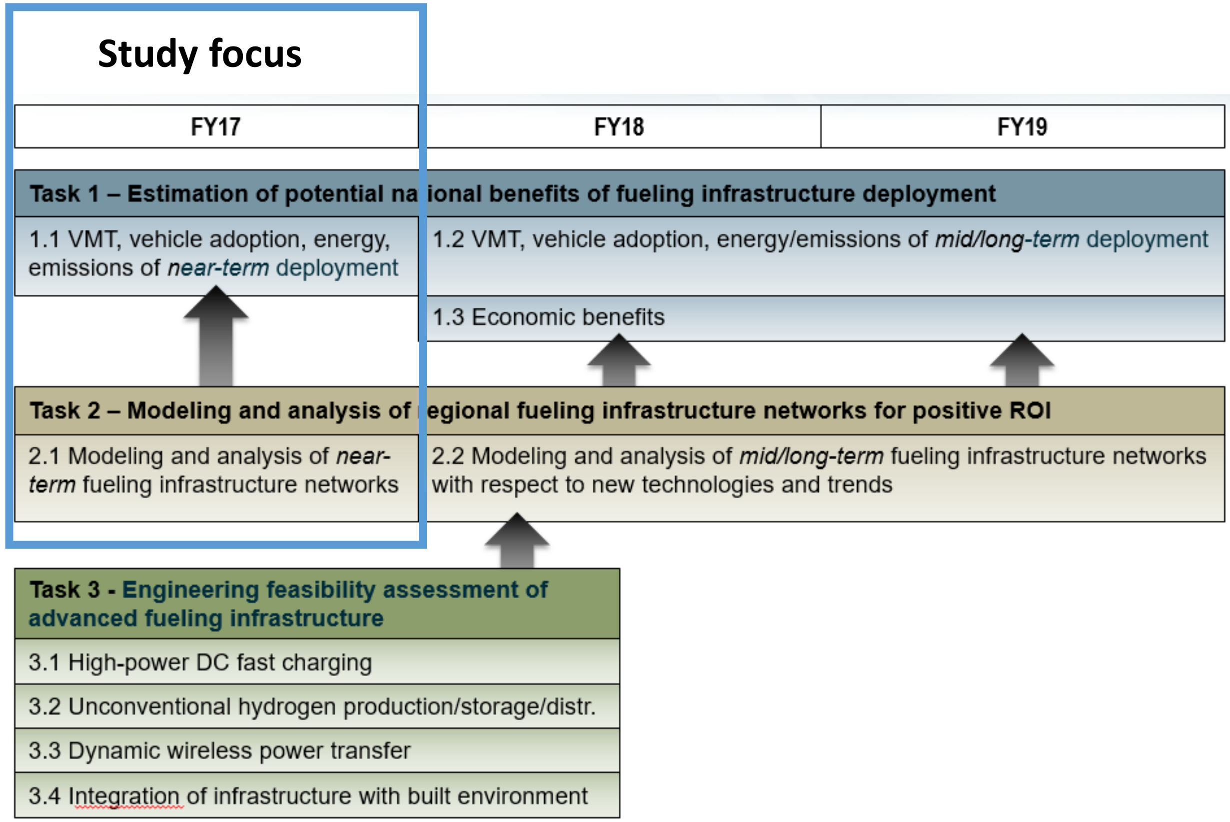
Partners

Argonne National Laboratory; Idaho National Laboratory; Oak Ridge National Laboratory; NREL National Renewable Energy Laboratory

Project Overall Objectives/Relevance

Task 1 and 2 under Advanced Fueling Infrastructure Pillar

- ❑ Design fueling infrastructure networks to meet the needs of the future transportation system and assess the national energy and economic benefits
- ❑ FY17 focus on **near term, intra-city charging** infrastructure for **shared** vehicles without full automation



Task Objectives/Relevance

- **Task 1:** Estimate national energy and GHG impacts of near-term AFV infrastructure deployment to support intra-city travel based on regional results
- **Task 2:**
  - Use advanced tools to model near-term charging infrastructure deployment in 3 regions (Columbus, OH; Texas Triangle; Seattle, WA) supporting **intra-city car/ride-sharing** fleets
  - Consider the cost for both drivers and service providers

CAV
- MaaS and CAV penetration rate
- Charging decision

MDS
- Charging behavior

MM
- Freight demand

CAV
- Infrastructure location
- National fuel mix by year

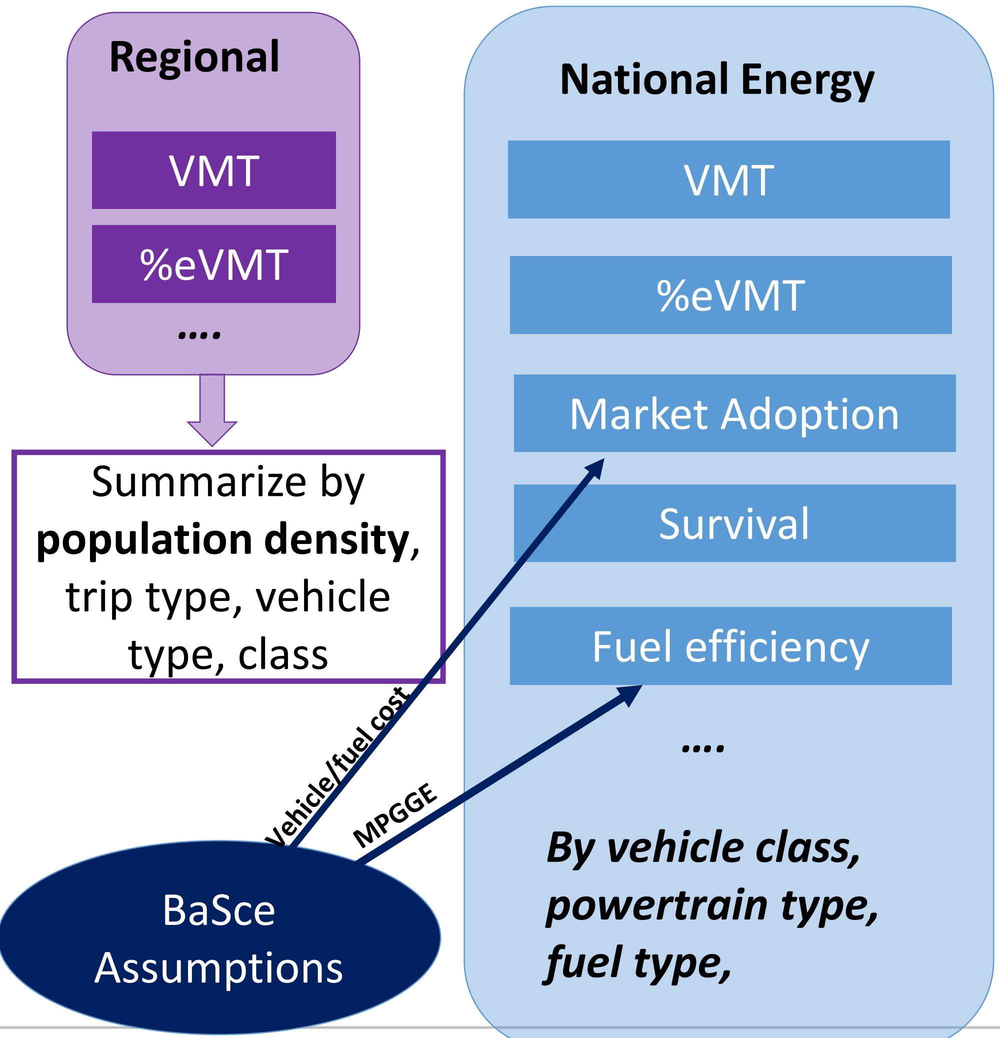
MDS and MM
- Infrastructure location

CAV: connected and automated vehicle,
MDS: mobility devision science, MM: multi-modal

Schedule/Milestones

Year	Q	Quarterly Milestone	Progress
FY17	Q1	Identify geographic areas for study and external partners.	Completed
	Q2	Complete design of revenue/cost model framework for infrastructure deployment planning.	Completed
	Q4	For selected regions, complete near-term infrastructure planning analysis supporting inter-city travel of privately-owned light duty vehicles and intra-city car/ride-sharing fleets.	In Progress

Overall Approach



- **Identify short-term market potential of shared mobility**
  - Types of shared mobility
  - # of shared vehicles vs. population density
- **Analyze travel survey data and model EVSE demand**
  - Types of trips could be shared
  - Maximum eVMT with infrastructure support
- **Model EVSE Return of Investment (ROI)**
- **Extrapolate from regional to national**

BaSce: Prospective Benefits Assessments of Vehicle Technologies, Argonne

Approach for Analyzing Infrastructure Impacts on Electric Vehicle Market Share and Energy Use

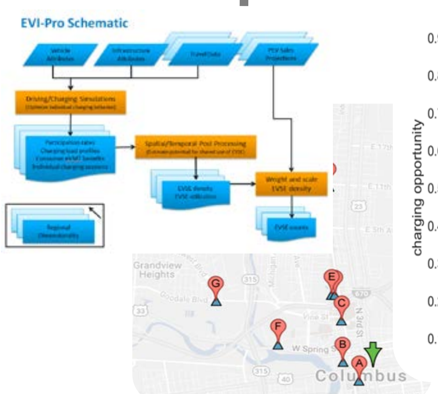
Charging Infrastructure Scenarios
- Locations of Charging Stations
- Number of chargers per station

Charging Opportunity
- Probability of finding a charging station at a stop

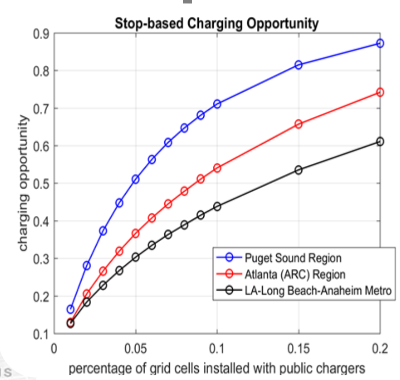
Extended Electric Vehicle Range
- Recharging at charging stations can extend electric vehicles' range

Vehicle Market Share
- Sale & Fleet Size: SI/CI/HEV/ PHEV/BEV

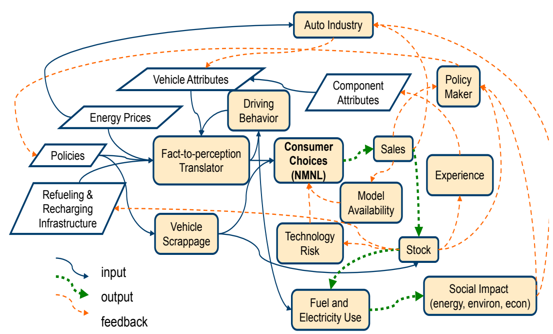
Energy Use & VMT by Fuel, vehicle Type
- Energy use by fuel type
- GHG
- VMT and eVMT



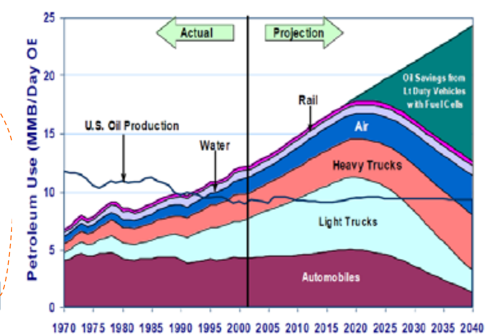
EVI-Pro Model



Charging opportunity Model



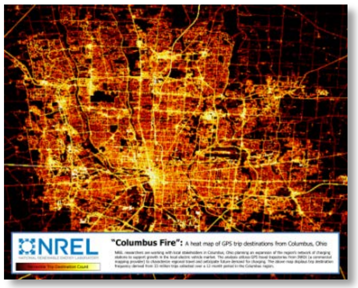
MA3T Model



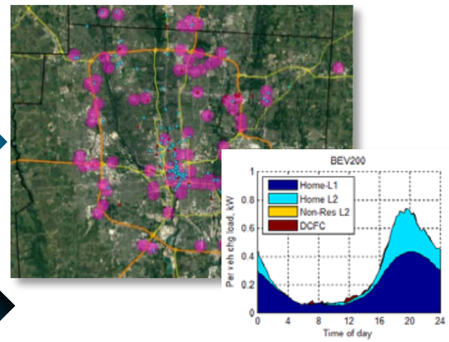
VISION Model

Demand/Cost Modeling Framework for Regional Infrastructure Planning

Driving/parking data (NREL, INL)



Simulated charging station demand (NREL)



(INL)

Revenue scenarios

- $ per session
- $ per kWh
- $ per hour
- Alternative revenue sources (ads, concessions, etc.)

Revenue estimation

Charging site Selection (NREL)

(INL)

Installation cost = f($X_1 \ldots X_5$)

- **X_1: Electrical service upgrades required or not**
- **X_2: Aboveground or underground service**
- **X_3: Surface condition**
- **X_4: Size of trenching or boring required**
- **X_5: Distance from the power source**

(ANL, INL)

Operating cost

- Operators' utility rate structure
- Operators' electricity consumption and demand
- Other costs (warranty, data, maintenance, etc.)

Cost estimation

Iterate to develop fueling infrastructure network siting plan that serves driver demand and is financially sustainable

Summary of Technical Accomplishments

Developed approach for 1) analyzing infrastructure impacts on electric vehicle market share and energy use, and 2) modeling demand/cost framework

Task 1

- Identified three types of sharing: **car-sharing, ride-hailing, ride-sharing,** each one has different impacts on VMT, vehicle ownership and fleet turnover
- Work/home trips have greater VMT reduction potential if shared, however, such potential varies by population density
- MA3T: Bridged the gap between infrastructure deployment and charging opportunity information

Task 2

- Identified cost drivers of DC fast charger installation
- Identified inputs to charge rate structure of a utility company to various customers
- Developed framework for synthesizing shared mobility data from GPS trajectories

Three Types Of Sharing Has Different Impacts On Energy Consumption

Energy consumption are affected by ownership, mileage, fleet turnover rate

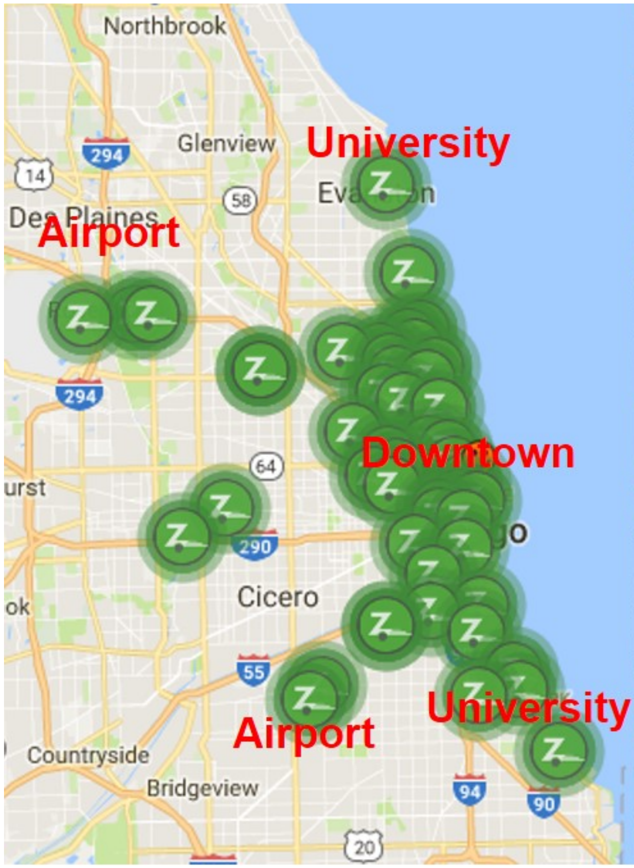
- ❑ **CAR-SHARING**: short-term rental, involves use of a vehicle that may be fleet-owned or privately owned. E.g. Car2Go, Zipcar
- ❑ **RIDE-SHARING**: also known as carpooling and often happen peer-to-peer, involves two or more people utilizing shared transportation to reduce costs, emissions and fuel use. E.g. WazeRider/Carpool
- ❑ **RIDE-HAILING**: encompasses traditional taxi services and non-licensed services. E.g. Uber, Lyft

Mobility Type	Transaction Type (charge per)	Trip Type	Impacts on		
			Ownership	VMT (fixed demand)	Fleet Turnover
Car Sharing	minute or hours	unscheduled	↓	Not much	Not much
Ride Sharing	mile	Fixed, regular	Not much	↓	Not much
Ride Hailing	mile	unscheduled regular trips	↓	↓	↑

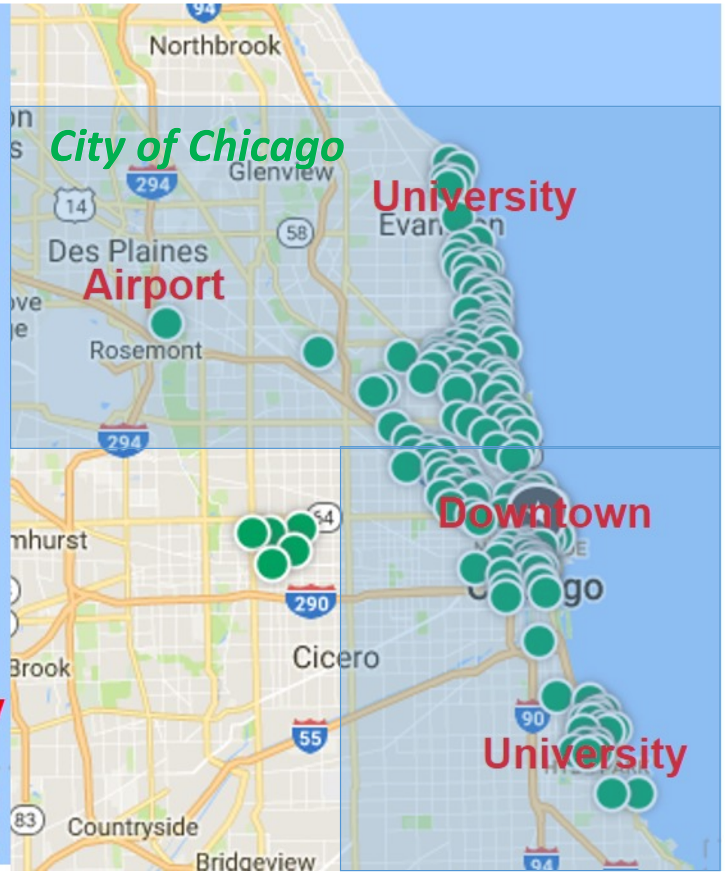
Car Sharing Services Heavily Focus On Downtown>Universities>Airport

Chicago: Zipcar and Enterprise CarShare

Most of the cars are in garage, where it's relatively easier to install EVSE
Some of them are on the streets



Zipcar



Enterprise

Chicago:

850+ vehicles
Zipcar

About 200 vehicles
Enterprise CarShare

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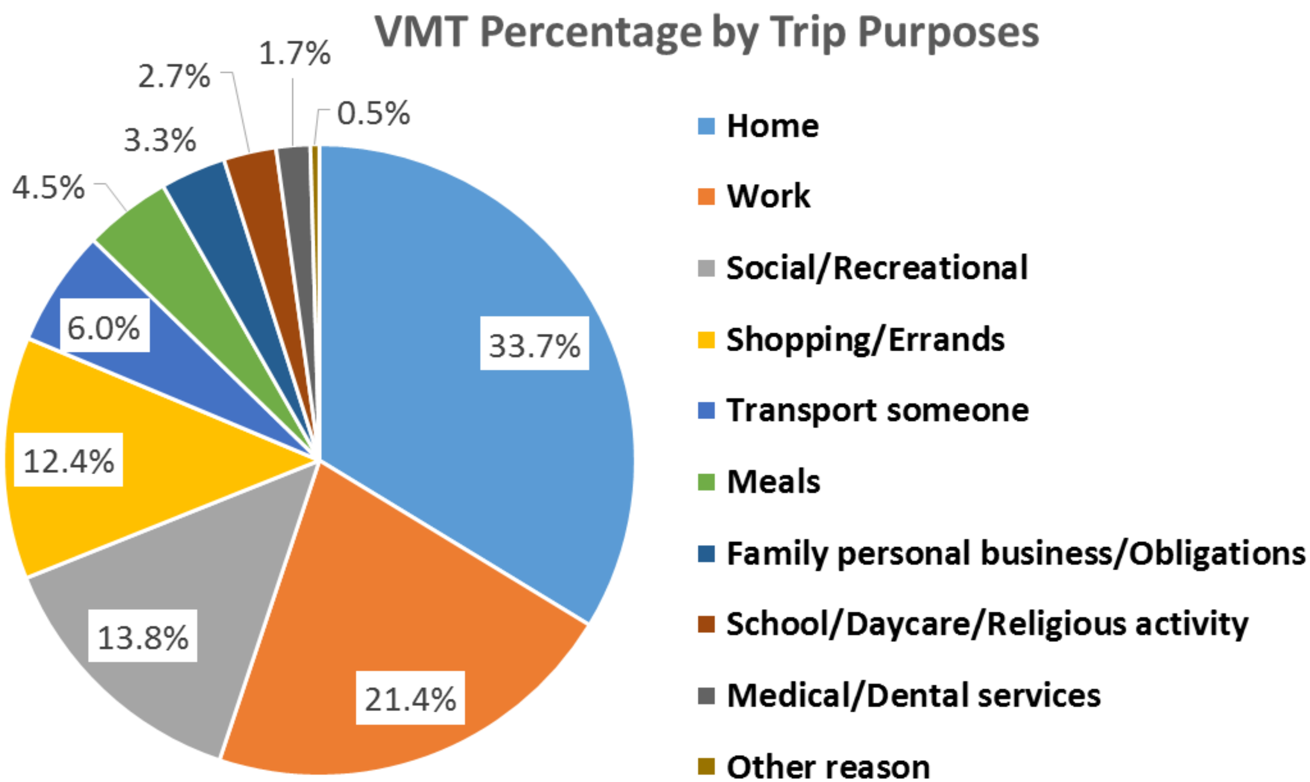
Infrastructure Electrifying Home and Work Related Miles Have Greater Potential Energy Reduction With Sharing

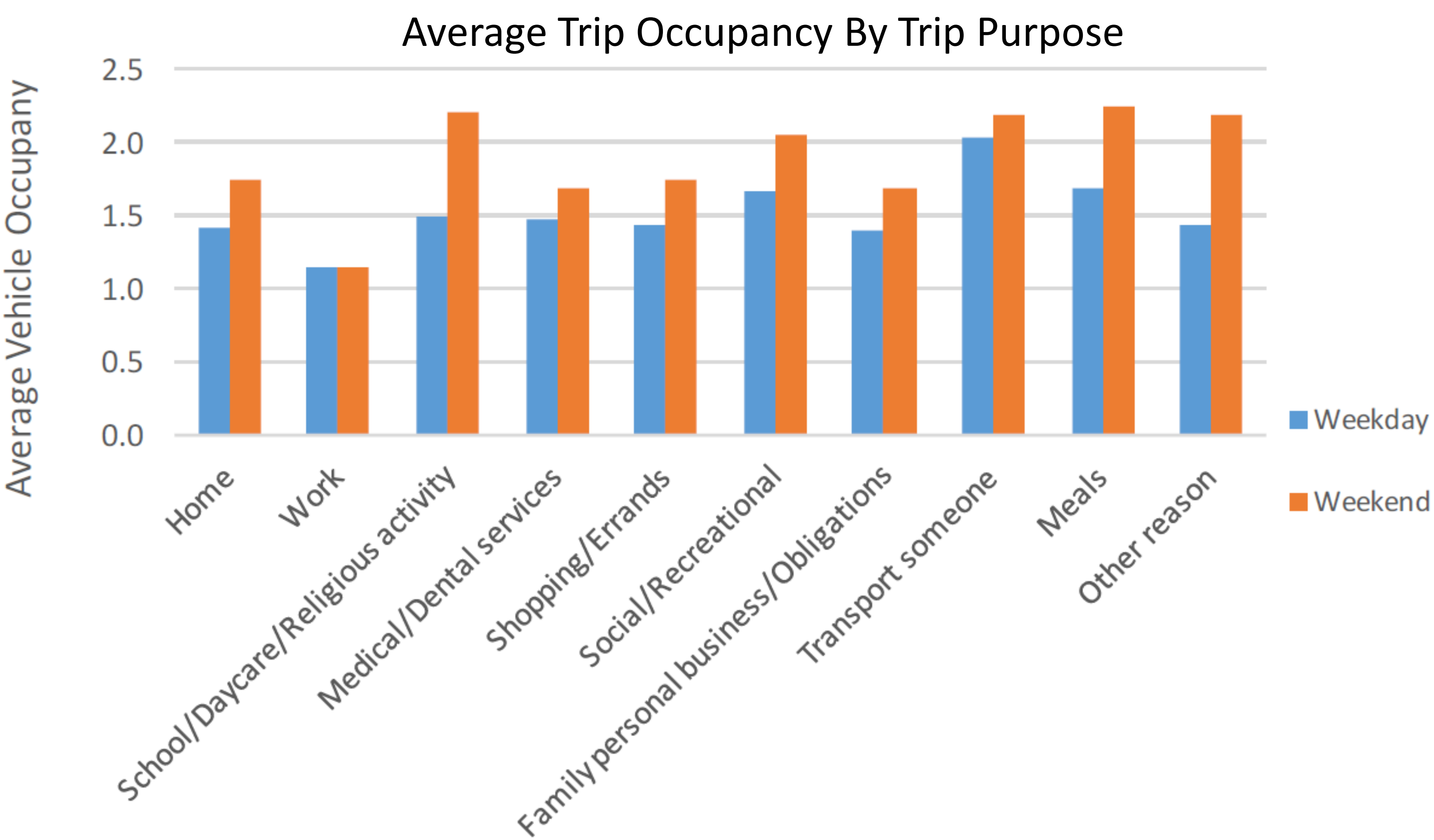
Home and work trips have lower occupancy rate than other trip types



2009 National Household Travel Survey

Infrastructure Electrifying Home and Work Related Miles Have Greater Potential Energy Reduction With Sharing

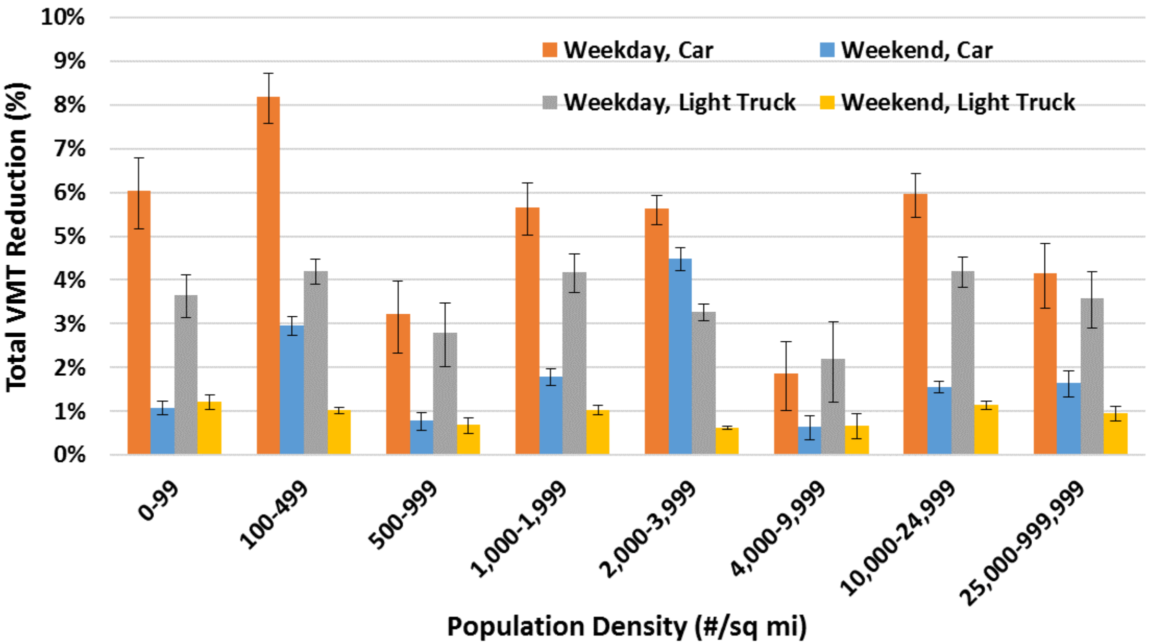
Home and work trips have lower occupancy rate than other trip types



2009 National Household Travel Survey

Work Related VMT Could Be Reduced By 4-8% In Weekdays
Estimates based on National Household Travel Survey

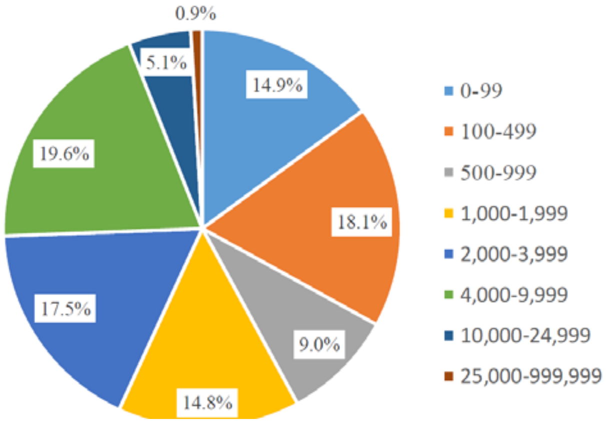
If we increase occupancy rate by 20% - 90% based on population density



% represents reduction of the total VMT of each population and vehicle type group (e.g. 6% total reduction of all weekday car travel by drivers in 0-99 density group)

However, dense areas have much less work VMT on private vehicles

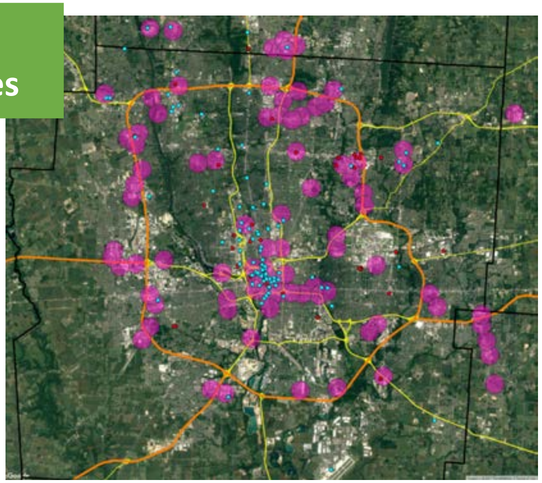
Weekday Work VMT (%) by Population Density



Developed Framework For Rescheduling Movements Of Personally Owned And Operated Vehicles To Emulate Shared Mobility Services

- ❑ Modeling advanced fueling infrastructure requires spatially-resolved knowledge of vehicle activity patterns
- ❑ Developing algorithms to synthesize shared mobility vehicle trajectories from personal vehicle GPS trajectories to simulate EVSE charger demand and locations
- ❑ Project EVSE demand and location considering sharing and cost

Real-world travel profiles



Rescheduling algorithms to emulate car sharing, ride sharing, or ride hailing

Car-sharing preliminary results: scenario 1.i)

1.i) Free floating scenario w/o relocation and unlimited size fleet

Table 1.1 Synthetic Austin TX car-sharing trip results (*1363 trips-231 drivers*)

	Personal car	Shared Car synthetic data *y*=0.1 miles	Shared Car synthetic data *y*=0.25 miles	*acceptable walking distance
Total Vehicle Count	231	296	333	
Trip Count	1363 (constant in all cases); avg. trips per person 5.9			
Avg VMT per person	22.27 (constant in all cases)			
% car-sharing trips	0	43.8%	53.41%	*of trips that are used by drivers in car-sharing
Car sharing vehicles	0	153	212	*used by individuals who are not operating personal cars
Users of car share	n.a.	88	110	*of all drivers population
Avg # users/shared car/per day	n.a.	1.32	1.31	*of single occupancy car/day
Avg VMT/shared car/day	n.a.	12.93	11.39	*refer to total avg. VMT/day
Avg VMT/personal car/day	22.27	22.71	22.84	
Avg shared car VMT/trip	n.a.	3.49	3.39	*refers to avg. VMT/trip
Avg personal car VMT/trip	3.78	4.00	4.20	

Data sources: Transportation Secure Data Center. (2017). National Renewable Energy Laboratory. Accessed February 15, 2017: *www.nrel.gov/tsdc*.

Preliminary Results

Collaboration

- DOE's SMART Mobility Laboratory Consortium: ANL, INL, ORNL and NREL
- Engaging shared mobility and AFV fueling infrastructure service providers to develop industry partnerships (e.g. ReachNow, ChargePoint)
- Purchased INRIX GPS travel data
- Leveraged work:
  - NREL Columbus infrastructure assessment
  - INL charging site cost work
  - Argonne BaSce analysis assumptions

Remaining Challenges and Barriers

- Data availability and quality: challenges for all models and analysis
  - Travel demand with shared mobility
  - EVSE usage data of shared vehicles
  - Infrastructure installation cost data

- Modeling methodologies
  - Modification of public charging opportunity definition (DCFC only, previously defined as a mix of L1, L2, and DCFC) for BEVs in MA3T
  - Potential data transfer inconsistency between EVI-Pro, MA3T, and VISION
  - Fundamental EVI-Pro assumption: Consumers prefer to maximize eVMT and minimize operating cost (real vs. perceived)
  - EVI-Pro home dominant charging preference for simulated consumers with economically efficient behavior

Planned/Proposed Future Work

FY17

- ❑ Convert regional charging infrastructure demand to charging availability/opportunity used in MA3T and analyze market adoptions
- ❑ EVSE demand modeling with EVI-Pro application to synthetic car/ride-sharing trip datasets
- ❑ Design cost efficient EVSE network for the three identified regions
- ❑ Estimate national energy and emissions impacts based on regional results

FY18/19

- ❑ Design fueling infrastructure for energy efficient shared-automated fleets using various fuels
- ❑ Estimate market penetration of shared-automated vehicles using different fuels, based on cost/benefit analysis of vehicle and infrastructure technologies for shared-automated fleet applications

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

Summary

- Objective of this project is to design fueling infrastructure for energy efficient shared-automated fleets using various fuels and assess the national energy and economic impacts, with FY17 focus on charging infrastructure supporting intra-city shared mobility

- The main product of this project is regional infrastructure network design for three selected regions and estimated national impacts

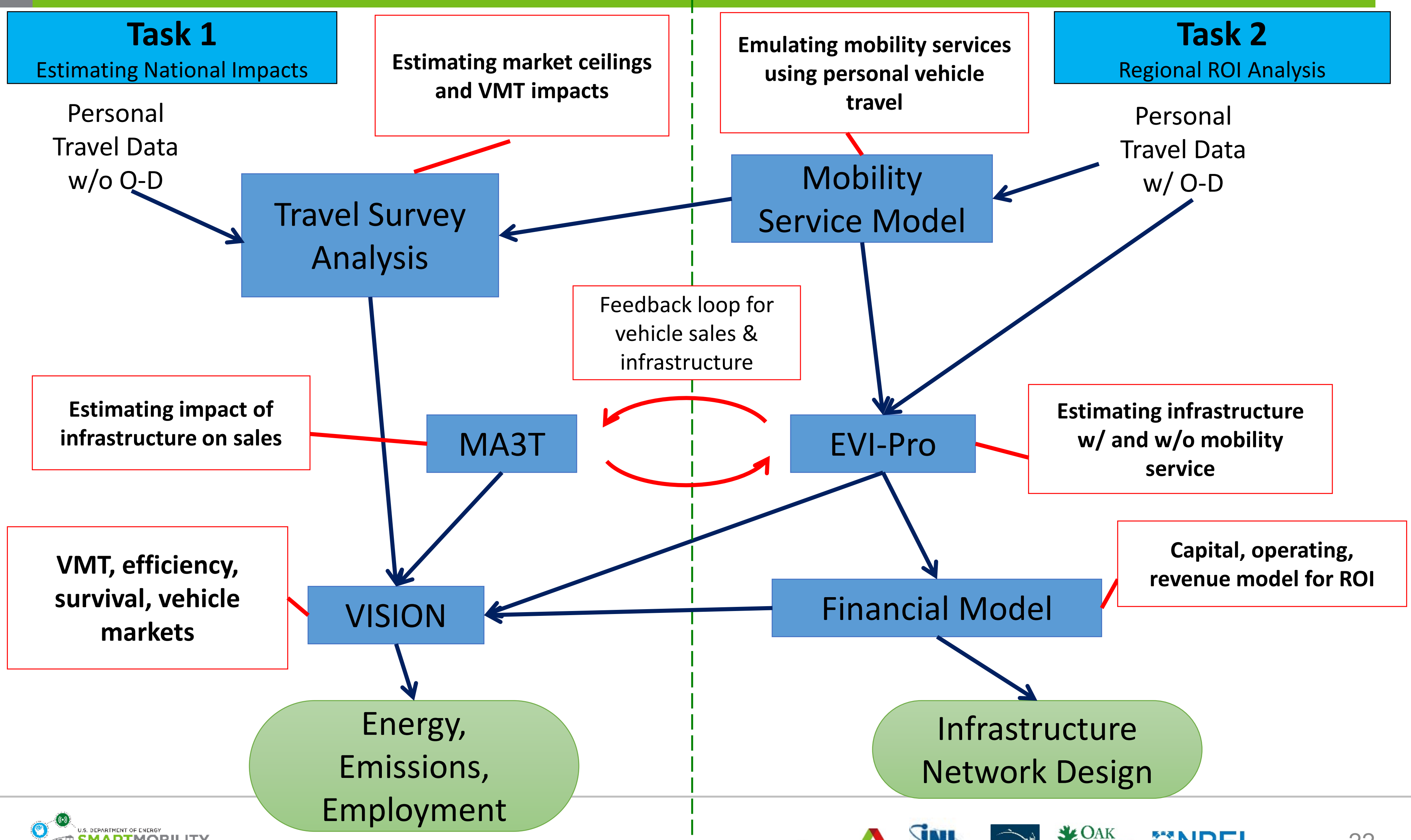
- The project utilizes national labs' sophisticated tools (VISION, EVI-Pro, MA3T, etc), database (Transportation Secure Data Center, EV Project), and expertise to identify solutions that overcome barriers to future sustainable transportation

- Key factor for project success is the continuing interactions with DOE sponsors, partner laboratories within Smart Mobility Consortium, and industry partners

THANK YOU!
QUESTIONS?

Technical Back-Up Slides

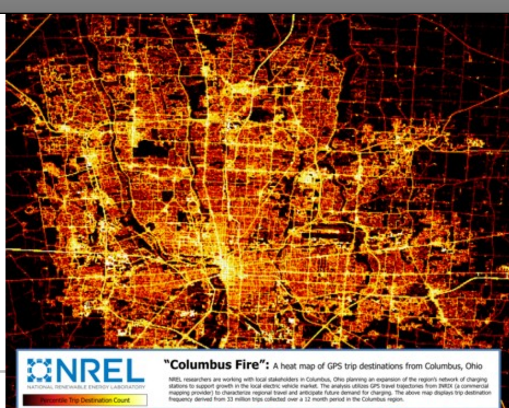
Approach and Interaction



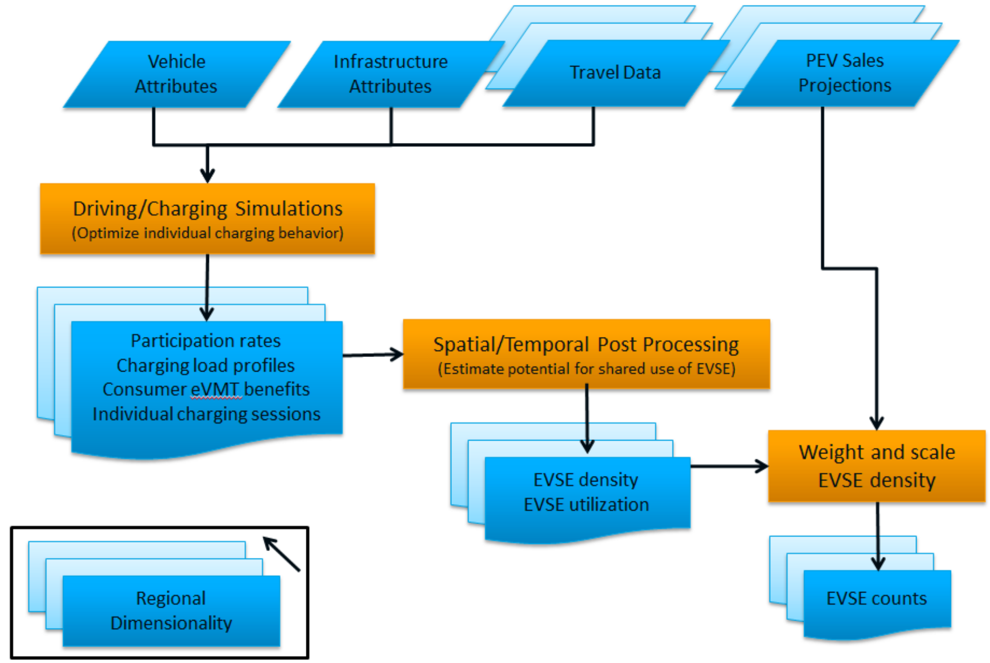
Approach of Electric Vehicle Infrastructure Projection Tool (EVI-Pro)

- ❑ PEV driving/charging simulator + Real-world travel profiles
- ❑ Economically efficient consumer charging behavior
  - ❑ Home dominant (default scenario)
- ❑ Estimates EVSE requirements for
  - ❑ Shared mobility environments
  - ❑ PHEV and BEV powertrains
  - ❑ Single- and multi-unit dwellings
  - ❑ Weekday and weekend travel

Columbus GPS Travel Data



EVI-Pro Schematic



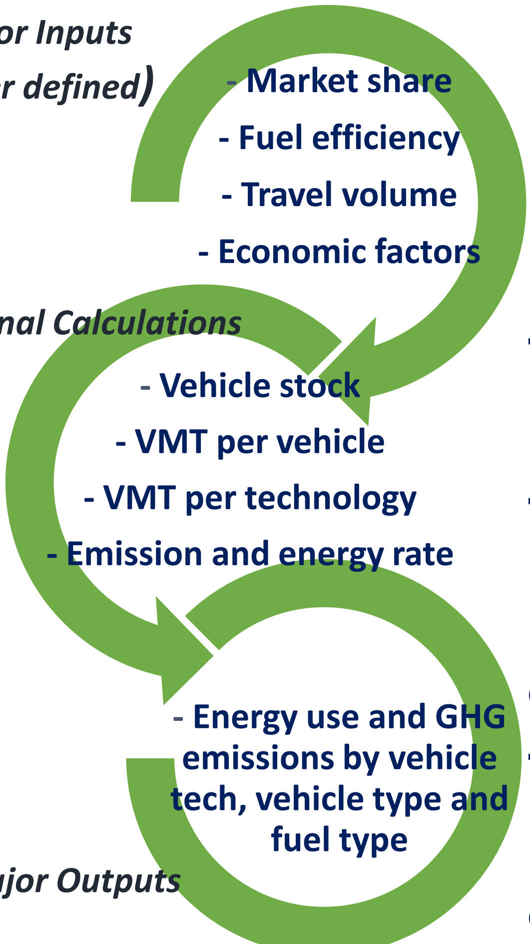
EVI-Pro Vehicle/Infrastructure Attributes For EVSE Demand Modeling

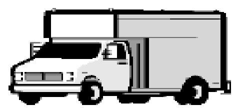
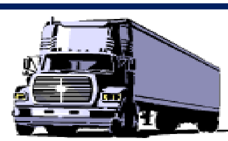
- Travel profiles are simulated using six vehicle models
- A matrix of charging options are made available to each combination of travel profile and vehicle type
- Optimization algorithm selects charging behavior at the individual level to maximize eVMT and minimize charging cost
  - Simulated consumers have an assumed preference for charging type and location (based on electricity price) which is home dominant by default

Vehicle Types
PHEV20
PHEV40
PHEV60
BEV100
BEV200
BEV300

EVSE Type / Location	Home-SUD	Home-MUD	Non-Residential
Level 1	Available	Excluded	Excluded
Level 2	Available	Available	Available
DC Fast	Excluded	Excluded	Available

Approach of VISION: Fleet Impact Modeling



Vehicles	Technology & Fuel
 Cars  Light Trucks	4 ICEVs (gasoline, diesel E85, CNG) 3 HEVs (gasoline, diesel, E85) 3 PHEVs (2 gasoline types, diesel) 2 EVs 1 FCEV
	Gasoline ICEV, diesel ICEV, CNG ICEV, diesel HEV
 Class 7-8 Single Unit Trucks	Gasoline ICEV, diesel ICEV, CNG ICEV, diesel HEV
 Class 7-8 Combination Trucks	Diesel ICEV and LNG ICEV

Fuel Pathways

- Crude oil to gasoline and diesel
- Natural gas To CNG, LNG, F-T diesel
- Soybeans to biodiesel
- Corn, sugarcane, Switchgrass, etc. to ethanol
- Coal, nuclear, Renewables, etc. to electricity
- NG, coal, Biomass, etc. to H2

Approach of PEV Infra Cost Model

Estimates infrastructure installation costs based on:

1. Electrical service upgrade
2. Materials
3. Ground surface conditions

Estimates infrastructure operational costs based on:

1. Mainly focus on electricity cost
2. Electricity rate determined by operators' business type defined by the utility company
3. Operators' current and future electricity consumption and demand capacity information

Locate sites of low installation/operation costs for required EVSE