U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

Advanced Fueling Infrastructure – Task 2.1
Fuel Selection of Privately Owned Shared Vehicles

Project ID: eems038

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And Peer Evaluation Meeting
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Argonne NATIONAL LABORATORY | INL Idaho National Laboratory | BERKELEY LAB | OAK RIDGE National Laboratory | NREL NATIONAL RENEWABLE ENERGY LABORATORY

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Overview

Timeline

- Start: October, 2016
- End: September, 2019
- ~50% Complete

Budget

- FY18: $325,000
  - INL: $200,000
  - NREL: $100,000
  - ANL: $25,000
- FY17: $250,000

Barriers

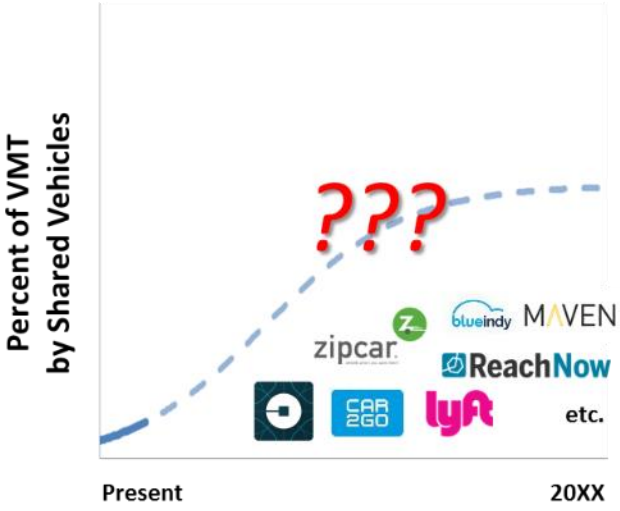
- Infrastructure requirements and impacts are not yet understood
- High risk to develop and purchase advanced vehicles and infrastructure
- Limited understanding of energy impacts of shared mobility applications

Partners

- Project Lead: INL
- Partners: NREL, ANL
- Data Partners:
  - INRIX
  - RideAustin
  - Yellow Cab of Columbus

Relevance

- The growth of ride-hailing and shared mobility as a means of personal travel could have major impact on transportation energy use
- Ride-hailing services will continue to involve human drivers for the foreseeable future
- These drivers use their own vehicles for both shared and personal driving
- Electric vehicles (EVs) have generated interest as ride-hailing vehicles due to the potential for lower operating cost and increased energy efficiency
- Infrastructure needs of ride-hailing EVs are unknown, and may be very different than for typical EV owners



(AP Photo/Jeff Chiu)

Objectives

- Understand travel patterns and operations of ride-hailing vehicles
- Determine the fueling infrastructure needs of shared vehicles
- Compare the relative advantages of PEVs and ICEVs in ride-hailing use

Image source: www.shutterstock.com

FY17/18 Milestones

Quarter	Milestone	
FY17 Q4	Complete near-term infrastructure planning analysis supporting intra-city car/ride-sharing fleets	Complete
FY18 Q2	Complete EVI-Pro shared PEV simulations to assess charging needs	Complete
FY18 Q3	Complete cost model for comparing PEV and gas economics	In progress
FY18 Q4	Energy consumption and economic evaluation of PEVs vs. ICEVs, inclusive of fueling infrastructure costs	In progress

Project Approach

- Define vehicle and charging needs of ride-hailing drivers
- Analyze data from real-world vehicle travel
- Simulate travel data in Electric Vehicle Infrastructure Planning Tool (EVI-Pro) within the applicable context
- Feed EVI-Pro outputs into cost models
- Charging network cost and overall cost of ownership for EVs vs ICEVs

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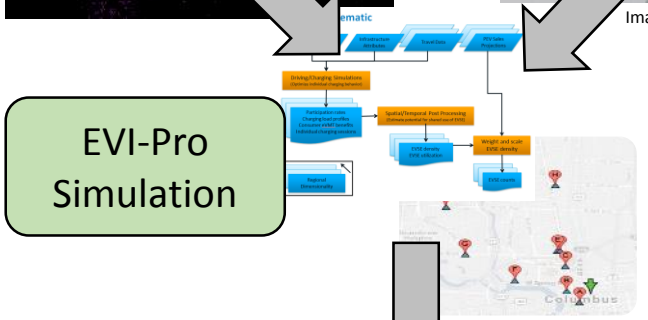


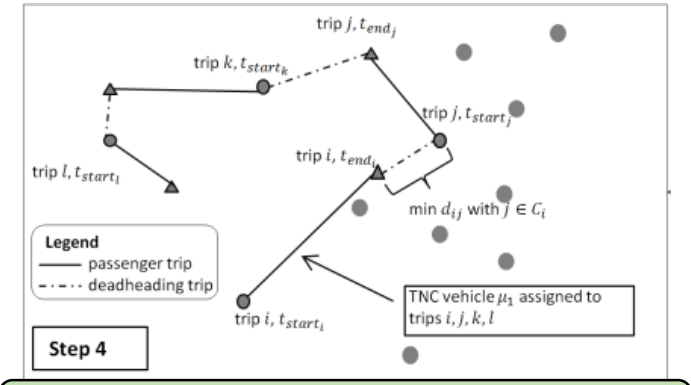
Location	No. of Sessions (monthly)	Daily total energy usage (kwh)	Monthly total energy usage (kwh)	Maximum demand (KW)	Monthly charge ($)	Demand charge ($)	Riders ($)	Total ($)	Cost efficiency ($/kwh)
1	180	117.81	3534.40	82.06	9.04	331.11	899.14	1239.29	0.35
2	510	297.11	8913.42	61.5	9.04	248.03	1140.04	[illegible]	
3	60	85.24	2557.22	61.5	9.04	248.03	669.39	[illegible]	
4	60	91.51	2745.31	61.5	9.04	248.03	683.12	[illegible]	
5	180	94.17	2825.13	66.85	9.04	269.81	730.34	[illegible]	
6	180	155.66	4669.68	61.5	9.04	248.03	825.67	[illegible]	
7	1440	638.35	19150.64	78.91	9.04	318.20	2029.36	[illegible]	
8	60	17.58	527.32	28.93	9.04	116.55	268.79	[illegible]	
9	90	30.75	922.40	28.75	9.04	115.75	296.71	[illegible]	
10	60	26.63	798.9	20.5	9.04	82.68	224.78	[illegible]	
11	210	52.91	1587.35	33.55	9.04	135.51	383.75	[illegible]	
12	90	23.36	700.90	20.5	9.04	82.68	217.48	[illegible]	
Average	260	135.92	4077.73	50.50	9.04	203.7	697.35	910.09	0.36

Cost Modeling

TNC Emulation and EVI-Pro Analysis

- A heuristic algorithm was developed to emulate operation of EVs in a hypothetical ride-hailing fleet using a large GPS dataset from Columbus, OH
- Compared travel of 5,000 real personal-use vehicles vs. same travel in simulated shared vehicles
- EVI-Pro simulation results show shared vehicles:
  - have **30% higher** daily VMT
  - need **2x more** fast chargers
  - use fast chargers **3.5x more**

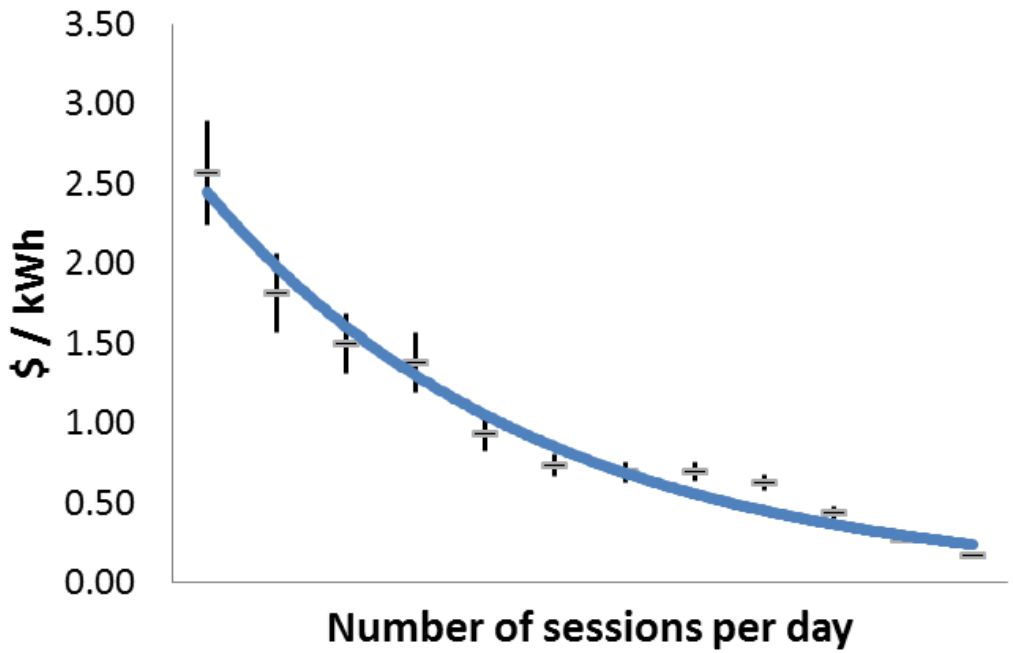
INRIX GPS Data (Columbus, OH)



Ride hailing emulation example

DCFC Station Costs

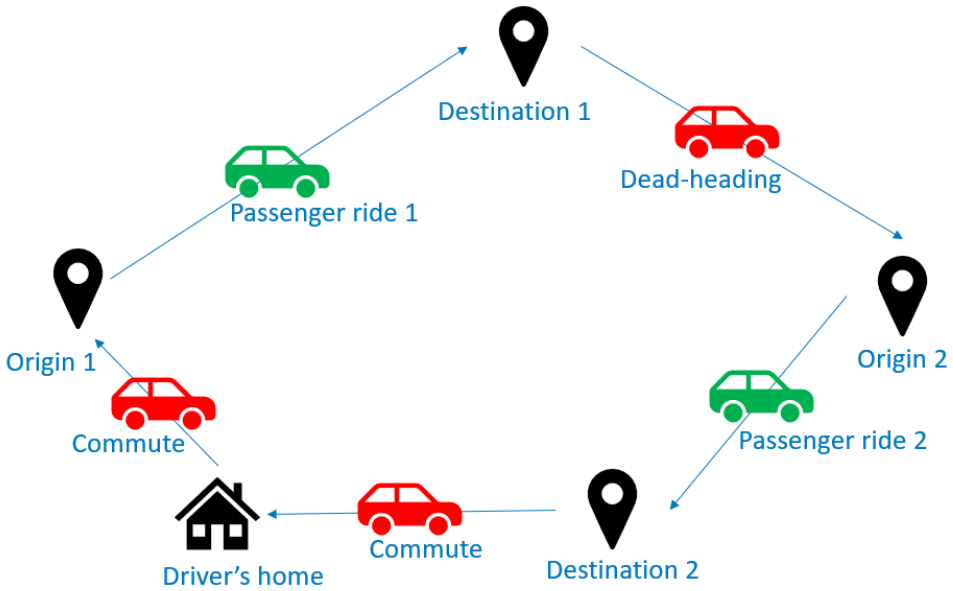
- Operating and installation costs were calculated for DC fast charging (DCFC) stations recommended by EVI-Pro simulations
- Installation costs can vary widely based on location, electrical availability, other factors
- As fast charger utilization increases, overall ownership cost becomes less sensitive to variation in installation cost

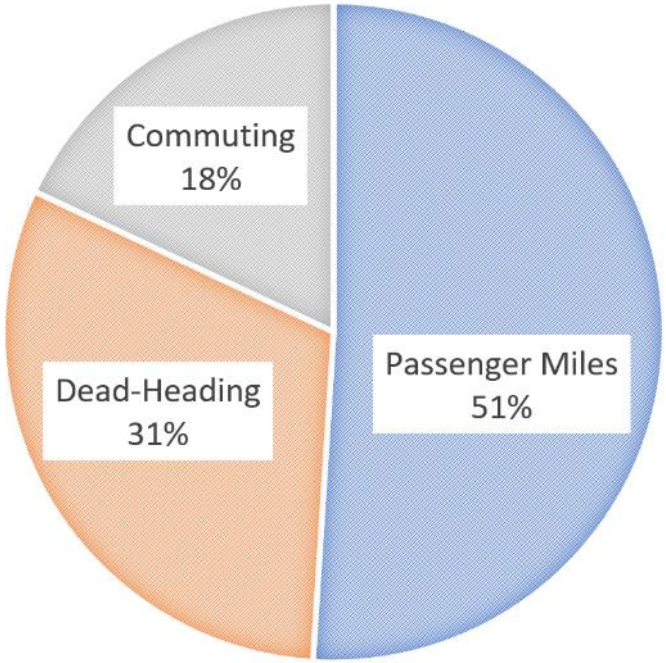


Key Takeaway
When planning fast charger location, **prioritize utilization**

Ride-Hailing Travel Patterns

- RideAustin released a dataset of over 1 million ride-hailing passenger trips, including origins and destinations
- Empty miles (driving w/o a passenger) are inferred using conservative assumptions for commuting and dead-heading
- Results appear consistent with other works

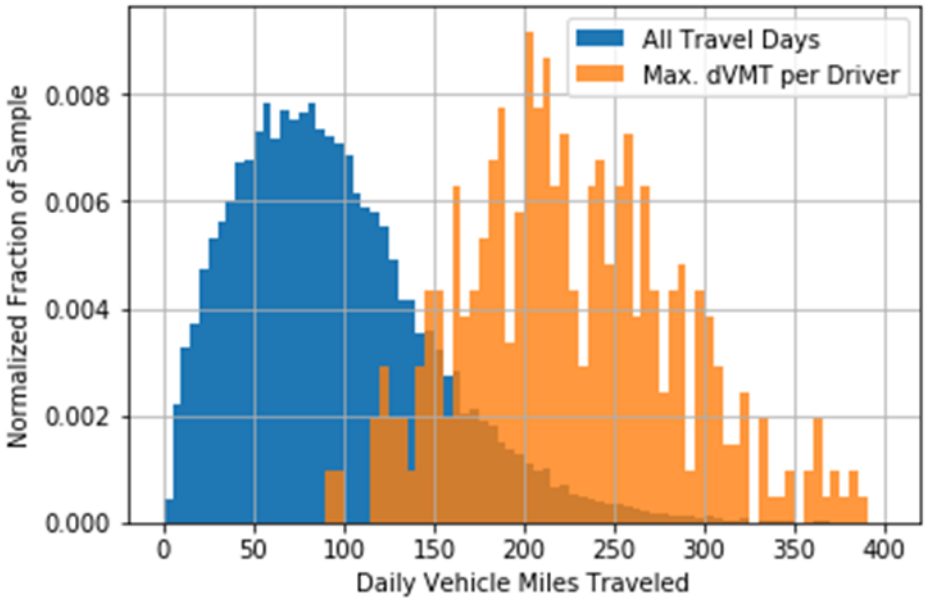




Dead-heading is the distance from previous drop-off to next pick-up (includes over-heading). Distances are computed using a haversine equation with correction factor of 1.419. Drivers' 'home' locations inferred as 2D median of first pickup of every driving day. Dead-heading trips and commutes added to and from 'home' to each driving day

Ride-Hailing Travel Patterns

- 60% of days worked by full-time TNC drivers had under 100 miles of driving
- About 2/3 of full-time drivers never exceed 250 miles in a day
- Drivers were segmented based on hours worked per week (minimum 2 weeks service)
- VMT efficiency was found not to vary by driver segmentation



Part-time Drivers	**Half-time Drivers**	**Full-time Drivers**
Less than 10 hours/week	10-35 hours/week	More than 35 hours/week
49% of drivers	40% of drivers	11% of drivers
14% of rides	57% of rides	29% of rides
Annualized VMT = 7k mi	Annualized VMT = 13k mi	Annualized VMT = 29k mi

Simulating Infrastructure Needs

- Driving/charging simulations conducted in EVI-Pro utilizing full-time driver data
- Three illustrative scenarios were developed to illustrate potential effects of advancing technology and markets

Simulated Results	"Yesterday"	"Today"	"Tomorrow"
TNC EV Count	100	1,000	10,000
EV Driving Range	100 mi	250 mi	400 mi
DCFC Power	50 kW	150 kW	400 kW
Simulated DCFC Plug Count	6	10	48
DCFC Plugs per 1000 BEVs	60	10	5
Daily DCFC Participation Rate	30%	2%	1%
Daily P-L2 Participation Rate	17%	3%	3%
Daily Home Participation Rate	53%	96%	96%

Overall DCFC requirements increase as more TNC BEVs are on the road, but requirements per TNC BEV decrease with driving range increases.

"Yesterday" scenario results in significant DCFC demand from TNCs, but as driving range increases nearly all profiles are satisfied with home charging alone.

Results assume 100% of drivers have home charging

Simulating Infrastructure Needs

- 53% of Austin residents live in single family homes; others may not have access to home charging
- "Tomorrow" scenario repeated with varying charging availability
  - All drivers have access to home charging
  - 53% of drivers have access to home charging*
  - 53% of drivers have access to home charging*, no public level 2 charging
- DCFC demand is increased significantly by decreasing availability of home charging

Simulated Results	100% home	53% home	53% home, no public L2
Simulated DCFC Plug Count	48	356	604
DCFC Plugs per 1000 BEVs	5	36	60

Response to Previous Reviewers' Comments

- A reviewer "commented that the use of home charging to support home and work trips for ridesharing should have greater consideration in this model."
  - Home charging and its potential importance for ride-sharing drivers is a large focus of this analysis.

- One reviewer noted a possible missed opportunity in considering the interaction between electrification and automation for shared mobility. Specifically, "automated shared EVs are distinct from non-automated shared EVs in how efficiently they use EVSE and their range."
  - AFI Task 2.3 is investigating infrastructure needs of automated shared EVs.

Collaboration and Coordination

DOE SMART Mobility Laboratory Consortium: ANL, INL, LBNL, ORNL, NREL

- Idaho National Laboratory
  - Determine needs of ride-hailing drivers and calculate costs of shared mobility
- National Renewable Energy Laboratory
  - Perform data analysis and simulation of shared-mobility data to determine usage patterns and infrastructure needs of shared EVs
- Argonne National Laboratory
  - Provide applicable/potential electricity rate structures and input to cost modeling
- Data partners: INRIX, RideAustin, Yellow Cab of Columbus

Remaining Challenges and Barriers

- The future of shared mobility and its impact on travel requires further research
  - Technologies and markets are rapidly advancing
- The number of human-driven shared vehicles may change as automated vehicles come to market, but timing and impact is unknown
- EV batteries are known to degrade with use and time, and more research is needed to understand how this will affect EV suitability for shared mobility
- Infrastructure and vehicles capable of charging at >120 kW are not yet on the market; timing is uncertain for their release

Proposed Future Research

FY18

- Develop scenarios that represent potential future ride-hailing markets by analyzing the vehicle and charging needs of ride-hailing drivers
- Determine charging infrastructure required to meet needs of ride-hailing EVs
- Calculate costs associated with ride-hailing EVs and compare to ICEVs

FY19

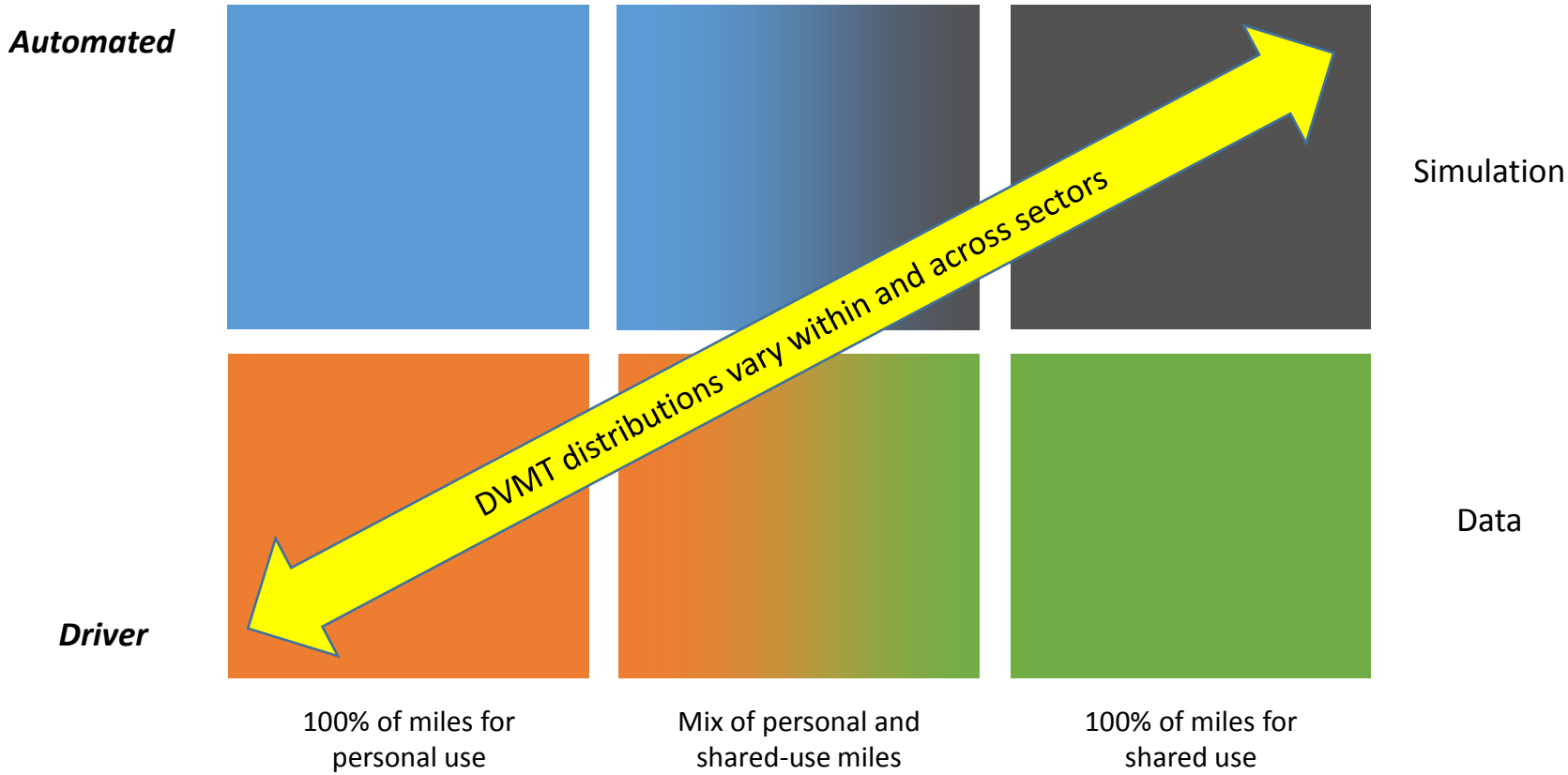
- Use laboratory expertise, data, and modeling tools to incorporate EV battery degradation into analysis
- Compare real-world ride-hailing data, taxi data, and pseudo-synthetic data
  - What are the differences between ride-hailing and taxi operation? Do they need to be considered as separate use cases from infrastructure perspective?
  - Is pseudo-synthetic ride-hailing a suitable surrogate?

Summary

- As the transportation system trends toward shared and shared-automated mobility, the value proposition of EVs and their requirement for fueling infrastructure are also changing
- This project's objective is to determine the fueling infrastructure needed to support EVs for human-driven ride-hailing vehicles and determine the relative advantages of EVs and ICEVs in different usage scenarios
- Real-world data and sophisticated modeling tools were used to understand the operation of ride-hailing vehicles and investigate how driving range and charging access affect infrastructure needs of ride-hailing EVs
  - When siting fast charging stations, prioritize high utilization over low installation costs
  - Long range EVs and home charging could likely support most ride-hailing operation, but DCFC needs increase drastically for drivers without home charging
- Analysis is being performed to define the vehicle and infrastructure needs of EVs to be competitive with ICEVs

Technical Backup Slides

Relevance: AFI Segmentation of Shared-Vehicle Opportunity Space



Vehicle Use:	***Personal***	***Shared***
Vehicle Ownership:	***Private***	***Commercial***
Fueling Infra Access:	***Public (i.e. distributed)***	***Public and/or restricted (i.e. centralized)***

Emulated Ride-hailing Data Analysis

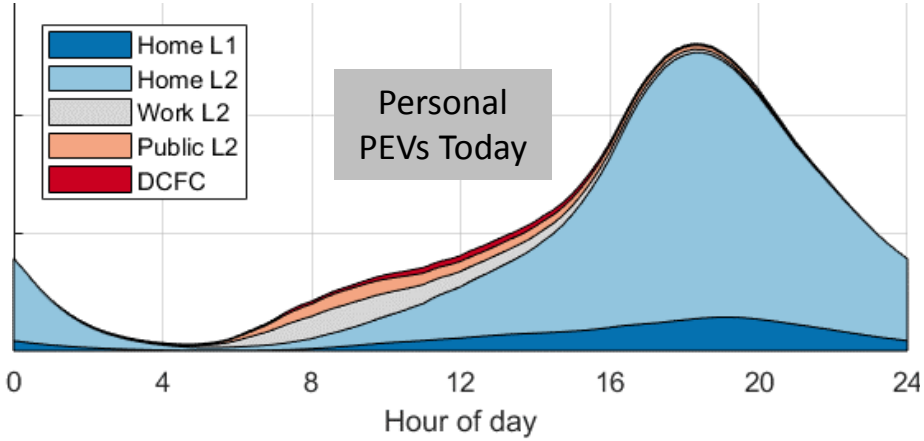
- Data received from personal travel in Columbus, OH area
  – Down-selected to travel of 5,000 vehicles
- Personal vehicle trips were chained together as if served by emulated ride-hailing EVs
- Ride-hailing could serve travel with fewer vehicles
  – 29% higher VMT per vehicle

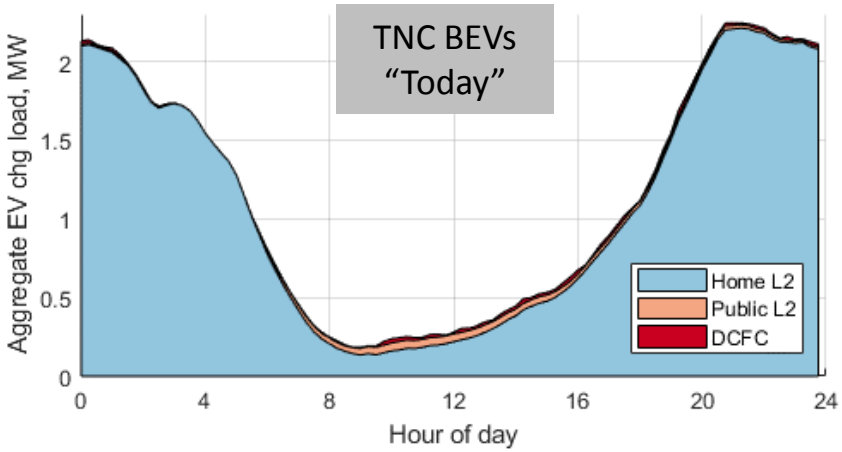
Metrics	Personal vehicles	Ride-hailing vehicles
Number of vehicles	5,000 individual vehicles	4,834 vehicles (-3.3%), among which: - 3,726 ride-hailing vehicles (-25%) - 1,108 'single-trip'/individual vehicles unable to chain trips (22%)
Number of trips	18,460 total trips	25,115 total trips (+36%), including 7,112 additional 'deadheading' trips
Total System VMT	143,139 miles	148,149 miles (+3.5%)
Mean daily VMT	28.6 miles	37.0 miles * (+29%)
Trip mean distance	7.8 miles	5.9 miles (-24%)

Personal BEV vs TNC Infrastructure Needs
(with home charging at 100% of residences)

Simulated Results	"Yesterday"	"Today"	"Tomorrow"
TNC BEV Count	100	1,000	10,000
TNC DCFC Count	6	10	48
Non-TNC PEV Count*	1,000	5,000	10,000
Non-TNC DCFC Count	3	16	31

*PEV fleet based on NREL National EVSE analysis from 2017 (50% PHEV, 50% BEV). A total of 3,700 PEVs were registered in Austin as of 2016.





Questions?

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