Project ID: EEMS044
Pillar: AFI

U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

Quantify National Energy Impact of Electrified Shared Mobility with Infrastructure Support

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Argonne National Laboratory
2019 Vehicle Technologies Office Annual Merit Review
June 11, 2019

Argonne National Laboratory | Idaho National Laboratory | Berkeley Lab | Oak Ridge National Laboratory | NREL National Renewable Energy Laboratory

OVERVIEW

Timeline

- Project start date: October 1. 2017
- Project end date: September 30, 2019
- Percent complete: 75%

Barriers

- Aggregate limited regional results to national
- Accurately measuring the transportation system-wide energy impacts of advanced fueling infrastructure supporting mobility of service (e.g. ride-hailing)

Budget

- Total project funding:
  - DOE share: 100%
  - Contractor share: 0%
- Funding for FY 2018: $250,000
- Funding for FY 2019: $500,000

Partners / Collaboration

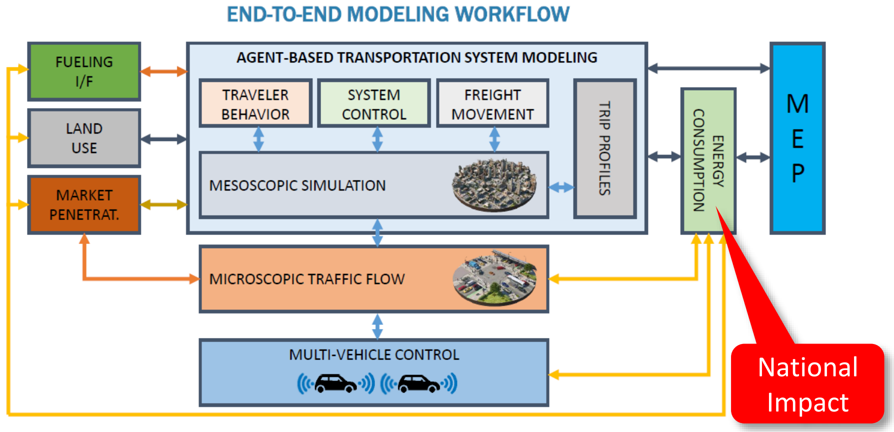
- ANL (lead) – Yan (Joann) Zhou (PI), Zicheng (Kevin) Bi
- Oak Ridge National Laboratory (Fei Xie)
- National Renewable Energy Laboratory (Eric Wood)
- Coordination with SMART AFI Task 2

RELEVANCE

- **Overall objectives:**
  - Quantify the national energy impact of Ride-hailing Plug-in Electric Vehicles (PEVs) as compared with privately owned PEVs and ride-hailing ICEVs with varying infrastructure support (e.g. Level 2, DCFC, high power FC)
  - Mathematically:

    National Energy Impact = f (# of ride-hailing vehicles, PEV market penetrations)

- **Impact:**
  - Understand changes in petroleum and electricity consumption while providing mobility of service (e.g. ride-hailing) using electrification supported by infrastructure.
  - Supports workflow by quantifying energy consumption of using charging infrastructure to support electrified ride-hailing at national level



RELEVANCE

- FY2019 Focus:
  - Further enhance the method that expands on regional EVSE deployment findings (AFI task 2) to understand national PEV market adoptions (both shared and private)
  - Quantify reduction in national energy consumption using the key variables identified above and considering different levels of ride-hailing usage and electric vehicle demand in ride-hailing fleet.
  - Analyze trade-offs between fast charging infrastructure and number of electrified shared vehicles needed and estimate national energy impacts

MILESTONES

Date	Type	Milestones Go/No-Go	Status
12/31/2019	Quarterly	Report on national energy impact of different scenarios (ANL)	Complete
3/31/2019	Quarterly	Presentation on regional results (NREL)	Complete
6/30/2019	Quarterly	Presentation on market penetration scenario analysis (ORNL)	On-track
9/30/2019	Annual	Report on updated national energy impact and sensitivity analysis (ANL)	On-track

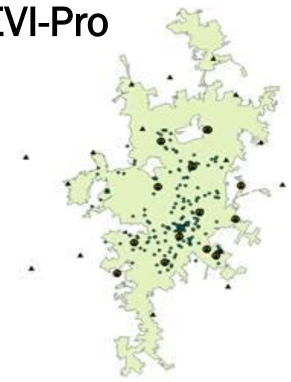
APPROACH

From Charging Coverage to Charging Opportunity, then to National Energy

When charging infrastructure is optimized to support ride-hailing vehicles, the increase in charging opportunities for private vehicle travel is much less

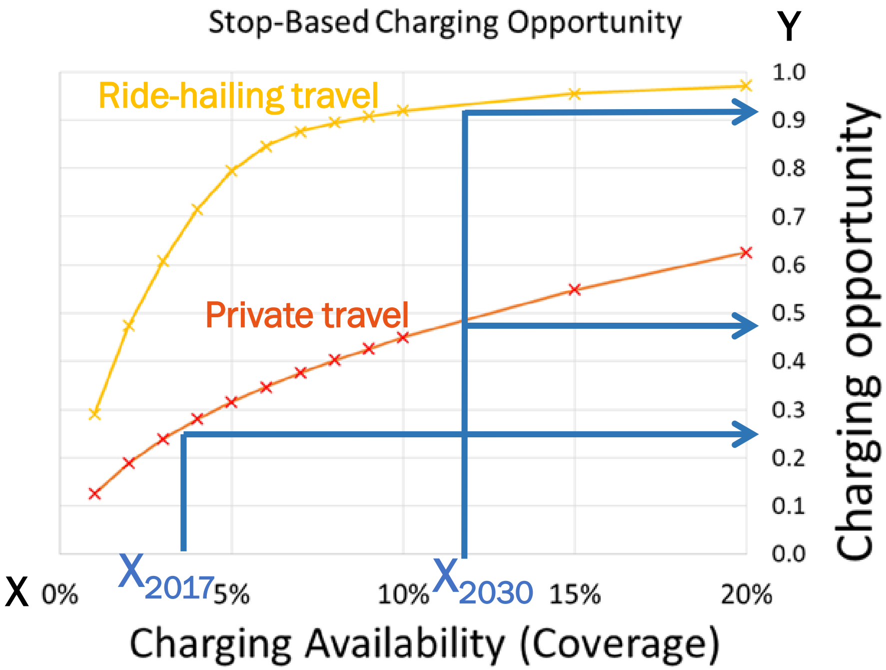
Charging demand of a given city/area in a given year

EVI-Pro



- *# of chargers*
- *Charging power*

X_{2030}

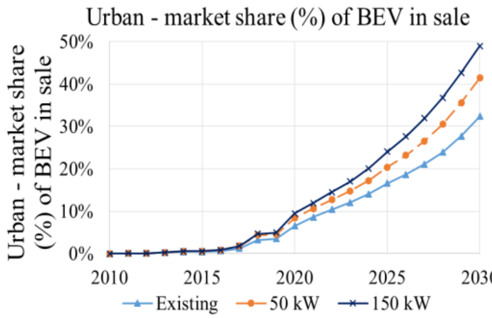


Y_{2030}

National Energy Impact

VISION

BEV market share growth



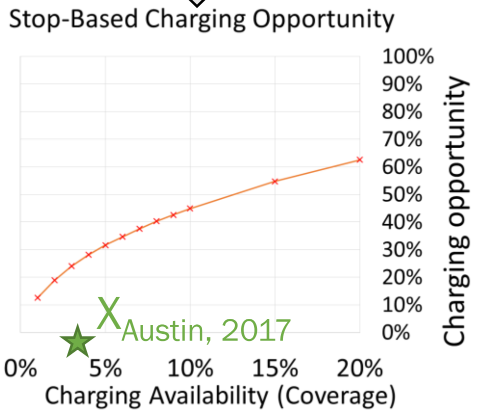
MA3T

- Generated using travel survey & GPS data of seven different cities: *Atlanta, Austin, Chicago, Columbus, Los Angeles, New York, Seattle*
- X: # of grid cells (0.25 mile *0.25 mile) with a charger
- Y: % of trips that ends in the cells (from the most popular to least popular)

APPROACH

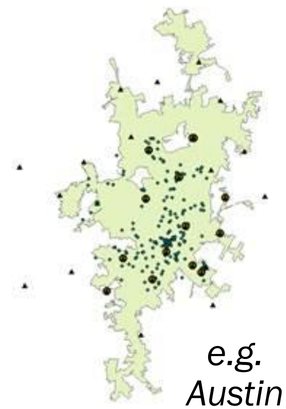
From city/regional results to national

Alternative Fuel Data Center:
2017 Charging Coverage



Charger Coverage in 2017
$X_{Austin, 2017}$

Simulation: e.g., EVI-Pro
For given # of RH BEVs and miles, count the charging events at each locations



e.g. Austin

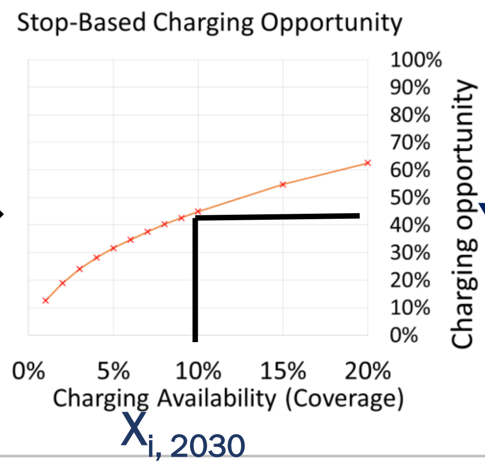
Charger Coverage in 2030
$X_{Austin, 2030}$

$$\text{Growth Rate} = \frac{X_{Austin, 2030}}{X_{Austin, 2017}}$$

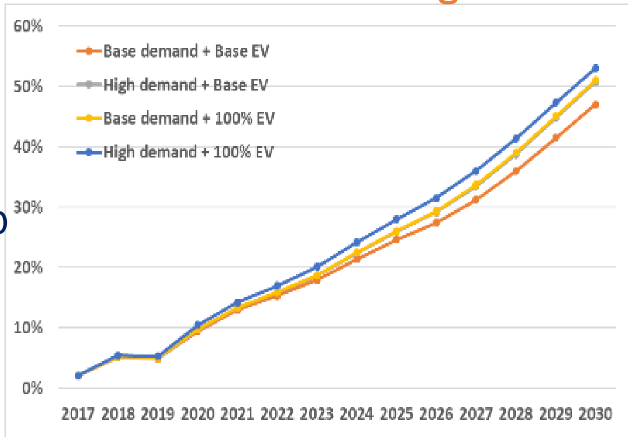
For 50 states

$Coverage_{2017}$		$Coverage_{2030}$
$X_{1, 2017}$		$X_{1, 2030}$
$X_{2, 2017}$		$X_{2, 2030}$
$X_{3, 2017}$	✖	$X_{3, 2030}$
.	Growth Rate i	.
.		.
.		.
$X_{50, 2017}$		$X_{50, 2030}$

Growth rate i for each state (adjusted based on current ride-hailing demand and charging coverage of a typical city in that state)



MA3T: BEV market share growth



VISION

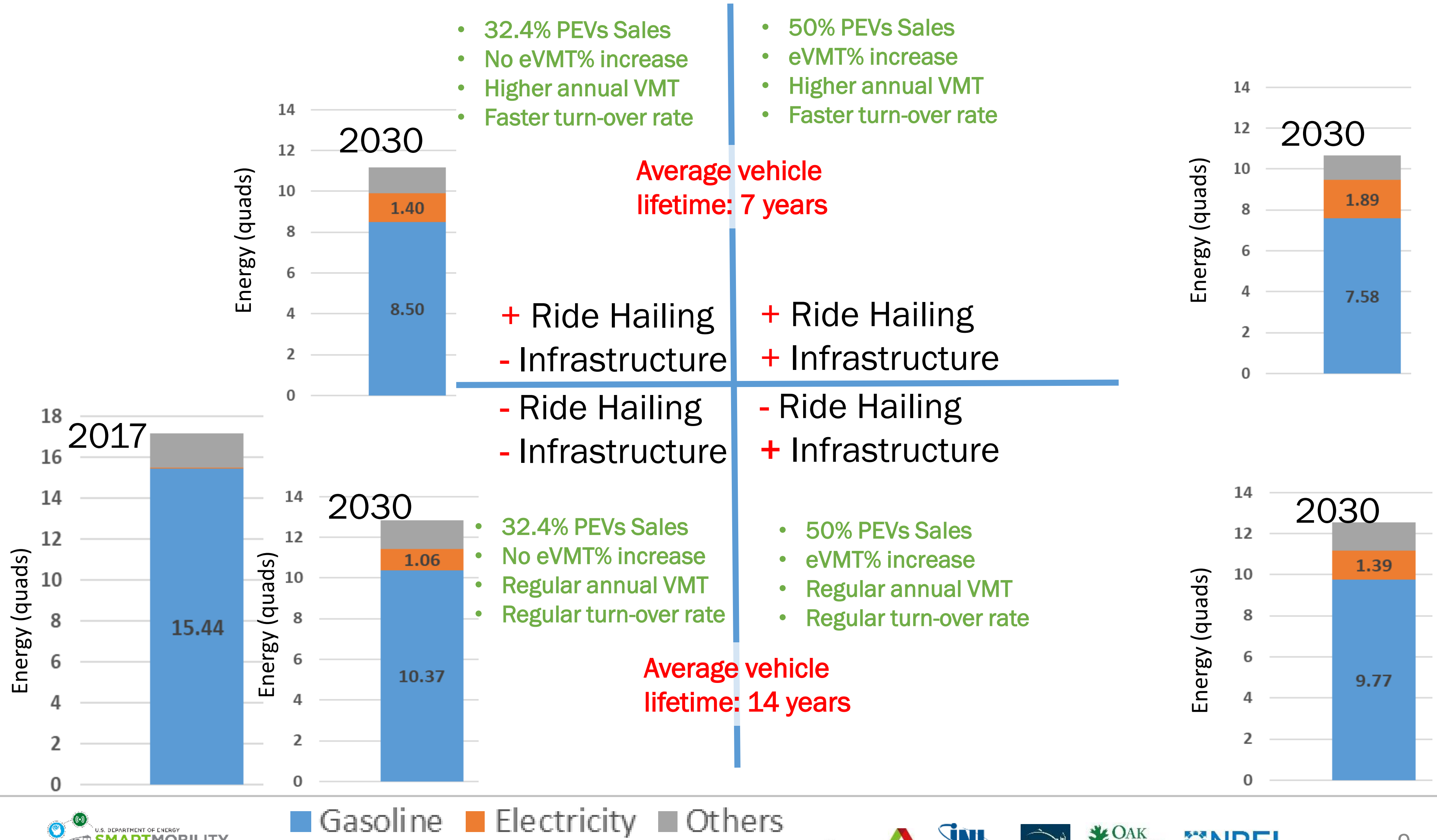
National Energy Impact

SUMMARY OF TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- **Developed a methodology to aggregate city/regional results to national**
  - Quantified charging opportunities from analysis of regional travel pattern
  - Analyzed the difference in charging opportunities between ride-hailing and private travel
  - Developed a method to estimate “weighted” growth rate in charging coverage based on current ride-hailing demand and charging availability of each state
- **Estimated private PEV adoptions based on the charging infrastructure optimized for ride-hailing travel**
  - Separated marginal impact of charging infrastructure on electric vehicle adoption
  - Estimated adoption for each state
- **Quantified the national energy impact of ride-hailing PEVs as compared with privately owned PEVs and ride-hailing ICEVs**
  - Separated the impact due to increased ride-hailing vehicles and improved infrastructure
  - Ride-hailing travel brings high annual mileage and faster vehicle turn-over rate
  - Improved infrastructure coverage and power enable more PEV adoption
- **Developing a strategy to overcome limitations in data availability**
  - Bottom-up approach: More simulation scenarios to test a range of ride-hailing demand
  - Top-down approach: mathematically identify charging station requirements for different ride-hailing BEV fleet size *(details in technical back-up slide)*

NATIONAL ENERGY IMPACT OF ELECTRIFIED RIDE-HAILING LDVs IN 2030

(High Ride hailing Case, 150 kW Public Charging, Urban Only)



NATIONAL ENERGY IMPACT OF ELECTRIFIED RIDE-HAILING LDVs IN 2030
(Low Ride Hailing Case (1.4% RTP), 150 kW Public Charging, Urban Only)

RTP =Ride-hailing miles/Private miles

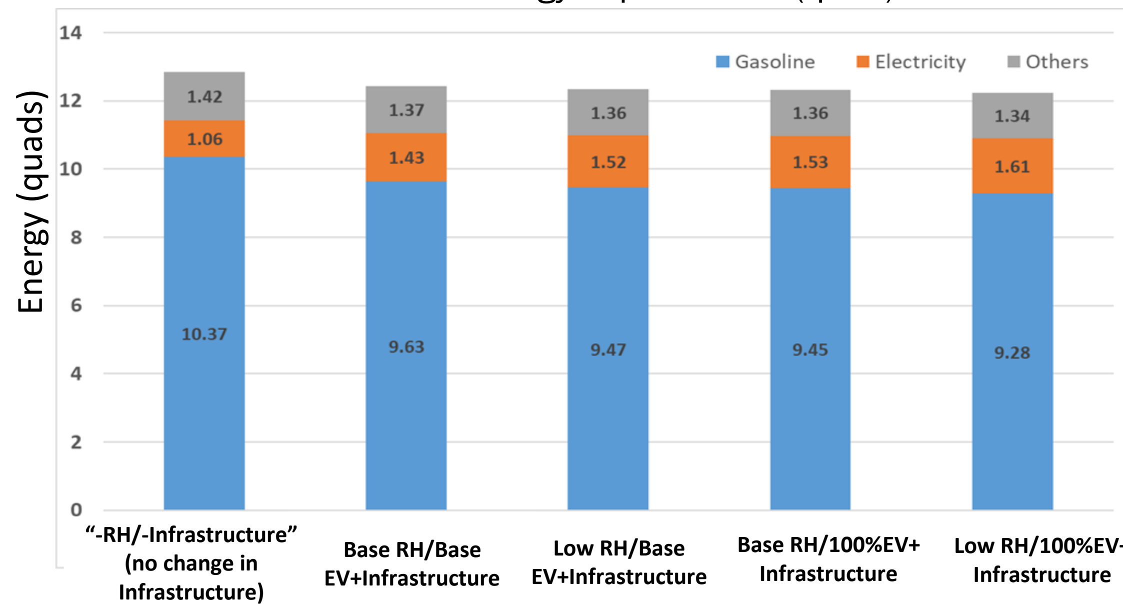
4 Scenarios

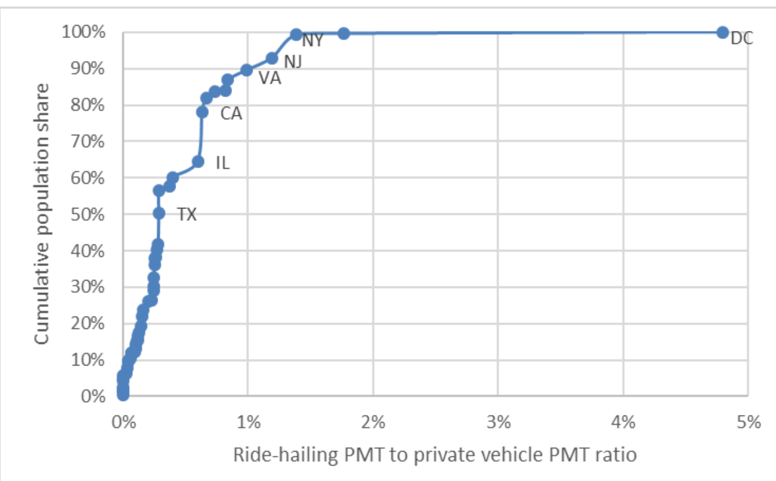
Ride Hailing Electrification

	Base Ride-Hailing Same as TX ride-hailing demand	Low Ride-Hailing Same as NY ride-hailing demand
100% EV in full-time ride-hailing fleet in 2030	0.29% RTP 100% EV	1.4% RTP 100% EV
Base EV Same BEV % in ride-hailing and private vehicles	0.29% RTP Base EV	1.4% RTP Base EV

Ride Hailing Demand

National Energy Impact 2030 (quad)





Charging Power and Charging Availability in Austin (2030)

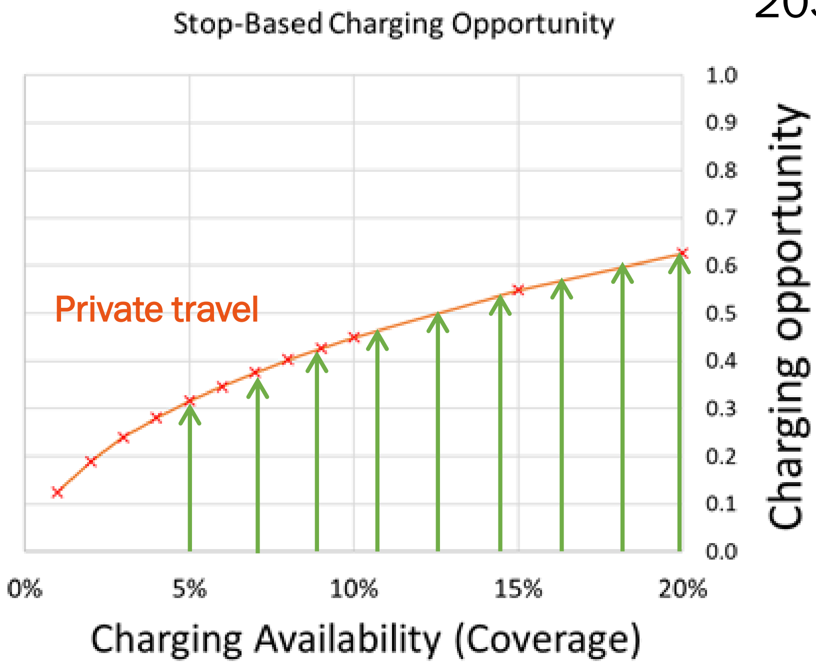
Scenarios	Existing chargers[1]		Additional chargers[2]	Charging Availability	Average power (KW)
	Public L2 (6.3 KW)	DCFC (50 KW)	DCFC (150 KW)		
Existing	603	25	NA	11.07%	7.9
Base RH + Base EV	603	25	8	11.15%	9.7
Low RH + Base EV	603	25	39	11.46%	16.2
Base RH + 100% EV	603	25	43	11.50%	17.1
Low RH + 100% EV	603	25	210	13.09%	43.6

RH = Ride-Hailing

NEXT STEPS (BOTTOM UP):

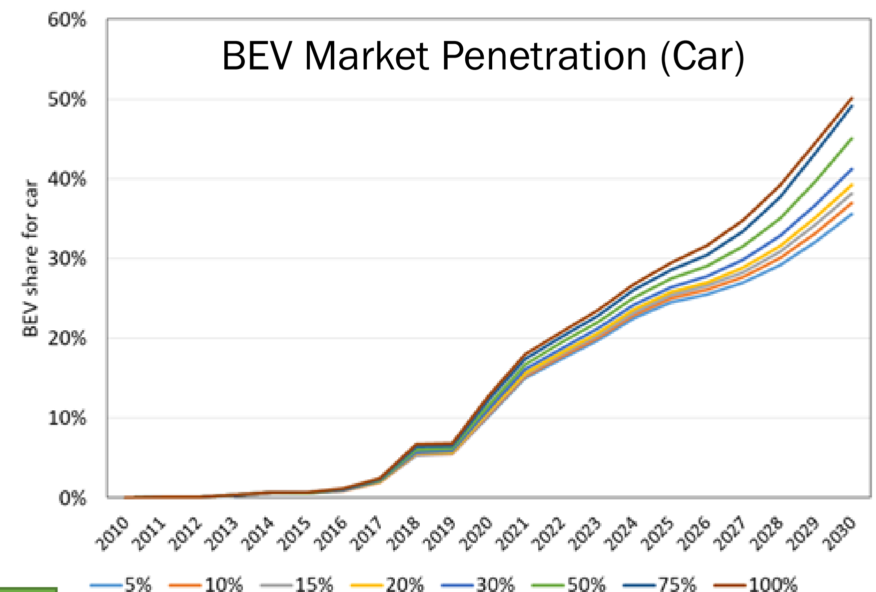
More simulation scenarios to test a range of ride-hailing demand (RTP varies from 0-100%)

2030



Y1
Y2
Y3
Y4
Y5
Y6
Y7
Y8

National Energy Impact =
F (of # of ride-hailing vehicles, PEV market penetrations)



2030: X1 X2 X3 X4 X5 X6 X7 X8

Electric Ride-hailing vehicle: RV1- RV8

Ride-hailing miles: RM1-RM8

(RTP varies from 0% - 100%)

Example

Other Key assumptions:

- *BEV electric range*
- *# of ride-hailing trips/day/vehicle*

RESPONSES TO PREVIOUS YEARS REVIEWERS COMMENTS

- **…the availability, locations, price, and nature (direct current fast, Level 2) of charging will have an effect (potentially a major one) on the economics of mobility services.**
  - This project is built on the city/regional simulation results from NREL's EVI-Pro. EVI-Pro is a charging infrastructure planning tool which estimates # of chargers needed based on demand. There is not feedback loop or adaptive behavior considered in the effect of charging availability on economics of mobility services.
- **The reviewer asked besides fueling, what are the other factors that will determine what the ramp-up for EVs will be, and is the amount of unoccupied miles in ride-hailing vehicles going to factor into the potential energy savings.**
  - The EV penetration in ride-hailing vehicles are given assumption in EVI-Pro.
  - MA3T projects the increased EV adoption in private vehicle fleet due to the increased charging availability (optimized for ride-hailing fleet). MA3T considers other factors such as fuel price, vehicle price, travel pattern when projecting the EV adoption.
  - We considered unoccupied miles in ride-hailing vehicles
- **The reviewer commented that results presented had a clear story to tell regarding the marginal benefits of charging infrastructure with regard to reducing energy consumption**
  - Thanks for the good suggestion! We did additional analysis this year, and quantifying marginal benefits from charging infrastructure is included.

RESPONSES TO PREVIOUS YEARS REVIEWERS COMMENTS

- **The reviewer said the future work is refining the analytic results by investigating regional variations in key independent variables. This work will increase the accuracy of the model estimates.**
  - In FY19, this study conducted additional analysis understanding the charging opportunities using the GPS/travel survey data from different cities. The results shows for the same charging coverage, the charging opportunities of different cities are very similar to each other. However, for the same charging coverage, there is a significantly difference between ride-hailing travel and private travel.
  - When apply growth rates we identified from one region (e.g. Austin) to other regions, this year we considered regional variation in existing charging coverage and ride-hailing demand.
- **The reviewer said good collaboration given the project size. The reviewer noted that there is evidence each of the partners have made significant contributions to delivering strong project results. The reviewer thought the project could benefit from applying some of their analysis to data from applicable cities to see how real-world impacts may affect findings.**
  - Thanks reviewers for recognizing the good collaboration between all three labs involved. We do plan to look into some DOE supported city/regional projects to understand the real-world impact.

REMAINING CHALLENGES AND BARRIERS

- Data availability for understanding charging opportunities for both ride-hailing and private travel
  - Trip origin and destination data are needed
  - More cities need to be studied to approve the general relationship between charging availability and opportunities
- Sensitivity of results to the assumptions about BEV electric range and # of ride-hailing trips/day/vehicle in simulations
- Cross-validation between bottom-up (simulation) and top-down (mathematical probability) approaches. We are in the process of developing top-down approach (see back-up slides).

PROPOSED FUTURE RESEARCH

- FY19
  - Sensitivity analysis to test a range of ride-hailing demand and energy implications
  - Sensitivity analysis to test other key assumptions, e.g. VMT/ride-hailing vehicle
  - Complete the bottom-up approach, a more robust way to test different assumptions
  - Quantify the energy impacts as a range instead of a single points based on sensitivity analysis
- Proposed FY20+
  - This project will be completed in FY19
  - However, further research needs to consider changes in vehicle ownership and total vehicle miles traveled due to ride-hailing

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

SUMMARY

- Ride-hailing trips have much higher spatial concentration than private vehicles trips. When future charging infrastructure is optimized to support ride-hailing vehicles, the increase in charging opportunities for private vehicle travel is much less.

- Reduction in national petroleum consumption is due to the impact of both *improved charging infrastructure availability* and *increased ride-hailing*
  - Improved charging availability and charging power significantly induces PEV adoption and increases eVMT
  - Increased ride-hailing demand enables faster vehicle turnover rate so the fleet average fuel efficiency is improved

- A high ride-hailing case shows that use of public charging infrastructure to support electrified ride-hailing vehicles could significantly reduce petroleum consumption of all LDV by 7.68 quadrillion BTUs in 2030 compared to energy consumption in 2017

- Future research needs to analyze the infrastructure requirement at the national level more robustly. The research team has developed a strategy to address some of the remaining challenges

QUESTIONS?

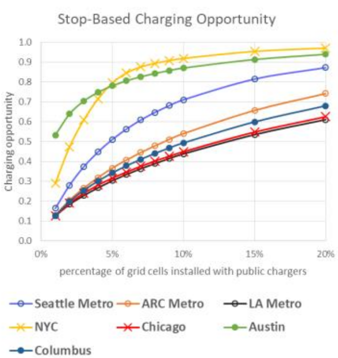
TECHNICAL BACK-UP SLIDES

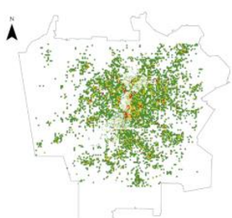
APPROACH

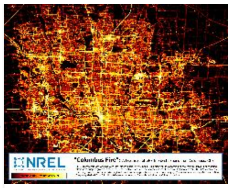
Charging Opportunity: Ride-hailing travel vs. Private travel

Ride-hailing trip destinations have much higher spatial concentration

	Seattle	Atlanta	Los Angeles	New York	Chicago	Austin	Columbus
Type of travel	Household	Household	Household	Taxi	Household	Ride-hailing	Household
# of destinations	220,045	12,424	30,740	468,894	43,141	1,048,523	7,767,545
Area, mi^2	414	163	450	188	117	507	544
λ ($y = 1 - e^{-\lambda x}$)*	13.8%	9.1%	7.4%	28.3%	7.6%	31.7%	8.3%







Quantitative λ: *average percentage of trips ending in 1% of grid cells in the region

WEIGHTED GROWTH RATE

For 50 states

Coverage$_{2017}$ Coverage$_{2030}$

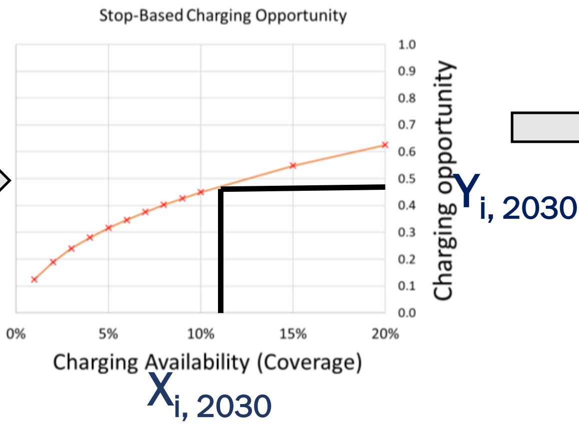
$X_{1,\ 2017}$ $X_{1,\ 2030}$

$X_{2,\ 2017}$ $X_{2,\ 2030}$

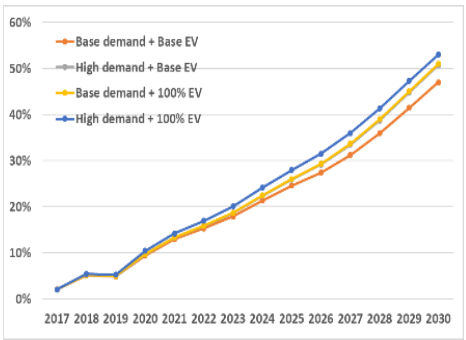
$X_{3,\ 2017}$ ✖ Growth Rate i $X_{3,\ 2030}$

. . .

$X_{50,\ 2017}$ $X_{50,\ 2030}$



MA3T: BEV market share growth



VISION

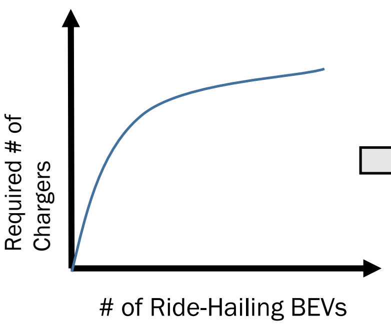
National Energy Impact

- **Growth rate (GR) for each state i** is adjusted based on current ride-hailing vs. passenger miles traveled ratio (RMT) and charging coverage (x) for a typical city in that state
  - Growth rate in city 1 (Austin): $GR - 1 = k * RMT_{2030}/RMT_{2017} * (1/x_{2017})$
  - Growth rate in city 2 (any city): $GR' - 1 = k * RMT'_{2030}/RMT'_{2017} * (1/x'_{2017})$
- Therefore, $GR' = (RMT_{2017}/RMT'_{2017}) * (x_{2017}/x'_{2017}) * (GR-1) + 1$ (the upper limit of GR' is set at 5)
- Austin, Texas (benchmark): $RMT_{2017} = 0.3\%$, $x_{2017} = 4.4\%$, $GR = 2.71$, $x_{2030} = 12\%$

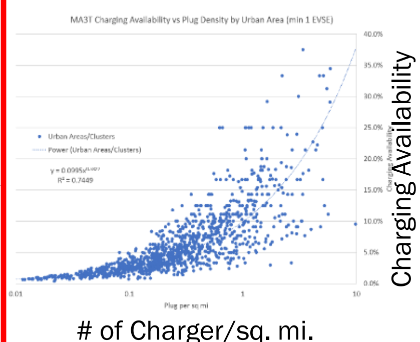
  e.g., Illinois: $RMT'_{2017} = 0.6\%$, $x'_{2017} = 5.4\%$, $GR' = 1.7$, $x'_{2030} = 9\%$

NEXT STEPS (TOP DOWN APPROACH):
Required # of chargers is a function of ride-hailing BEV fleet size

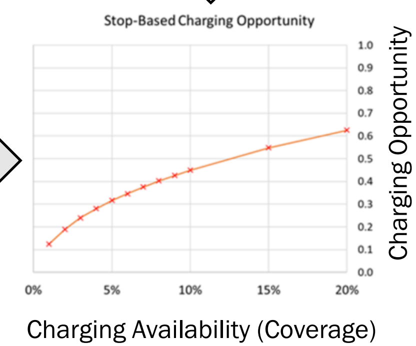
Top-down approach (without simulation):
Mathematically identify the required # of chargers for given # of RH BEVs based on probability of charging activity per stop



Given # of Ride-Hailing BEVs



Travel survey & GPS data

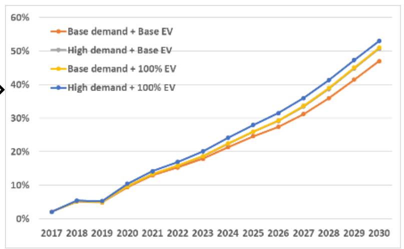


MA3T

National Energy Impact

VISION

BEV market share growth



MA3T-MC

Why this is important?

- A universal model that approximates # of charging stations needed to determine charging opportunity
- Being able to analyze the infrastructure requirement at the national level robustly
- Not restricted to regional simulation results which are subject to data availability