DECEMBER 17, 2020

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

EVALUATING EV CHARGING INFRASTRUCTURE NEEDS IN A SMART MOBILITY SYSTEM

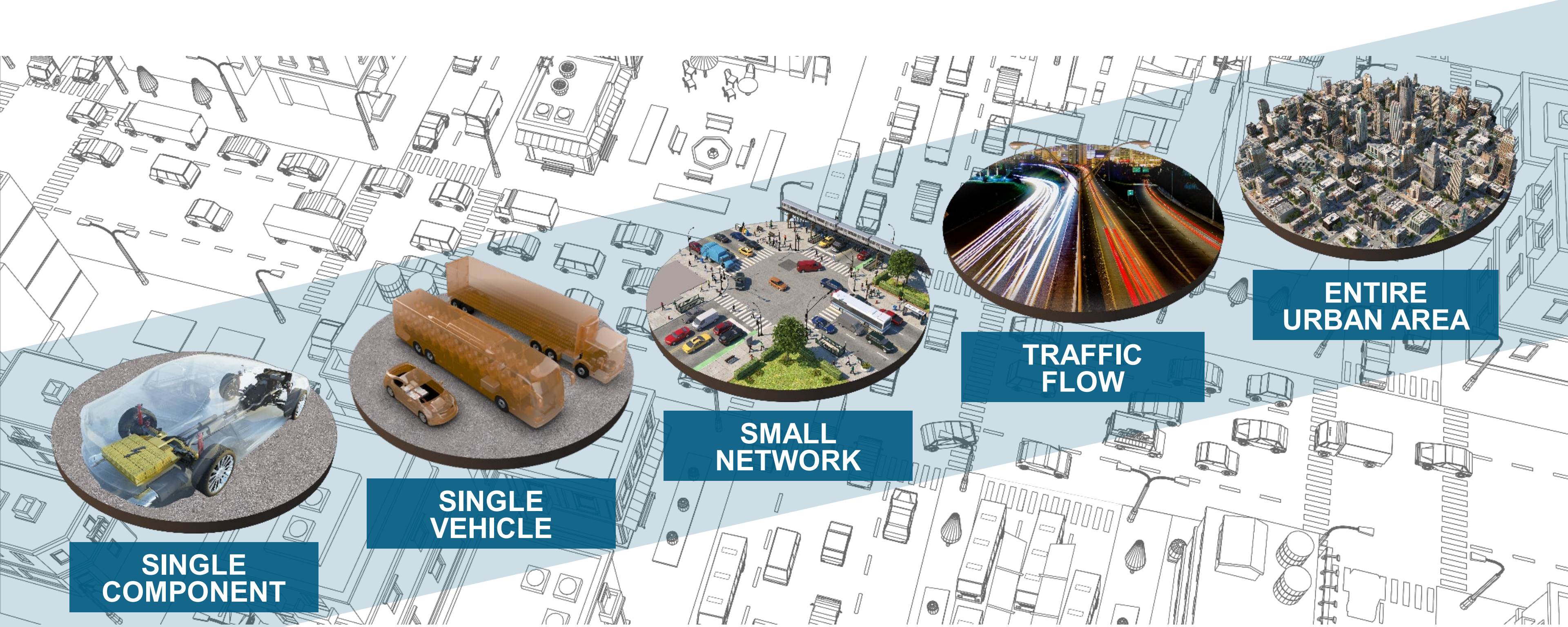
DAVID ANDERSON
Program Manager
Energy Efficient Mobility Systems (EEMS)
Vehicle Technologies Office
U.S. Department of Energy

For more information, contact:
eems@ee.doe.gov

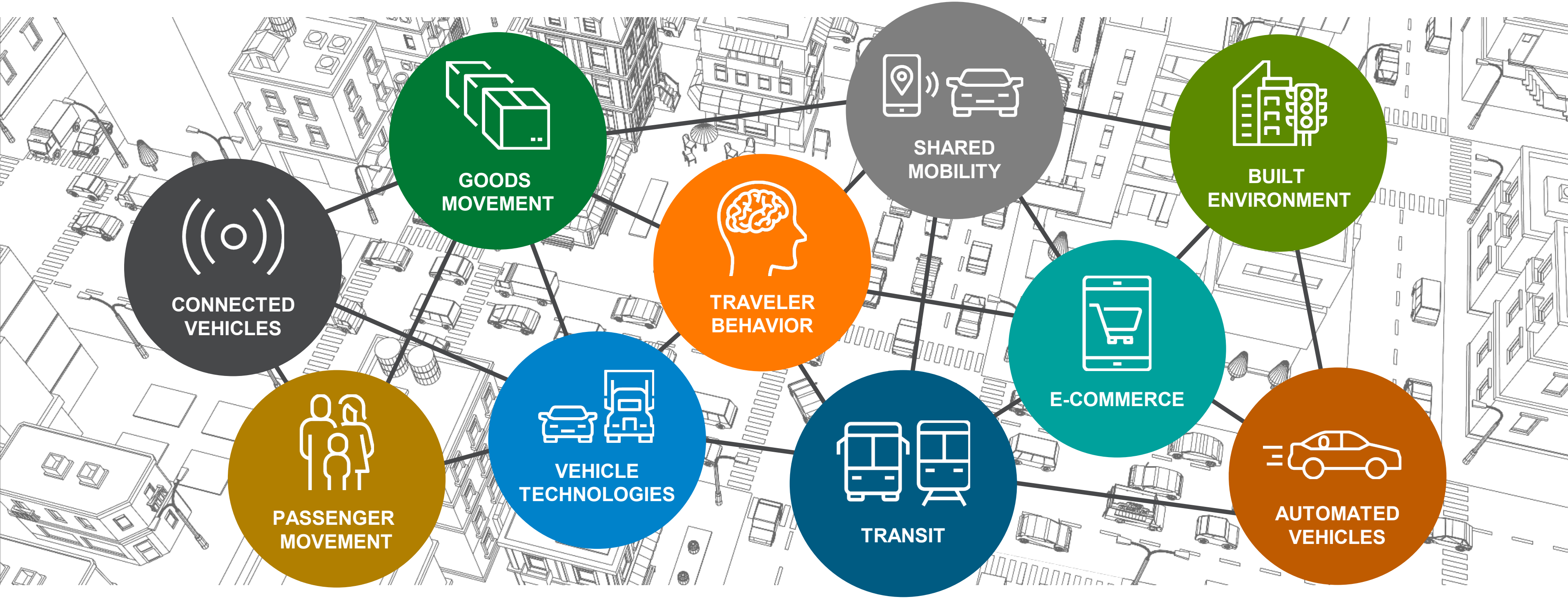
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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

VTO SYSTEMS-LEVEL R&D



TRANSPORTATION IS A SYSTEM OF SYSTEMS



SMART MOBILITY CONSORTIUM

The SMART Mobility Consortium is a multi-year, multi-laboratory collaborative dedicated to further understanding the energy implications and opportunities of advanced mobility solutions.

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

FIVE RESEARCH FOCUS AREAS

CONNECTED AND AUTOMATED VEHICLES

Identifying the energy, technology, and usage implications of connectivity and automation and identifying efficient CAV solutions.

MOBILITY DECISION SCIENCE

Understanding the human role in the mobility system including travel decision-making and technology adoption in the context of future mobility.

MULTI-MODAL FREIGHT

Evaluating the evolution of freight movement and understanding the impacts of new modes for long-distance goods transport and last-mile package delivery.

URBAN SCIENCE

Understanding the linkages between transportation networks and the built environment and identifying the potential to enhance access to economic opportunity.

ADVANCED FUELING INFRASTRUCTURE

Understanding the costs, benefits, and requirements for fueling/charging infrastructure to support energy efficient future mobility systems.

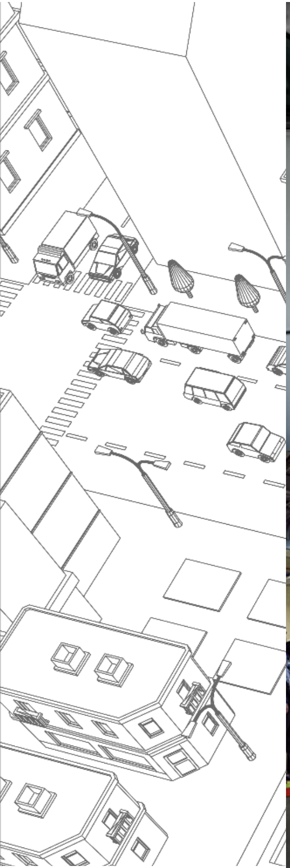


Photo Credit: NREL

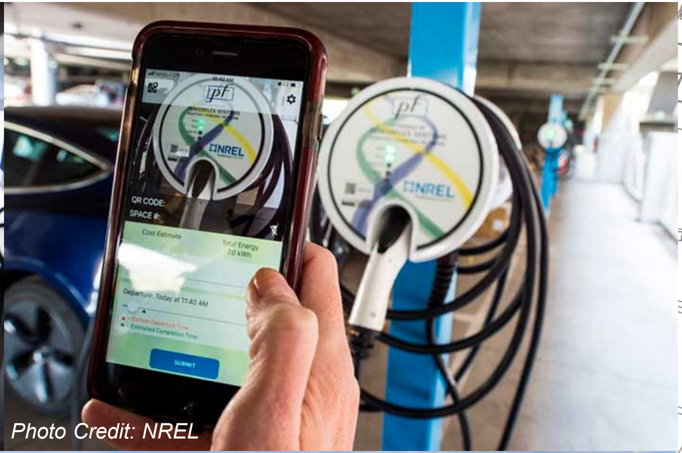
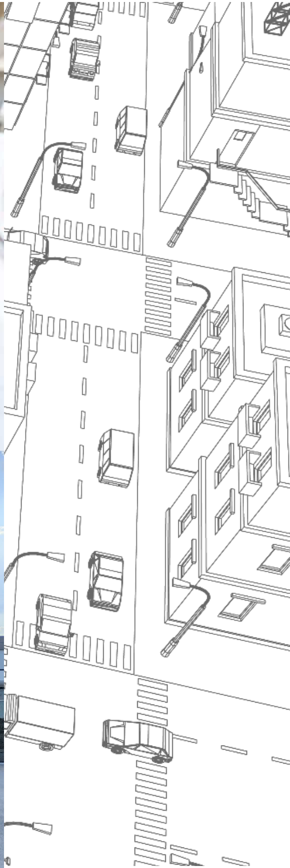


Photo Credit: NREL

Photo Credit: ORNL

Photo Credit: ANL/Stutenberg



RESEARCH TOPICS

- Charging needs of future market segments
- Costs & benefits of different infrastructure approaches
  - Light-duty ride-hailing
  - Class 7/8 freight transport
- Opportunities for automated vehicle charging
- National benefits of charging infrastructure deployment

MOBILITY: CONNECTING PEOPLE TO OPPORTUNITY

The solutions we are developing will power the next transportation revolution, ushering in a new era of

SMART Mobility.

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

EVALUATING EV CHARGING INFRASTRUCTURE IN A SMART MOBILITY SYSTEM

DECEMBER 17, 2020

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

EVALUATING EV CHARGING INFRASTRUCTURE NEEDS IN A SMART MOBILITY SYSTEM

JOHN SMART
Idaho National Laboratory

ERIC WOOD
National Renewable Energy Laboratory

For more information, contact:
eems@ee.doe.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

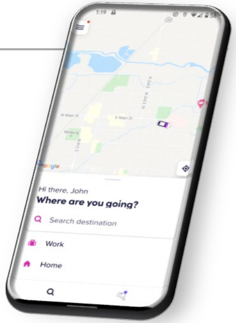
Argonne NATIONAL LABORATORY · BERKELEY LAB · INL Idaho National Laboratory · NREL NATIONAL RENEWABLE ENERGY LABORATORY · OAK RIDGE National Laboratory

NEW MODES PROMPT NEW QUESTIONS

Electric transportation is growing increasingly diverse

- What kind of charging infrastructure is needed?
- How much?
- Where?

Ride hailing



Automated vehicles

Source: Waymo

Medium and heavy-duty delivery vehicles

Source: Freightliner

Source: Amazon

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

NOW MORE THAN EVER

Market developments are increasing need for charging infrastructure

Waymo opens driverless robo-taxi service to the public in Phoenix

Lyft Announces Commitment to a Total Electric-Vehicle Fleet by 2030

Uber pledges to shift to '100 percent' electric vehicles by 2030

Driverless shuttle launches in downtown Tampa

Freightliner electric trucks surpass 500,000 real-world miles

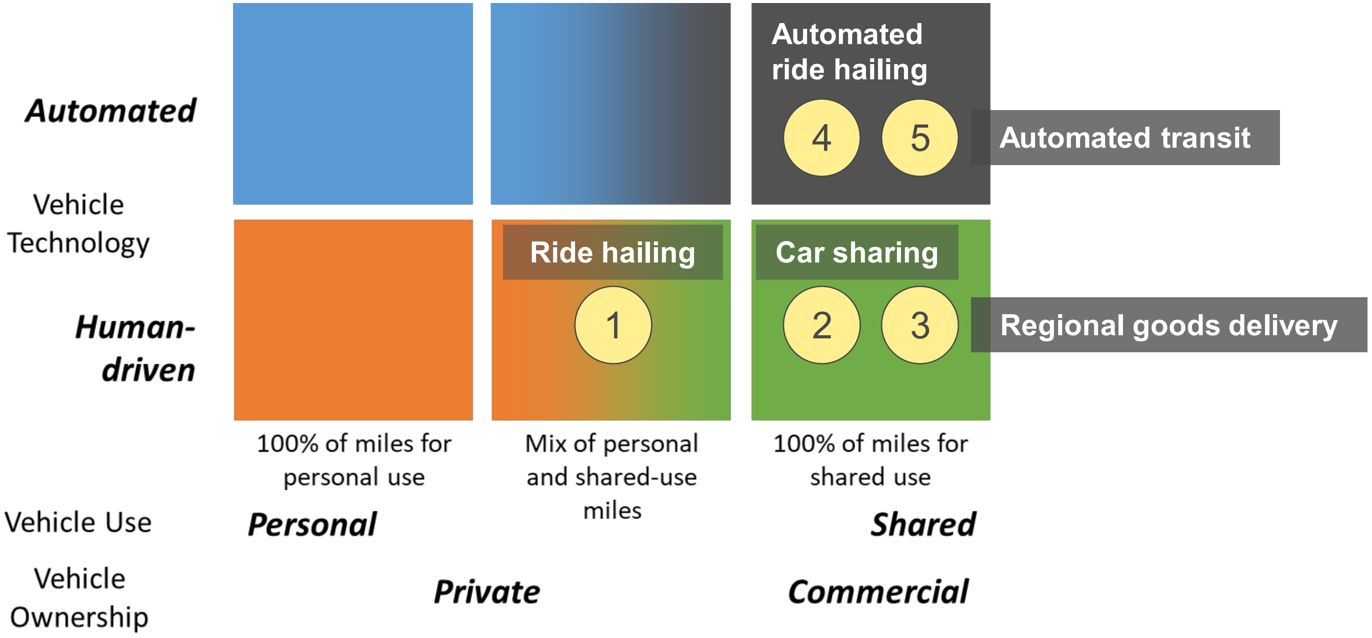
https://www.reuters.com/article/us-waymo-autonomous-phoenix/waymo-opens-driverless-robo-taxi-service-to-the-public-in-phoenix-idUSKBN26T2Y3
https://www.theverge.com/2020/9/8/21427196/uber-promise-100-percent-electric-vehicle-ev-2030
https://www.caranddriver.com/news/a32885490/lyft-all-electric-vehicle-fleet-2030
https://www.fleetowner.com/running-green/press-release/21147736/freightliner-electric-trucks-surpass-500000-realworld-miles
https://www.tampabay.com/news/transportation/2020/10/09/driverless-shuttle-launches-in-downtown-tampa

UNDERSTANDING USE CASES IS KEY

Infrastructure needs vary

- There is no universally “right” amount of charging infrastructure
- Trade-offs should be managed to meet case-specific objectives
- Must understand behavior and interests inherent to use cases

FIVE USE CASES STUDIED



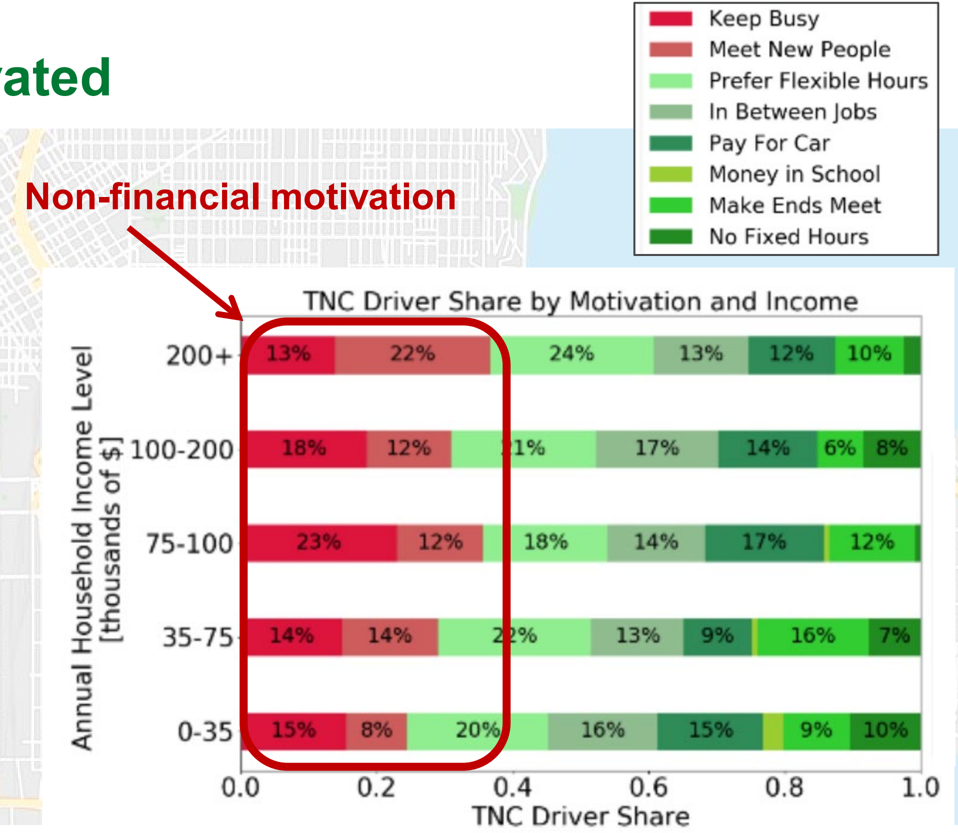
CHARGING INFRASTRUCTURE FOR: HUMAN-DRIVEN ELECTRIC RIDE HAILING

TNC DRIVERS HAVE DIFFERENT MOTIVATIONS…

…and not all are financially motivated

- Results from survey of 1,000+ TNC drivers in 10 cities showed nearly a quarter of drivers reporting non-financial motivations

- Only ~10% drove for a TNC daily and over half of drivers drove for a TNC for two days per week or less



Credit: Populus, NREL

A MINORITY OF TNC DRIVERS OPERATE FULL TIME

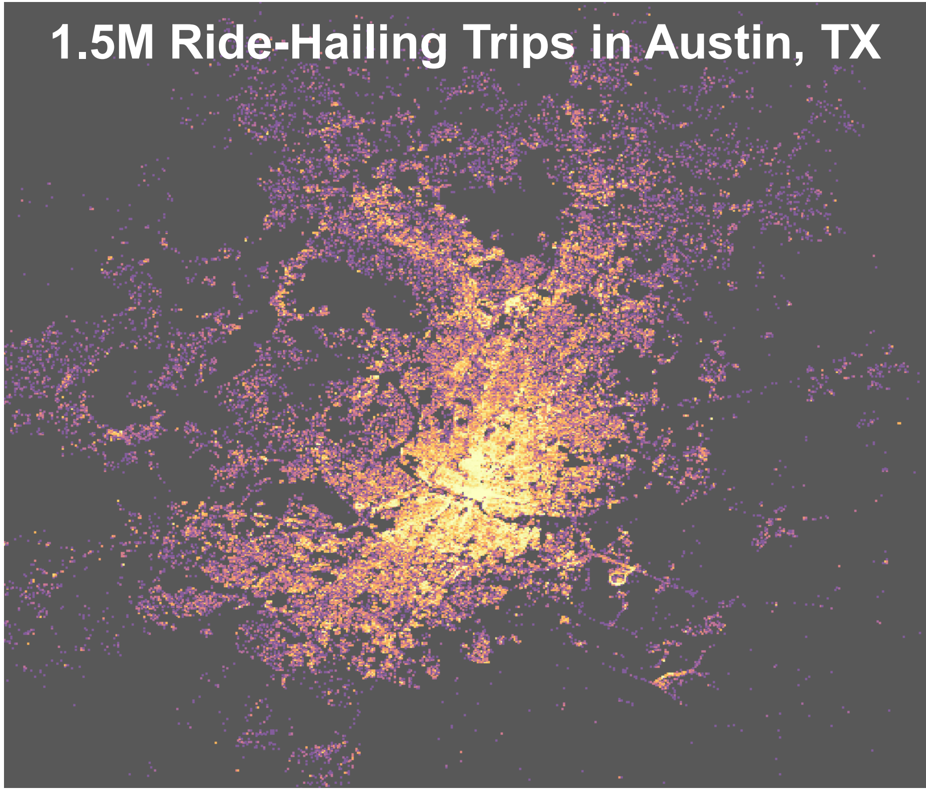
U.S. DEPARTMENT OF ENERGY SMARTMOBILITY Systems and Modeling for Accelerated Research in Transportation

Part Time Drivers
Less than 10 hours/week
49% of drivers
14% of rides
Annualized VMT = 7k mi

Half Time Drivers
10-35 hours/week
40% of drivers
57% of rides
Annualized VMT = 13k mi

Full Time Drivers
More than 35 hours/week
11% of drivers
29% of rides
Annualized VMT = 29k mi

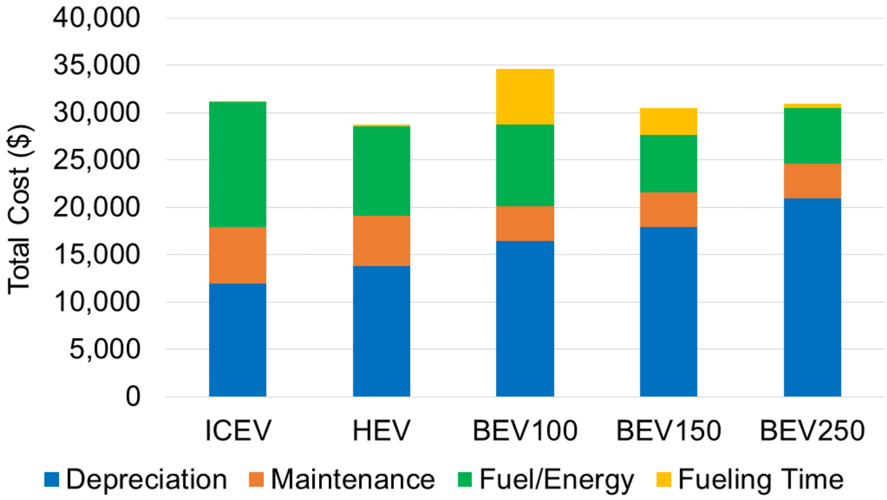
Full-time drivers have greatest economic incentive to electrify



Credit: Ride Austin, NREL

RIDE-HAIL ELECTRIFICATION APPROACHING COST PARITY

- Under present-day prices, EVs are not yet cost competitive for most TNC drivers (without purchase incentives)
- Projections for continued decreases in battery cost are likely to make BEVs more competitive
- Low-cost electricity (EV tariffs) and purchase incentives can also tip the scale in favor of BEVs



Assumptions:

- Avg full-time driver: 29k mi/yr
- 5-year ownership period
- No travel/queueing time to charge
- All drivers can charge at home
- No purchase incentives

Credit: INL

OVERNIGHT CHARGING ENABLES RIDE HAILING ELECTRIFICATION

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

	"Yesterday"	"Today"	"Tomorrow"
	 Range: 100 miles DCFC Power: 50 kW	 Range: 250 miles DCFC Power: 50 kW	? Range: 400 miles DCFC Power: 400 kW
 &  Overnight L2 & Public DCFC		Evaluate design tradeoffs	
Public DCFC Only 			

OVERNIGHT CHARGING ENABLES RIDE HAILING ELECTRIFICATION

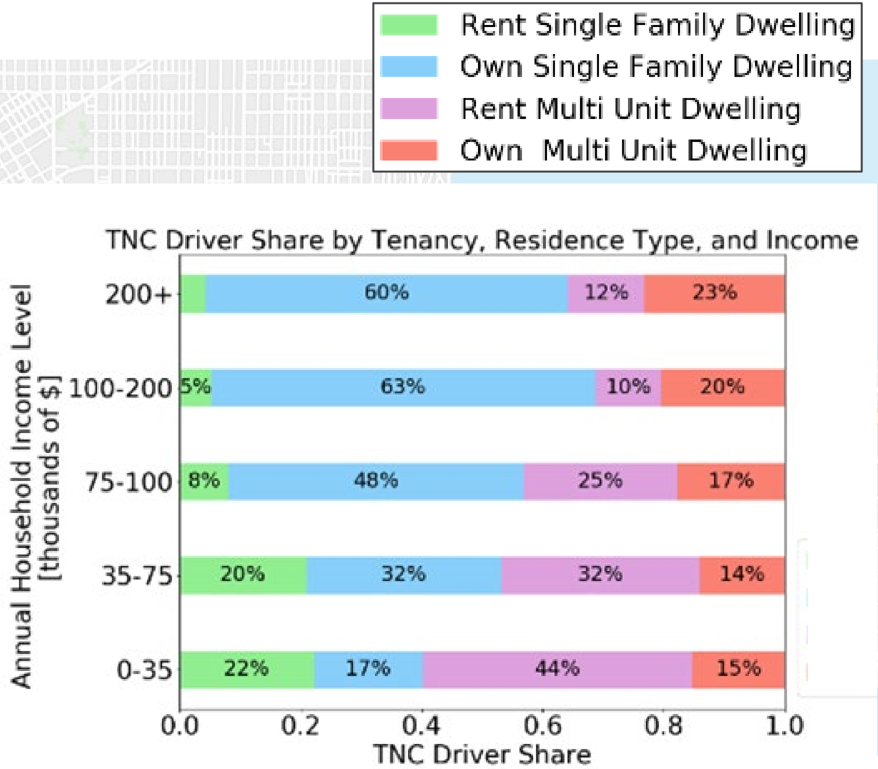
- Home charging obviates most of the need for public fast charging
- With overnight charging, simulations show 9% of the fleet relying on public fast charging
- Without overnight charging, 100% of the fleet fast charges 1-2 times per day

Data credit: Columbus Yellow Cab, NREL

MIXED REPORTS ON OVERNIGHT CHARGING ACCESS

- Populus survey reported 40% of TNC drivers live in multi-unit dwellings where home charging is traditionally problematic

- This data suggests the potential for poor access to residential charging for many TNC drivers, especially those with low income



Credit: Populus, NREL

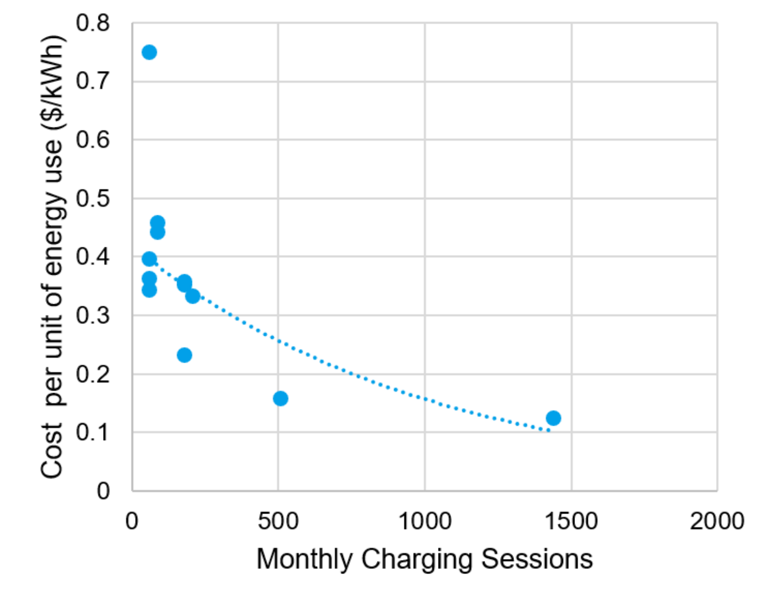
DEMAND-BASED NETWORK DESIGN

Low-cost installations are tempting in the short-term, but not financially viable in the long-term

- Simulation study in Columbus, OH using data from the local electric utility (AEP)

- Priority should be placed on siting fast charging at locations with high potential utilization

- Such sites are likely to include urban cores, transit hubs, and airports



Credit: ANL, INL, NREL

FAST CHARGING SYNERGIES

Overall EV sales benefit from infrastructure support for ride hailing

- Consumer choice modeling finds that fast charge support for ride hail drivers can increase overall EV sales by up to 10% by 2030
  - Electric rides and infrastructure visibility improves perception of EV technology
  - Increased infrastructure utilization improves economics for charging networks

Ride-hailing BEVs → Charging infrastructure → BEV market adoption → National energy impact

Credit: ANL, NREL, ORNL

CHARGING INFRASTRUCTURE FOR:

HUMAN-DRIVEN ELECTRIC CAR SHARING

CHARGING TIME DOMINATES DOWN TIME

Increasing charge power is more effective than adding stations to keep cars in service

Source: ReachNow

SEATTLE

50-kW DCFCs

VS.

50-kW DC fast chargers (DCFCs)

4% REDUCTION IN DOWNTIME

or

100-kW DCFCs

36% REDUCTION IN DOWNTIME

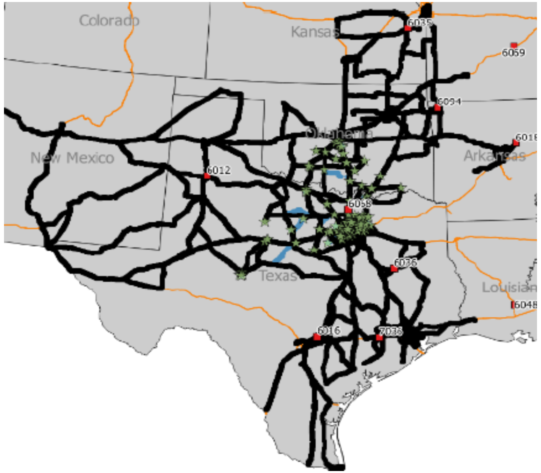
Credit: INL

CHARGING INFRASTRUCTURE FOR: REGIONAL GOODS DELIVERY

REGIONAL-HAUL PRIVATE MOTOR CARRIER

Modeled electric truck fleet based on real-world operations data

- Class 8 truck fleet based in Dallas, Texas area
- Data loggers on 22 trucks
- Data collected over 1 month
- Private delivery locations



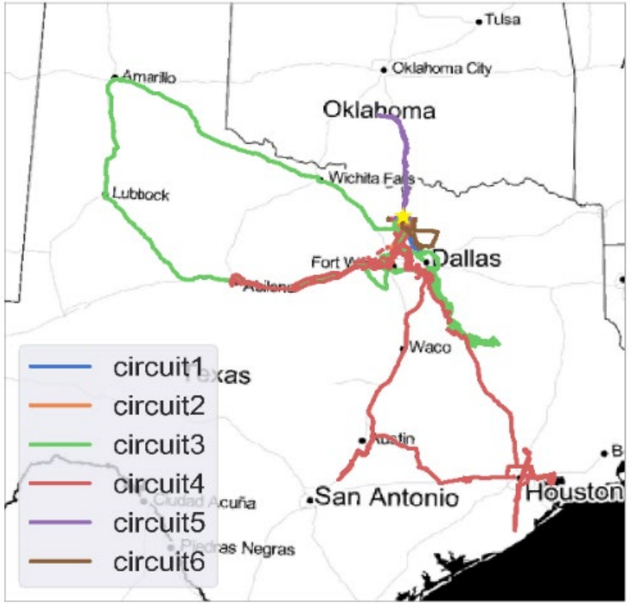
Modeled different EV range, charging power, and charging opportunity

Assessed ability to complete daily driving per current operations

REGIONAL-HAUL PRIVATE MOTOR CARRIER

Individual vehicles used for variety of routes

- A trip is travel between delivery locations or regional distribution centers (RDC)
- A circuit is the group of trips starting from and returning to the home RDC
- Assumed charging entire time stopped at an RDC



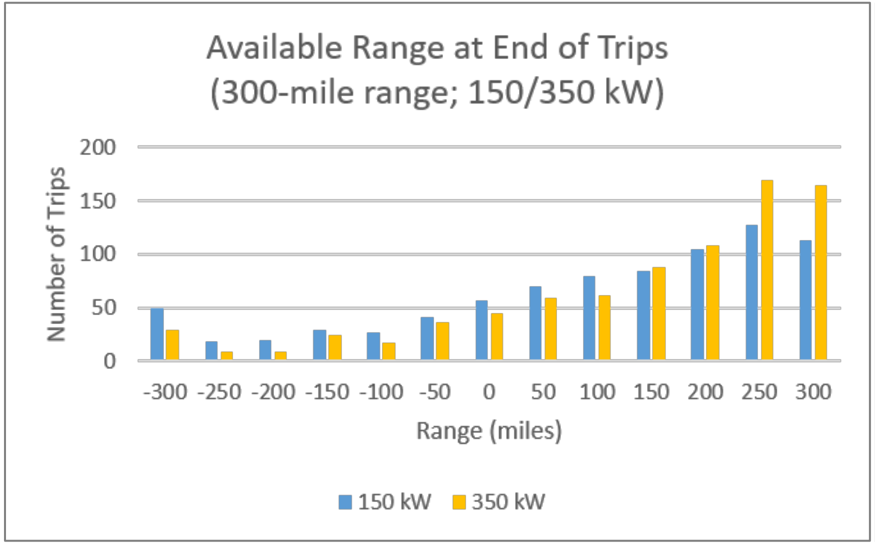
Summary of Single Truck Case Study	
Total distance driven (miles)	3,733
Number of trips	24
Total dwell time (hours)	144
Number of trips exceeding 300-mile range	4
Number of trips exceeding 500-mile range	0
Circuits (trip chains starting and ending at home RDC)	6
Number of stops at home and other RDCs	**11**

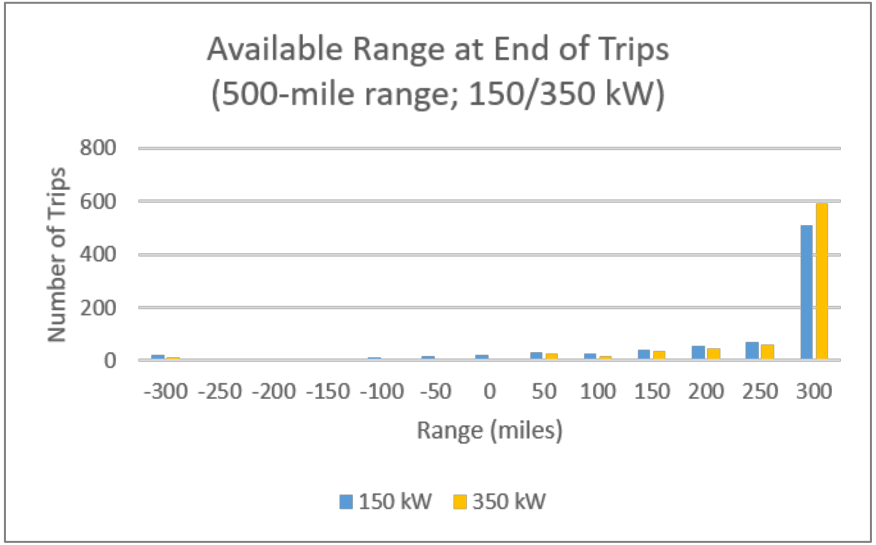
Credit: INL, NREL, ORNL

LONG RANGE AND PRIVATE FAST CHARGING MAY NOT BE ENOUGH

This fleet would need to change operations to electrify trucks

- Uninterrupted charging while dwelling at all destinations did not provide sufficient range for all trips





CHARGING INFRASTRUCTURE FOR: AUTOMATED ELECTRIC RIDE HAILING

CHARGING INFRASTRUCTURE IMPACTS MOBILITY, ENERGY, COST

Fleet and charging network design are inter-related

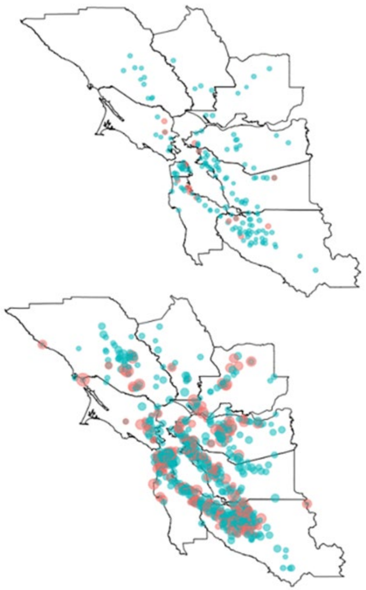
- Charging network density
- Charging power
- EV range
- Fleet size

→

- Customer wait time
- Vehicle miles traveled (VMT)
- Energy consumption
- Deadheading miles traveled
- Vehicle idle time between rides
- Vehicle time out of service (i.e., downtime)

→

- Passenger miles traveled (PMT)
- Fleet operating cost ($)



Depot chargers for automated ride-hailing EVs

Public chargers for human-driven ride-hailing and personal-use EVs

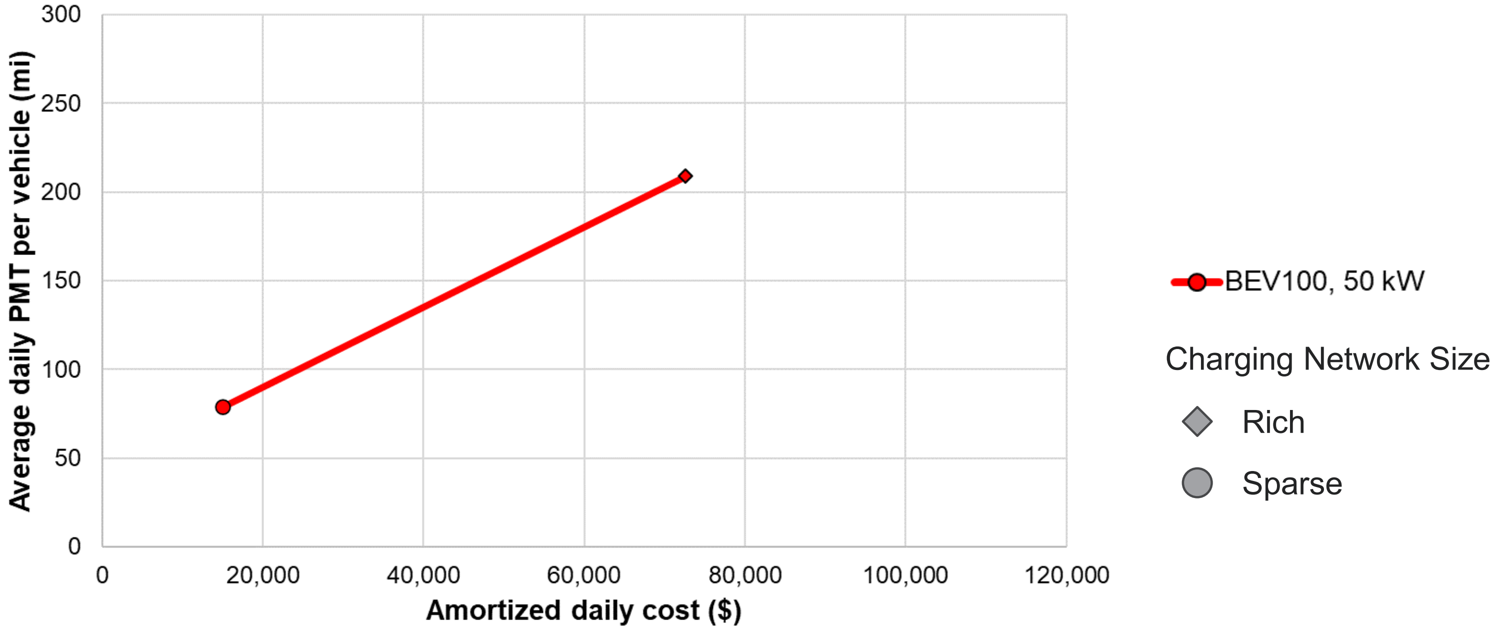
Maps show distribution of fast charging stations in San Francisco Bay Area for Sparse (top) and Rich (bottom) networks

Credit: ANL, INL, LBNL, NREL

QUANTIFYING CHARGING NETWORK COST AND BENEFIT TO THE FLEET

Charging network size affects fleet's capacity to serve passengers

SAN FRANCISCO

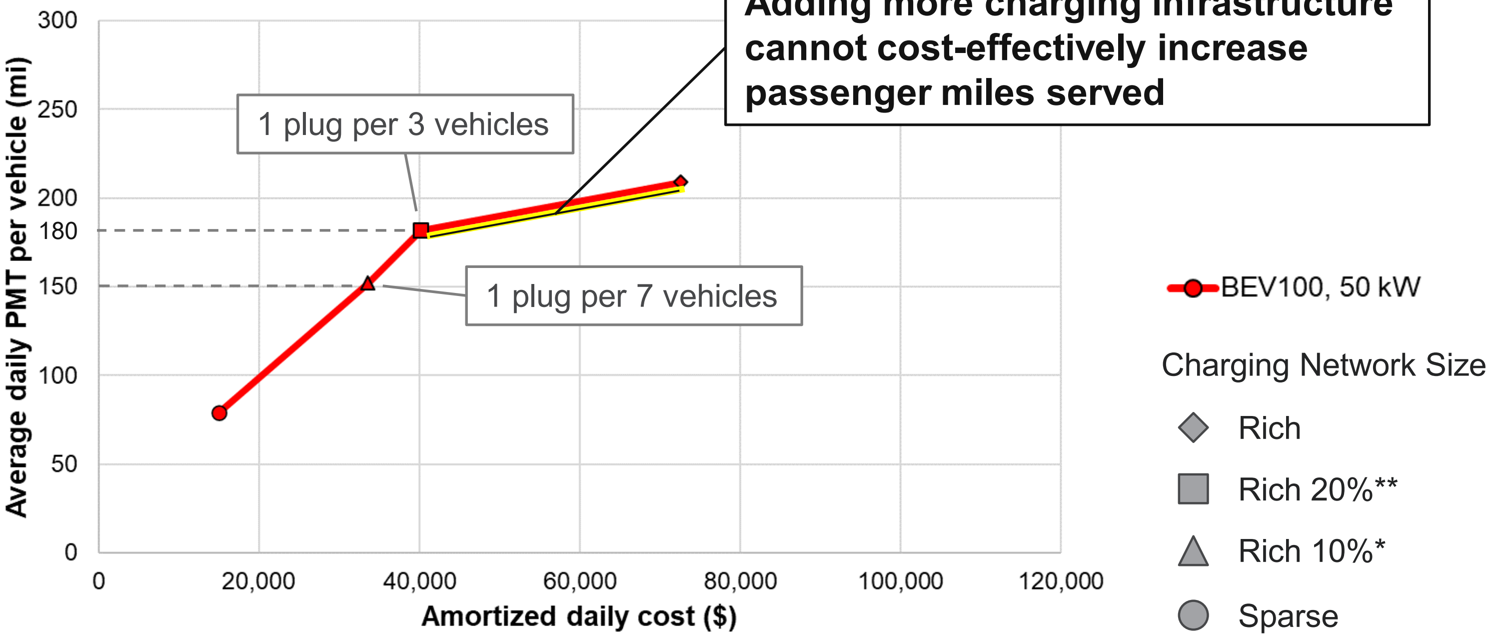


INTERMEDIATE CHARGING NETWORK SIZES ADD CLARITY

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

PMT served is linear with cost until point of diminished returns

SAN FRANCISCO



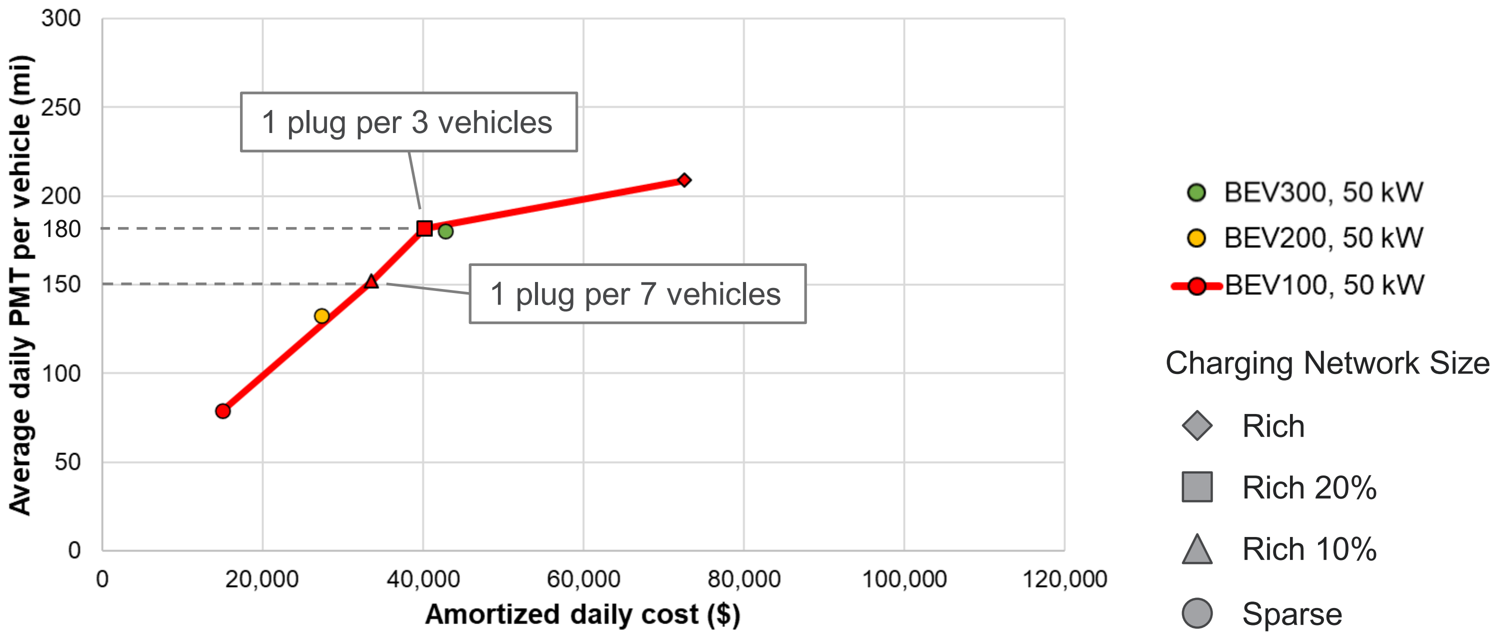
Credit: ANL, INL, LBNL, NREL

** Rich 20% has same number of stations as Rich but 20% of the plugs
* Rich 10% has same number of stations as Rich but 10% of the plugs

INCREASING EV RANGE INCREASES PMT

Provides same rate of return as increasing charging network size

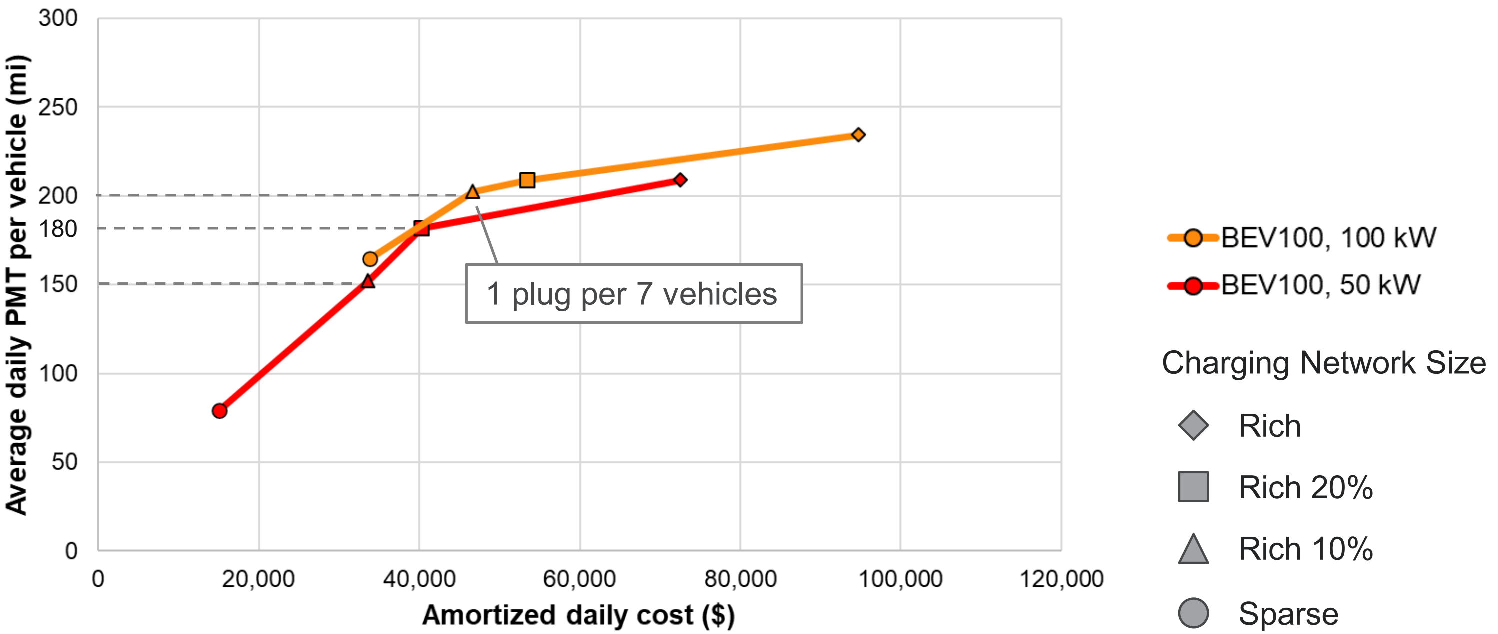
SAN FRANCISCO



Credit: ANL, INL, LBNL, NREL

INCREASING CHARGE POWER SURPASSES PMT THRESHOLD

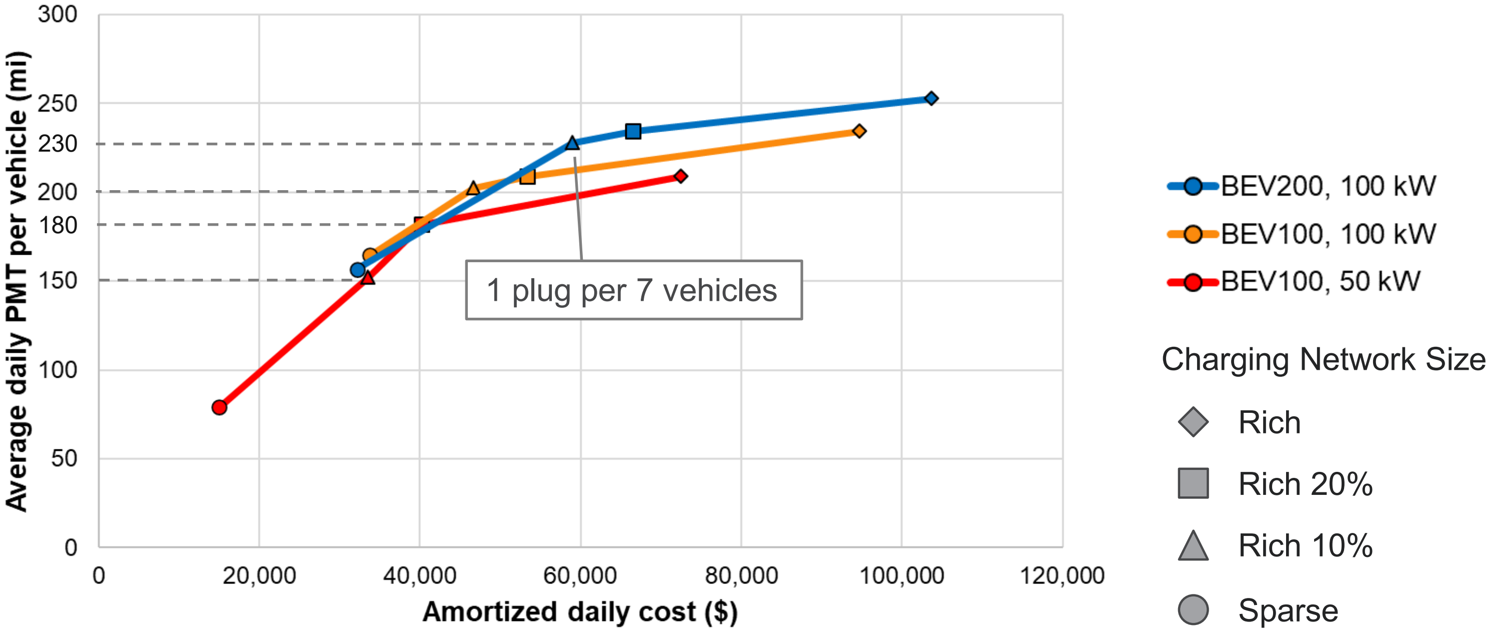
Upgrading to 100-kW charging cost-effectively increases PMT to 200 mi/day per vehicle



Credit: ANL, INL, LBNL, NREL

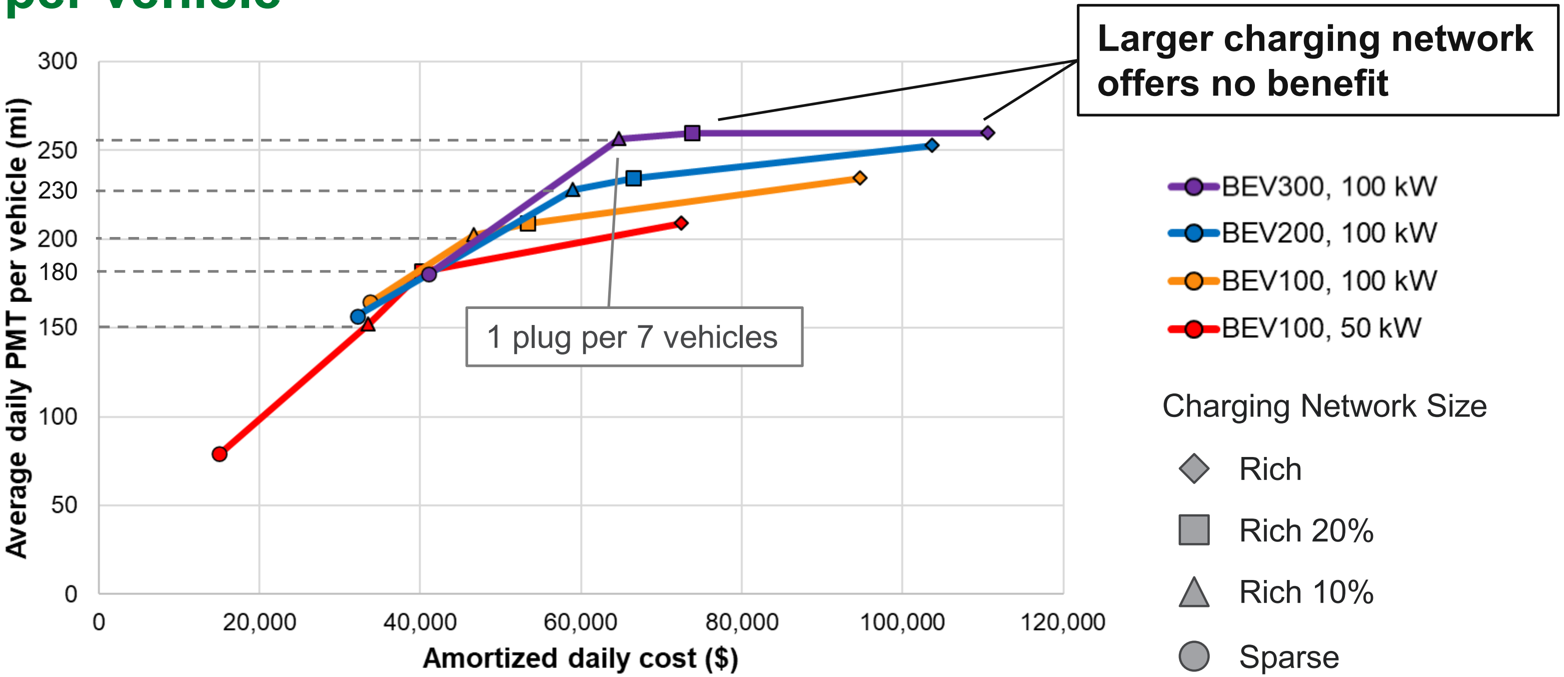
INCREASING CHARGE POWER *AND* EV RANGE INCREASES PMT FURTHER

BEV200s with widespread 100-kW charging cost-effectively serve 230 passenger mi/day per vehicle



TREND HOLDS WHEN INCREASING EV RANGE FURTHER

BEV300s with widespread 100-kW charging surpass 250 passenger mi/day per vehicle

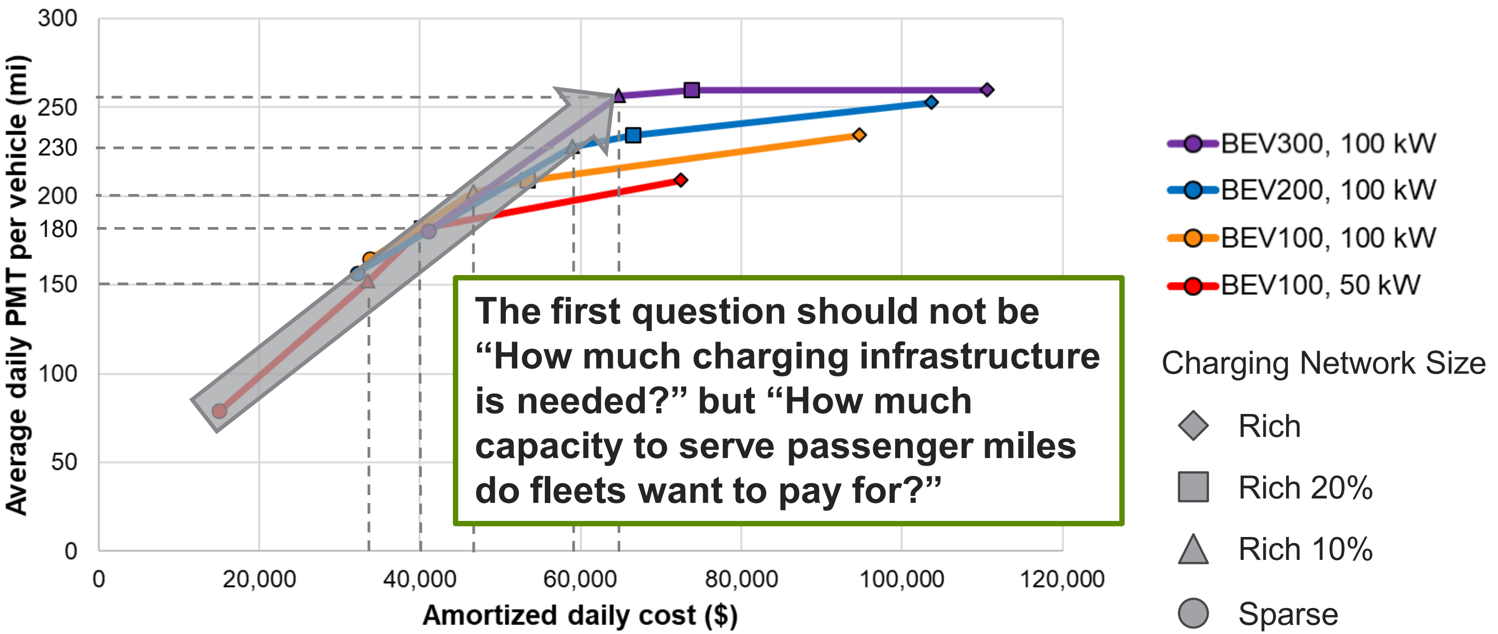


Credit: ANL, INL, LBNL, NREL

DIFFERENT SOLUTIONS AFFORD DIFFERENT LEVEL OF SERVICE

Quantifying level of service vs. cost prompts a new question

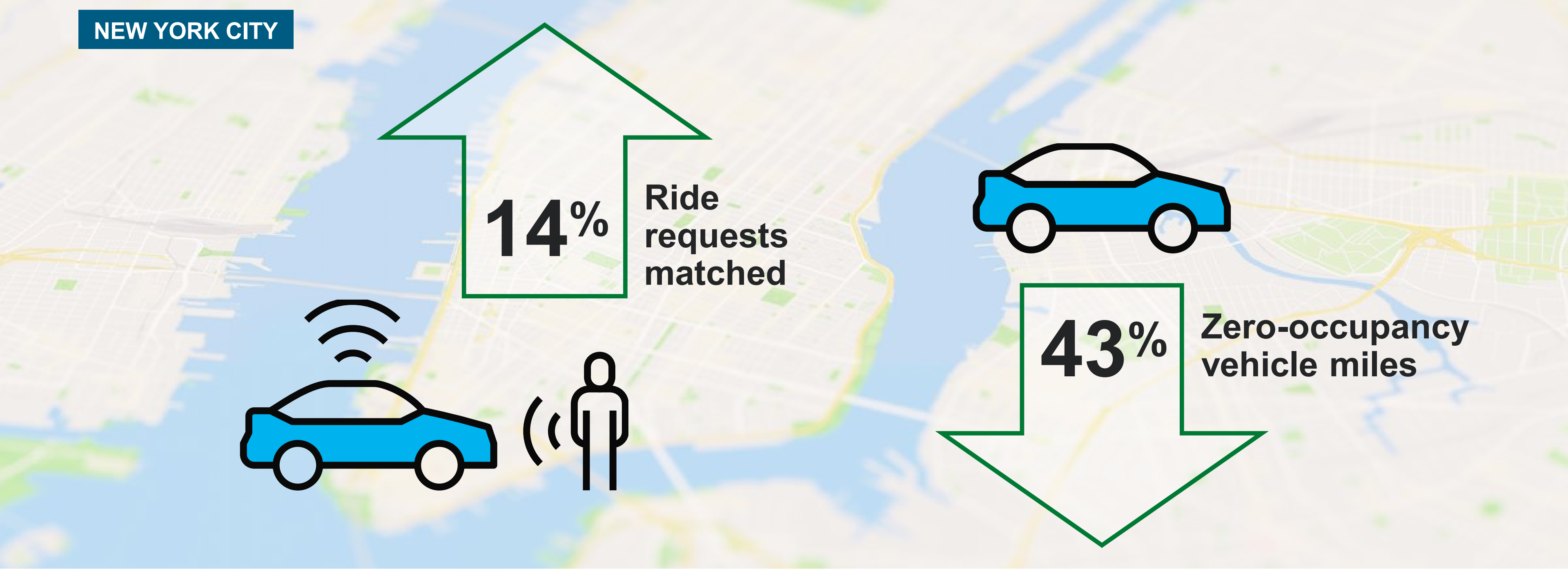
SAN FRANCISCO



Credit: ANL, INL, LBNL, NREL

CENTRALIZED DISPATCH IMPROVES EFFICIENCY OF AUTOMATED RIDE-HAIL FLEET

Compared to independent repositioning & charging decisions



CHARGING INFRASTRUCTURE FOR: AUTOMATED TRANSIT SHUTTLES

DYNAMIC WIRELESS CHARGING

Enables continuous automated shuttle bus operation

Stops one-mile apart along fixed route for buses with 8–12 passenger capacity*

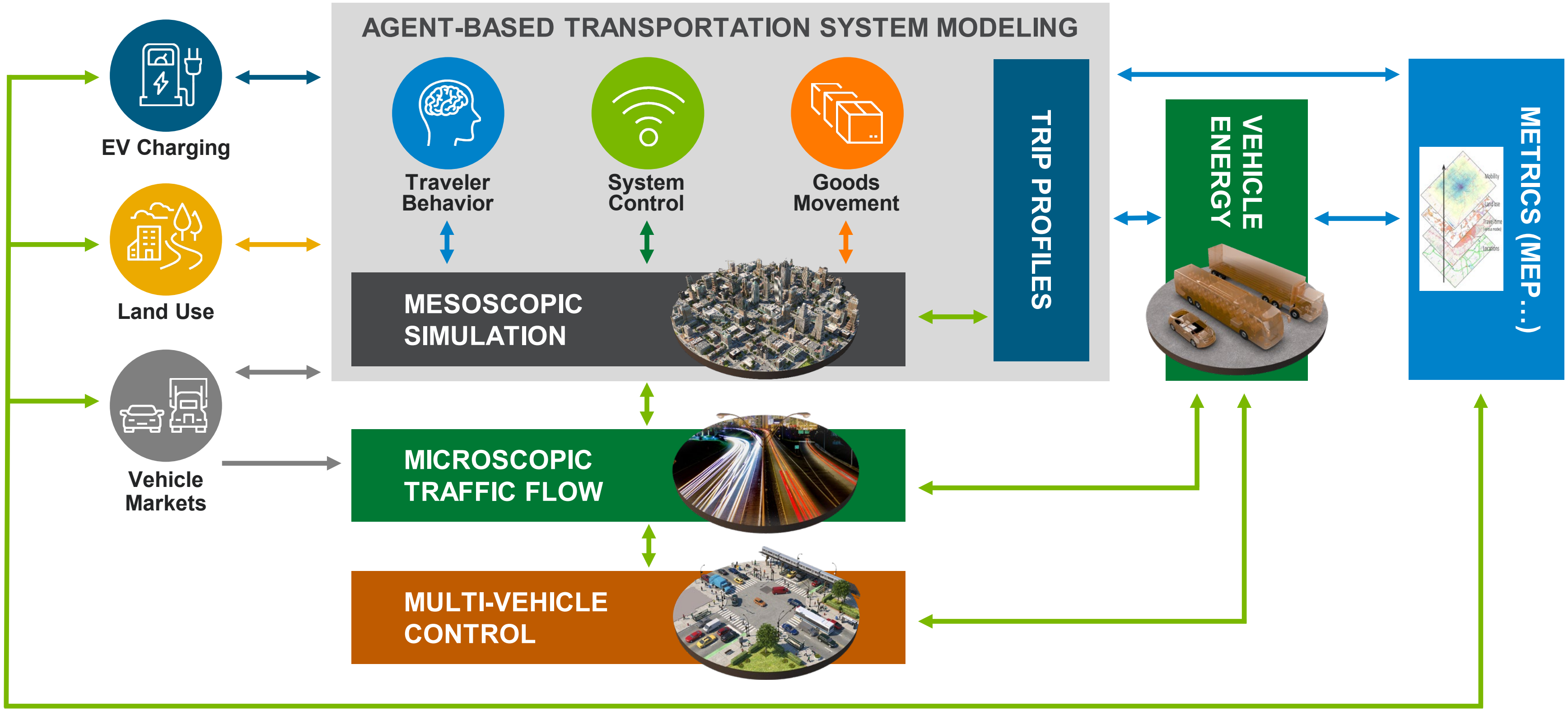
Credit: NREL, ORNL

*Each stop has a 5-meters wireless charger, with 100-kW charging capacity

CHARGING INFRASTRUCTURE FOR:

SMART MOBILITY MODELING WORKFLOW

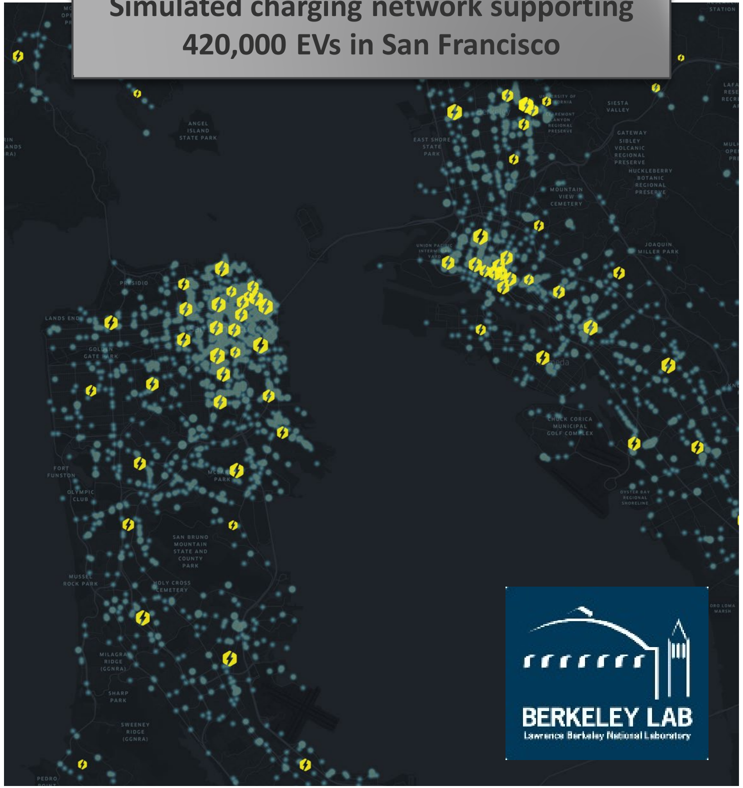
END-TO-END MODELING WORKFLOW



AGENT-BASED MODELS ENABLE ANALYSIS OF HIGH EV FUTURES

- Modeling enables unprecedented glimpse into high EV futures, including:
  - Station utilization
  - Ride hailing synergies
  - Impacts of residential access

EVI-Pro



Simulated charging network supporting 420,000 EVs in San Francisco

Simulated charging network supporting 1,000,000 EVs in Chicago

Argonne NATIONAL LABORATORY

BERKELEY LAB Lawrence Berkeley National Laboratory

WHAT’S NEXT?

PUBLIC, PRIVATE SECTOR IMPACT

DOE Research Informing Real-World Investments

- On-going statewide evaluation of charging infrastructure investment necessary to support state ZEV goals
- Includes detailed agent-based modeling of electric ride hailing in NYC
- With consideration for "supply side constraints" (parking, electrical access)

- Developed agent-based models of high ride-hailing futures in four US cities
  - Austin, Detroit, Miami, Washington D.C.
- Considered five possible future electric generation mixes in each location
- Found annual cost of charging SAEV fleets to **decrease 13-46%** as a result of connectivity between electric utilities and SAEV fleets

CONCLUSION

- Design charging networks around demand
- Look beyond simply adding more charging stations
  - When less downtime or more range is needed, increasing charging power and EV range may be prudent (if not necessary)
  - Changing business operations may be needed
  - Define objectives to “right-size” system
- Optimize AEV fleets through coordinated control
- Leverage DWPT to keep automated transit vehicles on the road

RESEARCH TEAM

Argonne National Laboratory	Idaho National Laboratory	Berkeley Lab	NREL	Oak Ridge National Laboratory
Zicheng Bi	Yutaka Motoaki	Timothy Lipman	Alicia Birky	Amy Moore
Yan Zhou	Mohammad Roni	Zachary Needell	Brennan Borlaug	Omer Onar
Zhi Zhou	Shawn Salisbury	Colin Sheppard	Erin Burrell	Fei Xie
	John Smart	Teng Zeng	Eleftheria Kontou	
	Lionel Toba	Hongcai Zhang	Dong-Yeon Lee	
	Victor Walker		Andrew Meintz	
	Zonggen Yi		Eric Miller	
			Ahmed Mohamed	
			Matthew Moniot	
			Clement Rames	
			Nicholas Reinicke	
			Dustin Weigl	
			Eric Wood	

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

MOBILITY FOR OPPORTUNITY

FOR MORE INFORMATION

David Anderson
Program Manager
Energy Efficient Mobility Systems (EEMS)
Vehicle Technologies Office
U.S. Department of Energy
eems@ee.doe.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy