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

TRANSPORTATION ELECTRIFICATION

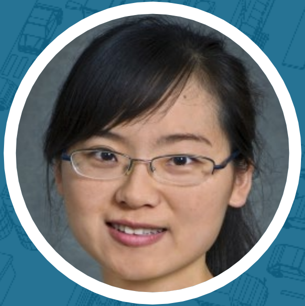
August 08, 2023

SMART Webinar Series
Webinar #7

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

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

TODAY'S SPEAKERS



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PREVIOUS WEBINARS

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

FEBRUARY
OVERVIEW, KEY METRICS AND INSIGHTS SNEAK PEEK

MARCH
MULTIMODAL TRAVEL
Transit & Ridehail

APRIL
MULTIMODAL TRAVEL
Micromobility
Drones

MAY
CONNECTED & AUTOMATED VEHICLES (CAVs)
Vehicle and powertrain control
Traffic signal control

JUNE
CAVs and Intelligent Transportation Systems
Transportation system impact, induced VMT, parking, curb management, land use, policies

JULY
FREIGHT
Last mile delivery

TODAY

AUGUST
ELECTRIFICATION
EV charger deployment
Grid impact

2023

Webinar Materials

IMPACT OF ELECTRIFICATION

- What are potential impacts of Zero Emissions Vehicle (ZEV) technology progress and sales mandates on vehicle transactions?
- How might complimentary policies (such as incentives and tax credits) influence the rate and equity implications of household vehicle fleet turnover?

- What is the impact of vehicle electrification on fleet size and operation?
- Is coordinated repositioning and EV charging beneficial to TNC operators?

- What are the impact of different levels of personal EV ownership and charger deployment on energy consumption, GHG emissions, waiting times, and plug utilization?

- What are the benefits of electric trucks in terms of consumption, emission, total cost of ownership and equity?

EV = electric vehicle; GHG = greenhouse gas; TNC = transportation network company (like Uber and Lyft)

VEHICLE TECHNOLOGY PROGRESS AND ZEV MANDATE IMPACT ELECTRIC VEHICLE SALES, FLEET TURNOVER, AND EQUITY

Supply Focused Levers

2035 ZEV Mandate	Aggressive scenario
DOE R&D Targets/Goals	Technology Success
Stagnating Battery Price	Conservative scenario

↓

Market Penetration Tool

↓

Fleet Composition in SF Bay Area

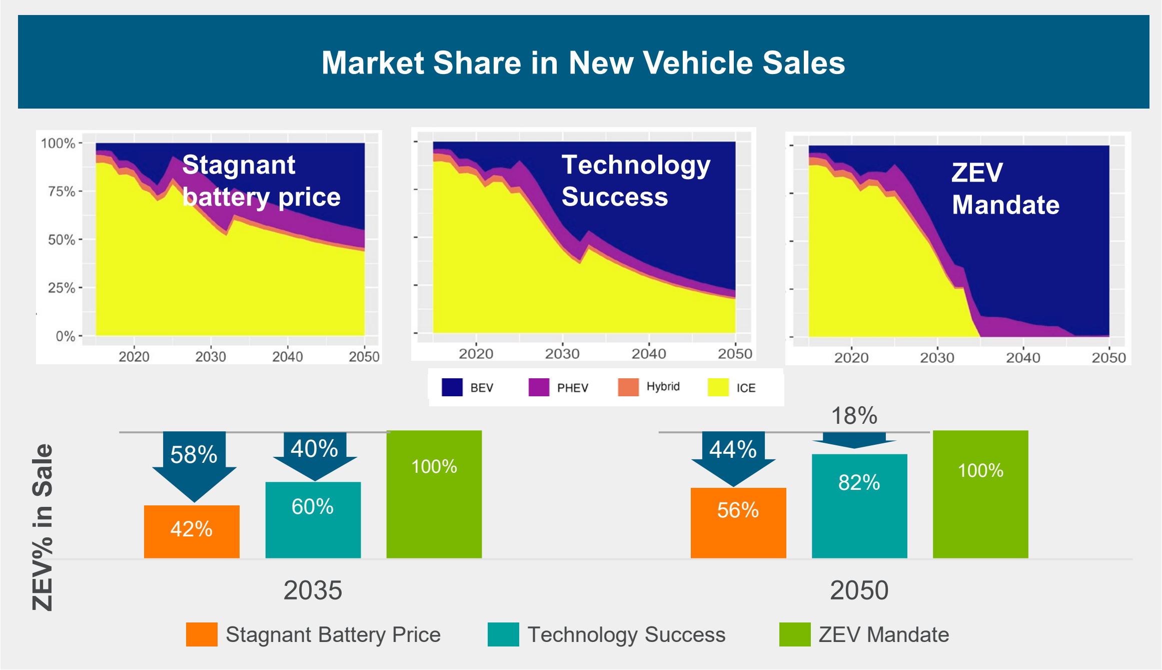
- How do technology progress and ZEV Mandate affect ZEV sales over time?
- How does the household fleet transition to ZEV technology play out?
- Is the transition just and equitable and what are the underlying drivers?

ZEV: zero emission vehicles or “clean vehicles” defined as battery electric, plug-in hybrid, and fuel cell vehicles

DOE R&D TARGETS AND ZEV MANDATE SIGNIFICANTLY INCREASE ZEV MARKET SHARES

- **The 2035 ZEV Mandate scenario results in the greatest growth of ZEV sales**
- **The Technology Success scenario results in fast growth in ZEV sales, narrowing the gap to ZEV mandate over time, leading to 82% ZEV market shares in 2050**
- **The Stagnant Battery Price scenario results in lower (56%) ZEV market share by 2050**

- **Continued public and private stakeholder investment in technology progress together with supportive policies are important to transition the fleet to ZEVs**

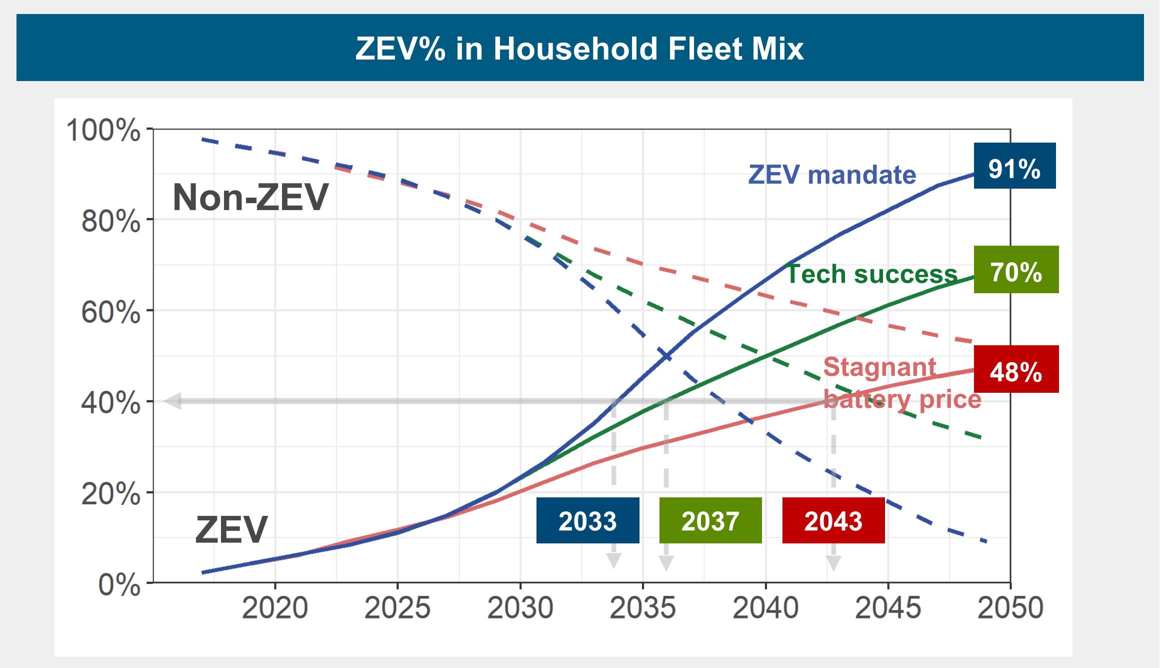


*Preliminary results in San Francisco Bay Area

DOE R&D TARGETS AND ZEV MANDATE ACCELERATE FLEET TURNOVER

- **Technology success alone results in 40% ZEV household stock share by 2037**
- **Stagnated battery price reductions delays process by ~6 years**
- **Implementing the 2035 ZEV mandate along with technology success accelerates the turnover by ~4 years**
- **Technology success and ZEV mandate combined enable a transition to ZEV dominant (>50%) ownership by 2037**

- **Stagnant battery prices and no mandate could delay the transition to ZEV household fleet stock by as much as 10 years**



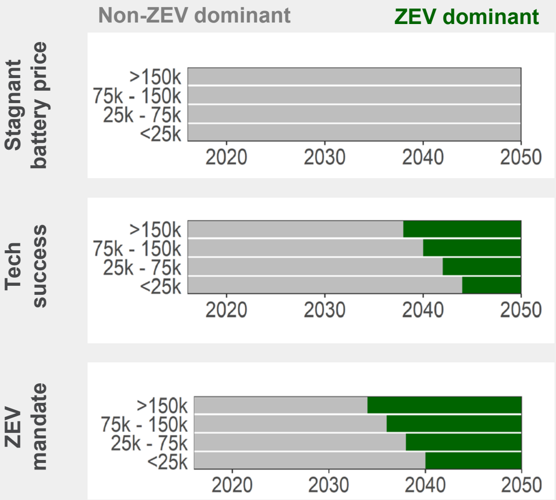
*Preliminary results in San Francisco Bay Area

INCOME DISPARITY PRESENT ACROSS SCENARIOS BUT DECLINES OVER TIME

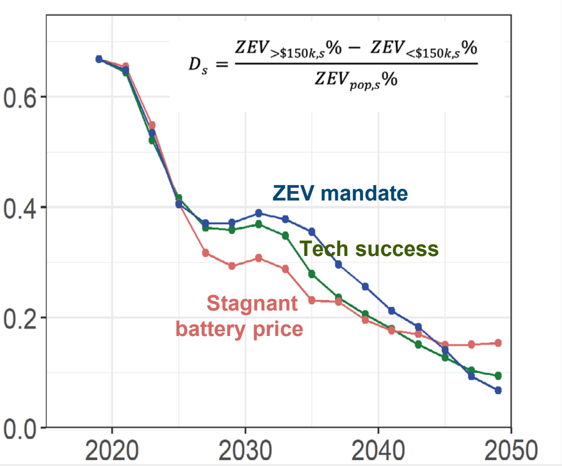
- **Highest income group transitions to ZEV ownership ~5 years earlier than the lowest; if battery prices do not stagnate then all income groups transition to >50% ZEV ownership by 2050**
- **Relative income disparity in ZEV ownership shrinks over time across all scenarios**
- **Equity implications are path-dependent and differ by time frame of consideration; technology progress + ZEV mandate reduces income disparity the most in the long run**

- **Policymakers could consider approaches to minimize income disparity with respect to differential ZEV adoption in the mid to long run**

Transition to ZEV Ownership by Income Groups



Income Disparity in ZEV Ownership



*Preliminary results
D_s = Relative difference in ZEV% between income groups above and below $150K for scenario "s"

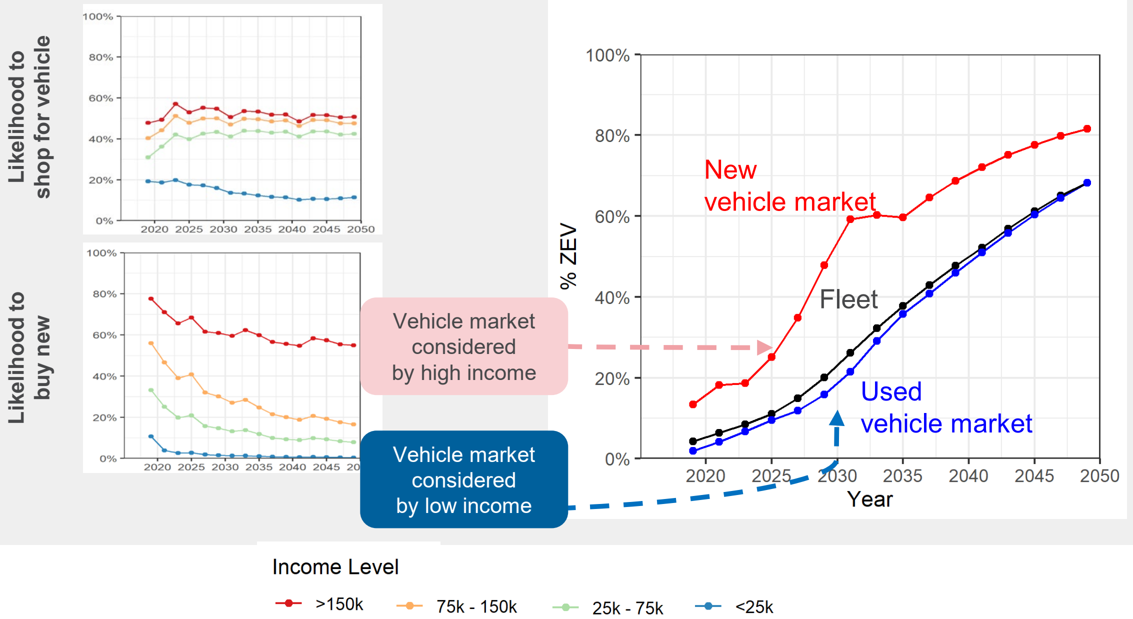
INCOME DIFFERENCE IN ZEV ADOPTION DRIVEN BY TRANSACTION FREQUENCY, VINTAGE CHOICE, AND AVAILABILITY IN USED MARKET

- **Faster ZEV penetration in higher income groups is due to**
  - **More frequent vehicle transaction opportunities**
  - **Higher likelihood of purchasing new vehicles**
  - **Greater ZEV availability in new vehicle market**
- **There is a ~10-year lag in ZEV supply between new and used vehicle markets**

- **Policies that promote retirement of aging vehicles and increasing ZEV supplies in the used market may help address the income disparity in ZEV adoption**

ZEV adoption process by income groups

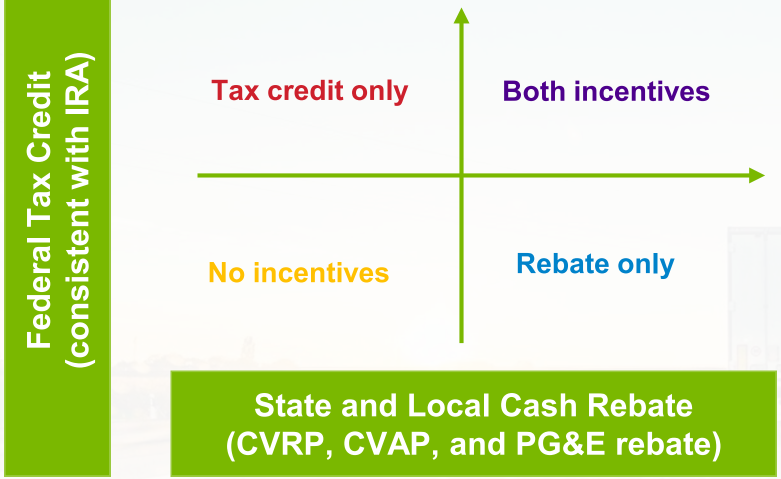
Available ZEV in used market lags behind new vehicle market



*Preliminary results

PURCHASE INCENTIVES REDISTRIBUTE ZEV ADOPTION AMONG INCOME GROUPS AND REDUCE INCOME DISPARITY IN ZEV OWNERSHIP

KEY LEVERS



What are the relative impacts of purchase incentives toward reducing ZEV adoption income disparity?

Photo from iStock 1222147442

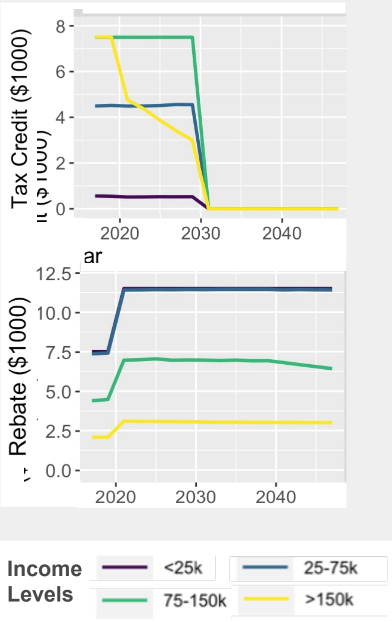
IRA = Inflation Reduction Act; CVRP = California's Clean Vehicle Rebate Project; CVAP = Clean Vehicle Assistance Program; PG&E = Pacific Gas and Electric

PURCHASE INCENTIVES REDUCE THE INCOME DISPARITY IN ZEV OWNERSHIP

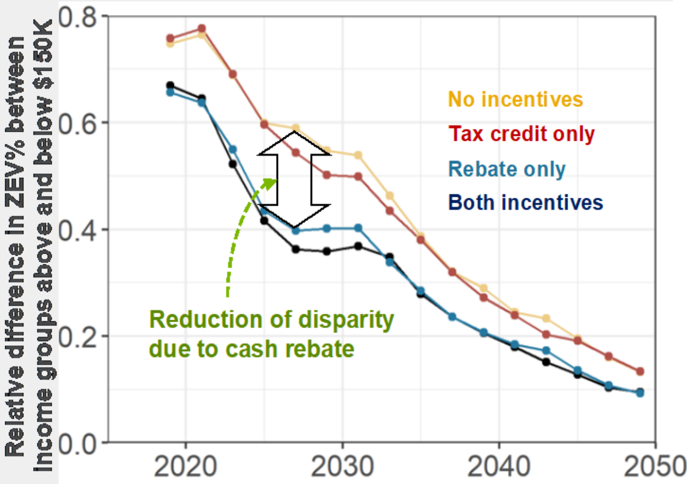
- Available incentives differ by income groups driven by
  - Income eligibility
  - Tax liability
  - Incentive types
- Federal tax credit and state and local rebate programs reduce income disparity in ZEV ownership
- Cash rebates improve equity more than a tax credit; cash rebate accounts for 80% to 90% of the reduction in income disparity with combined purchase incentives

- Alternative incentive forms, rate structures, and income eligibility can be considered to further reduce income disparity

Incentives Differ by Income Groups and Incentive Types



Purchase Incentives Reduce Income Disparity in ZEV Ownership



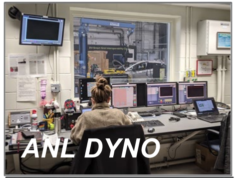
Relative difference in ZEV% between income groups above and below $150K for central technology success scenario is shown here.

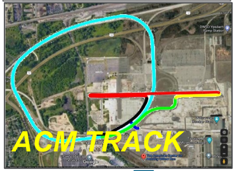
*Preliminary results

CONNECTED/AUTOMATED DRIVING CAN IMPROVE BEVS ENERGY-EFFICIENCY

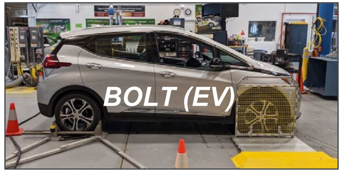
- **Non-connected automated driving can save 5%**
- **With connectivity, adding eco-approach with SPaT* can save 18.5%**
- **Results highly depend on scenario**
- **Energy savings measured in XIL testing, mixing real and virtual systems, on track and on chassis dyno**

- **Stakeholders could consider driving automation and connectivity as levers for increased EV range**



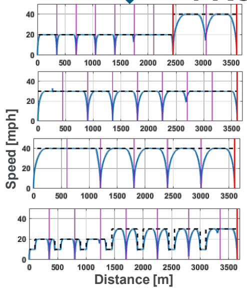


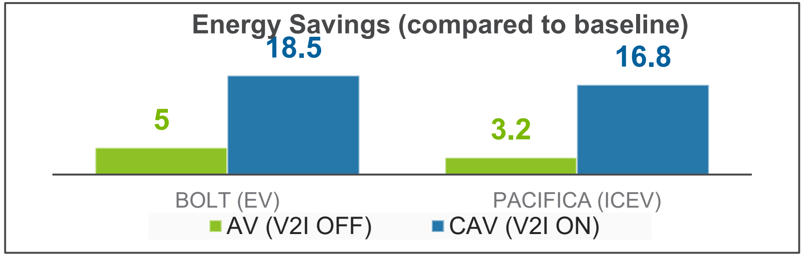
Custom "eco" connected and automated driving implemented in real experimental vehicle



- **AV**: Automated driving, no SPaT info from V2I
- **CAV**: AV + SPaT received via virtual V2I
- **Baseline**: AV with more "human-like" acceleration

4 Routes



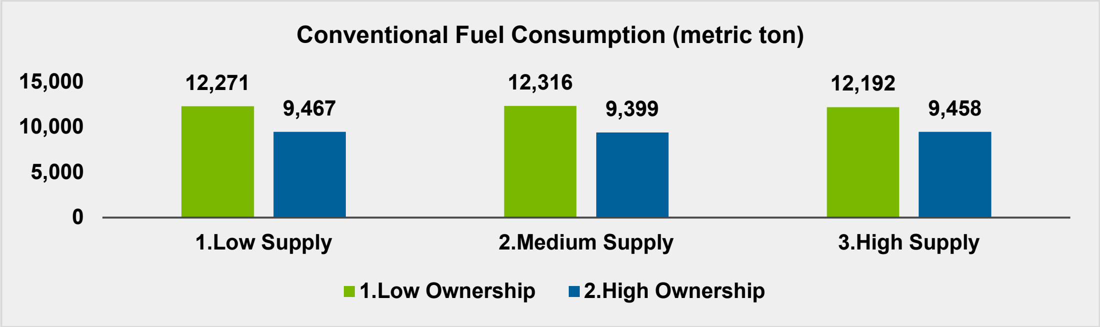


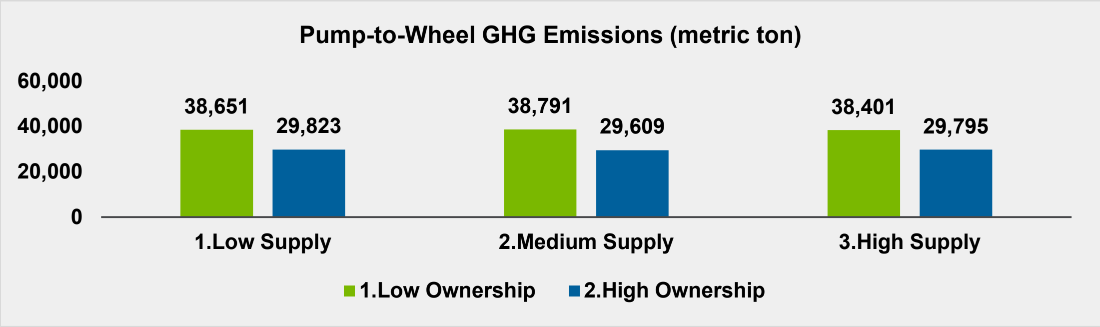
ICE-V: Internal Combustion Engine; EV: Electric Vehicle ; SPaT: Signal Phase and Timing ; XIL: Anything-in-the-Loop

TRANSPORTATION ELECTRIFICATION CRITICAL TO REDUCING ENERGY CONSUMPTION AND PUMP-TO-WHEEL (PTW) GHG EMISSIONS

- As EV ownership goes from 20% to 40%, electricity consumption increases 100%
- As conventional car ownership drops from 80% to 60%, fuel consumption reduces by 25%
- PTW GHG emissions are reduced by 25%
- Well-to-wheel reduction is around 10% but the wheel-to-pump (WTP) portion is US average only

- Public agencies should continue to incentivize xEV adoption across all vehicle classes



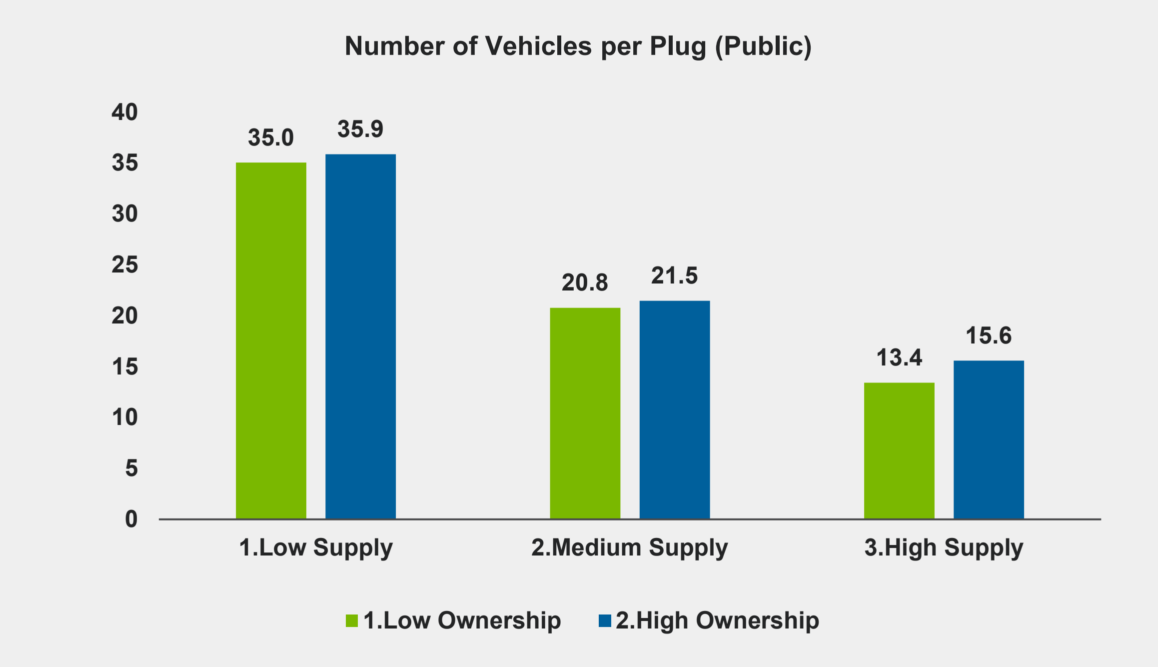


SIMULTANEOUS CONSIDERATION OF BEV USAGE AND EVSE NUMBER/LOCATION CRITICAL

Optimization algorithm used to minimize system costs

- 2 BEV ownership levels:
  - Low (20%)
  - Medium (40%)
- 3 EVSE deployment levels
- 50 kW chargers
- 2019 land use and population
  - Multi-unit: 5% residential charging
  - Single-unit: 61%
- Prioritizing user cost decreases the number of vehicles per plug

- Stakeholders could consider individual EV owners' travel patterns to place chargers so as to minimize user and operator costs

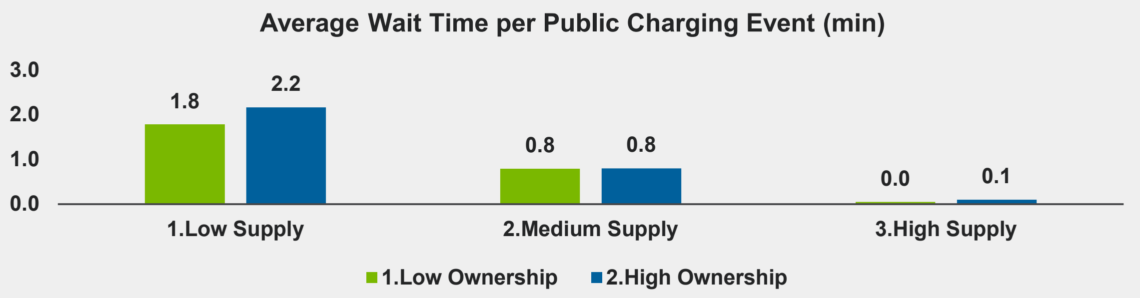


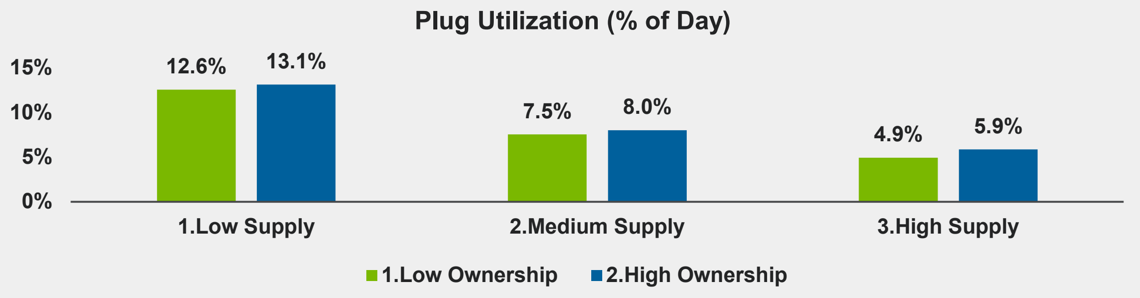
EVSE = electric vehicle supply equipment (i.e., vehicle chargers)

INCREASED EVSE DEPLOYMENT IMPROVES TRAVELER EXPERIENCE AT THE EXPENSE OF EVSE BUSINESS MODEL

- High EVSE deployment drives waiting times effectively to zero
- This results in very low utilization rates
- 35 vehicles/plug (low deployment) sufficient to achieve charging needs given the plugs are located optimally!

- EVSE providers and public agencies should collaborate to provide excellent user experience while ensuring profitability, especially during BEV market growth





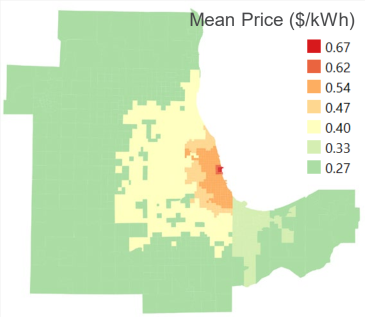
EVSE = electric vehicle supply equipment (i.e., vehicle chargers)

UTILITY COST AND CHARGING PRICE IMPACTS TRAVEL BEHAVIOR AND OPTIMAL EVSE DEPLOYMENT

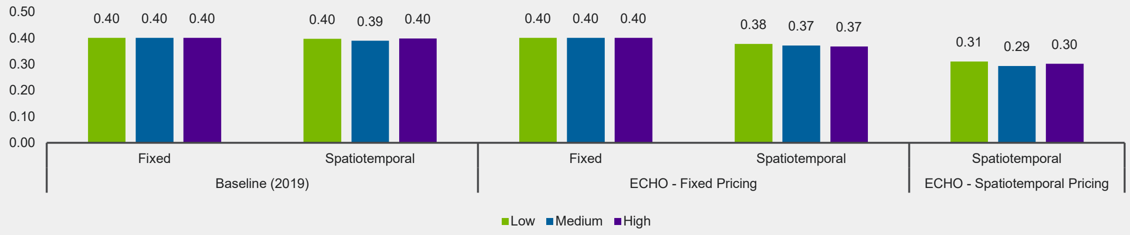
- **Travelers try to minimize their total charging cost for waiting time, detour time and monetary cost**
- **Spatiotemporal electricity price changes charger selection criteria and results in different configuration of optimum charging infrastructure**
- **Electricity price decreases moving from central business district to rural and changes in each period**

- **Electricity pricing structure could be considered by EVSE stakeholders when deciding on deployment to drive down user cost without compromising service quality**

		Off Peak (10pm-6am)			Peak (6am-2pm & 7pm-10pm)			Super Peak (2pm-7pm)		
Area Type	#Area	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
CBD	1	0.4	0.6	0.5	0.51	0.76	0.63	0.81	1.22	1.01
	2	0.35	0.55	0.45	0.44	0.7	0.57	0.71	1.11	0.91
	3	0.3	0.5	0.4	0.38	0.63	0.51	0.61	1.01	0.81
	4	0.25	0.45	0.35	0.32	0.57	0.44	0.51	0.91	0.71
	5	0.2	0.4	0.3	0.25	0.51	0.38	0.41	0.81	0.61
	6	0.15	0.35	0.25	0.19	0.44	0.32	0.3	0.71	0.51
Rural	7	0.1	0.3	0.2	0.13	0.38	0.25	0.2	0.61	0.41



Experienced Average Unit Price ($/kWh)

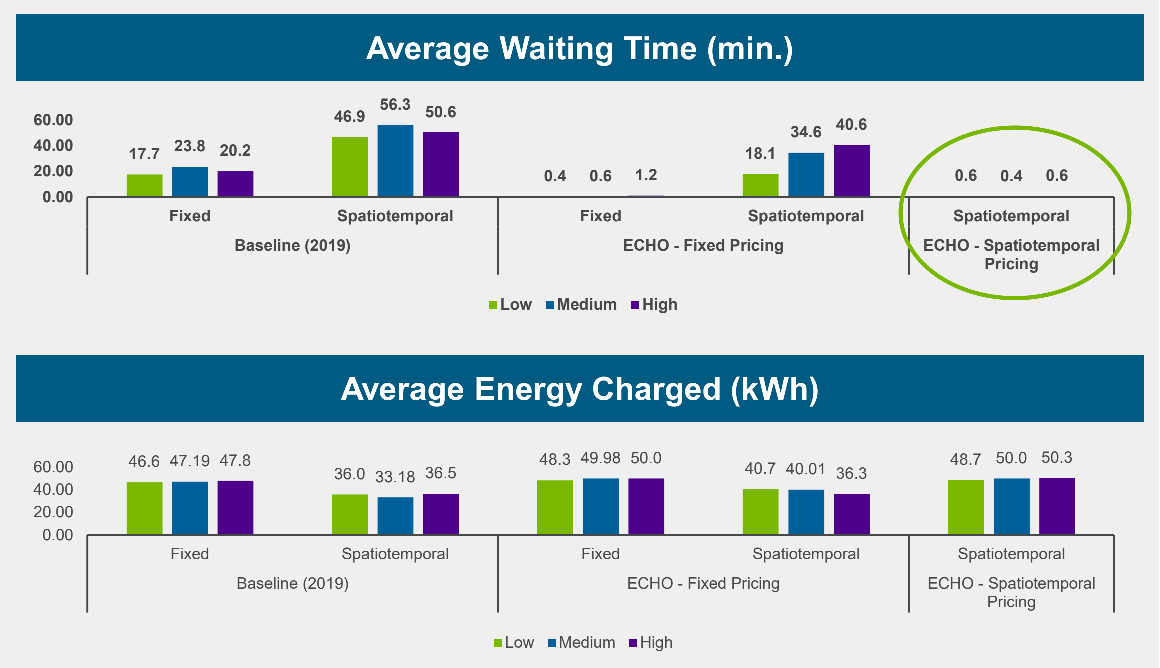


CBD: Central Business District

WAITING TIMES ARE LOW FOR PROPERLY OPTIMIZED SCENARIO PAIRINGS

- 150 kW public chargers
- 3 ownership levels: 8%, 22%, 60%
- 3 sets of EVSE deployment
  - Magnified baseline
  - Optimized for fixed pricing
  - Optimized for spatiotemporal pricing
- Very high waiting times if
  - Not optimizing
  - Optimizing assuming fixed pricing but the world has spatio-temporal pricing

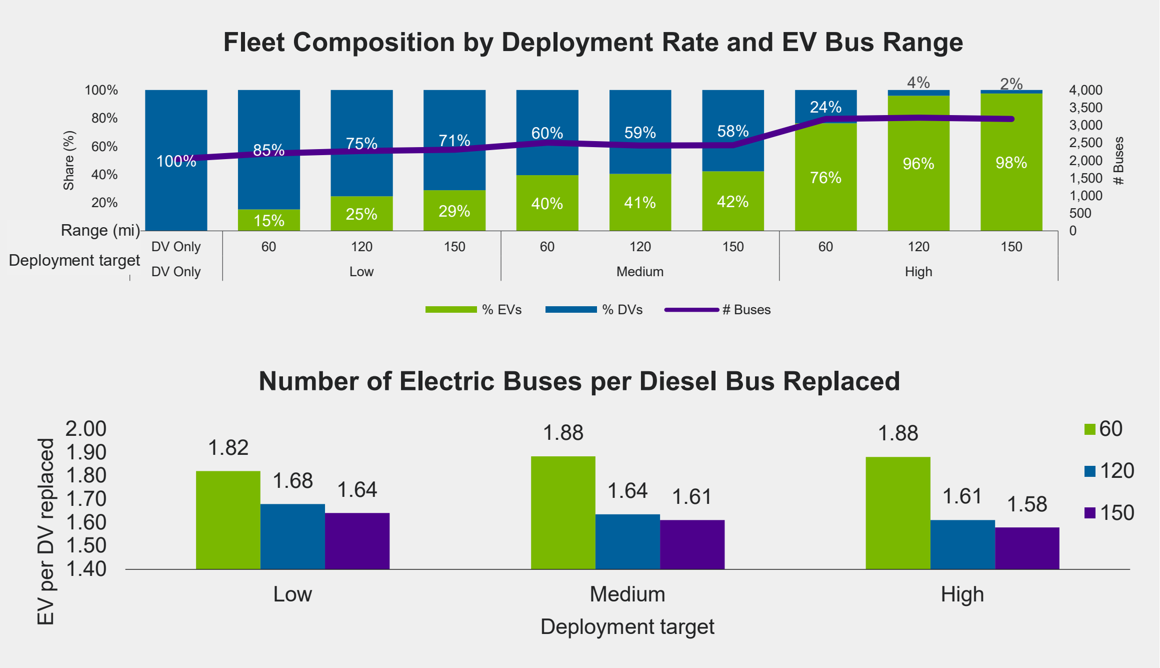
- **Data sharing across stakeholders could provide significant impact on successful deployment of EVSE and EV adoption**



EV TRANSIT BUSES ARE NOT 1:1 REPLACEMENT FOR CURRENT VEHICLES

- **Conventional buses can be mostly driven as long as labor regulations allow**
- **Electrification requires a replacement ratio of ~1.6 even for a high range of 5 hours**
- **To reach 40% and 100% electrification, the fleet size needs to increase by 20% and 55% respectively**

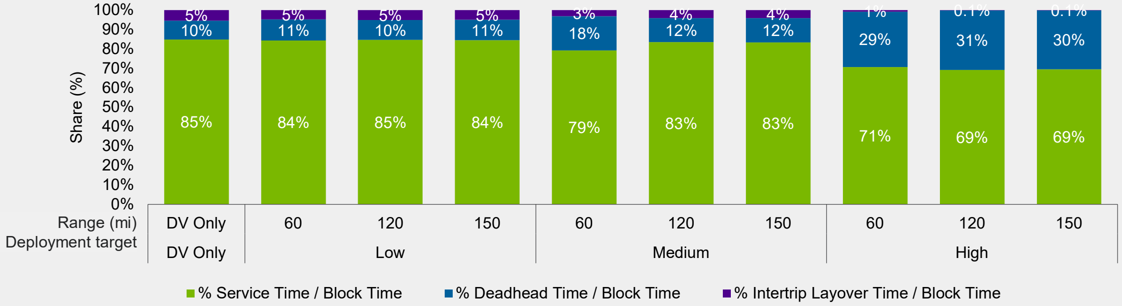
- **Transit agencies could consider electrification impact on number of vehicles, depots and operations**

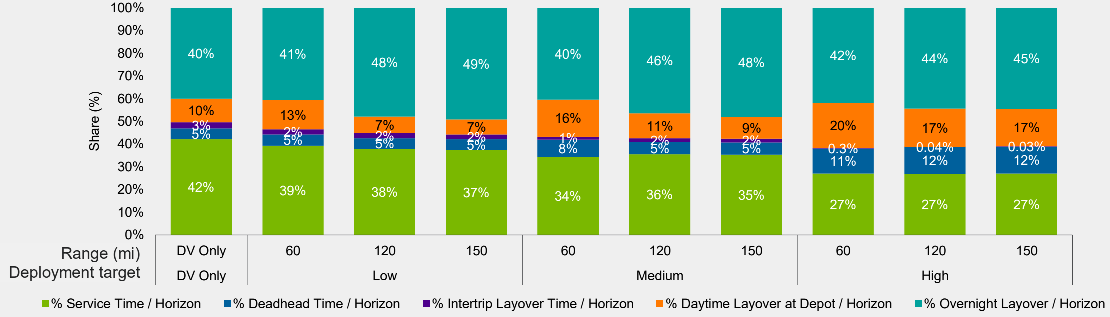


FULL TRANSIT ELECTRIFICATION COULD RESULT IN ~36% REDUCTION IN SHARE OF REVENUE HOURS

- **Deadhead times increase with higher EV deployment because buses have to return to depots more frequently**
- **As a result, service time share decreased from 85% to 70%**
- **Layover time at the depot increases from 50% to 62% as buses need to return to depots more often and stay there to recharge**

- **Agencies could address BEV schedule inefficiencies by adding chargers at non-depot locations, re-optimizing their timetables under the new charging constraints**



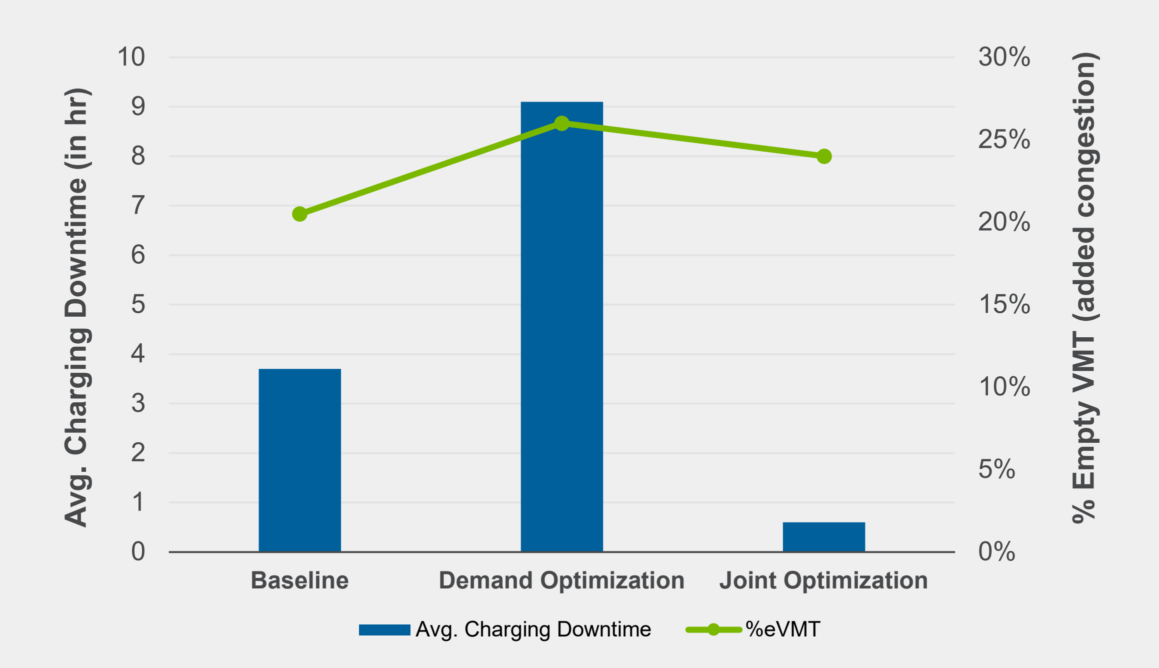


COORDINATED REPOSITIONING AND CHARGING REDUCE EV TNC FLEET DOWNTIME BY UP TO 84%

While also decreasing empty VMT by 8%

- **Electrified fleets need dedicated management to improve service for daily operation**
- **Focusing on charging only increases traveler wait time up to 15%**

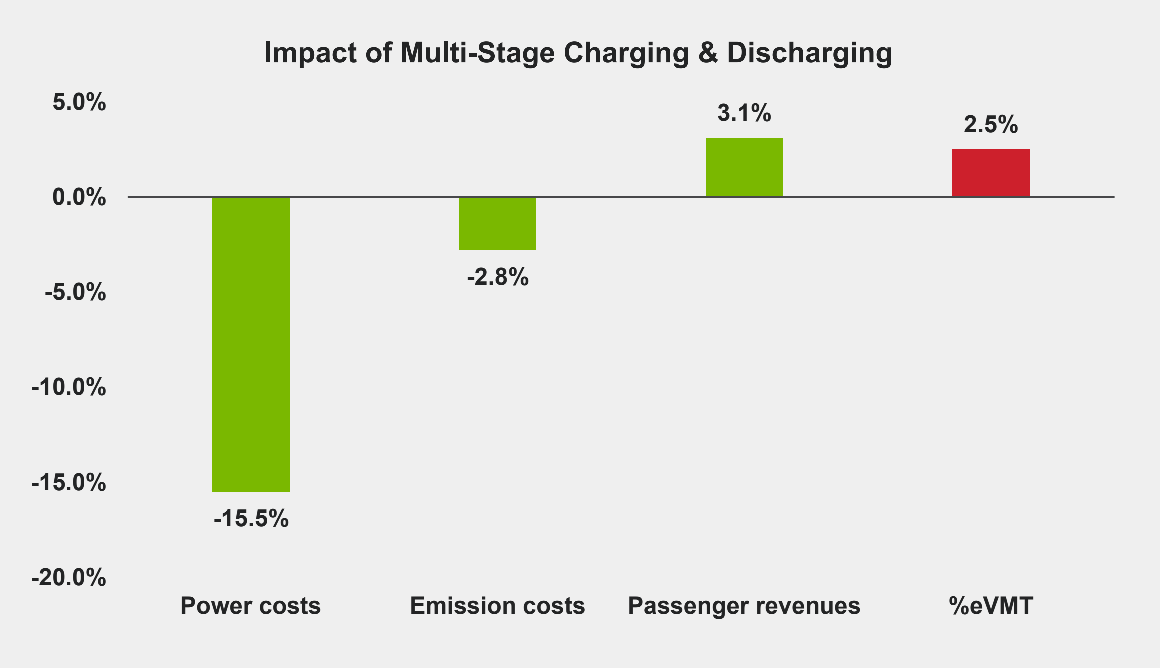
- **Fleet operators could simultaneously consider wait time and charging needs to minimize downtime and empty VMT**



MULTI-STAGE CHARGING & DISCHARGING REDUCES TNC FLEET ELECTRICTY COSTS BY 16% & EMISSION COSTS BY 3%

- Considering grid-related costs are critical for determining interactive costs
- Managing fleet charging and discharging is beneficial
- Lowers power & emission costs, and increases passenger revenues & percent empty VMT

- Joint analysis between grid and EV fleets could facilitate synergistic reductions in costs & emissions



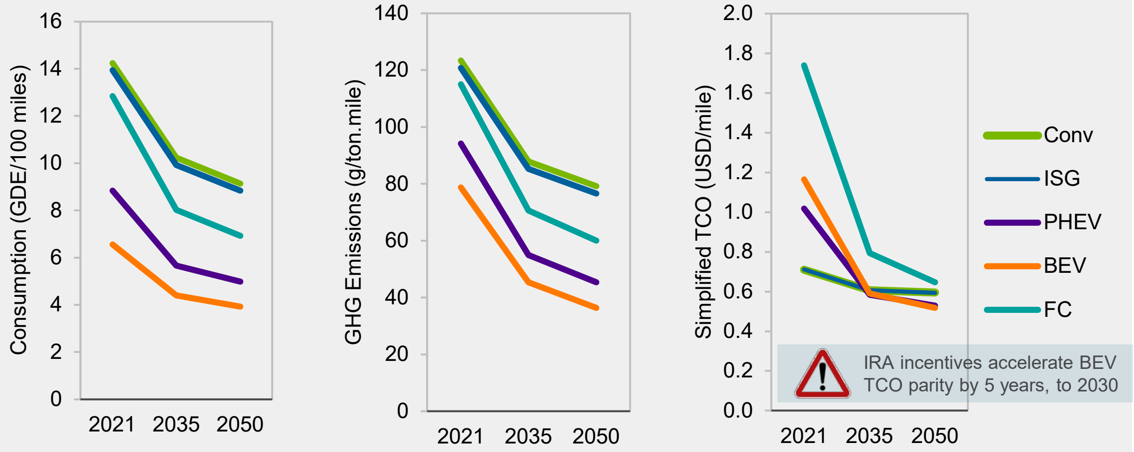
LONG-HAUL TRUCK ELECTRIFICATION CURRENTLY CHALLENGING

But become more competitive by 2035 and 2040

- Compared energy consumption, emissions and cost of electric long-haul trucks to diesel
- Current: BEV trucks reduce emissions by 36% but have higher TCO and lower payload
- Long-Term (2050): BEV trucks offer a 13% TCO and 54% WTW emissions reduction

- Technology improvement of electric long-haul trucks and incentives through policy support are essential for the transition to cleaner trucks

BEV reach TCO parity by 2035 and offer 13% TCO, 54% WTW emissions reduction in 2050



California

TCO: total cost of ownership
WTW: well-to-wheel

Conv: conventional internal combustion engine
ISG: integrated starter generator

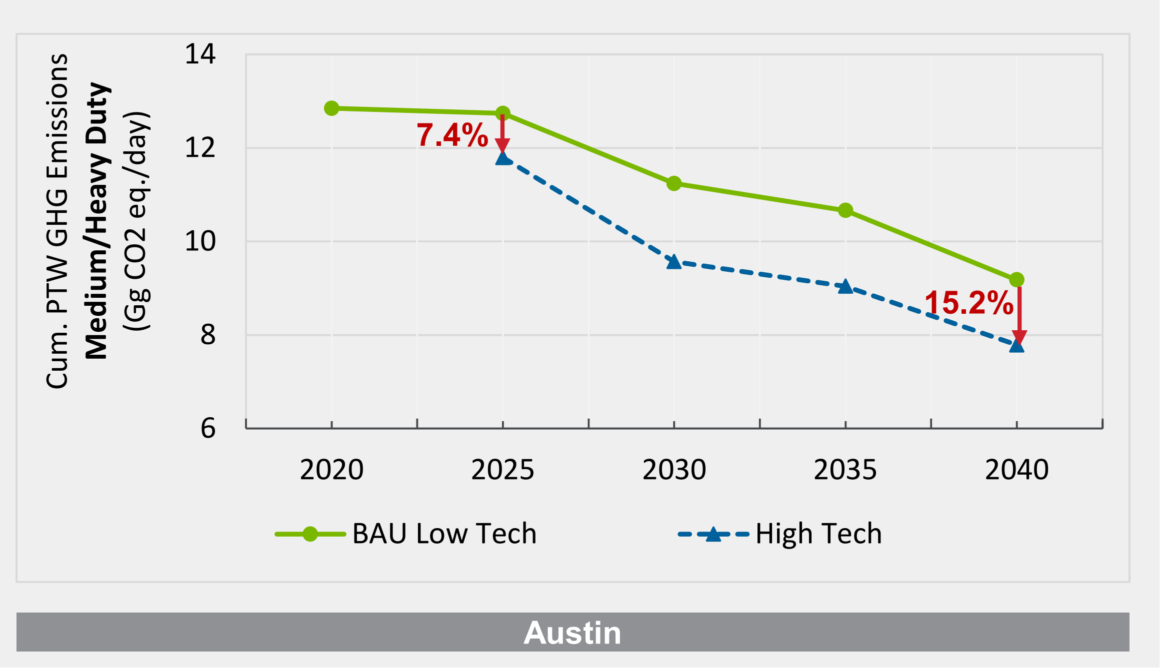
PHEV: plug-in hybrid vehicle
BEV: battery electric vehicle
FC: fuel cell

ADVANCED VEHICLE TECH COULD HELP REDUCE TRUCK EMISSIONS BY 15%

Vehicle technologies R&D crucial to reducing trucks' impact

- **Impact assessed under real-world driving conditions using transportation systems simulation for a 20-year period**
- **Two scenarios:**
  - **Business as usual**
  - **DOE vehicle technology targets (high tech)**
- **Substantial emissions reduction observed for high-tech scenarios**

- **Advanced automotive and infrastructure technology R&D is crucial in decarbonizing the freight industry**



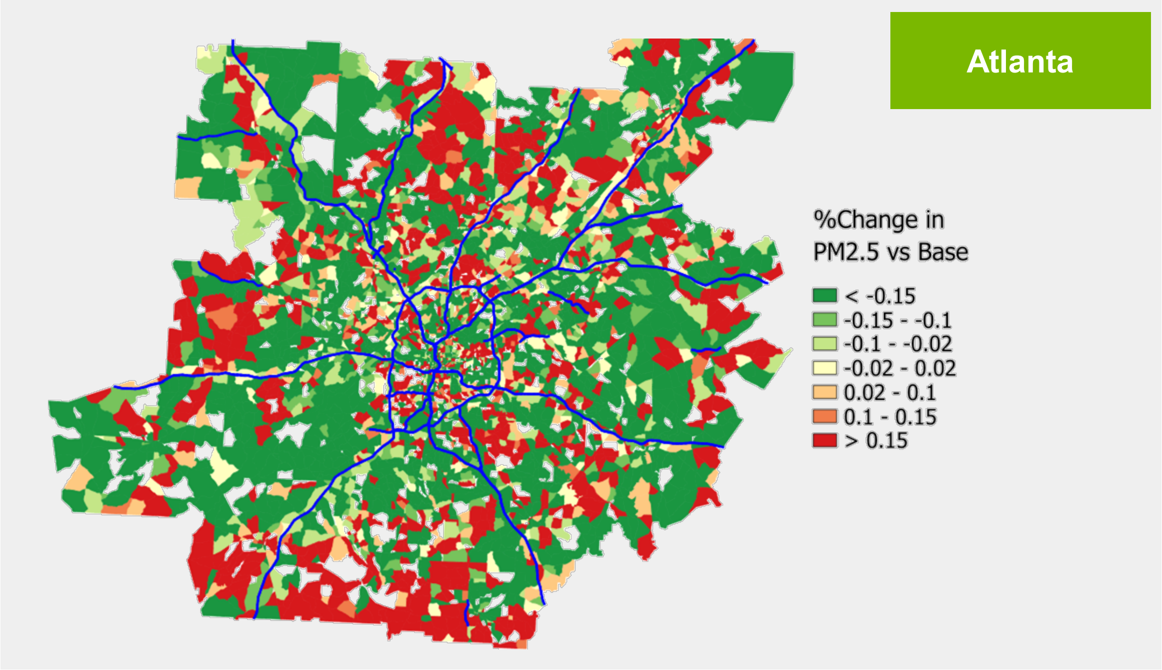
R&D: research and development

INCREASED BEV TRUCKS LEAD TO SIGNIFICANT PM EMISSION REDUCTION

PM2.5 reduced up to 15% in high BEV vs. base

- Business as usual vs. high R&D on vehicle technology ~8% - 20% electrification
- Highest reductions concentrated in downtown and along radial highways

- Adoption of BEV trucks could help reduce emissions and increase quality of life in the truck centric areas such as warehouse / distribution centers



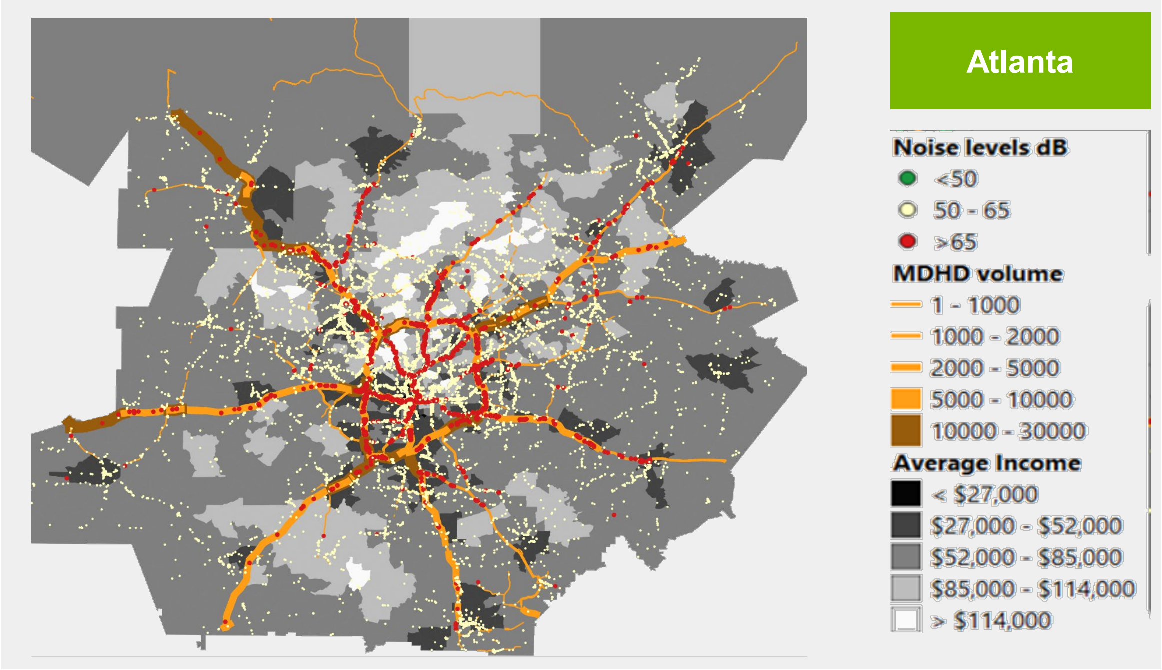
BEV: battery electric vehicle
PM2.5: fine particle matter with < 2.5 microns in width

BEV TRUCKS CAN HELP REDUCE NOISE IMPACTS ON LOW-INCOME POPULATIONS

High-income population has lesser exposure to noise

- Atlanta-Chattanooga-Knoxville region transportation system
- Free-field noise level computed for each location in a 125-m radius buffer from roadways
- Noise exposure at five income levels suggest higher exposure for lower quantiles

- Planners and policymakers could consider ways to mitigate negative impacts of freight transport on low-income neighborhoods

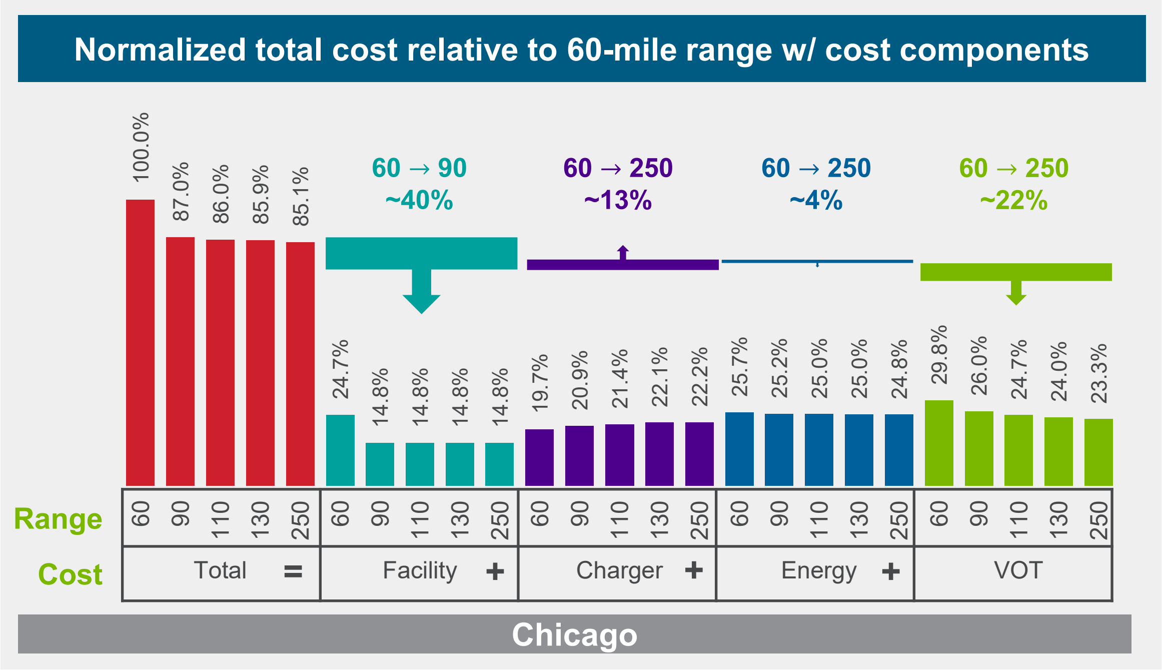


LONGER ELECTRIC TRUCK RANGE REDUCES TOTAL COSTS

Networks may need fewer facilities but additional and faster chargers

- Optimized delivery truck charger location and numbers for 50, 180, 360 kW
- Facility cost reduced by 40% for short range from 60 to 90 miles
- 250 miles EV range leads to an optimum of more and faster chargers with 13% higher total costs
- Longer EV range → reduction in total non-vehicle cost of 15%

- Stakeholders could consider range when planning urban electric delivery truck infrastructure



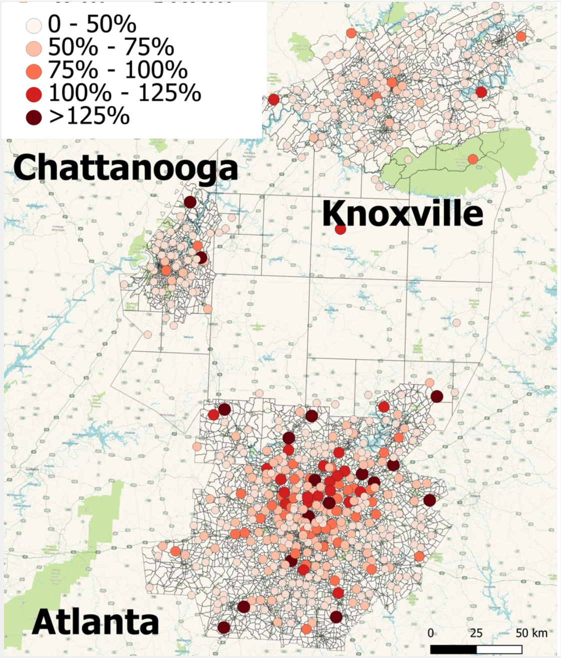
ELECTRIFYING FREIGHT COULD HAVE HIGH IMPACT ON ELECTRIC GRID LOAD

Effect in Atlanta mitigated through efficient powertrain technology

- Freight operations <200 mi/day considered
- 2040 BEV penetrations rates:
  - LDV 57%
  - MDT 25%
  - HDT 7%
- >40% of the grid nodes will need to provide >50% of the current demand

- Utilities and freight fleet managers could work together to assess the electric grid demand impact

% change in electric demand vs. baseline



2040 High-Tech Scenario

LDV: Light-duty vehicle
MDT: Medium-duty truck
HDT: Heavy-duty truck

BEV: battery electric vehicle

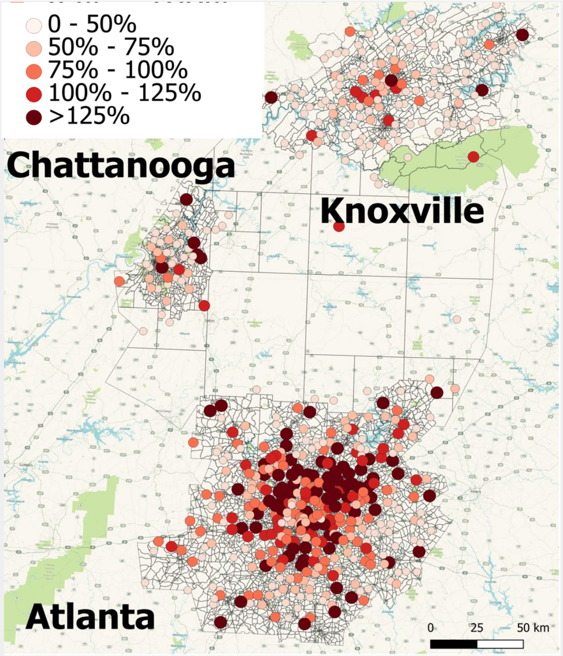
100% BEV PENETRATION RATE HAS A SIGNIFICANT IMPACT ON THE GRID

Electricity demand reduced by 30% using high vehicle technology

- Entire transportation system electrified: 100% BEV share for LDV, MD/HDT
- In 2040,
  - >70% of the grid nodes will need to provide >50% of the current demand
  - MD/HD electric demand is 43% of LD vehicles with only 12% of VMT

- Higher participation of utility providers and planners could help to coordinate future electrification plans to adapt grid changes according to BEV penetration goals

% change in electric demand vs. baseline



100% BEVs

LDV: Light-duty vehicle
MDT: Medium-duty truck
HDT: Heavy-duty truck

BEV: battery electric vehicle

SUMMARY OF KEY INSIGHTS

Vehicle technology R&D and policies are critical to accelerate ZEV sales and reduce income disparity in ZEV ownership

Efficient advanced vehicle technologies (xEVs) are critical to mitigate/lower energy, emission, and grid impacts

Collaboration across stakeholders to simultaneously support xEV adoption along with EVSE deployment and electric grid upgrades is vital

Fleets should carefully consider the impact of electrification on number of vehicles, operations and EVSE investments

Addressing system level considerations from vehicle design/usage to EVSE location/usage and electric grid impacts are critical for success

Electrification plays a key role for equity by reducing emissions and noise, plus providing a cost-efficient mobility option

US DOE SMART CONSORTIUM 2.0 IN NUMBERS 125+ INSIGHTS

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20+ CAVs System / ITS

20+ Electrification

20+ Freight

10+ Micromobility

10+ Drones

10+ Ridehail

Webinar Materials

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General questions, comments, please contact
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