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

FREIGHT

July 11, 2023

SMART Webinar Series
Webinar #6

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

Argonne NATIONAL LABORATORY
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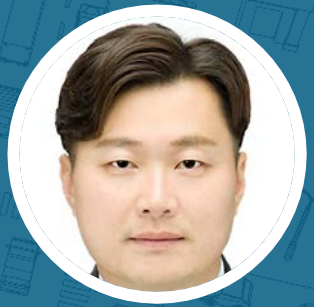

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PREVIOUS & UPCOMING WEBINARS

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

TODAY

JULY
FREIGHT
Last mile delivery

AUGUST
ELECTRIFICATION
EV charger deployment
Grid impact

2023

Webinar Materials

IMPACT OF FREIGHT

- What mode share and operational impacts may result from truck connectivity and automation?
- What are the potential influencing factors and outcomes from increasing penetration of electrified and alternative fuel vehicles into the freight fleet?
- What are the differing impacts of business-to-business versus business-to-consumer freight operations on the transportation system along with energy and greenhouse gas emissions?

- What are the potential impacts of and strategies to deal with further growth of E-commerce?
- What roles might strategies such as off-hour delivery, drone delivery, and delivery lockers play?

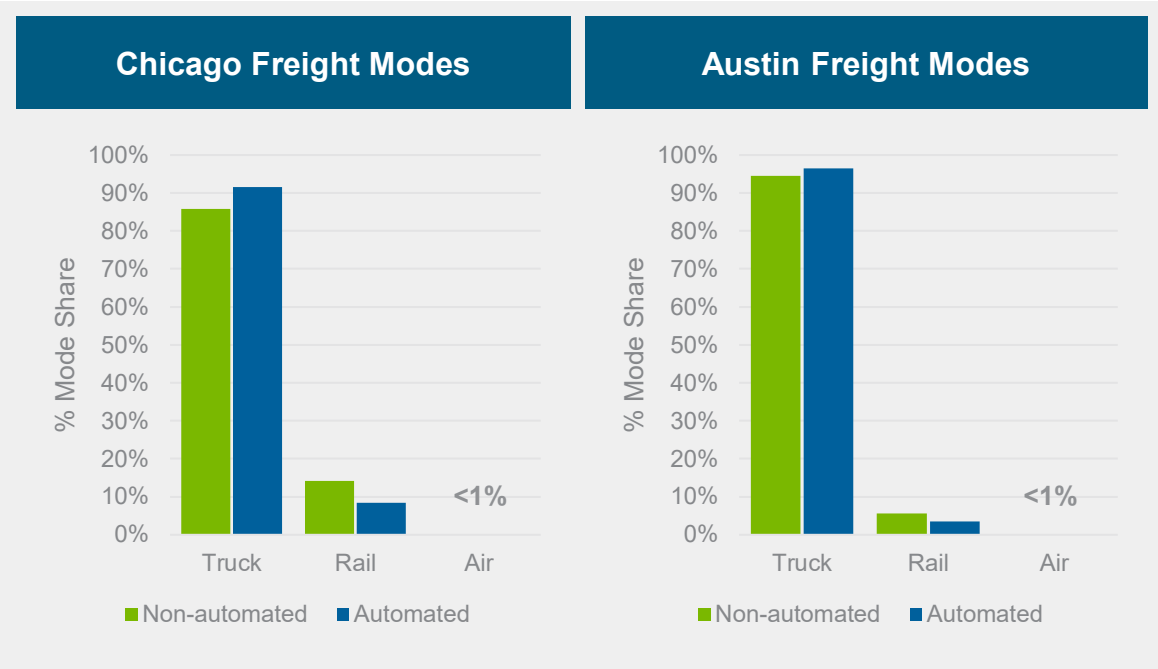
- What are the potential noise and pollutant exposure impacts on low-income communities?

AUTOMATION INCREASES TRUCK MODE SHARE 5% OVER RAIL MODE

Automation could help solve the driver shortage in long-haul operations

- Removed driving time restriction and driver cost from Freight mode-choice model
- Cost of truck decreased 0.6%
- Fully automated trucks preferred due to their flexibility on driving time and availability

- Land use policies could regulate the expected impact on the network, e.g., by relocating warehouse-distribution center to suburban areas.



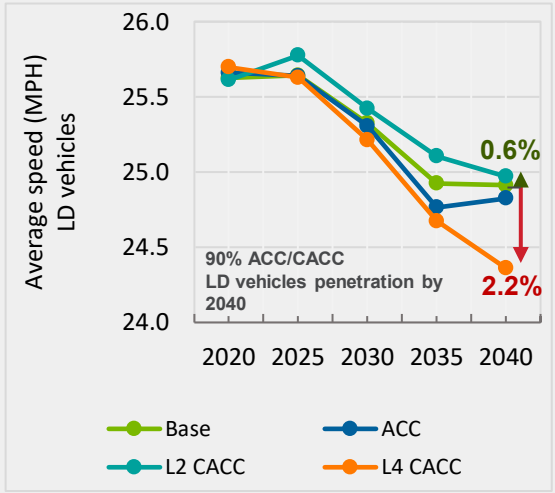
HIGHLY AUTOMATED LD VEHICLES COULD REDUCE TRUCK SPEED BY 7% IN 2040

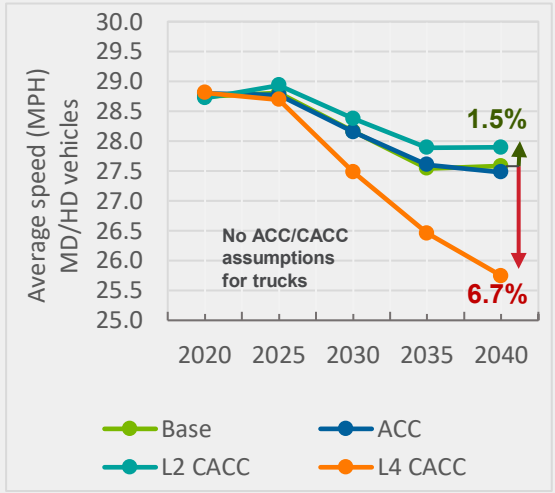
But low automation could improve highway throughput and trucks speed

- Expected land use changes over years included
- 4 scenarios evaluated for LD vehicles: base vs. adaptive cruise control (ACC), and cooperative adaptive cruise control (CACC) with automation level 2 (L2) and level 4 (L4)
- Significant network speed reductions for MD/HD trucks

- Freight changes and highway operation improvements could help reduce the impact of passenger CAVs on trucks.

Population growth increases baseline congestion and reduces speed over time





Austin

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LD: Light-duty
MD: Medium-duty
HD: Heavy-duty

CAVs: connected and autonomous vehicles

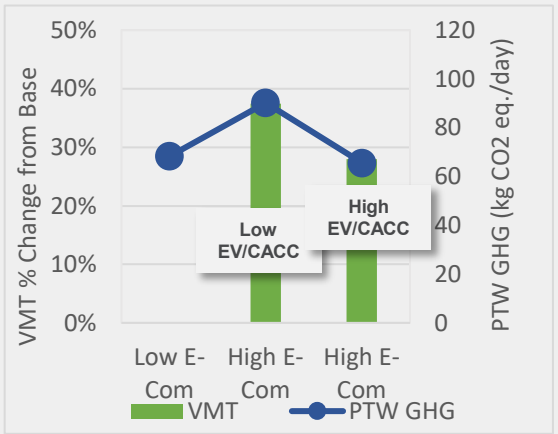
HIGH E-COMMERCE PENETRATION INCREASE ITS VMT UP TO 40%

Greenhouse gases increase up to 50% but mitigated by vehicle technology

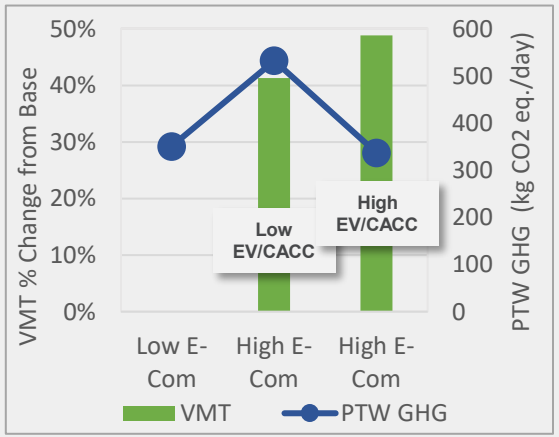
- Expected E-Commerce growth estimated from transportation behavior survey
- Scenarios in year 2035:
  - Low- vs high- e-commerce (2 vs 6 orders per week)
  - Low- vs high- vehicle technology
- Advanced vehicle technology helps to mitigate e-commerce growth impact

- City planners and fleet operators could work together to implement decarbonization measures to mitigate the effect of e-commerce growth.

Analysis of medium duty vehicles serving e-commerce operations



Austin



Chicago

VMT: vehicle miles traveled
PTW GHG: pump-to-wheels greenhouse gas emissions
EV: electric vehicles
CACC: cooperative adaptive cruise control

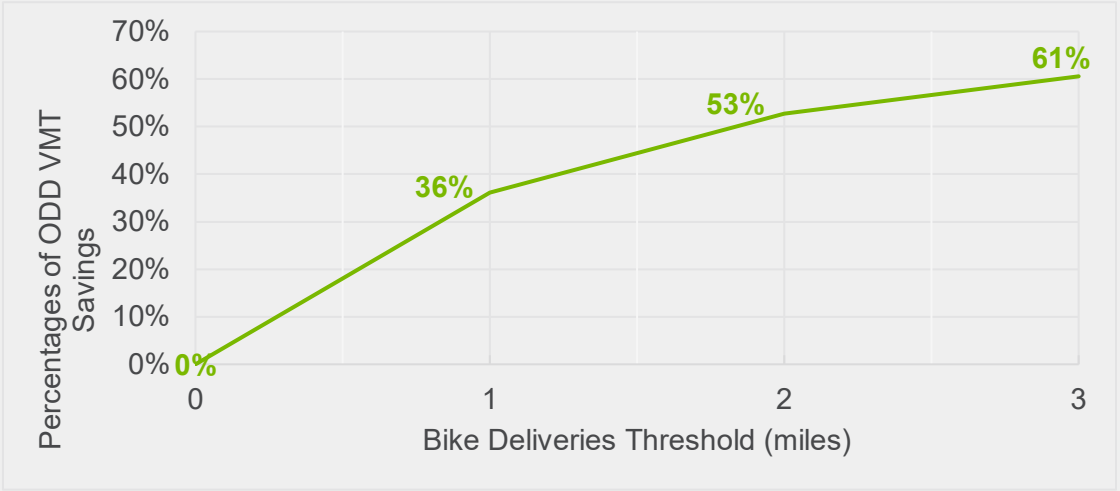
ON-DEMAND DELIVERIES ARE RESPONSIBLE FOR MORE VMT THAN E-COMMERCE

Fostering bike deliveries could reduce VMTs by up to 60%

- Meals and groceries ODD generate high VMT due to lack of consolidation and their urgent nature
- More than 60% of the ODD VMTs in Austin, TX are generated by meal deliveries with <3 mi range
- Geo-fencing short-distance deliveries to use bikes only could significantly reduce VMTs

- City planners, restaurants, and fleet operators could coordinate to foster a shift toward bike deliveries under specific ranges.

VMT savings by shifting to bike deliveries under different mile ranges



Austin

VMT: vehicle miles traveled
ODD: on demand delivery

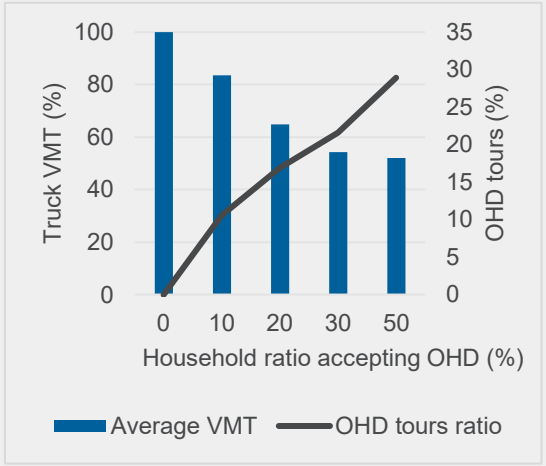
B2C OFF-HOUR E-COMMERCE DELIVERIES COULD HELP REDUCE TRUCK VMT UP TO 35%

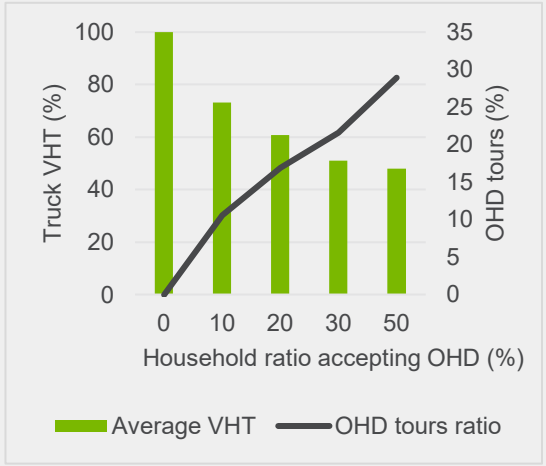
When 20% or more households participate

- OHD for e-commerce modeled based on municipality policies
- Different ratios of households accepting OHD were considered
- Effective nighttime delivery requires low household penetration ratio of about 20%

- Fleet owners could reduce energy cost by shifting tours into nighttime with legal and technological supports.

Shifting delivery tours into nighttime reduces average VMTs and VHTs





Austin

VMT: vehicle miles traveled
B2C: Business to costumers
OHD: off-hour deliveries

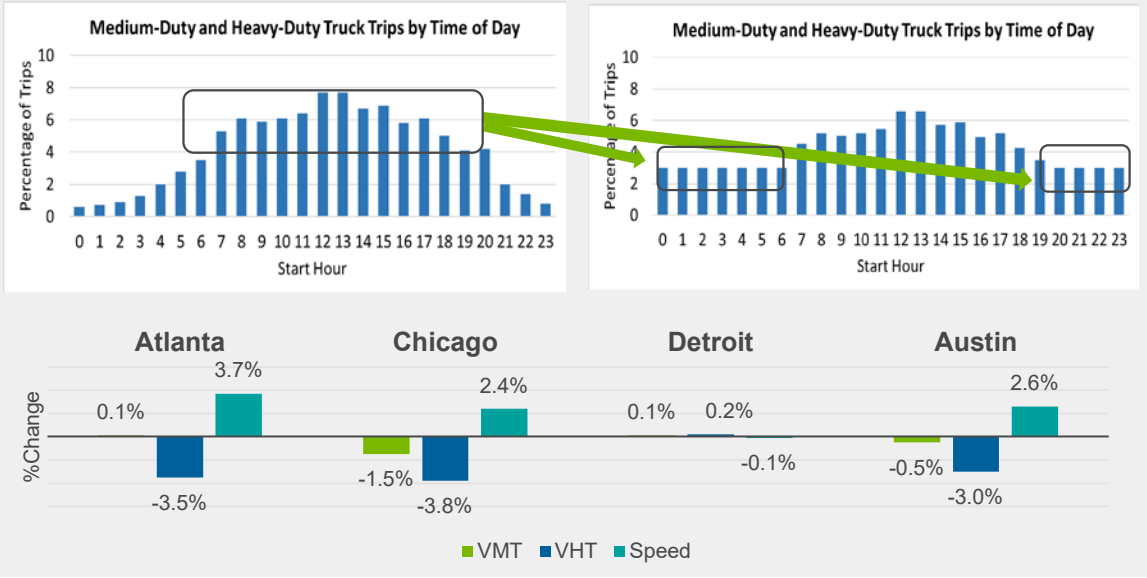
B2B OFF-HOUR DELIVERY INCREASES SYSTEM SPEED BY OVER 3%

Reduces system VMT, fleet energy use, and delivery cost

- Commercial locations identified based on their NAICS code and willingness to accept OHD estimated using a behavioral model
- 5% of B2B trips' delivery times shifted from daytime to overnight (7 PM–6 AM)
- OHD improved VMT, network speeds and energy savings

- Municipalities could relax OHD restrictions to reduce network-wide congestion, energy use, and emissions.

Shifting delivery tours into nighttime reduces average VMTs and VHTs



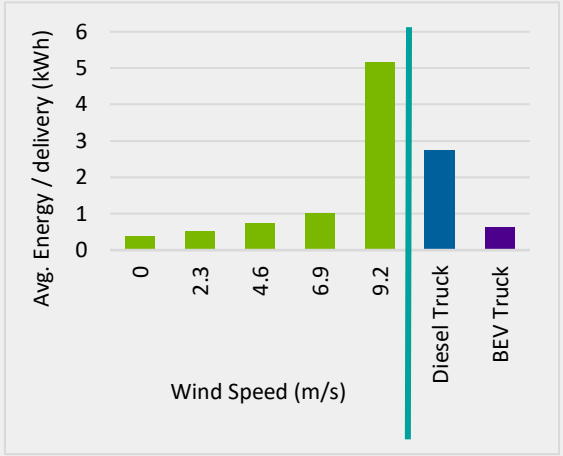
VMT: vehicle miles traveled
B2B: Business to Business
OHD: off-hour deliveries

DRONE DELIVERY ENERGY IMPACT HIGHLY DEPENDS ON WIND SPEED

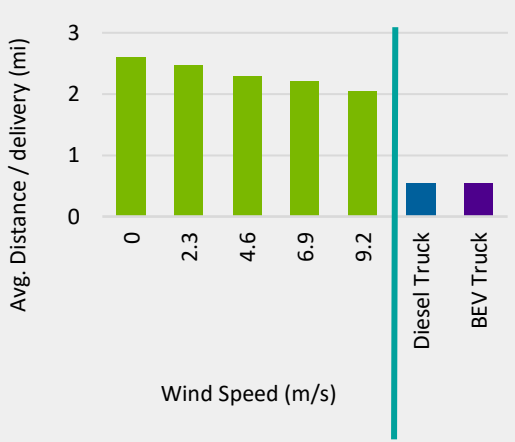
- Analyzed optimal number of fulfillment centers and drones required to complete deliveries for packages < 5 lb
- Wind speed above 10 mph significantly increases drone energy consumption
- In a 20-mph wind, a drone will use twice the energy per customer than a diesel truck

- A mix of delivery approaches— drones and trucks—could be considered to optimize efficiency depending on prevailing wind patterns.

Per Delivery Average Energy Drone vs. Ground Vehicles



Per Delivery Average VMT Drone vs. Ground Vehicles



Chicago

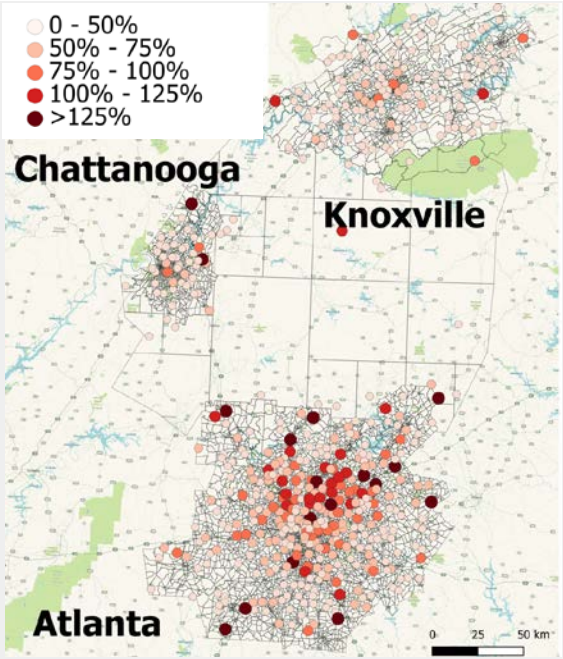
ELECTRIFYING FREIGHT HAVE HIGH IMPACT ON ELECTRIC GRID LOAD

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

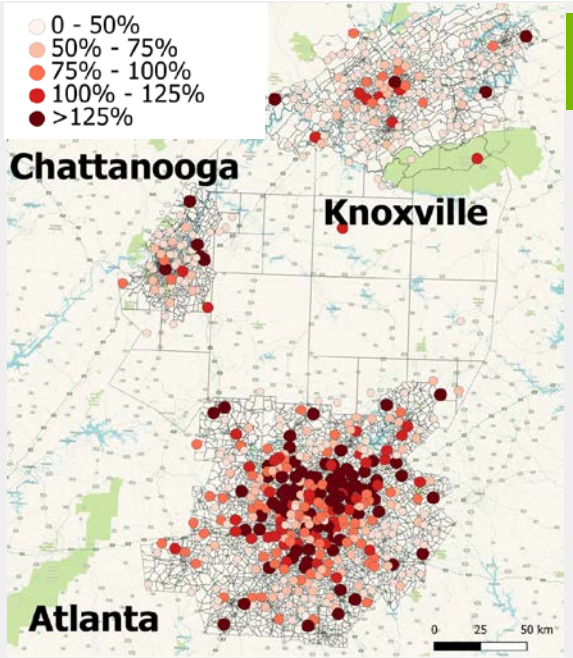
EXTREME BEV PENETRATION RATE HAS A SIGNIFICANT IMPACT ON THE GRID

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

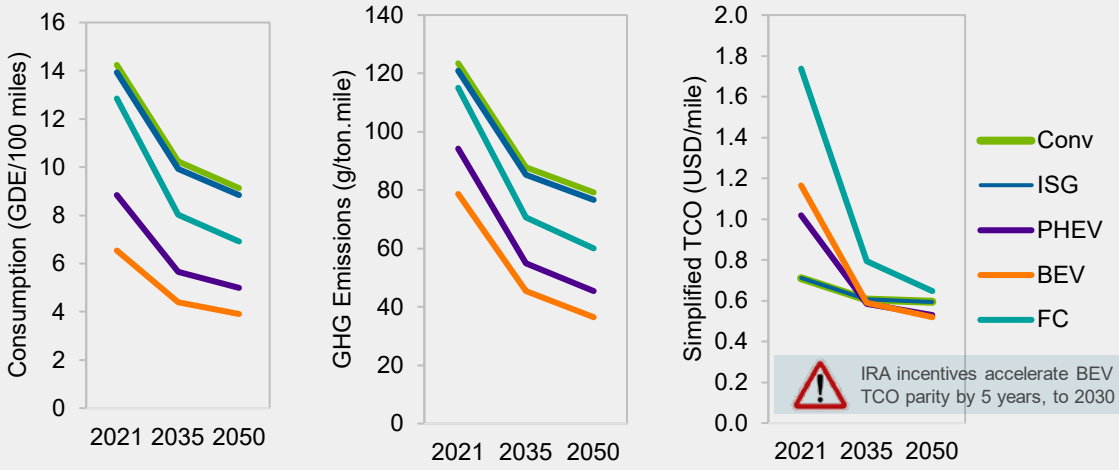
LONG-HAUL TRUCKS ELECTRIFICATION CURRENTLY CHALLENGING

But become more competitive by 2035 and 2040

- Compared energy consumption, emissions and cost of long-haul trucks to diesel
- Current : BEV trucks reduce emissions by 36% but have higher TCO and 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

Conv: conventional internal combustion engine
ISG: integrated starter generator
PHEV: plug-in hybrid vehicle
BEV: battery electric vehicle
FC: fuel cell

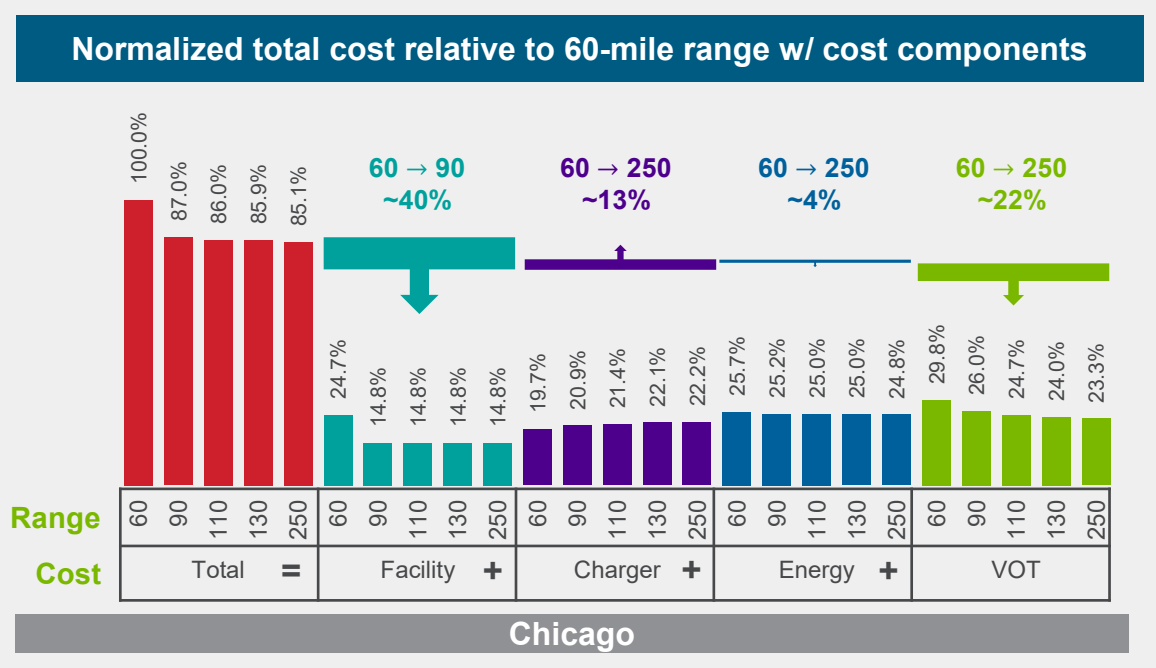
TCO: total cost of ownership
WTW: well-to-wheel

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

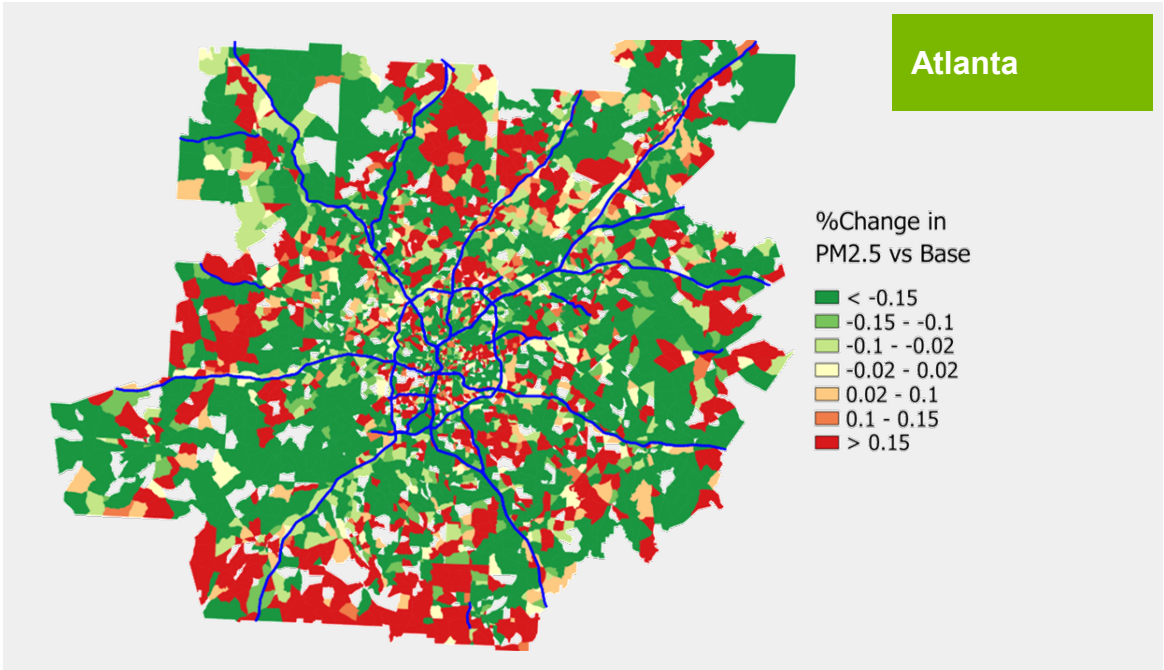


INCREASED BEV TRUCKS LEAD TO SIGNIFICANT PM EMISSION REDUCTION

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

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



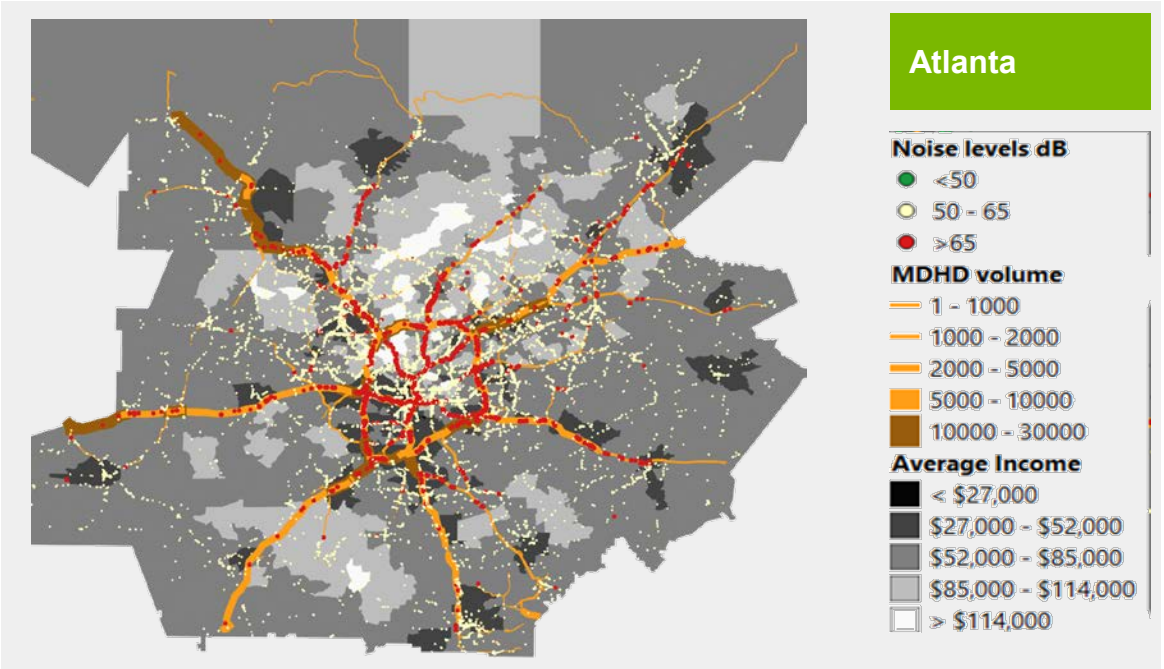
BEV: battery electric vehicle
PM2.5: fine particle matter with < 2.5 microns in width

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.

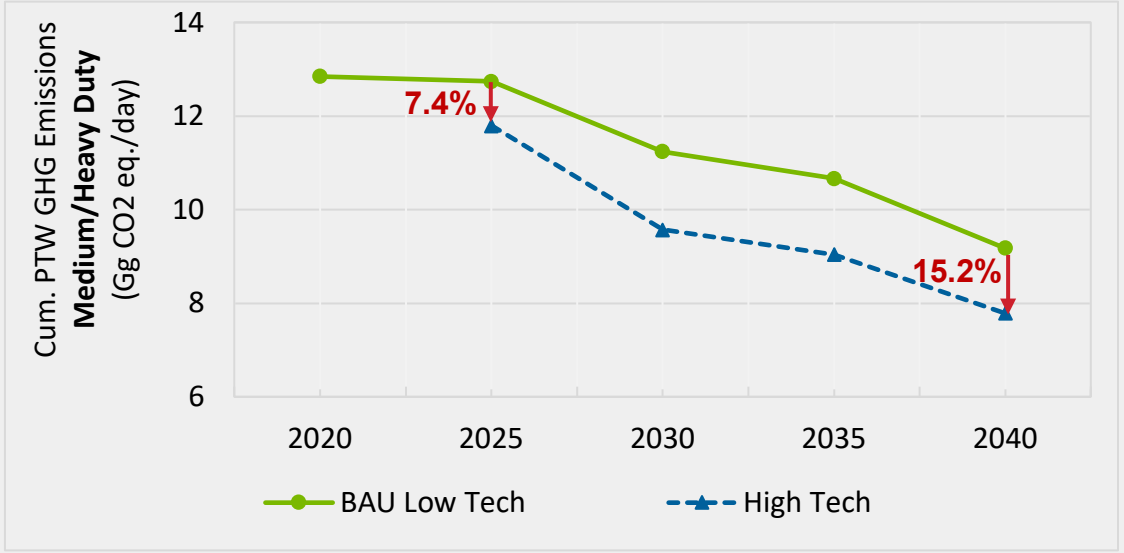


ADVANCED VEHICLE TECH COULD HELP REDUCE TRUCK EMISSIONS BY 15%

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

VEHICLE TECHNOLOGY, FUEL PRICE CHANGES IMPACT ON FLEET COMPOSITION, OPERATIONS, AND ENERGY CONSUMPTION

KEY LEVERS

Low	Fuel/Electricity Price	High
Expiring in 2032	Vehicle Incentives	Extended
Business As Usual (BAU)	DOE R&D Targets/Goals	Technology Success

Market Penetration Tool

Fleet Composition in Austin

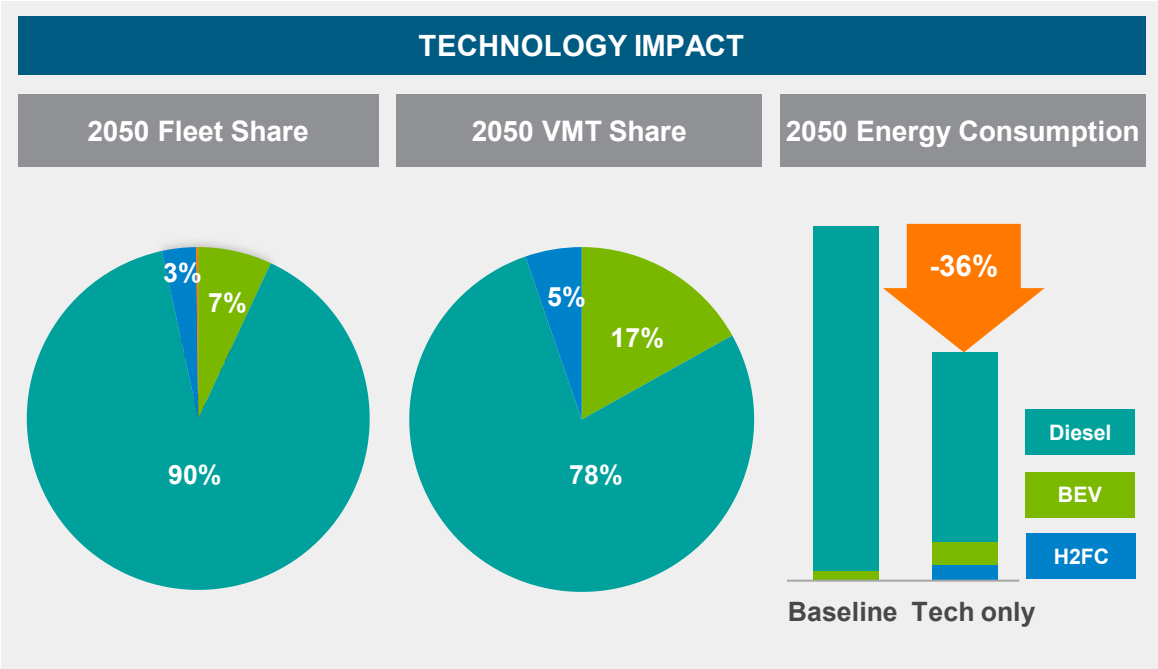
How much do accompanying financial factors complement technology-driven outcomes for freight vehicle operations in the Austin region case study?

Photo from iStock 1222147442

DOE R&D TARGETS RESULT IN SIGNIFICANT REDUCTION IN FREIGHT ENERGY USE

- Technology progress with relatively low oil price and high electricity price results in 90% of MD/HD fleet stock remaining diesel and 78% of VMT share
- Increase in diesel vehicle fuel efficiency, including hybridization, can contribute to substantial energy reduction

- Continued public and private investment in technology advancements stands to significantly reduce freight vehicle energy consumption



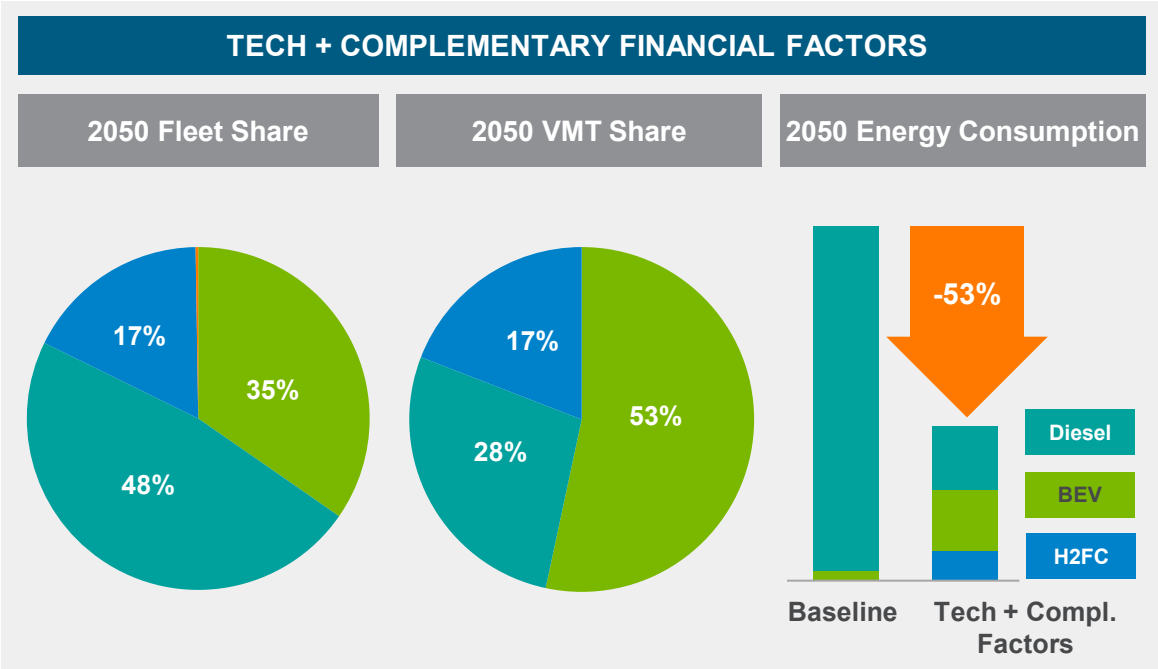
Austin Results

Baseline scenario: Tech BAU in 2030, High electricity price, Vehicle incentives expire in 2032
Tech only scenario: Tech success in 2050, High electricity price, Vehicle incentives expire in 2032

COMPLEMENTARY FINANCIAL FACTORS CAN INCREASE TRANSITION TO ALTERNATIVE FUEL VEHICLES AND ENERGY SAVINGS

- Combining high technology progress with complementary financial incentives and alt-fuel favorable pricing:
  - Reduces diesel truck fleet share by more than half
  - Cuts freight energy consumption by more than half

- Policymakers could consider complementary financial incentives and fuel pricing policy to gain more freight sector energy benefits



Austin Results

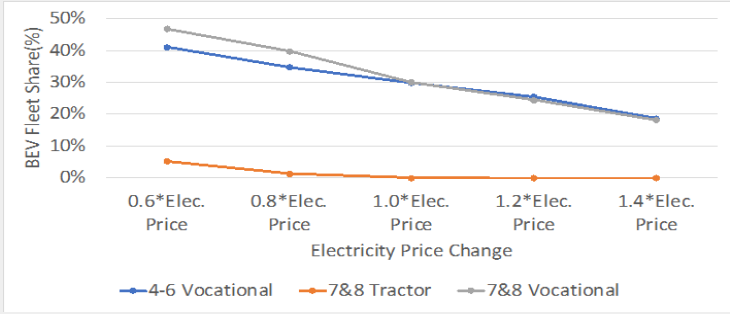
Baseline: Tech BAU in 2030, High electricity price, Vehicle incentives expire in 2032
Tech + Compl. Factors: Tech success in 2050, Low electricity/High diesel price, Vehicle incentives extended

LOWER ELECTRICITY PRICES HAVE SIGNIFICANT IMPACT ON VOCATIONAL TRUCKS, BUT MARGINAL IMPACT ON TRACTOR TRUCKS

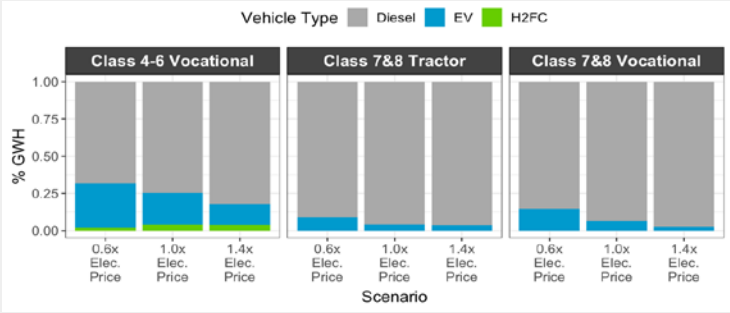
- Reducing electricity prices can increase BEV share for vocational trucks, but has little impact for long-haul class 7&8 tractor trucks
- Energy consumption is higher under higher electricity price scenarios as more carriers stay with diesel based trucks
- Incentives, cost reductions, and megawatt-level charging infrastructure investments may be needed to accelerate class 7&8 tractor decarbonization

- Policymakers could consider incentives to counteract potential high electricity costs

2050 BEV Share



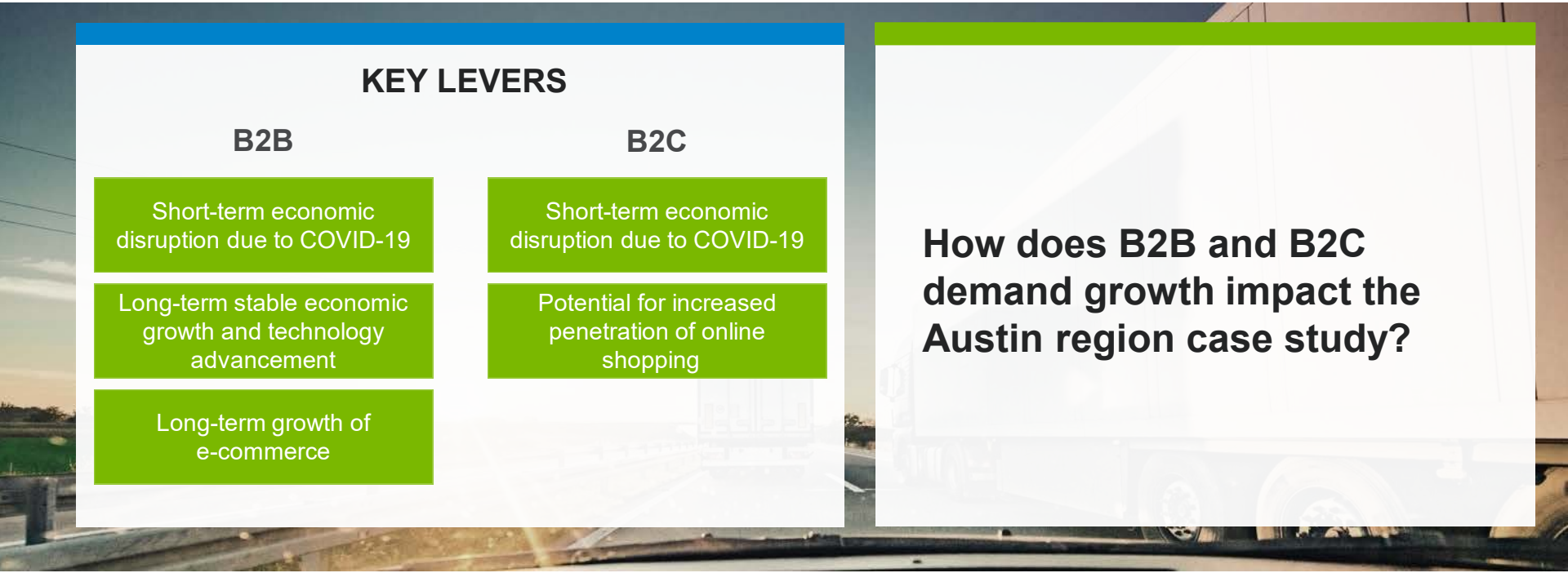
2050 % Energy Consumption



Austin Results

Other factor assumptions for illustrated scenarios:
Tech success in 2050, Reference diesel price, Vehicle incentives expire in 2032

SHIPMENT DEMAND CHANGES HAVE IMPACT ON VMT AND ENERGY CONSUMPTION



KEY LEVERS

B2B	B2C
Short-term economic disruption due to COVID-19	Short-term economic disruption due to COVID-19
Long-term stable economic growth and technology advancement	Potential for increased penetration of online shopping
Long-term growth of e-commerce	

How does B2B and B2C demand growth impact the Austin region case study?

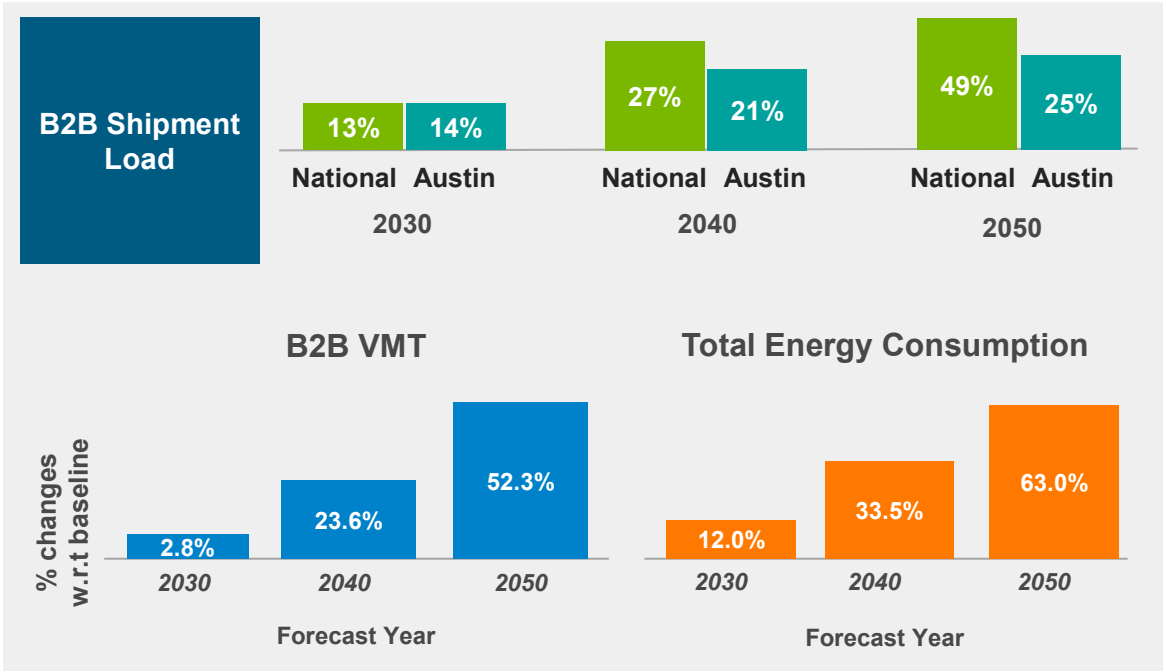
Photo from iStock 1222147442

B2B = business to business
B2C = business to consumer

LOCALIZED FACTORS RESULT IN DISPROPORTIONAL TRADE AND TRUCK OPERATION

- Total shipment load in Austin increases 25% by 2050 compared to 2017 baseline, which is lower than national freight demand growth
- Different trade patterns can lead to different levels of demand growth impacts on freight traffic and energy consumption
- More efficient logistics are needed to reduce one-to-one delivery

- Agencies should consider transition to more energy efficient modes to reduce the impact of B2B growth



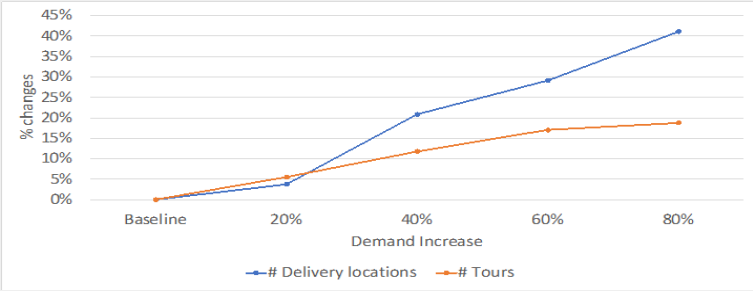
Austin Results

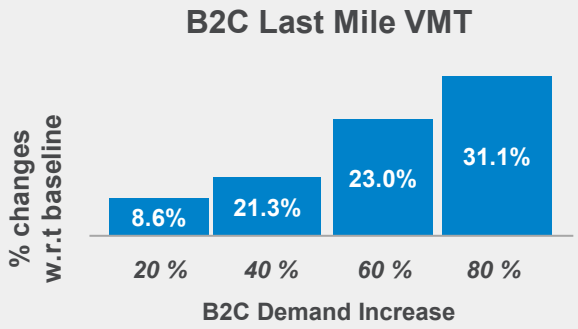
MORE ONLINE SHOPPING INCREASES VMT, BUT ONE-TO-MANY DELIVERY MAY HAVE AN OFFSETTING EFFECT

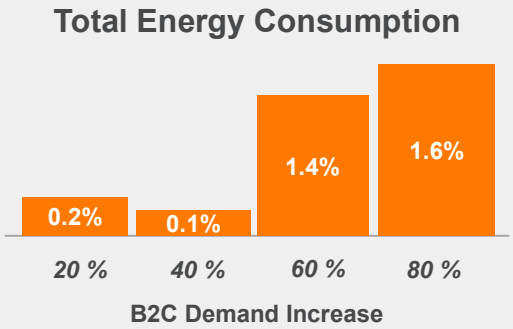
- An offset effect is observed due to the nature of tour formation of last mile delivery
- 80% more online shopping demand increases delivery tours by 19%, B2C last mile delivery VMT by 31%, and energy consumption in the overall freight system by 1.6%

- Agencies and logistics companies could consider policies encouraging one-to-many logistics efficiencies to minimize VMT and energy under increasing online shopping demand

% changes in # delivery locations and # tours along with demand increase



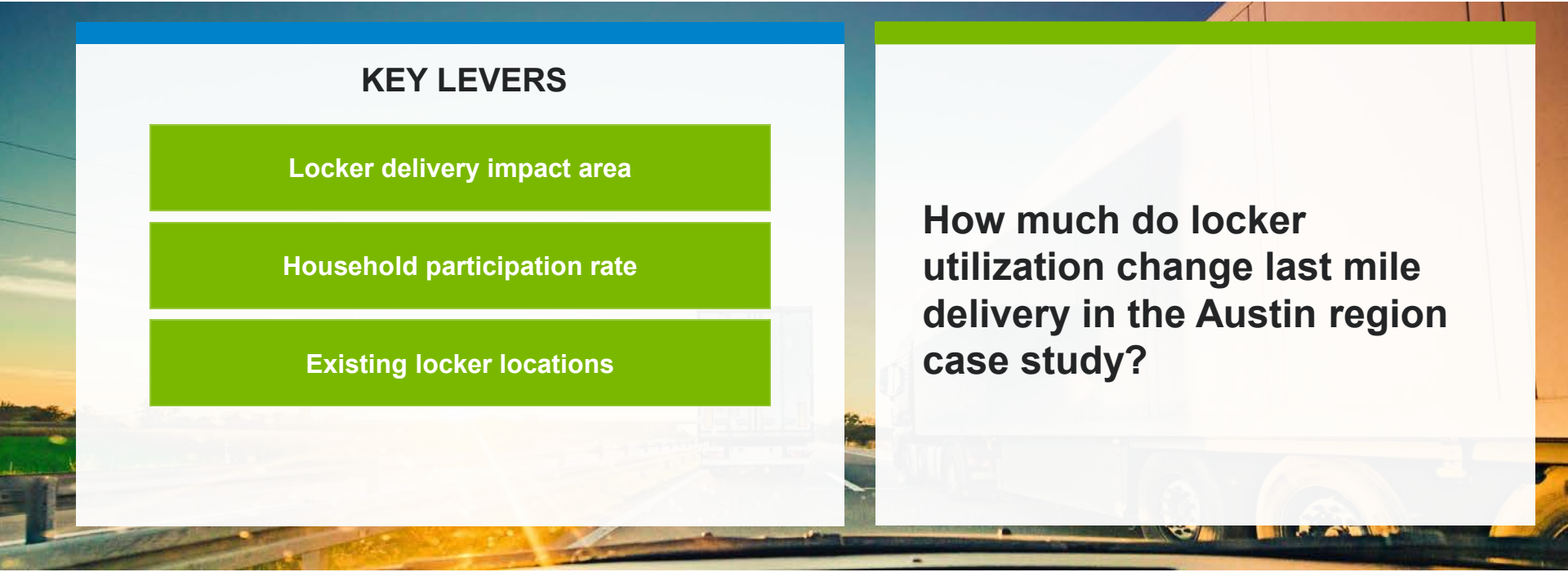




Austin Results

Other factor assumptions for illustrated scenarios: B2B demand based on 2040 forecast

CONSOLIDATED DELIVERY HAS POTENTIAL TO FURTHER INCREASE LAST MILE DELIVERY EFFICIENCY



KEY LEVERS

- Locker delivery impact area
- Household participation rate
- Existing locker locations

How much do locker utilization change last mile delivery in the Austin region case study?

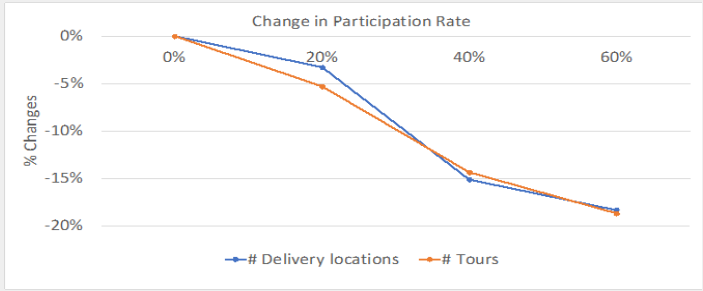
Photo from iStock 1222147442

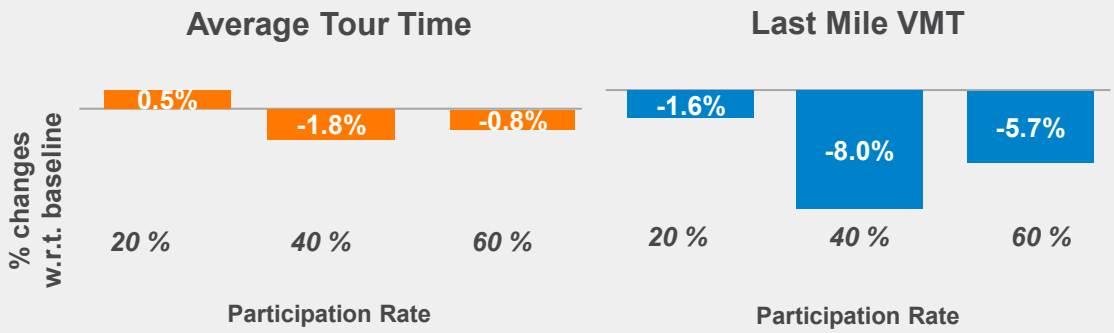
LEVEL OF PARTICIPATION IN LOCKER DELIVERY IMPACTS LAST MILE DELIVERY EFFICIENCIES

- 60% participation of households who can access existing lockers reduces # tours up to 19%
- 40% participation rate leads to higher last-mile VMT reduction than 60% due to locker capacity constraint and non-collaborate operations across carriers
- The small decrease in last-mile VMT had minimal impact on congestion and tour duration

- Agencies and logistics companies could consider incentives that encourage locker delivery participation and align locker capacity with growing demand

% changes in # delivery locations and # tours along with participation rate





Austin Results

Other factor assumptions for illustrated scenarios: B2B demand based on 2040 forecast; Existing Amazon locker locations as baseline

SUMMARY OF KEY INSIGHTS

Freight could be positively and negatively impacted by automation (e.g., driving time restriction vs increased VMT from passenger cars)

Advanced vehicle technologies (xEVs) critical to mitigate/lower energy and emission impact of freight growth

New modes and services have a critical role to play: bikes for on-demand deliveries, drones for last-mile deliveries, locker deliveries

xEVs provide a unique opportunity to enhance equity for energy and environmental justice

Policies (e.g., IRA) and continuous R&D critical to accelerate truck electrification market penetration

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

PREVIOUS & UPCOMING WEBINARS

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

AUGUST
ELECTRIFICATION
EV charger deployment
Grid impact

Up Next

2023

Webinar Materials

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

General questions, comments, please contact
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