DECEMBER 3, 2020

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

MOVING GOODS IN A SMART MOBILITY SYSTEM

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OAK RIDGE National Laboratory

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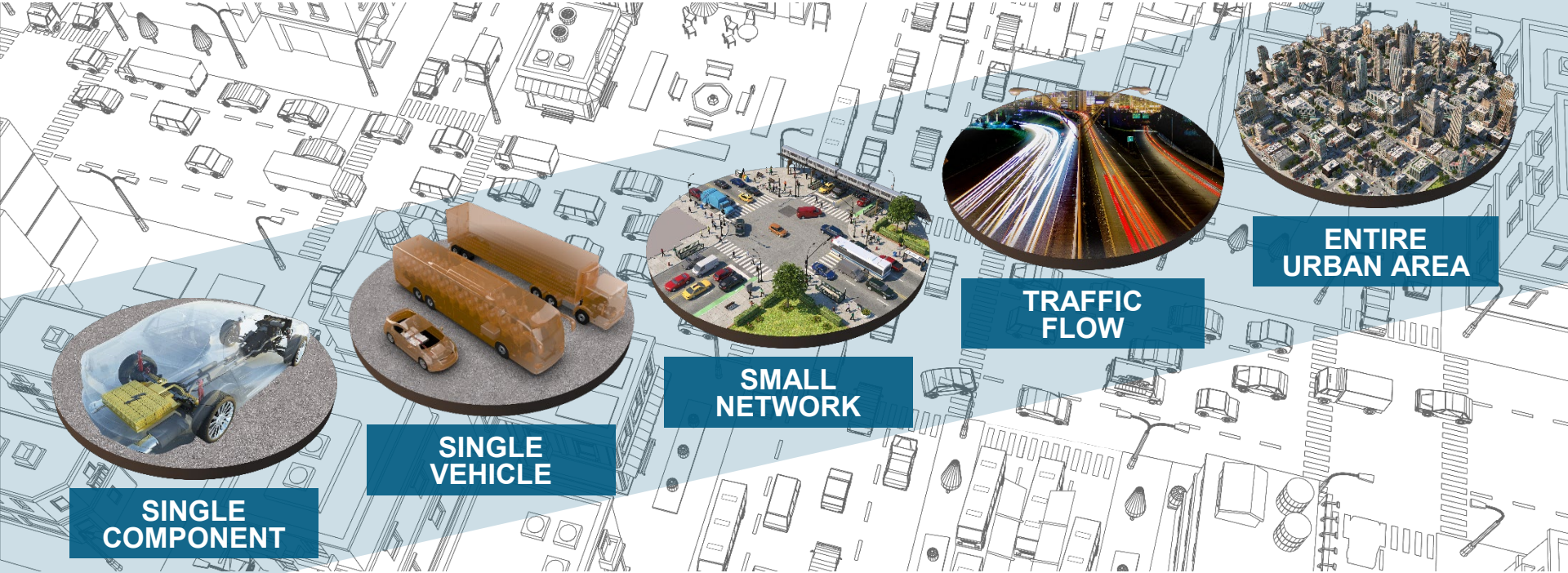
VTO SYSTEMS-LEVEL R&D



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.

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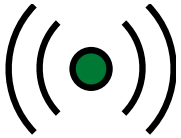
BERKELEY LAB

INL Idaho National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

FIVE RESEARCH FOCUS AREAS

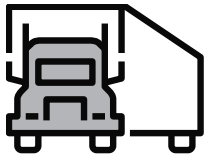


CONNECTED AND AUTOMATED VEHICLES

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.

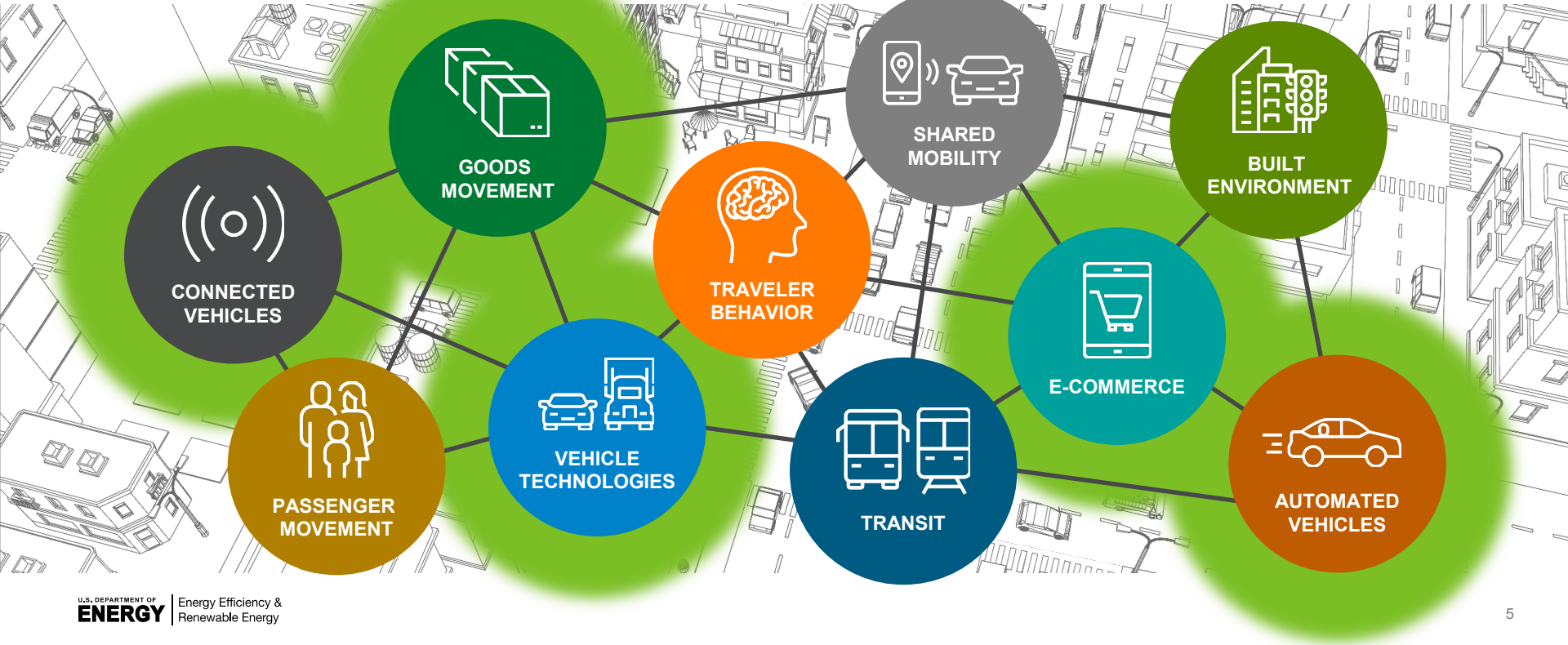
URBAN SCIENCE

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

ADVANCED FUELING INFRASTRUCTURE

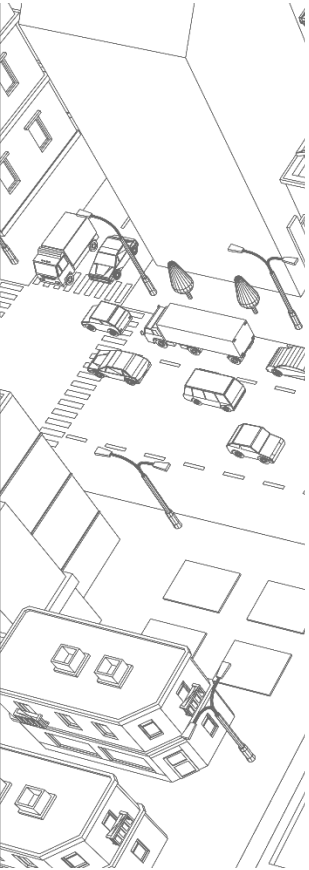
Understanding the costs, benefits, and requirements for fueling/charging infrastructure to support energy efficient future mobility systems.

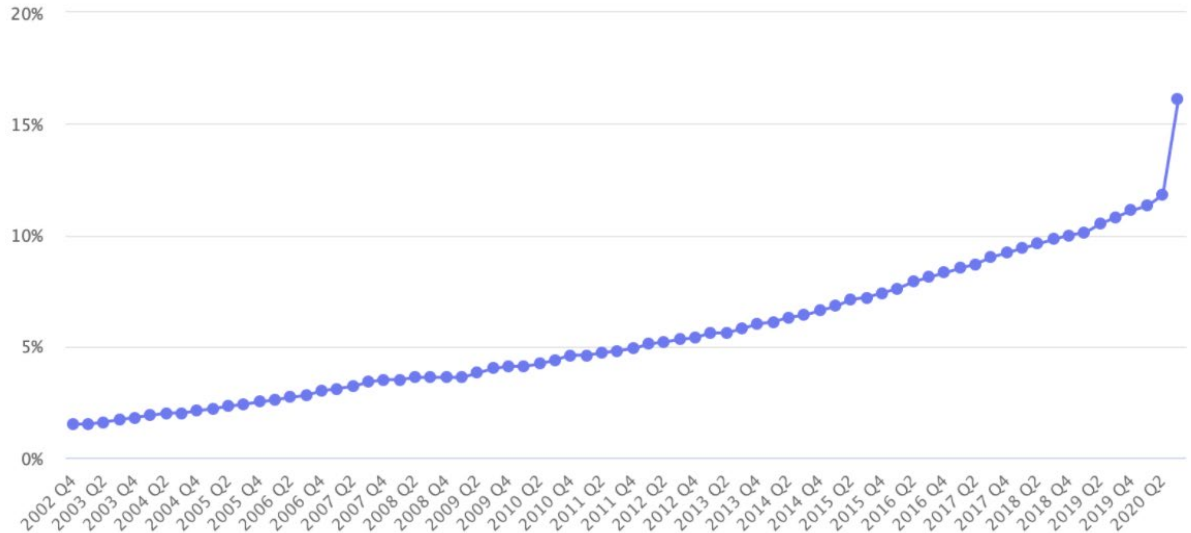
TRANSPORTATION IS A SYSTEM OF SYSTEMS

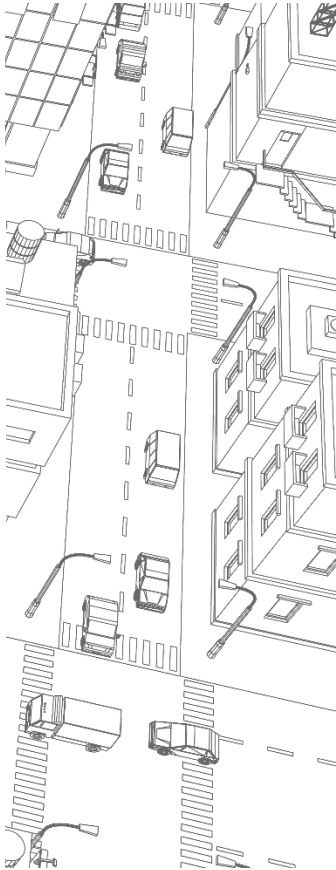


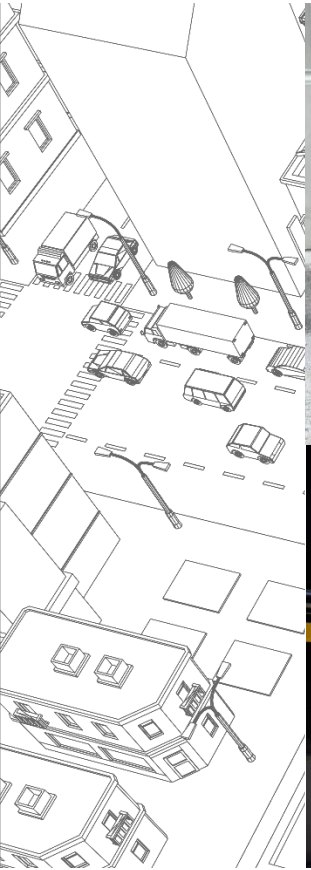
U.S. E-Commerce Sales as a Percent of Total Sales

Source: Marketplace Pulse, U.S. Department of Commerce









Source: Shutterstock

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DOE's Request for Information on Medium/Heavy Duty Truck R&D

Webinar on Key Findings:

Tuesday, December 15, 2020
1:00 – 4:00pm EST
https://www.energy.gov/eere/vehicles/events/webinar-discuss-key-findings-does-request-information-support-medium-and-heavy

FREIGHT MOVEMENT WILL BE INCREASINGLY IMPORTANT

Due to increased light duty electrification and freight demand

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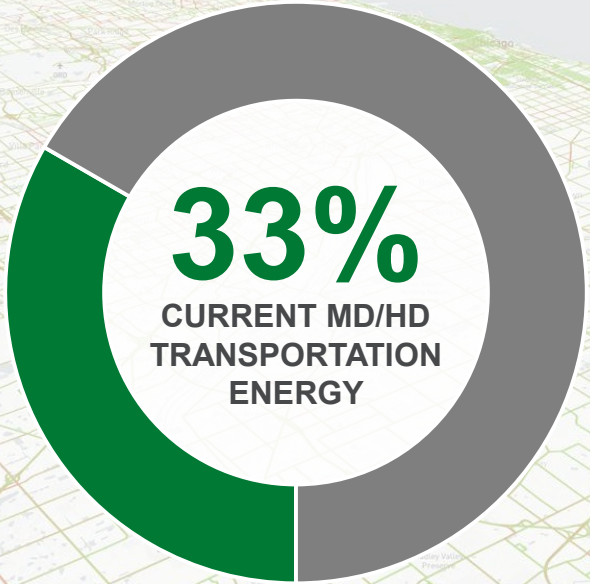
CHICAGO



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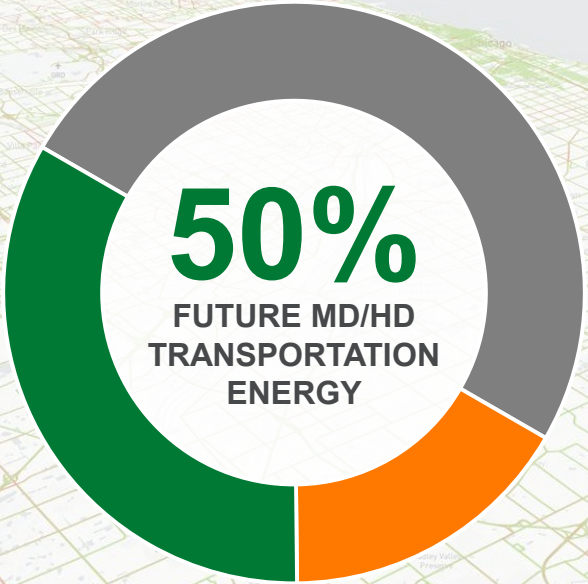

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MOBILITY FOR OPPORTUNITY

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MOVING GOODS IN A SMART MOBILITY SYSTEM: NEW FREIGHT MODES AND TECHNOLOGIES

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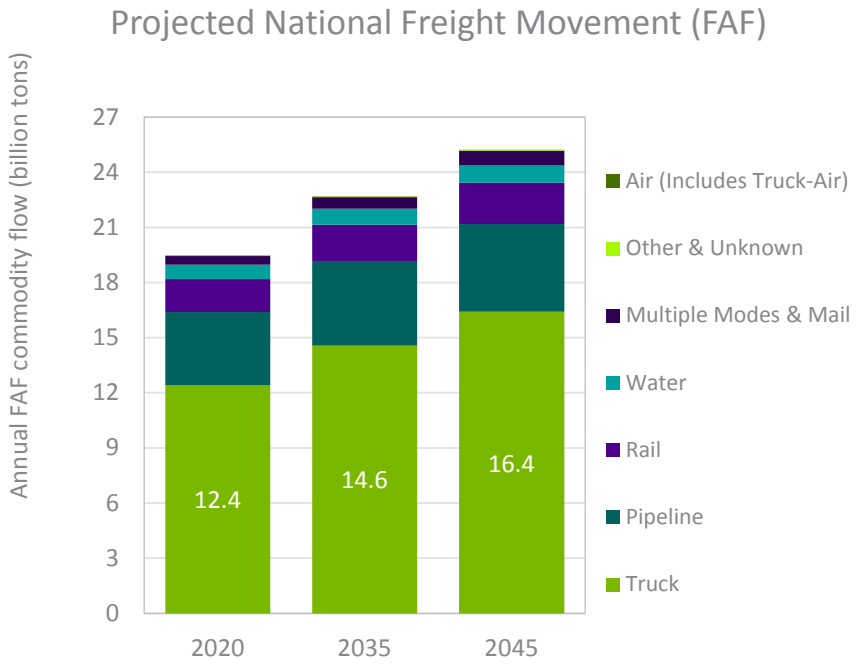
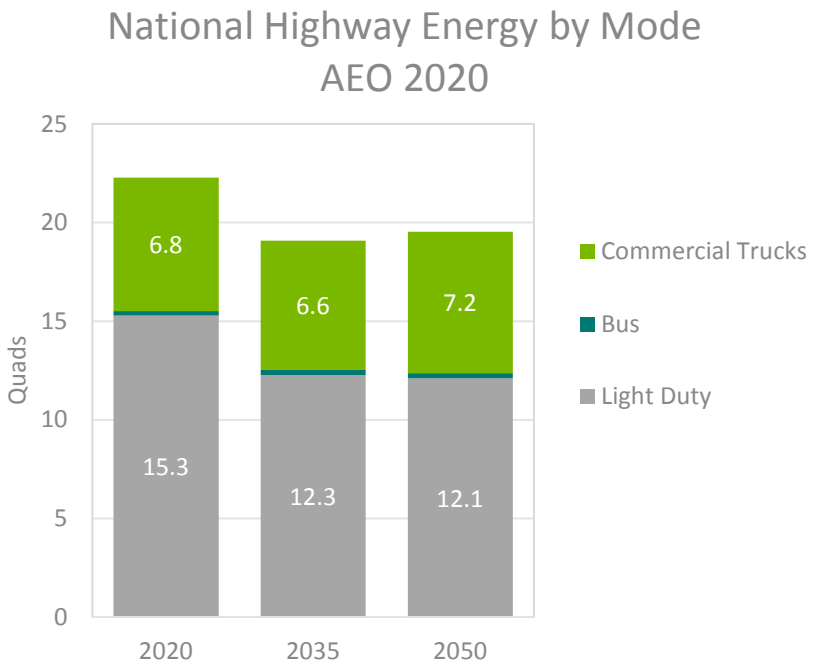
MOVEMENT OF GOODS BY TRUCKS IS CRITICAL TO THE ECONOMY AND MOBILITY

Share of highway energy is expected to grow





Note: projections made pre-COVID

HOW WILL EMERGING FREIGHT TECHNOLOGIES IMPACT ENERGY CONSUMPTION?

Individual Technology Assessments

- New urban delivery modes
  - Drones
  - Vehicle electrification
  - Parcel lockers
- Technologies for Class 7-8 regional to long-haul freight trucks
  - Truck platooning
  - Vehicle electrification

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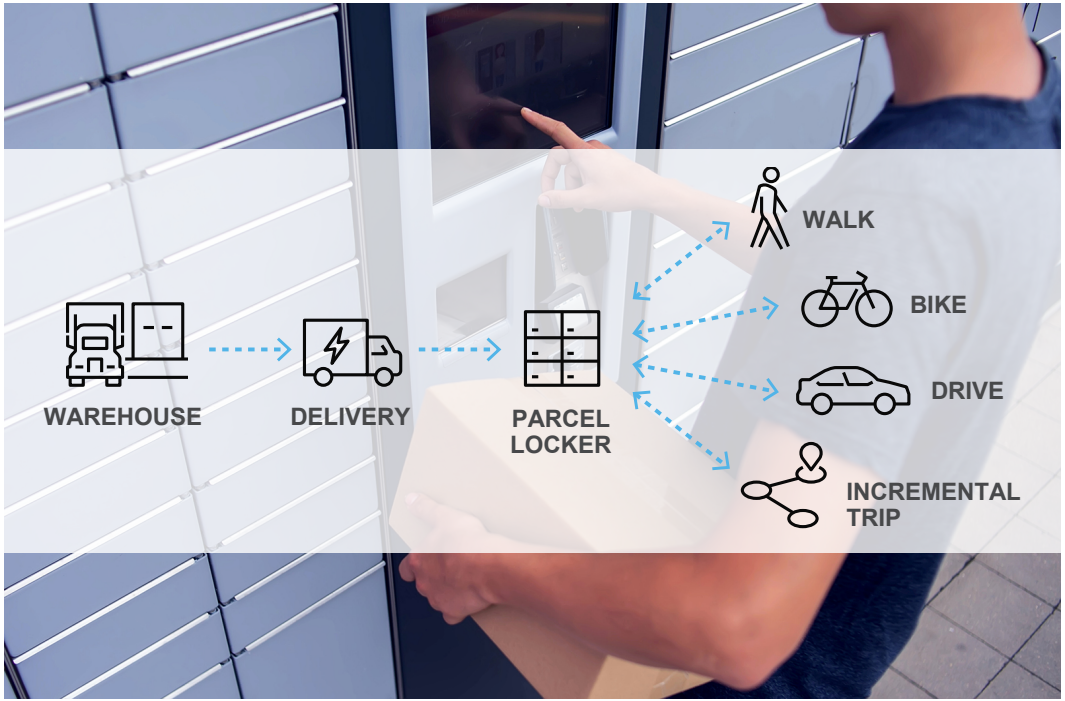
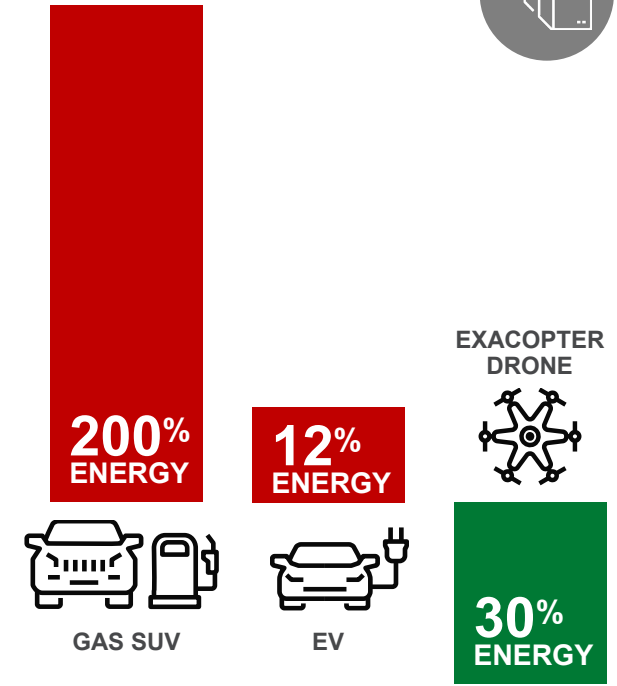
NEW URBAN DELIVERY MODES

PARCEL LOCKERS MAY BE AN INNOVATIVE LAST MILE SOLUTION

Consumer transport choice may negate commercial EV impact





LAST MILE DELIVERY MODES

Approach

Evaluate energy-saving potential:

- Characterize drone energy consumption via testing
- Use real world data to
  - Estimate parcel freight delivery demand
  - Establish freight delivery tour locations and routes
- Model baseline and alternative scenarios using innovative modes and methods
- Calculate energy consumption for each scenario

Support system level analysis by:

- Modeling freight origin facilities and service areas
- Estimating and modeling delivery tours for baseline energy usage
- Estimating freight deliveries that are replacing passenger vehicle shopping trips within Chicago

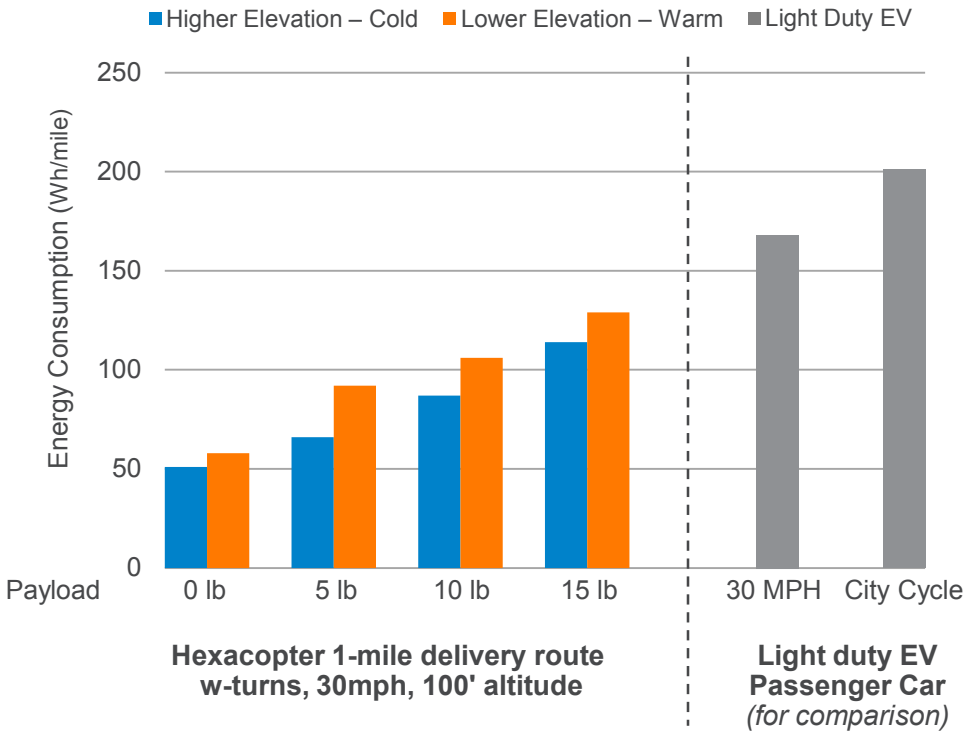
DRONE ENERGY CHARACTERIZATION

- Weighted Drone Tests:
  - High Altitude / Cold
  - Low Altitude / Warm
- Drone:
  - Matrice 600 Pro
  - Weight: 21 – 22 lbs
  - Max takeoff weight: 34 lbs
  - Max speed: 40 mph
- Flight Patterns:
  - 50 Foot Lift – Hover - Drop
  - 100 Foot Lift - Hover – Drop
  - 1 Mile route at 100 feet
    - 6 turn box route
    - 30 mph flight speed
    - 17 mph in Idaho only
- Payload Weights:
  - 0, 5, 10, and 15 lbs

ENERGY USE FROM DRONE DELIVERIES, LIGHT-DUTY BEVS COMPARABLE

How Drones are used will impact overall efficiency

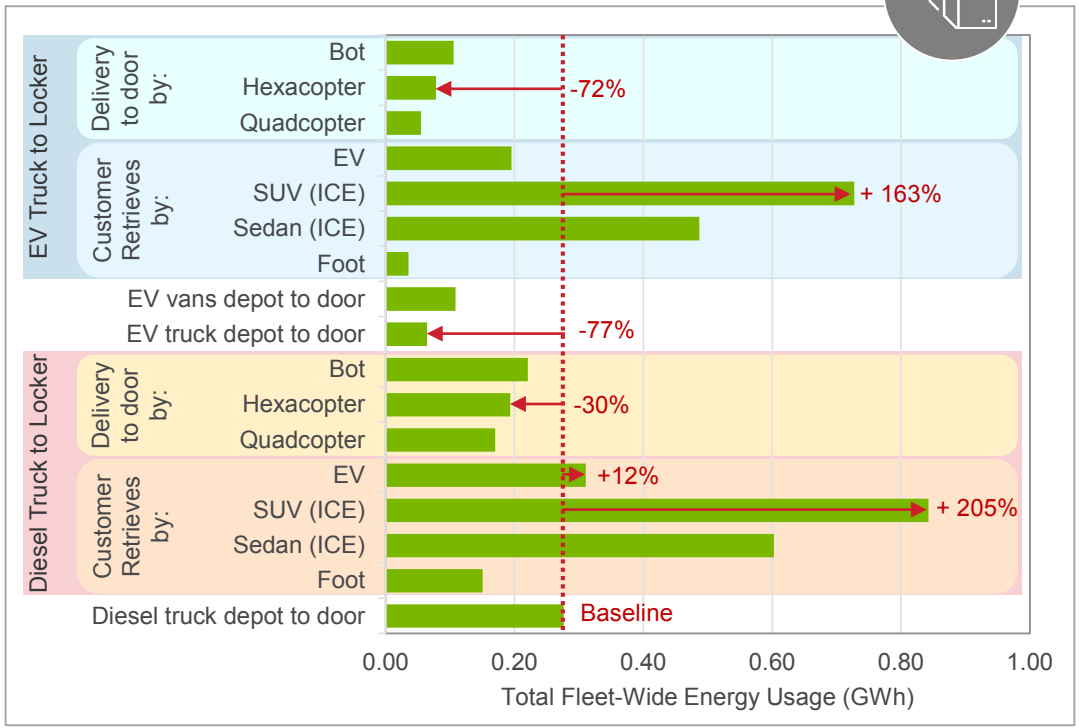
DRONE ENERGY USAGE IS SIGNIFICANT



PARCEL LOCKER ANALYSIS RESULTS

Energy impact depends on carrier and consumer transport choice

- Customers driving SI SUVs to pick up their package in a dedicated trip could increase energy by >200% (over standard diesel delivery to homes).
- Customers driving EVs to pick up their package in a dedicated trip could increase overall energy by ~10%.
- Home package deliveries by drone could reduce overall energy by 30%.



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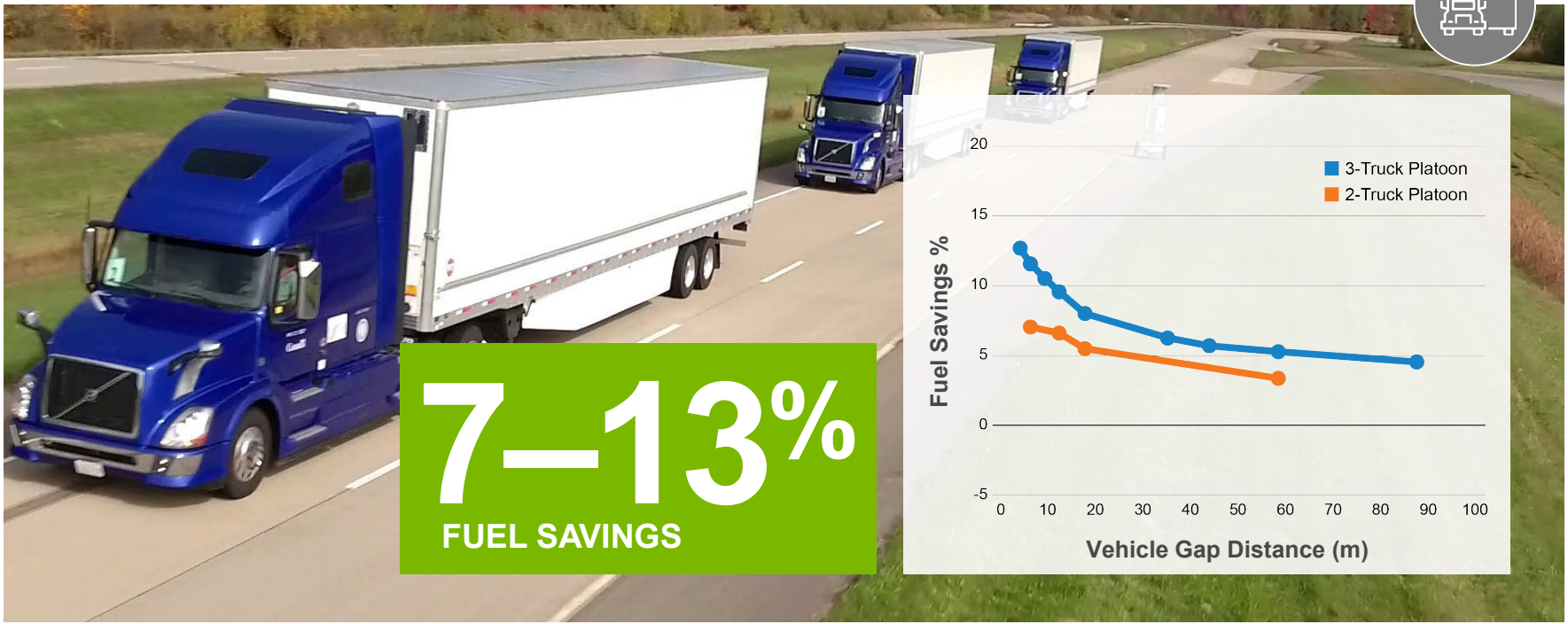
TECHNOLOGIES FOR REGIONAL & LONG-HAUL FREIGHT

PLATOONING REDUCES TRUCK FUEL USE

Savings depend on truck spacing, speed and position



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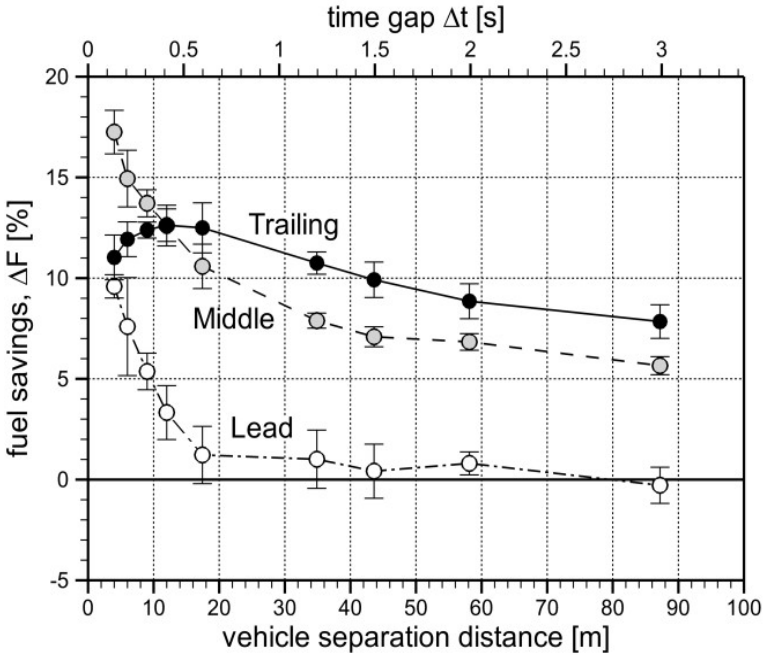
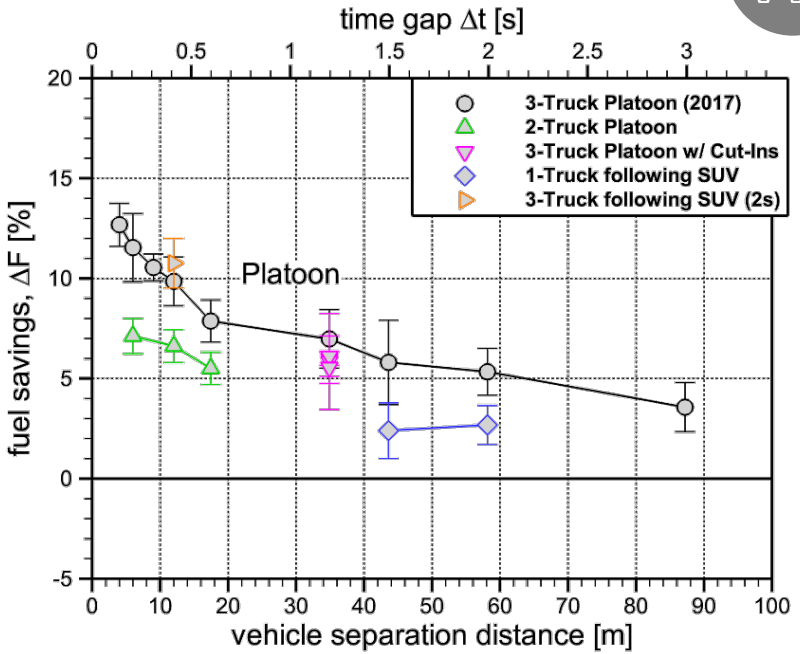




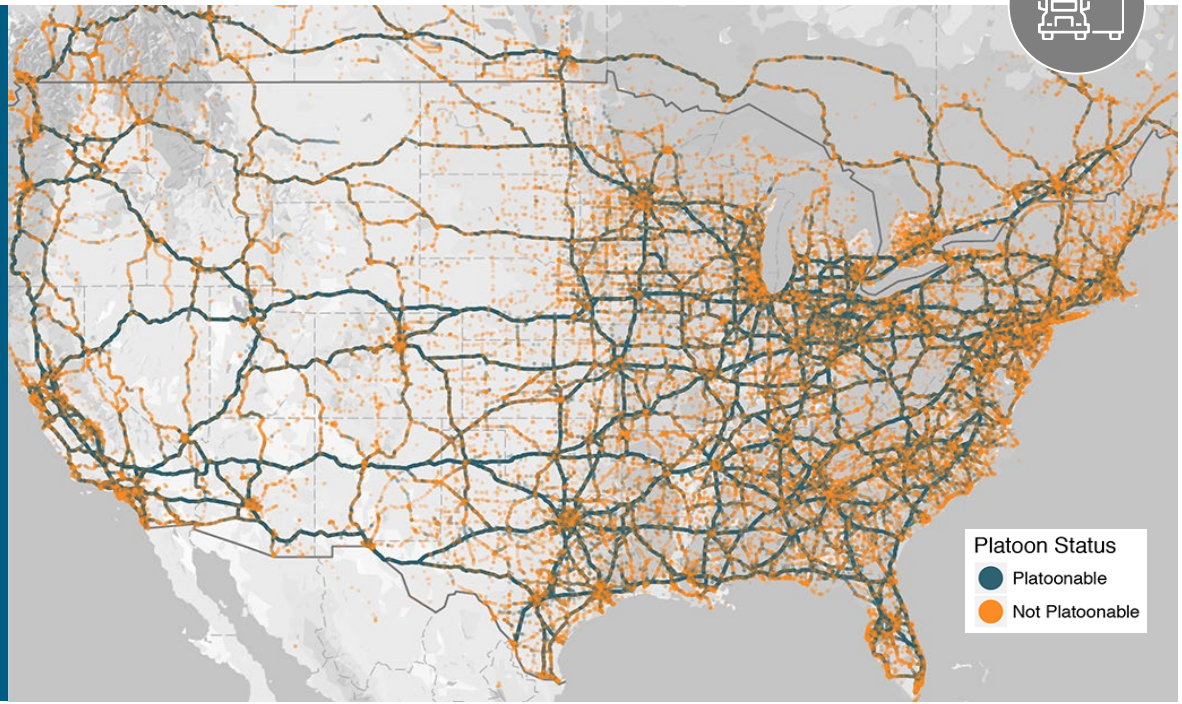
60% OF INTERSTATES AND HIGHWAY MILES MAY BE PLATOONABLE

Platooning could cut diesel use by over 1 billion gallons

CLASS-8 TRUCK ON-ROAD PLATOON OPPORTUNITIES

Analysis of freight survey and real-world operational data

- **Travel speed at least 50 mph for aerodynamic benefit**
- **Truck locations and schedules considered in platoon formation:**
  - within a **15 mile** radius
  - within a **15 minute** travel time window



CLASS 7/8 PRESENTS MAJOR ELECTRIFICATION OPPORTUNITY

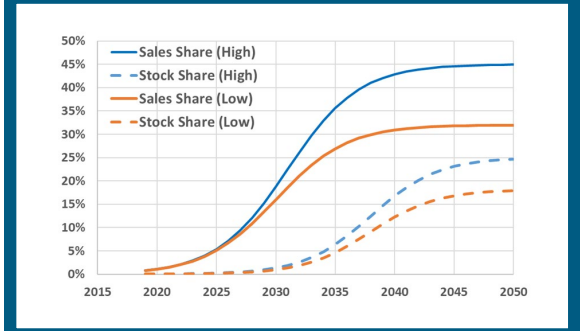
For freight moved under 500 miles, with operational changes

ENERGY REDUCTION POTENTIAL FROM CLASS 7&8 TRUCK ELECTRIFICATION

Analysis Approach

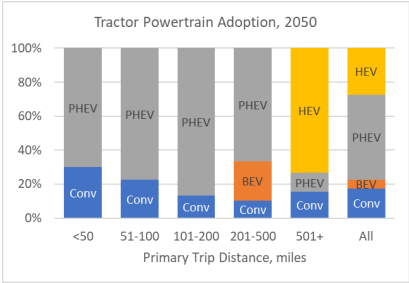
Study 1: Electrify all freight movement under 500 miles by 2050

- Battery electric vehicles (BEVs)
- No charging infrastructure constraints



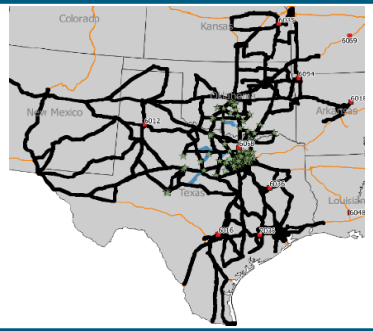
Study 2: Electrification portfolio

- Hybrids (HEV), plug-in hybrids (PHEVs), and BEVs
- Adoption where payback (compared to diesel) is ≤ 4 years
- No charging infrastructure constraints



Study 3: BEV suitability for regional fleet

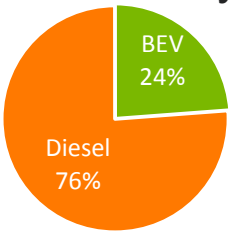
- Real world truck movement data
- Consider range and charging opportunities
- Assess ability to complete daily operations



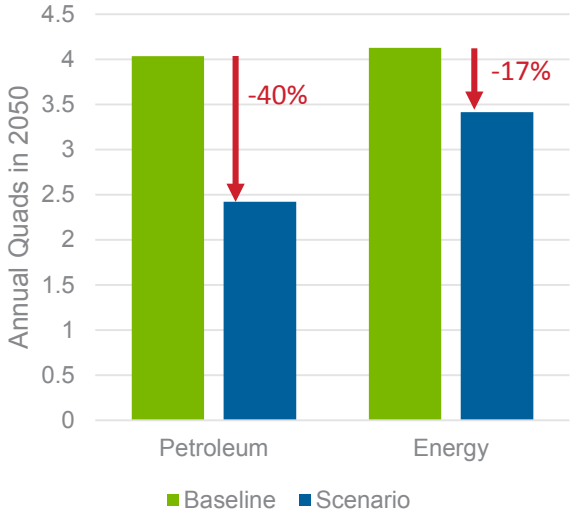
TRUCK ELECTRIFICATION STUDIES 1 & 2 RESULTS

Battery Electric Trucks for All Freight Moved < 500 miles (48% of ton-miles)

- Fully electrify 16 to 24% of class 7&8 trucks by 2050



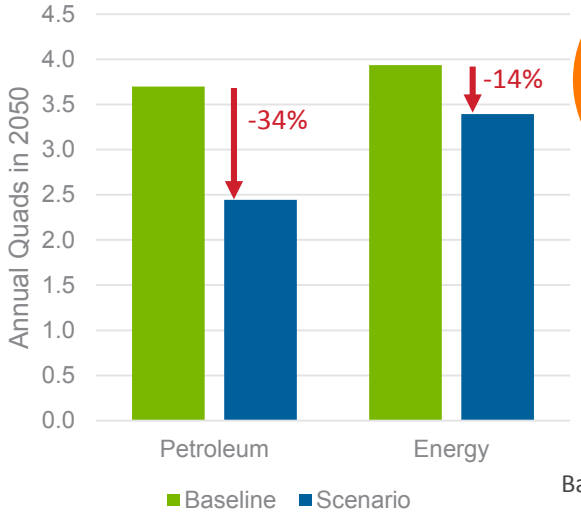
2050 Truck Stock

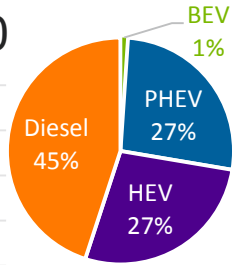


Baseline is AEO 2017 Reference Case

Portfolio of HEV, PHEV, and BEV Adopted with 4-year Payback

- Some amount of electrification in 55% of class 7&8 trucks by 2050





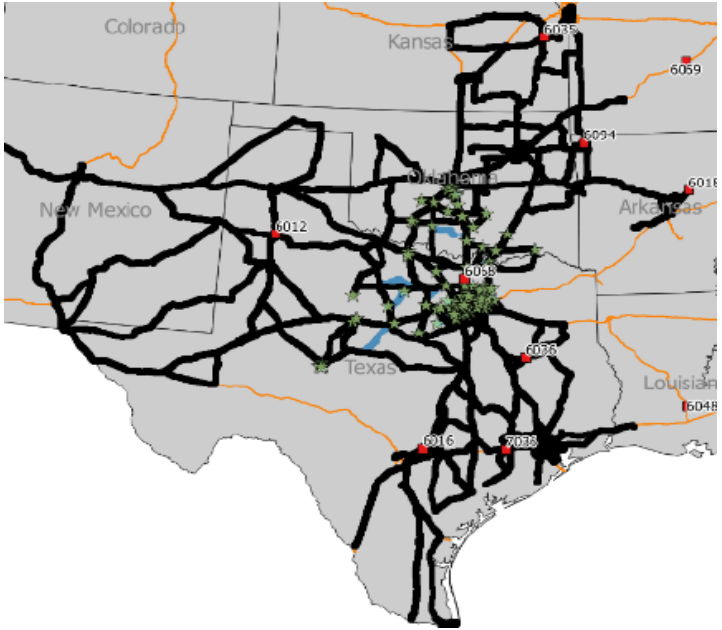
2050 Truck Stock

Baseline is AEO 2018 Reference Case

REGIONAL-HAUL PRIVATE MOTOR CARRIER

Examining real-world operations data

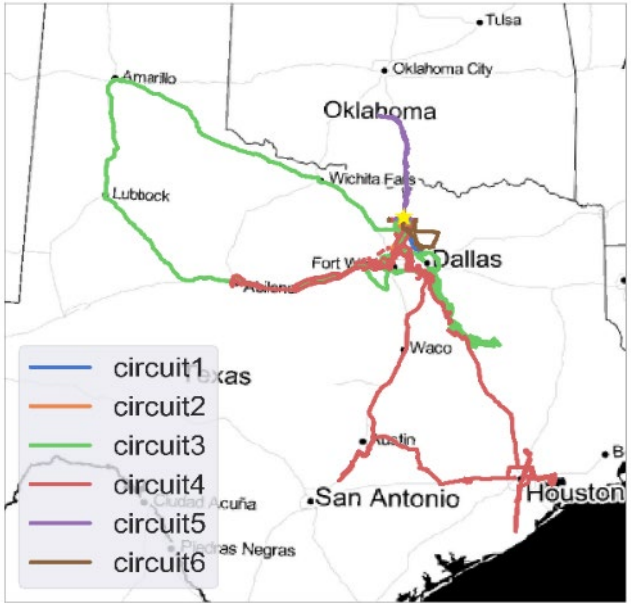
- Based in Dallas, Texas area
- Data loggers on 22 trucks
- Data collected over 1 month
- Class 7-8 trucks
- Private delivery locations



REGIONAL-HAUL PRIVATE MOTOR CARRIER

Single vehicle used in varied ways

- 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
- Assume charging entire time stopped at an RDC

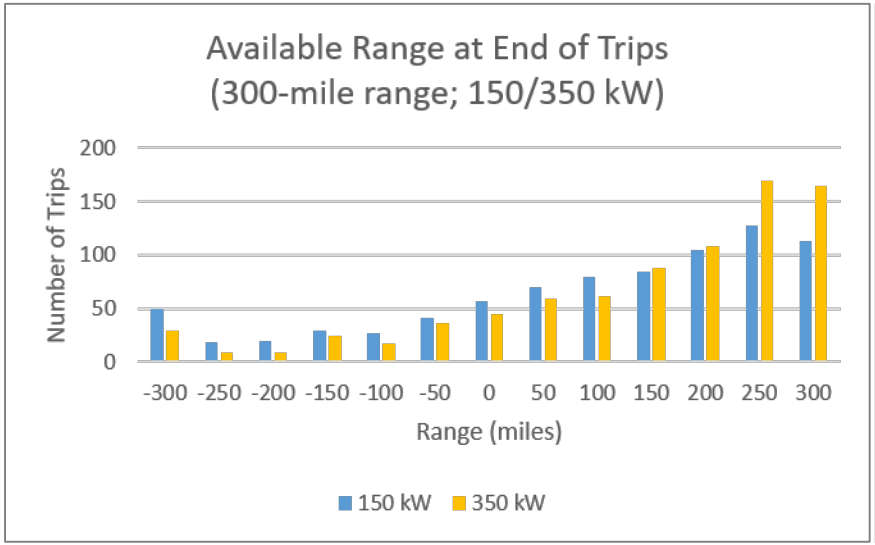


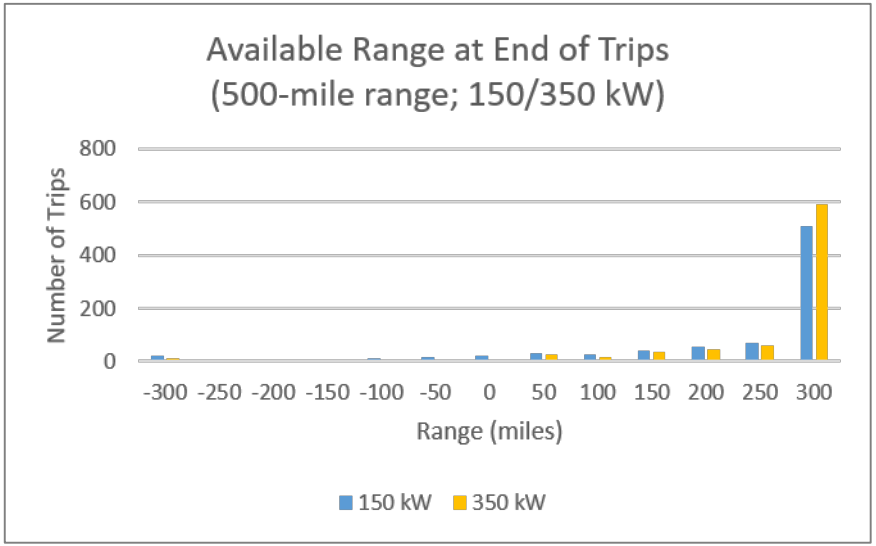
Summary of Single Truck Case Study	
Total distance driven (miles)	3,733
Number of trips	24
Total dwell time (hours)	142
Number of trips exceeding 300-mile range	4
Number of trips exceeding 500-mile range	0
Circuits (trip chains starting and ending at home RDC)	6
Number of stops at home and other RDCs	11

REGIONAL-HAUL PRIVATE MOTOR CARRIER STUDY RESULTS

Longer range vehicles enable more operations

- 300-mile range may require more shifts in operations than 500-mile
- Some trips not met by any private charging solution





THANKS TO THE MULTI-MODAL FREIGHT PILLAR LEAD AND PRINCIPAL INVESTIGATORS

David Smith, ORNL

Amy Moore, ORNL

Victor Walker, INL

Joanne Zhou, ANL

Kyungsoo Jeong, NREL

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MOVING GOODS IN A SMART MOBILITY SYSTEM: METROPOLITAN ANALYSIS

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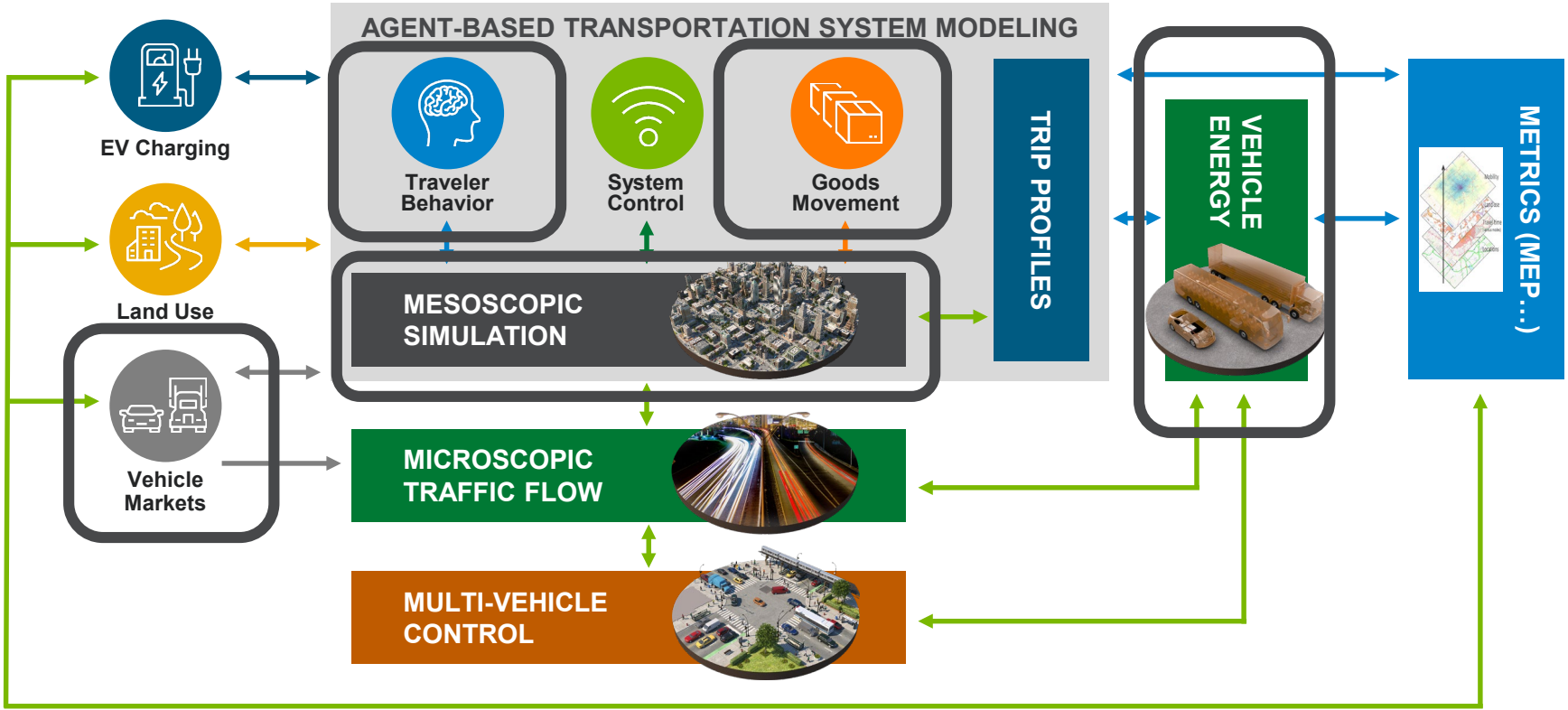
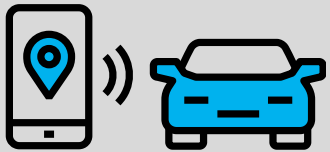
END-TO-END MODELING WORKFLOW



MOBILITY SCENARIOS CONSIDERED

A world of

HIGH SHARING, PARTIAL AUTOMATION (A)



New technology enables people to significantly increase the use of **transit, ride-hailing** and **multi-modal travel. Partial automation** is introduced and is primarily used on the highway.

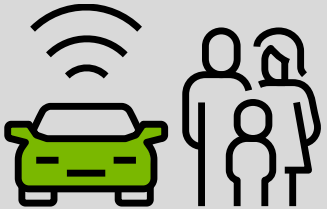
3 deliveries per week

HIGH SHARING, HIGH AUTOMATION (B)

Technology has taken over our lives, enabling **high usage of fully automated driverless vehicles, ride-hailing and multi-modal trips**, which are convenient and inexpensive. As a result, **private ownership has decreased** and **e-commerce has increased**.

5 deliveries per week

LOW SHARING, HIGH AUTOMATION (C)



Fully automated privately owned driverless vehicles dominate the market. The ability to own AVs leads to **low ride-sharing** and an expansion of urban/sub-urban boundaries, while **e-commerce has increased.**

BASELINE DESCRIPTIONS

Different Timeframes Considered

TODAY	SHORT TERM (A)	LONG TERM (B/C)
Baseline developed based on large number of diverse data sets representing current ▪ Population, ▪ Land use, ▪ Transportation network, ▪ Mode availability (e.g. ride-hailing), ▪ Light duty vehicle fleet distribution and geographical location by ZIP code, ▪ Freight demand, ▪ Vehicle technology	▪ Increased population (8%), ▪ New land use ▪ Moderate vehicle fleet electrification (up to 7% BEV, 5% PHEV and 7% HEV for LDV) Increased freight demand (10%) Two improved vehicle technology cases ▪ business as usual, or ▪ VTO R&D targets achieved *No changes related to connectivity, automation, sharing or e-commerce are considered*	▪ Increased population (20%), ▪ New land use ▪ Aggressive vehicle fleet electrification (up to 39% BEV, 11% PHEV and 12% HEV for LDV) Increased freight demand (28%) Two improved vehicle technology cases ▪ business as usual, or ▪ VTO R&D targets achieved *No changes related to connectivity, automation, sharing or e-commerce are considered*

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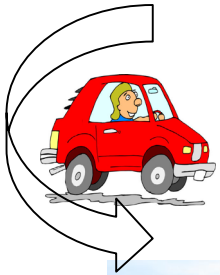
RESEARCH QUESTIONS

RESEARCH QUESTION:
NET EFFECT OF E-COMMERCE



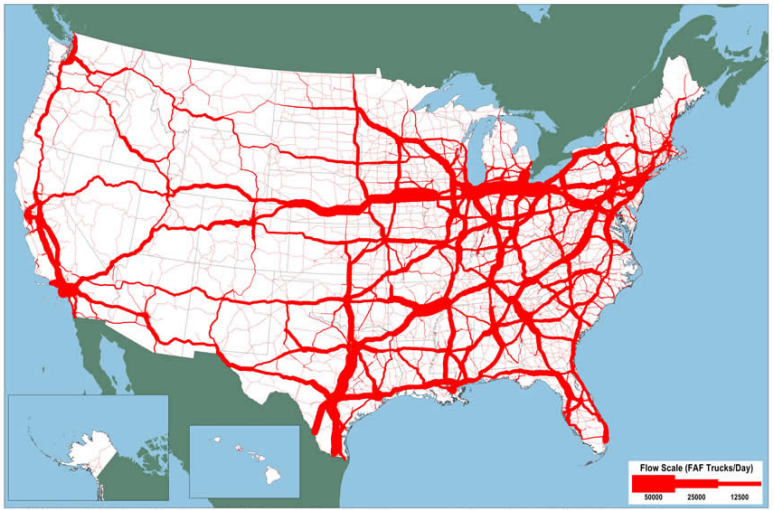
RESEARCH QUESTION: COMMODITY FLOW GROWTH

What are the regional impacts?

Average Daily Long-Haul Truck Traffic on the National Highway System: 2015

Note: Major flows include domestic and international freight moving by truck on highway segments with more than twenty five FAF trucks per day and between places typically more than fifty miles apart.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2017.

Average Daily Long-Haul Truck Traffic on the National Highway System: 2045



Note: Major flows include domestic and international freight moving by truck on highway segments with more than twenty five FAF trucks per day and between places typically more than fifty miles apart.
Source: U.S. Department of Transportation, Federal Highway Administration, Office of Freight Management and Operations, Freight Analysis Framework, version 4.3, 2017.

Source: https://ops.fhwa.dot.gov/freight/freight_analysis/nat_freight_stats/index.htm

RESEARCH QUESTION: VEHICLE TECHNOLOGY IMPACTS

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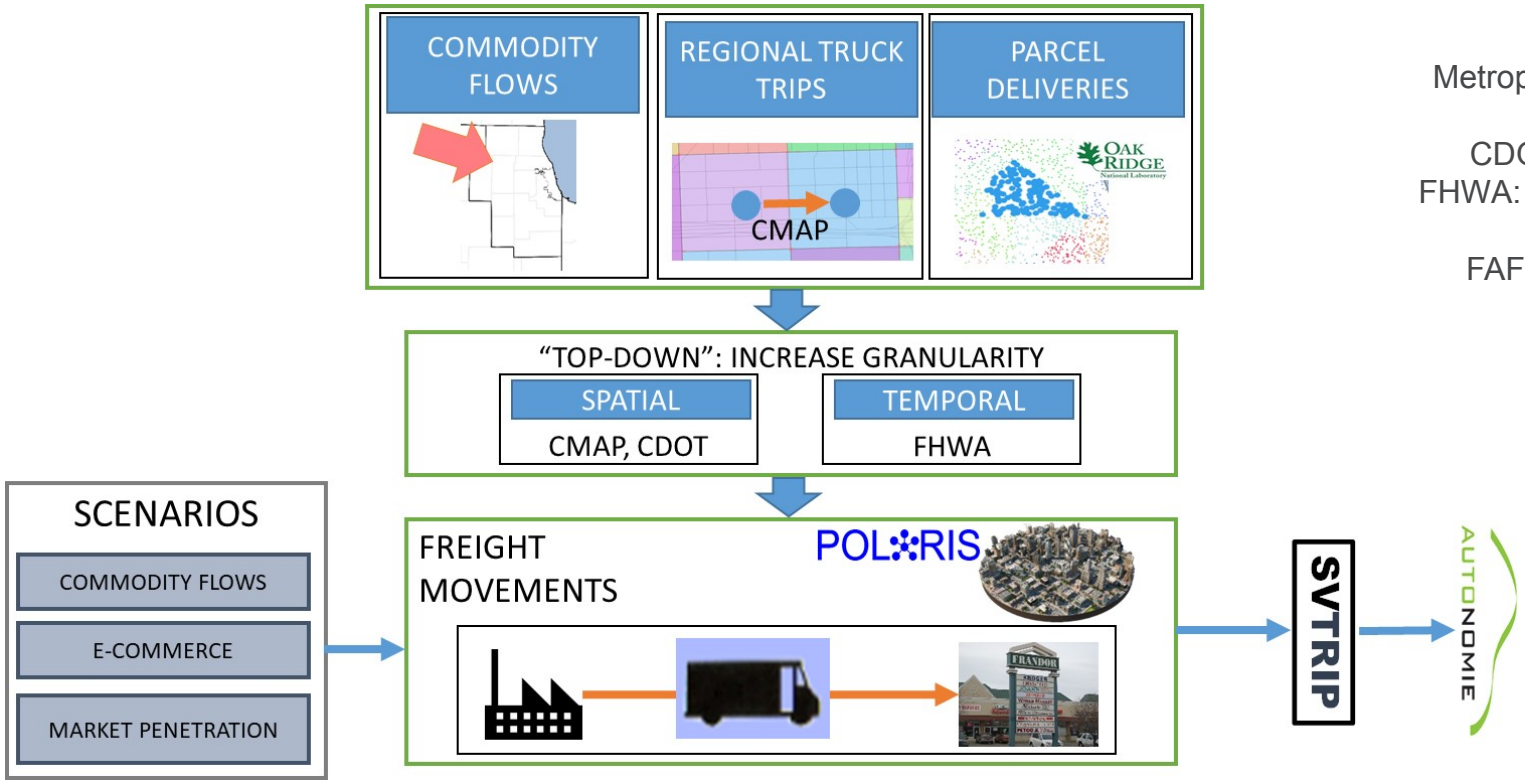
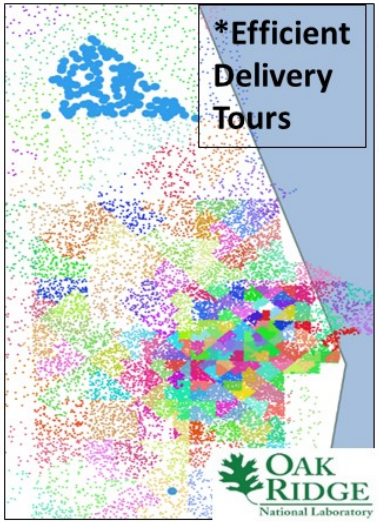
APPROACH

“TOP-DOWN” FREIGHT MODEL

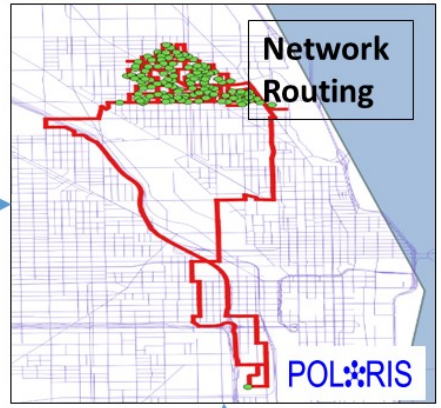


CMAP: Chicago Metropolitan Agency for Planning
CDOT: Chicago DOT
FHWA: Federal Highway Administration
FAF: Freight Analysis Framework

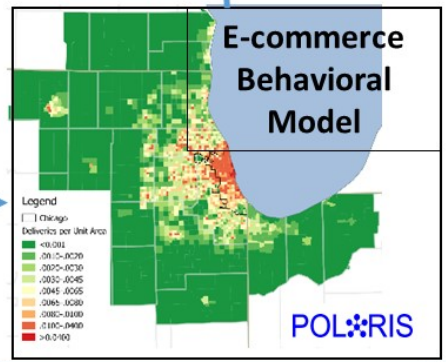
E-COMMERCE MODULE



Base year:
Zone-Level: Total Parcel Deliveries
Stop-Level: Random Delivery Locations
->MDT Delivery Tours



WholeTraveler — BERKELEY LAB — Survey Data



SVTRIP → AUTONOMIE

HOUSEHOLD E-COMMERCE DEMAND BEHAVIORAL MODEL

More e-commerce demand for <u>households with:</u>

- Higher incomes
- More children

Less e-commerce demand for <u>households with:</u>

- More vehicles
- Fewer adults
- Residence is walkable or close to transit

Binary Choice: Whether Participates in E-commerce or not		
Variables	Estimates	t-stat
Constant	-0.103	-1.64
# of HH Children	0.104	1.39
HH income less than 25k	-0.459	-2.33
HH income between 25k and 50k	-0.54	-3.37
HH income between 50k and 100k	-0.154	-1.41
HH income greater than 200k	0.355	3.32
Distance to nearest transit stop from home (in 100th of miles)	0.077	1.18
Ratio of Delivery to Retail Shopping		
Parameters to the latent propensity		
Constant	2.882	11.7
# of HH Adults	-0.146	-2.49
HH income greater than 200k	0.369	3.29
Walk Score (Range 0 to 10)	-0.057	-3
# of HH Vehicle	-0.18	-2.8
Threshold Parameters		
Theta 0	-ve Infinity	Fixed
Theta 1	0	Fixed
Theta 2	1.576	11.86
Theta 3	2.162	15.74
Theta 4	2.738	19.23
Theta 5	3.482	22.34
Theta 6	+ve Infinity	Fixed
Summary		
Number of Observations	971	
Final Log-likelihood	-1362.45	

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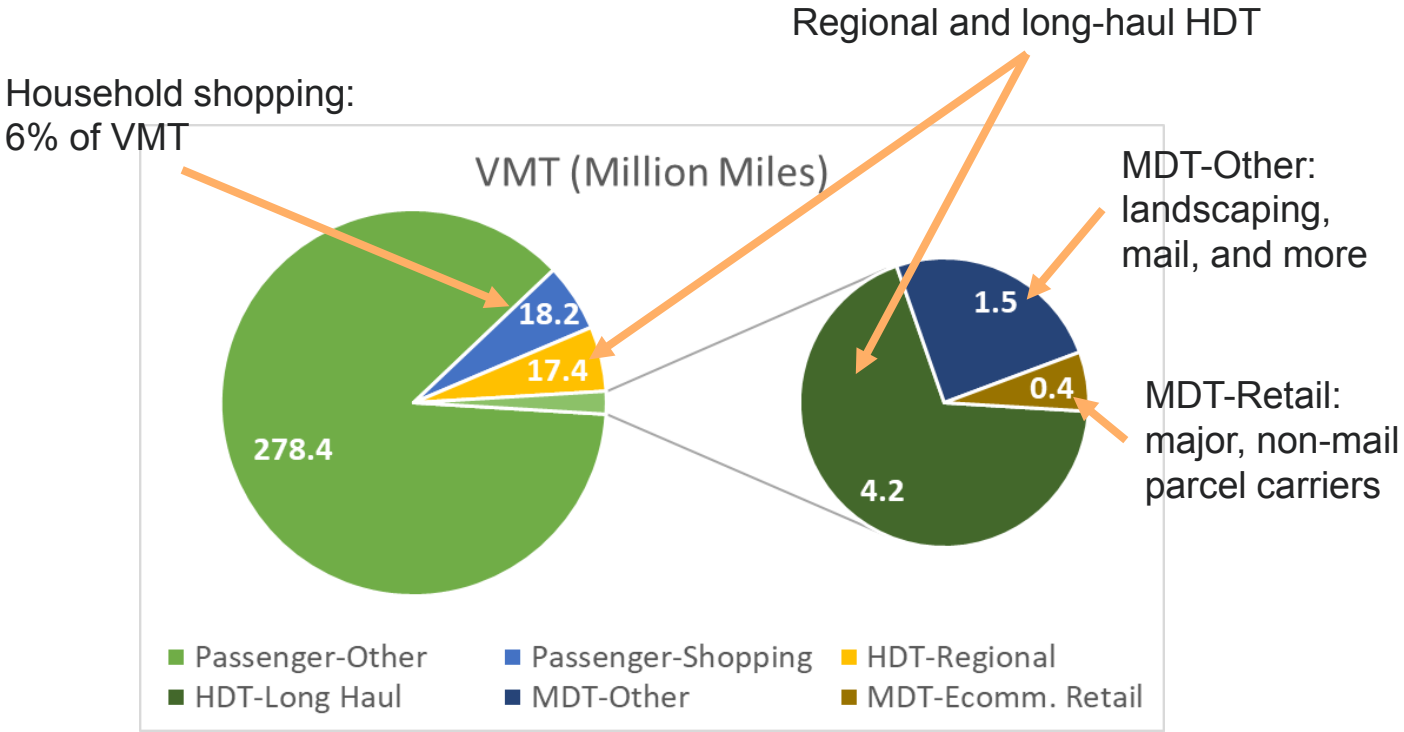
REGIONAL FREIGHT IMPACTS

In the Chicago Area Today, *MDT and *HDT Make Up 10% VMT and One-Third of Energy

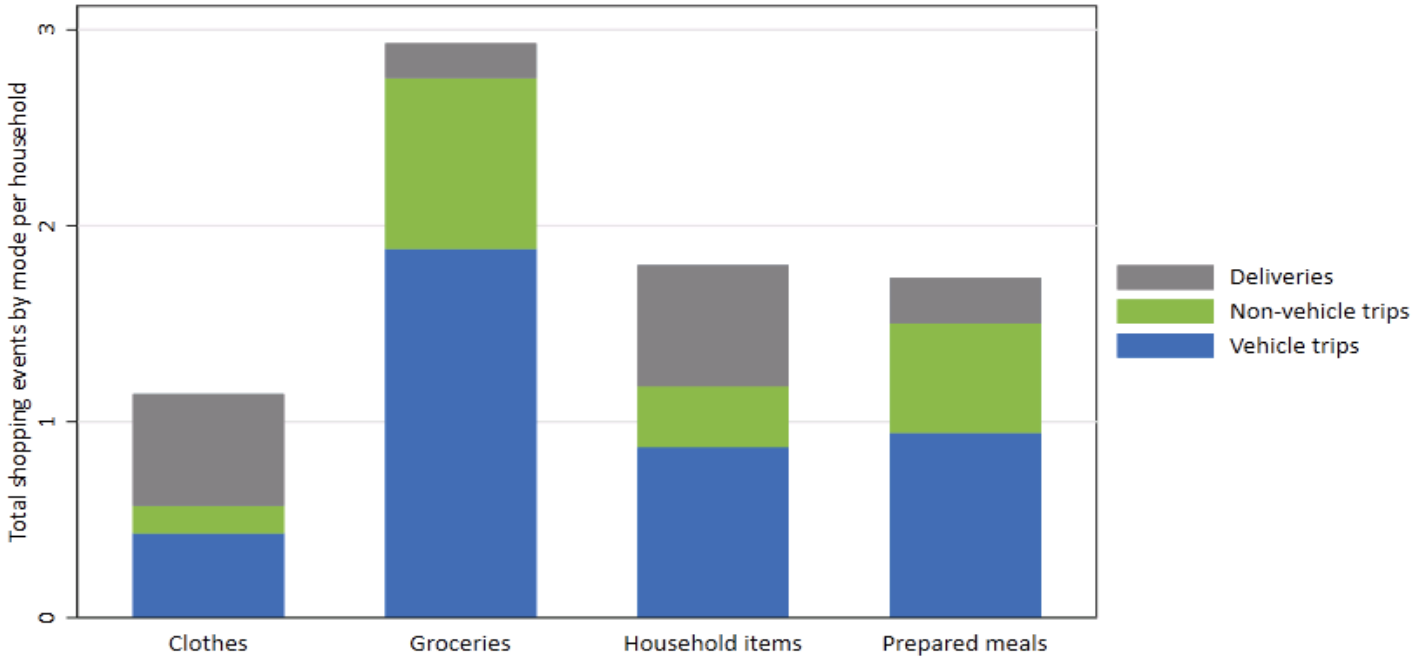


*MDT, HDT: Medium-duty truck, heavy-duty truck

DELIVERY VS. BRICK-AND-MORTAR SHOPPING VARIES BY TYPE OF ITEM*

Prepared meals and grocery: mostly in-person

SAN FRANCISCO

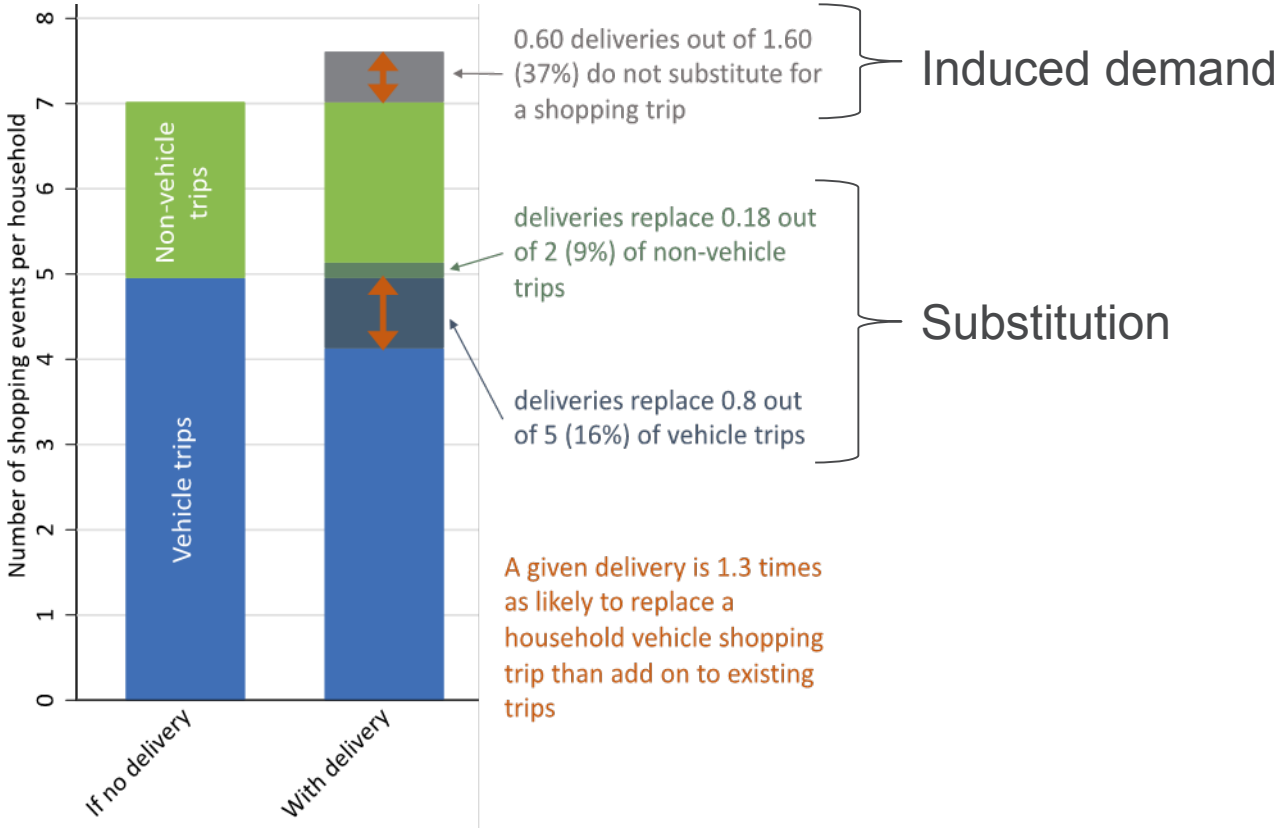


*pre-COVID

TODAY: 1 IN 7 SHOPPING EVENTS HAS BEEN REPLACED BY A DELIVERY TRIP

Deliveries replace both vehicle trips and non-vehicle trips

SAN FRANCISCO



INCREASE IN E-COMMERCE LOWERS OVERALL SYSTEM VMT AND ENERGY

Fewer shopping trips, more deliveries make the difference

CHICAGO

SHOPPING TRIP = 7 to 8 miles, one way

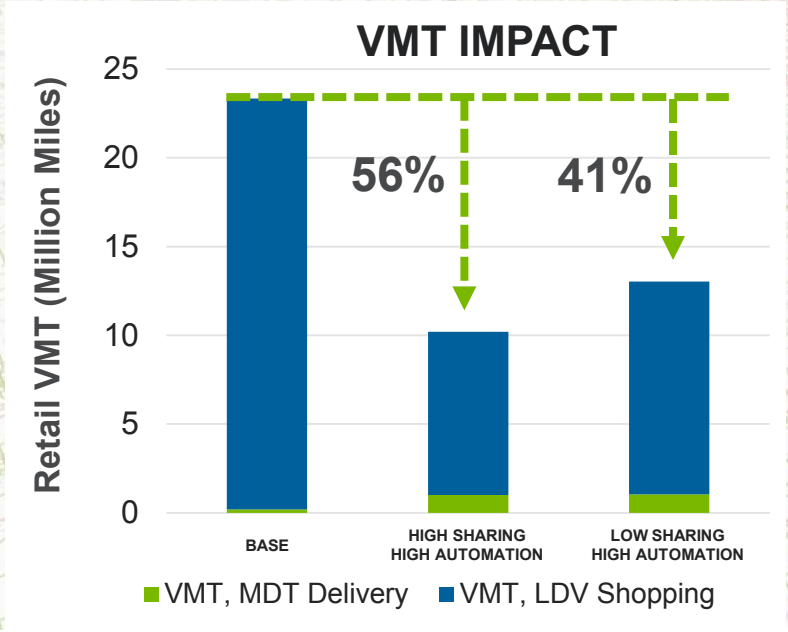
DELIVERY TRIP

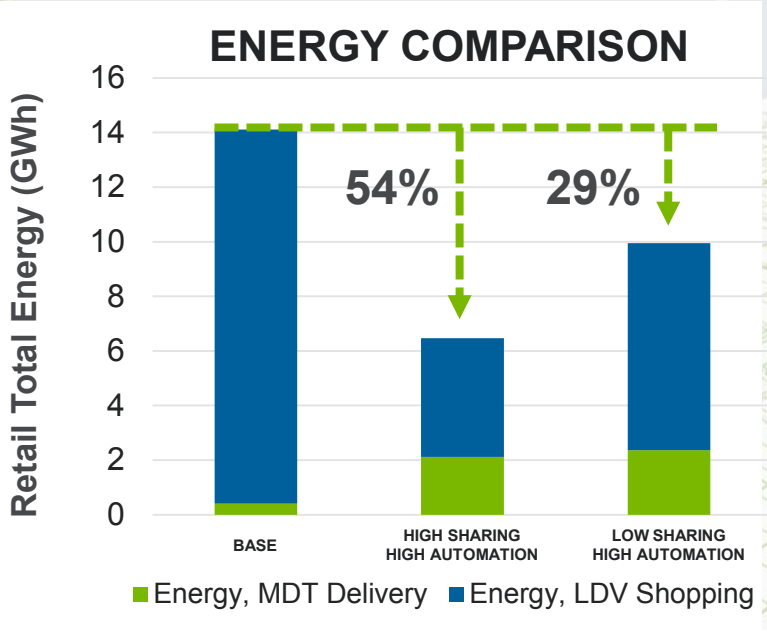
1 ADDED STOP = 0.4 mile

HOME DELIVERIES CAN DECREASE TRANSPORTATION ENERGY USE

Energy savings from e-commerce and vehicle technologies

CHICAGO

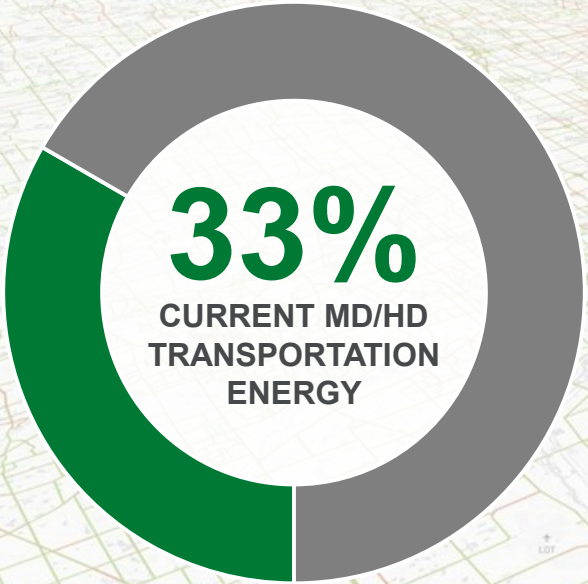


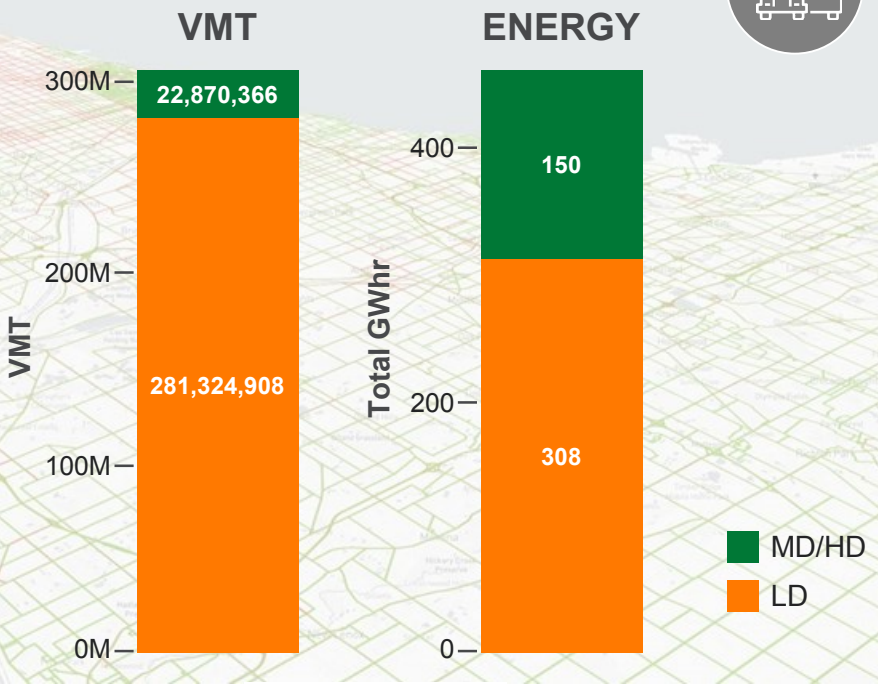


FREIGHT MOVEMENT WILL BE INCREASINGLY IMPORTANT

Due to increased light duty electrification and freight demand

CHICAGO





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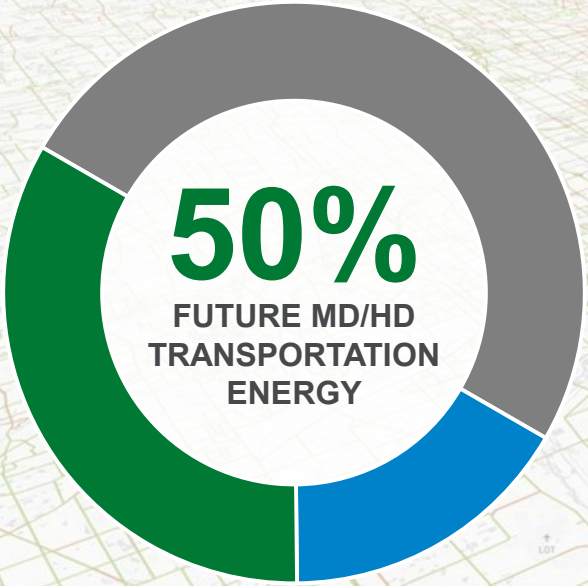
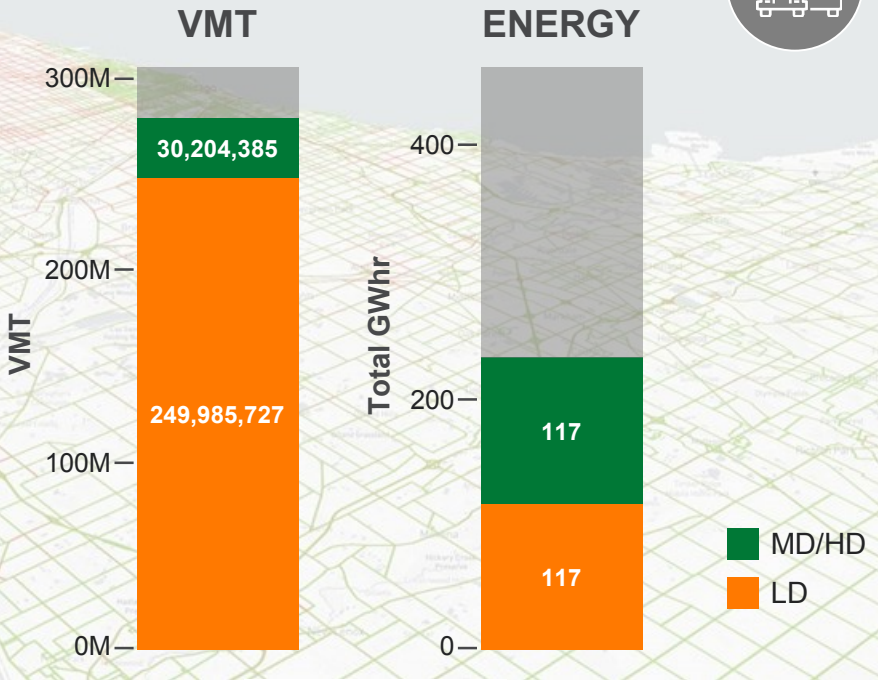
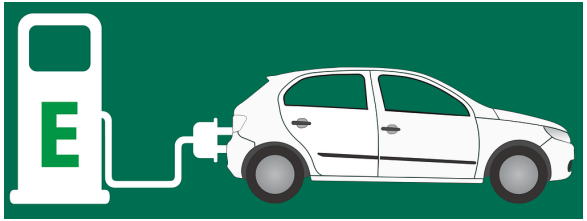


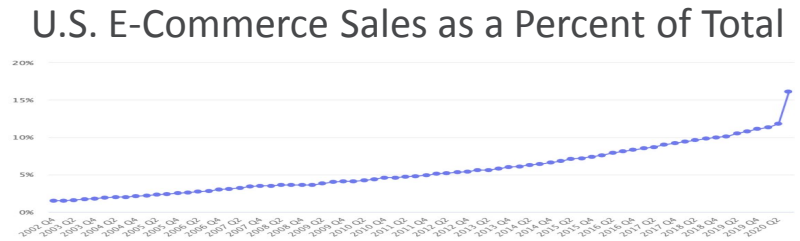


HIGH SHARING
HIGH AUTOMATION

SUMMARY

- A retail system with e-commerce delivery appears to be more efficient than one based on household shopping trips alone
- Passenger vehicle technologies are progressing more quickly than those for freight, leading to freight's increasingly outsized impacts on the system
- The study reflects pre-COVID trends!





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