

JUNE 4, 2020



# OPTIMIZATION OF INTRA-CITY FREIGHT MOVEMENT WITH NEW DELIVERY METHODS

**AMY M. MOORE, PH.D.**  
Oak Ridge National Laboratory

This presentation does not contain any proprietary, confidential, or otherwise restricted information.

Project ID: eems034

# OVERVIEW

## Timeline

- Project start date: Oct 2016
- Project end date: Sep 2019
- Percent complete: 100%

## Budget

- Total project funding  
—DOE share: 100%
- Funding for FY 2019:  
\$745,000

## Barriers

- None. Project completed.

## Partners

- Oak Ridge National Laboratory
- Idaho National Laboratory
- Argonne National Laboratory
- National Renewable Energy Laboratory
- United Parcel Service
- Chicago Metropolitan Agency for Planning

# OVERVIEW

## Overall Objective

Evaluate energy-saving potential of new intra-city freight delivery methods by:

- Estimating parcel freight delivery demand
- Establishing freight delivery tour locations and routes
- Modeling baseline and alternative scenarios using innovative modes and methods
- Calculating energy consumption for each scenario

## Focused Efforts

Collaborate with ANL and support further development of freight agents within POLARIS by:

- Estimating freight deliveries that are replacing passenger vehicle shopping trips within Chicago
- Modeling freight origin facilities and service areas
- Estimate and model delivery tours to provide as baseline to POLARIS

# RELEVANCE

## Growth of e-commerce

- E-commerce is quickly replacing traditional consumer shopping trips (shopping to shipping)

## Urban Pressure

- Growing congestion levels, failing infrastructure, and growing populations within urban areas are leading to problems for delivery vehicles (trucks) by:
  - Increasing VMT
  - Increasing time and cost of delivering goods
  - Preventing adequate parking and temporary curb space

## New Technology

- New transportation modes are changing how people and goods move (TNCs, scooters, robots, drones), but they need further evaluation

# MILESTONES

Milestone Name/Description	Criteria	End Date	Type
Q2 - Analyze consumer behavior data and existing passenger and freight movement data for Chicago and provide data set to Polaris.	Dataset estimates provided to Polaris	1/31/2019	<b>COMPLETE</b>
Q3 - Characterize energy use for new freight technologies and incorporate micro-models based on the results  Using the modeled tour routes developed by integrating OD freight flows in POLARIS, develop micro-level/last-mile multi-modal scenarios and evaluate energy impacts	Report on energy use and scenario results	3/30/2019	<b>COMPLETE</b>
Q4 - Provide detailed data and analysis on intra-city freight movements (baseline and projected) for Chicago using delivery scenarios	Report on scenario results and baseline changes in energy.	9/30/2019	<b>COMPLETE</b>

# APPROACH

## Investigate Technologies

- Work with partners to look at future delivery methods
- Investigate new delivery modes (drones, bots, EVs)

## Gather and Model Delivery Data

- Work with partners to understand delivery demand
- Estimate delivery demand

## Model Scenarios

- Use advanced GIS tools to model scenarios using existing and new delivery modes

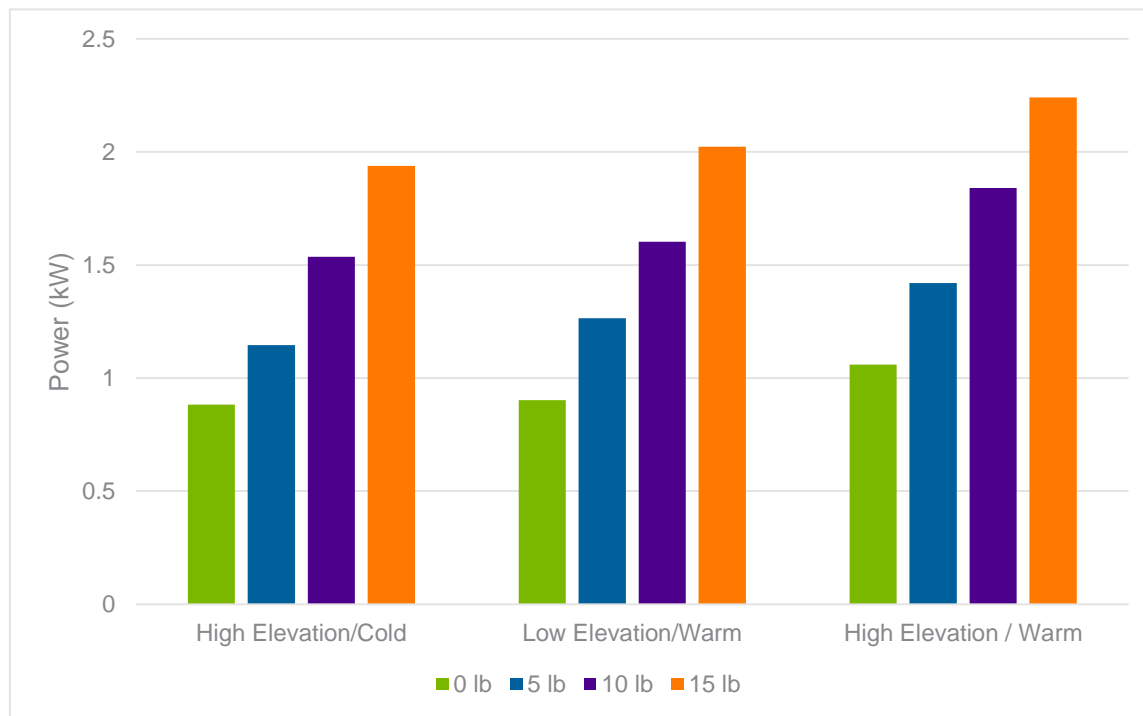
## Expand to Regional Impacts

- Collaborate with Argonne and POLARIS to model impacts on entire Chicago region

# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

## Drone Energy Use

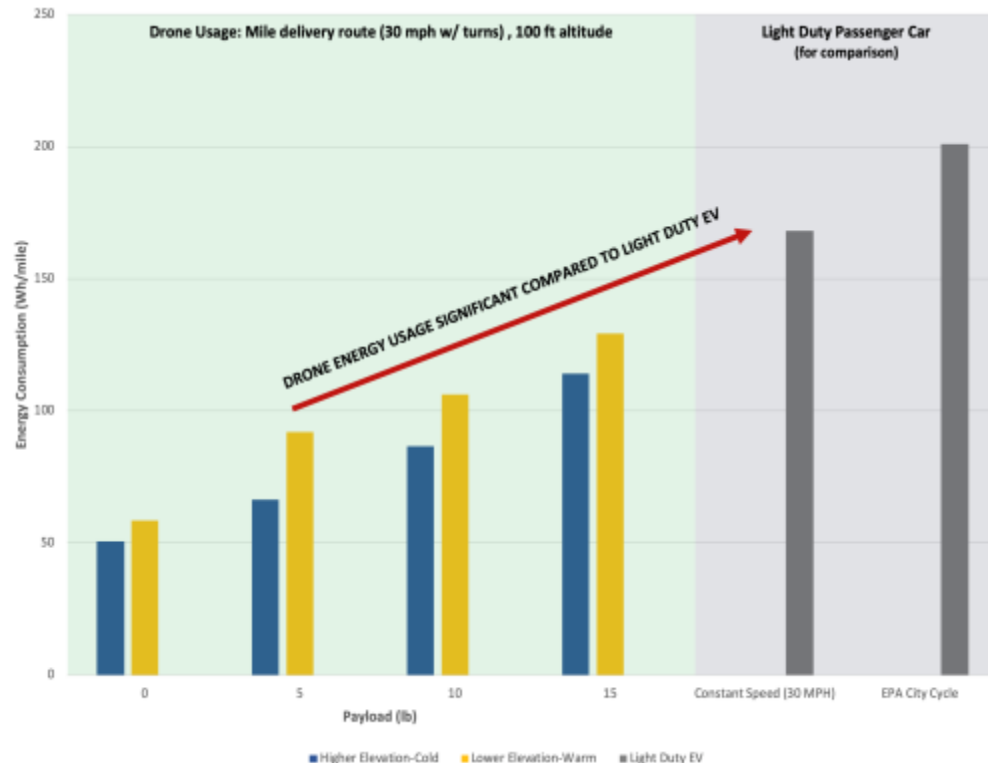
- Average drone energy use for a one-mile trip by payload at varying altitudes and temperature
- Higher payload and higher temperature had a significant increase in energy use.



# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

## Drone Energy Use

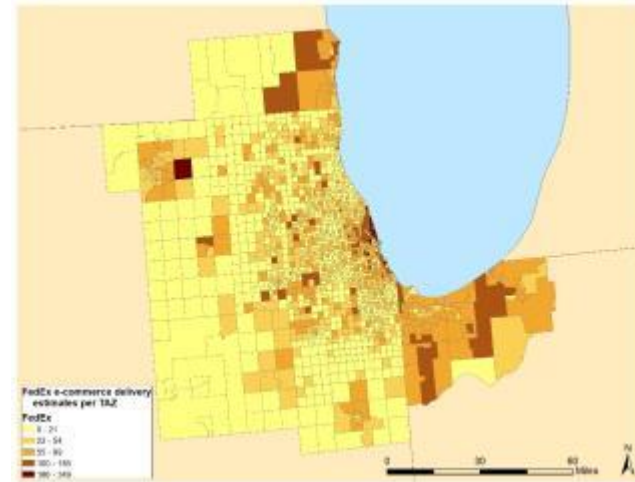
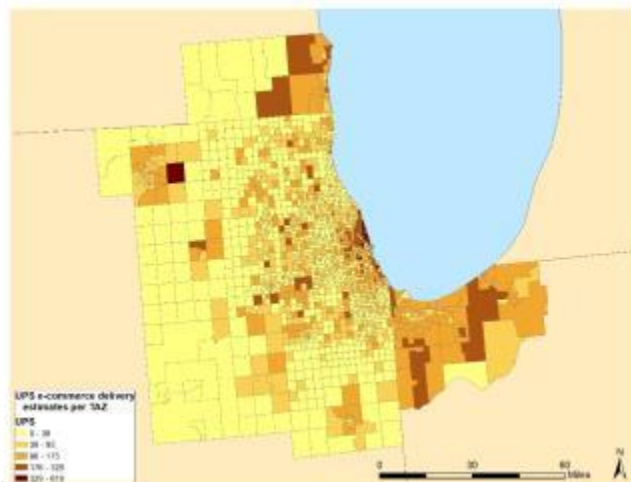
- Experimental drone energy consumption results for a one mile route indicates significant energy use even compared to EV passenger cars.



# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

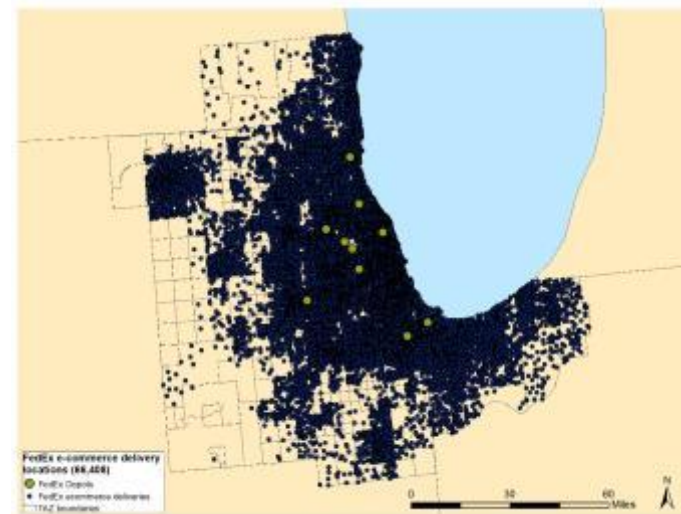
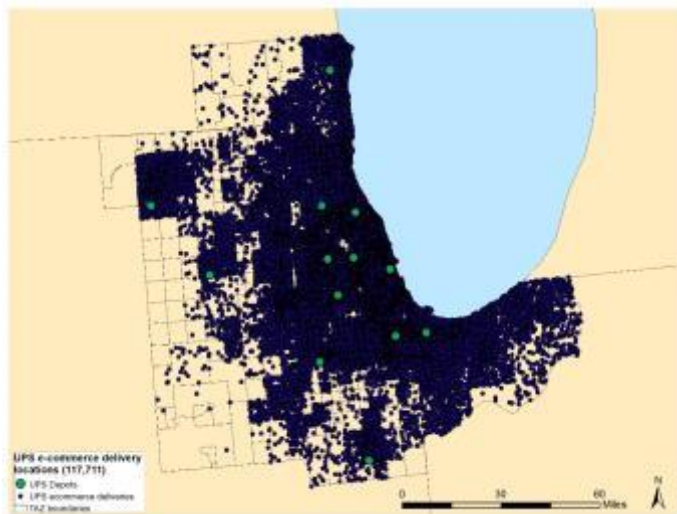
Traffic Analysis Zone (TAZ)-level e-commerce delivery destinations were estimated using:

- Average household total shopping estimates per TAZ (based on 5-day average) – obtained from UPS model and POLARIS estimates
- Current percentage of e-commerce shopping
- Current market shares for UPS and FedEx



# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- Estimated 117,711 average, daily UPS e-commerce deliveries
- 13 UPS depots in Chicago MSA
- Estimated 66,408 average, daily FedEx e-commerce deliveries
- 10 FedEx depots



# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

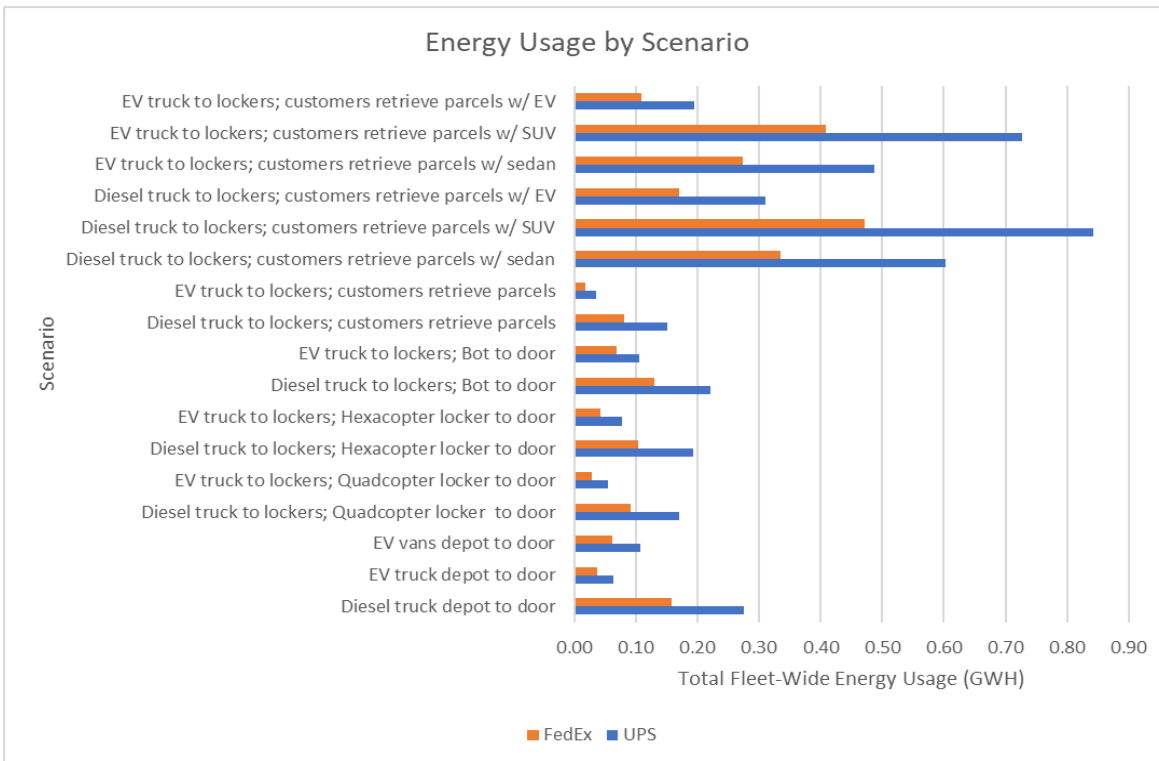
## Scenario development

- 17 alternative scenarios were compared with the baseline of diesel class six truck (standard UPS/FedEx delivery truck)
- Modes used in alternative scenarios included:
  - electric class six truck
  - electric delivery van (Sprinter)
  - delivery bot (Nuro, - Kroger and Domino's)
  - two drone models (hexacopter and quadcopter)
  - three passenger vehicles (SUV, sedan, EV)
  - parcel lockers

# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

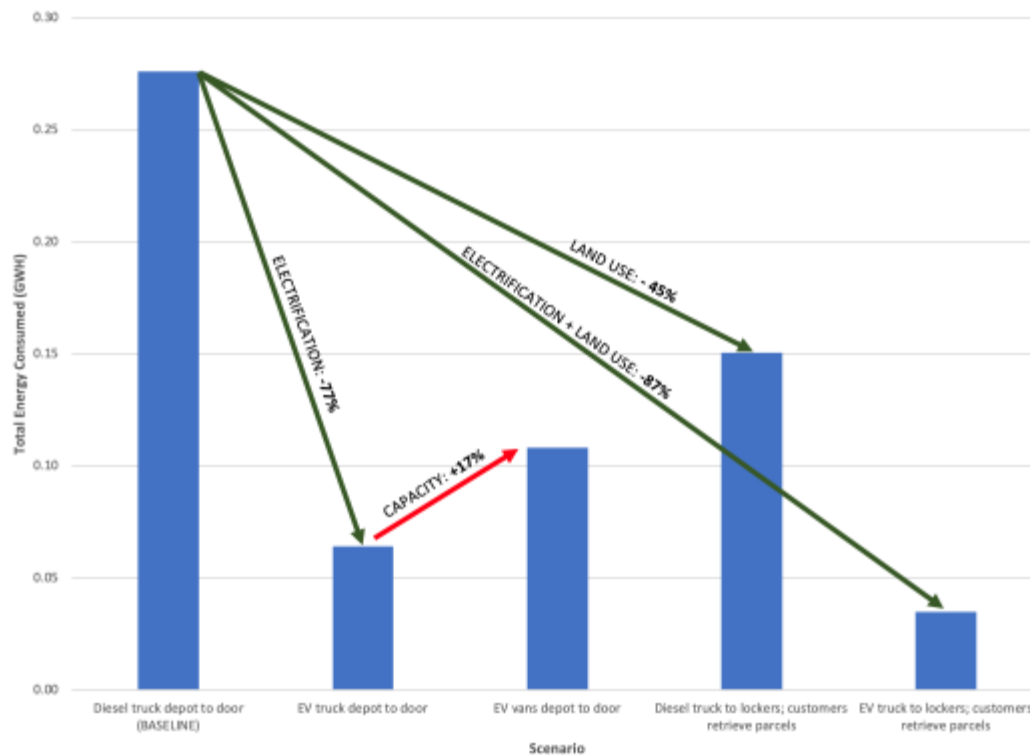
## Findings- Chicago

- EV class six trucks have a lot of potential
  - Pairing them with other modes (depending on context)
- EV vans weren't as energy-efficient as expected
  - Capacity is key
- EV trucks to lockers resulted in the greatest reduction from baseline (only involves UPS/Fed Ex not customer)
  - non-EV passenger vehicles retrieving parcels from lockers resulted in the highest overall energy usage
- EV trucks and quadcopters resulted in the second greatest reduction
  - average parcel weight of 5 lbs
  - represents only ~half of the parcels in a given truckload



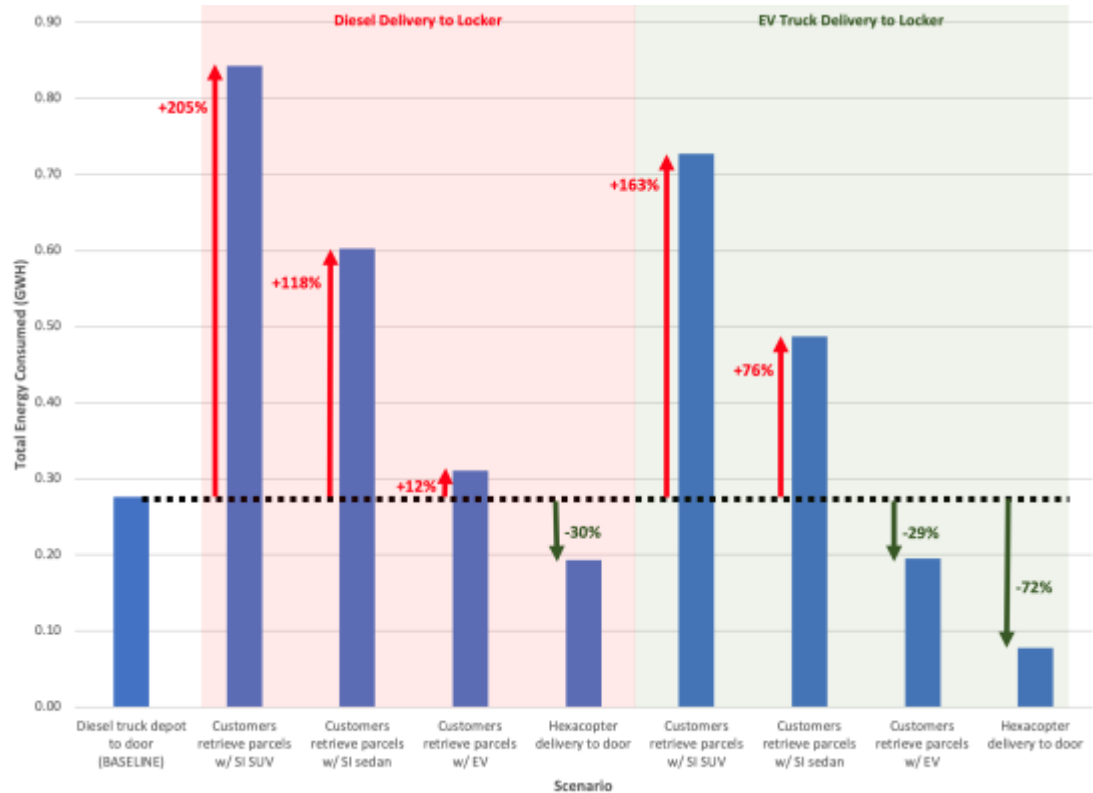
# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- Effect of alternative technologies on average daily fleet-wide energy usage for Chicago
- Although vans are less energy-intensive compared to trucks, carrying capacity is limited



# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

- Effect of parcel lockers on total energy usage: Chicago
- Significant increase in energy usage when all customers retrieve parcels and average vehicle type is SUV



# RESPONSES TO PREVIOUS YEARS' REVIEWERS' COMMENTS



## Results applicable to other regions?

- We are addressing this in our extension work with ANL and POLARIS by applying the methodology to Atlanta-Knoxville-Chattanooga, Austin, and Detroit metropolitan regions

# COLLABORATION AND COORDINATION WITH OTHER INSTITUTIONS

- Intra-city freight tour modeling work performed by ORNL and INL
- Drone testing and validation performed by INL
- ANL provided guidance and baseline energy estimates from POLARIS
- NREL provided energy estimates for several delivery modes and was responsible for data collection in initial phase of project
- LBNL provided data on e-commerce and consumer shopping preferences
- UPS provided truck movement data and parcel characteristics data for Columbus, Ohio as part of the FY 17 and FY 18 work, which was the basis for model development in Chicago
- The Chicago Metropolitan Agency for Planning (CMAP) provided Census-level data for model development

# REMAINING CHALLENGES AND BARRIERS

## Data Needs

- Parcel delivery data
- Alternative mode performance data for refined energy calculations
- Advanced data on energy use for new alternatives (such as Autonomous ground systems)

## Alternative Applicability

- Look at impacts based on availability and use
- Impacts of freight on passenger congestion

# PROPOSED FUTURE RESEARCH

- Expand work with ANL in the further development of freight agents within POLARIS to better understand the effects of e-commerce on the transportation network
- Expand upon drone testing work

Any proposed work is subject to change based on funding levels.

# SUMMARY

- **Relevance:** Evaluate energy-saving potential of new intra-city freight delivery methods
- **Approach:** Investigate Technologies, Gather Delivery Data, Model Scenarios, Expand to Regional Impacts
- **Collaborations:** ORNL, INL, ANL, NREL, UPS, CMAP
- **Technical Accomplishments:**
  - Estimated O-D pairs, provided to ANL to be used as input for POLARIS to represent displaced passenger vehicle shopping trips
  - Evaluated energy-intensity of alternative freight delivery modes
- **Future Work:**
  - Expand work with ANL in the further development of freight agents within POLARIS to better understand the effects of e-commerce on the transportation network
  - Expand upon drone testing work

# SUMMARY

## Key Take-Aways:

- Intra-city delivery needs will only increase
- Issues continue to increase with demand (congestion, lack of parking, etc.)
- Many options have potential to provide solutions to transportation issues
- Further evaluation needed to fully characterize issues and solutions
- Context-specific solutions exist to enhance energy use
- Using alternative delivery points and multiple modes appear to be more effective at reducing energy usage



U.S. DEPARTMENT OF ENERGY

**SMARTMOBILITY**

Systems and Modeling for Accelerated Research in Transportation

# MOBILITY FOR OPPORTUNITY

FOR MORE INFORMATION

**Amy M. Moore, Ph.D.**

National Transportation Research Center  
Oak Ridge National Laboratory  
[mooream@ornl.gov](mailto:mooream@ornl.gov)

**Victor Walker**

Idaho National Laboratory  
[victor.walker@inl.gov](mailto:victor.walker@inl.gov)





U.S. DEPARTMENT OF ENERGY

# SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

# TECHNICAL BACK-UP SLIDES

# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

## Delivery Technologies



### Drone Delivery

- Key emerging technology
  - Quick delivery
  - Reduced congestion
  - Force Multiplier
- Characterization needed to understand how to best utilize drone options:
  - Understand energy requirements
  - Research on how package delivery impacts use and energy
  - Look at key elements driving costs

# TECHNICAL ACCOMPLISHMENTS AND PROGRESS

Scenario	Total Daily Fleet Energy Usage kwh	Reduction in Energy Usage from Baseline
Class 6 Truck	2,450	N/A
EV Class 6 Truck	570	77%
EV Delivery Van (eNV200)	1,482	40%
Class 6 Truck/lockers	1,273	48%
EV Class 6 Truck/lockers	295	88%
Drone	2,128	13%
EV Passenger Car (Nissan Leaf)	1,349	45%

