

U.S. DEPARTMENT OF  
**ENERGY**

Office of  
ENERGY EFFICIENCY &  
RENEWABLE ENERGY

# Changing Mobility and Implications for ICE's – Change is Happening Fast

SAE - ICE 2019

September 17, 2019

Michael Berube

Acting Deputy Assistant Secretary for Transportation



# US DOE TRANSPORTATION SECTOR

**\$700m/year  
Transportation  
R&D**

## 17 National Laboratories



## World-class capabilities:

- High Performance Computing
- Artificial Intelligence
- Tools and Modeling

## Vehicle Technologies

- Electrification
- Combustion engines
- Low cost lightweight materials
- New mobility & transportation systems

## H2 & Fuel Cell Technologies

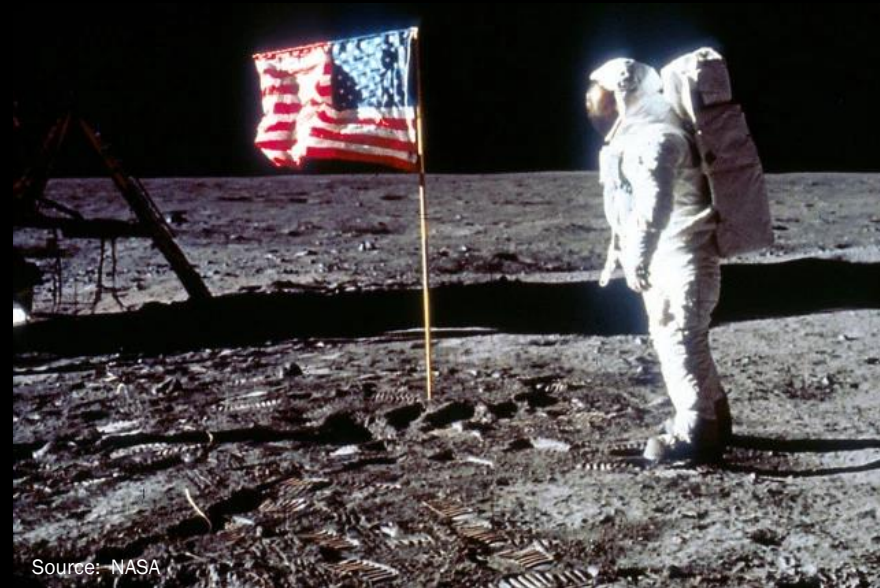
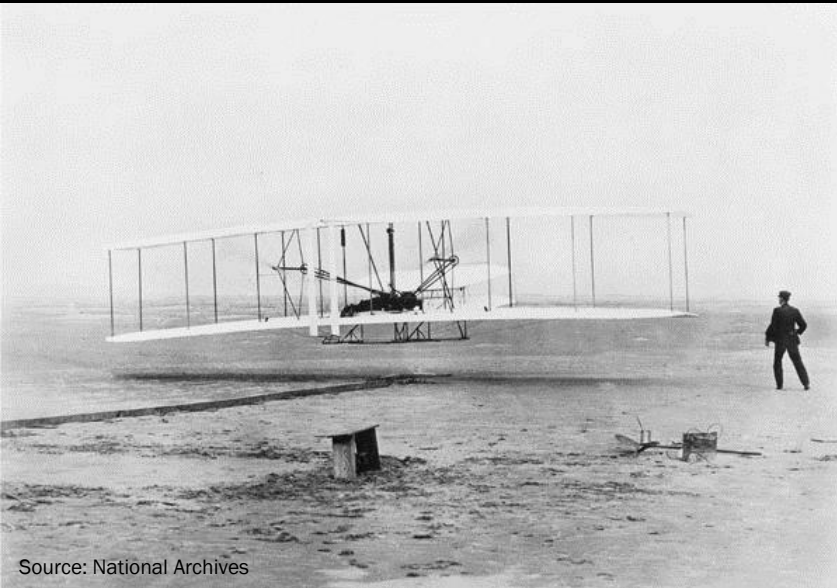
- Hydrogen production (photo-electrochemical, electrolysis)
- Fuel Cell systems
- H2@Scale

## Bioenergy Technologies

- Biofuels and bioproducts
- New products, fuels, and chemicals from waste
- Energy crops



Source: WTOP



1903

Wright Brothers  
First Flight

1969

Apollo 11  
Moon Landing

2019

Modern Commercial  
Aviation



Model A



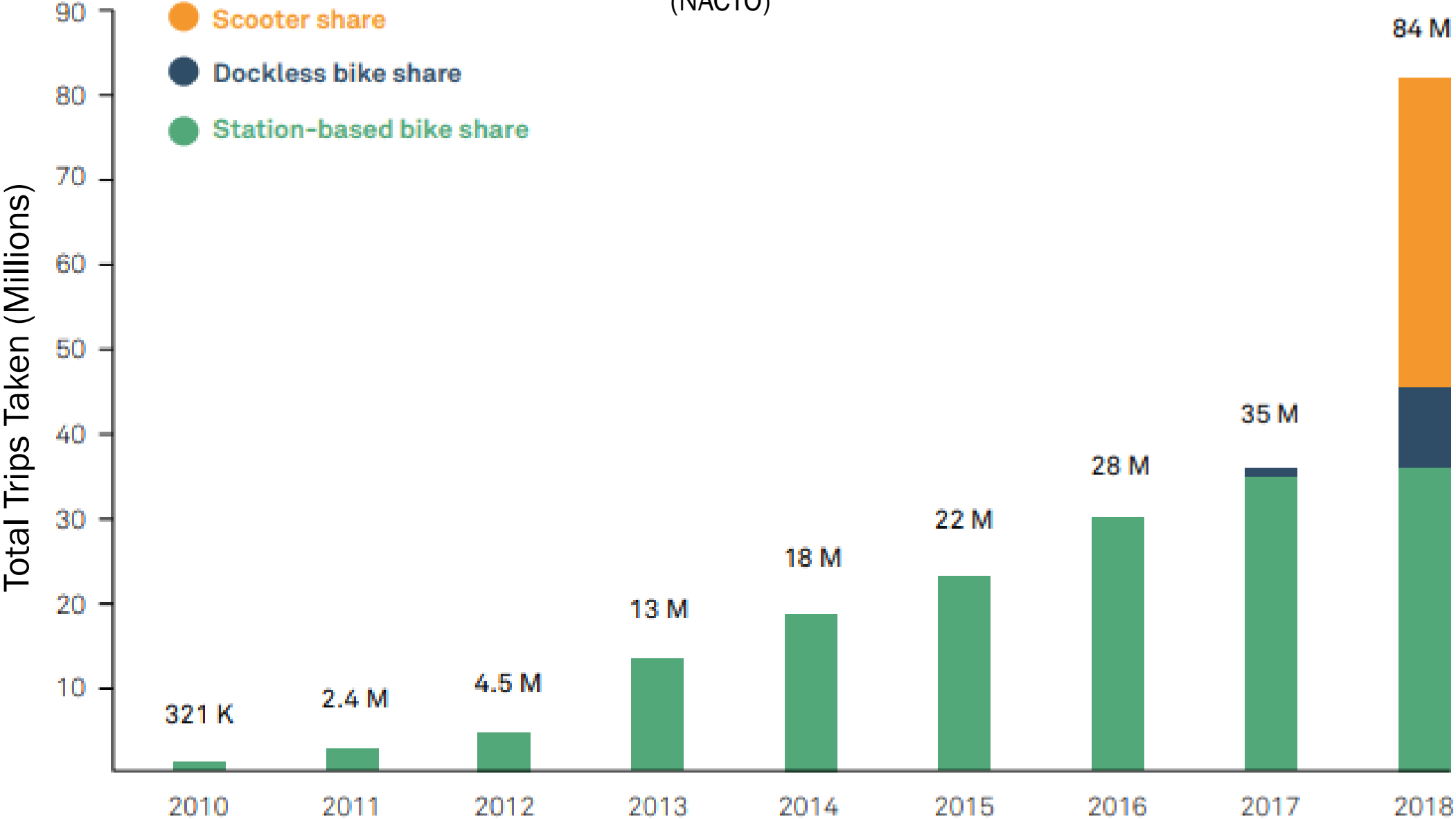
Mustang



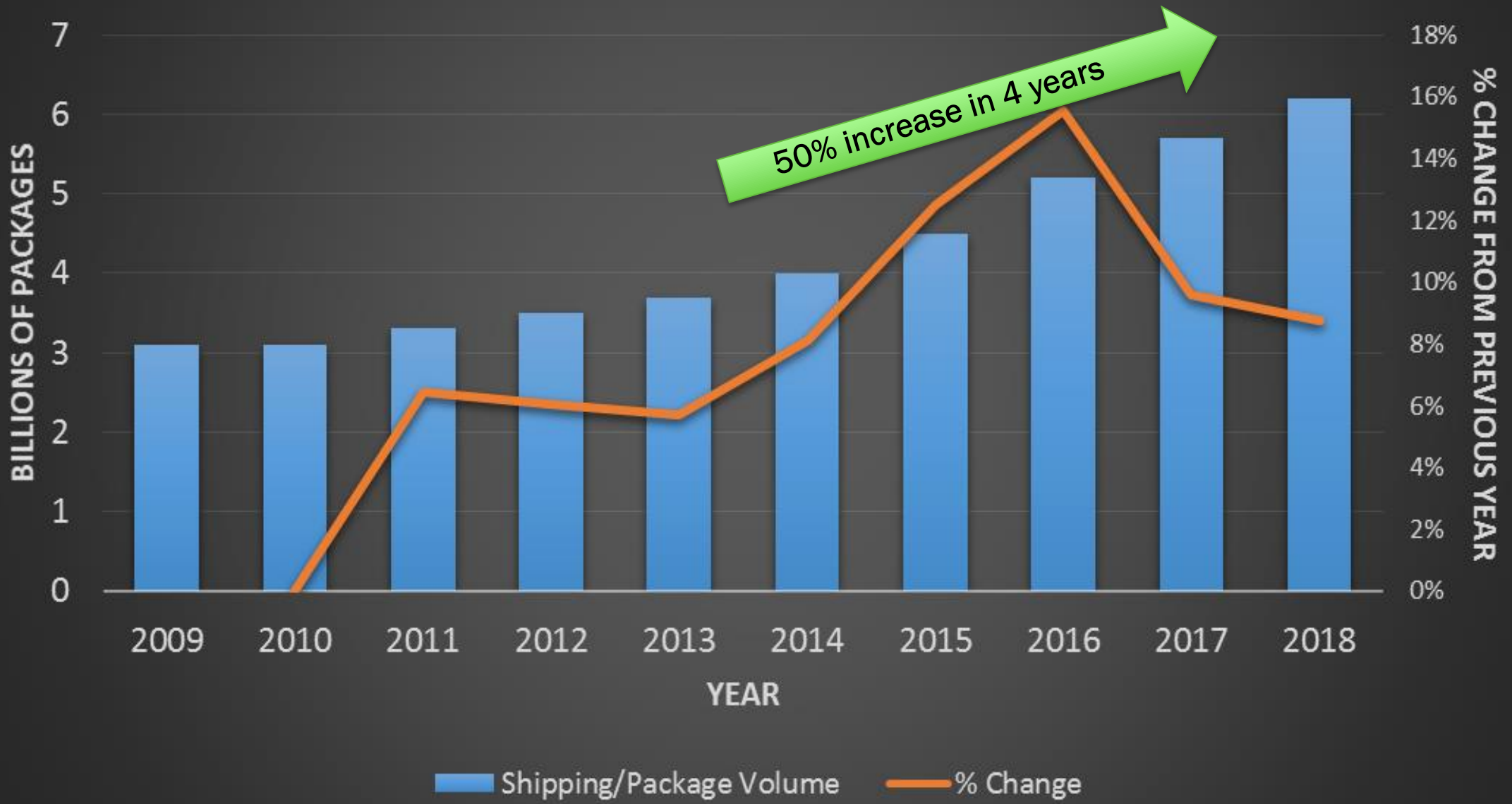
AV Development Vehicle

# SHARED MICROMOBILITY TRIPS

(NACTO)

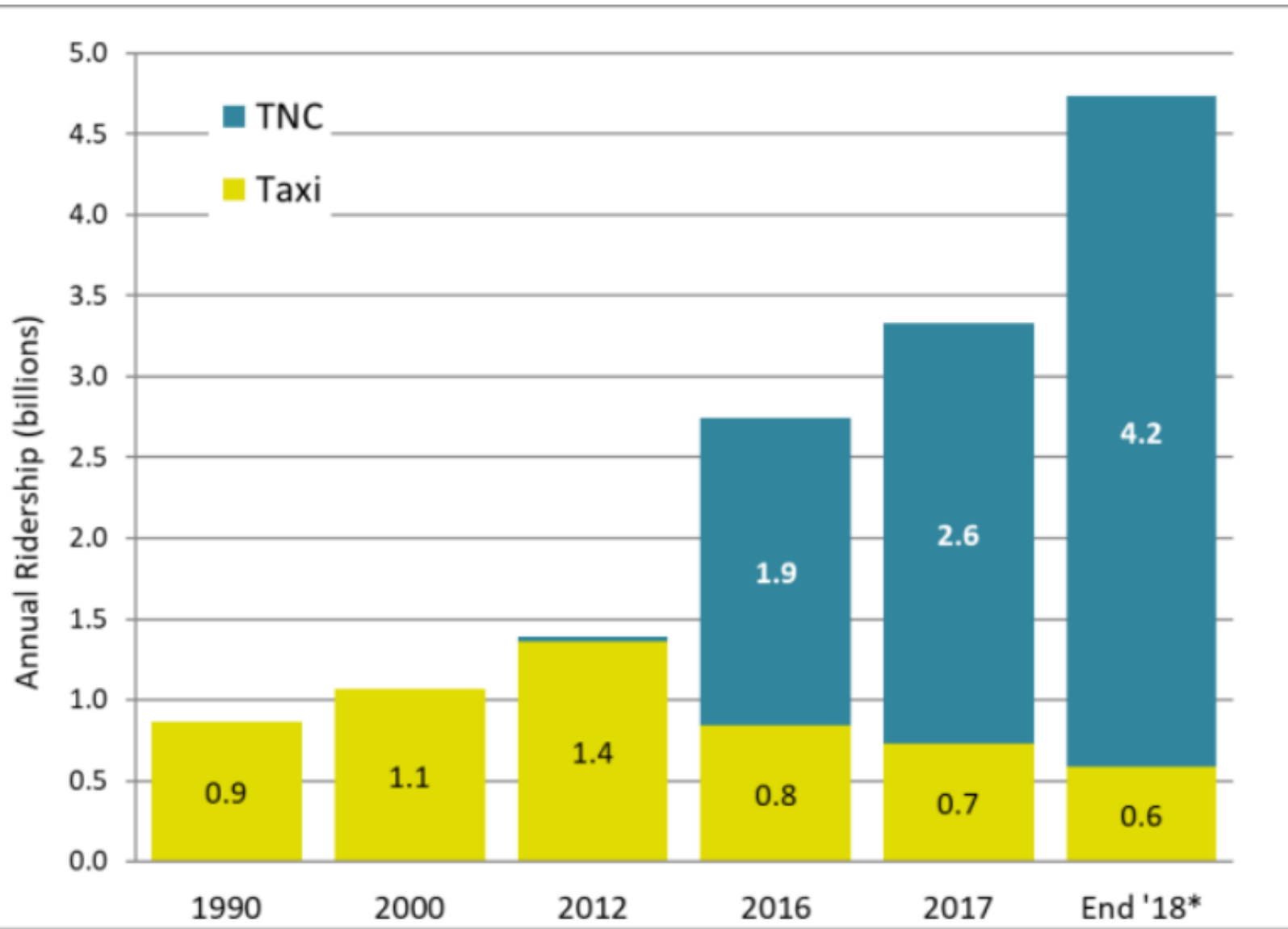


# USPS Annual Shipping & Package Volume



# TNC & Taxi Ridership in the U.S., 1990-2017

Bruce Shaller, Shaller Consulting



Source: GETTY IMAGES (M)

Source: David Goldman/

© Getty Images



**NEW TECHNOLOGIES &  
BUSINESS MODELS ARE  
DRIVING  
DISRUPTION**



**Shared  
Mobility**



**Mobility  
On Demand**



**e-Commerce**



**Connected &  
Automated Vehicles**



**Emerging Fuels  
& Powertrains**



**New Modes  
of Transport**

# TWO KEY DRIVERS FOR DISRUPTION ....

## ECONOMIC OPPORTUNITY

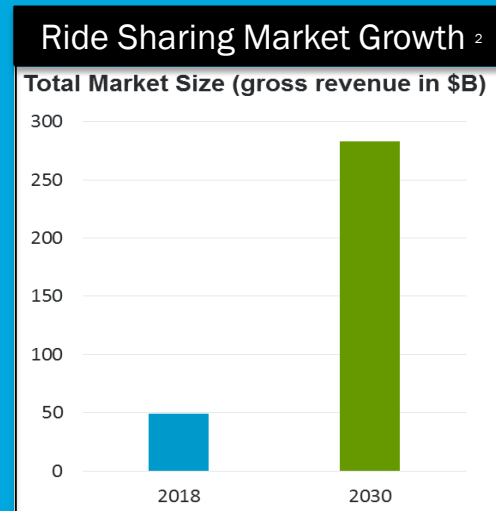
Transportation is the 2<sup>nd</sup> most expensive spending category after housing<sup>3</sup>

## UNDER UTILIZED ASSETS

Today's Cars Are Parked 95% of the Time<sup>1</sup>

Implication -> Moving from Asset based to Service based transportation - - -  
BIG impacts on technology & usage

## NEW & GROWING MARKETS



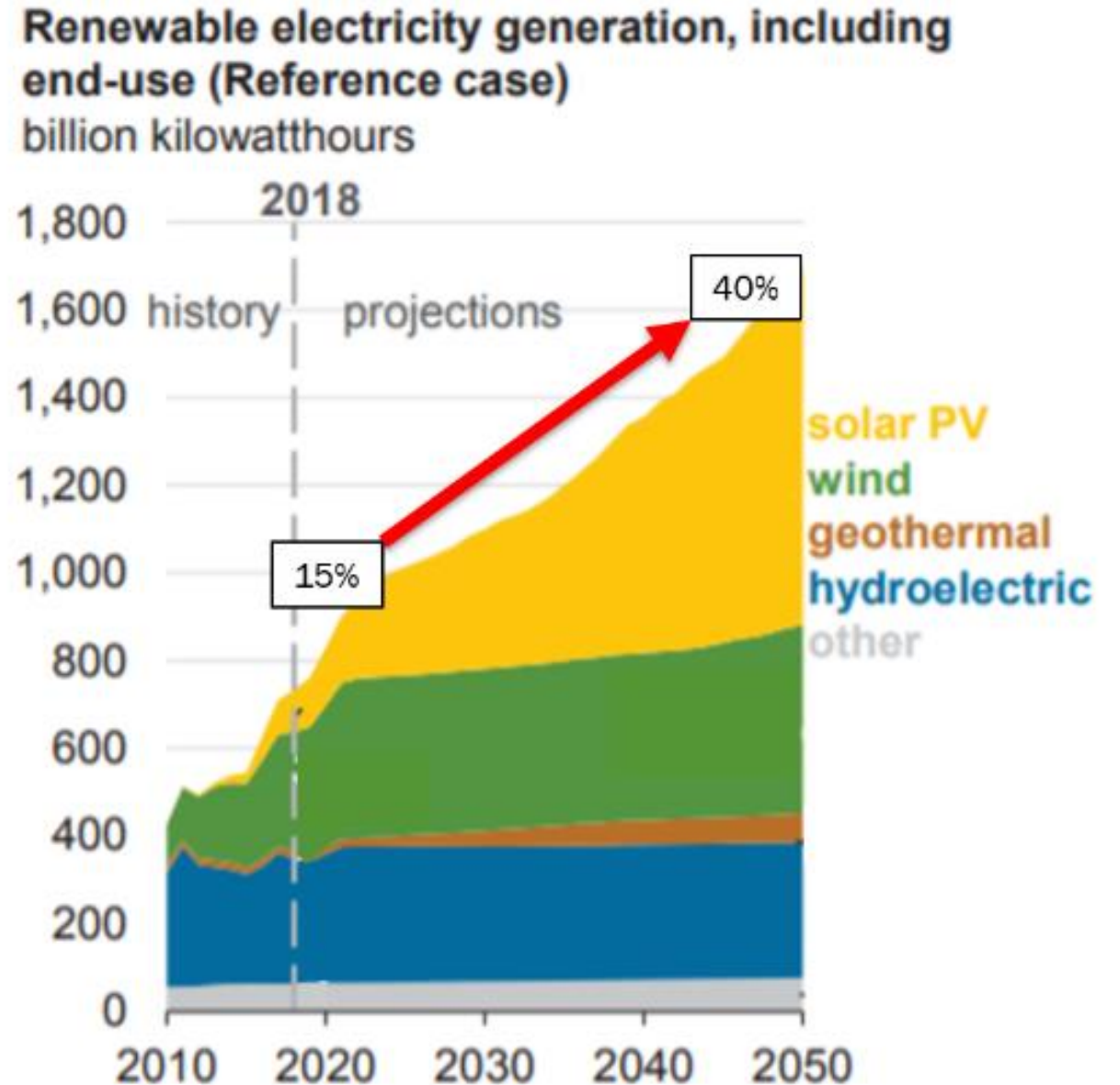
1 RAC Foundation (<https://www.racfoundation.org/research/mobility/spaced-out-perspectives-on-parking>)

2 Goldman Sachs ([https://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Rethinking%20Mobility\\_GoldmanSachsMay2017.pdf](https://orfe.princeton.edu/~alaink/SmartDrivingCars/PDFs/Rethinking%20Mobility_GoldmanSachsMay2017.pdf))

# THIRD DRIVER OF CHANGE...

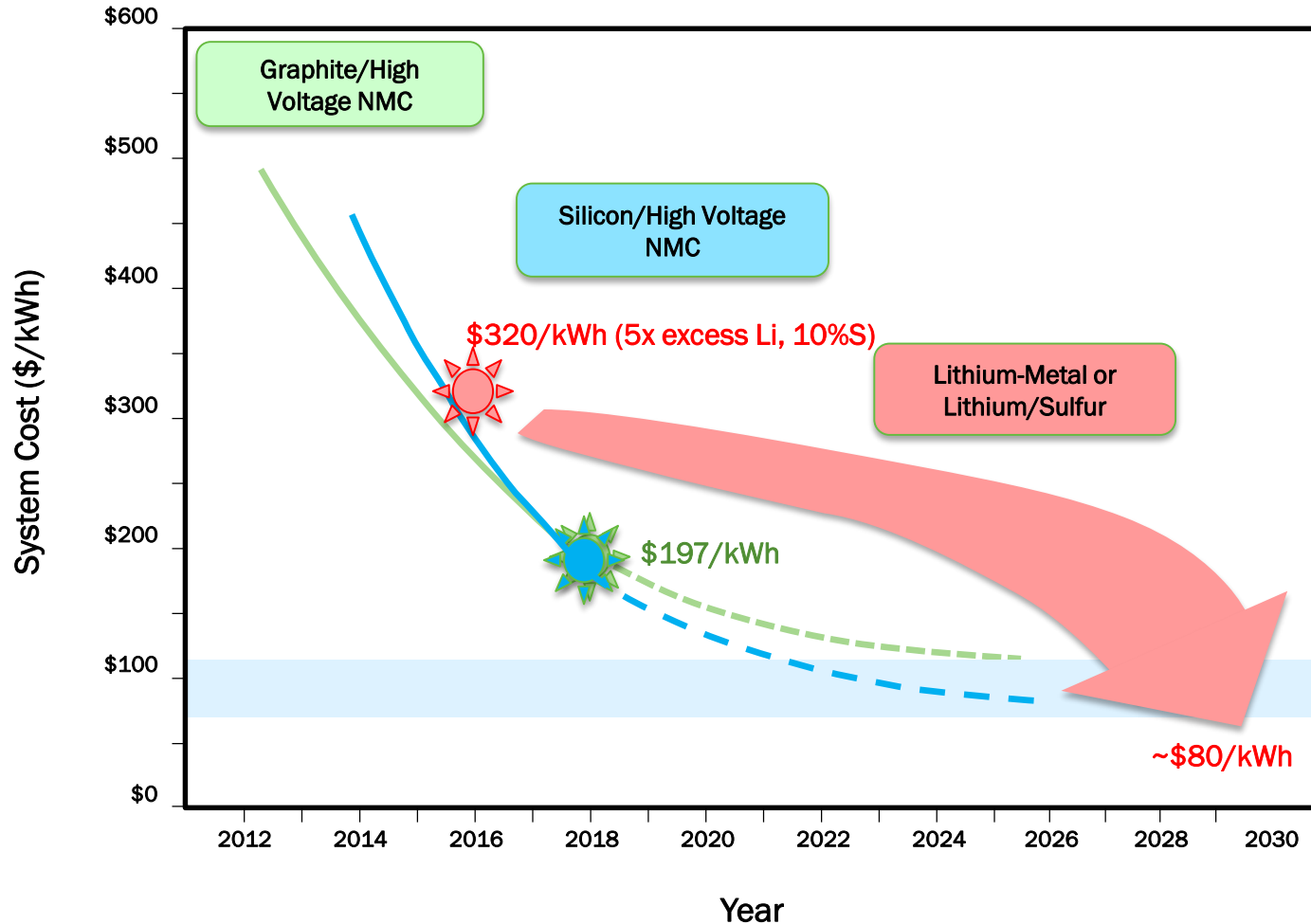
## CHANGES IN ELECTRIC GRID IMPACT TRANSPORTATION

- High level of renewables
- Low marginal cost of electrons
- Flexible Loads



EIA Energy Outlook to 2050, <https://www.eia.gov/outlooks/aeo/pdf/aeo2019.pdf>

# Cost Trends for Lithium-based EV Batteries



## Graphite/High Voltage NMC

R&D Focus: Higher cathode capacity (220+ mAh/g), low/no Cobalt, recycling, fast charge

## Silicon/High Voltage NMC

R&D Focus: Higher anode capacity (1000+ mAh/g), cycle/calendar life, fast charge

## Lithium-Metal & Li/Sulfur

R&D Focus: Solve cycle life/ catastrophic failure issues, reduce excess lithium, reduce excess electrolyte, reduce lithium metal cost

ReCell - \$5M/yr Battery Recycling Research  
+ \$5M Battery Prize



# Electric Drive System - Volume Reduction Required

## Current Status



## 2025+



- 33 kW/ liter density
- 8x increase
- 50% cost reduction



20+ Liter Volume



3 Liter Volume

# INTEREST IN ELECTRIFIED TRUCKS IS GROWING

**Green Car Reports**  
The ultimate guide to electric cars

News | First Drives | Guides | Electric | Car Types | Video | Follow

## Electric trucks coming from Daimler, Freightliner, Volvo, and others

Wired

MEET THE TESLA SEMITRUCK, ELON MUSK'S MOST ELECTRIFYING GAMBLE YET

TRANSPORTATION 11.16.17 11:08 PM

electrek

Automakers | All Transport | Autonomous Driving | Energy

JUNE 7

## Daimler unveils electric eCascadia semi truck to compete with Tesla Semi, launches electric truck group

Freightliner eCascadia semi truck

## Tesla Unveils New Electric Semi-Truck and Roadster

MOTOR AUTHORITY

Home / News / Electric Cars / Volvo introduces electric delivery/garbage truck with 186-mile range

## Volvo introduces electric delivery/garbage truck with 186-mile range

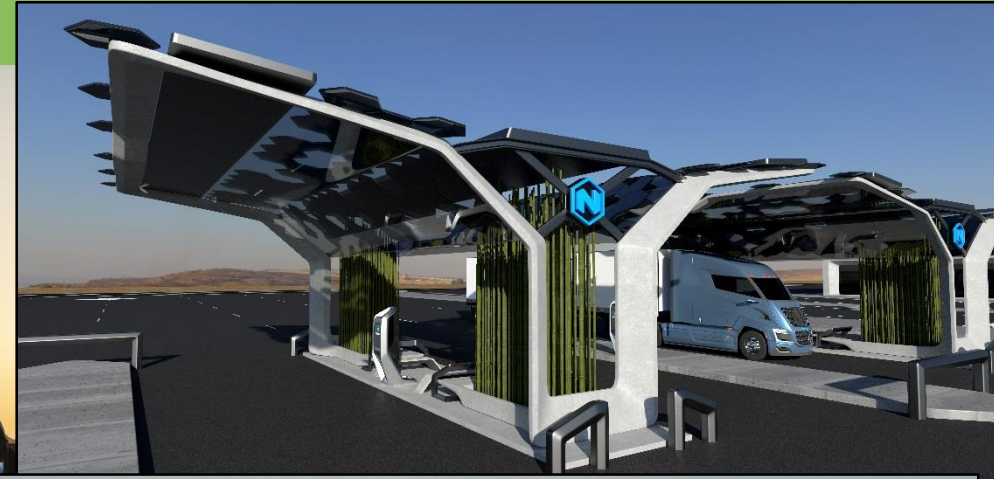
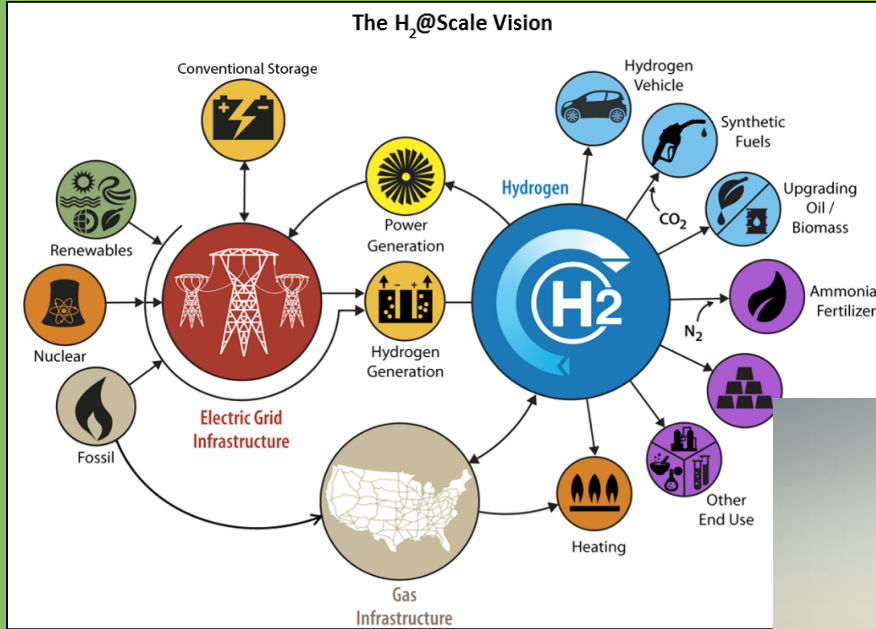


This massive 0 miles t.<sup>1</sup>

# ELECTRIFICATION & RENEWABLES

## ALSO DRIVING HYDROGEN

Nikola has 13,000 Hydrogen Fuel Cell trucks on Order



Toyota/PACCAR Fuel Cell Truck

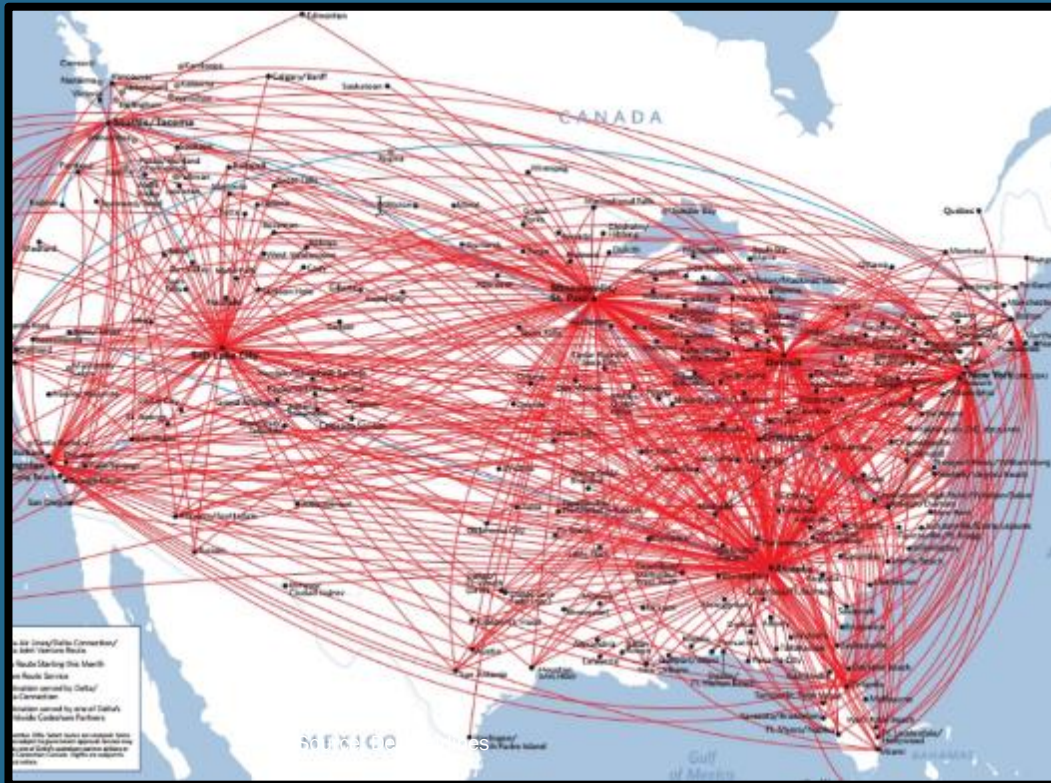


Photo Credit: Toyota



# CHANGING BUSINESS MODELS

1980's -> AIRLINE: Hub & Spoke



Challenges / Opportunities in Freight:

- Driver Shortages: 50,000 in 2018
- ATA TRAC study: decreasing trip lengths
- Traffic Congestion: 1.2 billion hours
- Fuel Efficiency & Operational Costs

50% of goods moved less than 100 miles between origin and destination

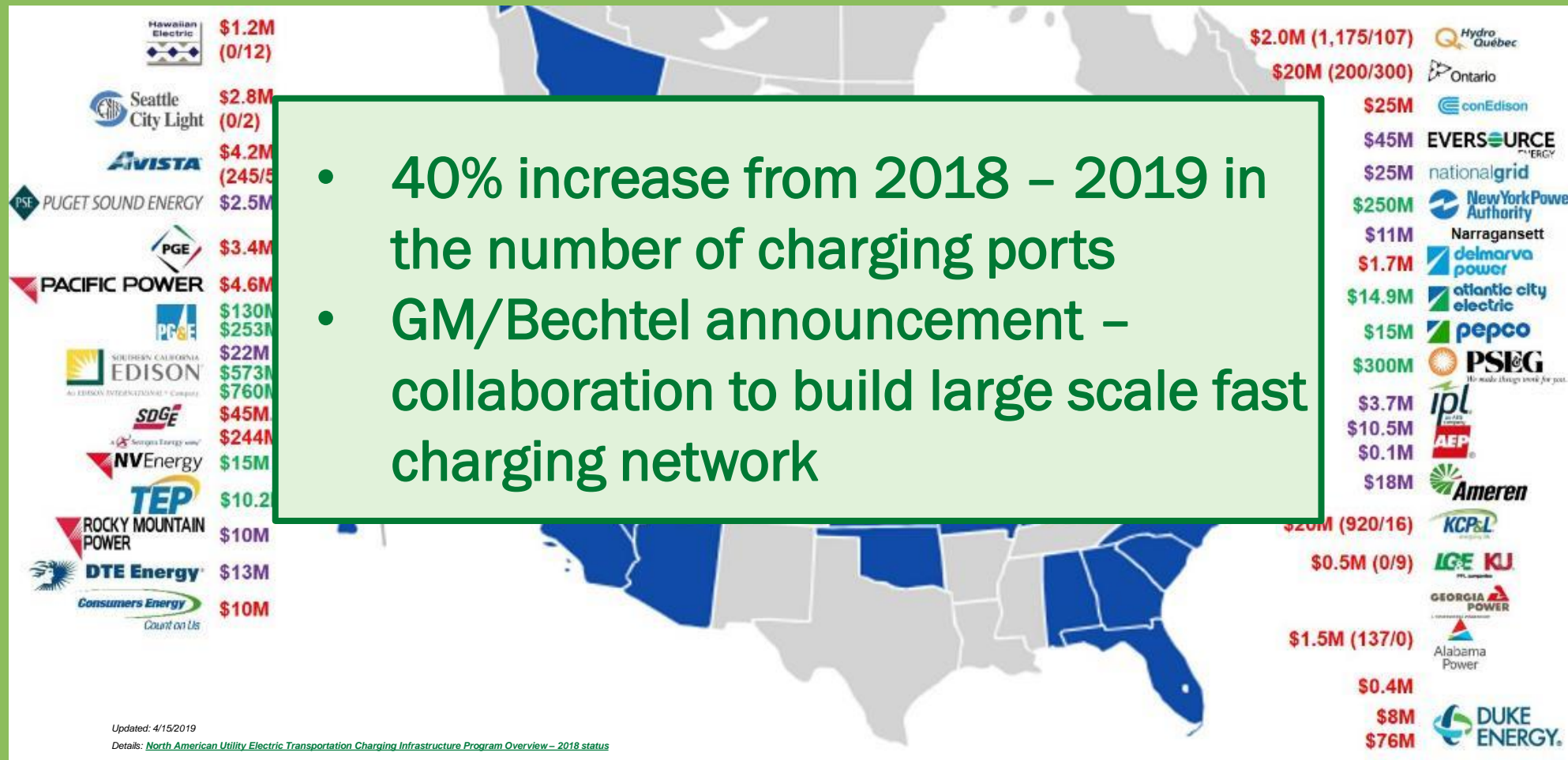


# UTILITIES Have Announced - \$3.7B in EV Infrastructure

## ELECTRIFY AMERICA (over 10yrs) \$2.0B in EV Charging

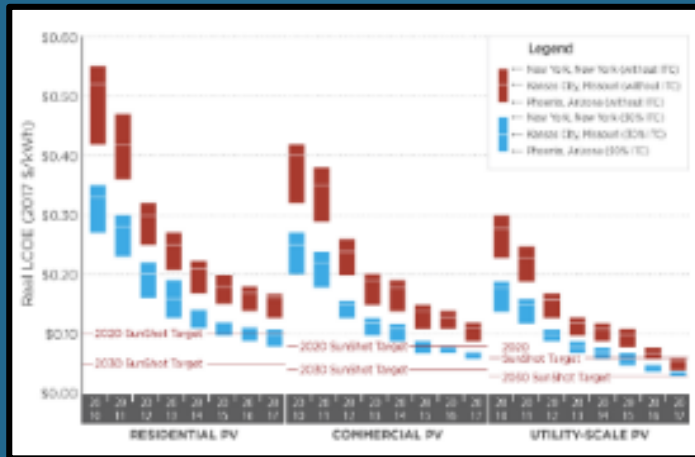
(currently 27,000 stations in US/Canada)

- 40% increase from 2018 – 2019 in the number of charging ports
- GM/Bechtel announcement – collaboration to build large scale fast charging network



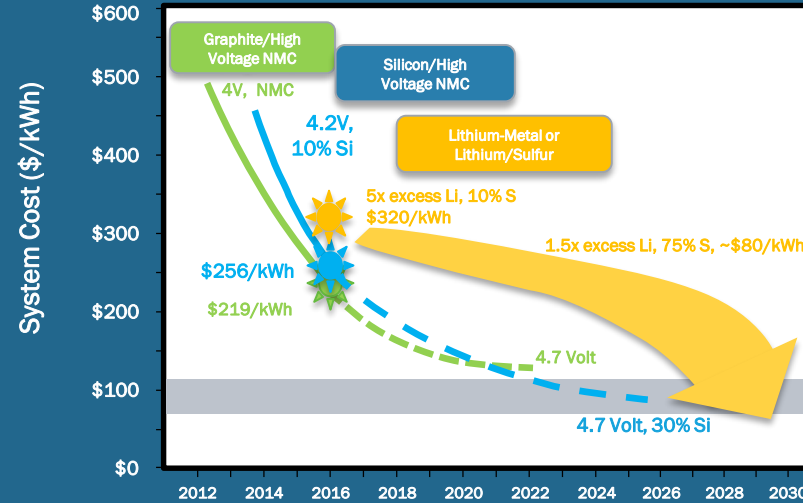
# LOW COST RENEWABLES & BATTERIES: INCREASED EV MARKET PENETRATION

PV LCOE Benchmark Summary

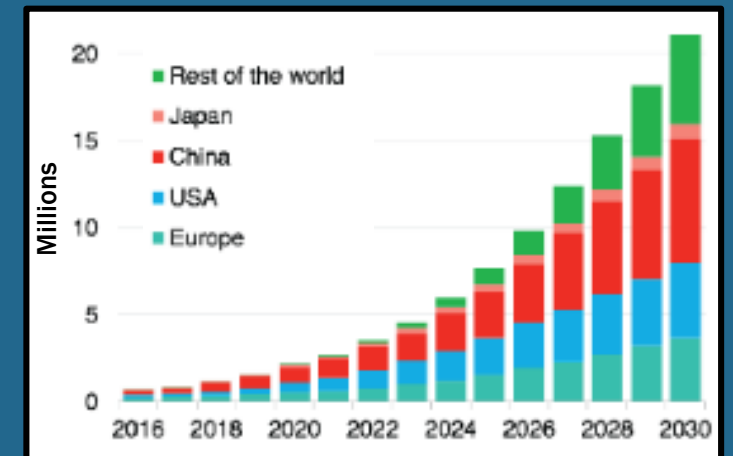


Source: NREL

Cost Trends for Lithium-based EV Batteries



Global EV Forecast



Source: Bloomberg New Energy Finance

RENEWABLE

Costs



BATTERY

Costs



PEV

Penetration



# PIONEERING RESEARCH

EXPLORES POTENTIAL  
ENERGY IMPACTS



**Shared  
Mobility**



**Mobility  
On Demand**



**e-Commerce**



**Connected &  
Automated Vehicles**



**Emerging Fuels  
& Powertrains**



**New Modes  
of Transport**

# SYSTEM-LEVEL APPROACH IS NEEDED



Additional research needs to understand the **System Level Impacts**

**Most Focus** is on development of technologies at the **component & vehicle level** or **stand-alone services**

# BUILDING INTEGRATED, SCALABLE MODELS FROM VEHICLE TO CITY LEVEL

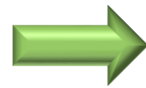
Single Vehicle



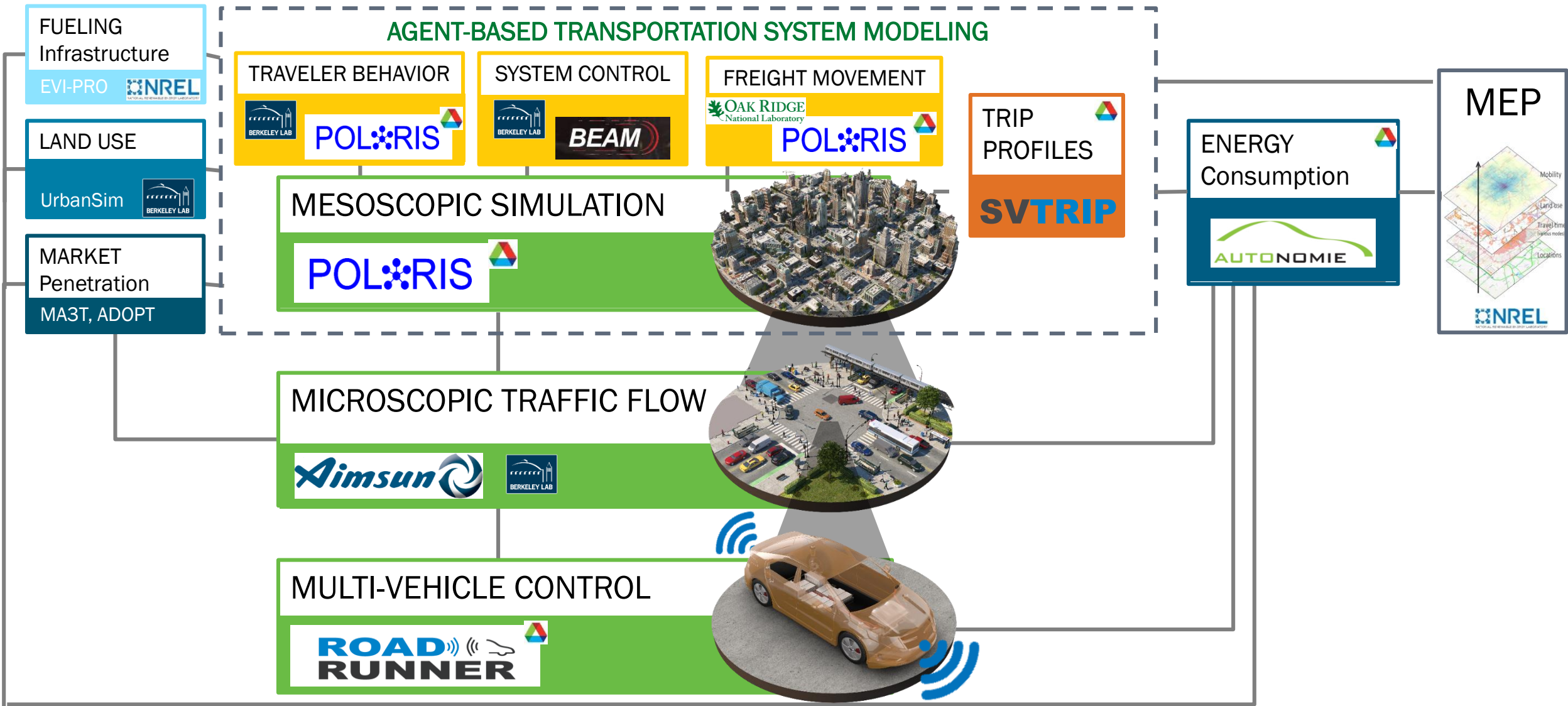
Corridor / Small Network



Entire Urban Area



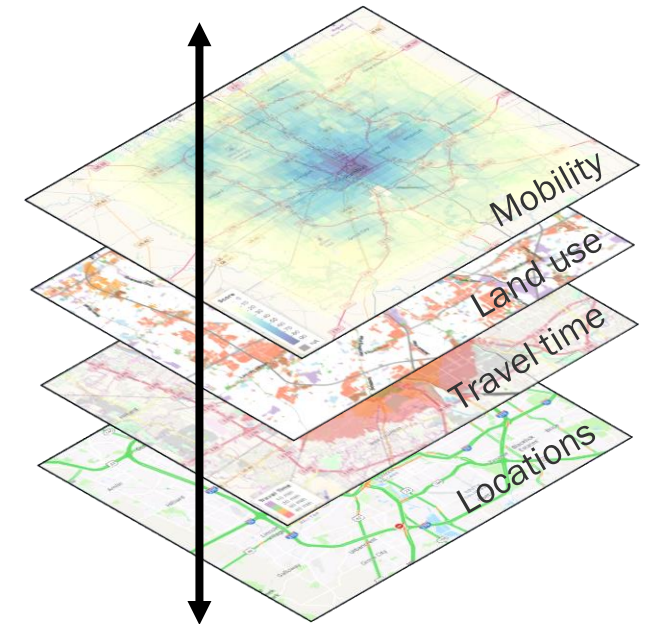
# COMPREHENSIVE APPROACH TO COMPLEX QUESTIONS



HOW DO WE

# EVALUATE PROGRESS?

- What is Mobility?
- How do we quantify Mobility?
- Currently no recognized Mobility metric
- Productivity = Mobility Benefits / Costs



**Mobility: The quality of a network or system to connect people to goods, services, and employment that define a high quality of life.**

# MOBILITY ENERGY PRODUCTIVITY

- MEP is defined as cumulative utility-weighted opportunities in a geographically defined area

$$o_{ikt} = \sum_j o_{ijkt} \cdot \frac{N^*}{N_j} \cdot \frac{f_j}{\sum_j f_j}$$

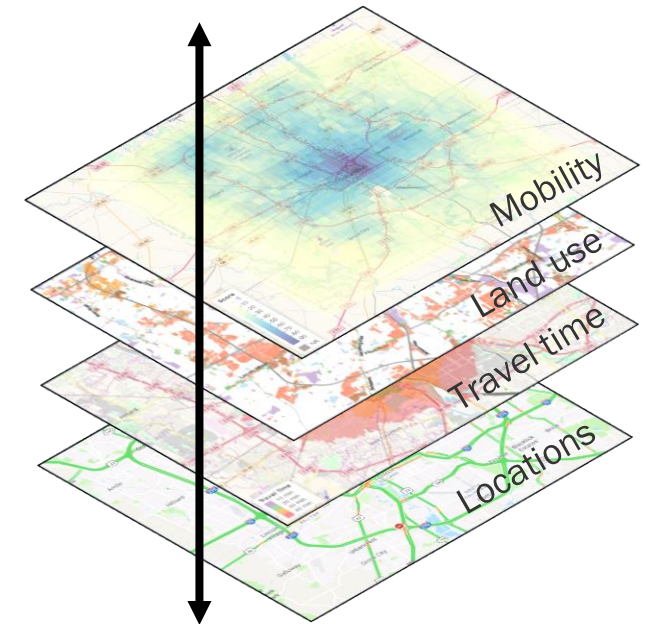
$$\text{MEP}_i = \sum_k \sum_t (o_{ikt} - o_{ik(t-10)}) \cdot e^{U_{ikt}}$$

where  $U_{ikt} = \alpha e_k + \beta t + \sigma c_k$

$e_k$  - energy intensity of mode  $k$

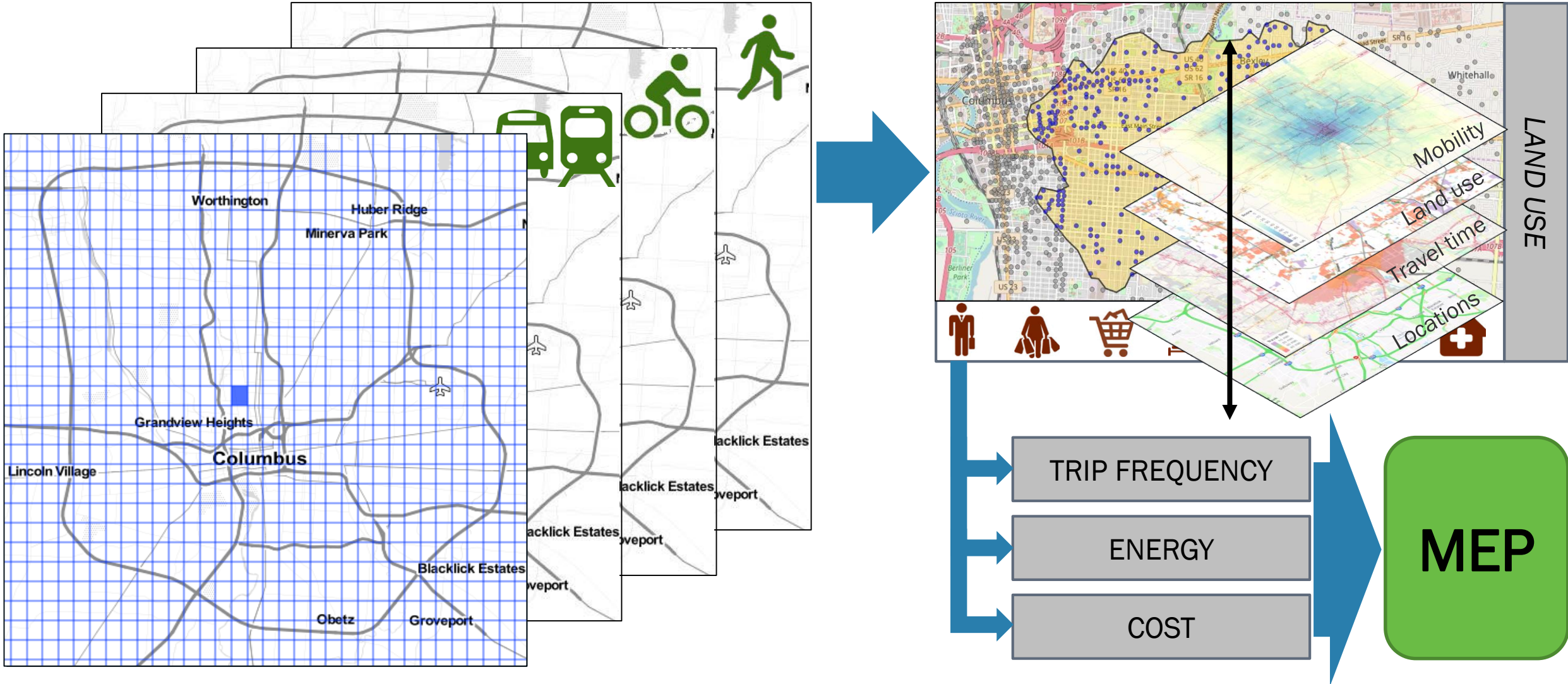
$c_k$  - cost of mode  $k$

$\alpha, \beta, \sigma$  - weighting parameters





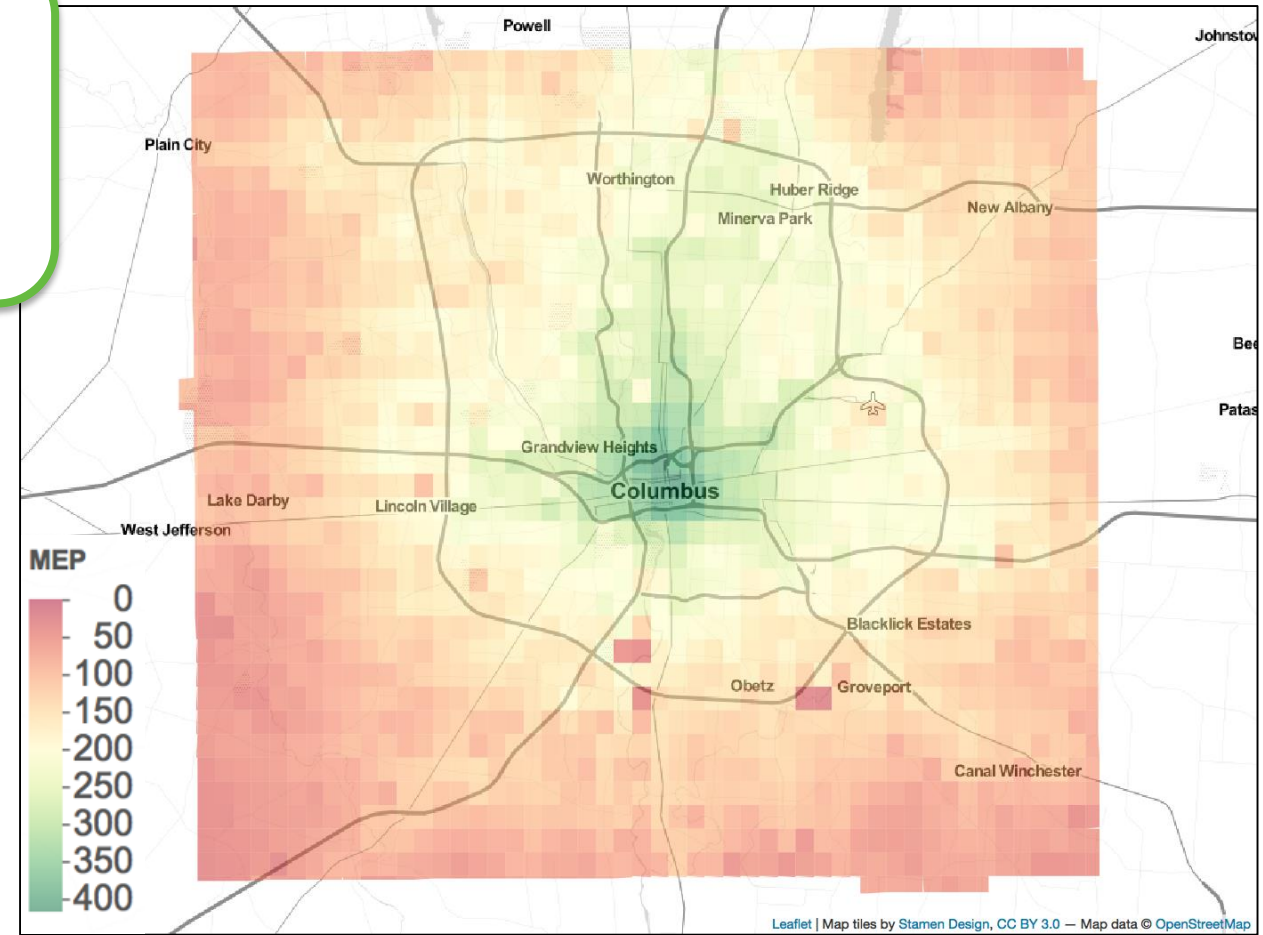
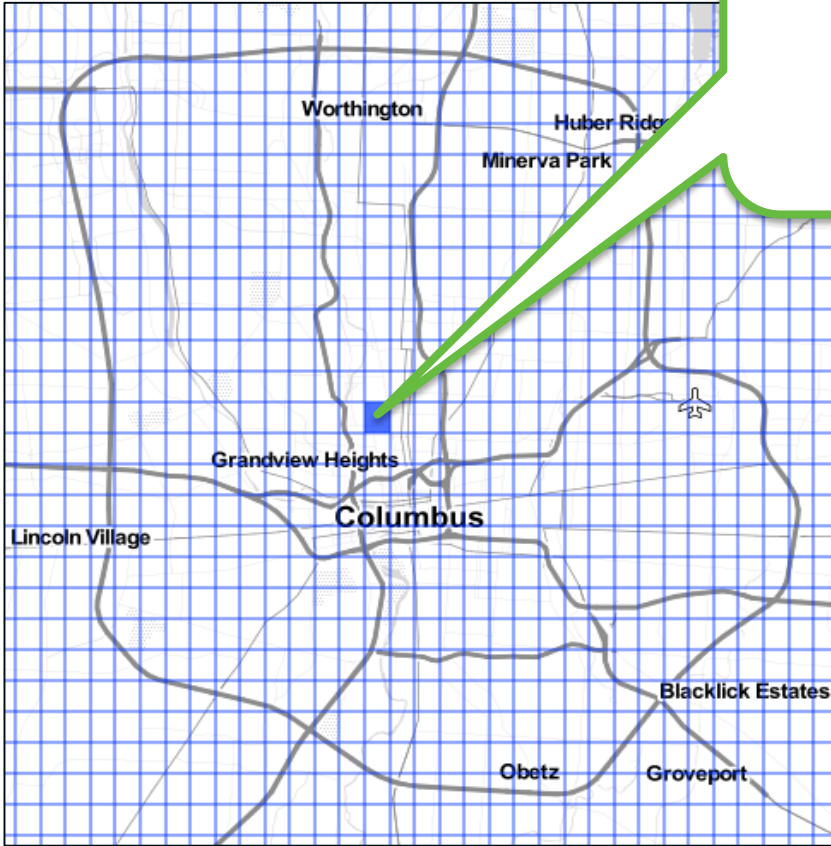
# MOBILITY ENERGY PRODUCTIVITY



# MOBILITY ENERGY PRODUCTIVITY

Final Energy Weighted  
Mobility Metric

263



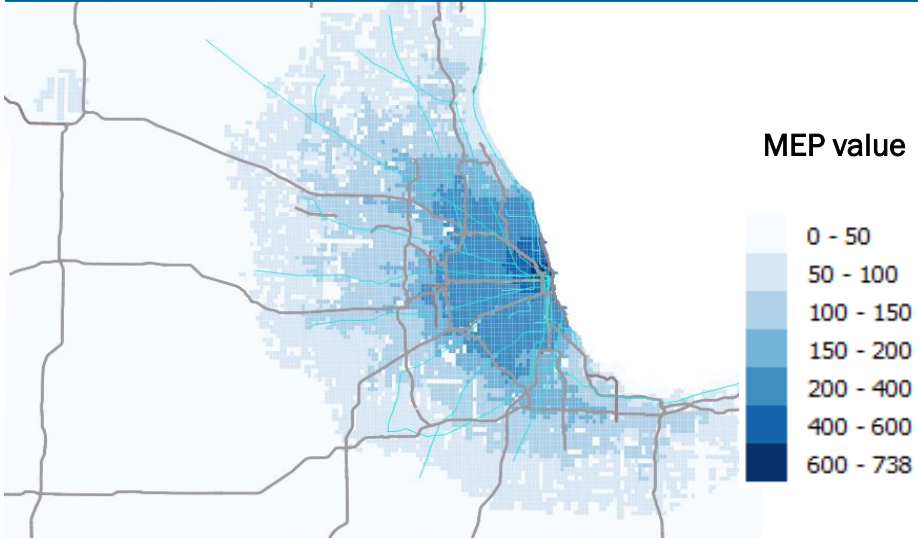
**ENERGY EFFICIENT MOBILITY SYSTEMS**

# **RESULTS & INSIGHTS**

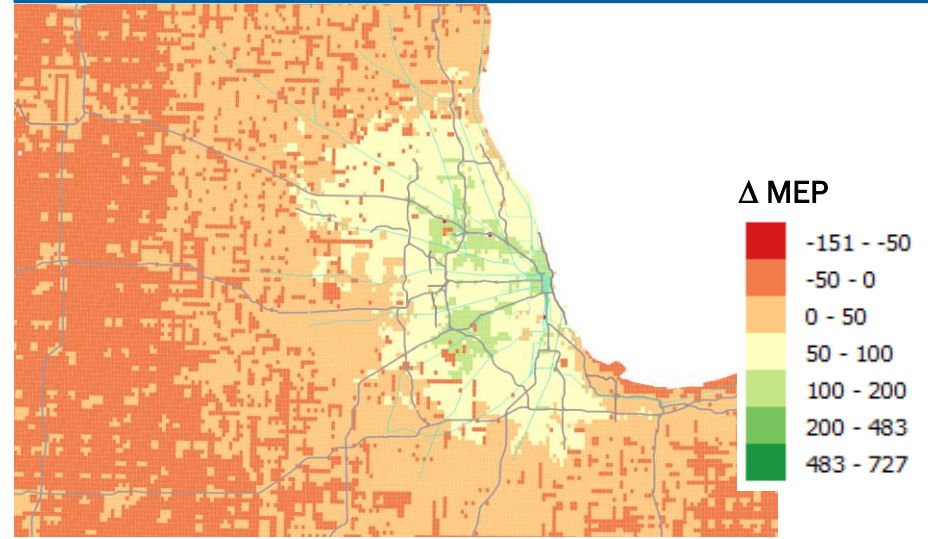
# WORKFLOW RESULTS

## MOBILITY ENERGY PRODUCTIVITY

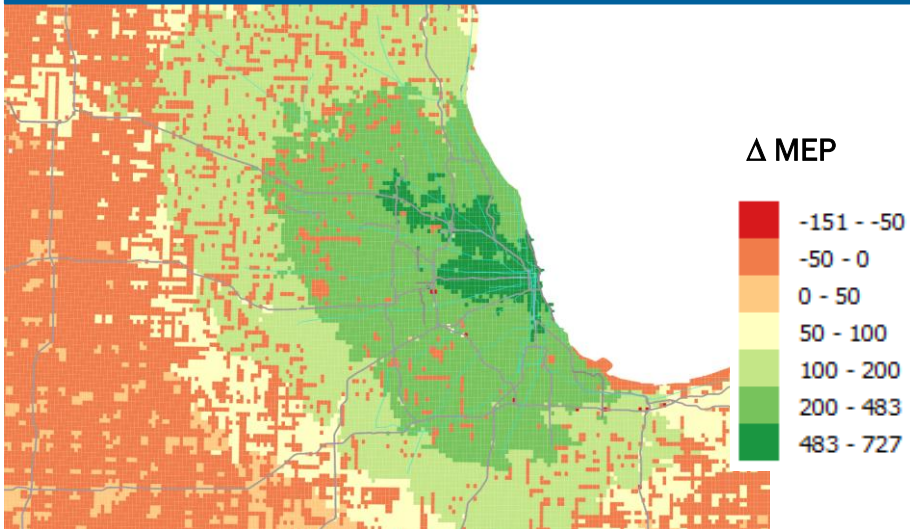
Baseline MEP distribution



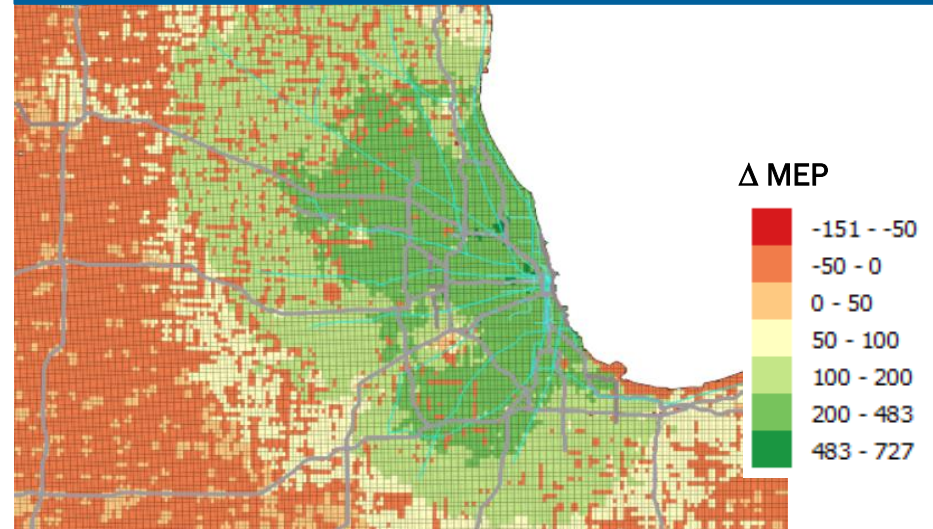
Scenario A: Sharing is Caring



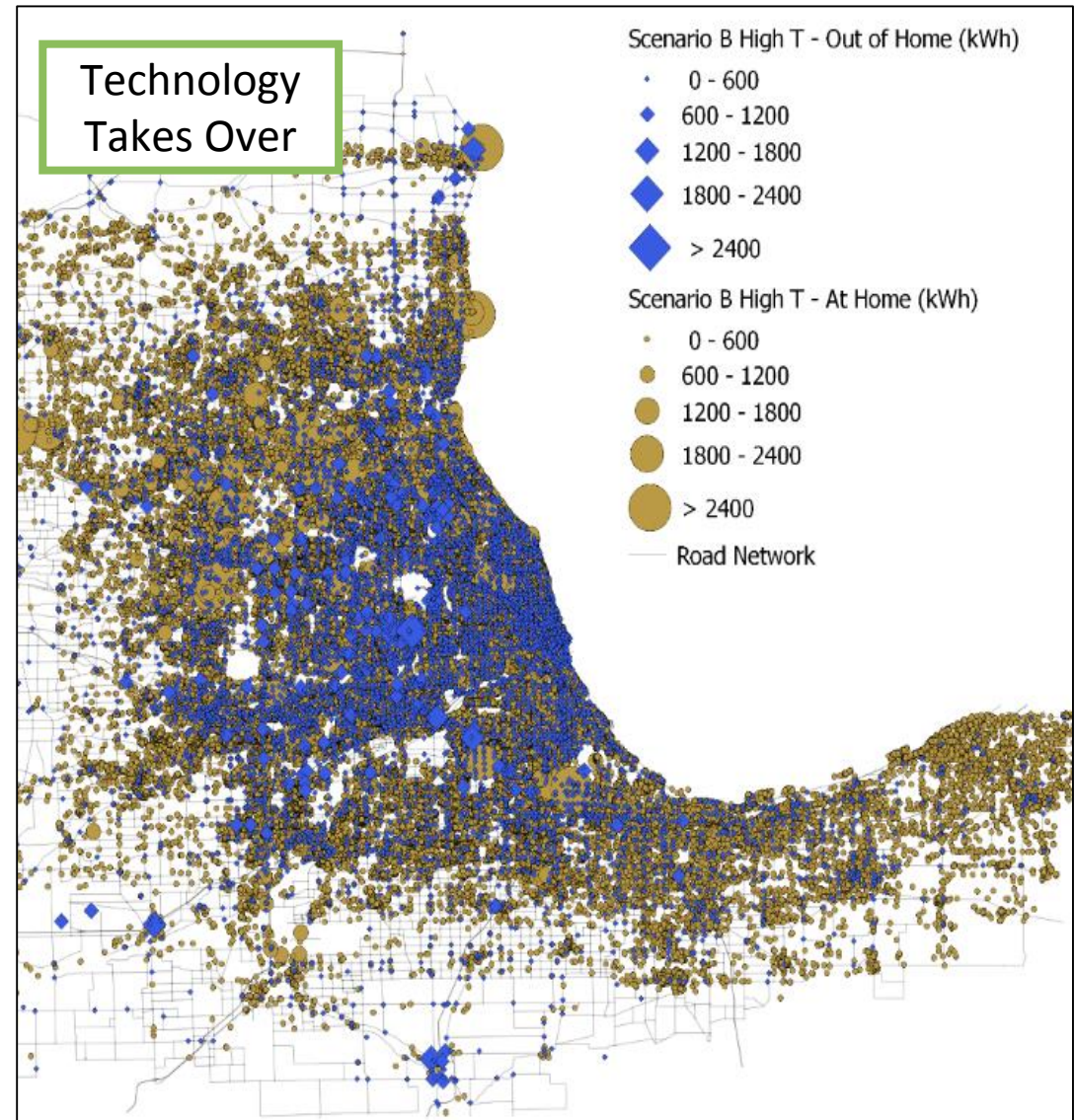
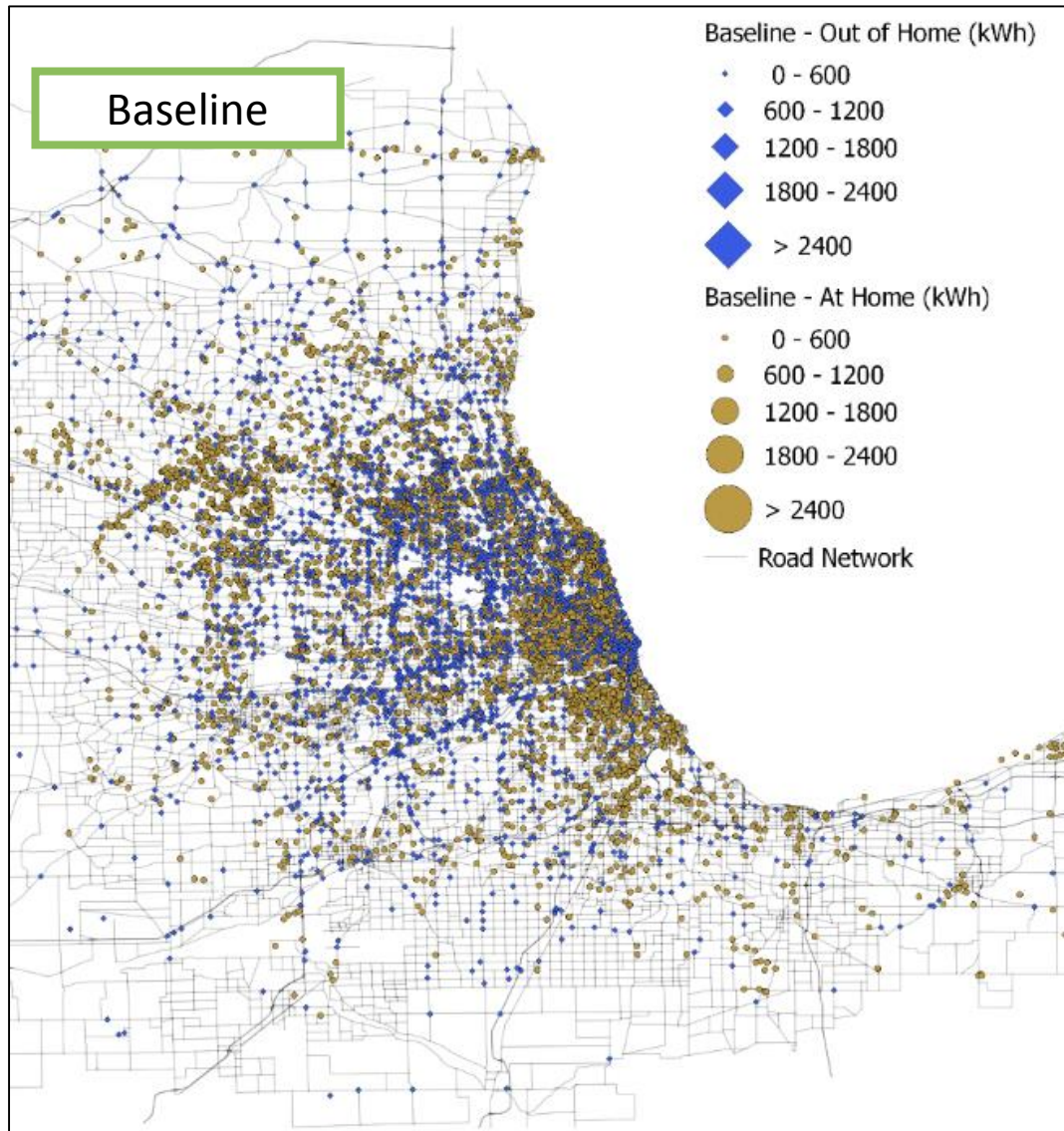
Scenario B: Technology Takes Over



Scenario C: All About Me



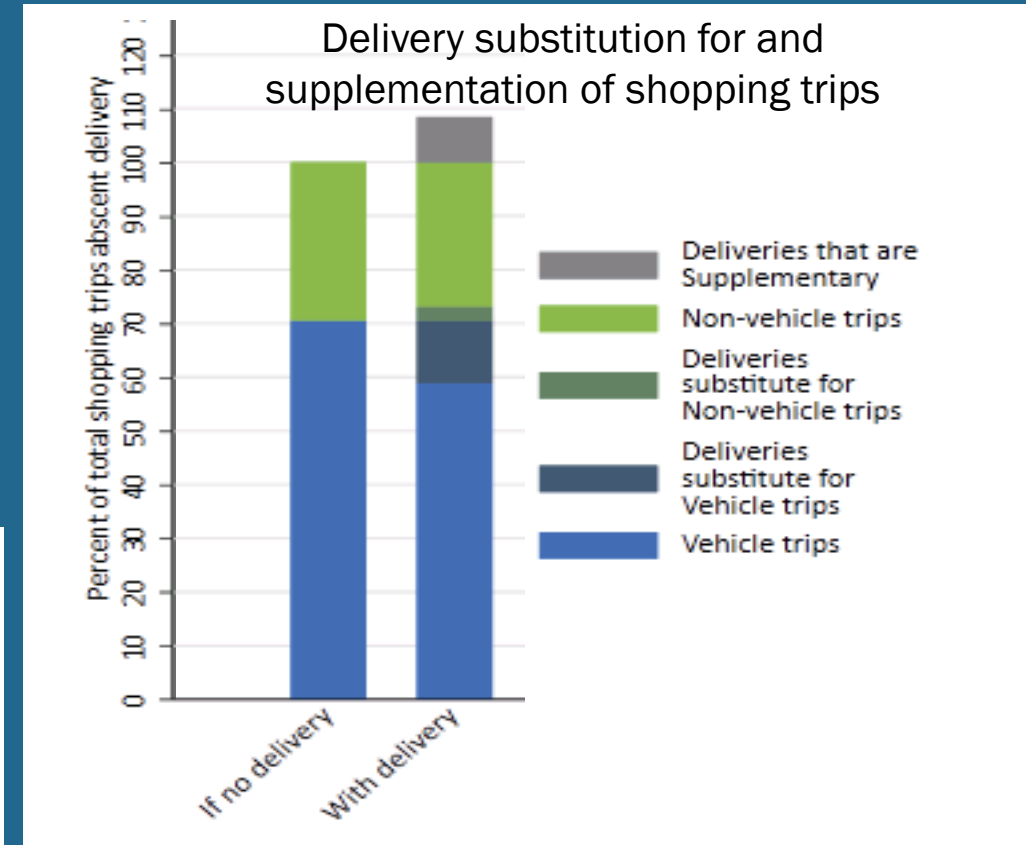
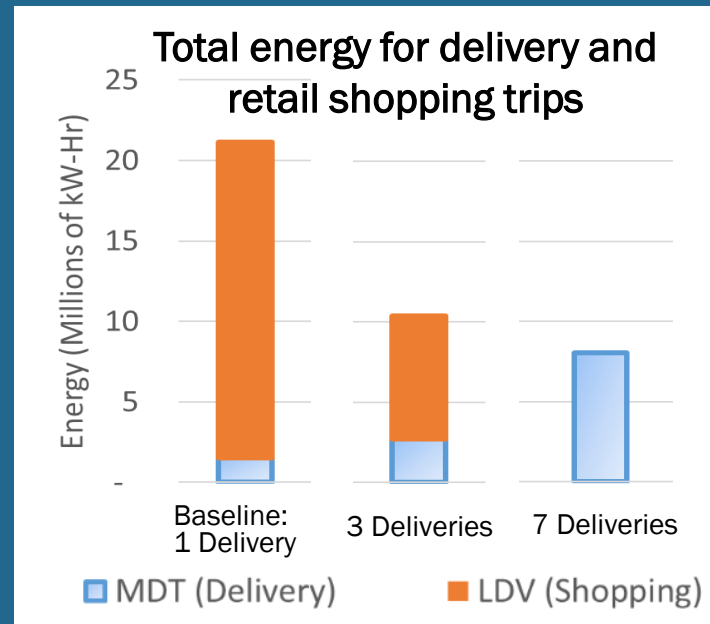
# WORKFLOW RESULTS PEV CHARGING DEMAND



# EXAMPLE OF MODELING RESULTS

## ENERGY EFFICIENT MOBILITY SYSTEMS

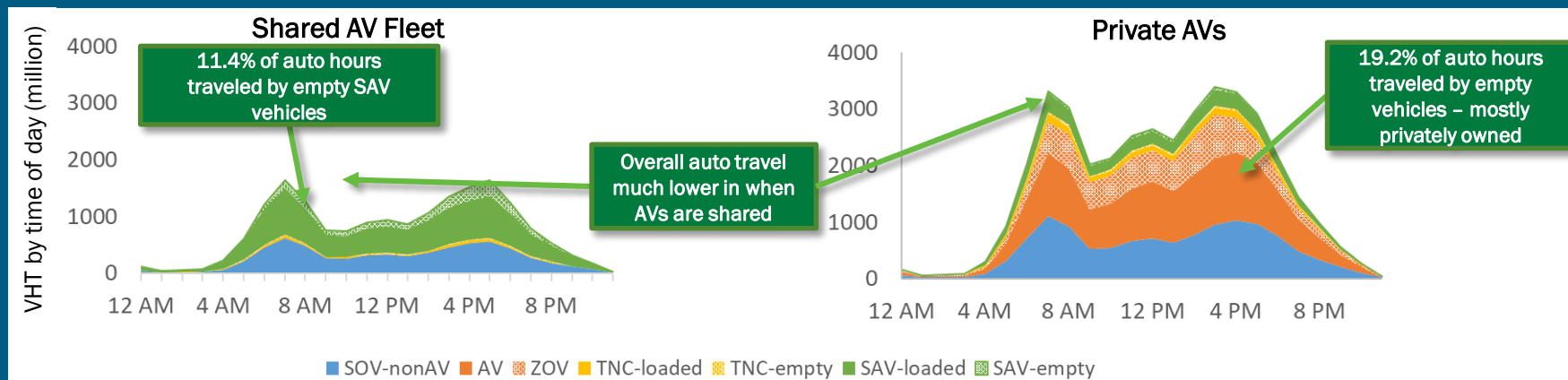
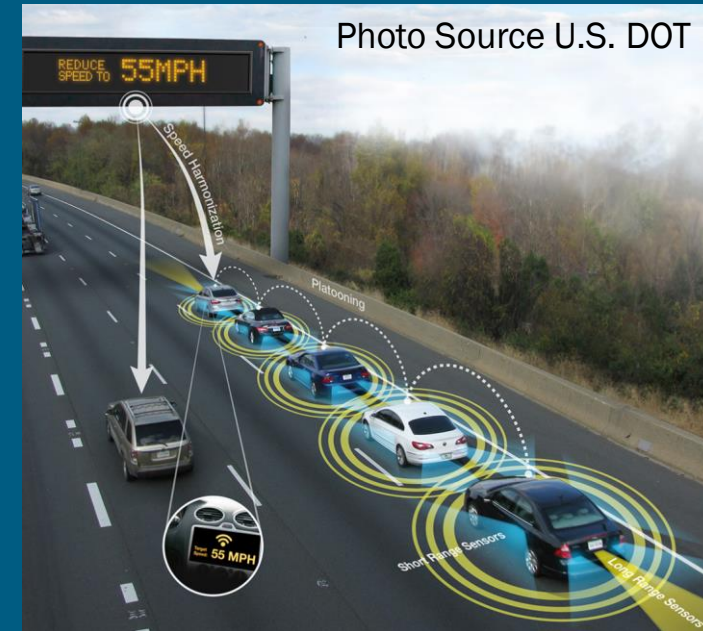
- E-commerce increased All purchasing by 9%
- BUT, overall energy due to e-commerce could decrease 40-60%



# EXAMPLE OF MODELING RESULTS

## ENERGY EFFICIENT MOBILITY SYSTEMS

- Connectivity has the potential to reduce energy and smooth traffic
- The impact of high levels of CAVs will be very different if they are primarily in personally owned vehicle vs central fleets.





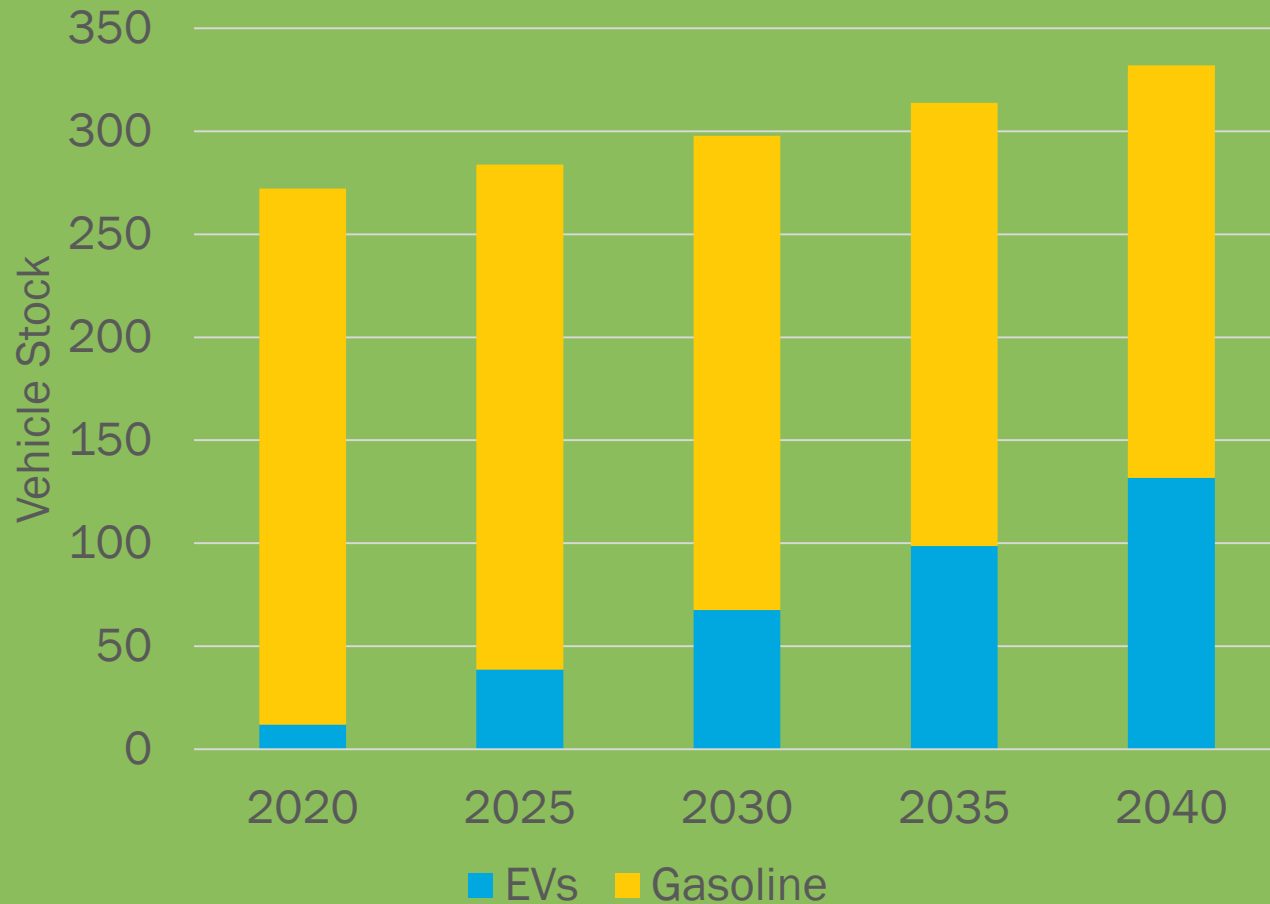
NEW OPPORTUNITIES FOR  
**HPC4MOBILITY & BIG DATA ANALYTICS**

**Exascale Computing Available in 2021**





# EVEN WITH NEW TECHNOLOGIES, MOST CARS ON THE ROAD STILL GAS

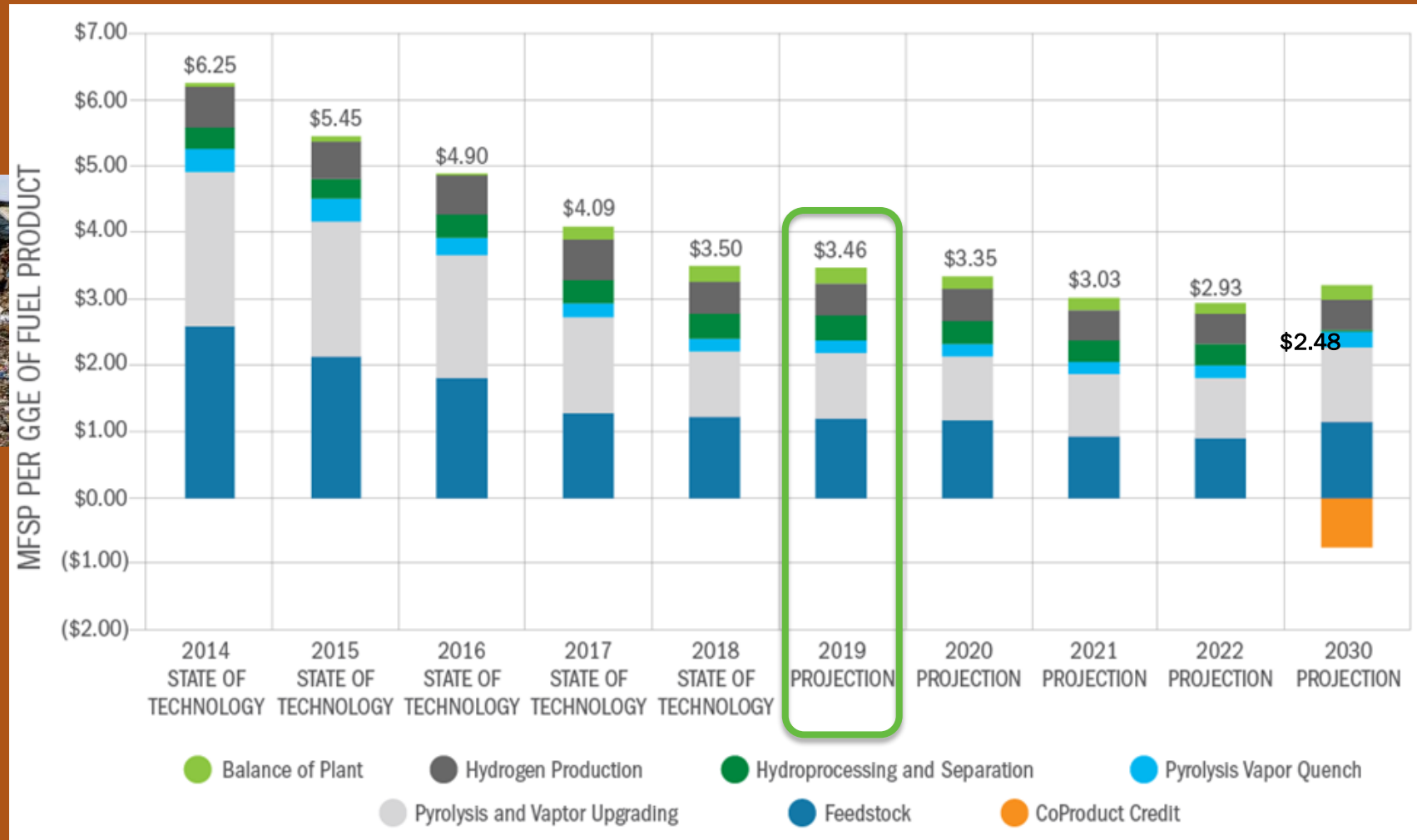


Simple calculation shows:

- Even with 30% new car sales PEV starting in 2020 and growing linearly to 40% in 2040
- Still 60% of vehicle stock (~200M cars) remains gas

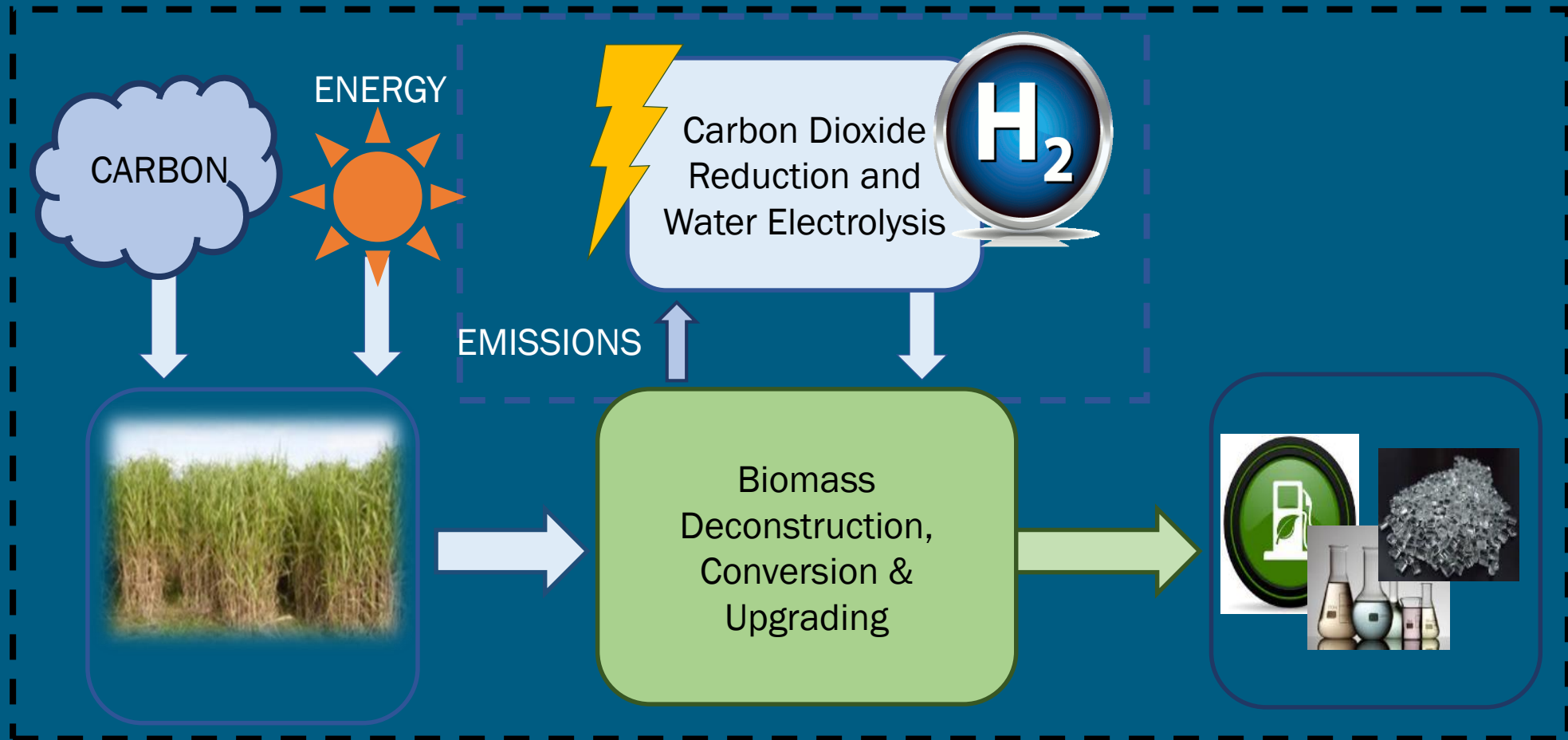
\*assumes all retirements are gas cars at 15M/year

# WHAT ARE THE Options for Liquid Fuels ?



# NEW OPTIONS: CARBON EFFICIENT FUELS

## ENABLED BY H2@SCALE



# TRANSPORTATION

# PRIORITIES

**AFFORDABILITY**



- Electrification
- New Mobility Systems
- Low-Carbon Drop-in Fuels



**COLLABORATION**

# Thank you.

## Michael Berube

Acting Deputy Assistant Secretary for Transportation  
Office of Energy Efficiency and Renewable Energy  
U.S. Department of Energy

[Michael.Berube@ee.doe.gov](mailto:Michael.Berube@ee.doe.gov)