EQUITABLE ELECTRIC MOBILITY

Dr. Bruce Race, FAIA, FAICP
Gerald D. Hines College of Architecture and Design
Center for Sustainability and Resilience

Interdisciplinary Approach

Skill Sets

- Community, environmental, and transportation planning
- Artificial Intelligence (AI) and scenario modeling
- Remote sensing and networks
- Community and market economics
- Technology integration and partnerships

Dr. Bruce Race
Environmental Planning

Dr. Aron Laszka
Computer Science

Dr. Driss Benhaddou
Computer Engineering Technology

Kimberly Williams, J.D.
METRO Innovation Officer

Dr. Vikram Maheshri
Economics

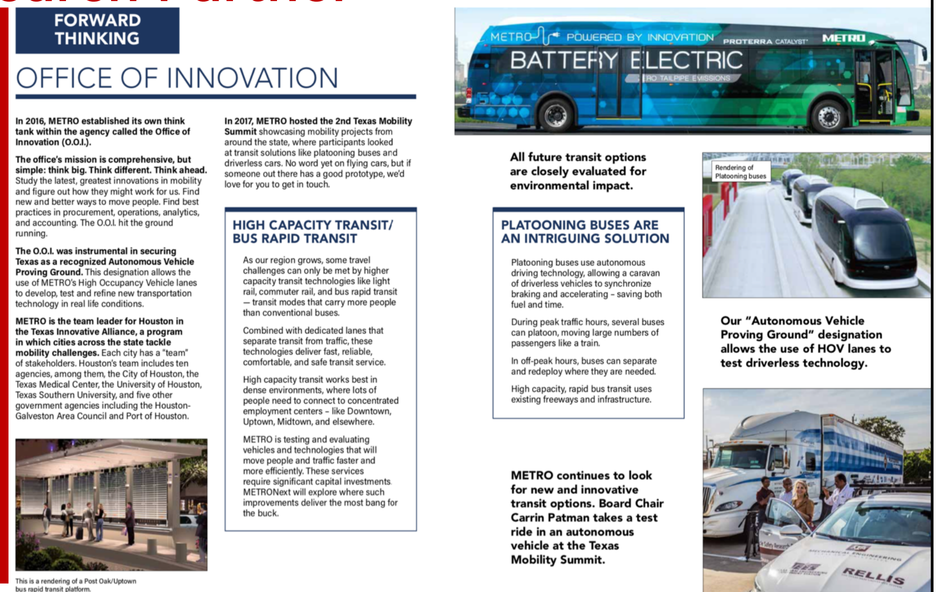
Dr. Ramanan Krishnamoorti
UH Energy

METRO Research Partner

Smart Transit Hub Concepts

- Integration of transit, energy, and IoT technologies
- Improved mobility access and performance
- Lower environmental impacts

Templet for smart transit hubs



FORWARD THINKING

OFFICE OF INNOVATION

In 2016, METRO established its own think tank within the agency called the Office of Innovation (O.O.I.).

The office's mission is comprehensive, but simple: think big. Think different. Think ahead. Study the latest, greatest innovations in mobility and figure out how they might work for us. Find new and better ways to move people. Find best practices in procurement, operations, analytics, and accounting. The O.O.I. hit the ground running.

The O.O.I. was instrumental in securing Texas as a recognized Autonomous Vehicle Proving Ground. This designation allows the use of METRO's High Occupancy Vehicle lanes to develop, test and refine new transportation technology in real life conditions.

METRO is the team leader for Houston in the Texas Innovative Alliance, a program in which cities across the state tackle mobility challenges. Each city has a "team" of stakeholders. Houston's team includes ten agencies, among them, the City of Houston, the Texas Medical Center, the University of Houston, Texas Southern University, and five other government agencies including the Houston-Galveston Area Council and Port of Houston.

This is a rendering of a Post Oak/Uptown bus rapid transit platform.

In 2017, METRO hosted the 2nd Texas Mobility Summit showcasing mobility projects from around the state, where participants looked at transit solutions like platooning buses and driverless cars. No word yet on flying cars, but if someone out there has a good prototype, we'd love for you to get in touch.

HIGH CAPACITY TRANSIT/ BUS RAPID TRANSIT

As our region grows, some travel challenges can only be met by higher capacity transit technologies like light rail, commuter rail, and bus rapid transit — transit modes that carry more people than conventional buses.

Combined with dedicated lanes that separate transit from traffic, these technologies deliver fast, reliable, comfortable, and safe transit service.

High capacity transit works best in dense environments, where lots of people need to connect to concentrated employment centers – like Downtown, Uptown, Midtown, and elsewhere.

METRO is testing and evaluating vehicles and technologies that will move people and traffic faster and more efficiently. These services require significant capital investments. METRONext will explore where such improvements deliver the most bang for the buck.

All future transit options are closely evaluated for environmental impact.

PLATOONING BUSES ARE AN INTRIGUING SOLUTION

Platooning buses use autonomous driving technology, allowing a caravan of driverless vehicles to synchronize braking and accelerating – saving both fuel and time.

During peak traffic hours, several buses can platoon, moving large numbers of passengers like a train.

In off-peak hours, buses can separate and redeploy where they are needed.

High capacity, rapid bus transit uses existing freeways and infrastructure.

Rendering of Platooning buses

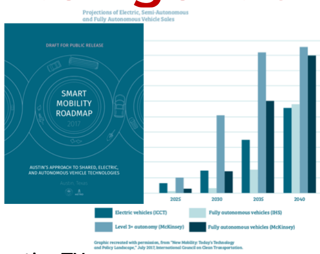
Our "Autonomous Vehicle Proving Ground" designation allows the use of HOV lanes to test driverless technology.

METRO continues to look for new and innovative transit options. Board Chair Carrin Patman takes a test ride in an autonomous vehicle at the Texas Mobility Summit.

Overall Objectives

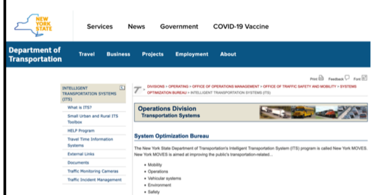
- This project will identify how the **deployment of smart technologies** can improve the reliability, comfort, and affordability of transit services.
- This project will apply **emerging data analytics, smart technologies, and machine learning** to tackle a national challenge of equitable access to EV ownership and electric mobility.
- Defines incentive programs reflecting:
  - National need to **stimulate equitable access** to EV ownership;
  - Regional policy impact demonstrating **collaborative partnerships** between cities, EV companies, fast charging developers, and ridesharing services; and
  - Research that opens up opportunities to use the data for **EV impacts on the energy grid** and future smart grid research and predicting **improvements to air quality**.

Intelligent and Smart Transit Systems

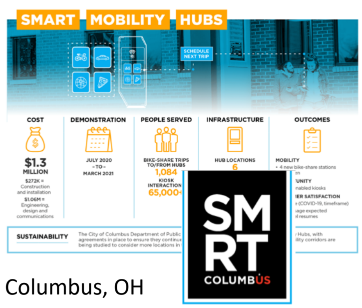


Austin, TX

San Francisco Bay Area, CA



New York DoT

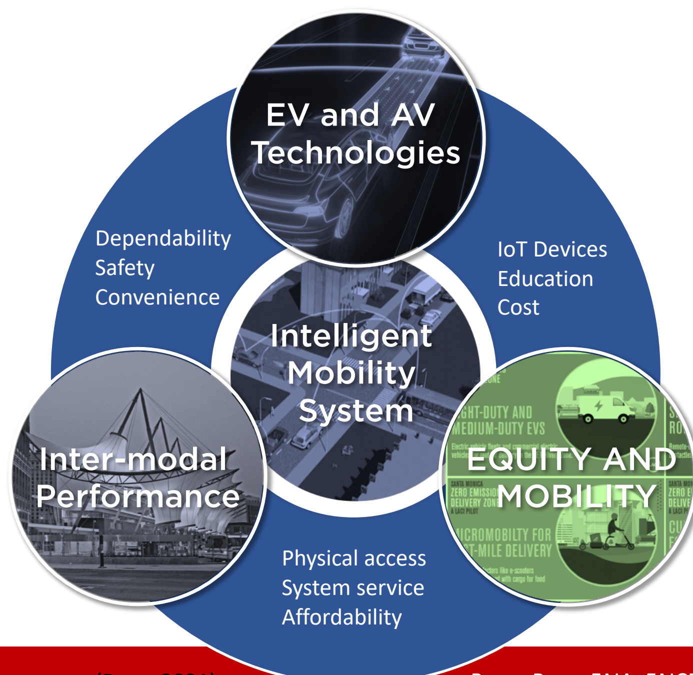


Columbus, OH

- Coastal cities and regions (and university towns) with high percentage of knowledge employers and workers
- Progressive transportation (demand reduction) policies
- Markets full of early adopters and financial incentives for EV ownership
- **HOWEVER.** They are not focused on leveraging early adopter markets to support equitable access

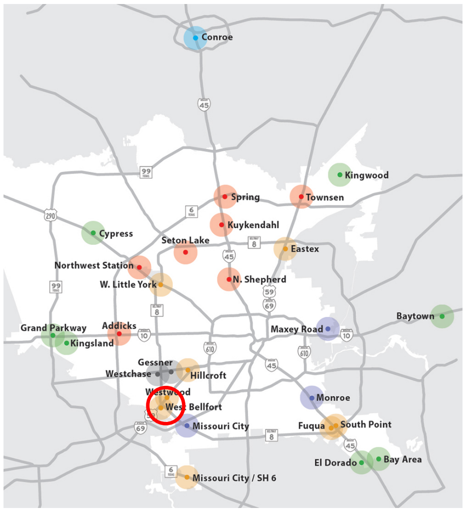
Equitable Access

- Improving end-to-end travel experience
- System-wide access and affordability
- Universal access of transportation system facilities and vehicles
- Sharing economic and environmental upsides



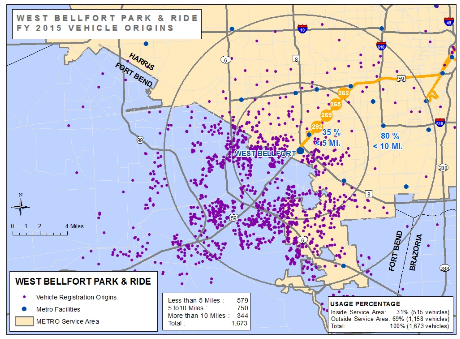
(Race, 2021)

Pilot: West Bellfort METRO Park and Ride



(METRO, 2021)

- Southwest Houston at intersection of I-69/59 and Beltway 8
- Serving SW Houston and Ft. Bend County - - high educational attainment and income



(METRO, 2015)

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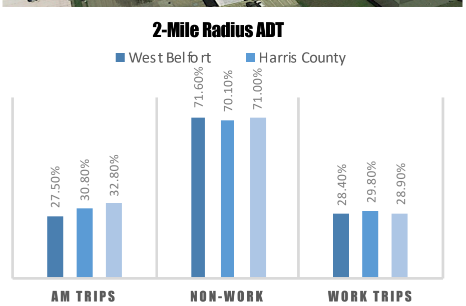
West Bellfort METRO Park and Ride

- Principal express bus destinations: TMC and Downtown
- 1,828 existing parking spaces
- 3,200 total spaces with new parking structure
- 1,500 spaces available during construction



(Race, 2020)

MARKET

- Regional (Ft. Bend) market with high income, educational attainment working in the med center and downtown (early adopters can support access for local resdients)
- Local market high percentage of low wage households, still driving to dispersed workplaces

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Broad Community Access: Smart Mobility Hub Vision

Seamless integrations of technology - - transit apps, pilot IoT (5G) and Bluetooth infrastructure corridor(s), operations and management, payment, and enforcement

Smart Shuttles (Autonomous/EV) - - routes, length, headway, span of service (hours/day), vehicles required, layout time (minutes)

Smart parking and charging - - real time data service, mobile payment app, lic plate recognition, equipment/cameras, parking management integrator (flow of information)

Parking permit types - - monthly with bus pass, monthly parking only, daily on-line, daily pay by phone

Smart bus shelter technology - - location is critical, USB charging and hotspot

Smart trips - - personalizing transit trips

Ridesharing - - commercial carshare services, carpooling, and vanpooling

Private partners - - employer shuttle bus

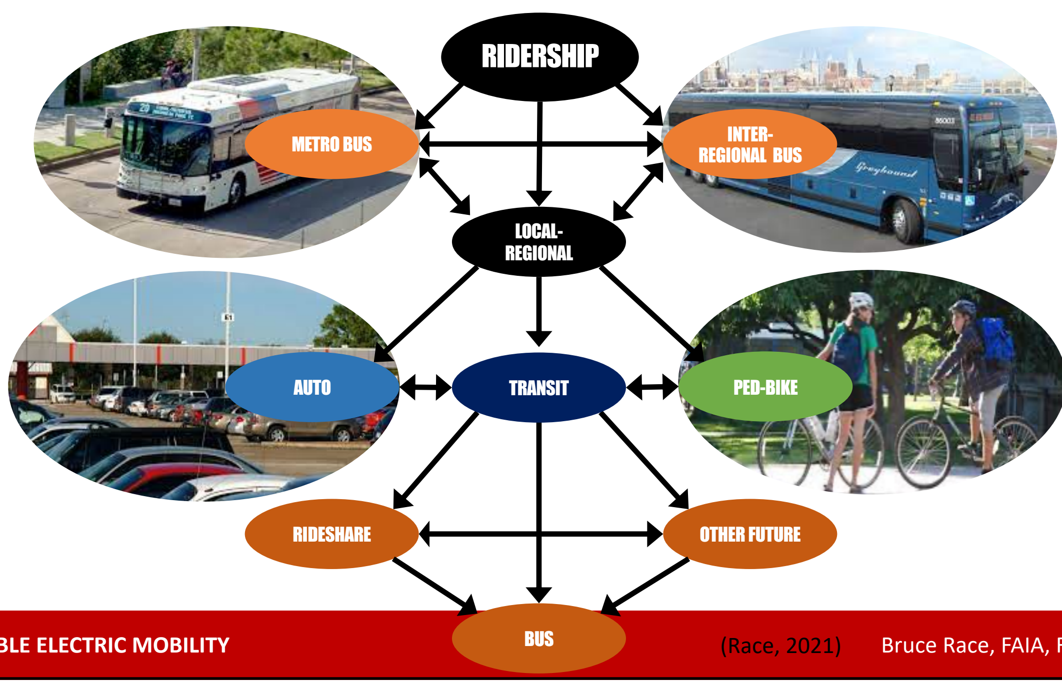
IMPLEMENTATION

Marketing - - customer data, short term marketing, continuous outreach, technology-enabled marketing

Partner leadership - - agencies, jurisdictions, other stakeholders

Cost planning and sharing - - capital costs (infrastructure), operating costs, funding sources

Intermodal Transfer and Last Mile Connections



(Race, 2021)

Intermodal Transfer and Last Mile Connections

	Inter-City		Regional			Local			
Facilities	Greyhound (Future)	Ft. Bend Transit (Future)	METRO Bus	Auto Parking	Bike Parking	Local Shuttle (Future)	Auto Drop-off	Bike Parking	Pedestrian
BUS TRANSIT									
Inter-City Bus		•	•	•	•	•	•	•	•
METRO X-press									
METRO Local			•		•		•		•
AUTO DROP OFF									
Kiss n Ride			•						
Rideshare Services									
PASSENGER PARKING									
Park n Ride			•			•			•
Rideshare						•	•		
ACTIVE TRANSIT									
Private Bike			•		•			•	•
Rental Bike/Scooter			•			•			
On-site Pedestrian	•	•	•	•	•	•	•	•	•
Off-site Pedestrian			•						•

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Issues and Opportunities:

Grid impact:

As the number of EVs increases, so will the **impact of EV charging on the power grid**. To minimize the impact on the grid, we need to "smoothen" the load and avoid charging many EVs at the same time.

- Can we plan the charging schedules and locations of ridesharing EVs in a way that minimizes the impact on the grid while providing equitable mobility supply across Houston (i.e., do not charge all the vehicles at a time when lower-income areas need them)?
- How can we (or Uber) incentivize drivers to follow these planned charging schedules?

Charging schedules need to take into account the impact on the grid, the availability of charging stations, and mobility demand (maintaining or providing a seamless integration between different modes of transportation).

- Can we plan integrated charging schedules and locations for all ridesharing, personal, and transit EVs?
- Can we incentivize drivers to follow these schedules?

Equitable distribution of charging hubs:

Higher-income neighborhoods may have higher levels of EV adoption. Hence, to maximize the utilization of charging hubs, it would make sense to place them in higher-income neighborhoods and locations with high-income jobs. However, this would put low-income populations at a disadvantage. We need to consider the locations of residences, public services (schools, hospitals, etc.), and jobs.

- How can we **balance maximizing utilization with providing equitable distribution**?

Park-and-charge-and-ride:

- How can we **integrate park-and-ride with EV charging** for personal vehicles?
- Can we adapt public transit routes and schedules, so that it is easy to transfer from charging hubs to public transit?
- If a person's preferred park-and-ride garage does not have the appropriate charging infrastructure, can we incentivize them to park elsewhere (e.g., by lower cost charging)?
- Can we integrate with BCycle to provide park-and-charge-and-bike service?

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Issues and Opportunities:

Community outreach and incentives:

- What are the **barriers to the adoption** of EVs (besides higher up-front prices)?
- Do people subjectively prefer EVs or ICEVs? How do these preferences vary by socio-economic status and by neighborhoods?
- How can we incentivize people to use EVs as drivers and as riders?
- What concerns do people have about EVs (e.g., limited driving range, battery explosions)?

Post COVID-19 mobility:

- What will mobility look like in **a post COVID-19 world**?
- Which modes of transit will be more popular and which will be less popular?
- How will mobility demand change temporally and spatially?
- Can we plan the distribution of charging hubs anticipating long-term changes?

Privacy-preserving data collection:

To answer the above questions, we need data, which may include personal information, such as location traces and travel destinations.

- Can we **collect and analyze data in a privacy preserving manner**, which enables us to answer the above questions without storing or publishing any personally identifiable information?

Real-time data collection, processing, and distribution:

We need to collect real-time data from charging hubs and vehicles to plan (e.g., when to charge which ridesharing vehicle) and to inform drivers (e.g., about the availability of charging stations).

- How can we **collect, process, and distribute this detailed data** for a city as large as Houston?

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Smart Charging and Parking Goal and Objectives

GOAL: To be able to provide seamless travel experience for EV charging, parking, and METRO pass system services - - EQUITABLY

SMART SYSTEM OBJECTIVES:

- To be able to **monitor the number of available spaces and chargers** in park and ride lots
- To be able to provide available **space information to requested by drivers** to assist in decision-making for parking location and transit schedules
- To be able to provide available **space information to METRO/parking operator**
- To be able to provide available **space information and bus schedules to traveler information applications**
- To **facilitate virtual METROpass, EV charging, and parking payments**

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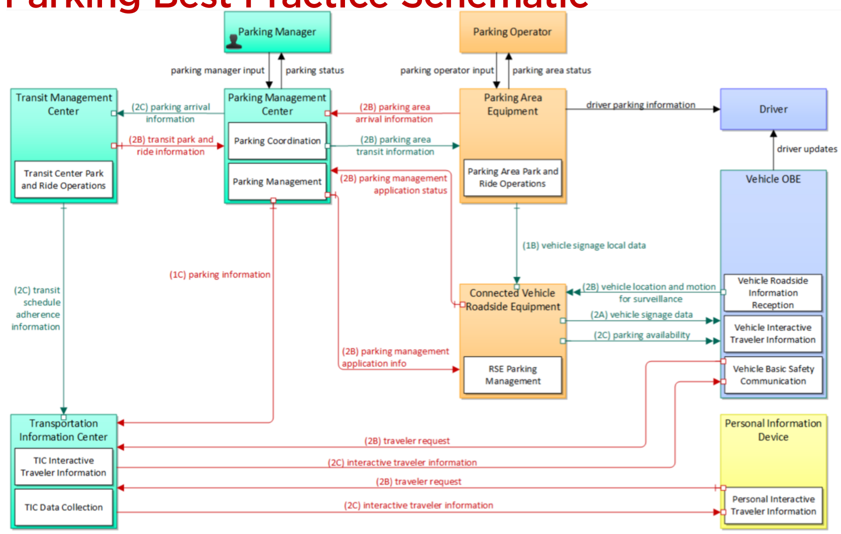
Park and Ride Smart Parking Best Practice Schematic

Smart Transit Hub Concepts

- Integration of transit, energy, and IoT technologies
- Improved mobility access and performance
- Lower environmental impacts

Templet for smart transit hubs



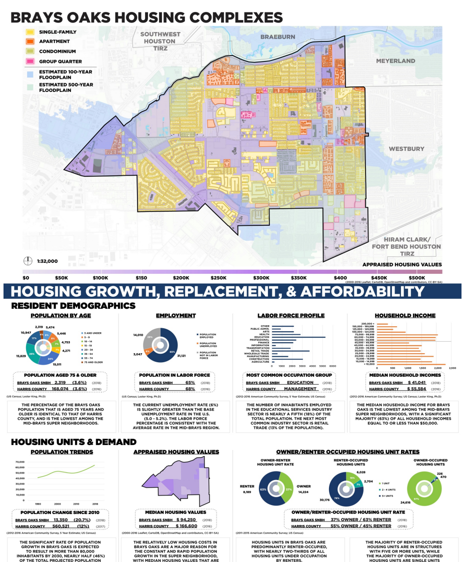
https://local.iteris.com/arc-it/html/servicepackages/sp69.html#tab-3

(DOT, Architecture Reference for Cooperative and Intelligent Transportation, 2020)

PM02: Smart Park and Ride System

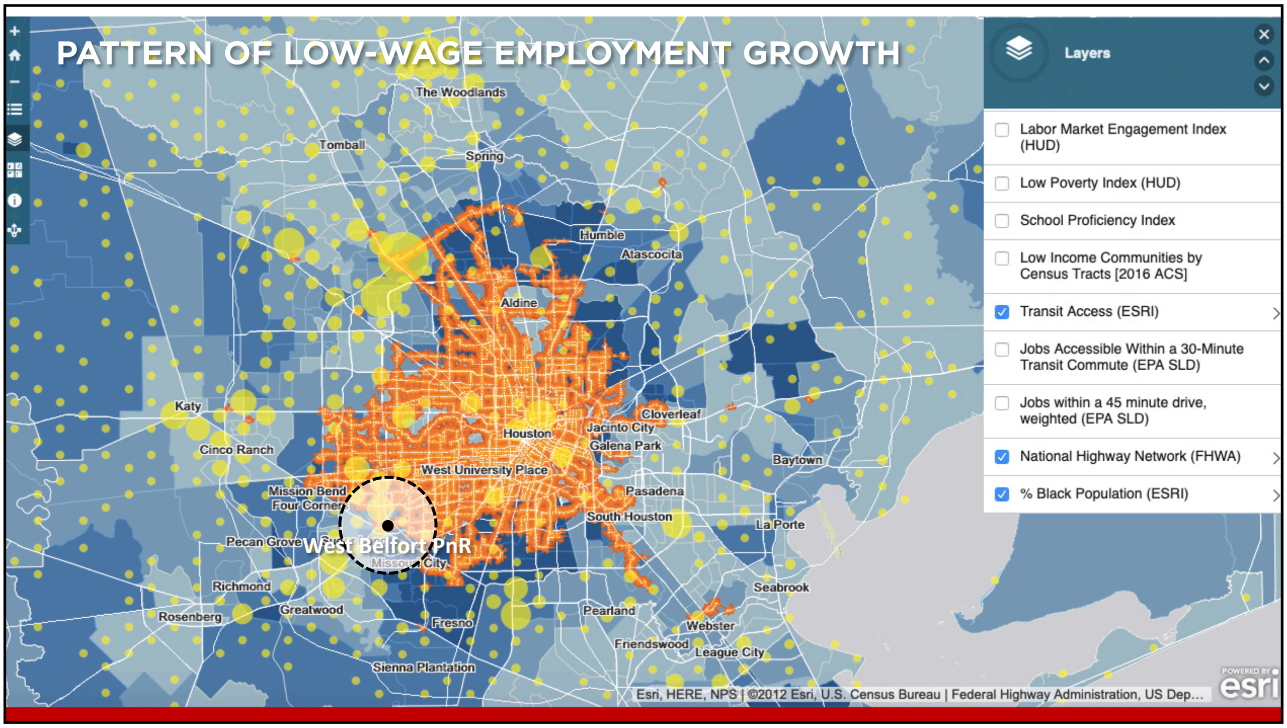
6	Physical	Feb 10, 2020	NAT

Critical Questions Addressed



- Q1. What are the opportunities to increase the **broader access** to the electric mobility revolution?
- Q2. What are the **barriers** to EV ownership?
- Q3. What are the potential larger contributions to GHG and PM2.5 **emission reductions**?

(CeSAR, 2018)


PATTERN OF LOW-WAGE EMPLOYMENT GROWTH
Layers
Labor Market Engagement Index (HUD)
Low Poverty Index (HUD)
School Proficiency Index
Low Income Communities by Census Tracts [2016 ACS]
Transit Access (ESRI)
Jobs Accessible Within a 30-Minute Transit Commute (EPA SLD)
Jobs within a 45 minute drive, weighted (EPA SLD)
National Highway Network (FHWA)
% Black Population (ESRI)
The Woodlands
Tomball
Spring
Humble
Atascocita
Aldine
Katy
Cinco Ranch
Houston
Cloverleaf
Jacinto City
Galena Park
West University Place
Baytown
Mission Bend
Four Corners
Pasadena
South Houston
La Porte
Pecan Grove
West Belfort PnR
Missouri City
Richmond
Rosenberg
Greatwood
Fresno
Pearland
Seabrook
Webster
Friendswood
League City
Sienna Plantation
Esri, HERE, NPS | ©2012 Esri, U.S. Census Bureau | Federal Highway Administration, US Dep...
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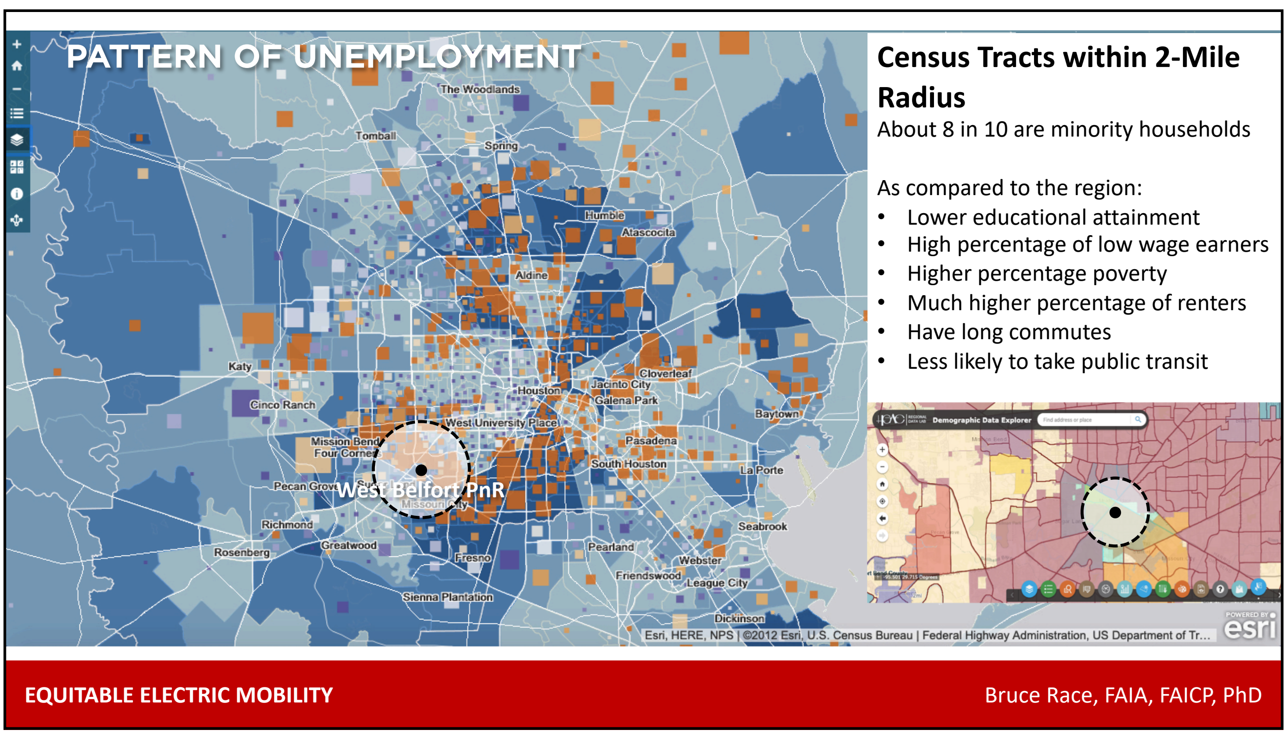
PATTERN OF UNEMPLOYMENT
Census Tracts within 2-Mile Radius
About 8 in 10 are minority households
As compared to the region:
• Lower educational attainment
• High percentage of low wage earners
• Higher percentage poverty
• Much higher percentage of renters
• Have long commutes
• Less likely to take public transit
Demographic Data Explorer
The Woodlands
Tomball
Spring
Humble
Atascocita
Aldine
Katy
Cinco Ranch
Houston
Cloverleaf
Jacinto City
Galena Park
West University Place
Baytown
Mission Bend
Four Corners
Pasadena
South Houston
La Porte
Pecan Grove
West Belfort PnR
Richmond
Rosenberg
Greatwood
Fresno
Pearland
Seabrook
Webster
Friendswood
League City
Sienna Plantation
Dickinson
Esri, HERE, NPS | ©2012 Esri, U.S. Census Bureau | Federal Highway Administration, US Department of Tr...
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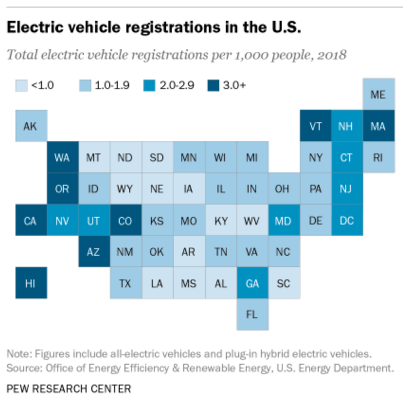
Barriers to EV Ownership



UNDERSTANDING BENEFITS AND INCENTIVES OF EV OWNERSHIP

- Missing out on benefits of EV ownership is an **OPPORTUNITY COST** to working families.
- **Tax Credits**
  - Small second hand market for EV
  - Up to $7,500 in tax credits for new cars (US EPA, 2021)
  - Access to Biden incentives for 500,000 new fast charging stations
- **Employee Benefits**
  - Incentives for "eco-commuters"
  - Knowledge-based employers more likely to provide incentives
- **Local Incentives**
  - Uber and City of Houston partnership for EV

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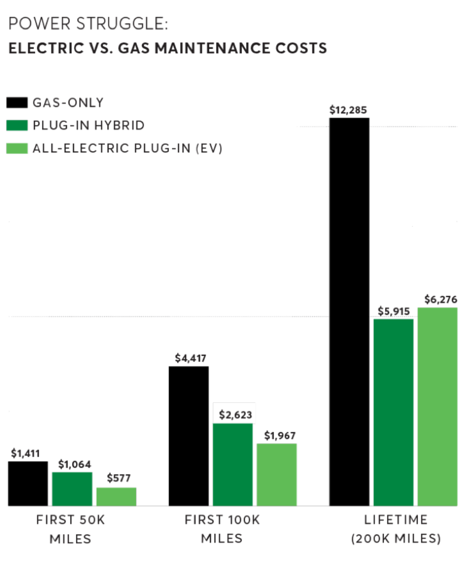
Barriers to EV Ownership



MANY LOW INCOME HOUSEHOLDS ARE IN THE SECOND HAND CAR MARKET

- The **INITIAL PURCHASE COST** as a barrier to EV ownership. Until there is a second hand EV market, low wage earners will have a difficult time gaining access to affordable EVs.
- **Initial Purchase Price**
  - EVs cost more to purchase but save families money over the life of the car
- **Realizing Economic Benefits from Affordable Fueling and Maintenance**
  - Average auto **maintenance costs are 40% lower** for EVs compared to combustion engine vehicles (Office of Energy Efficiency & Renewable Energy, 2021).
  - A 2021 standard range **Tesla 3 will save an owner $643 per year compared to an entry-level Camry** (US DOE, 2021) .

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Choices for Working Families

2021 Tesla Model 3

$39,190 Starting Price

4.2 ★ Expert **4.8** ★ Consumer

141 MPGe Combined Fuel Economy

2010 GMC Yukon

$12,800 Starting Price

Expert (N/A) **4.5** ★ Consumer

21 MPG Combined Fuel Economy

Kelley Blue Book
THE TRUSTED RESOURCE

- A low-income family driving a used 2010 GMC SUV is spending $1,361 per year more than a basic Tesla. Over 15 years, the Tesla would cost over $20,000 less to own vs. keeping used SUVs on the road (US DOE, 2021).

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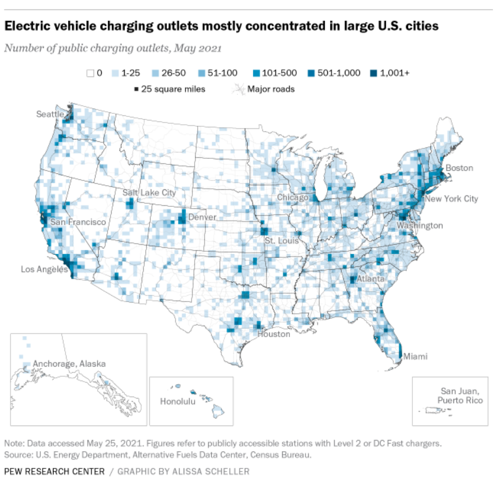
Barriers to EV Ownership



THERE ARE FEWER FAST CHARGERS LOCATED IN LOW INCOME COMMUNITIES

- Many low wage households are renters in communities without fast charging options. These families pay a higher **COST OF CONVENIENCE** for access.
- **Lack of Local Fast Charging Infrastructure**
  - The lack of convenient and accessible charging for low wage families is a **household cost in time**
  - In 2018, fast charger to EV ratio in U.S. was 1:17.4 compared to 1:10 in the EU
- **Poor EV Charger Access of Low-Income Renters**
  - Low income rental housing does not have access to onsite EV charging
  - More dependent on off-site public fast charging
- **Cost of Installing Home Level 2 Charger**
  - Over 80% of EV charging happens at home (Energy Star, 2018)
  - Level 2 charger can cost up to $2,600 to install in a home

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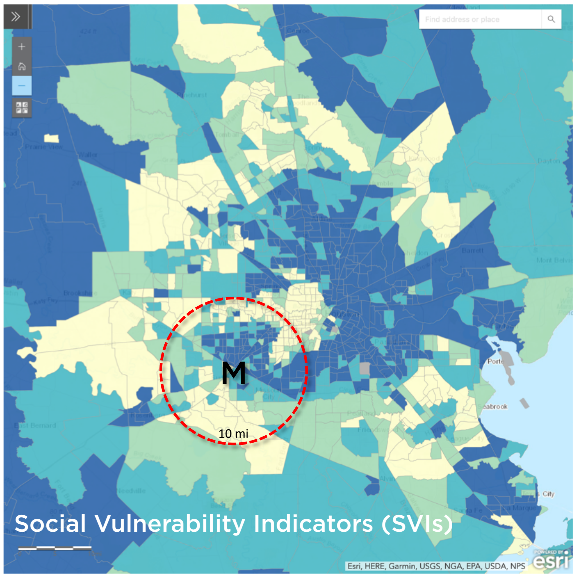
Equitable EV and Public Transit Mobility



Leveraging Early Adopters

Understanding **indicators for early adoption**:

- High educational attainment and income
- Single family home ownership
- Multi-car households
- Car-sharing
- Public charging
- Political party affiliation

Understand the market segmentation of early adopters - - men in their 30s-50s, home owners, higher education attainment and income

Understanding **equity indicators** for access to electric mobility:

- Social Vulnerability Indicators (SVIs)
- EV affordability and diversity of EV fleet
- Innovation of EV access (car sharing, etc.)
- Awareness of incentives and benefits

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Regional View

Pollution Sources

Annual PM2.5 pounds/mile

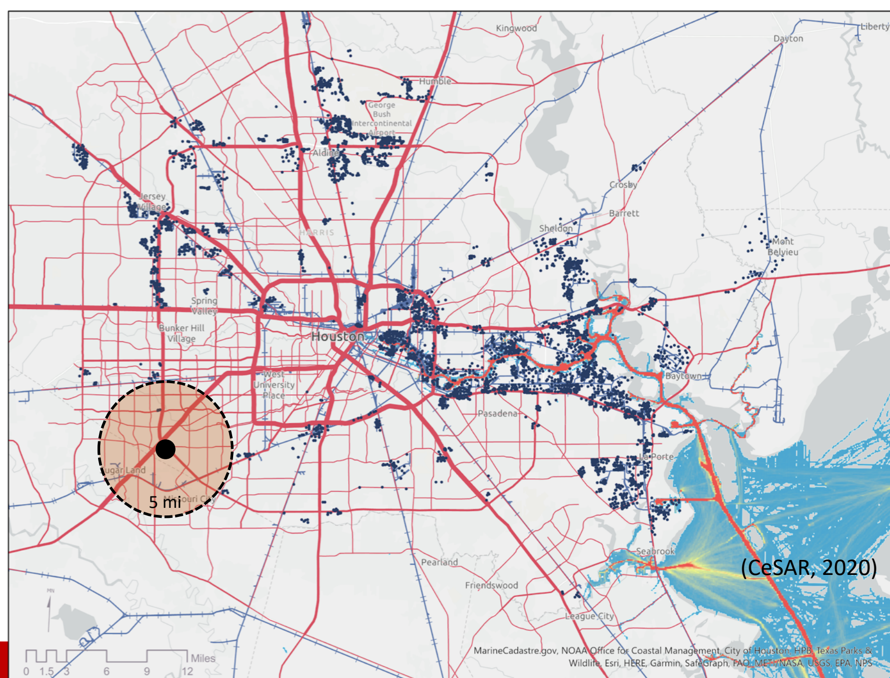
- ≤14532737.640273
- ≤27536502.809979
- ≤40540267.979686
- ≤53544033.149392
- ≤66547798.319098
- ≤79551563.488804
- ≤92555328.658511
- ≤105559093.828217

Railroads

Vessel Density

- High : 675.156
- Low : 0

Warehouse Distribution



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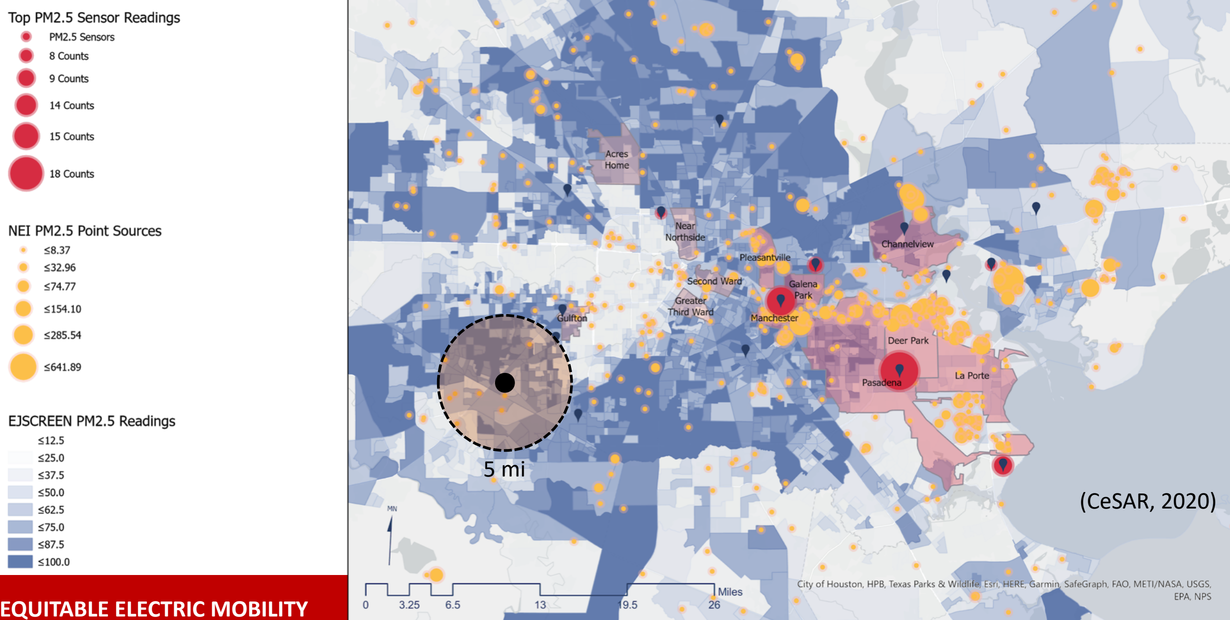
Regional View

PM2.5 & Outliers



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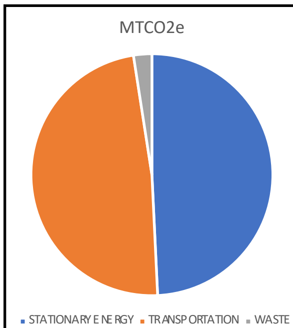
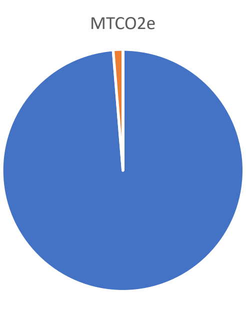
Houston CAP-Baseline Emissions (2014)



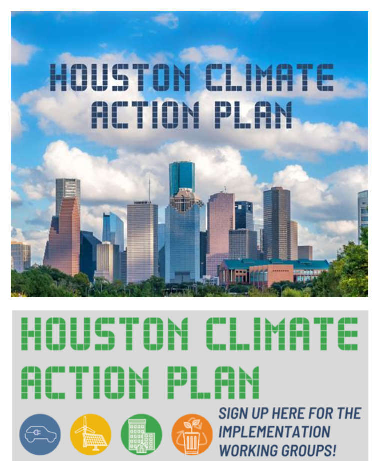
GHG Emissions by Source

	MTCO2e	
STATIONARY ENERGY	16,454,686	49%
TRANSPORTATION	16,140,987	48%
WASTE	818,344	2%
	33,414,017	



Transportation GHG

	MTCO2e	
ON-ROAD	15,932,882	99%
RAILWAYS	207,451	1%
AVIATION	654	0%
	16,140,987	



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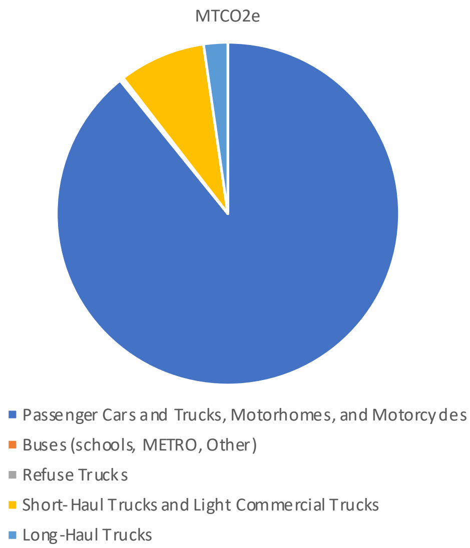
MTCO2e by On-Road Mode



- Focus on passenger cars and small trucks (89% of MTCO2e)
- Short-haul trucks and commercial small trucks are important (8%)
- Long-haul trucks are a supply chain issue - - national policy and regional partnerships are important (3%)
- Fleet vehicles - - local policy (<1%)

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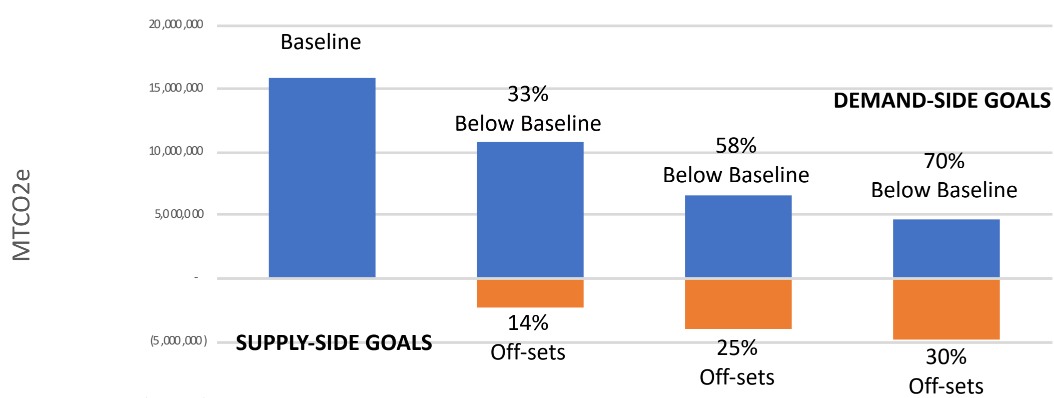
On-Road Transportation Goals with Policy Scenario 4



	2014 Baseline	2030	2040	2050
Off-sets/Renewables	0	(2,211,168)	(3,951,327)	(4,779,865)
MTCO2e	15,932,883	10,751,243	6,673,363	4,731,771

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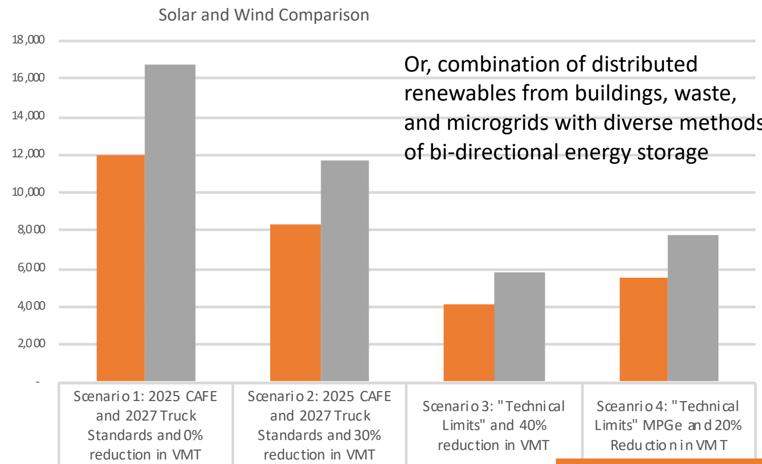
Achievement Gap: Electrifying the Fleet



6 to 20 SM of PV

	Scenario 1: 2025 CAFE and 2027 Truck Standards and 0% reduction in VMT	Scenario 2: 2025 CAFE and 2027 Truck Standards and 30% reduction in VMT	Scenario 3: "Technical Limits" and 40% reduction in VMT	Sceanrio 4: "Technical Limits" MPGe and 20% Reduction in VMT
Acres of PV based on 2.8 gWh/acres (2)	11,978	8,384	4,149	8.6 SM
West Texas 2gWh wind turbines	16,769	11,738	5,809	2.2 SM @ 4a/site (2)

(Race, 2021)

(2) NREL (2013)

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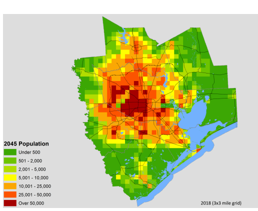
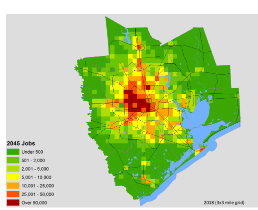
Regional and Local Growth and EV Implementation

Ruffino Hills Town Center (CeSAR, 2020)





Projected Regional Growth (HGAC, 2018)

- Assumptions based on current 3,000 daily bus ridership
- SCENARIO 1: Status Quo (Today - - Baseline)
  - 70%-30% regional and local ridership
  - 20% reduction in VMT
  - 3,000 bus boardings
  - 23 MPGe (2014)
- SCENARIO 2: Increased Regional Ridership and Growth in Ft. Bend County (Sprawl Model)
  - 90%-10% regional and local ridership
  - 30% reduction in VMT
  - 5,000 bus boardings
  - 54 MPGe (Obama era CAFE standards)
- SCENARIO 3: Redevelopment of I-69/Loop 8 (Infill Model)
  - 60%-40% regional and local ridership
  - 40% reduction in VMT
  - 7,000 bus boardings
  - 112 MPGe Technical Limits

(CeSAR, 2021)

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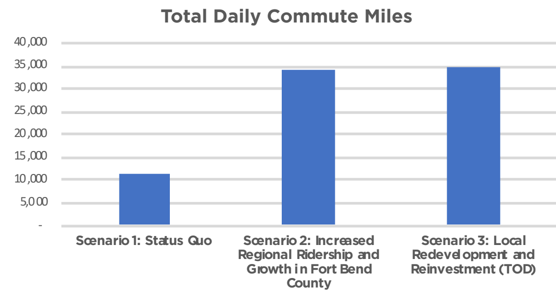
Reducing Commuter Emissions



F-150

Prius

Ford Mach-E

Focusing on transit-oriented infill development significantly decreases VMT

- Assumptions based on current 3,000 daily bus ridership
- SCENARIO 1: Status Quo (Today - - Baseline)
  - 70%-30% regional and local ridership
  - 20% reduction in VMT
  - 3,000 bus boardings
  - 24 MPGe (2014)
- SCENARIO 2: Increased Regional Ridership and Growth in Ft. Bend County (Sprawl Model)
  - 90%-10% regional and local ridership
  - 30% reduction in VMT
  - 5,000 bus boardings
  - 54.5 MPGe (Obama era CAFE standards)
- SCENARIO 3: Redevelopment of I-69/Loop 8 (TOD Model)
  - 60%-40% regional and local ridership
  - 40% reduction in VMT
  - 7,000 bus boardings
  - 112 MPGe EV Fleet

(CeSAR, 2021)

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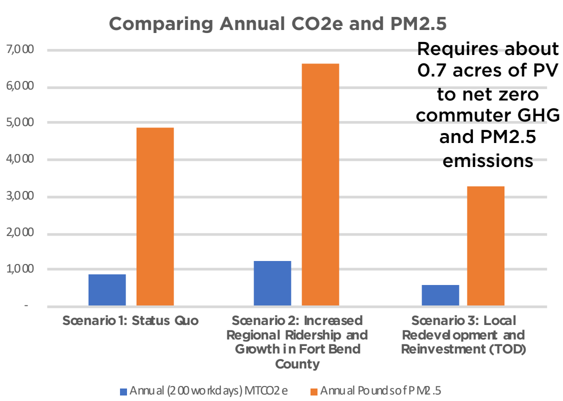
Reducing Commuter Emissions



Requires about 0.7 acres of PV to net zero commuter GHG and PM2.5 emissions

Growing the suburbs and not electrifying the fleet significantly increases GHG emissions and PM2.5

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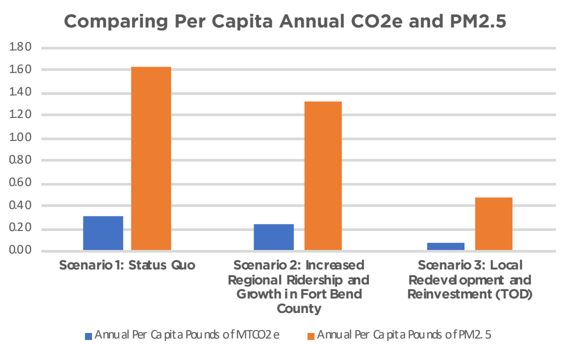
Reducing Commuter Emissions



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  - 112 MPGe EV Fleet

Focusing on transit-oriented infill development and electrifying the fleet significantly decreases GHG emissions and PM2.5 for each of us - - what we drive and where we live

(CeSAR, 2021)

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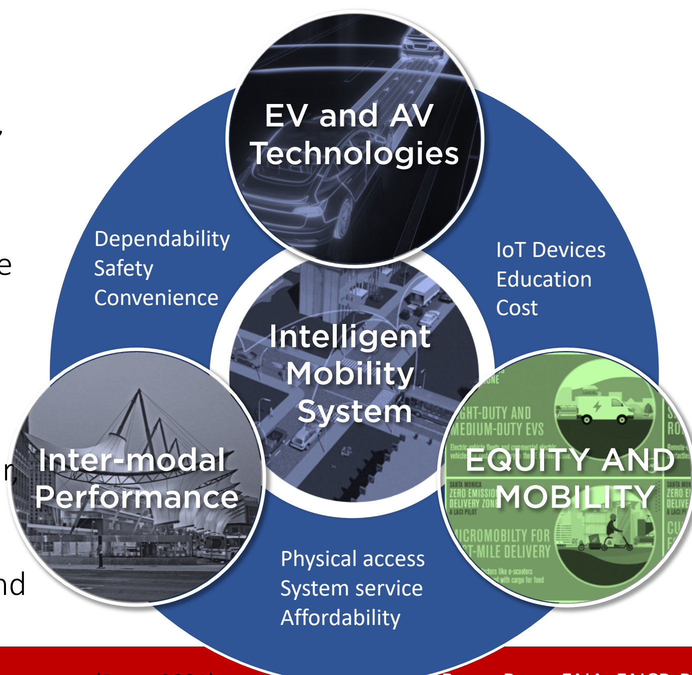
Equity is about …

- Improved transit service
  - Smarter, more comfortable and safe, and reliable
  - Is an end-to-end experience
- Inclusive where the benefits of innovation are a shared experience
- Breaking barriers to EV ownership and sharing
- Recognizing early adopters can underwrite EV infrastructure
- There are co-benefits - - cleaner air, reduced climate impact, and a healthier
- AND - - new green energy, tech, and sales jobs



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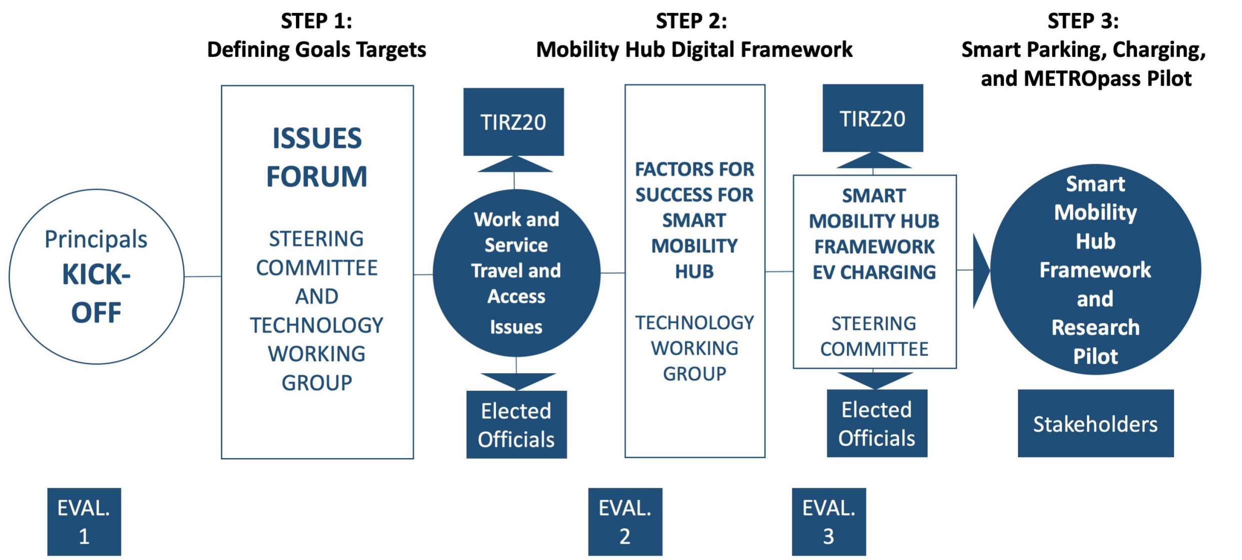
Engaging Community and Partner Process



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Conclusions and Discussion

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