



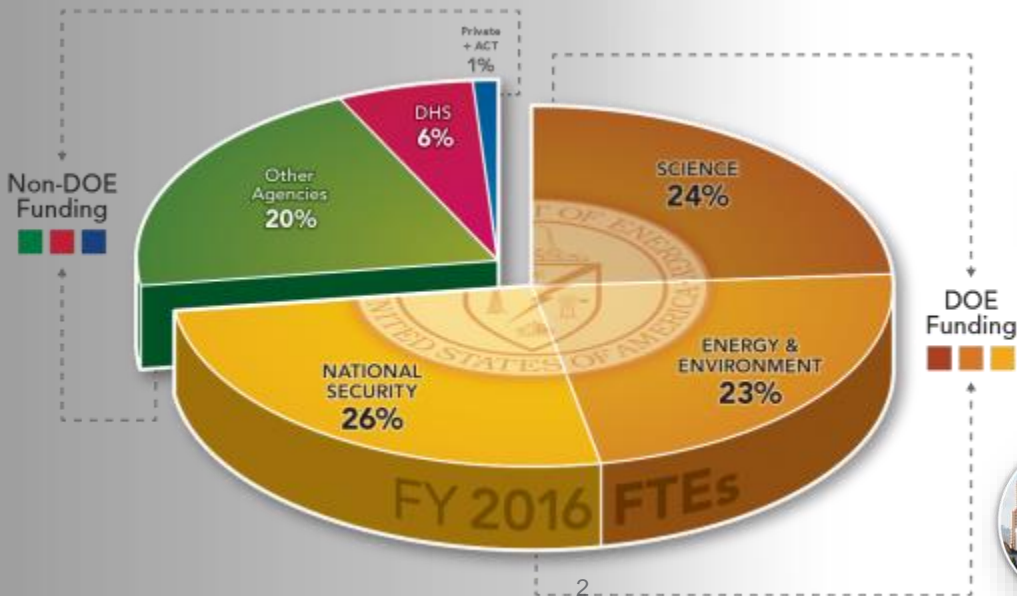
Smart Transportation: What is smart about it and how might it impact you?

MICHAEL KINTNER-MEYER

Pacific Northwest National Laboratory
Richland, WA

PNNL – FY2016 at a Glance

- ▶ \$920.4M in R&D expenditures
 - ▶ 4,400 scientists, engineers and non-technical staff
 - ▶ 104 U.S. & foreign patents granted
 - ▶ 2 FLC Awards, 2 R&D 100 Awards
 - ▶ 1,058 peer-reviewed publications
- ▶ Mission-driven collaborations with government, academia and industry
 - ▶ Among DOE's top-performing labs; a premier chemistry, environmental sciences and data analytics laboratory



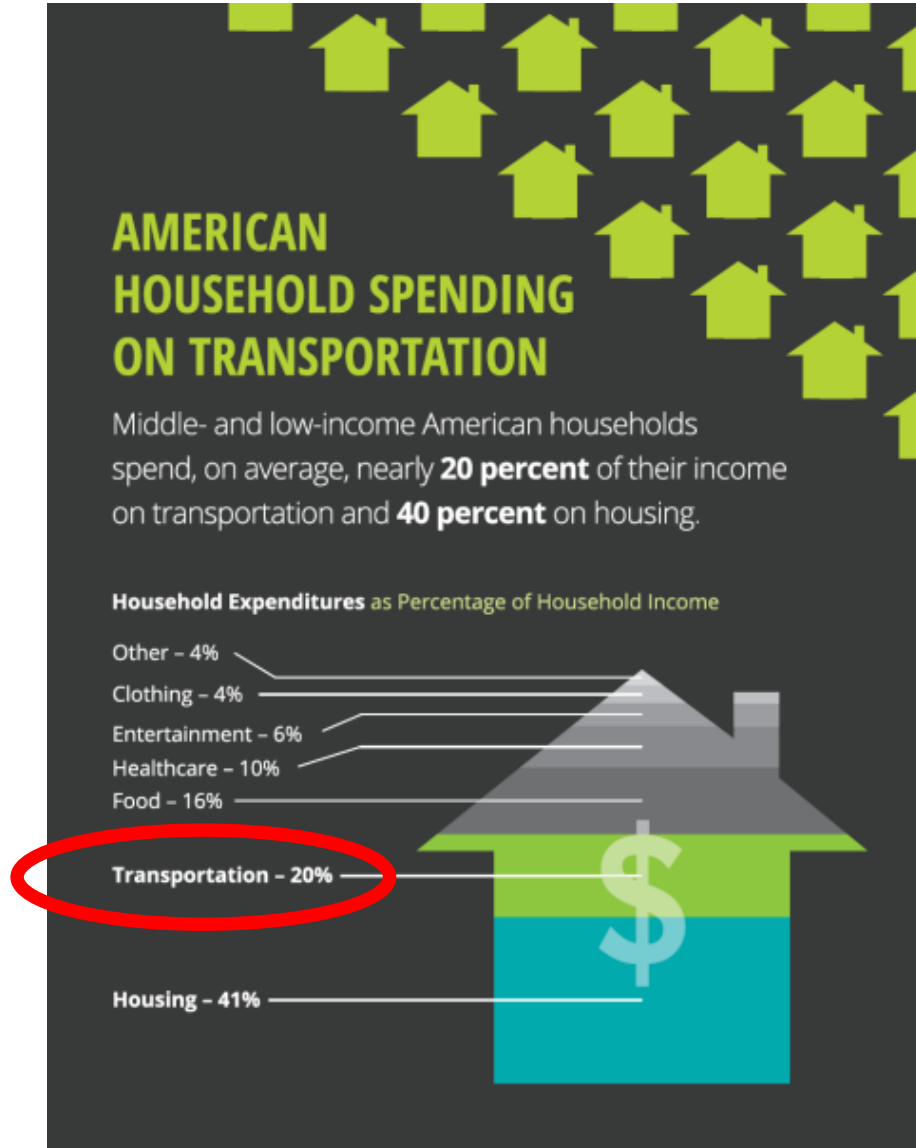
Mobility is Foundational to Modern Economies



Transportation is a Large Part of the Energy Economy



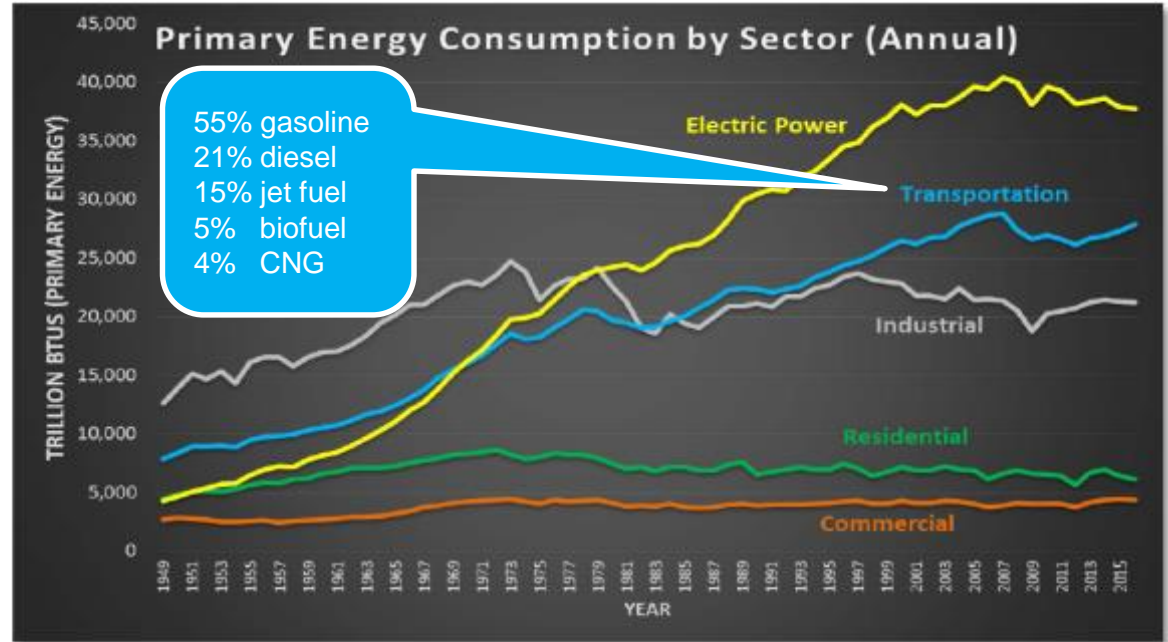
Transportation is the **2nd** largest expense for U.S. households



Transportation is a Large Part of the Energy Economy



Transportation is the **2nd** largest expense for U.S. households



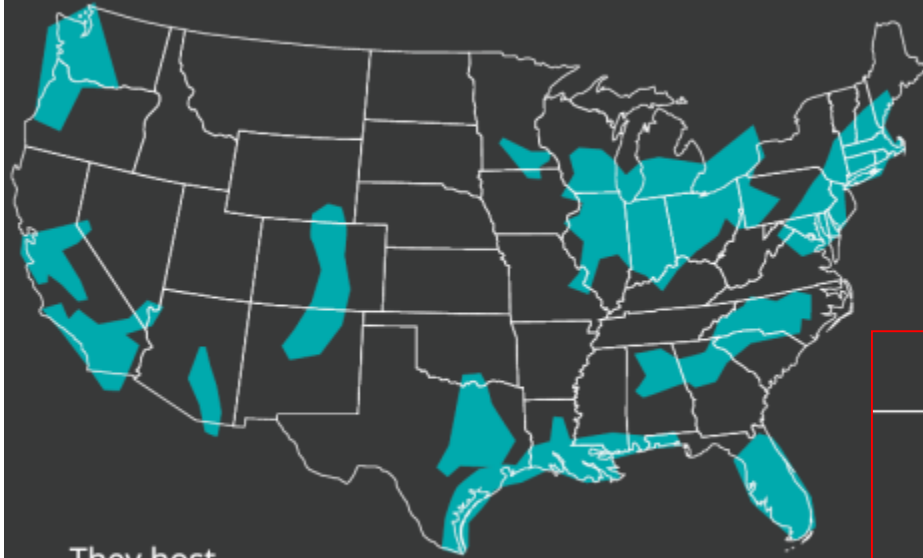
70% of total U.S. petroleum usage is for transportation

On-road vehicles account for **85%** of transportation petroleum usage



Trends Shaping Mobility - Population

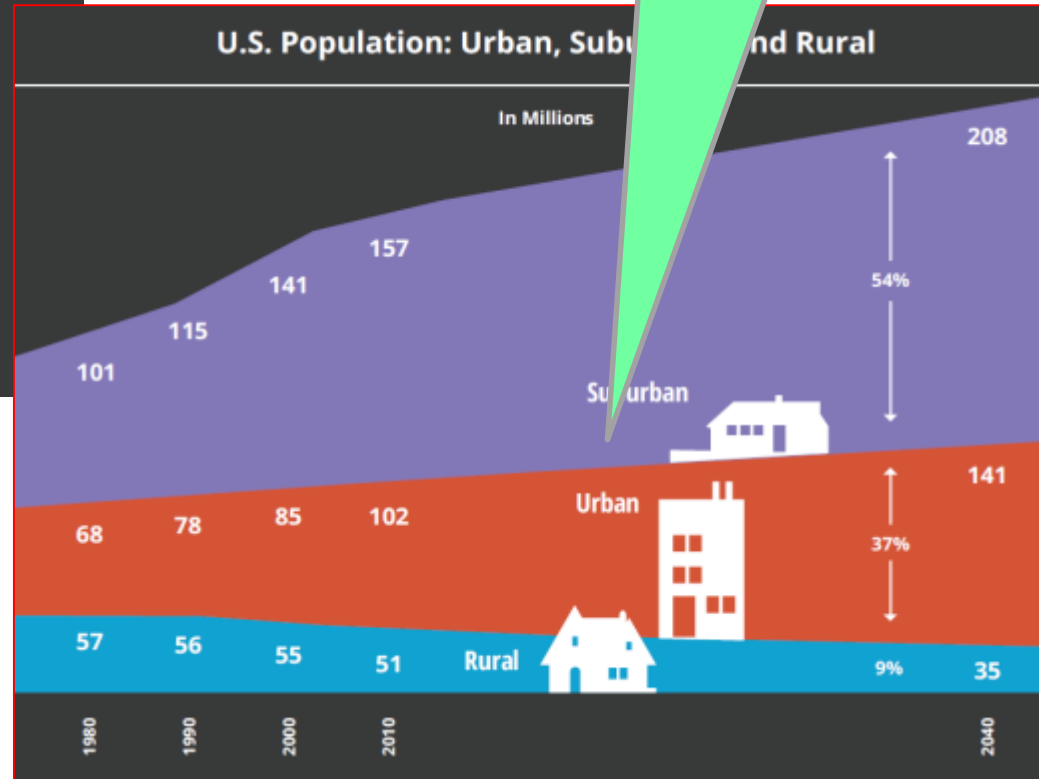
11 megaregions are linked by transportation, economics, and other factors.



They host
75% of America's
population and employment.

U.S. Population growth uneven:

- Urban and suburban will increase
- Rural will decrease



Trends Shaping Mobility – Increasing Demand

Each Year, Traffic Congestion Costs Us:

Time



6.9 Billion Hours

Fuel

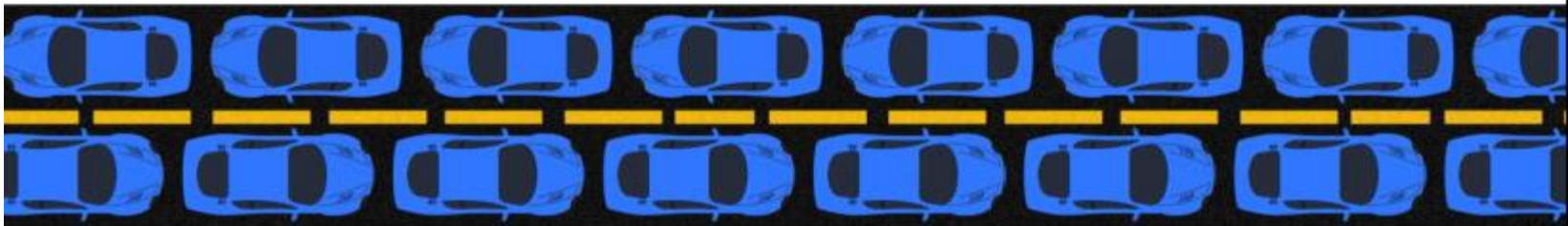


3.1 Billion Gallons

Money

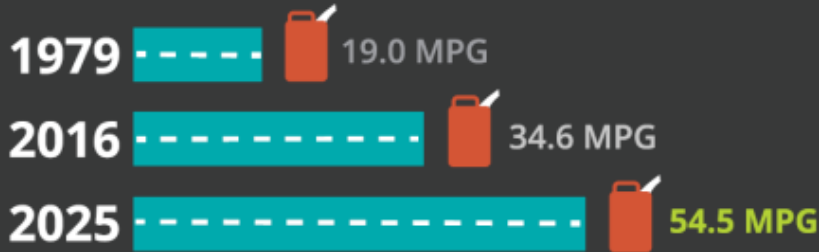


\$160 Billion

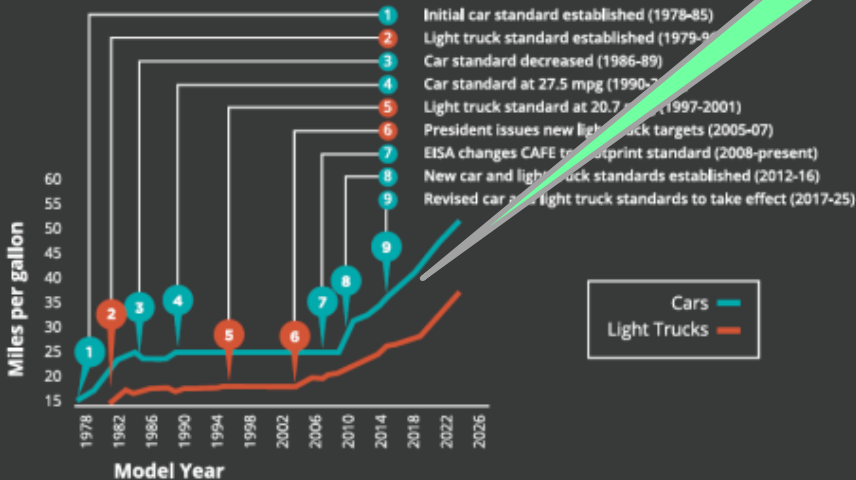


Trends Shaping Mobility – Policy

New stronger fuel economy standards will double the efficiency of our cars and trucks. Corporate Average Fuel Economy Standards have saved 14 billion tons of CO₂ emissions since 1970.



New Standards in Fuel Efficiency: Milestones

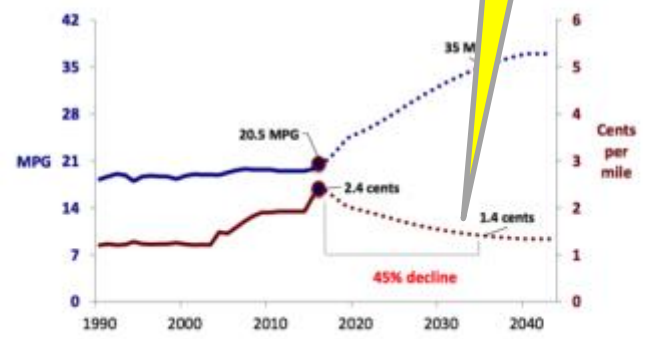


Erosion of revenues from gasoline tax

New approaches: Road Use Charge

Improving Vehicle MPG Threatens Our Gas Tax Revenues

Conservative forecasts: Washington's vehicles will reach 35 MPG by 2035 - a potential 45% reduction in gas tax revenue per mile driven.



State fuel tax rate increases in 1990, 2003, 2005-2008, and 2015-2016

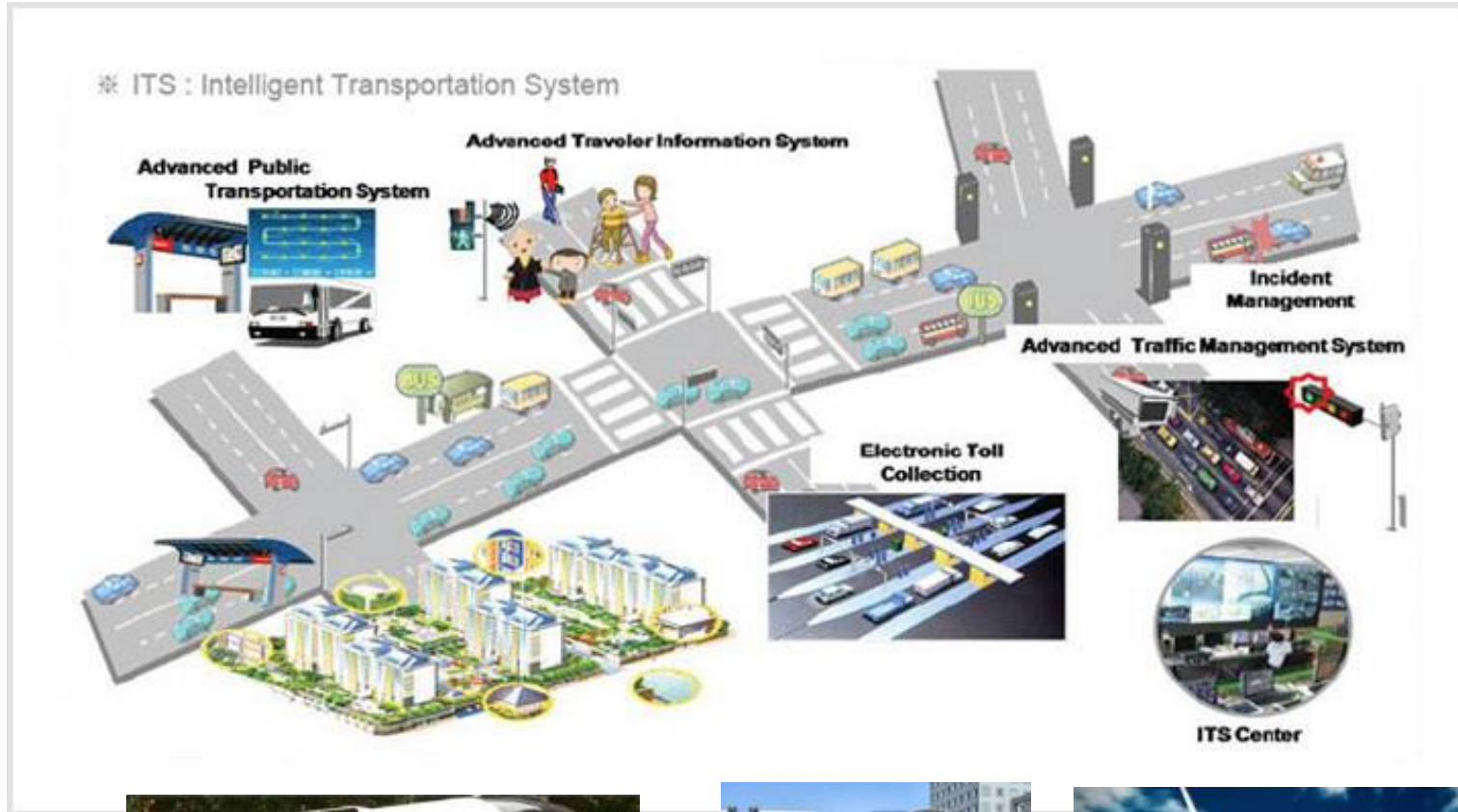
Source: WA- State Transportation Commission

Trends Shaping Mobility – Technology



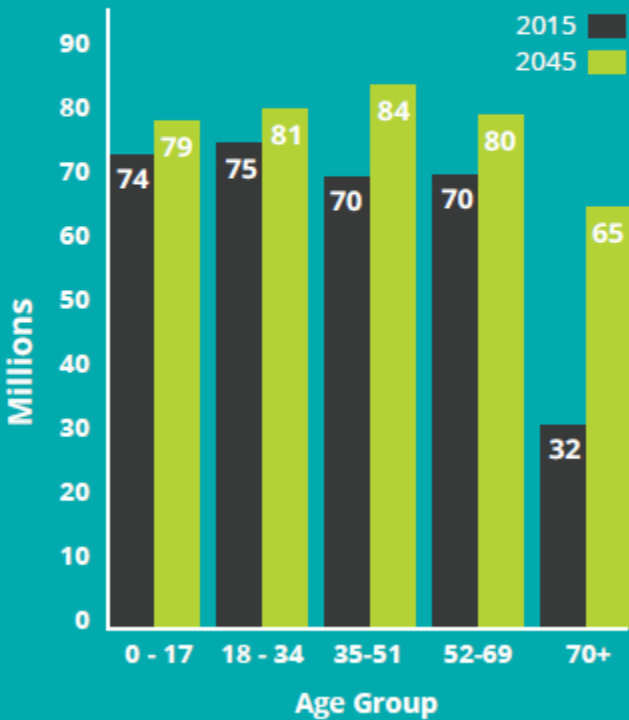
Source: Ericsson Technology Review, #1, 2016

Trends Shaping Mobility – Technology



Trends Shaping Mobility – Population/Demographics

Projected Additional Population by Age Group



Americans are Living Longer



By 2045, the number of Americans over age 65 will increase by **77%**. About **one-third** have a disability that limits mobility.



Millennials are Connected & Influential

There are **73 million** Americans aged 18 to 34, and they drove **20% fewer miles** in 2010 than at the start of the decade.

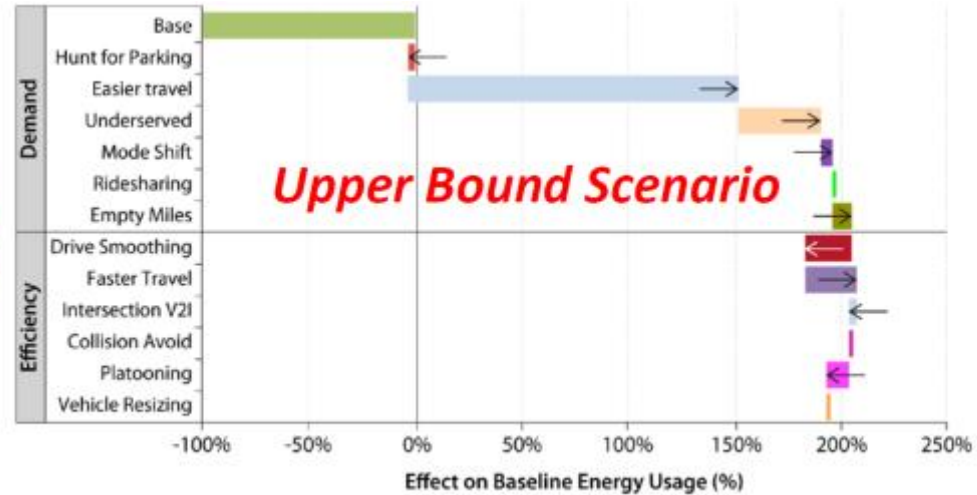


Source: U.S. DOT. Beyond Traffic 2045.

Disruptive Technology – uncertain energy impacts

+200%

Potential Increase in Energy Consumption



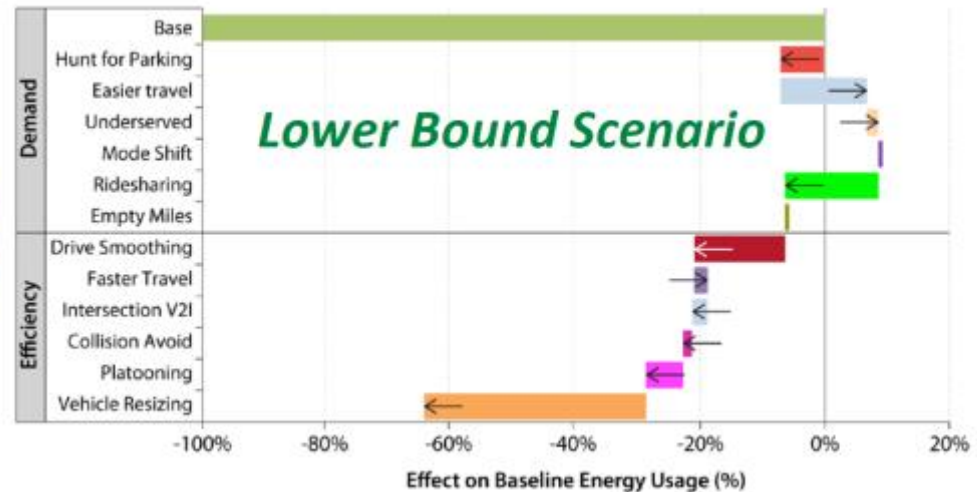
2050 Baseline

Energy Consumption



Potential Decrease in Energy Consumption

-60%



What are the Key Drivers Toward Smart Transportation

Regulatory Perspective

- ▶ Reduction of fatalities/accidents
- ▶ Managing congestions
- ▶ Environmental constraints
 - GHG mitigation
 - Cleaner air
- ▶ Fuels security

Market Forces and Compelling Business perspective

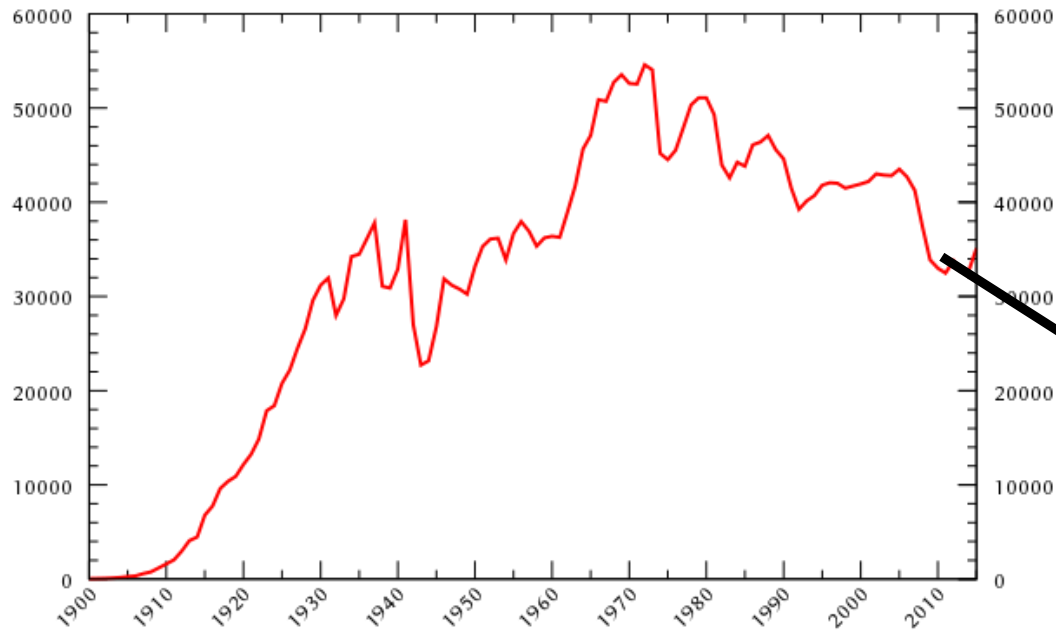
- ▶ Cost reduction
 - Long-haul trucking
 - Last-mile delivery
- ▶ New business models
 - Ride-sharing
 - Transportation as a service



Source: US DOT

Total US Traffic Fatalities

Of all accidents 94% were caused by human failure
At total loss of \$836B per year



Source: NHTSA, 2015

Additional 90% reduction
With autonomous cars
By mid-century

Source: McKinsey, June 2015

Managing Congestion

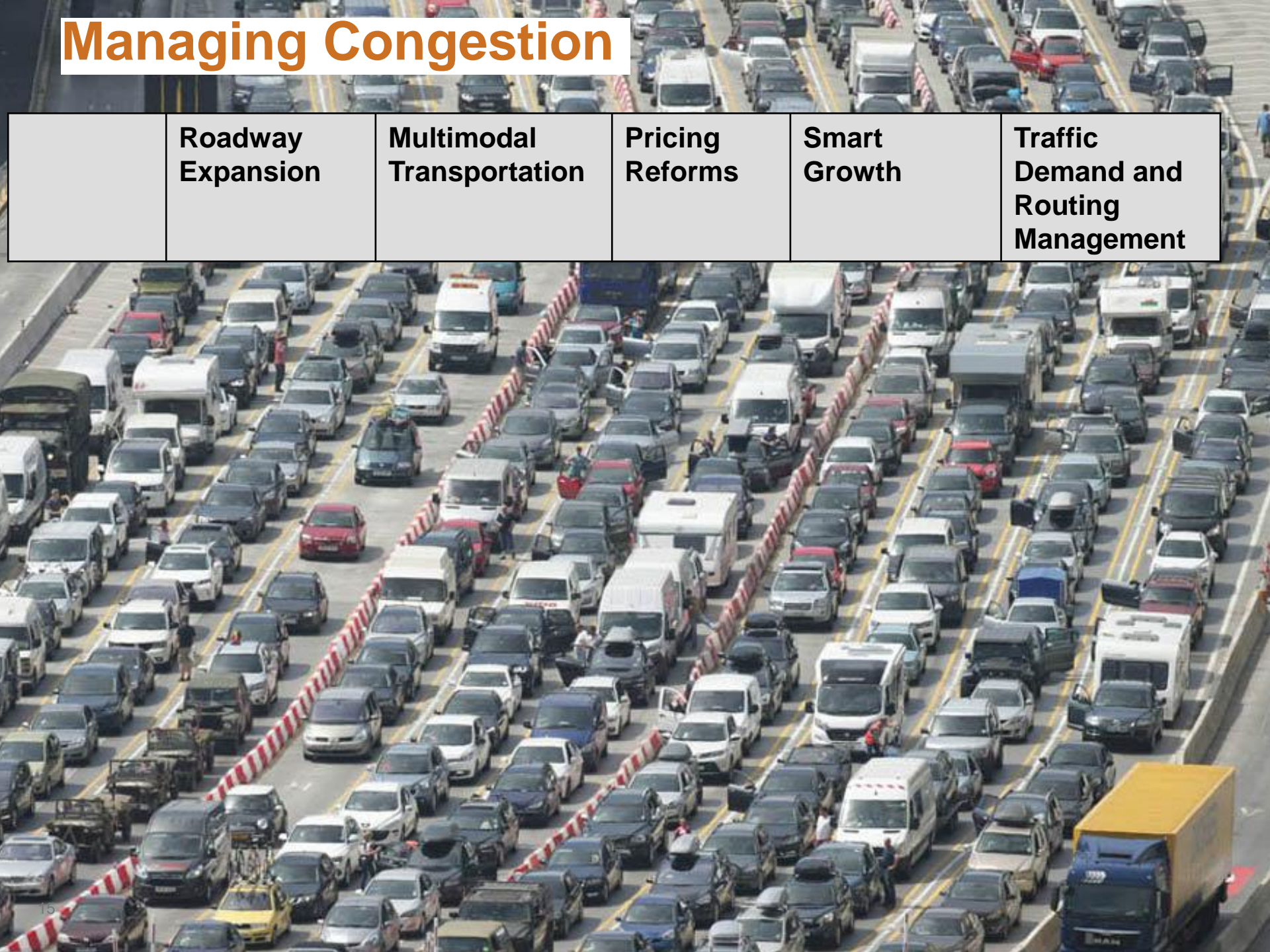
**Roadway
Expansion**

**Multimodal
Transportation**

**Pricing
Reforms**

**Smart
Growth**

**Traffic
Demand and
Routing
Management**



Managing Congestion

	Roadway Expansion	Multimodal Transportation	Pricing Reforms	Smart Growth	Traffic Demand and Routing Management
Congestion impacts	Reduces short-run congestion, but diminishing efficacy due to newly generated demand (build and they will come)	Reduces but often does not eliminate congestion	Can significantly reduce congestion	May increase local congestion intensity, but reduces regional congestion	Can reduce congestion delays, however, could require large infrastructure investments



Old paradigm



Managing Congestion

	Roadway Expansion	Multimodal Transportation	Pricing Reforms	Smart Growth	Traffic Demand and Routing Management
Congestion impacts	Reduces short-run congestion, but diminishing efficacy due to newly generated demand	Reduces but often does not eliminate congestion <i>(Requires shift in human behavior)</i>	Can significantly reduce congestion	May increase local congestion intensity, but reduces regional congestion	Can reduce congestion delays, however, could require large infrastructure investments



Source: Stanley consultants



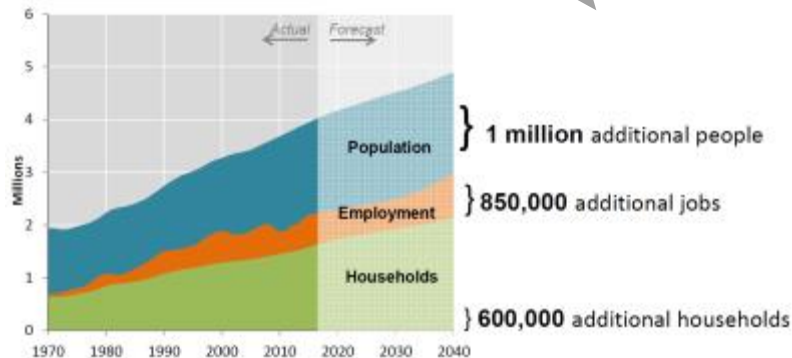
Source: door2door.io



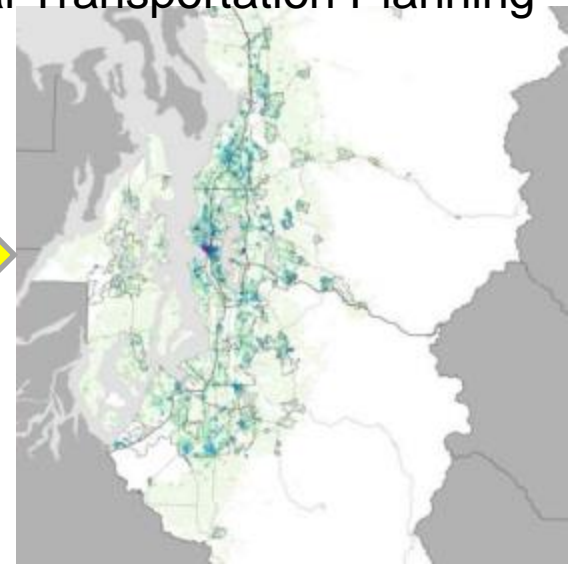
Managing Congestion

	Roadway Expansion	Multimodal Transportation	Pricing Reforms	Smart Growth	Traffic Demand Management Programs
Congestion impacts	Reduces short-run congestion, but diminishing efficacy due to newly generated demand	Reduces but often does not eliminate congestion	Can significantly reduce congestion	May increase local congestion intensity, but reduces regional congestion	Can reduce congestion delays, however, could require large infrastructure investments

Example: Puget Sound



Regional Transportation Planning



Managing Congestion

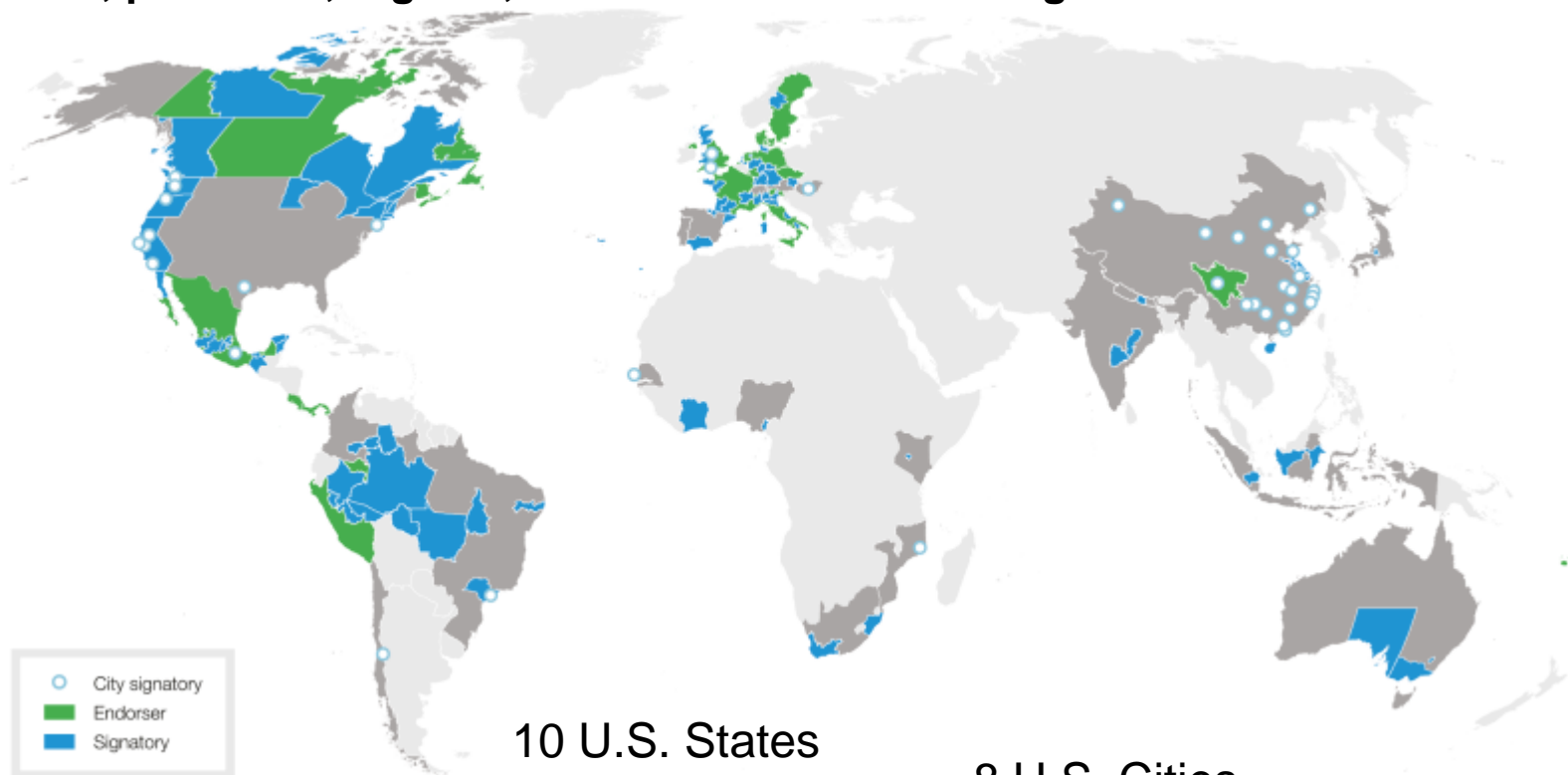
	Roadway Expansion	Multimodal Transportation	Pricing Reforms	Smart Growth	Traffic Demand and Routing Management
Congestion impacts	Reduces short-run congestion, but diminishing efficacy due to newly generated demand	Reduces but often does not eliminate congestion	Can significantly reduce congestion	May increase local congestion intensity, but reduces regional congestion	Can reduce congestion delays, however, could require large infrastructure investments

- Central signal systems
- Transit signal priority
- Ramp metering
- Active traffic management



GHG Emissions Reductions

176 states, provinces, regions, cities and nations have signed or endorsed the Under2 MOU



10 U.S. States

- ▶ California
- ▶ Connecticut
- ▶ Massachusetts
- ▶ Minnesota
- ▶ New Hampshire
- ▶ New York State
- ▶ Oregon
- ▶ Rhode Island
- ▶ Vermont
- ▶ **Washington (May 2015)**

8 U.S. Cities

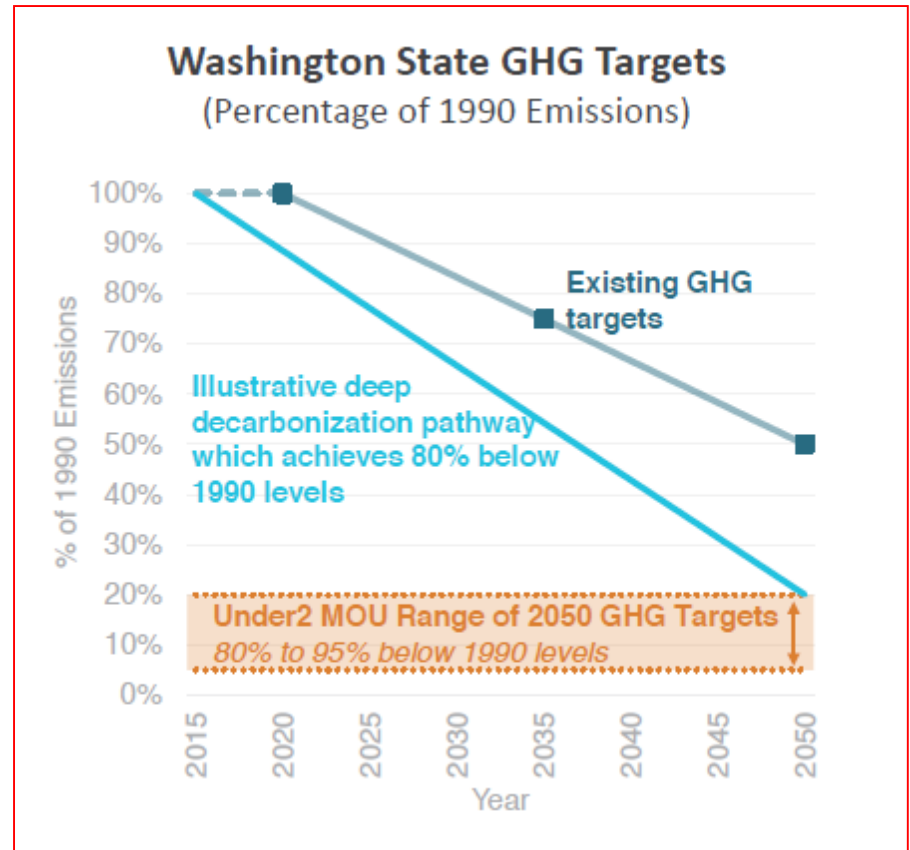
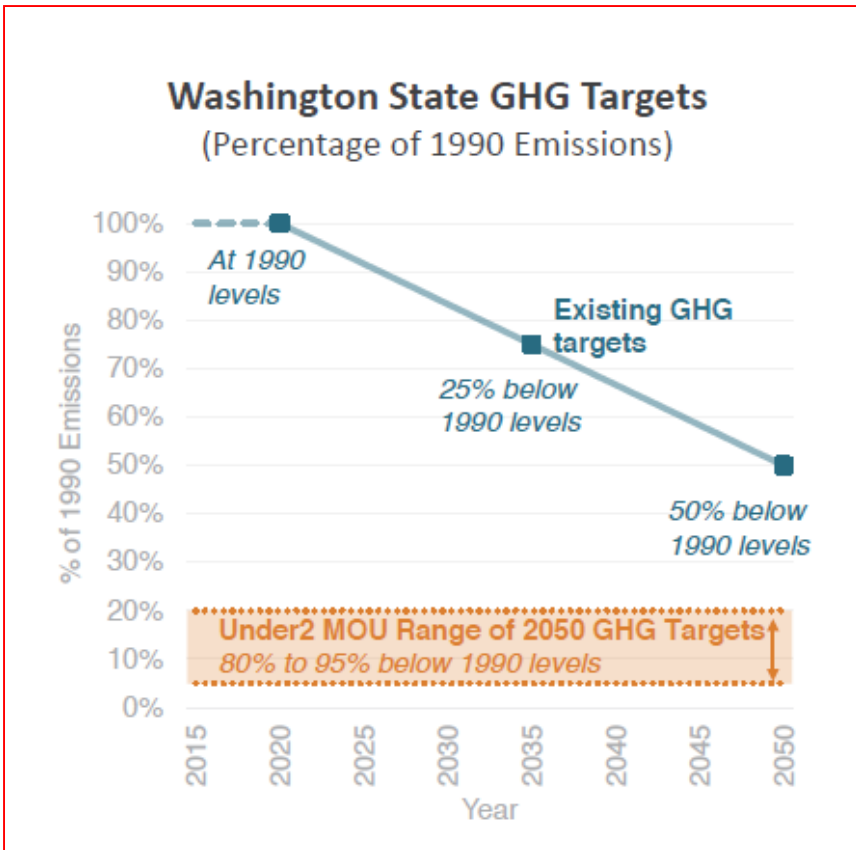
- ▶ Austin, TX
- ▶ LA
- ▶ NYC
- ▶ Oakland, CA
- ▶ Portland, OR
- ▶ Sacramento
- ▶ SF
- ▶ Seattle

Source: www.under2mou.org

WA State: Deep Decarbonization Pathways

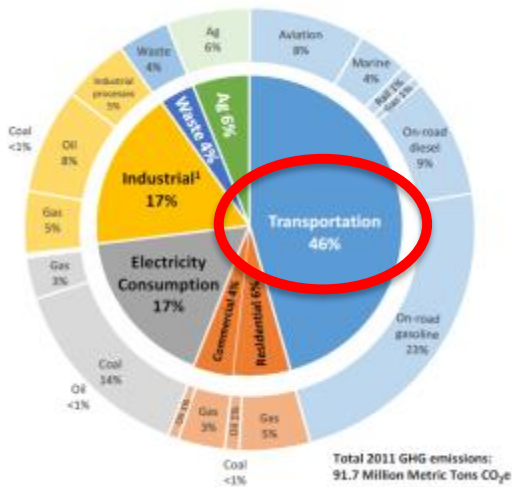
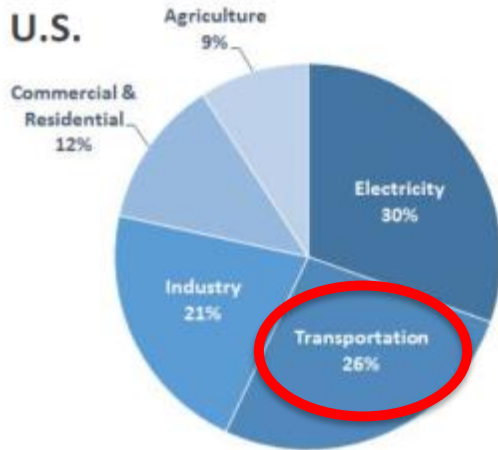
- ▶ WA-State current law (RCW 70.235.040) : existing limits (below 1990 levels)
 - 25% by 2035
 - 50% by 2050

Deep Decarbonization Pathway



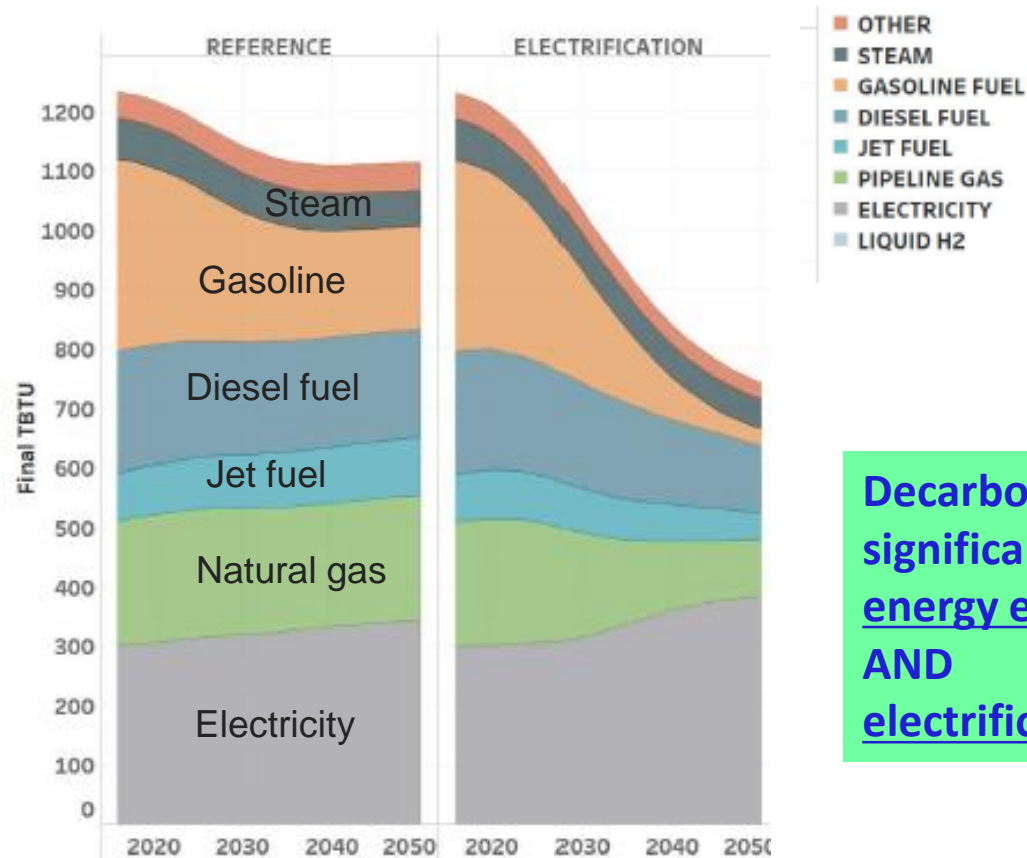
Sectoral Contribution to GHG Emissions

GHG Emissions by Sector



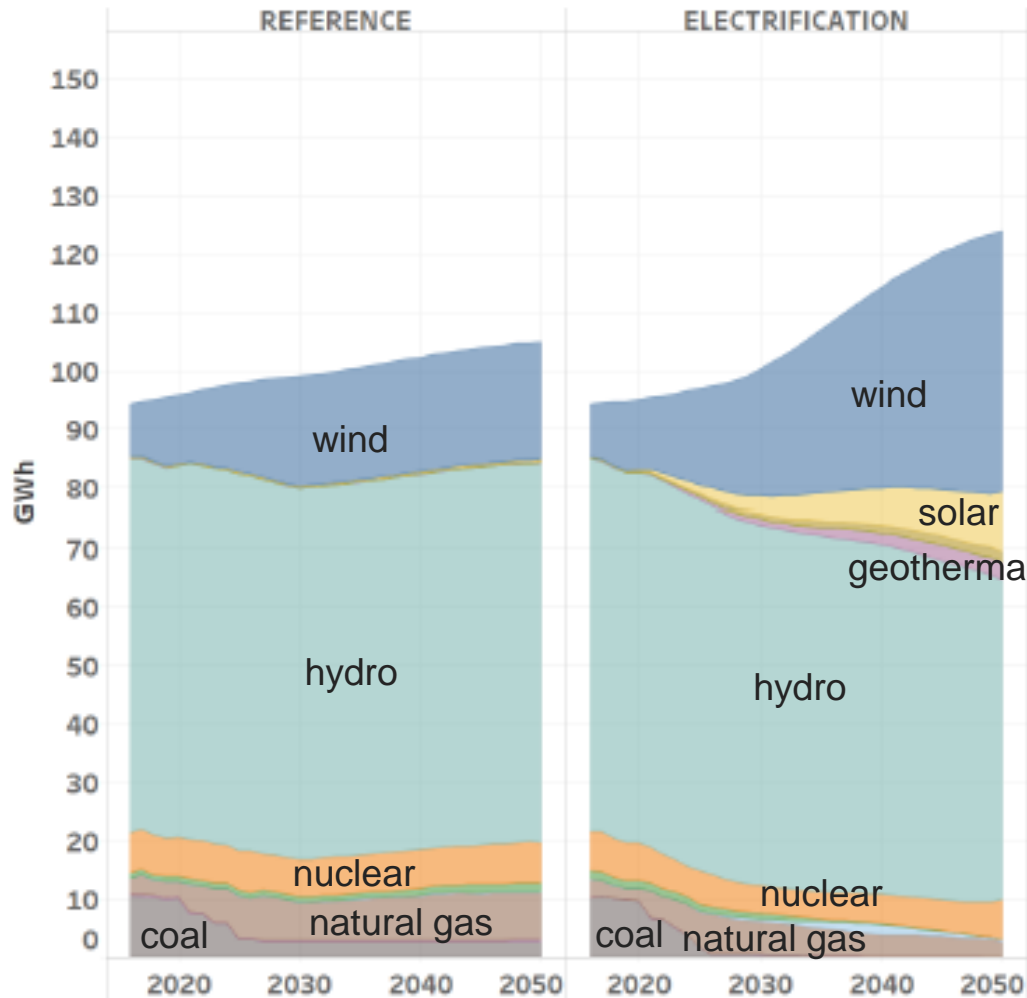
WA State GHG reduction strategy must address foremost **Transportation!!**

Final Energy Demand



Decarbonization pathways result in significantly lower consumption through energy efficiency improvements AND electrification of transportation

Electricity Generation



Decarbonization pathways requires Deep electrification

- primarily transportation (on-road)
- space heating
- industrial processes

Added Capacity of:

- Wind
- Solar
- Geothermal


Clean Air Regulation (International Perspective)

Announcements:

- Britain: banning sales of gasoline and diesel cars (2040)
- France: ending sales of gasoline and diesel vehicles (2040)
- India: all vehicles sold must be electric (2030)
- Norway: clear government target: all cars and vans must be zero-emission by 2025



Court rules that Stuttgart must ban diesel engines from city centre



Diesel Pollution Workshop & Dinner

.....



Diesel pollution is a problem in N/NE Portland. We breathe in some of the dirtiest air in the country. How did this happen & what we can we do about it?

.....

WEDNESDAY, JANUARY 18
6 PM - 8 PM (DINNER 6-6:30)
LOCATION: UNITE OREGON
700 N. KILLINGSWORTH ST.
OFFERING BUS PASSES

.....

Hosted by Neighbors for Clean Air and Northeast Coalition of Neighborhoods
Questions? Contact: 503-388-5030, communications@necoalition.org
Visit: www.whatsinourair.org



Compelling Business Cases: Autonomous Vehicles

► Cost Reduction for Long-Haul Trucking

- Estimated ROI: 3 years
- Benefits:
 - Higher fuel efficiency and lower maintenance due to optimized truck operations
 - Driver satisfaction: drivers don't have to work for long periods
 - Improved safety
- First manifestations of AV: truck platooning
- Market introduction: mid-2020s



Source: Mercedes-Benz

► Transportation-as-a-service (TaaS)

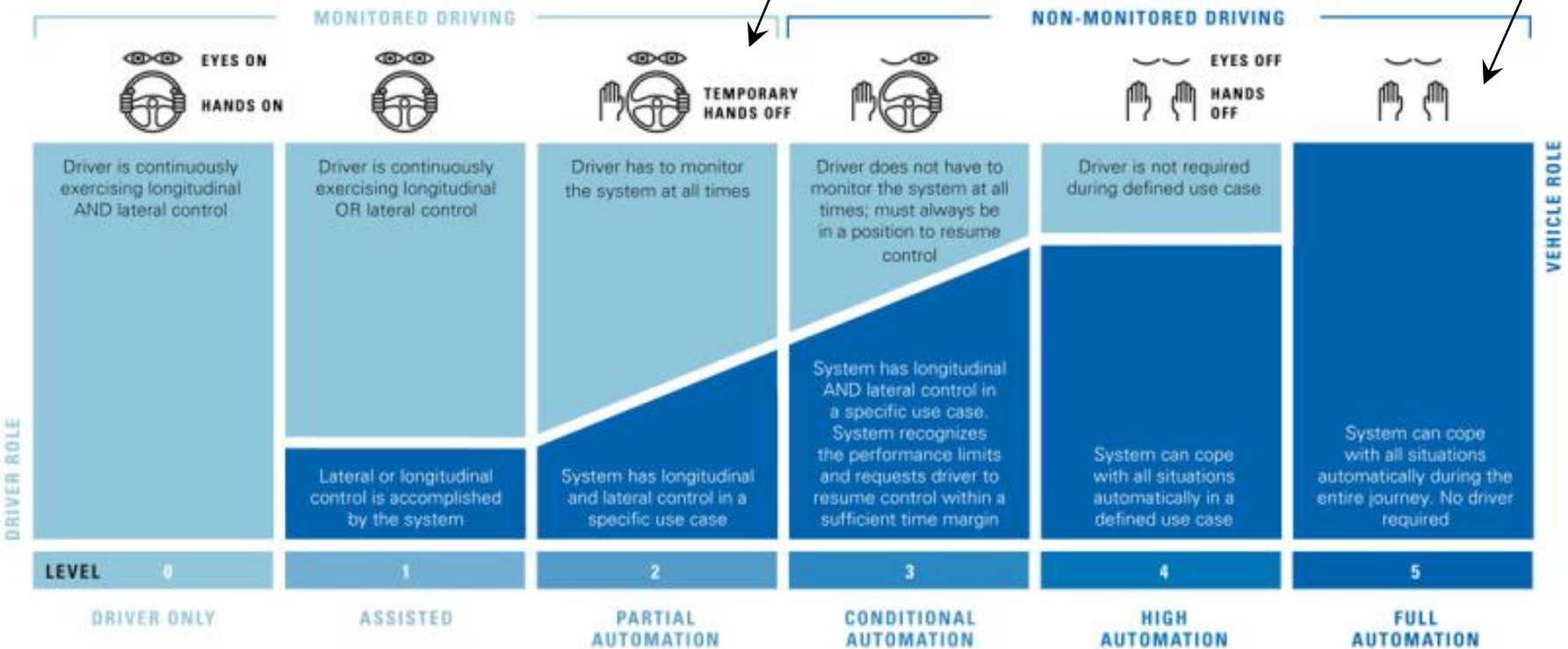
- New business models by accessing fleets without owning vehicles
 - Uber, Lyft, Didi, GETT, Hailo, Addison Lee, Ola Cabs, Meru, BlaBla Car, Mytaxi, Grab Taxi, Kako Taxi, Hailo, Sidecar, Flywheel, VIA, Curs, Ingogo, Chauffeur-Prive, Lecab, Easy, Careem



Source: Iveco autonomous vehicle concept

Definitions of Autonomous Driving Capabilities

Tesla Autopilot: Level 2



Modified: SAE J3016 Taxonomy and Definitions or Terms Related to On-Road Motor Vehicle Automated Driving Systems

What Technology to Expect in the Automotive Showrooms?

- ▶ **GM:** in 2016 bought start-up company Cruise Automation (\$586 M) and developed R&D center. Also acquired 9% of Lyft. No timeline
- ▶ **Ford:** announced to have Level 4 vehicle by 2021. Announced to buy Argo AI for \$1B.
- ▶ **Honda:** announced to offer vehicle for self-driving on highways in 2020. Showcasing for the 2020 Summer Olympics. In discussion with Waymo.
- ▶ **Toyota:** most skeptical companies. Catching up with peers. Investing \$1 B.
- ▶ **BMW:**
 - Collaborating with Intel
 - Level 4 and 5 by 2021
- ▶ **Tesla:** Autopilot (level 2): in 2017

What Technology to Expect in the Automotive Showrooms? (continued)

▶ **Renault/Nissan:**

- Working with Microsoft
- Announced to provide self-driving vehicle by 2020 for urban environments
- Likely by 2025 truly driverless vehicle

▶ **Volvo:**

- Self-driving on highways by 2021
- Joint venture with Uber (\$300M)
- Will take over full liability for self-driving vehicles to boost customer confidence

▶ **Hyundai:**

- Self-driving on highway 2020 and in urban environments by 2030
- Investing \$1.7B

▶ **Daimler (Mercedes-Benz):**

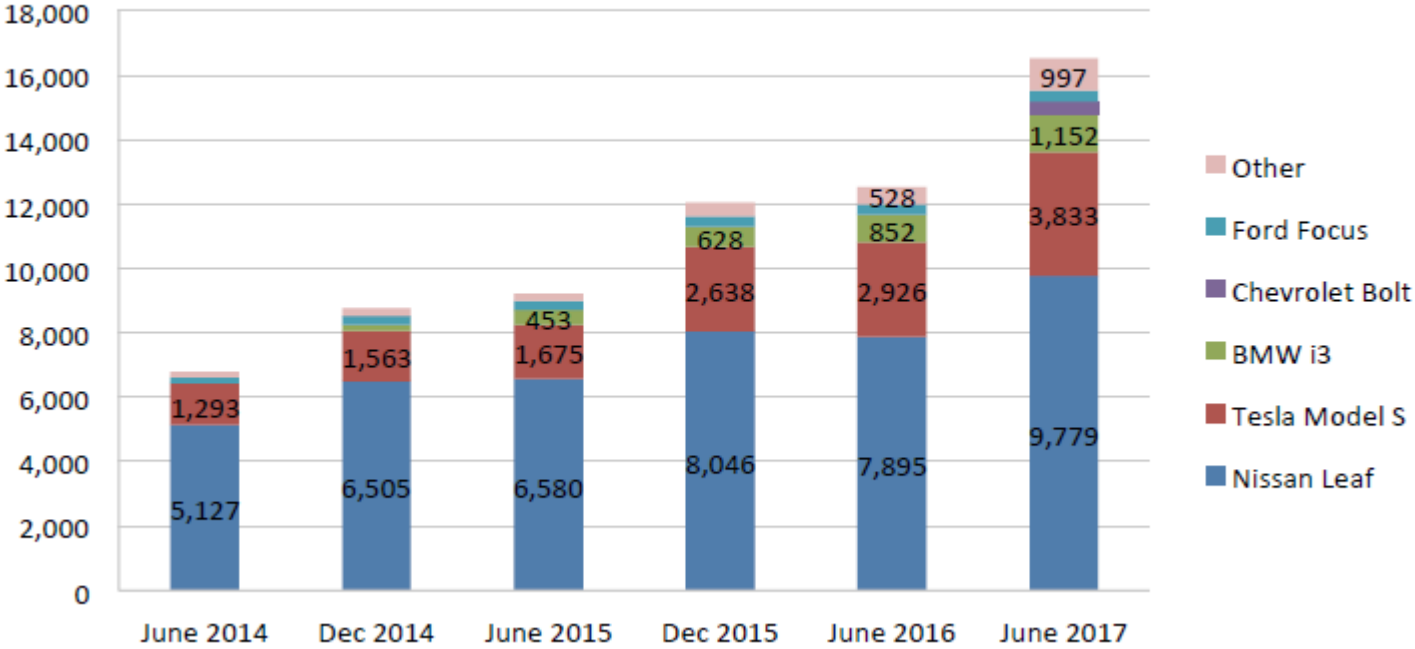
- Collaborating with Bosch
- Deal with Uber
- Announced level 4 and 5 at the beginning of 2020s

▶ **Fiat-Chrysler:**

- Teamed with Waymo
- Expects self-driving within 5 years

How are we doing in Washington State?

Battery Electric Vehicle Registrations by Model¹

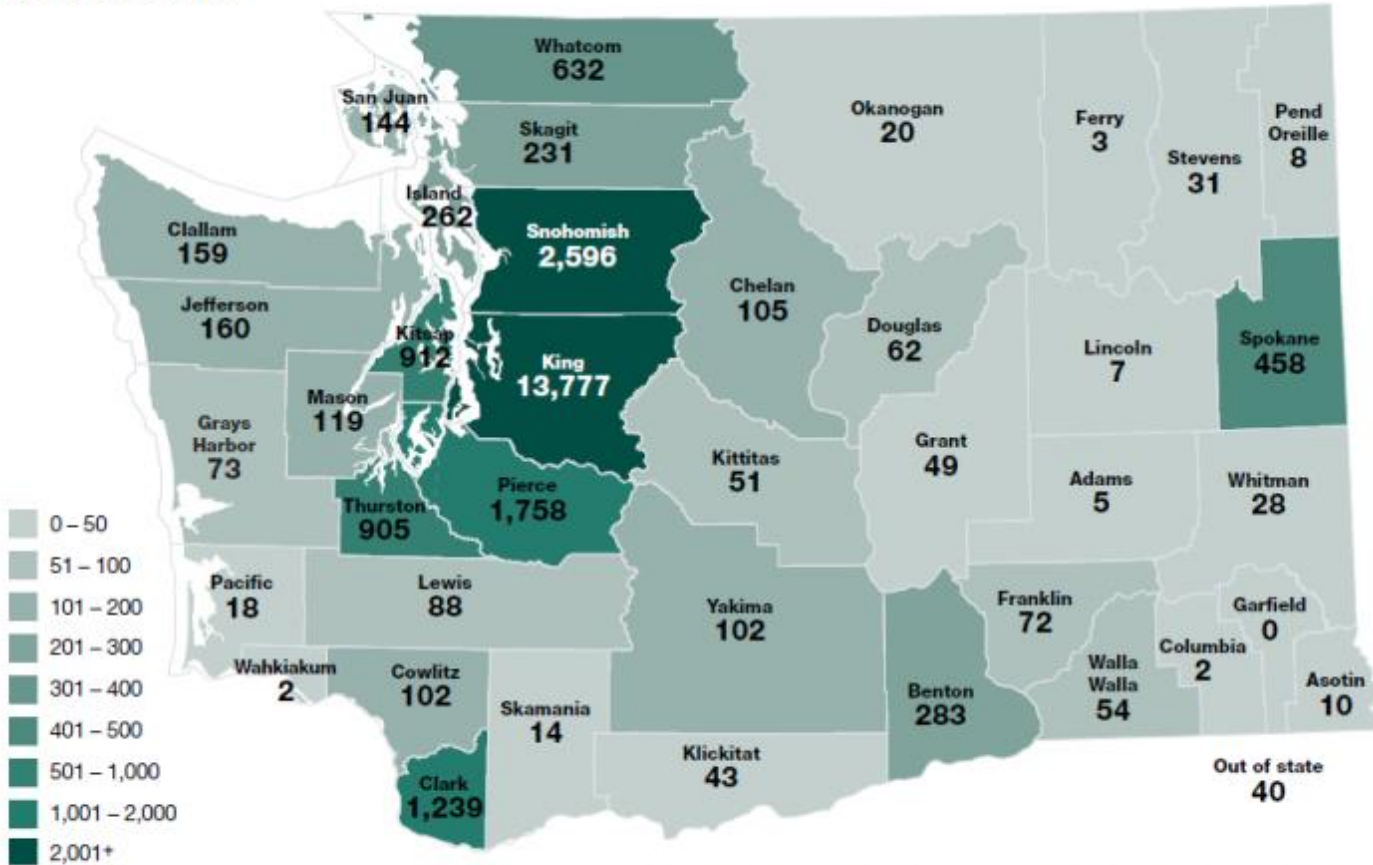


Source: WSDOT: WA Plug-in electric vehicle update through June 2017

How are we doing in Chelan County?

24,624 Plug In Electric Vehicles Registered in Washington

As of June 30, 2017



Map includes Electric Vehicles (EVs) produced by major automakers since about 2011. It does not include cars that were converted to EVs by their owners, neighborhood EVs or EV models from the 1990's that are still registered in Washington, or motorcycles. WSDOT created this map based on data provided by the Washington State Department of Licensing.

17-09-0390

How to Charge the Vehicle at Home?

Level 1



Charging outside: 120V (Level 1)
With 120V: 8-12 hours charging



Level 2



Charging inside: 240V (Level 2)
With 240V: 1-3 hours charging



Fast Charging in 15 Minutes using DC electricity



240V (AC)
(Level 2)

DC connection
(Level 3)



DC connection
(Level 3)

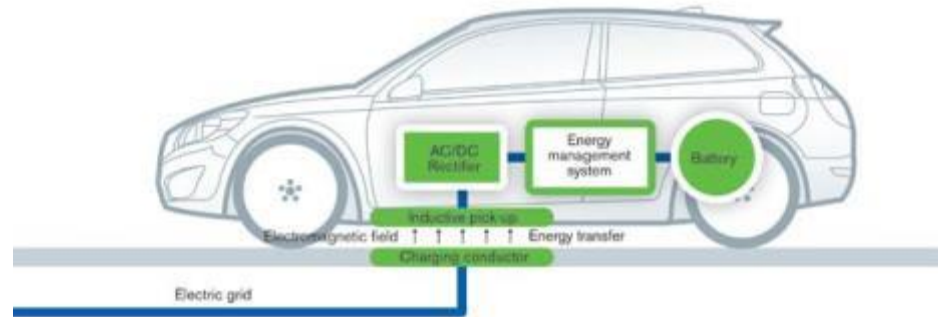
240V (AC)
(Level 2)

Do We Need a Cord for Charging

Wireless Charging



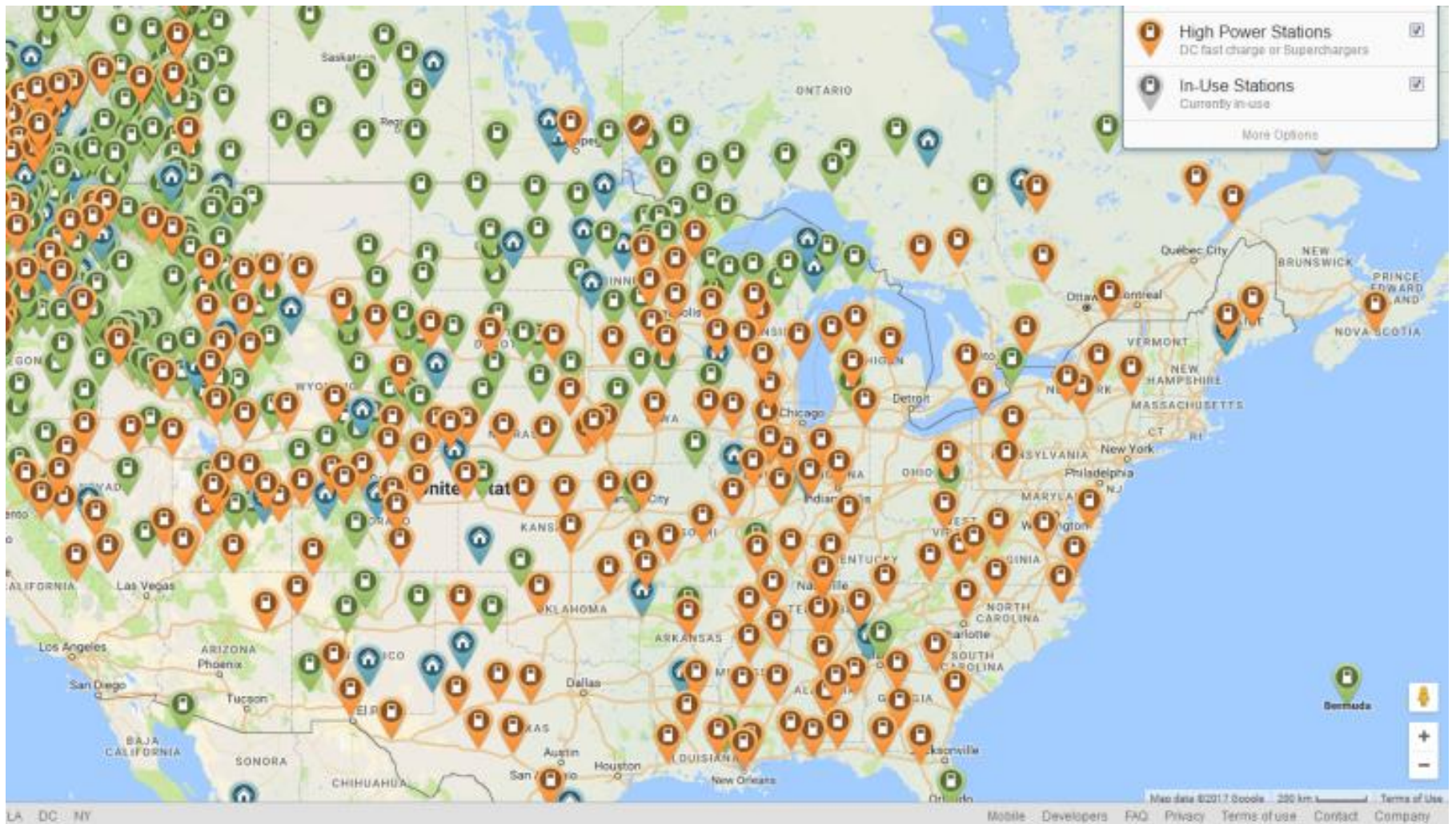
Inductive energy transfer



Dynamic wireless charging



EV Charging Infrastructure



Source: <https://www.plugshare.com/>

EV Trip-Tick: Richland to UW, Seattle (228 miles)

To UW: 32 mi

To Snoqualmie Pass: 32 mi

To North Bend: 24 mi

To Cle Elum: 25 mi

To Ellensburg: 36 mi

To Yakima: 50 mi

To Prosser: 29 mi

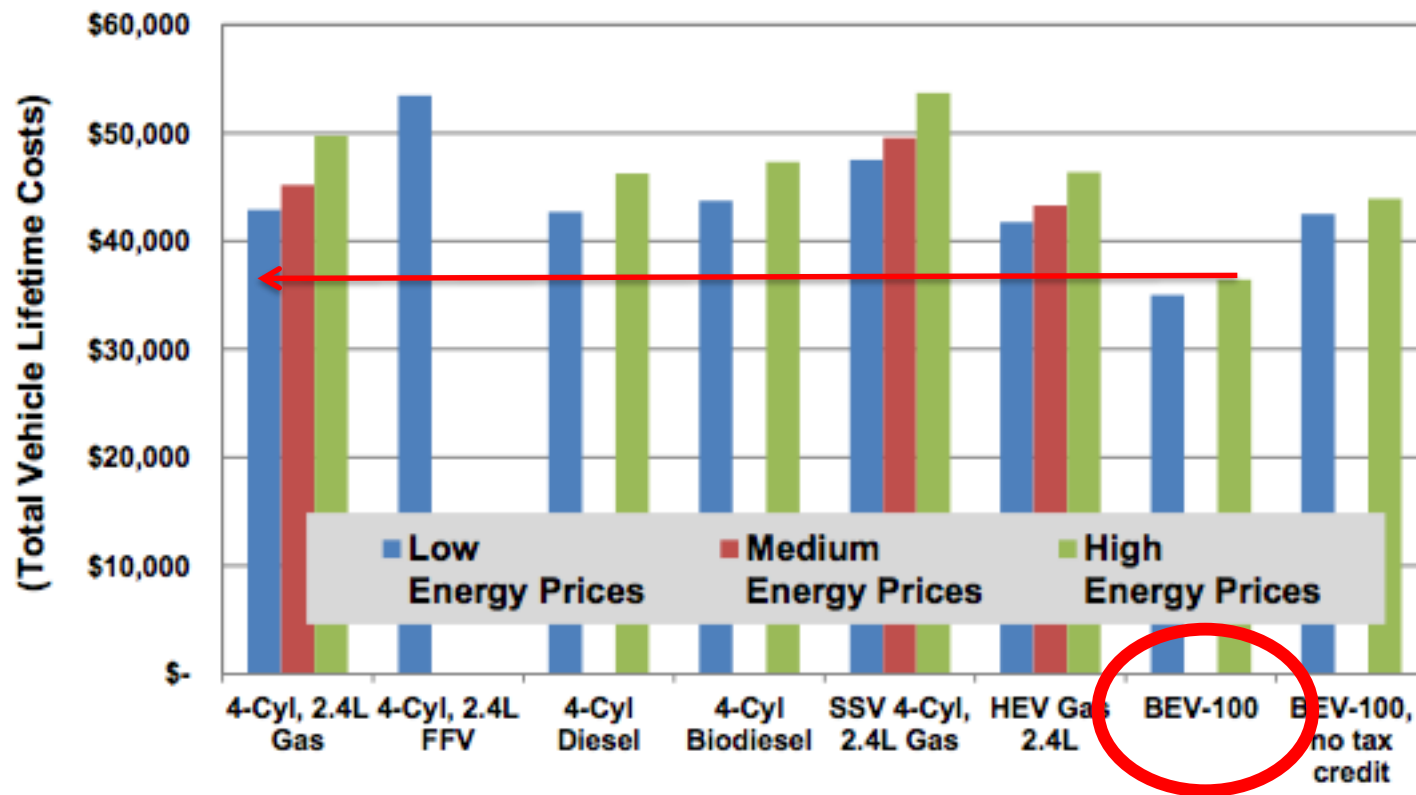


Five Reasons for Considering Buying an Electric Vehicle

5. EV's lowest total cost of ownership today
- 4.
- 3.
- 2.
- 1.

Total Cost of Ownership

Estimated Total Cost of Ownership Comparison for Mid-Size LDV Options with 120,000 Lifetime Miles, United States: 2012



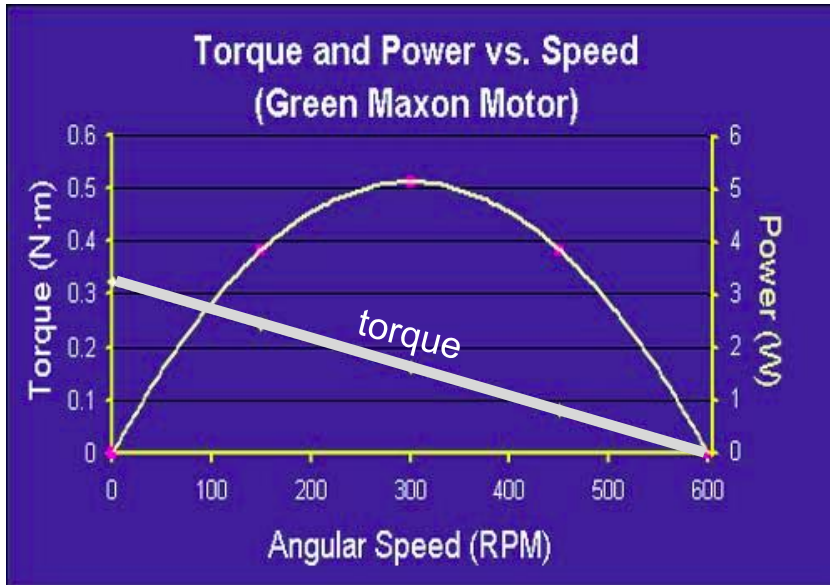
(Source: Pike Research)

Five Reasons for Considering Buying an Electric Vehicle

5. EV's lowest total cost of ownership today
4. Excellent performance
- 3.
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- 1.

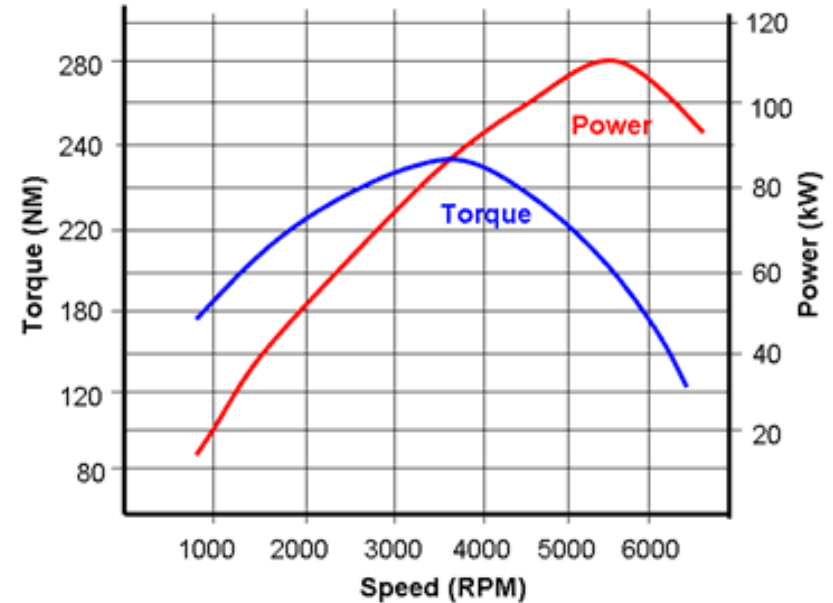
Performance: Electric motor generates maximum torque at lowest speeds

Electric motor



Internal combustion engine

Engine Power and Torque Curves



Tesla Roadster

Five Reasons for Considering Buying an Electric Vehicle

5. EV's lowest total cost of ownership today
4. Excellent performance
3. It is good for the environment
- 2.
- 1.

No Emissions from Well-to-Wheel Perspective

Clean Hydropower

No generation emissions



No tailpipe emissions

(PM, NO_x, HC, CO)

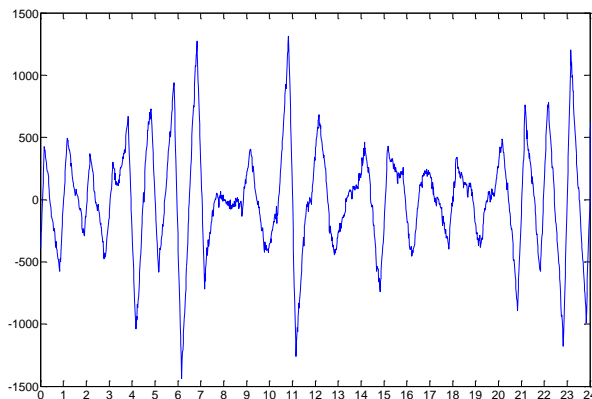


Clean Well-to-Wheel for Chelan County

Five Reasons for Considering Buying an Electric Vehicle

5. EV's lowest total cost of ownership today
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3. It is good for the environment
2. It is good for the grid
- 1.

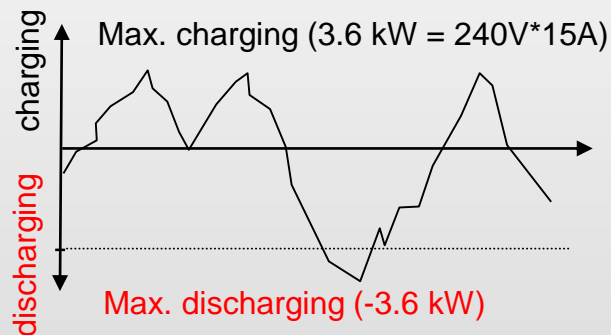
Electric Vehicles Can Provide Balancing Services for Integration of Wind Energy



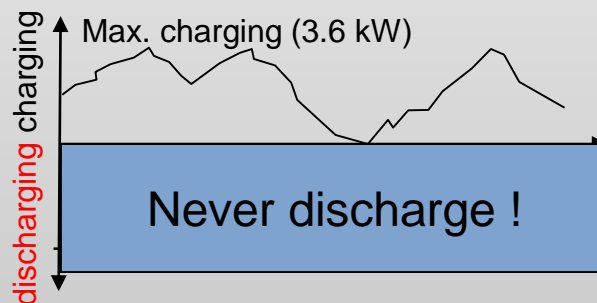
New Balancing Requirements

Single day of additional balancing requirements for 10 GW of additional wind in NWPP.

Solution Options



V2GFull

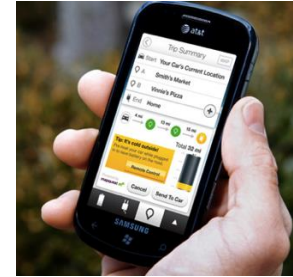


V2GHalf

Five Reasons for Considering Buying an Electric Vehicle

5. EV's lowest total cost of ownership today
4. Excellent performance
3. It is good for the environment
2. It is good for the grid
1. It is “cool” technology, it will be part of the future

“Cool” Technology.... An essential part of tomorrow’s transportation technology



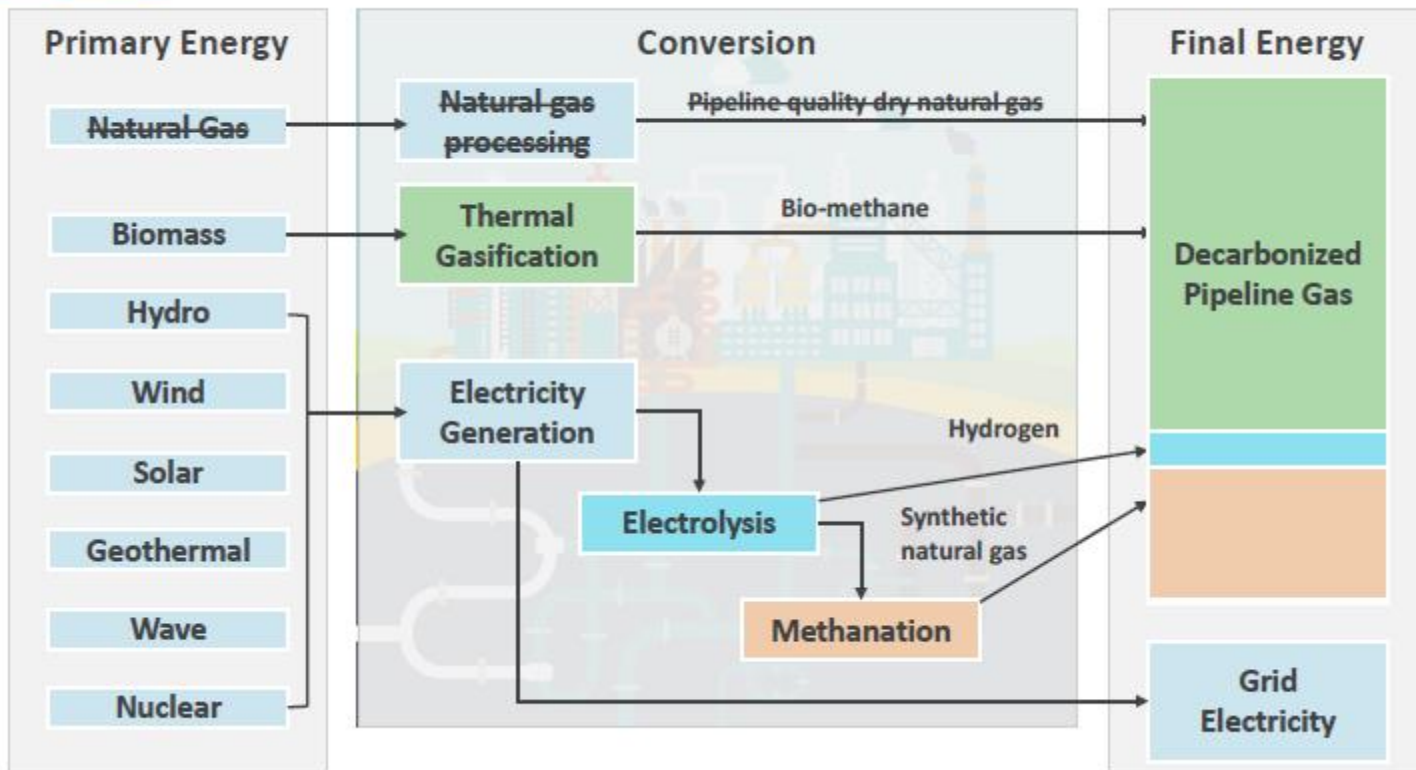
Final thoughts

The best way to predict the future is to create it

Abraham Lincoln and Peter Drucker

Backup Slides

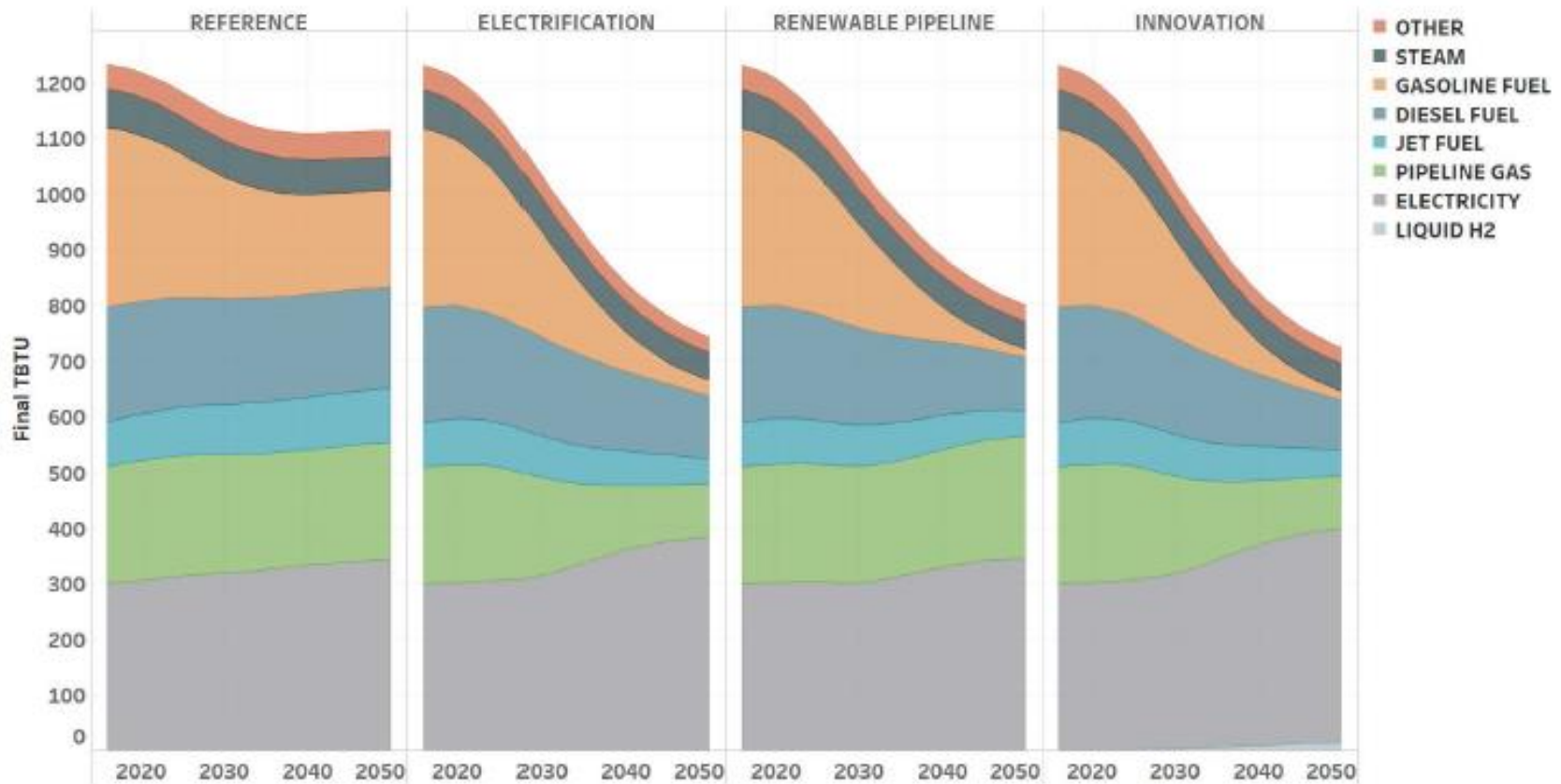
Decarbonized Pipeline Gas



Final Energy Demand

All decarbonization pathways show:

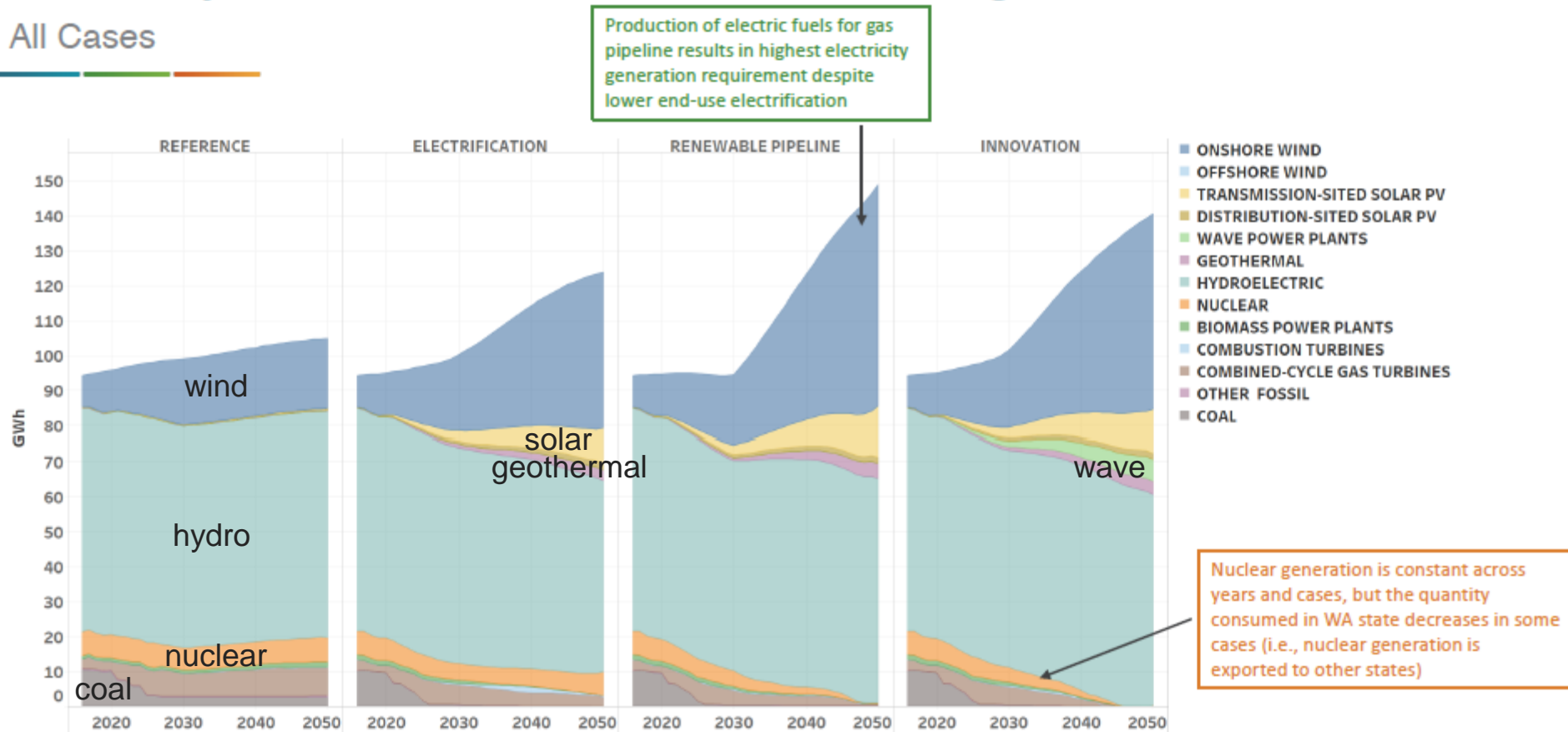
- lower final energy
- Increased electricity consumptions



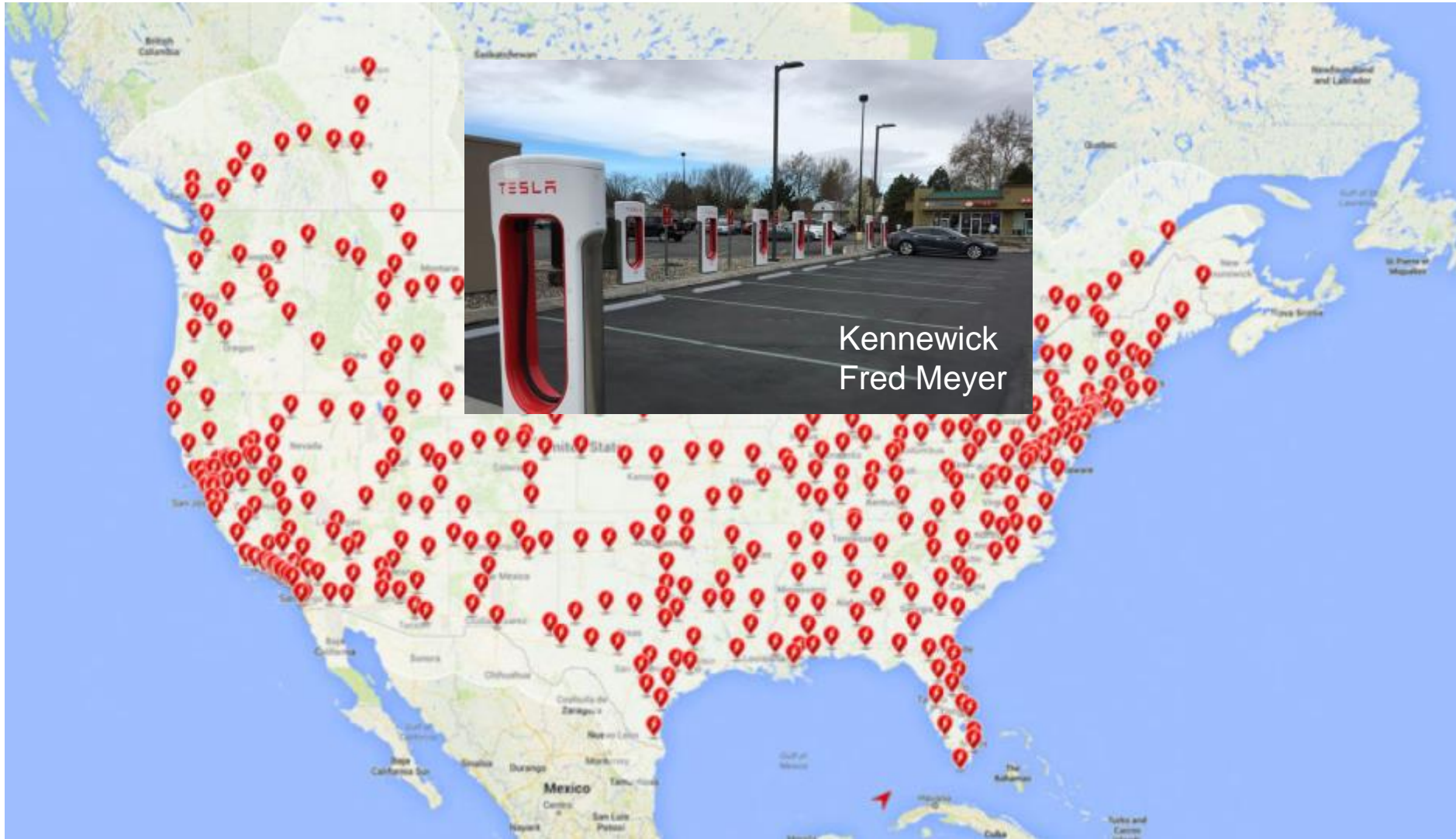
Electricity Generation

Electricity Generation Consumed in Washington State

All Cases



Tesla Charging Network



Source: Tesla Motors, 2015

Tesla Motors: World-Wide Charging Network



Source: Tesla Motors, 2016

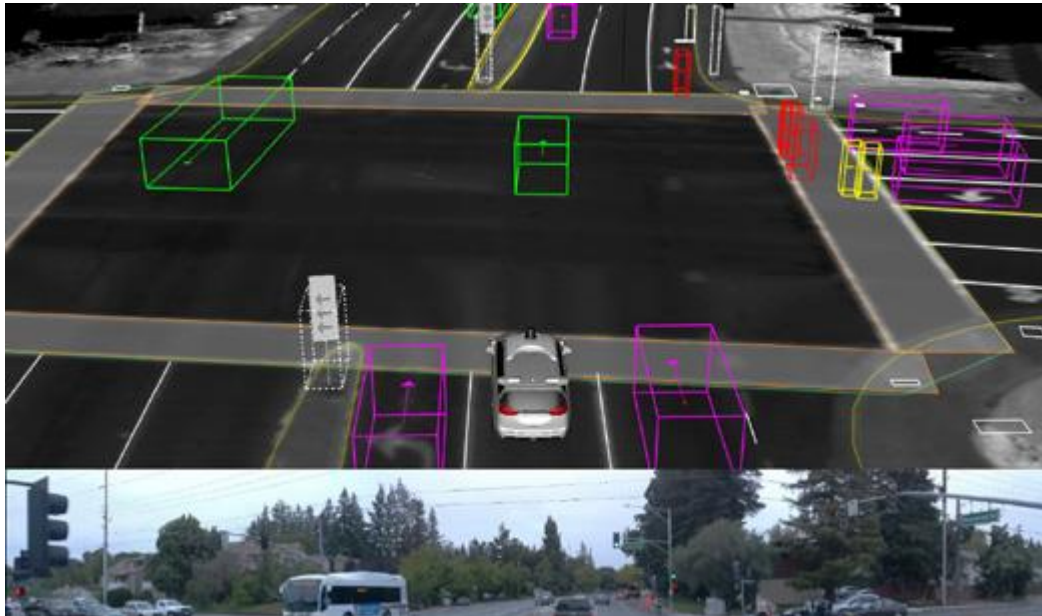
How “Self-Driving” vehicles work?



Where Am I?

Source: On the Road to fully self-driving. Waymo Safety Report, September 2017

How “Self-Driving” vehicles work?



What is around me?

Source: On the Road to fully self-driving. Waymo Safety Report, September 2017

How “Self-Driving” vehicles work?

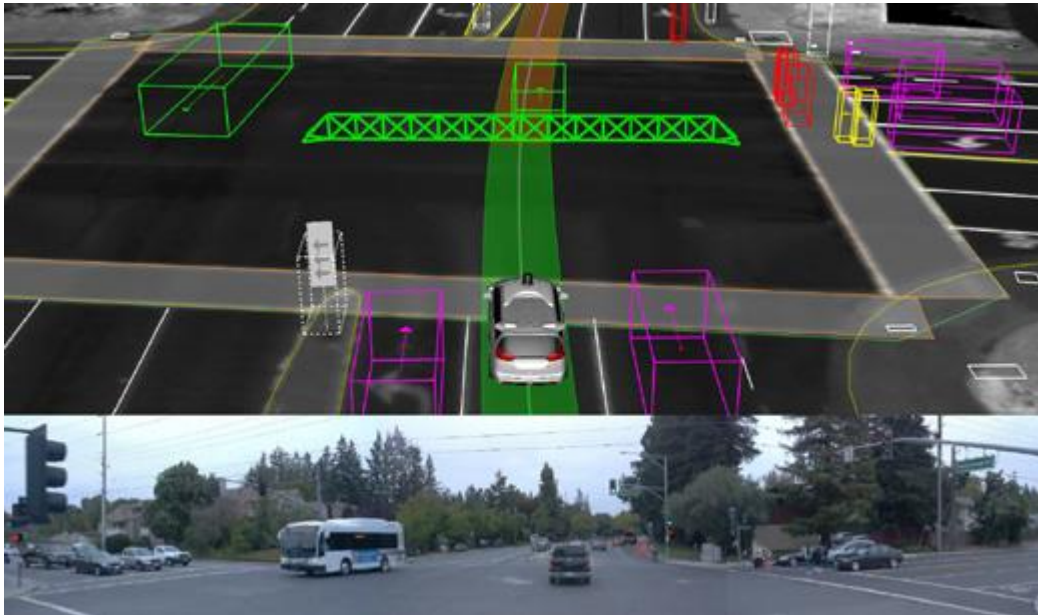
What will happen next?



Source: On the Road to fully self-driving. Waymo Safety Report, September 2017

How “Self-Driving” vehicles work?

What should I do?



Source: On the Road to fully self-driving. Waymo Safety Report, September 2017