What is the Potential for Off-Cycle Technology for Connected Autonomous Vehicles (CAVs)?

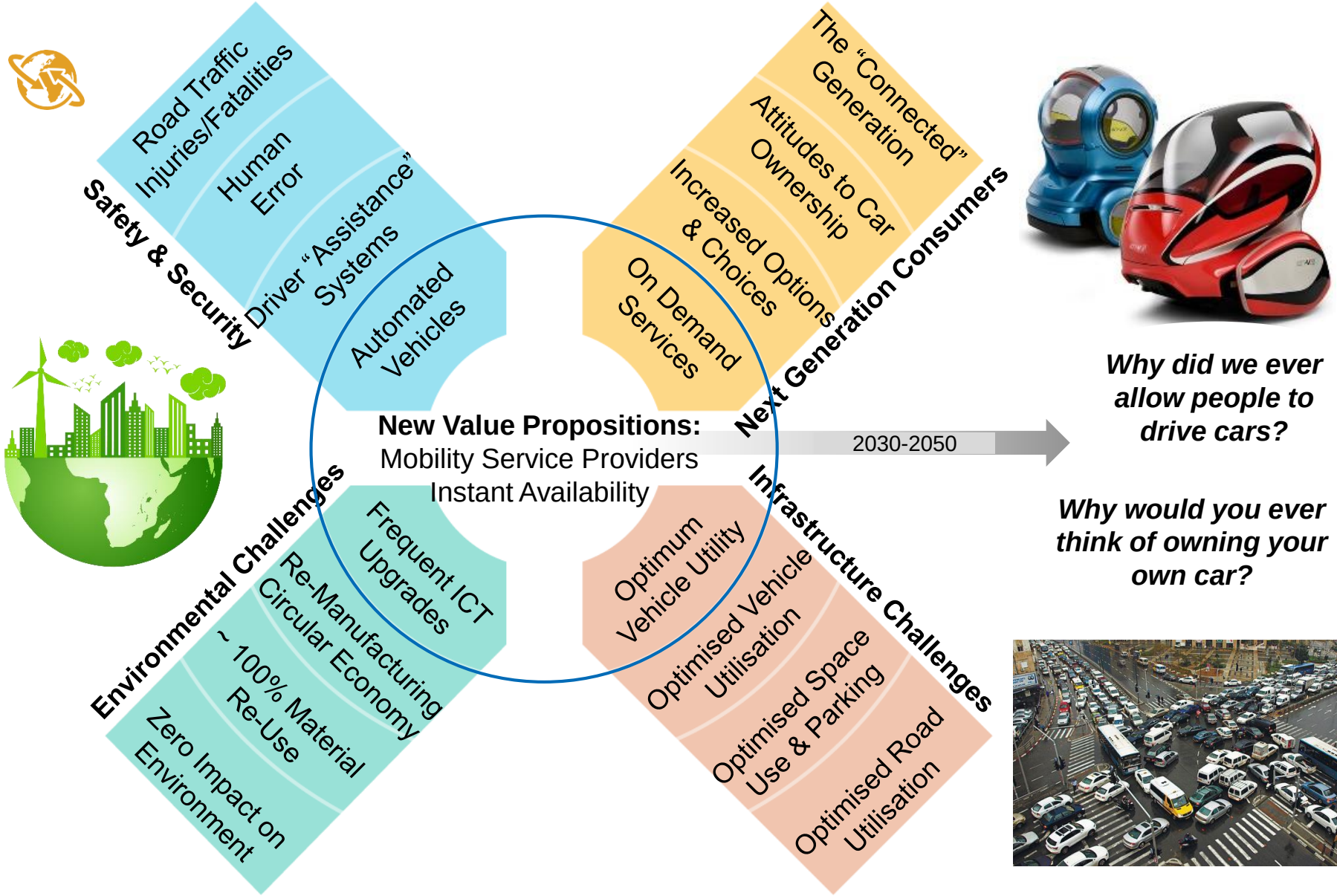
ARB Advanced Clean Cars Symposium: The Road Ahead

28th September 2016

The Great Transformation to the fully automated vehicle

- Future Mobility
- Impact of vehicle miles travelled and efficiency
- Transition path for automated features to the steering wheel-less car

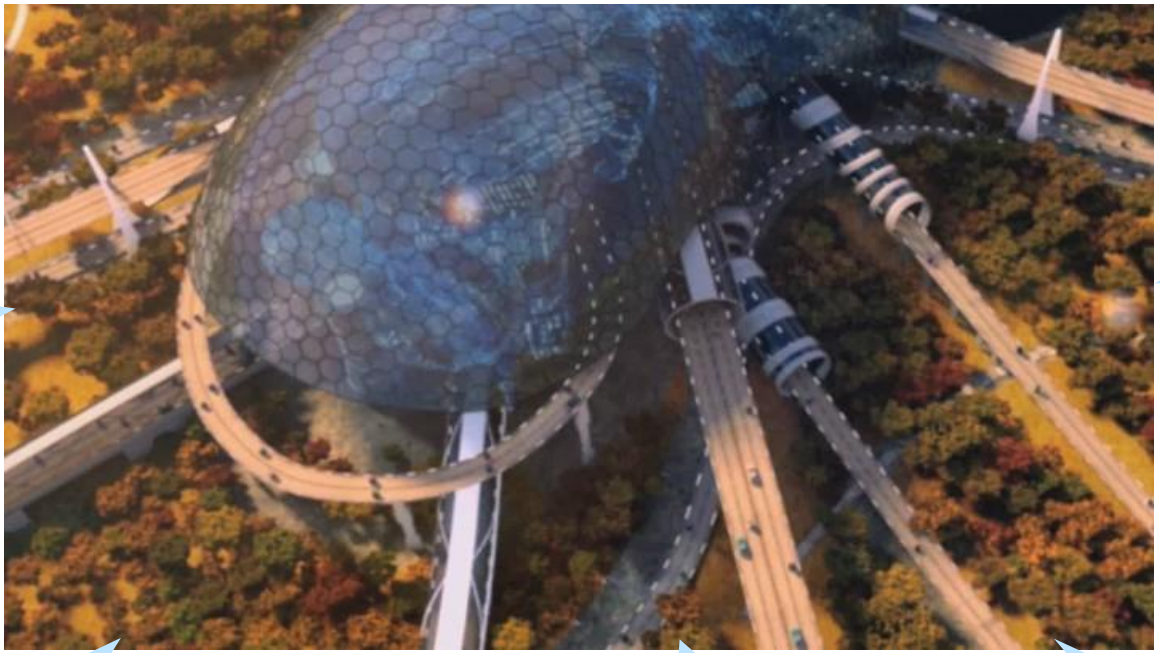
Congestion, safety, convenience, accessibility & connectivity will result in automated, on-demand mobility



Why did we ever allow people to drive cars?

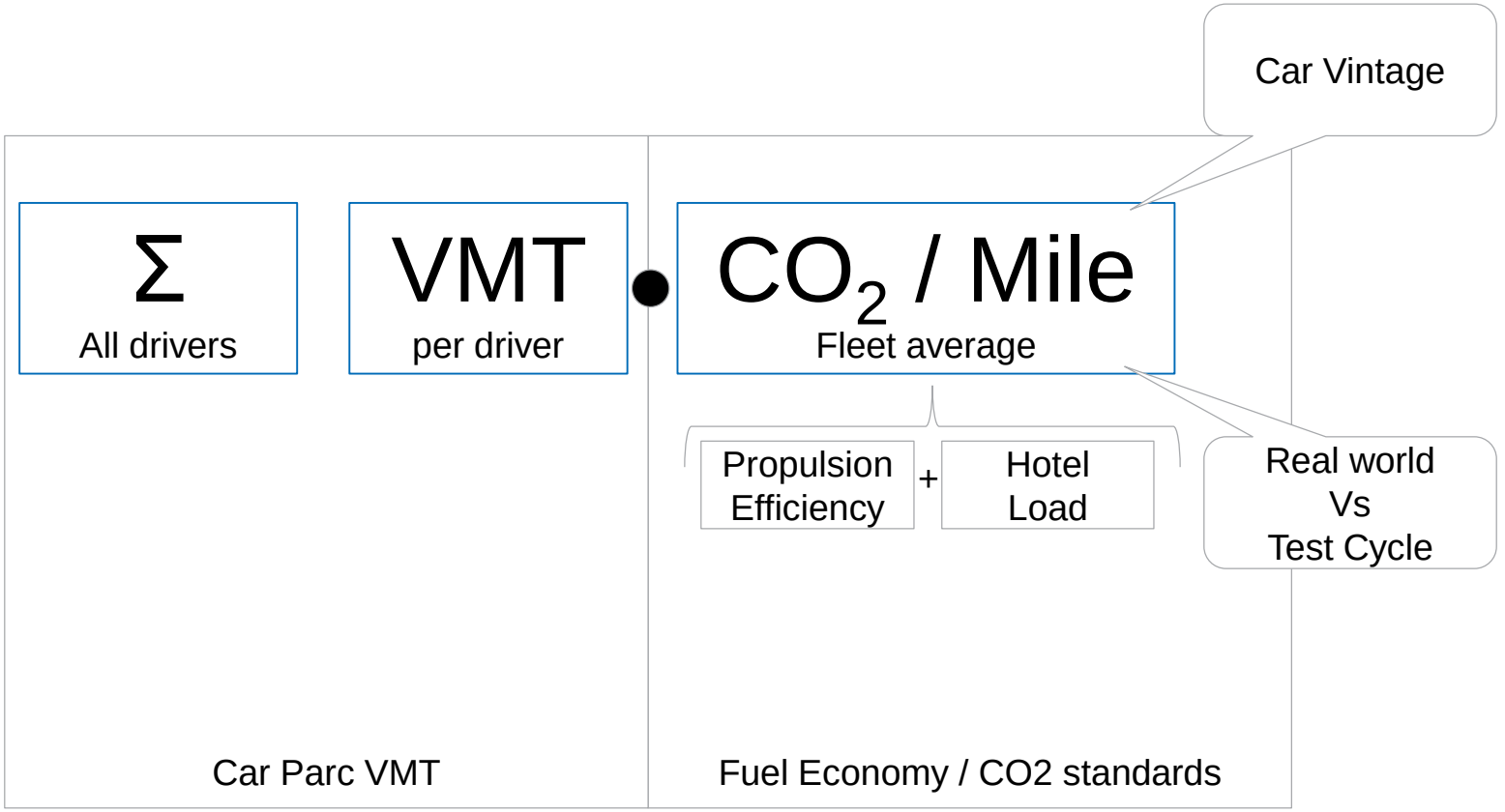
Why would you ever think of owning your own car?

Future mobility scenarios have significant changes to vehicle types and uses and will impact the built environment

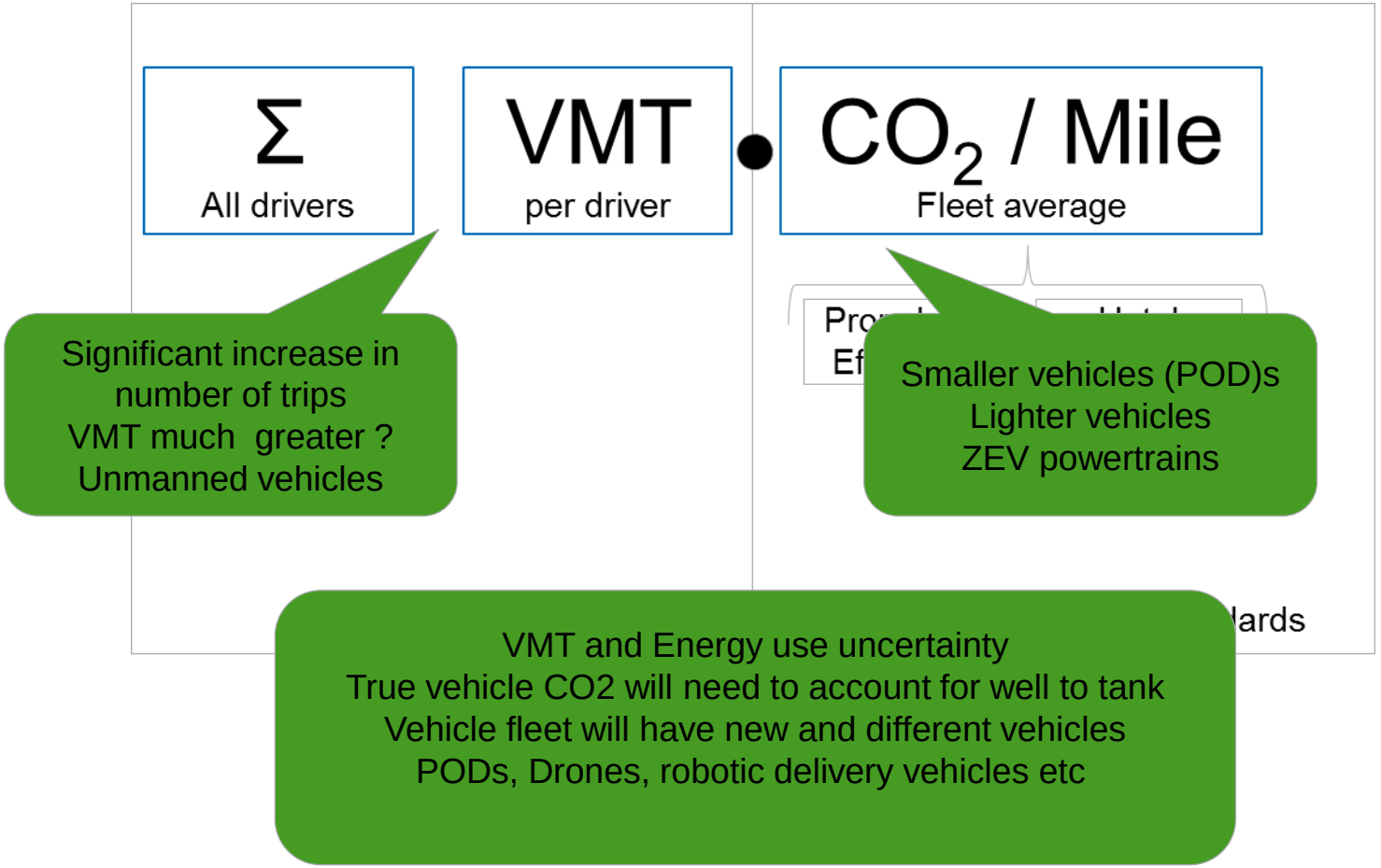


Source: General Motors / Shanghai Expo

Traditionally fleet emissions are determined based on vehicle miles travelled and emissions per mile

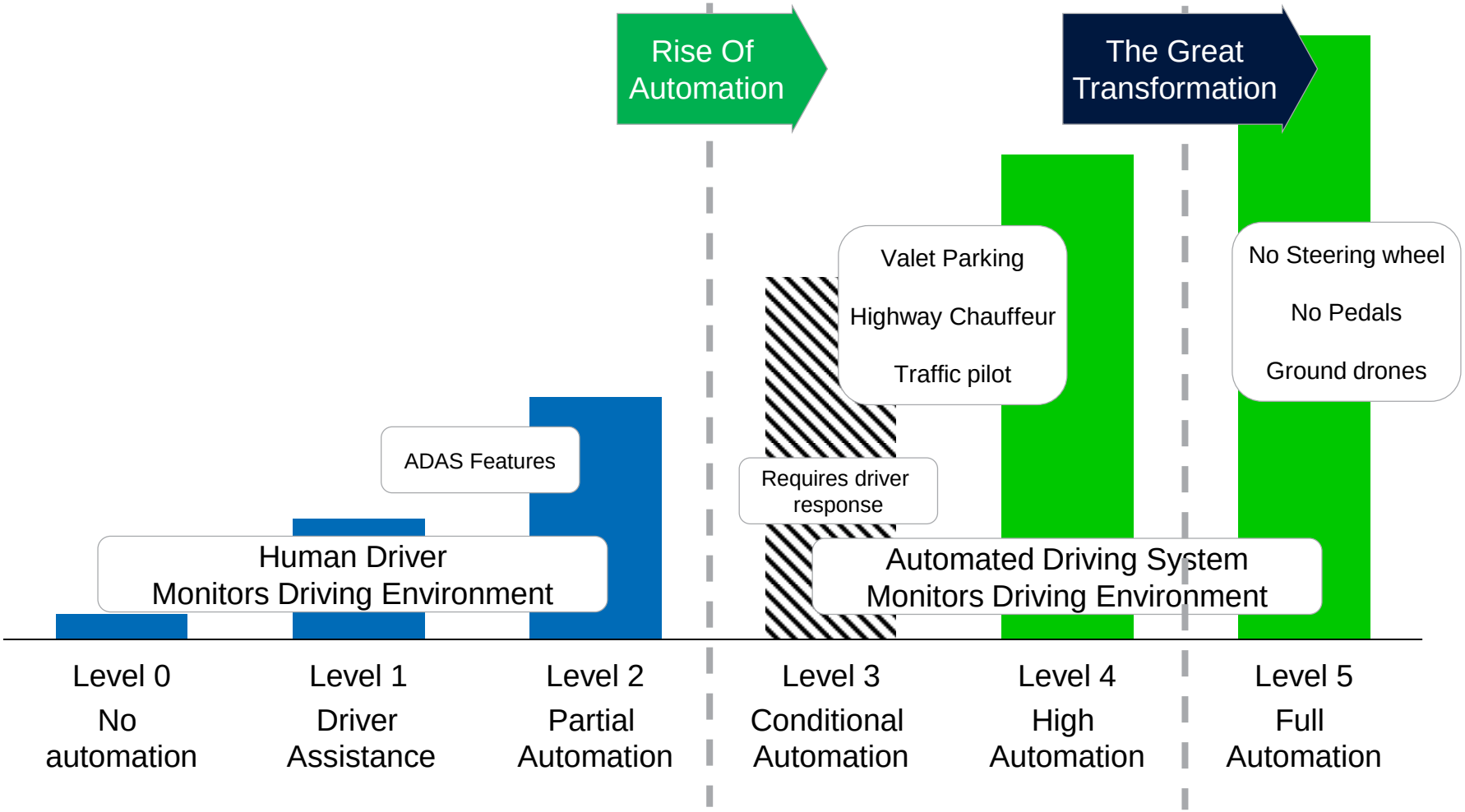


Regulating the CO2 for the fully autonomous world could be very different to todays MPG and CO2e approach



Automated driving features are expected to rise quickly and ultimately lead to a transformation of personal mobility

Autonomous Capabilities as defined by SAE



Source SAE.org and SAE standard J3016

There are significant societal benefits for connected autonomous vehicles both short and long term

Conditional / High Automation

- Connectivity
- Platooning possible
- Valet parking
- Congested driving management
- Highway Chauffeur

- **Improved Safety**
- Improved Quality of Life

- No new access
- No unmanned trips
- Dynamic routing

- Marginally higher VMT
- **Opportunity for better efficiency**

Soon

The Great Transformation

Full Automation

- Fully Automated Transportation
- Mobility 4.0
- Revolutionized future

- **Approaching Zero Crashes**
- Improved Quality of Life

- Manned and un-manned vehicles
- Ride and ownership sharing
- Much greater accessibility

- **Likely much higher VMT**
- **Improved efficiency of movement**
- **Move to zero tailpipe emissions**

2020 ?

Future

2030 ?

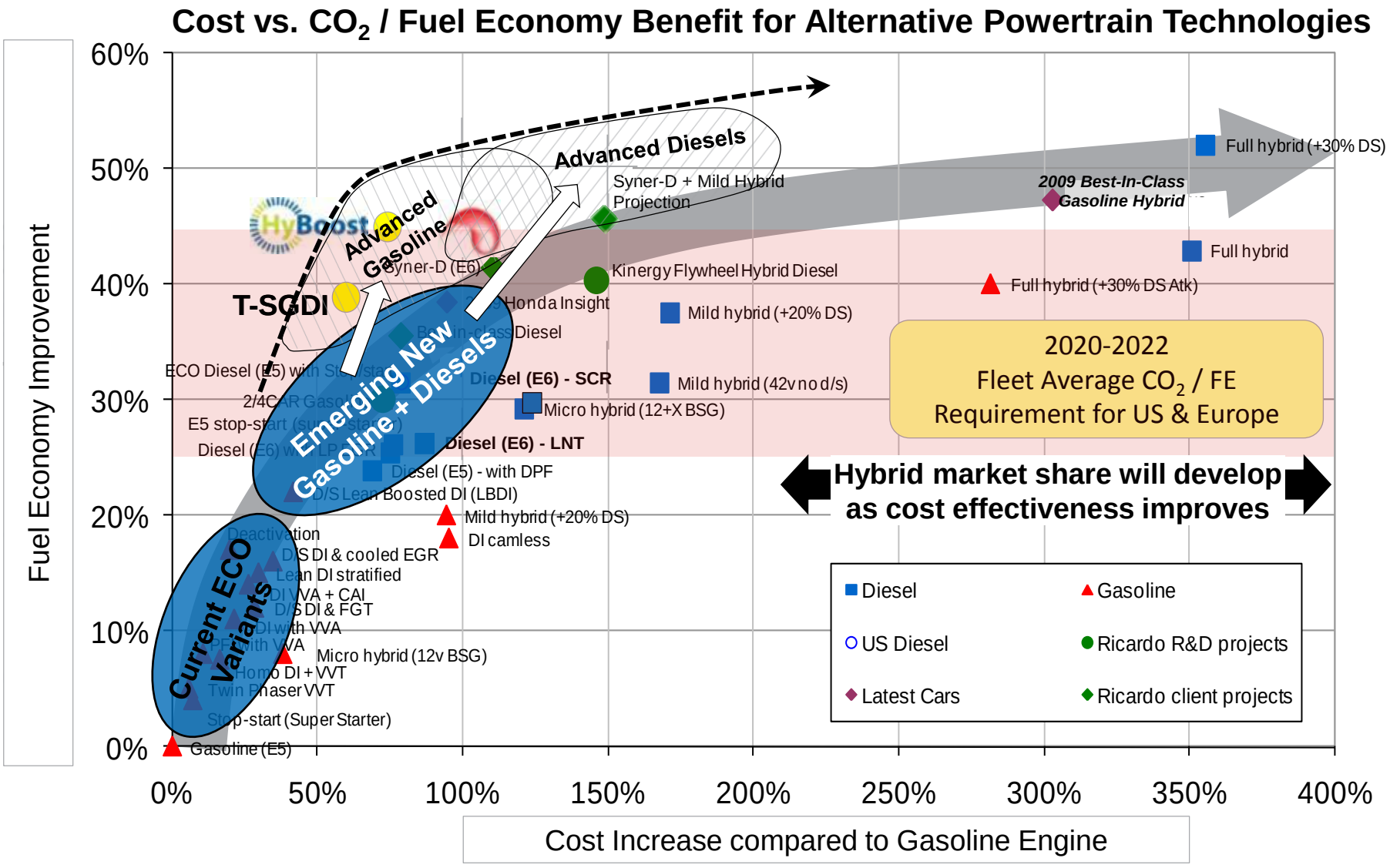
2040 ?

Opportunities to incentivize deployment of CAV technology through benefits to fuel savings and reduced CO2

- Value of Fuel Economy Technologies
- Can fuel economy value help offset cost of CAV
- Example CAV fuel savings in the real world
- Off cycle credits and their potential applicability to CAVs

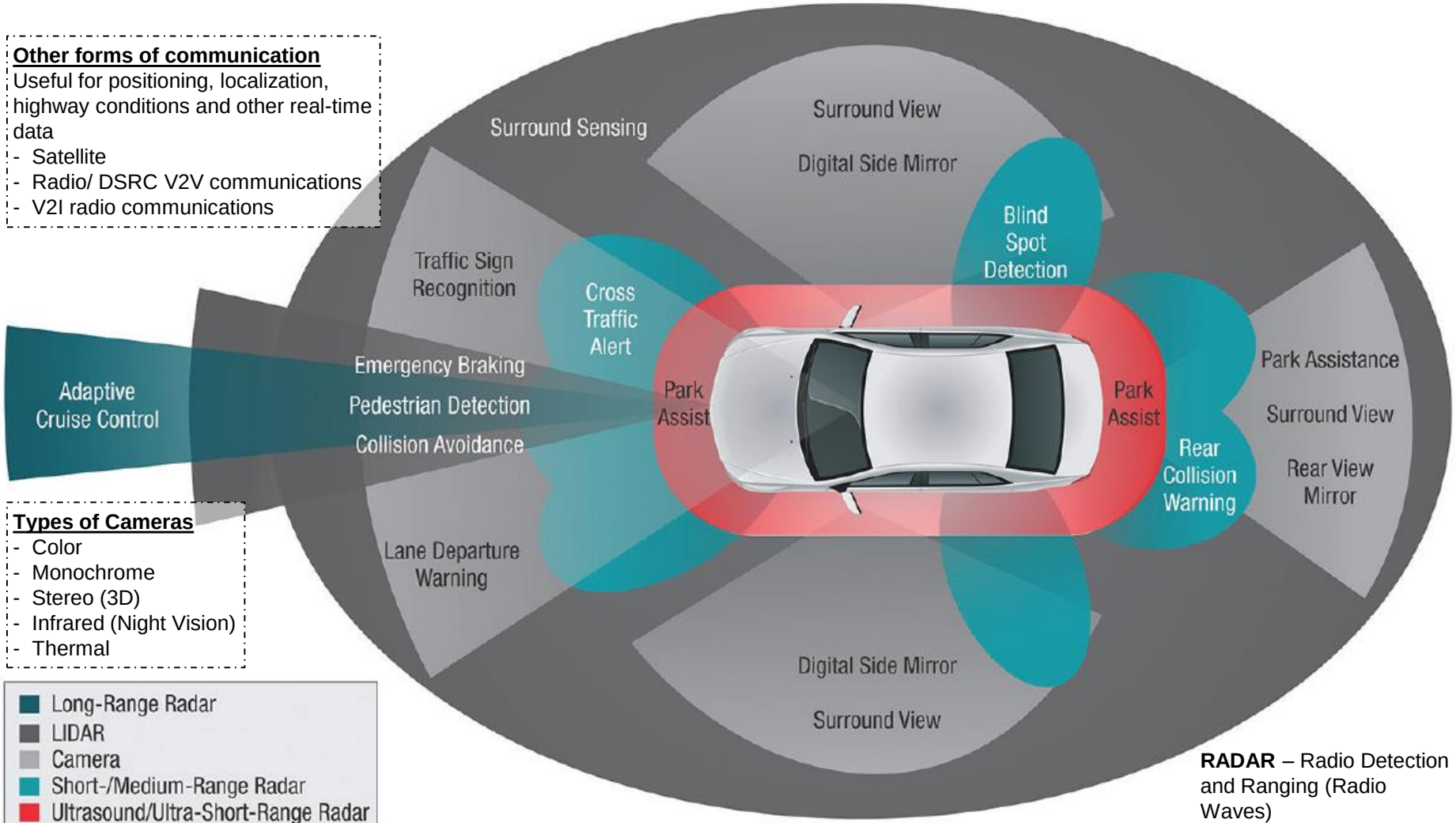
Fuel Economy technologies have value in their ability to allow OEMs to achieve CAFE compliance

Illustrative



CAVs require a significant increase in complexity and hence have additional costs for sensors, processors and controllers

Other forms of communication
Useful for positioning, localization, highway conditions and other real-time data
- Satellite
- Radio/ DSRC V2V communications
- V2I radio communications



Types of Cameras
- Color
- Monochrome
- Stereo (3D)
- Infrared (Night Vision)
- Thermal

RADAR – Radio Detection and Ranging (Radio Waves)

LIDAR – Light Detection and Ranging (Laser)

Source: Texas Instruments white paper - "Making cars safer through technology innovation", Staszewski, R. and Estl, H.

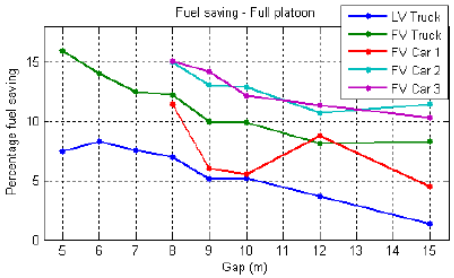
Although technology is often safety/convenience focused, CAVs can yield real world fuel economy benefits

Example Fuel Economy Benefits from CAVs

Platooning reduces vehicle drag and can yield 5 – 15% fuel savings

SARTRE - Cooperative control of automated platoon vehicles improves safety and fuel economy

- Control system performance is enhanced using real-time V2V data
- Five vehicle road train of mixed types
- Based on existing technologies with some software enhancements, combined with advanced control software
- Up to 90 km/h and 4m gaps
  - 90 km/h is truck speed limit



- Interactions with non-platoon traffic
- Tested on test tracks and public roads
- Demonstrator system - not a production implementation
- Fuel consumption results
  - 16% for following vehicles
  - 8% for lead vehicle

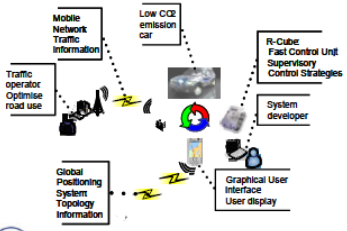
Optimizing speed, energy storage and HVAC based on real world data - 5- 10% fuel savings

Intelligent Vehicles & Transport

Sentience uses Electronic Horizon Information to optimise vehicle speed control, energy storage whilst minimising HVAC load

- Analysis has shown that Hybrid systems offer the most potential from Electronic Horizion Information – Ford Escape selected for system demonstration
- The first step was to create and validate a model of the vehicle to assess baseline vehicle performance
- The potential impact of "look ahead" was assessed during the simulation phase
- A combination of simulation and dynamic programming was used to shortlist functions for implementation
- The Sentience Architecture Incorporates Vehicle to Infrastructure Communications integrated with the Vehicle/Powertrain control system
- 3 new control systems were added:
  - Enhanced Hybrid system efficiency
  - Enhanced air conditioning
  - Enhanced Acceleration / Deceleration (EAD)

Hills, speed variance, wind and additional engine load are areas worthy of e-horizon input to control strategies



OEMs have already claimed off cycle credits for a range of fuel efficiency technologies which provide real world savings

Examples

Efficiency Focus	Technology Examples
Active Aerodynamics	Grill Shutters Ride Height Adjustment
Thermal Control Technologies	Passive Cabin Ventilation Active Cabin Ventilation Active Seat Ventilation Special Glazing Solar reflective surface coating
Engine and Transmission warmup	Active Engine Warm up Active Transmission Warm up
Energy Savings	Engine Idle Stop-start High Efficiency LED lights Solar panel

Although standard cycles can support certain off-cycle credits, CAVs will need to prove benefits in on-road driving

Standard US Test Cycles

Cycle name	City	Highway	High Speed	Air Conditioning	Cold
Cycle number	FTP	HWFET	US06	SC03	FTP20
Miles	11.04 miles	10.2 miles	8.01 miles	3.58 miles	11.04 miles
Time	1874 secs	765 secs	596 secs	596 secs	1874 secs
Average MPH	21.2	48.3	48.4	21.6	21.2

N/A

- Standard FTP and Highway tests used for regulated vehicle fuel economy and CAFE and CO2
- Supplemental cycles are used to represent real world or ‘on-road’ fuel economy

CAV benefits will not be captured by dynamometer testing over a prescribed test cycle

Source: FuelEconomy.gov

Considering off-cycle credits for CAVs may be beneficial for enabling wider deployment, but has challenges

Benefits	Challenges
• CAV technology can yield fuel savings / CO2 reduction which would not be measured on standard test cycles • There is a societal benefit for wider deployment of CAV technology (reduced accidents and better quality of life during trips). • Fuel economy savings have value to OEMs in meeting CAFE and CO2. Off-cycle credits could help offset the CAV technology costs	• Fuel savings from CAVs can be depend on availability of real world data (V2I), and local driving conditions • Initially it is likely the driver will need to be active in deciding if the technology is used on a certain trip. • Fuel economy test procedures may eventually be required to adapt to the new autonomous/connected world

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