Transportation Scenarios for 2050

Southern Nevada Tourism Infrastructure Committee

10/22/2015

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AUTOMOTIVE FUTURES

Automotive Futures
University of Michigan
Transportation Research Institute

Funding

Affiliate Program	Research	Conferences
–Supporting Members –Research Partners	–Globalization –Powertrains –IT	– 5 Annual Conferences

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Automotive Futures Affiliate Program

Affiliates Members and Research Partners

IT Organizations
Oracle Corporation
IBM
HP
Siemens-PLM

OEMs
General Motors
Toyota Tech Center
Nissan Tech Center
Ford Motor Company
Chrysler LLC

Government/NGOs
NREL / EPA
NSF
Motor Carrier
Energy Foundation
The Hewlett Foundation
National Resources Defense Council
Union of Concerned Scientists
CALSTART
Argonne National Labs

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Automotive Futures Affiliate Program

Affiliates Members and Research Partners

Suppliers
Chevron
Visteon
Denso
Dana
Delphi
Peterson Spring
Continental
TRW
Valeo

Suppliers
Michelin
Continental
JCI
BorgWarner
Yazaki
Eaton
BASF
Dow
Bosch

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Automotive Futures
Current Research Programs

- Powertrains
  - 2014 Powertrain Strategies for the 21st Century Survey (Sponsor: Affiliates)
    - Survey continuing
  - Total Cost of Ownership: Comparing Diesel and Gas Vehicles (Bosch)
    - Based on resale value of 30K vehicles sold through Mannheim auctions in 2012 / 2013
    - Report available

Automotive Futures
Current Research Programs

- ITS
  - Stuck in Traffic: Analyzing Real Time Traffic Capabilities of Personal Navigation Devices and Traffic Phone Applications
    - Final report available

  - Integrated Mobile Observations: Micro-level weather reporting using cell phones in MDOT vehicles (Sponsor: MDOT and FHWA)
    - Continuing data collection through October, 2015

Automotive Futures
Current Research Programs

- ITS
  - Roadway Evaluation Project: Measuring road roughness via accelerometers in cell phones mounted in MDOT vehicles
    - Final report available

  - Deploying Safety Technologies in Commercial Vehicles
    - Familiarity and penetration currently and in the future of: Forward Collision Warning / Lane Departure Warning / Blind Spot Detection / ESC / Vehicle Communications
    - Final report available (Sponsor: ITS America)

Upcoming UMTRI-AF Conferences

- November 11, 2015: *Inside China: Understanding China's Current and Future Automotive Industry.* Our 8th annual conference provides insight into the Chinese auto industry from experts in specific areas of the industry including the Chinese market, suppliers, trade, Chinese manufacturers, labor, and marketing.

☐ February 17, 2016: *New Mobility: The Future of Freight*. A new conference that examines the major changes IT-enabled goods movement will have on the freight movement industry.

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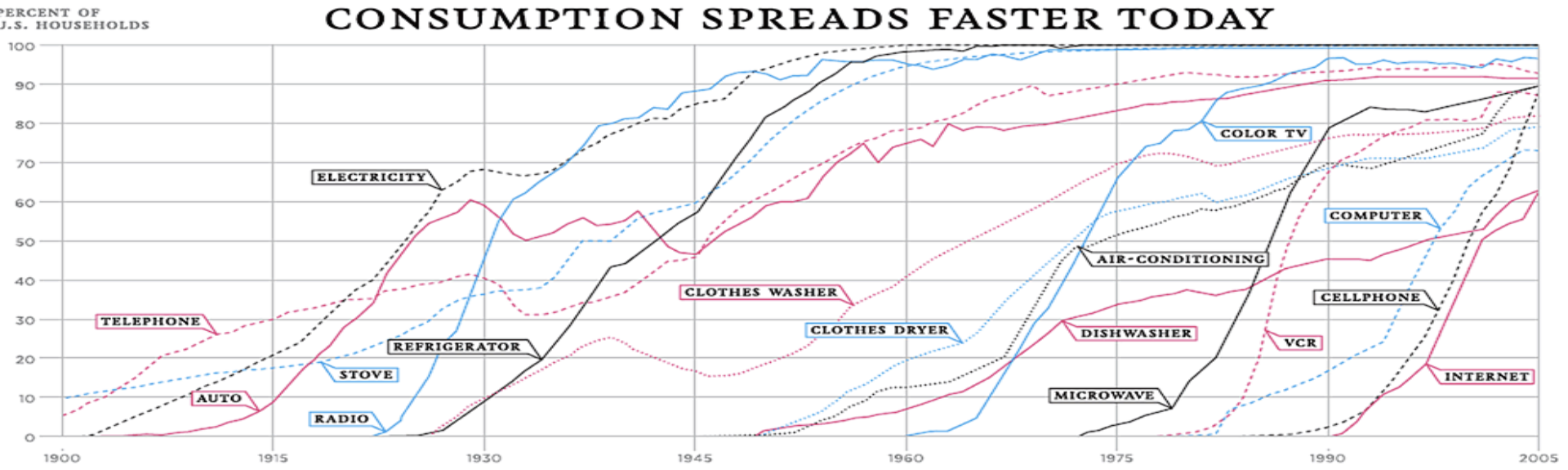
Upcoming UMTRI-AF Conferences

- April 13, 2016: *Globalization of the Automotive Industry: The 2016 Update*. A new conference that brings everyone up to date on the trends in the globalization of the automotive industry from a manufacturer and supplier perspective.

- July 20, 2016: *Powertrain Strategies for the 21st Century*. Our 8th annual conference will provide an overview of all the electrification progress that has been made in the global auto industry.

The Pace of Technology Adoption



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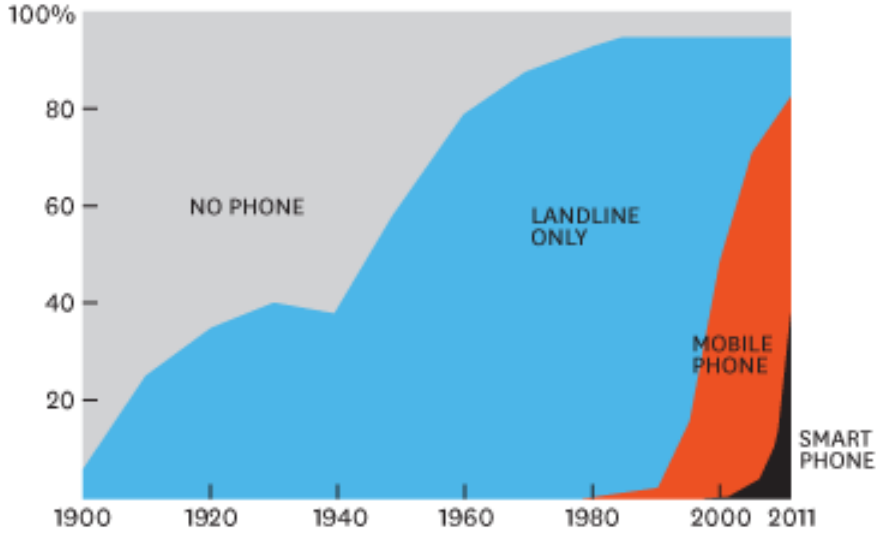
The Pace of Technology Adoption

FROM NO TELEPHONE TO SMART PHONES

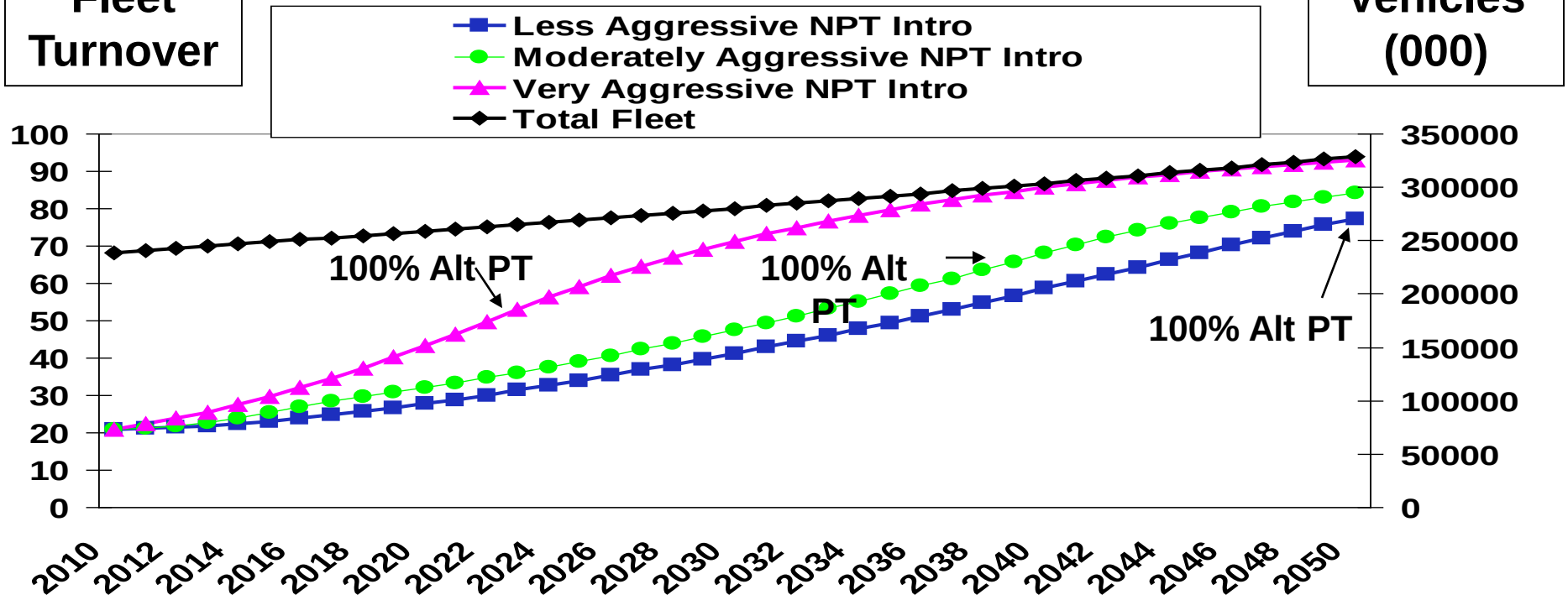
U.S. HOUSEHOLDS BY TYPE OF PHONE, 1900–2011



SOURCE MICHAEL DEGUSTA AT THE MIT TECHNOLOGY REVIEW USING DATA FROM FORRESTER, KNOWLEDGE NETWORKS, NEW YORK TIMES, PEW, U.S. CENSUS

HBR.ORG

Turnover of the U.S. Fleet



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Predicting 2050 Transportation Trends

- 2015 to 2050: 35 years
- 1980 to 2015: 35 years ago
  - Government regulations of vehicle safety, emissions, and fuel economy were about 10 years old
  - Vehicle electronics were used only for starters, radios/cassette players, heating and cooling, and lighting

Predicting 2050 Transportation Trends

- 1980 to 2015: 35 years ago
    - Future vehicle development focused on development of airbags, more reliable / longer lasting vehicles, improved performance, and improved fuel economy
    - No computer modeling and simulation
    - No discussion of electric vehicles, hybrids, connected / autonomous vehicles: vehicle computers and electronics were too slow or non-existent
    - Moore's Law was in its 15th year: (the number of transistors on an integrated circuit will double every two years)

Predicting 2050 Transportation Trends

- 1980 to 2015: 35 years ago
    - Transportation was similar to today's: low levels of public transport (relative to other developed countries)
        - Reliance on personal transportation except for longer distances that were covered by air

- Industry driven: Company differentiation and competitive advantage in the marketplace

- Government driven: Government regulations related to clean air, fuel economy, and safety

Company differentiation and competitive advantage in the marketplace

- Historically, industry innovation has taken place across the different company functions in the forms of process, product, and strategic innovation:

- R&D: Moving from the entire R&D from within the company to a combination of company, national labs, and universities

- Engineering: the introduction and improvement of modeling and simulation technologies (reduced time to market)

- Purchasing: The reduction of vertical integration and the introduction of global purchase through IT supported web-based auctions

Company differentiation and competitive advantage in the marketplace

- Manufacturing: The introduction of the Toyota Production System with just in time delivery, kanban, and continuous improvement strategies.

- Products: Minivans, SUVs, electric, fuel cell, and hybrid vehicles; IT-based passive and active safety systems (ABS, traction control, forward collision systems, blind spot detection, and adaptive cruise control)

- Sales and Marketing: Social media marketing and tracking of potential warranty problems, shopping and sales of vehicles via the Internet

- Aftermarket: sales of upgraded vehicle features after initial sale (Tesla)

Company differentiation and competitive advantage in the marketplace

- Strategy: The development of truly global companies aided by information technology including the globalization of manufacturing, R&D, product development and purchasing

Government regulations related to clean air, fuel economy, and safety: Results

- National Highway Traffic Safety Administration (NHTSA) creation in 1970 through the Highway Safety Act
  - Shoulder belts for left and right front-seat vehicle occupants, side marker lights, collapsible steering columns, head restraints, airbags, child safety seats, advanced braking systems (ABS), and electronic stability control (ESC)
  - Crash test ratings for each vehicle for front end crashes (driver and passenger), side crashes (front seat and rear seat), rollovers

Government regulations related to clean air, fuel economy, and safety: Results

- Clean Air Act of 1970 and the Environmental Protection Agency
  - Created some of the strictest vehicle emissions rules in the world, but was prodded by California and the northeast states to create stricter emissions rules and the first electric vehicles
  - Significant reductions in carbon monoxide, nitrogen oxide, particulate matter, carbon dioxide, and sulfur oxide
  - Randomly tests 15 percent of new vehicles for emissions
  - Technology innovation: the catalytic converter, forced the creation of unleaded gasoline and reduced sulfur in fuel

Government regulations related to clean air, fuel economy, and safety: Results

- Corporate Average Fuel Economy (CAFE) Standards in 1975
  - 1970s: Began the introduction of smaller, more fuel efficient vehicles into the US fleet
  - 1980s-1990s: Lack of government support for increased fuel economy allowed the introduction of SUVs
  - 1990s: California requirements for zero emissions vehicles led to the introduction of the first electric vehicles, hybrids, and fuel cell vehicles.

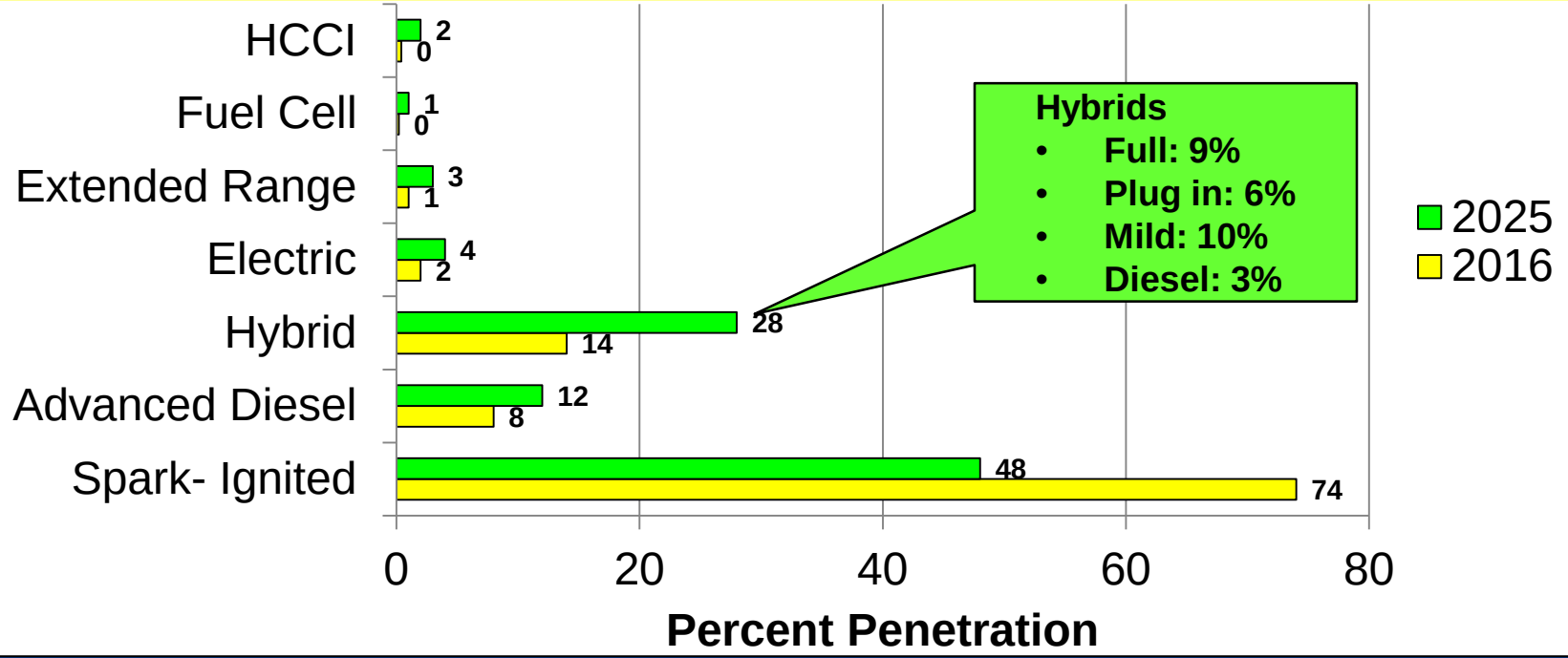
The Future: The Greening of the U.S. Auto Industry

- EPA given authority to regulate CO2 emissions: 2007
  - 2016: 263 CO2 grams per mile
  - 2020: 250 CO2 grams per mile
  - 2025: 163 CO2 grams per mile
- Advanced technologies:
  - Electric, fuel cell, and hybrid vehicles
  - Advanced after-treatment devices
  - Waste heat recovery systems
  - Stop-start systems
  - Ultra low sulfur fuel

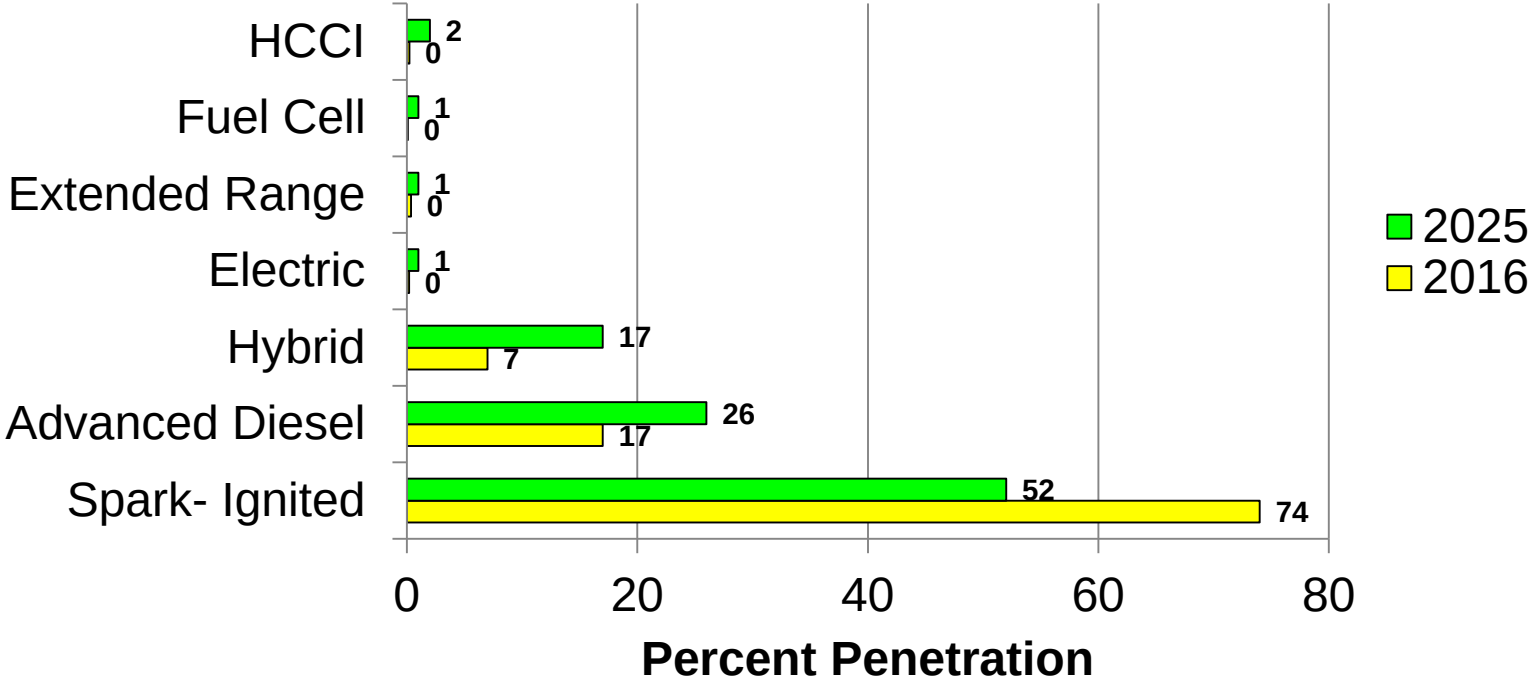
The Future: The Greening of the U.S. Auto Industry

- Obama administration combines expansive R&D with new CAFE regulations for 2016 and 2025.
    - 2016: 34.1 miles per gallon
    - 2020: 38.9 miles per gallon
    - 2025: 54.5 miles per gallon
- Advanced technologies include:
    - Electric, fuel cell, and hybrid vehicles
    - Advanced battery technology
    - Stop-start systems
    - Advanced transmissions
    - Advanced materials for lightweighting vehicles
    - New aerodynamic body designs

By 2025, the decrease in spark-ignited powerplants is predicted to drop to slightly more than 50 percent for passenger cars while hybrids and advanced diesels increase their share



For light trucks, hybrids and advanced diesels increase their share of powerplants in 2025 at the expense of spark-ignited engines



Vehicle Electrification

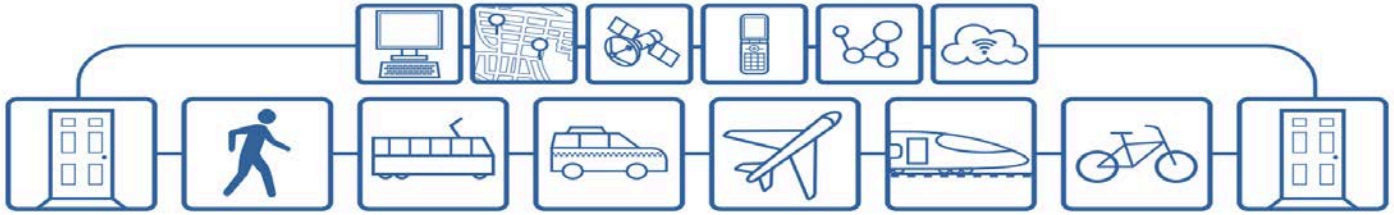
- **Hybrids/Electric Vehicles**
  - Low penetration
  - Not expected to have significant impact by 2025
  - Range anxiety / charging infrastructure
  - Tesla is “breaking the mold” for an auto manufacturer

The Future: The Greening of the U.S. Auto Industry

- NHTSA Connected and Autonomous Vehicle support
  - Attempting to reduce the 30K deaths and millions of injuries
  - Technologies:
    - Dedicated short range communications (DSRC)
    - Radar/Lidar/camera/ultrasonic sensors
    - Advanced GPS systems
    - But connected vehicles represent infotainment as well as safety and offer other innovative options

The Future: The Greening of the U.S. Auto Industry

SMART



Accelerating Sustainable Transportation SYSTEMS
Advancing the emerging global New Mobility Industry
to supply them

MICHIGAN

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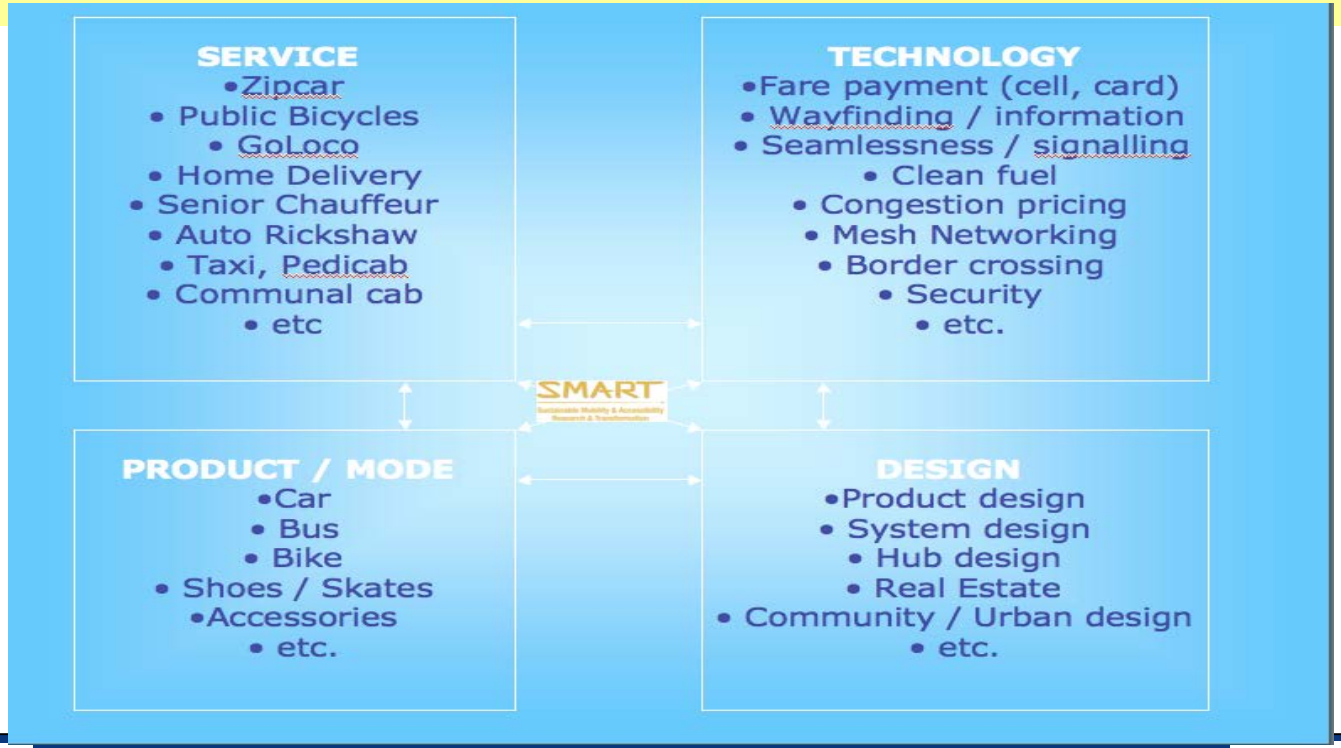
The Future: The Greening of the U.S. Auto Industry



The Future: The Greening of the U.S. Auto Industry

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The Future: The Greening of the U.S. Auto Industry

Transportation Trends

- **$240B death and injury**
- **$100B stuck in traffic**

- **30 % of carbon emissions**
- **70 % of oil consumption**

- **Population growth**
  - **Additional ~100M Americans by 2050**

- **VMT will increase 50% by 2050 to 4.5T**
- **Interstates/Highways will still carry largest portion of travel**
- **Energy costs will increase**
- **Congestion will become much worse for many cities and regions – usage restrictions**
- **New business models will evolve (car sharing, VMT-based usage fees, etc)**

Connected/Autonomous Vehicles

- Connected means different things to different companies
  - Some consider connected to mean connections to the Internet through the console/entertainment center
  - Others consider it the connections between vehicles that support advanced safety technologies

Connected/Autonomous Vehicles

- Autonomous Vehicles will go through five major levels:
- No-Automation (Level 0): The driver is in complete and sole control of the primary vehicle controls – brake, steering, throttle, and motive power – at all times.

Connected/Autonomous Vehicles

- Function-specific Automation (Level 1): Automation at this level involves one or more specific control functions. Examples include electronic stability control
- Combined Function Automation (Level 2): This level involves automation of at least two primary control functions. An example of combined functions enabling a Level 2 system is adaptive cruise control in combination with lane centering.

Connected/Autonomous Vehicles

- Limited Self-Driving Automation (Level 3): Vehicles at this level of automation enable the driver to give up full control of all safety-critical functions under certain traffic conditions. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time.

Connected/Autonomous Vehicles

- Full Self-Driving Automation (Level 4): The vehicle is designed to perform all safety-critical driving functions and monitor roadway conditions for an entire trip. Such a design anticipates that the driver will provide destination or navigation input, but is not expected to be available for control at any time during the trip. This includes both occupied and unoccupied vehicles.

Connected/Autonomous Vehicles: Applications

V2V

- Cooperative Crash Imminent Braking
- Emergency Brake Lights
- Intersection Movement Assist
- Left Turn Assist
- Blind Spot / Lane Change Warning
- Do Not Pass Warning
- Right Turn in Front of Transit Vehicle

+ V2I

- Adaptive Signal Control
- Advanced Traveller Info System
- Work/Speed Zone warning
- Motorist Weather
- Advisories/Warnings
- Pedestrian in Crosswalk
- Agency Probe Data
- Smart Parking, etc

Connected/Autonomous Vehicles: Applications

Automated

- lane keeping
- traffic jam assist
- highway autopilot
- parking assistant

Automated + Connected
AV + V2V + V2I

- platooning
- auto intersection
- eco-approach/departure
- auto-valet
- full urban operation amongst pedestrians

Connected/Autonomous Vehicles: Pros and Cons

	pros	cons
Connected		
V2V	proven effective for safety - avoiding collisions	relies on driver reaction
	inexpensive - can be applied on many vehicles	relies on other vehicles (critical mass)
	retrofittable	requires security system
	sees around corners	perception of privacy loss
	sees through fog/rain/snow	
	sees at longest sensor range	
	sees multiple vehicles ahead	
	knows much more about road partners	
+ V2I	enhances mobility thru adpative signal control	requires infrastructure investment
	enhances energy-use through eco routing/timing	requires added security system
	enables weather apps	further perception of privacy loss
	enables 0/1st level eco-driving	
	enables pedestrian detection in crosswalk	
	enables smart parking	
Automated		
AV	relies less on human intervention	expensive - can't be applied on many vehicles
	doesn't rely on other vehicles	technology not fully ready
	added driver convenience	not yet proven reliability
	high customer interest	not retrofitatable
	potential for improved safety, unproven	requires security system
	potential for improved eco-driving	requires policy decisions/changes
		unclear if all veh data can remain private/anonymous
		may add VMT due to convenience

Connected/Autonomous Vehicles: Pros and Cons

Automated + Connected: Pros		Cons
AV + V2V + V2I	all advantages above	most disadvantages above
	adds reliability to sensing & decision making	added cost
	enables platooning at close following distance	added proveout requirements
	enables safer lane changing and passing	requires comprehensive security system
	communicates locations of map changes/updates	
	communicates road construction / maintainence	
	enables 2/3/4th level eco-driving	
	enables L4 driverless (on most roads)	
all + V2P	enables safe urban operation around pedestrians	requires smart phone/device solution
	enables rapid retrofit system	

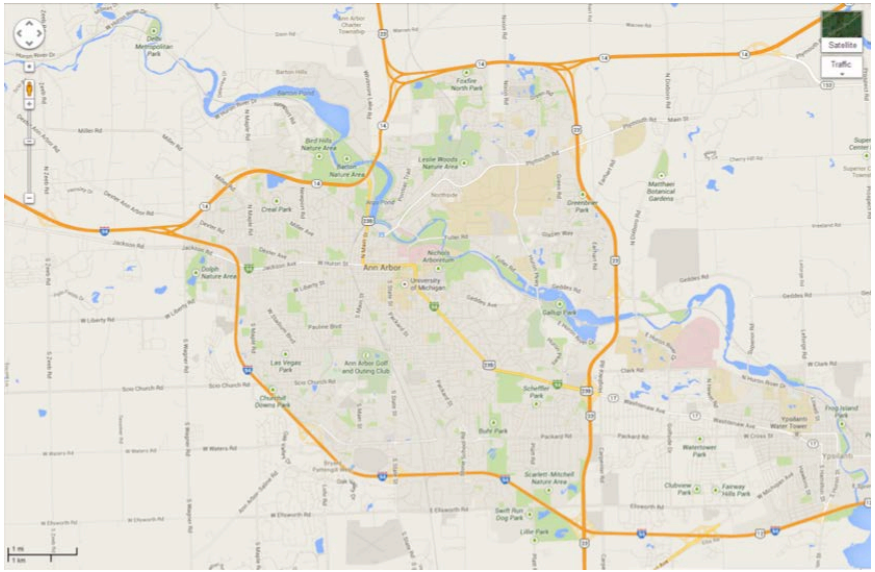
Autonomous Vehicles: Barriers

- Legal, Liability and Insurance issues
- Customer acceptance & understanding
- Standardized technology assessments & validation for safe operation
- AV operation in mixed traffic
- Catalog of human behavior in critical situations
- Transition of vehicle control with partial automation
- Cybersecurity of AVs

Connected Ann Arbor

- **60 Intersections**
- **3 Curve-related sites**
- **12 Freeway sites**
- **Over-the-air security**
- **All DSRC communications logged**
- **Backhaul communication network**
- **Back-end data storage**
- **Will test selected V2I functions**

- **Up to 9000 Vehicles**



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Connected Southeast Michigan

- **Up to 20,000 Vehicles**

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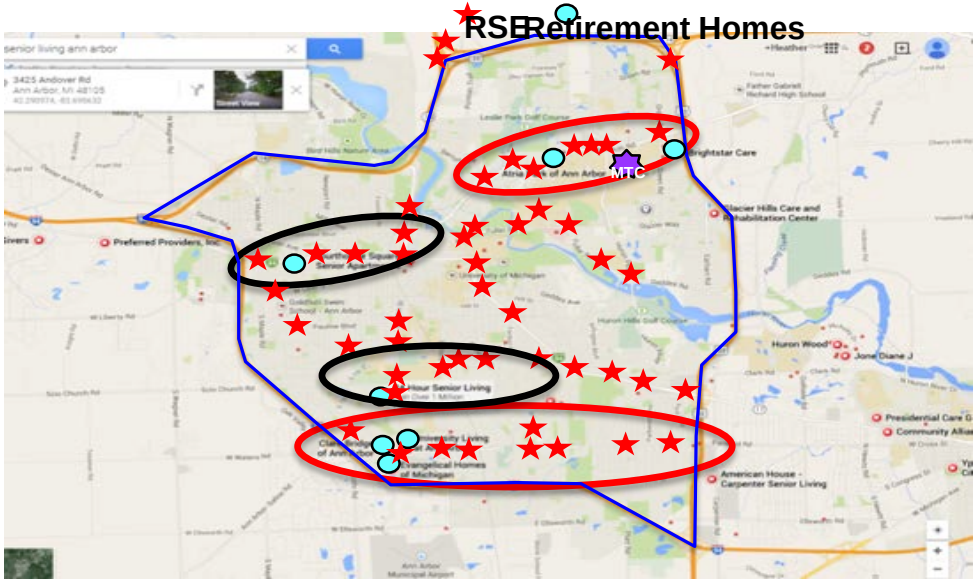
Connected Ann Arbor



Ann Arbor Automated Vehicle Field Operational Test (2016+)

- 2,000 connected and automated vehicles
- Including Level 4 automated vehicles
- 27 sq. miles of densely instrumented infrastructure

MCity

- Safe, repeatable, off-roadway test environment for AVs: simulated city
- Technology research, development, testing, and teaching
  - –$6.5M project; $3.0M funding from MDOT
  - –Grand opening: July 20, 2015

Conclusions

- The combination of the integration of advanced cars and trucks, new transport modes, and connected/autonomous vehicles offer a good look into the future of transportation
- Uncertainties:
  - Will government continue its push for reduced/zero emissions if administrations change?
  - Will reduced fuel prices negate the push for more fuel efficient vehicles?
  - How reliable will connected/autonomous vehicles become?
  - How will the public react to connected/autonomous vehicles?
  - Can cities afford to re-design their transport infrastructures to support connected/autonomous vehicles and alternative transport systems?
  - What new technologies will appear that can radically change transport?

QUESTIONS
&
ANSWERS

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