Reinventing the Automobile

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Columbia University

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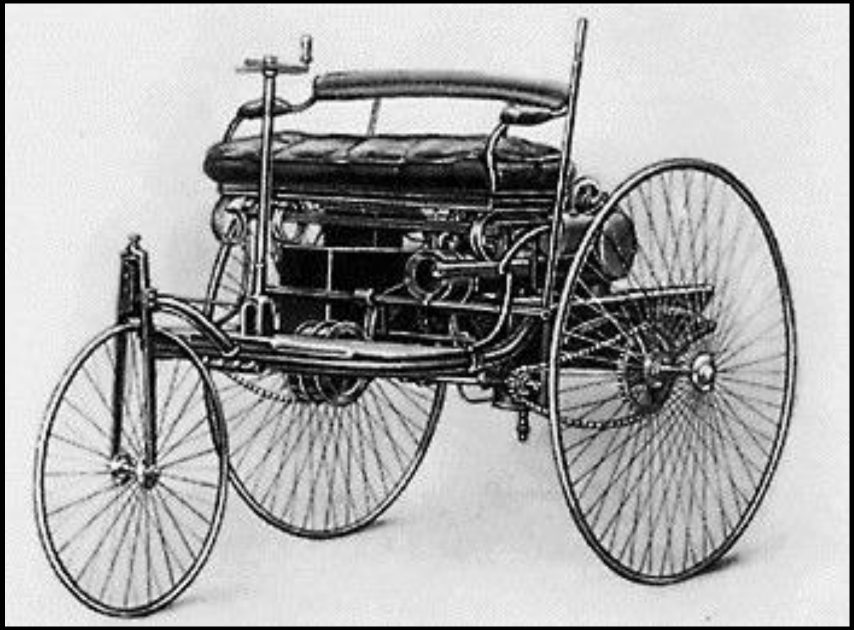
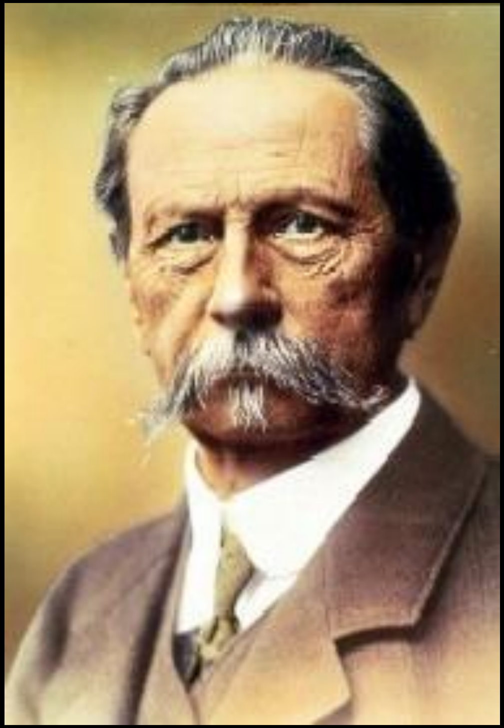
1886: From Horses to Horsepower

Karl Benz Granted Patent for First Gasoline Powered Automobile





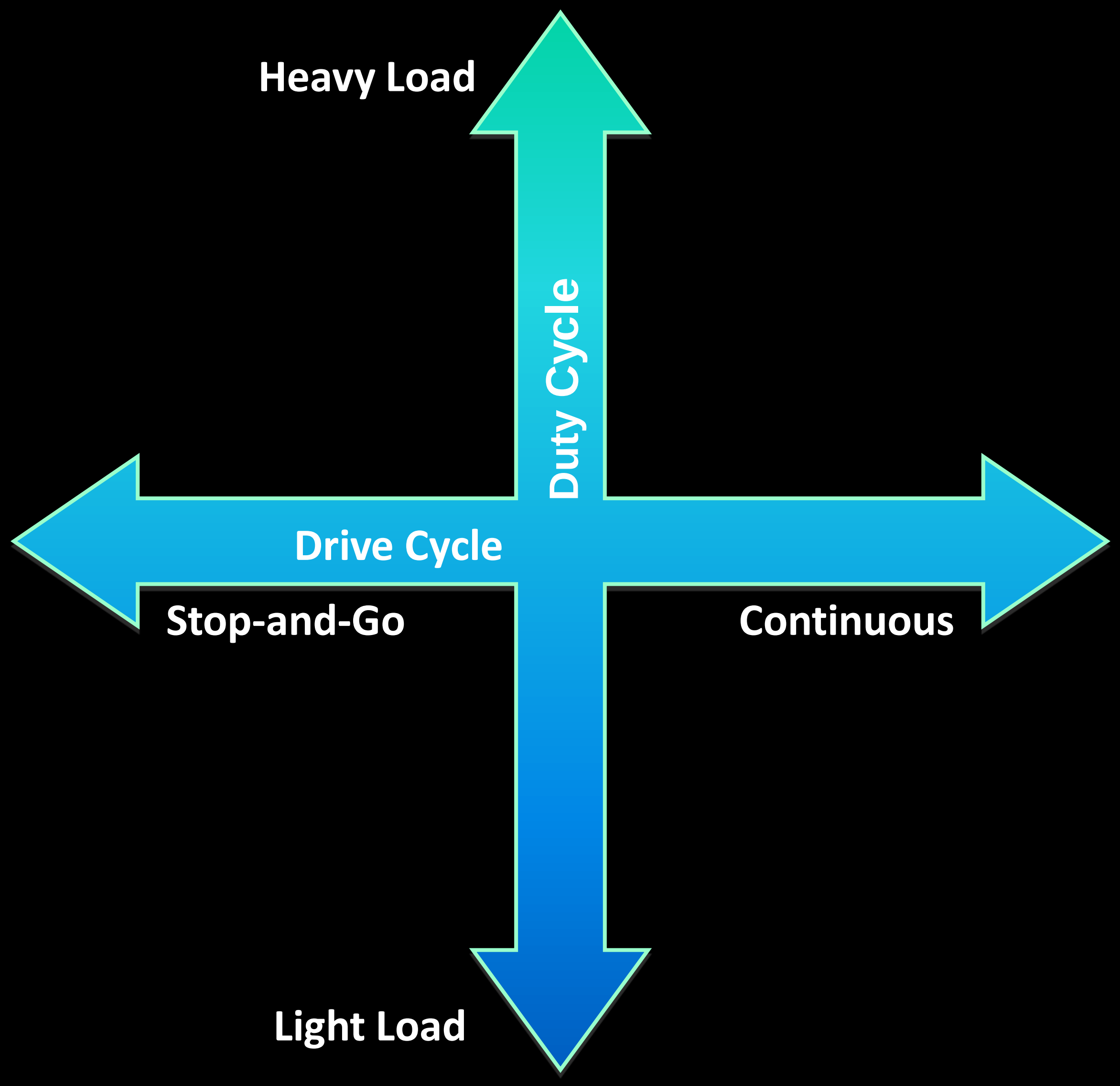
Historical Automotive "DNA"

- Mechanical Drive
- Combustion Engine
- Oil-based Fuel
- Mechanical & Hydraulic Controls
- Human Operated
- Stand-Alone
- General Purpose

Freedom to Go ....

- Where you want
- When you want
- With others
- With Goods

…. and With Broad Capability



~1 Billion
Automobiles Worldwide

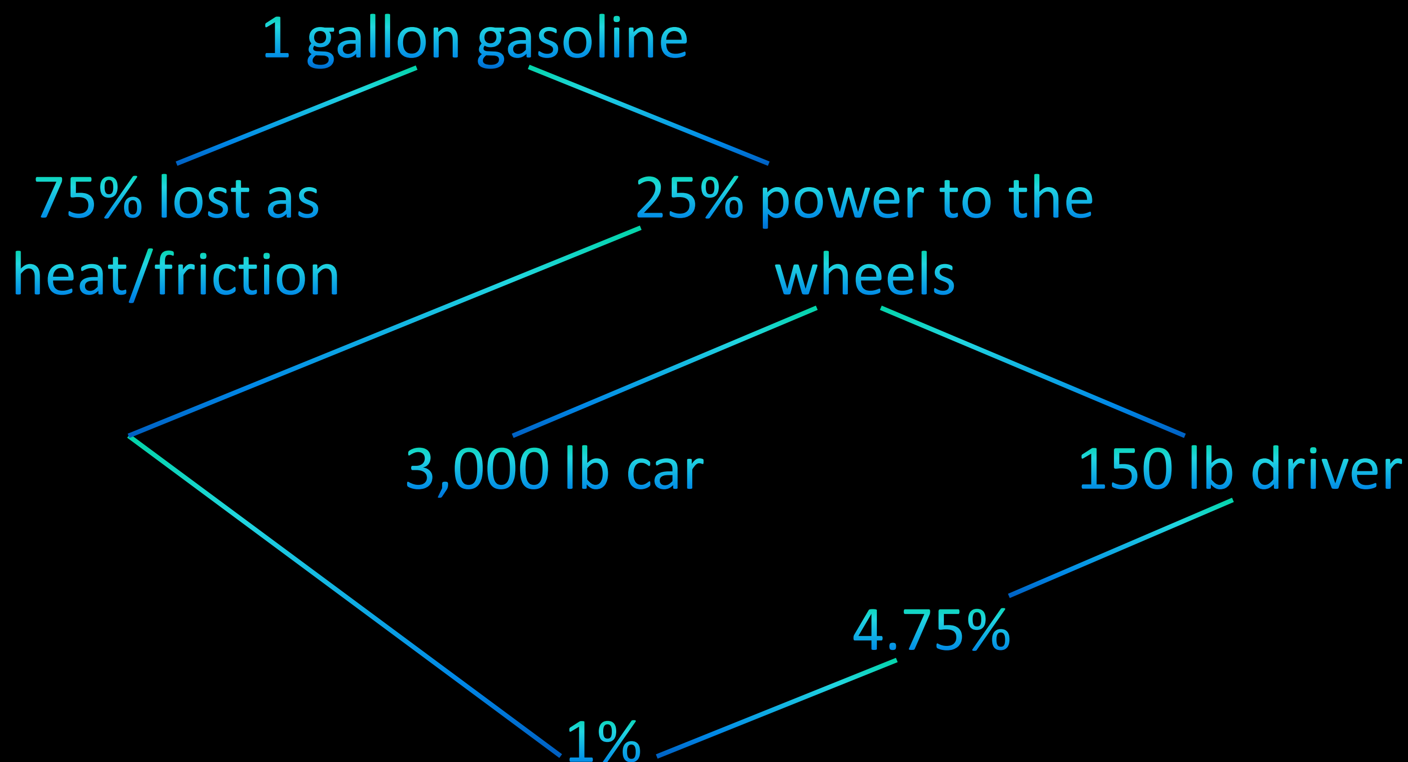
Challenges

- Safety: 1.2 M roadway fatalities worldwide
- Energy: 95% dependent on oil
- Congestion: Traffic delays
- Parking: Land use, delays, cost
- Environment: CO2 emissions
- Infrastructure: Aging and costly

Likely Unsustainable
Without
Transformational Change

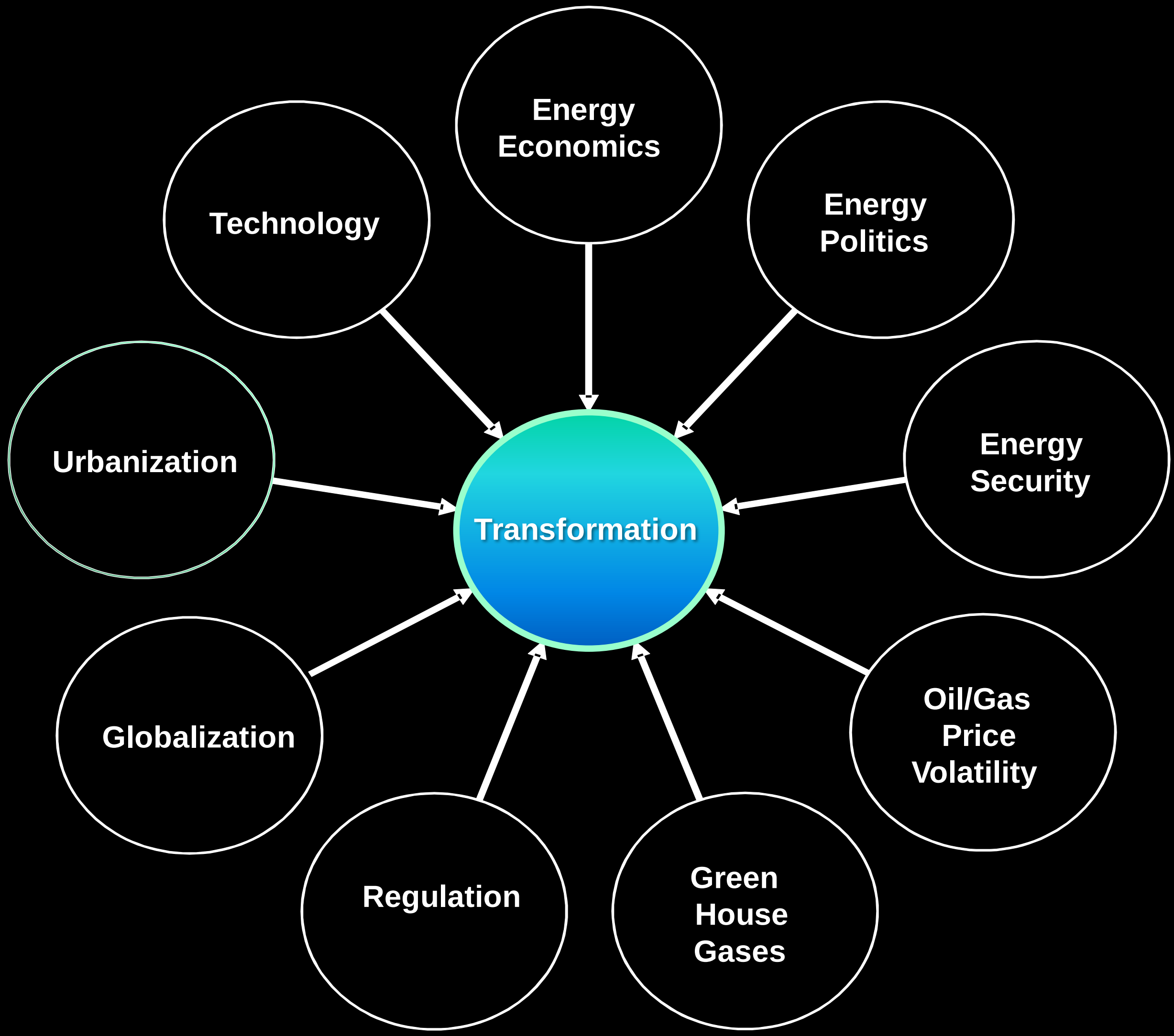
“Pop” Quiz

How much of the energy in a gallon of gasoline is used to move the driver of a car? 1%!



We have a system design opportunity not an energy problem!

Multiple Drivers of Change



Reinventing the Automobile

Historical "DNA"

- Mechanical Drive
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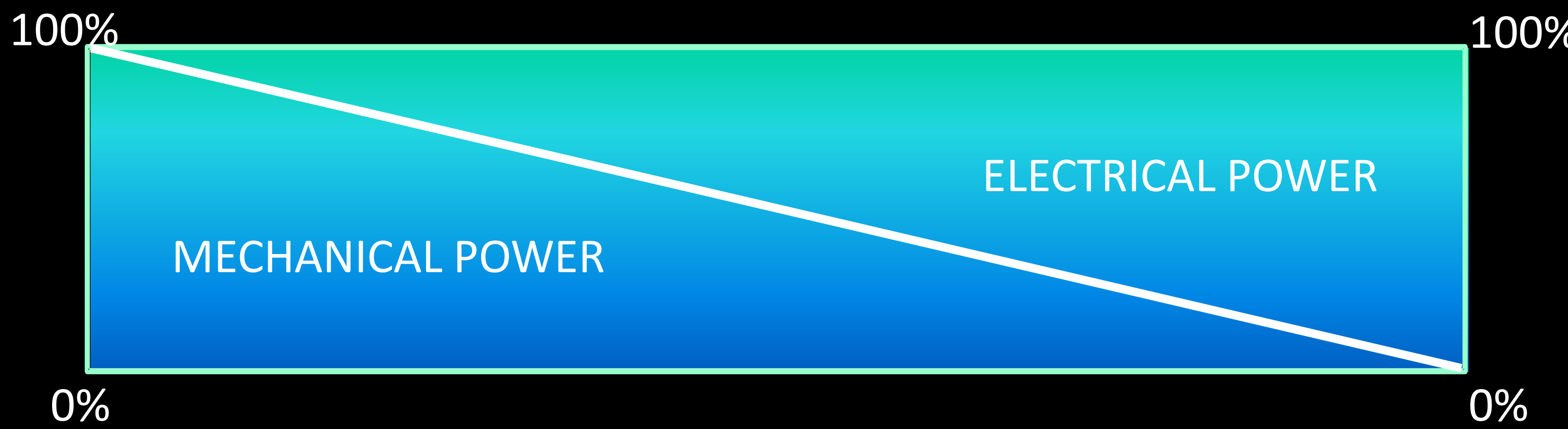
New "DNA"

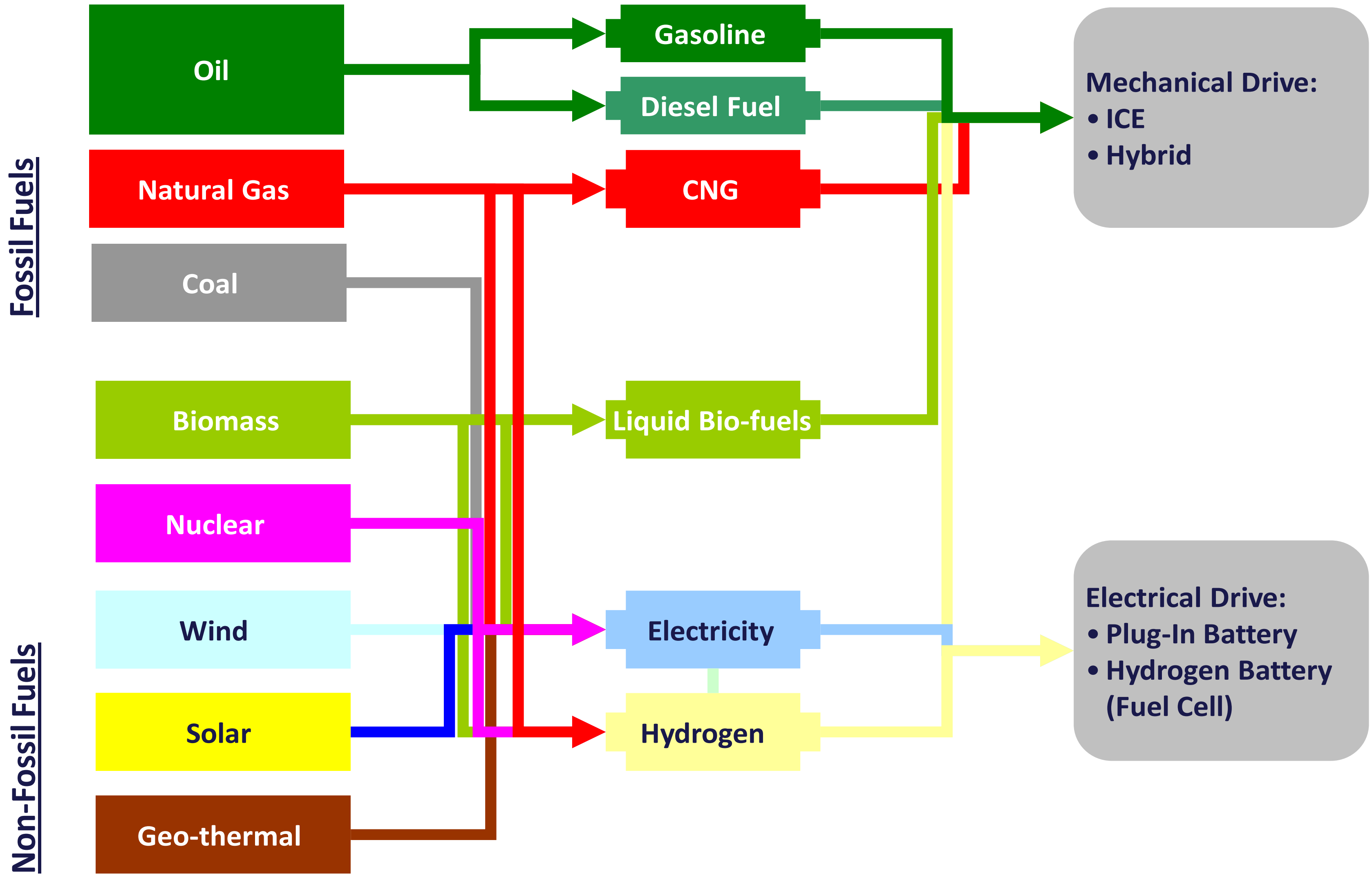
- Electrical Drive
- Electric Motors
- Diverse Energy Sources
- Electronic & Digital
- Driverless
- "Connected " and Coordinated
- Specific Purpose

Vehicle Propulsion



Internal Combustion Engine (ICE)	Hybrid (HEV)	Plug-In Hybrid (PHEV)	Extended Range Electric (EREV)	Battery Electric (BEV) Fuel Cell Electric (FCEV)
Mechanical Drive	Mechanical Drive with Electrical Assist		Electrical Drive with Mechanical Assist	Electrical Drive

Road Transportation Energy Supply



Non-Oil Energy Pathways

Natural Gas

- Compressed or Liquid → ICE
- Burn → Electricity → Plug-in EV
- Reform → Hydrogen → Fuel Cell EV or ICE

Biomass

- Liquid → ICE
- Burn → Electricity → Plug-in EV
- Reform → Hydrogen → Fuel Cell EV

Wind and Solar

- Electricity → Plug-in EV
- Electrolysis → Hydrogen → Fuel Cell EV

- Question?

  How much ***natural gas*** would the U.S. need to use for road transportation in 2025 ***to get off OPEC oil*** ?

- Answer

  ~ 5.9 quadrillion btu with CNGVs (~22% more)

  ~ 3.3 quadrillion btu with BEVs + FCEVs (~12% more)

- Note

  U.S. dry natural gas production grew 2.4 quadrillion btu from 2009-2011 (11% more)

- Question?

  How many ***vehicles using natural gas*** would the U.S. need in 2025 ***to get off OPEC oil*** ?

- Answer

  ~ 80 million CNGVs + BEVs + FCEVs

  ~ 30% of U.S. fleet in 2025

  ~ 40% of cumulative new vehicle sales 2013-2025

- Note

  ~ 13 million NGVs worldwide today

Self-Driving Cars

DARPA Urban Challenge

Google Self-Driving Car

Video of Google Self-Driving Car

Driverless Vehicles Are Compelling

- More value from time in vehicles
- Vehicles that don’t crash
- Lighter vehicles

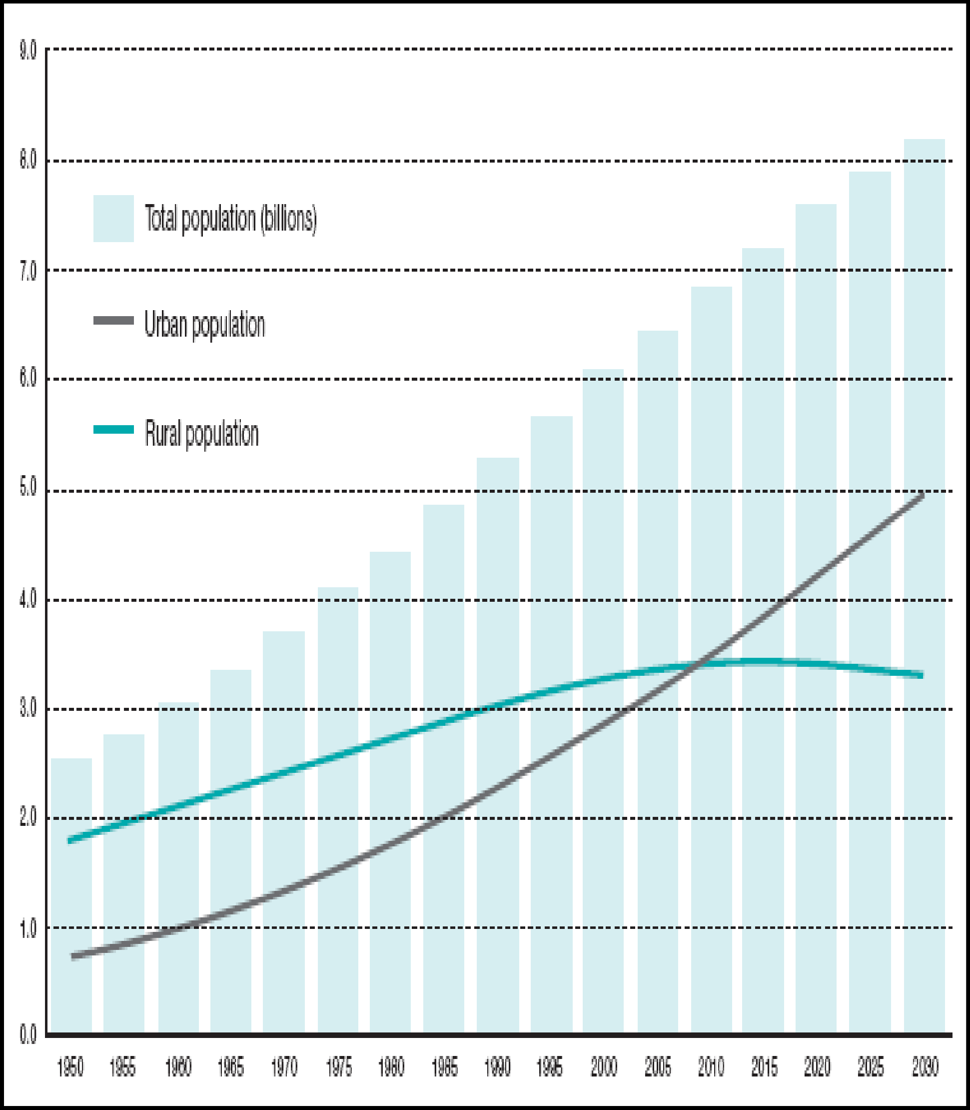
“Mobility Internet”: Connected and Coordinated

- Manages huge amounts of data
- Coordinates precisely
- Optimizes traffic flow and capacity utilization
- Does for vehicles what the Information Internet did for computers

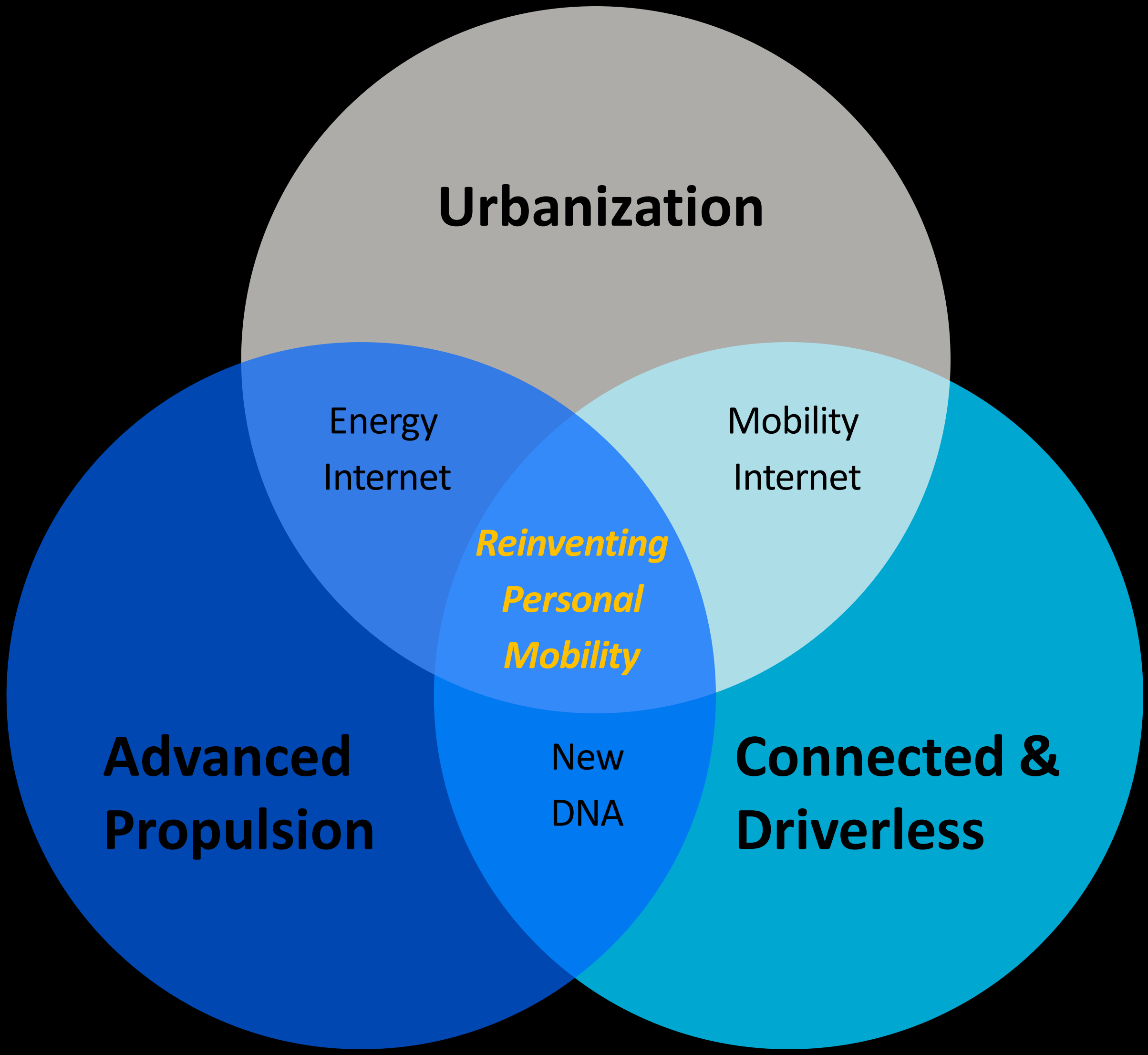
Specific Purpose Designs

- "Tailored" to
  - Driving cycles
  - Duty cycles
  - Trip characteristics (length, occupancy, top speed, …)
- More efficient
  - Energy
  - Space
  - Time
  - Cost

Megatrend Urbanization



Reinventing Personal Mobility

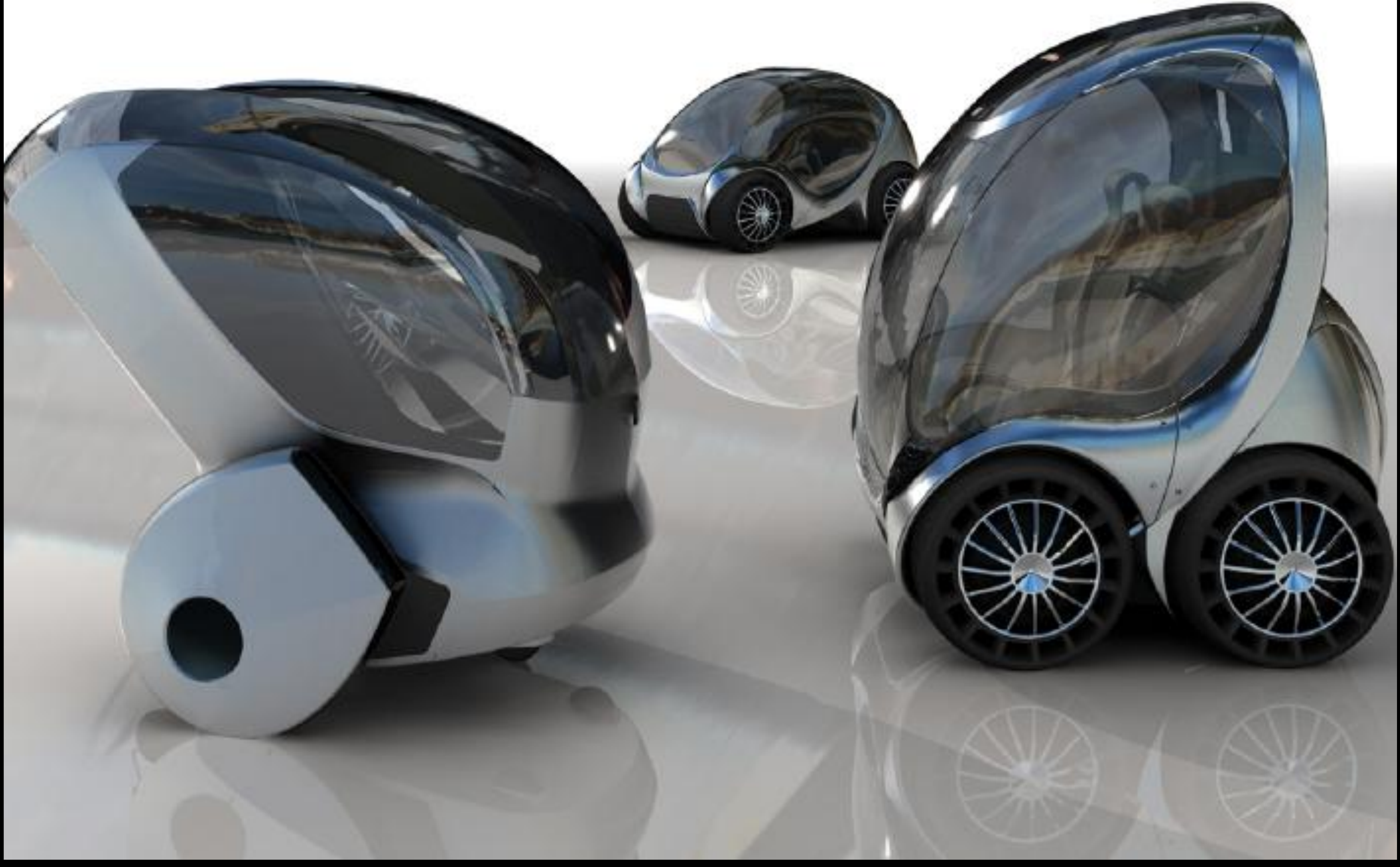


Video of GM's EN-V Concept at Shanghai World Expo

Reinventing the Automobile

Personal Urban Mobility for the 21st Century

William J. Mitchell, Christopher E. Borroni-Bird, and Lawrence D. Burns



15 X

10 X

5 X

0 X

Additional Opportunity

Driverless Vehicles

+

"Mobility Internet"

+

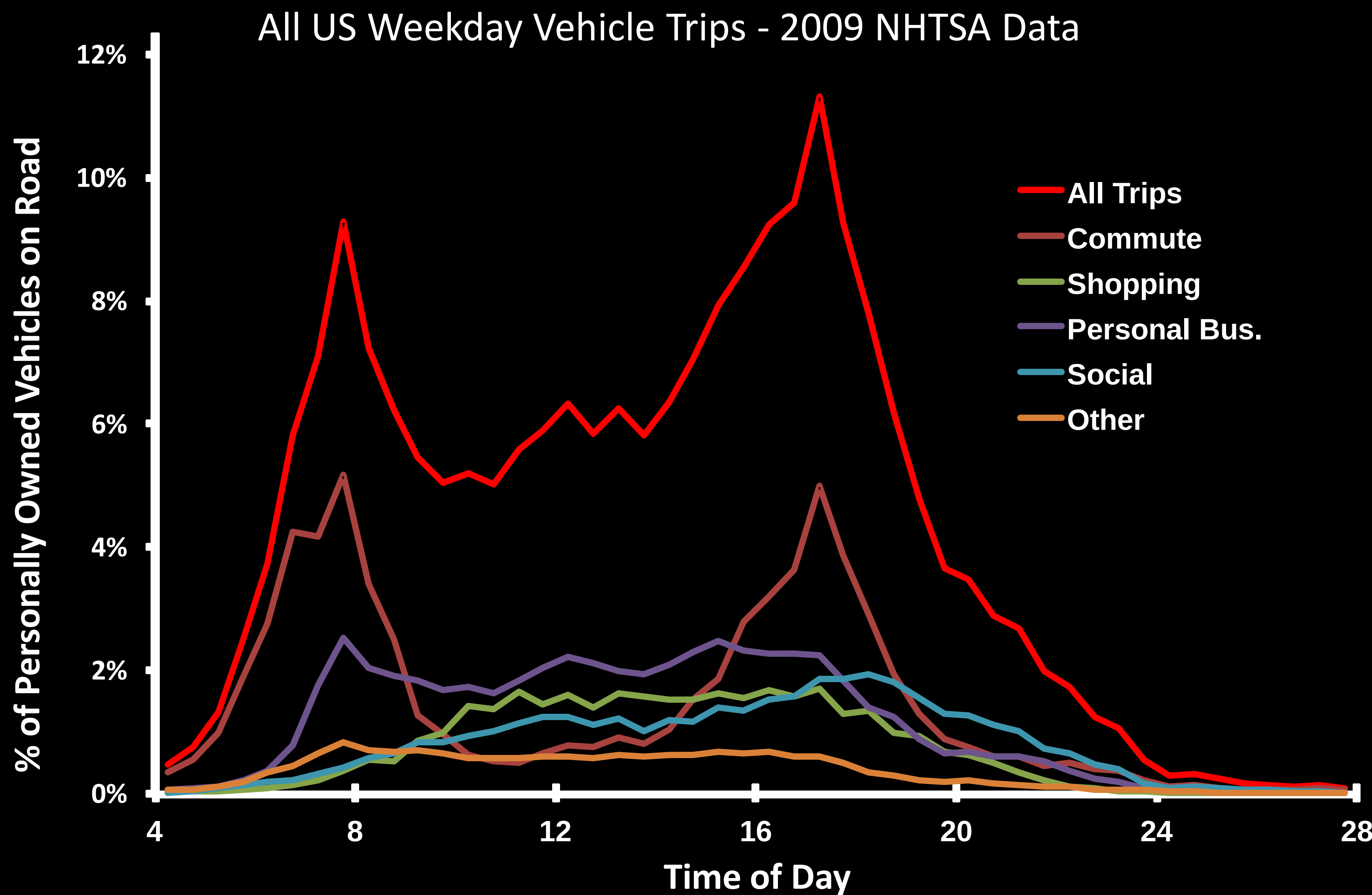
Specific Purpose Designs

+

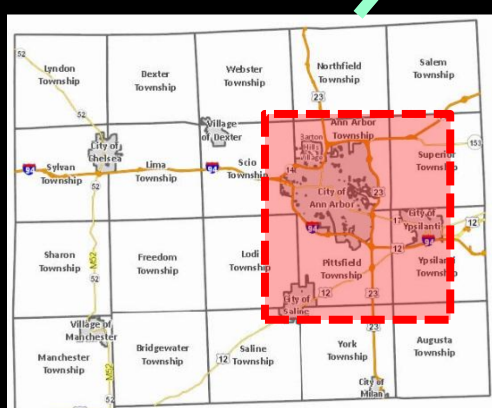
Shared Vehicles

Better Mobility Experiences
at Radically Lower Consumer and Societal Cost

Vehicle Use By Time of Day for Personally Owned Vehicles

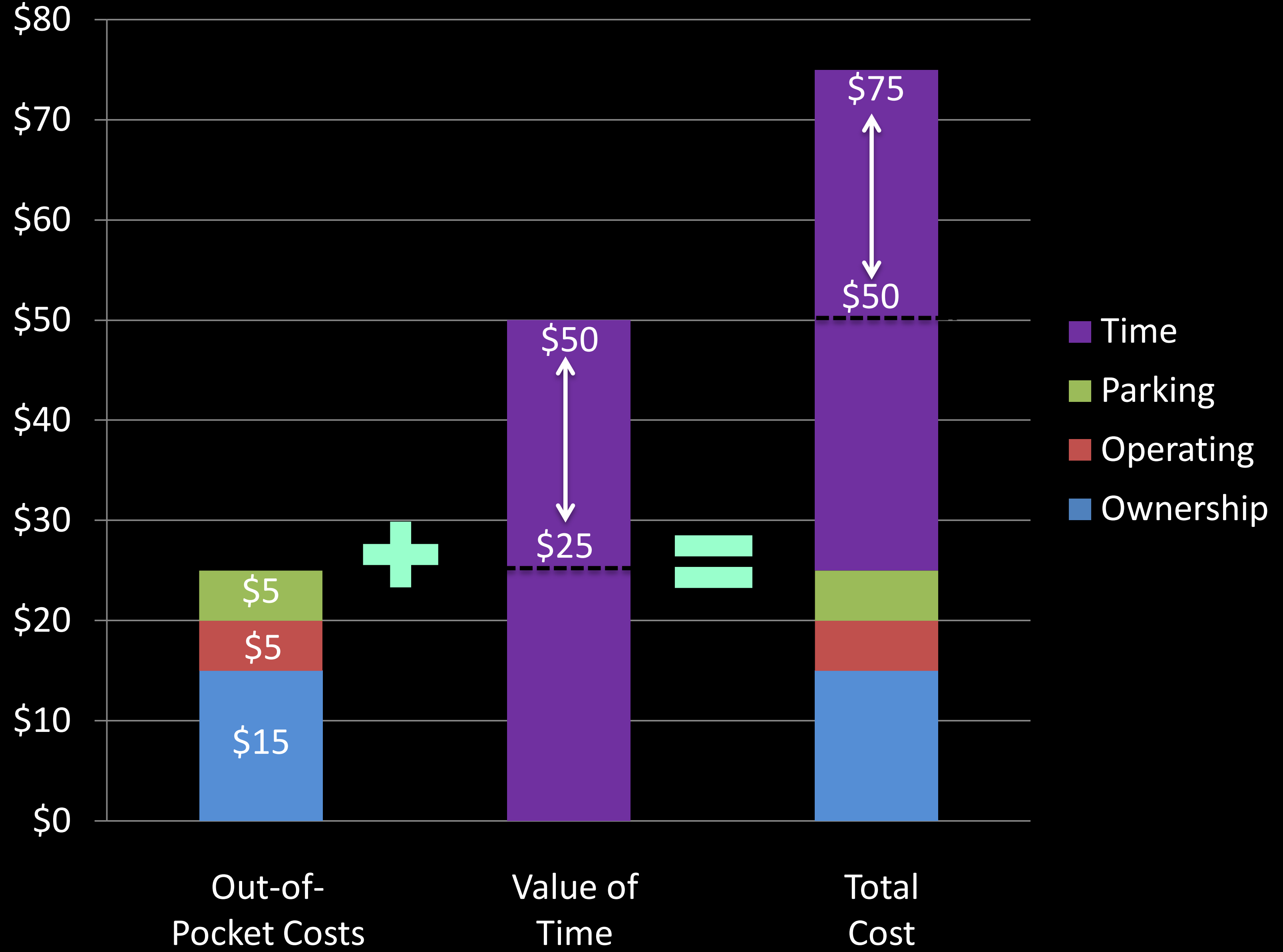


Example: Ann Arbor, Michigan USA



- 285,000 people
- 130 square miles
- 200,000 personally owned vehicles
- 3.7 trips/vehicle per day
- Average trip
  - 8.2 miles
  - 16.3 min
  - 30 mph
  - 1.5 people
- Vehicles used an average of 60 minutes/day (4%)

Cost Per Day to Own and Drive a Car (Ann Arbor)



What Might be Possible?

- Shared fleets of driverless, coordinated, specific purpose vehicles
  - 1 to 2 passenger for personal activities
  - 4 to 6 passenger for family/group activities
  - Light duty trucks for loads
- The right vehicle arrives at your origin when you need it and takes you to your destination while you use your time as desired …. ***undistracted by having to drive***
- Vehicle then goes to the best next location to serve someone else
- Fleets sized and coordinated to match accessibility freedom of personally owned vehicles
  - Same travel demand
  - Fewer vehicles ("tailored", highly utilized, minimal parking)
  - Optimized empty miles

Potential Exists for Transformational Change

Additional Case Studies

- Manhattan Taxis
  - Response time improved from 5 min to 1 min
  - Empty miles per loaded mile reduced from 0.60 to 0.05
  - Cost per taxi trip reduced from $7 to $1
- Babcock Ranch Florida
  - New town north of Ft. Myers
  - Eliminate need for second car
  - Cost per subscriber per day of $2.50

Risks of Disruption

- Examples of Disrupted Industries
  - Photography
  - Media
  - Entertainment
  - Computer
  - Telecom
  - Television
  - Pharmaceutical
- Incumbents Rarely Do Well When Industries Disrupt
- Transportation and Energy Industries Are Ripe For Disruption

Bottom-Line

- The convergence of new technology and innovative business models promise ***better mobility experiences at radically lower consumer and societal cost***
  – Significant business opportunity
  – Incumbent players are at risk of disruption
  – Sustainable mobility is within our grasp
- Focus on
  – Developing and selling ***mobility systems and services***
  – Attaining ***market "tipping points"*** (value > price > cost) efficiently and fast