Merging the Transportation and Electricity Infrastructures

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Sustainable Transportations Systems

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Sustainable Transportation Systems

Research Thrust areas:

- Alternative Energy Resources and carriers (fuels)
  - Fuel cycle performance
  - Fuel Performance
  - Vehicle technology
- Sustainable Systems Evaluation
- Vehicle market evolution via market simulation methods
- Sustainable Transportation Infrastructures

Ongoing work for a DOE supported PHEV/Infrastructure project

Agenda

- Drivers for Change
- Discuss Alternative Transportation Options
- Challenges to /Advantages of PHEVs
- Ongoing work at UMTRI
- Competition

OEM Position

- OEMs acknowledges the importance of reducing fossil carbon emissions
- They also recognizes the significance of the energy security issue, especially as it pertains to petroleum
- Biofuels appear to be an important viable near term opportunity to address, at least in part, these issues

A Systems View of a Product

- **Service rendered: passenger miles via personal mobility**
- **Carbon dioxide emissions from the operating vehicle**

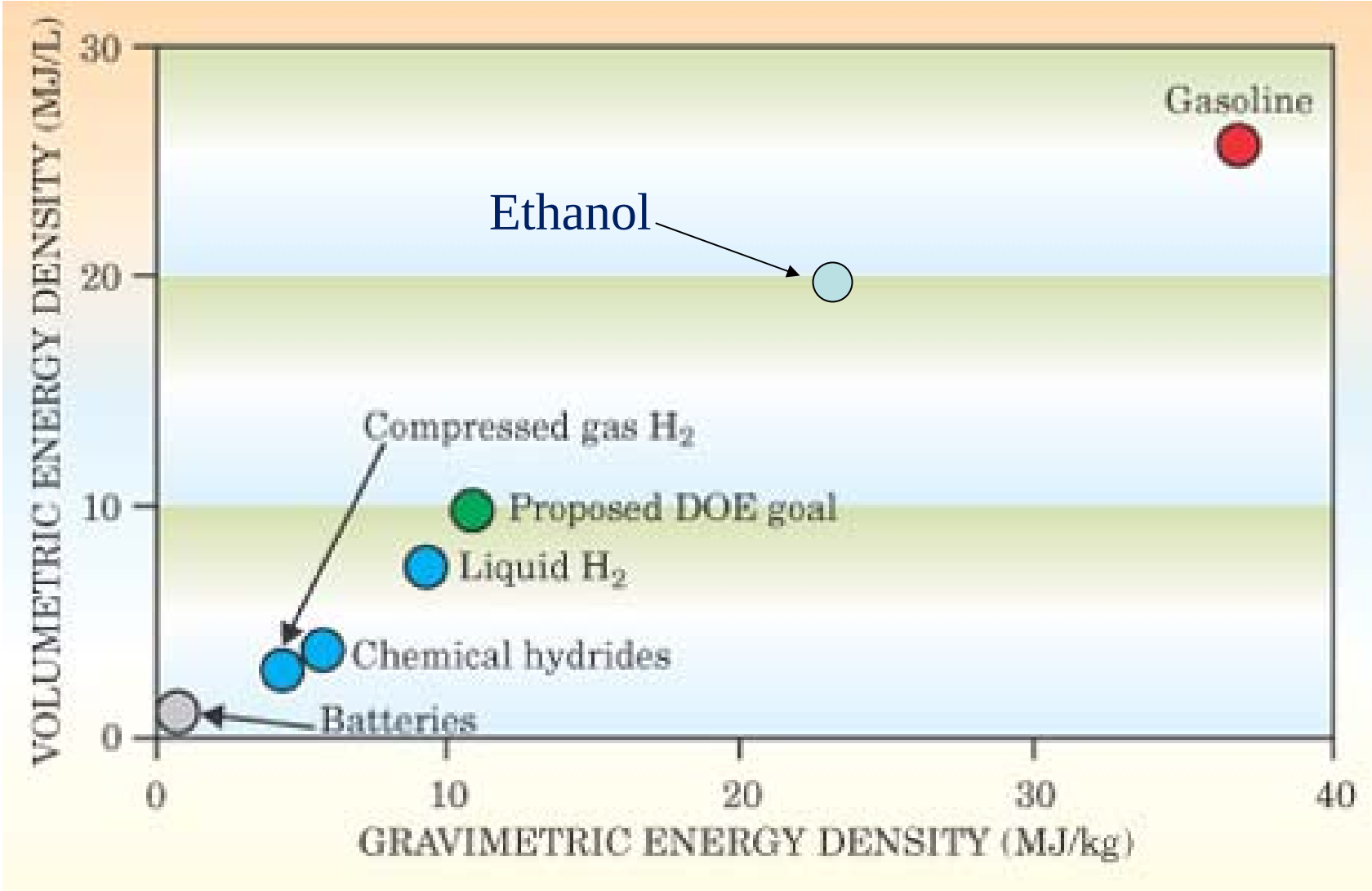
$$[CO_2] = FC * N * VMT * \langle CO_2 \rangle$$

  - **where FC is the effective fuel consumption (e.g.liters/100km)**
  - **VMT is vehicles mile traveled per year, $\langle CO_2 \rangle$ is the amount of CO_2 per unit fuel consumed, N is the number of vehicles**

- **Who influences this CO_2?**
  - **Car companies affect FC through choice of engine technology and vehicle weight and size - based on market demand!**
  - **Fuel producers make fuels with a $\langle CO_2 \rangle$!**
  - **Consumer determines VMT & FC, the latter through choice of product and type of driving done, i.e. city vs. highway!**

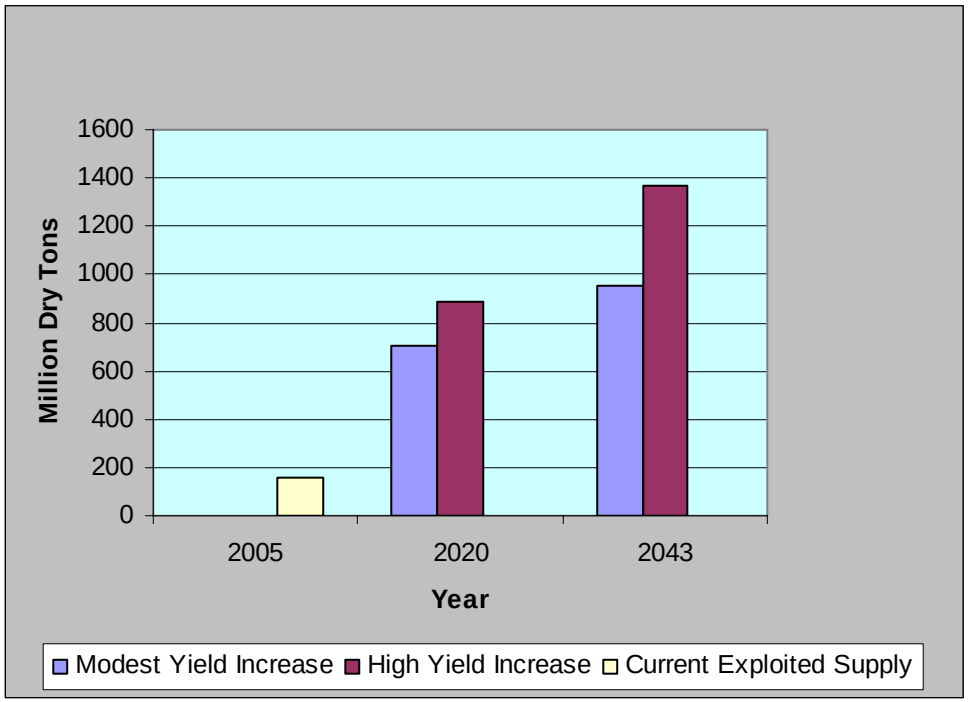
Options

- Alternative fuels:
  - biofuels
  - hydrogen
  - electricity
- Advanced powertrains
  - diesel
  - direct injection spark ignition
  - turbocharging
- Changes in habitation and work patterns
  - long time frame for change


VOLUMETRIC ENERGY DENSITY (MJ/L)
30
20
10
0
Gasoline
Ethanol
Compressed gas H_2
Proposed DOE goal
Liquid H_2
Chemical hydrides
Batteries
0
10
20
30
40
GRAVIMETRIC ENERGY DENSITY (MJ/kg)

Available Biomass

For North America, the potential for large amounts of biomass production is considerable – USDA/DOE Billion Ton Study



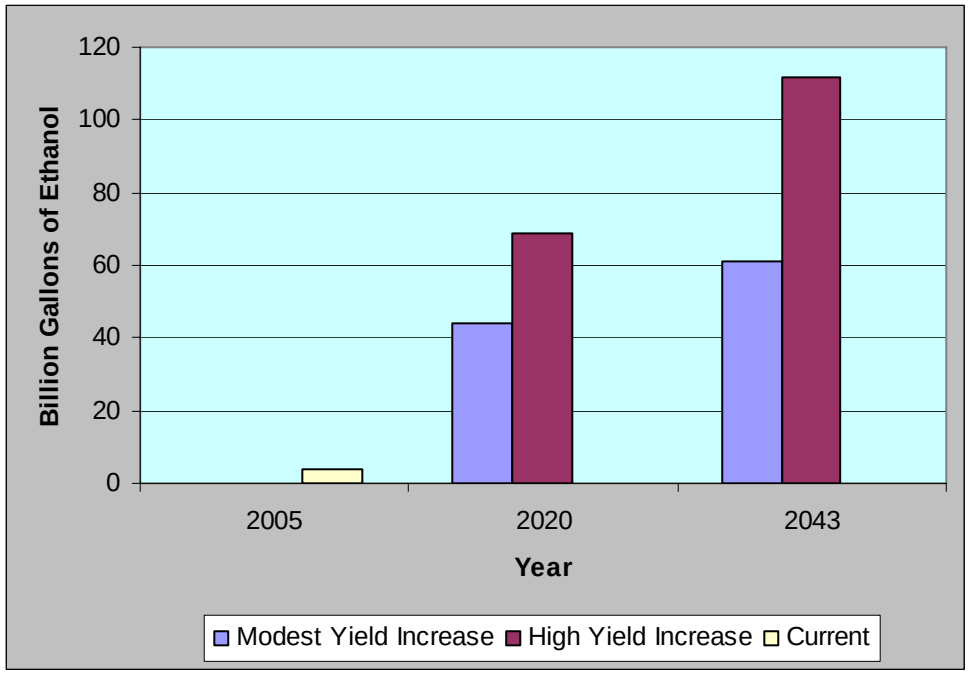
Dependent on:

1. Advanced agricultural practices
2. Greater removal of crop residues
3. Improved crop yields
4. Application of GMO technology
5. Greater use of perennials
6. Greater removal of logging residues
7. Fuel treatment of timberlands
8. Fuel treatment of forestland

60% or more of this biomass is from agricultural resources; the rest is from forestry resources

Generated Biofuels

From North America biomass, significant volumes of ethanol can potentially be produced.



Dependent on:

1. Improvement in crop yields
2. Increase in lignocellulose feeds
3. Improvement in lignocellulose to ethanol process yields

Gasoline consumption:

1. For 2020, 173 billion gallons (EIA)
2. For 2050, 222 billion gallons (scaled with population)

Alternative Vehicles Options

- Plug-In Hybrid Electric Vehicles
- Hybrid Electric Vehicles
- Diesel Vehicles
- Advanced Spark Ignition Vehicles
- Other, e.g. Electric and H_2 Fuel Cell vehicles

Advantages of PHEVs

- Help reduce U. S. dependence on imported oil
- Cleaner overall; lower fossil carbon emissions
  - depending on source of electricity
- Lower overall vehicle operating costs
- Fewer services station stops
- Stored energy for the power sector , hence improving its reliability
  - Grid can support them with ease given any plausible penetration rate
- Can combine advanced fuels (including the grid) and advance vehicle technology

Challenges to PHEVs

- Vehicle range supported by the battery
- Cost of vehicle
- Charging stations
- Charging frequency
- The value proposition needs to be stronger
- Unfamiliarity about a strong interdependency of the transportation and electric infrastructures: V2G or V2H

Work at UMTRI on PHEVs

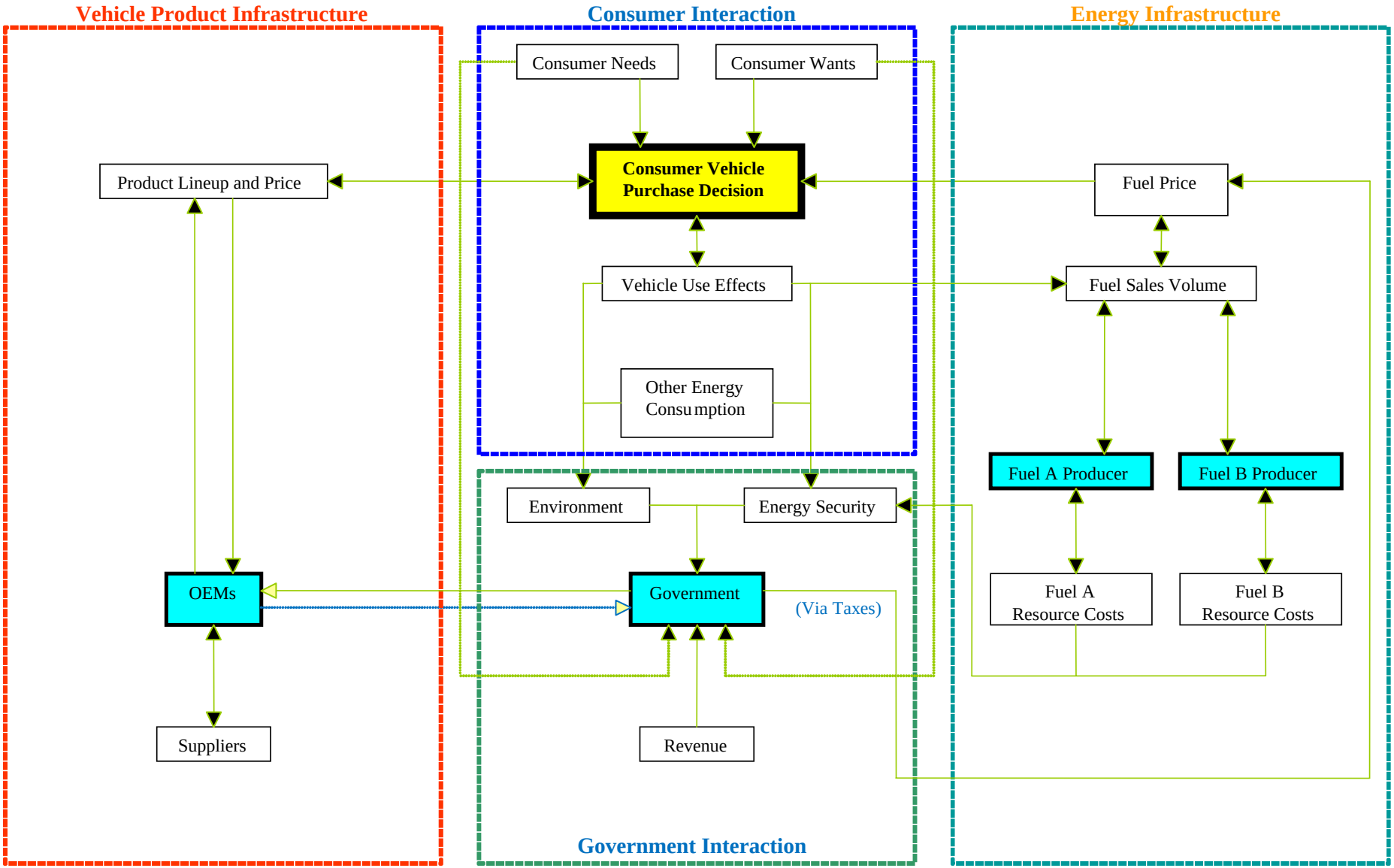
- Currently, PIs on a DOE Plug In Hybrid project:
  Technical Challenges of Plug-In Electric Vehicles and Impacts to the U. S. Power System
  Their Success in an Evolving and Uncertain Marketplace

- Working on three other initiatives on PHEVs which have been submitted to several agencies

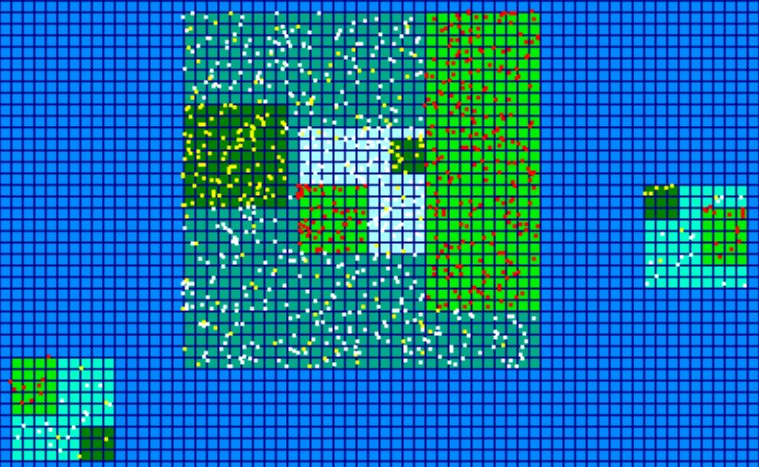
- Our part in the current project is market modeling:

Our Current Work
Anticipating the Market

- Towards that end, we use Agent based modeling, a Complexity Science tool
  - It is bottoms up approach
  - Systems dynamics is another approach: top down
- The model focuses on key players: consumers, OEMs, gov't, energy providers
  - Virtual decision makers in software, agents are motivated to act on some level by: economics, convenience, utility, ethics
- The objective is to characterize the collective market response:
  - Characterize market penetration of PHEVs under conditions of market stress
  - Develop market penetration profiles
  - Explore influence of policy (public/private) instruments on market penetration success
  - ID factors that enable a robust market penetration
  - Provides a sense of risk


Vehicle Product Infrastructure
Consumer Interaction
Energy Infrastructure
Consumer Needs
Consumer Wants
Consumer Vehicle Purchase Decision
Product Lineup and Price
Fuel Price
Vehicle Use Effects
Fuel Sales Volume
Other Energy Consumption
Fuel A Producer
Fuel B Producer
Environment
Energy Security
OEMs
Government
(Via Taxes)
Fuel A Resource Costs
Fuel B Resource Costs
Suppliers
Revenue
Government Interaction

Auto Island



Region includes a city, a suburban ring, and two towns, each with low, middle and upper income zones.

Modeling Output

- The modeling effort permits us:

  - ✓ to estimate PHEV penetration curves
    - ➢ robustness of a market penetration
    - ➢ rate of penetration

  - ✓ to elucidate the influence of :
    - ➢ policy instruments (carbon taxes, CAFE, etc.)
    - ➢ competing technologies
    - ➢ robustness of penetration
    - ➢ likelihood of success

Concluding Remarks

- PHEVs have the potential to enable significant reductions in:
  - Petroleum consumption
  - Fossil carbon emissions

- However, significant challenges exist to their successful penetration into the auto market place
  - Cost is the biggest

- If successful, PHEVs could
  - create volumes of new business for the electricity sector, a domestic energy transformer using most domestic energy resources
  - improve grid reliability
  - compounding benefits to the U. S. if bio-liquid fuels are also employed