Electricity, Biofuels or Hydrogen for Vehicles

What should states do?

Clinton J Andrews

RUTGERS
Edward J. Bloustein School of Planning and Public Policy
What is a Fuel?

\[
\begin{align*}
\text{H--C--H} & + \text{O=O} \rightarrow \text{C--H} & \quad \text{O±O} \\
\text{H--C--H} & & \text{O=O}
\end{align*}
\]

Courtesy of Daniel Nocera
Affordable, clean, secure?

http://www.4driversonly.com/50226711/OilPricesFirstBorn.jpg

https://documentingdissent.tv/catalog/images/Oil,%20War,%20&%20Geopolitics.JPG
NJ Energy Sources

- Petroleum: 51%
- Natural Gas: 23%
- Nuclear: 13%
- Electric Imports: 8%
- Coal: 4%
- Waste/Wood: 1%

2,500 Trillion Btu in 2001
EIA 2006
NJ Energy End-Uses

2,500 Trillion Btu in 2001

EIA 2006
1. Environment
2. Economy
3. Social
Aspirational, Long-Term Targets

1. Scenarios for NJ’s future (controllable & uncontrollable factors)
2. Model NJ’s performance using several indicators
3. Set targets for indicators but understand tradeoffs

![Graph showing CO2 Emissions over time with various targets and scenarios.](image-url)
Gasoline Prices

Cents per Gallon

Year

History
Baseline
High Growth
Low Growth
Scenarios

- Uncontrollable Factors:
  - Baseline, High Growth, Low Growth

- Controllable Factors: Baseline +
  - Medium carbon tax ($50)
  - High carbon tax ($200)
  - Full cost energy pricing
  - High efficiency
  - Super high efficiency
  - Advanced bio-fuels
  - Super advanced biofuels
  - Compact growth: VMT reduction
  - No More NIMBY
  - Bundle #1: High efficiency, Full cost, Advanced bio-fuels
  - Bundle #2: Super high efficiency, Compact growth, Adv. bio-fuels
Environmental Target: CO2 Emissions from Energy

**THE TARGET**
- Reduction to 1990 level by 2020 and 80% reduction from 2006 level by 2050.

**THE GAP**
- Aggressive policy scenario: Aggressive implementation of known policies and technologies can reduce emissions sufficiently to achieve the 2020 target. (see p. 7 for scenario description)
- The unknown future: After 2020, known policies fail to keep up with growth and we still need to reduce emissions dramatically to reach the 2036 and 2050 targets.
Economic Target: Energy expense as % of income

2003:
NJ 5.9% ($11.97/MMBTU)
NY 6.3% ($14.26/MMBTU)
PA 8.2% ($11.83/MMBTU)

USDOE 2007
Security Target: Percent of energy from local sources

PERCENTAGE OF NJ ENERGY CONSUMPTION MET BY LOCAL SOURCES

THE TARGET
10% of energy from local sources.

LEGEND
- HISTORY
- BASELINE
- AGGRESSIVE POLICY SCENARIO

New Jersey’s growing population and economy will place increasing burdens on the state’s energy supply and delivery infrastructure. If we do not ensure the future security and adequacy of this infrastructure, we leave New Jersey vulnerable to painful, costly disruptions.
NJ Findings

• The 2020 GHG target is achievable with **concerted** short-term effort
• Long-term GHG target gap exists: we need “Solution X”
• Synergies exist between global warming and security solutions
• NJ is no longer an energy-intensive state, so aggressive policies are not too big a drag on the economy as a whole
• Now is the time to pursue the next level of detail on energy choices
Energy for Transportation

- Petroleum
- Natural gas
- Biofuels
- Hydrogen
- Electricity
Energy for Transportation

• Petroleum
• Natural gas
• Biofuels
• Hydrogen
• Electricity
Why Biofuels?

- Uses today’s cars & fuel distribution
- Uses today’s liquid fuel infrastructure
- Leverages current trends: FFV’s, Hybrids
- Part of fuel market via “blending” - just add E85

V. Khosla www.khoslaventures.com
Long vs Short Carbon Cycle

10^7 years

10^0 years

Henry Joseph Jr., Brazilian Automotive Industry Association - ANFAVEA
Crops like corn are finely ground and separated into their component sugars. That is reabsorbed by the original crops.

\[ \text{CO}_2 \]

which releases carbon dioxide which can be used as an alternative fuel. The sugars are distilled to make ethanol,
Debate on Net Energy Benefits of Ethanol

Differences between Pimentel & Patzek and others lie in:
- Corn farming energy use
- Energy use for producing nitrogen fertilizer
- Ethanol plant energy use
- Credits for co-products from biofuel plants

![Graph showing Corn EtOH Energy Balance Results Among Completed Studies Show an Uptrend](http://www.transportation.anl.gov/pdfs/TA/347.pdf)

Energy balance here is defined as Btu content a gallon of ethanol minus fossil energy used to produce a gallon of ethanol.

Energy Benefits of Fuel Ethanol Lie in Reductions in Fossil Energy and Petroleum Use

Total Btu Spent for One Btu Available at Fuel Pumps

- Total Energy (Fossil + Renewable)
- Fossil Energy (NG + Coal + Petroleum)
- Petroleum Energy

Bar chart showing the energy spent for one Btu available at fuel pumps for different types of fuel ethanol (RFG, Corn EthOH: DM, Corn EthOH: WM, Cell. EthOH) and their energy allocation.
Use of Ethanol to Replace Gasoline Results in WTW Fossil Energy and Petroleum Benefits

- **Total Energy**
- **Fossil Energy**
- **Petroleum Energy**

|----------|--------|------------------|--------------------|-------------------|---------------------|-------------------|-------------------|--------------------|-------------------|-------------------|-------------------|
Technology Progression

Corn

Cellulosic Bioethanol

Gasification

Synthetic Biorefinery

Direct Synthesis?

Algae

V. Khosla www.khoslaventures.com
Almost All U.S. Ethanol Plants Are Located in U.S. Midwest

http://static.howstuffworks.com/gif/blackout-grid.gif
Energy for Transportation

- Petroleum
- Natural gas
- Biofuels
- Hydrogen
- Electricity
Hydrogen?

Extract primary energy

Transmit energy nearer to user

Transform primary energy into hydrogen

Transmit hydrogen to user

Use hydrogen for human benefit
Combustion of Hydrogen & Gasoline

Hydrogen car to the left, Gasoline car to the right

www.altfuels.com
Electrolysis and Reformation

H₂O - Water

Electric Current

2H

O

CH₄ - Methane (Natural Gas)

C

4H

Steam Heat
U.S. Hydrogen Production by Volume


There are four major types of Fuel Cells Commercially Available to the Market

- Polymer Electrolyte or Proton Exchange Membrane Fuel Cell (PEM)
- Phosphoric Acid Fuel Cell (PAFC)
- Molten Carbonate Fuel Cell (MCFC)
- Solid Oxide Fuel Cell (SOFC)
Height: 7 – 8 ft.
**DEdelivered H₂ Costs of Various Technologies**

- GEA = Gasoline Efficiency Adjusted – scaled to hybrid vehicle efficiency

National Research Council 2006
CARBON RELEASED DURING H₂ PRODUCTION, DISPENSING & DELIVERY (FUTURE TECHNOLOGIES)

Kilograms of carbon per kg of hydrogen

- Coal
- Coal w/ seq.
- NG
- NG w/ seq.
- Nuclear
- Biomass
- Electrolysis
- PV (grid backup)
- Wind
- Gasoline (GEA)

Indirect Release through Electricity
Direct Release

Centrally Distributed

National Research Council 2006
Focal Point of Federal Policy

• Research, development, and validation of fuel cell and hydrogen production, delivery, and storage technologies
• Developing hydrogen from various domestic resources
• Promote the use of hydrogen for clean, safe, reliable, and affordable energy for fuel cell vehicles and stationary power applications
• Ensuring abundant, reliable, and affordable energy supply through the 21st Century.
State Approaches to Hydrogen Policy:

California-- Minimizing the impact of car-dependency
Michigan-- Adapting key industry
New Jersey-- Hydrogen Learning Center & Experiments
   New York-- Hydrogen Energy Roadmap
Connecticut-- New economic development prospects
Hawaii-- Energy independence
Energy for Transportation

- Petroleum
- Natural gas
- Biofuels
- Hydrogen
- Electricity
U.S. Electricity Generating Capacity, including Combined Heat and Power, 2004-2030 (gigawatts)

New Nuclear

New Renewable

Existing Other Fossil Steam

Existing Combustion Turbine

Existing Coal Steam

Existing Combined-Cycle

Existing Renewable

Existing Nuclear

Existing Pumped Storage

Needed Capacity

Annual Energy Outlook 2006
Old World:

Customers purchased bundled service from a local utility having full responsibility for reliable service.

Electric Utility

Electric Customer

Terms and Conditions

DELIVERED ENERGY

PAYMENT

©Dominion Resources, Inc. 2001
New World: Restructured Markets

• Every arrow represents a possible contract interface.
• Expect each business will act in the interests of its shareholders.

Responsibilities
• The RTO will assume responsibility for operation of the transmission system.
• The LSE has the responsibility to procure supplies for customers.
• The Generators are responsible for meeting contract obligations with LSEs for supply.
• The Distribution Companies will provide local delivery service.
Load Aggregator can extend traditional Demand Response solutions like Thermostats and A/C cycling switches with Stored Energy reclamation from EVs, through reaction to wholesale price signals or regulation commands.
Key to V2G: Power Connection is Bi-Directional

Power can flow to or from vehicle

- Grid-tied
- Stand-alone

DC Power
300 - 450 V
0 - 50 A

Power Electronics Unit (Inverter)

AC Power
100 - 250 V
50 - 60 Hz
0 - 80 A

Motor

Conductive Connector

AC PROPULSION

pjm
Geographic Vulnerability & Limited Resources

<table>
<thead>
<tr>
<th>Year</th>
<th>Imports of Electricity to NJ (million kWh)</th>
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<tbody>
<tr>
<td>1960</td>
<td>3,785</td>
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<tr>
<td>1970</td>
<td>5,822</td>
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<tr>
<td>1980</td>
<td>73,410</td>
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<tr>
<td>1990</td>
<td>85,153</td>
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<td>2000</td>
<td>57,002</td>
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<tr>
<td>2005</td>
<td>82,877</td>
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</table>

Represents approx. 25% of total consumption in 2005.
Cost Structure of Electricity

Locational Marginal Pricing = Generation Marginal Cost + Transmission Congestion Cost + Cost of Marginal Losses

Load: 500 MW
Capacity: 150 MW
Bid: $10/MW
Capacity: 200 MW
Bid: $15/MW
Capacity: 400 MW
Bid: $12/MW
Capacity: 200 MW
Bid: $20/MW
Load: 350 MW
Capacity: 150 MW
Bid: $25/MW

Thermal Limit
Potential Effect of a Stressed Electric Grid

August 14, 2003 East Coast blackout

Summer 2007 Queens 9-day blackout
What limits rate of deployment of hybrids & plug-ins? Cost, cost, cost…

- Hybrid Prius vs. regular Prius: cost penalty = $3000 (2006 data Car & Driver, Financial Times) about enough to pay off at $3-4/gallon without interest
- About $2000 of the $3000 is for small fast battery, currently nickel hydride less than 1kwh.
- $1,000-$2,000 tax incentive per car, for the first million hybrids from each manufacturer, essential to speed of development, becoming cheaper, in US
- Outside the US, higher gas price bigger market now, but subsidized gasoline prices in China cheaper than US

Paul Werbos www.werbos.com/energy.htm
World’s First Mass Market PHEV
2nd half of 2008: BYD Motors F6DM

• 20 kwh battery, 65 miles all-electric driving range
• Made in Shenzhen, China
• Follow-on in 2009: F3DM, 100 miles all-electric
• www.byd.com
Other contenders

• GM Volt, 14kwh, 40 miles: planned for late 2010, using A123 or LG Chem advanced lithium battery. Enough for 90% of US to get to work in case of total gasoline embargo, if employer parking lots have recharge stations.

• Hyundai: US mass-market hybrid 2009, no comment on plug-in, deal with LG Chem and massive new Korean battery program

• Toyota: 2010 PHEVs to fleet owners only, a test, using proprietary advanced lithium-ion battery and power electronics technology GM cannot buy. Plans to keep doubling hybrid output every year.

• Chery (China) says by 2010: half of its million cars per year will be hybrids, half of them on alternate liquid fuels. 40% will be for export.

• Dongfeng Electric Car Company, and Chang’An
How To Zero Out Gasoline Dependency:
Best Near-Term Hope for 100% Renewable Zero-Net-CO2 cars & Total Security for Car Fuel

*GEM = Gasoline-Ethanol-Methanol

With GEM* fuel-flexible cars, biofuels might supply ¼ of present liquid fuel demand trends

Plug-in Hybrids with 10kwh batteries get half their energy from electricity

Highest mpg
Hybrids Cut Gas per Mile By 50%
Scales of Energy Markets

- **Oil**: once local, now global
- **Coal**: once local, now global
- **Natural gas**: once local, now continental
- **Electricity**: once local, now regional
- **Hydrogen**: now local, eventually continental?
- **State & local policies affect trajectories**
States & Localities Vary Greatly

- Preferences (Dem/Rep, hunter/enviro, …)
- Capabilities (large/small, rich/poor, …)
- Circumstances (producer/consumer, urban/rural, …)

- Seeds of technological transitions encounter more fertile soil in certain jurisdictions
Where will innovations take root?

- Innovative culture
- High capacity to act
- Attractive circumstances
  - e.g., Iceland
  - But no U.S. states have the ideal combo of preferences, capabilities, circumstances
## Hydrogen Economy Activity

<table>
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<th>Jurisdiction</th>
<th>Preferences</th>
<th>Capabilities</th>
<th>Circumstances</th>
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<tr>
<td>Washington</td>
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</tr>
</tbody>
</table>
State GHG Emission Targets

WA: 1990 levels by 2020
OR: 10% below 1990 levels by 2020
CA: 1990 levels by 2020
AZ: 2000 levels by 2020
WA: 1990 levels by 2020
MN: 15% below 2005 levels by 2015
NY: 10% below 1990 levels by 2020
ME: 10% below 1990 levels by 2020
VT: 25% below 1990 levels by 2012
NH: 10% below 1990 levels by 2020
MA: 10% below 1990 levels by 2020
RI: 10% below 1990 levels by 2020
CT: 10% below 1990 levels by 2020
NJ: 1990 levels by 2020
VA: 30% below BAU by 2025
FL: 2000 levels by 2017, 1990 levels by 2025, and 80% below 1990 levels by 2050
HI: 1990 levels by 2020

Renewable Portfolio Standards

Mandates and Incentives for Biofuels

Motivations for Local Action

• Motivations mirror those of states
  – Much to lose from climate impacts (sea level, storms, temperatures increases, water, etc.)
  – Much to gain from opportunities (economic development, energy savings, air quality)

• Localities have relevant authorities
  – Building and development permits (influence energy and land use)
  – Public transit
  – Building codes
  – Municipal electric utilities
  – Other

Efficient Land Use Patterns
Efficient Behaviors

- Carpool, vanpool
- Transit passes
- Flextime, telework
- Biking, walking
How Allocate Responsibilities?

• Federalism is key part of context
• **Centralize** responsibilities to take advantage of scale economies, enforce national norms, pool risks, reduce spillovers
• **Decentralize** responsibilities to allow experimentation, match local circumstances, encourage diverse civic cultures
Federal Government Role

• Sponsor fundamental research at significant & stable level
• Promote adoption of standards
• Subsidize state-level experiments, ensure shared learning from those experiments
• Reinvigorate the practice of nonpartisan technology assessment
State Government Role

- Sponsor or implement applied research, cost-effective demonstration projects
- Encourage regulated utilities to investigate PHEVs & hydrogen
- Develop more efficient land uses
- Sponsor outreach, education, esp. for leaders
So…

- Don’t decide indeterminate aspects of transportation future a priori using ideology or interests—centralized vs. decentralized, nuclear vs. renewables.
- Instead, experiment, find out empirically what approaches bring desired outcomes.
State actions buy us time to innovate

- Work at state level on no-regrets solutions today (smart behavior, smart growth, efficient electricity pricing)
- Deploy public policies to align private incentives (carbon tax/cap, land use regulation, efficiency standards)
- Pursue engineering advances for integrate-able systems (smart grids & loads, plug-in hybrid electric vehicles)
- Don’t seek engineering solutions in areas where basic science isn’t ripe (solar, biofuels, fusion)
- Support basic science for long-term solutions (chemistry, physics, biology)