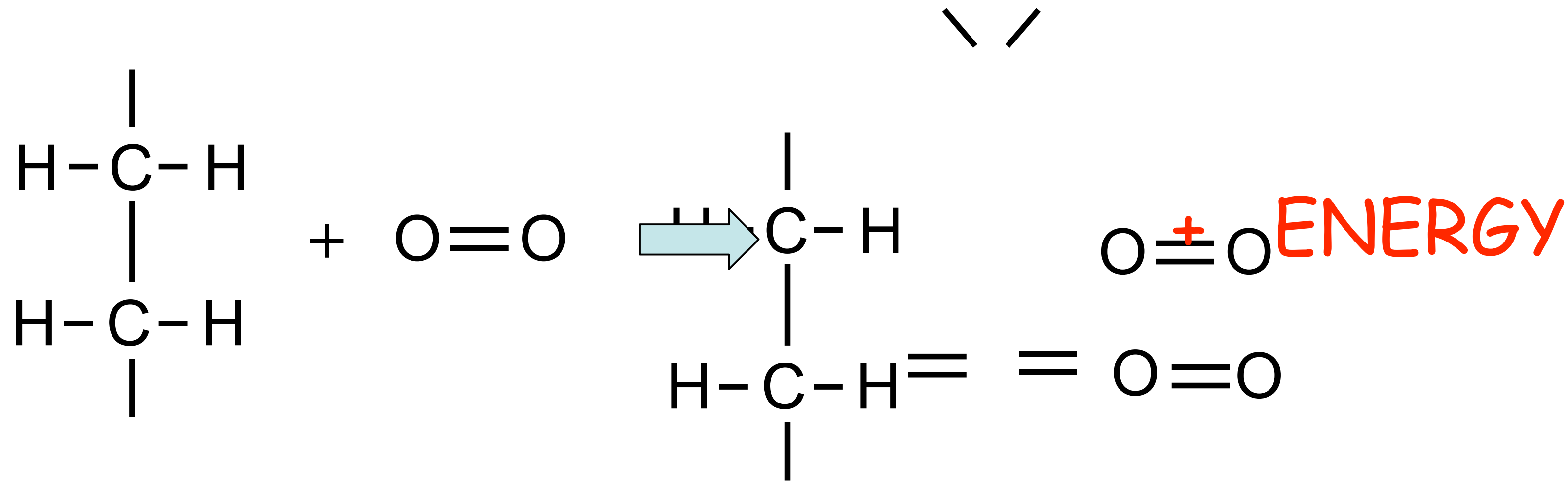
Electricity, Biofuels or Hydrogen for Vehicles

What should states do?

Clinton J Andrews

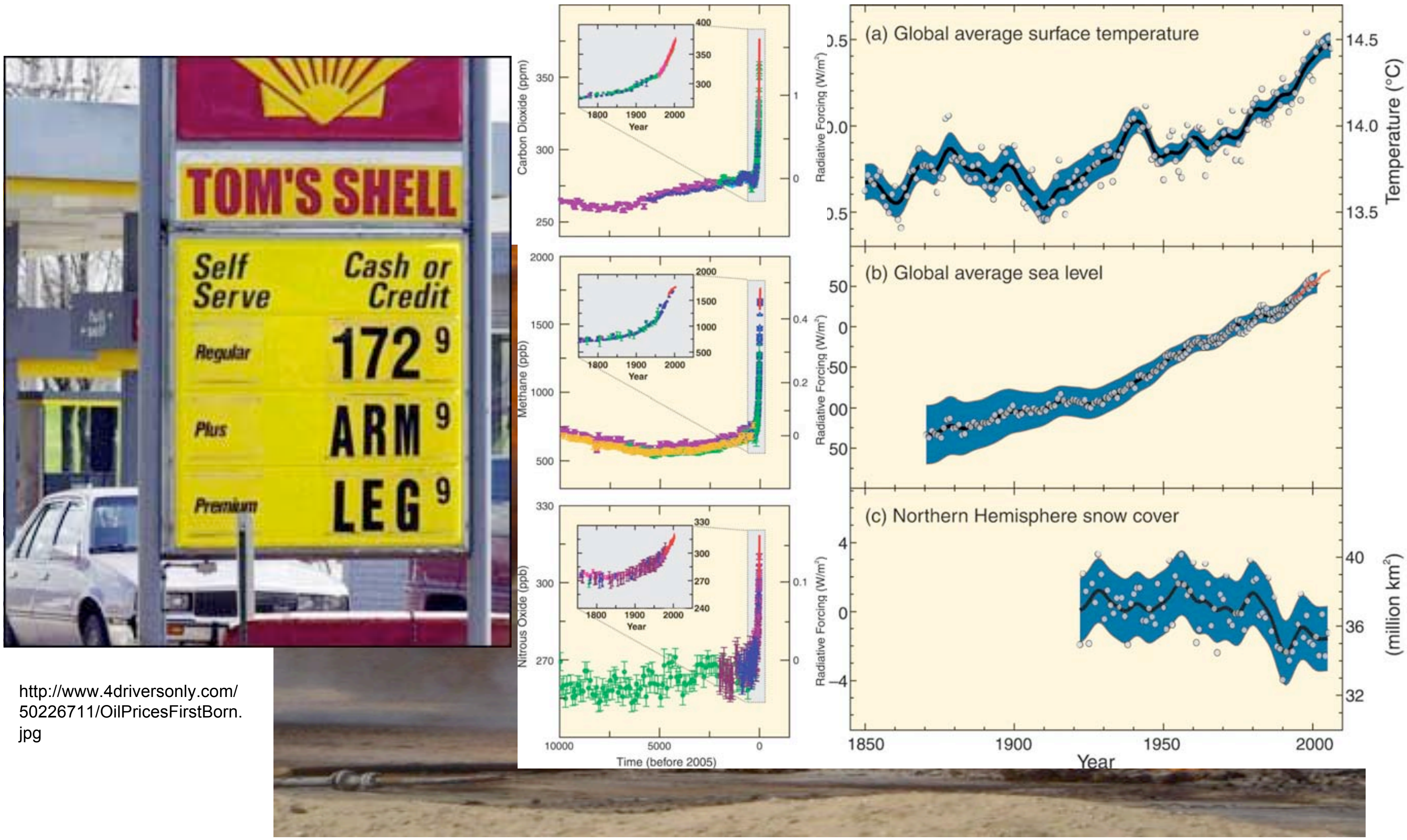
RUTGERS
Edward J. Bloustein School
of Planning and Public Policy

What is a Fuel?



Courtesy of Daniel Nocera

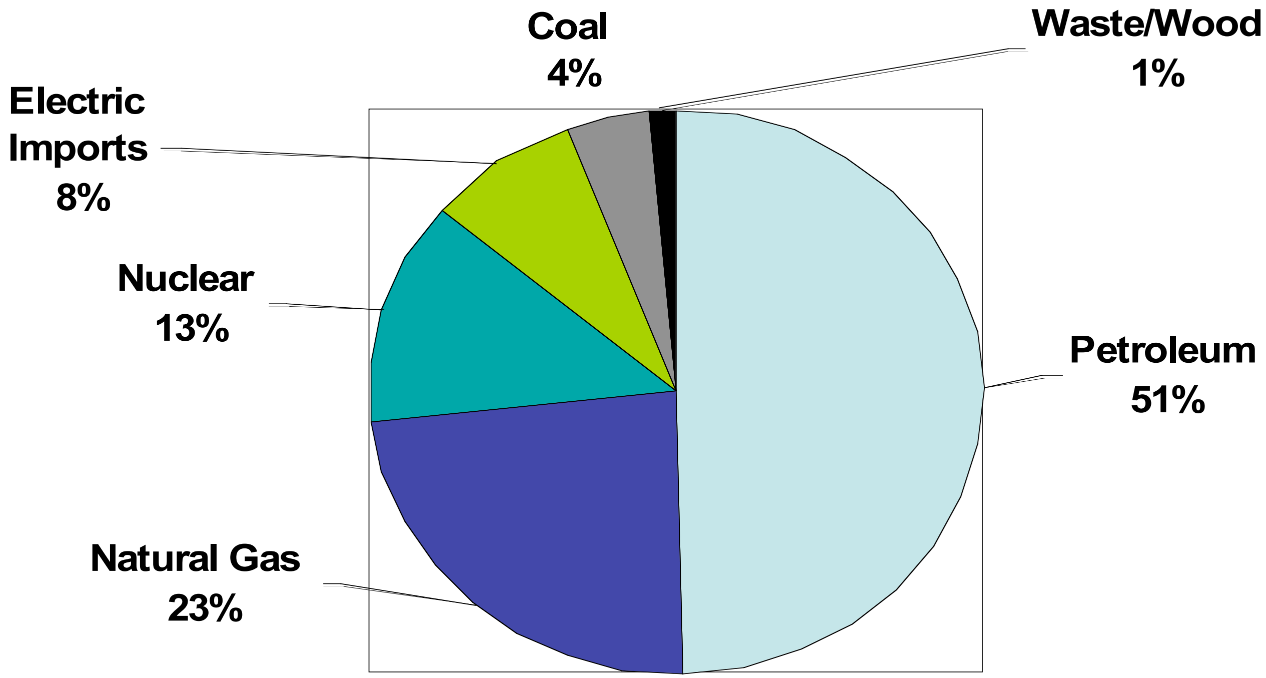
Affordable, clean, secure?



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

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

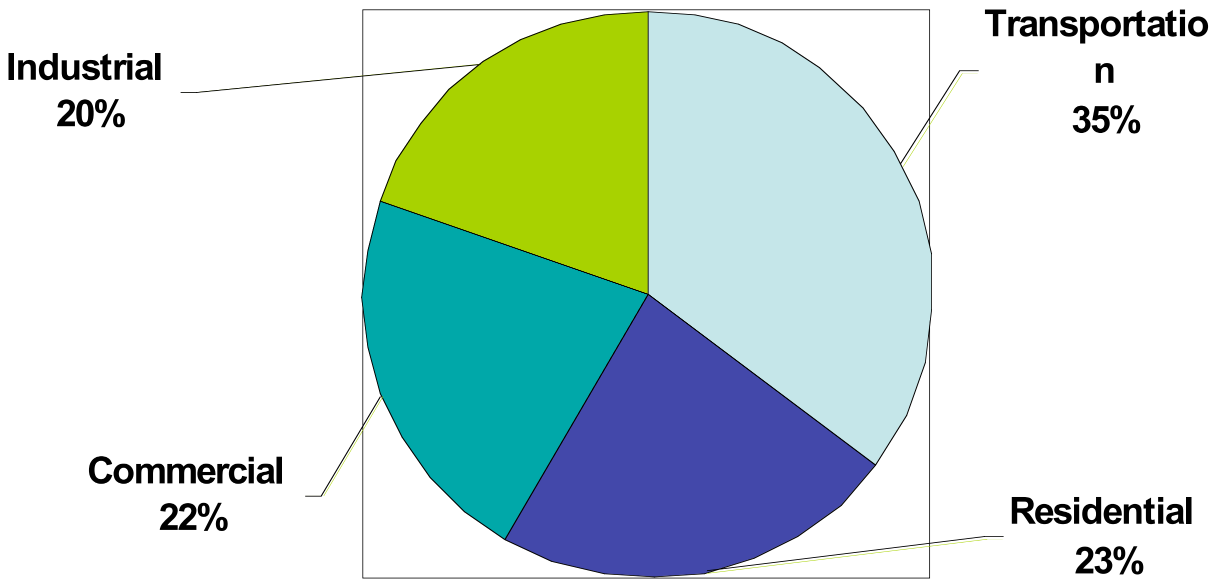
NJ Energy Sources



2,500 Trillion Btu in 2001 EIA 2006

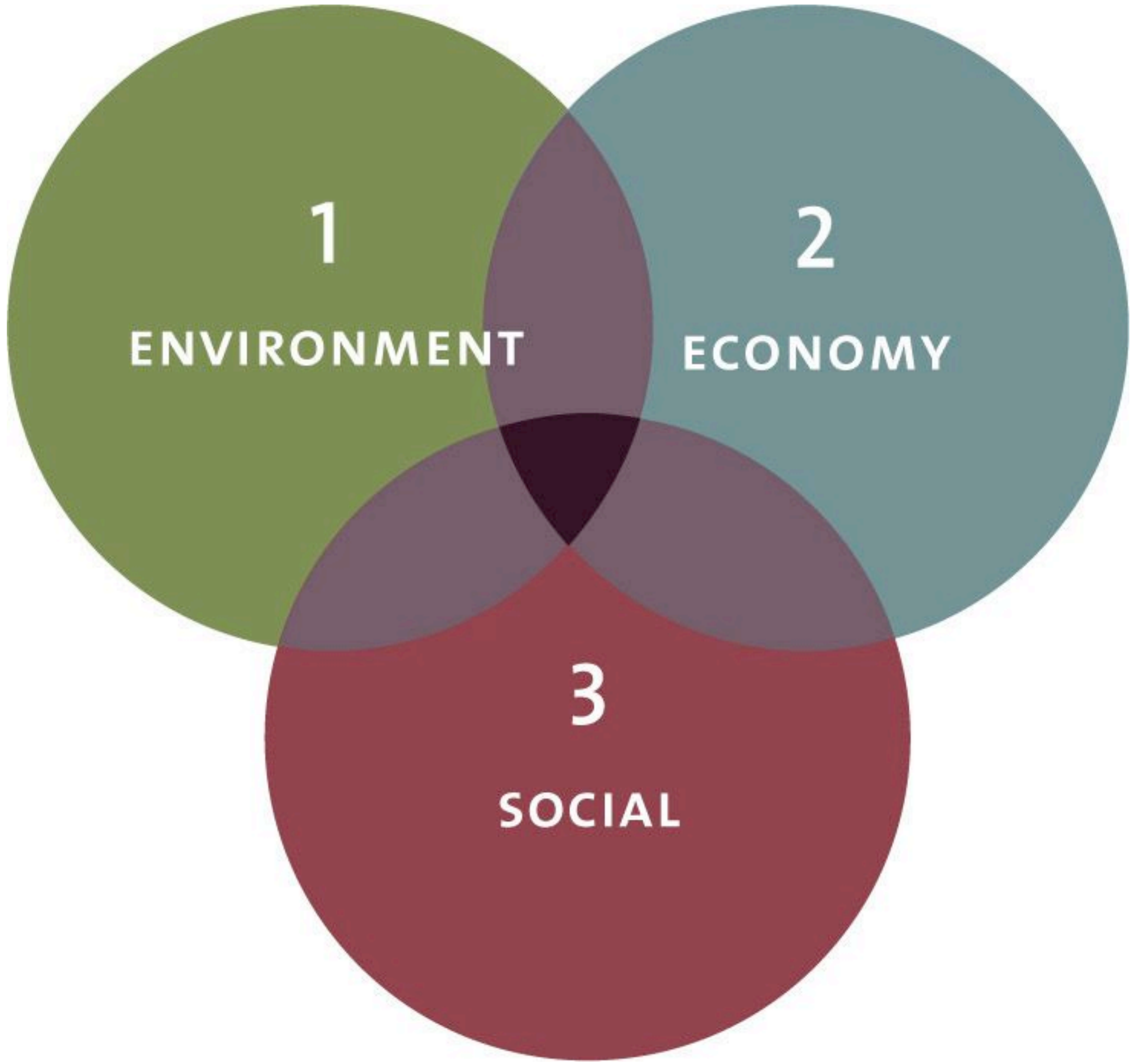
EIA 2006

NJ Energy End-Uses



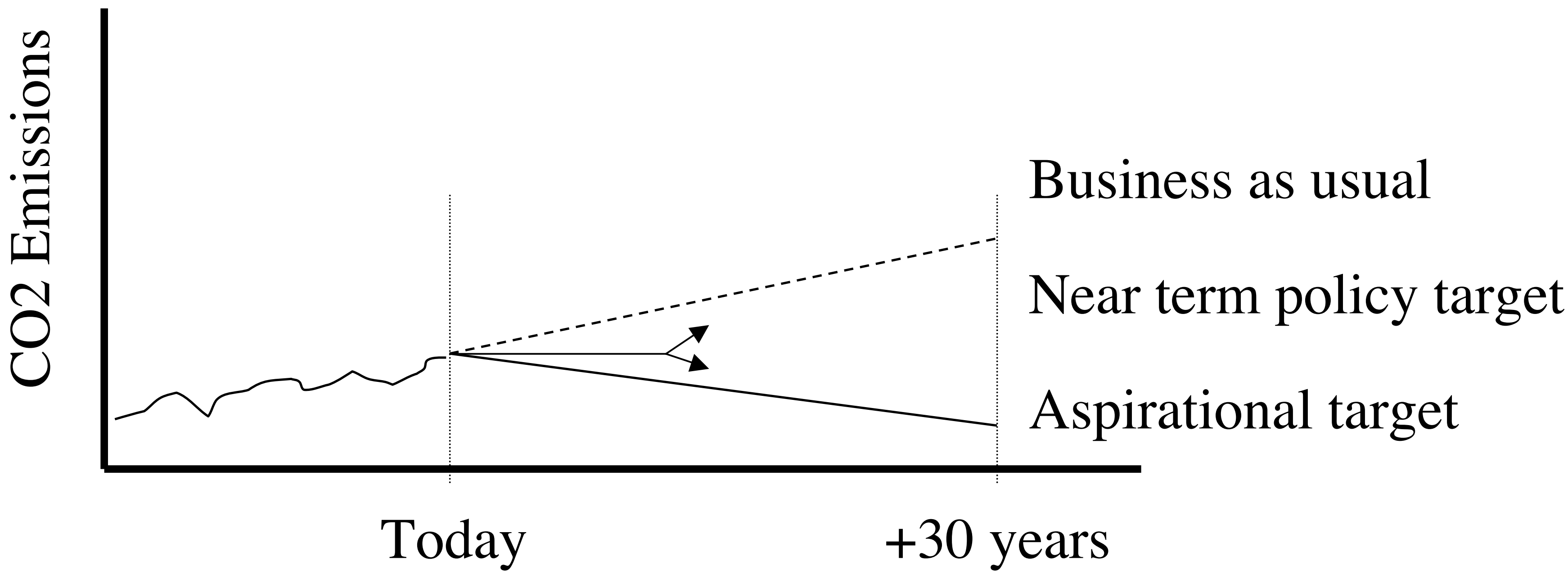
2,500 Trillion Btu in 2001 EIA 2006

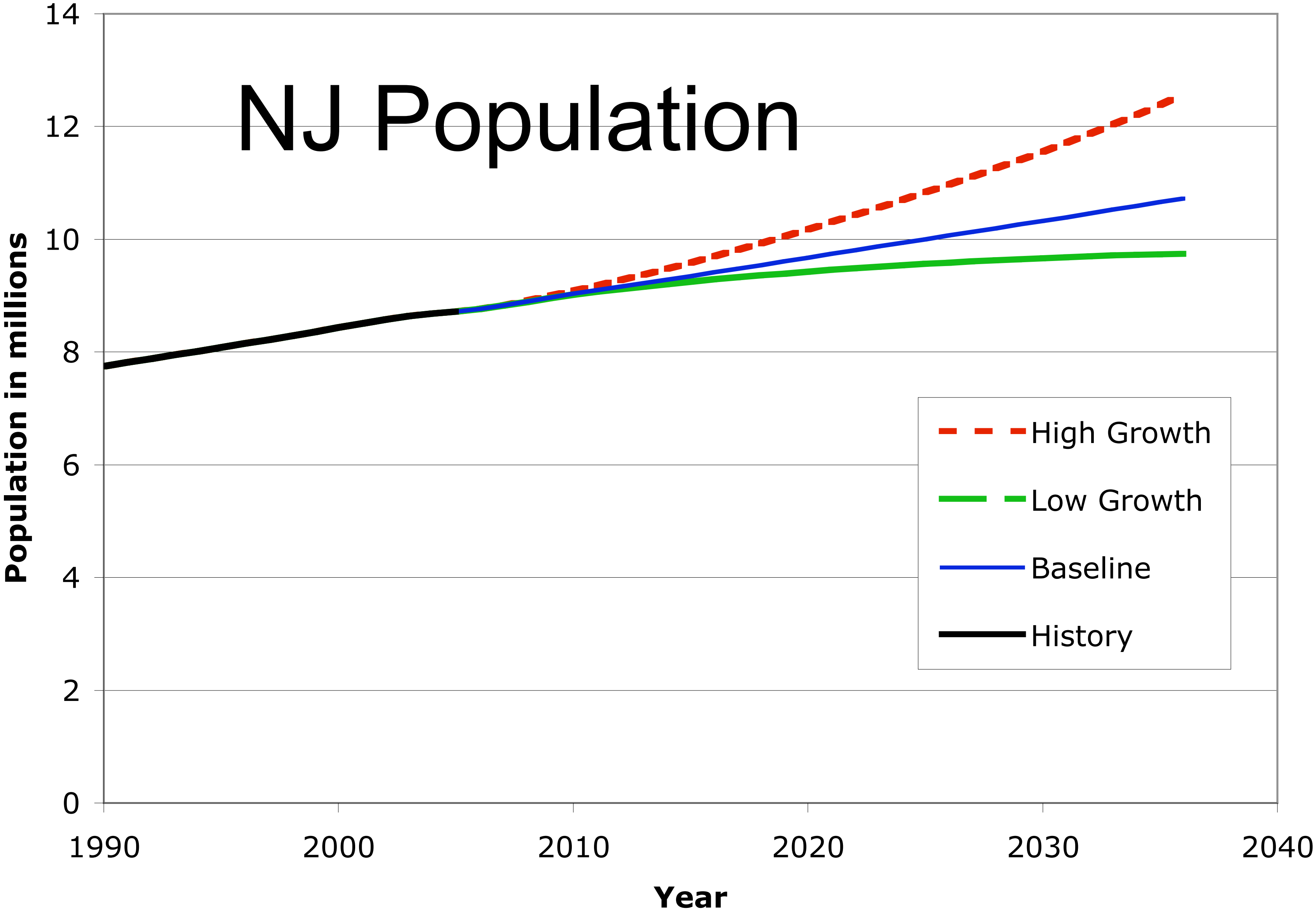
EIA 2006

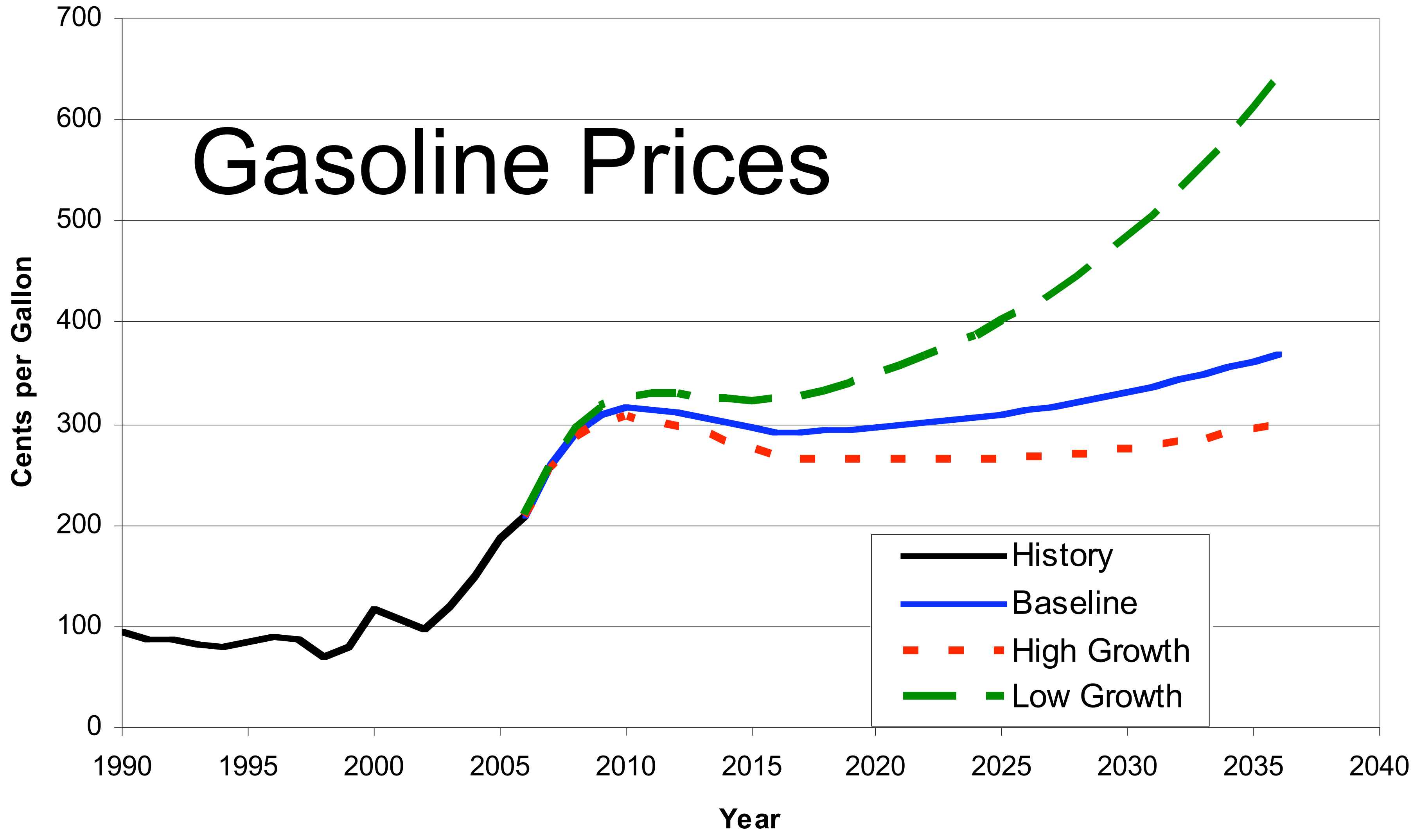

1
ENVIRONMENT
2
ECONOMY
3
SOCIAL

Aspirational, Long-Term Targets

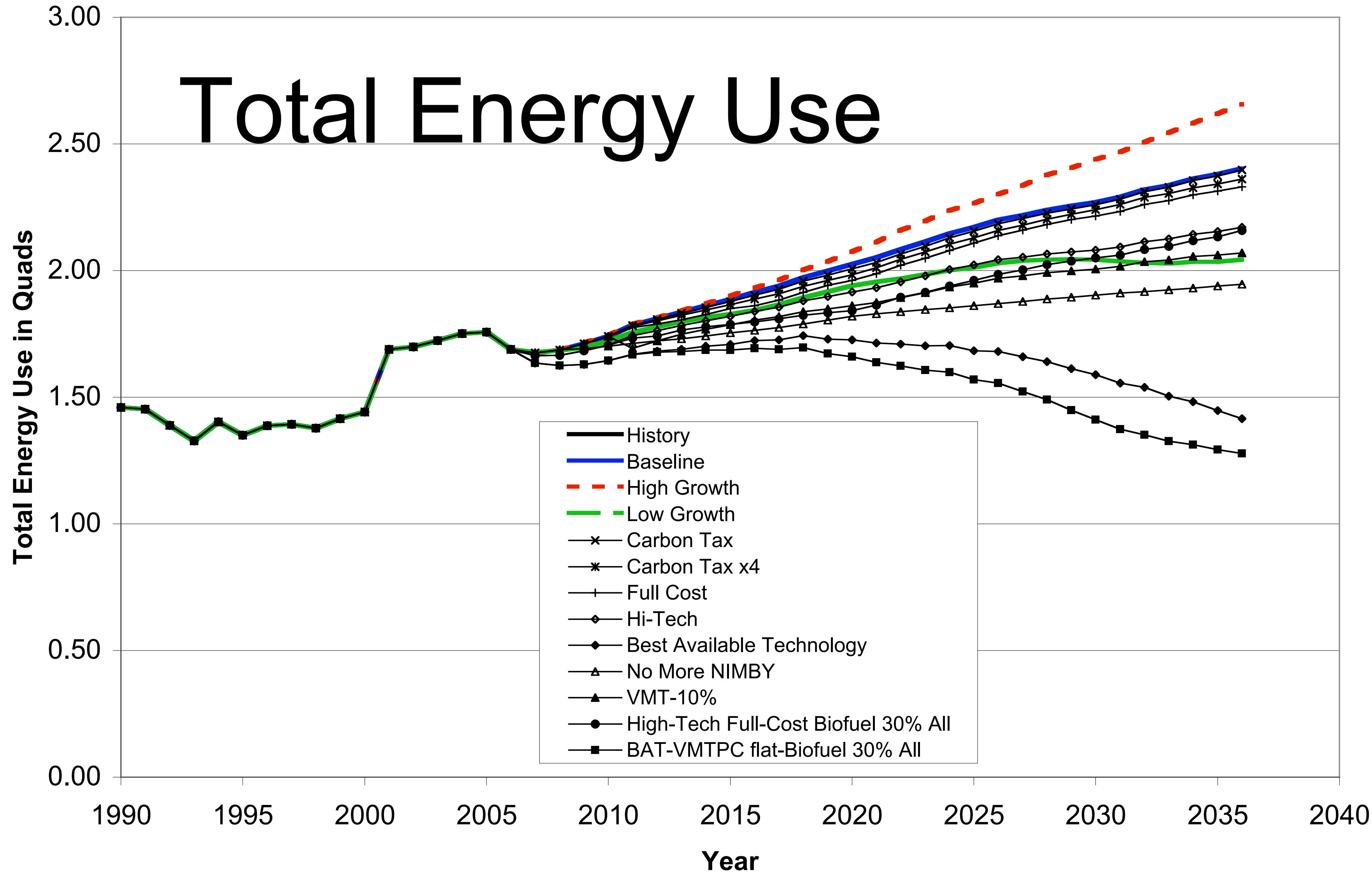
1. Scenarios for NJ’s future (controllable & uncontrollable factors)
2. Model NJ’s performance using several indicators
3. Set targets for indicators but understand tradeoffs




NJ Population
Population in millions
Year
0
2
4
6
8
10
12
14
1990
2000
2010
2020
2030
2040
High Growth
Low Growth
Baseline
History



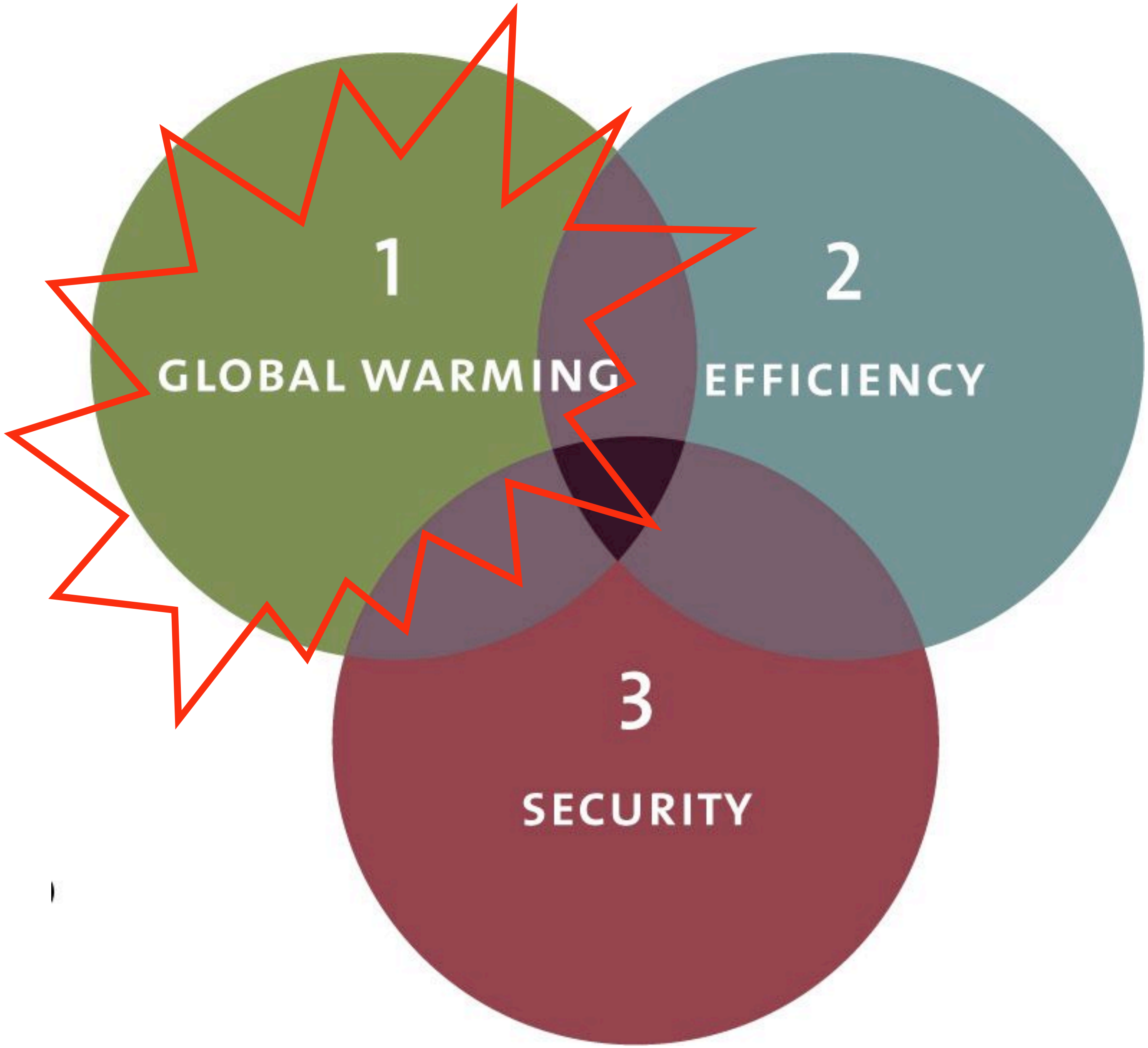
Gasoline Prices
Cents per Gallon
Year
700
600
500
400
300
200
100
0
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
History
Baseline
High Growth
Low Growth



Total Energy Use
Total Energy Use in Quads
Year
3.00
2.50
2.00
1.50
1.00
0.50
0.00
1990
1995
2000
2005
2010
2015
2020
2025
2030
2035
2040
History
Baseline
High Growth
Low Growth
Carbon Tax
Carbon Tax x4
Full Cost
Hi-Tech
Best Available Technology
No More NIMBY
VMT-10%
High-Tech Full-Cost Biofuel 30% All
BAT-VMTPC flat-Biofuel 30% All

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


1
GLOBAL WARMING
2
EFFICIENCY
3
SECURITY

Environmental Target: CO2 Emissions from Energy

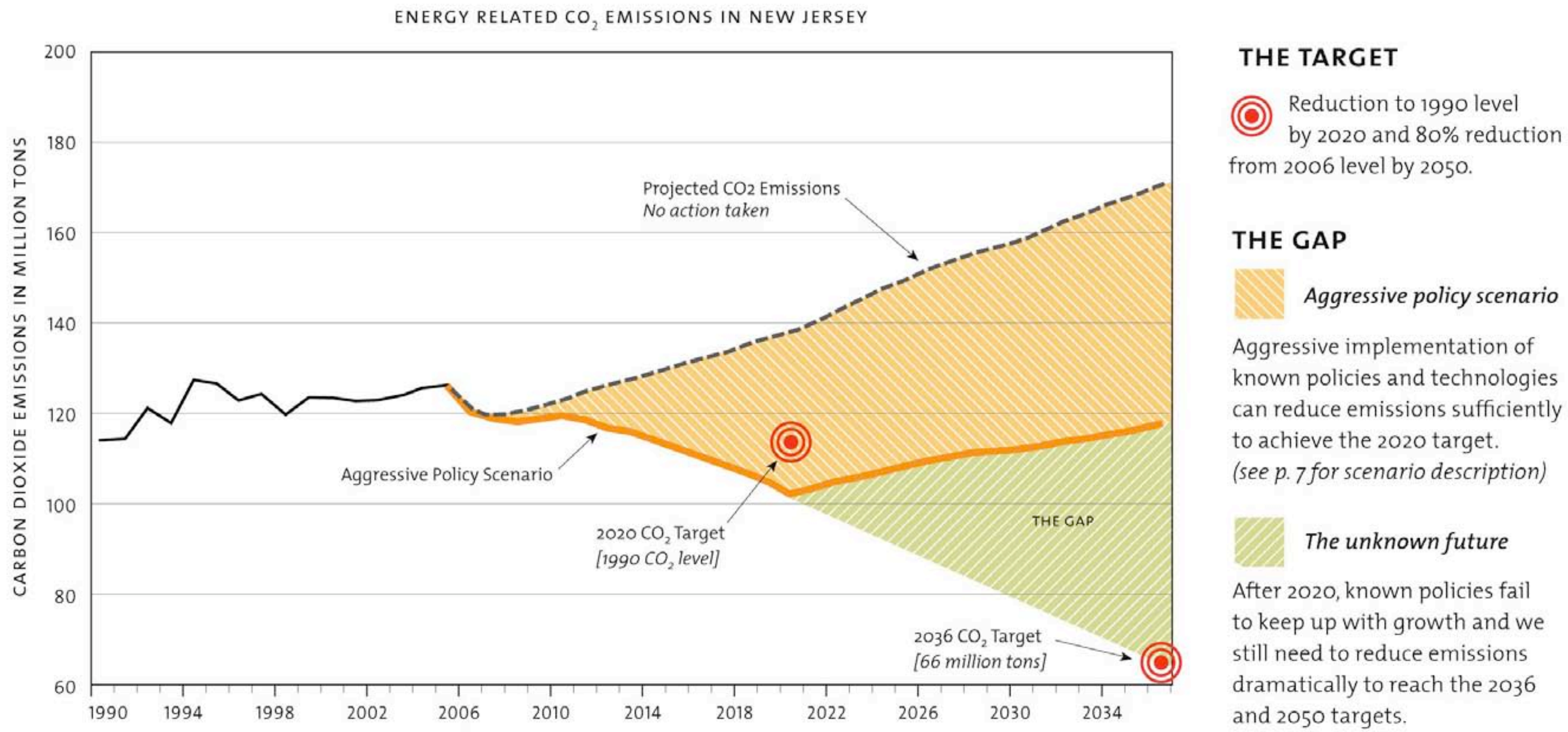
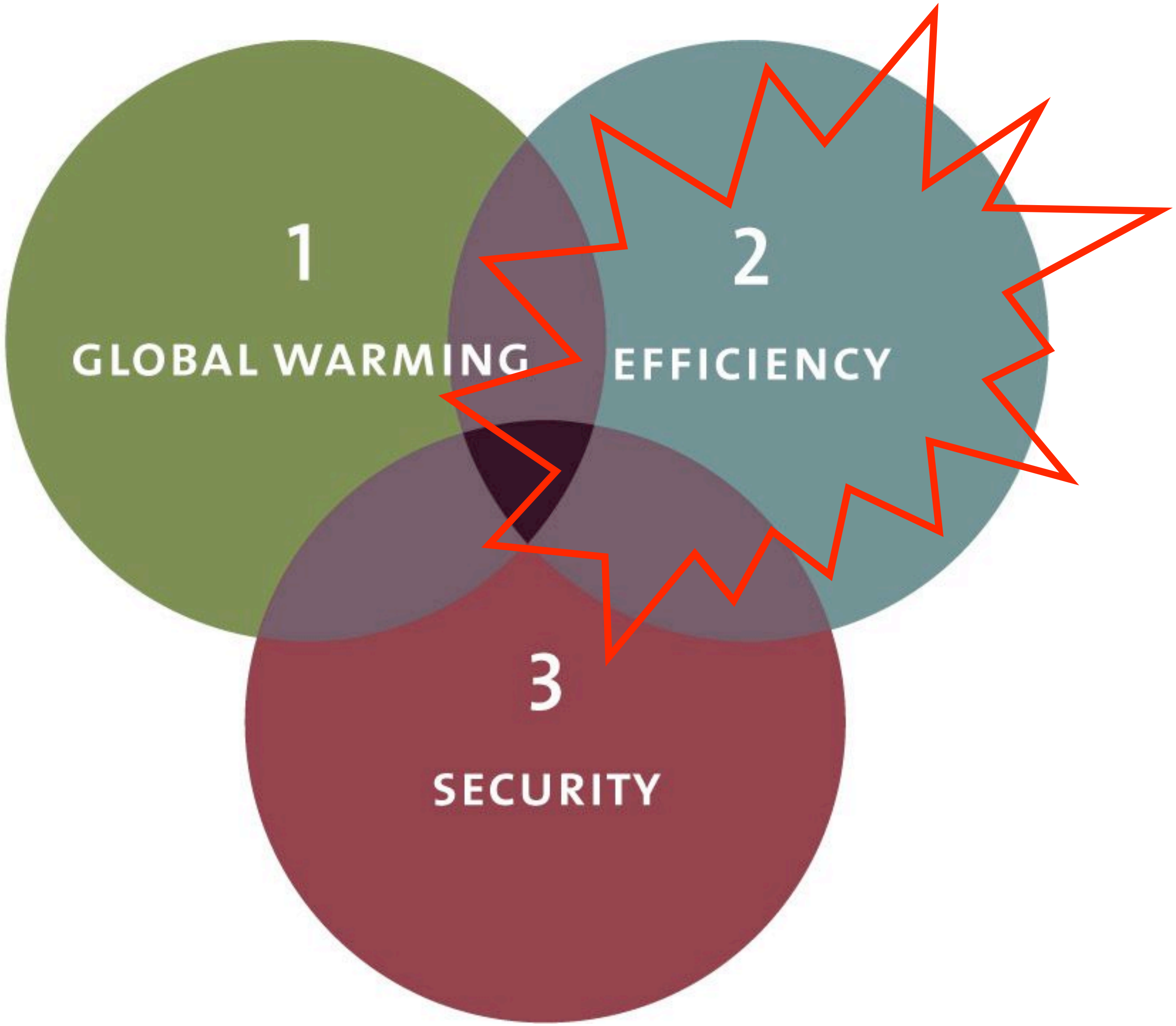


FIGURE 1


1
GLOBAL WARMING
2
EFFICIENCY
3
SECURITY

Economic Target: Energy expense as % of income

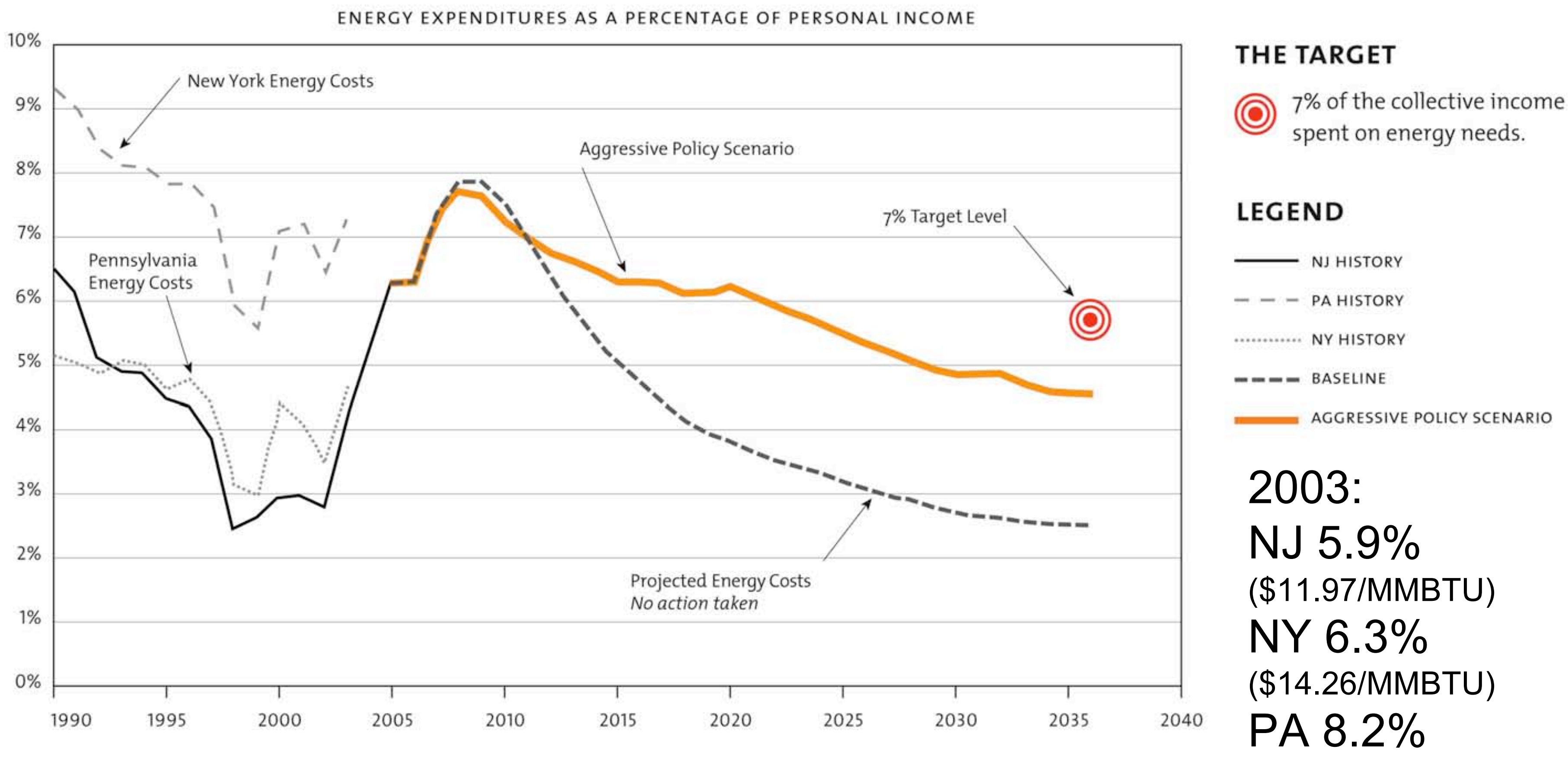


FIGURE 5

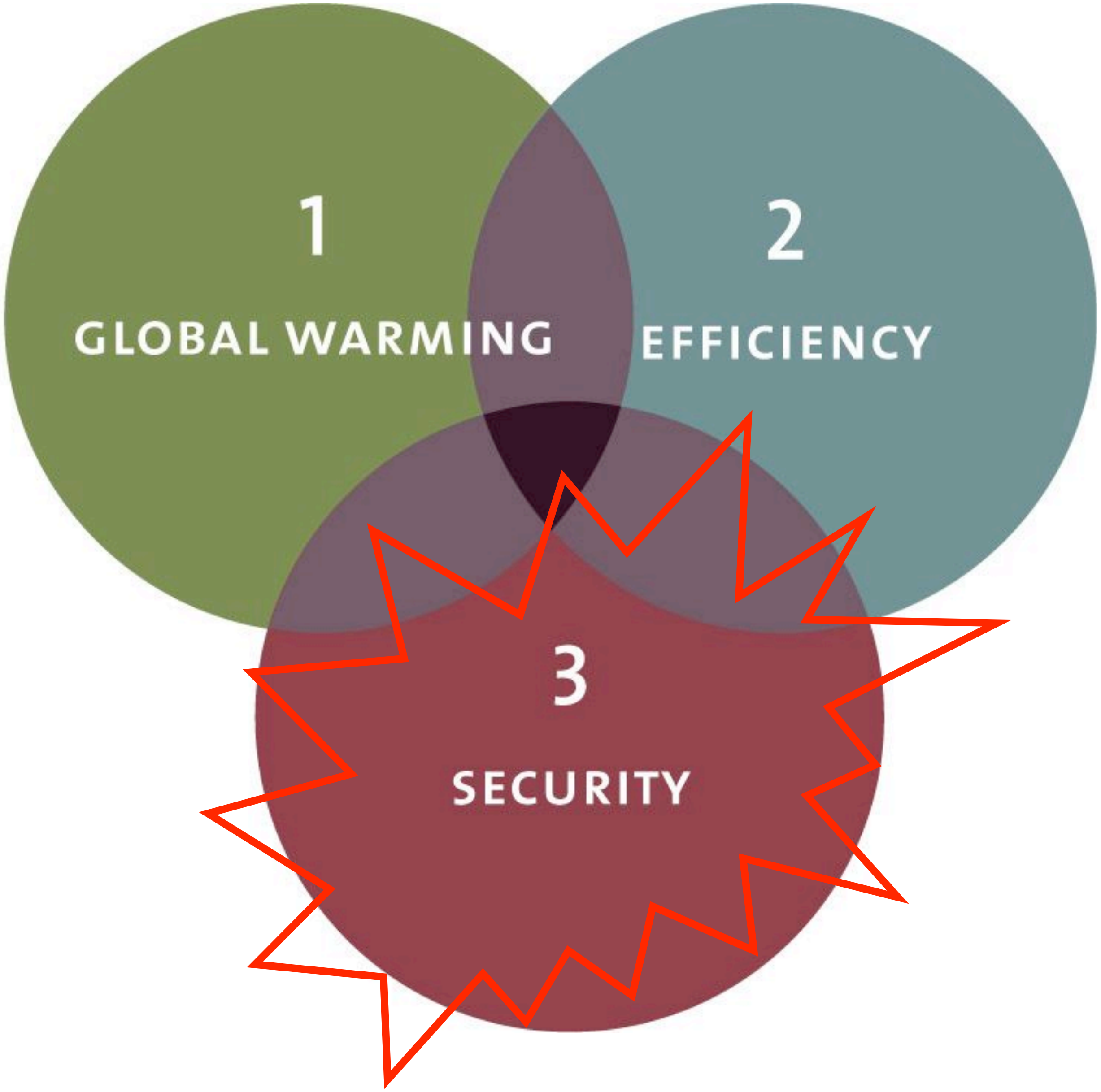
2003:

NJ 5.9%
($11.97/MMBTU)

NY 6.3%
($14.26/MMBTU)

PA 8.2%
($11.83/MMBTU)

USDOE 2007


1
GLOBAL WARMING
2
EFFICIENCY
3
SECURITY

Security Target: Percent of energy from local sources

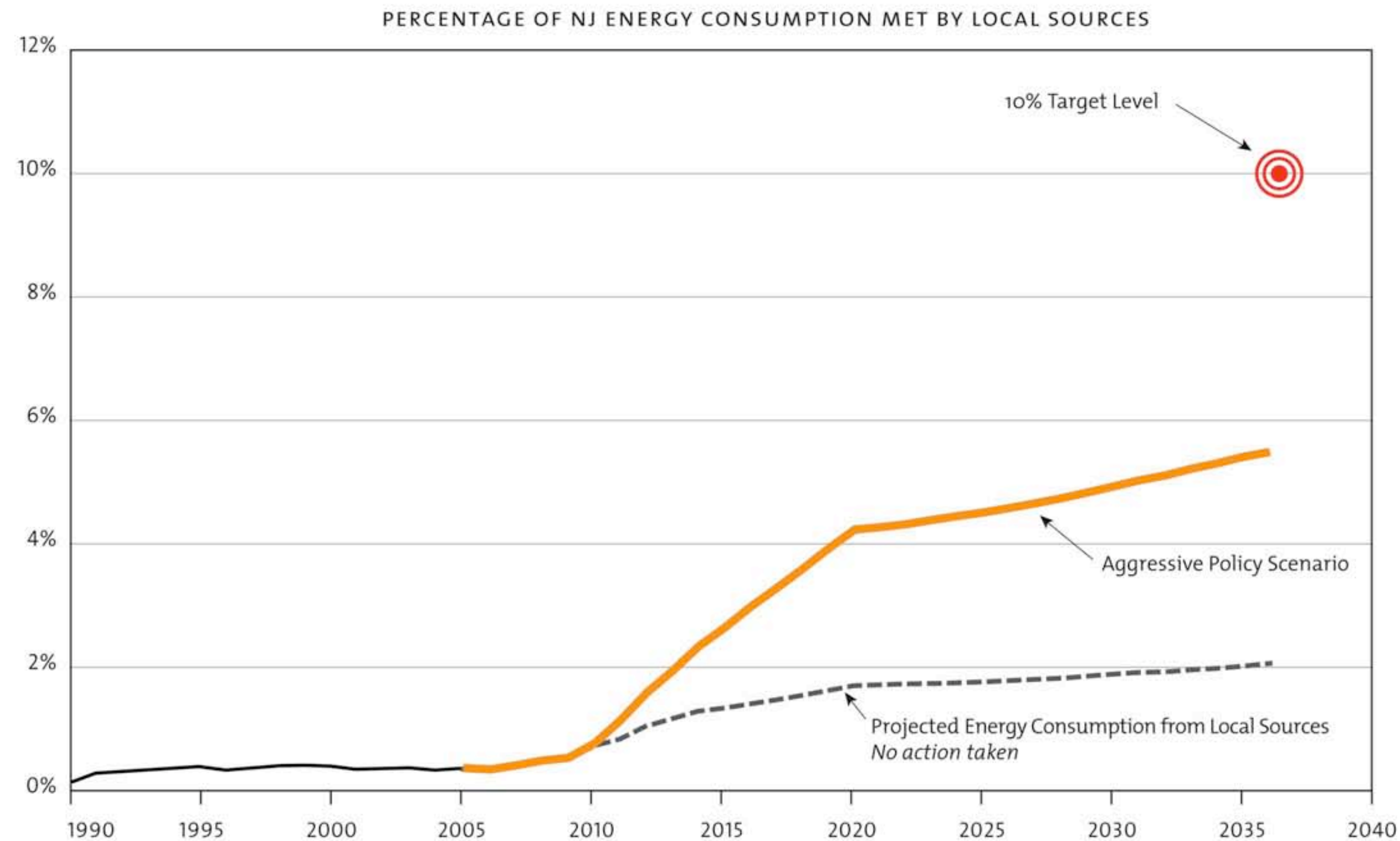


FIGURE 9

THE TARGET

10% of energy from local sources.

LEGEND

HISTORY

BASELINE

AGGRESSIVE POLICY SCENAR

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

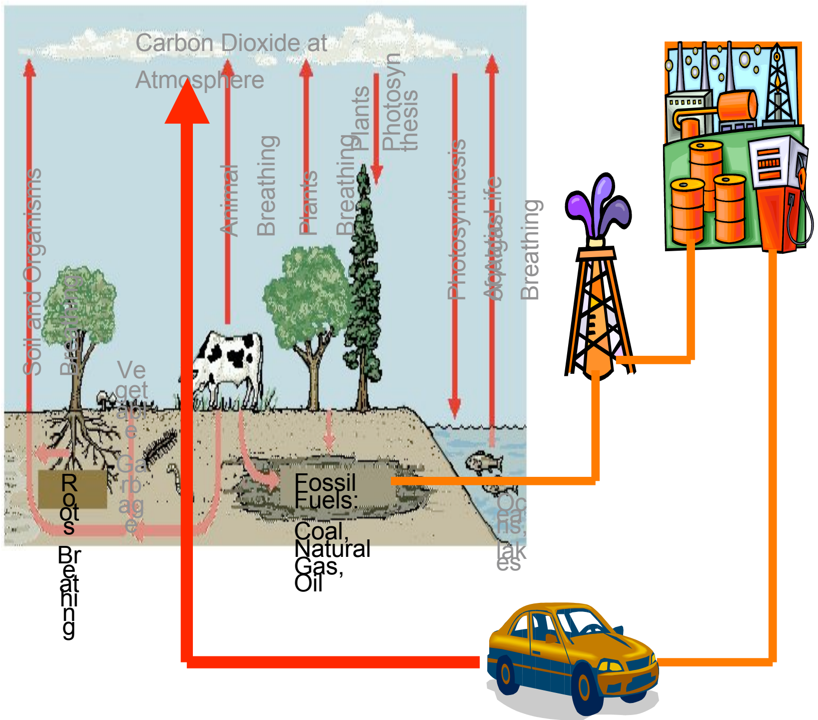
- Petroleum
- Natural gas

- Biofuels
- Hydrogen
- Electricity

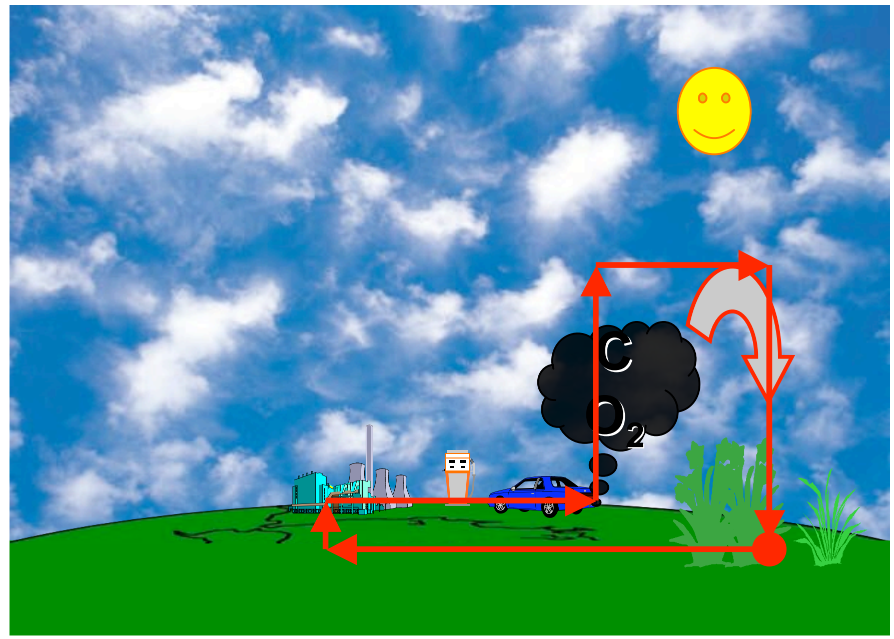
Why Biofuels?

- 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

Long vs Short Carbon Cycle



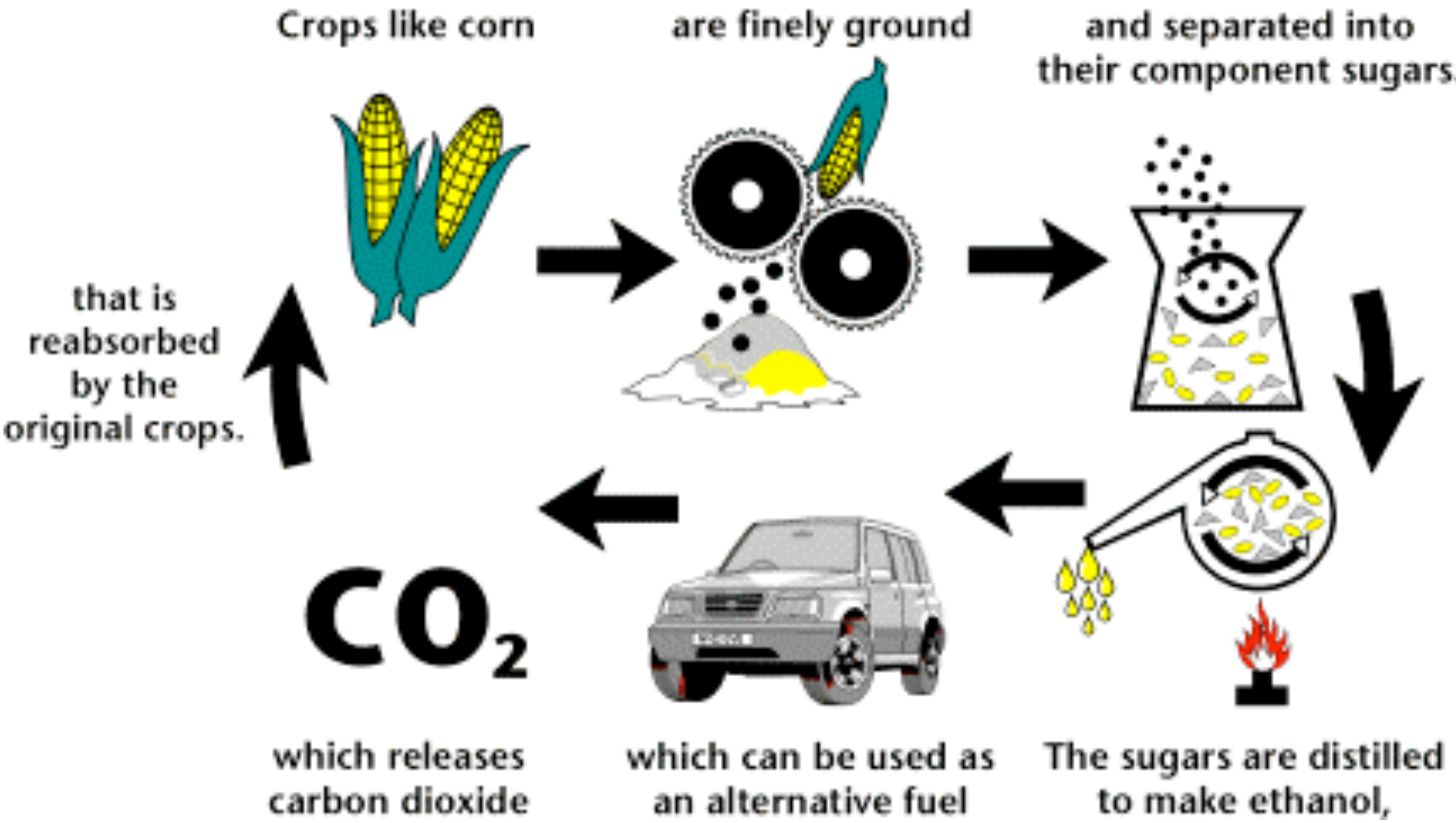
10^7 years



10^0 years

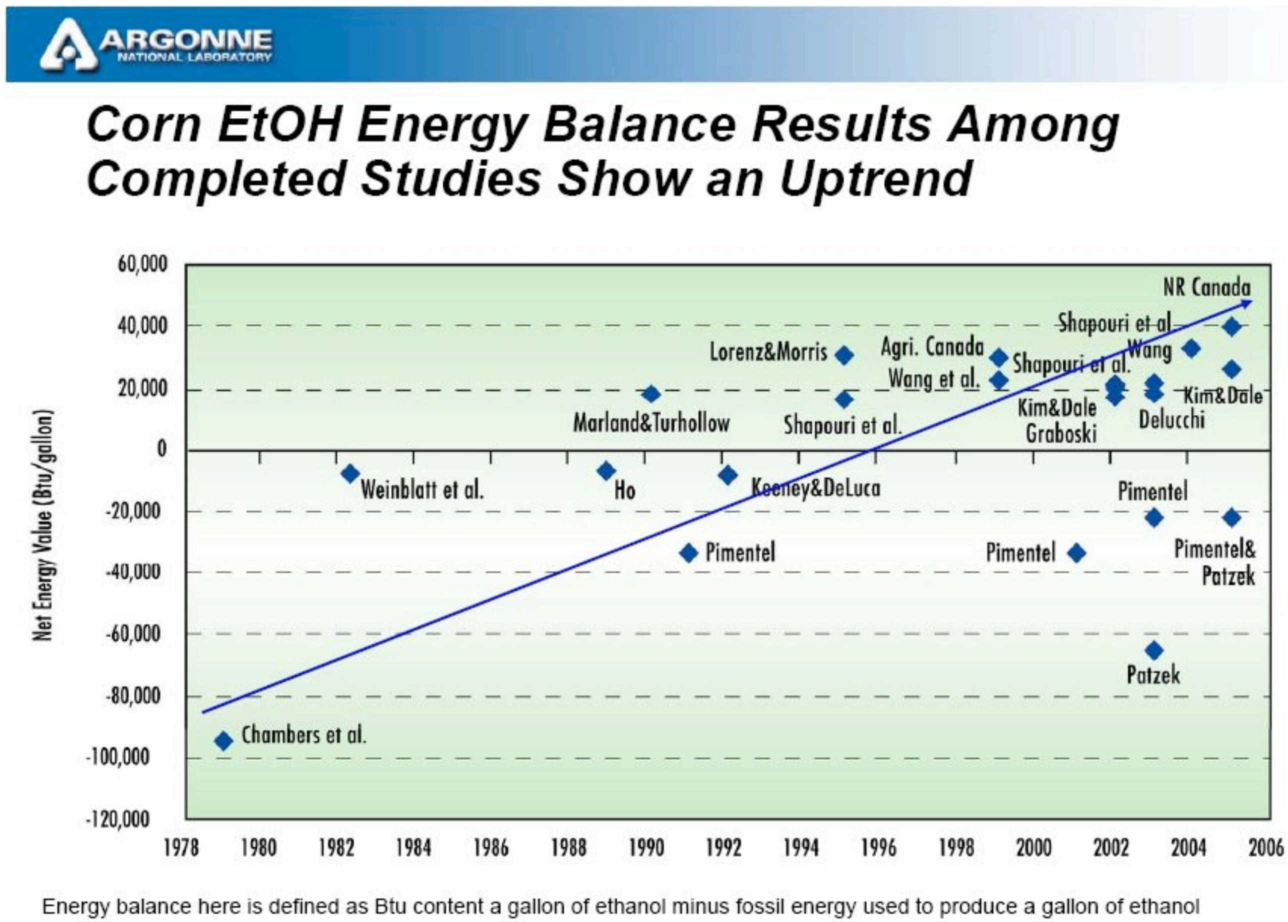
Henry Joseph Jr., Brazilian Automotive Industry Association - ANFAVEA

THE CARBON CYCLE



Debate on Net Energy Benefits of Ethanol

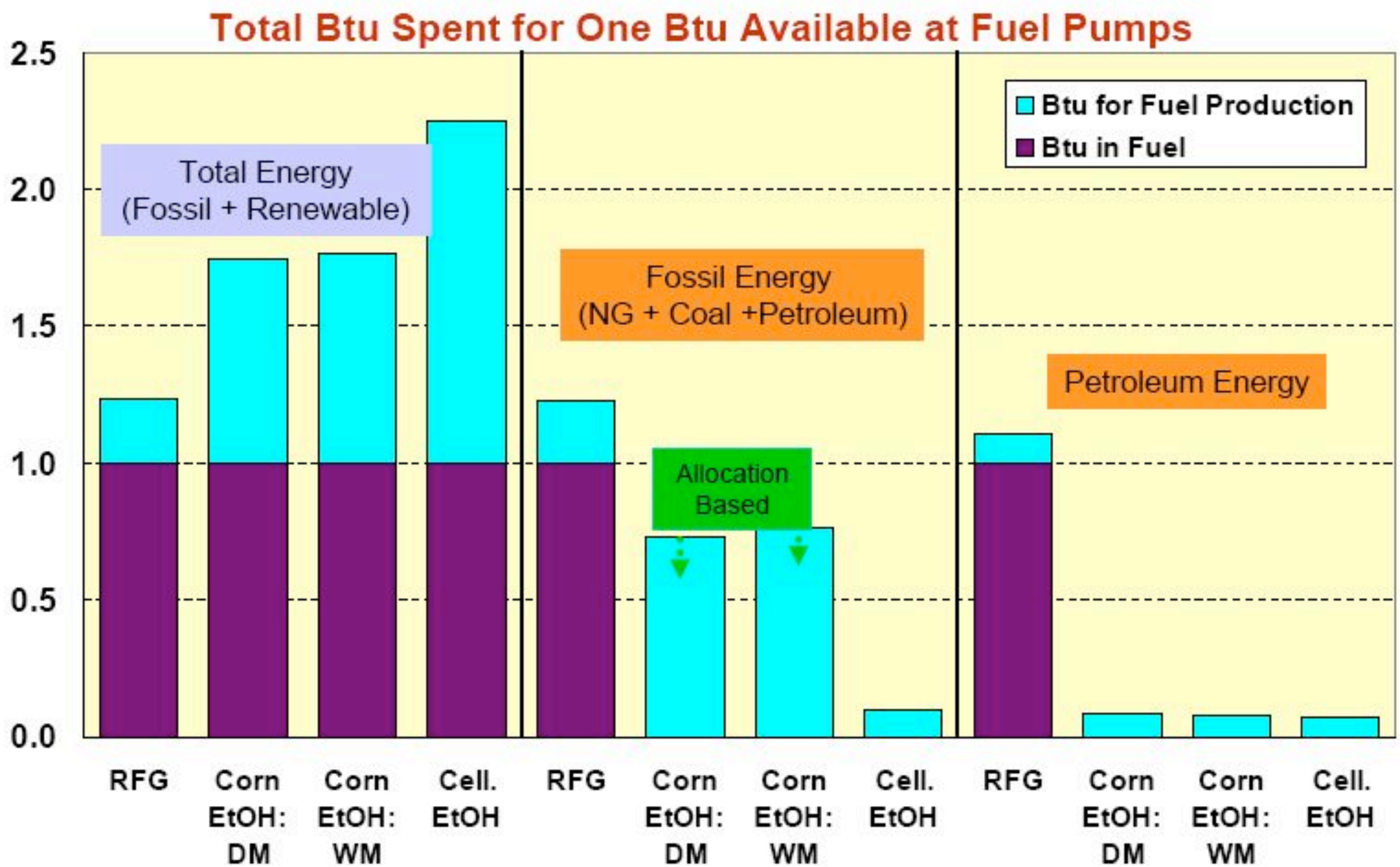
Differences between Pimentel & Patzek and others lie in:
•Corn farming energy use
•Energy use for producing nitrogen fertilizer
•Ethanol plant energy use
•Credits for co-products from biofuel plants



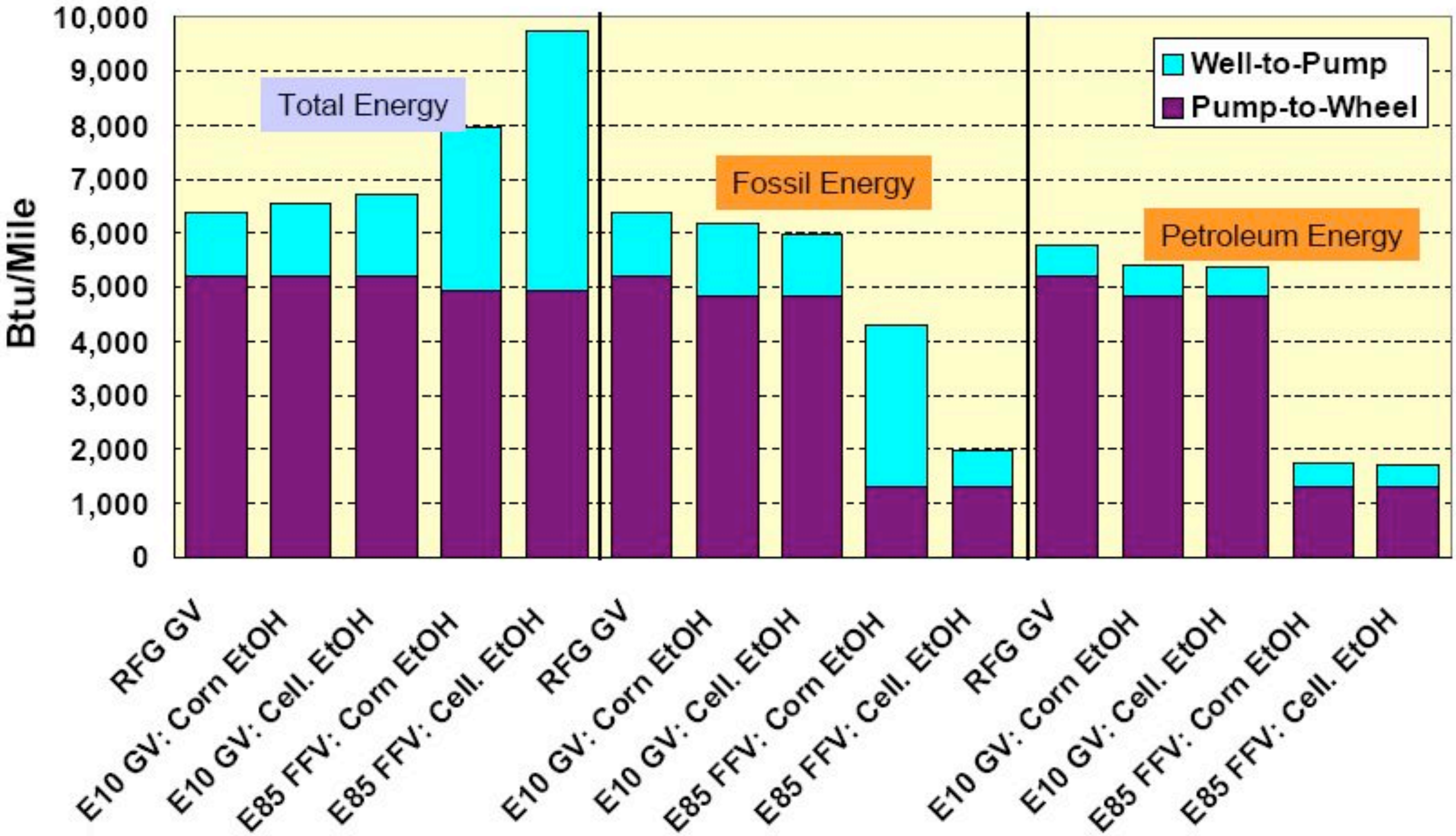
M. Wang http://www.transportation.anl.gov/pdfs/TA/347.pdf

ARGONNE NATIONAL LABORATORY

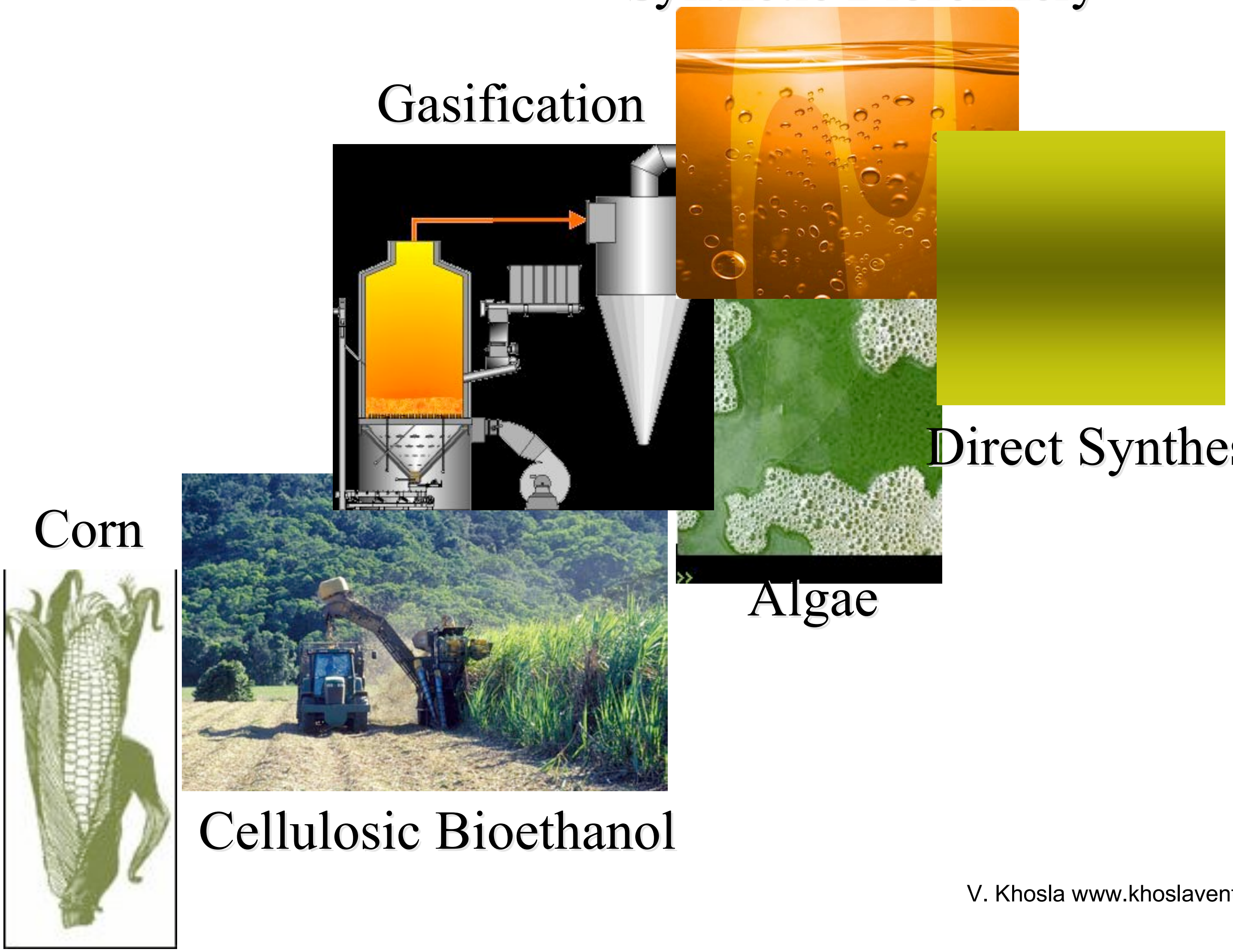
Energy Benefits of Fuel Ethanol Lie in Reductions in Fossil Energy and Petroleum Use

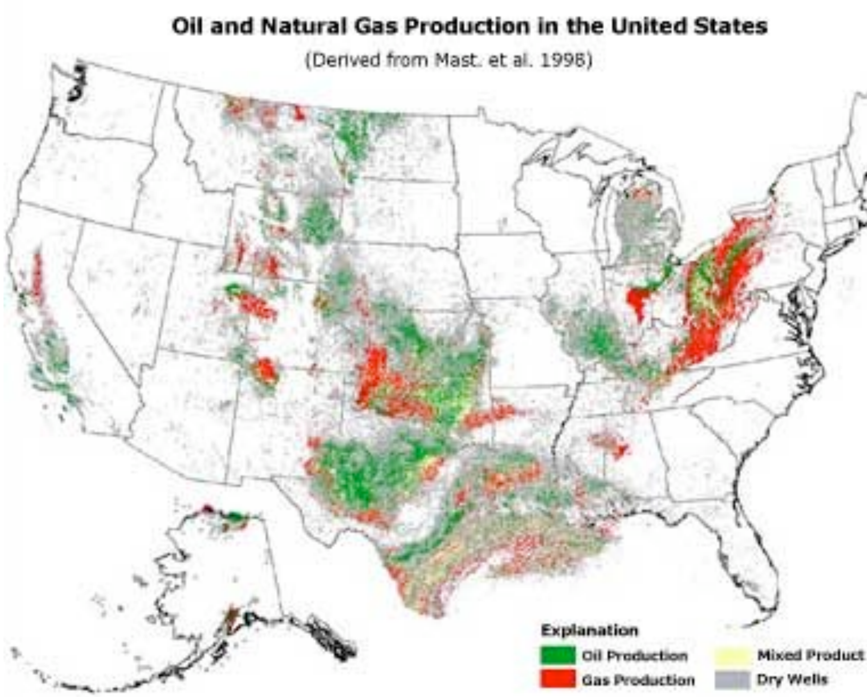


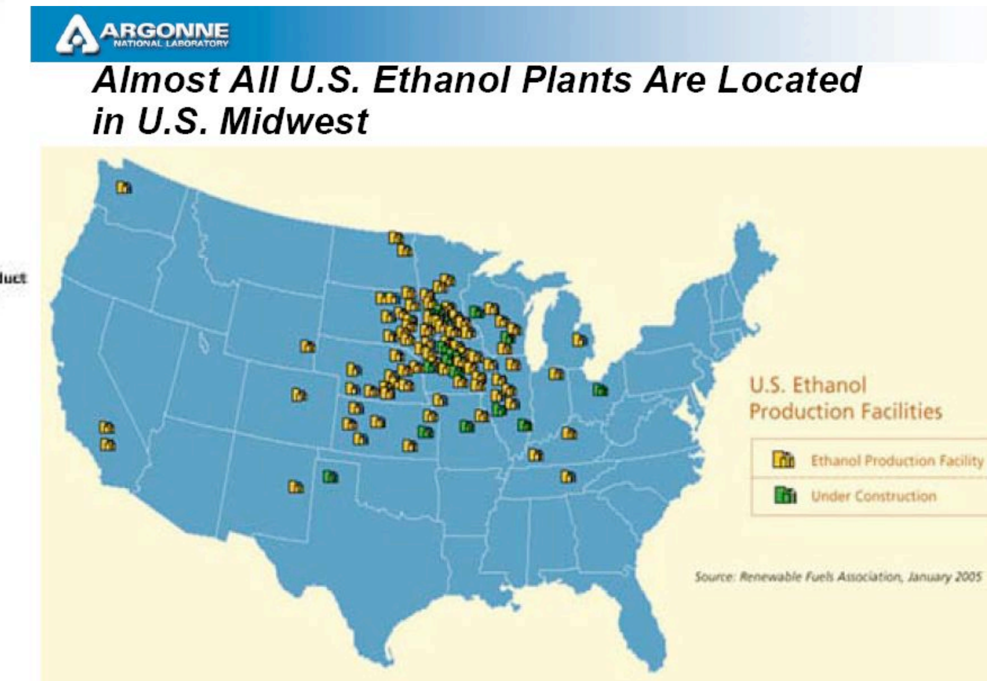
Use of Ethanol to Replace Gasoline Results in WTW Fossil Energy and Petroleum Benefits



Technology Progression



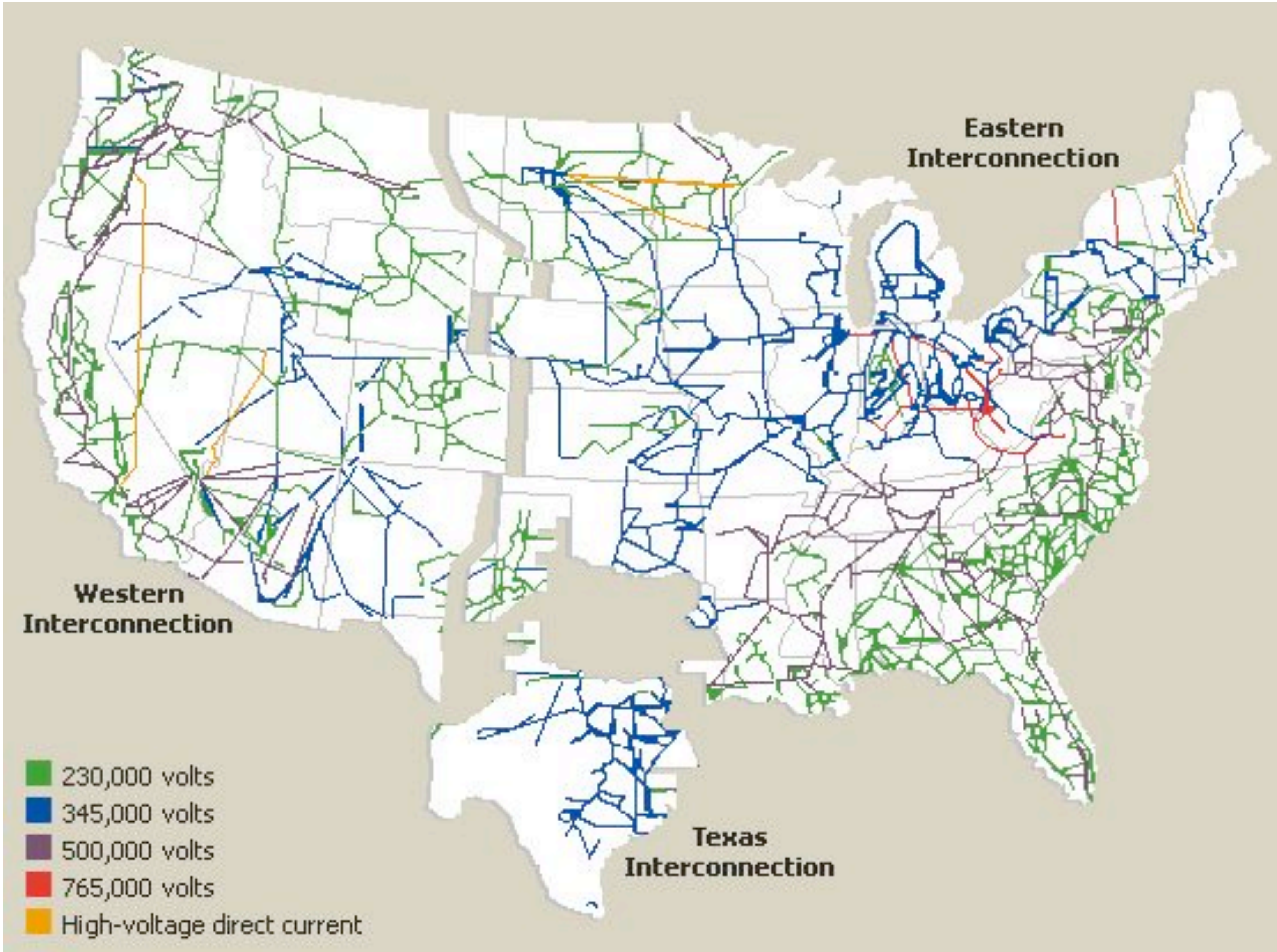




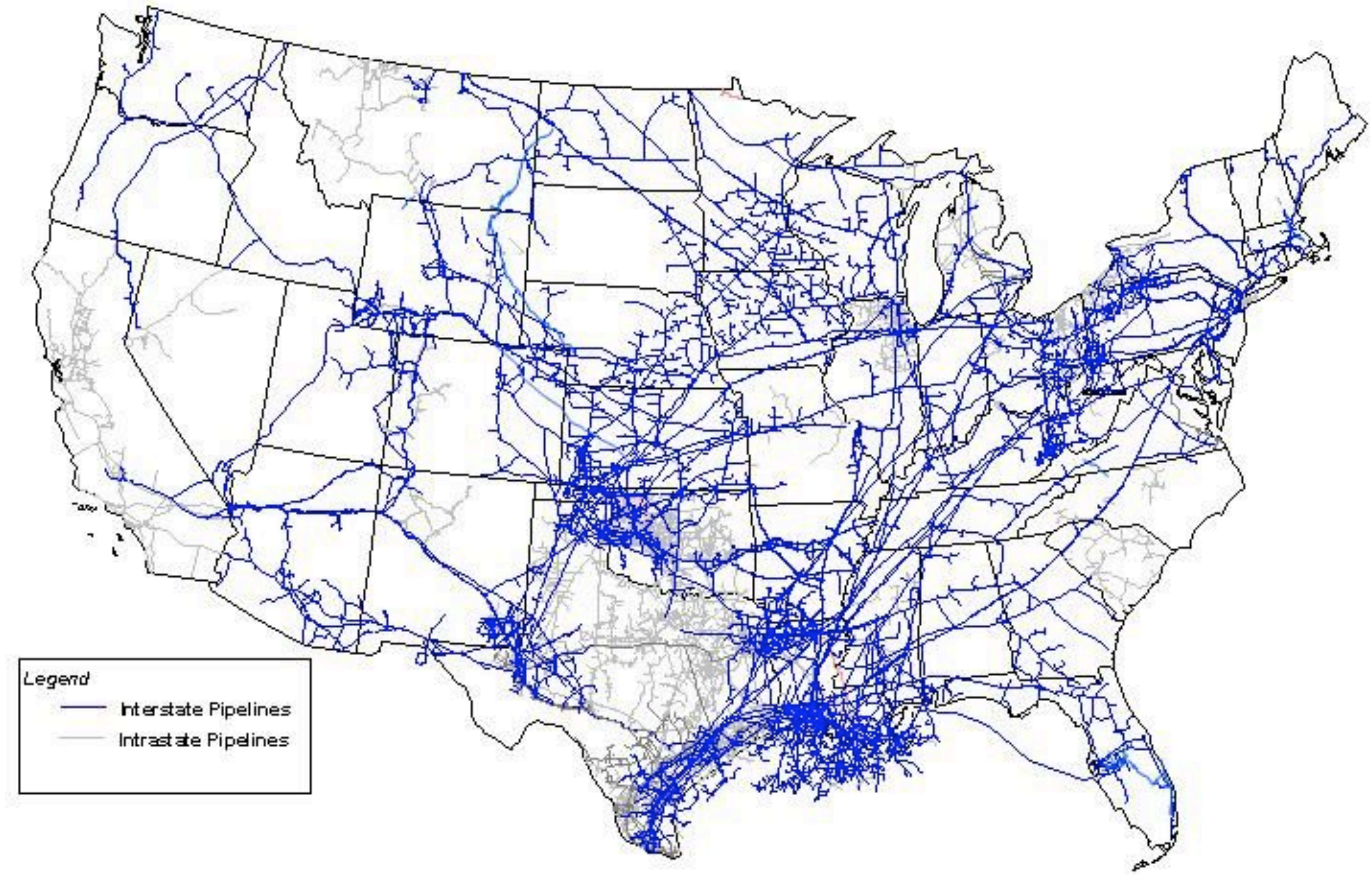
http://geology.usgs.gov/connections/images/shared/og-us_prodution_map.jpg

M. Wang http://www.transportation.anl.gov/pdfs/TA/347.pdf

http://static.howstuffworks.com/gif/blackout-grid.gif



http://images.encarta.msn.com/xrefmedia/aencmed/targets/maps/map/000a5302.gif



Source: Energy Information Administration, Office of Oil & Gas, Natural Gas Division, Gas Transportation Information System

http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/images/uspipe2007.jpg

Energy for Transportation

- Petroleum
- Natural gas

- Biofuels
- Hydrogen
- Electricity

Hydrogen?

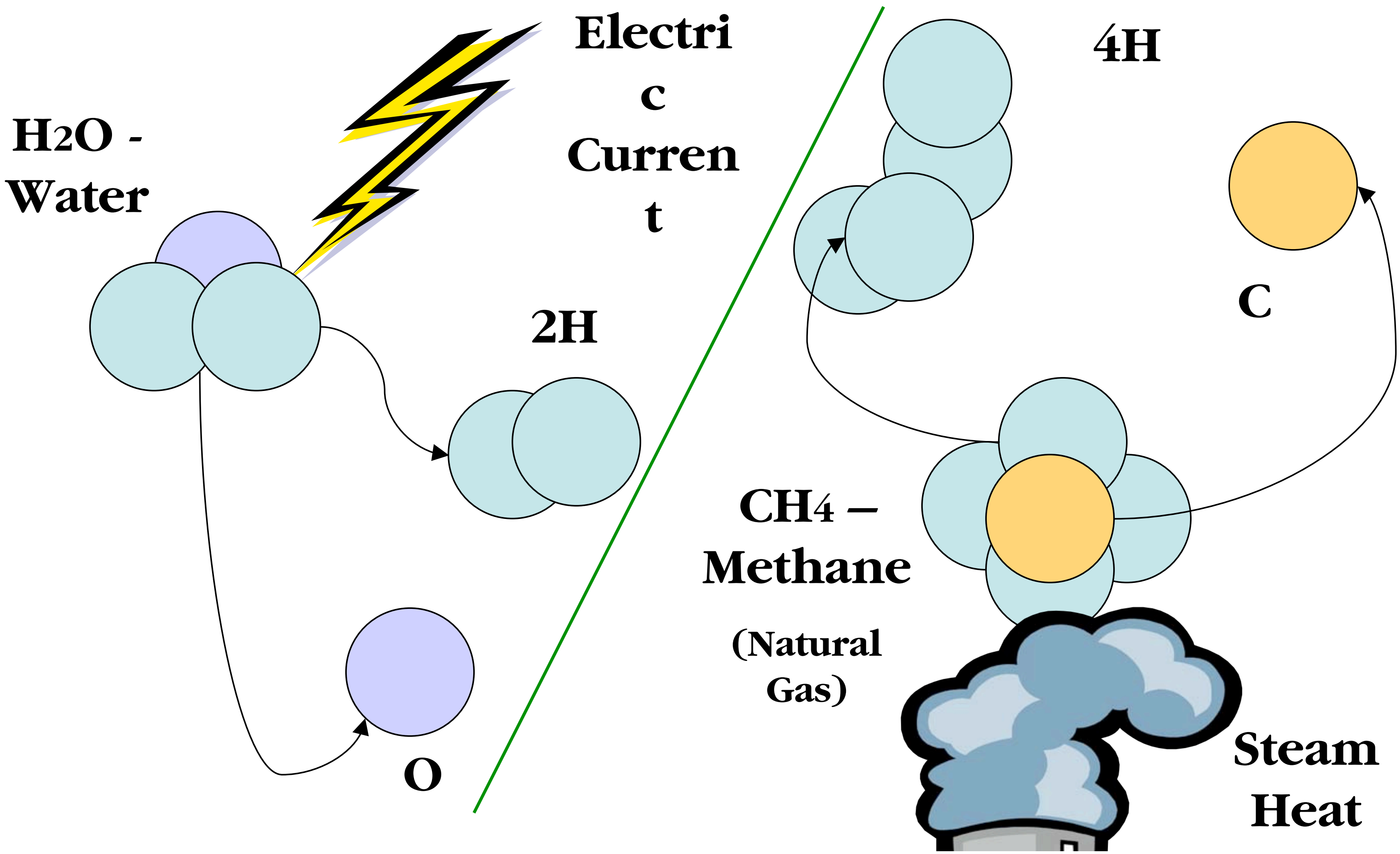
Extract primary energy → Transmit energy nearer to user → Transform primary energy into hydrogen → Transmit hydrogen to user → Use hydrogen for human benefit

Combustion of Hydrogen & Gasoline

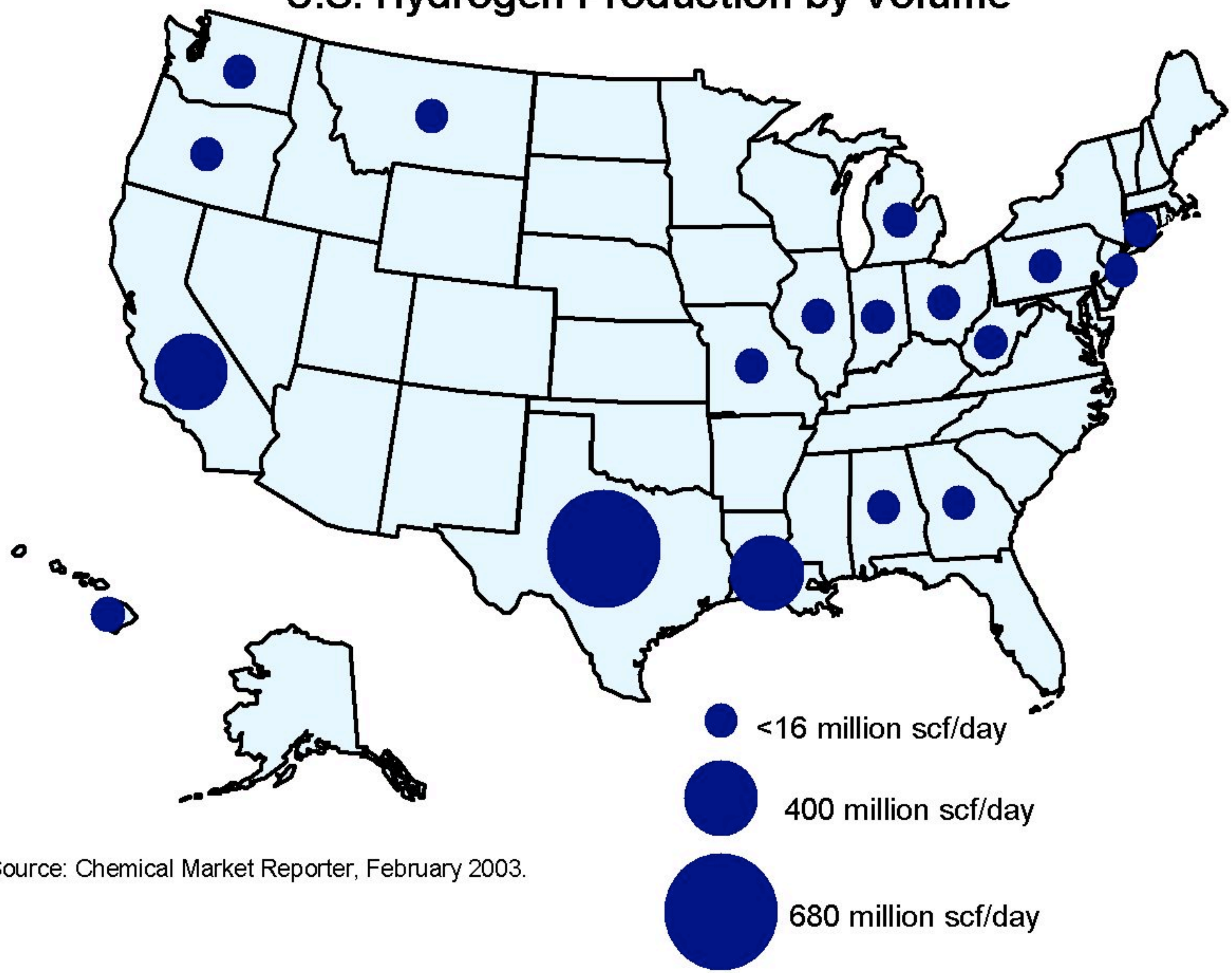
Hydrogen car to the left, Gasoline car to the right

www.altfuels,com

Electrolysis and Reformation



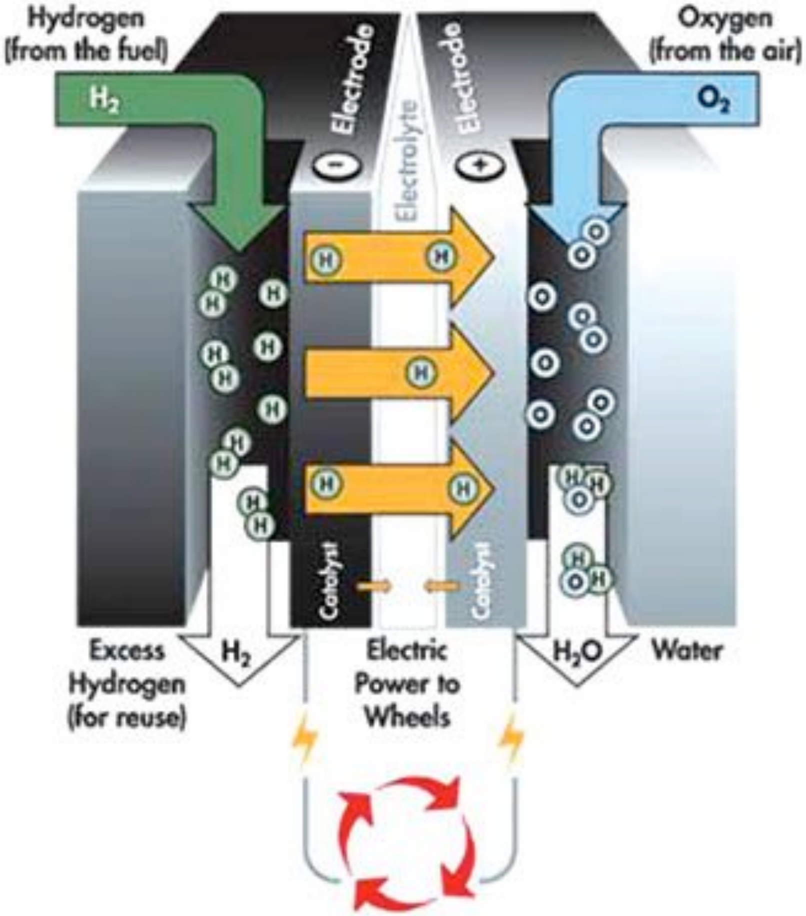
U.S. Hydrogen Production by Volume



Source: Chemical Market Reporter, February 2003.

https://apps3.eere.energy.gov/ba/pba/analysis_database/docs/image/hydrogen_production_by_volume.gif

Fuel Cells

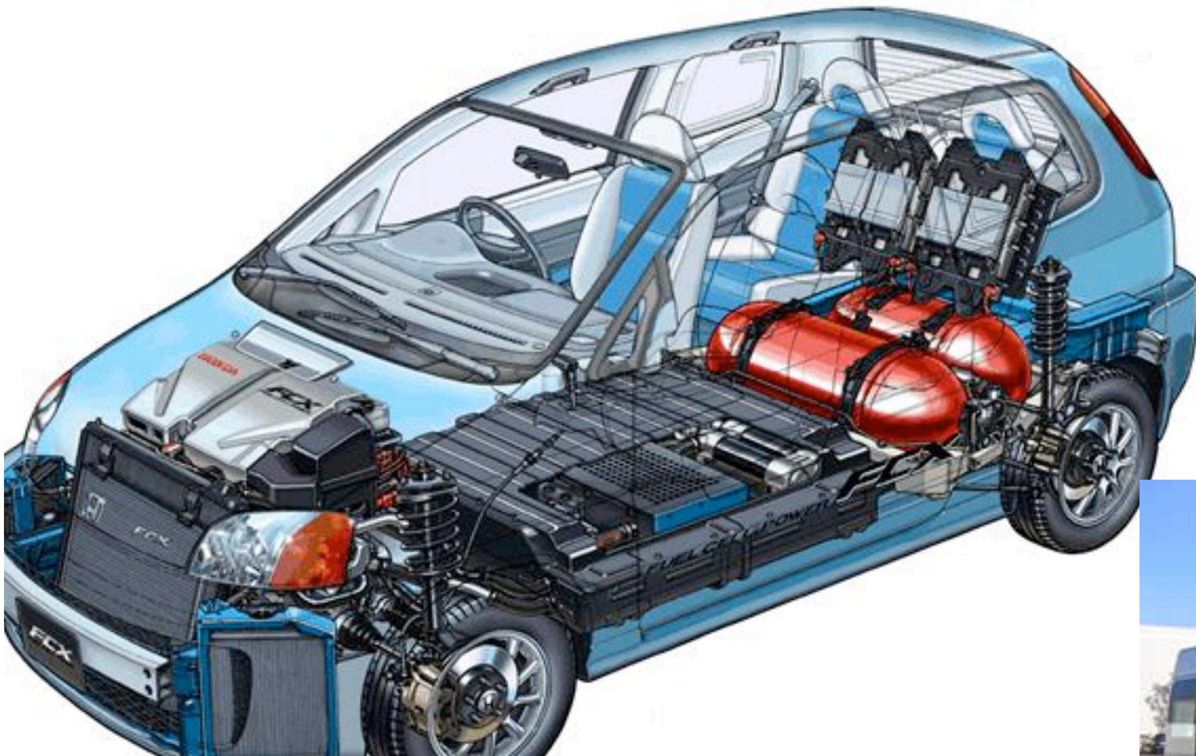


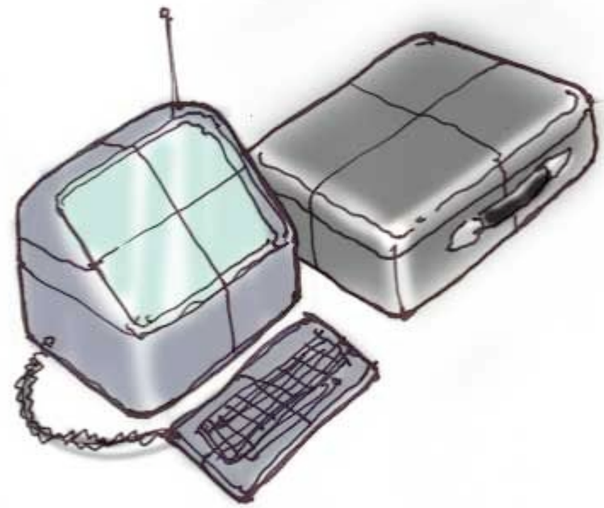
http://www.hcn.org/allimages/2007/jul23/graphics/070723-027.jpg

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)**

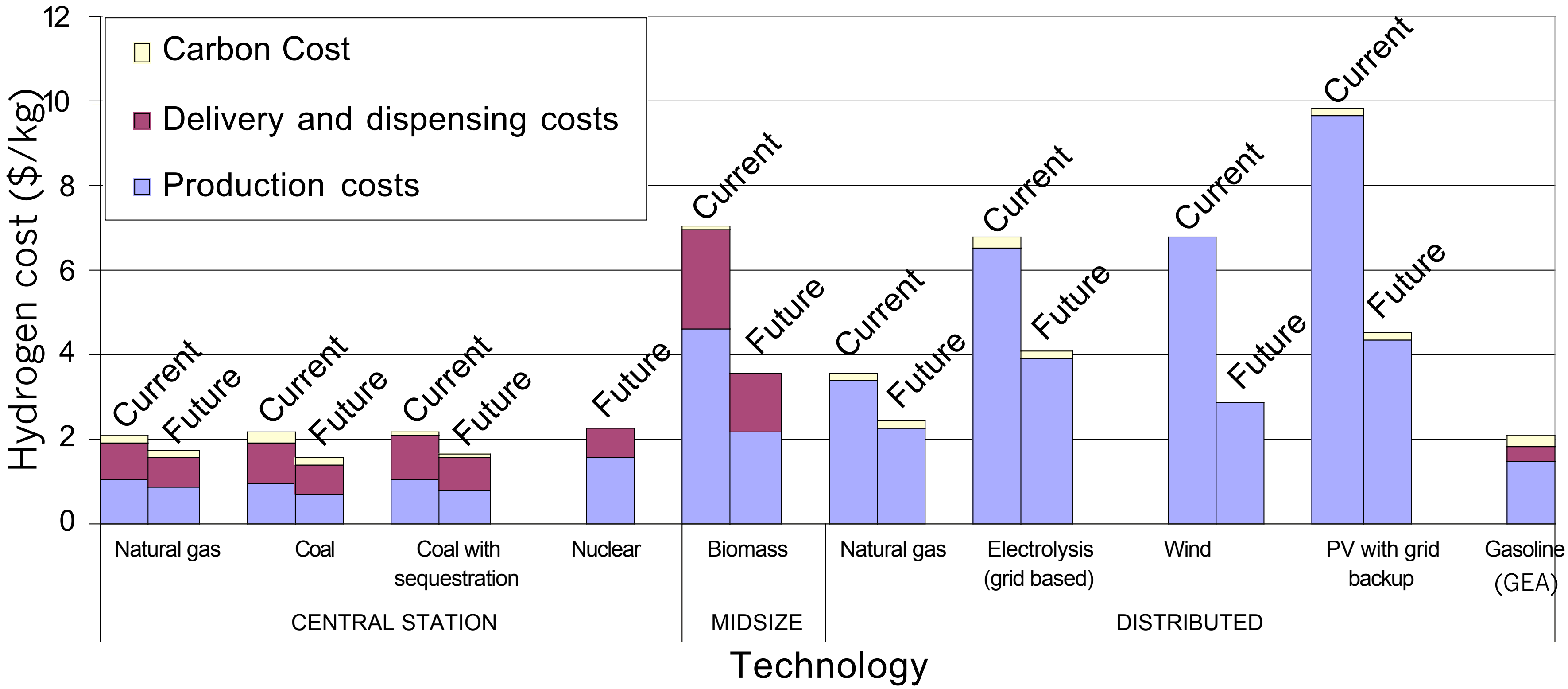

UTC Fuel Cells
DFC 300
Height:
7 – 8 ft.
HYDROGEN + OXYGEN (AIR) -> ELECTRICITY + HEAT + WATER
UTC Fuel Cells
HYDROGEN
FUEL CELL
INVERTER
HEAT
HYDROGEN SOURCE






ZERO EMISSION
HYDROGEN FUEL CELL HYBRID-ELECTRIC DRIVE

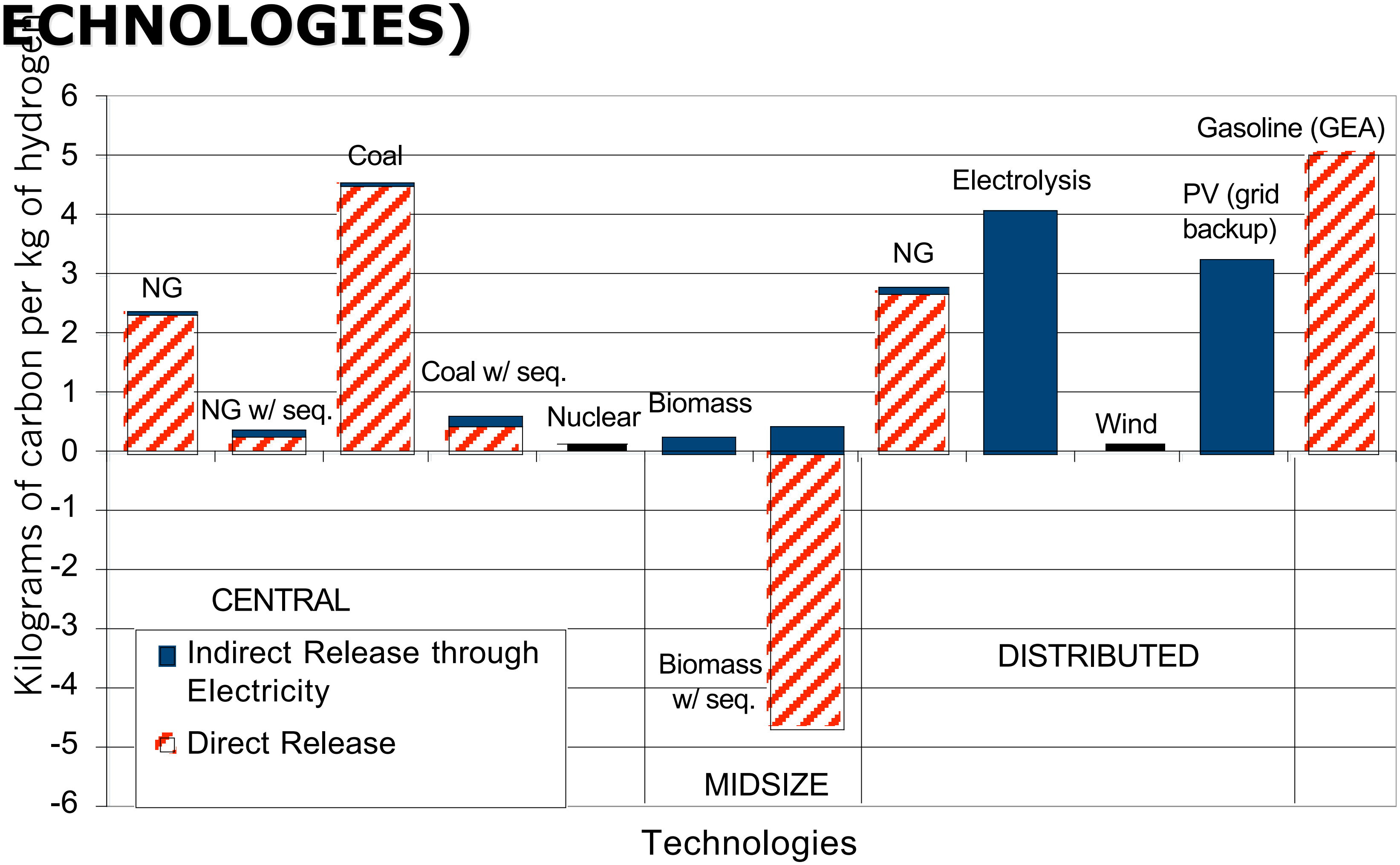
DELIVERED H_2 COSTS OF VARIOUS TECHNOLOGIES



• *GEA = Gasoline Efficiency Adjusted – scaled to hybrid vehicle efficiency*

National Research Council 2006

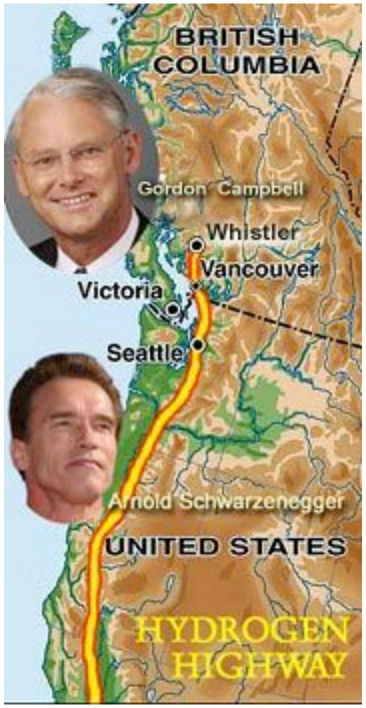
CARBON RELEASED DURING H_2 PRODUCTION, DISPENSING & DELIVERY (FUTURE TECHNOLOGIES)

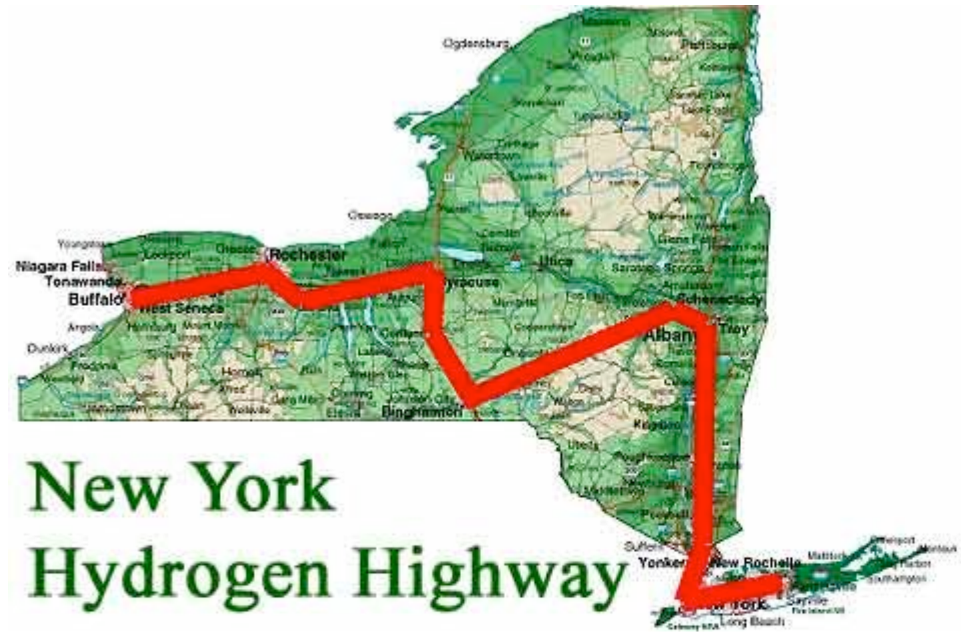


National Research Council 2006

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.





http://hydrogencommerce.com/images/BC-CalifHH.jpg

http://hydrogencommerce.com/images/mapNY.jpg

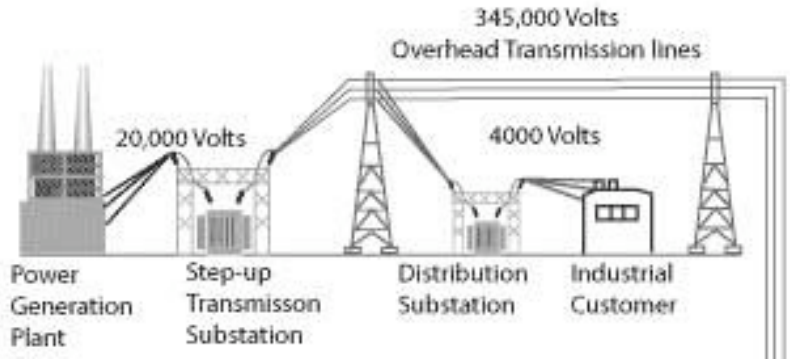
State Approaches to Hydrogen Policy:

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

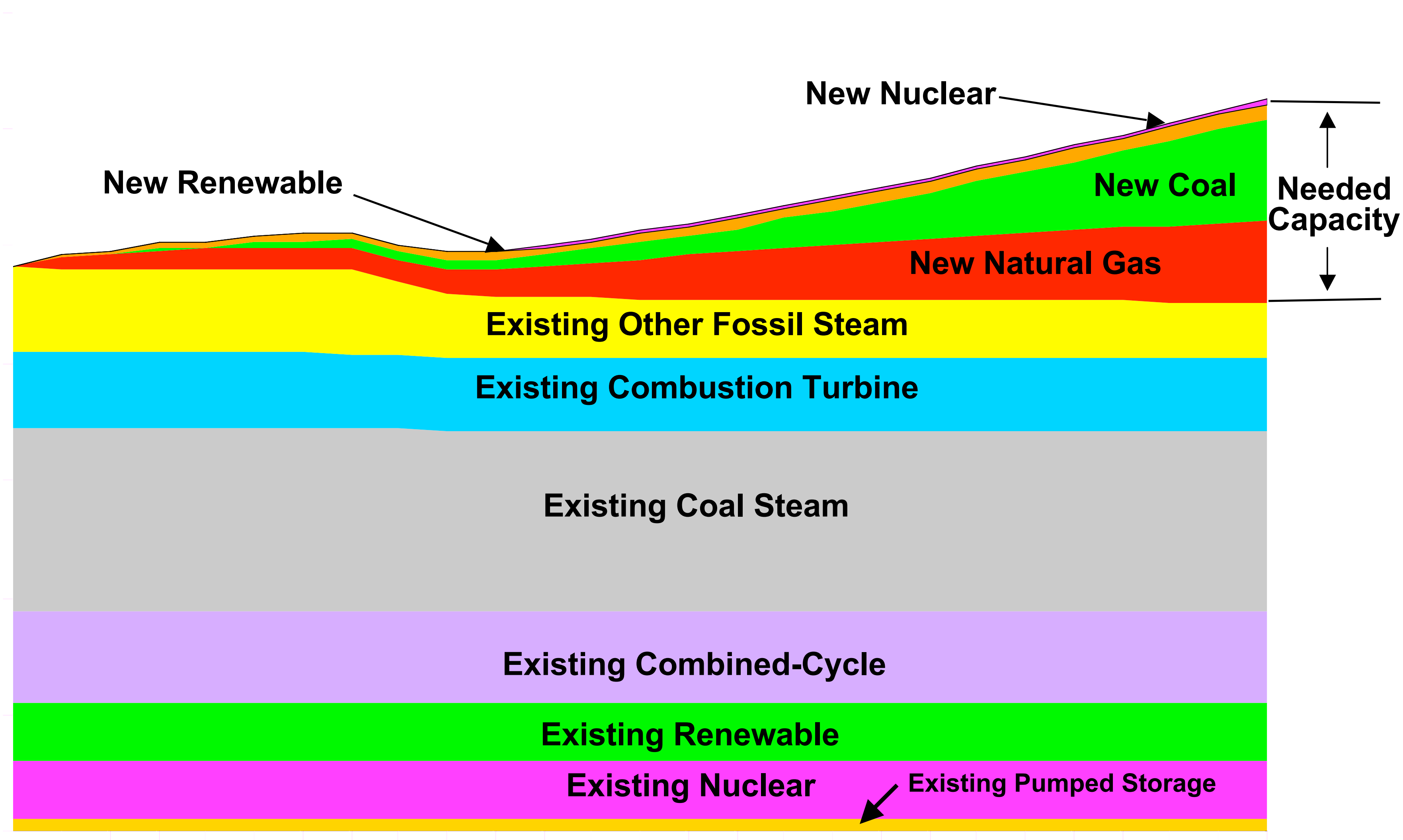
- Biofuels
- Hydrogen
- Electricity



Electricity

http://www.osha.gov/SLTC/etools/electric_power/illustrated_glossary/index.html

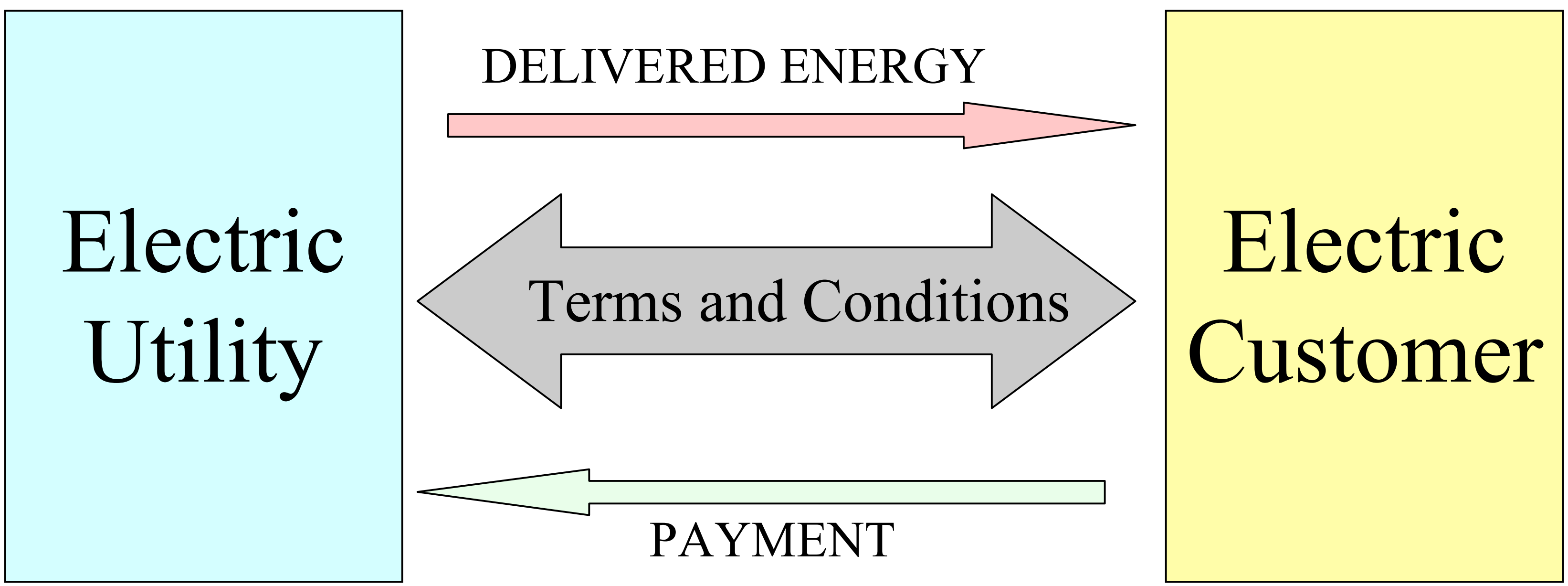
U.S. Electricity Generating Capacity, including Combined Heat and Power, 2004-2030 (gigawatts)



Annual Energy Outlook 2006

Old World:

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

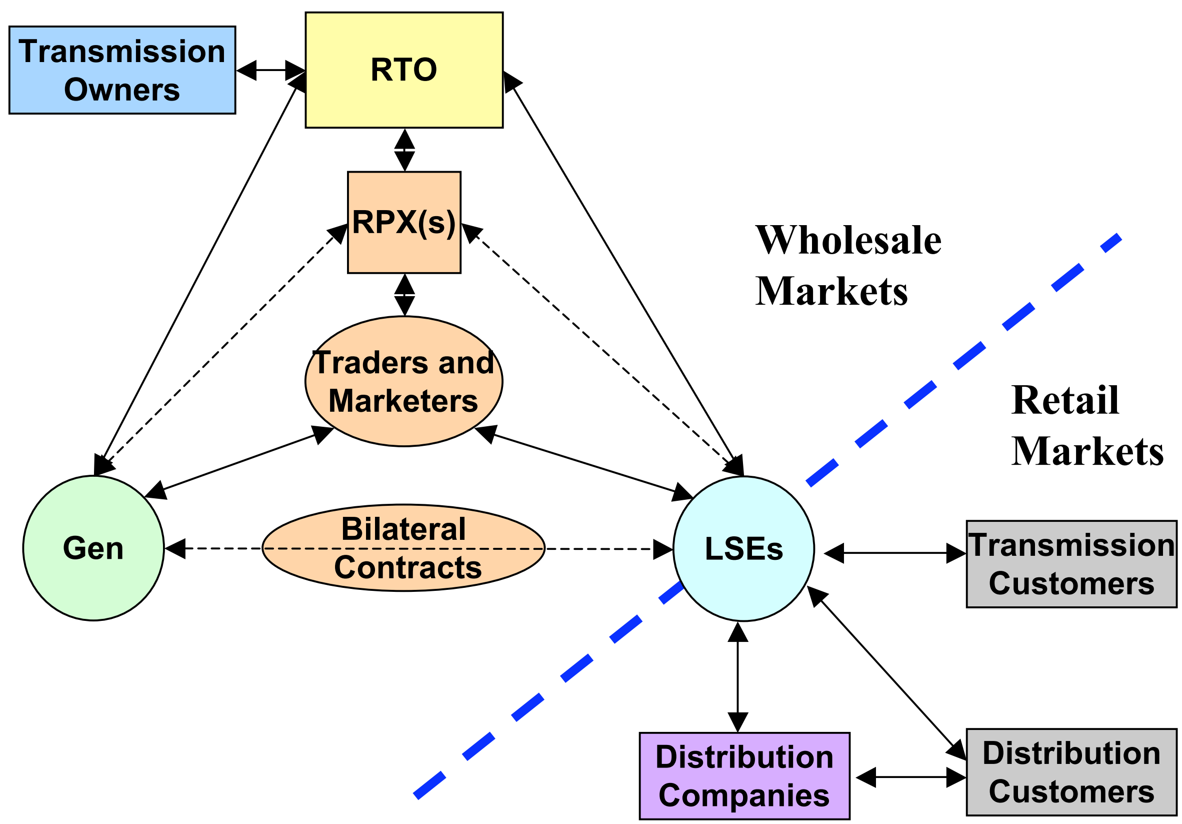


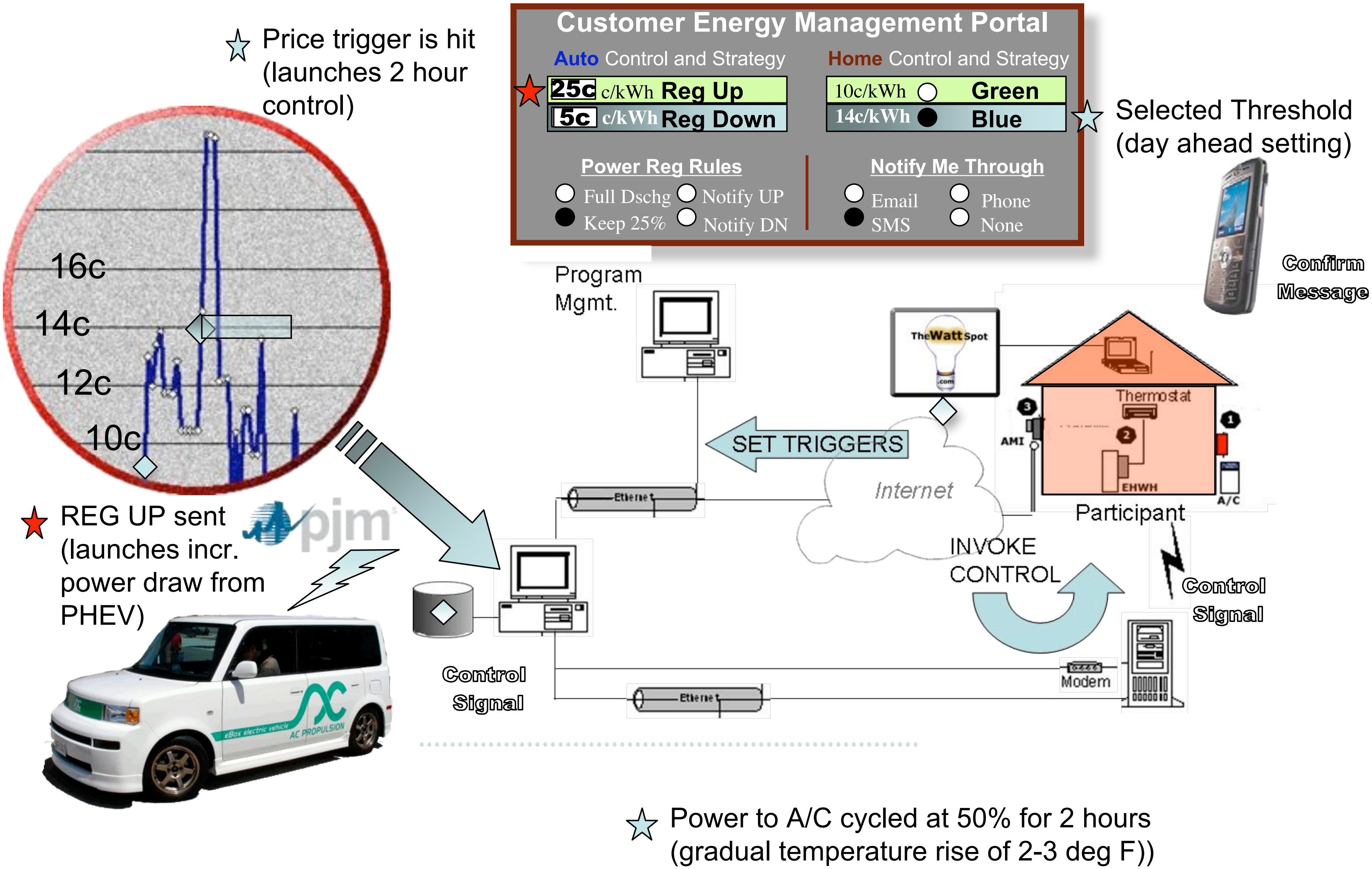
New World: Restructured Markets

- 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.

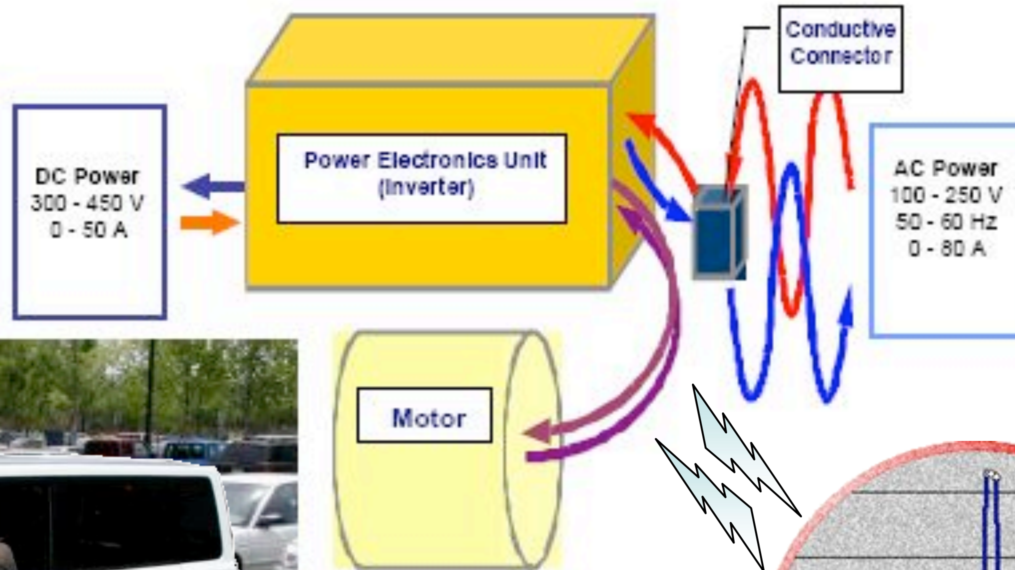




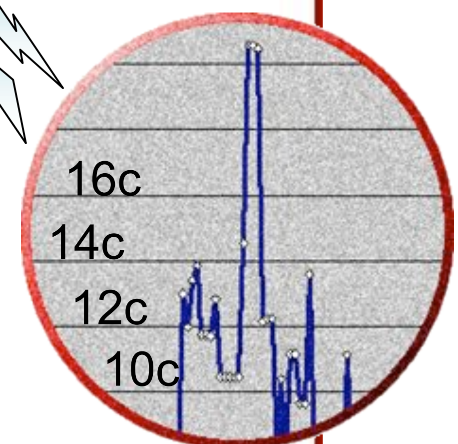
Load Aggregator can extend traditional Demand Response solutions like Thermostats and A/C cycling switches with Stored Energy reclamation from EVs, through reaction to wholesale ***price*** signals or ***regulation*** commands.

Key to V2G: Power Connection is Bi-Directional

Power can flow to or from vehicle



- Grid-tied
- Stand-alone



AC PROPULSION pjm

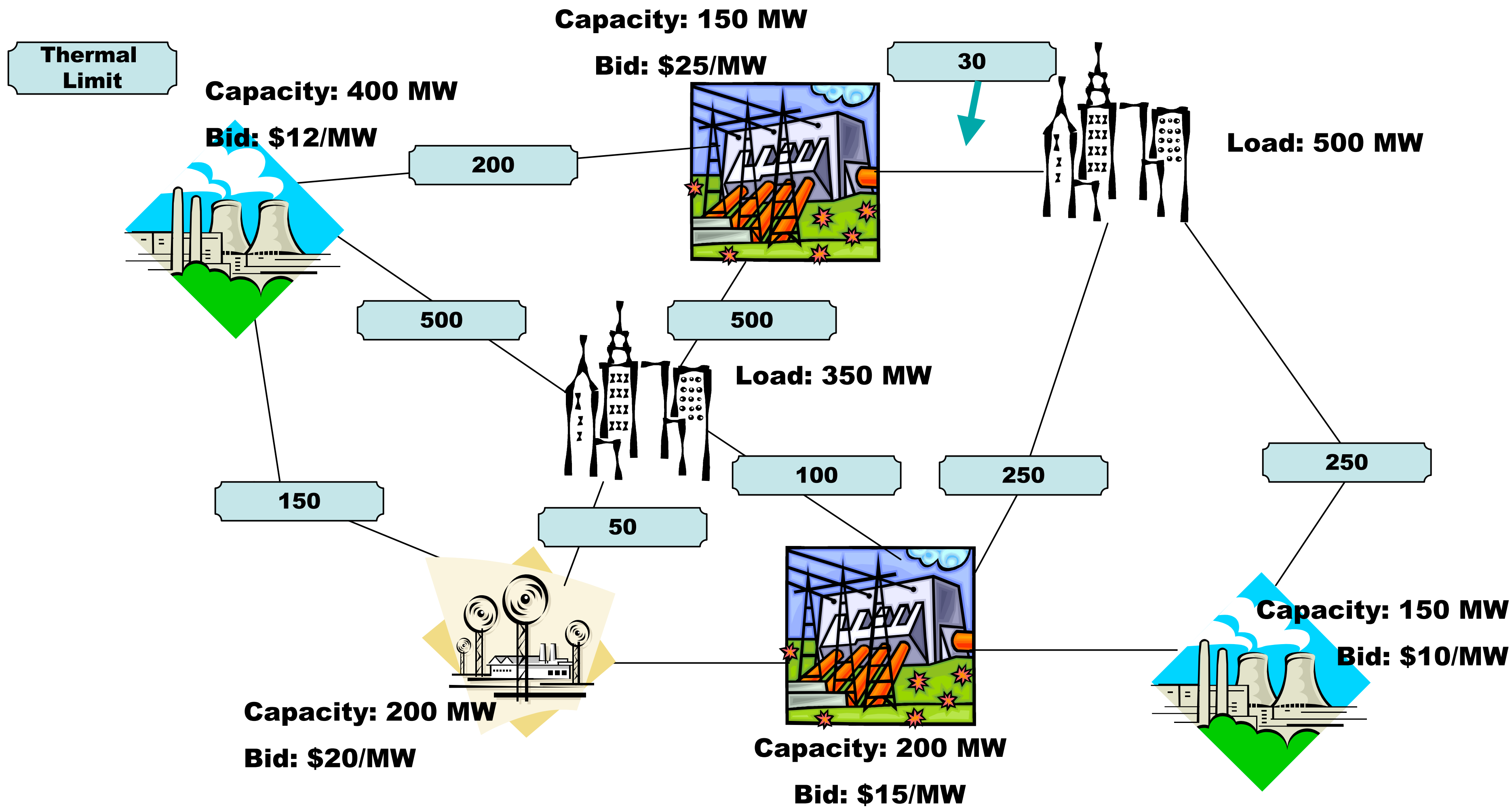
Geographic Vulnerability & Limited Resources

Imports of Electricity to NJ 1960-2005 (million kWh)	
1960	**3,785**
1970	**5,822**
1980	**73,410**
1990	**85,153**
2000	**57,002**
2005	**82,877**

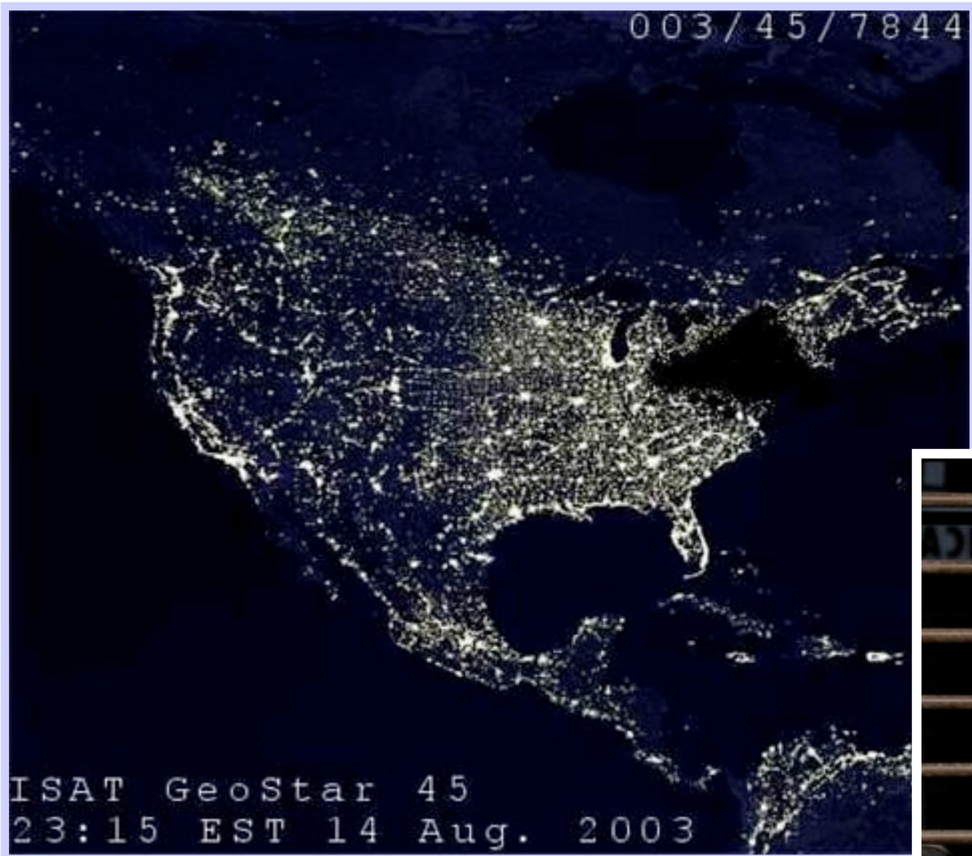
Represents approx. 25% of total consumption in 2005

Cost Structure of Electricity

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



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

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

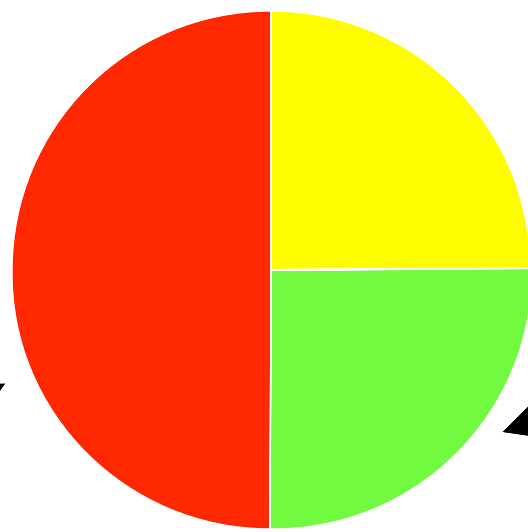
- GM Volt, 14kwh, 40 miles: planned for late 2010, using A123 or LG Chem advanced lithium battery. Enough for 90% of US to get to work in case of total gasoline embargo, if employer parking lots have recharge stations.
- Hyundai: US mass-market hybrid 2009, no comment on plug-in, deal with LG Chem and massive new Korean battery program www.eetimes.eu/power/196600822
- 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

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

Highest mpg Hybrids Cut Gas per Mile By 50%



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

*GEM = Gasoline-Ethanol-Methanol

Paul Werbos www.werbos.com/energy.htm

Scales of Energy Markets

- <u>Oil</u>: once local, now global
- <u>Coal</u>: once local, now global
- <u>Natural gas</u>: once local, now continental
- <u>Electricity</u>: once local, now regional
- <u>Hydrogen</u>: 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?

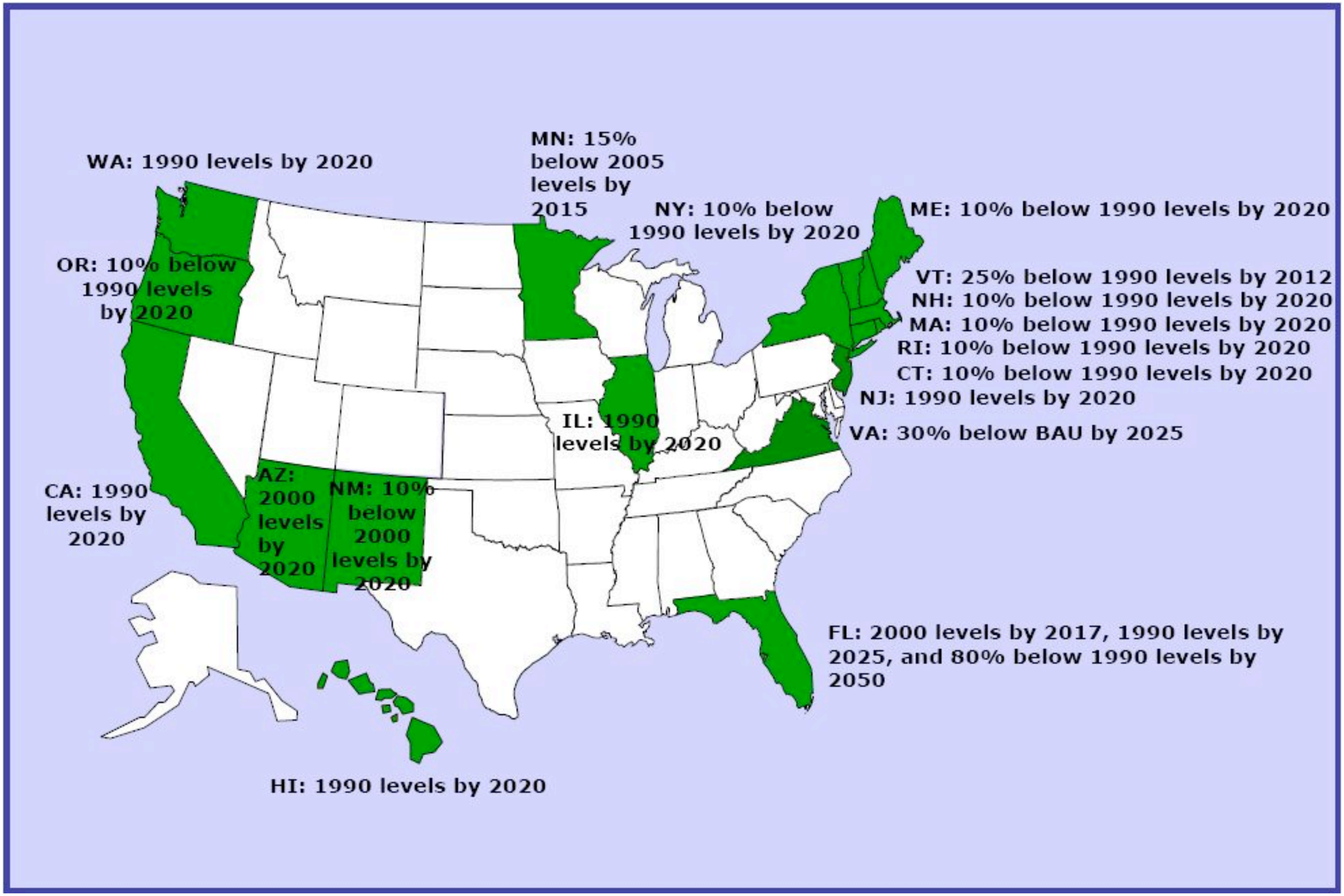
- Innovative culture
- High capacity to act
- Attractive circumstances

- *e.g., Iceland*
- *But no U.S. states have the ideal combo of preferences, capabilities, circumstances*

Hydrogen Economy Activity

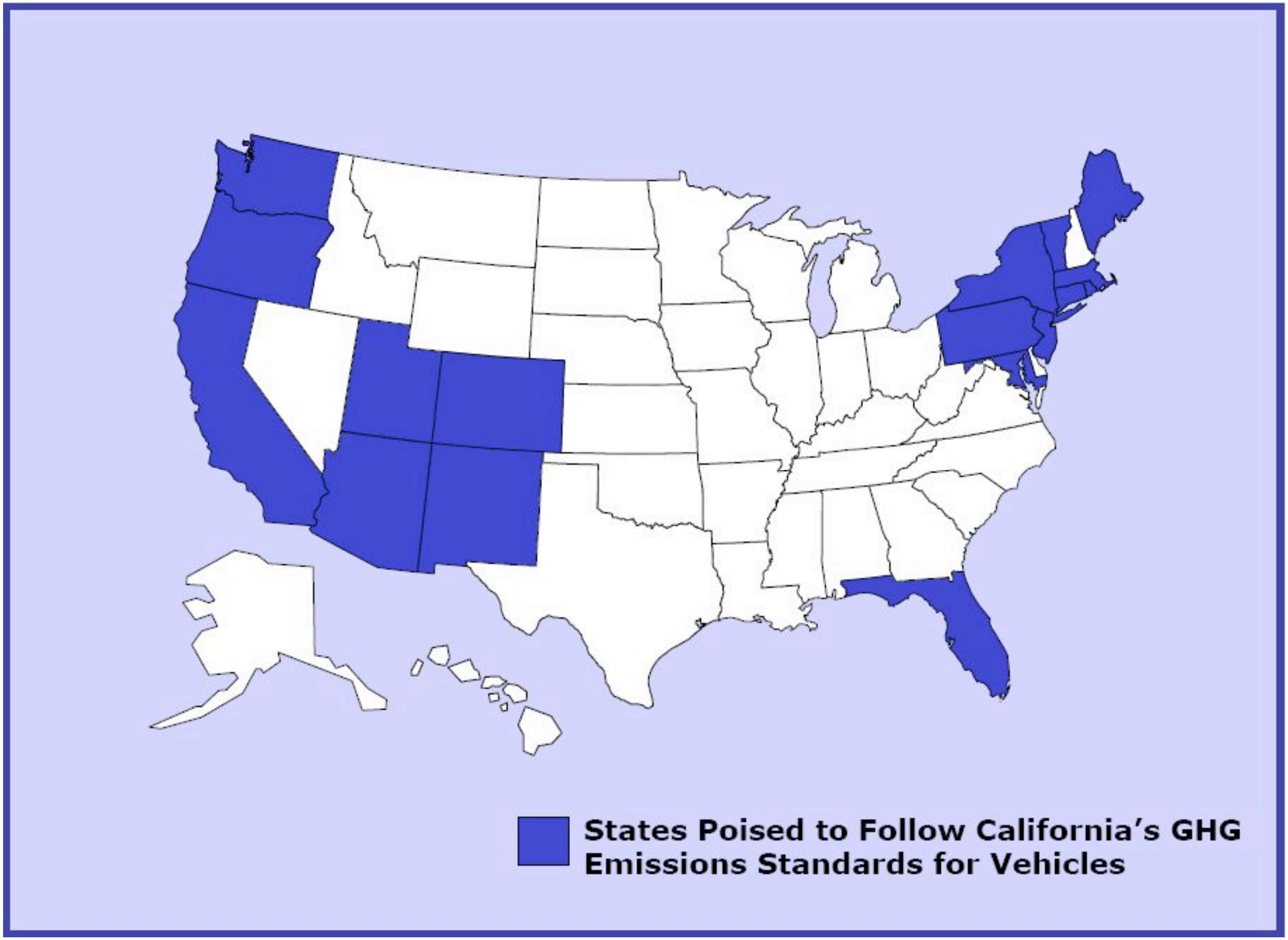
Jurisdiction	Preferences	Capabilities	Circumstances
California	X	X	
Connecticut	X	X	
Hawaii	X		X
Michigan		X	
New Jersey	X	X	
New York	X	X	
Texas		X	X
Washington	X	X	

State GHG Emission Targets



Patrick Hogan http://www.deq.virginia.gov/export/sites/default/info/documents/climate.march.2.LocalStateRegionalAction.pdf

Vehicle GHG Standards



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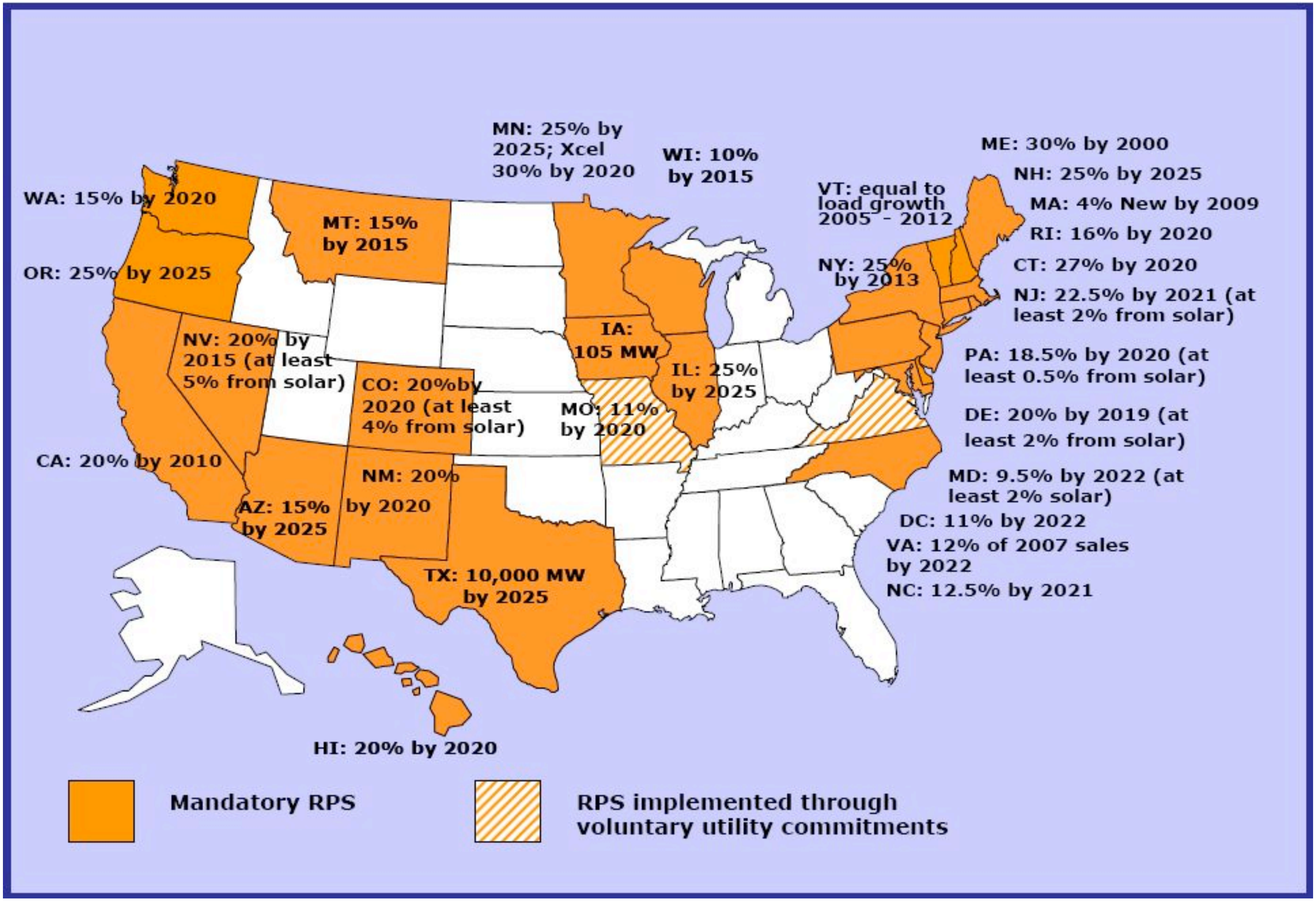
Renewable Portfolio Standards



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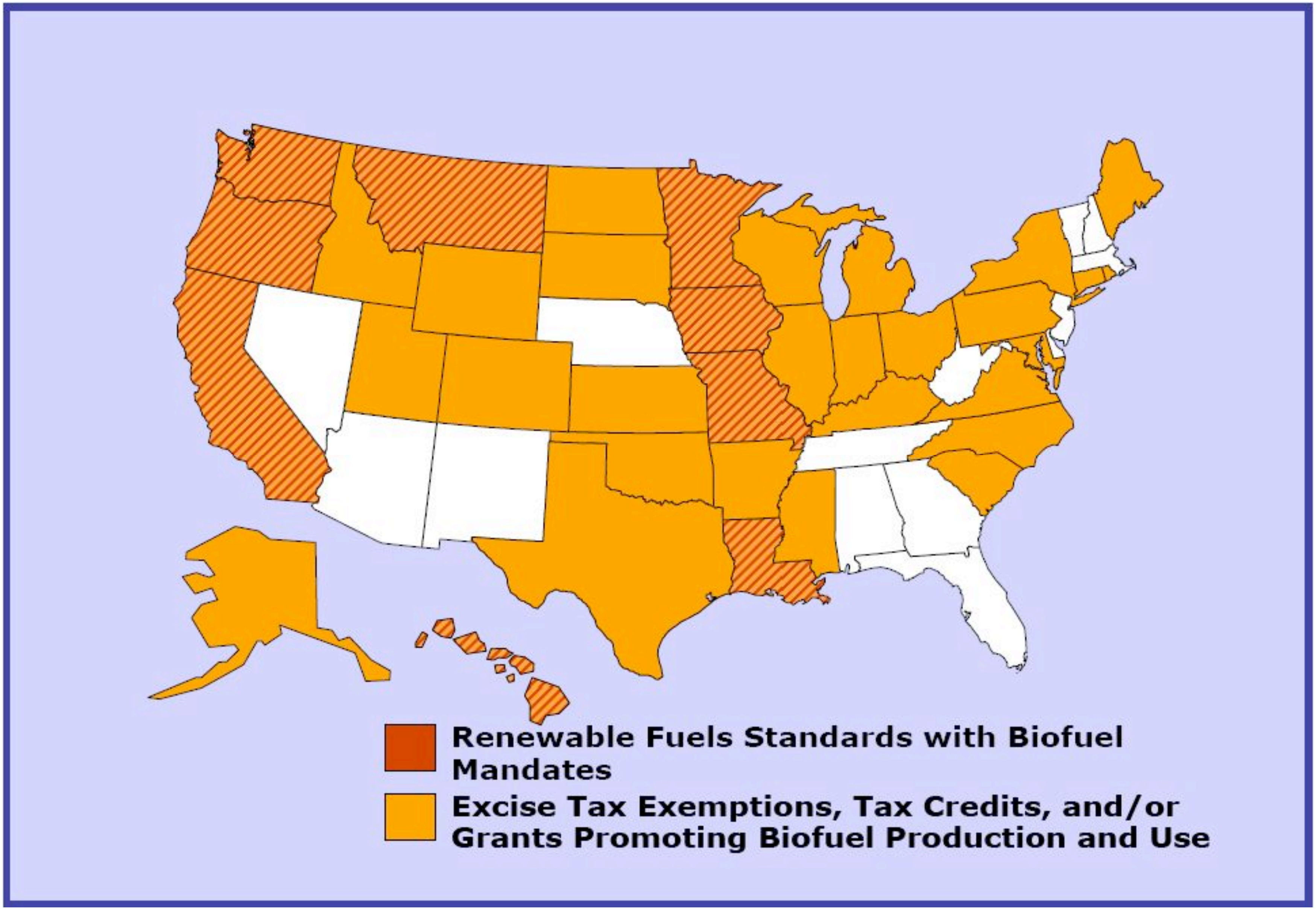
Mandates and Incentives for Biofuels



Patrick Hogan http://www.deq.virginia.gov/export/sites/default/info/documents/climate.march.2.LocalStateRegionalAction.pdf

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

Patrick Hogan http://www.deq.virginia.gov/export/sites/default/info/documents/climate.march.2.LocalStateRegionalAction.pdf

Adopted from http://public.fotki.com/MNCapital/twincitiespagecom-2/saint_paul_neighborhoods/neighborhood_battle/dr11.html

ted from http://www.cr.nps.gov/nr/newsuburbs.htm

Efficient Land Use Patterns

Adopted from http://www.census.gov/pubinfo/www/photos/communities.html

Efficient Behaviors

- Carpool, vanpool
- Transit passes
- Flextime, telework
- Biking, walking

http://www.emagazine.com/images/0199nd_telecommute.jpg

http://blog.lib.umn.edu/rivar050/architecture/images/russian_carpool.jpg

http://blog.nj.com/newsletters/2008/01/large_njt.JPG

http://www.viainfo.net/Images/OtherService/VanPoolVan.jpg

How Allocate Responsibilities?

- Federalism is key part of context
- <u>Centralize</u> responsibilities to take advantage of scale economies, enforce national norms, pool risks, reduce spillovers
- <u>Decentralize</u> 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

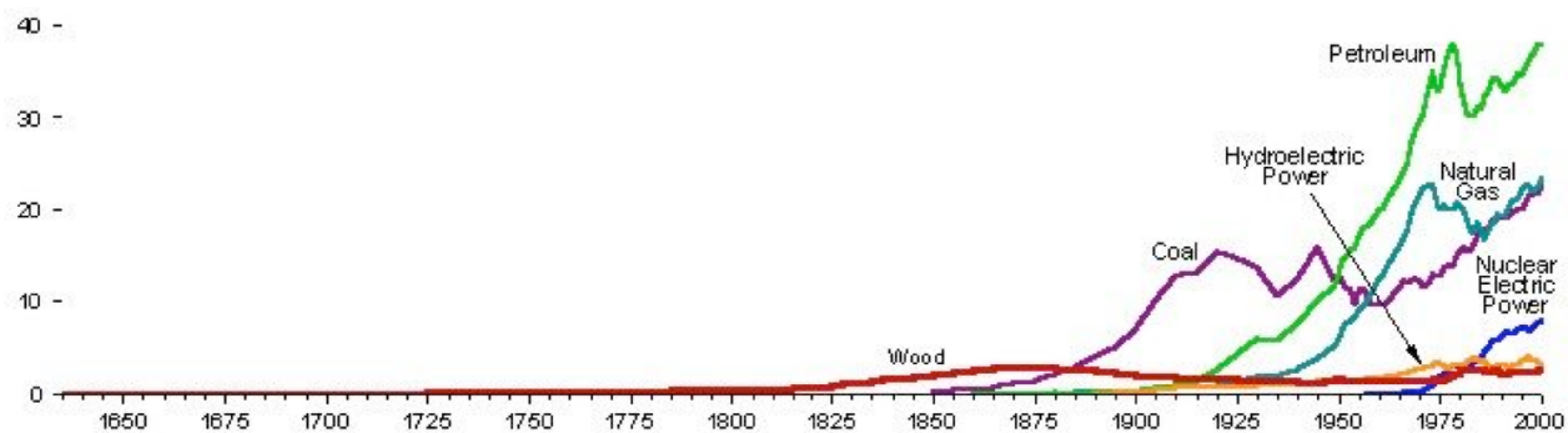
- Sponsor or implement applied research, cost-effective demonstration projects
- Encourage regulated utilities to investigate PHEVs & hydrogen
- Develop more efficient land uses
- Sponsor outreach, education, esp. for leaders

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)



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