Sustainable Energy: A National and International Security Imperative

Update 2009 L. David Montague

To frame the Issues and stimulate discussion of plausible solutions free of energy industry influence.

Draws and integrates data from Academic, USDA, Commerce and DOE EIA sources through 12/08

Proposes a holistic near term solution against a backdrop of national security and global warming concerns.

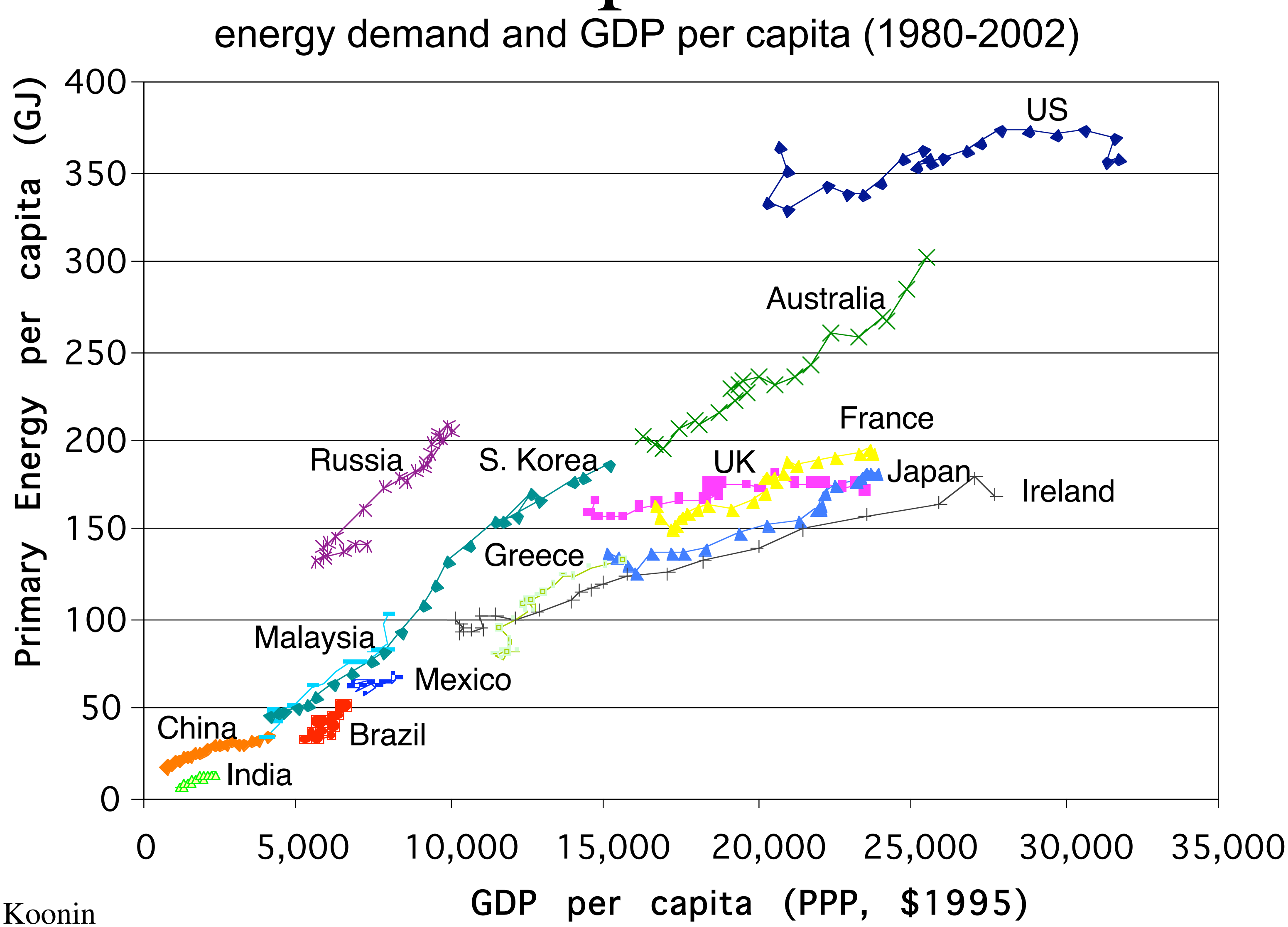
Examines controversial issues

Presented at the Center for International Security and Cooperation at Stanford University
February 2006; updated May 2009

Outline of Discussion

- Current and projected US and World energy consumption and supply by sector
- Carbon emissions and warming
- The nature of the options & issues
  - Transportation
    - Bio-fuels
    - Hydrogen, Fuel Cells
  - Electric Power
    - Solar, Wind,
    - Bio-fuels,
    - Nuclear
- A proposed quantifiable solution set for near and long term sustainable energy independence

Energy use grows with economic development



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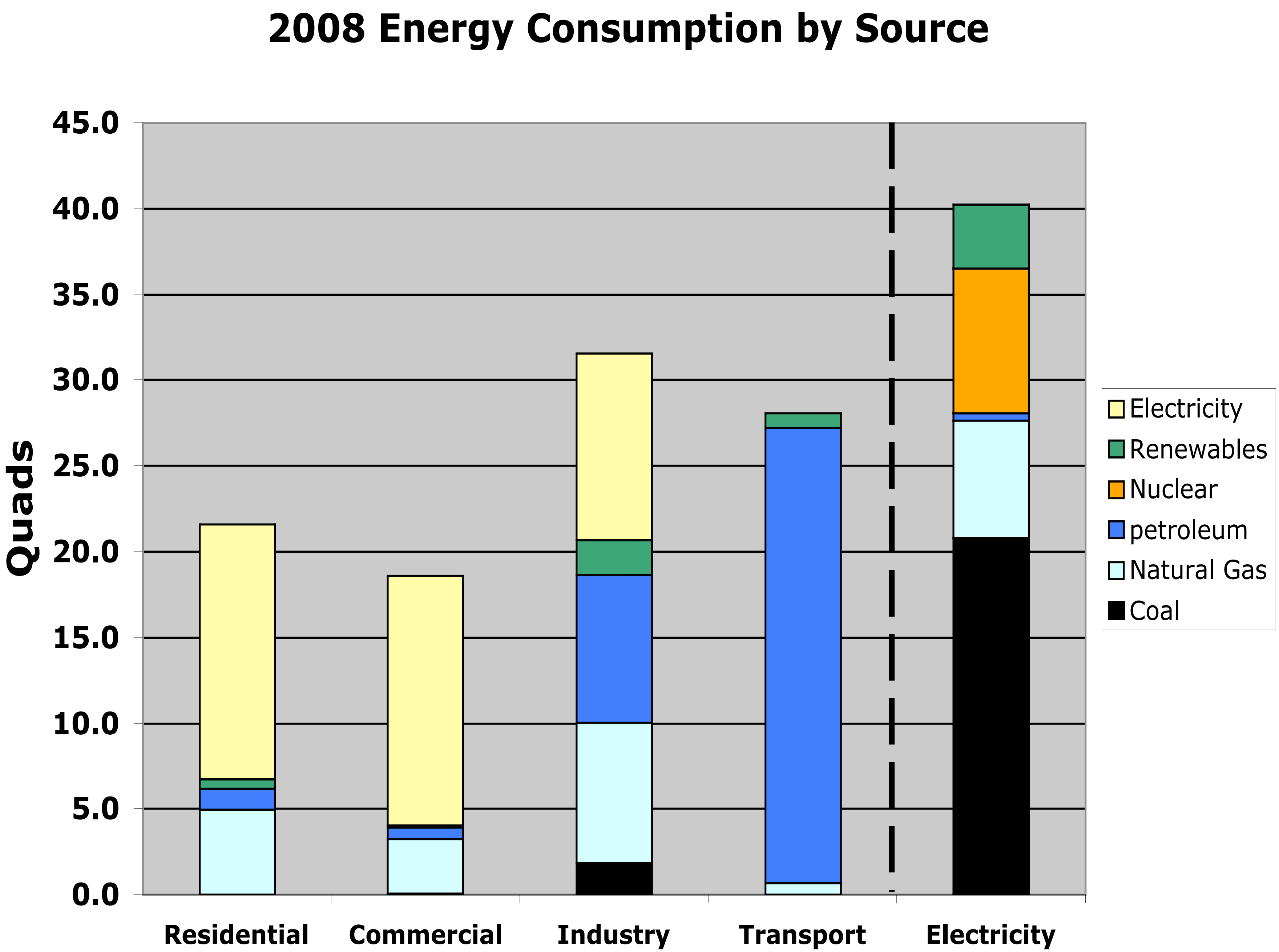
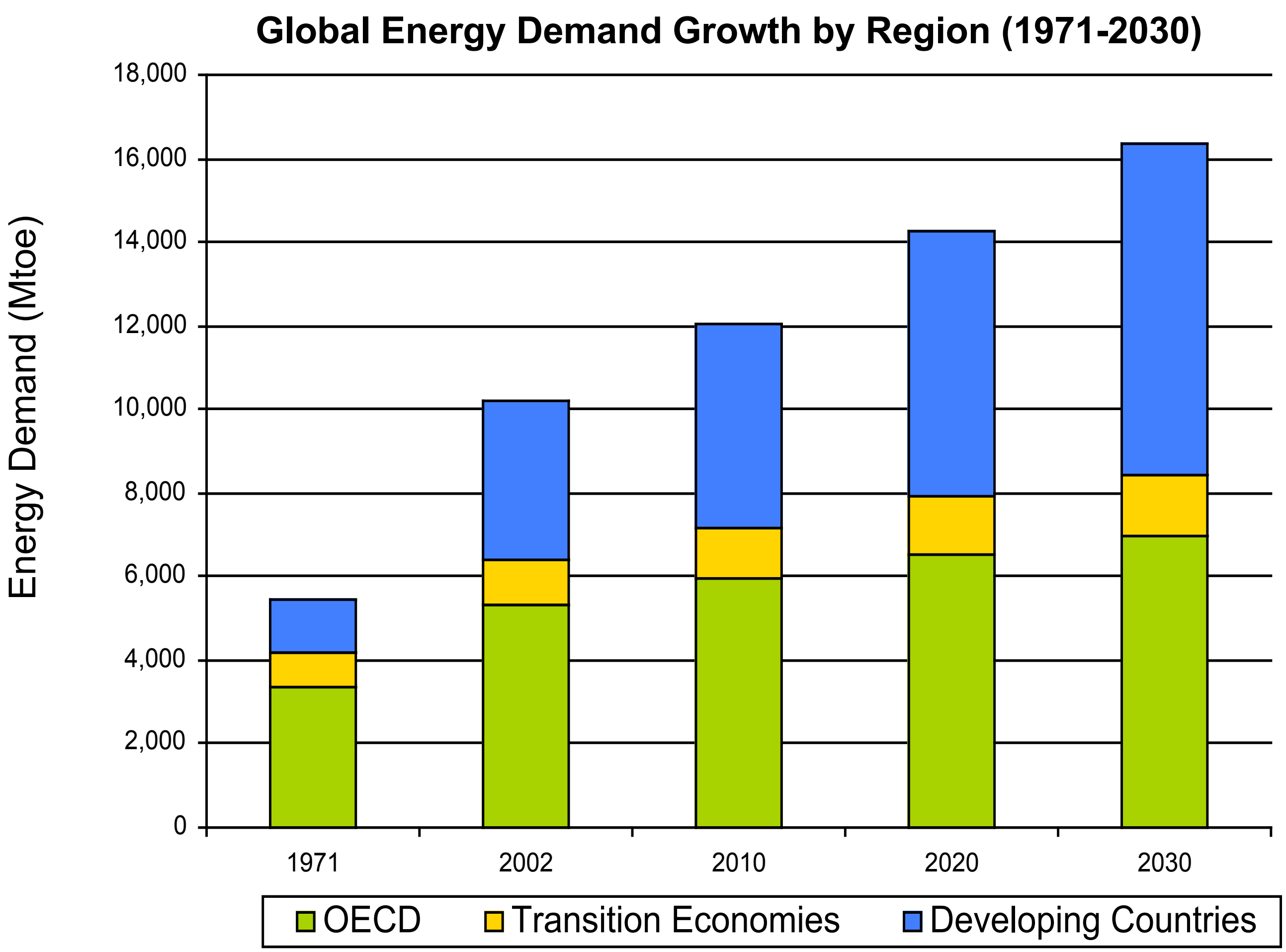
Source: UN and DOE EIA



2008 Energy Consumption by Source
Quads
45.0
40.0
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Residential
Commercial
Industry
Transport
Electricity
Electricity
Renewables
Nuclear
petroleum
Natural Gas
Coal

energy demand – growth projections

Global energy demand is set to grow by over 60% over the next 30 years – 74% of the growth is anticipated to be from non-OECD countries



Notes: 1. OECD refers to North America, W. Europe, Japan, Korea, Australia and NZ
2. Transition Economies refers to FSU and Eastern European nations
3. Developing Countries is all other nations including China, India etc.

Source: IEA World Energy Outlook 2004

growing dislocation of supply & demand

- N. America, Europe and Asia Pacific are the three largest demand centres
- But, have a small share of the remaining oil and gas reserves; coal is the exception
- Their collective shares are:
- Oil - 80% of demand; 15% of conventional reserves (28% incl. unconventional reserves)
- Gas – 61% of demand; 32% of reserves
- Coal – 89% of demand; 69% of reserves

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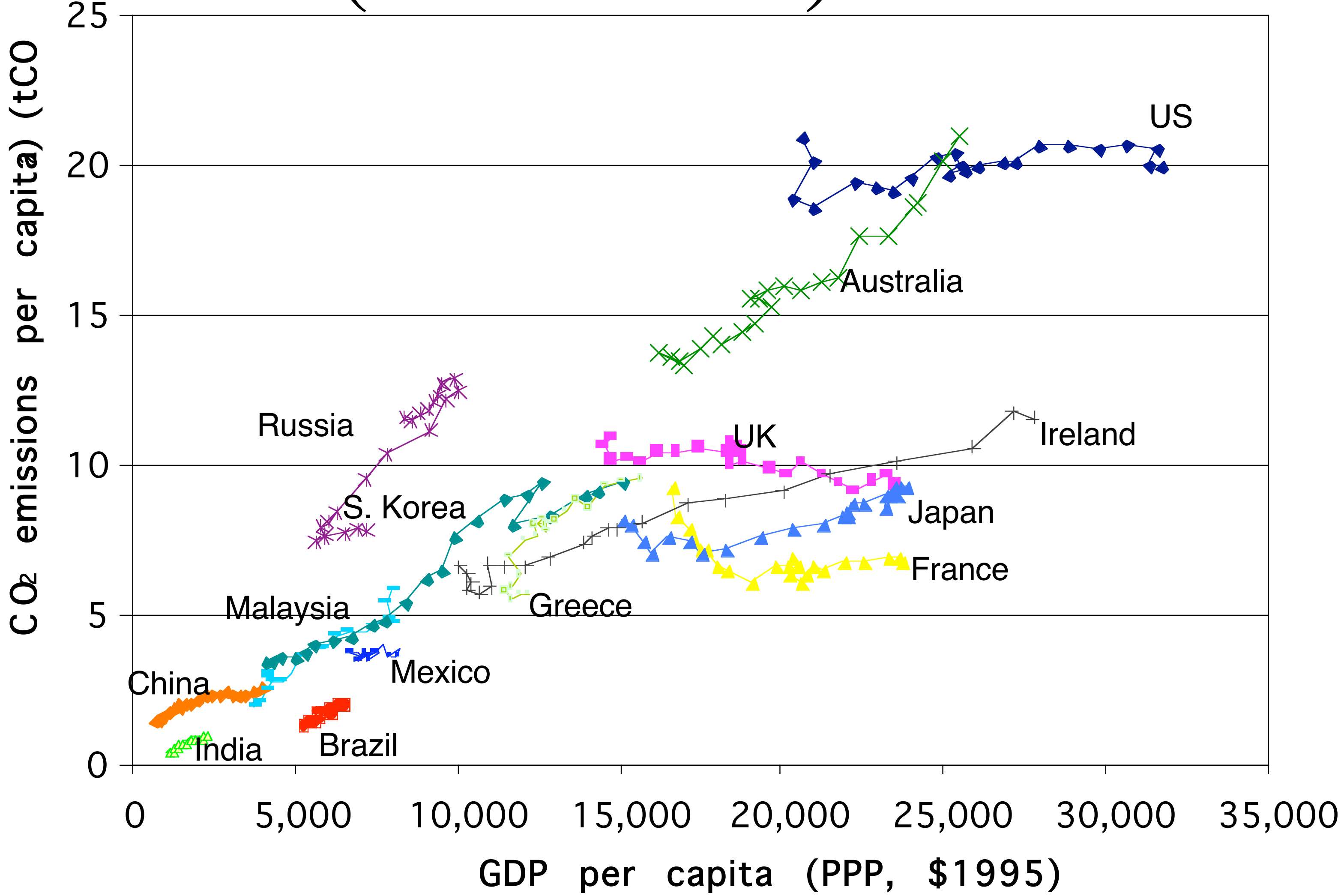
CO_2 emissions and GDP per capita (1980-2002)



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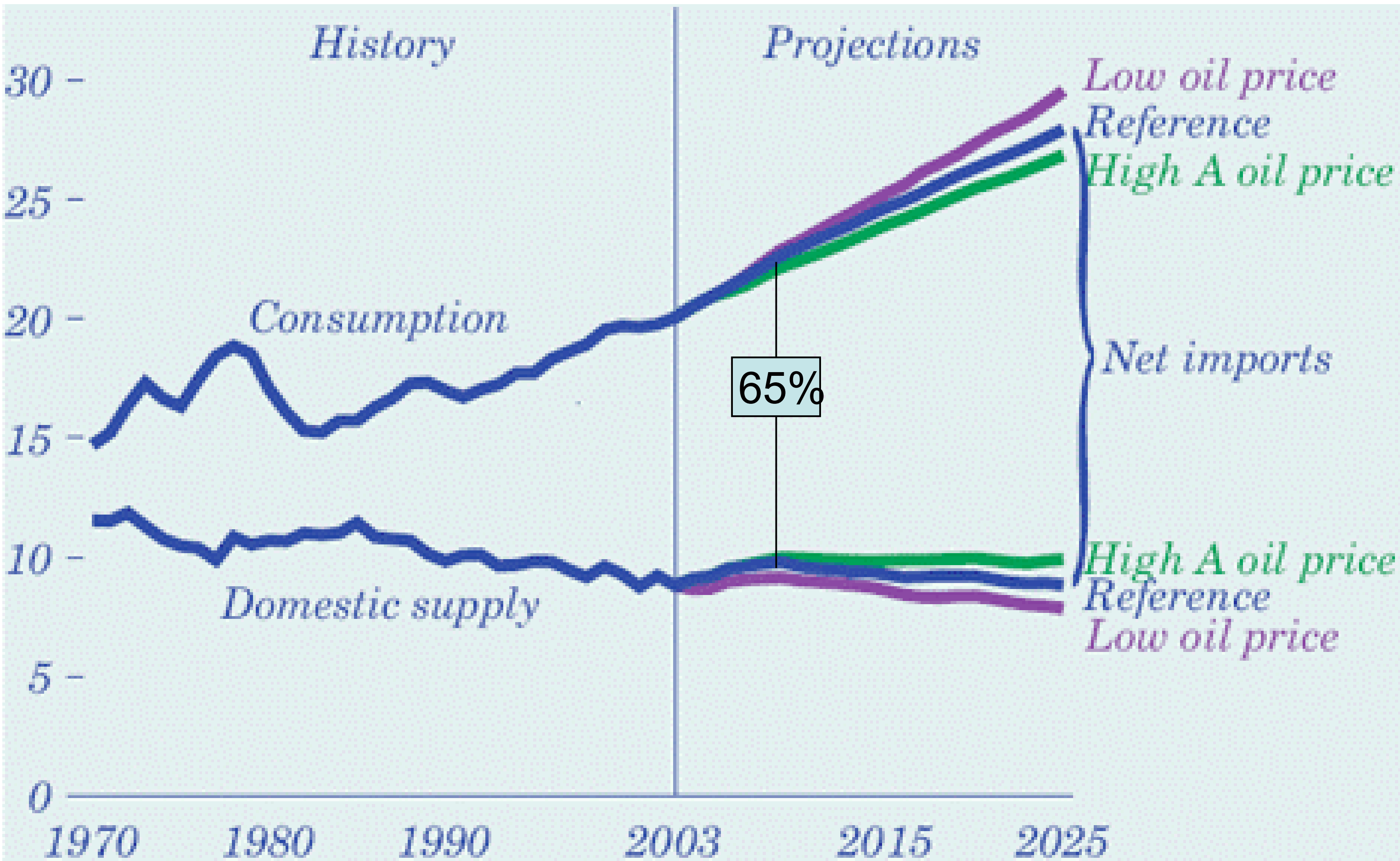
The Oil Problem

Nations that **HAVE** oil (% of Global Reserves)		Nations that **NEED** oil (% of Global Consumption)	
Saudi Arabia	26%	**U.S.**	**26%**
Iraq	11%	Japan	7%
Kuwait	10%	China	6%
Iran	9%	Germany	4%
UAE	8%	Russia	3%
Venezuela	6%	S. Korea	3%
Russia	5%	France	3%
Mexico	3%	Italy	3%
Libya	3%	Mexico	3%
China	3%	Brazil	3%
Nigeria	2%	Canada	3%
U.S.	**2%**	India	3%

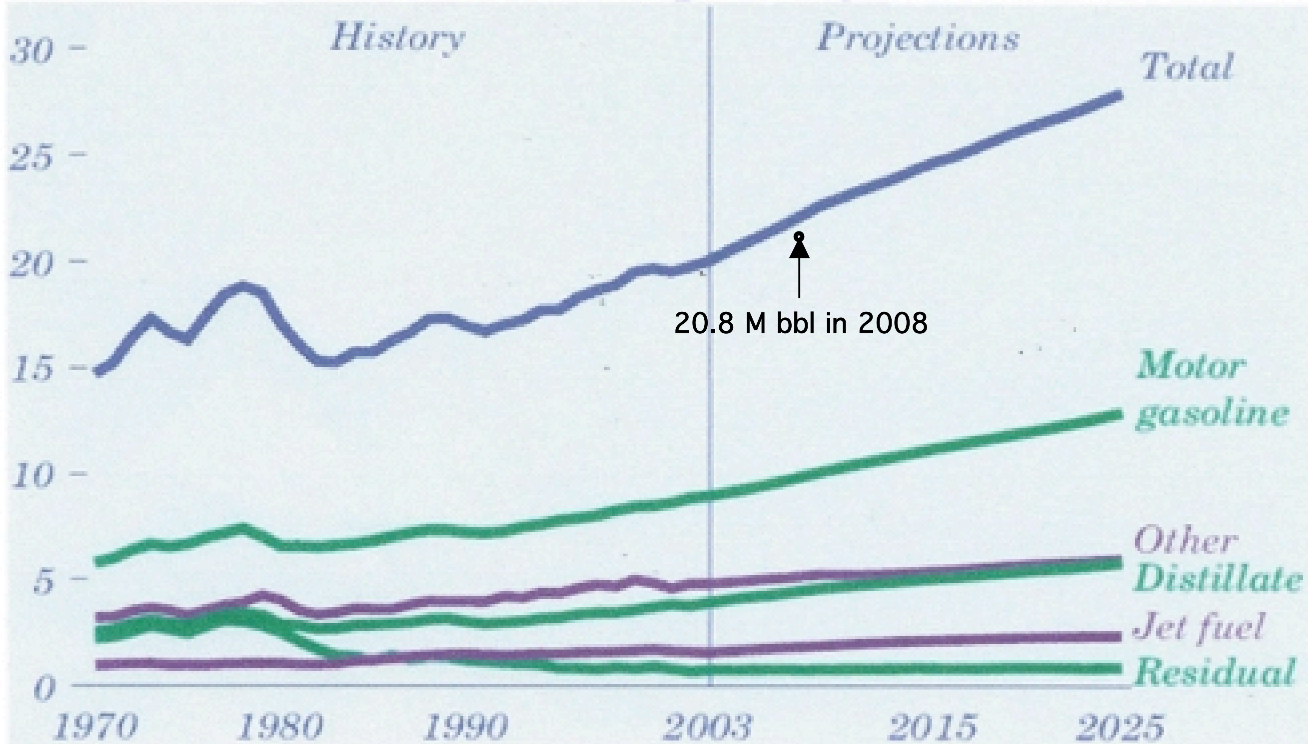
Source: EIA International Energy Annual

Petroleum supply, consumption, and imports, 1970-2025
(million barrels per day)



Annual Energy Outlook 2005 with Projections to 2025

Figure 99. Consumption of petroleum products, 1970-2025 (million barrels per day)



History: Energy Information Administration, Annual Energy Review 2003, DOE/EIA-0384(2003) (Washington, DC, September 2004). Projections: Table A11.

Released: February 2005

Key Issues

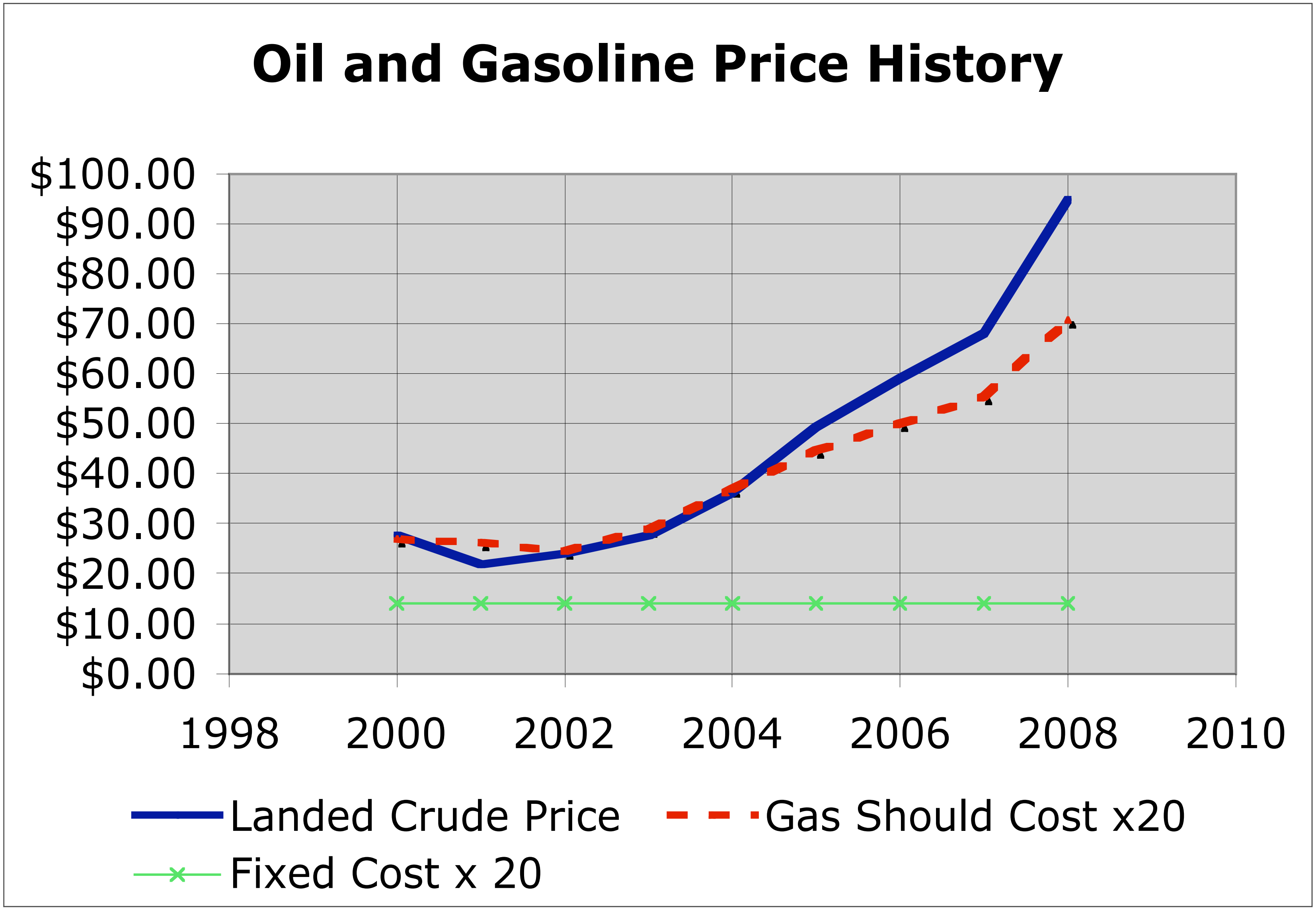
- Are we running out of oil?
- Do we have plenty of natural gas reserves?
- Is Hydrogen created by renewable electricity burned in fuel cells the right solution for clean transportation energy?
- Can biofuels -- especially ethanol -- ever realistically eliminate the need for imported oil without a major impact on food costs and land use?
- Can renewable wind and solar generated power with conservation meet our electricity needs?
- Nuclear power plants are seen as unsafe, inefficient and expensive and their radioactive waste will pollute the planet for thousands of years. And what about weapons grade fissile material?
- Can clean energy be made economically from coal with the CO2 sequestered by pumping it underground?

Are we running out of oil?

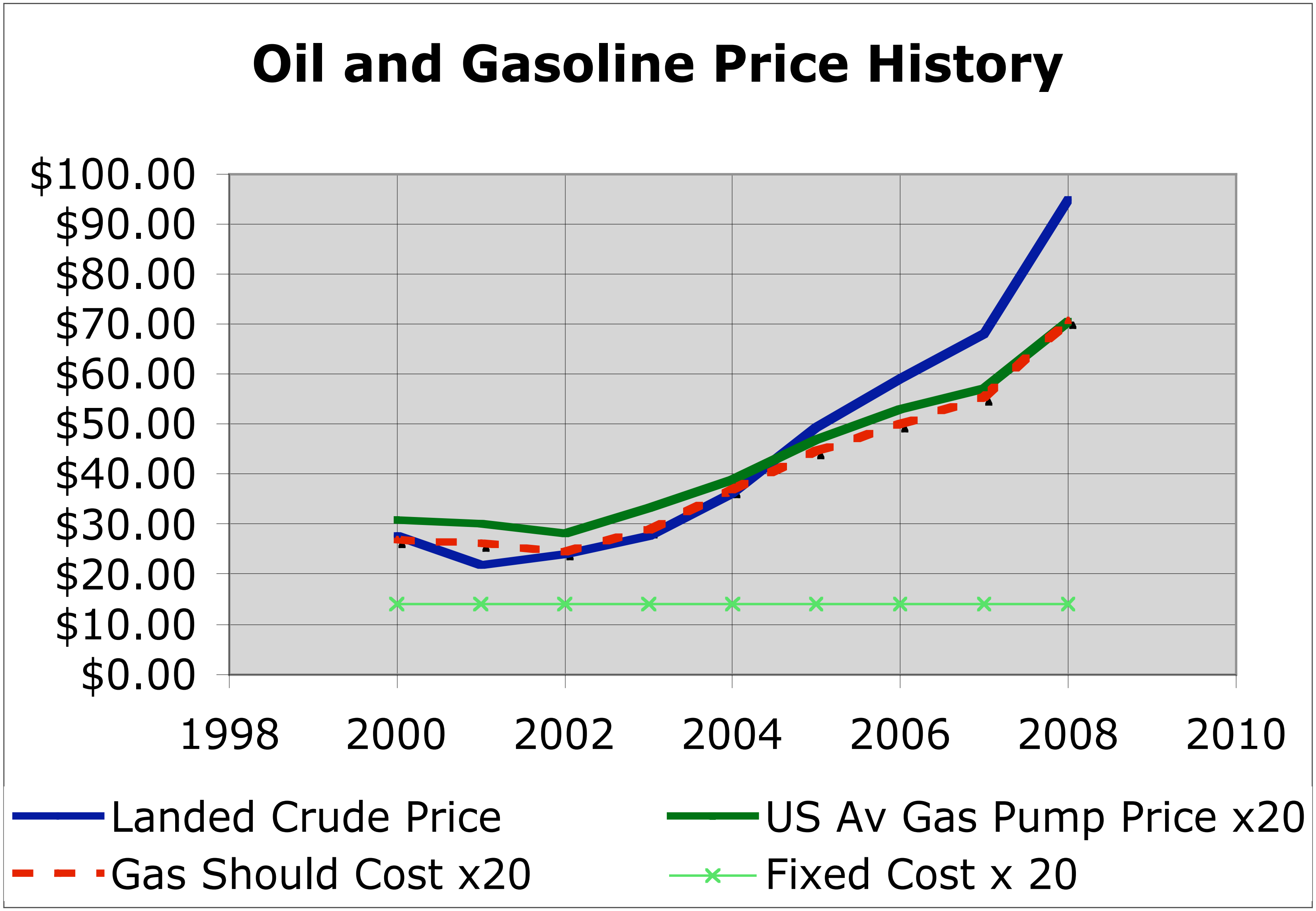
We are certainly running out of cheap oil.

Productivity of easily accessible oil reserves are is waning. Hence the assessment that the peak in supply has already occurred.

If worldwide demand for oil continues to grow, the price of oil will continue to increase. As the price increases, large more expensive and energy intensive "unconventional" reserves become economically viable if consumers are willing to pay that price. Even so, this simply postpones the inevitable depletion of oil resources, and exacerbates greenhouse emissions.



Oil and Gasoline Price History
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
1998
2000
2002
2004
2006
2008
2010
Landed Crude Price
Gas Should Cost x20
Fixed Cost x 20


Oil and Gasoline Price History
$100.00
$90.00
$80.00
$70.00
$60.00
$50.00
$40.00
$30.00
$20.00
$10.00
$0.00
1998
2000
2002
2004
2006
2008
2010
Landed Crude Price
US Av Gas Pump Price x20
Gas Should Cost x20
Fixed Cost x 20

Oil & Gasoline Market Behavior

- The oil market is not a free market
  - Demand is inelastic and growing while supply is elastic as long as reserves exist
  - The supply pipeline is easily manipulated or disrupted
- Demand inelasticity vs supply pipeline vulnerability encourages speculation and no relation to actual cost
- There is no incentive for oil companies to put downward pressure on oil prices, because profits rise directly with crude price
- Then there is the "Mysteresis" effect. Gasoline prices at the pump rise instantly with crude increases but lag significantly as crude prices go down. In reality the pipeline is weeks long and refiners rarely contract at the delivery day spot price.

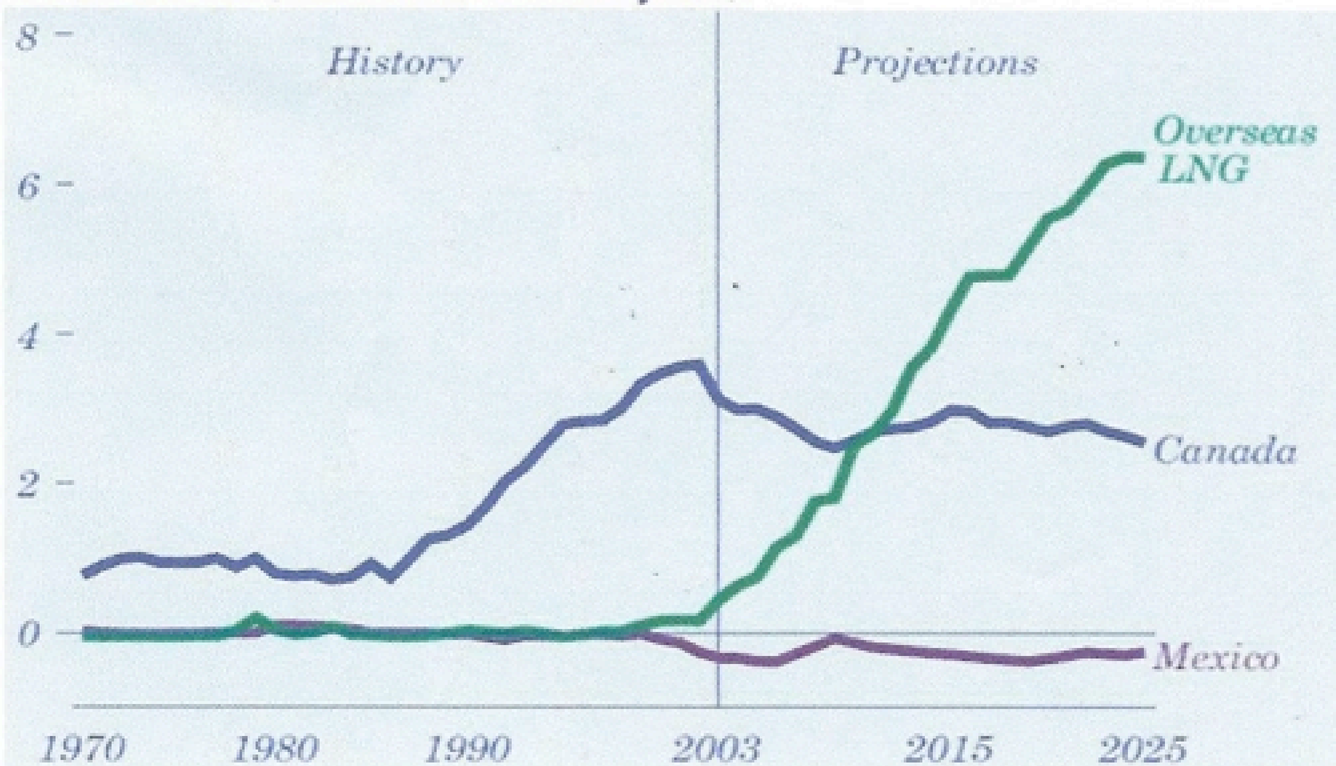
eia.doe.gov

Energy Information Administration

Search EIA by FirstGov

Annual Energy Outlook 2005 with Projections to 2025

Figure 85. Net U.S. imports of natural gas, 1970-2025 (trillion cubic feet)



History: Energy Information Administration, Annual Energy Review 2003, DOE/EIA-0384(2003) (Washington, DC, September 2004). Projections: Table A13.

Released: February 2005

Have We Plenty of Natural Gas?

Maybe, but....

- If so why are we importing 25% now soon to be 30%?
- And why are the energy companies clamoring to build LNG terminals to bring in more from the same countries that now are part of the oil cartel?

Approximate Trade Deficit Contribution of Crude Oil And Natural Gas Imports

Year	Trade Deficit	bbls Oil Imports	Unit Price	Total Oil $	kft^3 NG Imports	Unit Price	Total NG $	Total $	% of Deficit
2002	$424 B	3.34 B	$25	$84 B	4.02 B	$3.15	$13B	$97B	24 %
2003	$497 B	3.53 B	$30	$106 B	3.94 B	$5.17	$20B	$126B	25 %
2004	$608 B	3.69 B	$39	$144 B	4.26 B	$5.81	$25B	$169B	28 %
2005	$712 B	3.67 B	$57	$209 B	4.24 B	$6	$25B	$234B	33 %
2006	$753 B	3.72 B	$61	$227 B	4.26 B	$6.20	$26B	$253B	34 %
2007	$700 B	3.66 B	$68	$249 B	4.60 B	$6.87	$32B	$281B	40 %
2008	$677 B	3.59 B	$95	$342 B	3.98 B	$8.50	$34B	$376B	55 %

Sources: Dept of Commerce BEA and Dept of Energy EIA

Crude Oil and Natural Gas Imports Now Make Up 55% of The Trade Deficit

Vectors Are in The Wrong Direction

- Growing reliance on unreliable foreign supply of energy presents an unacceptable threat to our national security and economic stability
  - China's 10% annual growth along with other developing countries will worsen the pressures on oil and gas supply and prices.
  - We are increasingly vulnerable to economic disruption due to gas and oil supply interruption
  - The off-shore profits help fund terrorist and fundamentalist regimes that could cause that interruption
  - Increased greenhouse gas emissions
- Enacted energy legislation does little to alleviate the problem - time line is incompatible with the need
- There must and can be effective competitive energy sources to oil and gas suppliers that also reduce carbon emissions

PART 1 - TRANSPORTATION

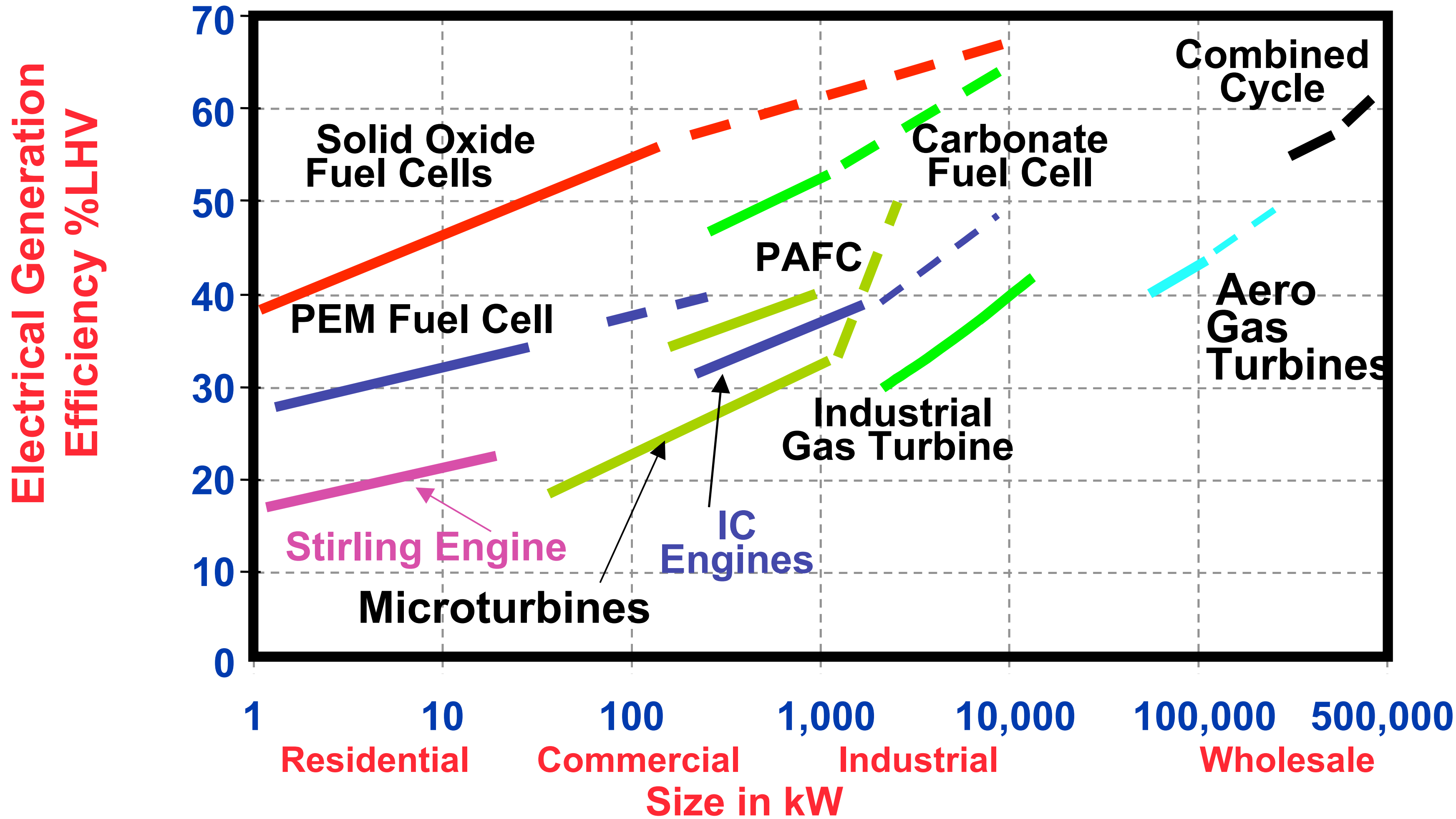
Is Hydrogen burned in fuel cells an answer for clean transportation energy?

While hydrogen occurs abundantly in hydrocarbons and water, much more energy is required to liberate distribute and store the hydrogen than it delivers.

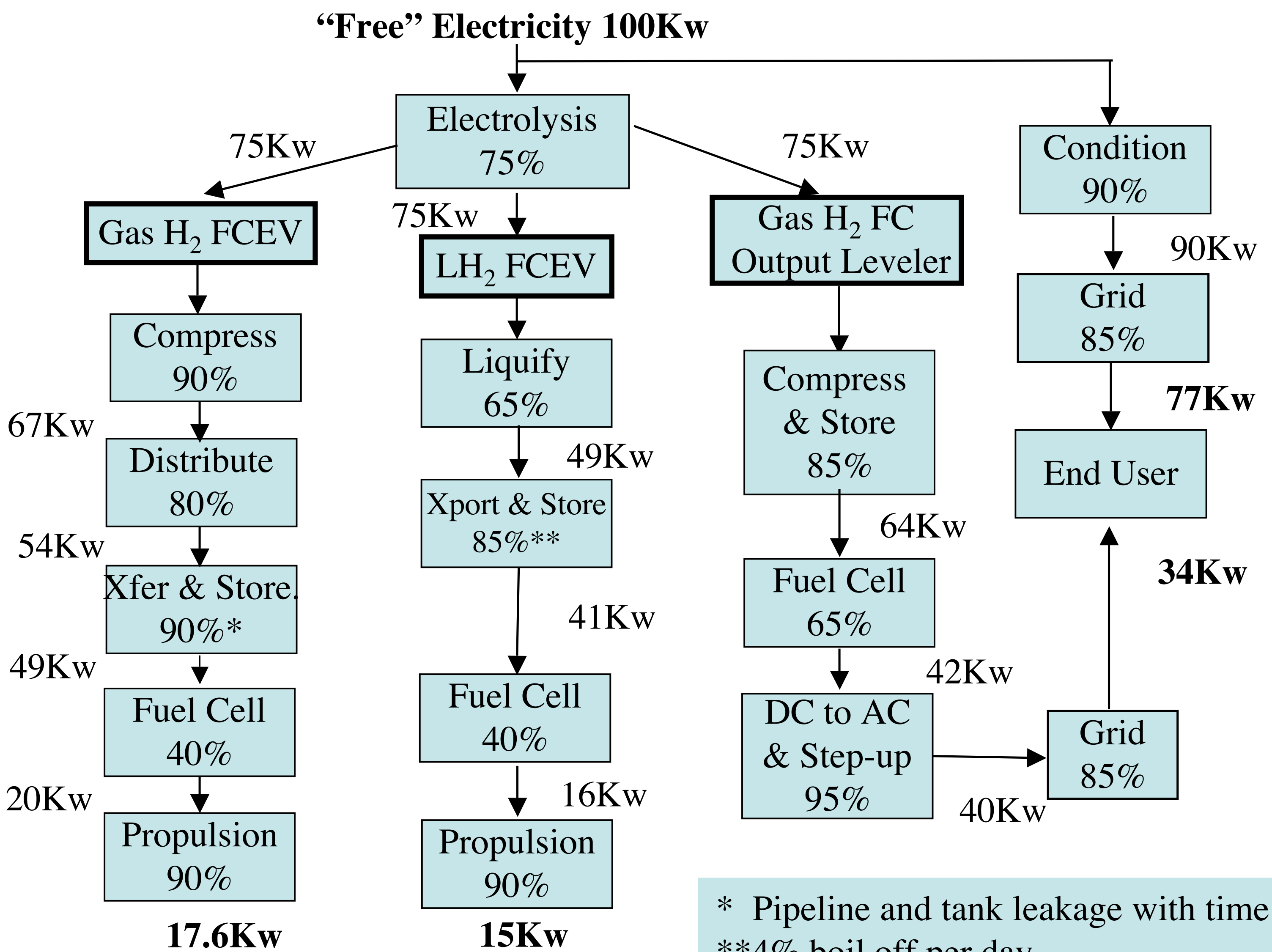
Storing the variable output from renewable wind and solar generated electricity as hydrogen from water to supply fuel cells in electric vehicles sounds attractive since the electricity for disassociation is unlimited and “free”.

However…….

Fuel Cell System Trends
Compared with other Distributed Generation Technologies



RENEWABLE ELECTRICITY DELIVERY WITH H_2 AS CARRIER



* Pipeline and tank leakage with time
**4% boil off per day

Hydrogen Bottom Line

Most commercial hydrogen is made by energy intensive steam reformation of natural gas which we have to import.

Using variable wind and solar generated electricity to produce hydrogen from water is a losing proposition.

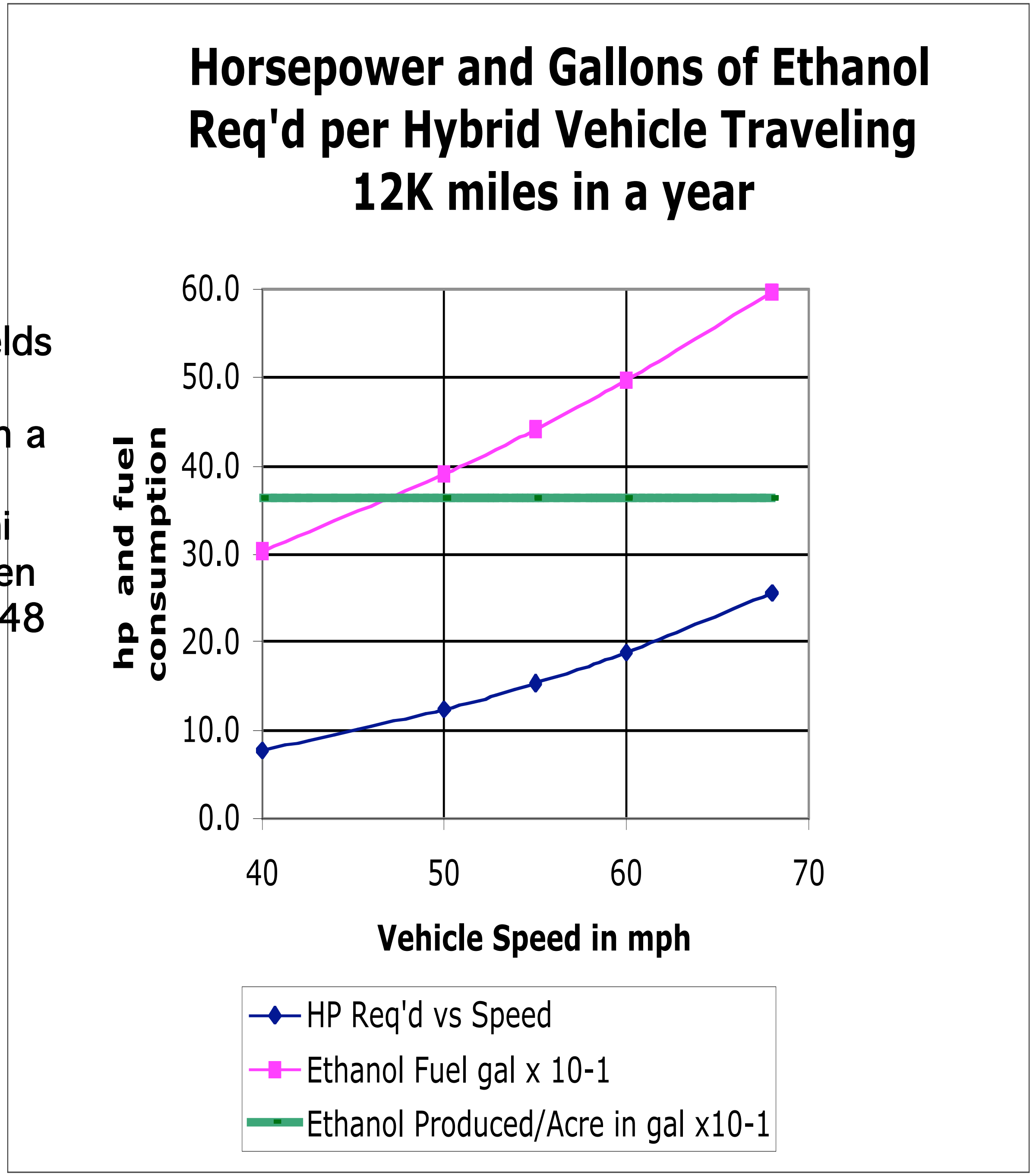
- Facility investors want the best return on their investment.
- Using the electricity directly is much more efficient reducing carbon emissions much more by displacing hydrocarbon fired electricity generation.
- Storing and distributing that energy is the problem.

Hydrogen is a diversion
without merit for earthly transportation.

What About Ethanol?

- Ethanol takes more energy to make it than it delivers
- Ethanol has lower energy content than gasoline so it is a poor fuel choice - 77,000 vs 116,300 btu/gal
- Ethanol costs much more per mile than gasoline
- Engines require redesign/modification to burn ethanol
- Ethanol production and distribution cannot be increased rapidly
- Most ethanol currently being produced is from corn which is unsustainable without seriously degrading the food supply. Diversion of food crops to bio-fuel already is the primary cause of increased food shortages and dramatically higher food prices
- Growing the feedstock for enough ethanol to eliminate dependence on imports requires more arable land than exists in the US
- Growing bio-fuel feedstock depletes nation’s fertile soils.

1 acre of corn yields enough ethanol (≥365 gal.) to run a full sized hybrid vehicle for 12K mi (the average driven during a year) at 48 mph.



2nd Generation Hybrid Vehicle Proposed For Long Term

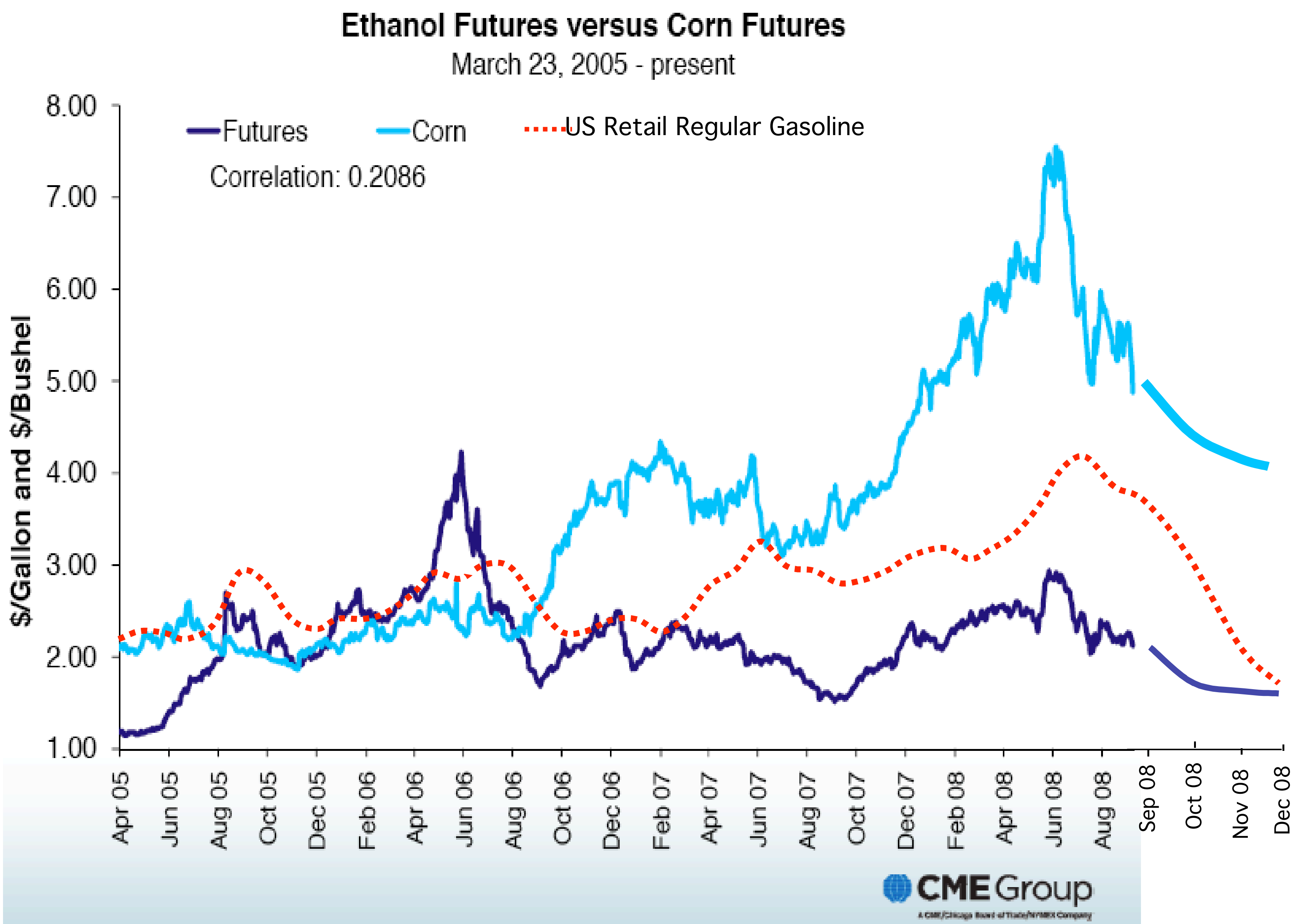
- Uses 35 average hp *flex fuel* engine to overcome drag and rolling friction and battery charging relying on battery power for acceleration at highway speeds as well as low speed operation. Plug in capability desireable.
- Requires more batteries with high energy density, high surge current capability, and long cycle life.
- Lithium Ion nanoelectrode battery technology appears most promising solution with potential for:
  - Many thousands of cycles with electrodes not susceptible to fatigue failure
  - High current capable, fast recharging
  - Good ruggedness and safety

  But not yet mature in required sizes.

How Much Ethanol to Run Half of all US Cars if They Were Hybrids as Proposed?

- A Ethanol fueled IC engine running at 35 hp augmented by battery usage for acceleration with regenerative braking is adequate for hybrid full size family vehicles
- to run 100 million hybrid cars for 12K miles at 48 mph on ethanol would take 365 gal. X100 X10^6 or 36.5 billion gallons of ethanol/yr.

US in 2008 produced about 9.2 billion gal/yr of ethanol



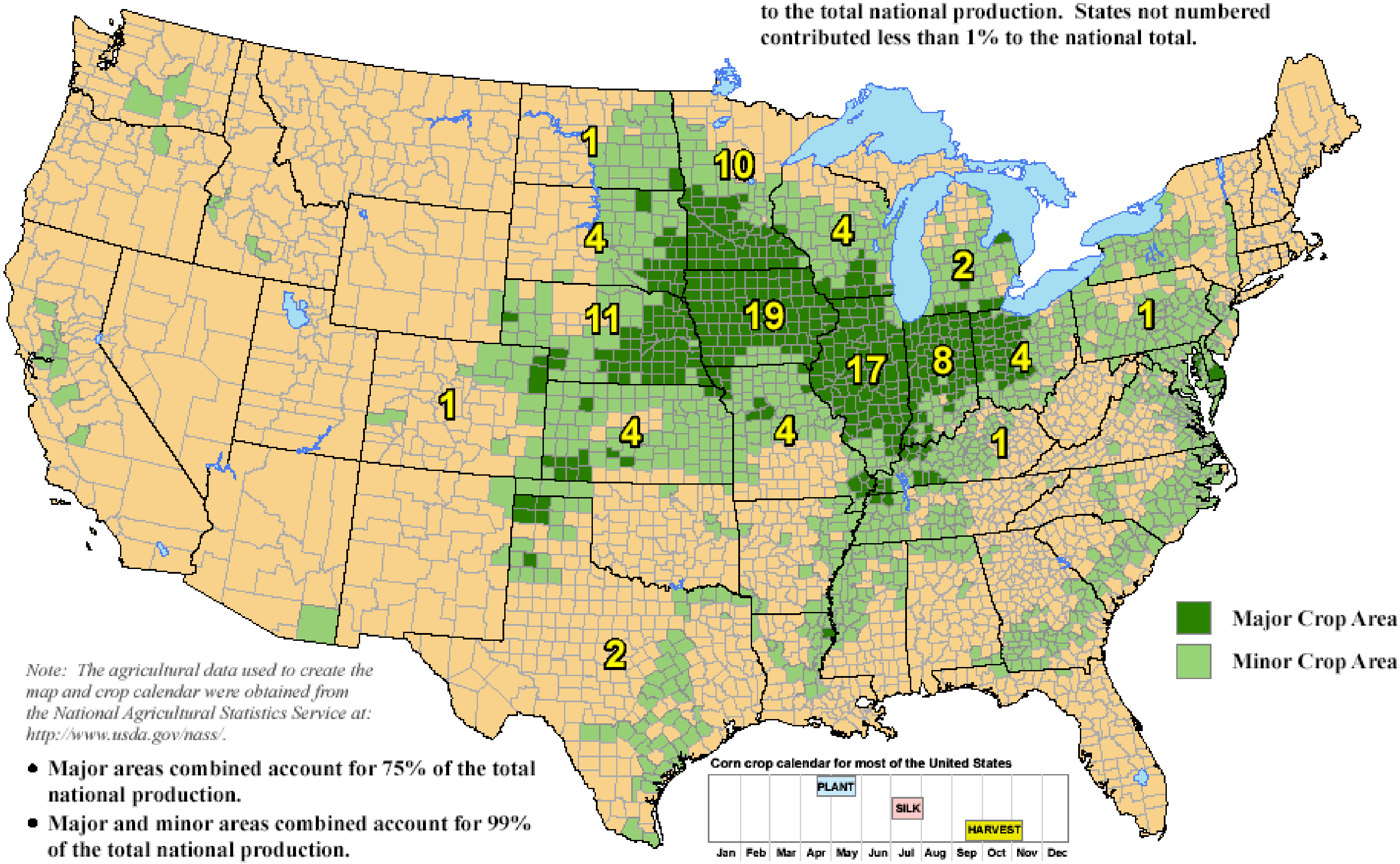
Ethanol Futures versus Corn Futures
March 23, 2005 - present
Futures
Corn
US Retail Regular Gasoline
Correlation: 0.2086
$/Gallon and $/Bushel
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
Apr 05
Jun 05
Aug 05
Oct 05
Dec 05
Feb 06
Apr 06
Jun 06
Aug 06
Oct 06
Dec 06
Feb 07
Apr 07
Jun 07
Aug 07
Oct 07
Dec 07
Feb 08
Apr 08
Jun 08
Aug 08
Sep 08
Oct 08
Nov 08
Dec 08
CME Group

How Much Biomass and Land to Grow and Transform to Ethanol?

- If it all came from corn:
  - Corn Crop yield ≥140 bushels per acre, and 2.6 gal of ethanol/bushel at least 365 gal of Ethanol per acre
  - 36.5×10^9 gal./365 gal./acre = 100 million added acres planted in corn compared to about 94 million acres currently in corn for all purposes
- But, other feed stocks offer large alternate sources
  - Sugar beets have a much higher yield per acre and crop could easily be increased ten fold.
  - Molasses by-product from sugar production also is attractive feed stock
  - Cellulosic/Algae process brings large additional supply later
- Since conversion process temperature is < 120ºC, “free” waste heat from electric generating power plants or solar boilers can be used.

United States: Corn

Yellow numbers indicate the percent each state contributed to the total national production. States not numbered contributed less than 1% to the national total.



Note: The agricultural data used to create the map and crop calendar were obtained from the National Agricultural Statistics Service at: http://www.usda.gov/nass/.

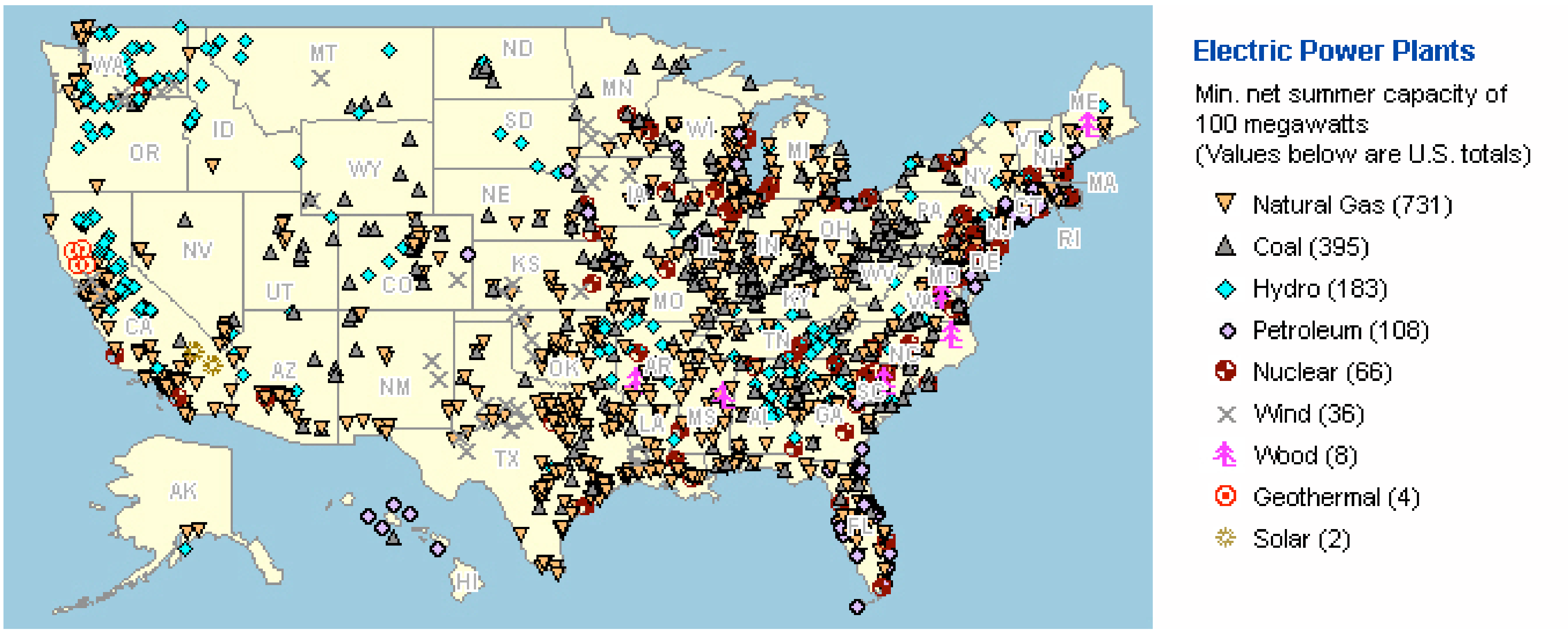
- Major areas combined account for 75% of the total national production.
- Major and minor areas combined account for 99% of the total national production.
- Major and minor areas and state production percentages are based upon averaged NASS county-level and state production data from 2000-2004.

Crop calendar dates are based upon NASS crop progress data from 2000-2004. The field activities and crop development stages illustrated in the crop calendar represent the average time period when national progress advanced from 10 to 90 percent.

USDA World Agricultural Outlook Board
Joint Agricultural Weather Facility

US Electric Power Plants

Source: Energy Information Agency

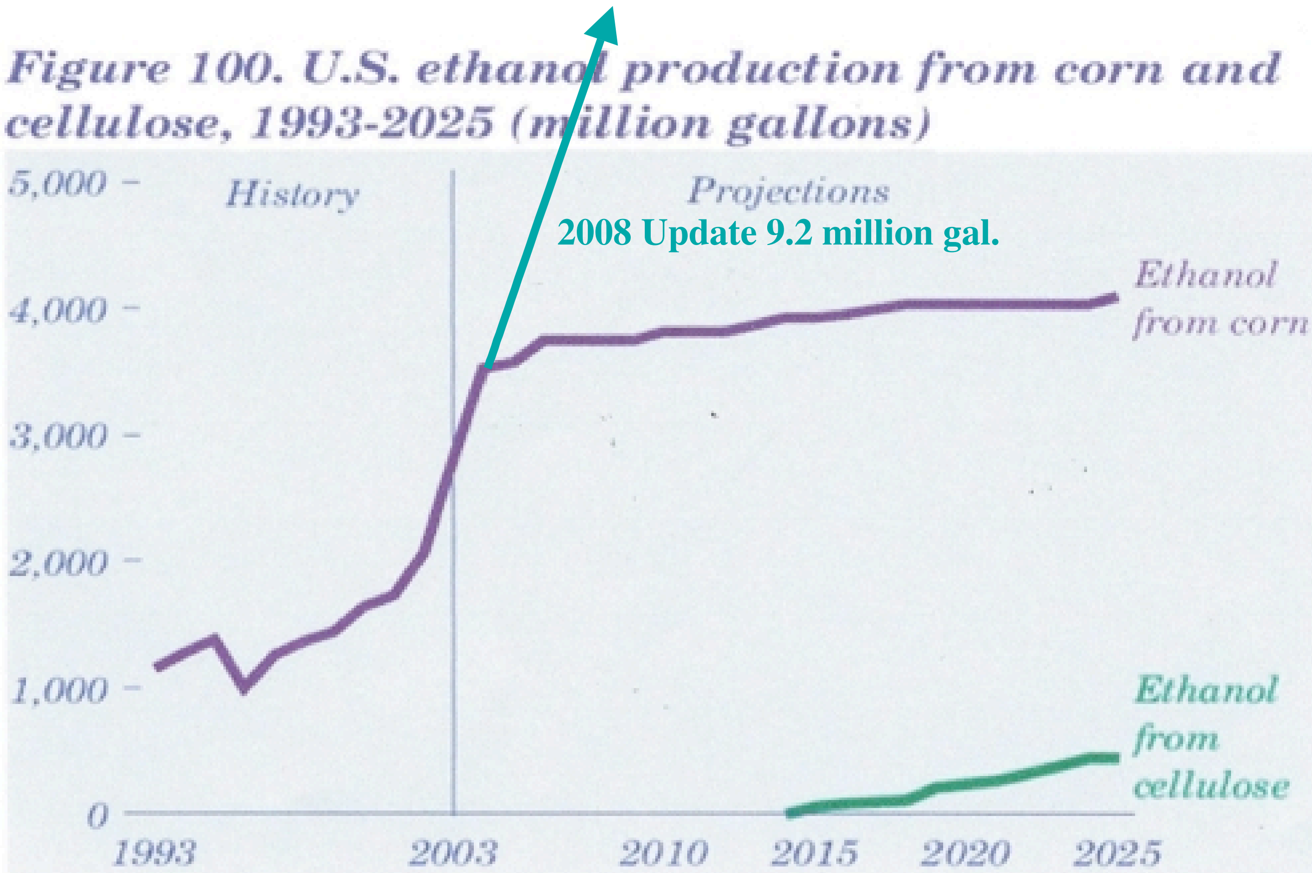


USING WASTE HEAT FROM POWER PLANTS FOR ETHANOL PRODUCTION

- 40 Quads of input energy used in 2007 to generate 13.6 Quads of electricity for 33% average efficiency
- Even if average efficiency improved to 50% (which it could and should to reduce natural gas consumption) the amount of waste heat would still be 20 $\times 10^{15}$ BTU.
- If ethanol plants were co-located with the power plants, that waste heat could be used at 35% efficiency to produce enough ethanol for 335 million hybrid cars and light trucks -- 42% more than currently registered in US
- 7 $\times$ 10^{15} less BTUs dumped into the environment

Annual Energy Outlook 2005 with Projections to 2025

Figure 100. U.S. ethanol production from corn and cellulose, 1993-2025 (million gallons)



History: Energy Information Administration, Petroleum Supply Annual 2003, Vol. 1, DOE/EIA-0340(2003)/1 (Washington, DC, July 2004). Projections: Table A18.

Released: February 2005

Claim: Ethanol produced from corn -- unsustainable without seriously degrading the food supply. Diversion of food crops to bio-fuel already is the primary cause of increased food shortages and dramatically higher food prices

Finding: In 2008 the average price of corn was between $4 and $5/bu. even though ethanol production grew to 9.2 billion gallons. The midyear spike in corn prices to $8 was due to speculation based on export demand stimulated by the decline in the dollar vs other currencies, spring flooding in the midwest, increased farm fuel costs, as well as anticipated additional bio-fuel demand

Claim: Growing corn for enough ethanol to eliminate dependence on imports requires more arable land than exists in the US

Finding: False, and based on faulty assumptions- i.e. no concurrent actions such as hybrid vehicles.

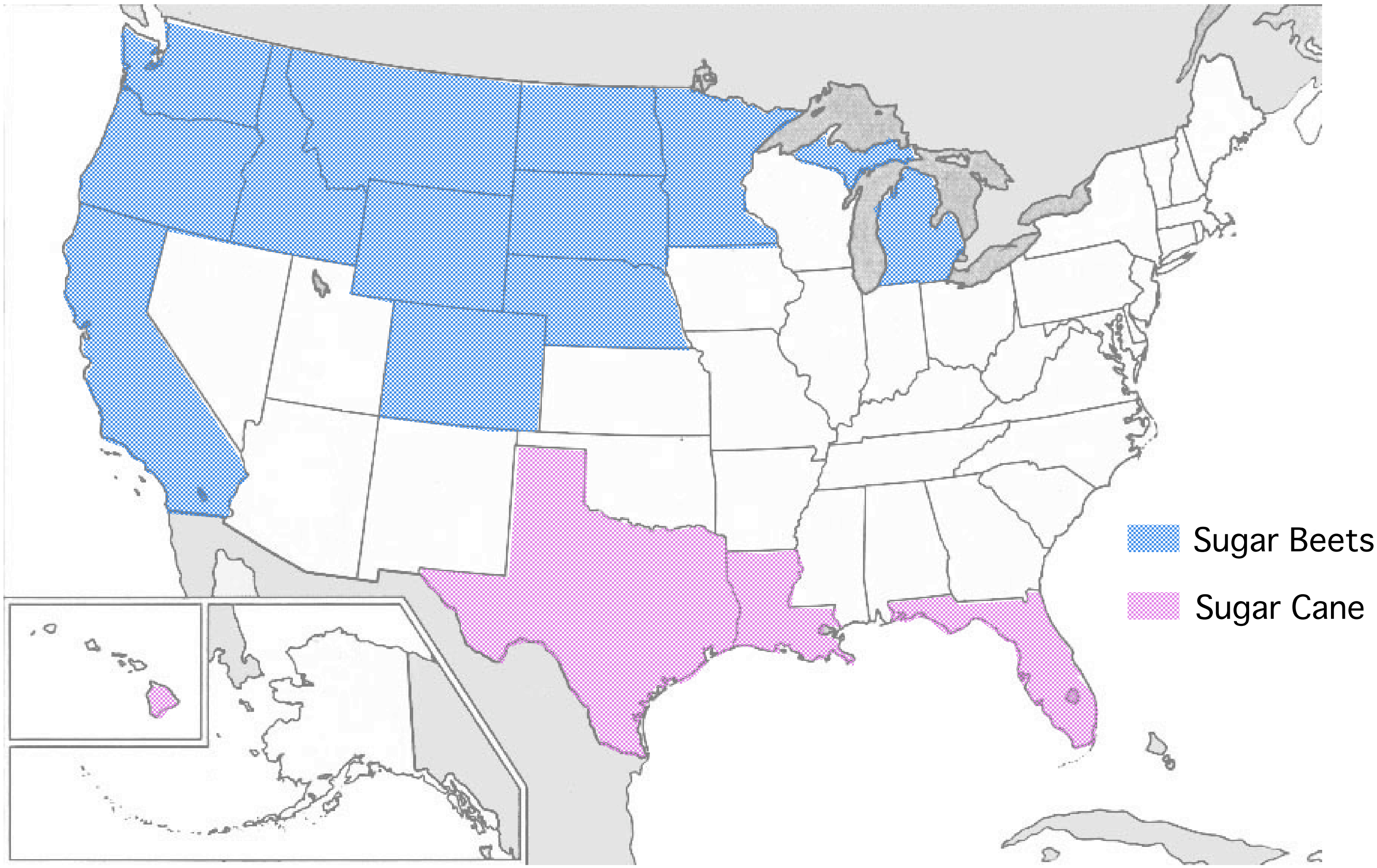
Ethanol Yields & Costs For Key Feedstocks - 2005

Commodity	Gal Ethanol per acre	Cost/gal
Corn wet mill dry mill	350-370* 400	$1.08
Sugar Cane	590	2.40
Sugar Beet	750	2.40
Sorghum	180	2.20
Cane Molasses* Beet Molasses*	264 - 300 216 - 250	1.27 1.27

*Bi-product of sugar production

Source: USDA

States Growing Sugar Beets & Cane



Key US Feedstock Production

Commodity	Total Acreage	Yield/acre	Total Crop	Gal Ethanol
Corn 2007 Peak yr 1944	94.4×10^6 95.5×10^6	151 bushels[1] 91 bushels	13.1×10^9 [2] 6.64×10^9	@ 20% of peak 6.2×10^9
Sugar Cane 2007 Peak yr 2001	1.03×10^6 1.03×10^6	29 tons 33.8 tons	29.73×10^6 32.78×10^6	@ 50% of peak $.3 \times 10^9$
Sugar Beet 2006 Peak yr 2000	1.24×10^6 1.56×10^6	21.3 tons 23.7 tons	27.54×10^6 32.54×10^6	@ 9 x peak 10.56×10^9
Sorghum 2004 Peak yr 1985	6.5×10^6 18.5×10^6	69 bushels 64 bushels	44.58×10^7 118.4×10^7	@ 50% of peak 1.67×10^9
Molasses[3] 2005 Peak yr. 2000-1	0.92×10^6 1.56×10^6	300 gal 210 gal	8.26×10^9 ga 6.72×10^9 ga	@ 50% of peak 1.5×10^9
Total postulated				19.87×10^9 ga Of Ethanol

[1] 2008 yield is 153.9 bu/acre

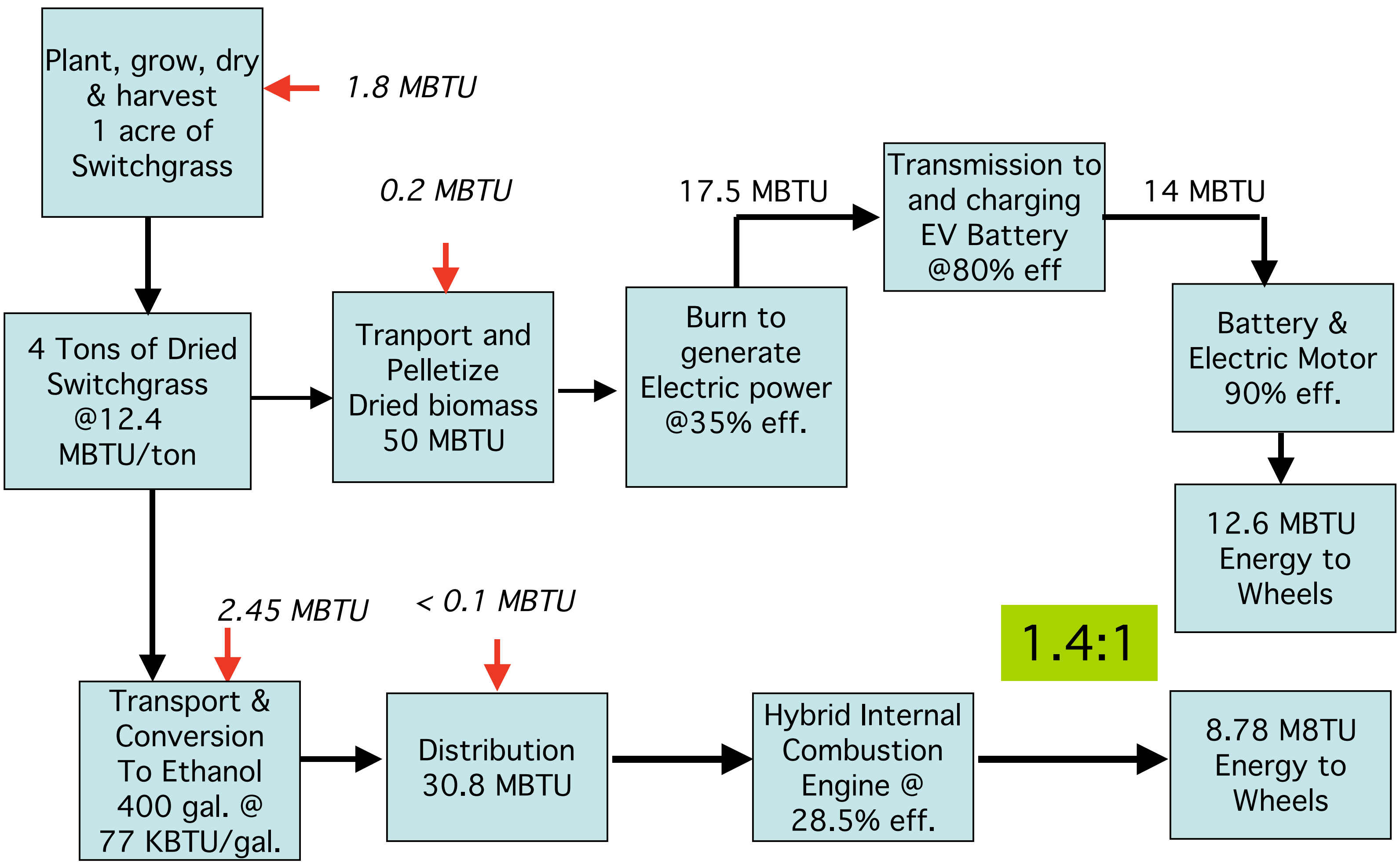
[2] 2008 total crop is 12.01B.

[3] Sugar production bi-product

Source USDA

THE PROMISE OF SWITCHGRASS (1)

Bio-ethanol to Hybrid Vehicle vs. Bio-electricity to EV



Ethanol Mythology and Reality

- Ethanol takes more energy to make it than it delivers
  - Depends how you allocate energy cost to bi-products
  - The argument is moot since all the energy for production can be power plant waste heat or otherwise wasted incident solar radiation
- Ethanol has lower energy content than gasoline so it is a poor fuel choice - 77,000 btu/gal 116,300 vs for gasoline.
  - Ethanol burns slower and more efficiently in an IC engine regaining about half of the difference due to energy content.
- Ethanol costs much more per mile than gasoline
  - A gallon of Ethanol has generally averaged about 75% the cost of gasoline in California - about the difference in mileage per gallon
- Engines require redesign/modification to burn ethanol
  - Many engines in currently produced US cars are flexible fuel engines that can burn any blend from pure gasoline to at least 90% ethanol
- Ethanol production and distribution cannot be increased rapidly
  - Existing gasoline distribution except pipelines can be readily used for ethanol and production facilities can and are growing to meet increased demand.

Butanol vs Ethanol*

Advantages

- higher energy content than ethanol
- Much less miscible with water -storable and transportable via pipelines
- Lower vapor pressure
- H_2 created as a byproduct
- Two production processes -syn gas and microbial
- BP, DuPont and others working on higher efficiency bio reactor processes

Issues

- High temperature Oxo syn gas production process has negative energy balance.
- ABE Bio-process is currently slow and requires more energy than ethanol production*
- Neither appear applicable to small operations like farm cooperatives
- Ethanol process from starch/sugar is mature and less esoteric
- Ethanol yields more btu/bu of transportation fuel than Butanol

Butanol vs. Ethanol*

- Corn-based butanol, produced by means of the current ABE process, could offer substantial fossil energy savings and moderate reductions in Green House Gas (GHG) emissions relative to petroleum gasoline on a WTW basis, when co-products are credited by energy allocation.
- The energy benefits associated with bio-butanol are significant when co- product corn-acetone is credited with displacement method.
- When acetone is credited by energy allocation, life-cycle energy benefits for corn butanol are less promising than those of corn ethanol generated from conventional dry milling processes. GHG emissions generated from bio- butanol life cycle are higher than those generated from corn ethanol.
- From a liquid fuel production standpoint, the ABE process examined may not be as effective as conventional corn ethanol production in that it produces less liquid fuel (on an energy basis) per bushel of corn than the corn ethanol process, in addition to increased process fuel use in the production plant.
- The impacts of corn-acetone (produced via the ABE process) on the acetone market need to be carefully examined, and new uses for bio-acetone need to be explored.

* Conclusions of Argonne National Laboratory entitled Life Cycle Assessment of Corn-Based Butanol as a Potential Transportation

Bio-fuels & Hybrids in Transportation *Can Eliminate* our need for imported oil

- We grow things better than any nation on earth
- Biomass (corn, sugar cane and beets, sorgum, fruit, cellulose algae and many other waste products) are logical feed stock for bio-fuels.
- CO_2 can be reduced by at least 30% using ethanol and more is absorbed in growing the biomass.
- Flex-fuel Hybrids double miles/gal. and allow a smooth transition to oil independence. Electric Vehicles Help.
- Arguments about ethanol life cycle net energy balance are moot if biomass is converted using waste heat from power plants, or the sun's energy.

PART 2
SUSTAINABLE ELECTRIC POWER

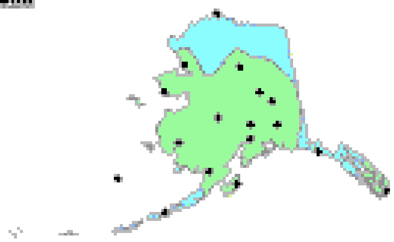
Can Solar and Wind Energy Provide The Clean Electricity we Need?

- Proliferation of reasonably priced distributed 3 kw PV systems
- Solar thermal distributed systems
- Large Solar Thermal facilities
- Large hybrid PV/thermal facilities
- Large scale wind energy

Average Daily Solar Radiation Per Month

ANNUAL

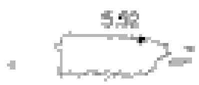
Alaska



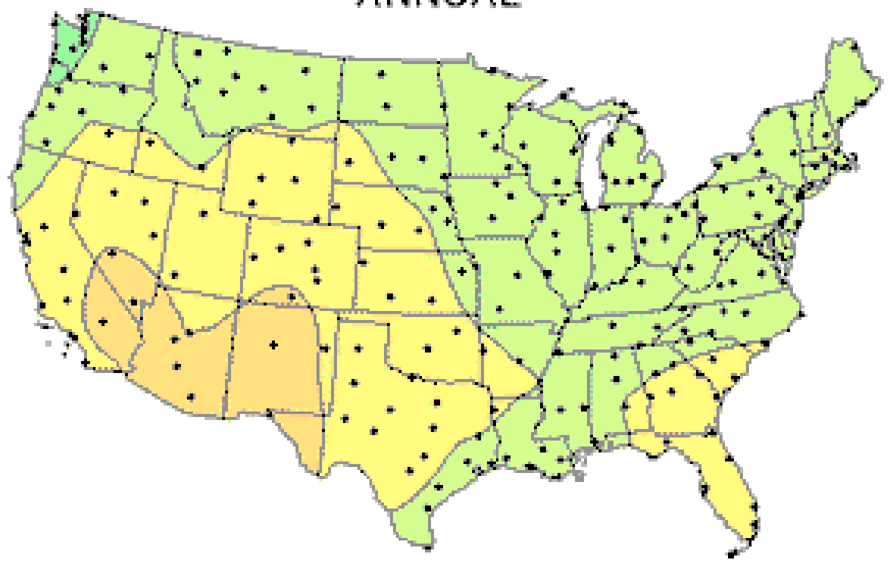
Hawaii

Hawaii, Puerto Rico, and Guam are not shaded.

San Juan, PR



Guam, PI



Flat Plate Tilted South at Latitude

Collector Orientation

Flat-plate collector facing south at fixed tilt equal to the latitude of the site. Capturing the maximum amount of solar radiation throughout the year can be achieved using a tilt angle approximately equal to the site's latitude.

This map shows the general trends in the amount of solar radiation received in the United States and its territories. It is a spatial interpolation of solar radiation values derived from the 1961-1990 National Solar Radiation Data Base (NSRDB). The dots on the map represent the 239 sites of the NSRDB.

Maps of average values are produced by averaging all 30 years of data for each site. Maps of maximum and minimum values are composites of specific months and years for which each site achieved its maximum or minimum amounts of solar radiation.

Though useful for identifying general trends, this map should be used with caution for site-specific resource evaluations because variations in solar radiation not reflected in the maps can exist, introducing uncertainty into resource estimates.

Maps are not drawn to scale.

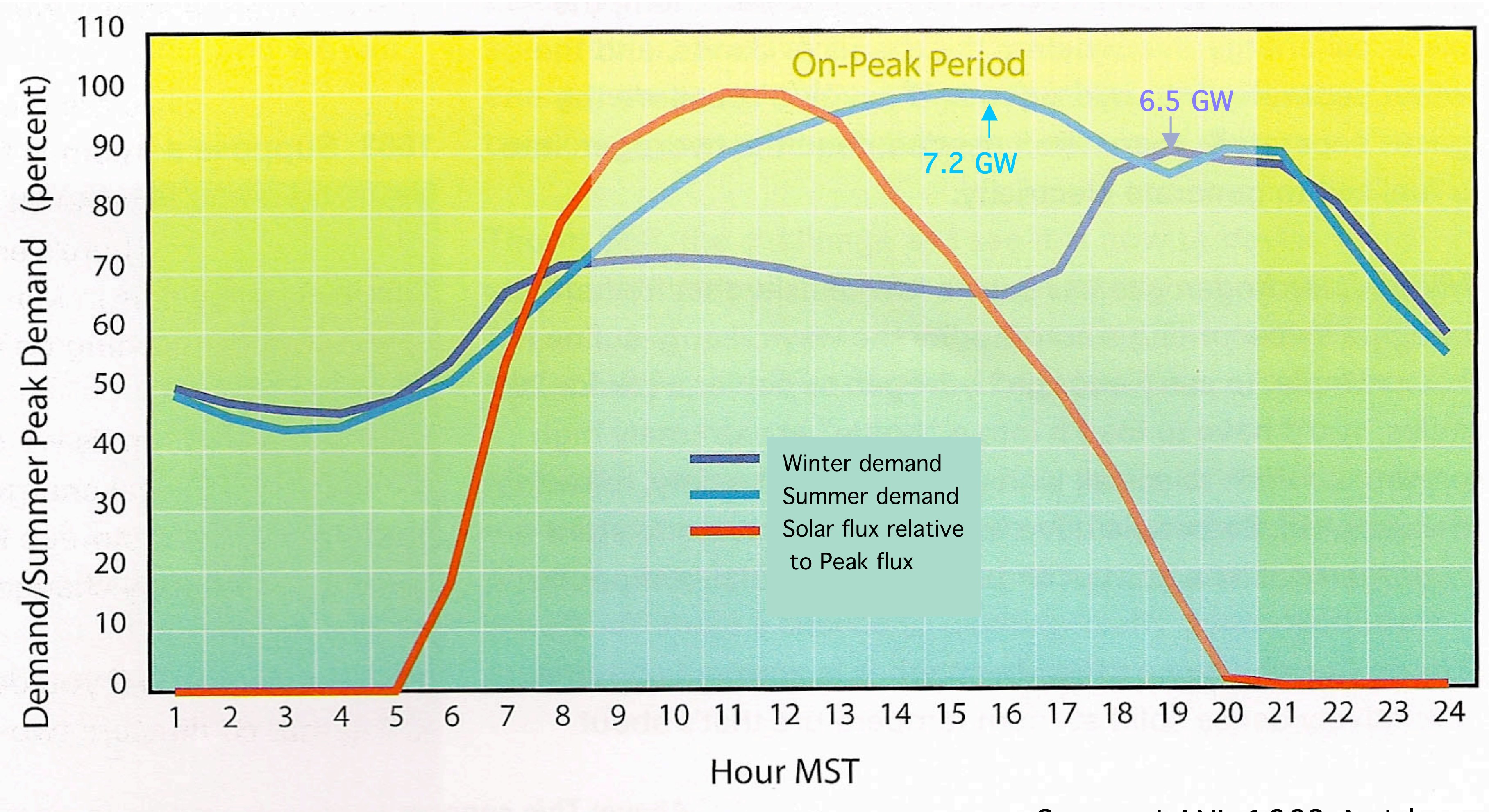
National Renewable Energy Laboratory
Resource Assessment Program

$kWh/m^2/day$

10 to 14
8 to 10
7 to 8
6 to 7
5 to 6
4 to 5
3 to 4
2 to 3
0 to 2
none

FLAT413-209

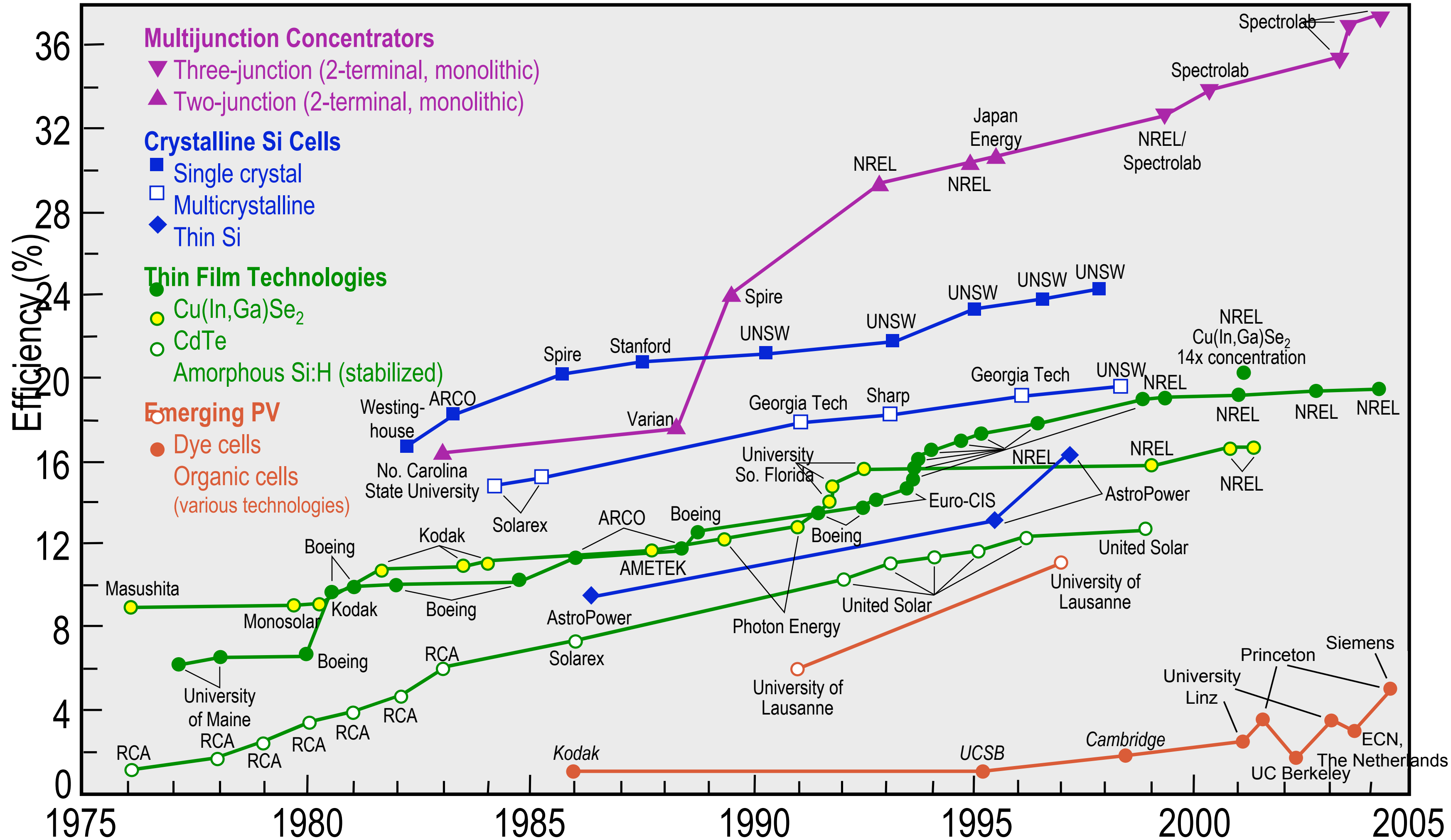
NM Electricity Demand Over 24 Hrs. Compared With Solar Flux



Source: LANL 1663 Article

Sam Baldwin
Chief Technology Officer
Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy

Best Research-Cell Efficiencies



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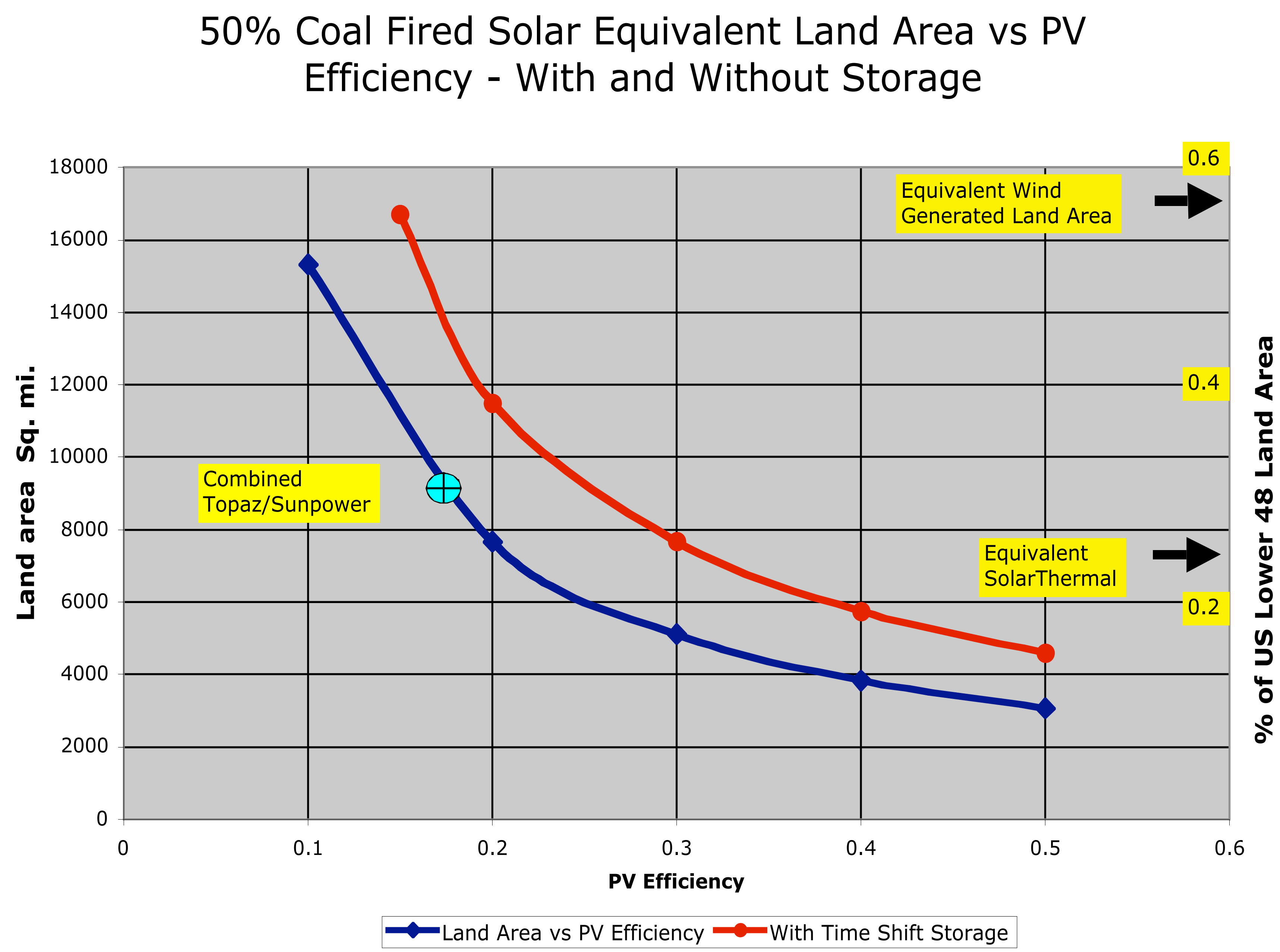
In Process Solar Facilities

- Topaz/Optipower 550 MW farm using thin film panels on 9.5 sq mi. or 58 MW/sq. mi. delivers 0.1 x 10^6 MWh/yr./sq. mi.*
- SunPower 250 MW high (18%) efficiency crystalline cell farm delivers 71.4 MW/sq mi. or 0.55 x 10^6 MWh on 3.5 sq. mi. w/ Suntrackers or 0.16 x 10^6 MWh/yr/sq.mi.*
- Solana Solar Thermal 284 MW on 1900 acres or 3 sq. mi.
  - 284/3 = 95 MW/sq.mi. or about 0.2 x 10^6 MWh/yr/sq.mi.

*These figures suggest that SunPower expects sun tracking to yield about 8 hrs. of output vs. 6 hrs for Topaz over about 285 days per year.


50% Coal Fired Solar Equivalent Land Area vs PV Efficiency - With and Without Storage
Land area Sq. mi.
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
0.1
0.2
0.3
0.4
0.5
0.6
PV Efficiency
% of US Lower 48 Land Area
0.6
0.4
0.2
Equivalent Wind Generated Land Area
Combined Topaz/Sunpower
Equivalent SolarThermal
Land Area vs PV Efficiency
With Time Shift Storage

Estimate For PV to Replace Half of Coal Fired Energy

- Coal fired electricity generation is about 2x10^9 MWh
- Affordable solar cell technology may reach 20% conversion efficiency, average daily incident energy of 700 w/sq. meter x 20% efficiency x 30% usable collector area x 2.59 x 10^6 sq, meters/sq. mi. = 109 MW/sq, mi. (farms being built will only deliver between 58 and 72 MW/sq, mi.)
- 6 hr/day x 200 days/yr estimate **x 109 = 131 x10^3 Mwh/sq.mi. /yr**

  or with suntracking x 72 as promised = 86.4 x10^3 Mwh/sq.mi. /yr
- Simply replacing half of coal fired generation (1 x 10^9 MWh) with photo voltaic technology would take between 7,634 and 11,574 sq. mi. of US land neglecting transmission and storage losses. When storage required for time shifting is considered, at least 11,448 to 17,361 sq miles are required.
- The total lower 48 state land area is 2.97 x 10^6 sq. mi.

Replacing half of US coal fired plants with solar arrays would take between 0.4 and 0.6% of US lower 48 state land area

Distributed PV Contribution
(Optimistic Estimate)

- If 100 Million households in the US had 3Kw PV panels at their residence and work place, that would represent 600 $x10^3$ Mw of generating capacity on a sunny day
- If the average number of equivalent sunny days* in US ignoring Alaska = 200, then the annual electrical energy generated = 200 x6hrs x 600x10^3= .72 x 10^9 Mwhrs/yr or about 2/3 of the coal generated electricity during daylight.

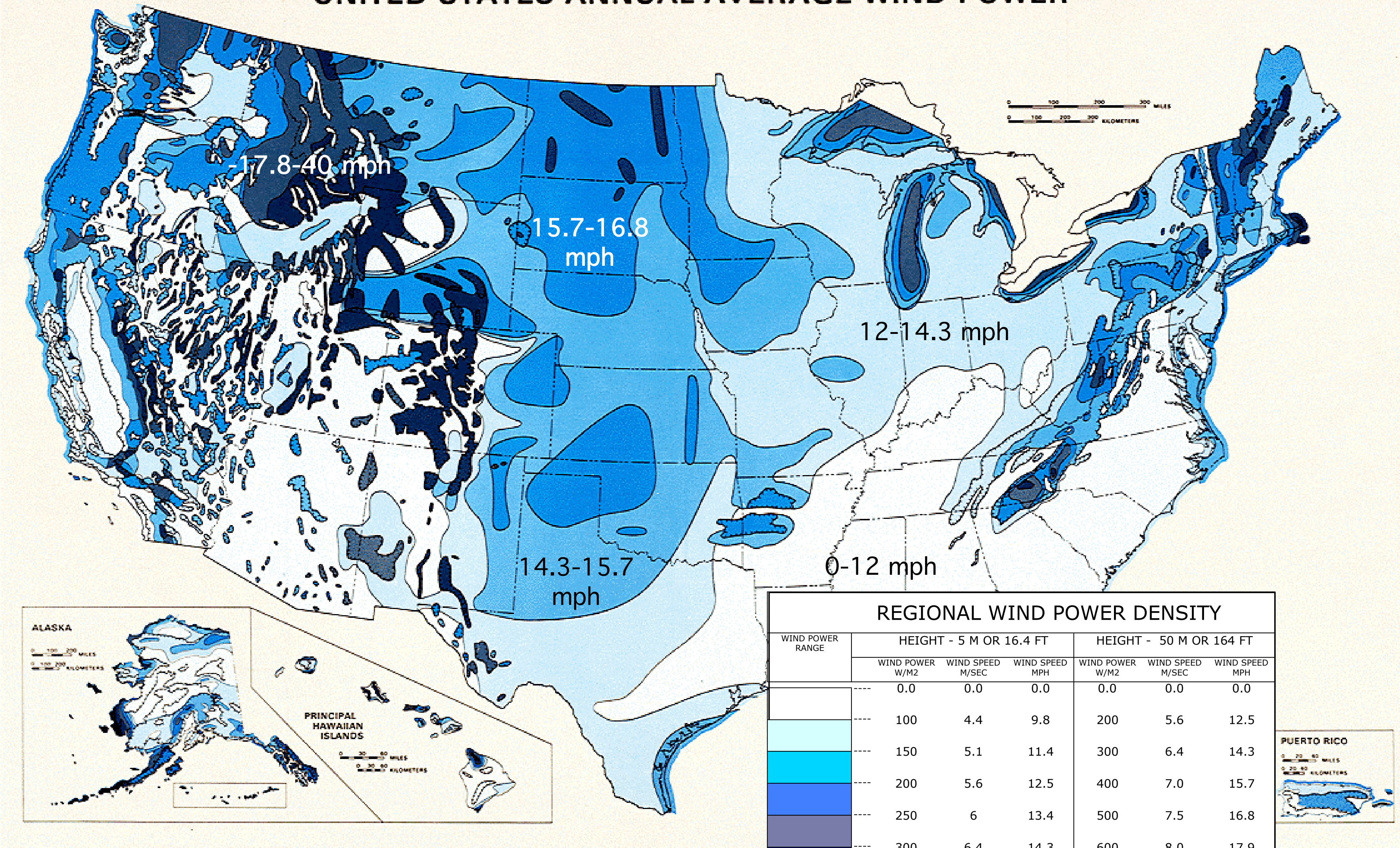
  * See text for definition

Estimate For Solar Thermal to Replace Half of Coal Fired Energy

- Coal fired electricity generation is about 2x10^9 MWh/yr
- Average daily incident energy of 700 w/sq. meter x 20% efficiency x 30% usable trough collector area x 2.59 x 10^6 sq, meters/sq. mi. = 109 MW/sq, mi. (current farms being built will deliver about 95 MW/sq, mi.)
- 6 hr/day x 200 days/yr x 109 = 131 x10^3 Mwh/sq.mi./yr. or 8hr/day x 200 x 95 = 152 x10^3 Mwh/sq.mi./yr.
- Replacing half of coal fired generation with solar thermal technology would take between 6,580 and 7,635 sq. mi. of land neglecting transmission losses.
- The total lower 48 state land area is 2.97 x 10^6 sq. mi.

Replacing half of US coal fired fired plants with solar thermal farms requires ~ 0.25% of US lower 48 state land area

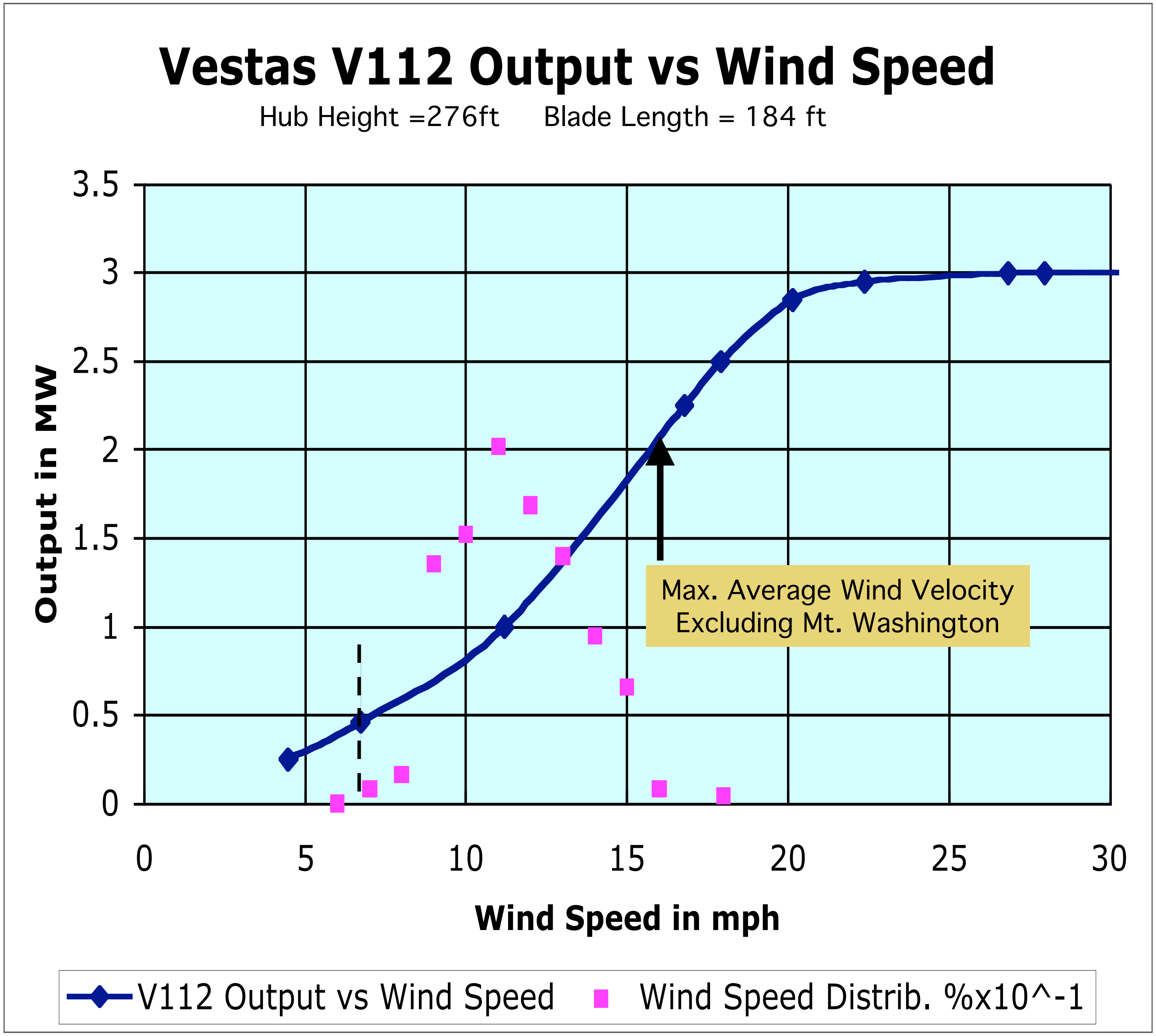
UNITED STATES ANNUAL AVERAGE WIND POWER



REGIONAL WIND POWER DENSITY

WIND POWER RANGE	HEIGHT - 5 M OR 16.4 FT: WIND POWER W/M2	WIND SPEED M/SEC	WIND SPEED MPH	HEIGHT - 50 M OR 164 FT: WIND POWER W/M2	WIND SPEED M/SEC	WIND SPEED MPH
	0.0	0.0	0.0	0.0	0.0	0.0
	100	4.4	9.8	200	5.6	12.5
	150	5.1	11.4	300	6.4	14.3
	200	5.6	12.5	400	7.0	15.7
	250	6	13.4	500	7.5	16.8
	300	6.4	14.3	600	8.0	17.9
	450	7	15.7	800	8.8	19.7
	1000	9.4	21.0	2000	17.9	40.0

_±__±__±__± RIDGE CREST ESTIMATES (LOCAL RELIEF > 1000 FT)


Vestas V112 Output vs Wind Speed
Hub Height =276ft
Blade Length = 184 ft
3.5
3
2.5
2
1.5
1
0.5
0
Output in MW
0
5
10
15
20
25
30
Wind Speed in mph
Max. Average Wind Velocity
Excluding Mt. Washington
V112 Output vs Wind Speed
Wind Speed Distrib. %x10^-1

Estimate For Wind Turbines to Replace Half of Coal Fired Energy

- Coal fired annual electricity generated is about 2 x10^9 Mwh
- Assume turbine locations that experience average wind speed of 16 mph x 360 days 12 hr/day = 2 Mw x 12 x 360 = <u>8.64 x 10^3</u> Mwh/ turbine.
- If half the coal generated capacity were replaced by 3 Mw wind turbines, 1 x 10^9 /8.64 x 10^3 = 115,740 turbines. Turbine spacing is 0.33 mi. or 9/sq. mi. requires <u>12,860 sq mi. without storage.</u>
- With storage, at least 1.33 times that area or 17,100 sq.mi. is required.

At least 0.6% of lower 48 state land mass required.
Two such Danish wind turbines failed catestrophically
In high winds in February 2008

Can Solar and Wind Energy Provide The Clean Electricity we Need?

- Proliferation of reasonably priced 20% efficient distributed 3 kw PV systems can make a significant contribution.
  - Not dependent on major grid upgrades.
- Solar thermal distributed systems can make a major reduction in consumption of heating oil and NG.
  - Current evacuated coax collector technology is very effective even in cold climates.
- Large hybrid PV/thermal facilities with large thermal mass in transfer fluid suitable for peaker plants, but depend on grid access and energy storage ability.
- Together, distributed solar systems and large installations might optimistically provide ~15-20% of future electrical energy albeit at a higher cost, but allow a major reduction in use of fossil fuels for heating (and possibly cooling) at a competitive cost.
- Large scale wind energy appears less attractive even when used in conjunction with pumped hydroelectric capability.

Assessment

- Ever-increasing reliance on foreign energy supply is a real and growing threat to national and economic security
- The US can be energy independent within 10-15 years and radically reduce greenhouse emissions in the process
  - Wind and Solar (thermal and Photo-voltaic) energy will help but can't realistically fill the gap in time if ever, even with conservation and improved efficiency.
- The solution seems straight forward:
  - Hybrid vehicles that use bio-fuels (ethanol, butanol and bio-diesel) for the transportation sector.
  - Pursuit of distributed solar (PV and Thermal) systems and wind where appropriate to reduce reliance on coal and NG
  - Reliance on new nuclear plants for major fraction of growing electric power demand with fuel reprocessing to reduce high level waste by 90 to 98%.

Biofueled Hybrids, Natural Gas and Nuclear Power Inexorably Linked

- To be energy independent, many natural gas fired power plants must eventually be replaced by nuclear or coal fired plants. Electrical energy demand will continue to grow.
  - Powering mass transit
  - Charging plug in hybrid and electric vehicles
  - Transporting water around the country
- Future fuel efficient hybrids depend on high energy density batteries - Li Ion technology.
  - Production and replentishment of such batteries for 100 million or more vehicles will increase electrical power generation demand.
  - Is there enough Lithium?

PERCEPTIONS OF NUCLEAR POWER

Claim: Nuclear power plants are unsafe, inefficient and expensive and their radioactive waste will pollute the planet for thousands of years.

Finding: Facts do not support these perceptions.

- The record for safe efficient operation is shown in slides that follow.
- There are lessons learned from previous and current generation of reactors.
- The naval reactor program has set the standard for reliable safe operations based on standardization and rigorous training.
- Closed fuel cycle/reuse with modern reactor technology reduces high level waste products dramatically - easily dealt with

The 21st Century Reemergence of Nuclear Power

- Improved nuclear power performance
- Global climate change and carbon emission constraints
- Increase in natural gas demand and costs
- Non-proliferation and arms reduction agreements require the consumption of fissile warhead materials
- Advanced systems for economic, versatile, sustainable, minimal waste and proliferation resistant nuclear power plants

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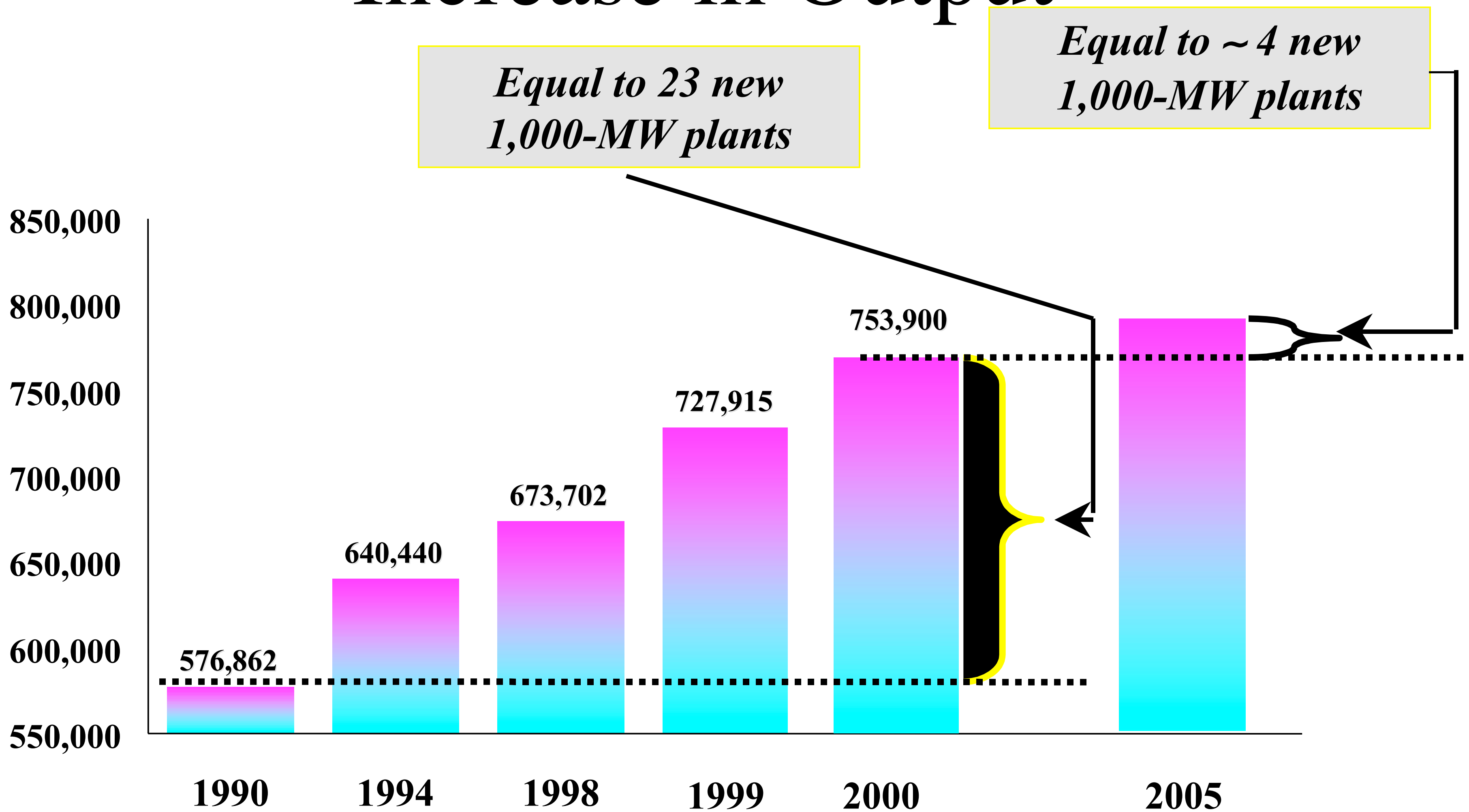
Current Status: A Dramatic Increase in Output



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3 Obstacles to Increased Use of Nuclear Power

- Fear about nuclear energy safety
- The cost of siting, approval process, & building
- The disposal of high level waste

There are effective solutions to remove these obstacles

A Safety Reliability and Cost Perspective

- US Naval Reactor Program has produced and operated well over 100 >50MW output reactors with an impeccable safety record. Operated by 4-5 personnel per shift
- The Keys:
  - Standard reactor designs and procedures
  - Excellent reactor school and training program
  - Streamlined regulatory processes

- French commercial reactors used standard designs
- By comparison most of US commercial reactors are one of a kind with widely different procedures
- Lots of bugs worked out before potential was realized
- Even so, the safety record including TMI is good.

Nuclear Safety

- Perspective: TMI and Chernobyl
- Status Today

Worldwide: **441 Reactors, 2574 terawatt hours**

31 Reactors under construction (several more ordered)

17% of world's electricity

North America: **118 Reactors, 118 Gigawatts**

(103 in U.S. = 20% of electricity

15 in Canada = 12% of electricity)

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Reducing The Cost of Siting, Construction and Operation of Nuclear Power Plants

- Standardization of plant design
- Streamlining regulatory requirements and approval process for siting of nuclear power plants
- Using the Naval Reactor model for standardization, design, construction, training and operating procedures
- Rethinking the waste problem

Nuclear Wastes

- All nuclear fuel cycle waste (except HLW) has been safely and reliably disposed of through DOE and NRC regulations (milling, enrichment, fabrication)
- Since 1982, US law 'defines' spent nuclear fuel as HLW, since reprocessing has not occurred since 1976
- Spent fuel is currently stored at >100 nuclear power plant sites with eventual storage/burial at Yucca Mt.
- All nuclear electricity is taxed at 1 mill/kwhr for a HLW fund (>$20 billion)
- HLW radiation exposure at disposal site less than natural background radiation levels in that region

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Nuclear Proliferation: Myths and Realities

- The US adopted a “once through” fuel cycle to minimize proliferation
- In fact, the “unintended consequence” has been the development of fuel reprocessing elsewhere to meet nuclear fuel needs
- The separation of uranium, actinides and fission products would reduce the requirements for long term geologic storage
- Advanced fuel cycles take all of this into account

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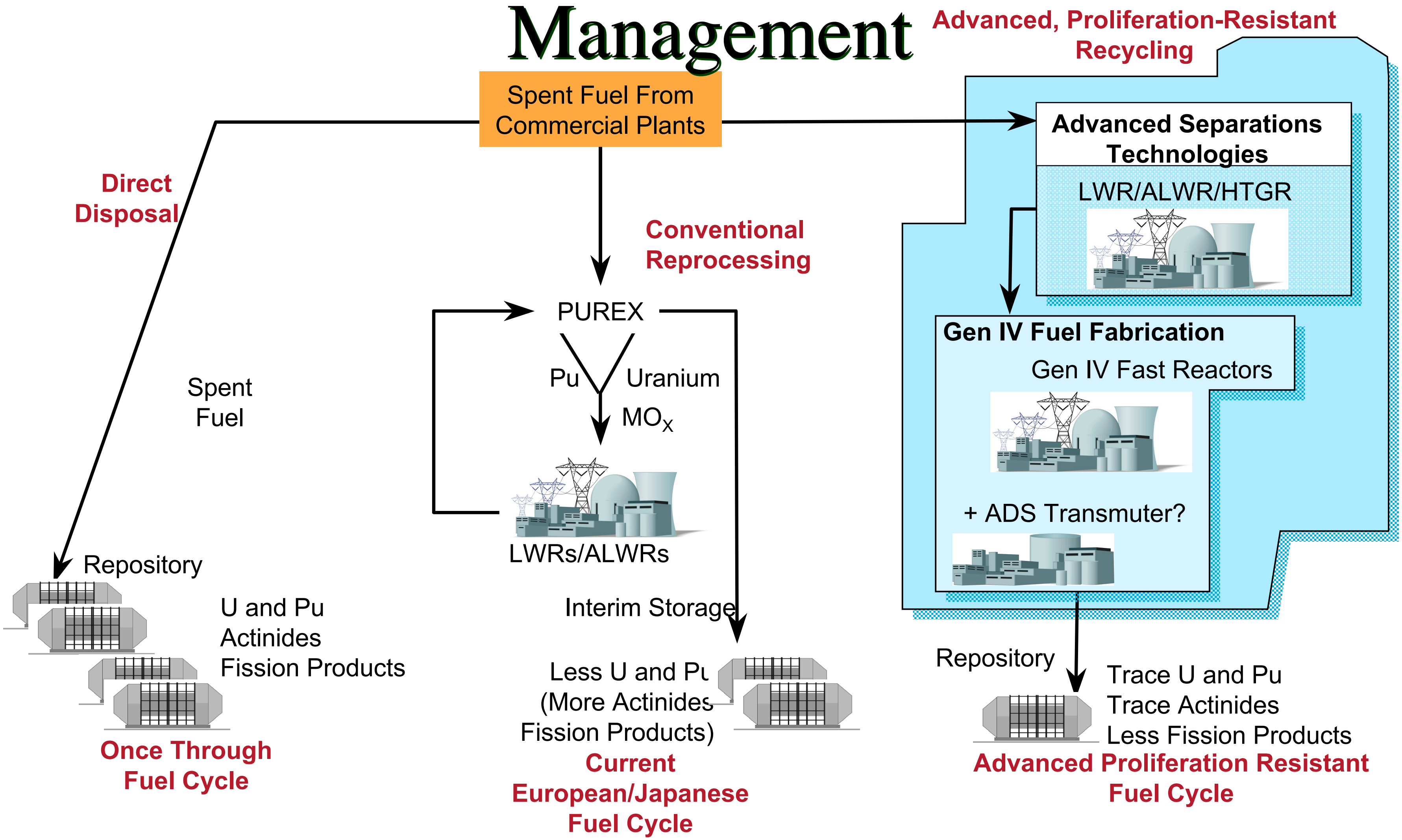
AFCI Approach to Spent Fuel Management



Conclusions

- Ever-increasing reliance on foreign energy supply is a real and growing threat to national and economic security.
- The US can be energy independent within 10-15 years and radically reduce greenhouse emissions in the process
- Solutions seem straight forward:
  - Flex fuel Hybrid vehicles transitioning to bio-fuels (ethanol, butanol and bio-diesel) for the transportation sector (Plug-in EV's too!)
  - Distributed Wind and Solar (thermal and Photo-voltaic) help replace coal, but can't fill gap even with conservation/ efficiency gains. Big solar farms depend on grid access, and must be roughly twice the capacity of coal generation they displace coupled with time shifting storage.
  - Growing Electricity demand requires reliance on new nuclear plants for electric power generation with fuel reprocessing to reduce high level waste by 90% or more.
- We need to get on with it much more aggressively
  - A major PR campaign is required
- Hydrogen is a diversion without merit for earthly transportation. It takes more energy to produce and deliver than it provides, but strangely no one notices.

Why My Conclusions Differ From Others

- Reducing vulnerability of national and economic security my primary motivation
- Sustainable clean energy independence the means
- Cost a major factor in realizing that goal
- Use of waste energy for biofuel processing, and flex fuel hybrid vehicles changes transportation equation
- A very different view of Hydrogen fuel cell vehicle and wind generated Hydrogen viability
- A very different view of nuclear and Hydrogen mortality assessments

Policy Recommendations (1 of 2)

Sustainable Energy Independence is a National Imperative

- US policy should mandate the following vehicle and fuel requirements:
  - All cars and light trucks sold after 2009 in the US to be flexible fuel capable. No exceptions, no excuses, no postponements
  - Pollution standards and mileage requirements that preclude non-commercial vehicles sold after 2012 other than hybrids that use flexible fuel plus batteries (or fuel cells) with all service stations required to pump at least 85% ethanol fuel in addition to petrol.
  - Focus subsidies that provide incentives for production of ethanol and other biofuels through creation of a strategic bio-fuel reserve to assure a stable market.
- Consider anti-trust provisions to insure a competitive environment for bio-fuels vs. petro fuels.

Policy Recommendations (2 of 2)

Sustainable Energy Independence is a National Imperative

- Mandate a study -- overseen by the National Academies to provide, within one year, a national standard for new generation nuclear fired power plants and fuel reprocessing with training and operation based on the Naval reactor program.
  - A streamlined siting, construction approval, and regulatory process.
  - Immediate implementation of fuel reprocessing to reduce high level waste by 90% starting immediately and by 98-99% by 2030
  - Retention of closed military bases adjacent to water for plant siting
- Work the international cooperation to safeguard the entire fuel cycle against terror exploitation
- Mandate that all fossil fuel power plants be upgraded to more efficient combined cycle plants
- Stop the “circular firing squad” syndrome and pursue all promising renewable energy technologies for applications where they make economic sense. Drop those that don’t.

Appendix & Back Up Data
(See Note Pages)

ABOUT THE AUTHOR

Hybrid Auto Horsepower Calculations

(See Note Pages)

Ethanol Fuel Usage per Auto

(See Note Pages)

US PETROLEUM PRODUCT PRODUCTION, IMPORT AND EXPORT DA
MILLIONS OF BBLS

PRODUCT	2000	2001	2002	2003	2004	2005	2006	2007	Est. 2008
Crude Oil & Products									
US Consumption	7210.6	7171.8	7212.9	7312.2	7587.6	7592.8	7550.9	7548.3	
Imports	4194	4333	4208.5	4476.5	4811	5005.5	5003	4916	
Exports	380.7	354.4	359.1	374.7	383.6	425.2	480.6	522.9	
Crude Oil									
US Production**	2130.7	2117.5	2097.1	2073.5	1983.3	1890.1	1862.3	1848.5	
Consumption	5432.3	5515.1	5429.8	5597	5665.5	5574.5	5546.3	5500	
Imports	3320	3405	3336	3528	3692	3696	3693	3661.5	
Exports	18.4	7.4	3.3	4.5	9.8	11.6	9	10	
Landing Pr. -Saudi lite	$27.54	$21.64	$25.01	$28.25	$38.01	$52.92	$60.51	$71.63	
Nigerian	$30.67	$28.16	$26.64	$31.49	$41.16	$57.12	$69.29	$78.00	
US Avg	$27.53	$21.82	$23.91	$27.69	$36.07	$49.29	$59.11	$67.95	$100.00
Cushing Futures	$30.26	$25.95	$26.15	$30.99	$41.47	$56.70	$66.25	$72.14	$125.00
Δ	9.9%	18.9%	9.4%	11.9%	15.0%	15.0%	12.1%	6.2%	25.0%
Petroleum Product Total									
US Consumption*	7210.6	7171.8	7212.9	7312.2	7587.6	7592.8	7550.9	7538.3	
Imports	874.3	928.1	872.4	948.5	1119	1309.5	1310	1254.5	
Exports	362.3	347	355.8	370.2	373.8	413.6	471.6	512.9	
--Finished Gasoline									
US Consumption	3100.7	3142.7	3229.5	3261.2	3332.6	3343.1	3377.2	3389.3	
Imports	156.2	165.9	181.9	189	181.7	220	173.5	150.6	
Exports	52.5	48.5	45.3	45.8	45.5	49.5	51.8	46.4	
Crude Landing Price/42	$0.66	$0.52	$0.57	$0.66	$0.86	$1.17	$1.41	$1.62	$2.38
Avg. Us Reg Retail Price	$1.54	$1.50	$1.41	$1.66	$1.94	$2.34	$2.65	$2.86	$3.31
in $ x20	30.8	30.0	28.2	33.2	38.8	46.8	53.0	57.2	66.2
Crude Cost	$0.69	$0.55	$0.60	$0.69	$0.90	$1.23	$1.48	$1.70	$2.50
"Fixed" Costs	$0.65	$0.76	$0.63	$0.75	$0.70	$0.71	$0.70	$0.71	$0.70
in $ x20	$14.00	$14.00	$14.00	$14.00	$14.00	$14.00	$14.00	$14.00	$14.00
15% Profit	$0.20	$0.20	$0.18	$0.22	$0.25	$0.31	$0.35	$0.37	$0.43
Total Should Cost	$1.34	$1.30	$1.23	$1.44	$1.69	$2.03	$2.30	$2.49	$2.88
In $ x 20	26.8	26.1	24.5	28.9	33.7	40.7	46.1	49.7	57.6
--Distillate Fuel Oils									
US Consumption	1362.3	1404.1	1378.2	1433.4	1385.3	1503.1	1521.7	1531.5	
Imports	108	125.6	97.6	121.7	119	120	133.1	111	
Exports	63.2	43.5	41	39	40.1	50.5	78.5	97.7	
--Jet Fuel									
US Consumption	631.5	604.3	591.5	576.1	596.6	612.8	596	592.2	
Imports	59.1	54.1	39.2	39.8	46.5	69.5	67.7	79	
Exports	11.6	10.5	3	7.4	14.8	19.2	14.9	15	
--Unfinished Oils									
US Consumpttion	-68.8	-12.9	-23.3	-8.7	-13	0.5	12.1	11.2	
Imports	100.1	138.2	149.7	122.2	179.3	212.6	251.5	261.7	
Exports	0	0	0	0	0	0	0	0	
--Gas Blend Components									
Consumption	All used in finished gasoline?:			0	0	0	0	0	
Imports	81.5	108.7	113.7	134	164.9	186.3	244.2	274.7	
Exports	6.7	3.7	12.1	10.9	11.9	8.1	2.9	6	
--Residual Fuel Oils									
US Consumption	332.5	296.1	255.4	281.8	316.5	335.8	251.4	263.9	
Imports	128.9	107.7	90.9	119.5	156	193.3	127.8	135.7	
Exports	50.9	69.8	64.7	72.1	74.9	91.6	103.2	120.4	
--All other Products									
US Consumption	1852.4	1737.5	1781.6	1768.4	1969.6	1797.5	1792.5	1750.2	
Imports	240.5	227.9	199.4	222.3	271.6	307.8	312.2	241.8	
Exports	177.4	171	189.7	195	186.6	194.7	220.3	227.4	

Sugar Cane Bi-products and Ethanol Yields

See Notes Page

Location and daily capacity of U.S. sugar beet factories, 2005

State & No. of Plants	Daily Capacity (tons)
California (2)	12,600
Colorado (2)	10,000
Idaho (3)	33,100
Michigan (4)	20,900
Minnesota (4)	38,600
Montana (2)	11,300
Nebraska (1)	4,800
North Dakota (3)	24,200
Wyoming (2)	8,400
Totals (23)	163,900

Source: U.S. Beet Sugar Association

Comparison of Capacity Factors and Cost per KWh

The net **capacity factor** is the ratio of the actual output of a power plant over a period of time and its output if it had operated at full nameplate capacity the entire time. To calculate the capacity factor, total the energy the plant produced during a period of time and divide by the energy the plant would have produced at full capacity.

Typical capacity factors	Cost per KWh
• Wind farms 20-40%.	.07
• Photovoltaic solar in Massachusetts 12-15%.	.30
• Photovoltaic solar in Arizona 19%	.20
• Thermal solar power tower 73%	.20
• Thermal solar parabolic trough 56%	.20
• Nuclear 60% to over 100%, U.S. average 92%.	.06
• Base load coal plant 70-90%	.04-.05
• Combined cycle gas plant, about 60%	.05

US Average Wind Speed (mph)

Source: National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center

City	Avg Wind Speed	City	Avg Wind Speed	City	Avg Wind Speed	City	Avg Wind Speed	City	Avg Wind Speed
MT.WASHINGTON, NH	35	WICHITA FALLS, TX	11	FORT WAYNE, IN	9	ROSWELL, NM	8	SALEM, OR	7
ST. PAUL ISLAND, AK	17	MILWAUKEE, WI	11	INDIANAPOLIS, IN	9	ALBANY, NY	8	HARRISBURG, PA	7
COLD BAY,AK	16	KING SALMON, AK	10	TOPEKA, KS	9	ISLIP, NY	8	WILLIAMSPORT, PA	7
BLUE HILL, MA	15	NOME, AK	10	CINCINNATI, OH	9	WILMINGTON, NC	8	GREENVILLE NC	7
BARTER IS.,AK	13	SAN FRANCISCO AP,	10	LEXINGTON, KY	9	COLUMBUS, OH	8	HOUSTON, TX	7
DODGE CITY, KS	13	COLORADO SPRGS	10	GRAND RAPIDS, MI	9	ASTORIA, OR	8	LYNCHBURG, VA	7
AMARILLO, TX	13	KEY WEST, FL	10	LANSING, MI	9	PENDLETON, OR	8	RICHMOND, VA	7
BARROW, AK	12	POCATELLO, ID	10	SAULT STE. MARI	9	AVOCA, PA	8	ROANOKE, VA	7
KAHULUI, HI	12	CHICAGO,IL	10	COLUMBIA, MO	9	CHARLESTON,SC	8	YAKIMA, WA	7
LIHUE, HI	12	SPRINGFIELD, IL	10	ST. LOUIS, MO	9	MEMPHIS, TN	8	MONTGOMERY, AL	6
CONCORDIA, KS	12	SOUTH BEND, IN	10	OMAHA, NE	9	NASHVILLE, TN	8	VALDEZ, AK	6
WICHITA, KS	12	DES MOINES, IA	10	VALENTINE, NE	9	EL PASO, TX	8	FLAGSTAFF, AZ	6
BOSTON, MA	12	WATERLOO, IA	10	LAS VEGAS, NV	9	SALT LAKE CITY, UT	8	PHOENIX, AZ	6
ROCHESTER, MN	12	CARIBOU, ME	10	ATLANTIC CTY NJ	9	SEATTLE SEA-AP	8	BAKERSFIELD, CA	6
GREAT FALLS, MT	12	WORCESTER, MA	10	ROCHESTER, NY	9	SPOKANE, WA	8	BLUE CANYON, CA	6
CLAYTON, NM	12	DETROIT, MI	10	SYRACUSE, NY	9	SAN JUAN, PR	8	EUREKA, CA.	6
NEW YORK (LAGUARD	12	FLINT, MI	10	WILLISTON, ND	9	BECKLEY, WV	8	FRESNO, CA	6
FARGO, ND	12	MUSKEGON, MI	10	AKRON, OH	9	LA CROSSE, WI	8	LONG BEACH, CA	6
OKLAHOMA CITY, OK	12	MINNEAPOLIS MN	10	DAYTON, OH	9	SHERIDAN, WY	8	LOS ANGELES, CA	6
CORPUS CHRISTI, TX	12	KANSAS CITY, MO	10	TOLEDO, OH	9	BIRMINGHAM,AL	7	REDDING, CA	6
LUBBOCK, TX	12	SPRINGFIELD, MO	10	YOUNGST'N, OH	9	ANCHORAGE, AK	7	SANTA BARBARA, CA	6
CASPER, WY	12	GLASGOW, MT	10	ALLENTOWN, PA	9	YUMA, AZ	7	GAINESVILLE, FL	6
CHEYENNE, WY	12	LINCOLN, NE	10	PHILADELPHIA, PA	9	FORT SMITH, AR	7	AUGUSTA,GA	6
KODIAK, AK	11	NORTH PLATTE, NE	10	PITTSBURGH, PA	9	LITTLE ROCK, AR	7	JACKSON, KY	6
BRIDGEPORT, CT	11	OMAHA AP, NE	10	AUSTIN, TX	9	LOS ANGELES AP,	7	MERIDIAN, MS	6
HONOLULU,HI	11	SCOTTSBLUFF, NE	10	DEL RIO, TX	9	SACRAMENTO, CA	7	TUPELO, MS	6
SIOUX CITY, IA	11	ELY, NV	10	PORT ARTHUR, TX	9	SAN DIEGO, CA	7	MISSOULA, MT	6
DULUTH, MN	11	NEWARK, NJ	10	SAN ANTONIO, TX	9	SANTA MARIA, CA	7	RENO, NV	6
BILLINGS, MT	11	BINGHAMTON, NY	10	VICTORIA, TX	9	STOCKTON, CA	7	CONCORD, NH	6
GRAND ISLAND, NE	11	BISMARCK, ND	10	BURLINGTON, VT	9	ALAMOSA, CO	7	COLUMBIA, SC	6
NORFOLK, NE	11	CLEVELAND, OH	10	GREEN BAY, WI	9	WASHINGTON DULLES	7	CHATTANOOGA, TN	6
BUFFALO, NY	11	MANSFIELD, OH	10	MADISON, WI	9	APALACHICOLA, FL	7	KNOXVILLE, TN	6
NEW YORK (JFK AP)	11	TULSA, OK	10	HUNTSVILLE, AL	8	JACKSONVILLE, FL	7	OLYMPIA, WA	6
CAPE HATTERAS, NC	11	BLOCK IS.,RI	10	MOBILE, AL	8	ATHENS, GA	7	QUILLAYUTE, WA	6
SEXTON SUMMIT,OR	11	PROVIDENCE, RI	10	JUNEAU, AK	8	MACON, GA	7	ELKINS, WV	6
ERIE, PA.	11	DALLAS-FT WORTH	10	TUCSON, AZ	8	SAVANNAH, GA	7	HUNTINGTON, WV	6
ABERDEEN, SD	11	SAN ANGELO, TX	10	WINSLOW, AZ	8	HILO, HI	7	LANDER, WY	6
HURON, SD	11	NORFOLK, VA	10	SAN FRANCISCO	8	PADUCAH KY	7	FAIRBANKS, AK	5
RAPID CITY, SD	11	WILMINGTON, DE	9	DENVER, CO	8	BATON ROUGE, LA	7	MCGRATH, AK	5
SIOUX FALLS, SD	11	WASHINGTON, D.C.	9	GRAND JCT'N CO	8	JACKSON, MS	7	MOUNT SHASTA, CA	5
ABILENE, TX	11	MIAMI, FL	9	PUEBLO, CO	8	HELENA, MT	7	ELKO, NV	5
BROWNSVILLE, TX	11	W PALM BEACH, FL	9	HARTFORD, CT	8	ASHEVILLE, NC	7	BRISTOL-JHNSN CTY	5
GALVESTON, TX	11	ATLANTA, GA	9	DAYTONA BCH, FL	8	CHARLOTTE, NC	7	CHARLESTON, WV	5
MIDLAND, TX	11	MOLINE, IL	9	FORT MYERS, FL	8	RALEIGH, NC	7	TALKEETNA, AK	4
WACO, TX	11	PEORIA, IL	9	ORLANDO, FL	8	EUGENE, OR	7	MEDFORD, OR	4
				PENSACOLA, FL	8	PORTLAND, OR	7	OAK RIDGE,TN	4

A test tells the story of ethanol vs. gasoline

By LOREN STEFFY

March 10, 2007, 9:46PM

In the past two weeks, I took a step toward breaking my oil addiction.I rented a Chevy Suburban that ran on both gasoline and E85 ethanol. I burned one tank of each fuel under comparable driving conditions. I wanted to see if, as a typical driver, E85 made sense.When I began my road test, I assumed the biggest factor would be cost. Consumers, I reasoned, wouldn't pay a lot more for ethanol, nor would they tolerate poor mileage, sluggish engine performance or other inconveniences such as a lack of availability. I detailed my experiment, dubbed "The Ethanol Chronicles," on my blog (**http://blogs.chron.com/lorensteffy/energy/the_ethanol_chronicles/**).

I didn't notice any difference in engine performance between the two fuels.My first tank of gasoline cost $2.20 a gallon in late February. A week later, I filled up with E85 ethanol in Conroe for $1.92 a gallon (87%).The pump price, though, is only part of the ethanol equation because ethanol is a less efficient fuel. Using gasoline, the Suburban got 16.4 miles a gallon. With ethanol, it got only 13.5.(82%)

Pumped Hydro Storage Calculations