Electric Power, CO_2 Controls and the Tough Choices Ahead

IEEE Meeting

May, 2010

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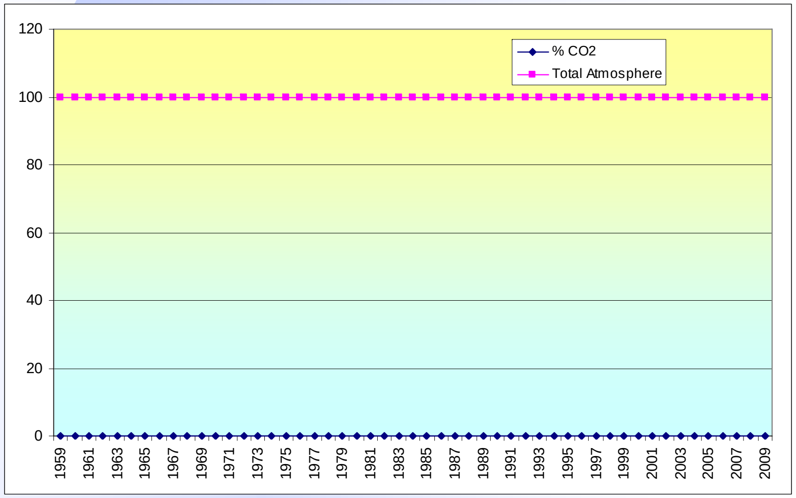
Major Electric Industry Issues
Popular and Political Attitudes, early 2010

- Global Climate Change is being caused by CO_2 emitted from the use of fossil fuels in electric power generation.
- Renewable energy sources can be rapidly deployed to reliably supply all of the energy needs of the US.
- The aging electric power grid must be expanded and modernized to distribute renewable power to load centers.
- “Smart Grid” initiatives will reduce the power demand on the system and decrease the need for new power generation.
- Hybrid and electric transportation for most land based transportation can be provided with little additional infrastructure.
- Removing fossil fueled electric power generation from the grid will reduce our dependence on foreign fuel imports.

Defining the CO_2 Issues

CO_2 vs. Temperature



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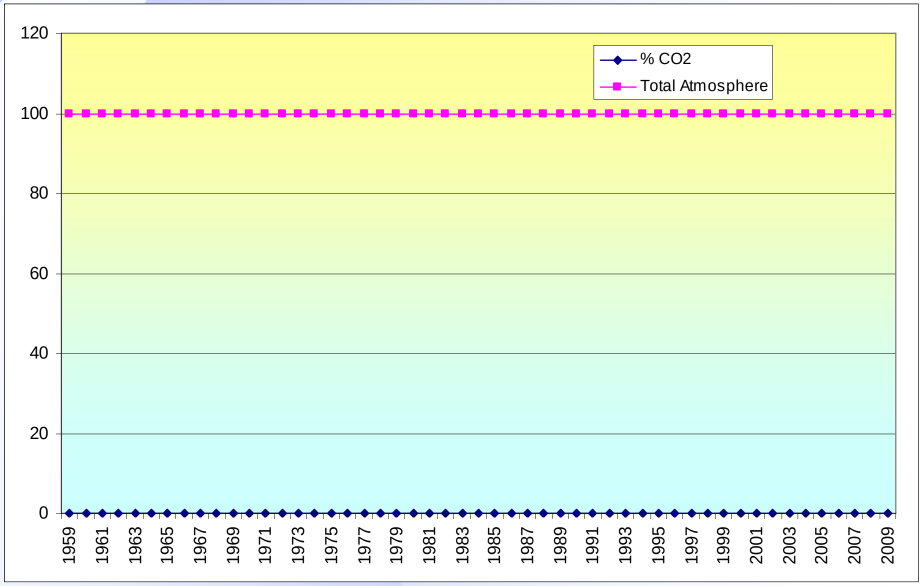

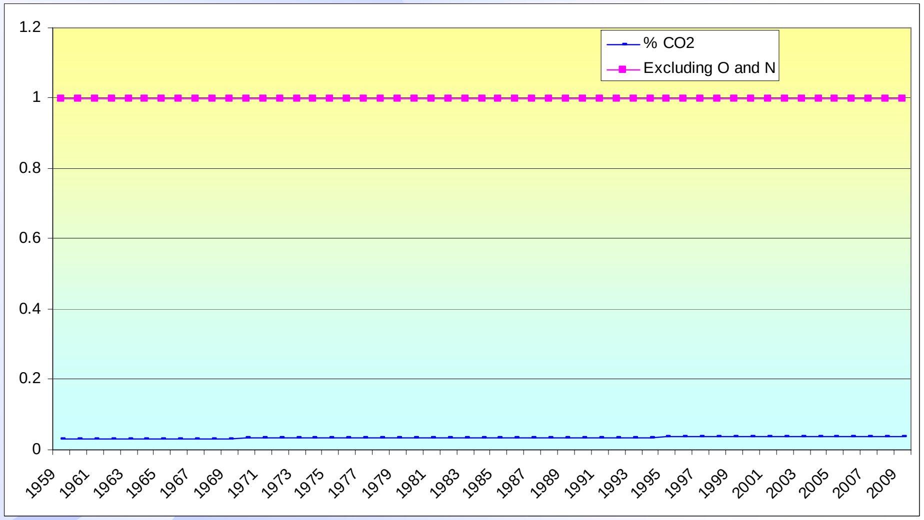

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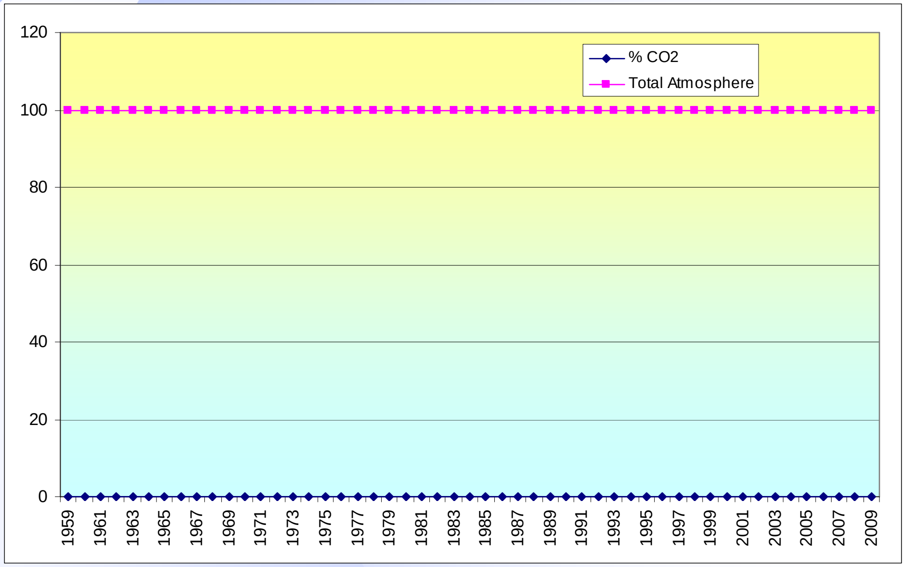

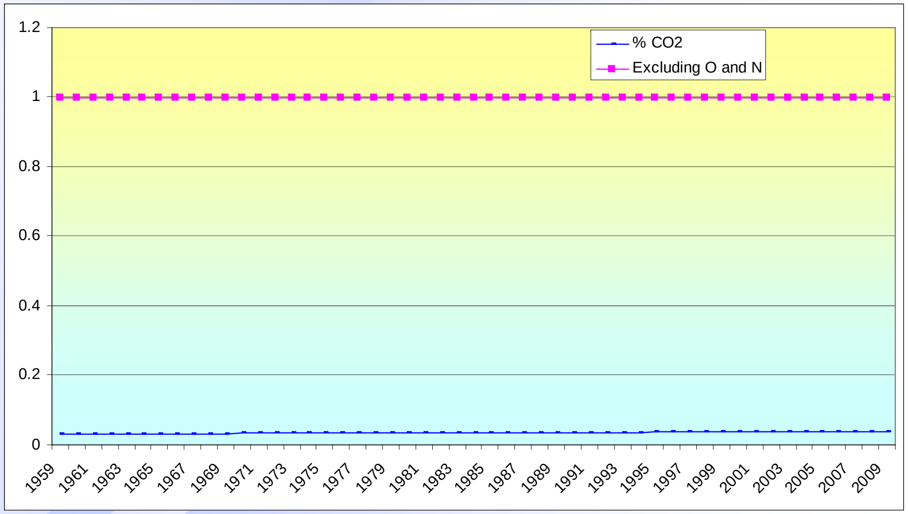

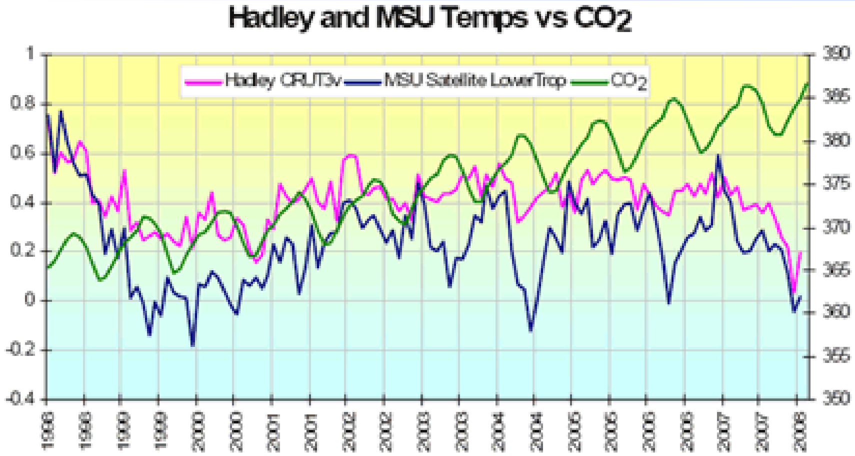

Figure 1. Earth Temperature and Atmospheric CO₂ Concentration

Source: D'Aleo, J. S., "Correlation Last Decade and This Century CO₂ and Global Temperatures Not There"
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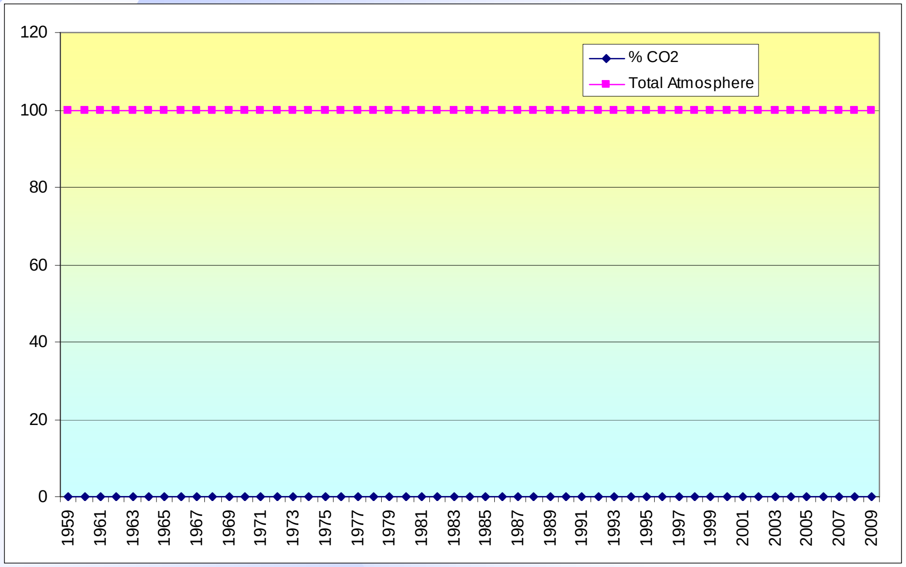
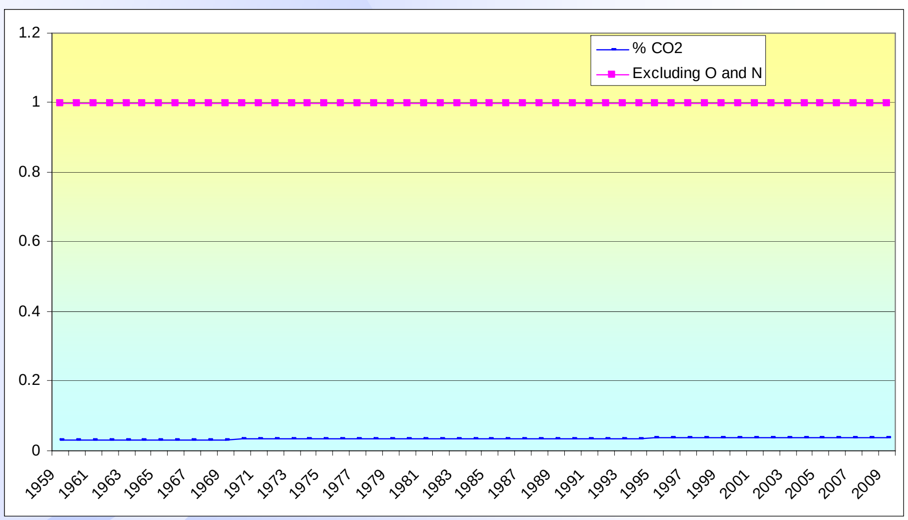
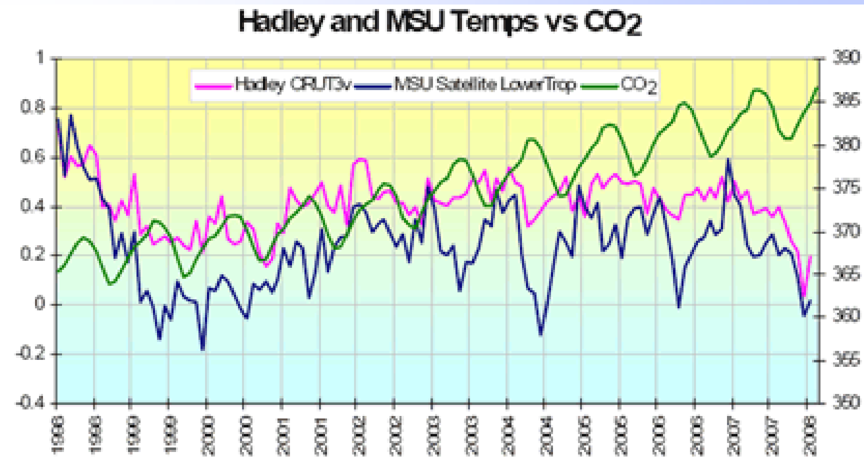




“If you torture data sufficiently, it will confess almost anything.”

Dr. Fred Menger (Prof. Chemistry, Emory Univ.)



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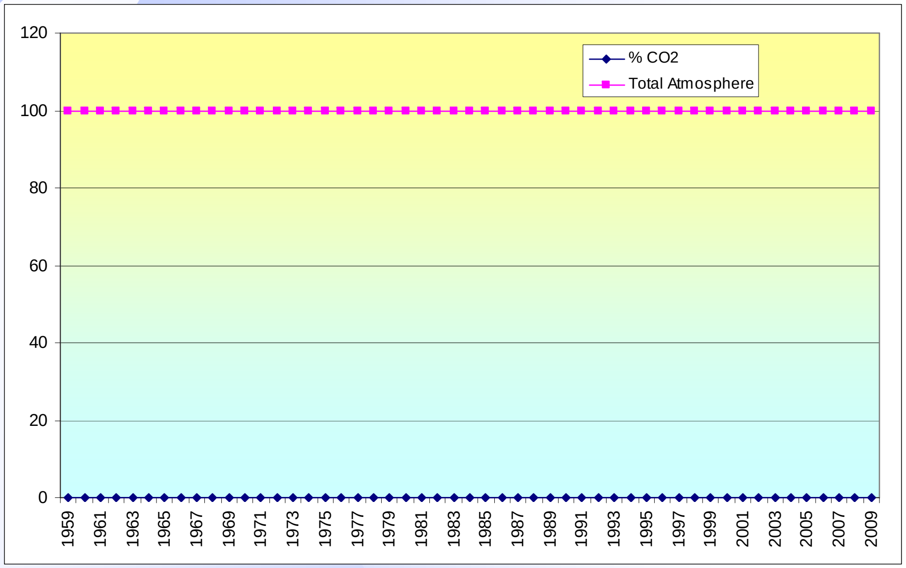

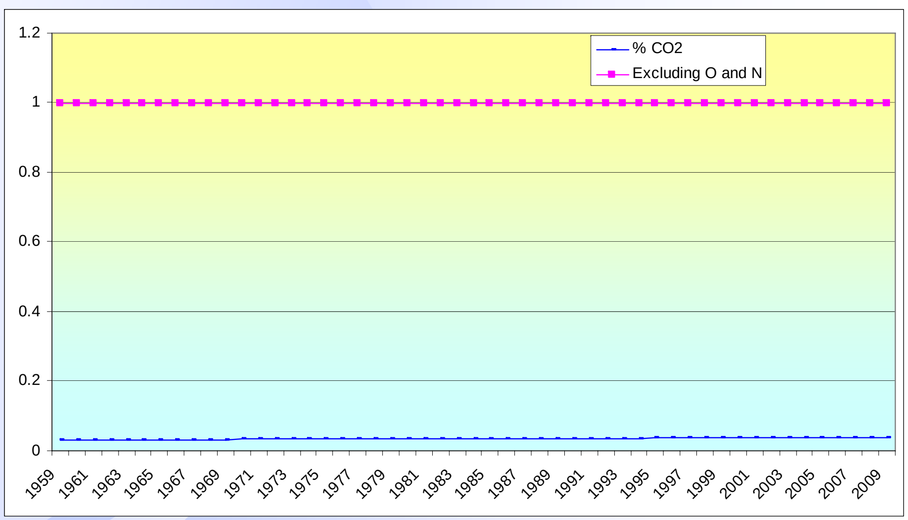

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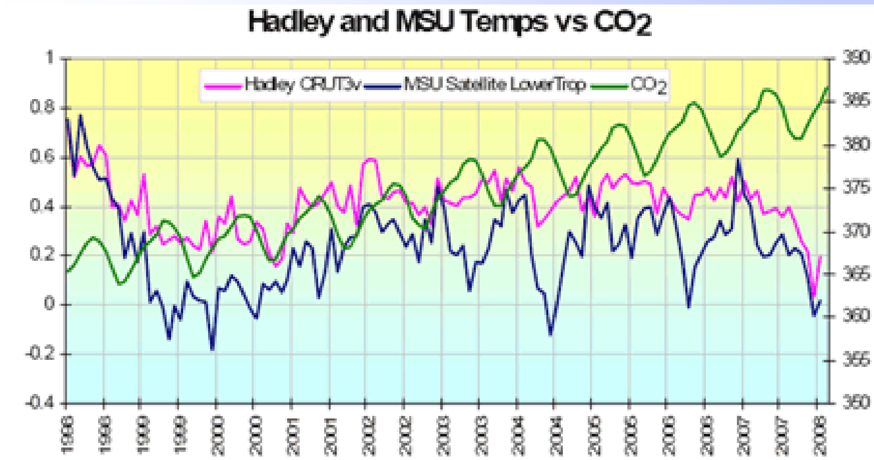

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<u>What do we know?</u>

CO_2 is a small fraction of the total atmosphere (< 0.04%).

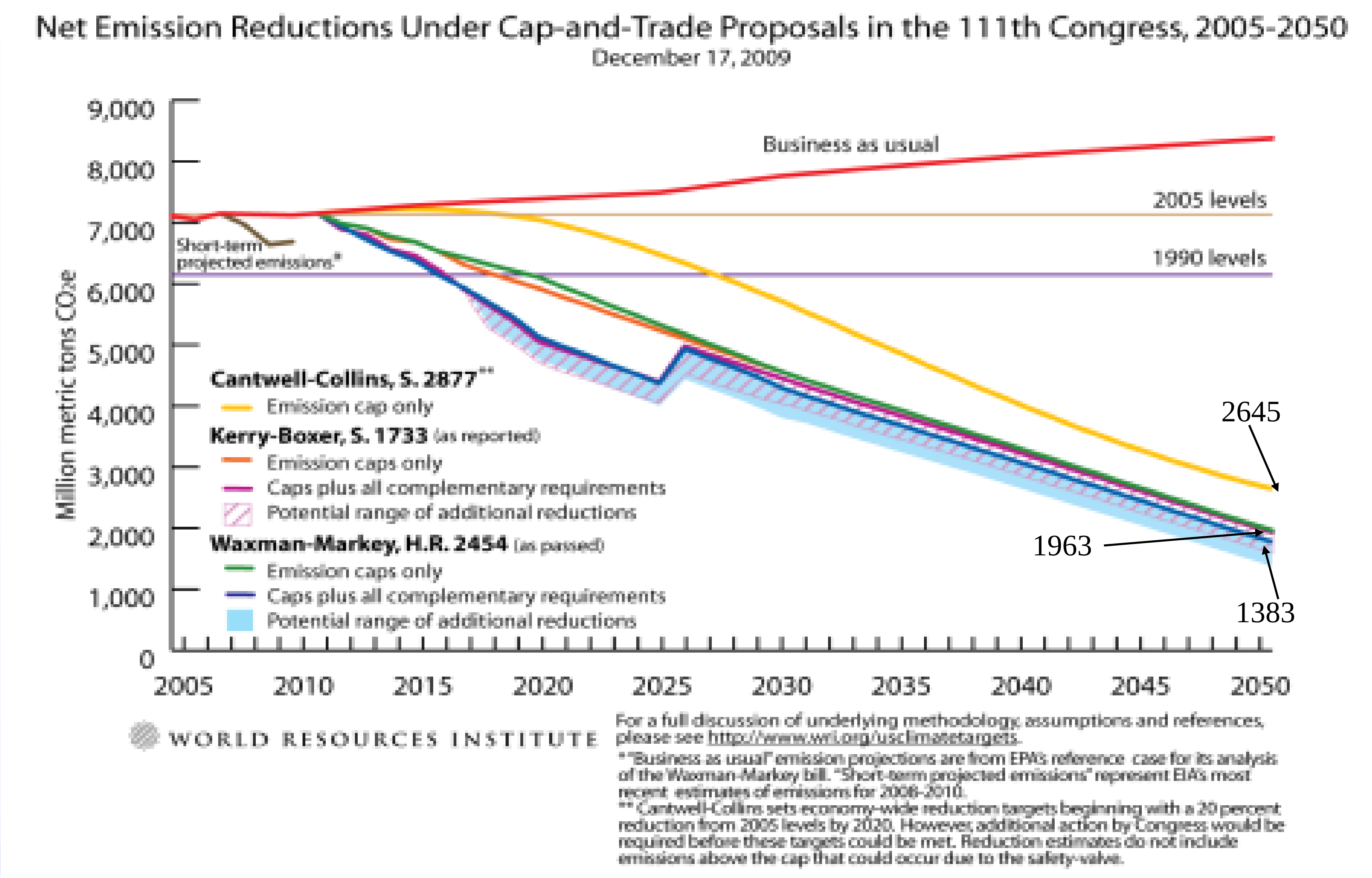
CO_2 has risen steadily but temperatures have been erratic.

Predicting long term climate is very difficult with many uncertainties.

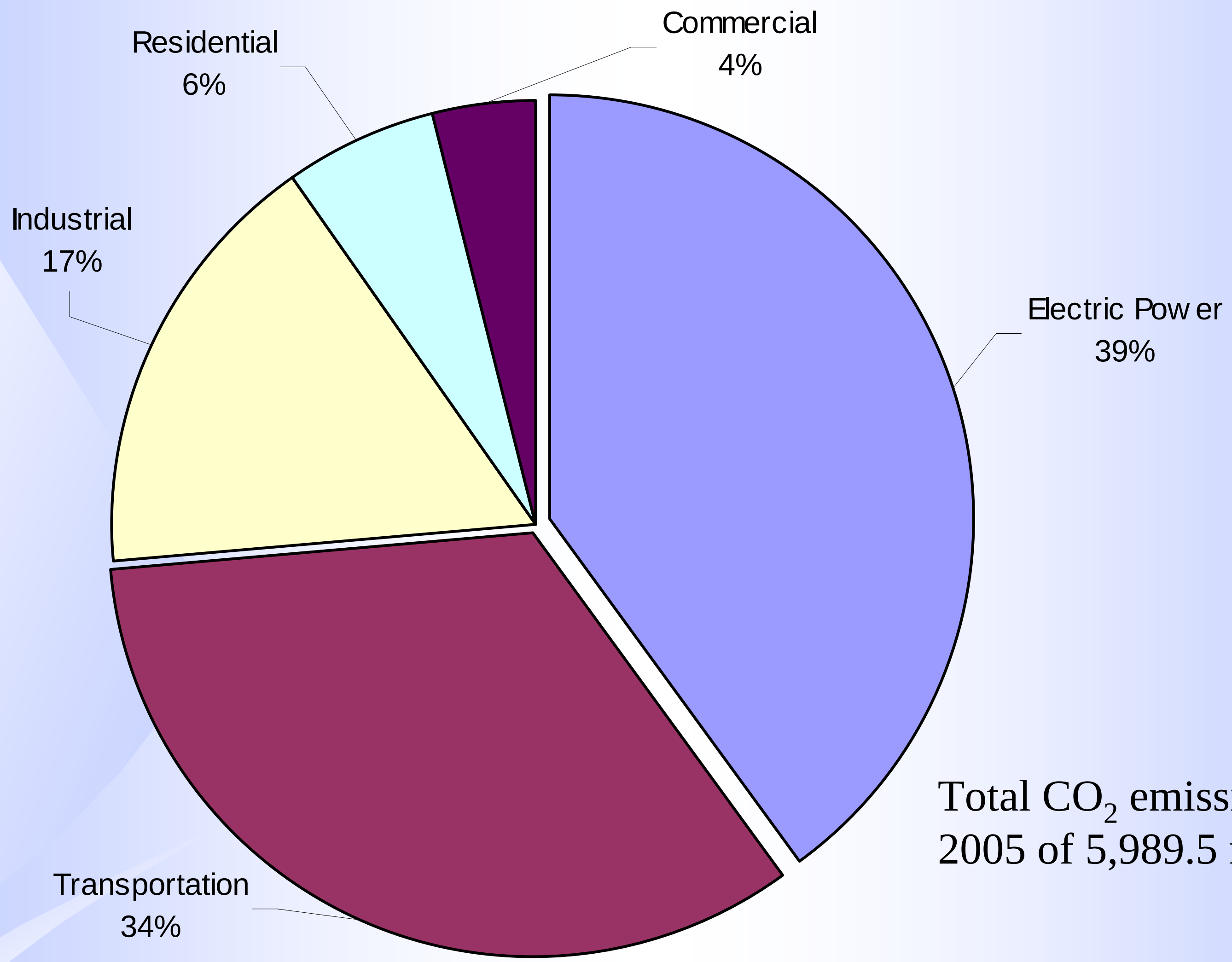
Computer models are notoriously difficult to validate.

There are other significant reasons to stop burning fossil fuels.

What is being contemplated?



Manmade CO_2 Emissions



Total CO_2 emissions in 2005 of 5,989.5 million MT

How do we get to the proposed 2050 limits?

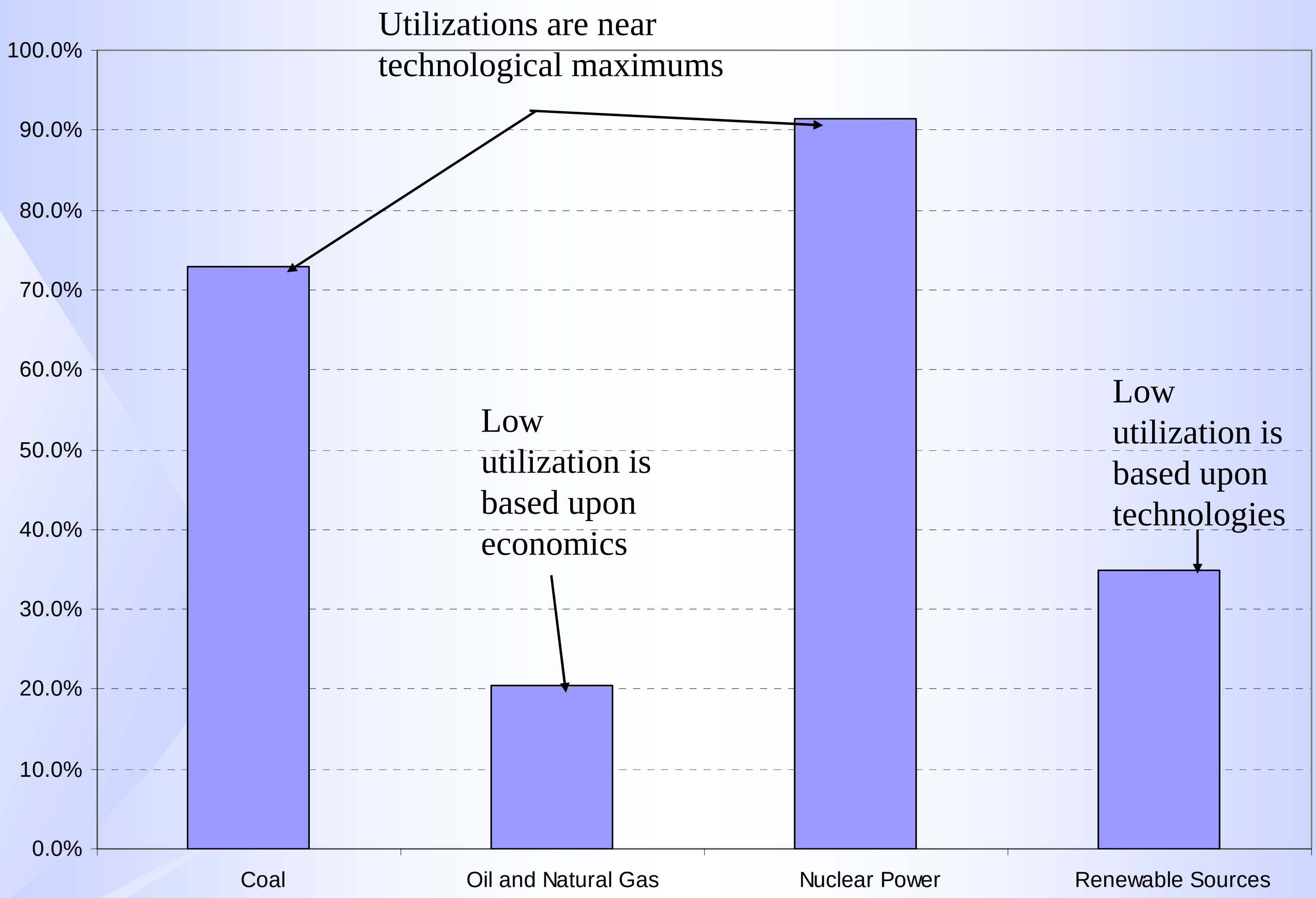
- Remember that the three proposals to achieve by 2050 are; 2,645, 1,963, 1,383 million metric tons (MMT). The 2005 emissions were 5,989.5 MMT.
- If all electric power generation emissions were eliminated (and there was no growth in the other sectors) the emissions would still be 3,591.5 MMT of CO_2. This would meet none of the proposals.
- If all transportation emissions were eliminated along with all electric power generation emissions (and no growth in the other areas occurred) there would still be 1,584 MMT of CO_2 emissions from other sources. This meets two out of the three proposals.
- Given that it is not possible to completely eliminate these segments, and that there would be some growth in other areas, ***something*** has to give in order to achieve these goals.
- Major technical leaps will be required to maintain a modern standard of living. In 1900, the per capita emission was around 6 MT per person equating to 1,830 MMT based on current population. Close to the middle target number.

Dept of Energy's projection of the future

Net Generation by Energy Source (GWh x 1000) **Source:** **US Department of Energy** **Annual Energy Outlook 2010 Early Release** **Report #:DOE/EIA-0383(2009)** **Release Date: December 14, 2009**						
Period	Coal	Petroleum	Natural Gas	Nuclear	Hydro + Renewable	Total
2005	2,013	122	774	782	370	4,061
2010	1,780	40	660	813	421	3,713
2020	2,026	42	568	883	626	4,145
2030	2,132	43	778	886	666	4,505

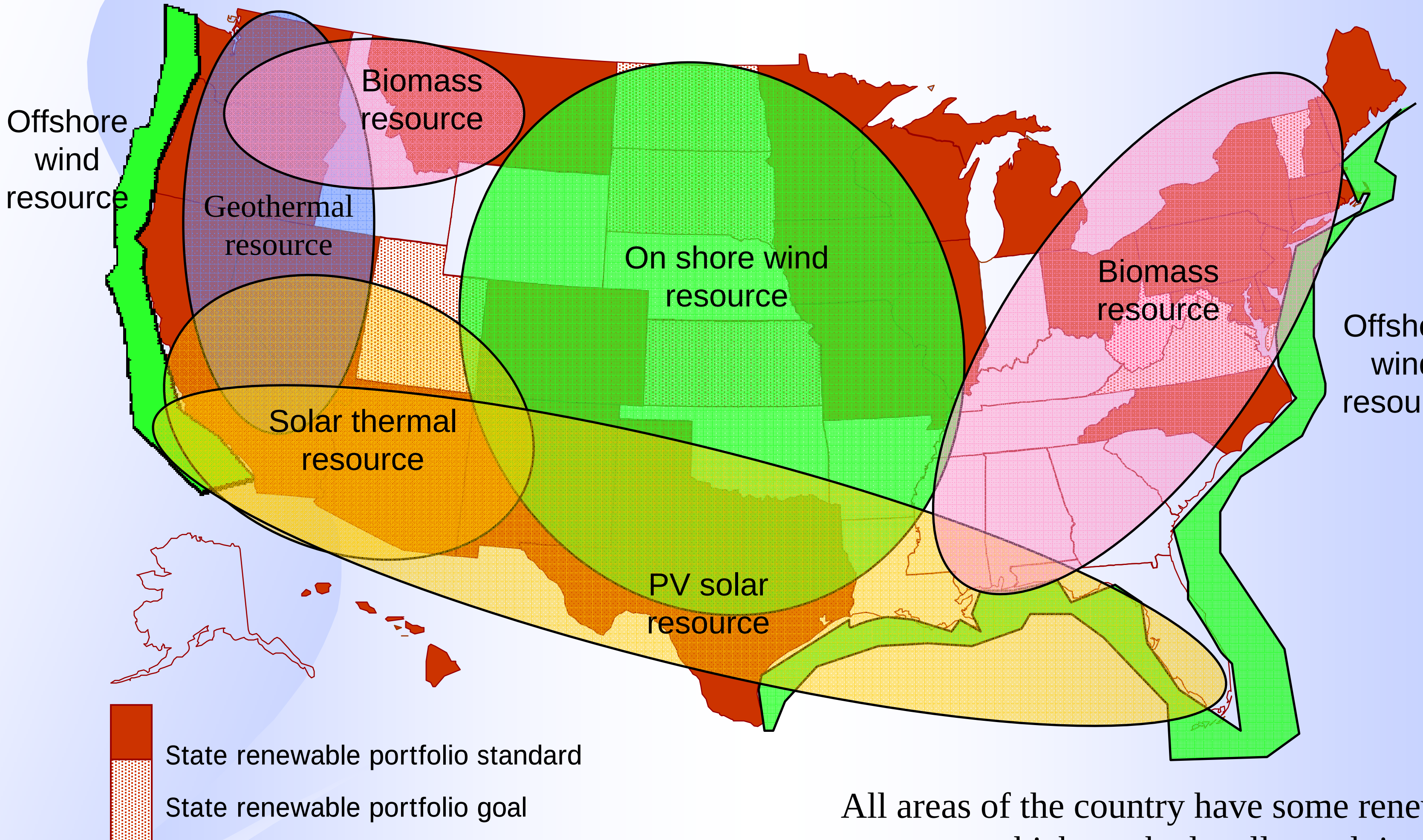
The EIA clearly has not included any possible impacts of the CO_2 limits in their future projections through 2030. CO_2 emissions would be greater in 2030 than they were in 2005 using this planned projection of the future. This gives us **no** insight as to the government's thinking on how to achieve the proposed limits.

Current Capacity Factor US Power Stations



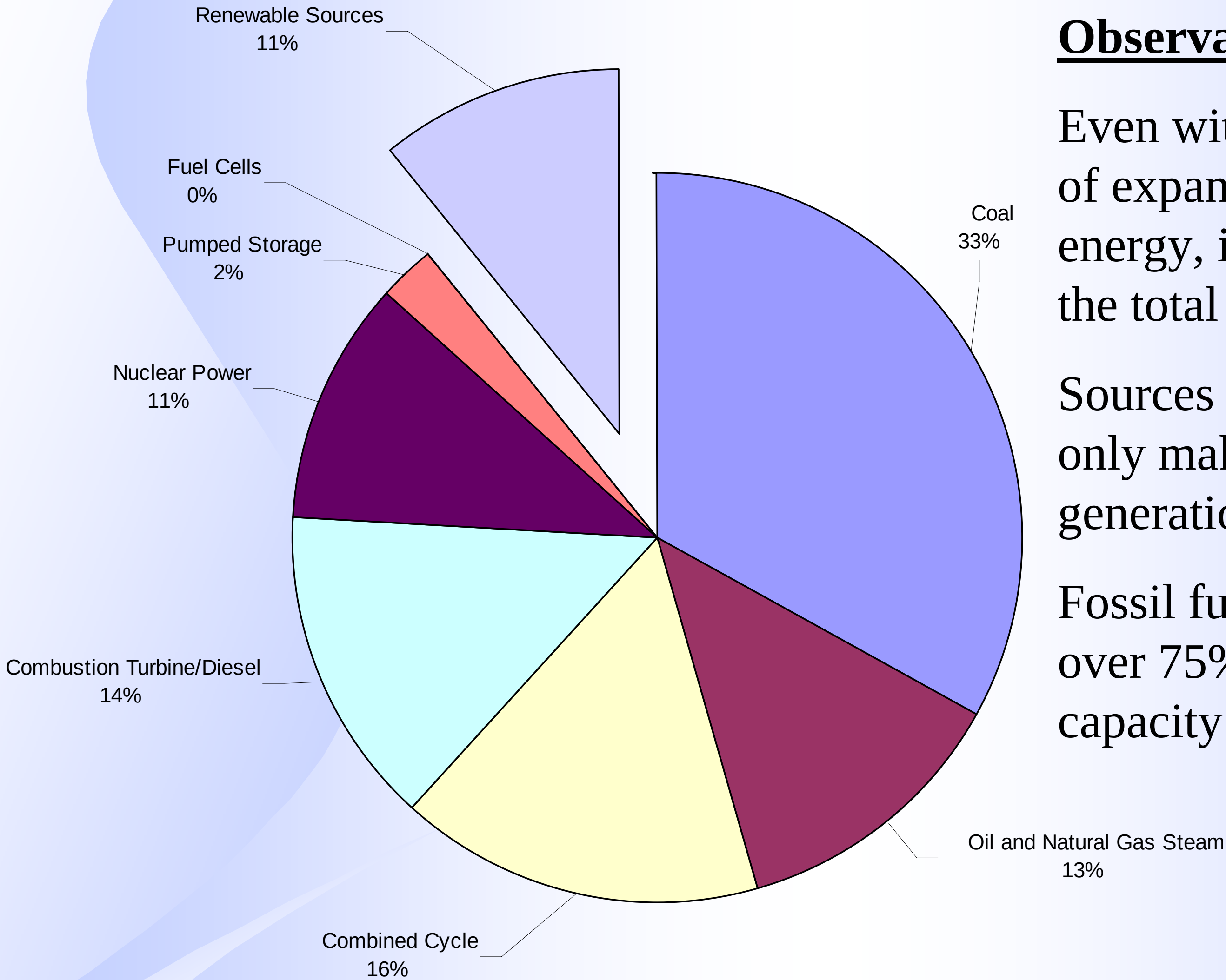
Renewable Energy Issues

Renewable Resource Locations



All areas of the country have some renewable resources which can be locally exploited to meet their state goals.

Current Generation Mix in the US (Capacity in GW)



Observations

Even with the recent high level of expansion of renewable energy, it makes up only 11% of the total energy produced.

Sources other than hydroelectric only make up around 4% of all generation capability

Fossil fuel sources constitute over 75% of all installed capacity.

Source:
US Department of Energy
Annual Energy Outlook 2010 Early Release
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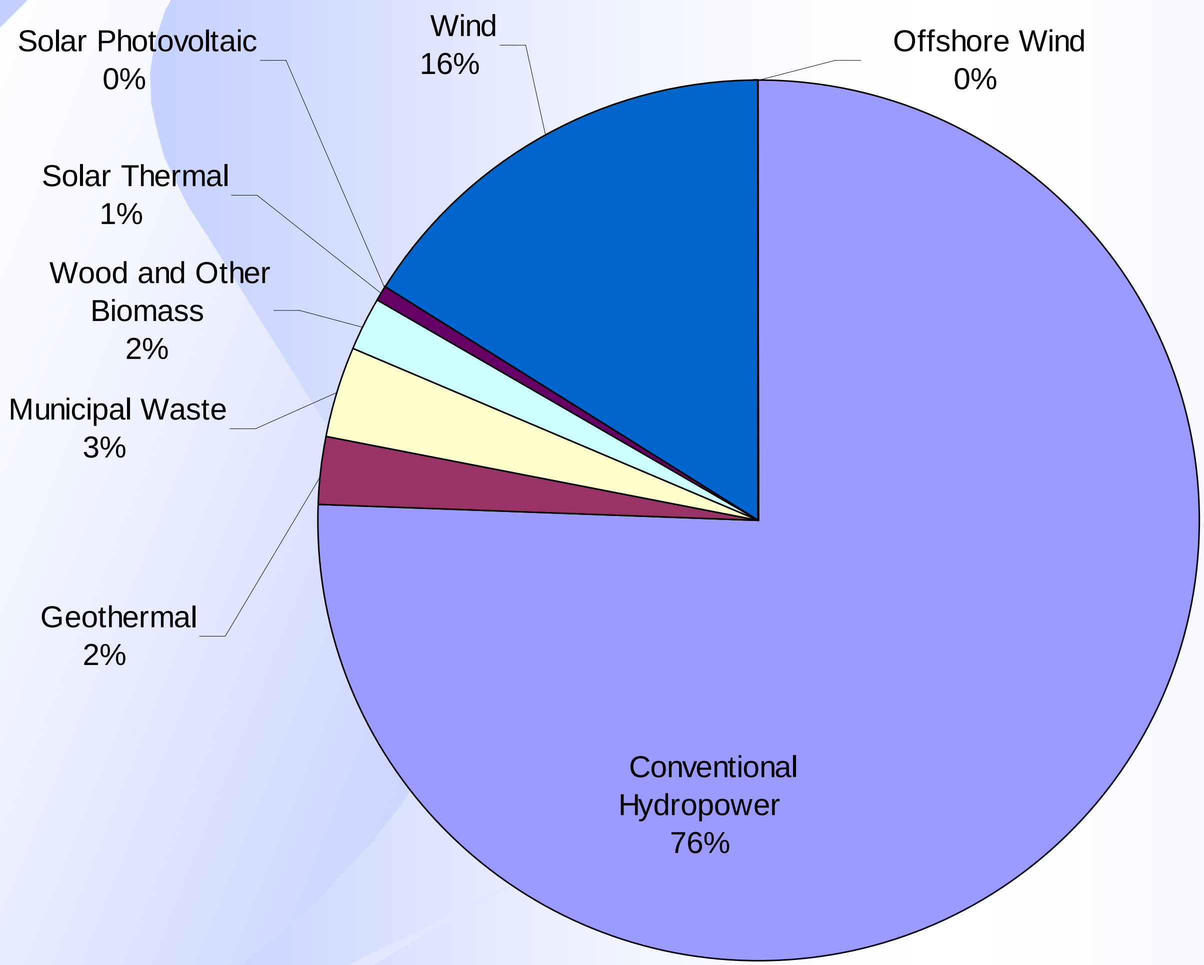
Current Renewable Mix in the US (Capacity in GW)



<u>Observations</u>

Biomass is widely available, commercially mature, and can provide baseload capacity, yet is only 2% of mix –indication of cost and/or operating limitations.

Offshore wind is a better resource than land-based wind, utilizes mature technology, and is adjacent to load centers, yet is 0% of mix – indication of cost and political challenges.

Source:
US Department of Energy
Annual Energy Outlook 2010 Early Release
Report #:DOE/EIA-0383(2009)
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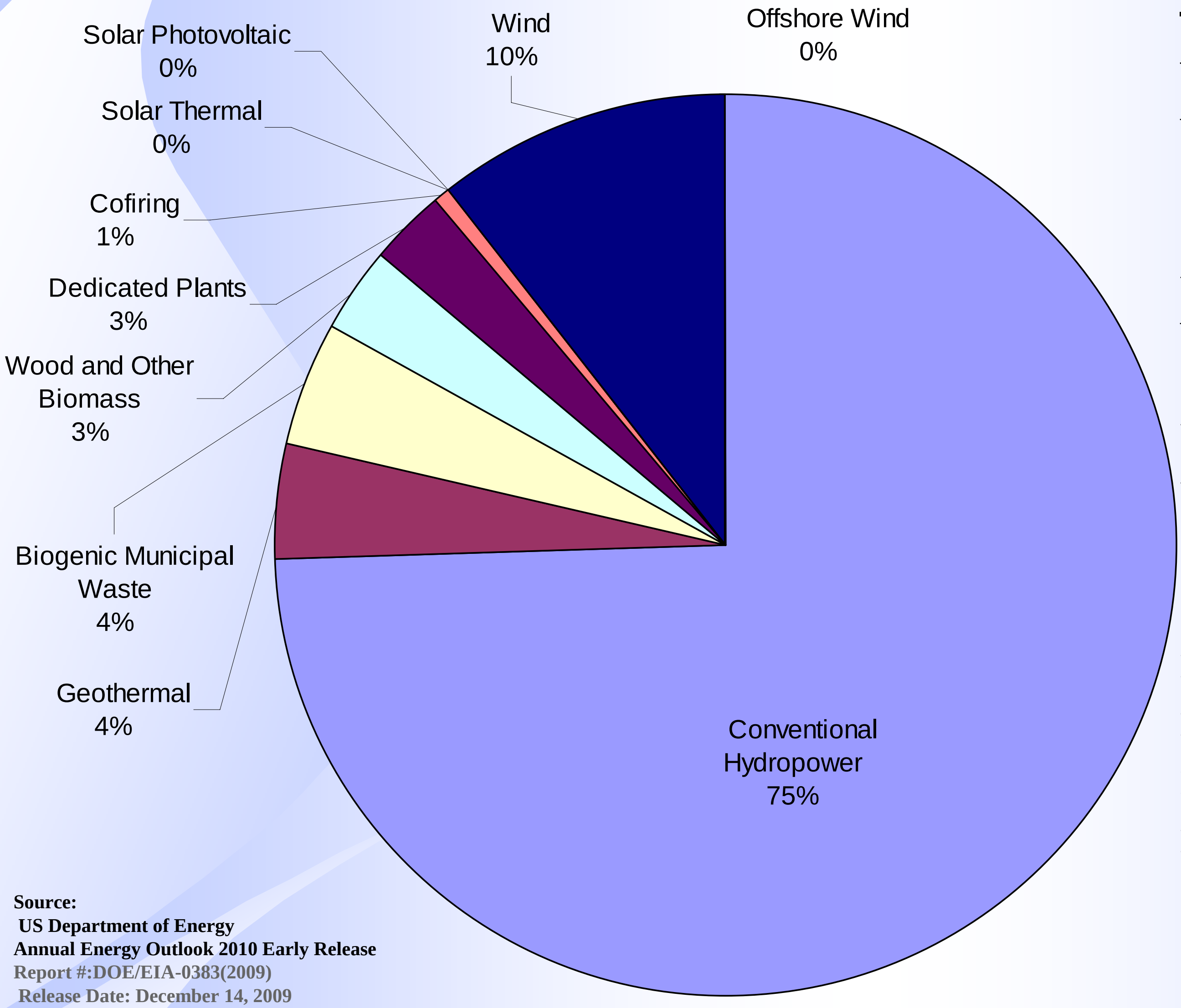
Current Renewable Mix in the US (energy in kWh)



Source:
US Department of Energy
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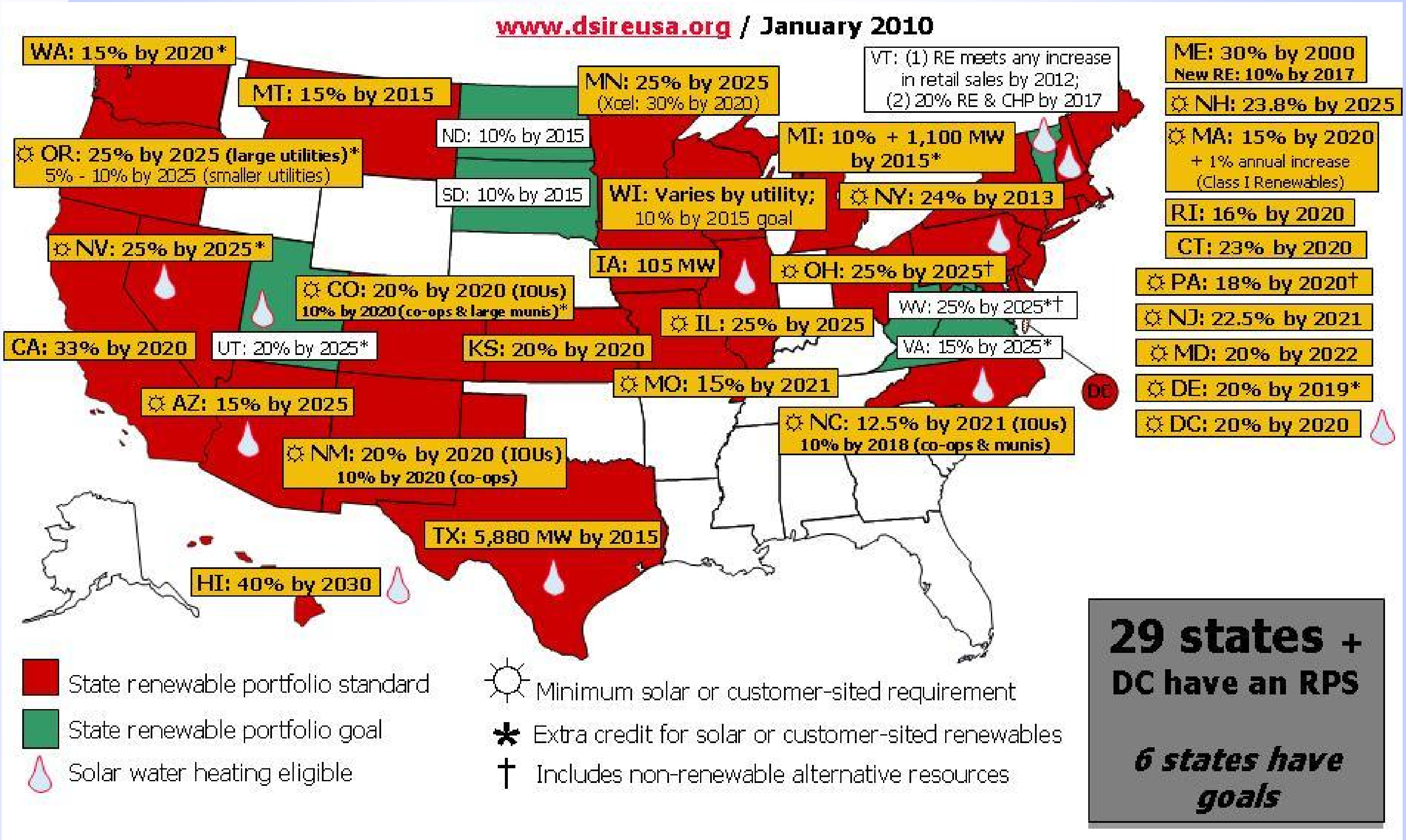
Observations

Wind is 16% of capacity but only 10% of the energy.

Hydropower generation in the US is largely built out but represents the largest portion of renewable power. (Some are being demolished)

Biomass is the next most reliable source of renewable energy providing more than 11% of all renewable energy with just 5% of the capacity

Renewable Portfolio Standards



There are 865 separate incentives for installation of renewable energy including state and federal regulations. All are designed to expedite deployment. Still renewables are lagging in acceptance. Why?

Example - Production Tax Credits

Resource Type	In-Service Deadline	Credit Amount
Wind	31-Dec-12	2.1¢/kWh
Closed-Loop Biomass	31-Dec-13	2.1¢/kWh
Open-Loop Biomass	31-Dec-13	1.1¢/kWh
Geothermal Energy	31-Dec-13	2.1¢/kWh
Landfill Gas	31-Dec-13	1.1¢/kWh
Municipal Solid Waste	31-Dec-13	1.1¢/kWh
Qualified Hydroelectric	31-Dec-13	1.1¢/kWh
Marine and Hydrokinetic (150 kW or larger)**	31-Dec-13	1.1¢/kWh

This is the mechanism which is being used to develop most wind energy projects. 2.1¢ /kWh for the first ten years of service. So, how much money is this for an average wind project?

Significant Taxpayer Money Involved

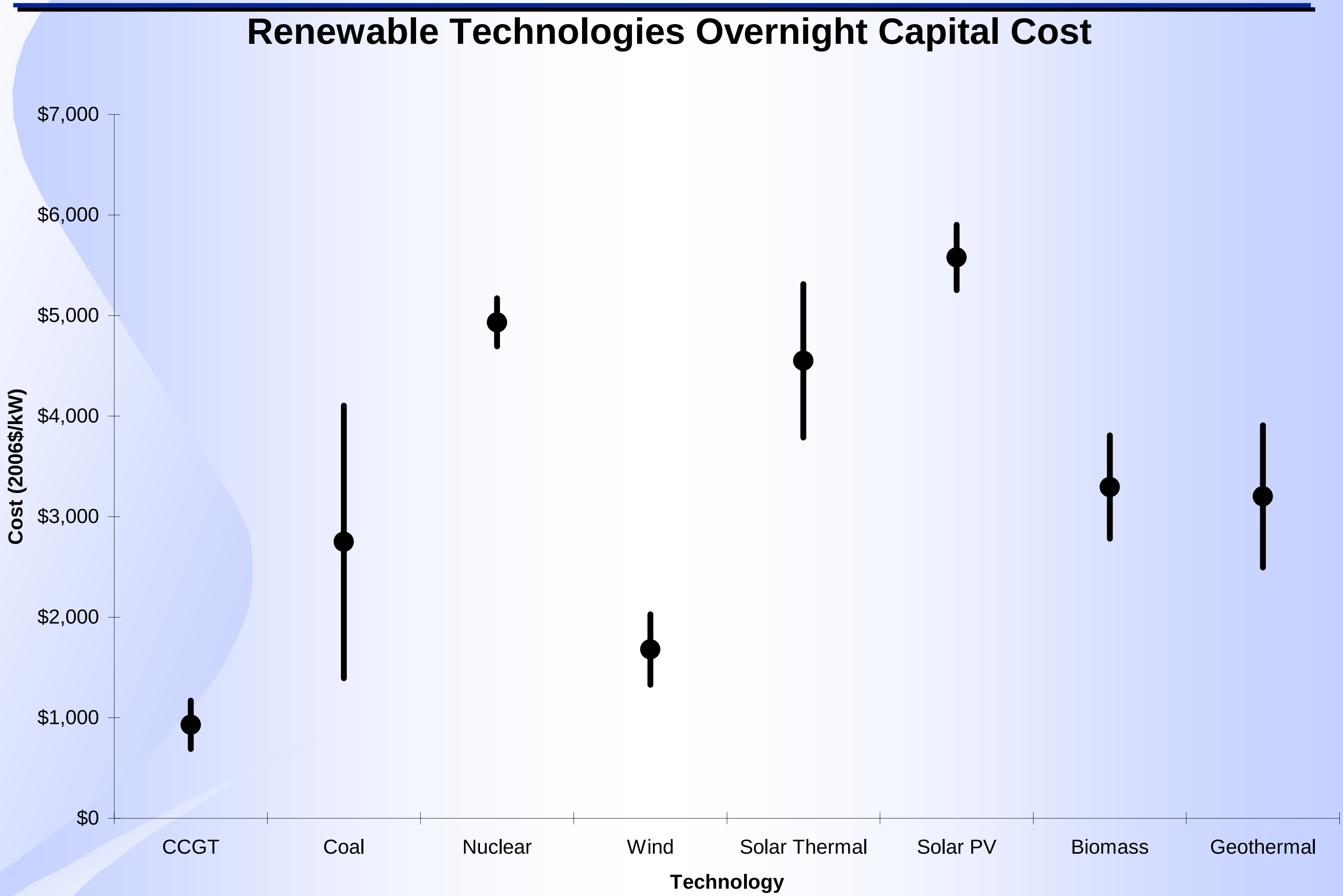
Coal: Annual Fuel Cost		**Wind: Annual Production Tax Credit**	
$2.13	per MBtu (Dec 08 actual avg)		
9,500	heat rate	2.1	cent/kWh production tax credit
$20.24	$/MWh fuel cost	$21.00	$/MWh PTC
1,000	MW of production capacity	2,429	MW of production capacity
85%	capacity factor	35%	capacity factor
7,446	GWh per year	7,446	GWh per year
$151	**annual fuel cost, $millions**	**$156**	**annual PTC, $millions**

PTC has same effect during 1st ten years of wind plant operation as if taxpayers bought power plant's coal

Significant Taxpayer Money Involved

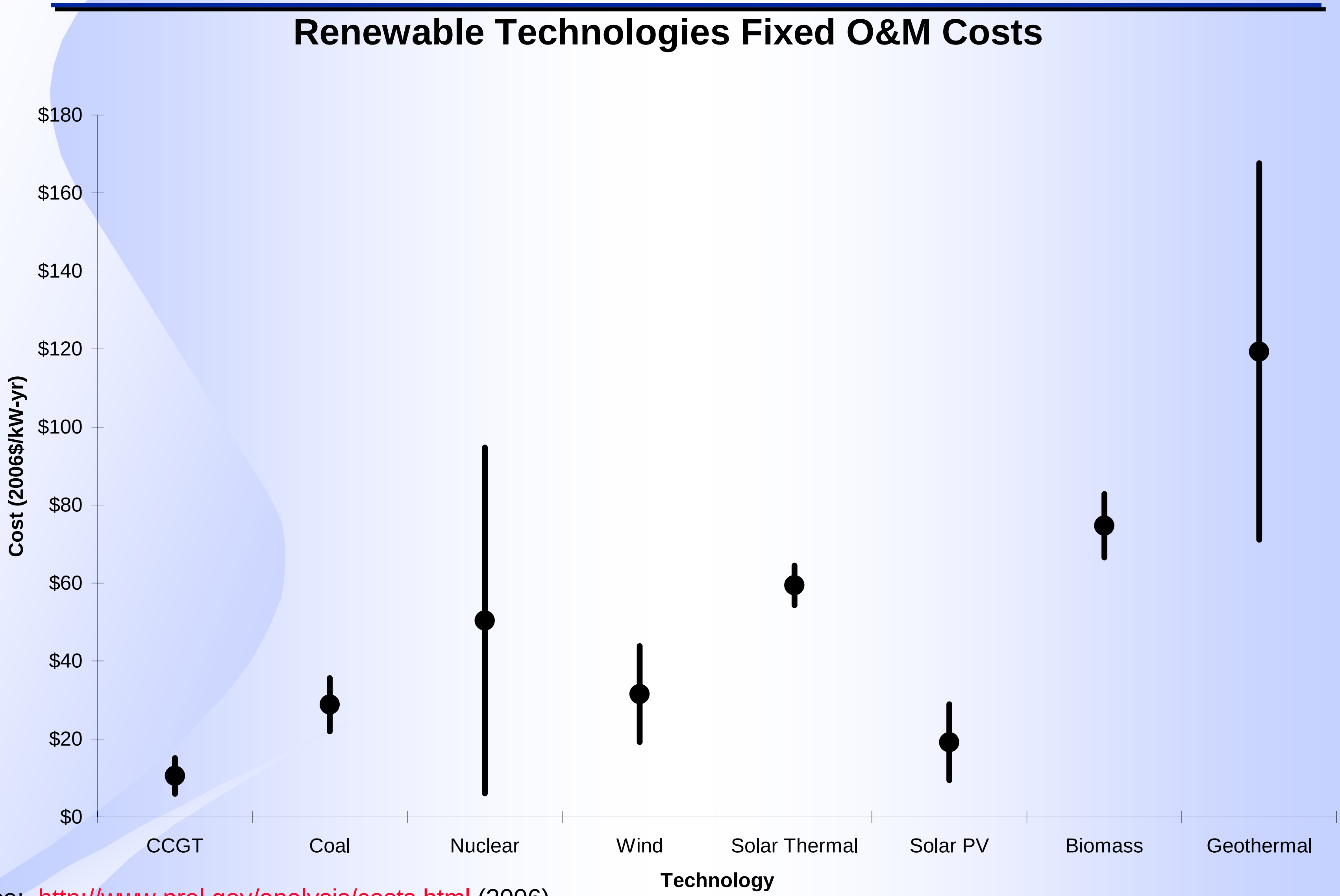
- Assume 20% wind is deployed based on the 2009 US electric power production of 3,798 Billion kWh.
- Using a 2.1¢/kWh production tax credit (taxes not required to be paid) as is currently in the regulations for wind.
- The tax credit from the Federal Government would be approximately $ 16 billion per year for ten years.
- Total incentive would be $160 billion over the life of the program.
- This cost discussion covers only one of the 865 regulations providing incentives.

Overnight Capital Cost Comparison



Source: http://www.nrel.gov/analysis/costs.html (2006)

Fixed O&M Cost Comparison



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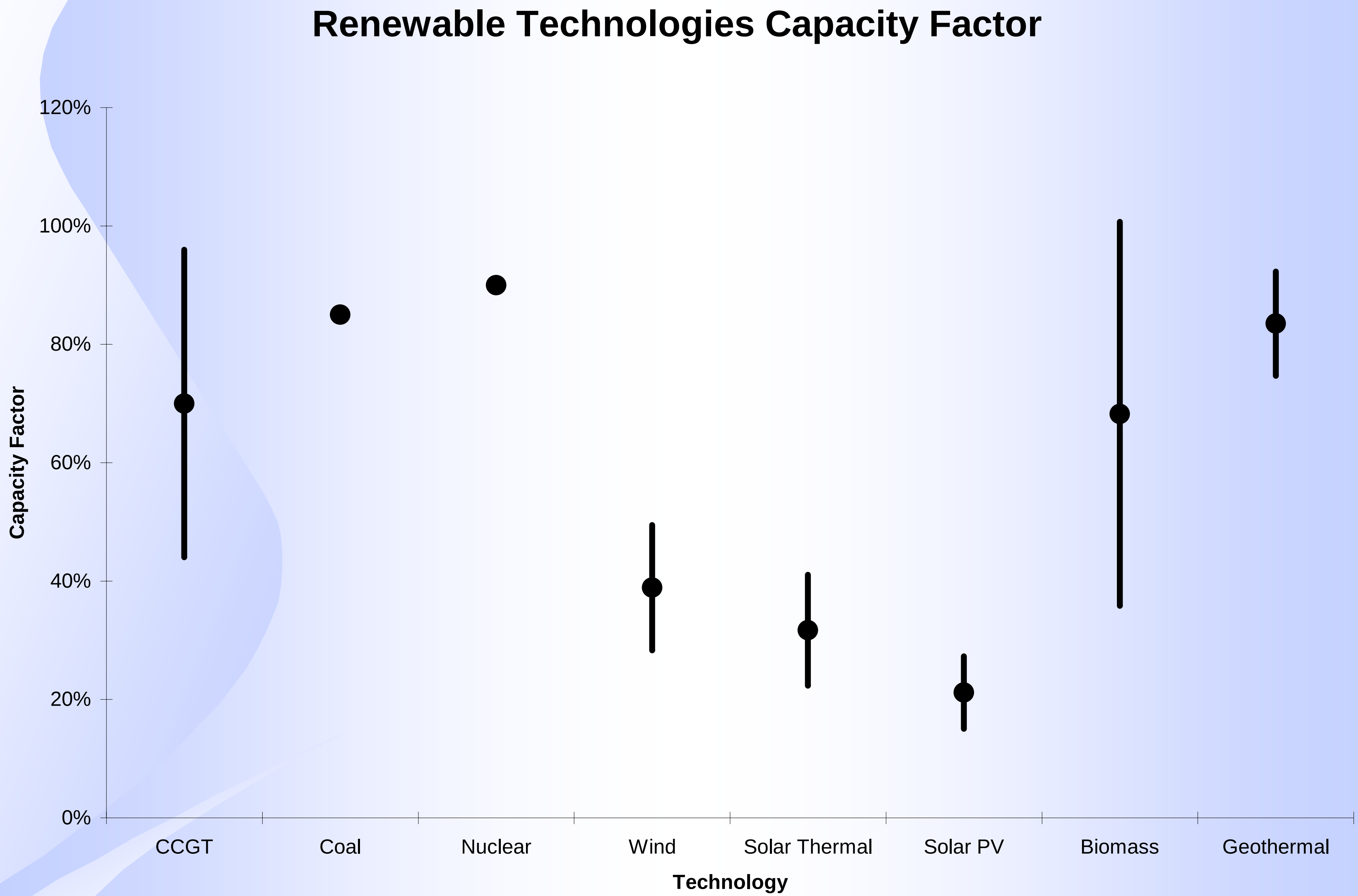
Capacity Factor Comparison



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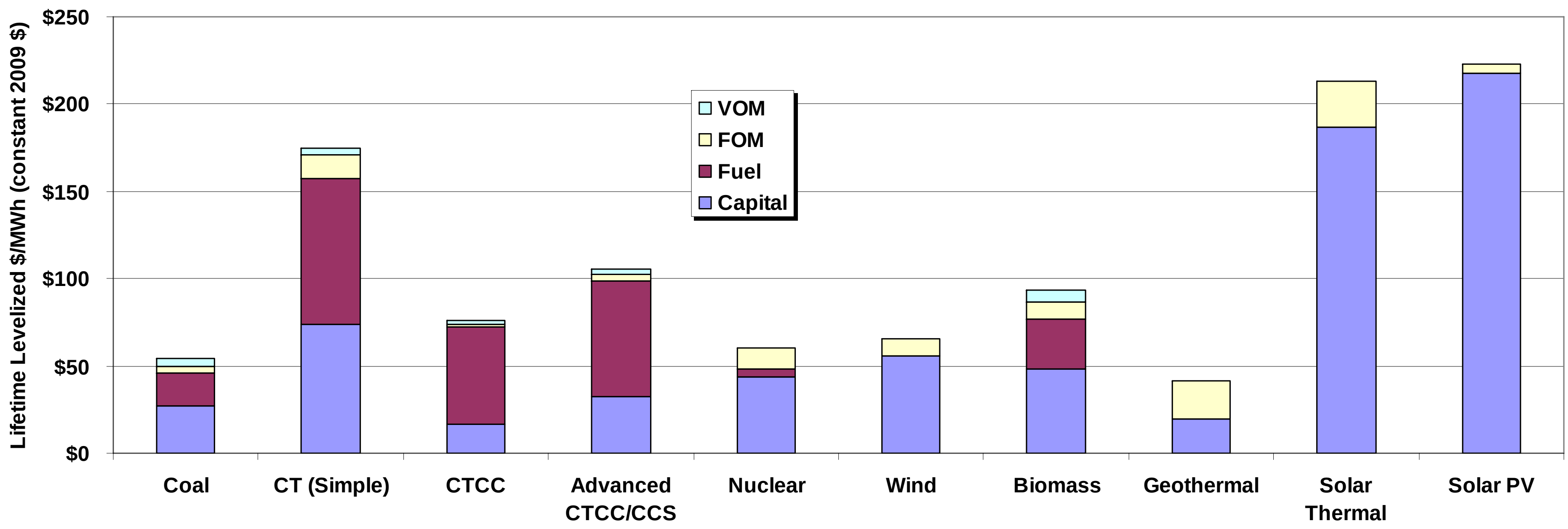
Wind & geothermal levelized costs are competitive with conventional generation; solar costs are high



- **Cost inputs per DOE's Annual Energy Outlook 2009. Evaluated in constant 2009 dollars**
- **Assumed capacity factors and capital recovery periods are typical of each technology.**
- **AEO 2009 Solar costs are higher than current S&L projections – costs are being reduced due to ongoing innovations.**
- **AEO Wind and Geothermal costs represent the use of the prime resource areas and costs are expected to increase going forward. Off-shore wind costs are expected to be double on-shore.**

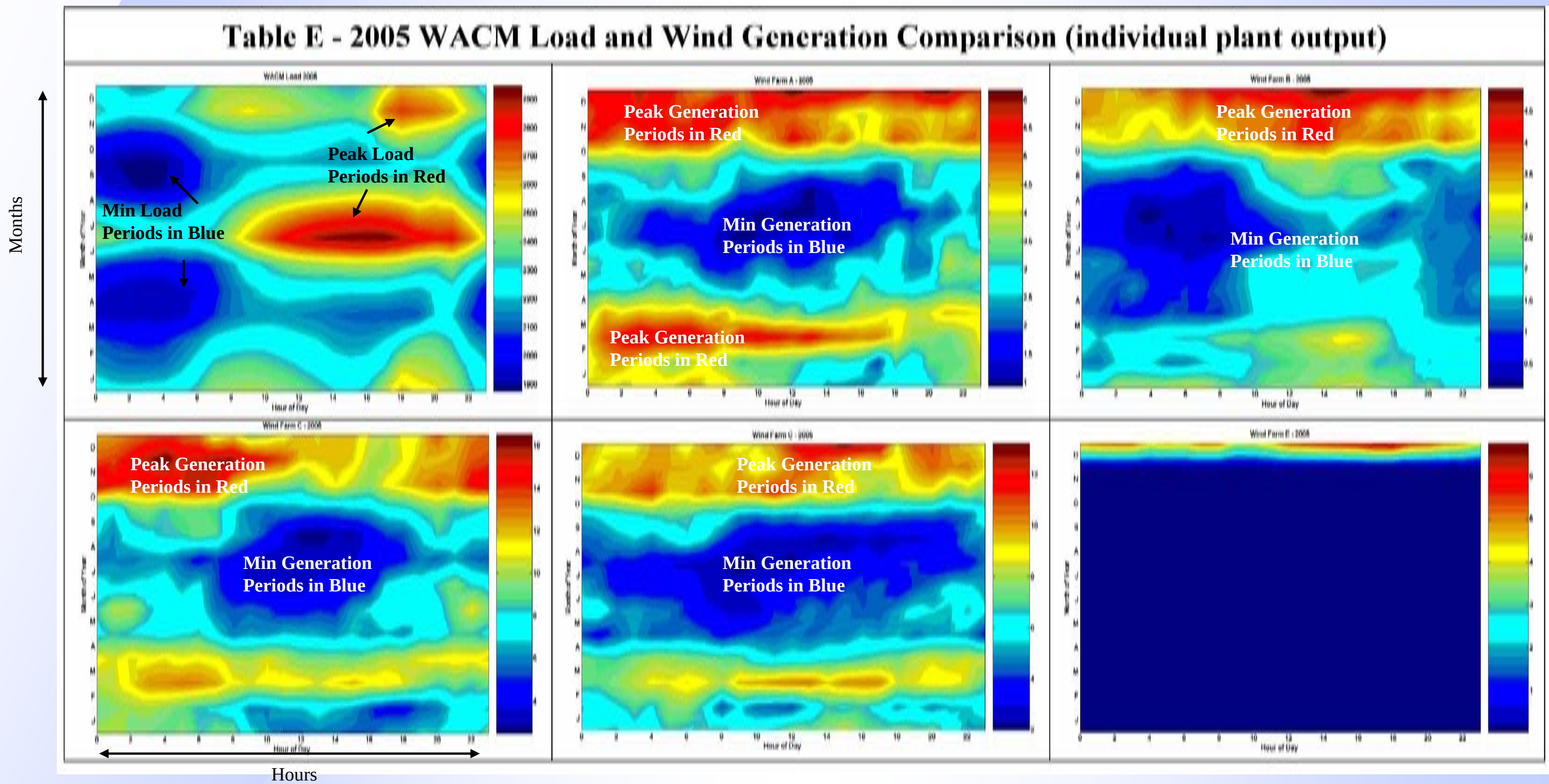
Financing Concerns

- Lenders want certainty of cost recovery in project finance.
  - Technical maturity
  - Supplier guarantees
  - PPA for off-take
  - O&M cost certainty
  - Equipment life
- Transmission interconnection costs are a significant portion of project costs.
- IPP developers want project finance. (No corporate guarantees in the event of project default)
- EPC contracts are difficult to obtain.

Energy Storage – Renewable Nirvana

- PV Solar and Wind are the two most proven variable resource technologies.
- Large rapid swings in generation frequently occur in these technologies.
  - Grid stability can be compromised if significant variable generation is lost.
  - Back-up generation is needed to support the stability of the grid.
- Resources do not coincide with load peaks when power price is high.
- The use of storage to shift generation would allow increased value.
- Energy storage technologies are very expensive
- Most technologies are useful for ancillary services rather than power shifting except for small scale applications.
- Significant research in this area is required to achieve the needed advances to allow wide scale implementation and cost reduction.

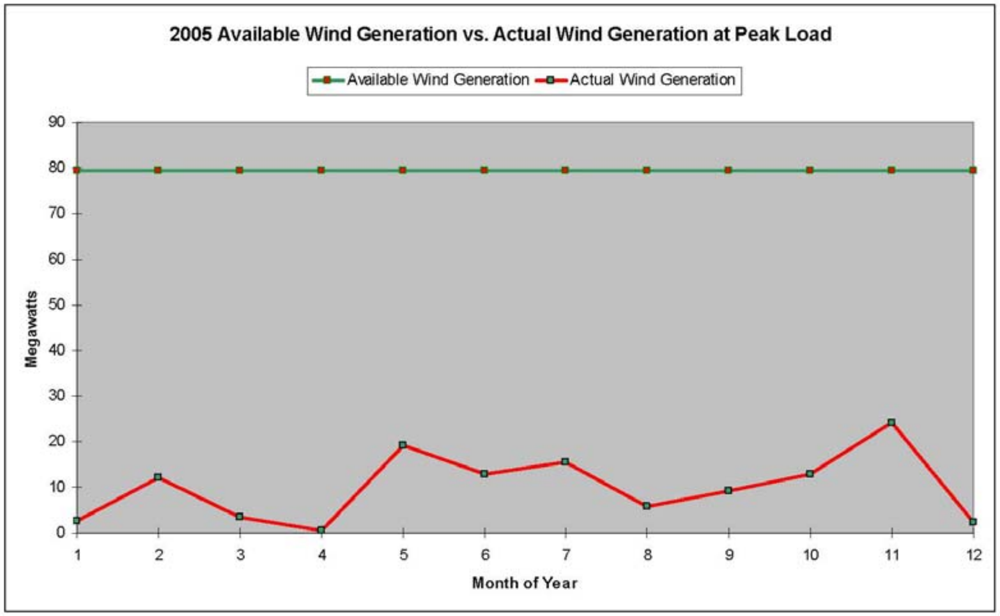
Typical Wind to Peak Load Comparison



During 2005 the best generation was during winter. During the summer peak load period wind was generally unavailable. Only during the winter peak late in the day was there significant concurrence of generation and load. This study covered a wide area in Colorado, Wyoming and Nebraska

Typical Wind to Peak Load Comparison

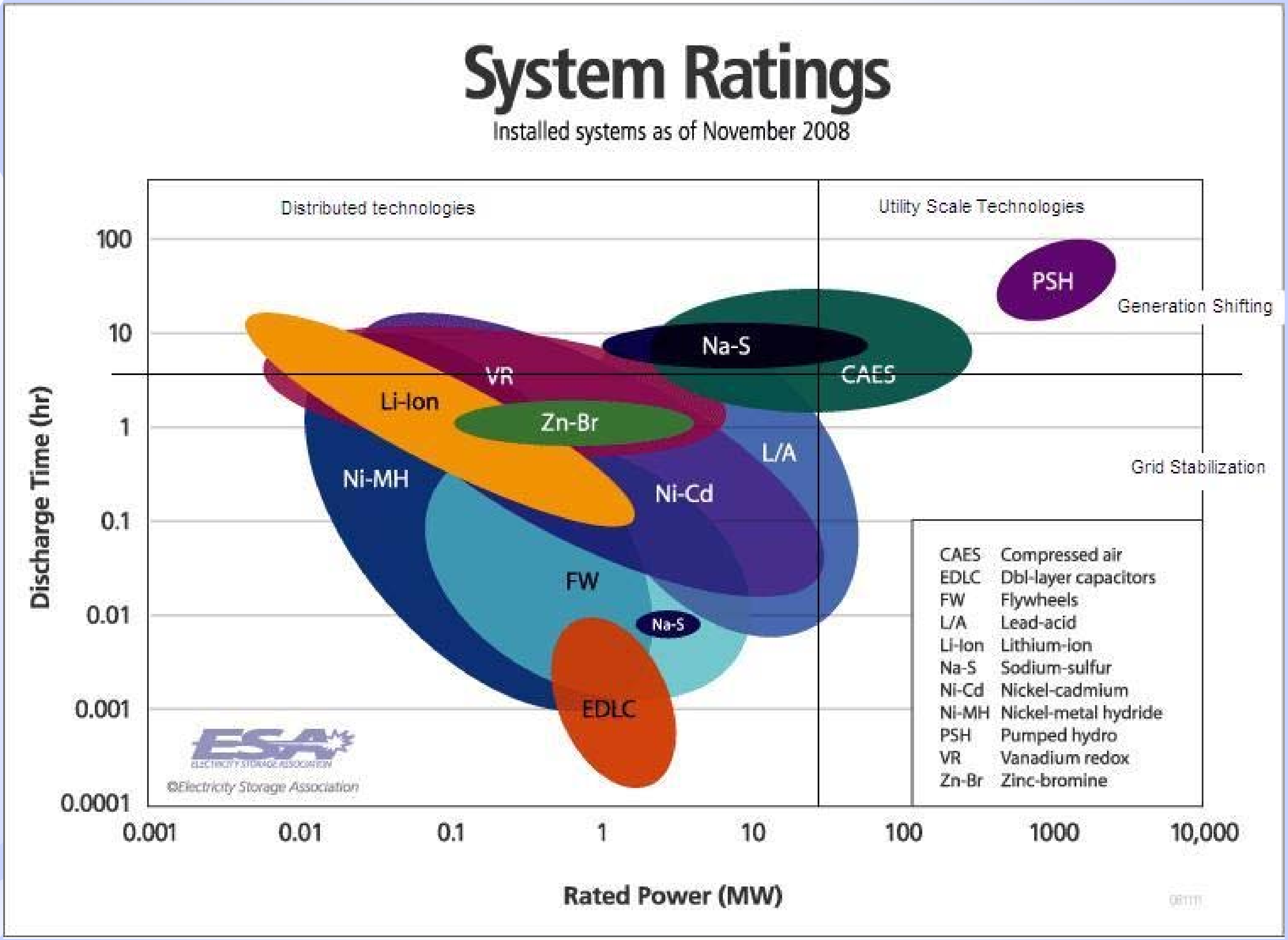
Table B					
2005	Control Area Peak Load MW/Day/Hour	Total Wind Capacity at Peak (MW)	Actual Wind Generation at Peak Load (WM)	Percent Wind Generation at Peak Load (%)	Percent Wind Contribution to Load at Peak
January	2867-5-19:00	79.5	2.71	3.4%	0.09%
February	2725-7-19:00	79.5	12.2	15.3%	0.45%
March	2553-14-20:00	79.5	3.5	4.4%	0.14%
April	2339-28-21:00	79.5	0.5	0.6%	0.02%
May	2609-20-16:00	79.5	19.3	24.3%	0.74%
June	2889-22-16:00	79.5	12.8	16.1%	0.44%
July	3320-22-16:00	79.5	15.6	19.6%	0.47%
August	3238-1-16:00	79.5	5.8	7.3%	0.18%
September	2800-8-16:00	79.5	9.16	11.5%	0.33%
October	2445-10-20:00	79.5	12.95	16.3%	0.53%
November	2799-28-18:00	79.5	24.3	30.6%	0.87%
December	3018-7-19:00	79.5	2.3	2.9%	0.08%



During 2005, the best month was November which generated at 30% capacity at peak load. Over the entire year wind averaged around 13% of capacity on peak.

Adding additional units would not help significantly because the wind was not available for generation.

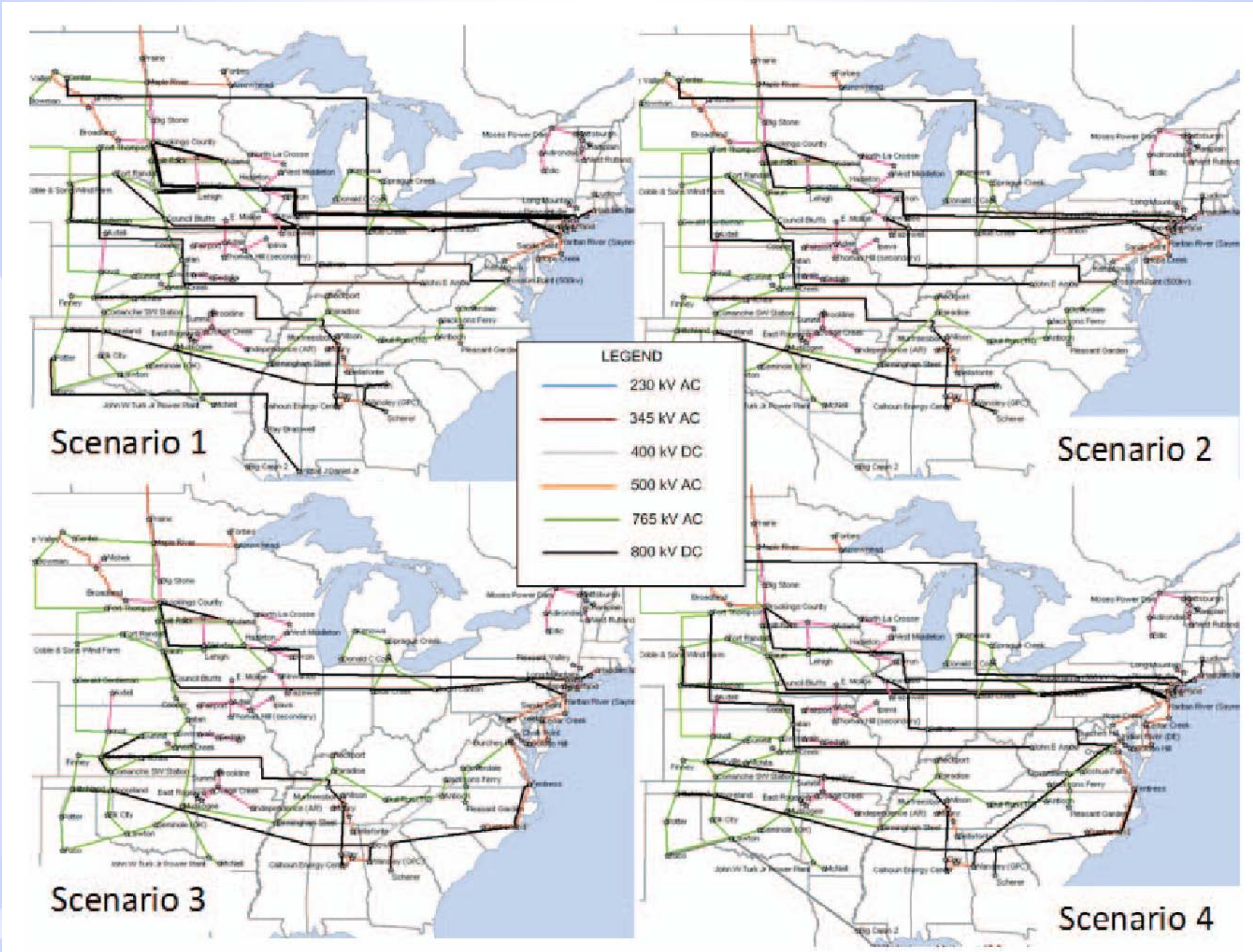
Energy Storage Systems
Different system work best for different usages



Transmission System Limitations

- The transmission grid was never intended to move large amounts of power extremely long distances.
- To support significant renewable power, the grid will need to be reinforced with overlays.
- Significant addition of EHV AC or DC transmission from the generation locations to the load centers.
  - Off-shore wind power from the coasts
  - On-shore wind power from the plains
  - Solar from the desert southwest
- The spinning reserve for grid stability could be reduced.

Green Power Super Highway



Source: Eastern Wind Integration and Transmission Study, January 2010, NREL

Overlay Costs & Issues

- Costs of the system (through 2024 to support 20% renewable)
  - The eastern grid will require $65 and $93 billion dollars will be needed in addition to $30 billion in upgrades to the existing system.
  - ERCOT will require investment of over $5 billion within Texas
  - $60 million is currently being spent to evaluate costs on the western grid. Its expected that costs will be similar since load is nearly as remote from the generation.
  - Total costs in the range of $200 to $300 billion for reinforcement to move renewables around the country.
- Obstacles to the deployment of the grid overlay
  - No mechanism to support the funding and development is in place
  - A new federal siting authority would be required.
  - Integrated system coordination between the over 100 balancing authorities would need to make the system work.

Environmental Concerns for Renewables

- Large majorities of the population are in favor of renewable when they are polled by industry groups
- Resistance to renewables seems to be inversely proportional to the distance the generation is from the individual involved.
- Every project faces resistance from neighbors when they are sited.
- Add in the challenges of siting transmission and the resistance increases.

Even renewables have NIMBY problems (recent examples)

A group that is identifying California renewable zones will need to go back to the drawing board in light of Senator Dianne Feinstein's plans to introduce a bill aimed at protecting thousands of acres in the Mojave Desert. The bill could thwart plans for thousands of megawatts of large-scale solar and wind projects. (Electric Utility Week, 30 March 2009)

The Massachusetts developer last week won a significant victory when a state board used its authority to supersede a local commission that had denied Cape Wind a permit to build transmission. In a tentative decision, the state Energy Facilities Siting Board overrode the Cape Cod Commission, which had rejected the project's application to build a 115-kV cable under water and land to connect the 130 offshore turbines to the grid. The commission had ruled in October 2007 that Cape Wind failed to provide enough information, a decision Cape Wind supporters called a mockery because the project had generated 50,000 pages of data over 32 months. (Global Power Report, 19 March 2009)

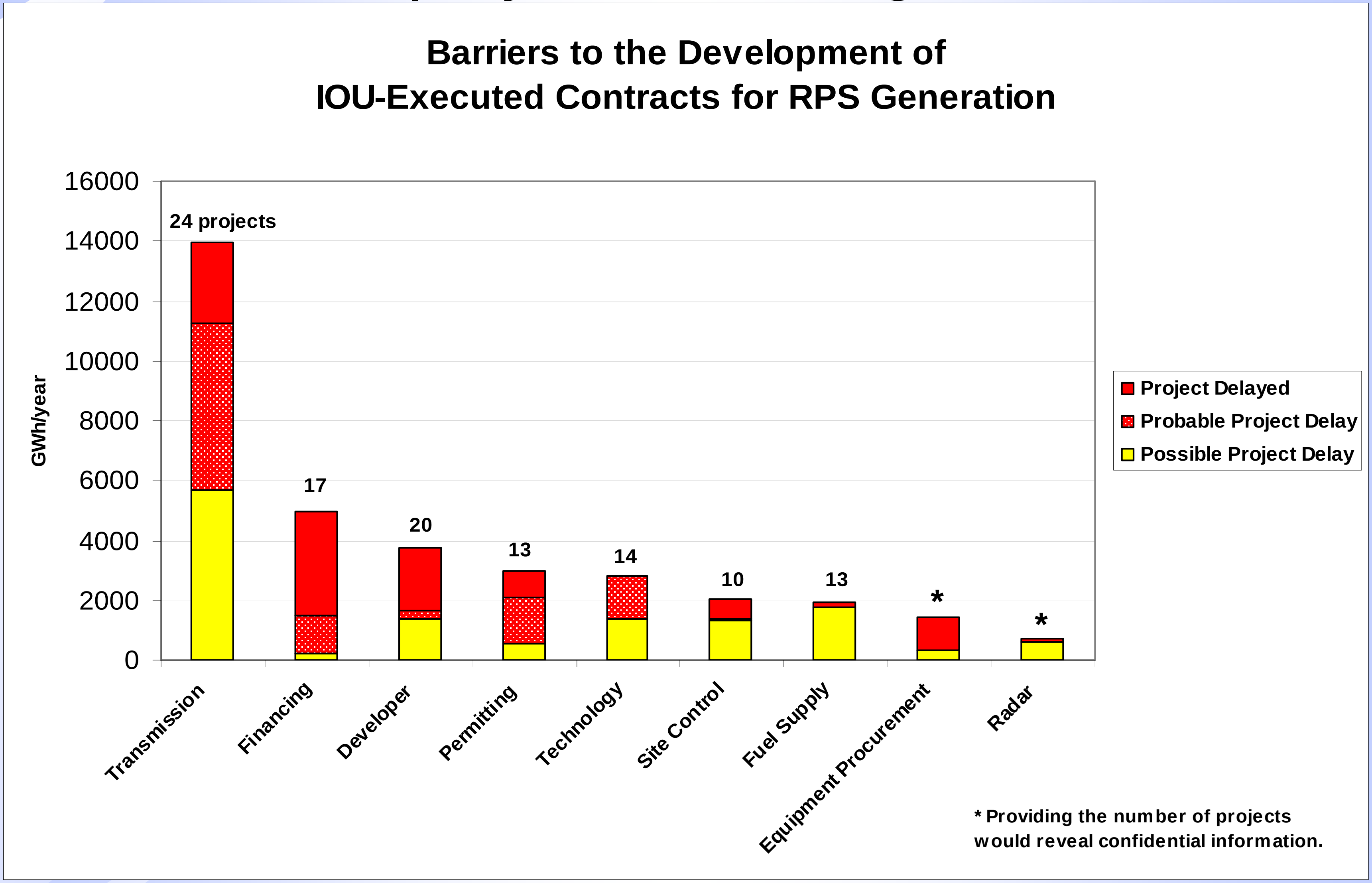
(Mar 4, 2010- McClatchy-Tribune Regional News - Nancy Madsen Watertown Daily Times, N.Y.)

Opponents of a proposal for offshore wind power projects raised a rallying cry at a meeting Wednesday night at the H. Douglas Barclay Courthouse. The members of the public gave economics, wildlife and viewshed as reasons to oppose the New York Power Authority's inclusion of eastern Lake Ontario as a possible site for turbines.

"I can't believe we're even sitting here tonight and discussing this thing," said James L. Jerome, president of North Rainbow Shores Association, Sandy Creek. "This is destroying and prostituting our whole environment."

NYPA asked developers in December to submit proposals to build up to 500 megawatts of wind power, possibly spread out over several potential sites, including 10 sites in Lake Ontario and 13 sites in Lake Erie. Those sites were chosen in part because they have average wind speeds of at least 16.8 mph, have water depths of less than 150 feet and lie 2.3 miles or farther offshore.

Renewable projects challenges



Source: California Public Utilities Commission

Why don’t we build more Renewables?

- Although fuel costs are nil (or minimal for biomass), capital and O&M costs are high – at this time the cost of renewable power is not generally competitive with thermal power.
- Financing of projects is difficult if technology is unproven, costs are uncertain, off-take price is not guaranteed or delivery method is complex.
- Cannot store either “fuel” or power – cannot provide base load power. Intermittent nature of resource cannot be compensated by building more capacity.
- Current development locations require new transmission systems, which is costly and presents significant and design siting challenges.
- Environmental concerns related to certain lands and locations are limiting growth (siting driven by location of renewable resources). The use of more local renewable sources are being protested by those they would serve.

Transportation Energy Usage

Transportation Energy Facts

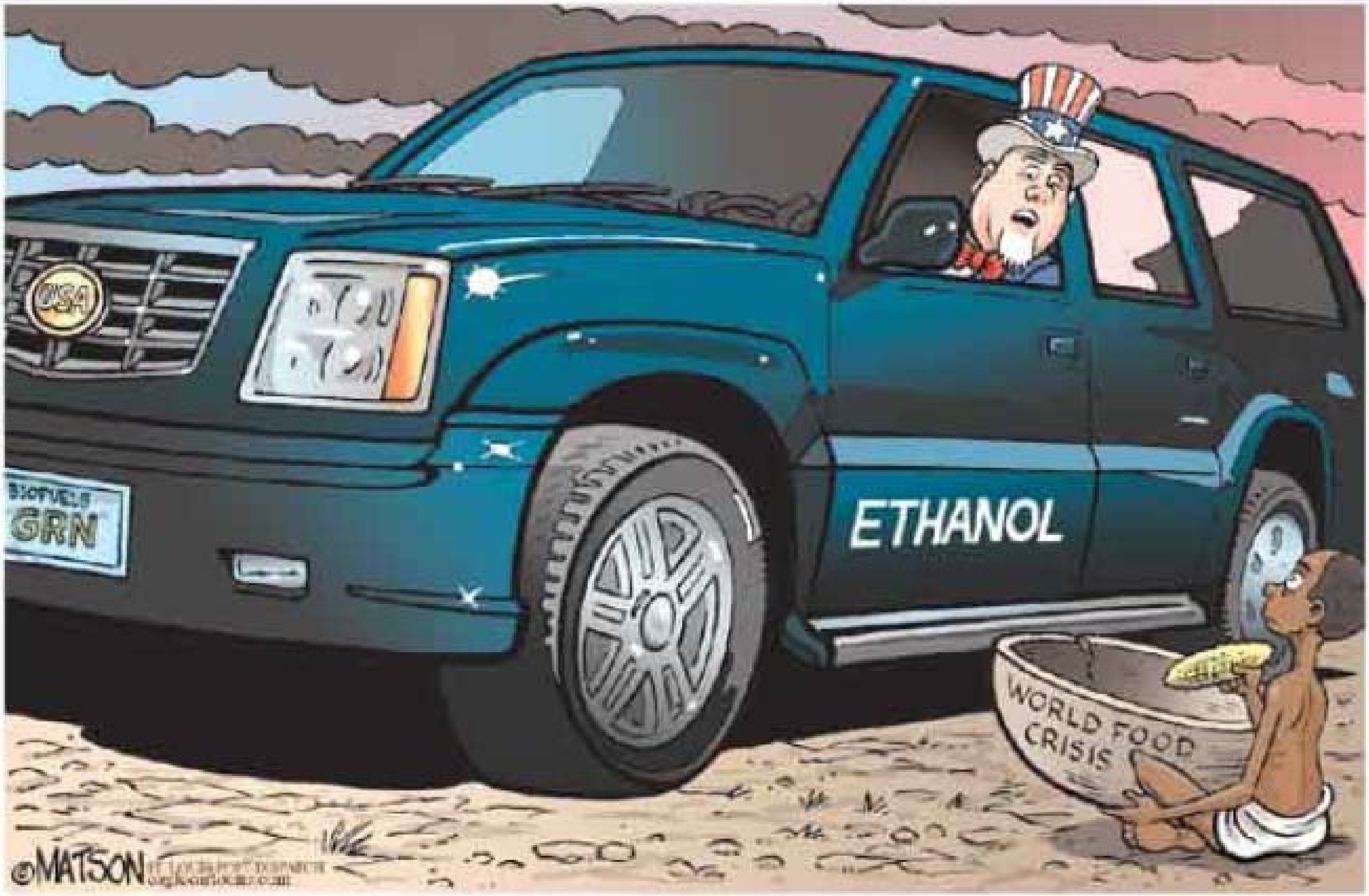
- Over 28,000 trillion BTU's of energy were used for transportation in 2007.
- Over 1/3 of all GHG emissions come for the transportation sector.
- Nearly all of the liquid petroleum usage in the US is for transportation (over 94%).
- The electric power industry uses almost no imported energy (less than 2% of energy used).
- This is what is often referred to as our dependence on foreign energy (28% of all energy used is for transportation).

Facts taken from: Transportation Energy Data Book: Edition 28

Transportation Realities

- Highway transportation (Cars(60%), trucks (19%) and buses(1%)) use 80 % of the transportation fuel.
- 20% is used for rail and air transport, electric is not viable.
- Bio-fuels currently supply 3% of US transportation energy and cannot be expanded much beyond 5% without impacting food prices.

Facts taken from: Transportation Energy Data Book: Edition 28



"YOU GONNA EAT THAT?"

Transitioning to Electric Energy for Transportation

- The amount of electrical energy needed to replace the transportation fuel energy equates to 8,206,000 GWh of electricity assuming all transportation vehicles used only electricity. (assumes equal efficiency)
- This would require 720 - 1300MW nuclear units operating 24 hours per day 365 days per year to meet the demand. Clearly, this is not a practical solution in the short term.
  - The US currently has 104 units in service.
  - There are only 440 units in service in the world.
- Renewable energy cannot nearly supply the electricity needed.

Transitioning to electric energy sources

- If the existing electric power generation fleet was used to supply this energy, it only has a reserve available to meet 36% of the total.
  - Existing nuclear and renewable sources are generating at their maximum capability now.
  - The existing coal and gas fleet capability is the only sector that can provide additional capability. This would negate the goal of using electricity for transportation.
- More energy efficient methods of transportation are required.
- Significant behavioral changes are required to reduce emissions and energy consumption in the transportation industry.

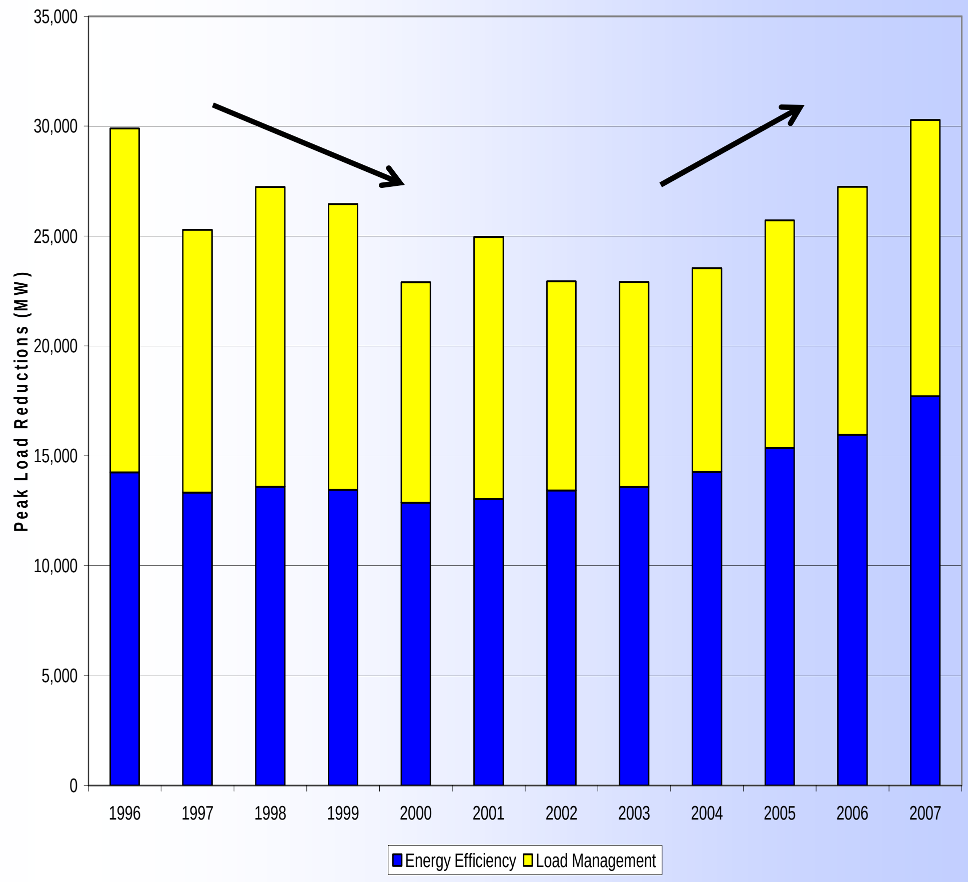
Demand Side Management & Smart Grid

Demand Side Management complements and supplements other approaches

- Energy efficiency reduces energy consumption and demand peaks.
- Load management reduces system load factor.
- This delays the need for new generation and transmission system upgrades.
- Historically, this requires investment and policies by utilities and governments on state or national scale.
- It is difficult for individual users to measure savings needed to justify significant investment.

DSM results decreased due to deregulation, have since recovered and are growing

- DSM <2% of total generation, but offsets peak power
- DSM costs:
  - $30/MWh avg (EIA)
  - $0 to $50/MWh (Lazard)
  - Other studies in similar range



Source: EIA Electric Power Annual (issued January, 2009)

Smart Grid has 3 Basic Components

1) Real time pricing of power.
   - *Users can shift to off-peak power*
2) Communication between grid operations and end users.
   - *Advanced appliances will be able to communicate with the utility allowing automated control of operation to avoid high price periods.*
3) Communication between generators and grid operations.
   - *Potentially, peak loads on the grid will be reduced.*
   - *Lower pricing for off peak service saves consumers money.*
   - *Peak load reduction delays the need for new generation.*

Smart Grid will require Smart Consumers

- Consumers will need to treat electric usage differently.
  - Smart users should be able to save money by shifting usage of electric power to off peak times
  - Business as usual customers will probably find that their energy costs will increase.
  - Automation will likely be required.
- Significant investment in new appliances *(refrigerators, air conditioners, space heaters, dishwashers, etc.)* will need to occur.
- Design changes in some appliances *(computers and TVs consume energy in sleep mode)* will be required.
- All of the above will take time. How long? Probably decades before significant change occurs.

What have we learned from this information?

Major Electric Industry Issues
A More Realistic View, early 2010

- Global Climate Change discussions are removing the option of low cost fossil fuel generation from the decision making process, but the linkage between fossil fuels and temperatures is tenuous and we cannot readily achieve the goals being proposed.
- Renewable energy sources are not currently able to meet the needs of consumers with the availability needed to provide reliable energy.
- Local issues with locating and permitting new transmission and renewable power generation have become increasingly more difficult.
- "Smart Grid" initiatives have begun with advanced metering but won't achieve their objectives unless "Dumb Appliances" are replaced and consumers become more educated.
- Transportation using electric power will require significant additional investment to become viable and only then with significant behavioral changes in how we move people and things around the country.
- Electric power generation uses very little imported fuel and changes will not significantly change the amount of imported energy in the near term.

What are we left with?

- The age of cheap electric energy will have to come to an end to achieve the CO_2 goals
- Electricity and transportation will cost significantly more than they cost today with the current plans.
- Significant behavioral changes will be required in all segments of society to achieve any significant reduction.
- To achieve significant CO2 reductions, all segments of society will be impacted.
- Some tough choices are required in the near future to allow renewable deployment to support legislation.
- Engineers will be critical to the development and deployment of these technologies.

An ancient Chinese curse says:

May you live in interesting times.

I think that we may.

Thank you for your kind attention