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Charting a Course to Energy Independence

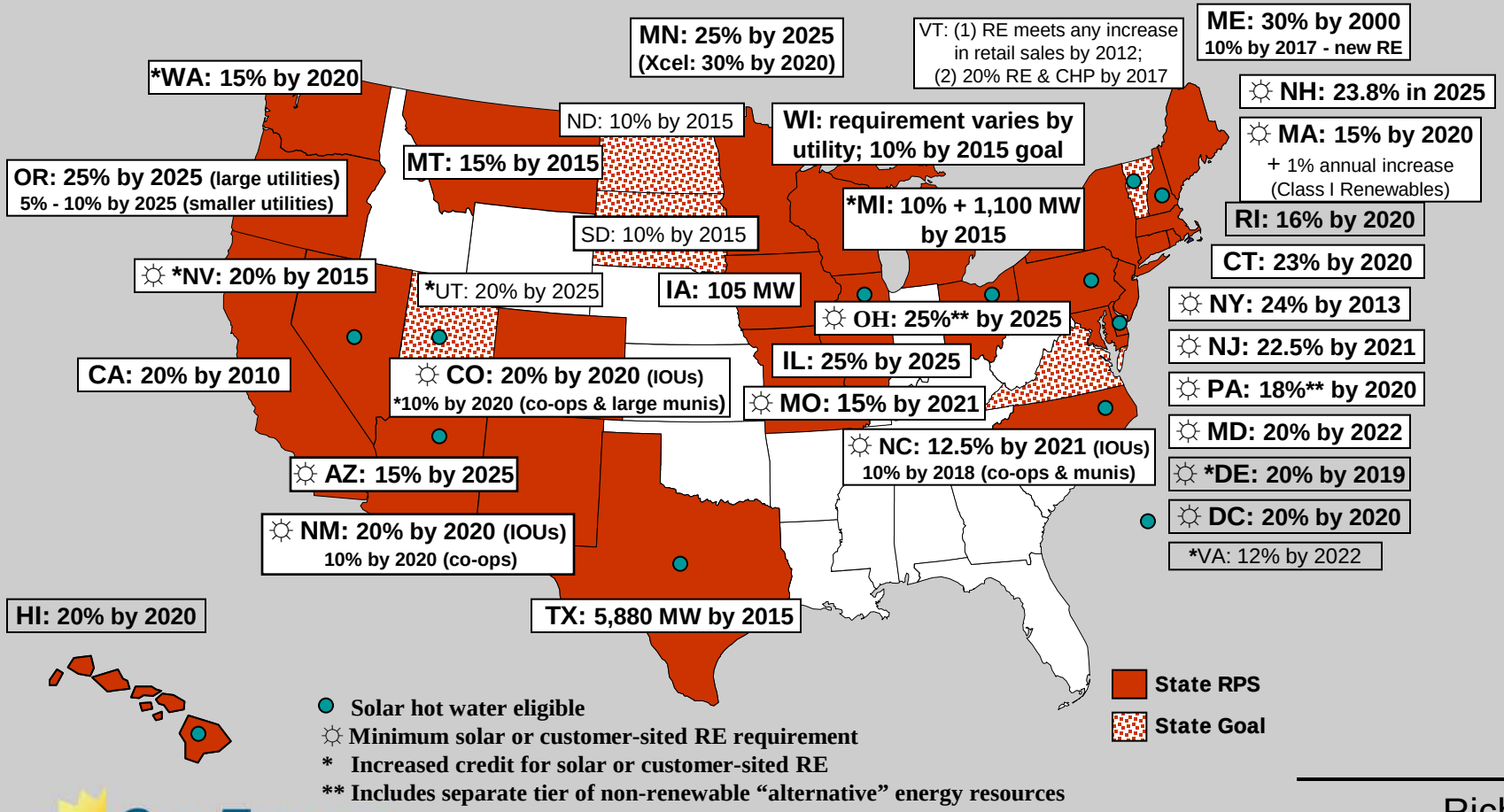
Providence, RI
August 9-12, 2009

Agenda

- Current status of renewable and market drivers
- Opportunities and challenges for the future
- Selected observations

There is increasing policy support for renewables at both the state and….

Renewables Portfolio Standards



- ● Solar hot water eligible
- ☼ Minimum solar or customer-sited RE requirement
- * Increased credit for solar or customer-sited RE
- ** Includes separate tier of non-renewable "alternative" energy resources

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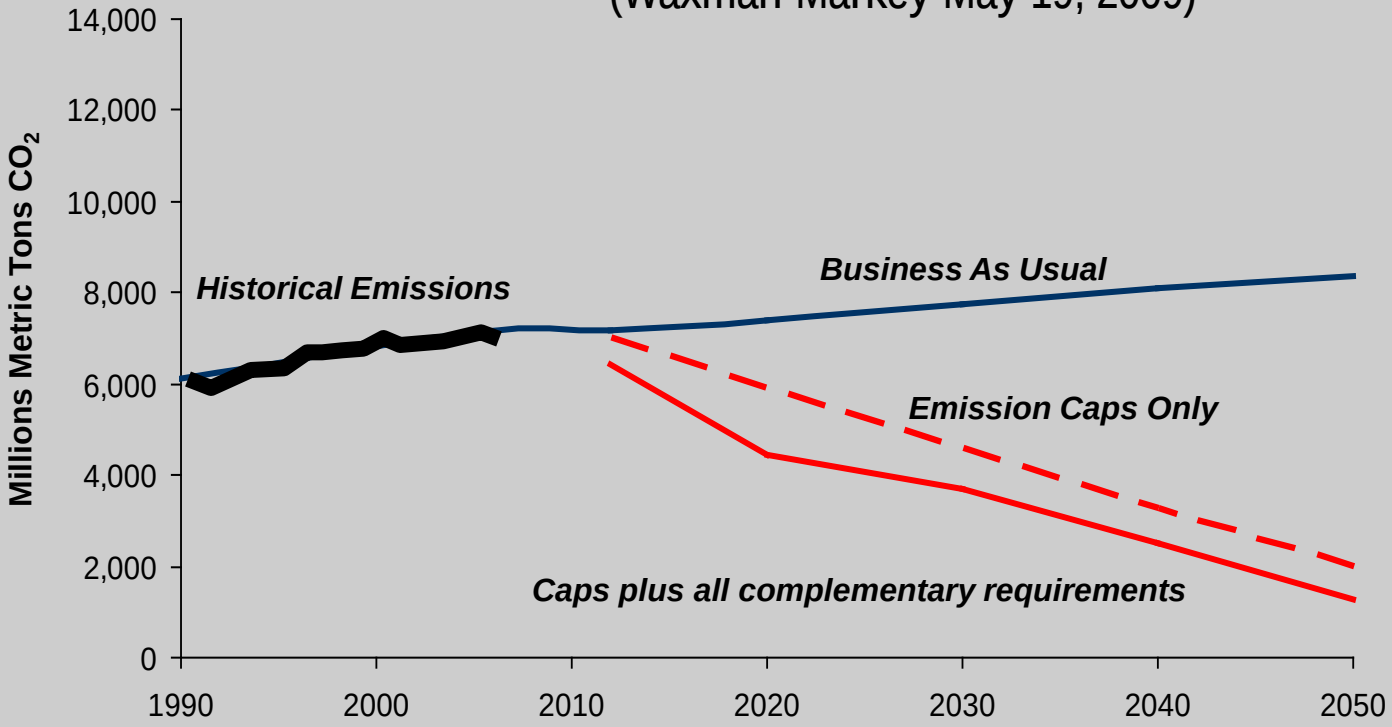
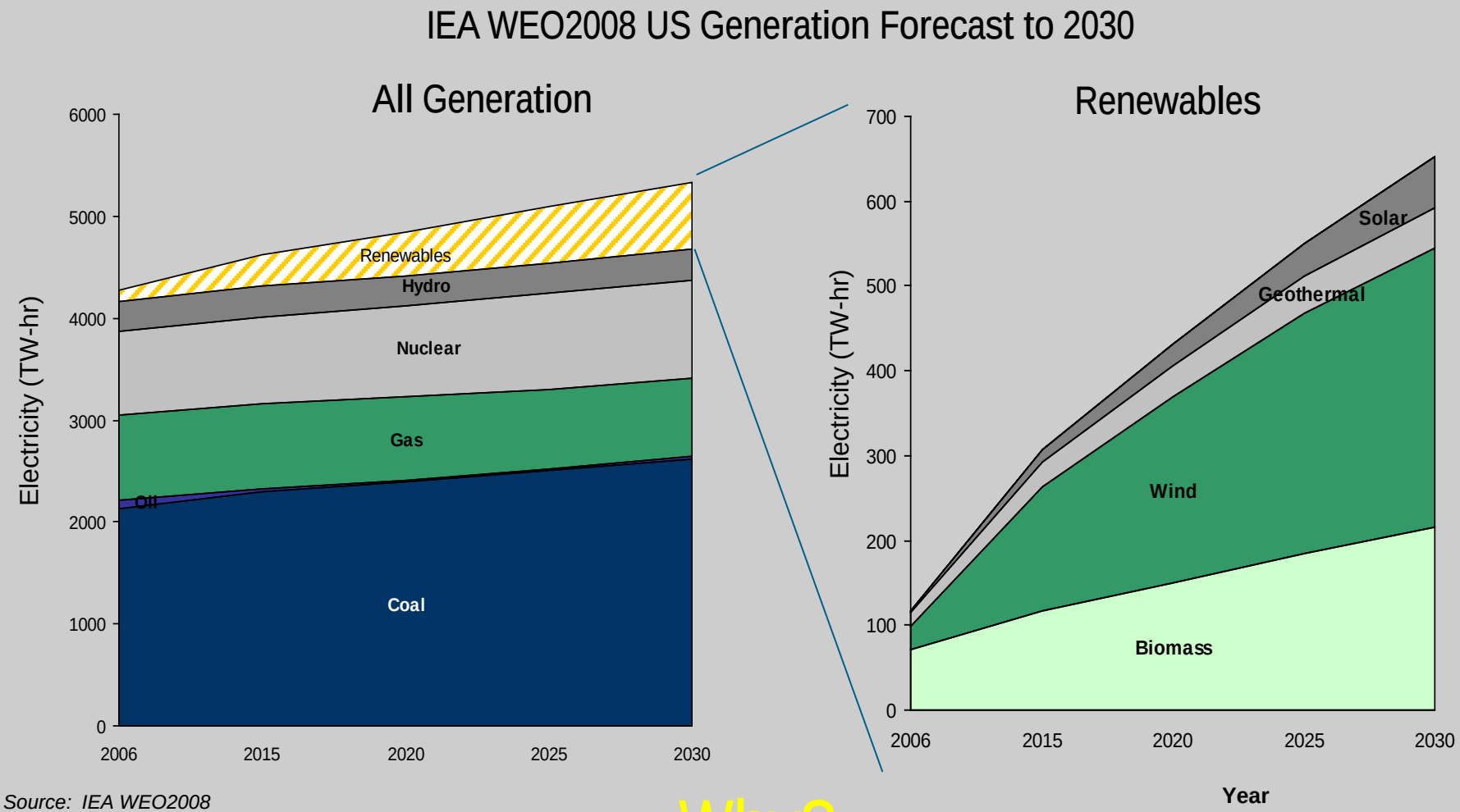
…Federal level with bills such as Waxman-Markey and the Senate's ACEL Act of 2009 that includes a national RPS

Estimates of Total GHG Emissions and Emission Reductions Achieved by H.R. 2454 the American Clean Energy and Security Act (Waxman-Markey May 19, 2009)



Sources: World Resources Institute; Booz Allen Hamilton Analysis

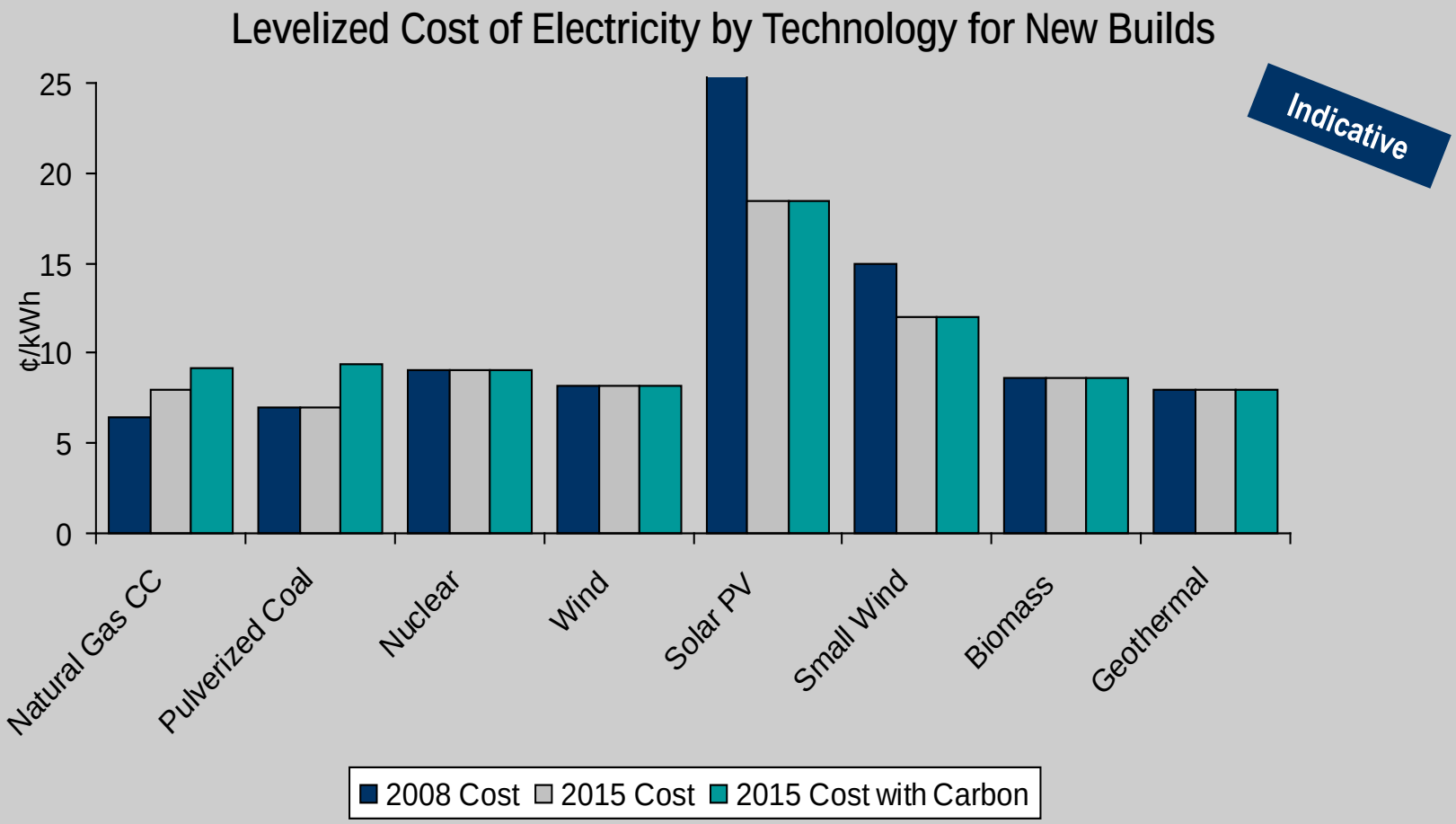
With this support renewables are a only relatively small percentage of the US electricity supply and will likely remain so through 2030



Source: IEA WEO2008

Why?

First, economics are, in general, neutral to unfavorable relative to coal and natural gas even with carbon pricing



Note: Carbon Price = $30/tonne of CO2, Natural Gas Price = $7/MMBTU in 2008 & $10/MMBTU in 2015

Solar PV for distributed applications also faces unfavorable economics when compared to retail prices in many markets

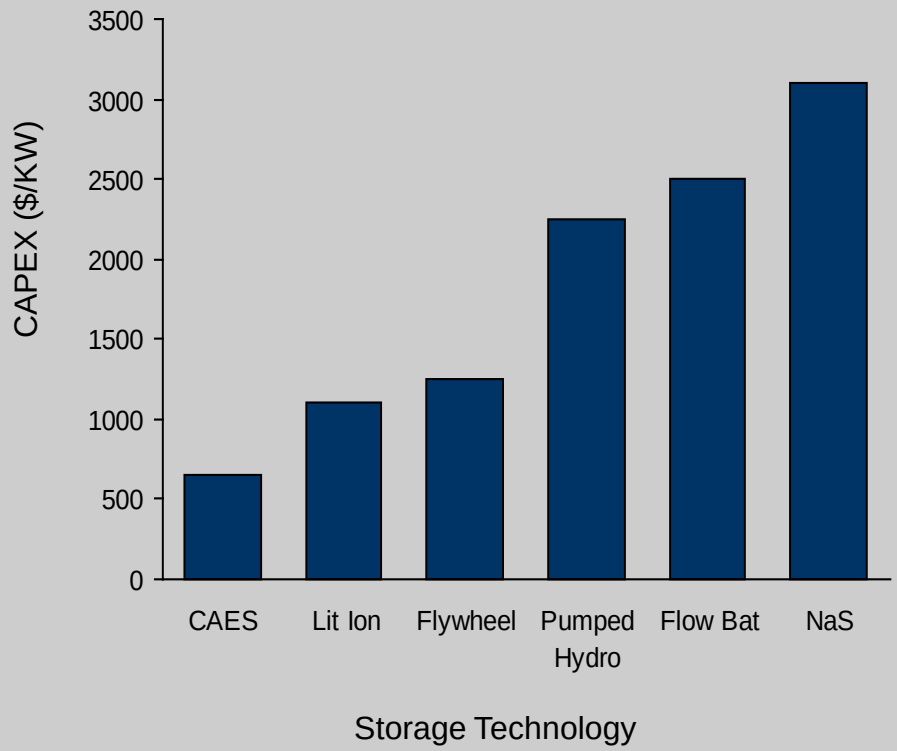
Location	Base Cost ($/kW)	Investment Cost with State and Federal Incentives in 2007 ($/kW)	Local Electric Price ($/kW-hr)	Annual Savings	Simple Payback (years)
New York (Albany)	$7200	$3067	$0.14	$168.13	18
Florida (Miami)	$7200	$3067	$0.09	$120.53	25
Arizona (Phoenix)	$7200	$3067	$0.085	$137.45	22

Note: Average American homeowner stays in the same house about 8 years

Sources: US National Renewable Energy Laboratory PVWATTS PV Cost Tool, Booz Allen Analysis

Intermittency also negatively impacts wind and solar and, in the US peak wind tends to be counter cyclic with peak demand

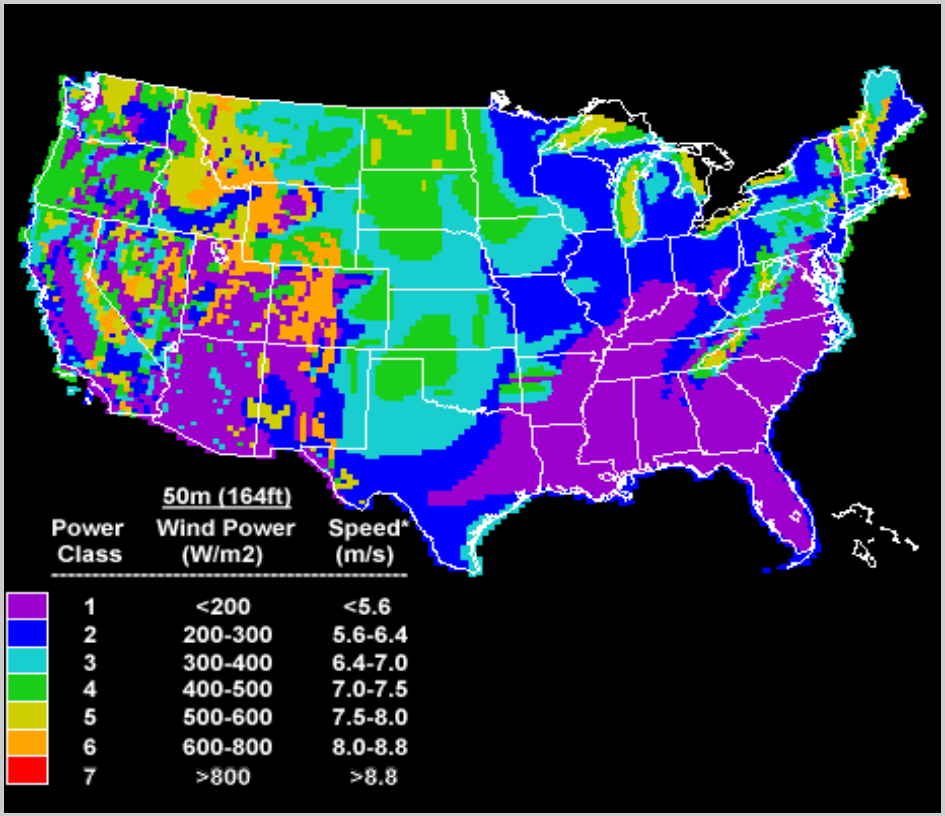
Intermittency can be mitigated with energy storage but costs are increased

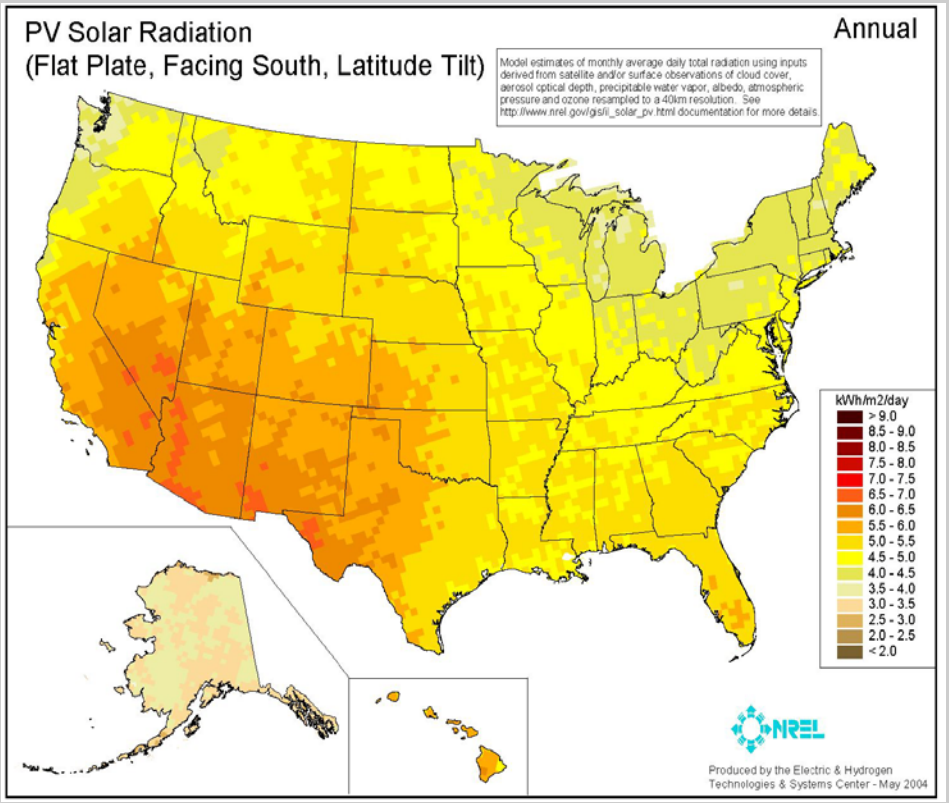


Comments

- Most published reports on the cost of wind power neglect the cost of backup power to account for the low capacity factor- around 30%
- While there is work being conducted to improve the forecasting of wind power generation the best results to date are measured in minutes ahead not the hours needed to control the grid
- Smart grid technology will mitigate the negative impacts of intermittency with respect to grid stability- it will do little to curb the need for backup power

Also, the quality of renewable resources vary widely across the US and in many cases is not located near demand





What are the developments needed to increase the uptake of renewables?

Needs

- Lower costs of electricity from renewables
  - Improved performance
  - Decreased investment
  - O&M costs
- Improved dispatchability
  - Lower cost energy storage
  - Improved forecasting of wind and cloud conditions
  - Improved grid response and stability to intermittency
- More transmission infrastructure connecting renewable resources to demand

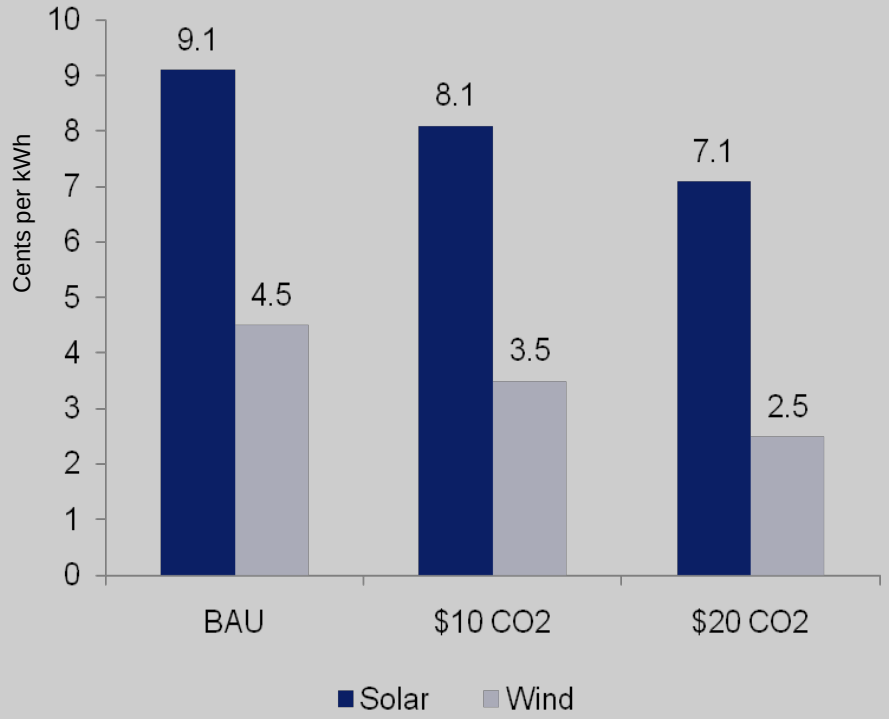
Levers

- Technology innovation
- Economies of Scale- learning curve
- Infrastructure Investment
- Policy/regulations

What Does the Future Look Like?

Breakeven generation costs come down across the board in any scenario with a carbon price

Indicative Break Even Cost by Generation Type

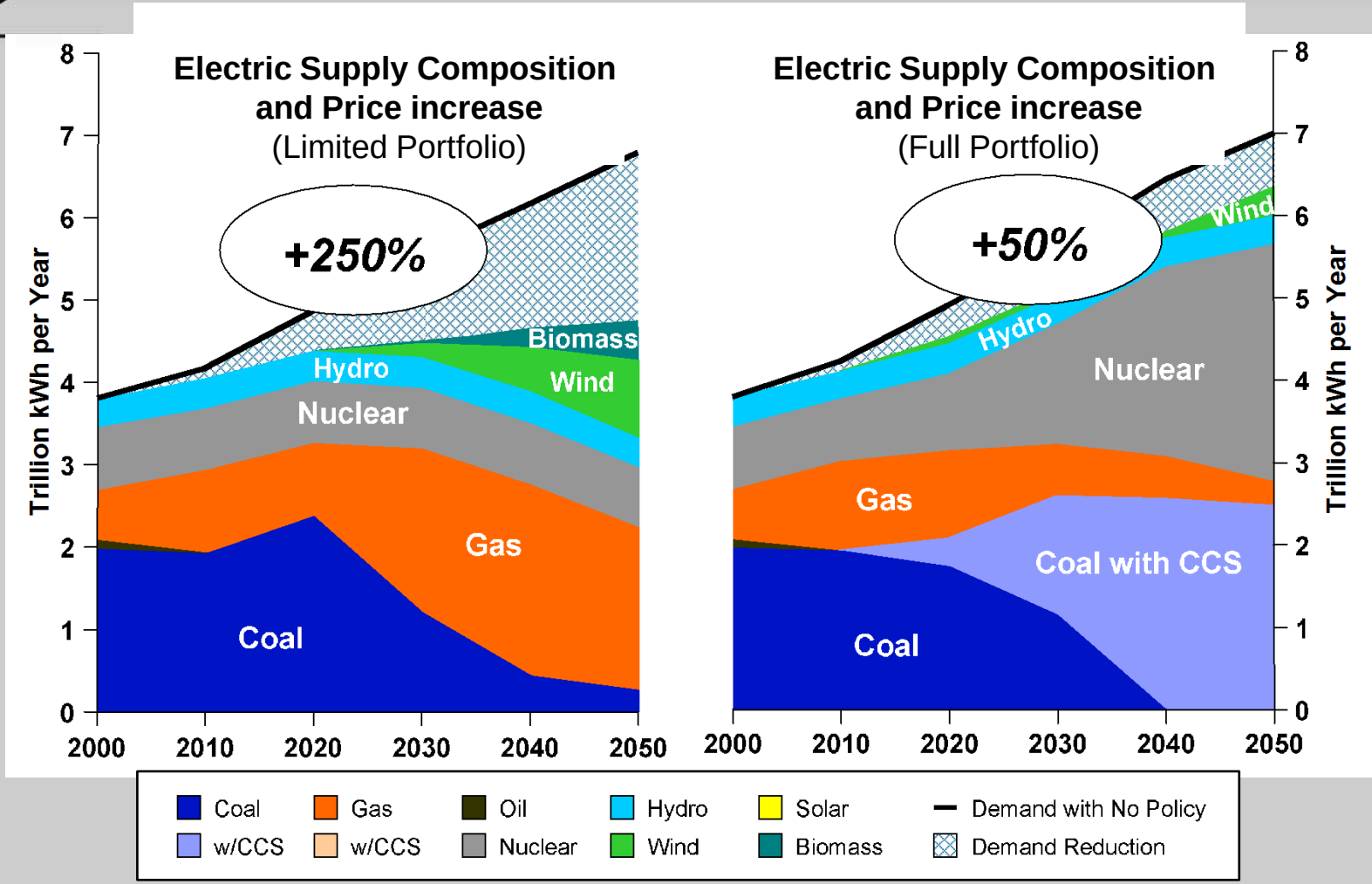


Discussion

- Any carbon price is effectively an incentive for all renewable development currently contemplated with emissions less than natural gas
- Economic advantages will create opportunities for greater development of these asset classes
- Any mitigating policy on the CO2 producing electric supply, such as a safety valve, will reduce impacts of CO2 prices on Renewable power breakeven costs

Assumptions: 20% and 27% dispatch factor , $1.00 and $3.00 /MWh variable O&M, $17,000 and 30,000 Fixed O&M and $3.5MM and $1.75 MM capital cost per MW for Solar and Wind respectively
BAU = Business as Usual
Source: Booz Allen Carbon Wargame

Power Prices Could Significantly Increase Under Carbon Constraints



Source: EPRI

EPRI estimated that power prices could increase over 250% to meet CO2 targets without CCS and increased use of nuclear power

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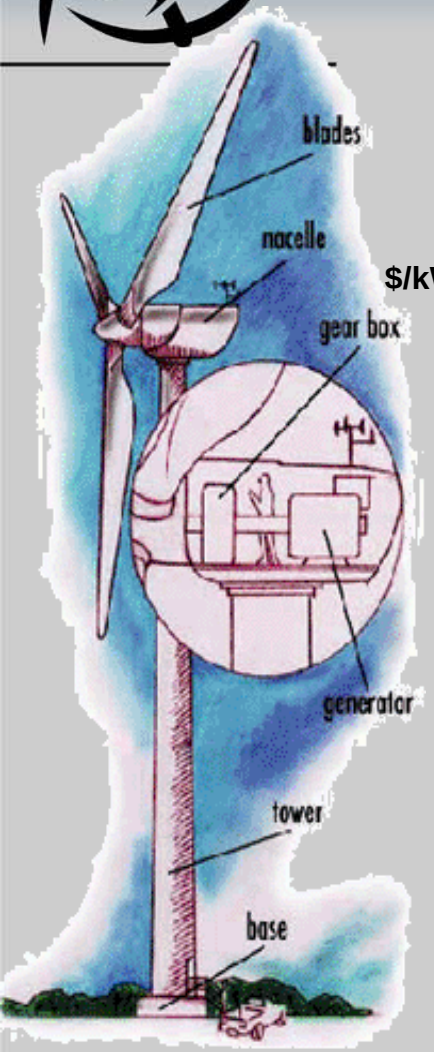
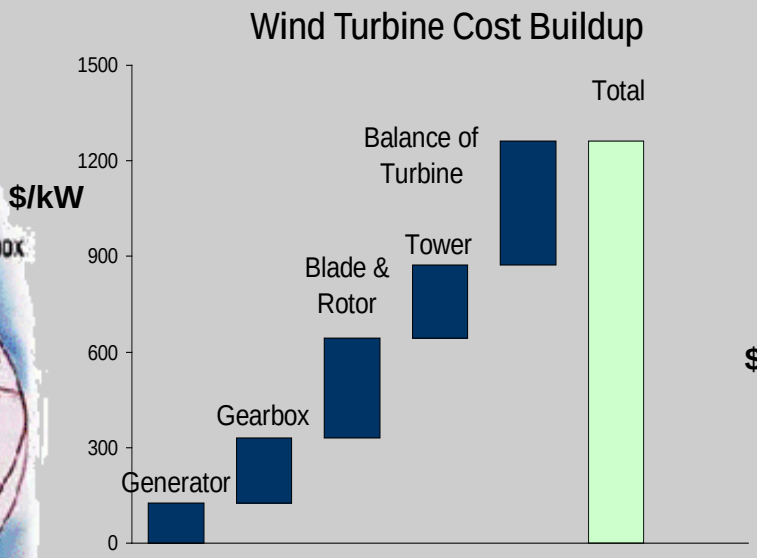
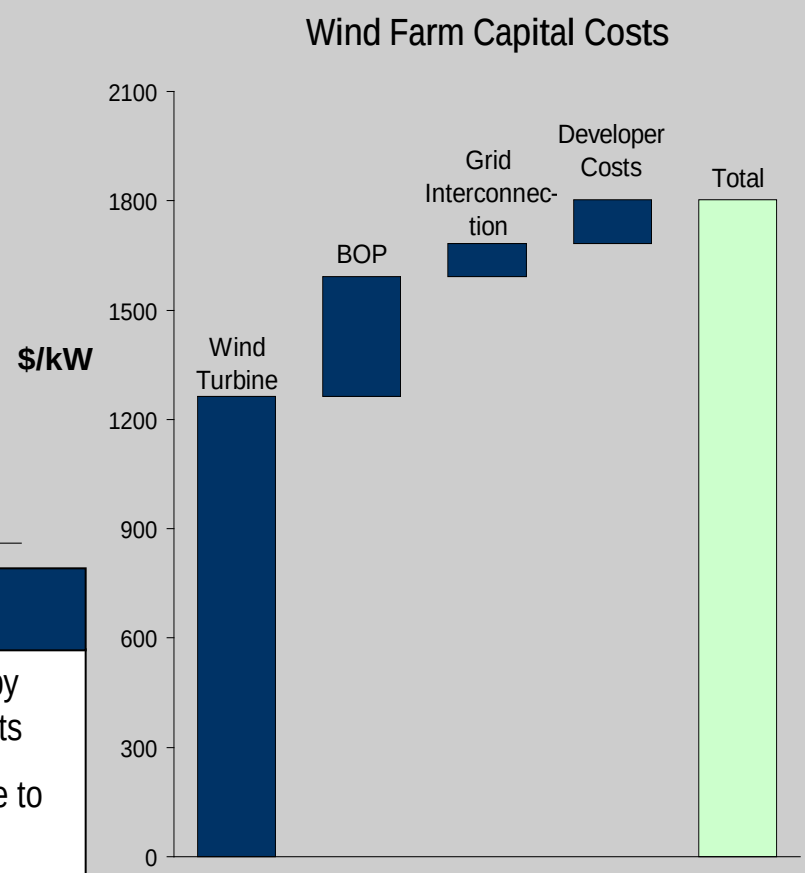
Large Scale Wind power is a relatively mature and cost competitive technology but has limited opportunity for technology innovation to dramatically lower costs



Typical Wind Turbine Configuration





Note: [1]Booz Allen Estimate
Source: EU, MADE Consulting, MTC, Booz Allen Analysis

Comments

- 45% price increase 2004-2007 driven by commodity prices and supply constraints
- Supply constraints are ameliorating due to increased production capacity and decreased demand
- Wide spread deployment leaves little room of additional cost reductions due to learning curve impacts

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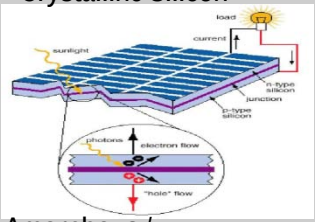
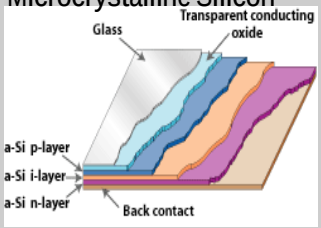
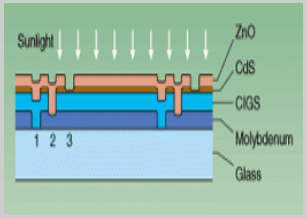
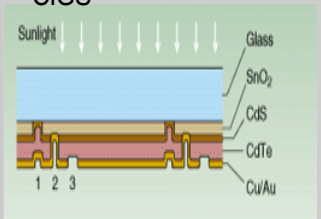
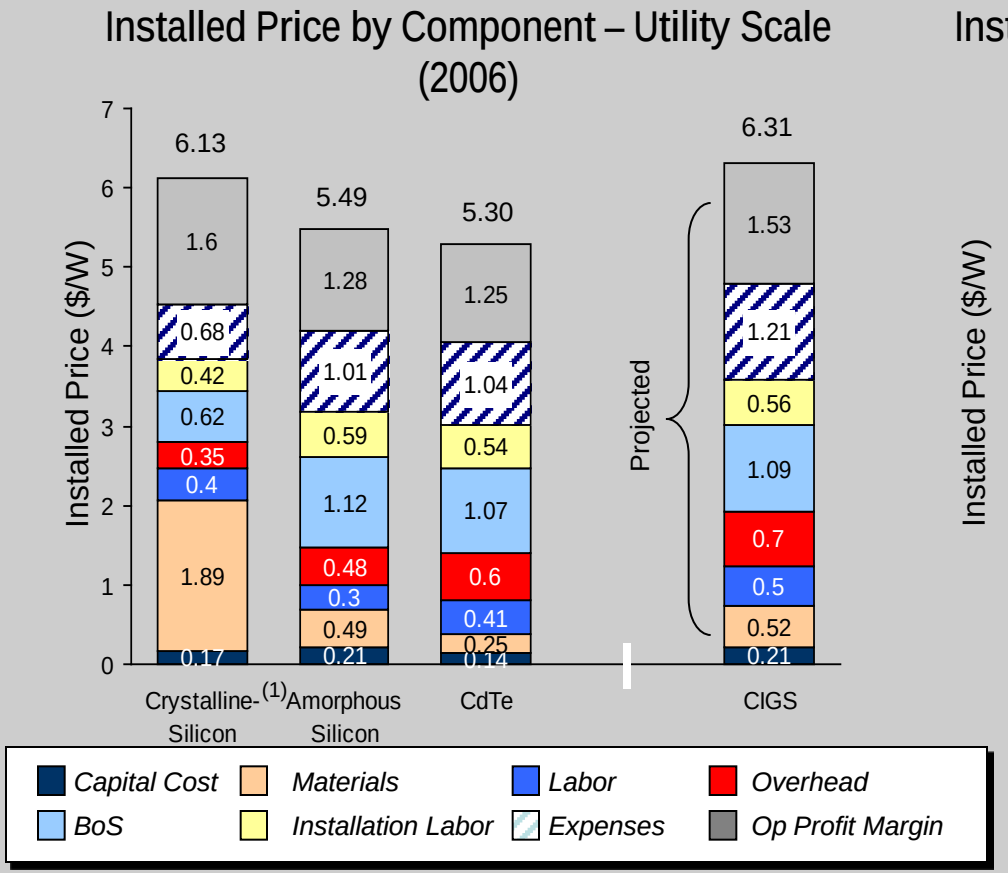
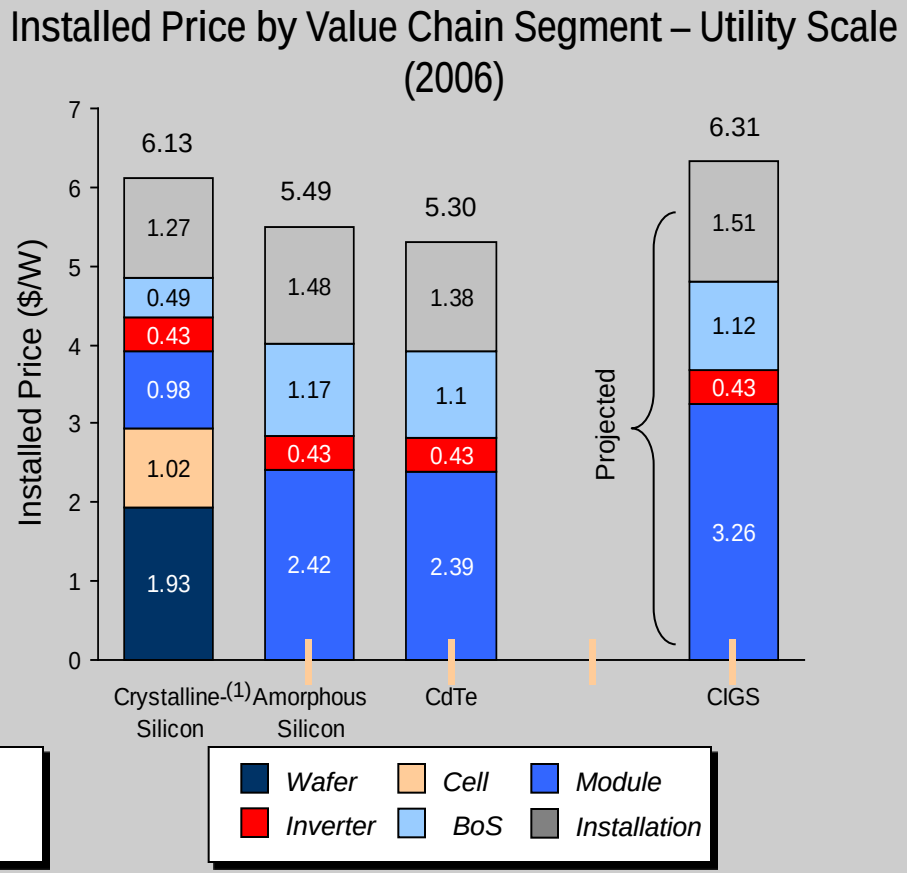
There are several commercially available alternative solar PV technologies

	Pros	Cons
Crystalline Silicon 	▸ Highest commercial efficiency ▸ Proven manufacturing process ▸ Proven durability ▸ Preferred application: All applications	▸ Constrained silicon feedstock supply ▸ Higher manufacturing costs compared to thin film
Amorphous / Microcrystalline Silicon 	▸ Inexpensive feedstock ▸ Better output at low light levels compared to crystalline ▸ Can use rigid or flexible substrates ▸ Preferred application: BIPV and ground mount	▸ Low efficiency factors and exhibits degradation over the years ▸ Flexibility limited ▸ Manufacturing high efficiency/low degradation modules increases complexity and cost ▸ Durability unproven
CdTe 	▸ Presence of a strong leader in the industry sub-segment ▸ Proven low cost manufacturing process ▸ Preferred application: Utility	▸ Cadmium poses health risk introducing manufacturing risks as well as a need to be properly disposed of ▸ Tellurium is a rare material current ▸ Currently uses glass as deposition surface in commercial applications ▸ Durability unproven
CIGS 	▸ Highest efficiencies of thin film technologies ▸ Exhibits little degradation over time ▸ Can use rigid or flexible substrates ▸ Potential for low-cost roll-to-roll processes ▸ Preferred application: All applications	▸ Indium is a rare element; production beyond requirement for 8 -10 GW per annum would cause price increase ▸ Durability unproven ▸ No large scale manufacturing yet

Thin film technologies have taken the lead in price competitiveness





(1) Multi-Crystalline Silicon module

Note: See next page for assumptions. Operating Profit margin defined as price – operating expenses – depreciation before interest and taxes; Cost includes purchase of previous value chain step through module and for installation

Sources: Prometheus, Photon Consulting, NREL, Company Reports, Interviews, Booz Allen analysis

In the near-term a number of cost reduction pathways are available to the major PV technologies

Cost Reduction Pathways (2007-2012)

Crystalline Silicon	▸ Decreased waste (smaller kerf) in wafer slicing ▸ Increased yields due to improved process control and quality ▸ Lower Silicon (Si) cost due to increased supply ▸ Evolutionary cost reductions- technology-based step changes unlikely
Microcrystalline / Amorphous Silicon	▸ Improved yields and increased efficiencies with batch processes ▸ Higher materials utilization through improvements in the deposition process ▸ Higher yield improves capital efficiency ▸ Three junction design significantly improves efficiency ▸ Potential to adopt LCD display technology to lower costs for glass substrates ▸ Potential for roll-to-roll continuous processes in mid-term to long-term (2012 or beyond)
CdTe Thin Film	▸ Improved yields and increased efficiencies with batch processes ▸ Standardization of batch processing equipment across manufacturers giving economies of scale ▸ Increase form factor to improve efficiency and uniformity of deposition ▸ Potential for roll-to-roll continuous processes in mid-term to long-term (2012 or beyond) ▸ Heighten efficiency/uniformity to improve form factor and efficiency
CIGS Thin Film	▸ Lower cost manufacturing with potential near term (2008-9) breakthrough with roll to roll continuous process ▸ Improved yields and increased efficiencies with batch processes ▸ Engineering nanostructure of the cell ▸ Utilizing large form factors with the ability to cut-up and resort the cells to match electrical properties

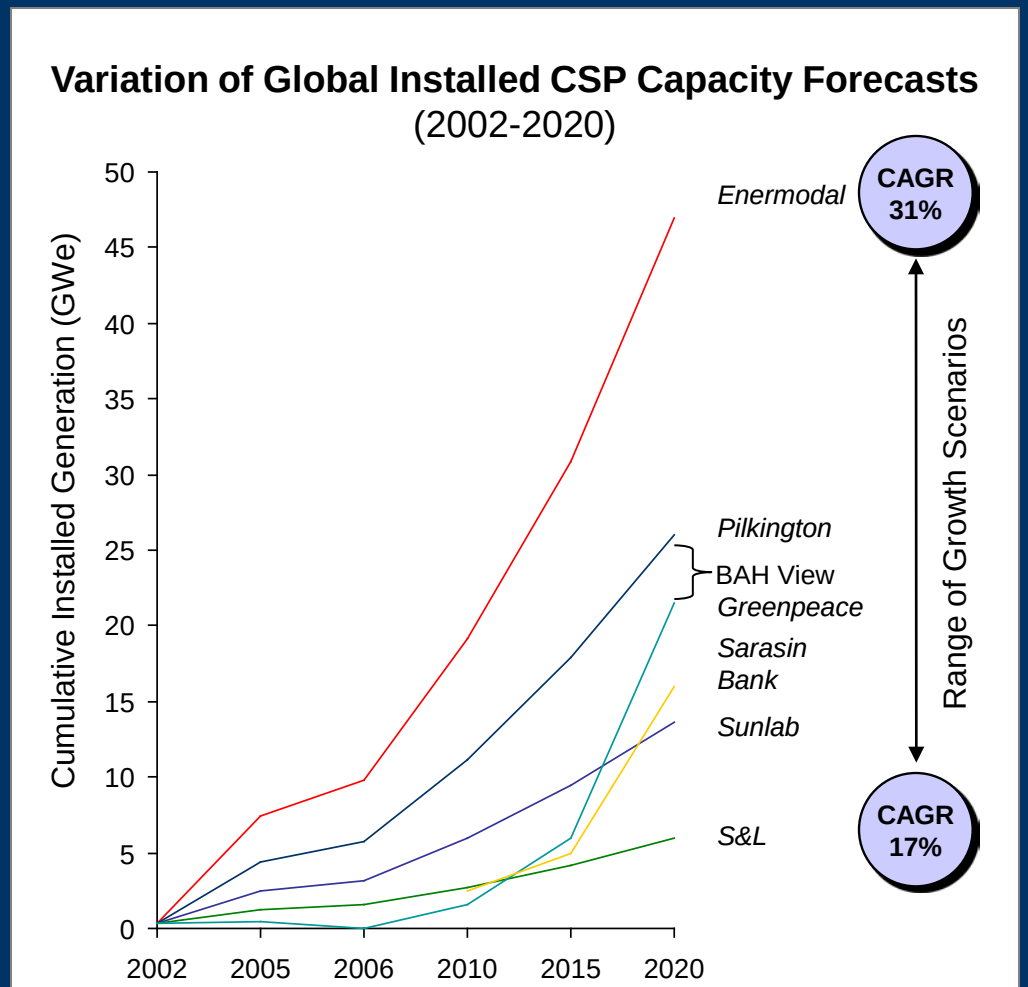
Next generation PV technologies have the potential to be game changers in the medium- to long-term

Examples

Technology	Description	Private and Public Backers	Key Barriers to Commercialization
Inorganic Quantum Structures (quantum dots & rods)	Researchers have found that nanotechnology may greatly increase the amount of energy produced by solar cells. Nanocrystals or quantum dots can increase cell efficiency through a process called "multiple exciton generation (MEG)". Unlikely to be commercial within the next 10 years	▸ Suniva (fka Solarity) ▸ US National Renewable Energy Laboratory ▸ US Los Alamos National Laboratory ▸ US DOE Energy Efficiency and Renewable Energy	▸ Still in the fundamental and exploratory research phase
Organic PV	Organic solar cells and polymer solar cells are built from thin films of organic semiconductors such as polymers and small-molecule compounds. Energy conversion efficiencies achieved to date using conductive polymers are low at 6% efficiency for the best cells to date. However, these cells could be beneficial for some applications where mechanical flexibility and disposability are important. This technology has low materials and manufacturing costs. Potentially commercial within 5 to 10 years	▸ Konarka ▸ General Electric ▸ Solaronix ▸ Shell ▸ Sharp ▸ Sony ▸ Toshiba, ▸ Aisin Seiki ▸ Sustainable Technologies International	▸ Conversion efficiencies are lower than PV thin film cells ▸ Degradation, though if costs fall sufficiently, not necessarily critical

Sources: GreenTech Media, The Venture Power Report, October 2007, NREL, Prometheus Institute

Concentrating Solar Power (CSP) is another option for which significant growth may occur, but will not materially displace traditional power plants



Uncertainty Factors

Regulatory:

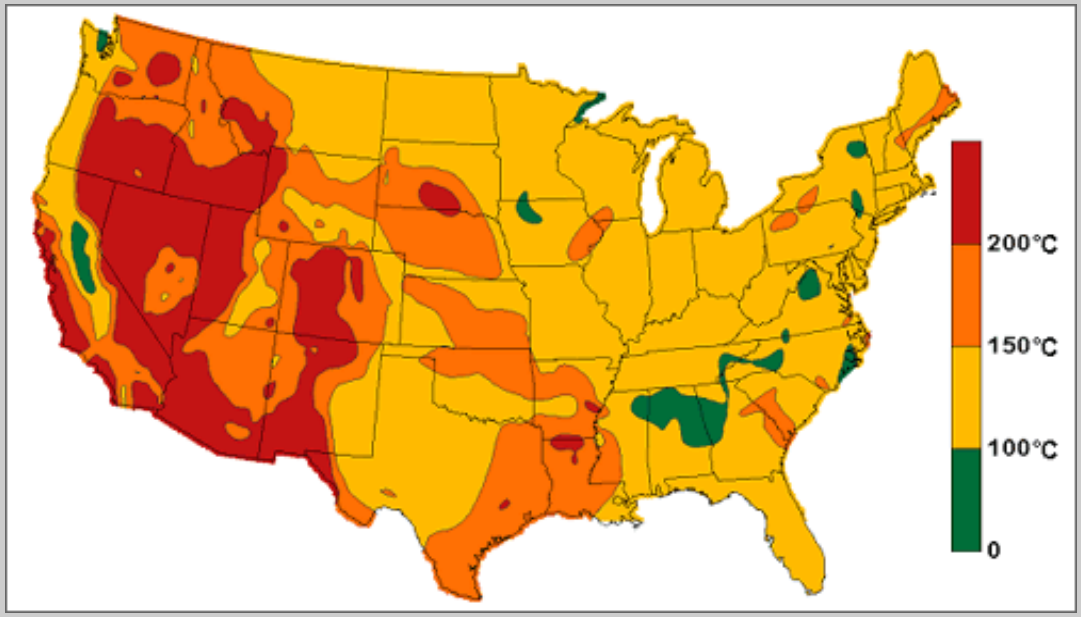
- *Pro-solar regulatory policies being reduced in existing markets or limited at this stage*
- *Anticipated Solar policies not being introduced into new key markets (e.g., middle east, Asia)*

Cost Competitiveness:

- *Grid parity key for major take-off for CSP, but this cost competitiveness strongly dependent on*
  - *Increased price of hydrocarbons*
  - *CSP manufacturing cost reductions*
  - *Increase in CSP efficiency*

Geothermal resources that can be exploited with current technology are limited to the West; new technology can expand this

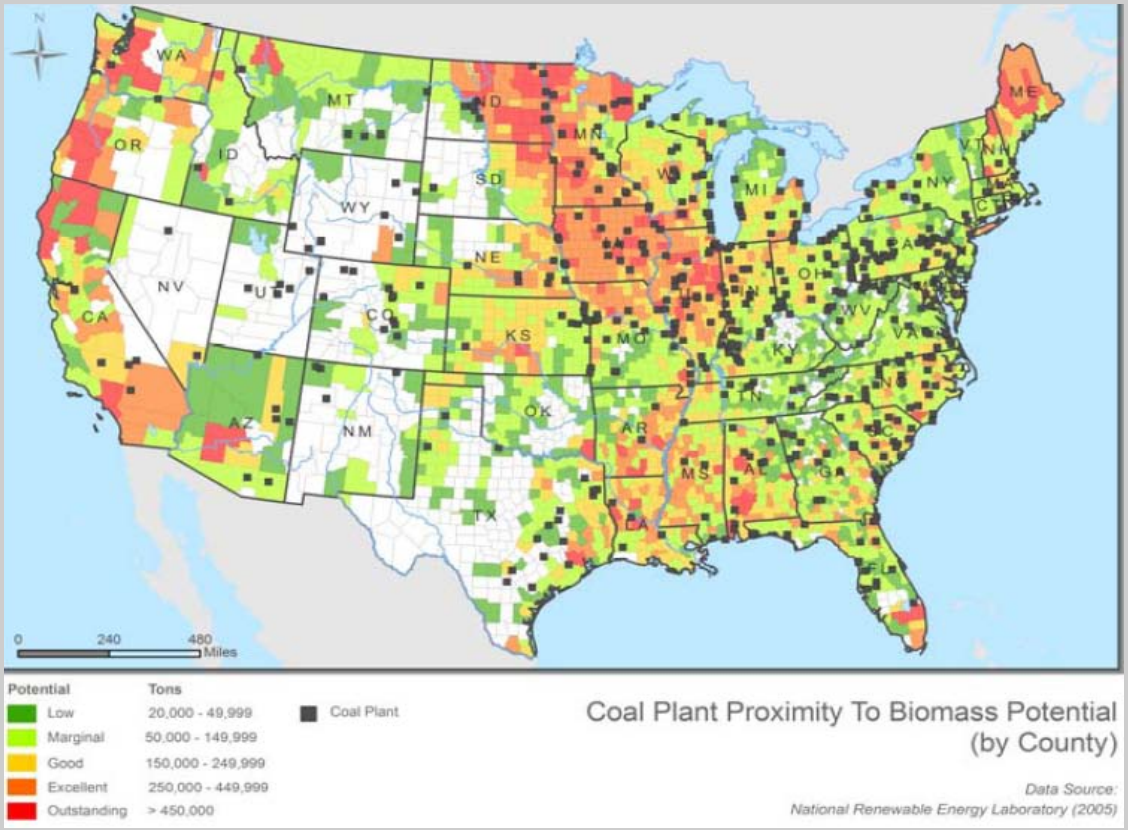
US Geothermic Resources



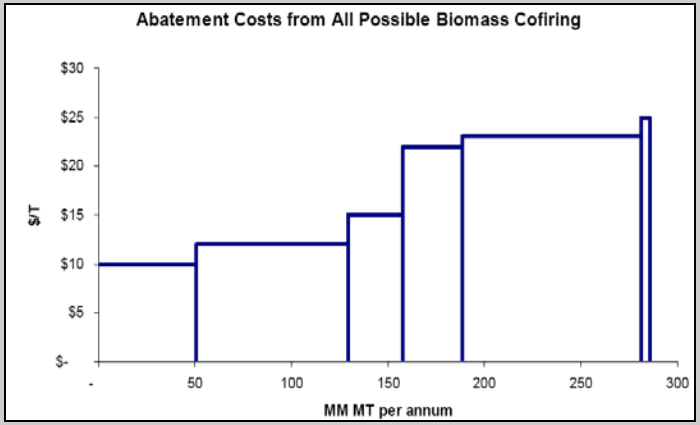
Advanced Technology- Hot Dry Rock & EGS

- Dispatchable- geothermal is one of the few non-intermittent renewables
- Some requirements for commercialization
  - Lower well drilling costs
  - Increased heat transfer fluid (i.e. water) flow rates while maintaining sufficient rock contact time
  - Improved micro fracturing technology
  - Improved seismic monitoring and control
- Safety/stakeholder issues- unintentionally induced seismic activity

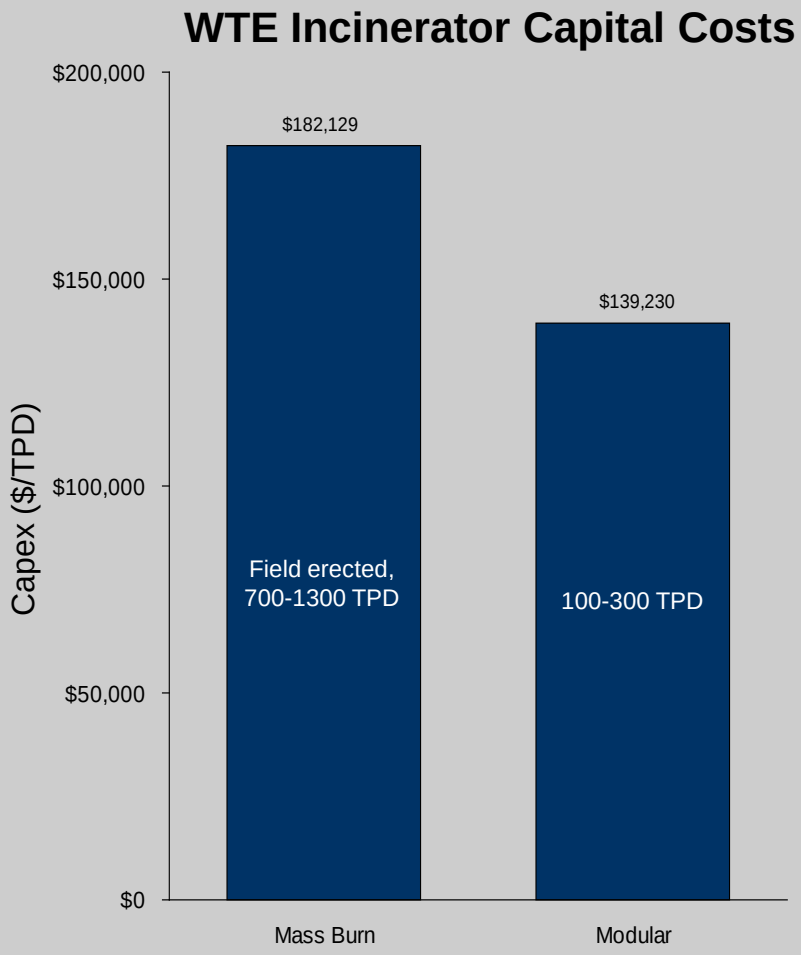
Biomass co-firing with coal is one of the most economical ways to use biomass and could abate significant CO2 at a cost less than ~$25 / ton



With much of the US coal fleet located relatively close to biomass resources, there are some regulatory barriers to making this a realistic option



Waste to energy is also an attractive biomass option, but is a relatively small resource compared to national power demand



Implications

- Operating Costs are of order:
  - O&M = $50/ton
  - Debt service/capital recovery = $34.50/ton
- At $50/ton tipping fee, about $0.07/kw-hr is required to meet costs and capital recovery
- Electricity generation of order 0.5 MW-hr per ton
- 135 million dry tonnes per year available
- Maximum 81 TW-hr electricity available from Municipal Solid Waste (MSW) if all US MSW currently landfilled was used for power generation

It is estimated that US grid modernization will require an investment of over a trillion dollars between now and 2030

Critical Issues

Integration of Renewables	▸ Variability or uncertainty around capacity and availability - Is the wind blowing? If so how much? ▸ Potential mitigation strategies - Increased reserve margins - Geographic diversity, wind is always blowing some place - Increased transmission, allows import/export of power to accommodate wind variability - Storage, cost and technology issues ▸ Levelized cost of wind power increases if the cost of these strategies are included
Transmission and Distribution (T&D) Infrastructure Investment	▸ Annual investment in T&D infrastructure through the late 1980s and 1990s was roughly half the historic values ▸ In that same time frame generation capacity doubled ▸ Estimates suggest that over $380 billion needs to be invested in the US T&D infrastructure by 2015 to meet demand growth and replace aging infrastructure with an additional $750 billion estimated by 2030 ▸ While over the last several years investment has increased to around historic levels ($5-$6 Billion/yr) a lot of catch up must be done ▸ American Recovery and Reinvestment Act authorizes $4.5 billion for grid modernization

Source: IEA, Booz Allen Hamilton analysis

Observations

What Could be Game Changers?

20 years of innovation

Solar PV technology innovation may offer the best hope to radically move the US generation mix towards renewables

- Solar PV offers a number of innovation pathways to dramatically improve cost performance of the next 20-30 years
- Solar PV could get lift from both energy efficiency and smart grid technologies
- Advanced geothermal technologies have potential to “MOVE THE NEEDLE” but face significant technology obstacles with limited pathways to maneuver around
- Biomass uptake could be improved with some regulatory changes but does not have “game changing potential”
- There is limited potential for “game changing” cost improvements for wind technology