Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy

- Minnesota Joint Meeting of the Legislative Energy Commission
- 24 March 2009

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Four Crises: Climate, oil insecurity, nuclear insecurity, food insecurity

Ansgar Walk (http://commons.wikimedia.org/wiki/Image:15_Walross_2001.jpg)

www.andysinger.com

NRC / PPL Susquehanna

Illustration by Victor Juhasz for ROLLING STONE MAGAZINE

Other issues: Mining waste & mill tailings (250 mn tons each in US), water (10 to 20 mn gal/day/reactor evaporative consumption), other radioactive waste (DU shown here). Uncertain water supply in a warming world could make nuclear reactors less reliable

U.S. Dept. of the Interior (www.osmre/oversight/wyomingaml03.pdf & http://commons.wikimedia.org/wiki/Image:Sunset_Uranium_Mine_Wyoming.JPG)

Credit: EPA (http://www.epa.gov/Region8/superfund/co/uravan)

WRONG: http://www.epa.gov/Region8/superfund/co/uravan .
SHOULD READ: Credit: NRC / Exelon Nuclear - Braidwood

Photo courtesy of the U.S. Department of Energy. Image ID-2010822

France perspective – positive elements

- Had a lot of oil in the electricity sector in 1973 and decided to go nuclear in a big way. Perspective was light water reactors first and transition to breeder reactors.
- In 25 years got to 75 percent nuclear electricity, showing a large transition can be done in a relatively short time with focus and adequate resources.
- Established reprocessing and built two breeder reactors

Problem areas

- French electricity is more expensive
- Central government monopoly in electricity and reprocessing (one company for each, now a little ~15 percent privatized).
- Breeder reactors have had unpredictable performance and have not been technically mastered. French demonstration plant, Superphénix operated at ~7 percent average capacity factor over 14 years; now closed, a technical failure. Sodium cooled reactors indicate no learning curve since the first one in 1951.
- Reprocessing and light water reactors were not meant for each other – high cost, low reuse, high pollution, no waste solution, proliferation risk

The French have not solved the waste problem

- 1% of spent fuel is plutonium (Pu), part reused to generate elect. but creates spent fuel that is more toxic than before (stored at reactor site)
- spend ~$800 million more each year on Pu fuel for less than 10 percent of the electricity
- surplus Pu: thousands of bombs equivalent
- discharge ~100 million gallons of liquid radioactive waste into English Channel per year, according to latest volume data (~10 years old); total radioactivity discharges about the same today; 12 of 15 Oslo Paris treaty governments want discharges stopped. French (& British) won't do it.
- Most contaminated uranium piling up in France; some in Russia. A little reused. High-level waste piling up as radioactive glass logs (smaller volume than spent fuel). Pu contaminated waste piling up.
- No repository open; much opposition; problems similar to Yucca Mountain
- British Pu program, essentially a total failure – worse than French. No Pu use in Britain Also rad. discharge into Irish sea.
- Summary: Small amount of Pu, U re-used at great expense in France, no reuse in Britain, most wastes piling up, more pollution and, overall, combed waste volumes is larger, no repository.

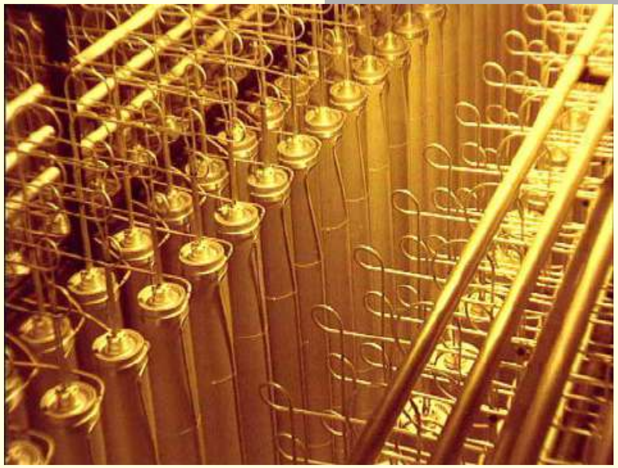

(Credit COGEMA)

View of the COGEMA-La Hague reprocessing plant, France

Yucca Mountain for nuclear waste? Pomegranates: 20 miles away

Nuclear reactors – proliferation

- Need 3,000 reactors – one a week
- 2 to 3 uranium enrichment plants per year (one proposed for Idaho, 50 miles from Jackson Hole)
- Annual global spent fuel: contain 90,000 bombs worth of plutonium per year if separated (separation research in Idaho)



Proliferation statements: Oppenheimer 1946; Gulf Coop. Council 2007; El Baradei, 2008

- 1946, Oppenheimer: "We know very well what we would do if we signed such a [nuclear weapons] convention: we would not make atomic weapons, at least not to start with, but we would build enormous plants, and we would call them power plants….we would design these plants in such a way that they could be converted with the maximum ease and the minimum time delay to the production of atomic weapons…"

Source: J. Robert Oppenheimer, "International Control of Atomic Energy," in Morton Grodzins and Eugene Rabinowitch, eds., *The Atomic Age: Scientists in National and World Affairs,* (New York: Basic Books, 1963), p. 55.

- 2006, Al Faisal, Saudi Foreign Minister: "It is not a threat. …We are doing it [nuclear power] openly. We want no bombs. Our policy is to have a region free of weapons of mass destruction. This is why we call on Israel to renounce [nuclear weapons]."

Source: as quoted in Raid Qusti. "GCC to Develop Civilian Nuclear Energy." *Arab News*, 11 December 2006, reprinted in Saudi-US Information Service

- 2008, El Baradei on "latent" capability: "You don't really even need to have a nuclear weapon. It's enough to buy yourself an insurance policy by developing the capability, and then sit on it. Let's not kid ourselves: Ninety percent of it is insurance, a deterrence."

Source: As quoted in Joby Warrick, "Spread of Nuclear Weapons IS Feared," *Washington Post*, May 12, 2008, p. A1.

New nuclear power is costly, too slow and too financially risky

- $5,000 to $10,000 per kilowatt, 10 to over 20 cents per kWh
- Wall Street does not want to finance it
- Industry seeking 100% federal loan guarantees for 80 percent of capital cost
- Nuclear investments likely to go sour (ratepayers, taxpayers, and/or investors will likely wind up holding the bag)
- In the last energy crisis, none of the reactors ordered after October 1973 were completed – overestimation of demand and underestimation of efficiency and cost
- Same may happen this time with so-called “nuclear renaissance”
- Only 4 to 8 can be built in the next ten years. Too little, too slow for getting to other side of CO2 peak emissions.
- In crisis should build shorter lead time projects – efficiency, CHP, renewables.
- Can do much more electricity generation with renewables in the same time.
- AREVA and Olkiluoto reactor in Finland

Nuclear: Opportunity Cost Perspectives for reducing CO_2 emissions

- Investment in efficiency, smart grid, ice-energy, CSP, makes nuclear investments uneconomical: San Antonio example: combination saves $1.4 billion to $3.1 billion relative to new nuclear investment.
- According to industry: 4 to 8 new nuclear plants can be built in 10 years. Too slow.
- Ten times or more the above level of generation can be achieved with wind and solar in ten years, with intermediate CO2 displacement Added cumulative CO2 emissions will be hundreds of millions of metric tons of CO2 over ten years. Additional emissions in the nuclear case will continue for years.
- At $50 per metric ton, cost of CO2 emissions due to emission reduction delay will be in the tens of billions in the first ten years alone.
- GE CEO Jeffrey Immelt: Gas and wind are better. "I don't have to bet my company on any of this stuff. You would never do nuclear. The economics are overwhelming." Financial Times, Nov. 2007
- Water use a huge issue: 10 to 20 million gallons per day per 1000 MW (evaporative consumption)

Cost comparisons - new low to zero CO_2 electricity sources per kWh

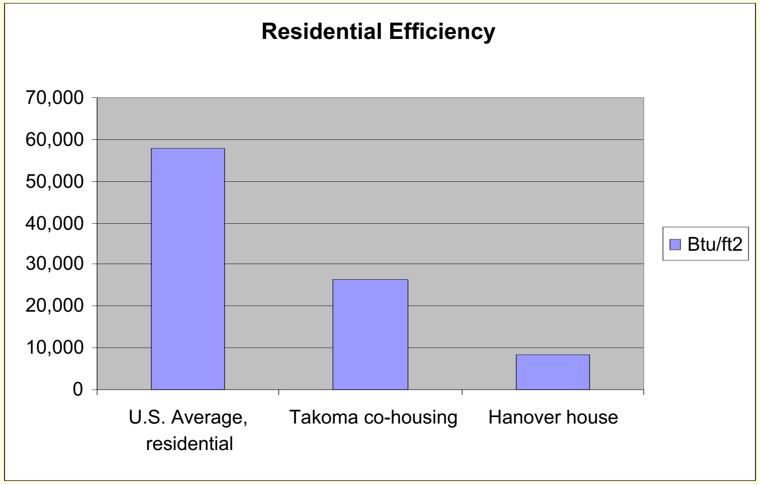
- Nuclear: 10 to more than 20 cents (plus water uncertainty and cost, plus long lead time risk)
- Wind: 8 to 12 cents. Baseload wind – add storage costs: ~3 cents per kWh at present for demonstration system in Iowa ($800 per kW for a large scale system of 268 MW, DOE estimate).
- Solar thermal: ~12 to 15 cents and coming down (cry cooling now commercial – SCE 1.3 GW order Feb. 09 dry cooling power tower technology). CSP going down to ~10 cents per kWh (Southwest)
- Solar PV: 15 cents large scale (Southwest), 20 to 25 cents intermediate scale (~1 MW per installation and many installations). Give a ~5 cent per kWh credit since no T&D investments involved in early stages. Single family residence ~40 cents per kWh.
- PV expected to be 10 cents or less in five years at intermediate and large scales

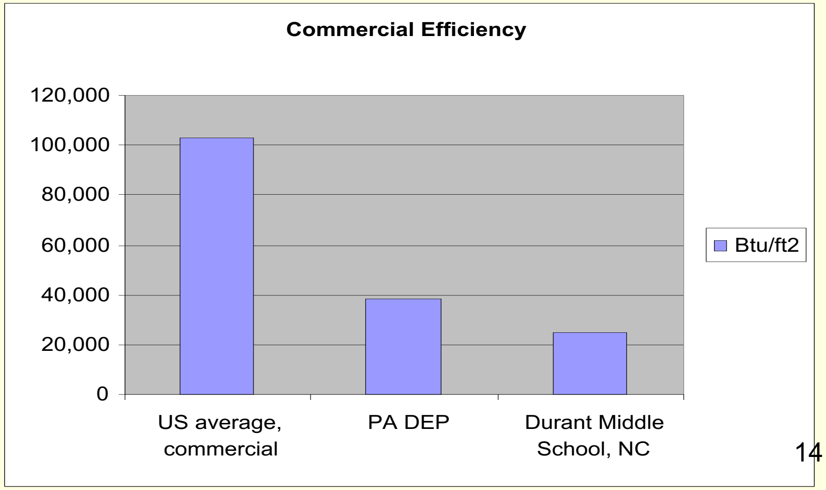
Problems with rescinding moratorium on nuclear

- If all is on the table, it treats energy like a smogasbord. It is not. It is an integrated system. No reason to leave nuclear on the table with all its headaches.
- Creates risks of high CO2 costs due to long lead times and delays.
- Loss of focus and remaining stuck in 20th century thinking when we need to move to efficient, renewable smart distributed grid.
- The lesson to learn from the French – set a goal and keep the focus and get it done.
- If a power plant is built here, it will need load guarantees, long term sound demand forecasts.
- While large power plants are comfortable because they are business as usual, in a world of software and laptops, the thinking about baseload, intermediate load, peak load is largely obsolete, though not fully so.
- High risk of default for long lead time capital intensive plants
- Federal government is not going to solve the waste problem any time soon.
- Energy services on demand should be the concept, plus shaping demand to available renewable sources.

Residential and Commercial Efficiency Examples

- Efficiency improvement of 3 to 7 times is possible per square foot
- Existing homes more costly to backfit but much is still economical
- Standards at the local and state level are needed
- Zero net CO2 new buildings and communities by 2020 or 2025 can be mandated





Baseload wind – Source NREL

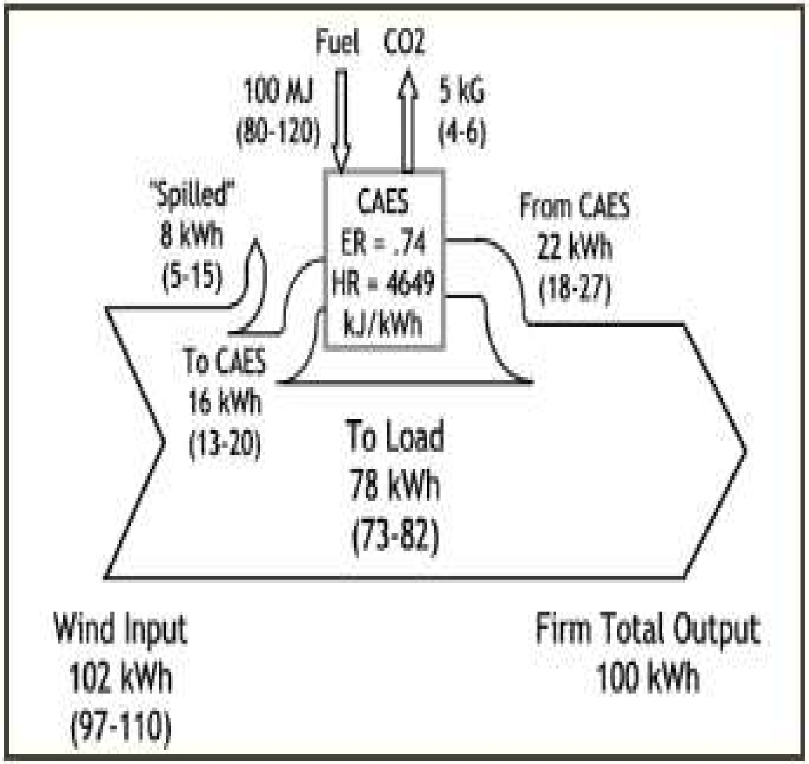


Figure 4: Energy Flow through a Baseload Wind Power Plant

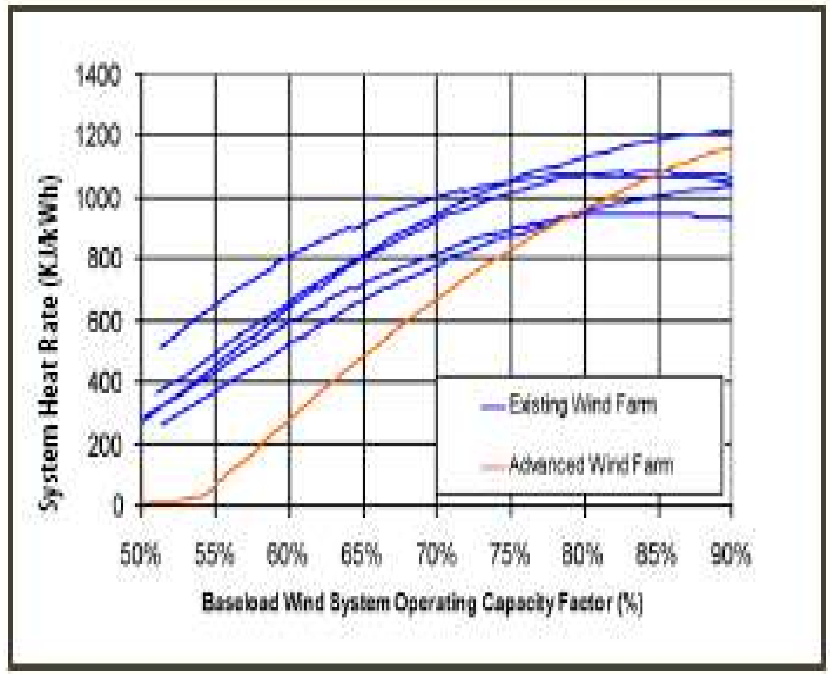


Figure 5: Baseload Wind Plant Fuel Requirements

Baseload output from wind + CAES

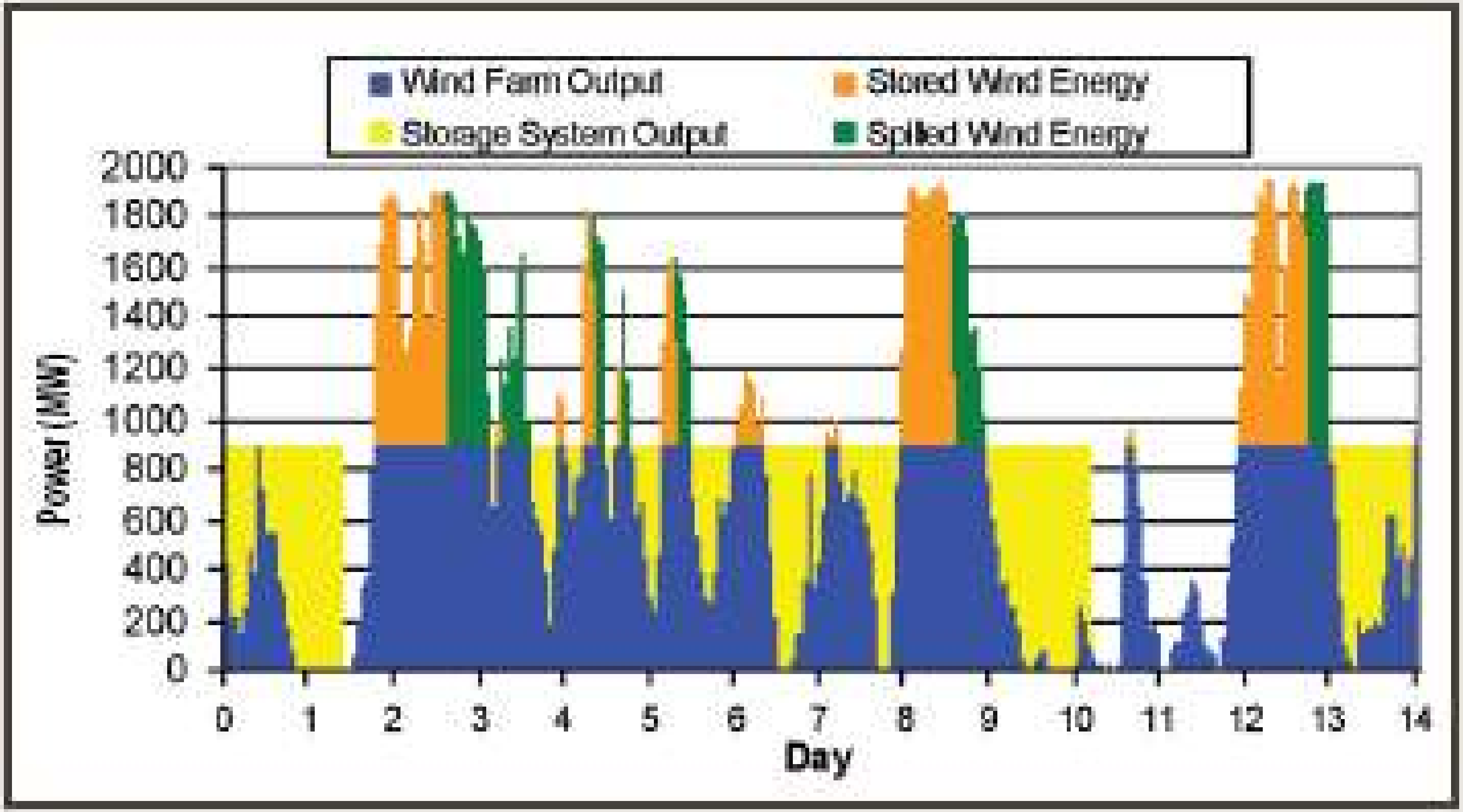
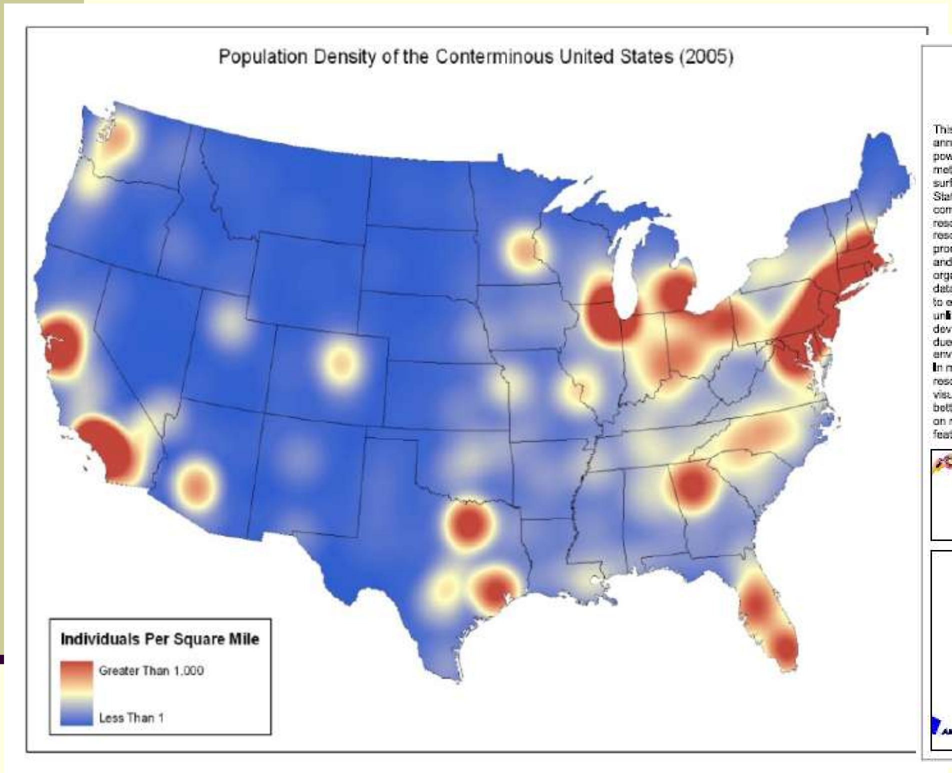
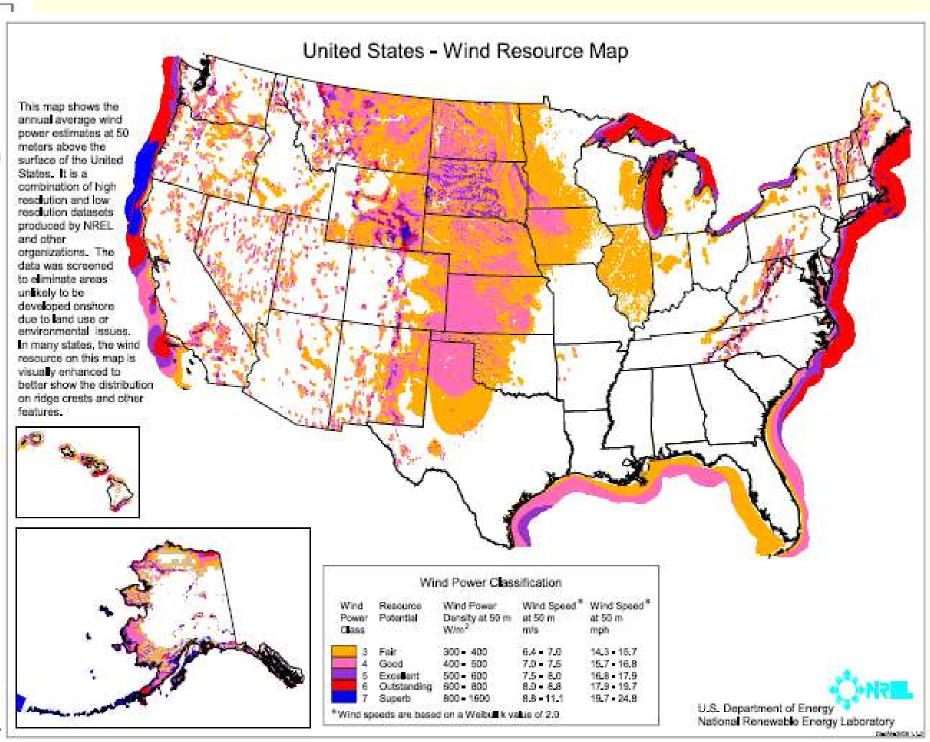


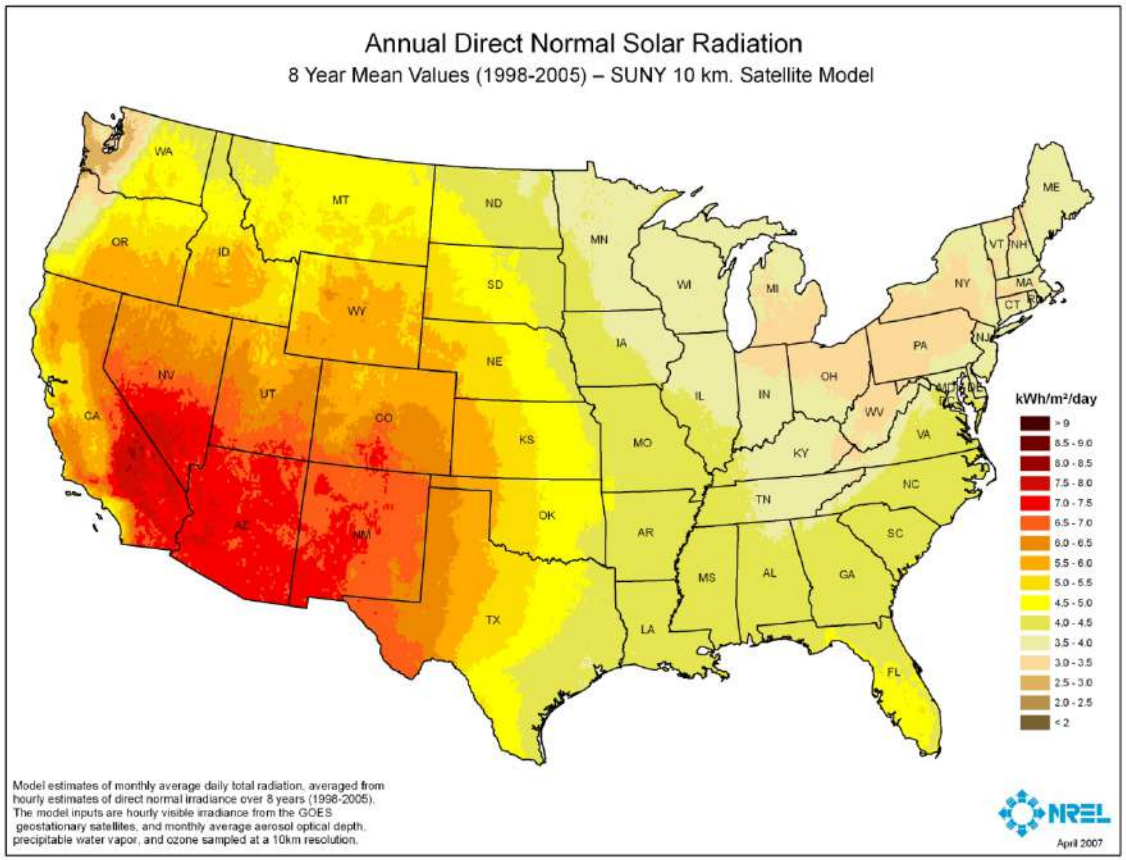
Figure 3. Sample Baseload Wind Generator Output (Target Output = 900 MW)

Wind total resource more ~3x U.S. electricity generation (on shore and offshore), excludes non-usable lands





Solar geography



Provided by National Renewable Energy Laboratory

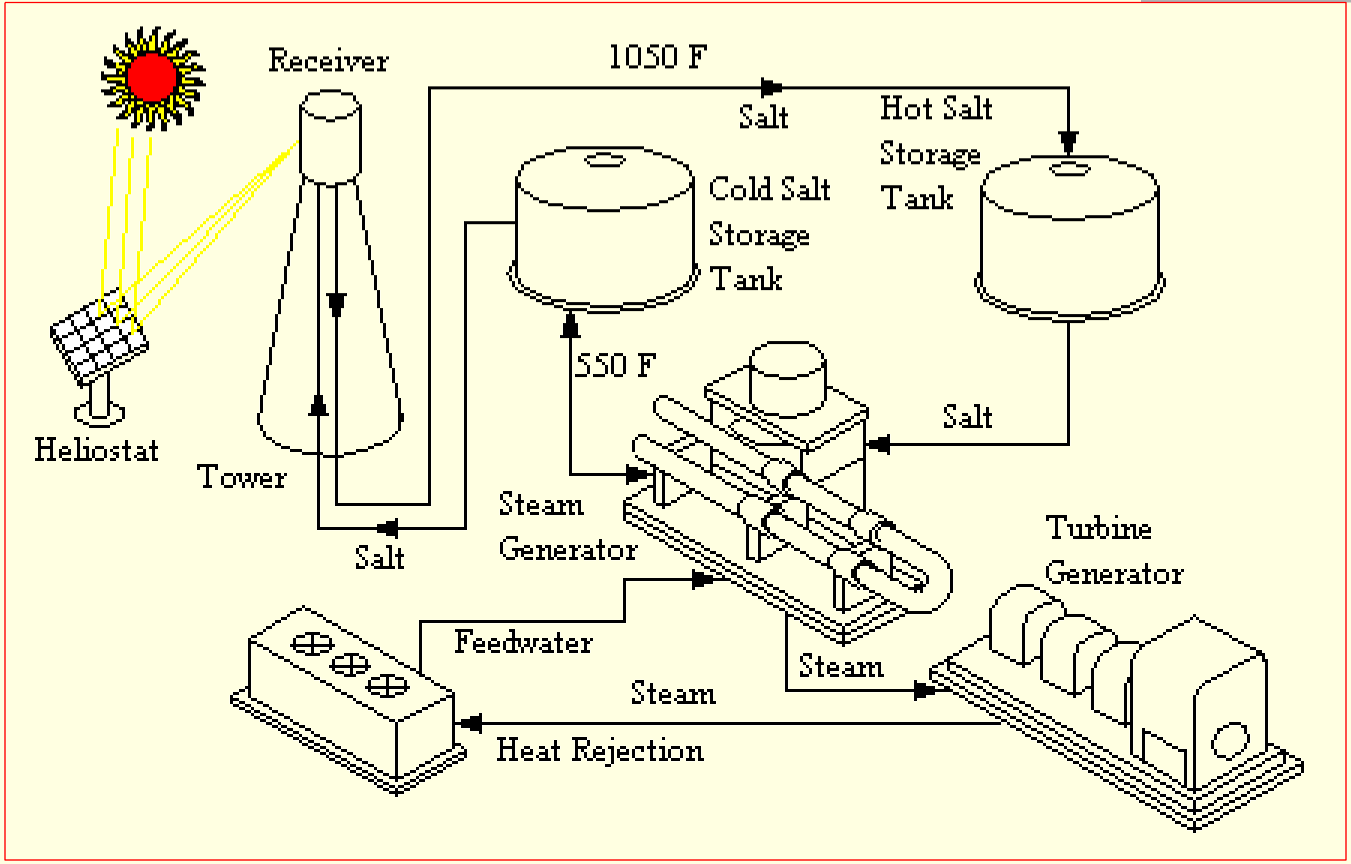
750 kW US Navy San Diego Parking Lot

Courtesy of PowerLight Corporation

Dealing with intermittency

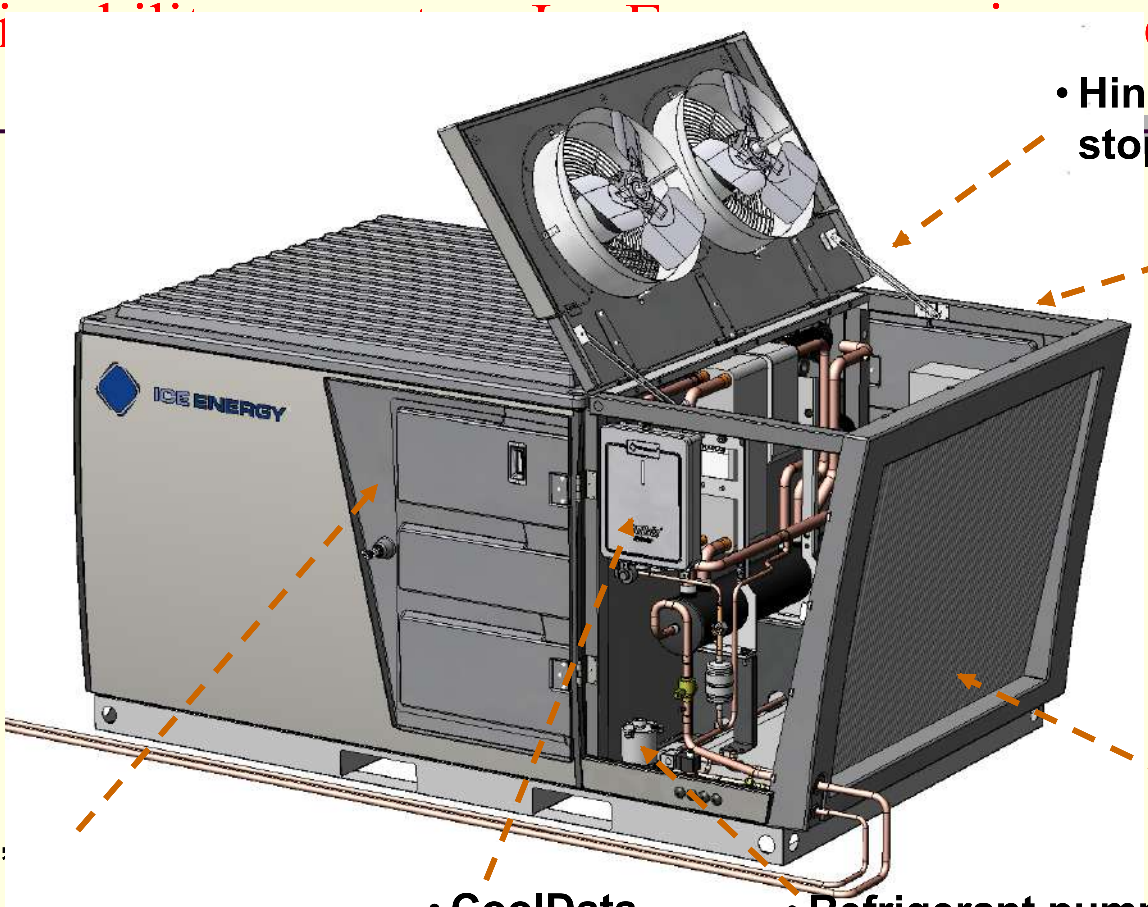
- Smart grid: consuming devices talk to producing devices; storage devices, smart meters, mediate conversation.
- Store heat while the sun shines.
- Store cold while the wind blows.
- Solar and wind integration
- Existing hydro backup
- Existing natural gas standby (U.S. has enormous surplus capacity), long-term: replace fuel with biogas (use aquatic plants, such as microalgae, as feedstock)
- IGCC solid biomass (e.g., algae), geothermal, CHP
- Other storage elements, medium to long-term (compressed air, including, vehicle-to-grid, dispatchable wind – produce compressed air instead of electricity at the turbine and generate electricity when needed, e.g. General Compression http://www.generalcompression.com

Storing heat – solar power at night



Credit: Sandia National Laboratories

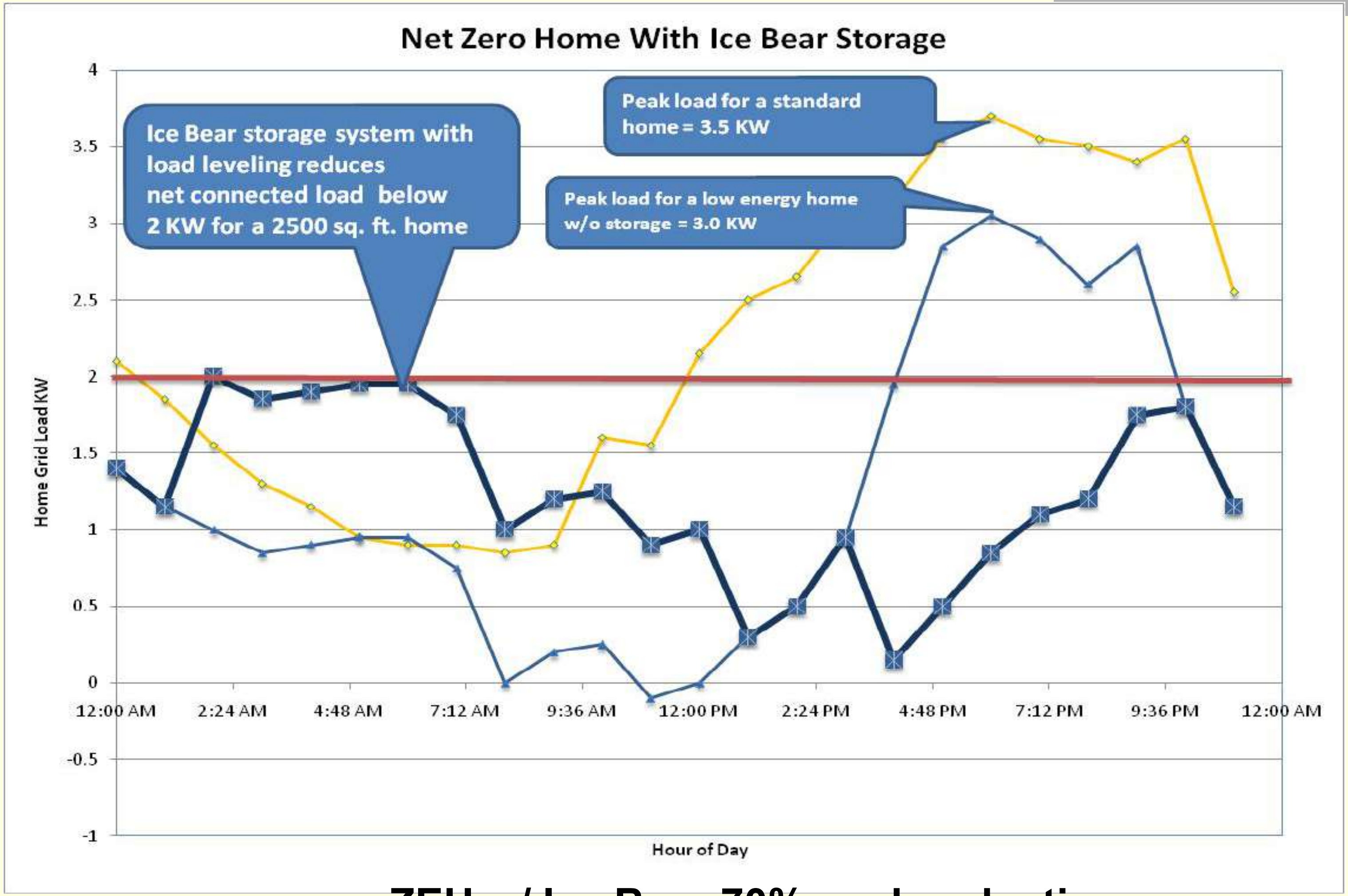
The Ice Bear - Designed for building controls, reliability and servi… ergy.com



- Hinge with positive stop and "latch"
- Door on opposite side for access to compressor and water pump
- Compressor location
- 30"
- magnetic "catch" in open position
- CoolData Controller™
- Refrigerant pump uses 100 W on peak

CoolData™ Controller is designed to monitor and control up to 200 building data points, serve as FDD and communicate with Ethernet

SMUD ZEH with Energy Storage, Courtesy Ice Energy



ZEH w/ Ice Bear 70% peak reduction

Electric car: Phoenix Motorcars Pickup - this type of battery useful for vehicle to grid

- All electric: Range 130 miles, about one-third kWh per mile

Altairnano batteries can be:

- charged in 10 minutes with special equipment
- Retain 85% capacity after over 10,000 charging and discharging cycles
- Suitable for vehicle to grid applications
- There are other similar lithium-ion batteries from other manufacturers now coming on the market
- Cost reduction needed – appears to be occurring rapidly

Tesla: 0 to 60 in 4 secs. (goal); 200 mile range, 0.2 kWh/mile, off-the-shelf lithium-ion batteries combined in special battery pack

Courtesy of Tesla Motors

Suggestions to consider

- Set a goal of a fully renewable, efficient smart electricity system for Minnesota in 30 years oriented to energy services.
- Ask your PUC to commission a feasibility study on this that will include costs, reliability, and resource considerations.

End note

Slides are primarily a summary of *Carbon-Free and Nuclear-Free: A Road Map for U.S. Energy Policy* by Arjun Makhijani

Find the source citations in the downloadable version of the book, available at no cost, on the Web at http://www.ieer.org/carbonfree/CarbonFreeNuclearFree.pdf or contact IEER .

The book can be purchased in hard copy at www.rdrbooks.com or www.ieer.org