The Integral Fast Reactor

A solution to world energy, a solution to climate change, an advancement in science, and oddly, one of the US government's best kept secrets.

by

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References:

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•Plentiful Energy, The IFR Story, by Charles E. Till and Yoon Il Chang
http://www.google.com/search?client=safari&rls=en&q=plentiful+energy+ifr&ie=UTF-8&oe=UTF-8
•Articles, papers, and books by James Hansen http://www.columbia.edu/~jeh1/
•Articles, papers, and books by Tom Blees
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•Beyond Fossil Fools by Joe Shuster http://www.beyondfossilfools.com/
•Brave New Climate websites and commentary by Barry Brook, moderator
http://www.google.com/search?client=safari&rls=en&q=brave+new+climate+barry+brook&ie=UTF-8&oe=UTF-8
•Articles by Steve Kirsch http://www.google.com/search?client=safari&rls=en&q=steve+kirsch+ifr&ie=UTF-8&oe=UTF-8
•A letter by movie producer and environmentalist Robert Stone:
http://www.huffingtonpost.com/robert-stone/pandoras-promise-documentary_b_2507213.html

The Integral Fast Reactor

An advanced nuclear reactor designed to:

- provide energy independence in the near future
- provide an energy source for centuries
- reverse the buildup of nuclear waste
- reduce waste repository toxicity to 1/1000 th
- produce maximum energy per lb of fuel
- do on-site processing of nuclear materials http://snipurl.com/26fzha8
- use pyroprocessing to prevent bomb making
- prevent a meltdown from being possible
- stop the buildup of atmospheric CO_2

Detrimental Presidental Actions

- ***President Ford's Administration***
  - created the NRC
  - cancelled the AEC
- ***President Carter's Administration***
  - cancelled Clinch River Breeder
  - created the one pass fuel rule http://www.presidency.ucsb.edu/ws/?pid=7316
  - ended nuclear fuel recycling, expecting other countries to also stop recycling spent nuclear fuel http://snipurl.com/26fzha8
  - inadvertently increased today's 'nuclear waste'
  - initiated treaties to force others to follow US policies
- ***President Reagan's Administration***
  - NRC charges hefty fees/reactor/year, hurts small reactors

Detrimental Presidental Actions

- ***President Clinton's Administration***
  - cancelled the Super Conducting Super Collider
  - cancelled the Advanced Liquid Metal Reactor (IFR)
  - stopped funding new reactor R&D
  - deregulated electric power, which has favored fossil fuels, making the CO_2 problem much worse
- ***President Obama's Administration***
  - cancelled Yucca Mountain waste repository
  - has appointed anti-nuclear people to key positions
  - will not approve funding for a new plant like IFR

See latest appt: http://www.foreignaffairs.com/articles/136544/ernest-moniz/why-we-still-need-nuclear-power?page=show
and this anti nuclear action http://www.power-eng.com/articles/2013/04/obama-exploring-sale-of-tva.html is another indicator

The Integral Fast Reactor

slides created by

Mark Lynas

Environmentalist and author, 'The God Species'

http://www.marklynas.org/wp-content/uploads/2012/08/PRISM-IFR.ppt

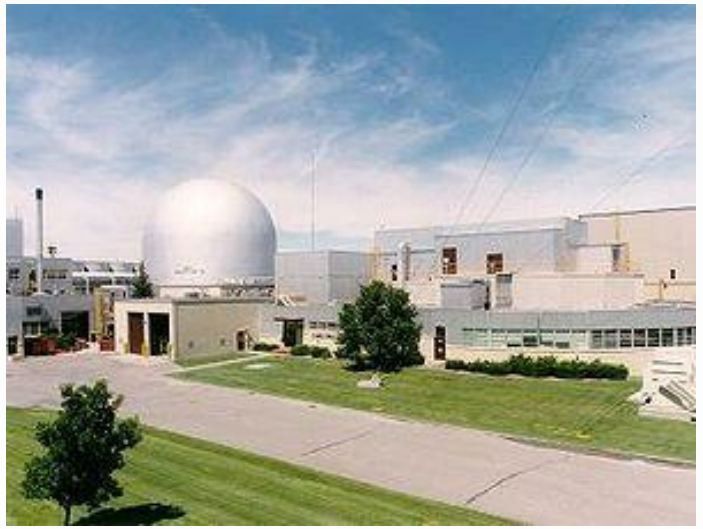
Nuclear's (perceived) unsolved problems

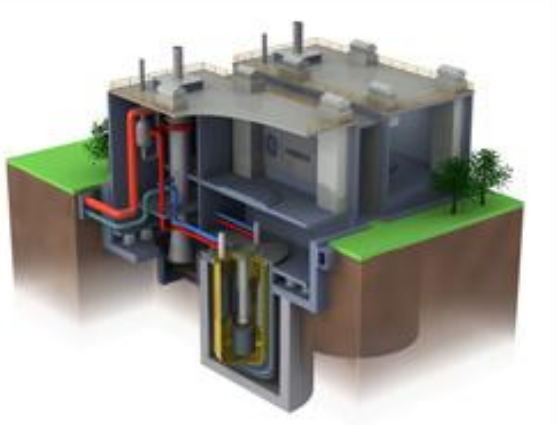
- Nuclear waste disposal
- Proliferation
- Fuel supply
- Safety
- Cost

<u>These problems are not 'real' in any technical sense, but are political, and must be seen to be solved for public acceptance of nuclear power</u>

The Integral Fast Reactor/PRISM

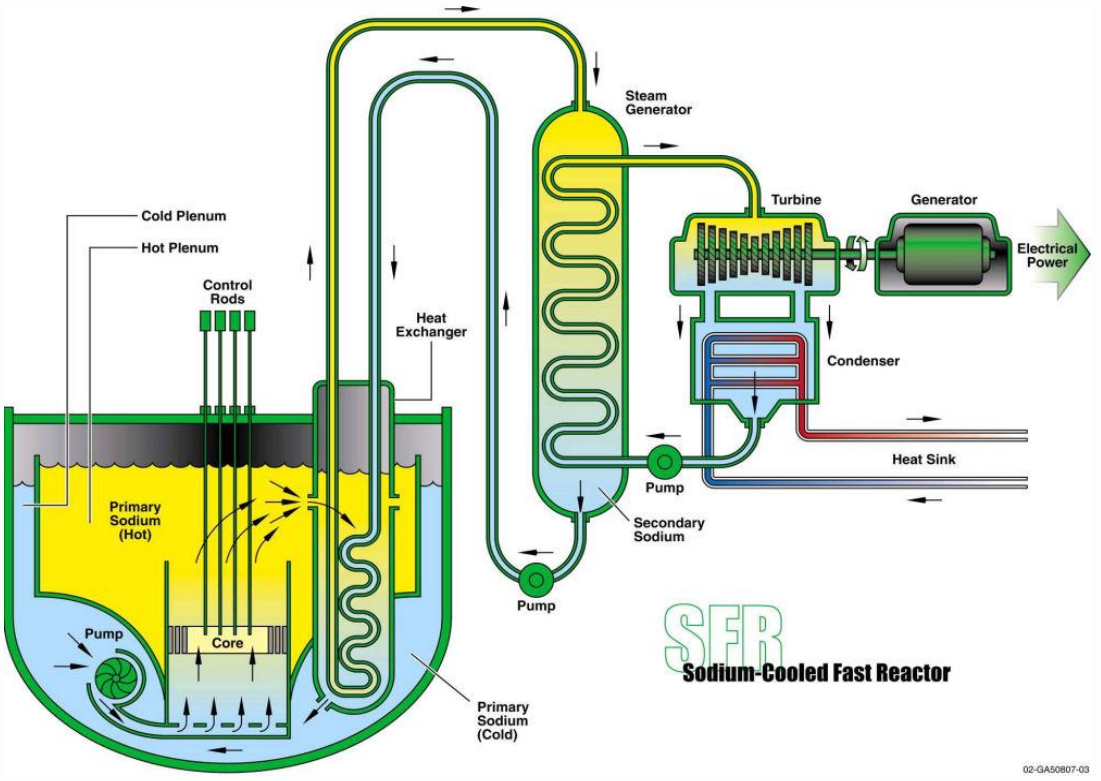
- Developed at Argonne National Laboratory, based on EBR II
- Cancelled by the Clinton administration/Congress in 1994
- Now marketed worldwide by GE-Hitachi as the PRISM (Power Reactor Innovative Small Module)
- Currently considered by UK, Russia, China, South Korea for deployment





IFR/PRISM technical specifications

- Liquid sodium-cooled fast reactor
- Can be operated as breeder or burner
- Reactor core sits in pool of coolant
- Power generation from secondary (non-radioactive) coolant loop
- Two units per PRISM of 300MWe = 600MWe



Problem solved: nuclear waste

- IFR can ‘burn’ all actinides/ transuranics using fast neutrons
- Turns ‘waste’ into ‘fuel’ http://snipurl.com/26fzha8

- Residual radiotoxicity of waste declines to original uranium ore toxicity in 300 years
- No need for geological repository with 1 million-year design life

Problem solved: proliferation

- No need to enrich uranium for fission
- Continuous plutonium breeding essential for the IFR reactor
- Potential Pu danger addressed by reprocessing technology called ‘pyroprocessing’

- Fuel reprocessing done remotely in hot cell – extremely radioactive; therefore, fissile material self-protecting
- Separating bomb-grade Pu would require PUREX reprocessing – inspections insure PUREX plants not being used

Problem solved: fuel supply

- Fast reactor uses 99% energy in uranium - 100 times more energy produced than in a Light Water Reactor
- UK has spent fuel/DU for 500 years of operation of fleet of IFRs generating entire 80 GW national electricity supply
- US has enough for around 1000 years with no uranium mining http://snipurl.com/26fzha8
- In next millenium thorium provides abundant fuel
- By year 4000 AD should have nuclear fusion working!

Problem solved: safety

- Fukushima demonstrated safety concerns of BWRs/PWRs
- IFR/PRISM designed for full passive safety
- Sodium 90x more effective in conducting heat than water

- EBR II experiment in 1986 switched off coolant pumps, reactor shut itself down in 300 seconds, temperature stabilized
- Meltdown impossible due to core design (at atmospheric pressure) and metal fuel (not oxide fuel)

Problem solved: cost

- Fully modular design, made on factory assembly line and shipped to site
- Costs offset by nuclear waste disposal
- MOX reprocessing ~30% more expensive
- GE-Hitachi proposal to UK: plutonium stockpile ‘disposition’ instead of MOX, no upfront costs
- But costs uncertain until completed and operational

Conclusions by Mark Lynas

- All the supposed ‘unsolved’ technical problems of nuclear power have actually been solved
- The problems are only ‘unsolved’ in the minds of anti-nuclear activists
- Anti-nuclear ‘Greens’ as much a threat to the climate as ExxonMobil, responsible for 10s billions tonnes CO_2
- IFR/PRISM just one of a variety of competing 4^{th} Gen designs, other fast reactors, SMRs, thorium LFTRs also important
- And Gen III+ also worth deploying at scale - need 1000s new reactors to solve climate change

Additional Comments by Gene Preston

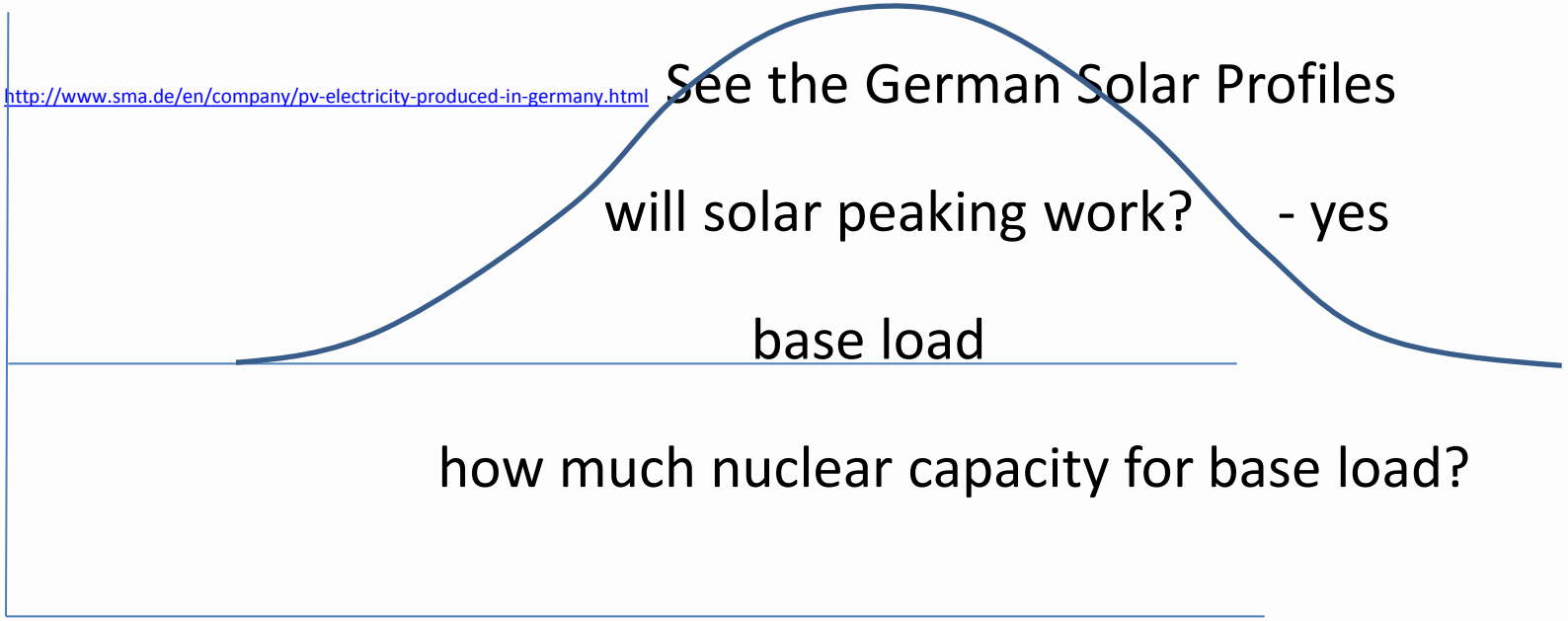
- There are two major groups affecting energy policies. Both are anti-nuclear. Neither group effectively solves the long range energy supply problem or the CO_2 build-up problem and neither wants to compete with IFR/Prism.
- The first group can be described as Fossil Fools who ignore the finiteness and rising costs of fossil fuels. As Pompeians they turn a blind eye to the rumblings of Mount Vesuvius.
- The second group are Renewable Radicals who falsely believe wind and solar power are all that is needed. This is worsening the CO_2 problem and is leading us to an energy deficiency.

US Investment Costs of Nuclear vs Solar

- Consider the electrical energy producing $16 trillion worth of electricity from nuclear or solar at 10 cents/kWh.
- This is 160 trillion kWh or 8 trillion kWh/yr for 20 years.
- This energy is roughly double the US electric consumption and is approximately the total US energy consumption.
- These sources could produce this much energy:
  - 1000 1000 MW nuclear plants costing $4 trillion ($4/W)
  - 4000 1000 MW desert solar plants costing $16 trillion ($4/W)
  - 800 million 10 kW rooftop panels costing $16 trillion ($2/W)

Grid Considerations:

- A Typical Daily Summer Load Profile:

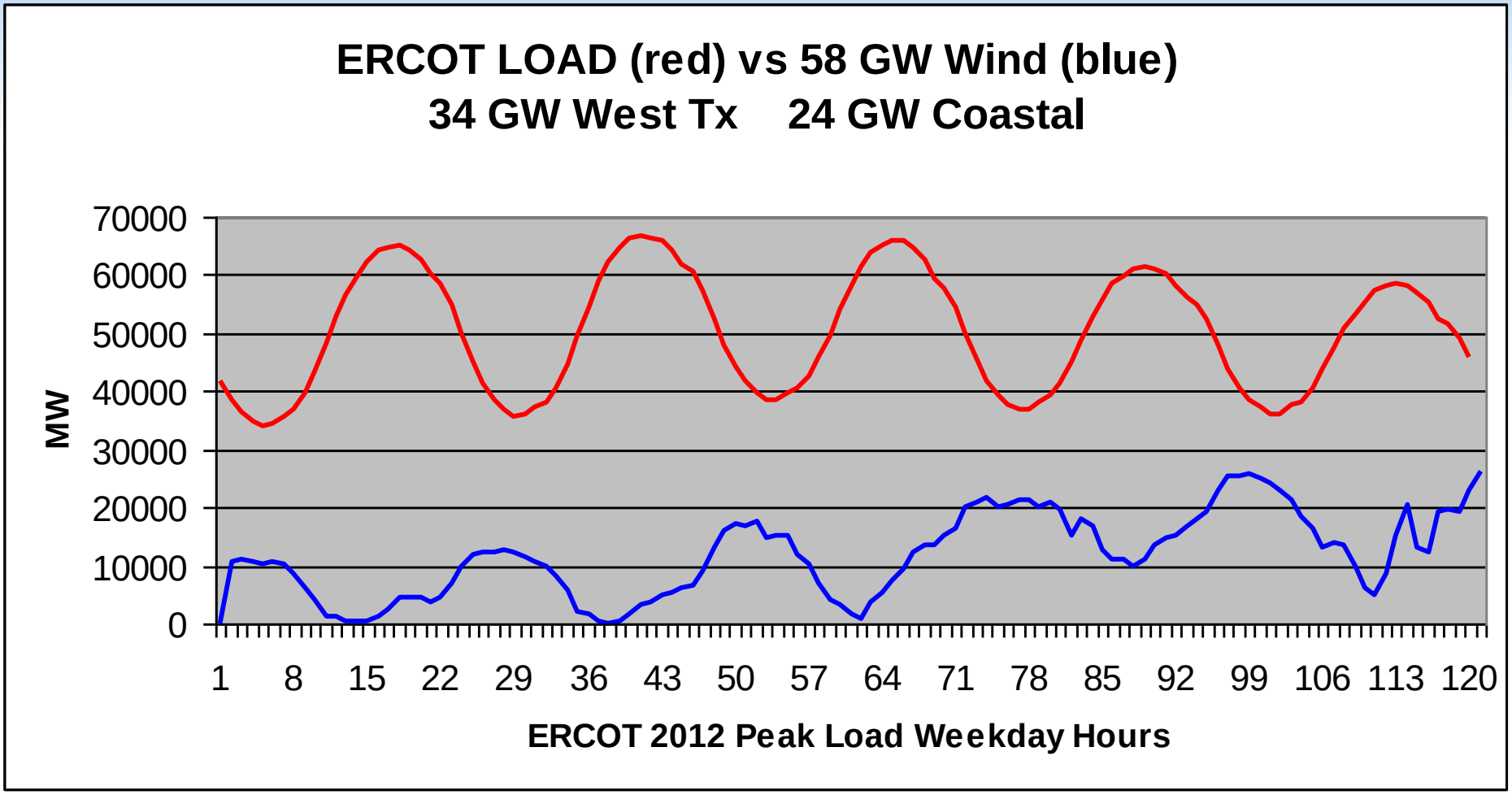


Grid Considerations:

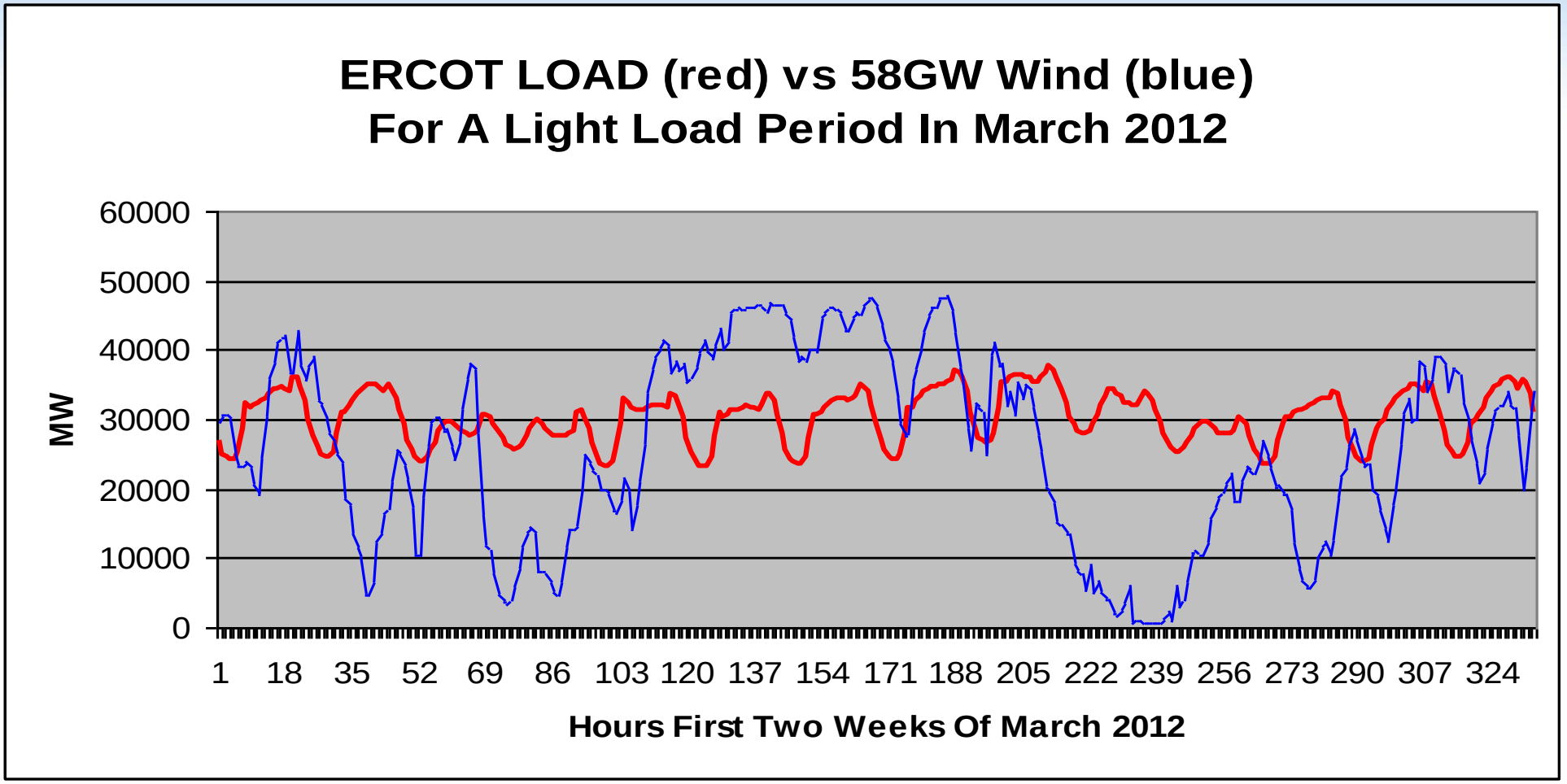
- Electric System Large Scale Low CO_2 Expansion Scenarios

1. A wind and natural gas plan is the current ERCOT plan. What is the maximum amount of wind ERCOT can utilize? (*~50% energy*) What is the capacity value of coastal wind versus West Texas wind? (*very little*) What is ERCOT wind annual capacity factor? *(~33%*) How well will wind solve the CO_2 emission problem? (*not very well*)

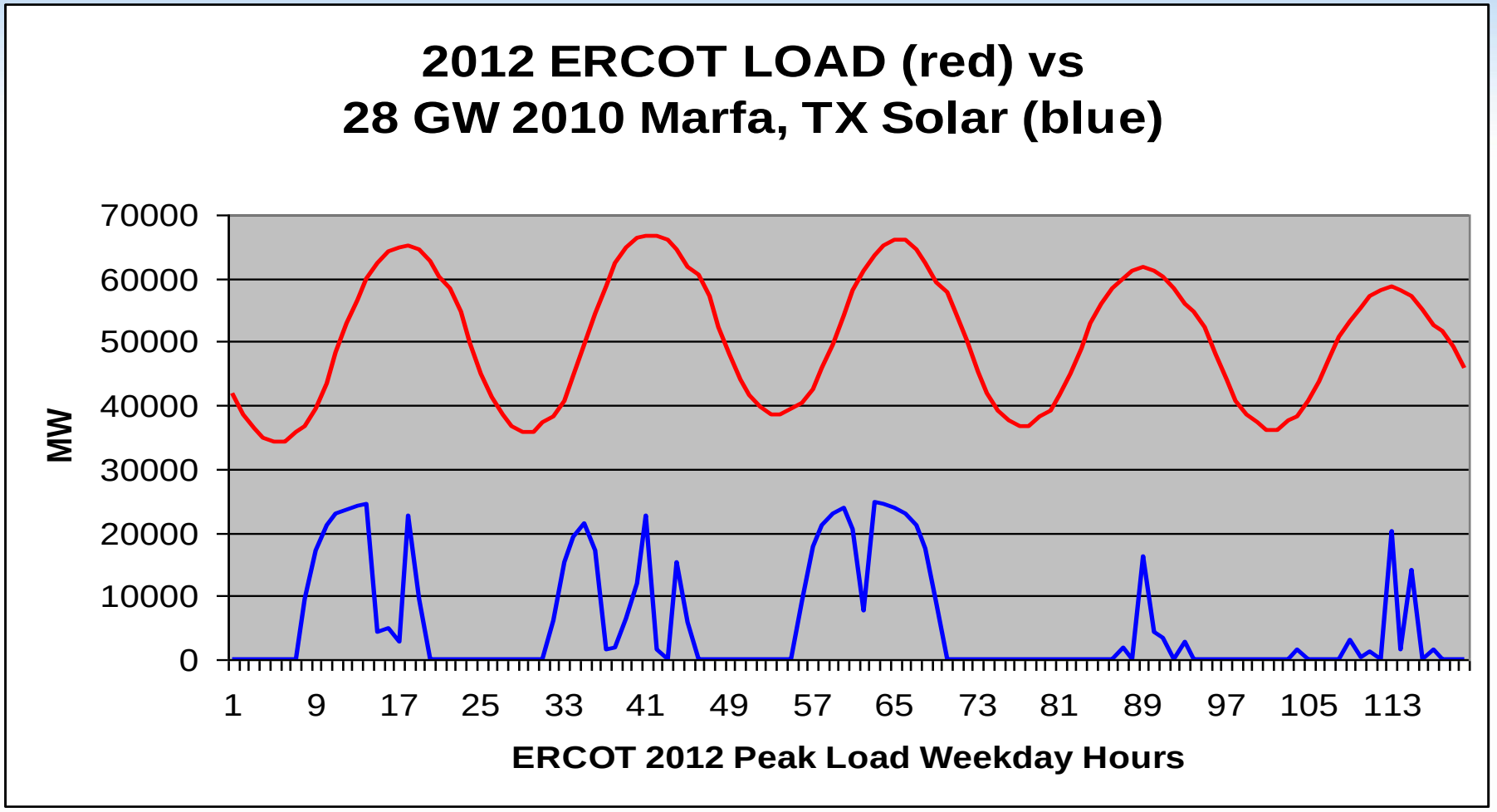
2. Is a solar daytime peaking and nuclear IFR night time generation base with some emergency quick start gas generation and storage a better long range solution? (*yes, however, there is a financing problem*)



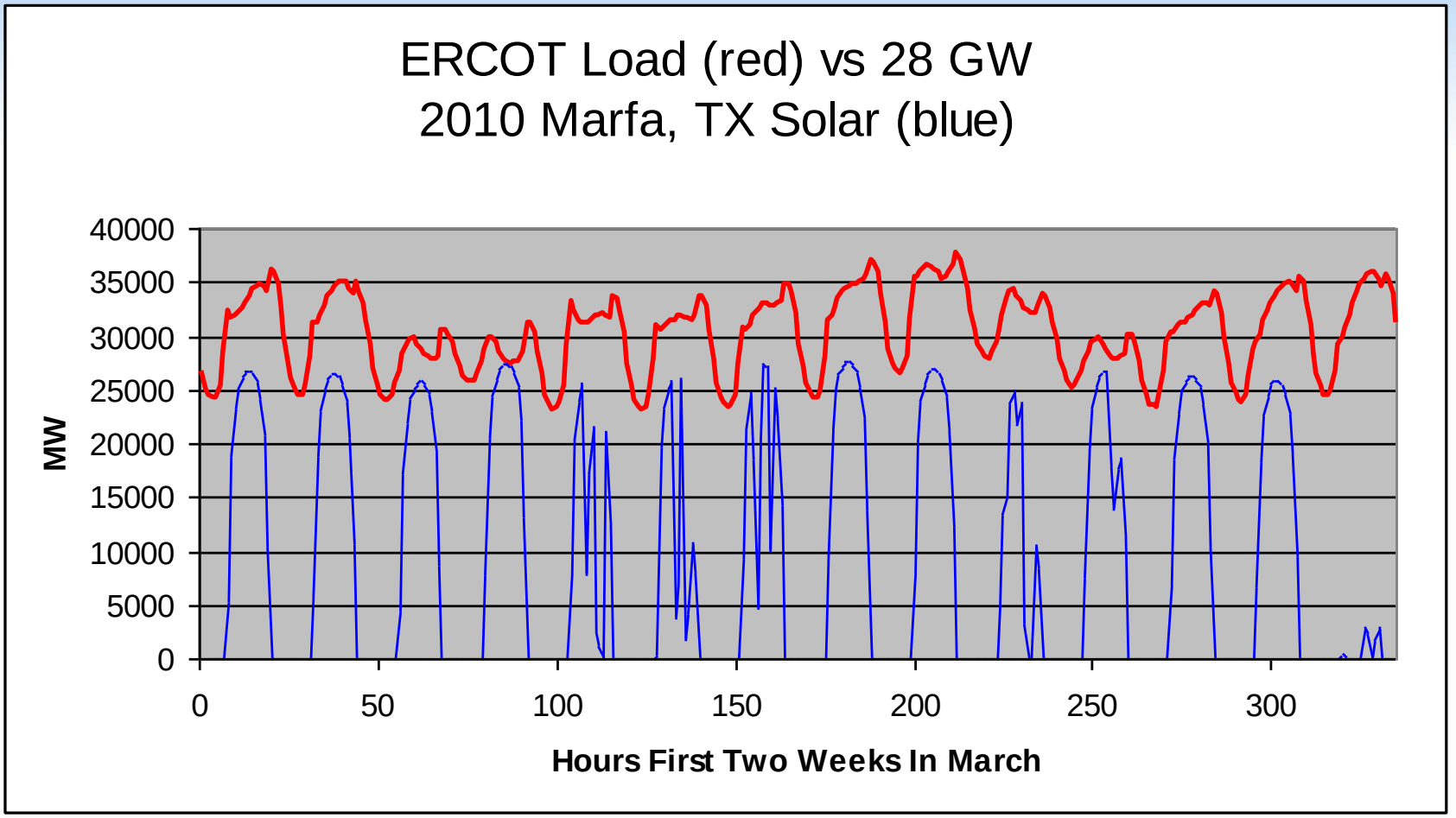
The 2012 ERCOT wind output was scaled to 58 GW to provide ~50% of the annual energy to the 66562 MW peak load system with a minimal ~4% spillage. Wind capacity is not reliable.



Natural gas generation makes up the difference between load and wind. This puts a real strain on gas dispatch. The 58 GW total wind output often exceeds the light load levels.



The summer daily peak load variation is ~28 GW. Many solar locations in ERCOT would smooth the total system solar output. However, ERCOT has no actual solar system data at this time.



The above West Texas 28 GW solar assumes tracking. Massive storage will be needed to store the solar energy for nighttime load and days when there is no sun, such as the last day above.

58 GW Wind vs X GW Nuclear

- Assume wind has 33% capacity factor
- Assume wind cost is $2/watt and nuclear is $4/watt **
- Wind 58 GW produces 58 * .33 * 8760 hours = 167.6 TWh
- Assume nuclear annual average capacity factor is 91%
- X = 58 * .33 / .91 = 21 GW nuclear capacity
- Nuclear 21 GW produces 21 * .91 * 8760 hours = 167.4 TWh
- Wind investment cost = 58 GW * 2 = $116 Billion
- Nuclear investment cost = 21 GW * 4 = $84 Billion

**US nuclear plants under construction are currently estimated to cost $4/watt.

Recommendations

- The US needs to restart nuclear R&D programs such as IFR to deal with the spent nuclear fuel problem.
- A long range US energy plan through 2100 is necessary.
- A carbon tax is needed to reflect the real cost of CO2.
- Market rules need to be changed to allow the financing of nuclear and solar projects (and natural gas projects for that matter!).
- Arctic and Antarctica ice melting is increasing at 8%/year. If this rate continues, new projections show we could have serious flooding problems by 2100. Possibly we should begin planning to relocate our coastal cities.