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Nuclear Costs and Alternatives

A Report Prepared by Dr. Arjun Makhijani and the Sustainable Energy and Economic Development (SEED) Coalition, April 2009

The COLA for Comanche Peak 3 and 4 fails to adequately analyze alternatives to the nuclear reactors that are proposed. Nuclear power is too costly and risky financially compared to other sources of electricity. Furthermore, the two reactors proposed for Comanche Peak are not needed in order to meet projected electricity demand.

Additional Generation is Not Needed

Energy efficiency efforts are expanding in Texas, spurred into motion by recent passage of House Bill 3693. The bill set state goals of meeting 15% of projected growth in demand through energy efficiency by 2008 and 20% of growth in demand by 2009, and further initiatives are now under consideration by the Texas legislature.

A September 2007 report by ACEEE American Council for an Energy-Efficient Economy, found that by utilizing more efficient buildings and appliances, expanding use of combined heat and power and onsite renewable energy and strengthening utility savings targets, the Dallas Ft. Worth area could meet 101% of the predicted growth in demand. Dallas has since adopted some of the best building codes in the nation and the Texas legislature is currently working towards increased efficiency requirements this session, including appliance standards, so the possibility of meeting increased demand in the region without building more generation is becoming a real possibility. The report estimated that the Dallas/Fort Worth area could achieve 1858 MW in demand savings per year by 2013 and 6,610 MW of demand savings annually by 2023.[1] This does not include generation of electricity using large-scale renewables that could be used to displace existing carbon-emitting sources in case restrictions are put on carbon emissions.

The Electric Reliability Council of Texas (ERCOT) operates the state's electric grid and manages the deregulated market for 75 % of the state. In March 2009, ERCOT approved Luminant's request to retire 2,114 MW of gas-fired power in Texas and confirmed that shutting them down would not hinder electric reliability in the state. One more gas plant is schedule to retire at the end of the summer and ERCOT is considering Luminant's request to retire two additional gas plants. Approval would result in an additional reduction of 1711 MW of power generation, of which 302 MW would be mothballed.[2]

In all, 3825 MW of gas-fired power may be retired or mothballed by Luminant, including some large and relatively new combined cycle plants. It appears that the 3400 MW of additional

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[1] R. Neal Elliott and Maggie Eldridge, American Council for an Energy-Efficient Economy, Role of Energy Efficiency and Onsite Renewables in Meeting Energy and Environmental Needs in the Dallas/Fort Worth and Houston/Galveston Metro Areas, September 2007, Pages 5-7.

[2] Reuters. March 13, 2009. ERCOT Okays Luminant's Request to Retire 2,114 MW of Gas-fired Power in Texas. Summary provided by the Department of Energy at http://www.oe.netl.doe.gov/docs/eads/ead031609.pdf

nuclear generation is not really needed at all if Luminant's existing plants can be retired. The question arises as to whether gas plants are being shut down in order to pave the way for the additional reactors that Luminant now seeks to build, reactors that would not be needed without their retirement. It is recognized that some of Luminant's natural gas capacity has rather high heat rates, which would make fuel costs high if natural gas costs rise again. But existing natural gas power plants can be coupled to the growing wind energy portfolio in Texas to provide intermediate or baseload power with relatively low CO2 emissions. There is no reason that Luminant cannot explore the use of its existing natural gas capacity to firm up wind capacity, thereby reducing the heat rate per kWh and increasing the value of wind energy as a resource that could be delivered on a firm basis. The natural gas could also be deployment with wind in other, even more efficient ways – notable with wind and compressed air energy storage (see below).

It is clear that efficiency is a real and viable option to reduce energy consumption in Texas and that the COL is inadequate in considering this option. It states in the environmental report, 9.2.1.3, "An analysis of the potential for conservation is not required if the applicant is proposing to build a merchant plant to sell electric power on the open market, which is the intent of CPNPP Units 3 and 4. Additionally the U.S. Nuclear Regulatory Commission (NRC) has already determined that conservation is not a reasonable alternative to a merchant plant whose purpose is to sell wholesale power. Therefore, although DSM is an important alternative to the application of the overall energy management strategy, it is not an adequate alternative to the proposed CPNPP Units 3 and 4."

However, energy efficiency should have been analyzed. Construction of a merchant plant does not negate the NEPA requirement to address all *practicable* alternatives. There is no reason that the Luminant or another subsidiary of its parent company, Energy Future Holdings, could not invest in efficiency. Further, Luminant is asking for federal government loan guarantees. Hence, the proposed plant is mainly putting taxpayers, who overlap with Texas ratepayer at least to some extent, at risk. In that sense, Luminant has an obligation as an electricity supplier to explore the various ways in which the same services that electricity provides can be delivered to ratepayers.

The dismissive COLA statement fails to recognize the reality that the proposed nuclear reactors are simply not needed, and no certification of need is being required, an egregious oversight that will needlessly create more nuclear waste than is already piling up at the Commanche Peak site and increase all the risks that are attendant on that storage and other risks attendant upon nuclear power plant electricity generation. Further, diverting scarce financial resources and federal government loan guarantees to new nuclear reactors threatens the ability of energy efficiency programs to be effectively implemented since their construction would act as a direct disincentive for efficiency and conservation. Sinking vast economic resources into the reactors would prevent Luminant or others from having a vested interest in pursuit of efficiency goals. These goals are especially undermined since federal subsidies, via loan guarantees as well as subsidies during the licensing process provide an undue advantage to an industry that should long ago have established itself in the marketplace on its own.

Distinguishing between electricity generation and the "services that electricity provides"

Society does not actually need to consume electricity in the same sense, for instance, that we need to consume food and water. We need the services that electricity provides, such as lighting and air conditioning, energy for powering computers and televisions, and so on. The actual amount of electricity consumed by these devices, the time at which the electricity is generated, or even whether many of these energy services are meet by electricity or some other form of energy is not relevant to our needs. We need to distinguish between electricity generation and the services that electricity provides because there are many ways of providing those services and there are also ways in which the time at which the electricity is generated can be disconnected from the time at which renewable energy sources such and solar and wind are actually available.

The cost of nuclear power

Nuclear power is far too costly and risky in the financial sense compared to other available sources of electricity. The risk of nuclear power relative to renewable energy sources is magnified by the long lead time between a decision to seek a license to build one and the time of commissioning for electricity generation and by the present economic crisis, which increases the risks of failure of any long-term project, for instance, due to a failure of long-term demand to rise to the projected levels.

Estimating of the capital cost of new nuclear power plants as of 2008

The most detailed estimate of the capital costs of nuclear power were presented in a late-2007 filing with the Florida Public Service Commission by Florida Power and Light.[3] This filing contains detailed breakdown of the overnight costs of a commercial nuclear reactor as well as

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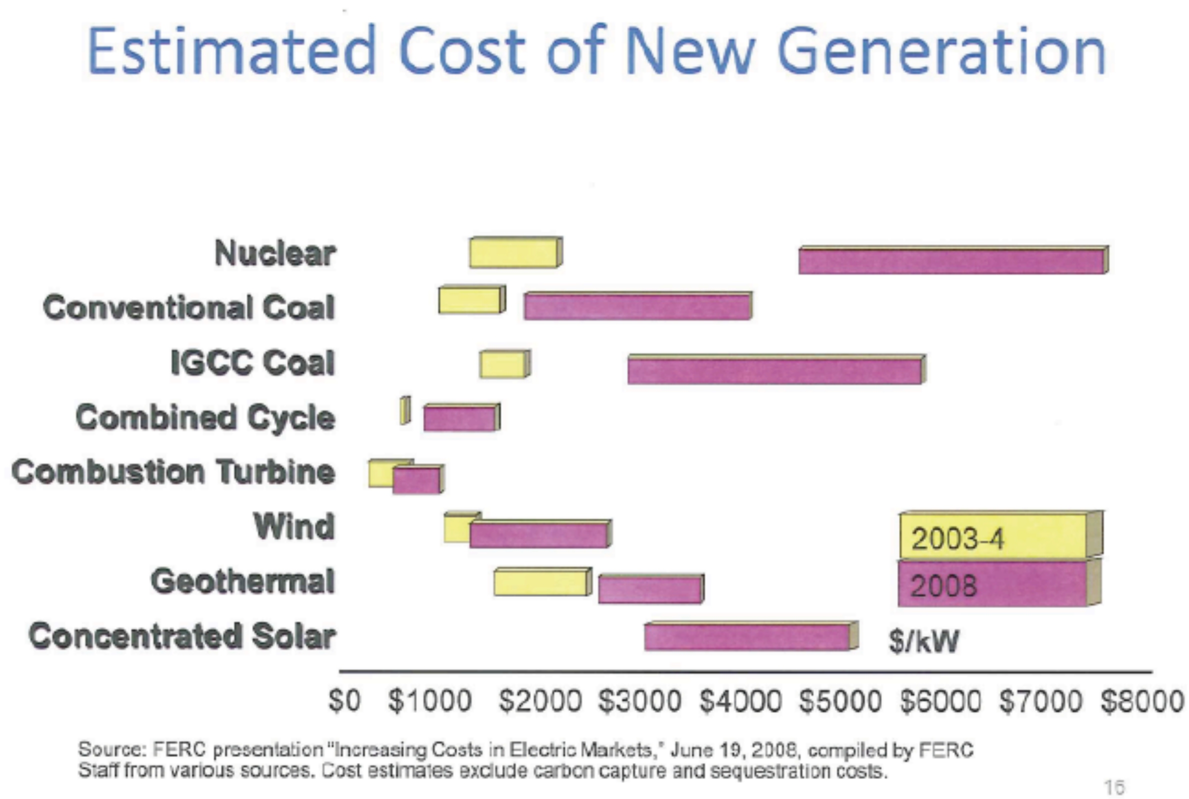
[3] FPL 2007.

estimates for cost escalation during construction and interest costs incurred during construction. The cost estimated for a 2,200 megawatt project with two reactors of 1,100 MW each ranged from $12.1 billion to $17.8 billion, yielding a per kilowatt cost range of $5,492 to $8,071. A larger two-reactor project was estimated to cost $5,426 to $8,005 per kW. A reasonable middle figure to use (in the absence of delays) for capital cost is about $6,500 per kilowatt, excluding any costs attributable to delays. This would put the total capital cost of a two-reactor, 2,700-megawatt project at $17.6 billion. It should be noted that these are not the highest cost estimates that have been made. For instance, Puget Sound Energy has made a cost estimate of $10,000 per kW.[4]

The Federal Energy Regulatory Commission presentation "Increasing Costs in Electric Markets" form Jun 19, 2008 shows nuclear power to be the most expensive form of electric generation in its slide below regarding costs of new generation.

[4] As cited in Harding 2008. Jim Harding was part of the 2007 Keystone study and did much of the economic work for that study. The Keystone study was cited in TVA 2008. Mr. Harding is also a consultant on nuclear energy costs to the National Research Council.



New nuclear plant proposals involve capital costs are higher than the market capitalization of many energy companies, including some that are proposing nuclear power projects. For instance, the market capitalization of Progress Energy, which is pursuing a two-reactor project in Florida, was $10.16 billion at 3:27 pm, Eastern Standard Time on February 11, 2009.[5] This is much less than the estimated $17 billion capital cost for the nuclear project that Progress Energy has estimated.[6] As another example, the entire value of the electrical plant of CPS Energy, the municipally-owned utility in San Antonio, Texas, in its Fiscal Year 2007 was $3.9 billion. It is considering a purchase of 40 percent of the capacity of two new nuclear units that have been proposed by NRG, Inc., at its South Texas Project site. The capital cost of this 40% share of the reactors is estimated to be in the range of $4.8 billion to $7 billion or between 23 percent and 79

[5] Yahoo Finance website at http://finance.yahoo.com/q?s=PgN, viewed on February 11, 2009 at 3:27 pm.

percent greater than the entire value of CPS Energy's electric plant.[7] Luminant is privately held and there is at present no stock market valuation of the company.

Comanche Peak reactor costs

Luminant has entered into a joint venture agreement with Mitsubishi Heavy Industries, Ltd. (MHI) for the Comanche Peak expansion, with Luminant retaining 88% ownership and MHI holding a 12% stake. [8]

The company has not provided official cost estimates for the proposed reactors. In the Comanche Peak COL Application Part 1, Administrative and Financial Information, pages 23-34, the attachments and tables that would contain basic financial information have been withheld from public disclosure and deemed proprietary. This includes market price projections and decommissioning funding assurance. Citizens in Texas who requested access to sensitive documents for Comanche Peak were denied. According to Reuters, Luminant CEO David Campbell said that "the price tag will depend on future construction costs once the license to build is obtained. He said Luminant would try to build its new reactors on the low end of current industry estimates which he said range from $2,500 to $6,000 a kilowatt, or roughly $8 billion to more than $19.2 billion for a 3,200 MW plant." [9] At public meeting held on June 12, 2008 in Glen Rose, Texas, citizens were provided with factsheets with a range of per kilowatt costs which, after calculations, indicate that costs could go as high as $22 billion for two reactors, and company officials agreed. A 2009 study by CJEnergy Consulting, Costs of Current and Planned

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[7] See Makhijani 2008.
[8] "Luminant seeks permission to expand nuclear power plant". *Dallas Business Journal*. 2008-09-19 http://www.bizjournals.com/dallas/stories/2008/09/15/daily72.html
[9] O'Grady, Eileen (2008-09-19). "Luminant seeks new reactor, 3rd Texas filing". Reuters. http://www.reuters.com/article/bondsNews/idUSN1952971720080919?sp=true.

Nuclear power Plants in Texas, A Consumer Perspective, states that "Luminant's stated ranges of $2,500 - $6,000/kW for CP 3 and 4 spans a range that is unrealistically low…"[10]
This report found that real costs in 2008 dollars would range between $5,922 - $6,160 per kW and with a future 2% inflation rate and construction starting in 2012, the nominal actual cost for a 2700 MW plant would be $20.5 - $22 billion, or $7,800 - $8,131 per kW.[11]

A range of $5,000 to $8,000 is reasonable for all-in capital costs of new nuclear power plants in the United States, exclusive of the costs of delays and extraordinary risk premiums on financing long lead time projects in the present crisis. The cost of a 3,400 MW[12] project on this basis would be between $17 billion and about $27 billion (rounded). Delays could add significantly to this cost (see below).

Financial Viability and Ratepayer Costs

Energy Future Holding Company, the parent company of Luminant, is over $39 billion in debt according to their March/April 2009 power point presentation (slide 34.)[13]

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[10] Johnson, Clarence, March 2009, Costs of Current and Planned Nuclear Power Plants in Texas, A Consumer Perspective, CJEnergyConsulting, Austin, Texas. Page 19. Hereafter Johnson 2009.
[11] *Ibid.* Page 28
[12] US APWRs are nominally rated at 1,700 MW, which is the figure used here. See the Mitsubishi fact sheet at http://www.mnes-us.com/htm/usapwrdesign.htm
[13] March/April 2009 Energy Future Holdings PowerPoint presentation, EHF Corp. Spring 2009 Discussion Deck, Slide #18

Table 4: EFH Corp. Net Debt Reconciliation
As of December 31, 2008
$ millions

Description	12/31/08
Short-term borrowings	1,237
Long-term debt due currently	386
Long-term debt, less amounts due currently	40,838
Total debt	42,460
Less:	
Cash and cash equivalents	(1,688)
Investments held in a money market fund	(142)
Restricted cash	(1,322)
Net debt	39,307

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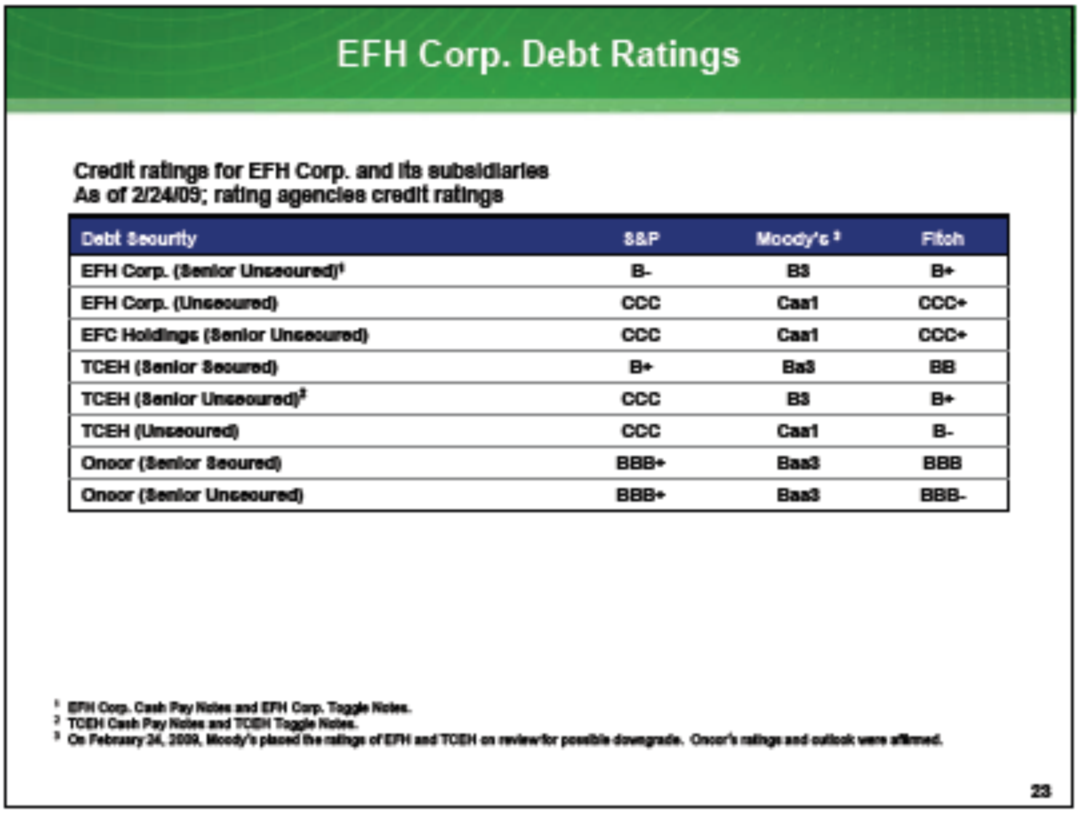
Energy Future Holdings has credit ratings from Standard and Poor's, Moody's and Fitch that range from B+ at best to CCC. [14] Investors should be wary. So should taxpayers because they are being asked to guarantee the loans of a company whose debt is not very well rated.

An Investor's Guide to Corporate Bonds is a website which advises investors as follows: "your number one priority is ensuring the safety, stability and security of your capital…Many investors will never want to venture outside investment grade debt (BBB or higher) and will only find themselves holding bonds which are considered junk after the debt has had its credit rating downgraded. The problem with junk debt is that there is little or no liquidity because few investors want to take on the risk of default or of a missed payment. Junk debt will often leave you holding until either one of two things happens: the debt you own matures or the debt is

[14] March/April 2009 Energy Future Holdings PowerPoint presentation, EHF Corp. Spring 2009 Discussion Deck, Slide #23

defaulted on."[15] The same website provides a credit ratings chart which describes BBB as medium grade, BB as speculative, B as highly speculative, and CCC as in poor standing. The slide below is from an Energy Futures Holding Company PowerPoint presentation from March/April 2009.[16]



EFH Corp. Debt Ratings

Credit ratings for EFH Corp. and its subsidiaries
As of 2/24/09; rating agencies credit ratings

Debt Security	S&P	Moody's [3]	Fitch
EFH Corp. (Senior Unsecured)[1]	B-	B3	B+
EFH Corp. (Unsecured)	CCC	Caa1	CCC+
EFC Holdings (Senior Unsecured)	CCC	Caa1	CCC+
TCEH (Senior Secured)	B+	Ba3	BB
TCEH (Senior Unsecured)[2]	CCC	B3	B+
TCEH (Unsecured)	CCC	Caa1	B-
Oncor (Senior Secured)	BBB+	Baa3	BBB
Oncor (Senior Unsecured)	BBB+	Baa3	BBB-

[1] EFH Corp. Cash Pay Notes and EFH Corp. Toggle Notes.
[2] TCEH Cash Pay Notes and TCEH Toggle Notes.
[3] On February 24, 2009, Moody's placed the ratings of EFH and TCEH on review for possible downgrade. Oncor's ratings and outlook were affirmed.

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Luminant has applied for federal loan guarantees from DOE, which has not stated how it will allocate the loan guarantees among the reactor applicants. Johnson has noted that "The ratio of requested loans to budgeted construction costs suggests that the applicants, on average, expect to finance their projects with 65% federal loans. ($122 billion requested for $188 billion of

[15] An Investors Guide to Corporate Bonds, http://seekingalpha.com/article/128479-an-investor-s-guide-to-corporate-bonds. As posted on April 5, 2009.
[16] March/April 2009 Energy Future Holdings PowerPoint presentation, EHF Corp. Spring 2009 Discussion Deck, Slide #23

projects.)…. Debt leverage of this magnitude on projects like nuclear plants will increase the risk of financial distress and abandonment."[17]

If cost overruns occur during construction, applicants will have to either reduce the originally targeted percentage of federal loan guarantee financing, or seek additional federal funds. Johnson has also described this problem correctly: "Assuming that the applicants seek more guaranteed loans, DOE and Congress would then face a dilemma: take on more financial responsibility of increasingly risky and over-budget nuclear projects in an attempt to "save" the guaranteed loan sunk costs; or deny the financing and increase the risk that the applicant will abandon the project and default on the loans. Both outcomes are likely to be very costly for taxpayers." [18]

The Comanche Peak site is within the ERCOT power region, a market that was deregulated in 2001. Claims are sometimes made that the nuclear plants in Texas, at Comanche Peak and the South Texas Project, have low operating costs. However, looking only at running costs ignores the very high capital investment costs. Clarence Johnson's analysis concludes that "Ratepayers of regulated investor-owned utilities had already paid off about $5 billion of these nuclear investments in Texas prior to the initiation of deregulation."[19] He further notes that utilities benefit more than consumers from the "low operating costs' of nuclear reactors, since ERCOT market prices are largely based on the cost of natural gas, even if nuclear power or other sources are generating the electricity. The weighted daily market price in ERCOT for 2007 – 2008 was $56-$83 per MWh but the Texas Comptroller reported in 2008 that nuclear operating costs at the South Texas Project equate to $13.56 per MWh, so consumers are paying four to six times the

[17] Johnson 2009, 35
[18] Johnson 2009, Page 35
[19] Johnson 2009, Page 6

presumed “low-cost” of nuclear power.

The history of past costs, including stranded costs, is worth noting here because generating companies do not always incur the actual full costs of nuclear generation; rather various ways of passing on these costs have been found in the past. The NRC is bound to take these into account when considering the potential alternatives, their costs, and what that might mean for future consumers.

The Cost of Delay

The above cost estimates do include cost increases due to delays. Delays have been and continue to be typical of relevant nuclear reactor construction experience in the West. The longest instance perhaps was the TVA Watts Bar project. Construction of TVA’s Watts Bar reactor project started in 1973; the completion date was 33 years later in 1996.[20] Or consider Olkiluoto reactor in Finland, for which the French company AREVA provided a turnkey, fixed cost of 3.2 billion euros and a completion date of 2009. This is a single reactor project – a 1,600 MW European Pressurized Water Reactor (EPR). The turnkey cost was therefore estimated as 2,000 euros per kW at the start of the project. As of February 2009, the capital had gone up by about 50%. The delay means that the Finnish utility, TVO, will have to purchase electricity from sources that emit carbon dioxide. As a result it faces substantial costs related to power purchases and CO_2 permits under its Kyoto Protocol commitments. It has filed a lawsuit claiming 2.4 billion euros in compensation from AREVA.[21]

[20] TVA website at http://www.tva.gov/sites/wattsbarnuc.htm
[21] HELSINGIN SANOMAT, April 4, 2009, *TVO seeks EUR 2.4 billion in damages for Olkiluoto nuclear reactor delays,* Online at

According to the FPL study cited by TVA, delay of a year could add between $800 million and $1.2 billion to the capital cost due an increase in the Allowance for Funds Used During Construction.[22] Reactor projects have experienced delays ranging from a short period to decades. A several-year delay could therefore increase the cost by billions of dollars.

Comanche Peak Unit One had a planned construction period of 5 years, but took over 11 ½ years to build, a 9½ year slippage.[23] Comanche Peak holds the distinction of being the most expensive completed nuclear power project built in the United States.[24] The 1975 definitive cost estimate (DCE) was $978 million, but the actual cost was $7.8 billion, a 690% cost overrun.[25] The total project cost, including capitalized financing charges, Allowance for Funds Used During Construction, was 140% above the average total for multi-unit nuclear power plants build during the 1980's.[26]

Overall, a range of $5,000 to $8,000 dollars per kW is a reasonable range for costs if there are no delays. In case of delays, costs could increase by several hundred to several thousand dollars per kW. It is important to note that delays can be very long, as is illustrated by prior Commanche Peak experience. Besides the current example of the Finnish reactor project cited above, the U.S. experience during the economically turbulent times is cautionary. Besides the cancelled plants that were never completed, the longest delay in a completed plant was about two decades.

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www.hs.fi/english/article/TVO+seeks+EUR+24+billion+in+damages+for+Olkiluoto+nuclear+reactor+delays+/1135243097398

[22] FPL 2007, p. 52.

[23] Johnson 2009, page 19

[24] *Ibid*. Page 14

[25] *Ibid*. Page 16

[26] *Ibid*. Page 14

Construction of the Watts Bar nuclear power plant started in 1973. Unit 1 was completed in 1996.[27] Unit 2 construction was suspended in 1988, but was resumed in 2007.[28]

Delays can also result in the need to purchase power on the open market, resulting in higher power costs. A part of the costs that TVO, the Finnish utility, is claiming from AREVA, include the added costs of power purchases created by the delay in completing the nuclear unit.

Given that delays have been frequent and are also being experienced by the first western nuclear reactor project in the West in a decade, it is prudent to include a contingency for delays in the upper limit cost estimate. A reasonable range of nuclear power plant capital costs for the purposes of planning is therefore $5,000 to $10,000 per kW, with the former value being used for a lower end of costs and no delays and no problems and the latter with modest delays and escalations. This would put the range of capital costs for the proposed plant at between $17 billion and $34 billion. Of course, if delays are comparable to the past Commanche Peak experience, the costs could be much higher.

The capital charges per kWh, without subsidies such as loan guarantees, can range from about 8 to 15 cents or more per kilowatt hour, depending on financing terms and the risk premium attached to nuclear power plants. Of course fuel costs, non-fuel maintenance costs, decommissioning costs, and waste disposal costs are in addition to the capital costs associated with nuclear generation. The total costs of electricity at the generating station switchyard

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[27] *Watts Bar Nuclear Unit*, Tennessee Valley Authority website at http://www.tva.gov/sites/wattsbarnuc.htm, viewed on March 4, 2009.

[28] Ashok Bhatnagar, TVA Nuclear Future, November 2007, on the web at http://www.tva.gov/power/nuclear/future_presentation.pdf

"busbar" costs – that is, transmission and distribution needed to deliver the electricity to consumers involve additional capital costs that have to be taken into account. This is true of all central station sources of electricity, including nuclear, large-scale wind, and central station solar energy projects. Local solar energy projects do not involve additional transmission investments but may involve distribution system investments.

Financial risks associated with nuclear power

High capital costs are only one part of the financial risk of nuclear power. The long lead times even in the absence of delays is a major risk factor, and delays, which are often likely, add to this problem. Successful investing high capital costs requires reliable demand forecasts for electricity. Yet, long lead times mean that a forecast must be reliable about 10 years or more from the date of significant expenditures on planning and half a dozen years from the start of construction, even in the absence of delays. There are a number of risk factors associated with long lead times.

For instance, there could be cost escalations during the planning and construction periods, with the latter being particularly problematic. According to estimates by Jim Harding, a former utility executive, cost escalation between zero and 14 percent per year increases the costs from 10.7 cents per kWh to 23 cents per kWh, when variation in the overnight costs is also taken into account.[29]

As another risk factor, forecasts of demand in a rapidly changing economic environment are very difficult. It appears that currently no utility uses and no Public Regulatory Commission requires

[29] Harding 2008.

the use of a model in which rates and demand are coupled. New power plants, whether nuclear, coal with carbon capture and sequestration, natural gas with carbon capture and sequestration, biomass, wind, or solar, are likely to result in electricity that is significantly more expensive on average than current generation costs.[30] As a result, there will likely be a demand response as there was during the mid- to late-1970's when the rate of electricity growth relative to the rate of economic growth declined sharply from the period prior to the onset of the energy crisis in 1973.

Many reactor projects were cancelled during that energy crisis. For instance, TVA's Bellefonte 1 and 2 units were cancelled before completion. They are on the way to likely complete or near-total depreciation without yielding any benefit to TVA ratepayers. ***In fact, all nuclear power plants ordered in the United States after October 1973 were cancelled at considerable loss to ratepayers, bondholders, and stockholders***. This was the date when the energy crisis began and changed the long-term relationship (over one or more decades) of energy growth to GDP growth in the United States.[31] A model coupling electricity demand to electricity rates showed that excess power plant construction of long-lead time projects could cause serious financial crises in utilities.[32]

The present situation is quite similar. Commodity prices have recently been even more volatile than in the crisis from 1973 to the mid-1980's. "The current recession is also more widespread than any other since the Depression. The Federal Reserve's readings show that 86% of industries

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[30] There are some projections that indicate that the costs of solar electricity will decline to the point of being about equal to present costs of ~5 cents per kWh. New nuclear power plants would become completely uneconomical long before such a low cost was realized. The present testimony is prepared for the conservative contingency that solar costs will not decline to such low levels in the next decade.
[31] Makhijani 2008b, Chapter 1.
[32] Kahn et. al. 1976.

have cut back production since November, the most widespread reduction in the 42 years the Fed has tracked this figure."[33]

It is well known that, other factors being equal, demand will decline in response to rising prices and supply will rise. When there is a shift in the underlying price structure, as is likely to occur due to the need to greatly reduce CO_2 emissions – i.e. due to an impending shift in the underlying technology structure – the demand supply curve is likely to shift. *This response of demand to price, which is familiar to any student of Economics 101, is still not integrated into electricity sector planning.*

Analyzing internal rate of return (IRR) is a useful financial analysis for a deregulated market, such as Texas, since generation companies in a competitive market would want to analyze profit which can be earned by equity owners of a proposed power plant. Clarence Johnson's recent analysis indicates that a nuclear project in ERCOT would have a negative internal rate of return for 15 years and would likely require "massive federal subsidies" to be viable[34] The validity of this analysis is indicated by the fact that Luminant and other merchant plants are applying for federal loan guarantees and the nuclear industry itself is not optimistic about a "nuclear renaissance" in the absence of such guarantees.

The risks of cancellation of nuclear power plants are serious. Since the cost of the projects is higher than the market capitalization of some utilities proposing them, there is the risk of

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[33] Isidore, Chris March 25, 2009The Great Recession: Economists generally agree this is the worst economic downturn since the Great Depression, but they say despite pain, another depression isn't likely. http://money.cnn.com/2009/03/25/news/economy/depression_comparisons/index.htm

[34] Johnson, Clarence, March 2009, Costs of Current and Planned Nuclear Power Plants in Texas, A Consumer Perspective, CJEnergyConsulting, Austin, Texas, Page 31-32

bankruptcy of entire companies. In the case of Luminant, a market valuation is not possible. But it high debt and relatively low debt ratings indicate the potential for problems. If Texas electricity planning proceeds on the assumption that this plant will supply power a decade or so hence, it could entail a risk of stability of electricity supply to consumers. For instance, utilities in dire financial straits may not be able to acquire the financing to purchase fuel. If Texas is not intending to rely on sales from this power plant, then it should not be licensed at all since there is no need for it. The problem of markets for merchant power plants and the interests of ratepayers are particularly acute in Texas, since the ERCOT grid, which serves most Texans, is only weakly connected with the rest of the country. This makes the prospect of large and consistent out of state power sales as an alternative rather bleak for a merchant generating company in Texas.

Costing of nuclear power plants needs to include both the cost of delays and the risk that the plant may not be completed for a variety of reasons, including the possibility that demand may be lower than projected.

The combined risks of large capital costs, long lead times, and possible increases in costs due to delays is reflected in the reluctance of utilities to go to banks or to equity markets to raise the capital to finance new nuclear plants and the reluctance of Wall Street in turn to provide that financing. In fact, no nuclear plant is proposed to be financed by any traditional combination of equity and bond financing. But an estimate of the costs can be made if we compare nuclear financing to high risk bonds (popularly known as "junk bonds"). In recent months, the premium over long term Treasury bonds in a turbulent economic time can be 15 to 20 percent. For instance, according to Fortune, the rates on junk bonds (also called "high yield bonds") "soared to 20 percentage points above those on Treasurys" towards the end of 2008 before easing off by a few points.[35] Hence, financing nuclear power plants in the absence of federal loan guarantees could mean interest rates of 20 to 25 percent.

If we use the high risk rates to approximate the real-world inability to obtain free market financing (even prior to this crisis), then the risk-informed capital cost per kWh of nuclear power would be much higher than that estimated by a calculation that ignores that risk. It is likely that no power plant could be financed on the open market with such high prospective interest rates; nor would any prudent company seek such financing. And the facts on the ground support this view, since all proposals to build nuclear power plants involve federal government loan guarantees of advance payments from ratepayers towards capital costs during construction ("Construction Work in Progress" or CWIP), or both.

Nuclear Power CO_2 Risks emissions compared to other low or zero CO_2 sources of supply or compared to efficiency investments

Since there are essentially no emissions of CO_2 at a nuclear power plant, the owners of such power plants, like the owners or wind or solar power plants, would not be liable for direct CO_2 emissions costs that might be imposed via a cap and trade or a tax system designed to reduce CO_2 emissions.[36] However, there are two other risks of high CO_2 costs associated with nuclear power plants.

[35] Mina Kimes, "There's Still Juice in Junk bonds, Fortune, February 18, 2009, on the web at http://money.cnn.com/2009/02/17/magazines/fortune/kimes_junkbonds.fortune/index.htm.
[36] Upstream CO_2 costs, such as those embedded in cement and steel or uranium enrichment would be reflected in the prices of those goods and these are not considered here. In general, they would not be expected to significantly affect comparisons between nuclear and renewable efficiency made here.

First, since nuclear power plants take much longer to build than solar or wind power plants, or combined heat and power systems or projects to increase efficiency, using nuclear power involves additional CO_2 emissions during the period of construction compared to incrementally increasing zero- or low-CO_2 capacity (including efficiency). Delays in nuclear power plants would also increase CO_2 costs in terms of added costs of acquiring CO_2 emissions allowances of payment of added taxes.

At $50 per metric ton of CO_2 costs and 90 percent capacity factor, each year's delay for a 3,400 MW plant would cost over $1.2 billion dollars per year in added CO_2 costs if coal-fired electricity had to be purchased instead.

Estimated total busbar costs of electricity from new nuclear power plants

The total busbar costs of nuclear power should include:

- Capital costs per kWh
- Non-fuel Operating and Maintenance (O&M) costs
- Fuel costs
- Decommissioning costs
- Waste management and disposal costs, including spent fuel management and disposal costs

In addition, any costs associated with delays and extraordinary financial risks need to be factored in.

At present, non-fuel O&M and fuel costs combined average about 2 cents per kWh in the United States. However, these do not reflect higher uranium prices, higher prices for enrichment services that may result from new plants being built, higher costs of disposal of depleted uranium, for which there is as yet no disposal path, and potentially higher security costs. The Joint Keystone Study, which included industry representatives, estimated the range of O&M and fuel costs to be between 2.4 and 3.2 cents per kWh.

In addition, the problem of spent fuel disposal has not been addressed. The Yucca Mountain repository program seems to be on its last legs. It is a technically poor site that neither President Obama nor the Senate Majority leader supports. The Obama Administration rejected the use of the site in the 2009 United States Federal Budget proposal, which would eliminate all funding except that needed to answer inquiries from the Nuclear Regulatory Commission, "while the Administration devises a new strategy toward nuclear waste disposal." [37] The cost of 0.1 cent per kWh estimated when the Nuclear Waste Policy Act was enacted is obsolete. Any new cost estimates must await a new program. However it must be noted that if reprocessing becomes part of the waste management policy, the costs would likely increase to 2 cents per kWh,[38] or more. Decommissioning costs are likely to be much smaller than this on a per kWh basis.

In sum, the costs other than capital costs per kWh are likely to be in the 2 cents to 5 cents per kWh (rounded) range, possibly more. At present no reliable estimate of repository cost is available, but it is assumed here for simplicity that this will be much less than 2 cents per kWh.

[37] ^ A New Era of Responsibility, Renewing America's Promise, Office of Management and Budget www.budget.gov p. 65.
[38] This is the estimated added cost of electricity from mixed oxide fuel made with reprocessed fuel in France. See Arjun Makhijani, *Plutonium End Game*, Institute for Energy and Environmental Research, January 2001

In reality, this is an uncertainty where a quantitative estimate at the present time that would provide a valid economic basis for comparison with other sources of electricity that do not have comparable uncertainties. It is incumbent upon the Nuclear Regulatory Commission to ask the company to provide such a cost, since provision for ultimate waste disposal must be made during the period of operation of the plant if taxpayers are not to be left holding the bag. New plants do not have contracts with the federal government to take charge of the waste, and hence the financial provisions for spent fuel and/or other high-level waste interim management for long periods and also ultimate disposal are especially important.

In sum, if there are no problems and no added risks and delays, the cost of nuclear power can be estimated in the 10 to 17 cent range. If the risk of non-completion is regarded as near 100 percent (based on post-October 1973 nuclear power plant cancellations), then zero net present value would be delivered to the ratepayers, in which case per kWh costs cannot be estimated.[39] If the risk of non-completion or default is regarded as 50%, the capital cost charge should be increased by 50%. Such a risk level, admittedly difficult to estimate, would put the cost per kWh in the 14 to 25 cent per kWh range. Harding's estimates are 10.7 cents for no escalation to 23 cents per kWh.[40] He does not explicitly factor in delays into his estimates.

We note that even this wide range does not reflect the cost of insurance, since nuclear power plant insurance is almost entirely subsidized by the federal government and liabilities are limited to well below the estimated damages from severe accidents. This is relevant because a proper

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[39] This is a divide by zero situation, since no electricity would be generated.
[40] Harding 2008, slide 6.

comparison between nuclear power and renewable sources of electricity should take into account the insurance subsidy provided to nuclear power.

Comparing electricity costs

In comparing cost estimates, it is important to compare costs without any subsidies such as loan guarantees of production tax credits.

The costs of nuclear power are clearly higher than available alternatives. For instance, costs of combined cycle natural gas power plants is about $1,000 per kW. Fuel costs would range from $4 per million Btu upward to a potential maximum of $14 per million Btu, which was the very peak of natural gas prices, but not sustained. A price of natural gas over $10 per million Btu has never been sustained for over a year. A reasonable range of natural gas prices is therefore $4 to $10 per million Btu (though gas prices have been as low as $2 per million Btu in the last ten years). Fuel costs per kWh for a combined cycle power plant would range from about 3 cents per kWh to 7 cents per kWh (rounded), while non-fuel O&M costs are about 2 cents per kWh.

These estimates do not include a cost for CO_2 emissions, which amount to about 350 grams per kWh. At a carbon cost of $50 to $100 per metric ton of CO_2 (the latter is very high) either for carbon capture and storage (CCS) or for purchasing allowances, the CO_2 charge per kWh works would to between 1.75 and 3.5 cents per kWh.

Adding all these costs, the total costs of electricity, including capital costs at 80 percent capacity factor would be between about 8 and 15 cents per kWh, which ranges from lower than the lowest new nuclear costs to about equal to the middle of the range of nuclear costs.

It should be noted in this context that the lead time for building natural gas-fired power plants is much less than that of new nuclear plants. Hence, the risk is correspondingly lower. If the risks of delay are taken into account, then natural gas fired combined cycle power plants would be cheaper than or at worst equal to the low end of expected nuclear costs with at least a modest risk element included.

Wind Power

Wind generated electricity requires no fuel and has no CO_2 emissions associated with it. Is also more economical than nuclear power. Current estimates of wind-generated electricity are in the 8 to 12 cents per kWh range.

The onshore and offshore wind resources in the United States are enormous.

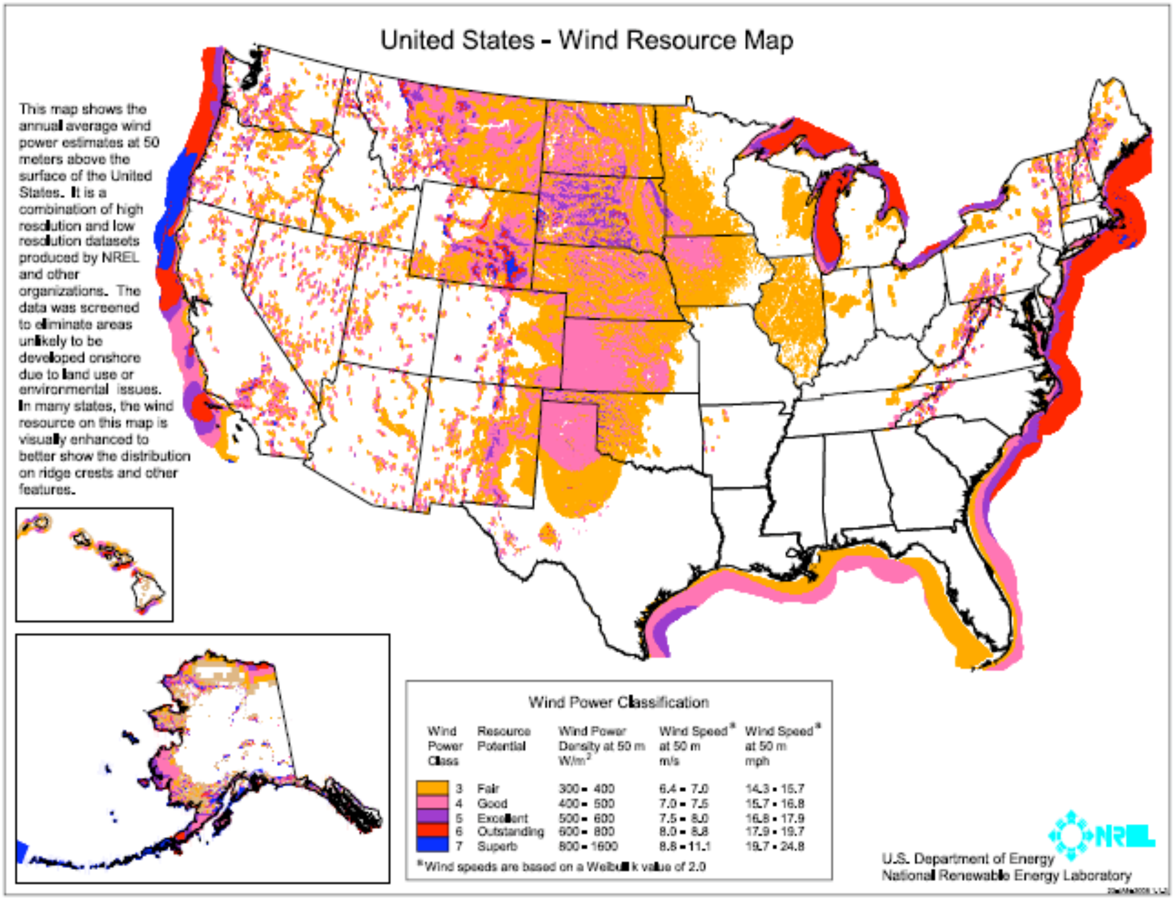


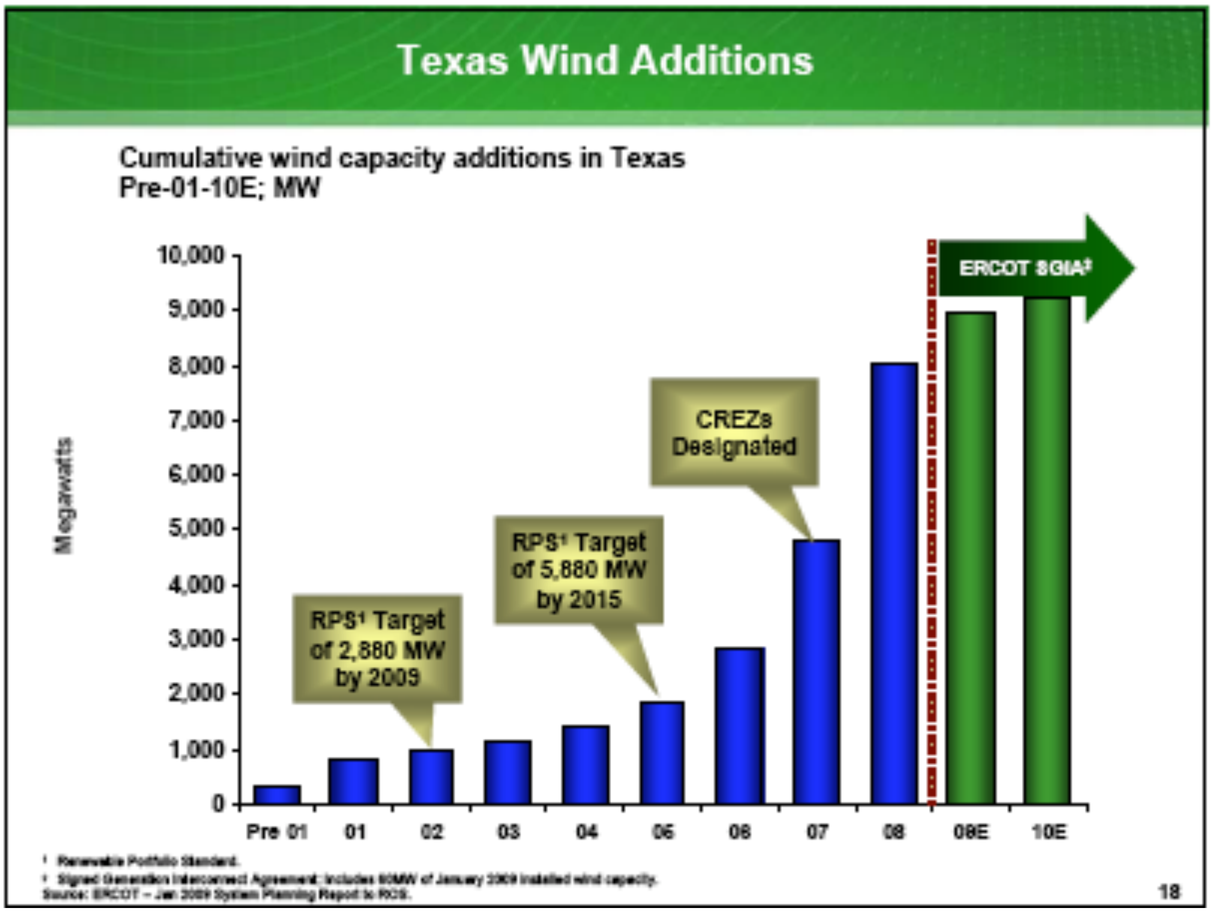
Figure 1: Wind Power Resources in the United States

Source: National Renewable Energy Laboratory,

Six states of the United States have more wind energy potential than the electricity output of all U.S. nuclear power plants combined. Texas wind energy is booming and is expected to continue to expand, with wind capacity of over 9000 MW by 2010.[41] Currently Texas leads the nation in wind energy generation, with 7115.66 MW of existing capacity as of the end of 2008. An additional 1651.35 MW of capacity will become available through projects that are under construction. California is the second largest wind generating state, and has just over a third the

[41] March/April 2009 Energy Future Holdings PowerPoint presentation, EHF Corp. Spring 2009 Discussion Deck, Slide #18

amount of existing wind that Texas has in place. There is still room to grow. In fact, Texas is ranked second nationally for wind potential, and the potential wind capacity is 136,100 MW.[42] Energy storage requirements of at least 1000 MW are likely to pass in the Texas legislature and utilizing this storage will help stabilize lines and maximize both solar and wind generation.



The Texas Wind Additions chart[43] was included in an Energy Futures Holdings/Luminant PowerPoint presentation for March/April 2009. It shows increasing wind capacity and the CREZ designation, which is preapproved transmission.

[42] American Wind Energy Association, U.S. Wind Energy Projects – Texas, as of 12/31/08, www.awea.org/projects/projects.aspx?s=Texas
[43] March/April 2009 Energy Future Holdings PowerPoint presentation, EHF Corp. Spring 2009 Discussion Deck, Slide #18

Oncor, the transmission and distribution utility that partners with Luminant in Energy Future Holdings, expects to invest about $1.3 billion in the next five years on new transmission lines to support the continued buildout of wind capacity in Texas. Oncor's investment in CREZ (Competitive Renewable Energy Zones) is expected to receive accelerated recovery, consistent with other transmission investment, mitigating regulatory lag.[44]

But a 100-meter resource assessment, also from the National Renewable Energy Laboratory, looks very different. As can be seen from Figure 2, such an evaluation shows that most of the state of Indiana has good to excellent to outstanding wind energy potential (according to the NREL definitions of those terms in Figure 1).

[44] *Ibid.* Slide #5

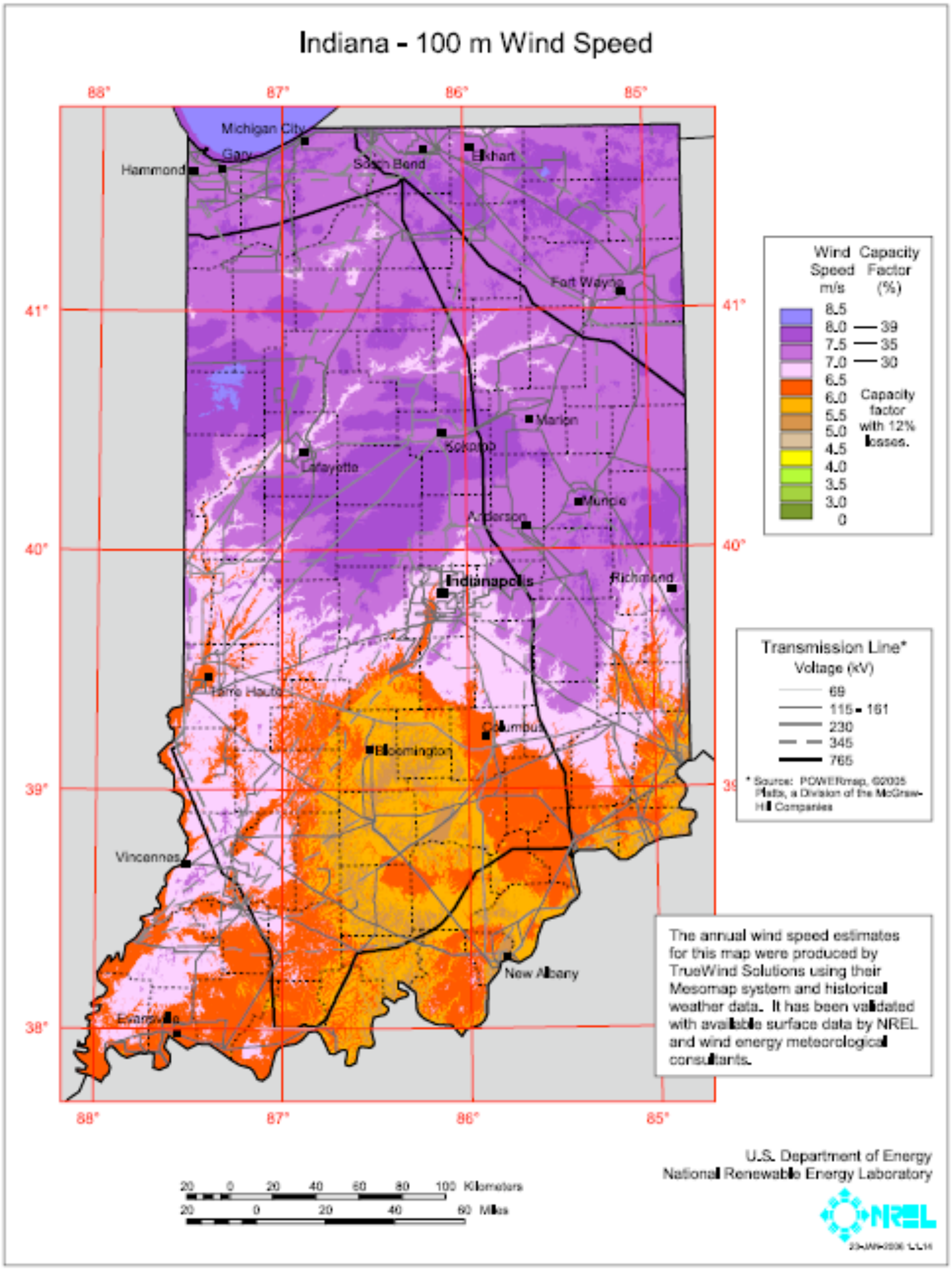


Figure 2: State of Indiana Wind Resource Potential
Source: National Renewable Energy Laboratory

http://www.indianacleanpower.org/NREL%20100%20Meter%20Wind%20Map%20With%20Transmission%20Lines%20January%202006.pdf

A similar pattern can be found in other states. For instance, Missouri at 50 meters has little potential (see Figure 1), but at 100 meters it has large potential – see Figure 3. It should be noted that 100-meter wind data are not available for all states, since assessment of wind energy potential at such heights is a recent development. But no nuclear project should be undertaken on the ground that wind energy resources are inadequate without an evaluation of wind energy potential at 100 to 130 meters heights.

The differences in wind resources for higher hub heights and larger turbines are so dramatic that wind farms that are only about two decades old are being replaced by larger turbines and taller towers. For instance, a 77-turbine wind farm in Denmark is being replaced by 13 turbines rated at 2.3 megawatts each. When complete, this repowering of the wind farm will generate more electricity from the 13 turbines and the same land area than the prior 77 sub-megawatt turbines. Such repowering of wind farms is also occurring in Germany and California.[45]

[45] IEEE 2009.

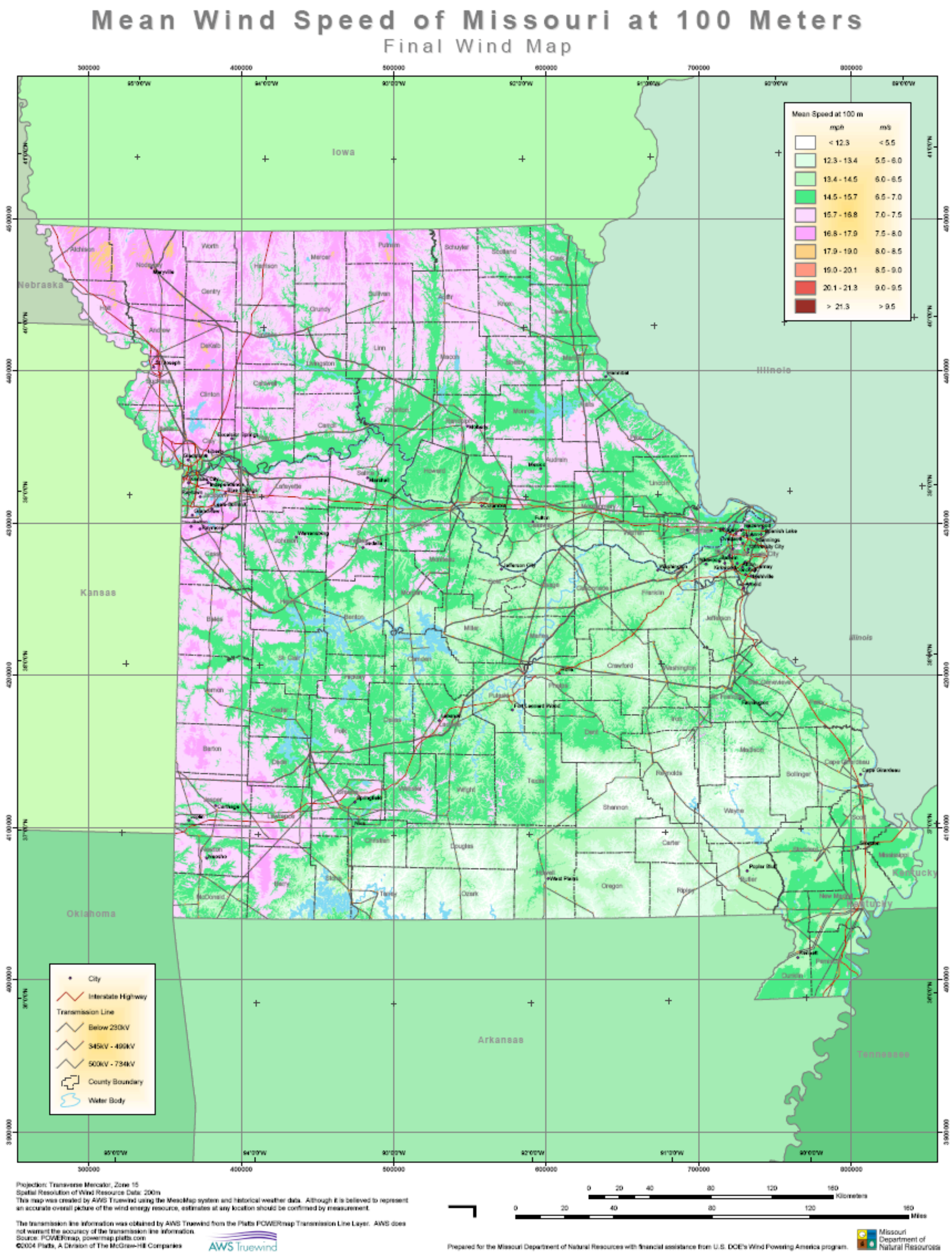


Figure 3: Missouri Wind Energy Potential at 100 meters

Source: http://www.dnr.mo.gov/energy/renewables/MO_Final_SPD100m_24Jan05.pdf

Costs of concentrating solar power are comparable to or less than new nuclear plants. The cost range of new CSP plants appears to be competitive with nuclear costs even though this technology is not yet mature in the sense of having a large and well-established manufacturing infrastructure. The Arizona Public Service plant, which will have 6 hours of heat storage and a 90 percent capacity factor in the summer, will have a cost of about 14 cents per kWh.

PG&E has ordered solar thermal power plants, starting with two tranches of 100 MW each and a third of 200 MW. The first tranche of 100 MW would cost $3,000 per kW; the second tranche of 100 MW is estimated to cost $2,800 per kW and the third of 200 MW trance is estimated at $2,600 per kW.[46] This includes equipment for a natural gas supplement for start up in the morning and for supplemental power during cloudy periods and in the evening. This project clearly indicates the expected trend of declining capital costs. Emissions on the order of 10 percent of those expected in a coal-fired power plant would be expected for a power plant operating in this configuration.

Assuming one-third of the generation comes from natural gas, a $50 per metric ton charge for CO2 emissions, and an overall capacity factor of 30 percent, the overall cost per kWh would be on the order of 16 cents per kWh, which is about equal to the middle of the full range of nuclear costs. It should also be noted that in these configurations, the problem of intermittency is generally addressed, in the case of the APS plant with zero CO2 emissions.

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[46] Ivanpah project description filed with the California Energy Commission at http://www.energy.ca.gov/sitingcases/ivanpah/documents/applicant/AFC/Volume1/ISEGS_005.10_Socioeconomics.pdf

Like wind and natural gas combined cycle power plants, CSP plants have relatively short lead times. They also have no extraordinary risk factors such as those associated with nuclear waste or the kinds of severe accident potentials that require government-provided insurance.

Central station solar power plants can also consist of photovoltaic technology. Pacific Gas & Electric Co. (PG&E) has ordered 800 megawatts of central station solar PV plant that it expects may be competitive with concentrating solar thermal power or wind energy.[47] The costs of large-scale development of the latter, without subsidies, are currently in the range of 8 to 12 cents per kWh. CSP is with storage is ~14 cent kWh. This means that solar electricity can be generated today on a large scale at a cost that is in the middle of the range of nuclear costs but without any of the generation risks. Solar power plants can be built relatively quickly (two to three years) and in modular amounts. A half completed project will yield half of the electricity,. While a half completed nuclear project will yield nothing but losses. If there is any risk with central station solar plants it is with transmission. However, with ERCOT's planning in place for renewables, an expansion of solar project similar to wind can be accommodated with an updated renewable energy zone transmission assessment and investments, so that the transmission risks would be minimal.

Solar projects at intermediate scale can be built even more quickly and without any of the tranmission risks. Southern California Edison is currently carrying out a 250 MW project that involves installation of solar PV on large commercial rooftops.[48] No new transmission lines would be required. PG&E has announced 500 MW of rooftop and parking lot solar PV, half of

[47] PG&E 2008.
[48] SCE 2008...

which it would own directly, while the other half would be purchased from third parties generating the solar electricity.

First Solar has recently announced that it is making solar panels at less than a dollar per peak watt. This does not include installation. But the rapid decline in solar PV costs makes is necessary to make a dynamic evaluation of the costs of solar PV when comparing it with nuclear or for that matter with wind. It is the expectation that these costs will decline significantly, probably coming down below 10 cents per kWh ($100 per MWh) in under ten years for large-scale installations.[49] When installed in megawatt-scale large rooftop and parking lot installations, solar PV is likely to be competitive with or cheaper than nuclear before the first nuclear units that are now planned come on line. Risking huge amounts of capital on any long-lead time project, like a nuclear power plant, is imprudent at a time when alternatives that are comparable in cost or cheaper are clearly available.

As an indication of how risky nuclear plants were even before the present acute phase of the economic crisis, consider the statement made by Jeffrey Immelt, CEO of GE, which makes nuclear power plants, wind turbines, and gas turbines, in November 2007, almost a year before the meltdown on Wall Street and the deep recession that came with it, about what he would do as a utility CEO:

> If you were a utility CEO and looked at your world today, you would just do gas and wind. You would say [they are] easier to site, digestible today [and] I don't

[49] DOE 2007.

> have to bet my company on any of this stuff. You would never do nuclear. The economics are overwhelming.[50]

Solar and wind can be used for reliable generation

The measures that are needed to maintain reliability as the proportion of solar and wind energy in the electricity system increases are different. At very low levels of penetration, a few percent of less, a small increase in standby capacity, which can be achieved in most places by redeploying existing natural gas generation, is sufficient. It is also important to coordinate solar and wind investments; this reduces the requirements for added reserve capacity. Geographic diversity in the deployment of renewables accomplishes the same thing.

Beyond these measures, heat storage at solar thermal power plants (molten salt storage for instance) and/or use of modest amount of natural gas with low overall (combined solar and natural gas) CO_2 emissions results in the provision of reliable electricity supply in certain regions of the country – notably the southwest. APS will be able to generate electricity for 90 percent of the summer days with six hours of molten salt heat storage.

It is also important to integrate renewables with the development of a smart grid – a grid in which consuming devices talk to producing devices. One of the keys is to think of energy services rather than electricity as the requirement of consumers. For instance, ice-energy technology and computers can connect air-conditioners to wind power availability. Ice would be made when the wind is blowing and air conditioning would be available when needed.[51]

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[50] As quoted in McNulty and Crooks 2007.
[51] See the website of Ice Energy, for instance, www.ice-energy.com

Oncor is the transmission and distribution utility which, along with Luminant, is part of Energy Future Holding Businesses. Oncor is leading the largest smart-meter deployment in the US with an initiative to have 3.4 million meters connected by 2012. With strong encouragement from the PUC, Oncor recovers its investment trough a PUC-approved surcharge.[52] This advance in smart grid technology calls into question the need for the Comanche reactors, which will not be far along by this time. The proposed Comanche Peak Unit 3 reactor is not even scheduled to finish site preparation until Fall 2012.

Installation of smart meters will enable customers to tailor their energy use to renewable energy availability, to avoid high cost peak times by various means such as turning on washing machines only during off-peak periods. When a smart grid is in place, the significance of baseload, intermediate load, and peak load will decline because changed usage patterns, heat and cold storage devices, and communication between consuming devices and producing devices will enable consumption of renewable electricity when the resource is available and consumption of energy services like heating and cooling and refrigeration and lighting when the customer needs it. Various renewable energy sources can be coordinated with each other and optimized in terms of the proportions on the grid. For instance, the amounts of solar PV and wind energy would be optimized to minimize the need for additional reserve capacity and storage. In time, local smart grids are likely to become part of a national smart grid that will probably be needed to help fulfill President-elect Obama's commitment to reduce U.S. greenhouse gas emissions by 80 percent below 1990 levels by 2050.

[52] March/April 2009 Energy Future Holdings PowerPoint presentation, EHF Corp. Spring 2009 Discussion Deck, Slide #6

Summarizing cost issues

Rejecting natural gas due to volatility is not sensible compared to nuclear. This does not take into account the fact the very high process of natural gas over $10 per million Btu have never been sustained for any length of time. Rejecting renewables on grounds of intermittency is also not sensible, especially with storage requirements underway at the Texas legislature. Efficiency has been dismissed in the COLA, despite the fact that the Texas Public Utility Commission finds that peak electric demand can be reduced by 23% and ERCOT has approved some gas plants to retire, stating that it will not affect grid reliability and to allow the retirement of up to 3825 MW of gas fired electric plants, significantly more than the 3200 MW that the proposed nuclear reactors would provide.

Furthermore, the economic downturn could affect demand, and this has not been considered in the COLA. San Antonio Texas municipal utility, CPS Energy, recently stated in a presentation that demand in their service area had declined 16% in the last two years. Analysis of the DFW market to see if demand has already declined would be prudent, as well as consideration of the impacts of stimulus funding that will boost energy efficiency and renewable energy industries. Recovery Act Funding for energy efficiency and renewable energy totals $16.8 billion, including $3.2 billion for Energy Efficiency and Conservation Block Grants, $5 billion for weatherization assistance, $3.1 billion for the State Energy Program, and $2 billion for grants for manufacturing advanced batteries and components and $3.5 billion for applied research, development, and demonstration and deployment activities. An additional $4.5 billion would go toward electricity delivery and energy reliability work – to modernize the grid through Smart Grid technologies.[53]

[53] NEPA Lessons Learned Quarterly Report, U.S. DOE, March 3, 2009, Issue No. 58, www.gc.energy.gov/NEPA/documents/2009_MARCH_LLQROnline.pdf

The impact on electric demand and on the viability of new nuclear generation from the economic downturn and the increased funding for energy efficiency and renewable energy sources has not been considered or analyzed.

The huge potential of peak shaving options such as ice-energy-driven central air conditioning and the increased use of combined heat and power, with absorption central air-conditioning for commercial buildings has not been analyzed.

Dr. Makhijani's study of San Antonio's municipal electric utility, CPS Energy showed that the utility would save between $1.4 billion and $3.1 billion using a combination of efficiency, storage, and solar energy, relative to buying new nuclear capacity.[54] Almost all of the added capacity would come from efficiency, storage and CHP, with solar playing a modest role.

Other Non-Intermittent Energy Options

Geothermal resources in the form of hot underground water are available in Texas. Hot rock geothermal energy, which is a widely available resource, is being rapidly commercialized and can be expected to be available well within ten years – that is, at or prior to the time that new nuclear units in the U.S. are planned to go on line. For instance, Geodynamics, an Australian company plans to have commercial scale generation consisting of nine 50 MW hot fractured rock plants to begin coming on in 2011.[55] It estimated that if 40 percent of the heat under the United States could be tapped, it would meet our nation's energy demand 56,000 times over.[56] The Texas Bureau of Economic Geology estimates that as much as 20,000 MW of renewable geothermal power lies under the state, enough yearly power to meet one-third of Texas'

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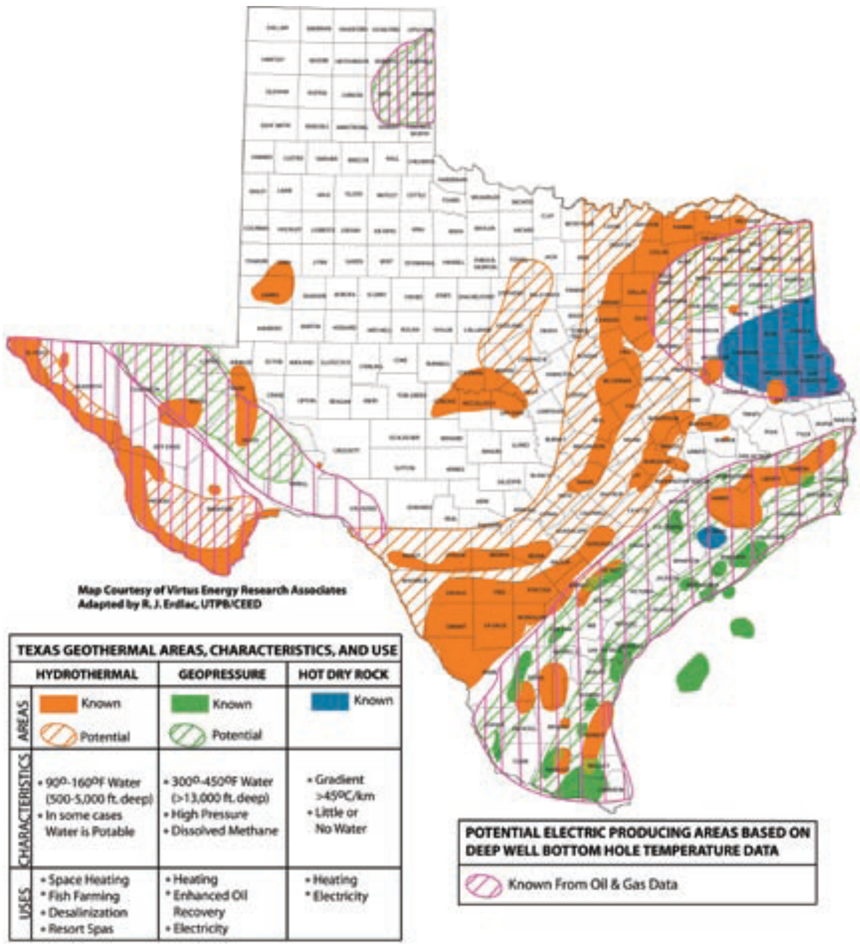
[54] Makhijani 2008.

[55] See http://www.geodynamics.com.au/IRM/content/gbp_threestage.html

[56] Massachusetts Institute of Technology, Future of Geothermal Energy, http://geothermal.id.doe.gov/publications/future_of_geothermal_energy.pdf, 2006

generation.[57] The COLA is wrong in their statement that geothermal power cannot generate as much electricity as the proposed Comanche Peak nuclear reactors (nominal capacity 3,400 MW)



[58]

Wind energy is also being reconfigured to be able to provide dispatchable electricity. General Compression is designing wind turbines with air compressors rather than electricity generators. Storage of compressed air for a few hours in a network of pipes can provide dispatchable electricity over the course of a day. Shell and Luminant have proposed to develop a compressed air energy storage facility in Texas near Comanche Peak.

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[57] Good Company Associates, Harnessing the Geothermal Power Potential of Texas, www.lonestar.sierraclub.org/newsreleases/20090318GeothermaTx.pdf

[58] U.S. DOE, Energy Efficiency and Renewable Energy, Geothermal Technologies Program – Texas, April 2006, http://smu.edu/geothermal/index.htm

> "Companies have experimented with batteries, flywheels, capacitors and hydroelectric systems to capture the wind's energy for later use. But one solution may see large-scale use on the windy ranch land in Briscoe County, Texas where Shell is considering plans to develop a 1,500- to 3,000-megawatt wind farm. The project may store energy underground in the form of compressed air, which would help generate additional electricity when used in gas-powered turbines" .[59]

In fact, the National Renewable Energy Laboratory (NREL) has developed a scheme for using wind power, compressed air energy storage, and natural gas for heating the compressed air as a baseload system. The compressed air storage does not have to be co-located with the wind farms, only connected to it via a communication system that allows joint functioning to provide dispatchable wind energy. NREL estimates that only about 1,000 Btu of natural gas would be required to provide baseload wind. The CO2 emissions would be between 40 to 80 grams per kWh,[60] or about 4 to 8 percent of a typical coal fired power plant, depending on the capacity factor. AN advanced wind-CAES plant can provide 90 percent capacity factor with natural gas use of less than 1,200 Btu per kWh, which would result in CO2 emissions of about 10 percent of that of a coal-fired power plant. The figures below are taken from the NREL reference and they illustrate the concept.

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[59] http://www.shell.com/home/content/responsible_energy/shell_world_stories/2008/wind

[60] National Renewable Energy laboratory, Creating Baseload Wind Using Advanced Compressed Air Energy Storage Concepts, on the web at http://www.nrel.gov/docs/fy07osti/40674.pdf

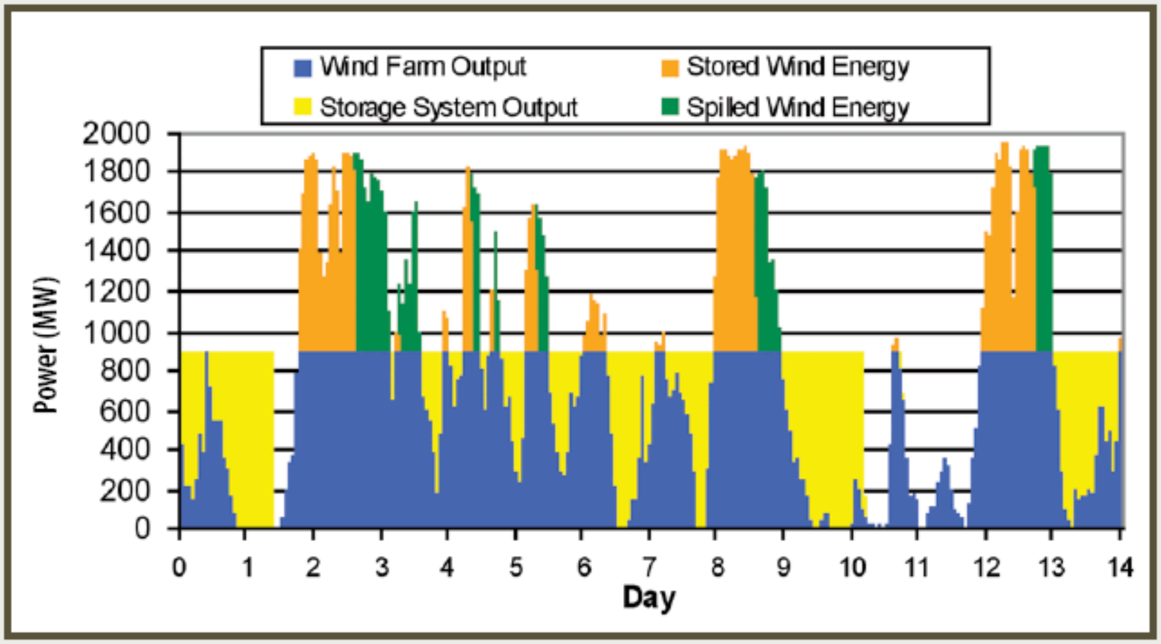

Figure 3. Sample Baseload Wind Generator Output (Target Output = 900 MW)

Source NREL. http://www.nrel.gov/docs/fy07osti/40674.pdf

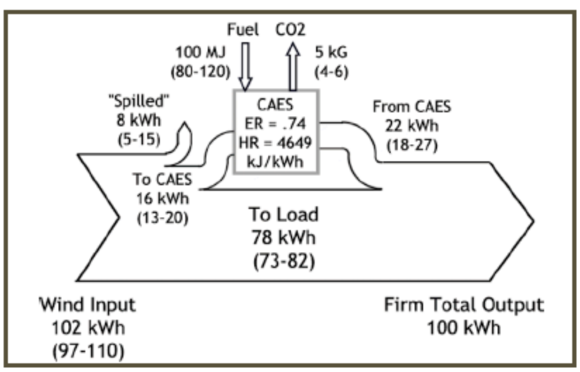

Figure 4: Energy Flow through a Baseload Wind Power Plant

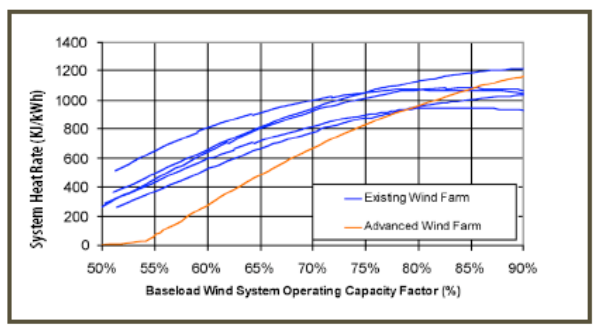

Figure 5: Baseload Wind Plant Fuel Requirements

Source NREL. http://www.nrel.gov/docs/fy07osti/40674.pdf

Since Texas is retiring natural gas capacity, the natural supplies now being used in such plants could be used to create several times the baseload capacity when combined with wind. CAES is a proven technology that has been used at a large power Alabama as well as in Germany. Given that Texas is rich in both wind and solar resources and that potential storage sites are also in plentiful supply, there is no need for new nuclear power plants or any new purely fossil fuel power plants. A modest amount of supplemental natural gas with wind or molten salt storage with solar can suffice. In the long term (more than a decade or two), natural gas can be replaced by biogas if necessary.

Finally, solid biomass can be used in a number of ways to provide dispatchable electricity. Integrated gasification combined cycle (IGCC) biomass plants have been demonstrated with a variety of biomass feedstocks. These plants can be used as combined cycle central station plants or as modular combined heat and power units. In either case they can provide an alternative to conventional generation. For instance, an 18 megawatt thermal input plant, with 6 MW electrical output and 9 MW thermal output combined cycle IGCC plant has been demonstrated in Sweden with a variety of biomass inputs and low emissions.[61]

There is a plethora of available technologies at comparable or lower cost than nuclear that do not involve the risks of nuclear, which are very large and range for uncertainty about waste disposal, to long lead times, to large unit sizes which must be fully completed in order to yield any benefits, to large unit sizes that make total capital costs that, in some cases, are higher than the entire market capitalization of companies. The options range from natural gas combined cycle

[61] Krister Stahl and Magnus Neergaard, IGCC Power Plant for Biomass Utilization, Värnamo, Sweden, Biomass and Bioenergy, Vol. 15, No. 3, 1998, pp. 205-211.

power plants, which are competitive or cheaper than nuclear even with a high carbon tax range up to $100 per metric ton of CO2 to baseload wind to solar thermal power plants with storage, to efficiency, CHP< and demand side management to geothermal to biomass IGCC plants. It is simply intellectually unacceptable to confine the comparison to coal vs. nuclear or coal vs. natural gas vs. nuclear. With the present stage and short-term prospects of credible alternatives, no license can legitimately be granted that would meet the requirements of NEPA that did not consider at least the range of options discussed in this paper.

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