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Comments Regarding Luminant's Revision to the Comanche Peak Nuclear Power Plant, Units 3 & 4 COL Application Part 3 – Environmental Report

I have reviewed Luminant's Revision to the Comanche Peak Nuclear Power Plant, Units 3 & 4 COL Application Environmental Report,[1] and I offer the following comments regarding the revision based on my best professional judgment.

Summary

The core position of the Applicant in its Revision to the Comanche Peak Nuclear Power Plant, Units 3 & 4 COL Application, Environmental Report (CP COL ER) appears in section 9.2.2.11.5, Conclusions of Combining New Generation Power Sources with Storage:

"…This evaluation does not change the conclusions in Subsections 9.2.2.1, 9.2.2.2, 9.2.2.10, 9.2.3.2 and 9.2.3.3 that natural gas, wind, solar; and energy storage either individually or in combination, are not viable alternatives that could both produce baseload power comparable to that generated by CPNPP Units 3 and 4 and be environmentally preferable to CPNPP Units 3 and 4."

The Applicant tries to justify its position with four tricks: (1) They restrict the alternatives considered. (2) They frame evaluation criteria narrowly around the form of the CP COL ER's desired solution (a large nuclear power plant) rather than its function (providing the requisite electricity), even though this form has significant problems that other forms do not have. (3) They argue in contradictory ways at different times. (4) They use quantitative facts out of proper context and stretch truths beyond reasonable limits.

After enumerating some detailed examples of these tricks, I conclude with an observation that suggests the applicants are hypocritical in their application of Criterion 1 – Developed, proven, and available in the relevant region ERCOT.

Details

1. The Applicant considers gas in combination with wind power and storage[2], and they consider gas in combination with solar power and storage[3]. They say that wind power is not good for producing a flat output because it is weaker in daytime than at night[4]. Later they say that solar power is not good for producing a flat output because it is limited to daytime[5]. After thus recognizing the complementary aspects of wind and solar power, why did the Applicant not also consider the possibility of *combining wind and solar* to produce a more uniform overall generation profile? These complementary wind and solar

[1] Luminant's Revision to Combined License Application Part 3, Environmental Report, December 8, 2009.
[2] Section 9.2.2.11.3.1.
[3] Section 9.2.2.11.3.2.
[4] Page 9.2-37, second paragraph in section 9.2.2.11.3.1. Also, page 9.2-39, last paragraph under Criterion 2.
[5] Page 9.2-41, last paragraph -- at bottom of page.

components could be in different places and connected only by the electrical grid. Such a combination would have been harder to deprecate as “inappropriate for baseload.”

2. Although the Applicant acknowledges the existence of the Iowa Stored Energy Park project[6], which will store compressed air in an aquifer, they do not recognize the fact that aquifers are fundamentally different from salt domes in potential storage capacity when they characterize CAES as having “finite storage capacity”.[7] Then, later, they use this restrictive assumption as the basis for the supposed requirement that a wind-and-CAES system be backed up by a full-size natural-gas plant. Their “finite storage capacity” characterization may be based on the relatively high cost of creating storage volume in a salt dome. In this case, the cost of creating storage increases linearly with the total amount of storage. In contrast, the cost of creating storage in an aquifer (or depleted gas well) increases only logarithmically with total storage. For example, increasing *salt-dome* storage time from 12 hours to 12 days would increases the initial cost of the storage by a factor of 24, whereas increasing *aquifer* storage time from 12 hours to 12 days increases the initial cost of the storage by a factor of only about 1.5.[8] Thus, with aquifer (or depleted gas-well) storage, the CAES storage capacity can economically be made large enough to make the loss-of-load probability of a wind-and-CAES system comparable to any conventional “baseload” plant, including a nuclear plant. This eliminates the applicant's supposed need for a full-size natural-gas back-up plant. It is worth noting that the application's “PEI 2008” reference – which will be discussed in more detail later – says that 88 hours of aquifer storage transforms wind power into a “baseload” resource. More than 88 hours might actually be needed, but if necessary, it's straight-forward to get more hours, as described above.

3. The Applicant recognizes that molten salts can store heat in a concentrated solar power system. Why do they not also recognize that such stored heat could be used instead of natural gas consumption in a CAES system? If thermal solar collectors were co-located with the CAES storage, sunshine could provide all of the heat needed in the expansion part of a CAES operation. Alternatively, molten-salt storage by itself (without any solar collectors) could be used to implement “adiabatic CAES”, i.e., CAES with no net heat transfer. In adiabatic CAES, the heat generated mechanically in the compression phase of CAES is stored and used later for the expansion phase of CAES. Either of these approaches could eliminate all natural gas consumption in a 100% renewable-energy alternative to nuclear power.

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[6] bottom of page 9.2-33.

[7] Section 9.2.2.11.3.1, at the top of page 9.2-38.

[8] The flow rate for a well of radius r_{well} in a permeable formation of radius $r_{formation}$ is $F \approx A / \log_e(r_{formation}/r_{well})$, where A depends on intrinsic formation properties. Typically, $r_{formation}/r_{well}$ is a large number, like 500, $\log_e(500) = 6.2$, and $F_1 \approx A / 6.2$. Now, suppose we increase $r_{formation}$ by a factor of 5, and thereby multiply the formation volume and storage capacity by a factor of 25. Then $\log_e(r_{formation}/r_{well}) = 9.4$. This reduces the flow rate to $F_2 = A / 9.4$, but we can compensate for this flow-rate reduction by increasing the total number of wells by a factor of 9.4 / 6.2 = 1.5. Thus, increasing the initial investment in aquifer (or depleted gas-well) storage by a factor of only 1.5 increases the storage capacity by a factor of 25.

4. The Applicant frames the evaluation criteria so that inconsequential distinctions are given inappropriately heavy weight:

    a. <u>The misleading "Not Developed Here" concept</u>:
    The Applicant abuses *Criterion 1 − Developed, proven, and available in the relevant region ERCOT*. Yes, it is appropriate to ask whether wind-power or solar-power potential exist within the region (both do exist within the region – in copious amounts). Similarly, it is appropriate to ask whether nuclear power consumes more water resources than wind or solar power (it does), and in arid regions with rapidly depleting fossil water resources (like western Texas), this is an important consideration. (The Applicant does not mention this unfavorable-to-nuclear fact in the parts of the application I have seen.) Also, it is appropriate to ask whether the relevant region has or will have adequate electrical transmission and whether electricity markets and management are flexible enough to support renewable development. The fact that Texas has implemented more wind power than any other state proves that the relevant region (Texas and ERCOT) is better suited for renewable alternatives than many other regions. Moreover, ERCOT "stands out among the other regions for the competitive performance of both its retail and wholesale markets…ERCOT is considered to be the first ISO in the United States to use real-time dynamic ratings from TSPs [Transmission Service Providers] to monitor and analyze system operations."[9] Also, "West Texas exhibits the highest levels of direct normal insolation in Texas as well as some of the highest levels in the entire nation."[10] Therefore, it is inappropriate to disqualify renewable technologies being implemented in other regions. It's astonishing that the applicant tries to disqualify[11] renewable technologies in this region, while simultaneously announcing[12] that another branch of the applicant's company is proposing impressively large installations of these same technologies in this same region.

    The relatively slow development of CAES in a porous aquifer in Iowa may be the basis of the applicant's deprecation[13] of this technology, but the applicant does not acknowledge the fact that the development task is much harder in Iowa than it would be in Texas. Iowa's problem is that it does not have old gas wells, and it does not have the vast amount of the geological data that was previously gathered to support drilling, developing, and producing such wells. This is an important

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[9] Hur, Boddeti, Sarma, Dumas, Adams, and Chi, "High-Wire Act: ERCOT Balances Transmission Flows for Texas-Size Savings Using Its Dynamic Thermal Ratings Application", *IEEE Power & Energy*, 8, No. 1, January/February 2010, pp 37-45.

[10] See Figure 3 in Solar Resources at the Texas State Conservation Office web site, www.InfinitePower.org > Solar

[11] Page 9.2-34, third paragraph down from top of page.

[12] Page 9.2-31 bottom, second paragraph under section 9.2.2.11.1; Page 9.2-38, middle of page; page 9.2-39, first paragraph under Criterion 3.

[13] Page 9.2-39 top, "The operation of a CAES facility in a bedded sedimentary formation also has not been attempted or demonstrated". That's what the Iowa Stored Energy Park has been doing.

example of where a technology being developed in a different region would be easier, not harder, to develop in the "relevant region."

b. The misleading "Not Demonstrated in Combination" concept:
This is another example of how the application abuses *Criterion 1 − Developed, proven, and available in the relevant region ERCOT*. The application attempts to disallow several combinations of electrical generation on the basis that these particular types of generation have not been used with each other, even though each has been used with other types of generation and varying loads.[14] This is a frivolous objection, because all of these types of generation have been used on "the grid." What really matters is whether grid managers understand, know how to deal with, and have experience dealing with them in the dynamic electrical-grid environment. For example, there are several decades of experience using CAES to absorb power from the grid when customer demand is weak and supply power to the grid when customer demand is strong. This is not significantly different from using CAES to absorb power from the grid when wind power is strong and supply power to the grid when wind power is weak.

5. The Applicant frames evaluation criteria so that the worst features of a nuclear system become constraints that disallow gas, renewable, and storage alternatives:

a. Misleading use of "Baseload" concept[15]:
It is harder to modulate the output of a nuclear power plant than it is to modulate the output of other types of power plants. The Applicant indirectly admits this when they claim that nuclear power "is" "baseload" power, whereas gas and wind power "are" "intermediate" or "peaking" power. The truth is that nuclear power cannot be anything else but "baseload" generation, whereas combinations of gas and renewable and storage can be any of the three types of generation – "baseload", "intermediate", or "peaking." In fact, "baseload" is actually the easiest and most reasonable application of either wind power plus natural-gas power or wind power plus CAES, for two reasons: (1) It takes less capital to construct a combination of gas and wind power that produces a flat demand profile than it takes to construct a combination of gas and wind power that produces a typical varying load profile. (2) The chief economic advantage of wind power with storage is its low operating cost, and low operating cost is the principle objective of "baseload" design. The unavoidable flatness of a nuclear plant's output is an undesirable attribute that is accepted in order to obtain the benefit of low operating cost. On the other hand, once a combination of gas, wind power, and storage has been constructed for a (flat) baseload application, that same physical system can be easily switched to (variable) intermediate or peaking applications whenever the marketplace calls for such a switch. A renewable-

[14] Page 9.2-37, first paragraph in Section 9.2.2.11.3; and later under Criterion 1 on page 9.2-48.
[15] Page 9.2-30, first paragraph in section 9.2.2.11, and many subsequent places. Characterizing (pure) wind power as "peaking" power is ironic. It suggests that the Applicant knows that any wind power exceeding a contracted "baseload" amount might be sold on the spot market for extra profit, and that the wind power equipment is always able to provide useful ancillary services for additional extra profit.

energy system designed originally for baseload application may not have the optimal economic mix of components for intermediate or peaking applications, but it will be able to serve such applications immediately and effectively, just as the Applicant asserts. However, the Applicant essentially infers that this ability of the combination of gas, wind and storage to serve intermediate and peaking applications somehow disqualifies that combination from serving baseload applications, even though those baseload applications would be *easier* for the combinations of gas, wind and storage to serve. The Applicant's "not-baseload" argument against renewable energy is very popular, but it is deeply and fundamentally flawed.

b. The misleading "Large Project" concept[16]:
The application abuses *Criterion 2 – Capacity equivalent to the planned generation*. The application also abuses *Criterion 3 – Available during the same time frame*. Although micro-nuclear systems have been informally proposed, commercial nuclear power needs to be very large to be economically viable. However, large size is also an economic liability. It creates a very large financial gamble on projected future electrical-energy demand, and it minimizes real options. Compared to a typical wind farm, a large nuclear plant takes a relatively long time to build. So the large initial investment must be made a long time before the benefits of that investment can start to be realized. Moreover, when a large nuclear power plant does finally come on line, it changes the generating capacity of the system by a very large amount in one big step. In contrast, market demand does not change in giant steps widely separated in time. So a nuclear plant's large size is inherently poorly matched to changes in actual market demand. On the other hand, combinations of gas, renewable energy sources, and storage can be committed to and installed gradually over time – with ongoing flexibility in the size of the ultimate commitment and ongoing flexibility in the detailed mix of components. In spite of the inherent riskiness (and suppression of real options) in a single large fixed investment in a nuclear plant, the Applicant essentially infers that the ability to implement wind-storage-gas systems gradually over time as market demand develops disqualifies those wind-storage-gas systems alternatives. In effect, they claim that the most conservative approach to a large long-duration hard-to-estimate future need should be "not allowed" because it is different from a more reckless approach that happens to be the only approach available to nuclear power. The applicant's demand that proposed alternatives to nuclear power must similarly put "all their eggs in one big basket" is very unreasonable.

6. Other misleading and contradictory statements:

a. Misleading Statements about Environmentally Impacted Areas:
The application abuses *Criterion 4 – No unusual environmental impacts or exceptional costs*. The application says[17] "the size of a wind farm to generate

[16] The "requirement" that alternatives to nuclear power be in similarly large units is implicit in all of the Criterion 2 evaluations.
[17] Section 9.2.2.11.3.1, Criterion 4, middle of Page 9.2-40.

3200 MW of energy was estimated to be between 452,000 to 816,000 ac of land." Here is what the reference cited by the Applicant[18] says:

> "The storage capacity of CAES systems designed to deliver baseload power would typically be several times that for other grid management applications, but even so the "footprint" of a 10-m thick aquifer capable of providing baseload wind/CAES power would occupy a much smaller (~14%) land area than that of the corresponding wind farm under typical conditions."

As an aside, note that the authors associate CAES aquifer storage with "baseload" power.

If "Environmental Impact" was assumed to mean "Visual Impact" and nothing else, four thousand wind turbines probably have a greater visual impact than two nuclear plants. However, the Applicant does not acknowledge that the individual wind turbines plus the roads and buildings serving these wind turbines actually occupy only a very small fraction of the land in which they reside. The area actually used (including service roads) is only about 3.5% of the stated area, and most of this area (the roads) can also be used for other purposes. The rest of the area (96.5% of the supposed impacted area) can still be used for other important purposes, like farming and ranching. Except for the "viewscape" aspect, the numbers given in the application *overstate the environmental impact by two orders of magnitude*.

The very next sentence in the application says[19] "For 88 hours of power generation, a CAES facility could therefore cover between 63,289 and 114,420 ac of land." Notice the applicant's misleading use of the word "cover". The CASE facility would not *cover* that amount of land. The indicated area[20] is the area of a 10-meter thick aquifer, which is two or three thousand feet *under*ground. The only above-ground impacts of CAES are the building that houses the compressors, expanders, heat exchangers, and combustors[21], plus scattered well heads and (probably) buried pipes connecting those well heads to the building. Since the net power coming out of a CAES expander is two or three times greater than the net power coming out of a combustion turbine having the same diameter,[22] the CAES equipment building will be substantially smaller than a building housing

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[18] Samir Succar and Robert H. Williams, "Compressed Air Energy Storage: Theory, Resources, and Applications for Wind Power", Princeton Environmental Institute, Energy Systems Analysis Group, Princeton, N. J, 8 April, 2008. With four 2.5 MW wind turbines per square mile and 40% capacity factor, the total average power generated by a 816,000 ac wind plant would be (4 * 2.5 * 0.4) MW/mi^2 * 816,000 ac / 640 ac/mi$_2$ = 4,080 MW. This is enough larger than 3,200 MW to account for storage losses.

[19] Middle of p 9.2-40

[20] Given the previous footnote's storage area equal to 14% of the wind plant's area, the total storage area is 0.14 * 816,000 = 114,240, which is exactly the area quoted by the Applicant.

[21] With the previously described adiabatic option, there would be no combustors.

[22] The Applicant essentially acknowledges this fact when on p 9.2-33, in the first paragraph in section 9.2.2.11.2.2 they say: "To generate the electricity from the CAES, the natural gas usage is between one third and one half the amounts needed to generate the same amount of electricity at a natural gas generating plant (DOE 2009; ESC 2002)."

conventional combustion turbines capable of the same electrical output. Moreover, if the CAES reservoir is large enough to convert wind power into conventional "baseload" power, as the (PEI 2008) reference cited by the Applicant and quoted above says, *an additional backup gas plant is not needed*.

The site for Comanche Peak's reactors and related facilities occupies 7950 acres.[23] The area actually occupied by the foundations of the 4000 wind turbines could range from 1000 to 2000 acres, plus the area of the CAES facility and scattered CAES well heads. The Applicant's use of the term "LARGE" to describe the relative environmental impact of an alternative wind-and-storage system[24] is not justified.

b. In the discussion of Wind Power Generation in Combination with CAES, the following sentence appears:[25] "Not only is wind an intermittent and unpredictable source of power, but in Texas, the wind resource is mainly available during non-peak and intermediate load demand periods and predominately unavailable during non-peak and intermediate load demand periods and predominately unavailable during the peak demand periods for power." Which is it? "unpredictable"? or: "predominately unavailable" and "predominately available" at the times described? Wind power is reasonably predictable, both in a statistical sense, as described in the latter part of the quoted sentence above, and specifically in time frames ranging from several days ahead to hours ahead.[26] System operators can and do predict and deal with wind-power variations in essentially the same way they can and do predict and deal with normal load variations. Unfortunately, the contradictory flourish at the beginning of the above quoted sentence is representative of similar subjective insertions that appear throughout the application. In particular, the Applicant makes frequent use of the misleading derogatory term, "intermittent," which, according to Webster, means "stopping and starting again at intervals." Wind does not "stop and start." It "varies." Although wind speed is *occasionally* very high or very low, in places where wind power is viable, most of the time it varies within a moderate range of intermediate speeds. Accordingly, leaders and editors of the IEEE Power Engineering Society and its publications have formally requested that engineers not use the pejorative characterization "intermittent" when referring to wind power, and instead use the more accurate characterization "variable":[27]

> "The other term we need to examine is intermittent. I often hear wind referred to as an intermittent resource. This is another term out of the

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[23] Comanche Peak Environmental Report, Rev 0, Section 1.1.2, p.1.1-2
[24] Top of page 9.2-40.
[25] Page 9.2-27 near the bottom, in second paragraph under section 9.2.2.11.3.1
[26] Ernst, Oakleaf, Ahlstrom, Lange, Moehrln, Lange, Focken, and Rohrig, "Predicting the Wind", *IEEE Power & Energy*, 5, No. 6, November/December 2007, pp 78-89. This special issue of the Power & Energy Magazine is dedicated to "Wind Integration: Driving Technology, Policy, and Economics."
[27] Charlie Smith and Brian Parsons, guest editorial, "What does 20% look like? Developments in Wind Technology in wind technology and systems", *IEEE Power & Energy*, **5** No. 6, November/December 2007, pp 22-33. In refererence to the aforementioned guest editorial, the magazine's editor says, "They further decry the use of the term "intermittent' by reviewing the operation of the wind plant and redefining that operation as one of 'variable output'."

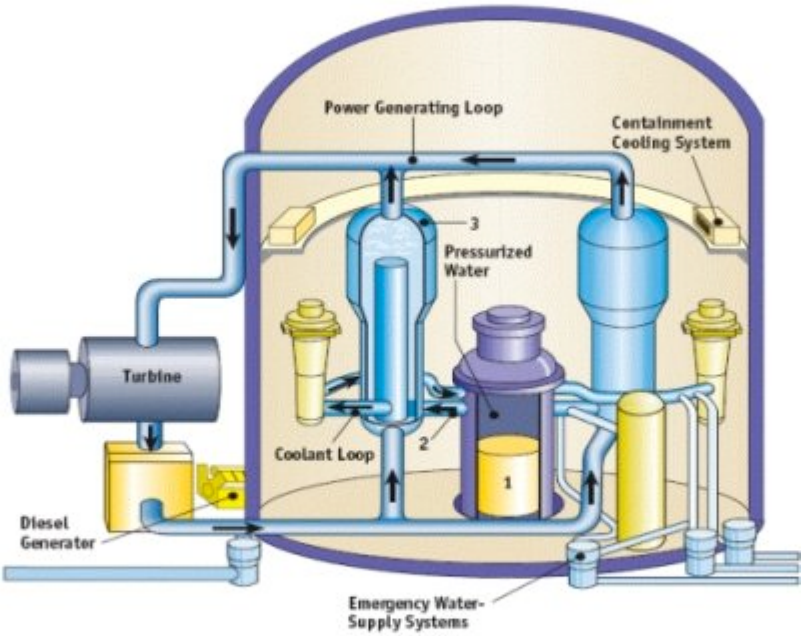
> distant past. To most people, the term intermittent means a random sort of unpredictable on-off behavior. This term is usually used in a negative sense. The understanding conveyed is that the output of the plant cannot be predicted and that it rapidly goes from no-load to full-load conditions, or vice versa. While this view was prevalent after looking at the output of a single wind turbine, before we had sufficient data to understand the behavior of large, modern wind plants [groups of wind turbines, informally called "wind farms"], it is no longer the case. We now know that the output of wind plants varies very little in the time frame of seconds, more in the time frame of minutes, and most in the time frame of hours. The typical standard deviations of the step changes at the one-second, ten-minute, and one-hour time frames vary from approximately 0.1% to 3% to 10% of rated capacity, which is far from intermittent. A good wind plant output forecast can also predict the changes that will occur with a good degree of accuracy most of the time. As a result of this improved understanding of the behavior of wind plants, we are making a transition away from the term intermittent to variable output, which describes much more accurately the nature of the quality with which we are dealing."

Subsequent papers appearing in this society's publications regularly conform to this recommendation. Therefore, the frequent use of the pejorative term "intermittent" in conjunction with wind power indicates that the authors of this COL application revision are probably not professional electrical power engineers and, in addition, they are probably subjectively opposed to use of renewable energy. When it comes to renewable energy, their knowledge and their objectivity are both questionable.

The Proposed Nuclear Plant Does Not Meet Applicant's Own Definition of Criterion 1

The CP COL ER application revision repeatedly rejects renewable energy alternatives using Criterion 1 – Developed, proven, and available in the relevant region ERCOT. As indicated previously, many of the Applicant's objections to renewable-energy alternatives are tenuous. But the Applicant's preferred nuclear power plant does not meet their definition of Criterion 1, either, and its failure to meet that criterion is substantial.

According to the U. S. Energy Information Administration, Comanche Peak Nuclear Power Plants 1 and 2 are Pressurized Water Reactors (PWR), built in 1990 and 1993. Here is what that PWR looks like:



The proposed new plants are different from these two original plants. They are U. S. versions of a *new* design called Advanced Pressurized Water Reactor (US-APWR).

The US-APWR has never been built before – anywhere! The Nuclear Regulatory Commission is now using a different approval process than that used when Comanche Peak Nuclear Power Plants 1 and 2 were approved. Now, they approve "standard" plant designs in a separate activity.

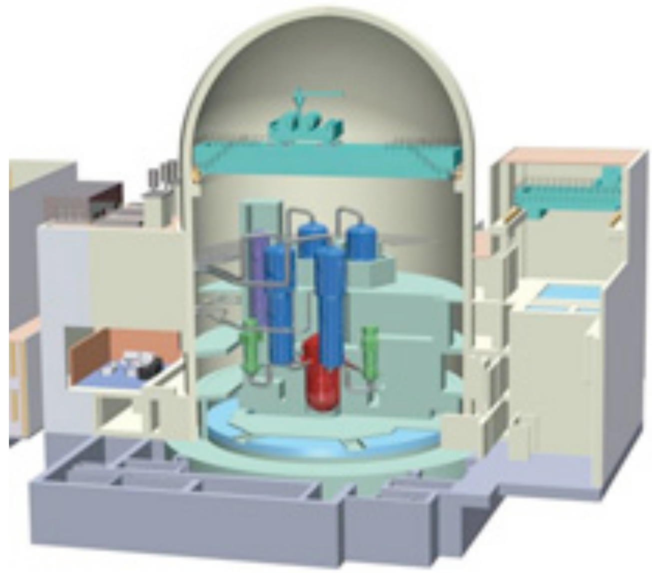
A web page[28] of the Nuclear Regulatory Commission (NRC) says:

> Currently there are four certified reactor designs that can be referenced in an application for a combined license (COL) to build and operate a nuclear power plant. They are:
>
> 1. **Advanced Boiling Water Reactor** design by GE Nuclear Energy (May 1997);
> 2. **System 80+** design by Westinghouse (formerly ABB-Combustion Engineering) (May 1997);
> 3. **AP600** design by Westinghouse (December 1999); and
> 4. **AP1000** design (pictured at left) by Westinghouse (January 2006).

Notice that the design being proposed for Comanche Peak Nuclear Power Plant Units 3 and 4 is not on this list. So it is not one of the plants that "can be referenced in an application for a combined license (COL)." How do the applicants handle this impossible reference? The proposed design is being developed by Mitsubishi. This is what the same NRC web page says about it, and what it looks like:

[28] See http://www.nrc.gov/reactors/new-reactors/design-cert/apwr.html

- **US-APWR** - Mitsubishi Heavy Industries (MHI), a Japanese firm, submitted a design certification application for the U.S.-specific version of its Advanced Pressurized Water Reactor (pictured at right) on Dec. 31, 2007. The staff expects the certification process to continue through 2011.



Notice that the NRC staff "expects the certification process to continue through 2011." In other words, not only has the proposed plant never been built before, it has never been designed before, and the design that is being worked on now is not likely to be certified until after 2011.

It looks like the applicants live in a glass house and are throwing rocks from their front porch.