RESPONSE TO LUMINANT'S MOTION FOR SUMMARY DISPOSITION OF CONTENTION 18 AND ALTERNATIVES CONTENTION A

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The applicant creates two particular renewable-energy scenarios and calls them "bounding cases," where "bounding" is defined with the statement: "Although other possible combinations could be postulated, the results of the analysis would not be materially different." The term "bounding" seems to imply that cases more favorable to renewable are highly unlikely. To promote this implication, the applicant generously employs three "conservative" assumptions that appear to obviously favor renewables. For example, on page 40 under **Results of Bounding Case Analysis**, the applicant says:

> Importantly, as noted above, these bounding cases conservatively assume that storage is 100% efficient and ahs no environmental impacts. Furthermore, these bounding cases conservatively assume that the solar plant and storage facilities are all on the same land as the wind farm; and that the solar facility can overlap areas covered by the wind turbines, roads, and support facilities. These cases also conservatively assume very high capacity factors for wind and solar generation facilities, and do not account for the environmental impacts of construction and operation of new transmission lines that likely would be needed to transmit power from new wind and solar facilities.

These proclaimed "conservative" assumptions seem to give the renewable-energy alternatives an unreasonable advantage. Then the applicant proceeds to conclude that even with these unreasonable advantages, the environmental impacts of their two "bounding" renewable cases exceed the environmental impacts of their preferred nuclear option. And, since their "bounding" cases are supposed to circumscribe all conceivable renewable options, therefore, the environmental impacts of all conceivable renewable options exceed the environmental impacts of their preferred nuclear option.

This is a masquerade. In their analysis the applicant also makes many implicit assumptions that weight against renewable energy, and together the negative effects of these many implicit assumptions overwhelm the positive effects of the loudly proclaimed assumptions that appear to excessively favor renewable energy.

Bounding Case 1

In this case, approximately 85% of the energy supplied comes from a conventional natural-gas facility, and only 25% comes from the combination of two renewable facilities. This case also includes both compressed-air storage (CAES) and molten-salt heat energy storage, ostensibly to provide all the benefits these storage systems can provide. And, as suggested above, the applicant generously does not assign any additional environmental impacts to these storage facilities.

On page 18, under the heading, "Natural Gas", the applicant says:

> Natural gas is the largest single technology for energy production in the ERCOT region. Natural gas provides approximately 70% of the energy generating capacity for the ERCOT

power grid. There are 18 natural gas power plants in the ERCOT system with capacities over 1000 MWe; an additional 33 natural gas plants have capacities between 500 and 1000 MWe. The largest of these are the 2241-MWe Cedar Bayou Units 1, 2, and 3 in Chambers County, the 2234-MWe PH Robinson Units 1, 2, 3, and 4 in Galveston County, and the 1804-MWe Forney Energy Center in Kaufman County. Modern natural gas plants have a capacity factor of approximately 85% and are capable of producing baseload power.

Thus, the percentage of renewable energy in this case is similar to the percentage of renewable energy already existing in many places, with no "assistance" from any kind of storage. In fact, there is no need for any storage in this relatively low renewable-energy penetration case. Assuming adequate ramping capability, this case's natural gas facility could easily accommodate all wind-power and solar-power variations. This case contributes nothing to the question of how renewable energy and associated storage might compete with nuclear power. This case is *completely irrelevant*, and it should be disregarded.

What this case does say is that a system based primarily on natural gas is inherently more flexible than a system based on nuclear. A natural gas system can provide the baseload function that nuclear power provides. But it can do more. It can *also* provide the function of accommodating the variations introduced by a modest amount of renewable energy. That's something nuclear power cannot do.

There is also one other thing this base case does. It helps the applicant establish a precedent for assigning unreasonably high negative environmental impacts to wind and solar energy sources. Endnote 1. below says: "ESRP 4.1.1 indicates that both the quality and quantity of the land should be taken into account in categorizing the land use impacts." The presence of the "quality" in this quotation presents a problem for the applicant.

Here is the problem. Nuclear power needs lots of water – arguably more water than any other kind of electric power generation.[1] Since humans, animals, and plants also need lots of water, nuclear power directly competes with humans, animals, and plants for this scarce resource. Thus, the environmental *value* of land and other factors influenced by land is dramatically inflated by proximity to water. In contrast, wind power and dry solar power do not need any water. Therefore, it's feasible to put wind power and dry solar power in desert (i.e., "deserted") places, where environmental/asethetic values are *much* less. To at least some extent, the economic value of land reflects its environmental value, and the economic value of land can vary by *orders of magnitude*. For example, the price of the land under my son's house in Davis, CA is about 1000 times higher than the price of the land under my house in Jefferson County, KS.[2]

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[1] Thus, in comparing nuclear power compared to other kinds of power, a reasonable and fair assessment of would assign nuclear power a LARGE negative impact "Water Use and Quality", rather than the MODERATE negative impact the applicant has generously given itself.

[2] The following is taken from Luminant's Motion for Summary Disposition:

Joint Affidavit of Donald R. Woodlan, John T. Conly, Ivan Zujovic, David J. Bean, John E. Forsythe, and Kevin Flanagan (footnote continued on following page)

…

As the applicant readily admits in the context of need for transmission, the best Texas sites for wind power and solar power are out west. And out west it's more arid. So out west, the environmental value of land and other factors affected by land is inherently lower than it is where a nuclear plant would need to be located.[3] Arguably, it might be orders of magnitude lower. Fortunately for wind and dry solar, out west is where wind and solar are better, so where wind and solar want to be is where their environmental impact is inherently lowest. But that's a problem for the applicant. Because most of the conceivable adverse environmental of wind and dry solar are related to land, the applicant needs to use the substantial *quantity* of land required for wind and solar to assign them a high adverse environmental impact. Endnote 1. below also says:

> Pages 4.1.1-10 to 11 of ESRP 4.1.1 provides the following land use categorization of land with relatively low quality:
> (1) For fewer than 500 hectares (1235 acres), the land use impact is "not of major significance," which roughly corresponds to a SMALL impact;
> (2) Between 500 and 5000 hectares (1235 to 12,350 acres), the land use impact is "adverse," which roughly corresponds to a MODERATE impact; and

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> X. FOUR-PART COMBINATIONS OF WIND AND SOLAR POWER, STORAGE, AND NATURAL GAS
> …
> 78. [IZ] In categorizing the land use impacts discussed above, we used NUREG-1555, Environmental Standard Review Plan ("ESRP") 4.1.1 as guidance. ESRP 4.1.1 indicates that both the quality and quantity of the land should be taken into account in categorizing the land use impacts. Since the site for the wind and/or solar power facility for this analysis is hypothetical, the quality is not known. However, since such facilities would like be in western Texas, we have assumed that the quality of land is low. Pages 4.1.1-10 to 11 of ESRP 4.1.1 provides the following land use categorization of land with relatively low quality:
> (1) For fewer than 500 hectares (1235 acres), the land use impact is "not of major significance," which roughly corresponds to a SMALL impact;
> (2) Between 500 and 5000 hectares (1235 to 12,350 acres), the land use impact is "adverse," which roughly corresponds to a MODERATE impact; and
> (3) Greater than 5000 hectares (12,350 acres), the land use impacts "are sufficiently adverse to require mitigation," which roughly corresponds to a LARGE impact.
> A hectare corresponds to 2.471 acres.

This passage, on page 83 of the 102 page document, contains the first usage of the word, "quality" in the context of "land" [highlighted in yellow]. All evaluations of "land" in the main part of the overall document seem to consider only the "quantity" of land. In other words, in the main part of the document there is no apparent differentiation in land quality or the affect that location might have on land quality. However, in real life, location is a very important factor.

[3] One could conceivably locate a nuclear plant where sufficient water is not available and transfer water to that place from some other place – as proposed for Comanche Peak 3 & 4, but that's effectively a misappropriation of the inherent environmental value of the place supplying the water transferred.

(3) Greater than 5000 hectares (12,350 acres), the land use impacts "are sufficiently adverse to require mitigation," which roughly corresponds to a LARGE impact.
A hectare corresponds to 2.471 acres.

In spite of their inherent ability to go into low-value land-use areas, this guideline still provides a way to assign them a LARGE impact. To get that needed LARGE impact rating, one must crowd all the resources into a big coherent group.

Although there is a first-cost economic advantage in clustering wind turbines, operationally we would much rather have electrically-associated wind turbines be widely dispersed in space. That's because disbursing wind turbines smoothes their composite variation and substantially reduces the ramp rates of whatever system components compensate for their variation. This dispersion logic creates another problem for the applicant, because it blows away the argument that allows them to assign a LARGE impact to wind power in low-value locations.

Perhaps in a last-ditch attempt to still assign a LARGE impact to those wind turbines on low-value land, the applicant clumsily[4] selects the largest single wind farm as a template for the wind turbine arrangement for their "Bounding Case 1".

Bounding Case 2

I belabored the wind-power clustering issue because the difference between high-quality land and low-quality land (and other factors like aesthetics associated with high-quality land) dominate the analysis not only of "Bounding Case 1" but also of "Bounding Case 2". This factor alone can overwhelm the three proclaimed excessively favorable assumptions that the applicant gives to renewable power.

Bounding Case 2 is more representative of renewable alternatives than Bounding Case 1. In this second case, because the renewable percentage dominates, storage is indeed necessary. However, in addition to the unreasonable implicit assumption that all land has equal environmental value, regardless of location, the discussion in Endnote 2 shows that the analysis employs excessively high assumptions about the quantity of land required for wind power: 2% to 5% instead of a more reasonable 1%. That unreasonably high capacity factor is 55%. A more reasonable capacity factor is the average of Texas capacity factors, ½ (29% + 55%) = 42%. Thus, the applicant's proclaimed gift to wind power is a favorable factor of 0.55 / 0.42 = 1.3, but the hidden cost of this gift is an unfavorable factor of ½ (2% + 5%) / 1% = 3.5. That's a terrible trade-off for renewable power. Fixing this factor-of-three discrepancy easily offsets the effect of removing the applicant's gift of unreasonably high capacity factor.

Those familiar with renewable energy know that wind power is currently more competitive than solar power. A design that uses more wind power than solar power is more likely to be

[4] The clumsy justification for this unreasonable clustering is that the unnaturally wind-power large scale is closest to the naturally large nuclear-plant scale. But of course, that's a silly argument, given that transmission is needed anyway to connect the wind turbines to the rest of the system. Given that already-existing need for transmission, those remote wind turbines might as well be distributed.

economically attractive, and therefore more likely to prevail in the economic comparison that would follow a possible victory for renewable power in the current environmental-impact competition. Compared to wind turbines, massive arrays of solar collectors distributed over undeveloped ground remove much more of that ground from other uses than wind turbines do. Although the applicant formally allows co-location of solar collectors within the territory used by wind turbines, it frequently warns the reader that this is actually unreasonable. And it is! Therefore, a reasonable reader is likely to discount the applicant's overlapping assumption and shift subjective weight toward nuclear. This covert anti-renewable set-up is made possible by the unreasonableness of the applicant's clumsy attempt to create a single all-inclusive circumscription. Whenever solar power is set up on bare ground, a sensible composite design uses a much smaller percentage of solar power relative to wind power.

This consideration does not necessarily force solar power into a negligible role, however. It's just that a sensible solar-power role would be different from the role established by the applicant in "Bounding Case 2".

Bounding Case 2 with a More Reasonable Solar Role – Rural Version

In a reasonable rural version of Bounding Case 2, the role of solar power would be to completely replace the natural gas consumption used by the CAES component of the composite system. This better solar-component still combines thermal solar collectors with thermal storage in molten salts. But instead of using the heat to boil water and drive a steam turbine, it uses the heat to warm air coming out of CAES storage as it expands and generates the electricity needed to supplement inadequate wind power.

Endnote 3 shows that the natural gas consumption required to support CAES is only about 3% of the heat needed if that CAES system were replaced by a 40% efficient combined-cycle gas-fired power plant operating continuously at maximum output.

This fact means that the quantity of rural land covered by solar collectors would be only about 6% of the land that would be covered by solar collectors in the applicant's Bounding Case 2 scenario. With that substantially reduced amount of solar-collector land coverage, and with proper recognition of the difference in value between the desert land and land near valuable water resources, one does not need the highly proclaimed but obviously unreasonable assumption that solar-collector land use is neglected simply because it is within wind-turbine territory.

Since the CAES expanders are inherently air-cooled devices, this solar-heated CAES subsystem does not require any water. And it also does not require any natural gas. In addition to eliminating valuable water, it also eliminates the complexity of bringing natural gas and burning it at the CAES site.

Luminant's clumsy idea about putting solar collectors within wind-turbine territory without properly accounting for their impact should be rejected, just as the creators of that unreasonable notion eventually say. They should be rejected not only because it's bad accounting, and not only because they might degrade the performance of wind turbines. But more importantly it should be rejected because the best places for wind power and not likely to be the same as the best places for solar power. In a large rural system, one should try to get the best of best of both worlds.

Bounding Case 2 with a More Reasonable Solar Role – Urban Version

Another obvious variation which outperforms the applicant's supposed "bounding case" is putting the solar collectors over already-developed land. In this case the solar collectors would be photovoltaic solar collectors, which of course, do not need water either.

This case takes advantage of the co-location notion but in a legitimate way, but putting PV solar collectors on the roofs of buildings and over parking lots in cities. These types of PV applications are already in wide use. These solar collectors would have the important advantage of being close to points of use. Because sunshine is well-correlated (though not perfectly correlated) with peak summer loading, this electrical generation near to end users tends to reduce peak currents in distribution systems as well as in transmission systems. Thus, it not only does not add to transmission problems, as the applicant is wont to say, it does the opposite. It helps reduce transmission problems – a very important added value for many utilities.

The idea of distributing part of an alternative "baseload" generator out among system consumers is not radical at all. Smart metering is one of the hottest areas in the utility world, and many utilities are eagerly embracing it because of how it might enhance profitability. Environmentally, it is much more benign than putting solar collectors over bare land in the country because it does not consume any additional land. It completely eliminates those substantial land-use solar penalties that severely burden the composite system when the applicant's unreasonable co-location "gift" is removed. It eliminates almost all of the value of that specious "gift."

ENDNOTES

1. Land-Based Criteria

The following is taken from Luminant's Motion for Summary Disposition:

> JOINT AFFIDAVIT OF DONALD R. WOODLAN, JOHN T. CONLY, IVAN ZUJOVIC, DAVID J. BEAN, JOHN E. FORSYTHE, AND KEVIN FLANAGAN
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> 78. [IZ] In categorizing the land use impacts discussed above, we used NUREG-1555, Environmental Standard Review Plan ("ESRP") 4.1.1 as guidance. ESRP 4.1.1 indicates that both the quality and quantity of the land should be taken into account in categorizing the land use impacts. Since the site for the wind and/or solar power facility for this analysis is hypothetical, the quality is not known. However, since such facilities would like be in western Texas, we have assumed that the quality of land is low. Pages 4.1.1-10 to 11 of ESRP 4.1.1 provides the following land use categorization of land with relatively low quality:
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2. Quantity of Land Required to Support Wind Power

Assume there are four 2.5 MW wind turbines per square mile, for a total average maximum wind power density of 10 MW/mi^2.

The applicant indicates that the quantity of dedicated to support a typical wind turbine is between one quarter and one half of an acre. Because our wind turbines are relatively large let's use the larger half-acre footprint for each turbine. At four turbines per square mile, the total turbine footprint density is 2 acres/mi^2, or 2 / 640 = 0.003125 mi^2, or about *0.3% for turbines*.

Assume these wind turbines are positioned at the centers of quarter sections. If county roads run on section lines, each such wind turbine can be accessed by a one-quarter-mile service road from the nearest count road. That implies a total of 4 * ¼ = 1.0 miles of dedicated wind-turbine service roads for each square mile of wind turbines. If each service road is 6 meters wide[5], the total dedicated service-road density is 6 / 1608 = 0.0037 mi^2, or about *0.4% for service roads*.

Assume that individual turbines in each square mile are connected by underground cables to a 10 MW local substation on an adjacent county road, and that local substation takes one half acre. This implies a dedicated local substation area of 0.5 / 640 = 0.0008 mi^2, or about *0.1% for substations*.

Although the wires are buried, assume a service easement for these wires having a total length of ½ + ½ + ¾ = 1.75 miles. If the easement is 2 meters wide, the total area covered by the easement is 0.0022 mi^2, or about *0.2% for wire service easements not along county roads*.

Building space for service equipment and personnel is modest. It is most logically placed near urban areas and highways to facilitate transportation. It's reasonable to expect that a total of 2,000,000 square feet would accommodate the combination of parts storage, servicing, and office space for 2000 3.5-MWe wind turbines distributed over about 500 square miles. That's approximately one 30 ft x 30 ft bay for each turbine. At 4 turbines per square mile, that's about 0.1 acre/mi^2, a negligible amount compared to other land uses.

Thus, the total such (private) land consumed and used is about 0.3% + 0.4% + 0.1% + 0.2% = 1.0%. This is significantly less than the 2% to 5% direct land-consumption range assumed by the applicant. The applicant's numbers are probably older numbers that applied when wind turbines were smaller, and when there were many more per unit of land area.

3. Quantity of Natural Gas Used by CAES

In a typical CAES system, the maximum electrical output power or "MWe capacity" is typically approximately equal to the maximum electrical input power. In other words, the ratio of maximum electrical output to maximum electrical input is typically around 1.0, or 100%. Depending on the details, this ratio might be either higher or lower than 100%. The possibility of this ratio being equal to or greater than 100% does not violate the Second Law of Thermodynamics, because a typical CAES system also has another energy input that supplies heat. And the combination of electrical input and heat input is such that the ratio of electrical output to the sum of electrical and heat inputs is well below 1.0, typically of order 2/3 or 67%, which is a reasonable value for the round-trip efficiency of a typical CAES system.

The maximum heat added in a well-designed CAES system is typically about 33% of the maximum electrical output. Therefore, it frequently happens that the heat added to a CAES system is roughly equal to heat lost in all system inefficiencies. There is no direct relationship

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[5] See, for example, http://www.wpi.edu/Pubs/E-project/Available/E-project-042810-230253/unrestricted/Auburn_Wind_Project_MQP_4-29.pdf
This indicates that service roads for 1.5 MW turbines need to be at least 14 feet wide. That's about 4.3 meters.

between inefficiency and heat added, however, so this rough equality is essentially accidental. But the fortuitous accident provides a handy heuristic, which helps one keep track of the various energy flows.

It's important to remember that a CAES system is an energy *storage* system, not a *source* of energy. Its purpose is *delaying* electrical energy flow, and it should be evaluated on how well it performs this delaying function. Maximum input and output powers, maximum delay time, and speed of response to changes in these powers (ramp rates) are key figures of merit.

In contrast to typical energy sources, a CAES system does *not* need a *high* "capacity factor". In fact, *a high capacity factor is bad*, because it implies much in-and-out sloshing, with the inevitable round-trip energy losses that accompany such in-and-out energy sloshing. The original CAES system in Germany was constructed in such a way that it was physically impossible to have a long-term capacity factor exceeding 50%. And that 50% would occur only if the system had only two modes of operation – either operating with maximum input or operating with maximum output. Such an extreme "binary" operation would never occur in practice.

If a CAES system is well designed, it rarely operates at the design extremes of maximum input or maximum input. With typical wind and/or load variation, it swings gradually and continuously, usually either accepting modest input or delivering modest output. When accepting input, it's reasonable to expect that the average input is 50% of maximum input. When supplying output, it’s reasonable to expect that the average output is 50% of maximum output. Since finite storage requires that average output equal average input, on overage output occurs only half the time. Therefore, the ratio of average output to maximum output (capacity factor) is typically about 25%.

Assuming continuous average output equal to 25% of maximum output, the average heat that needs to be added is about 25% of the heat that needs to be added at maximum output. As indicated previously, in a typical system, the heat that needs to be added is about 33% of the total output (approximately 67% of that output comes from electrical input). Therefore, on average, the heat that needs to be added to a typical CAES system is about 0.33 * 0.25 = 0.0825 times maximum output. In other words, the average heat needed by a continuously operating CAES system is 0.0825 * 0.40 = 0.033, or about *3% of the heat needed if that CAES system were replaced by a 40% efficient combined-cycle gas-fired power plant operating continuously at maximum output*.

4. Substituting Thermal Solar or Additional Wind Power for Natural Gas in CAES

On page 31, under **5. Molten Salt Storage**, Luminant's Motion for Summary Disposition says:

> Molten salt can be used to store heat. For example, the sun’s energy can be concentrated by a field of hundreds or thousands of mirrors called “heliostats” onto a receiver. The energy heats molten salt flowing through the receiver; the salt’s heat energy is used to boil water to create steam that generates electricity in a conventional steam turbine

generator. The molten salt retains heat relatively efficiently, so it can be stored for hours or even days before it loses its capacity to generate electricity.

On page 16 Under:

JOINT AFFIDAVIT OF DONALD R. WOODLAN, JOHN T. CONLY, IVAN ZUJOVIC, DAVID J. BEAN, JOHN E. FORSYTHE, AND KEVIN FLANAGAN

…

IX. ADDITIONAL INFORMATION TO SUPPORT THE MOTION

the applicant identifies molten salt as an independent storage capability, saying: "[JEF] There are several commercial molten salt storage systems in operation…" and "[KF] Molten salt thermal storage is relatively efficient…"

And on page 48 the applicant says, "There are several commercial molten salt storage systems in operation."

The applicant identifies the existing molten salt solar facility in the Mojave Desert of Southern California as an example of how molten salt storage stores thermal solar collection for later use in a steam boiler to generate electricity, and this particular combination serves as the exemplar for one of the four components in its **Bounding Case 1** in the main part of the document.

From this information, it is obvious that molten salt storage could alternatively store thermal solar collection for later use as the source of heat for the gas expander in a CAES system. In other words, it is obvious that solar thermal can alternatively be used to replace gas combustion in a conventional CAES system.

Another obvious alternative is using molten salt storage to store the heat of compression for later use as the source of heat for the gas expander in a CAES system. In other words, it is obvious that molten salt storage can be used to implement an adiabatic CAES system, which uses the energy source that compresses the air in a CAES system to also provide the heat added in the expansion phase of the CAES operation. Of course, this heat energy still is not free, and if the energy source is wind turbines, enough additional wind turbines are needed to create this heat. But the conversion of wind energy to this heat is essentially 100% efficient, and as the applicant acknowledges, molten salt storage is itself very efficient.