December 15, 2008

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

In the Matter of	)	
	)	Docket Nos. 52-014, 52-015
Tennessee Valley Authority	)	
	)	
(Bellefonte Nuclear Power Plant Units 3 and 4)	)	

DECLARATION BY DR. ARJUN MAKHIJANI
REGARDING TVA'S REVISED COST ESTIMATE
FOR NUCLEAR AND COAL-FIRED GENERATION

I, Dr. Arjun Makhijani, declare as follows:

1. I am Dr. Arjun Makhijani, President of the Institute for Energy and Environmental Research in Takoma Park, Maryland. On June 6, 2008, I submitted a declaration in support of Blue Ridge Environmental Defense League's hearing request regarding the Tennessee Valley Authority's (TVA's) application for a combined construction permit and operating license for Bellefonte Units 3 and 4. My curriculum vitae, which demonstrates my qualifications as an expert on the costs of nuclear power and other energy sources, is attached to my June 6, 2008, declaration.

2. The purpose of this declaration is to respond to TVA's November 5, 2008, update to the cost estimates for nuclear power and other energy sources.[1]

3. The TVA has filed incomplete and some outdated information on nuclear power plant costs, excluded high end cost estimates, failed to take account of potential cost escalations, and improperly excluded viable alternatives. TVA has also ignored the fact that the Yucca Mountain repository program is in considerable peril and that the costs of spent fuel management for new power plants, which do not have contracts with the federal government, may rise substantially above the $1 per MWh assumed by TVA.[2] With respect to consideration of the alternatives presented by TVA itself, it has ignored

[1] TVA 2008. *Revised Cost Estimates for Nuclear and Coal- and Gas-Fired Generation*, Enclosure attached to affidavit by Andrea L. Sturdis, Manager, New Nuclear Licensing and Industry Affairs, TVA, November 5, 2008. Hereafter TVA 2008.
[2] TVA 2008, p. 9.

the fact that there is one lower cost alternative even when costs are attached to CO2 emissions. That alternative is natural gas power plants with carbon capture and sequestration. TVA's conclusion that "the environmental impacts of proposed project are smaller than those related to the combinations of alternatives are equal to or greater than the environmental impacts of BLN"[3] is not scientifically supported.

A. Nuclear Power Cost Estimates.

4. TVA has cited a range of all-in capital cost estimates for new nuclear power plants of "$4374 to $7829 per KWe net. Applying this range to BLN would give a total construction cost of $9.8 billion to $17.8 billion."[4] However, the TVA has failed to include the highest capital cost estimate, that made by Puget Sound Energy, of $10,000 per kWe.[5] This would put the high end of the BLN project capital cost at over $22 billion.

5. Further, the TVA has failed to take account of cost increases due to delays. TVA's own reactor projects have been plagued by delays in the past or even cancelled. In fact, BLN 1 and 2 were cancelled before completion and are on the way to likely complete depreciation without yielding any benefit to TVA ratepayers. 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.[6]

6. In sum, despite the fact that TVA has availed itself of the opportunity to file revised cost estimates, the range still excludes the high end of potential costs and excludes cost overruns and the effects of delays.

B. Levelized costs per MWh

7. Ultimately, the most important figure of merit as regards cost is the levelized cost, which includes all costs, refers them to a particular year, and provides a basis for comparing the generation cost of electricity for various options that a consumer would be charged.

8. The TVA has cited a range of costs for nuclear power to be $66.5 to $122.7 per MWh (or $0.066 to $0.123 per kWh). These costs are then compared to alternatives, including coal- and gas-fired power plants as well as combinations of renewable and gas-fired options.[7]

9. The TVA's cost estimates and comparisons are grossly inaccurate because TVA has:

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[3] TVA 2008, p. 14.
[4] TVA 2008, p. 7.
[5] 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.
[6] FPL 2007, p. 52.
[7] TVA 2008, pp. 3-4.

- not included the full range of costs for nuclear,
- made apples-to-oranges comparisons with coal- and gas-fired options,
- improperly selected nuclear as the best of the options that it considers equivalent and available (nuclear, coal-fired, and gas-fired), and
- improperly excluded reasonable alternatives for procuring the same amount of electricity at lower cost by various combinations of options.

We consider each of these points in turn.

10, ***Failure to include the full range of costs per MWh.*** Among the references for levelized cost that the TVA has cited is the 2007 Keystone Center report.[8] This study is now obsolete. One of the members of the Keystone panel, Jim Harding, who did many of the cost estimates, and who is a consultant on cost to the National Research Council, has recently updated his cost estimates. He presented them at an October 2008 conference of the *Bulletin of Atomic Scientists* in Chicago.[9] While the Keystone study reported range of costs was $86 to $115 per MWh, Jim Harding's updated costs ranged from $107 to $230 per MWh, depending on capital costs and a wide possible range of cost escalations from 0 to 14 percent in real dollar terms.[10] Harding cites wide ranges of overnight capital costs and of real cost escalations leading to a wide range of cost estimates for new nuclear plants. Other experts also acknowledge that there is great uncertainty in the costs of nuclear power, notably as they are long lead time projects.[11] The uncertainty of nuclear power plant costs is also exacerbated by the current economic crisis. In a serious recession the growth of demand for electricity can slow greatly or that demand can even decline. Both occurred during the last energy crisis that began in October 1973 and ended around 1983. A large number of power plants were ordered in that period, but none were completed, leaving ratepayers and, in some cases, bondholders with large costs and no benefits. More than 100 were cancelled.[12]

11. The TVA's own experience during the last economic crisis of the late 1970s and early 1980s indicates that delays, cost escalations, declines in power growth rates can all hit a utility at the same time and reinforce one another. The range of cost estimates estimated by Harding represents one way to take into account a very uncertain economic environment for long-lead time projects. TVA has failed to take adequate account of its own history and of the range of current credible estimates of nuclear power at the upper end, though it has taken the lower end of the costs all the way down to a level that is beyond proper comparison levels with other options.

12. ***Apples-to-oranges comparison with other options.*** The lower end of the nuclear cost range considered by the TVA was $66.5 to $78.3 per MWh.[13] However, TVA's cost estimate includes a federal loan guarantee for 80 percent of the capital costs, and hence is

[8] See TVA table on p. 3.
[9] Harding 2008
[10] Harding 2008.
[11] O'Neill 2008.
[12] Wald 2008.
[13] TVA 2008, table on p. 3 and Note b to that table.

heavily subsidized. The actual amount of the subsidy would depend on an estimate of the risk of default – that is, it depends on the interest rate differential that would come with the federal loan guarantee and that obtained on the open market. However, Wall Street has so far not been willing to finance nuclear power plants without federal loan guarantees. Given that the interest rate on free-market financing under the current circumstances could be very high, the extent of this effective subsidy would be considerable.

13. Further, the TVA has stated that it "expects that its actual costs will be within the lower half" of the range of $66.5 to $123 per MWh;[14] that is, it expects its costs to be between $66.5 and about $95 per MWh. Most of this range is covered under the assumption of a federal loan guarantee, according to an estimate by the Nuclear Energy Institute (NEI) of $70 to $90 per MWh.[15] The use of this kind of cost estimate to compare to other options is technically incorrect for two major reasons:

(i) TVA's cost estimates for the other options do not include federal loan guarantees, so far as I can determine from their filing.[16]
(ii) Assuming that loan guarantees will be available for nuclear disproportionately lowers the cost of nuclear power relative to the others, because fuel and/or operating costs, to which loan guarantees do not apply in any option, are typically higher for coal- and gas-fired power plants.

Without loan guarantees, estimates of the range of costs for nuclear ranges from about $100 to well over $200 per MWh, as noted above from the independent estimates done by Jim Harding. These should be the basis for comparison with the other options.

14. ***Improper selection of nuclear as the best of the options.*** The TVA has made estimates of the cost of gas-fired power plants including a cost for CO2 emissions. In its revised Table 10.4-X3, it has a 2008 study of a natural gas-fired power plant by the Brattle Group, which concluded that the cost of electricity generation with carbon capture and storage would be $103 per MWh.[17] However, the TVA also cites an NEI estimate of $72 to $102 per MWh without carbon capture and storage. If one assumes a cost of $50 to $100 per metric ton of CO2 for carbon capture and storage (CCS) and emissions of 350 kilograms per MWh for combined cycle natural gas-fired power plants, CCS would increase the electricity costs from natural gas-fired power plants by $17.50 to $35 per MWh. A reasonable range of natural gas-fired power plant costs with CCS is therefore between about $90 and $137 per MWh.

15. This cost estimate is comparable to or less than the estimated unsubsidized costs of new nuclear power plants, if they are properly evaluated, as discussed above. Further, in December 2008, natural gas prices have declined to below the low end of the NEI's cost

[14] TVA 2008, p. 7.
[15] Myers 2008.
[16] The footnotes to the coal and gas options do not include mention of federal loan guarantees. These are new tables filed in TVA 2008, p. 16 and p. 18.
[17] TVA 2008, Table 10.4-X3, p. 17 and Notes on p. 18.

estimate range.[18] The TVA has the option of locking in natural gas prices for the long-term that may make natural gas with CCS the lowest cost option. While the option carries some financial risk and in terms of the availability of CCS, the nuclear option also carries a comparable or perhaps even a larger risk in terms of the availability of a nuclear waste repository. In fact, President-elect Obama stated during his campaign, but in his capacity as a Senator from Illinois, said that Yucca Mountain had "failed" in a formal letter sent in October 2007 for inclusion into a Senate hearing record:

> For these reasons, I believe that it is no longer a sustainable federal policy for Yucca Mountain to be considered as a permanent repository. Instead of re-examining the 20-year licensing process and the billions of dollars that have already been spent, the time has come for the federal government to refocus its resources on finding more viable alternatives for the storage of spent nuclear fuel. Among the possible alternatives that should be considered are finding another state willing to serve as a permanent national repository or creating regional storage repositories. The federal government should also redirect resources toward improving the safety and security of spent fuel at plant sites around the country until a safe, long-term solution can be implemented. Regardless of what alternative is pursued, two premises should guide federal decision-making. First, any storage option should be supported by sound science. We need to ensure that nuclear waste can be safely stored without polluting aquifers or soil and exposing nearby residents to toxic radiation.
>
> Second, we should select a repository location through a process that develops national consensus and respects state sovereignty, not one in which the federal government cuts off debate and forces one state to accept nuclear waste from other states. The flawed process by which Yucca Mountain was selected now manifests itself as a profoundly expensive endeavor of monumental proportion.
>
> In short, the selection of Yucca Mountain has failed, the time for debate on this site is over, and it is time to start exploring new alternatives for safe, long-term solutions based on sound science.[19]

In view of the above clear statements from the person who is now President-elect, it is certainly within the realm of realistic possibility and even likely that the Yucca Mountain project will be stopped. The costs of a new program to manage nuclear waste could be far higher than the projected costs of Yucca Mountain and the $1 per MWh nuclear waste fee now charged to existing nuclear power plants by the federal government to take charge of the wastes and dispose it off. It should be noted in this context that Dr. Steven

[18] TVA 2008, p. 15, where a low-end cost estimate of $6/million Btu is specified and a December 12, 2008, article in the *Oil an Gas Journal* (Dittrick 2008), which cites a spot market price of natural gas as having "climbed 13¢ to $5.83/MMbtu," indicating an even lower prior price of $5.70 per million Btu.
[19] Obama 2007.

Chu, the reported Secretary of Energy-designate, is on the record has being skeptical about the suitability of Yucca Mountain:

> The other thing is that storing the fuel at Yucca Mountain is supposed to be safe for 10,000 years. But the current best estimates - and these are really estimates, the Lab's in fact - is that the metal casings [containing the waste] will probably fail on a scale of 5,000 years, plus or minus 2. That's still a long time, and then after that the idea was that the very dense rock, very far away from the water table will contain it, so that by the time it finally leaks down to the water table and gets out the radioactivity will have mostly decayed.[20]

Dr. Chu's 2005 statement should be viewed in light of the fact that the EPA Yucca Mountain standards, as of October 2008, extend to a million years.[21]

Dr. Chu is also on the record as being in favor of reprocessing.[22] This would make spent fuel management costs far higher cost than $1 per MWh. France, for instance, spends about $800 million per year in excess costs for reprocessing and plutonium fuel use to generate less than 10 percent of its electricity.[23]

16. Finally, 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. Specifically, given that the first proposed BLN unit would not come on line until late in 2017 if it meets the schedule, and that the lead time for building a natural gas-fired power plant is only about two years,[24] TVA would not have to start construction until about 2015 for the same project; it would not have to begin planning and development until 2013. The grave risks incurred by starting a huge, capital intensive project at the present time of economic crisis could be avoided, thus reducing or eliminating the risk that the plant would have to be cancelled due to declines in demand growth rate or even declines in demand due to conservation, efficiency, both of which lead to reduce electricity growth per unit of economic growth, and lower economic growth, or some combination thereof. All occurred during the last economic-energy crisis of the 1970s and early 1980s.

17. ***Improper exclusion of reasonable alternatives.*** While the TVA has made some adjustments to the costs of other options, it has not seriously considered the feasibility, economics, or impact of other options. For instance, it is likely that efficiency could meet the entire load proposed to be met by the BLN units either alone or in combination with peak shaving options such as ice-energy-driven central air conditioning and/or increased use of combined heat and power, with absorption central air-conditioning for commercial buildings. My 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

[20] Chu 2005.
[21] EPA 2008.
[22] Chu 2005, op. cit.
[23] Makhijani 2001 and Makhijani and Makhijani 2006.
[24] Two years prior to construction would be required for planning. NWPPC 2002.

efficiency, storage, and solar energy, relative to buying new nuclear capacity at the kinds of costs included in the TVA update.[25] Almost all of the added capacity would come from efficiency, storage and CHP, with solar playing only a modest role. CPS Energy's peak load in 2007 was only about 13 percent of TVA's peak load.[26] The achievable efficiency potential alone was 600 MW by 2020. Scaling this to the TVA region indicates that the achievable efficiency potential could be in excess of 4,000 MW, or roughly twice the capacity of the proposed nuclear units. Peak shaving using absorption air-conditioning driven by combined heat and power units and ice-energy-storage air-conditioning would complement efficiency measures.[27]

18. TVA has also not made a dynamic evaluation of the costs of solar PV, which are declining. It is the expectation that these costs will decline significantly, probably coming down below $100 per MWh in under ten years for large-scale installations.[28] 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 proposed BLN units come on line. No new transmission lines would be required. Southern California Edison is currently carrying out a 250 MW project that involves installation of solar PV on large commercial rooftops.[29] 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.[30] The costs of large-scale development of the latter, without subsidies, are currently in the range of $80 to $120 per MWh., depending on the location.

19. 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 General Electric, 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 have to bet my company on any of this stuff. You would never do nuclear. The economics are overwhelming.[31]

20. Finally, TVA has stated that its region does not have large enough wind resources. This appears to be incorrect, as is indicated by the wind resource map published by the National Renewable Energy Laboratory. As can be seen from Figure 1 below, East

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[25] Makhijani 2008.
[26] See Makhijani 2008 for CPS Energy data and TVA 2007 Annual report for the TVA peak load. CPS Energy peak load was about 4,400 MW in 2007, while TVA's was over 33,000 MW.
[27] In this method, ice is made during off-peak hours and the stored ice and a fan are used to provide cool air for air-conditioning during peak hours. See Makhijani 2008 for discussion and references. See also the website of Ice Energy, www.ice-energy.com.
[28] DOE 2007.
[29] SCE 2008.
[30] PG&E 2008.
[31] As quoted in McNulty and Crooks 2007.

Tennessee has some very good wind resources (the darker shades of blue) over a considerable area. While some have argued that developing wind resources in such areas affects the view, this argument must be weighed against the nuclear waste generated by nuclear power plants, the far larger water use by nuclear power plants, and other similar factors. TVA has not done this. It has rejected the wind resource out of hand as insufficient and not reliable enough. (For the latter point, see paragraph 21 below.) Further, TVA also has the option of signing a Purchased Power Agreement with independent wind development companies, which can benefit from the Production Tax Credit either for wind resources in the TVA region or outside it. For instance, a transmission line from high wind areas in Oklahoma and/or Arkansas (see Figure 1) can be built to carry electricity into the TVA region. For reference, the estimate of connecting windy areas to the grid in Texas for over 18,000 MW of wind (about three times the proposed generation of the two BLN units) would be $4.9 billion.[32] Given that the total amount of power involved would much smaller than that planned in Texas, TVA transmission lines from high wind areas would likely cost considerably less than the Texas cost cited here. TVA has also done nothing to explore this option.

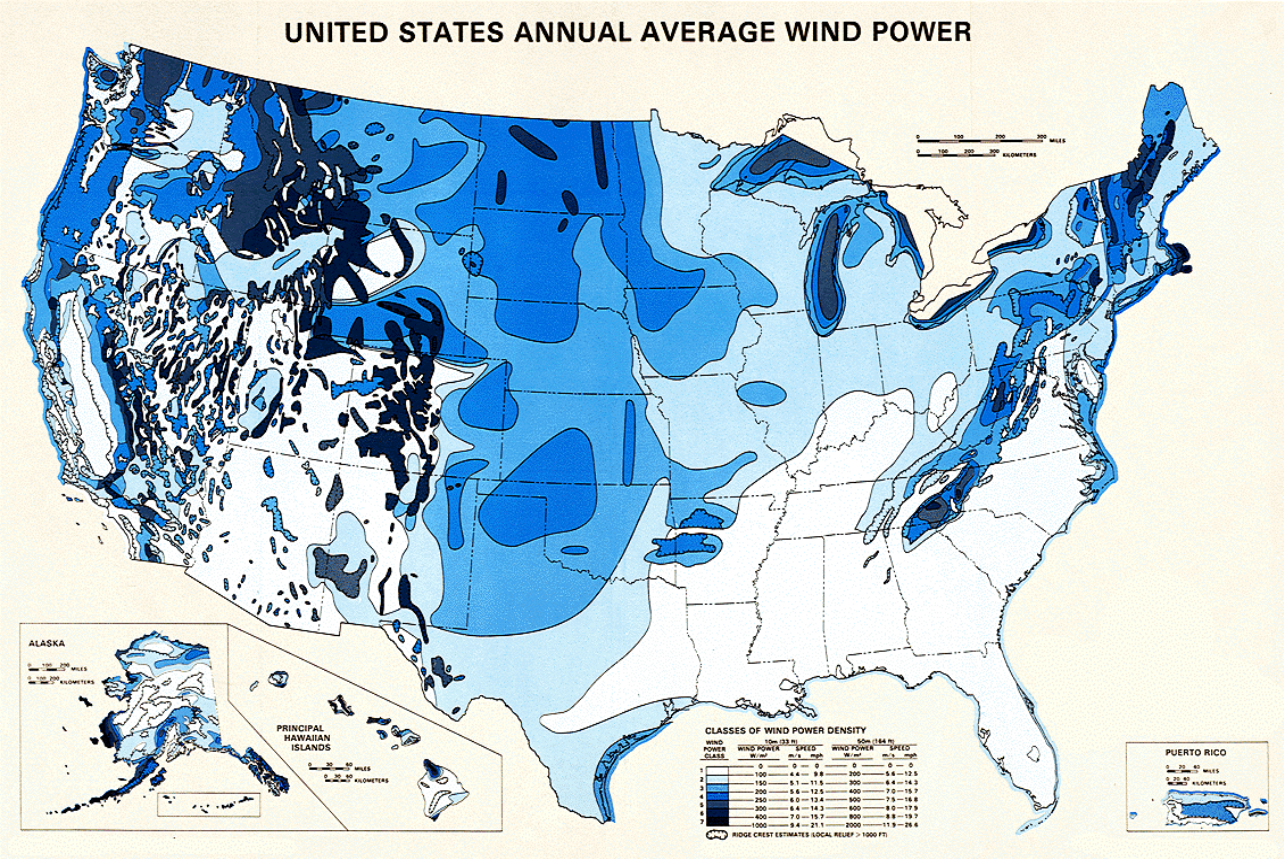

Figure 1: Wind Power Resources in the United States
Source: National Renewable Energy Laboratory, on the Web at http://rredc.nrel.gov/wind/pubs/atlas/maps/chap2/2-01m.html

[32] ERCOT 2008, p. 24.

21. The intermittency of wind is not a bar to such a project. 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.[33] The TVA has not explored smart grid approaches in which such devices would be located, to reduce or eliminate the impact of intermittency. Among other things, a smart grid is one in which consuming devices communicate with producing devices, as illustrated above in the example regarding the use of ice to store wind energy for air-conditioning. Smart grids are beginning to be built today and will likely be here faster than the proposed nuclear power plant, at least in some locations. For instance, Xcel Energy is currently building a local smart grid in Boulder, Colorado, covering the whole city of about 50,000 customers and 100,000 people.[34] Installation of smart meters that 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. It is expected to be complete by the end of 2009. 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. The various renewable energy sources will also 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. It is my opinion that the TVA could well be jeopardizing the economic future of the region by considering only twentieth century options, such as coal, gas, and nuclear, and rejecting or failing to consider advanced technologies that are being implemented today.

Under penalty of perjury, I declare that the foregoing factual statements in this declaration are true and correct to the best of my knowledge, and that the statements of opinion are based on my best professional judgment.

Arjun Makhijani

December 15, 2008

[33] See the website of Ice Energy, for instance, www.ice-energy.com
[34] Xcel 2008 and Xcel 2008a.

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