

UNITED STATES OF AMERICA
U.S. NUCLEAR REGULATORY COMMISSION
BEFORE THE COMMISSION

In the Matter of

Southern Nuclear Operating Co.)
(Vogtle Electric Generating Plant,) Docket Nos. 52-025-COL & 52-026-COL
Units 3 and 4))

**DECLARATION OF DR. ARJUN MAKHIJANI IN SUPPORT OF
MOTION TO STAY EFFECTIVENESS OF VOGTLE COL APPROVAL**

I, Arjun Makhijani, declare as follows:

1. Introduction and Statement of Qualifications

1.1 I am President of the Institute for Energy and Environmental Research (“IEER”) in Takoma Park, Maryland. Under my direction, IEER produces technical studies on a wide range of energy and environmental issues to provide advocacy groups and policy makers with sound scientific information and analyses as applied to environmental and health protection and for the purpose of promoting the understanding and democratization of science. A copy of my curriculum vita is attached.

1.2 I am qualified by training and experience as an expert in the fields of plasma physics, electrical engineering, nuclear engineering, the health effects of radiation, radioactive waste management and disposal (including spent fuel), estimation of source terms from nuclear facilities, risk assessment, energy-related technology and policy issues, and the relative costs and benefits of nuclear energy and other energy sources. I have conducted numerous studies and written extensively regarding investment planning in the electricity sector, the comparative costs of nuclear power plants and other energy sources, and the safety of nuclear power.

1.3 I am the principal author of a report on the 1959 accident at the Sodium Reactor Experiment facility near Simi Valley in California, prepared as an expert report for litigation involving radioactivity emissions from that site. I am also the principal author of a book, *The Nuclear Power Deception: U.S. Nuclear Mythology from Electricity “Too Cheap to Meter” to “Inherently Safe” Reactors*” (Apex Press, New York, 1999, co-author, Scott Saleska), which examines, among other things, the safety of various designs of nuclear reactors. I am also the author of *Securing the Energy Future of the United States: Oil, Nuclear and Electricity Vulnerabilities and a Post-September 11, 2001 Roadmap for Action* (Institute for Energy and Environmental Research, Takoma Park, Maryland, December 2001). In 2004, I wrote “Atomic Myths, Radioactive Realities: Why nuclear power is a poor way to meet energy needs,” *Journal of Land, Resources, & Environmental Law*, v. 24, no. 1 at 61-72 (2004). The article was adapted from an oral presentation given on April 18, 2003, at the Eighth Annual Wallace Stegner Center Symposium entitled, “Nuclear West: Legacy and Future,” held at the University of Utah S.J. Quinney College of Law. In 2008, I prepared a report for the Sustainable Energy & Economic

Development (SEED) Coalition entitled *Assessing Nuclear Plant Capital Costs for the Two Proposed NRG Reactors at the South Texas Project Site*. I am a co-author of a forthcoming report reviewing the official post-Fukushima safety evaluation reports of Electricité de France and AREVA.

1.4 I am generally familiar with the basic design and operation of U.S. nuclear reactors, the safety and environmental risks they pose, and the economic costs of their operation. I am also familiar with 10 CFR 52 Appendix D, which relates to AP1000 design certification, the Environmental Assessments for the revised and original AP1000 designs, and other literature relating to the AP1000 and more generally to pressurized water reactors. In addition, I have examined vulnerabilities relating to the use of zircaloy as a fuel cladding material, hydrogen generation in reactors, spent fuel pool accidents and their consequences, and other matters relating to light water reactor and spent fuel pool accidents.

1.5 I am generally familiar with materials from the press, the Japanese government, the Tokyo Electric Power Company, the French government safety authorities, and the U.S. Nuclear Regulatory Commission (“NRC”) regarding the Fukushima Daiichi (“Fukushima”) accident and its potential implications for the safety and environmental protection of U.S. reactors. I have also read *Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-chi Accident*, July 12, 2011 (the “Task Force Review”),¹ published by the NRC. After the Fukushima accident began on March 11, 2011, I was one of the first experts in the United States to call attention to the dangers and potential consequences of spent fuel accidents. The analysis was written on March 13 and first issued on March 14, 2011.²

2. Affirmation of Previous Opinions Regarding Environmental Implications of Fukushima Accident

2.1 In the spring of 2011, I evaluated the environmental significance of the Fukushima accident with respect to the safety of U.S. reactors and new reactor designs for a group of environmental organizations. In mid-April 2011, I completed work on a declaration stating my opinion that although the causes, evolution, and consequences of the Fukushima accident were not yet fully clear a month after the accident began, it was already presenting new and significant information regarding the risks to public health and safety and the environment posed by the operation of nuclear reactors. In my declaration I also stated my conclusion that the integration of new information from the Fukushima accident into the NRC’s licensing process could affect the outcome of safety and environmental analyses for reactor licensing decisions by resulting in the denial of new licenses or existing license extensions or the imposition of new conditions and/or new regulatory requirements. I also expressed the opinion that the new information could also affect the NRC’s evaluation of the fitness of new reactor designs for certification. The environmental organizations submitted my declaration to the NRC in support of a legal petition

¹ NRC 2011. A bibliography is attached.

² Makhijani 2011-03.

to suspend licensing decisions while the NRC investigated the regulatory implications of the Fukushima accident.³

2.2 In July 2011, the NRC's Fukushima Task Force issued the above-described Task Force Review. Shortly thereafter, I evaluated the environmental and safety significance of the Task Force Review's conclusions with respect to U.S. reactors and new reactor designs for the same environmental organizations. On August 8, 2011, I prepared a declaration explaining why the Task Force Review provides further support for my opinions that the Fukushima accident presents new and significant information regarding the risks to public health and safety and the environment posed by the operation of nuclear reactors and that the integration of this new information into the NRC's licensing process could affect the outcome of safety and environmental analyses for reactor licensing and relicensing decisions and the NRC's evaluation of the fitness of new reactor designs for certification. My declaration was submitted by environmental organizations who requested hearings on the environmental implications of the Fukushima accident and Task Force Review.⁴

2.3 My opinion is that the Fukushima accident and the Task Force Review present new and significant information regarding the risks to public health and safety and the environment posed by the operation of nuclear reactors. Further, the integration of this new information into the NRC's licensing process could affect the outcome of safety and environmental analyses for reactor licensing decisions and the fitness of new reactor designs for certification has been reinforced by events at Fukushima Daiichi since then. To my knowledge, no one had imagined that a multi-reactor accident could continue for nearly a year. This makes it critical to consider and incorporate the safety lessons of the Fukushima accident before licensing new reactors or certifying their designs. It is reasonable to expect that the implementation of the Fukushima Task Force recommendations will affect the NRC's requirements for the Vogtle 3 and 4 reactors and the underlying AP1000 standardized design, which were both recently approved by the NRC. The new and significant information presented by the Fukushima accident and the Task Force Review should have been considered in a supplemental EIS for Vogtle 3 and 4 before the combined license ("COL") was issued, and that the supplemental environmental review should have included all relevant issues in the Task Force recommendations for the AP1000 design.

3. Purpose of Declaration and Summary of Expert Opinion

3.1 The purpose of this declaration is to support the Motion for a Stay of Construction Pending Judicial Review that has been submitted to the NRC by the Southern Alliance for Clean

³ Declaration of Dr. Arjun Makhijani in Support of Emergency Petition to Suspend all Pending Reactor Licensing Decisions and Related Rulemaking Decisions Pending Investigation of Lessons learned from Fukushima Daiichi Nuclear Power Station accident (April 19, 2011), submitted in support of Emergency Petition to Suspend All Pending Reactor Licensing Decisions and Related Rulemaking Decisions Pending Investigation of Lessons learned From Fukushima Daiichi Nuclear Power Station Accident (April 14-18, 2011).

⁴ Declaration of Dr. Arjun Makhijani Regarding Safety and Environmental Significance of NRC Task Force Report Regarding Lessons Learned From Fukushima Daiichi Nuclear Power Station Accident (August 8, 2011), submitted in support of Motion to Reopen the Record and Admit Contention to Address the Safety and Environmental Implications of the Nuclear Regulatory Commission Task Force Report on the Fukushima Dai-ichi Accident (August 11, 2011).

Energy, Blue Ridge Environmental Defense League, Center for a Sustainable Coast, and Georgia Women’s Action for New Directions (collectively, “Petitioners”). I will explain why, in my professional opinion, continuing construction of Vogtle 3 and 4 while the D.C. Circuit Court of Appeals reviews the licensing decision and AP1000 design certification would cause irreparable harm to the environment and persons living nearby. This harm could be avoided by issuing a stay of construction.

3.2 I will also explain why the comparative harm to Southern Nuclear Operating Company (“Southern Co.,”) caused by the issuance of a stay of construction would be much less than the harm to Petitioners.

3.3 Finally, I will explain why the public interest would be served by halting construction on the new reactors pending completion of a supplemental environmental impact statement (“EIS”) that addresses the environmental implications of the Fukushima accident and the conclusions and recommendations of the Task Force Review.

4. Statement of Professional Opinion

4.1 Irreparable Harm to Petitioners

4.1.1 In my professional opinion, the construction activities planned for Vogtle 3 and 4 over the next year will have significant and irreparable adverse environmental impacts by irretrievably committing a large amount of natural resources and generating significant emissions of carbon to the environment.

4.1.2 On February 10, 2012, the NRC issued the COL for Vogtle, which allows it to conduct all aspects of construction and operation. Prior to February 10, Southern Co. had cleared the Vogtle 3 and 4 site.⁵ A recent slide presentation to the NRC by Southern Co. shows that it plans to do a substantial amount of construction in 2012, including installation of rebar, laying of the turbine building foundation, and construction of other structures on the site.⁶

4.1.3 The scale of construction required to build new reactors is immense, utilizing a vast amount of construction materials. For example, the following table shows typical materials requirements for each new evolutionary light water reactor designs (AP1000, ABWR, ESBWR, EPR):

Concrete	350,000 cubic meters
Reinforcing steel and embedded parts	46,000 metric tons
Structural steel and miscellaneous steel	25,000 metric tons
Large bore pipe	8,000 meters
Small bore pipe	13,000 meters
Cable tray	67,000 meters
Conduit	370,000 meters

Source: World Nuclear Association 2011

⁵ Southern Company 2012 Update, Slides 36 and 37

⁶ Southern Company 2012 Update, Slide 13

4.1.4 For the Southern Company Vogtle project, all these estimates must be doubled since two reactors are proposed to be built.

4.1.5 In addition to committing natural resources, construction will also impact air quality. More than one-and-a-half million metric tons of concrete will be needed for two AP1000 units, which in turn will require huge amounts of cement. Cement kilns emit large amounts of mercury and other hazardous air pollutants, like hydrochloric acid, hydrocarbons, and fine particulates responsible for increasing respiratory disease, so much so that the EPA has recently issued rules tightening emissions.⁷ Similarly steel production from ore involves considerable pollution. According to the EPA, iron and steel production involves air emissions of carbon monoxide, sulfur oxides, nitrogen oxides, and fine particulates, discharges of contaminants in wastewater, and generation of hazardous and solid wastes.⁸

4.1.6 Further, on-site, the use of the construction equipment involves the use of diesel engines, which cause emissions of particulates, hydrocarbons, and nitrogen oxides. Finally, transportation of these vast amounts of materials to the site will also directly cause similar air pollution and, indirectly, water pollution and soil pollution impacts associated with petroleum production and refining.

4.1.7 The generation of carbon dioxide (CO₂) during construction of Vogtle 3 and 4 is irreversible and significant. For instance, the construction of two Vogtle units, which will generate on the order of one-and-a-half million metric tons of carbon dioxide,⁹ is equivalent to the CO₂ emissions from nearly 300,000 typical cars in one year.¹⁰

4.2 Harm to Southern Co.

4.2.1 The potential harm to Southern Co. from a stay of construction is essentially economic; indeed, if changes are ordered after substantial construction is done, Southern will benefit from a stay rather than be harmed. This is because costs to all parties involved – Southern Company, workers, ratepayers and taxpayers, will be greater in case of later backfits compared to incorporation of safety changes before licensed construction begins. The loss to its workers will be severe in case of late changes, which make an abandonment of the project more likely than early changes, because a sudden halt to construction and abandonment will mean essentially instant unemployment for thousands of workers. This has happened many times before, in the 1970s and 1980s, when dozens of plants were cancelled due to high costs and declining growth rate of electricity use. But the financial exposure of Southern Co. is likely to be small compared to that of other parties. Southern Co. is exposed to minimal economic risk for the primary reason that Georgia electric ratepayers, not Southern Co., carry the primary financial risk for the Vogtle

⁷ EPA 2011

⁸ EPA Steel 2011.

⁹ World Nuclear Association 2011. Converted from energy data provided using average US CO₂ emissions per unit of energy use. Estimates of the energy input into construction vary somewhat. The variations are likely due to different assumptions about energy inputs into the materials used and on the on-site energy using during construction. In any case, the CO₂ emissions associated with the construction of nuclear plants are very large.

¹⁰ Rounded to one significant figure.

project. It is my understanding that under Georgia’s Construction Work in Progress (“CWIP”) law, Southern Co. may recover from the ratepayers all of the costs of construction for which they are responsible, including costs of delays or default, unless the cost is explicitly disapproved by the Public Service Commission for reasons of “fraud, concealment, failure to disclose a material fact, imprudence, or criminal misconduct.”¹¹ This is very high bar for denial of recovery. Southern Co. has been given the go-ahead both by state regulators and the NRC. Therefore, it will very likely be able to recover whatever its own investment may be from the ratepayers even if it abandons the project. In effect, at present, it has, as the popular saying in investment circles goes, little or no “skin in the game” in the sense that it stands to lose little, and maybe none, of stockholders money in the event of abandonment of the project. It can look forward to construction, believing that all expenses incurred are prudent and recoverable.

4.2.2 Further, the Vogtle 3 and 4 project has received a conditional commitment for a loan guarantee from the federal government amounting to \$8.3 billion, and the loan will likely come from the Federal Financing Bank.¹² So, in the event Southern Co. abandons the project and defaults on the loan, the United States taxpayer carries the risk.

4.2.3 The cost of delaying construction must also be compared to the cost of delaying consideration of the Fukushima Task Force recommendations after a great deal of capital has been invested, all the way to the eve of operation, as proposed by the NRC in CLI-12-02. It is very costly to retrofit a plant after it is nearly completed. This is a cost that Southern Company has previously stated that it wishes to avoid. Southern has posted on its website a statement that the NRC’s current process for issuing combined construction permits and operating licenses is preferable to the previous practice of separately issuing a construction permit before the operating license, because the previous process resulted in “costly redesigns:”

The cost of U.S. nuclear power units built in the 1970s and 80s increased dramatically from original cost estimates. The nuclear industry has taken a number of steps to reduce the risk of capital cost escalations for new plants.

To avoid lengthy licensing processes and *cost overruns* that occurred during the construction of the current fleet of nuclear plants, the U.S. Nuclear Regulatory Commission has implemented changes to its licensing process that provide for the resolution of all safety and environmental issues before construction begins. The NRC, manufacturers and utilities have worked together to make changes to help prevent price escalations experienced in the 1970s and 80's.

¹¹ Ga. Code Ann. § 46-3A-7(d) (2010).

¹² The official description of the Federal Financing Bank is as follows: “The Federal Financing Bank (FFB) is a *government corporation*, created by Congress in 1973 under the general supervision of the Secretary of the Treasury. The FFB was established to centralize and reduce the cost of federal borrowing, *as well as federally-assisted borrowing from the public*. The FFB was also established to deal with federal budget management issues which occurred when off-budget financing flooded the government securities market with offers of a variety of government-backed securities that were competing with Treasury securities. Today the FFB has statutory authority to purchase any obligation issued, sold, or guaranteed by a federal agency to ensure that fully guaranteed obligations are financed efficiently.” Federal Financing Bank 2012. Italics added.

The prior licensing approach granted an operating license after construction was completed. *During construction, it was common for licensing requirements to change, resulting in costly redesigns.*

Licensing Process Today

Today's design certification process enables plant designers to secure advance NRC approval of standardized plant designs. The early site permit process also enables companies to obtain approval from the NRC for a nuclear power plant site before deciding to build a plant. And today's process provides for issuance of a combined construction permit and operating license before construction begins. Granting a combined construction permit and operating license *signifies resolution of all safety issues associated with the plant.*¹³

4.2.4 Therefore, by Southern Company's own logic, the issuance of a stay until resolution of all safety issues would be in its interest.

4.3 Public Interest in Issuance of a Stay

4.3.1 In my professional opinion, the public interest would be served by the issuance of a stay in this case for three reasons. First, the costs of Fukushima-based retrofits may be significant, and if they are considered before construction of Vogtle 3 and 4 begins in a supplemental EIS, the cost-benefit analysis for Vogtle 3 and 4 may change and tip toward other more affordable energy sources. Second, the possibility that backfits would be ordered later in the process has been raised by the NRC itself.¹⁴ If these backfits are postponed until after construction is well advanced ratepayers—and potentially taxpayers—will bear increased costs of delays due to redesign and backfits. Finally, issuance of a stay is in the public interest because it would be consistent with past NRC policy regarding the consideration of the implications of the Three Mile Island accident, and because considering safety improvements before construction and operation is, as a matter of policy, the most effective way to ensure that they will be implemented in a timely way. Indeed, a principal reason for issuing new regulations enabling a single combined construction and operating license, rather than two licenses, one for construction and another for operation, was to avoid the inefficiencies, delays, and high costs that typified the two-step licensing process. This is recognized by Southern Company as illustrated by the quote above. The Nuclear Energy Institute, association of the nuclear industry, has expressed a similar view:

Shortcomings of Old Licensing Process

The federal government licensed most of today's 104 U.S. nuclear power plants during the 1960s and 1970s. Commercial nuclear energy was an emerging technology, and the regulatory process evolved with the new industry. The regulatory agency issued a construction permit for a plant based on a preliminary design. Safety issues were not fully resolved until the plant was essentially

¹³ Southern Company 2012 Plan

¹⁴ NRC Comment Response 2011, p. 16.

complete—a process flaw that had substantial financial implications.

Another shortcoming of the process was that the public did not have access to the details of the design until construction was almost finished.

...

Combined Construction and Operating License

The licensing process for new nuclear power plants provides for issuance of a combined construction permit and operating license (COL). *Granting a COL signifies resolution of all safety issues associated with the plant.*¹⁵

4.4 Potentially significant costs of Fukushima backfits

4.4.1 The recommendations of the Task Force cover a range of significant regulatory issues related to both the design and operation of nuclear reactors, including new reactors such as Vogtle 3 and 4. As summarized by NRC Chairman Jaczko in his dissent from CLI-12-02:

The Task Force identified twelve overarching recommendations for improving safety of operating and new nuclear reactors. These included measures to ensure protection against earthquakes and flooding, measures to minimize potential hazards from those events and measures to improve emergency preparedness and responses. More broadly, the Task Force recommended strengthening our regulatory framework by making it more logical, systematic and coherent. Taken together, the recommendations were intended to clarify and strengthen our regulatory framework to protect against and mitigate the consequences of natural disaster, enhance emergency preparedness, and improve the effectiveness of our regulatory programs.¹⁶

4.4.2 As Chairman Jaczko points out in his dissent, “new safety enhancements are under development, some of which I consider necessary for adequate protection...”¹⁷ Those that are necessary for adequate protection cannot be rejected on the basis of their cost. They have not been applied to Vogtle 3 and 4. .

4.4.3 As Chairman Jaczko also points out, the NRC “expect[s] to issue a number of orders imposing new requirements relating to flooding, seismic events and station blackout as well as information requests in March 2012.”¹⁸ And these are “only the initial phase” of the NRC’s post-Fukushima regulatory actions.¹⁹ The recommendations that must be implemented also include rulemakings, which by their very nature have an even broader reach.²⁰

¹⁵ NEI 2012, italics added.

¹⁶ Dissenting Opinion, p, 5 in CLI-12-02 .

¹⁷ *Id.* at 5.

¹⁸ *Id.* at 5.

¹⁹ *Id.* .

²⁰ NRC SECY-11-0124

4.4.4 The costs of these requirements are likely to be significant, given that protection against flooding, seismic events, and station blackout all involve changes to reactor design rather than mere administrative measures. The costs of backfits for protection against seismic events, flooding, and station blackouts will be all the more expensive if they are postponed until after significant aspects of construction are complete. As recognized in Southern Company's website statement quoted above in par. 4.2.3, as a general rule it is more costly to redesign and backfit a reactor under construction than it is to resolve all issues before beginning reactor construction.

4.4.5 For instance, if the ground acceleration for the design basis earthquake was raised to correspond to more severe earthquakes than were incorporated into the original Vogtle or AP1000 design, the same level of safety would require more robust reactors. Seismic upgrades are likely to be expensive if they are backfitted after construction is advanced or completed. The U.S. Department of Energy's "K-Reactor" at the Savannah River Site in South Carolina, located just across the Savannah River from Vogtle, provides a good example of how changes in a seismic hazard analysis can drastically affect the cost of a nuclear reactor. At 3,415 megawatts-thermal, the AP1000²¹ is more than a third larger than the K-reactor, which had a rated thermal power of 2,500 megawatts.²² The K-reactor was built in the early 1950s; seismic upgrades were made after safety became a very public concern towards the end of the Cold War in the late 1980s, more than two decades prior to the most recent conclusions of elevated hazards in the eastern region. The cost of these upgrades, completed in the early 1990s, was about \$870 million, or about \$1.3 billion in today's dollars for a single reactor that was somewhat smaller than the proposed Vogtle reactors.²³

4.4.6 A cost comparable to the K-reactor seismic backfit for both Vogtle units could run into billions of dollars, with additional costs for carrying the capital during the delays. Near the end of the construction process, when the two reactors would be nearly complete, Georgia ratepayers and the federal government will have an extremely large amount of capital at risk – up to \$14 billion just before completion, presuming there are no cost overruns before then. At a nominal carrying cost of capital of about 10.6 percent (usual in such calculations²⁴), NRC requirements that result in delays due to design and implementation of backfits would be \$20 million to \$29 million *per week* (rounded) if the capital invested at the time the retrofit is ordered is in the \$10 billion to \$14 billion range. The costs of the backfits would be in addition to these costs.

4.4.7 It is important to note that, the possibility of seismic upgrades to reactors in the eastern United States looms larger with the publication of a recent EPRI- DOE-NRC 2012 study. On January 31, a week-and a half before issuing the license for Vogtle, the NRC announced the publication of a study on seismic hazards in the Central and Eastern United States.²⁵ In announcing the study the NRC noted that "[t]he new seismic model will be used by nuclear power plants in the central and eastern United States for these re-evaluations, *in addition to being used for*

²¹ Westinghouse 2003

²² Bailey, Kalinich, and Chou 1992, p. 1

²³ Wald 1991 and SRS 2011.

²⁴ This represents 8.6% for the constant dollar weighted cost (mix of equity and bonds) cost of capital and 2% inflation. CEC 2008.

²⁵ EPRI- DOE-NRC 2012

*licensing of new nuclear facilities.*²⁶ But the NRC did not conduct this review for Vogtle 3 and 4 prior to licensing, even though Vogtle lies about 120 miles from the 1886 Charleston earthquake, a major seismic event. Moreover, it is highly important to note that the NRC announcement stated that the results of the study “indicate that estimates of the seismic hazard have increased with respect to some operating nuclear plant sites in the Central and Eastern United States” and that “sample calculations indicate that *the largest predicted ground motions could occur in the vicinity of repeated large magnitude earthquake sources, such as New Madrid, Mo., and Charleston, S.C.*”²⁷

4.4.8 If more severe earthquakes than were incorporated into the original design were required for safety, the costs could be significant and increase the attractiveness of alternatives. Protection of the Vogtle reactors against updated flood hazards could also involve significant costs, if the updated evaluations indicate the need for backfits at the Vogtle site.

4.5 Ratepayers and taxpayers will bear the brunt of costs

4.5.1 Under the Construction Work in Progress (“CWIP”) law cited above, ratepayers currently contribute to the financing of construction for the Vogtle project via their monthly power bills. Taxpayers are also at risk because an \$8.33 billion federal loan guarantee will secure the project if Southern Co. defaults.²⁸ The loan will likely be provided by the Federal Financing Bank.²⁹ Retrofits substantially increase costs of the project, increasing the risk of default and eroding the competitive costs of nuclear power compared to alternative forms of energy. Therefore it is in the interest of the ratepayers and taxpayers who are very likely to ultimately bear the costs of the project’s failure, to issue a stay and ensure that all pertinent safety issues are resolved before construction resumes

4.6 Postponing Fukushima safety improvements until after construction severely undermines consideration of alternatives

4.6.1 If Southern is permitted to go ahead with construction of Vogtle 3 and 4 and Fukushima-related backfits are imposed after a significant amount of construction is complete, it will not be possible to evaluate whether going ahead with construction of the reactors is cost-effective. Not only are the costs of retrofits likely to be greater if they are imposed after construction has been completed – or even substantially completed -- but an up-front accounting of the costs allows a comparison with other alternative energy sources that are more cost-effective. Even the Nuclear Energy Institute has acknowledged (as is clear from the quote above) that the public is deprived of timely information under the old licensing process when regulatory changes happened during construction. (“Another shortcoming of the process *was that the public did not have access to the details of the design until construction was almost finished.*”³⁰) One of the needed details is of course, the estimated cost of the project.

²⁶ NRC News 2012, italics added.

²⁷ NRC News 2012, italics added.

²⁸ DOE 2011

²⁹ Southern Company 2010

³⁰ NEI 2012, italics added.

4.6.2 As noted above, if seismic backfits are required at a late stage, the delays could stretch for a year or more, the backfit costs could run into billions; carrying costs of capital would added roughly a billion dollars per year of delay. The cost of power from Vogtle is already high compared to the alternatives. At \$14 billion and 90 percent capacity factor, with 10.6 percent average cost of capital, a 2% inflation rate, and assuming no delays and cost overruns, the levelized cost of power from Vogtle at the busbar of the power plant would be about 9 cents per kWh. When the cost of transmission and distribution is added, the cost of power from the new Vogtle units would be in the range of 13 to 14 cents per kWh. This is greatly in excess of the residential electricity cost of about 10 cents per kWh in Georgia.³¹ The cost of natural gas on the spot market today is about \$2.50 per million Btu. At \$5 per million Btu (the approximate cost of natural gas for Georgia power plants in 2010³²) for a long term contract delivered to the power plant, the levelized cost of power from a combined cycle power plant at the busbar would be about 6 cents per kWh, including a 2% inflation rate in the price of gas (capital and operating costs for combined cycle power plants based on an advanced natural gas combined cycle plant³³). Hence, the cost to residential customers of this power from combined cycle plants would therefore be about the same as at present, even if there were a two percent per year inflation in natural gas costs. Vogtle is already uneconomical – being about 50 percent more expensive at the busbar than combined cycle power (9 cents per kWh for Vogtle compared to 6 cents for combined cycle natural gas). This is a central reason there is no nuclear renaissance in sight. Significant cost increases are likely to be devastating to the project and reduce the growth rate for electricity.

4.6.3 Finally, to stay construction of Vogtle 3 and 4 is in the public interest because it ensures that Fukushima-related regulatory changes and backfits will be fully and adequately considered. In his dissent, Chairman Jaczko noted “is the difficulty of requiring timely compliance with new safety requirements that are not tied down in the license.”³⁴ This in essence means that to be assured of implementation, safety changes should be tied to the granting of the license. This was implicitly recognized by the NRC in responding to the Three Mile Island accident, when the NRC suspended all licensing decisions while it studied the regulatory implications of the accident. In explaining his dissent, Chairman Jaczko noted that after the TMI accident there was a “comprehensive assessment” and “licensing pause” to “ensure that “lessons learned from the accident were appropriately accounted for with respect to operating reactors and new reactor applications that were under review.”³⁵ Yet, no licensing pause has followed the Fukushima accident, even though it was far more serious and severe in every respect than the TMI accident. By suspending reactor licensing while it investigated the implications of the accident and strengthened its regulations, the NRC ensured that safety improvements would be made before operation began.

³¹ EIA 2012, p. 65.

³² EIA 2012, p. 64. Prices of natural gas have been declining since 2010. The most recent data for prices to electricity producers published by the Energy Information Administration shows a price of \$4.47 in October 2011. (EIA Natural Gas Prices 2012) In contrast, the calculation for natural gas electricity costs here actually assumes that prices will rise at 2% per year.

³³ EIA 2010, Table 1, estimated at 80 percent capacity factor.

³⁴ Dissenting opinion at 6. in CLI-12-02

³⁵ *Id.* at 11.

5. Conclusion

5.1 The construction of nuclear reactors involves a vast amount of materials like steel and cement. Their production and transport creates considerable amounts of water and air pollution, including emissions of mercury, particulates, and hydrocarbons. In addition, construction causes emissions of huge amounts of CO₂ – equivalent to emissions from about 300,000 typical cars over one year. This environmental harm cannot be remedied or fixed if the new Vogtle reactors are cancelled or significantly altered as a result of Fukushima-related regulatory backfits ordered after construction is well advanced. This irreparable harm should be avoided.

5.2 Moreover, regulatory changes are in the offing as a result of the review of the Fukushima accident by the NRC and the acceptance of all the recommendations of the Task Force by the Commission. These regulatory changes will likely require changes in the reactor design for Vogtle 3 and 4. And, as noted above, such changes are far less expensive to make at the start of the process than after construction is well advanced or nearly complete. Thus, the public interest is served by staying construction while the U.S. District Court of Appeals determines if the Vogtle EIS must be supplemented to account for the lessons learned from Fukushima. The stay is all the more important, because allowing construction to continue, and then requiring backfits at a later date, puts the public's money at risk; based on present approvals, Southern Company faces little or no financial risk. Taxpayers, via a loan guarantee, and ratepayers via payments called "construction work in progress," will bear essentially all of the costs that are incurred if Southern Company walks away from high post-Fukushima retrofit costs after construction is well advanced.

5.3 It is far better and much more prudent, environmentally and economically, to consider the changes that will be required of the Vogtle reactor - before construction continues, not after it is well advanced or nearly complete. Indeed, it appears that the Southern Company's own website indicates agreement with this view as indicated in the quotation in par. 4.2.3 above. So apparently does the nuclear industry, as represented by the Nuclear Energy Institute, which has stated that "[g]ranting a COL signifies resolution of all safety issues associated with the plant."³⁶ In the case of the Vogtle 3 and 4 project, all safety issues were not resolved prior to the issuance of the combined construction and operating license.

The facts presented above are true and correct to the best of my knowledge, and the opinions expressed therein are based on my best professional judgment.



Dr. Arjun Makhijani

Date: 16 February 2012

³⁶ NEI 2012, italics added.

Bibliography

Bailey, Kalinich, and Chou 1992	R.T. Bailey, D. A. Kalinich, and C. Y. Chou. <i>SRS K-Reactor PRA LOCA Analyses Using Best-Estimate Methods</i> (U). (WSRC-MS--92-386-Del .Ver.; DE93 003380) Aiken, SC: Westinghouse Savannah River Company, [9-28-92?]. On the Web at http://www.osti.gov/bridge/servlets/purl/6659523-YjXmpK/6659523.pdf . “A paper proposed for at/in the Probabilistic Safety Assessment International Topical Meeting (PSA '93), Clearwater Beach, FL, 01/26-29/93.”
CEC 2008	Mike Ringer. <i>Discounting Future Fuel Costs at a Social Discount Rate: Staff Paper</i> . Presented at 2008 IEPR Update Committee Workshop, Sacramento, California, August 18, 2008. (CEC-200-2008-004) Sacramento: Electricity Analysis Office, Electricity Supply Analysis Division, California Energy Commission, August 2008. On the Web at http://www.energy.ca.gov/2008publications/CEC-200-2008-004/CEC-200-2008-004.PDF .
CLI-12-02	United States. Nuclear Regulatory Commission. <i>Memorandum and Order</i> . CLI-12-02. In the Matter of Southern Nuclear Operating Co. (Vogle Electric Generating Plant, Units 3 and 4). Docket Nos. 52-025-COL & 52-026-COL. On the Web at http://www.nrc.gov/reading-rm/doc-collections/commission/orders/2012/2012-02cli.pdf . Commissioners: Gregory B. Jaczko, Chairman, Kristine L. Svinicki, George Apostolakis, William D. Magwood, IV, William C. Ostendorff. Includes the Dissenting opinion of Chairman Gregory B. Jaczko.
DOE 2011	United States. Department of Energy. <i>Secretary Chu Statement on AP1000 Reactor Design Certification</i> . Washington, DC: DOE, December 22, 2011. On the Web at http://energy.gov/articles/secretary-chu-statement-ap1000-reactor-design-certification . Press Release.
EIA 2010	United States. Department of Energy. Energy Information Administration.. <i>Updated Capital Cost Estimates for Electricity Generation Plants</i> . Washington, DC: DOE, EIA, Office of Independent Statistics and Analysis, November 2010. On the Web at http://www.eia.gov/oiaf/beck_plantcosts/pdf/updatedplantcosts.pdf .
EIA 2012	United States. Department of Energy. Energy Information Administration. <i>State Electricity Profiles 2010</i> . (DOE/EIA-0348(01)/2) Washington, DC: EIA, Assistant Administrator for Energy Statistics, Office of Electricity, Renewables, and Uranium Statistics, January 2012. On the web at http://www.eia.gov/electricity/state/pdf/sep2010.pdf , from links at http://www.eia.gov/electricity/state .
EIA Natural Gas Prices for 2011	United States. Department of Energy. Energy Information Administration. <i>Natural Gas Prices</i> . Washington, DC: DOE, EIA, Office of Independent Statistics and Analysis, January 30, 2012. On the Web at http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm .
EPA 2011	United States. Environmental Protection Agency. “National Emission Standards for Hazardous Air Pollutants From the Portland Cement Manufacturing Industry and Standards of Performance for Portland Cement Plants,” <i>Federal Register</i> v. 76, no. 11 (January 18, 2011): pp. 2832-2837. On the Web at http://www.epa.gov/ttn/atw/pcem/fr18ja11.pdf . “Direct Final rule; amendments.” Re: 40 CFR Parts 60 and 63. “EPA-HQ-OAR-2002-0051; EPA-HQ-OAR-2007-0877; FRL-9253-4” “RIN 2060-AQ59”

EPA Steel 2011	United States. Environmental Protection Agency. <i>Iron and Steel</i> . (Sector-Based Information and Resources: Sector Programs) Washington, DC: EPA, January 12, 2011. On the Web at http://www.epa.gov/sectors/sectorinfo/sectorprofiles/steel.html .
EPRI- DOE- NRC 2012	Electric Power Research Institute (EPRI), the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC). <i>Central and Eastern United States Seismic Source Characterization for Nuclear Facilities</i> . (NUREG-2115). Palo Alto, CA: EPRI; Washington, DC: DOE and NRC, 2012. On the Web at http://www.ceus-ssc.com .
Federal Financing Bank 2012	Federal Financing Bank. [<i>Home page</i>]. Washington, DC: U.S. Department of the Treasury, FFB, viewed on February 15, 2012. On the Web at http://www.treasury.gov/ffb .
Ga. Code Ann. 2010	<i>Official Code of Georgia. Title 46 - Public Utilities and Public Transportation. Chapter 3a - Integrated Resource Planning</i> . On the Web at http://law.justia.com/codes/georgia/2010/title-46/chapter-3a . “2010 Georgia Code.” § 46-3A-7 - Construction costs as part of rate base; review of construction work in progress; verification of expenditures; recovery of costs of canceled construction, at http://law.justia.com/codes/georgia/2010/title-46/chapter-3a/46-3a-7/ .
Makhijani 2011-03	Arjun Makhijani. <i>Post-Tsunami Situation at the Fukushima Daiichi Nuclear Power Plant in Japan: Facts, Analysis, and Some Potential Outcomes</i> . Statement. Takoma Park, MD: Institute for Energy and Environmental Research, March 14, 2011. On the Web at http://www.ieer.org/comments/Daiichi-Fukushima-reactors_IEERstatement.pdf .
Makhijani 2011-04	Arjun Makhijani. <i>Declaration of Dr. Arjun Makhijani in Support of Emergency Petition to Suspend All Pending Reactor Licensing Decisions and Related Rulemaking Decisions Pending Investigation of Lessons Learned from Fukushima Daiichi Nuclear Power Station Accident</i> (April 19, 2011) (ML111101504), submitted in support of Emergency Petition to Suspend All Pending Reactor Licensing Decisions and Related Rulemaking Decisions Pending Investigation of Lessons Learned From Fukushima Dai ichi Nuclear Power Station Accident (April 14-18, 2011). On the Web at http://www.ieer.org/comments/Makhijani-Declaration_NRC_Licensing_Suspension_ML111101504.pdf .
Makhijani 2011-08	Arjun Makhijani. <i>Declaration of Dr. Arjun Makhijani Regarding Safety and Environmental Significance of NRC Task Force Report Regarding Lessons Learned From Fukushima Daiichi Nuclear Power Station Accident</i> (August 8, 2011) (ML11222A100), submitted in support of Motion to Reopen the Record and Admit Contention to Address the Safety and Environmental Implications of the Nuclear Regulatory Commission Task Force Report on the Fukushima Dai-ichi Accident (August 11, 2011). On the Web at http://www.ieer.org/comments/Makhijani_Declaration_new_Fukushima_Contention_2011_ML11222A100.pdf .
NEI 2012	Nuclear Energy Institute. <i>New Nuclear Plant Licensing</i> . (Key Issues). Washington, DC: NEI, 2012. On the Web at http://www.nei.org/keyissues/newnuclearplants/newnuclearplantlicensing/ .
NRC 2011	United States. Nuclear Regulatory Commission. <i>Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-chi Accident</i> , July 12, 2011. On the Web at http://pbadupws.nrc.gov/docs/ML1118/ML111861807.pdf .

NRC Comment Response 2011	United States. Nuclear Regulatory Commission. <i>NRC Responses to Public Comments: Amendment to AP1000 Design Certification Rule, 10 CFR Part 52, Appendix D (RIN 3150-A181)</i> . (ML113480018) [Washington, DC: NRC, December 2011. On the Web at pbadupws.nrc.gov/docs/ML1134/ML113480018.pdf .
NRC News 2012	United States. Nuclear Regulatory Commission. "New Seismic Model Will Refine Hazard Analysis at U.S. Nuclear Plants," <i>NRC News</i> , no. 12-010 (January 31, 2012). On the Web at http://pbadupws.nrc.gov/docs/ML1203/ML120330098.pdf . Press Release
NRC SECY-11-0124	United States. Nuclear Regulatory Commission. <i>Recommended Actions to be Taken Without Delay from the Near-Term Task Force Report</i> . (SECY-11-0124) (ML11245A127) (Policy Issue (Notation Vote)) [Washington, DC: NRC], September 9, 2011. On the Web at http://www.nrc.gov/reading-rm/doc-collections/commission/secys/2011/2011-0124scy.pdf .
Southern Company 2010	Southern Company. <i>DOE Loan Guarantees Background</i> . [Atlanta: Southern, June 10, 2010]. On the Web at http://www.southerncompany.com/nuclearenergy/presskit/docs/GTF_DOE_loan_guarantees_background.pdf . Press release
Southern Company 2012 Plan	Southern Company. <i>Nuclear Energy: The Plan</i> . Atlanta: Southern, viewed on February 12, 2012. On the Web at http://www.southerncompany.com/nuclearenergy/plan.aspx .
Southern Company 2012 Update	Southern Company. <i>Vogtle Units 3&4 Project Update</i> . [Atlanta?] Southern; Westinghouse; Shaw, February 8, 2012. (ML12034A190) On the Web at http://pbadupws.nrc.gov/docs/ML1203/ML12034A190.pdf . At head of title: Vogtle Units 3&4 Nuclear Development.
SRS 2011	Savannah River Nuclear Solutions. K Reactor Complex. (Facts enterprise.srs) (11PA00218JA) [Aiken, SC] SRNS, November 2011. On the Web at http://www.srs.gov/general/news/factsheets/esrs_kac.pdf .
Wald 1991	Matthew L. Wald. "The Nation; How an Old Government Reactor Managed to Outlive the Cold War," <i>New York Times</i> , December 22, 1991. On the Web at http://www.nytimes.com/1991/12/22/weekinreview/the-nation-how-an-old-government-reactor-managed-to-outlive-the-cold-war.html .
Westinghouse 2003	Westinghouse Electric Co. <i>The Westinghouse AP1000 Advanced Nuclear Plant: Plant description</i> . [Cranberry, PA]: Westinghouse, 2003. On the Web at http://www.ne.doe.gov/pdfFiles/AP1000_Plant_Description.pdf .
World Nuclear Association 2011	World Nuclear Association. <i>Energy Analysis of Power Systems</i> . London: WNA, updated January 2011. On the Web at http://world-nuclear.org/info/inf11.html .

Curriculum Vita of Arjun Makhijani

Address and Phone:

Institute for Energy and Environmental Research
6935 Laurel Ave., Suite 201
Takoma Park, MD 20912
Phone: 301-270-5500
e-mail: arjun@ieer.org
Website: www.ieer.org

A recognized authority on energy issues, Dr. Makhijani is the author and co-author of numerous reports and books on energy and environment related issues, including two published by MIT Press. He was the principal author of the first study of the energy efficiency potential of the US economy published in 1971. He is the author of *Carbon-Free and Nuclear-Free: A Roadmap for U.S. Energy Policy* (2007).

In 2007, he was elected Fellow of the American Physical Society. He was named a Ploughshares Hero, by the Ploughshares Fund (2006); was awarded the Jane Bagley Lehman Award of the Tides Foundation in 2008 and the Josephine Butler Nuclear Free Future Award in 2001; and in 1989 he received The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, with Robert Alvarez. He has many published articles in journals and magazines as varied as *The Bulletin of the Atomic Scientists*, *Environment*, *The Physics of Fluids*, *The Journal of the American Medical Association*, and *The Progressive*, as well as in newspapers, including the *Washington Post*.

Dr. Makhijani has testified before Congress, and has appeared on ABC World News Tonight, the CBS Evening News, CBS 60 Minutes, NPR, CNN, and BBC, among others. He has served as a consultant on energy issues to utilities, including the Tennessee Valley Authority, the Edison Electric Institute, the Lawrence Berkeley Laboratory, and several agencies of the United Nations.

Education:

- Ph.D. University of California, Berkeley, 1972, from the Department of Electrical Engineering. Area of specialization: plasma physics as applied to controlled nuclear fusion. Dissertation topic: multiple mirror confinement of plasmas. Minor fields of doctoral study: statistics and physics.
- M.S. (Electrical Engineering) Washington State University, Pullman, Washington, 1967. Thesis topic: electromagnetic wave propagation in the ionosphere.
- Bachelor of Engineering (Electrical), University of Bombay, Bombay, India, 1965.

Current Employment:

- 1987-present: President and Senior Engineer, Institute for Energy and Environmental Research, Takoma Park, Maryland. (part-time in 1987).
- February 3, 2004-present, Associate, SC&A, Inc., one of the principal investigators in the audit of the reconstruction of worker radiation doses under the Energy Employees Occupational Illness Compensation Program Act under contract to the Centers for Disease Control and Prevention, U.S. Department of Health and Human Services.

Other Long-term Employment

- 1984-88: Associate Professor, Capitol College, Laurel, Maryland (part-time in 1988).
- 1983-84: Assistant Professor, Capitol College, Laurel, Maryland.
- 1977-79: Visiting Professor, National Institute of Bank Management, Bombay, India. Principal responsibility: evaluation of the Institute's extensive pilot rural development program.
- 1975-87: Independent consultant (see page 3 for details)
- 1972-74: Project Specialist, Ford Foundation Energy Policy Project. Responsibilities included research and writing on the technical and economic aspects of energy conservation and supply in the U.S.; analysis of Third World rural energy problems; preparation of requests for proposals; evaluation of proposals; and the management of grants made by the Project to other institutions.
- 1969-70: Assistant Electrical Engineer, Kaiser Engineers, Oakland California. Responsibilities included the design and checking of the electrical aspects of mineral industries such as cement plants, and plants for processing mineral ores such as lead and uranium ores. Pioneered the use of the desk-top computer at Kaiser Engineers for performing electrical design calculations.

Professional Societies:

- Institute of Electrical and Electronics Engineers and its Power Engineering Society
- American Physical Society (Fellow)
- Health Physics Society
- American Association for the Advancement of Science

Awards and Honors:

- The John Bartlow Martin Award for Public Interest Magazine Journalism of the Medill School of Journalism, Northwestern University, 1989, with Robert Alvarez
- The Josephine Butler Nuclear Free Future Award, 2001
- Ploughshares Hero, Ploughshares Fund, 2006
- Elected a Fellow of the American Physical Society, 2007, "*For his tireless efforts to provide the public with accurate and understandable information on energy and environmental issues*"
- Jane Bagley Lehman Award of the Tides Foundation, 2007/2008

Committee Member, Radiation Advisory Committee, Science Advisory Board, U.S. Environmental Protection Agency, 1992-1994

Invited Faculty Member, Center for Health and the Global Environment, Harvard Medical School: Annual Congressional Course, Environmental Change: The Science and Human Health Impacts, April 18-19, 2006, Lecture Topic: An Update on Nuclear Power - Is it Safe?

Consulting Experience, 1975-1987

Consultant on a wide variety of issues relating to technical and economic analyses of alternative energy sources; electric utility rates and investment planning; energy conservation; analysis of energy use in agriculture; US energy policy; energy policy for the Third World; evaluations of portions of the nuclear fuel cycle.

Partial list of institutions to which I was a consultant in the 1975-87 period:

- Tennessee Valley Authority
- Lower Colorado River Authority
- Federation of Rocky Mountain States
- Environmental Policy Institute
- Lawrence Berkeley Laboratory
- Food and Agriculture Organization of the United Nations
- International Labour Office of the United Nations
- United Nations Environment Programme
- United Nations Center on Transnational Corporations
- The Ford Foundation
- Economic and Social Commission for Asia and the Pacific
- United Nations Development Programme

Languages: English, French, Hindi, Sindhi, and Marathi.

Reports, Books, and Articles (Partial list)

(Newsletter, newspaper articles, excerpts from publications reprinted in books and magazines or adapted therein, and other similar publications are not listed below)

Hower, G.L., and A. Makhijani, "Further Comparison of Spread-F and Backscatter Sounder Measurements," *Journal of Geophysical Research* 74 (1969): 3723.

Makhijani, A., and A.J. Lichtenberg, *An Assessment of Energy and Materials Utilization in the U.S.A.*, University of California Electronics Research Laboratory, Berkeley, 1971.

Logan, B. G., A.J. Lichtenberg, M. Lieberman, and A. Makhijani, "Multiple-Mirror Confinement of Plasmas," *Physical Review Letters* 28 (1972): 144-147.

Makhijani, A., and A.J. Lichtenberg, "Energy and Well-Being," *Environment* 14 (June 1972): 10-.

Makhijani, A., A.J. Lichtenberg, M. Lieberman, and B. Logan, "Plasma Confinement in Multiple Mirror Systems. I. Theory," *Physics of Fluids* 17 (1974): 12911301.

A Time to Choose: America's Energy Future, final report of the Ford Foundation Energy Policy Project, Ballinger, Cambridge, 1974. One of many co-authors.

Makhijani, A., and A. Poole, *Energy and Agriculture in the Third World*, Ballinger, Cambridge, 1975.

Makhijani, A., *Energy Policy for the Rural Third World*, International Institute for Environment and Development, London, 1976.

Kahn, E., M. Davidson, A. Makhijani, P. Caeser, and S. Berman, *Investment Planning in the Energy Sector*, Lawrence Berkeley Laboratory, Berkeley, 1976.

Makhijani, A., "Solar Energy for the Rural Third World," *Bulletin of the Atomic Scientists*, May 1977.

Makhijani, A., "Energy Policy for Rural India," *Economic and Political Weekly (Bombay)* 12 (1977).

Makhijani, A., *Some Questions of Method in the Tennessee Valley Authority Rate Study*, Report to the Tennessee Valley Authority, Chattanooga, 1978.

Makhijani, A., *The Economics and Sociology of Alternative Energy Sources*, Economic and Social Commission for Asia and the Pacific, 1979.

Makhijani, A., *Energy Use in the Post-Harvest Component of the Food Systems in Ivory Coast and Nicaragua*, Food and Agriculture Organization of the United Nations, Rome, 1982.

Makhijani, A., *Oil Prices and the Crises of Debt and Unemployment: Methodological and Structural Aspects*, International Labour Office of the United Nations, Final Draft Report, Geneva, April 1983.

Makhijani, A., and D. Albright, *The Irradiation of Personnel at Operation Crossroads*, International Radiation Research and Training Institute, Washington, D.C., 1983.

Makhijani, A., K.M. Tucker, with Appendix by D. White, *Heat, High Water, and Rock Instability at Hanford*, Health and Energy Institute, Washington, D.C., 1985.

Makhijani, A., and J. Kelly, *Target: Japan - The Decision to Bomb Hiroshima and Nagasaki*, July 1985, a report published as a book in Japanese under the title, *Why Japan?*, Kyoikusha, Tokyo, 1985.

Makhijani, A., *Experimental Irradiation of Air Force Personnel During Operation Redwing - 1956*, Environmental Policy Institute, Washington, D.C., 1985.

Makhijani, A., and R.S. Browne, "Restructuring the International Monetary System," *World Policy Journal* (Winter 1985-86).

Makhijani, A., R. Alvarez, and B. Blackwelder, *Deadly Crop in the Tank Farm: An Assessment of Management of High-Level Radioactive Wastes in the Savannah River Plant Tank Farm*, Environmental Policy Institute, Washington, D.C., 1986.

Makhijani, A., "Relative Wages and Productivity in International Competition," *College Industry Conference Proceedings*, American Society for Engineering Education, Washington, D.C., 1987.

Makhijani, A., *An Assessment of the Energy Recovery Aspect of the Proposed Mass Burn Facility at Preston, Connecticut*, Institute for Energy and Environmental Research, Takoma Park, 1987.

Makhijani, A., R. Alvarez, and B. Blackwelder, *Evading the Deadly Issues: Corporate Mismanagement of America's Nuclear Weapons Production*, Environmental Policy Institute, Washington, D.C., 1987.

Franke, B. and A. Makhijani, *Avoidable Death: A Review of the Selection and Characterization of a Radioactive Waste Repository in West Germany*, Health & Energy Institute, Washington, DC; Institute for Energy and Environmental Research, Takoma Park, November 1987.

Makhijani, A., *Release Estimates of Radioactive and Non-Radioactive Materials to the Environment by the Feed Materials Production Center, 1951-85*, Institute for Energy and Environmental Research, Takoma Park, 1988.

Alvarez, R., and A. Makhijani, "The Hidden Nuclear Legacy," *Technology Review* 91 (1988): 42-51.

Makhijani, A., Annie Makhijani, and A. Bickel, *Saving Our Skins: Technical Potential and Policies for the Elimination of Ozone-Depleting Chlorine Compounds*, Environmental Policy Institute and Institute for Energy and Environmental Research, Takoma Park, 1988.

Makhijani, A., Annie Makhijani, and A. Bickel, *Reducing Ozone-Depleting Chlorine and Bromine Accumulations in the Stratosphere: A Critique of the U.S. Environmental Protection Agency's Analysis and Recommendations*, Institute for Energy and Environmental Research and Environmental Policy Institute/Friends of the Earth, Takoma Park, 1989.

Makhijani, A., and B. Franke, *Addendum to Release Estimates of Radioactive and Non-Radioactive Materials to the Environment by the Feed Materials Production Center, 1951-85*, Institute for Energy and Environmental Research, Takoma Park, 1989.

Makhijani, A., *Global Warming and Ozone Depletion: An Action Program for States*, Institute for Energy and Environmental Research, Takoma Park, 1989.

Makhijani, A., *Managing Municipal Solid Wastes in Montgomery County*, Prepared for the Sugarloaf Citizens Association, Institute for Energy and Environmental Research, Takoma Park, 1990.

Saleska, S., and A. Makhijani, *To Reprocess or Not to Reprocess: The Purex Question - A Preliminary Assessment of Alternatives for the Management of N-Reactor Irradiated Fuel at the U.S. Department of Energy's Hanford Nuclear Weapons Production Facility*, Institute for Energy and Environmental Research, Takoma Park, 1990.

Makhijani, A., "Common Security is Far Off," *Bulletin of the Atomic Scientists*, May 1990.

Makhijani, A., *Draft Power in South Asian Agriculture: Analysis of the Problem and Suggestions for Policy*, prepared for the Office of Technology Assessment, Institute for Energy and Environmental Research, Takoma Park, 1990.

Mehta, P.S., S.J. Mehta, A.S. Mehta, and A. Makhijani, "Bhopal Tragedy's Health Effects: A Review of Methyl Isocyanate Toxicity," *JAMA* 264 (December 5, 1990): 2781-2781,.

Special Commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, *Radioactive Heaven and Earth: The Health and Environmental Effects of Nuclear Weapons Testing In, On, and Above the Earth*, Apex Press, New York, 1991. One of many co-authors.

Makhijani, A., and S. Saleska, *High Level Dollars Low-Level Sense: A Critique of Present Policy for the Management of Long-Lived Radioactive Waste and Discussion of an Alternative Approach*, Apex Press, New York, 1992.

Makhijani, A., *From Global Capitalism to Economic Justice: An Inquiry into the Elimination of Systemic Poverty, Violence and Environmental Destruction in the World Economy*, Apex Press, New York, 1992.

Special Commission of International Physicians for the Prevention of Nuclear War and the Institute for Energy and Environmental Research, *Plutonium: Deadly Gold of the Nuclear Age*, International Physicians Press, Cambridge, MA, 1992. One of several co-authors.

Makhijani, A., "Energy Enters Guilty Plea," *Bulletin of the Atomic Scientists*, March/April 1994.

Makhijani, A., "Open the Files," *Bulletin of the Atomic Scientists*, Jan./Feb. 1995.

Makhijani, A., " 'Always' the Target?" *Bulletin of the Atomic Scientists*, May/June 1995.

Makhijani, A., and Annie Makhijani, *Fissile Materials in a Glass, Darkly: Technical and Policy Aspects of the Disposition of Plutonium and Highly Enriched Uranium*, IEER Press, Takoma Park, 1995.

Makhijani, A., and K. Gurney, *Mending the Ozone Hole: Science, Technology, and Policy*, MIT Press, Cambridge, MA, 1995.

Makhijani, A., H. Hu, K. Yih, eds., *Nuclear Wastelands: A Global Guide to Nuclear Weapons Production and the Health and Environmental Effects*, MIT Press, Cambridge, MA, 1995.

Zerriffi, H., and A. Makhijani, *The Nuclear Safety Smokescreen: Warhead Safety and Reliability and the Science Based Stockpile Stewardship Program*, Institute for Energy and Environmental Research, Takoma Park, May 1996.

Zerriffi, H., and A. Makhijani, "The Stewardship Smokescreen," *Bulletin of the Atomic Scientists*, September/October 1996.

Makhijani, A., *Energy Efficiency Investments as a Source of Foreign Exchange*, prepared for the International Energy Agency Conference in Chelyabinsk, Russia, 24-26 September 1996.

Makhijani, A., "India's Options," *Bulletin of the Atomic Scientists*, March/April 1997.

Ortmeyer, P. and A. Makhijani, "Worse than We Knew," *Bulletin of the Atomic Scientists*, November/December 1997.

Fioravanti, M., and A. Makhijani, *Containing the Cold War Mess: Restructuring the Environmental Management of the U.S. Nuclear Weapons Complex*, Institute for Energy and Environmental Research, Takoma Park, October 1997.

Principal author of three chapters in Schwartz, S., ed., *Atomic Audit: The Costs and Consequences of U.S. Nuclear Weapons Since 1940*, Brookings Institution, Washington, D.C., 1998.

Franke, B., and A. Makhijani, *Radiation Exposures in the Vicinity of the Uranium Facility in Apollo, Pennsylvania*, Institute for Energy and Environmental Research, Takoma Park, February 2, 1998.

Fioravanti, M., and A. Makhijani, *Supplement to Containing the Cold War Mess - IEER's Response to the Department of Energy's Review*, Institute for Energy and Environmental Research, Takoma Park, March 1998.

Makhijani, A., "A Legacy Lost," *Bulletin of the Atomic Scientists*, July/August 1998.

Makhijani, A., and Hisham Zerriffi, *Dangerous Thermonuclear Quest: The Potential of Explosive Fusion Research for the Development of Pure Fusion Weapons*, Institute for Energy and Environmental Research, Takoma Park, July 1998.

Makhijani, A., and Scott Saleska, *The Nuclear Power Deception - U.S. Nuclear Mythology from Electricity "Too Cheap to Meter" to "Inherently Safe" Reactors*, Apex Press, New York, 1999.

Makhijani, A., "Stepping Back from the Nuclear Cliff," *The Progressive* 63, no. 8 (August 1999),

Makhijani, A., Bernd Franke, and Hisham Zerriffi, *Preliminary Partial Dose Estimates from the Processing of Nuclear Materials at Three Plants during the 1940s and 1950s*, Institute for Energy and Environmental Research, Takoma Park, September 2000. (Prepared under contract to the newspaper *USA Today*.)

Makhijani, A., and Bernd Franke, *Final Report of the Institute for Energy and Environmental Research on the Second Clean Air Act Audit of Los Alamos National Laboratory by the Independent Technical Audit Team*, Institute for Energy and Environmental Research, Takoma Park, December 13, 2000.

Makhijani, A., *Plutonium End Game: Managing Global Stocks of Separated Weapons-Usable Commercial and Surplus Nuclear Weapons Plutonium*, Institute for Energy and Environmental Research, Takoma Park, January 2001.

Makhijani, A., Hisham Zerriffi, and Annie Makhijani, "Magical Thinking: Another Go at Transmutation," *Bulletin of the Atomic Scientists*, March/April 2001.

Makhijani, A., *Ecology and Genetics: An Essay on the Nature of Life and the Problem of Genetic Engineering*. New York: Apex Press, 2001.

Makhijani, A., "Burden of Proof," *Bulletin of the Atomic Scientists*, July/August 2001.

Makhijani, A., "Reflections on September 11, 2001," in Kamla Bhasin, Smitu Kothari, and Bindia Thapar, eds., *Voices of Sanity: Reaching Out for Peace*, Lokayan, New Delhi, 2001, pp. 59-64.

Makhijani, A., and Michele Boyd, *Poison in the Vadose Zone: An examination of the threats to the Snake River Plain aquifer from the Idaho National Engineering and Environmental Laboratory*, Institute for Energy and Environmental Research, Takoma Park, October 2001.

Makhijani, A., *Securing the Energy Future of the United States: Securing the Energy Future of the United States: Oil, Nuclear, and Electricity Vulnerabilities and a Post-September 11, 2001 Roadmap for Action*, Institute for Energy and Environmental Research, Takoma Park, November 2001.

Makhijani, A., and Sriram Gopal, *Setting Cleanup Standards to Protect Future Generations: The Scientific Basis of Subsistence Farmer Scenario and Its Application to the Estimation of Radionuclide Soil Action Levels (RSALs) for Rocky Flats*, Institute for Energy and Environmental Research, Takoma Park, December 2001.

Makhijani, A., "Some Factors in Assessing the Response to September 11, 2001," *Medicine and Global Survival*, International Physicians for the Prevention of Nuclear War, Cambridge, Mass., February 2002.

Makhijani, Annie, Linda Gunter, and A. Makhijani, *Cogema: Above the Law?: Concerns about the French Parent Company of a U.S. Corporation Set to Process Plutonium in South Carolina*.

A report prepared by Institute for Energy and Environmental Research and Safe Energy Communication Council. Takoma Park, MD, May 7, 2002.

Deller, N., A. Makhijani, and J. Burroughs, eds., *Rule of Power or Rule of Law? An Assessment of U.S. Policies and Actions Regarding Security-Related Treaties*, Apex Press, New York, 2003.

Makhijani, A., "Nuclear targeting: The first 60 years," *Bulletin of the Atomic Scientists*, May/June 2003.

Makhijani, A., "Strontium," *Chemical & Engineering News*, September 8, 2003.

Makhijani, A., and Nicole Deller, *NATO and Nuclear Disarmament: An Analysis of the Obligations of the NATO Allies of the United States under the Nuclear Non-Proliferation Treaty and the Comprehensive Test Ban Treaty*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 2003.

Makhijani, A., *Manifesto for Global Democracy: Two Essays on Imperialism and the Struggle for Freedom*, Apex Press, New York, 2004.

Makhijani, A., "Atomic Myths, Radioactive Realities: Why nuclear power is a poor way to meet energy needs," *Journal of Land, Resources, & Environmental Law* 24, no. 1 (2004): 61-72. Adapted from an oral presentation given on April 18, 2003, at the Eighth Annual Wallace Stegner Center Symposium titled "Nuclear West: Legacy and Future," held at the University of Utah S.J. Quinney College of Law."

Makhijani, A., and Michele Boyd, *Nuclear Dumps by the Riverside: Threats to the Savannah River from Radioactive Contamination at the Savannah River Site*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 2004.

Makhijani, A., and Brice Smith, *The Role of E.I. du Pont de Nemours and Company (Du Pont) and the General Electric Company in Plutonium Production and the Associated I-131 Emissions from the Hanford Works*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 30, 2004.

Makhijani, A., Peter Bickel, Aiyou Chen, and Brice Smith, *Cash Crop on the Wind Farm: A New Mexico Case Study of the Cost, Price, and Value of Wind-Generated Electricity*, Institute for Energy and Environmental Research, Takoma Park, Maryland, April 2004.

Makhijani, A., Lois Chalmers, and Brice Smith, *Uranium Enrichment: Just Plain Facts to Fuel an Informed Debate on Nuclear Proliferation and Nuclear Power*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 15, 2004.

Makhijani, A., and Brice Smith, *Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES*, Institute for Energy and Environmental Research, Takoma Park, Maryland, November 24, 2004.

Makhijani, A., project director, *Examen critique du programme de recherche de l'ANDRA pour déterminer l'aptitude du site de Bure au confinement géologique des déchets à haute activité et à vie longue: Rapport final*, prepared for the Comité Local d'Information et de Suivi du Laboratoire de Bure (CLIS); coordinator: Annie Makhijani; authors: Detlef Appel, Jaak Daemen, George Danko, Yuri Dublyansky, Rod Ewing, Gerhard Jentzsch, Horst Letz, Arjun Makhijani, Institute for Energy and Environmental Research, Takoma Park, Maryland, December 2004.

Institute for Energy and Environmental Research, *Lower Bound for Cesium-137 Releases from the Sodium Burn Pit at the Santa Susana Field Laboratory*, IEER, Takoma Park, Maryland, January 13, 2005. (Authored by A. Makhijani and Brice Smith.)

Institute for Energy and Environmental Research, *Iodine-131 Releases from the July 1959 Accident at the Atomics International Sodium Reactor Experiment*, IEER, Takoma Park, Maryland, January 13, 2005. (Authored by A. Makhijani and Brice Smith.)

Makhijani, A., and Brice Smith. *Update to Costs and Risks of Management and Disposal of Depleted Uranium from the National Enrichment Facility Proposed to be Built in Lea County New Mexico by LES*. Institute for Energy and Environmental Research, Takoma Park, Maryland, July 5, 2005.

Makhijani, A., "A Readiness to Harm: The Health Effects of Nuclear Weapons Complexes," *Arms Control Today* 35 (July/August 2005).

Makhijani, A., *Bad to the Bone: Analysis of the Federal Maximum Contaminant Levels for Plutonium-239 and Other Alpha-Emitting Transuranic Radionuclides in Drinking Water*, Institute for Energy and Environmental Research, Takoma Park, Maryland, August 2005.

Makhijani, A., and Brice Smith, *Dangerous Discrepancies: Missing Weapons Plutonium in Los Alamos National Laboratory Waste Accounts*, Institute for Energy and Environmental Research, Takoma Park, Maryland, April 21, 2006.

Makhijani, Annie, and A. Makhijani, *Low-Carbon Diet without Nukes in France: An Energy Technology and Policy Case Study on Simultaneous Reduction of Climate Change and Proliferation Risks*, Institute for Energy and Environmental Research, Takoma Park, Maryland, May 4, 2006.

Makhijani, Annie, and A. Makhijani. *Shifting Radioactivity Risks: A Case Study of the K-65 Silos and Silo 3 Remediation and Waste Management at the Fernald Nuclear Weapons Site*, Institute for Energy and Environmental Research, Takoma Park, Maryland, August 2006.

Smith, Brice, and A. Makhijani, "Nuclear is Not the Way," *Wilson Quarterly*.30 (Autumn 2006): 64.

Makhijani, A., Brice Smith, and Michael C. Thorne, *Science for the Vulnerable: Setting Radiation and Multiple Exposure Environmental Health Standards to Protect Those Most at Risk*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 19, 2006.

Makhijani, A., *Carbon-Free and Nuclear Free: A Roadmap for U.S. Energy Policy*, IEER Press, Takoma Park, Maryland; RDR Books, Muskegon, Michigan, 2007.

Makhijani, A., *Assessing Nuclear Plant Capital Costs for the Two Proposed NRG Reactors at the South Texas Project Site*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 24, 2008.

Makhijani, A., *Energy Efficiency Potential: San Antonio's Bright Energy Future*, Institute for Energy and Environmental Research, Takoma Park, Maryland, October 9, 2008.

Makhijani, A., *The Use of Reference Man in Radiation Protection Standards and Guidance with Recommendations for Change*, Institute for Energy and Environmental Research, Takoma Park, Maryland, December 2008.

Makhijani, A., *Comments of the Institute for Energy and Environmental Research on the U.S. Nuclear Regulatory Commission's Proposed Waste Confidence Rule Update and Proposed Rule Regarding Environmental Impacts of Temporary Spent Fuel Storage*, Institute for Energy and Environmental Research, Takoma Park, Maryland, February 6, 2009.

Makhijani, A., *Technical and Economic Feasibility of a Carbon-Free and Nuclear-Free Energy System in the United States*, Institute for Energy and Environmental Research, Takoma Park, Maryland, March 4, 2009.

Fundación Ideas para el Progreso, *A New Energy Model For Spain: Recommendations for a Sustainable Future* (originally: *Un nuevo modelo energético para España: Recomendaciones para un futuro sostenible*), by the Working Group of Foundation Ideas for Progress on Energy and Climate Change, Fundación Ideas, Madrid, May 20, 2009. Arjun Makhijani contributed Section 2.2. The cost of nuclear energy and the problem of waste.

IEER Comments on the Nuclear Regulatory Commission's Rulemaking Regarding the "Safe Disposal of Unique Waste Streams Including Significant Quantities of Depleted Uranium," Institute for Energy and Environmental Research, Takoma Park, Maryland, October 30, 2009.

Makhijani, A., "The Never-Ending Story: Nuclear Fallout in the Marshall Islands, a book review," *Nonproliferation Review* 17, no. 1 (March 2010):197-204.

Makhijani, A., "Detailed Comments on *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington (TC & WM EIS)* (DOE/EIS-0391), EIS October 2009," March 18, 2010, appears as Attachment 3 IN Harry Smiskin (Yakama Tribal Council). Letter dated March 19, 2010, transmitting the comments of the Confederated Tribes and Bands of the Yakama Nation on the *Draft Tank Closure and Waste Management Environmental Impact Statement* (Draft TC & WM EIS) for the Hanford Site, Richland, Washington (DOE/EIS-0391-D) to David A. Brockman (Richland Operations Office, U.S. Department of Energy) and Mary Beth Burandt (Office of River Protection, U.S. Department of Energy).

Makhijani, A., *The Mythology and Messy Reality of Nuclear Fuel Reprocessing*, Institute for Energy and Environmental Research, Takoma Park, Maryland, April 8, 2010.

Makhijani, A., "Civil Liability for Nuclear Claims Bill, 2010: Is Life Cheap in India?" *The Hindu*. June 21, 2010

Ferguson, Charles D., Lindsey E. Marburger, J. Doayne Farmer, and A. Makhijani, "A US nuclear future?" *Nature* 467 (23 September 2010): 391-393. "Comment."

Makhijani, A., eUtah: A Renewable Energy Roadmap, HEAL Utah, Salt Lake City, December 14, 2010.

Richardson, Bill, with Gay Dillingham, Charles Streeper, and A. Makhijani, "Universal Transparency: A Goal for the U.S. at the 2012 Nuclear Security Summit," *Arms Control Today* 41 (January/February 2011): 8-13.

Makhijani, A., OPINION: Spent nuclear fuel pools vulnerable to terrorist attacks: *Kyodo News*, March 21, 2011. In Japanese and English.

Makhijani, A., project director, *Examen Critique du Programme de l'Andra sur les Recherches Effectuées dans le Laboratoire Souterrain de Bure et sur la Zone de Transposition Pour Définir une ZIRA: Rapport Final*, prepared for the Comité Local d'Information et de Suivi du Laboratoire de Bure (CLIS); coordinator: Annie Makhijani; authors: Jaak Daemen, George Danko, Gerhard Jentzsch, Elena Kalinina, Arjun Makhijani, et Krishan Wahi. Institute for Energy and Environmental Research, Takoma Park, Maryland, 9 mars 2011, avec corrections 20 avril 2011.

Makhijani, A., *IEER's Comments on Unique Waste Streams Rulemaking (10 CFR Part 61) - including Depleted Uranium Disposal*. Institute for Energy and Environmental Research, Takoma Park, Maryland, June 18, 2011. Addressed to the Nuclear Regulatory Commission.

A. Makhkhijan, "Comments of the Institute for Energy and Environmental Research on the Department of Energy's *Draft Environmental Impact Statement for the Disposal of Greater-Than-Class C (GTCC) Low-Level Radioactive Waste and GTCC-Like Waste* (DOE/EIS-0375-D), published in February 2011." (9 June 2011). Included as Attachment 3 to the Yakama Nation Comments on DOE's Greater-Than-Class C Waste Draft EIS (DOE/EIS-0375-D), June 27, 2011.

Makhijani, A., *Institute for Energy and Environmental Research (IEER) Comments on Docket ID NRC-2010-0267: NRC "Draft Regulatory Basis for a Potential Rulemaking on Spent Nuclear Fuel Reprocessing Facilities"*. Institute for Energy and Environmental Research, Takoma Park, Maryland, 7 July 2011.

Makhijani, A., "IEER's Preliminary review of the NRC's July 12, 2011, Recommendations for Enhancing Reactor Safety in the 21st Century: The Near-Term Task Force Review of Insights from the Fukushima Dai-ichi Accident. U.S. Nuclear Regulatory Commission, July 12, 2011" Prepared for Friends of the Earth. Institute for Energy and Environmental Research, Takoma Park, Maryland, July 19, 2011.

Makhijani, A., Comments on the July 29, 2011, *Draft Report to the Secretary of Energy*, of the Blue Ribbon Commission on America's Nuclear Future (BRC) Prepared by the Institute for Energy and Environmental Research (IEER) on behalf of the Yakama Nation, 30 September 2011. Conveyed to the Blue Ribbon Commission on October 11, 2011.

Makhijani, A., *Comments of the Institute for Energy and Environmental Research on the Nuclear Regulatory Commission's Draft Policy Statement on Volume Reduction and Low-Level Radioactive Waste Management (76 FR 50500 (August 15, 2011))*. Institute for Energy and Environmental Research, Takoma Park, Maryland, October 14, 2011.

Makhijani, A., and Yves Marignac, *Sûreté Nucléaire en France Post-Fukushima : Analyse critique des Évaluations complémentaires de sûreté (ECS) menées sur les installations nucléaires françaises après Fukushima*. (Forthcoming February 2012)

CV updated February 16, 2012