"The cost of nuclear electricity: France after Fukushima"

(November 2013)

Discussant's Report, 12 February 2014

Because of problems with English in this paper, I have a few misunderstandings that I'd like to clear up:

(1) The "Projected Cost of Electricity Generation" is a joint report between the International Energy Agency and the Nuclear Energy Agency, both of which are agencies in the Organization for Economic Cooperation and Development, OECD. The NEA has taken the lead in producing the next edition, which will be published in 2015.

(2) Cooper (2011) was never published in a peer-reviewed journal (p. 1). Mark Cooper has a PhD in sociology and has participated in many anti-nuclear intervener law suits. See http://www.vermontlaw.edu/academics/environmental_law_center/institutes_and_initiatives/overview/institute_staff.htm The regime change in US nuclear regulation started with the passage of the National Environmental Policy Act of 1969 requiring an Environmental Impact Statement for all facilities regulated by the US Government. Also, the Nuclear Regulatory Commission began operation in 1975. After the accident at Three Mile Island on March 28, 1979, there was a limit on licensing nuclear facilities until the publication of the TMI Action Plan in July 2002. There have been "regime changes" in the nuclear power industry throughout its history. Cost escalation increased after 1969 due to changing regulations and intervener law suits.

(3) The accident at Chernobyl on April 26, 1986, took place in a Water-Cooled, Graphite Reactor, RBMK. This was a specific technology for the dual purpose of generating electricity and producing plutonium. The N-Reactor in Richland, Washington, was of the same technology and was retired soon after the Chernobyl accident. The Soviets produced other technologies included pressurized water reactors (VVERs) and fast-reactors. They have just loaded fuel into their most recent fast reactor and are building VVERs in many countries. Therefore, the statement, "soviet technology (as well as management) was dangerous and is therefore not worthy of study" (p. 1 of the reprint) is both arrogant and naïve.

*(4) The concept of "negative learning by doing" (p. 2) is not useful unless used in the context of forgetting how to do something, see, for example, Roland Sturm, "Nuclear power in Eastern Europe: Learning or forgetting curves?" *Energy Economics* 15(3): 183-189 (July 1993). The term is always used in association with a measure of learning, e.g., cumulative output. Recently, it has been used repeatedly in the nuclear power economics literature, but it has nothing to do with "learning," as such, and is associated with cumulative output. **A new theory is required.**

(5) In France and in many countries, nuclear power plants are built in pairs. This is because of scale economies associated with site preparation, site security, and transmission. In construction accounting common costs are generally assigned to the first unit (because in some rate-of-return regimes, plant investment cannot enter the rate base until the plant is "used and useful;" so plant-site common costs can enter the rate base with the first unit). Therefore, there is nothing artificial about bundling of reactors by pairs. What is artificial is to assign costs such that "we (*sic*) split the mother plant cost between two child reactors in proportion to the construction time of each." (p. 2) Concrete for the second reactor can be poured by the same crew that has poured the base mat for the first plant, thus construction can start for the second plant near the time of the start of the first plant, but commercial operation can happen much later than for the first plant because, over time, the duration for each stage of construction accumulates.

*(6) There were over 130 commercial nuclear power plants built in the US from the 1950s to the 1990s. There were several different technologies, several reactor vendors, several architect-engineers, and several utilities with different requirements operating under several regulatory regimes leading to several dissimilar reactors. The statement, "This cost containment contrasts with the US where 100 similar reactors were built at prices growing at 19% every year." (p. 2) **is false**.

*(7) The statement "We (*sic*) thus come to the conclusion that the low capacity factor has a technical or organizational origin that EDF has not been able to solve for decades (and is therefore unlikely

to improve upon in the future)" (p. 4) assumes that the author knows more about running nuclear power plants in a disconnected European electricity market than EDF. The European electricity market is in formation and will not be complete until transmission capacity is expanded. Because of the subsidization of intermittent renewables, there has been a surge of investment in Germany and Spain. These renewables rely on French nuclear power for back-up. As the European electricity network becomes more integrated, and subsidies are discontinued, the Germans and Spanish will be glad that there have been nuclear reserves in France. Therefore, **it is unfair** of the author to conclude that nuclear power plants in France will not improve in the future.

(8) Fuel fabrication is a separate step in the front-end of the fuel cycle. Therefore, it should not be excluded from fuel accounting as is done on page 5. Further, there is only one recycling of used fuel because recycling MOX has not proved commercially viable. Used MOX is being held for future fast reactors. Therefore, it is possible to calculate the costs of France's closed system, which is incomplete in Section 5.2.

(9) It is beyond the scope of this discussion to disentangle the costs of Operation and Maintenance in Section 5.3, but it is unlikely to follow the IEA/NEA/OECD levelized cost methodology. It appears that many charges that are beyond the busbar (central services, taxes, research, and "the many perks enjoyed by employees") are not accounted in other analyses of nuclear power O&M costs. Therefore, I doubt that the following statement is correct: "Even in the absence of the special Fukushima charge, O&M weights almost 10bn€ each year, thrice the cost of fuel. This is unusually large when compared to international studies." (p. 5)

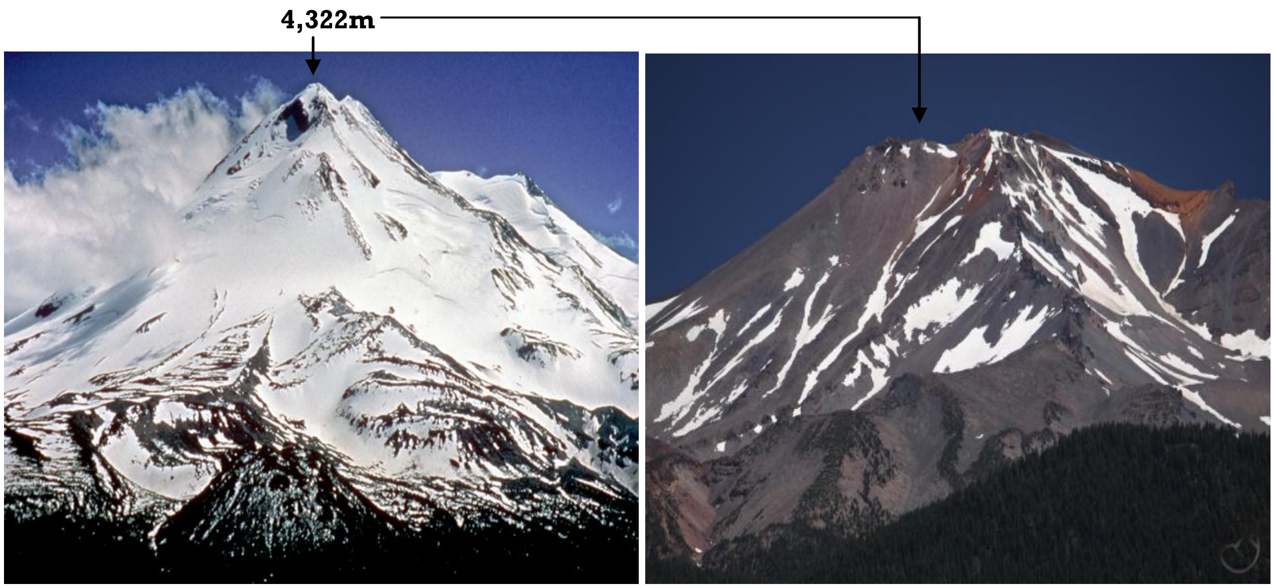
*(10) In normal parlance the "Back-end cycle" refers exclusively to the "back-end of the fuel cycle," not to decommissioning, including decontamination and dismantlement. The author, while identifying the standardization of the French nuclear power plants, then ignores this standardization when considering their decommissioning. EDF will be decommissioning their standardized reactors in a systematic way when the time comes. This is why their estimates are so much lower than in Belgium (with 3 power plants), Japan with several types of power plants, Germany with several power plant owners, the UK with gas-graphite reactors, and the US with little standardization (p. 6). All these countries are facing much higher decommissioning costs.

*(11) "Lastly, an oft forgotten item is the non-irradiated fuel inside the reactor at shutdown. The disposal of these 'last cores' is expected to cost 3.8 bn€ thereby raising the dismantling bill to at least 24 bn€." (p. 6) What is a "non-irradiated" core? If there it is "non-irradiated," it could be used in another reactor. **Such statements question the credibility of the entire paper.**

*(12) "Lastly, the long-term management of radioactive waste, i.e., deep geological disposal is a highly uncertain undertaking since none has been constructed yet on earth." (p. 6) I suggest that readers google the Waste Isolation Pilot Project (WIPP) in Loving, New Mexico, to see what an earth-based geologic repository looks like. Or go to http://energy.gov/em/waste-isolation-pilot-plant Or, to see what it looks like, go to the following site (which if you zoom all the way out will show that it is actually on Earth). Or, check out yesterday's *New York Times*:
https://maps.google.co.uk/maps?q=Waste+Isolation+Pilot+Project&safe=strict&ie=UTF-8&ei=zt74UvmFIOW70wWTm4AY&ved=0CAoQ_AUoAg
http://www.nytimes.com/2014/02/10/science/earth/nuclear-waste-solution-seen-in-desert-salt-beds.html

*(13) Consider the contradiction in the statement, "the Senate (2012) recommends to add an additional 4 bn€ yearly insurance premium to cover damages up to 100 bn€ in the case of a major accident. The proposed insured amount is the economic damage of hurricane Katrina." (p. 6) Hurricane Katrina is the tip of the climate change iceberg. Climate change is happening now. Its probability is 100%. Consider the 500-year drought now happening in the state of California. On the right (below) is the picture of Mt Shasta as I remember it driving between the Bay Area and Seattle from 1978 to 2013. On the left is what it looks like today (or at least last November when I drove by it). The question is not "What is the **price** of carbon," but "What is the **cost** of gashouse gases, including carbon dioxide?" Hurricane Katrina happened. There is only a possibility of an accident at a nuclear power plant in France. Therefore, if the cost of a hypothetical accident is going to be included in the levelized cost of nuclear power, then the cost of climate change must

be included in the cost of fossil fuels, as discussed later in the present paper. Note, the Price-Anderson Act is composed primarily of a "retrospective" premium to be paid after an accident.



*(14) "We (*sic*) have also decided to count the full cost of the first generation [gas-graphite] reactors (6 bn€) treating them as a training for the nascent French nuclear power industry. After adding the dismantlement cost of these early reactors, we (*sic*) arrive at a grand total of 77 bn€ as shown in Table 5. The development cost is spread uniformly over the cumulative nuclear power output from 1968 to 2010." (p.7) However, given "plants have on average 15 more years of operation" (ft. 21), there are many more TWh coming from the fleet and the author should have amortized the grand total over the historic and anticipated output of the current fleet.

*(15) In "Section 5.7 *Summary*" of current levelized costs, "The 'worst case' scenario then uses future cost that is twice greater and a 10% discount rate to reflect the switch to an investor owned business." (p. 7) But (1) the arguments that the future costs are twice as great as previous estimates is fallacious, as shown above, and (2) there hasn't been a switch to investor-owned utilities in France, so there is no basis in reality for the author's so-called "worst case" scenario.

(16) "We (*sic*) leave aside the development cost that has been carried by French tax payers over six decades and set an improved commercial availability (aka CF) rate at 85%." (p. 8) There is a common misunderstanding in this literature that the availability factor is the same as the capacity factor. The capacity factor is the percentage of achieved output divided up the potential output. The availability factor is the percentage time that the plant is available to produce electricity. The difference is the "service factor," see Rothwell, "Utilization and Service: Decomposing Nuclear Reactor Capacity Factors," *Resources and Energy* 12: 215-229 (1990). Further, because of uprates in thermal power at nuclear power plants in the US and because the "size" of the plant has not been increased, some US plants are running over a 100% capacity factor. This has led to another set of misunderstandings about the productivity of US nuclear power plants, e.g., that deregulation has increased productivity. See http://www.world-nuclear-news.org/C-Regulator-approves-US-plant-uprates-1102147.html

*(17) Compare the two sequential sentences on page 8: "This may be the reason why some NGOs are now pursuing a novel opposition strategy, namely emphasizing the cost of building nuclear power plants (at least in developed countries). To conclude, our projection reveals that the issue with nuclear power today remains its most basic economic characteristic, capital cost." It appears that either the author is following anti-nuclear NGOs in focusing on the high capital cost of building nuclear power plants, or that the NGOs are following the author's focus on identifying high nuclear power plant construction costs.

(18) Regarding subsidies to the nuclear power industry, "The Energy Information Administration (EIA) has reported on this topic for the years 1992, 1999, 2007, and 2010. On average, the nuclear sector received 1.6 bn$ per year, so that a minimum of 32 bn$ of subsidies should be assigned to the period 1991-2010. Repeating the previous calculation over the longer period, we (*sic*) find that the development cost is better amortized at 9.5$/MWh instead of 23 $/MWh." (p. 8) First, there are no EIA publications cited in the references with these publication dates in which these so-called subsidies can be found. Second, there is no discussion of what these subsidies subsidize. Third, the range is so large that no credible information can be obtained.

(19) "The capital cost escalation that the literature has previously identified is thus accompanied by an operational cost overrun probably engendered by the absence of cost cutting incentives in the US regulatory compact." (p. 9) This logic flies in the face of all fact. During the 1980s, the regulatory compact was changed with the introduction of incentive regulation (see Rothwell and Che, "Performance-Based Pricing for Nuclear Power Plants," *The Energy Journal*, 1995). During this time, capacity factors increased from about 70% to 85%. During the 1990s, the regulatory compact was again changed with the deregulation of electricity markets. O&M costs declined with the consolidation of nuclear electric utilities. The reason why O&M costs are a higher proportion of total costs is because the cost of capital is sunk (not subject to annual inflation) and O&M costs are on-going (subject to annual inflation increases). Hence, it appears that even with the capital cost escalation, nuclear power was a good bet in the US.

(20) "Fuel cost the same [*sic*] while the US back-end cycle is unrealistically low since firm's provisioning was devised at least a decade ago and did not take into account the novel security requirements that have appeared since then." (p. 9) I have no idea what this means.

*(21) "Natural gas is a flexible source with limited carbon emission but not a baseload technology." (p. 9) This is non-sense. Natural gas is methane, CH_4. When burned with oxygen it produces tons of CO_2 (although only one half of that of coal: 469g/kWh). Further, CH_4 is a greenhouse gas, 20 times more potent than CO_2 for 100 years in the atmosphere. It is a myth perpetrated by the oil and gas industry that natural gas is naturally clean. It is not. Both CO_2 and CH_4 are deadly and are killing the life on this planet. Also, **carbon capture and storage is a myth**. It has not proven to be commercially feasible in any country. It will not be considered in the next "Projected Costs of Electricity Generation."

*(22) "We (*sic*) thus pit wind against nuclear in purely economic terms, neglecting other important dimensions, such as scalability, intermittency, security of supply, environmental impact, social impact or nuclear proliferation… The comparison between these two electricity generating technologies in the US is even clearer since the wind resource is better and the nuclear economics look worse, once we (*sic*) account for future liabilities." (p. 10) Once you forget about all the problems associated with wind and all the subsidies given to wind producers (in Germany, Spain, and the US, in particular), of course, wind might be "better," but you can't run an electricity grid on intermittent resources and maintain access to the Internet while charging your smart phones, watching TV, warming up your dinner in the microwave, and running a heat pump heating or cooling your space.

If you are trying to reduce greenhouse gases, <u>the inconvenient truth</u> is that you need nuclear for base load until electricity storage becomes available.