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The economics of new nuclear power plants in liberalized electricity markets

Pedro Linares [a,b,c,*], Adela Conchado [a]

[a] U. Pontificia Comillas, Instituto de Investigación Tecnológica, C/Alberto Aguilera 23, 28015 Madrid, Spain
[b] Economics for Energy, Spain
[c] MR-CBG, Harvard Kennedy School, United States

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ABSTRACT

Even after Fukushima, the nuclear debate is strong in many countries, with the discussion of its economics being a significant part of it. However, most of the estimates are based on a levelized-cost methodology, which presents several shortcomings, particularly when applied to liberalized electricity markets. Our paper provides results based on a different methodology, by which we determine the break-even investment cost for nuclear power plants to be competitive with other electricity generation technologies. Our results show that the cost competitiveness of nuclear power plants is questionable, and that public support of some sort would be needed if new nuclear power plants are to be built in liberalized markets.

1. Introduction

The nuclear industry has been riding a roller coaster lately. After much talk of a "renaissance", both in popular (e.g. Crumley, 2009) and academic sources (Nuttall, 2009; Nuttall and Taylor, 2009), the accident at Fukushima triggered a backlash that has resulted in proposed phase-outs in Germany or Switzerland, and even talks about them in nuclear-heavy France. Davis (2012) concluded recently that the prospects for nuclear power plants in the US were quite bleak.

However, as Joskow and Parsons (2012) point out in their review of the nuclear prospects after Fukushima, although a full-blown "renaissance" was probably not realistic (particularly in developed countries), the accident's effects will likely be modest at a global level. Indeed, Steven Chu, the former US Secretary of Energy, declared recently that "I think nuclear power is going to be a very important factor in getting us to a low carbon future". The recent European Energy Roadmap 2050 (EC, 2011a, 2011b) also considers that nuclear power plants will be needed to achieve the ambitious decarbonization targets imposed. Even Japan seems to be reconsidering their decision to phase-out nuclear power plants after Fukushima. Most recently, the UK has cleared one of the last administrative hurdles for building a new nuclear power plant in Hinckley Point.

This possible renaissance for nuclear power plants is fueled basically by two arguments: one, its relatively low carbon emissions[1]; and second, its higher security of supply and lower price volatility compared to fossil fuel alternatives.[2] These have been joined recently by an additional one, cost. Although cost has usually been considered to be one of the four "problems" of nuclear power plants, together with safety, proliferation, and waste (e.g. MIT, 2003), some studies recently put nuclear power plants as a competitive alternative for electricity generation, particularly when introducing a price for carbon emissions (e.g. Joskow and Parsons, 2009; Nicholson et al., 2011). This has prompted some to formulate the nuclear debate as a trade-off question: either we have nuclear, or we must pay more for our electricity. In turn, others argue that nuclear electricity needs some kind of support by governments (e.g. Newbery, 2010).

We find this discussion about costs very relevant for energy policies worldwide: if nuclear energy is required for achieving a low carbon future, or for having more stable electricity prices, we should ascertain whether this will take place spontaneously, that is, if firms will invest in new nuclear plants just out of its cost competitiveness; or if we rather need some degree of public support — and, in this case, if this support is justified or not.

Therefore, a careful analysis of the cost of new nuclear power plants, and of its comparison with other electricity generation alternatives seems more than warranted. However, most of the studies looking at the costs of nuclear power do so by using a levelized-cost methodology, which in turn depends critically on assumptions of investment cost,

* Corresponding author. Universidad Pontificia Comillas. Alberto Aguilera 23, 28015 Madrid, Spain.
E-mail addresses: pedro.linares@upcomillas.es (P. Linares), adela.conchado@iit.upcomillas.es (A. Conchado).

[1] See Sovacool (2008) or Beerten et al. (2009) for surveys of lifecycle assessments of greenhouse gas emissions for nuclear power plants.

[2] These arguments do not seem to have had much impact on improving public acceptance of nuclear power plants, at least in the UK, where a recent study found that "concern about climate change and energy security will only increase acceptance of nuclear power under limited circumstances — specifically once other (preferred) options have been exhausted" (Corner et al., 2011).

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and is also of limited application for deregulated markets (which are currently the standard in Europe and also in many states in the US).

The objective of this paper is to try to contribute to a better understanding of the cost competitiveness of new nuclear power plants in liberalized electricity markets, by using an improved methodology to undertake the analysis. Our results can be read in two ways: from a private perspective, if nuclear power is competitive in a purely monetary basis; and also, if deemed appropriate due to other reasons, if it will require economic support from governments for private companies to invest. Section 2 presents a review of some of the current studies and discusses their shortcomings. Section 3 describes the methodology, data used in the paper, and the results obtained. Finally, Section 4 offers some conclusions and recommendations.

We would like to make clear before going on that we acknowledge that a nuclear policy should not only take into account economic costs: all advantages and disadvantages of nuclear power plants should also be considered to make a final decision: whether to allow new investments or forbid them, whether to penalize nuclear power plants or support them. In order to do that a full cost-benefit analysis or at least a quantification of the externalities to be considered should be carried out — see e.g. Kennedy (2007) as an example of this approach. However, we believe that the discussion of monetary costs is rich enough as to focus just on it in this paper.

2. Assessing the costs of nuclear power

As mentioned before, most of the studies looking at the cost of new nuclear power plants are based on a levelized-cost (LEC) methodology. Koomey and Hultman (2007) offer a fine example of this approach, as well as a review of previous studies. Rothwell (2004) also discusses the fundamentals of the costs of nuclear. The most relevant and updated study may be the update of the MIT report "The future of nuclear" (Du and Parsons, 2009). Other up-to-date study worth citing is Cooper (2009). The LEC methodology has become very popular, since it provides a single indicator of the competitiveness of the different electricity generation technologies. However, it also has several shortcomings, particularly for liberalized markets, which we discuss below.

First, it is critically dependent on the assumption of investment cost. Of total costs for nuclear electricity, approximately 70% come from investment cost (20% from O&M costs, and 10% from fuel). However, as Joskow and Parsons (2009) correctly point out, the lack of reliable contemporary data for the actual construction costs of real nuclear plants make very uncertain any estimate of future construction – and therefore electricity generation – costs. Indeed, some of the studies pointing to cost competitiveness for nuclear were based on the MIT (2003) figure of $1500/kW, which was not a real construction cost but just a target to be attained. Therefore, it would be better to use a method that does not require assuming an investment cost ex-ante.

Another critical assumption in LEC studies is the number of hours of operation for the different technologies. Since investment costs are distributed among all operating hours to calculate the final cost of generating electricity, the more hours a plant is assumed to operate, the cheaper it will be. However, the number of hours a plant operates also depends on its cost, and therefore this becomes endogenous to the problem. Although this is not usually a critical issue for nuclear[3] – since nuclear plants usually provide baseload power, and therefore run continuously –, it is for marginal units such as gas combined cycles or coal power plants, that is, the alternatives against which nuclear should be compared.

Another endogeneity issue is the correlation between fuel prices, carbon prices, and electricity prices — more salient in liberalized markets. The competitiveness of power plants will depend not only on their costs, but also on their income. And this income will be basically the electricity market price, which is in turn determined by the cost of the marginal unit.[4] Since these are usually gas or coal power plants, the price will be determined by gas, coal, and carbon allowance prices. Again, this affects differently baseload technologies – nuclear – and marginal technologies — coal or gas.

These two latter problems are further complicated by the general inability of LEC methodologies to account for different electricity load levels (and therefore different prices and operating hours). Joskow (2011) has already pointed out this problem for renewables, although the argument can easily be extended to other non-baseload technologies such as natural gas: it is not only how many hours a plant operates, but which hours.

We also mentioned before that the LEC methodology is not well suited for liberalized electricity markets. First, in these markets cost recovery is not guaranteed, and new, cheaper technologies may easily displace existing investments before the end of their expected lifetime (Linares and Isoard, 2001), therefore reducing their cost competitiveness. Second, the LEC methodology does not handle well the risks underlying liberalized electricity markets (Kessides, 2010). Real options approaches have been developed (Roques et al., 2006; Rothwell, 2006) to address, at least partially, these concerns. Unfortunately, these methods also suffer from similar shortcomings regarding the assumptions to be made about costs and operating hours.

Finally, LEC studies only take into account costs, but not the volume of new investment in an electricity market: other constraints coming from energy policy (renewable energy promotion, for example), the shape of the load curve (with no requirements for new baseload power) or the extension of the license of existing power plants – as has been the case for over half of US nuclear plants (Davis, 2012) – may not allow for new investments in nuclear plants.

Therefore, we believe that the analysis of the cost competitiveness of new nuclear power plants would be improved by using a different methodology such as the one presented in this paper. This method assesses the cost competitiveness of new nuclear power plants by inquiring whether there would be any spontaneous (that is, based on cost competitiveness alone) investments in the electricity system studied, and which should be the investment cost required to allow for these investments to take place.

To do that, we simulate the behavior of the electricity market in the long term, with a generation-expansion model. The model optimizes investment and operation decisions for the power system until 2054, based on the existing fleet, and on the expected demand growth, investment costs, fuel prices, and technical constraints. The model also includes a representation of carbon and renewable energy support policies (although it considers RES production as deterministic, not stochastic). It has a large level of load block detail. Although the model allows for representing oligopolistic conditions, for this exercise we have run it as a cost-minimization, linear version due to the computational constraints. A full description of the model can be found in (Linares et al., 2008a), or can be requested from the authors.

We leave the investment cost for nuclear power plants as a decision variable, and iterate until we find the break-even investment cost, that is, the investment costs that makes it profitable to build new nuclear power plants.

This allows us to solve most of the problems related to LEC: we do not have to assume ex-ante any investment cost for nuclear or operating hours for all technologies, since these are outputs of the model; we account not only for costs, but also for income, since the price of the electricity market is endogenously determined by the model — even considering the effect of market power, since the model allows for

[3] This clearly changes in a system with a large penetration of intermittent renewables. In this case, nuclear power plants must regulate production to accomodate the variable production of renewables, and therefore will reduce the number of hours it operates according to the amount of renewables in the system.

[4] We are assuming here a uniform pricing auction. However, although less common, liberalized markets might also be organized around a pay-as-bid scheme, in which this connection between income and marginal unit bid is removed or at least mitigated.