Fukushima's Challenge: Is a Low Carbon Economy Without Nuclear Power a Realistic Goal? Insights from Spain

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Introduction: Energy for the Future Post-Fukushima

Our industrial civilization runs on energy and 85% of the world's energy is provided by fossil fuels; coal, oil and gas. However, at the present rate of consumption fossil fuels are estimated to be exhausted by about 2050 to 2100. Coal is the greatest contributor to global warming and renewable generation is currently incapable of supplying the energy required to sustain economic growth. Thus, despite the fact that renewable sources are important, they must be complemented by nuclear power in order to fulfill the energy needs of a growing low-carbon industrial civilization.

The recent disaster at the Fukushima nuclear plant has put new challenges for energy policy on the table. First, it may force governments to adopt a clear position in the ongoing nuclear energy debate. Second, environmental concerns make governments rethink the current energy mix, from a fossil-non renewable configuration to an alternative low carbon emissions scenario. Hence, Post-Fukushima energy policy design has to deal with the trade-off between environmental requirements and reinforced social pressures against nuclear power. The problem is not inconsequential: a substantial reduction in CO_2 emissions due to a significant decrease in the use of fossil sources must be covered by parallel increments in alternative sources of energy inputs. These alternatives are renewable energy sources and nuclear power.

There are at least two main reasons that advocate against a short term nuclear shutdown. First, there are a number of nuclear power plants at the beginning of their useful life cycle. Thus, a suppression of these would cause income losses due to non recovered investment projects. This fact may provoke higher prices in the short term in order to minimize the impact of closing nuclear plants. Moreover, firms involved in closing programs are in a better position to demand government compensation in the form of subsidies. In the medium and long term, by substituting nuclear power plants, firms must involve themselves in new research projects and investment in alternative technologies. This is costly and the availability of new GW is not immediate. Therefore, we think that a short-term scenario without nuclear generation is unrealistic because it would seriously harm the system's reliability and create a misallocation of financial resources to compensate for the capacity expansion of new sources.

Nuclear Energy, the Environment, and the Electricity Sector

The debate covers not just nuclear energy but also the alternatives to fossil fuels and renewable sources. An option arising from such a debate might be that governments should invest in safer nuclear energy power plants and continuously support the development of renewable technologies. Whilst there is no opposition to renewable investments, it is unfortunately the case that the nuclear industry has had a bad safety reputation. Not all of this reputation has been deserved.

The overwhelming majority of nuclear reactors have functioned safely and effectively for their entire lifetimes. Today over 400 nuclear reactors provide base-load electric power in 30 countries. There have been only three serious accidents in the commercial exploitation of nuclear power: Three Mile Island (TMI) in 1979 (in Pennsylvania, USA), Chernobyl in 1986 (in the Soviet Union, now the Ukraine), and more recently Fukushima in 2011 (in Japan, after an earthquake). However, the fact that these fatal disasters occurred in the civilian nuclear power industry within fifty years is less than those that have occurred in any year in the fossil fuel industries.

Despite these accidents, nuclear power is relatively clean, safe, reliable, compact, competitive and practically inexhaustible.[1] Nuclear reactors provide base-load power and are available over 90% of the time. The cost of nuclear power is competitive and stable. Moreover, uranium is found everywhere in the crust of the earth. A nuclear power station is very compact, typically occupying the area of a football stadium and its surrounding parking lots. Solar cells, wind turbine farms and growing biomass, all require large areas of land.

The global electricity supply sector accounts for the release into the atmosphere of over 8000 million tons of carbon dioxide annually, this being 37.5% of total CO_2 emissions. The electricity sector is likely to become a prime target in any future world where $C0_2$ emission controls are implemented and $C0_2$ mitigation is valued. In order to meet this challenge we must adopt the following mea-

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See footnotes at end of text.

sures,

1. As suppression of fossil sources is almost impossible in the mid term, we may mitigate its effects on the environment by,
   a. Increasing efficiency conversion: the current world average efficiency is 30% but new technologies lay claim to 60% in under two decades.
   b. Moving to low carbon fossil sources emissions.
   c. Carbon dioxide sequestration and decarbonisation.
2. Increase of proven and alternative sources, mainly,
   a. To promote the use of nuclear power under safety standards,
   b. Entering renewable sources by using technological advances.

Nuclear Generation in the Spanish Electricity Sector

Spain, as an EU Member State is committed to the EU target of a sustainable energy system to avoid climate change. The *Europe 2020 Strategy* includes headline targets to be effective by 2020. Concerning energy and climate change it includes a reduction of greenhouse gas emissions of 20%, increasing the share of renewables in the energy mix to 20%, and achieving the 20% energy efficiency target by 2020. Two of these three targets have been met but energy efficiency will not be met unless further efforts are made.

Powe Plant Name	Starting Year of Operation	Power (MW)
Sta.María de Garoña	1971	466
Almaraz I	1981	977
Ascó I	1983	1032
Almaraz II	1983	980
Cofrentes	1984	1092
Ascó II	1985	1027
Vandellós II	1987	1087
Trillo	1988	1066

Table 1. Nuclear Plants in Spain
Source: Ministry of Industry, and own construction.

Nuclear generation has traditionally played a key role in Spain to meet base load demand. There are six nuclear plants under operation. These eight light-water reactors have a total installed capacity of 7728 MW. Table 1 summarizes the power and starting year of operation of each plant.

Table 2 also shows the evolution of GWh produced by each type of resource from 2002 to 2010 to highlight the main power sources in electricity generation and to show to what extent it may determine the near future. In particular, the table shows the role that nuclear generation plays in the electricity mix and the eventual effect that its drastic reduction or even suppression would cause in the current Spanish electricity mix.

From Table 2, it is clear that Spain has a rather diversified technology mix that is made up of conventional thermal generation (nuclear, coal-burning, oil-fired, cogeneration and combined cycle plants) as well as renewable energy generation (mainly hydroelectric and windmills). However, there is a significant dependence on fossil fuel imports. The table shows an increase of wind and solar from less than 13000 GW/h to almost 50000 GW/h. Small hydro remains between 3000 and 4000 GW/h.

	----------Special Regime----------					----Ordinary Regime----			
Year	Wind	Solar	Small Hydro	Cogeneration	RSR	Large Hydro	Nuclear	Conventional	Total
2002	9,257	-	3,901	18,290	4,749	22,599	63,016	100,550	213,144
2003	11,720	-	5,091	18,995	6,336	38,874	61,875	95,267	229,265
2004	15,753	-	4,752	19,269	7,126	29,777	63,606	113,029	243,631
2005	20,520	-	3,820	18,808	8,623	19,169	57,539	136,291	253,884
2006	22,736	107	4,148	16,782	8,410	25,330	60,126	135,417	262,204
2007	27,221	495	4,126	17,715	8,697	26,352	55,102	142,369	271,636
2008	31,393	2,547	4,638	21,191	9,096	21,428	58,973	139,939	278,301
2009	35,424	5,429	4,188	17,548	1,120	23,236	52,765	116,461	251,305
2010	42,656	6,910				38,001	61,944	89,132	259,940

Table 2. Generation by Technology (GWh)

The investment path shows that most of it has been directed towards renewables generation and combined cycle plants.

In this context, nuclear power emerges as an alternative to cover the expected decrease in thermal generation, coal burning and oil-fired. Thus, it appears that the electricity mix might be dominated by nuclear power and renewable technologies. However, the share of each source largely depends on technology improvements and the regulatory framework. Eventually, transitory demand shocks should be covered by efficient cogeneration plants and large hydro.

Figure 1(a) plots the share of total capacity that comes from nuclear, renewable and thermal technologies, and part (1b) on the right represents the effective generation. Note that the nuclear share of total generation capacity has been declining over the past few years. There are two reasons; the lack of investment in new generation and the orientation of new investments towards renewable and combined cycle.[2]

The question is the impact on electricity prices. If the mix is based only on fossil fuels and renewables, avoiding nuclear, then there are potential price booms, as further increases in demand must be covered by fossils whose prices are more volatile. Alternatively, if the system is based on nuclear power and

renewable sources, prices are expected to be more stable in the medium and long term.

In Spain, the electricity market is organized into two segments: the Day-ahead market and the futures and bilateral contracts market. The existence of a futures and bilateral contracts market aims to alleviate the potential for market power abuse in the Day-ahead market, provided the former and the latter markets are not highly concentrated.

In the Day-ahead market there is a diversified composition of generation mix, which varies over time in relation to weather conditions and the relative prices of natural gas and coal, thus affecting the order of dispatch. It can be observed that there has been a significant increase in wind production and a corresponding reduction in gas combined cycle and an almost constant level of coal generation. In this segment, the contribution of nuclear generation is low. Since concentration is low most of the renewable generation comes from smaller agents.

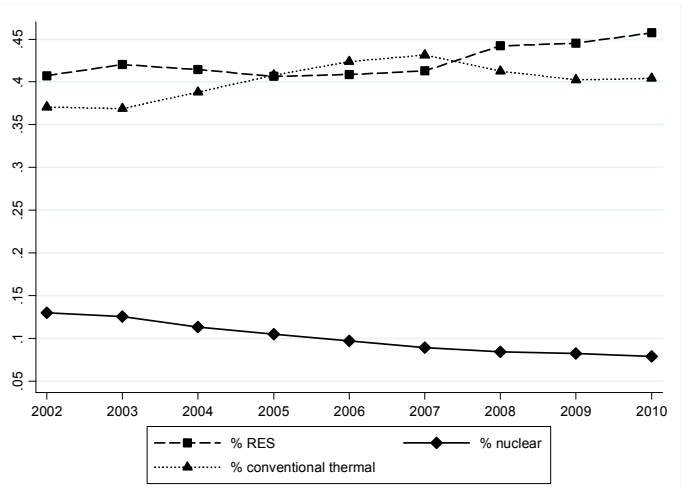

Figure 1(a)

In the futures and bilateral contracts market nuclear and coal technologies provide, on average, 80 percent of the total. Most of the nuclear and coal plants are under the ownership of the two largest generators, thus concentration is high.

The effect on competition of having a highly concentrated futures and bilateral contracts market and a low concentration in the Day-ahead market is not clear. As a result, the investment decisions on either type of technology determine the evolution of prices. It can be shown that there are diverging trends. On the one hand, fossil generation is declining in the technology mix. On the other hand, renewable sources are strongly increasing. The generation share of nuclear power and renewable sources is larger than the share of installed capacity. This is the result of a combination of technical advantages and a regulatory policy desire to enter first in the order of merit. The fact that nuclear power plants are used to meet base load demand is the main reason why, although the capacity share is currently below 10 percent, the share from total generation is clearly above 20 percent. Note from Figure 1b that conventional thermal is more volatile in terms of share of generation. A closer look at the daily pattern of production indicates that this is the case. The result is that prices are more stable. Thus, if the target is stable, competitive prices, the generation mix should be a system based on nuclear and renewable sources, together with combined cycle generation to meet unexpected shifts in demand.

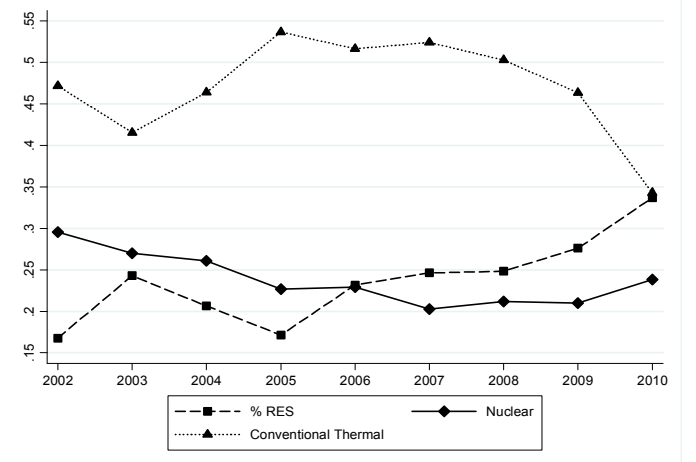

Figure 1(b)

An open issue is the subsidies to nuclear and renewables. These mean that price does not reflect real market conditions. Finally, the subsidy invoice must be covered by final consumers so electricity may be more expensive in the future unless technological improvements are offsetting. This applies to both subsidies to invest in nuclear and subsidies to enter renewable sources.

Conclusions

The needs of our industrial civilization and the growing needs of developing nations yield a rapid accumulation of atmospheric CO_2. Nuclear power is relatively safe, capable of ensuring the continuation of our industrial civilization and protecting the environment. It is a source of energy that can replace a significant part of the fossil fuels (coal, oil and gas) which massively contribute to the greenhouse gas effect. In addition, we must promote the more efficient use of renewable energies – wind and solar – wherever possible. Hence, nuclear power should be deployed together with renewable technologies to replace coal, oil and gas in industrial and developing countries. The Spanish electricity mix tends to be dominated by a mixture of a renewables and nuclear power to cover the bulk of primary electricity needs. However this system is insufficient to cover demand peaks. In these cases, it is necessary to increase generation with more efficient processes that use fossil sources in order to preserve price stability over time.

(See page 37 for footnotes and references)