The economics of nuclear energy. What is true and what is false in the Italian debate.

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The problem of climate change has now reached top priority, and with it the necessity of moving towards a 'low carbon society' has become urgent. It therefore doesn't come as a surprise that the re-launching of nuclear energy in Italy is declared to be based on the pursuit of this target (low carbon society). In addition, it is also asserted that it will reduce the households' energy bill. While the first motivation may be true, to a certain extent, the second one is totally unconvincing. Taking *facts* into account we aim to underline which among the most common arguments in the debate have a sound basis, and which have not.

To address these issues costs must be analyzed, starting with the production costs of a MWh from different sources. As a reference point we can take the figures published by the European Commission in 2008, as they provide current costs in 2007, projected costs for 2020 and 2030, and also GHG emissions per source. Knowledge of GHG (or CO_2eq) emissions is a precondition, but not the only one, for calculating the true costs of electricity production for the society.

Figure 1

Energy source	Power generation technology		Production Cost of Electricity (COE): State-of-the-art 2007	Projection for 2020	Projection for 2030	Net efficiency 2007	Lifecycle GHG emissions: Direct (stack) emissions	Indirect emissions	Lifecycle emissions	Fuel price sensitivity
			$€_{2005}$/MWh	$€_{2005}$/MWh	$€_{2005}$/MWh		kg CO_2/MWh	kg CO_2(eq)/MWh	kg CO_2(eq)/MWh	
Natural gas	Open Cycle Gas Turbine (GT)	-	65 ÷ 75 [(b)]	90 ÷ 95 [(b)]	90 ÷ 100 [(b)]	38%	530	110	640	Very high
	Combined Cycle Gas Turbine (CCGT)	-	50 ÷ 60	65 ÷ 75	70 ÷ 80	58%	350	70	420	Very high
		CCS	n/a	85 ÷ 95	80 ÷ 90	49% [(c)]	60	85	145	Very high
Oil	Internal Combustion Diesel Engine	-	100 ÷ 125 [(b)]	140 ÷ 165 [(b)]	140 ÷ 160 [(b)]	45%	595	95	690	Very high
	Combined Cycle Oil-fired Turbine (CC)	-	95 ÷ 105 [(b)]	125 ÷ 135 [(b)]	125 ÷ 135 [(b)]	53%	505	80	585	Very high
Coal	Pulverised Coal Combustion (PCC)	-	40 ÷ 50	65 ÷ 80	65 ÷ 80	47%	725	95	820	Medium
		CCS	n/a	80 ÷ 105	75 ÷ 100	35% [(c)]	145	125	270	Medium
	Circulating Fluidised Bed Combustion (CFBC)	-	45 ÷ 55	75 ÷ 85	75 ÷ 85	40%	850	110	960	Medium
	Integrated Gasification Combined Cycle (IGCC)	-	45 ÷ 55	70 ÷ 80	70 ÷ 80	45%	755	100	855	Medium
		CCS	n/a	75 ÷ 90	65 ÷ 85	35% [(c)]	145	125	270	Medium
Nuclear	Nuclear fission	-	50 ÷ 85	45 ÷ 80	45 ÷ 80	35%	0	15	15	Low
Biomass	Solid biomass	-	80 ÷ 195	85 ÷ 200	85 ÷ 205	24% ÷ 29%	6	15 ÷ 36	21 ÷ 42	Medium
	Biogas	-	55 ÷ 215	50 ÷ 200	50 ÷ 190	31% ÷ 34%	5	1 ÷ 240	6 ÷ 245	Medium
Wind	On-shore farm	-	75 ÷ 110	55 ÷ 90	50 ÷ 85	-	0	11	11	nil
	Off-shore farm	-	85 ÷ 140	65 ÷ 115	50 ÷ 95	-	0	14	14	
Hydro	Large	-	35 ÷ 145	30 ÷ 140	30 ÷ 130	-	0	6	6	nil
	Small	-	60 ÷ 185	55 ÷ 160	50 ÷ 145	-	0	6	6	
Solar	Photovoltaic	-	520 ÷ 880	270 ÷ 460	170 ÷ 300	-	0	45	45	nil
	Concentrating Solar Power (CSP)	-	170 ÷ 250 [(d)]	110 ÷ 160 [(d)]	100 ÷ 140 [(d)]	-	120 [(d)]	15	135 [(d)]	Low

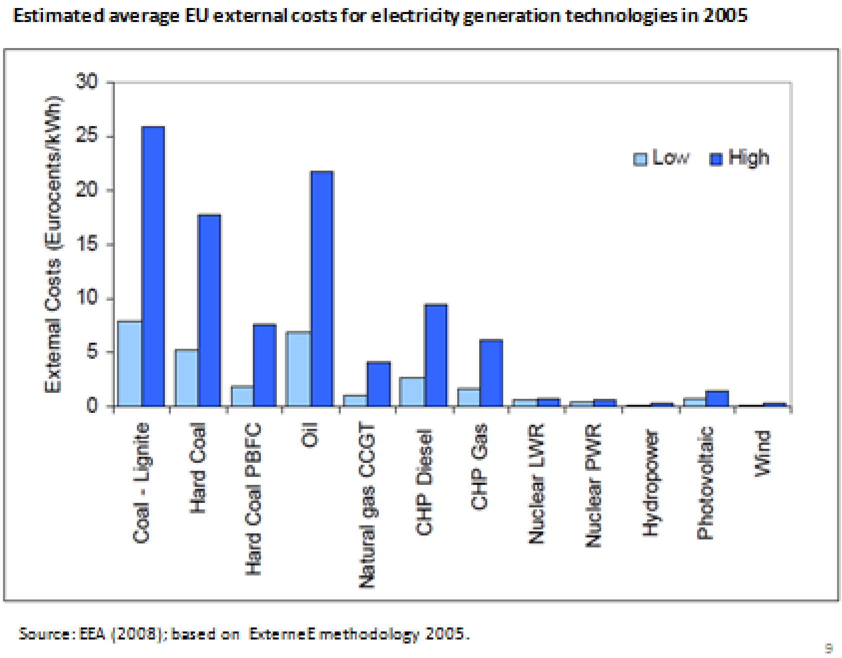
[(a)] *Assuming fuel prices as in 'European Energy and Transport: Trends to 2030 - Update 2007' (barrel of oil 54.5$_{2005}$ in 2007, 61$_{2005}$ in 2020 and 63$_{2005}$ in 2030)*
[(b)] *Calculated assuming base load operation*
[(c)] *Reported efficiencies for carbon capture plants refer to first-of-a-kind demonstration installations that start operating in 2015*
[(d)] *Assuming the use of natural gas for backup heat production*

Source: Commission of the European Communities, (2008), *Commission Staff Working Document. Second Strategic Energy Review. An EU Energy Security and Solidarity Action Plan. Energy Sources, Production Costs and Performance of Technologies for Power Generation, Heating and Transport*, COM(2008) 781 final.
(GHG: greenhouse gases; MWh: mega watt per hour; CO_{2eq}: CO_2 equivalente)

As a matter of fact it is the external costs to the power plant that are responsible for climate change and that therefore call for an international/global commitment to a low carbon society.

To estimate these external effects is no easy task, but again the problem has been addressed and we now have several such evaluations. Among the most well-received and internationally accepted methodologies we find 'ExternE', which is the product of a research project launched by the European Commission in 1990. By using the ExternE methodology the European Environment Agency has produced the following estimates in 2008. On a first reading of these facts (**figures 1** and **2**) one may get the impression that nuclear energy is a rather low cost source and, even more important, that it is practically the best in terms of negative externalities, i.e. of CO_2 emissions, both with respect to the older LWR technology and to the newer PWR one.

Figure 2



Source : European Environmental Agency (2008), 'EN35 External costs of electricity production', available on http://www.eea.europa.eu/data-and-maps/indicators/en35-external-costs-of-electricity-production-1

Moreover it has been argued that the reduction in the Italian costs of electricity production (such costs are incidentally higher than the European average) would be substantial, around 20% according to ENEL (based on undisclosed sources).

We shall now read these facts less superficially and in reverse order, beginning with the asserted 20% reduction in production costs. Actually, according to a more transparent, though rough, estimation by Alberto Clò[1], costs' reduction would vary in a range from 2% to 5%. The social benefits may be quite lower but still positive. The problem is then to investigate who benefits from the cost reduction: the producers or the consumers. To answer this question the structure of the market has to be considered. One may expect consumers to gain if competitive conditions prevail while the less competitive are the markets the greater will be

[1] Alberto Clo, *Si fa presto a dire nucleare*, Il Mulino, 2010.

the gains secured by producers. We will come to this later, but it is immediately clear that *costs' reduction does not coincide with tariffs' reduction* (the household bill) and therefore the current argument about consumers' benefits/gains is flawed because it is referred to costs' reduction. Furthermore, notwithstanding its neatness and transparency, the ExternaE methodology does not consider all the externalities due to energy production because it is concerned only with the impact of CO_{2eq} emissions. This is a serious shortcoming if we want to compare the 'true' social cost of energy production from several sources. In the case of nuclear energy the external effects to be evaluated are not CO_2 emissions (even if it is not totally carbon free because plants construction do produce CO_2), but the risk of accidents. Nuclear accidents are a very special type of risk-based events, in that their probability is very low but their damage is enormously high. As a matter of fact it is extremely difficult to evaluate such external costs, but giving the impression that nuclear energy comes with no externalities is a falsity. In theoretical terms the problem is as fascinating as it is difficult. It has an historical tradition in science and it also enjoys a revival. As recently as in 2009, Weitzman[2] has addressed the issue by providing an economic-statistical model of high-impact, low probability catastrophes. In empirical terms the difficulties are all there, but to go without any estimation cannot be justified on the basis of the practical difficulties of attempting quantification, when honest comparisons are at stake. One way of overcoming such difficulties might be to look for some reasonable proxy, which could be represented by an estimation of people's 'risk aversion'. This can be performed through a contingent valuation exercise that quantifies people's willingness to pay to avoid a negative external effect.[3] After all, when the building site of a nuclear power station (or of a waste disposal plant) is announced, people take to the streets to oppose it, thereby showing their preferences. Using questionnaires meant to evaluate people's WTP allows to translate such preferences into a monetary valuation. Once the risk of an accident is evaluated a more reasonable comparison will emerge. This means that **fig. 2** needs integration in order to deserve its name as a table showing estimated external costs. But also **fig.1** needs additional clarifications. The last column gives qualitative information in terms of sensitivity to fuel price. Once more, nuclear energy looks appealing because it has a much better performance than oil and gas and a better one than coal and biomass. But again, a less superficial reading of the table suggests the information of the last column to be either redundant or insufficient, since the price of raw materials, namely uranium, accounts just for 8% of total costs, and therefore its price variations cannot have a high impact[4]. What might have a non-negligible impact is a shortage in the industrial capacity required for its enrichment, since it is enriched uranium that enters

[2] Weitzman Martin L., 2009, 'On modeling and interpreting the economics of catastrophic climate change', *The Review of Economics and Statistics*, vol XCI, n. 1

[3] Longo, A., Markandya, A., Petrucci, M. (2008), 'The internalization of externalities in the production of electricity: Willingness to pay for the attributes of a policy for renewable energy', *Ecological Economics*, 67, 140-152.

[4] Although uranium price increases cannot have a great impact, uranium price does increase with the changing of market conditions. 'New' and increasing demand for it from China, India and Russia is causing production to be below requirements while at the same time a transition from an inventory-driven supply market to a production-driven one (mining) has taken place. Furthermore market production has become more concentrated. Economic conditions in the uranium market have undergone large and fast changes whose impact needs to be investigated. Just in 2009 Kazakhstan has become the largest exporter of uranium production with a share of 27%, followed by Canada with a 20% and Australia with 16%, *Uranium Market Outlook*, December 2010.

the reactor. But industrial capabilities, and the associated costs, for the enrichment of uranium do not enter the figures. What we want to draw attention to is the fact that energy production processes are so different from each other that a mere comparison of the type shown in **figure 1** and **2** can be misleading. In other words, the fact that nuclear energy does not create the same problems of fossil fuels, namely CO_2 emissions, does not mean that it is problem-free. And although, contrary to the geographic concentration of oil-fields, uranium ore deposits are diffuse, uranium needs conversion and enrichment processes whose capabilities may be concentrated in few countries. And indeed they are. Large commercial enrichment plants are in operation in France, Germany, the Netherlands, the UK, the USA and Russia, with only smaller capacity plants in other countries. Again, comparing oil-fields concentration to non-concentrated uranium deposits does not capture the essence of the problem: in terms of the vulnerability of importing countries, industrial capabilities for uranium enrichment may play a similar role to that played by specific oil supply sources.

Let us now turn to the construction costs of a nuclear plant and then to the market structure. Estimating the costs of construction of a nuclear plant is no easy task, mainly because they are very sensitive to the distinctive features of its location. It is therefore incorrect in principle to predict how much it will cost to build a nuclear plant in Italy on the basis of the available data pertaining to plants in existence or under construction in other countries. In other words, in order to figure out how much the building of a reactor of a given type and power will cost, its geographical location is a most important factor. Keeping this general warning in mind we discuss the figures that have been circulated, beginning with those circulated by ENEL. According to ENEL, building a 1700 MWh power plant would cost around 3-3 ½ billion €, while according to other international sources, such as E.ON, Florida Power & Light and Moody's , it would cost two or three times as much. And notice that Moody's estimates are likely to be more credible because, contrary to ENEL, it is not a candidate for construction. If we now look at the only new nuclear plant under construction in Europe, the Olkiluoto plant in Finland[5], we can compare such figures on paper with the ones emerging in practice and learn some important lessons. The Olkiluoto is an EPR (European Pressurized Reactor[6]) of 1600 MWh, with 60 years of service life, whose construction begun in 2005, after many years of debate, in the Baltic Sea island of the same name, and with 4 billion € production cost at its start. The French Areva is the company in charge of construction, and since it has built around 1/3 of all nuclear reactors in the world its expertise is not questionable. Nevertheless the costs have already reached 5 billion and a three years and a half delay in the construction timetable is acknowledged. Moreover Areva itself says that *today*'s cost of building such reactor is between 6 and 8 billion. With no need to enter into the specifics of the current disputes among the company, Finland's government and the financial partners, we can learn just from this experience that at the start costs are known very imprecisely, and that they are constantly increasing, at a substantial rate (approximately doubling in 5 years). A dynamics of constantly increasing construction costs combined with a long and delayed construction time emerge as

[5] In non democratic countries nuclear plants are under construction while where democracy prevails, specifically in Europe, Olkiluoto is the only example to look at. In France at Flamanville another reactor of EPR type (European Pressurized Reactor) is under construction since 2006, but it is not a completely new location.
[6] Third generation of Pressurized Water Reactor, PWR.

the typical features of nuclear industry. They must be kept in mind, and this is precisely what the market does. In fact, while in the general debate it seems easy to disregard these aspects and to talk only of the competitive nuclear energy production costs, *once the plant has been produced*, the market does incorporate the special construction costs' features, and is reluctant to enter the business, as shown by the USA experience, where in the last 20-30 years no completely new nuclear plants were built[7]. This fact casts doubts on the asserted competitiveness of nuclear energy. In a liberalized energy market, private capital would have flown in if investment had been profitable. According to the mentioned MIT study, 'nuclear power is much more costly than the coal and gas alternatives even in the high gas price cases,…(therefore), with current expectations about nuclear power plant construction costs, operating costs and regulatory uncertainty, it is extremely unlikely that nuclear power be the technology of choice for merchant plant investors'. An updating of the MIT Study by Du-Parsons[8] has found that construction costs would amount to the double of those calculated in 2003. Looking honestly at the particular features of nuclear industry it emerges that a long service life, between 40 to 60 years, *determines a low levelized unit cost of production but also requires such a huge investment and so much delayed returns as to discourage capital inflows*. We may conclude that the combination of a high capital intensity with the difficulties in reliably forcasting construction costs, which every country's experience shows to be generally increasing over the construction period, prevents investment to flow in. Not surprisingly president Obama enters the scene and guarantees loans in an attempt to attract investments. But this means that the structure of the energy market is affected. Government intervention in the form of guaranteed loans, or of a minimum level of tariffs, or of any other ones, will take the risk of investment away from producers and onto the taxpayers. Under such circumstances is hard to regard this market as a competitive one.

We are now in a position to take a closer look at Italy, adding some specific features of our national energy market to the general ones, and revolving around two main questions. We ask first whether we need more power plants to generate energy, and secondly whether we want to proceed with the liberalization of our energy market. The unpredicted economic crisis, started in 2008 and not at all over yet, had the inevitable effect of a fall on the demand for electricity. Just before the start of the crisis the demand was at 353 TWh against a production of 313 TWh, giving way to an import level of 40 TWh. Since then, while demand has not recuperated, new gas power plants have started operation (and other have started construction). In this situation it is completely reasonable to expect that in 2020, the reference year for most of the projections at the international and European level, we'll probably have *excess supply*. The demand has been projected to be at around 370 TWh[9] while the share of energy produced by renewable sources will need to be increased up to the level agreed within the European Union (99 TWh). In this optimistic scenario, as far as the demand for energy is concerned, there will be capacity underutilization, which implies higher and increasing unit

[7] MIT, *Study on the Future of Nuclear Power*, 2003, p.40.
[8] Yangbo Du- John E.Parsons, *Update on the Cost of Nuclear Power*, Center for Energy and Environmental Policy Research, CEEPR, May, 2009
[9] In projecting these figures TERNA specifies that the demand for energy will 'hopefully' reach such level in 2020.

costs of energy production. It is true that the decision to build new gas power plants was taken under the then internationally prevailing scenario of a projected doubling of the demand for energy in 2030, and that it therefore had its consistency. But that scenario has been proved to be unrealistic, having been constructed on the extrapolation of the growth rate of energy demand experienced in the past few years, with no prediction of a possible set back in the global economy, which instead started in 2008 and has not yet ended. Incidentally, the fact that the 2008 global crisis was completely left out of any prediction greatly weakens the reliability of the global energy market figures that have been circulated, since they do not account for the impact of the crisis on energy demand. A substantial revision of estimates is now necessary. Giving due weight to these facts, i.e. a sluggish demand for energy and an increasing power capacity (the new gas power plants produced and under construction) will lead to the conclusion that no large, if any, new investments in power plants are needed. Rather, what the Italian energy market does need is investment in the 'grid'. As is largely known, our grid is old and its leakages are above the average. New investments are necessary both to repair it, so to speak, and to modernize it. Moreover, if we consider the effort in terms of money and technology that the leading European countries are putting into the construction of a 'smart grid', the necessity of investing in our grid becomes indeed urgent. To participate from the start into the building of a smart grid will probably prevent from running into higher costs later, but also, and more important, it will not let our country lag behind in technology, because a smart grid incorporates a lot of it.

The second question is concerned with the structure of the energy market, namely with its liberalization process, which is still under way. It was started on the usual assumption that a competitive free market will bring about costs and price reductions, and although Italian households haven't yet seen this result, the hope is still there. The task ahead is to further liberalize the market and wait for the reduction in costs, which will necessarily follow since Italian costs are currently higher than the European average. Now, while the terms under which the 'renaissance' of nuclear energy in Italy will take place are not yet finalized, from what is apparent so far this renaissance will likely *reduce*, not increase, the still limited competition in the energy market. Three points are worth mentioning, representing three types of government intervention. The first is the Decree Law n. 31, 2010, which provides firms investing in nuclear power with financial and insurance protection against the risks of *delay* in plant construction and operation. The second provision comes in the form of nuclear producers being given *priority* in the dispatch to the grid, while the third one, still rather unclear, involves selling prices. This last provision seems to really go against any useful market function because the idea is to protect nuclear producers against changes in the demand for energy and also against price changes from other energy sources. Actually, the special features of nuclear industry do not seem to be compatible with a free competitive market, this being true not only in principle/theory but also in practice, as signalled by the US experience. Thus a decision has to be made, either to rely on a liberalized energy market, which will (probably) not lead to nuclear energy production, or to go for nuclear renaissance on political reasons, and therefore envisage government interventions aimed at making such renaissance possible, which would be limiting free competition in the energy market even further. In the latter scenario no reduction in tariffs (selling prices) can be expected because competition is not at work. Moreover, even if construction costs are mainly financed by the taxpayer, consumers of electricity are not going to gain because nuclear industry leads, for its very nature, to a monopolistic market which does not pass down (possible) cost reductions to selling prices. This is what the economic theory of monopolistic markets teaches us, and the fact that at the *global* level three companies (AREVA, WESTINGHOUSE, ROSACOM) are practically making up the whole nuclear market is the empirical confirmation of the functioning of nuclear industry.

In conclusion, if there are advantages for Italy in turning to nuclear energy, they are *not* on the economic side. The energy market liberalization process is not compatible with nuclear energy, costs reductions are not at all granted when the costs of production of a reactor are realistically accounted for (and we did not address the issue of the waste disposal costs because a specific study of the industrial processes involved would have been necessary), and, finally, our country *will be not less dependent from imports*, as suggested by another much repeated but equally false argument. The reason for this is not only the fact that we do not possess uranium (it may be considered of little importance because its price volatility would be practically irrelevant, as reported in the last column of **Fig.1**), but chiefly the fact that we do not possess the industrial capability for enriching it and will therefore continue to be dependent from a foreign equally concentrated market.

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