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On the Dynamics of Photovoltaics vs Nuclear power

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Abstract-In the last decade the dynamic development of Photovoltaics (PV) vs Nuclear was tremendously different. While PV starting at very low levels of installed capacity and high costs increased its capacities considerably and managed to bring down the costs remarkably with respect to nuclear the situation was vice versa: capacities stagnated and costs increased. In this paper we analyze the comparative dynamics especially of economics and try to identify the future prospects for capacity increases. An important role in this context play the discussion of upfront investments, construction times, interest rates and corresponding generation costs.

I. INTRODUCTION

Comparing the dynamic development of Photovoltaics (PV) vs Nuclear in the last two decades we find considerable differences with respect to capacities installed and costs. Regarding world-wide capacities of Nuclear we can see stagnation since about 1990 at a level of about 400 GW, see Fig. 1. Moreover, the recent political decisions in Germany even led to a capacity reduction. On the other hand, PV capacity is growing with growth rates of about 70%/year (in 2011) almost exponentially since the early 1990s reaching about 67 GW by the end of 2011 with no sign of a stop in this trend, see Fig. 2.

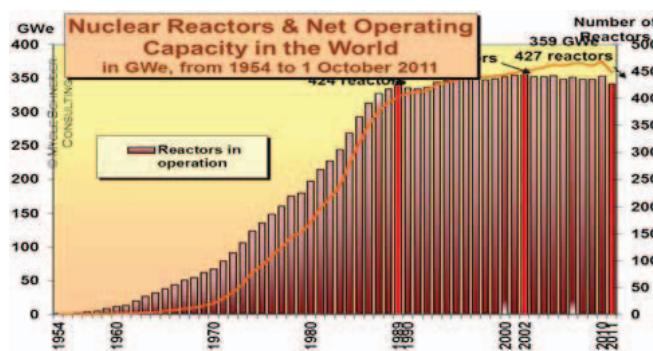


Fig. 1. World-wide installed cumulative nuclear capacity 1954 – 2011
(Source: BC CARE & FFU, Lutz Mez [2])

With respect to economics high generation costs of electricity generation from Photovoltaics (PV) are still today used broadly to argue against this technology. On contrary, discussing future prospects of electricity generation from nuclear power plants low costs are even today a major argument put in the discussion by its promoters. Yet, the dynamics in recent years and the situation today provides signs for a completely different picture looming. On the one

hand, with respect to nuclear power in the Western world in recent years no signs for constructing plants even close to cost-effectiveness has been shown. On the other hand, Photovoltaics is still more far away from being competitive in a wholesale electricity market. Yet, recent drops in costs – mainly in Germany – has led to system market prices which are at least close to the household electricity price – the major benchmark for a decentralized applied technology. In some papers the argument is raised that there is already even a historical cross-over now (2010) and solar electricity is cheaper than nuclear, see e.g. [1].

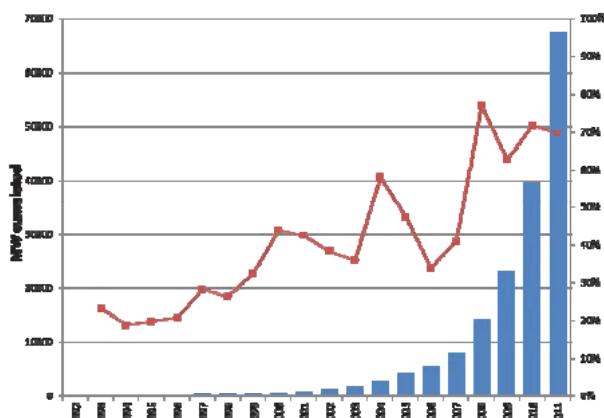


Fig. 2. World-wide installed cumulative capacity of PV plants
(Sources:IEA[6], IEA [7])

In this paper we analyze the comparative dynamics especially of economics and try to identify the future prospects for capacity increases. An important role in this context play the discussion of upfront investments, construction times, interest rates and corresponding generation costs. The core objective is to analyze past and compare recent cost developments for these two technologies with focus on Western Europe. Moreover, we investigate the likely future trend in capacity development. Regarding the costs we also consider the difference as nuclear as a central technology vs PV as a decentral one. Hence, the corresponding cost comparison has to be conducted on different levels of electricity use.

II. METHOD OF APPROACH

Our method of approach is based on dynamic historical cost comparisons of PV systems vs nuclear power plants. For

the analyses of historical developments we use Technological Learning rate analysis from the Literature. For the latter delays in construction times and corresponding increases in interest payments play a major role. We conduct comparisons with wholesale and household electricity prices. Finally we analyze possible future developments of capacities and electricity generation for PV and nuclear.

III. TECHNOLOGICAL LEARNING

The first issue we compare is historical Technological Learning. Fig. 3 depicts the basic principle of technological learning applied to PV. Until 2003 it followed clearly the expected Learning path. Then it deviated. Why? The reasons are explained in chapter. It is mainly because of temporally increases in demand for PV systems in Germany at that time (see also Fig. 8).

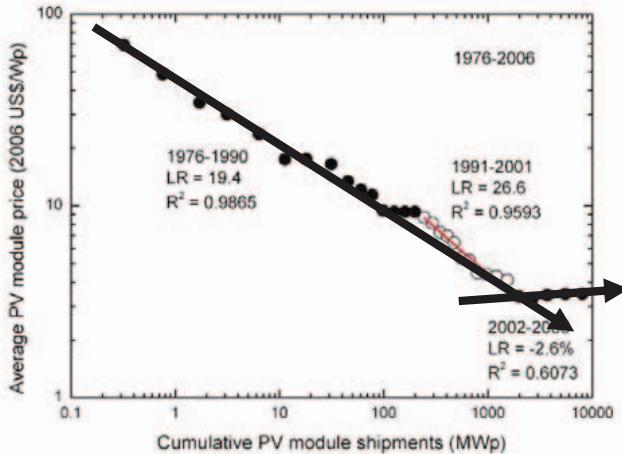
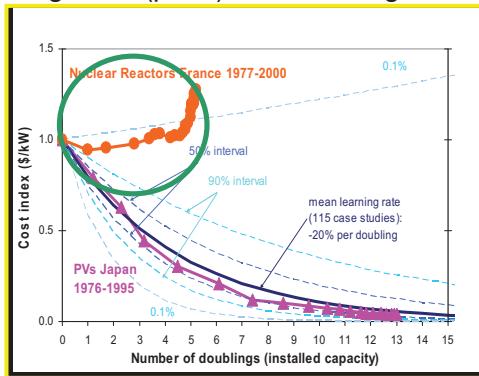


Fig. 3. The basic principle of TL applied to world-wide PV (Source: Yu [11])

Technological Uncertainties: Learning rates (push) and market growth (pull)



Source: Nakicenovic, Schratzenholzer, Grübler various papers

Fig. 4. Technological learning for various technologies: Nuclear is the only technology

With respect to “Learning” for nuclear the following is important: As Fig. 4 depicts nuclear was even the times of booming plant construction one of the few exceptions in the sense that additional capacities constructed did not lead to resulting cost reductions. The reasons are explained in Fig. 5,

see also [4] and [5]. They are that for the early plants no real costs were revealed. Costs were distorted by public subsidies, subsidies from industry (from the constructor of plant to get into the market) and of financing subsidies due to very favourable interest rates. In course of the time these subsidies were gradually removed and costs increased instead of following the classical Learning theory.

Technological learning: why not for nuclear?

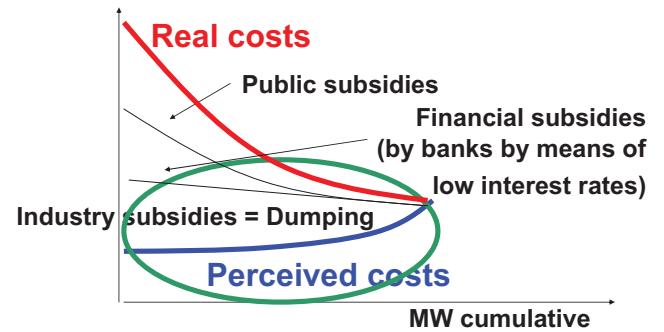
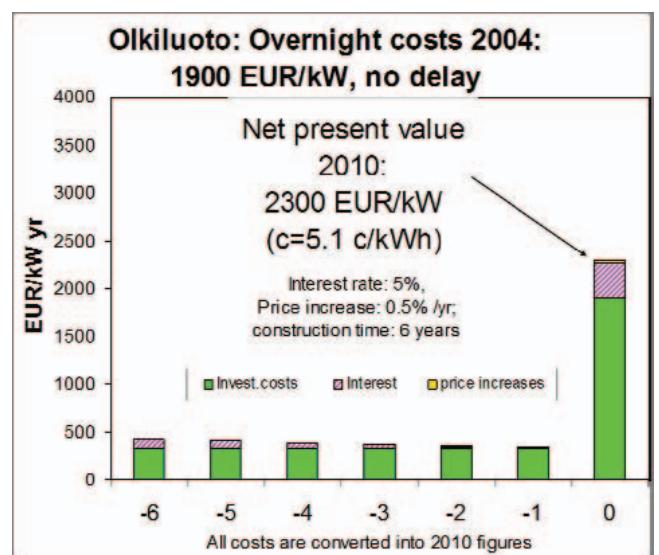


Fig. 5. Why technological learning did not take place for nuclear

IV. DYNAMICS OF NUCLEAR POWER

With respect to nuclear the major developments in recent years were the following. Fig. 6 depicts the principle of cost increases due to delays in construction times for the currently constructed nuclear power plant in Olkiluoto in Finland. We can see for the example of a delay in construction time of 4 years lead to a cost increase from 5.1 cent /kWh to 7.1 cent/kWh mainly due to the increases in interest costs.



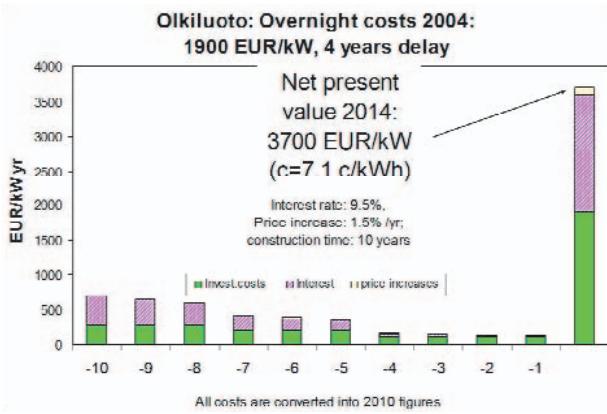


Fig. 6. Principle of cost increases due to delays in construction times for the nuclear power plant Olkiluoto in Finland: Initial expectations (in 2003) (upper picture) vs current (2012, lower picture) appraisal of generation costs

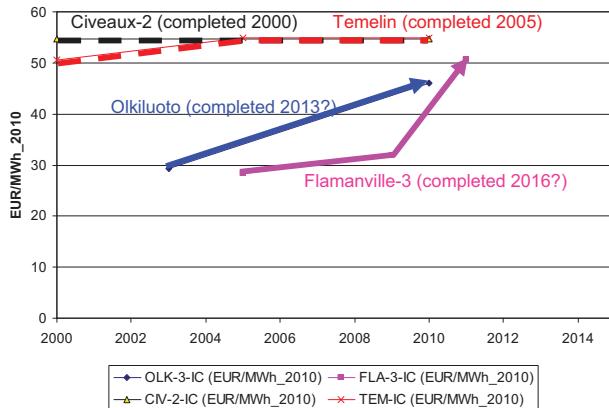


Fig. 7. Development of investment costs of European nuclear power plants between 2000 and 2011

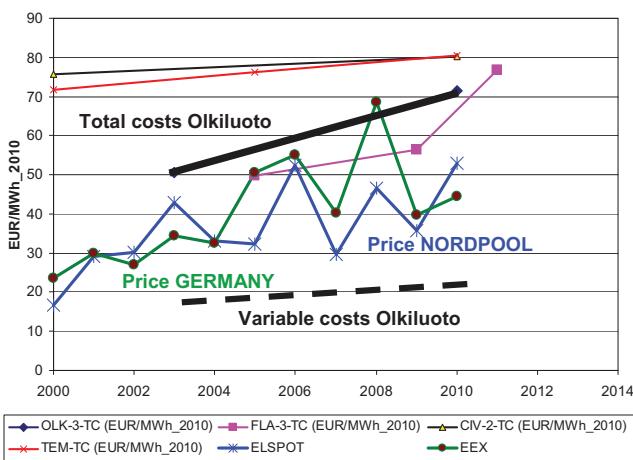


Fig. 8. Total costs developments of nuclear power plants vs European electricity market prices from 2000 to 2011

Fig. 7 shows the development of investment costs of

European nuclear power plants between 2000 and 2011. From the four reactors completed or under construction all are expected or has shown that investment costs per MWh are at least higher than 45 EUR/MWh. Fig. 8 shows the corresponding total costs of nuclear power plants vs European electricity market prices. We can see that nuclear based on the example of Olkiluoto – has been – based on full costs – never competitive in recent years – except the high price year 2008. Only if we compare the fuel costs of nuclear with electricity market prices nuclear can survive economically, see Fig. 8.

V. DYNAMICS OF PHOTOVOLTAICS

With respect to PV historically, the prices were influenced mainly by two countries: By Japan up to about 2005 and then by Germany afterwards, see [3], [8], [9], [10]. Fig. 9 shows the development of PV system costs and subsidies of small grid-connected PV systems in Japan.

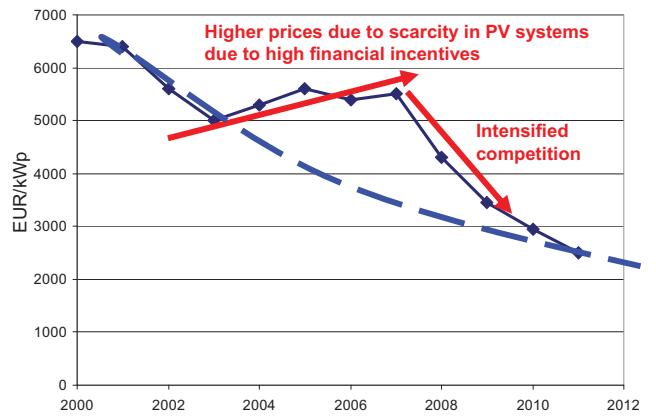


Fig. 9. Development of PV system costs in Germany from 2000 to 2011 (Figure for 2011 preliminary)

Between 2003 and 2005 the German government introduced a new FIT for PV. This tariff led to a considerable uptake of PV systems installed in Germany see Fig. 9. This introduction of higher support led temporarily to price increases which we suspect to be at least partly due to the scarcity in PV systems due to high financial incentives, especially from 2003 to 2007, see Fig. 6.

However intensified competition afterwards led to a rather steep decrease in recent years leading to a skyrocketing in capacities installed in Germany and some other countries. Fig. 10 depicts the development of Feed-in-tariffs (FITs), costs in major European countries 2005 - 2010 (historically) and provides a forecast up to 2012.

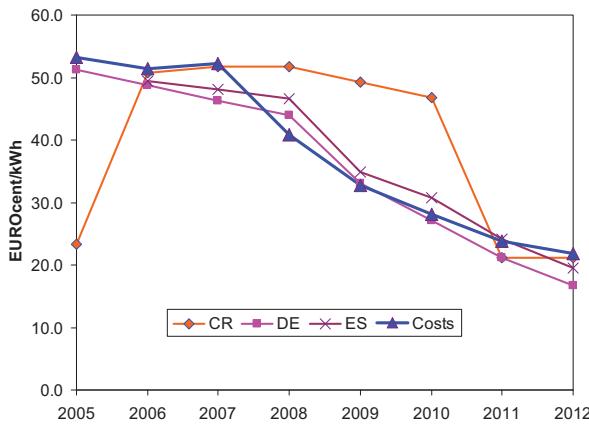


Fig. 10. Feed-in-tariffs (FITs) and costs in major European countries 2005 -2010 (historically) and 2011-2012 (forecast)

Fig. 11 depicts for Germany possible developments up to 2020 for small-scale (top) and large-scale (bottom) systems in an upper and a lower “corridor” depending on the capacity of systems installed. As can be seen from Fig. 11 where also household electricity prices are included for small-scale systems in the lower corridor scenario the so-called grid parity could already be brought about before 2015

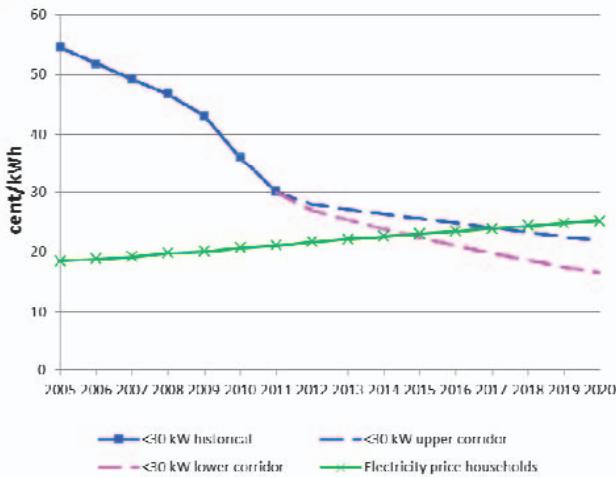


Fig. 11. Historical development of PV costs for small systems in Germany and expectations up to 2020 vs household electricity prices leading to “grid parity” between 2012 and 2018

So the situation for Germany can be considered rather promising for PV grid parity. The only reason why there might be some backlash would be if the market – which is still very sensitive – depending on imports from China and the effective financial support from government – collapses and system prices start to increase again as depicted in Fig- 9 for the past.

VI. FUTURE SCENARIOS

The currently looming future development of nuclear vs PV for the Western and Central European electricity market (AT, CH, DE, FR, PL, PT, ES, SL, CZ, SK, HU, IT) is

described in the following figures. Fig. 12 shows development of capacities. Without life-time extensions and if the German phase-out policy holds nuclear capacities will decrease from about 120 GW in 2010 to about 65 GW in 2030. Note that most important for the realization of this development is how the policy in France develops. In this scenario by 2030 more than two third of the remaining capacity is situated in France.

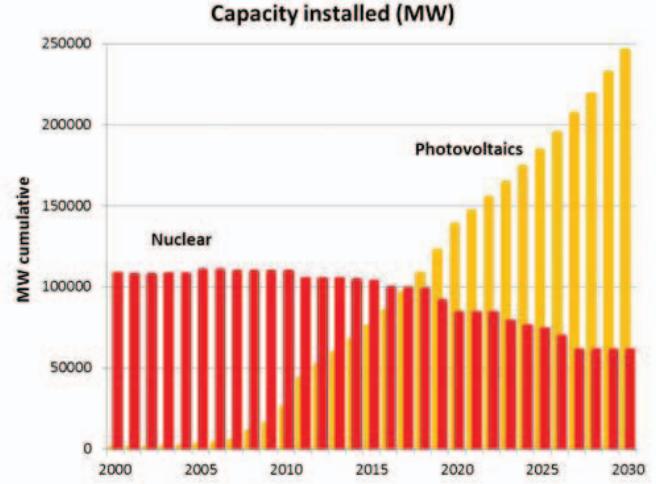


Fig. 12. Looming future development of nuclear vs PV capacities for the Western and Central European electricity market (Source: decommissioning report IAEA, PV scenarios of various German research institutes and German regulator)

In the same time period PV capacity is expected to increase from about 43 GW to about 250 GW. So by about 2018 PV might surpass Nuclear in terms of capacity. However, in terms of energy (TWh produced) it will take until the end of the 2020s until PV will produce similar quantities than the nuclear plants, see Fig. 13.

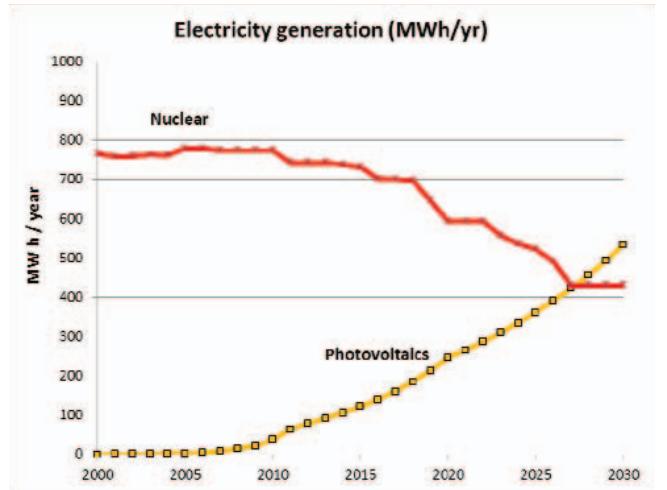


Fig. 13. Looming future development of electricity generation from nuclear vs PV capacities for the Western and Central European electricity market (Source: decommissioning report IAEA, PV scenarios of various German research institutes and German regulator)

VII. CONCLUSIONS

Regarding the economics of nuclear power plants in recent years in Western countries there is only one core perception: Actual prices has always been higher than announced and promised construction times have never been met. Hence regarding “cheap” nuclear power no evidence is provided and for the next years there are no signs of a reversal of the currently upward going cost trends.

With respect to Photovoltaics the opposite development can be observed. Since the early 1990s an almost continuous decrease in system costs took place with a steep plummeting in recent years.

Summing up, we state that currently, in 2011 nuclear is still cheaper than Photovoltaics on a wholesale market level, based on conventional investment cost analysis and interest rates. Yet there are three major features to consider: (i) trends in costs are significantly different; (ii) taking into account levels of use – e.g. using household electricity as benchmark for cost-effectiveness, the so-called “grid parity” – leads to much smaller differences in the economic performance; (iii) investment risk is clearly lower for PV systems given the fact that there are virtually no uncertainties in construction times and operation performance. This leads to the final conclusion that we can expect within the next five years that PV systems in many countries will deliver cheaper electricity for household customers than new nuclear plants will.

However, regarding the over-all quantities of electricity produced from PV compared to nuclear in Western Europe it will take some further years until at least the mid of the 2020s until quantities from PV will compete with those from nuclear. Of course, these developments hold only if the current policies prevail.

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