

Mycle Schneider: Nuclear Power in a Post-Fukushima World

*“Solar energy is democratic.
Nuclear energy is anti-democratic by nature.”*

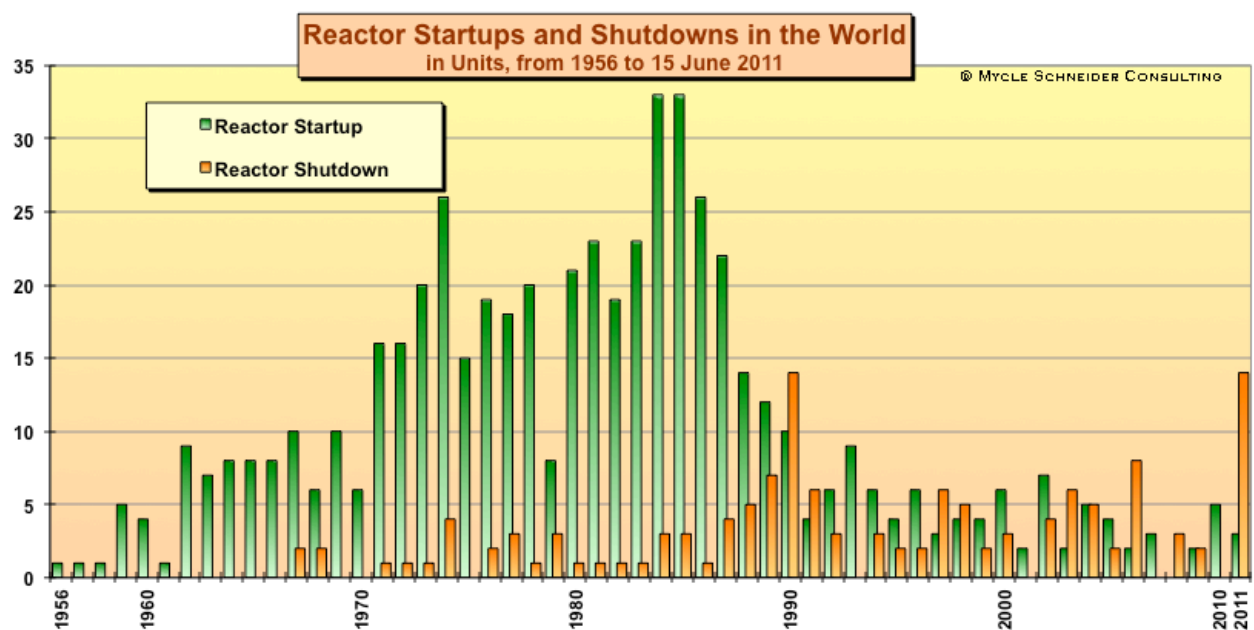
Ulrich Beck
Sociologist and philosopher
Le Monde, 10 July 2011

Before getting into the debate, what I will try to do, is to provide you with some background data on where international nuclear programs come from, where they stand and where they likely will go and what the energy context is, where investments are being made, where indicators increase and where they decrease.

Energy analysis is only possible over time. One has to look at the movie, the entire movie. Just a picture, a photograph does not tell you anything. It just gives you an idea about the situation at a given moment. In order to understand you have to look at a longer period of time to see what happens. That's what we have been trying to do for a number of years with the *World Nuclear Industry Status Report*¹.

I'll try to give you the general overview. I'll be showing you a lot of graphs. Do not care too much about the numbers. What I'm interested in is where it goes up and down, what is large, what is small, what are the tendencies.

Figure 1



Source: IAEA-PRIS, MSC², 2011

Here we have the reactors that were started up and shut down (see Figure 1). These green bars represent the number of reactors started up worldwide. The red bars are reactors shut down. It is simple to see the two great green waves prior to 1990, since then, the red is taking at least as much space as the green.

¹ Mycle Schneider, Antony Froggatt, Steve Thomas, "World Nuclear Industry Status Report 2010-2011 – Nuclear Power in a Post-Fukushima World", *Worldwatch Institute*, Washington, April 2011. A short, updated version has been published by the *Bulletin of the Atomic Scientists*, July-August 2011.

² MSC stands for Mycle Schneider Consulting throughout the paper.

This is the cumulated overview of reactors in operation worldwide (see Figure 2). It went up and reached first a maximum in 1989 and since then the development is really flat. It does not make a difference whether it is 424 or 430 reactors operating, over a twenty year time period it is the same order of magnitude. The historic maximum was reached in 2002 with 444 reactors in operation.

Figure 2

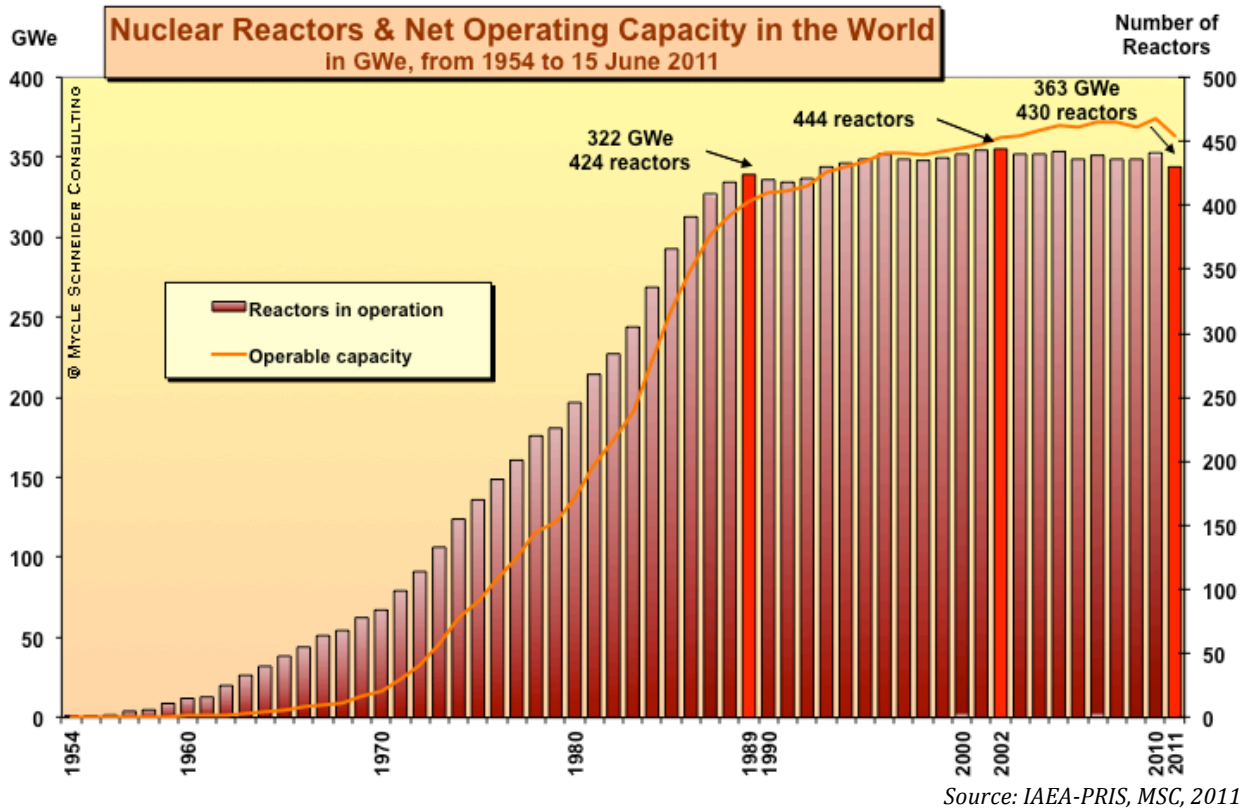
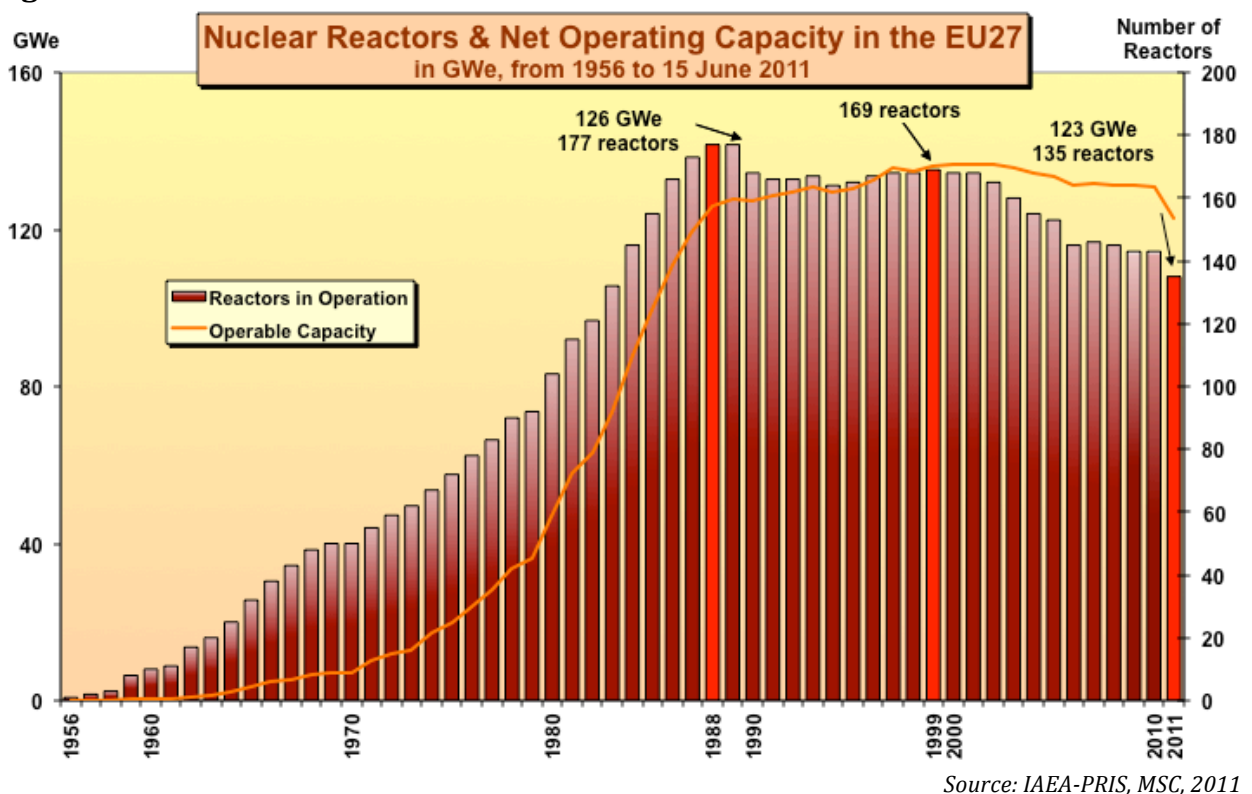


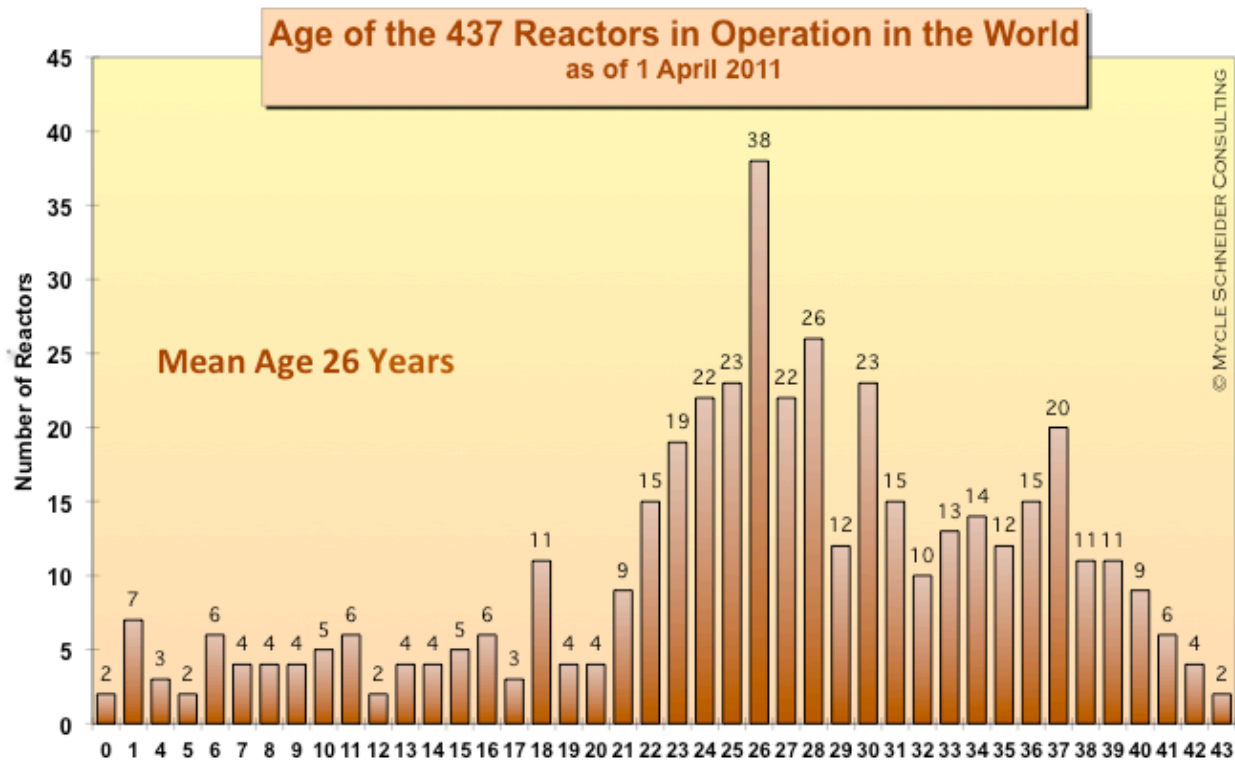
Figure 3



This is the same picture only for the European Union (see Figure 3). The historic peak was reached about the same time as on the worldwide scale, actually one year earlier in 1988 with 177 reactors, and since then there is an obvious decline. Now, after Fukushima, as of 15 June 2011, we have 135 reactors in operation in the European Union. This takes into account the shutdown of six reactors in Fukushima and eight reactors in Germany.

There are 42 reactors less in operation in the European Union today than at its height at the end of 1980s. That is to be kept in mind if you hear about one reactor under construction in Finland and one in France: it would take a long, long time to get back to the status of the past.

Figure 4

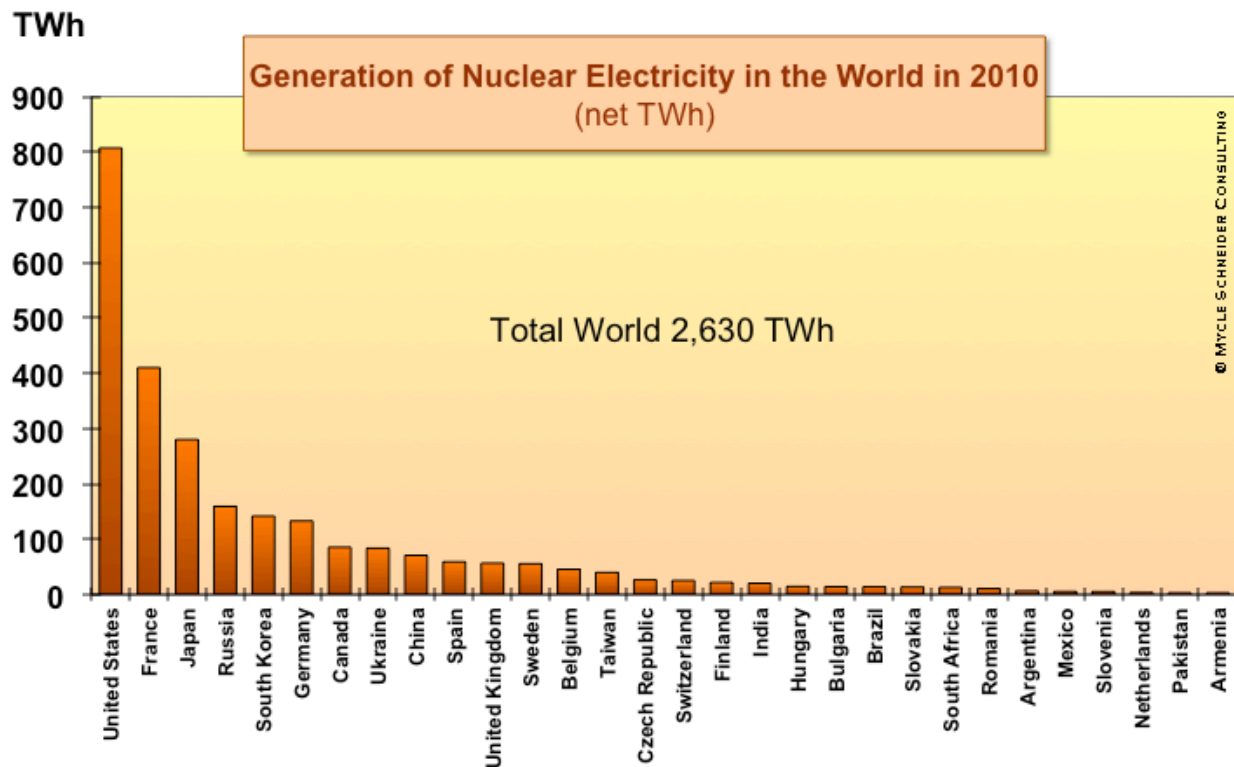


Source: IAEA-PRIS, MSC, 2011

In the absence of major new-build, it is obvious that the age pyramid increasingly moves into the higher numbers of years (see Figure 4). These reactors are getting old and more and more reactors move into very old age, over 40 years. Until now, there is hardly any industrial experience of reactors operating for so long, but more and more units attain that age. The average age is standing at 26 years. Do you remember the car you drove 26 years ago? That is the average technology age of these operating reactors in the world.

We have seen the installed number of reactors, we have seen the capacities. This is the electricity generation by nuclear power plants in the world last year (see Figure 5). There are now 30 countries operating nuclear power plants. The first thing you can see, it is not a phenomenon that is spread out over the world in some kind of equal manner, but there is a small number of countries, that concentrate, depending on the year, between two thirds and three quarters of the nuclear electricity generation in the world. It is the US, France, Russia, Japan, South Korea and Germany. Now, you imagine well that Japan and Germany will most likely not be in that category as of next year. So, two of the major producers will play a much lower role in the future.

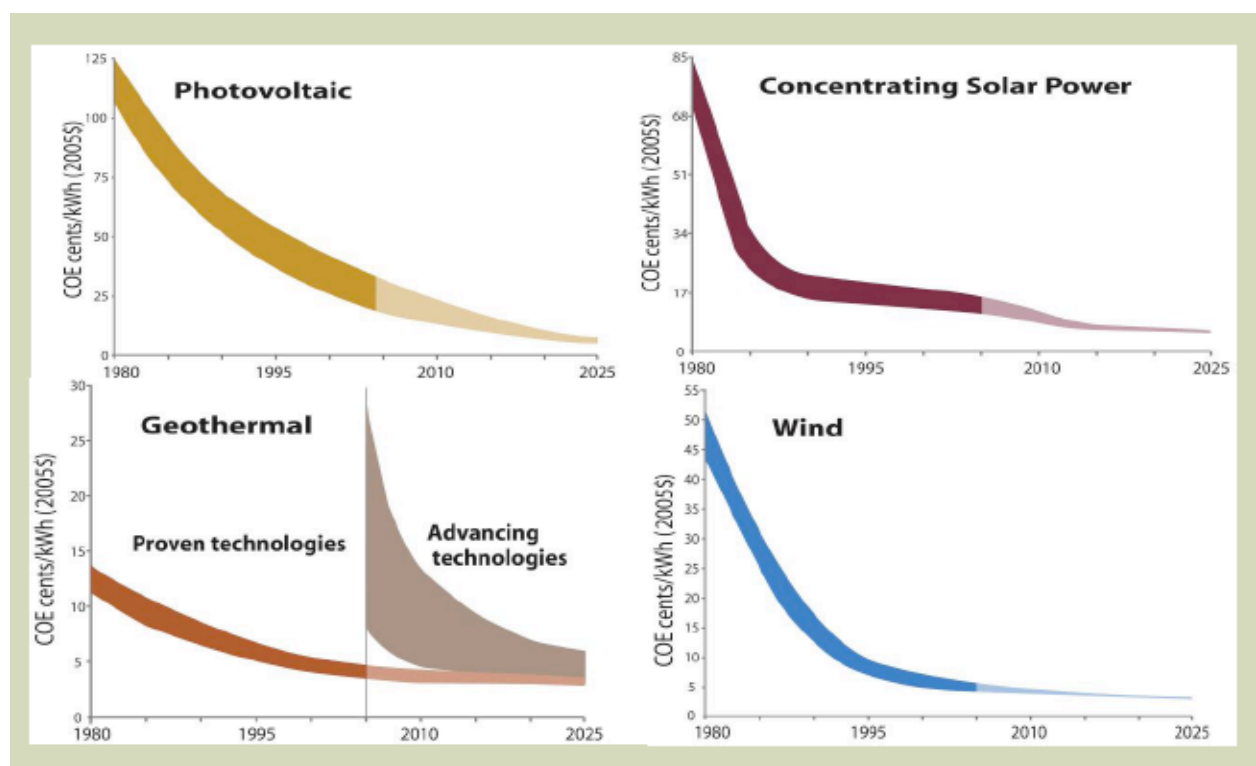
Figure 5



Source: IAEA-PRIS, MSC, 2011

Let us have a look at the question of economic costs. Those are so-called technology learning curves from other areas, from the renewable energy field (see Figure 6). I am not so much interested in the absolute numbers, they are given here in cents per kilowatt hour (2005 US\$). I'm interested in the form and shape of the curves, how steeply they have gone down since 1980 in those various areas,

Figure 6: Technology Learning Curves

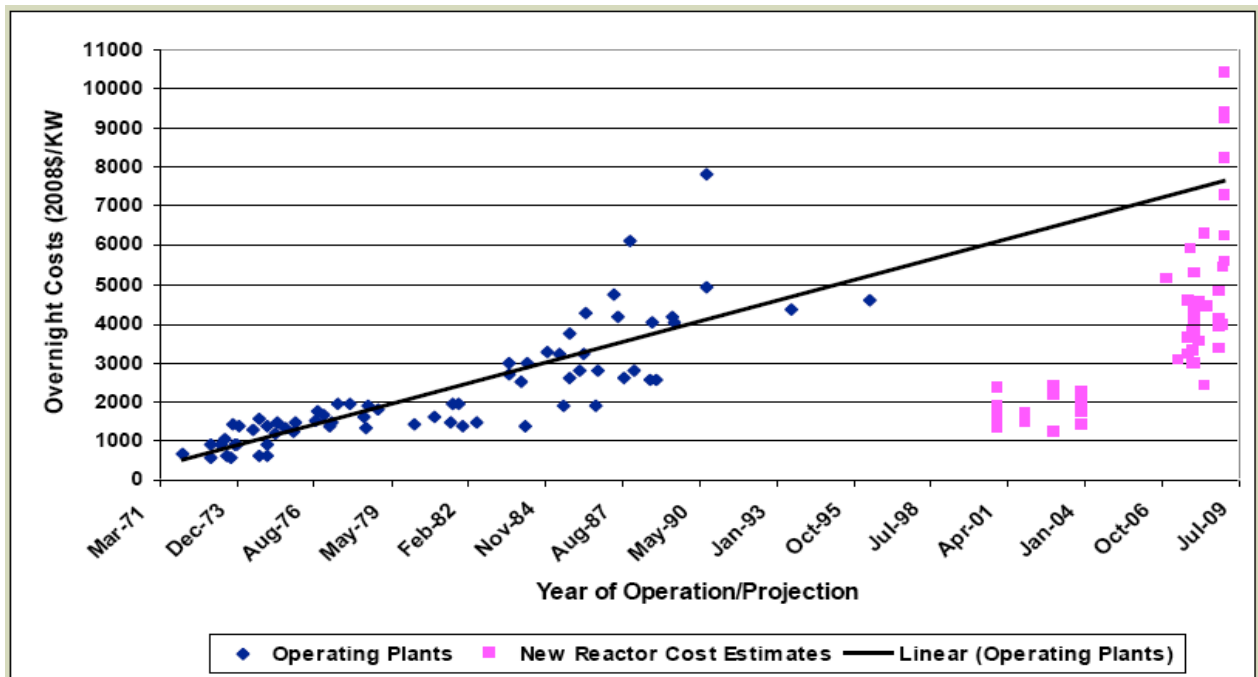


Source: Mark Cooper, "Cost Escalation and Crowding Out Alternatives: Policy Challenges in Nuclear Reactor Construction", September 2010

photovoltaic, concentrating solar power, geothermal and wind. It is a very steep decline in the cost of electricity generating costs.

If you look at nuclear power it is exactly the opposite (see Figure 7). Some people call it *forgetting by doing*, it is a negative learning curve. Instead of becoming less and less expensive, projects become more and more expensive. This is happening for a whole number of reasons. One of the reasons is that safety is being reassessed all the time, and costs a lot of money. Upgrading, continuous upgrading of the technical designs is expensive. Overall investment costs have been increasing, with increasing knowledge of environmental and safety issues, etc. These blue spots are all of the operating reactors in the US - that is where data availability is most prominent.

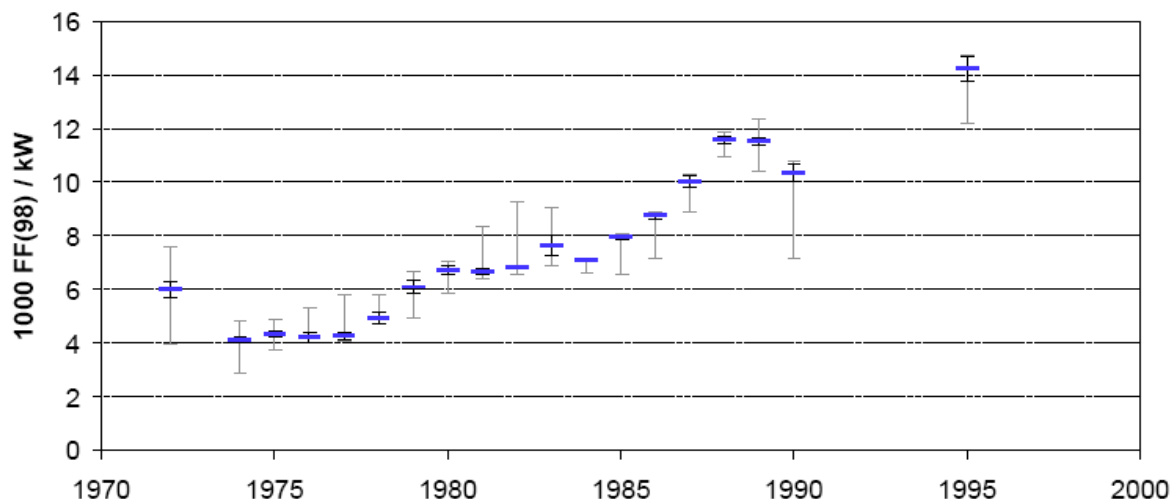
Figure 7: Negative Learning Curve of US Nuclear Reactors



Source: Mark Cooper, "Cost Escalation and Crowding Out Alternatives: Policy Challenges in Nuclear Reactor Construction", September 2010

These pink dots here in the early 2000 were the first cost estimates for new reactors. They were kind of low, about 1,000 – 2,500 Dollars per installed kilowatt, but only a few years later, all those cost estimates just exploded with detailed engineering advancing. The more precise the definition of the projects became, the more expensive they turned out to be.

Figure 7: Negative Learning Curve of French Nuclear Reactors



Source: Arnulf Grübler, «An assessment of the costs of the French nuclear PWR program 1970–2000 », October 2009

And if you think that France, because they have standardized reactors, have a different experience, it is disappointing to see that it is exactly the same kind of experience as in the US, a negative learning curve (see Figure 8). And if you put the reactors that are currently under construction in Finland and France on the curve, they would be off-scale.

Figure 9: Excessive Lead Times and Cost Overruns: Example Olkiluoto-3, Finland

1998-1999	Finnish utility TVO submits Environmental Impact Assessment report.
2005	First concrete in August.
2006	Project running 18 months late.
2007	Project running 24 months late.
2008	Project running at least 36 months late.
2010	Project running at least 42 months late
2013	Start-up?

Lead Time: at least 14-15 years since EIA

Official Price: ca. €3 Billion (Guaranteed Fix Price)

Cost Overrun at 6 Years after Construction Start: €2.7 Billion (90%)

Estimated Total: >€5.7 Billion or \$8.3 Billion

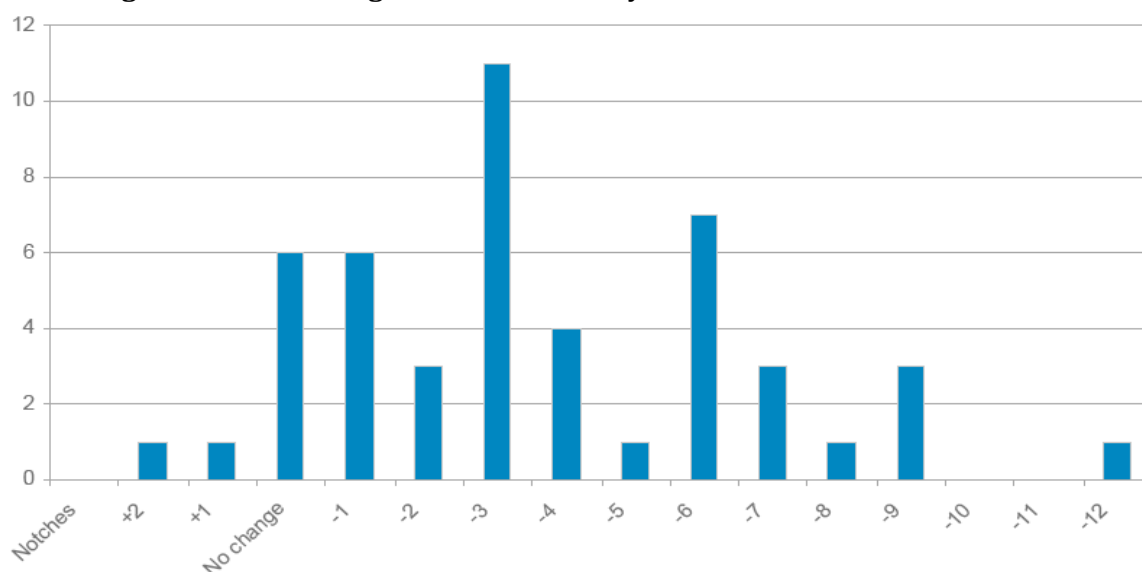
Sources: Various, compiled by MSC

This chronology concerns one of the two European Pressurized Water Reactors or EPRs that are under construction in Europe, the one in Finland (see Figure 9).

Two comments: the first point is that there is a very long lead-time. Those are not projects where you can put the shovel in the ground and at the horizon you can see the time when you can switch on the machine. In this case, if the project, which has been delayed over and over again—it is now approximately 4 years late—if it starts in 2013, the lead-time will have been between 14 and 15 years from the environmental impact assessment onwards. Which is not even the beginning of the project. So it is very long.

The second point is that time delays obviously cost a lot of money, large amounts of money, because financing becomes a very substantial part of the overall project cost. In this case, the largest builder of nuclear plants in the world, AREVA, provisioned a loss of 2.7 Billion Euro, so the total cost estimate now is over 90% over budget, and it is more likely to be 100% at least. Instead of 3 billion Euros we are standing at 5.7 billion Euros or 8.3 billion Dollars. This is reality, it is not based on modeling.

Figure 10: Changes in Credit Rating of 48 US Electricity Utilities

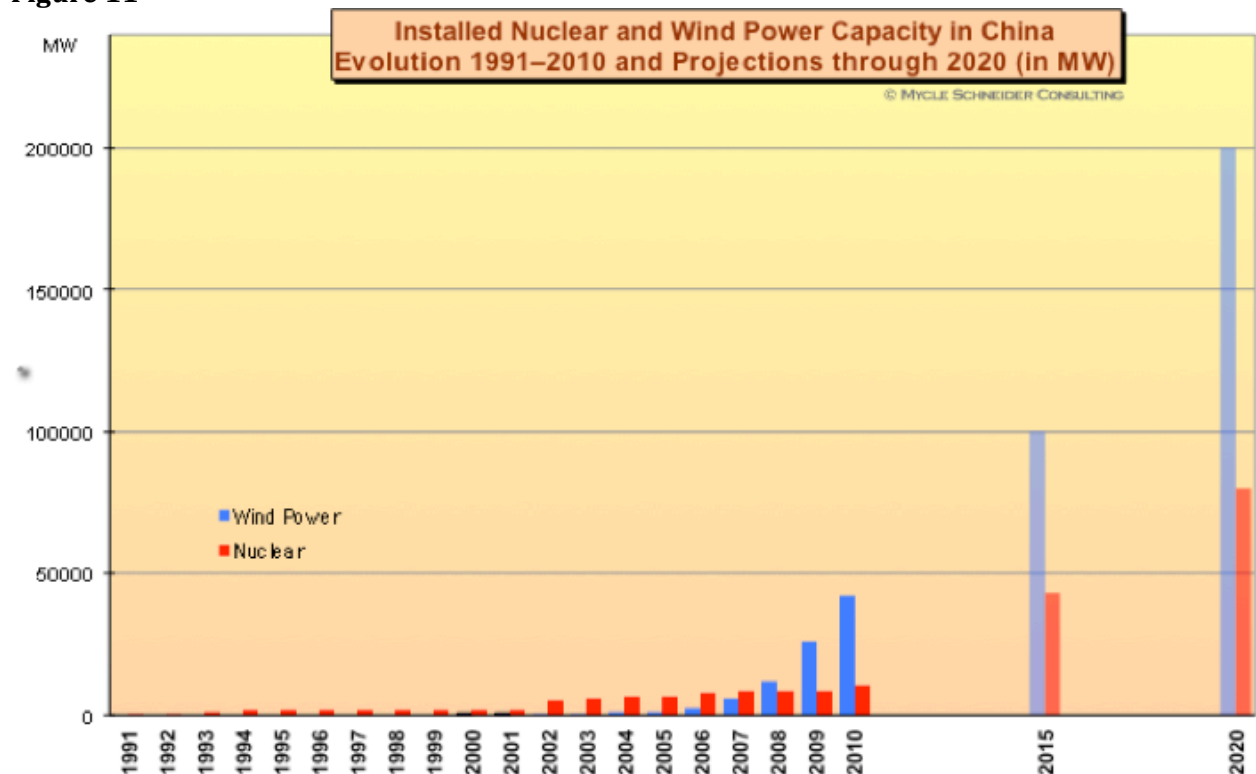


Source: Moody's, "New Nuclear Generation: Ratings Pressure Increasing", 2009

With this kind of experience, the credit-rating agencies have started to have a closer look at nuclear power projects (see Figure 10). Moody's, one of the biggest agencies, looked at 48 US utilities that invested in nuclear power projects in the past. Out of those 48 utilities, 40 had a negative impact on their credit rating, 6 remained unchanged and two were positive. The agency concluded: "“Moody's is considering applying a more negative view for issuers that are actively pursuing new nuclear generation.”"

What does a negative impact on credit rating mean? It is very simple, it means that *any* investment the utility wishes to carry out will be more expensive, because access to credits and capital is more expensive. Downgrading has a significant overall impact on investment strategies and opportunities of companies and countries.

Figure 11



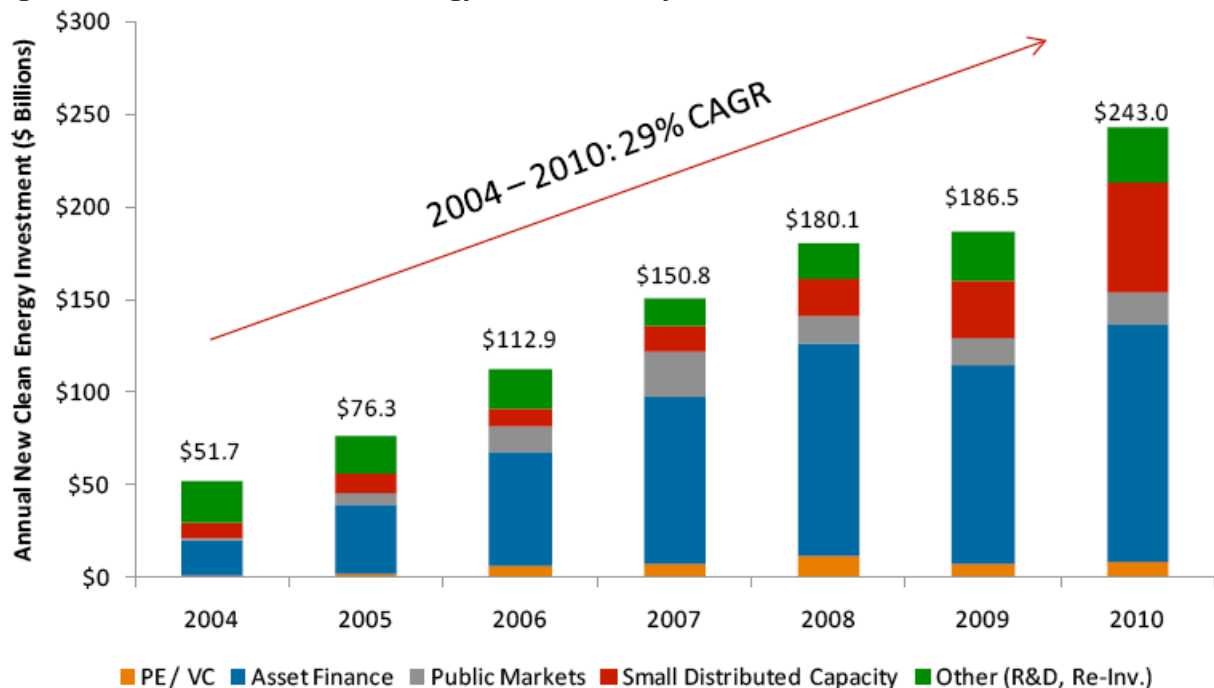
Source: IAEA-PRIS, GWEC, 2011, various

There is only one country that is massively investing in nuclear power, that is China, with 27 out of 65 reactors that are listed as “under construction” in the world. It raises a lot of attention, but a lot less attention is paid to the fact that China is investing a lot more money in other energy technologies, already prior to the beginning of the Fukushima crisis. The installed capacity of wind power was over four times higher than nuclear power in China by the end of 2010 (see Figure 11). This makes it very likely that China will generate more power from wind than with nuclear plants in 2011. It is remarkable that this is not to go away with massive investment in nuclear power. According to Chinese projections, a big advance for wind energy will remain, in spite of potential continued massive investment in nuclear power. However, Chinese post-Fukushima decisions – freeze of all new licensing procedures, abandoning of the standardized Generation II reactors – indicate rather a significant slow-down of nuclear expansion.

Looking at overall, annual worldwide investment in new clean energy - again without looking at the detailed types of investments - the skyrocketing development is staggering: +29% annually on average between 2004 and 2010, we are getting close to US\$250 billion dollars in 2010 (see Figure 12). More than 20%, over US\$50 billion dollar, were spent by China alone. This means that China invested more in renewable energy in 2010 than the entire world in 2004. Can you imagine what it means in terms of signal to the markets, to investment and technology development? It is

phenomenal. The other point is, again, the comparison with nuclear investment. The estimated investment in China in nuclear energy is about 10 billion per year, which means that in 2010 the country invested five times more in renewables than in nuclear power.

Figure 12: Annual New Clean Energy Investment by Asset Class 2004-2010



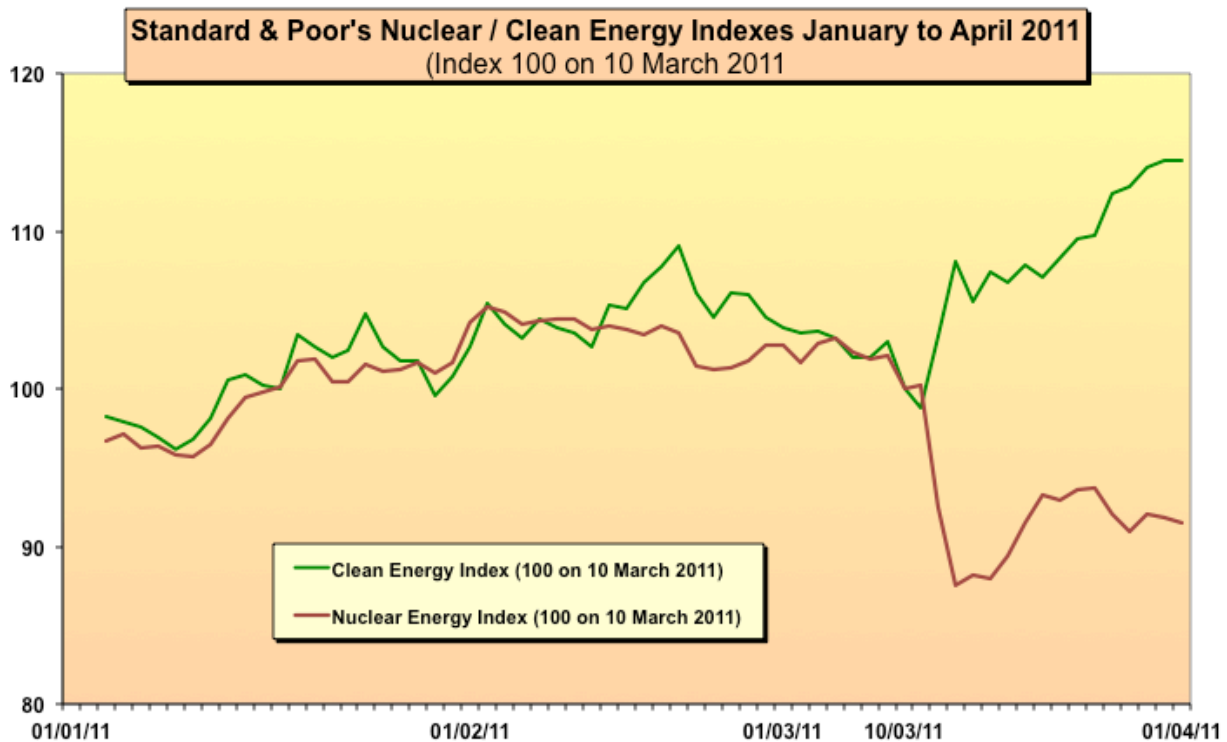
Source: Bloomberg/Deutsche Bank, 2 May 2011

Note: CAGR = Compound Annual Growth Rate; PE = Private Equity; VC = Venture Capital

A brief comment on public opinion, but it is very important: It has been shown after the Fukushima disaster began that there is a major shift, a global study on 24 countries shows that a quarter of the people polled have changed their mind on nuclear power. In France, between March and June 2011, the number of people in favor of a *rapid* nuclear phase-out decreased, but the amount of people in favor of a *slow* phase-out phenomenally increased. In France, which is the country with the largest share of nuclear energy in the world, over three quarters of the citizens polled are now in favor of a nuclear phase-out.

Talking about signals to markets, I did a little exercise with indexes of Standard & Poor's, another big rating agency. They have a specific stock market clean energy index and a nuclear index and I put my own index on the 10th of March, the day before Fukushima began (see Figure 13). Since the beginning of the year and until Fukushima the development of the clean energy and nuclear indexes is pretty much the same. Then it went in opposite directions. The stock markets have reacted immediately to Fukushima, in boosting renewable energy values and triggering a huge decline for nuclear companies. French nuclear giant AREVA declined in share value by 30% since February 2011. In fact, the company has been declining for years and it has lost over 60% its share value since 2007. In 2010 AREVA made an operational loss of €423 million.

Figure 13



Sources: Standard & Poor's, MSC 2011

Conclusion

Nuclear power globally plays a very limited and highly overestimated role. It represents roughly 13% of electricity, 5% of commercial primary energy and 2% of final energy (that, after transformation and distribution losses, is effectively available to the consumer) worldwide.

Nuclear power is expensive and slow. I am insisting on the time factor, because we are discussing energy issues within the framework of global climate change. We need to react to the challenge of climate change with solutions that are affordable and fast. Fukushima adds to nuclear costs, in terms of safety, insurance and finances and obviously other problems like public opinion and competence, an issue I did not touch upon, but which is also important.

The financial sector is more skeptical than ever towards nuclear power. Renewables and, interestingly, energy efficiency are the winners on the stock market, while nuclear power declines. In 2010, for the first time, overall installed capacity of just four categories of renewables—wind, solar, small hydro and biomass—exceeds nuclear. So, after Fukushima and following spectacular reactions in the world's leading economies, at this point, there are no identifiable prospects for nuclear power as a major energy technology for the future.

The future lies in affordable, distributed, which means decentralized, super efficient technologies, smart grids and sustainable urbanism. Nuclear policy, which is centralized, inflexible and generally autocratic, symbolizes the opposite.