Renewal of nuclear electricity production: an economic trend

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Abstract:

The change in market prices in 2004 raises questions about the profitability and competitiveness of nuclear power. There has been excess electricity production in Europe for several years, but electricity consumption is steadily increasing and this surplus will more or less have disappeared by the end of the decade.
Worldwide, the demand for electricity is increasing twice as much as the demand for energy, so there is a need to invest in new electricity generation facilities.
The recent blackout in the US illustrates the need for secure energy supply as well as reliable transmission and distribution.
The competitiveness of the different possible sources of energy therefore needs to be carefully assessed by all decision makers in the field of power generation throughout the world.
In France, the economy of the electricity production industry is regularly assessed in a French government study called "Reference costs of electricity generation" which compares the levelized cost of baseload power produced by a nuclear unit (latest design available) and other conventional power stations. In the latest release published in 2003, the nuclear option (the EPR) is compared with three fossil-fired units: a twin 400 MW combined-cycle gas plant, a twin 900 MW pulverized coal station and a 400 MW fluidized bed combustion coal plant. In all cases, the nuclear option is the cheapest. If external costs, based on EU studies (ExternE), are taken into account, the advantage of the nuclear option is increased considerably.
In Finland a study performed in 2000 by the Lappeenranta University also concluded that the nuclear option was the most competitive. This result was important for the decision-making process which resulted in the Finnish parliament's decision, in principle, to give the green light for the construction of the fifth nuclear power station, for which the EPR was selected.
In China the government authorities also decided recently to launch new nuclear projects.
These three examples, in three countries where political decision makers have recently confirmed the need to rely on the nuclear option, show that the situation is changing in Europe and throughout the world. The paper will discuss this new context.

Keywords: *Economy, Nuclear energy, New reactor design, Electricity*

1. Introduction

Throughout the world, the demand for electricity is increasing twice as much as the demand for energy. According to IEA-World Energy Outlook (2002), IEA/OECD (2003) and AREVA-DS/DEEP estimates (2004), this worldwide demand, which cumulated at just over 15,000 TWh in 2003, will slightly exceed 30,000 TWh in 2030 (see Figure 1).

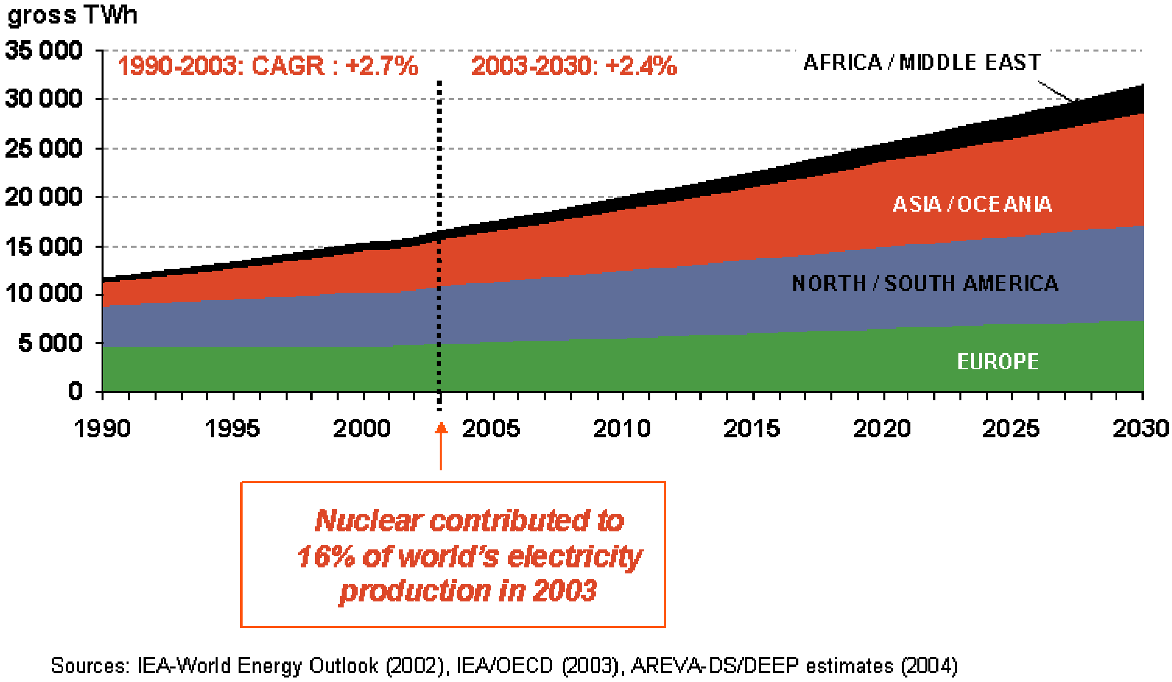


Figure 1

In Europe, there has been a surplus of electricity in recent times, and electricity prices have stayed rather low, but according to IEA projections, electricity consumption is steadily increasing; meaning that the surplus will have disappeared as early as the end of this decade.

IEA (World Energy Investment Outlook 2003 Insights-see Figure 2) 2000-2030 projections also show that global investment in the electricity sector is expected to triple during that period compared to the previous 30 years, to reach a cumulated US$4,079 billion for generation capacity add-on during the period 2000-2030.

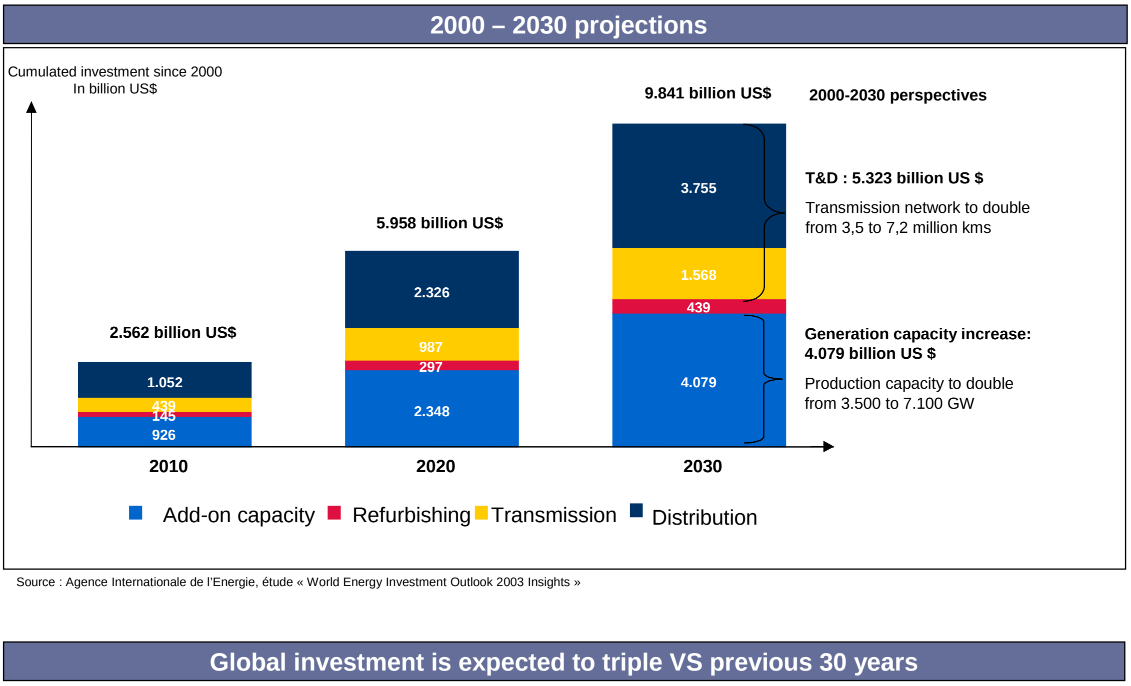


Figure 2

To achieve this increase in overall electricity production, different technologies are of course in competition:
-nuclear,
-hydroelectricity,
-renewable energies (wind, solar, biomass, etc.),
-combined cycle gas turbines (CCGT),
-pulverized coal,
-fluidized coal bed,
-oil fired, etc.

The success of the nuclear industry thus depends on the profitability and competitiveness of nuclear power plants, which are assessed through comparative analyses performed by institutes in different countries worldwide.

This paper focuses on the results obtained by two of these studies, one performed by the French "Direction Générale de l'Energie et des Matières Premières" (DGEMP) in 2003, and the other by the Lappeenranta University of Technology in Finland in 2000, updated in 2002. Their conclusions explain the renewal of the nuclear industry already decided in Finland, and decided-in-principle in France. The changing status of the nuclear industry in these two countries is also described.

The paper concentrates on baseload electricity generation techniques, and does not discuss competitiveness, or the advantages and disadvantages of complementary means such as renewable energies, which cannot reach a sufficient production capacity to match the demand for electricity, and are not yet on the open market, as their development is based on subsidies.

2 Conclusions of the December 2003 DGEMP "Reference costs of electricity generation" study

2a Purpose of the study

"Reference costs" for electricity generation are calculated periodically by DGEMP; the last issue prior to the one described below dates back to 1997.
The "Reference cost" is the constant cost of generation during the lifetime of the equipment according to a set of predefined economic assumptions, aimed at providing a comparison between the different means of electricity generation rather than the absolute costs which are obtained through industrial bids.

The objectives of the study are two-fold:
-to help establish the energy policy of the State, (i.e. France),
-to check the relevance of current electricity rates.

In a context of excessive electricity production as in Europe today, electricity prices are depressed, and investors cannot afford to invest in new production capabilities in the short term, as the market price for electricity is determined by the cash cost (fuel expenses plus O&M fixed and variable charges including taxes and indirect charges) of the last unit to be called according to an order of priority (see Figure 3).

The market price is determined by the cash cost of the last unit to be called according to an order of priority: example

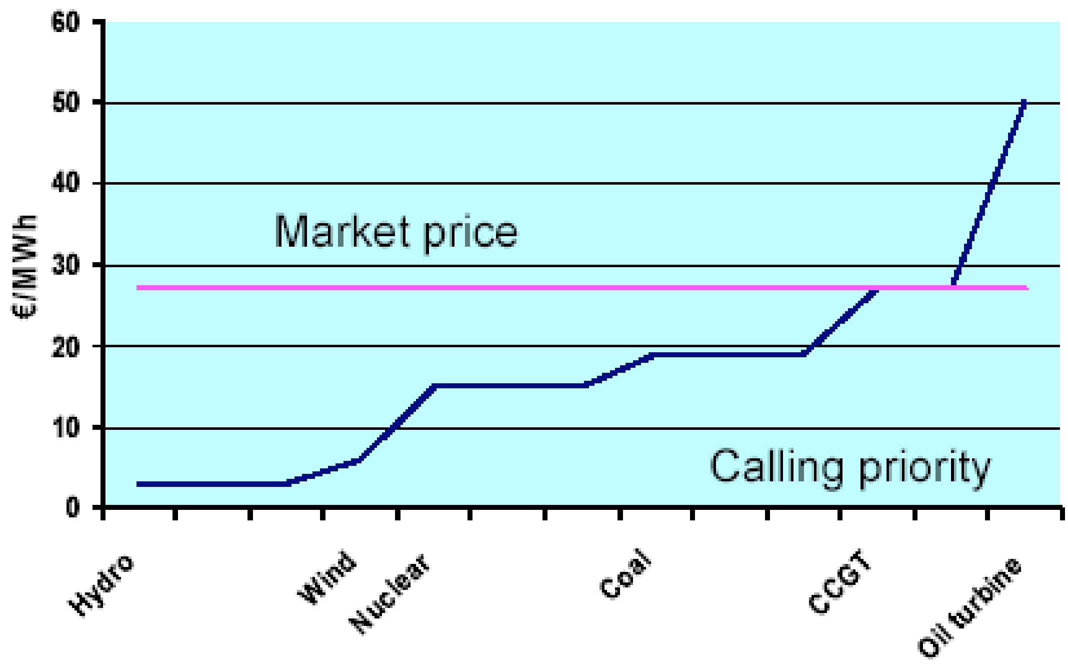


Figure 3

In the medium to long term, the decommissioning of existing units and increases in average and peak demand finally result in an increase in the market price, thus providing profitability for new investments to be launched. But considering the construction times of new facilities, decisions by investors to build new plants may come too late to match the increase in electricity requirements; therefore, surveys performed by government or governmentally appointed institutions are necessary in order to establish the energy policy of States in the long term.

In the DGEMP studies, a comparison was made between a series of ten nuclear units (EPR), a pair of pulverized coal with flue-gas treatment units, a pair of circulating fluidized coal bed units and combined-cycle gas turbines.

2b Main assumptions

Reference costs include all investments including interest during construction, generation, fuel and dismantling costs.

The study distinguishes the private investor standpoint from the public investment. It takes into account all generation costs including fiscal ones, and adopts different real discount rates. For private investment, the discount rate of 8% used to assess the expenses and revenues for different years is consistent with the expectations of investors in terms of return on investments. A 3% discount rate represents the public investment standpoint. The reference date for escalation calculations is always taken as the commercial operation date of the new production facility.

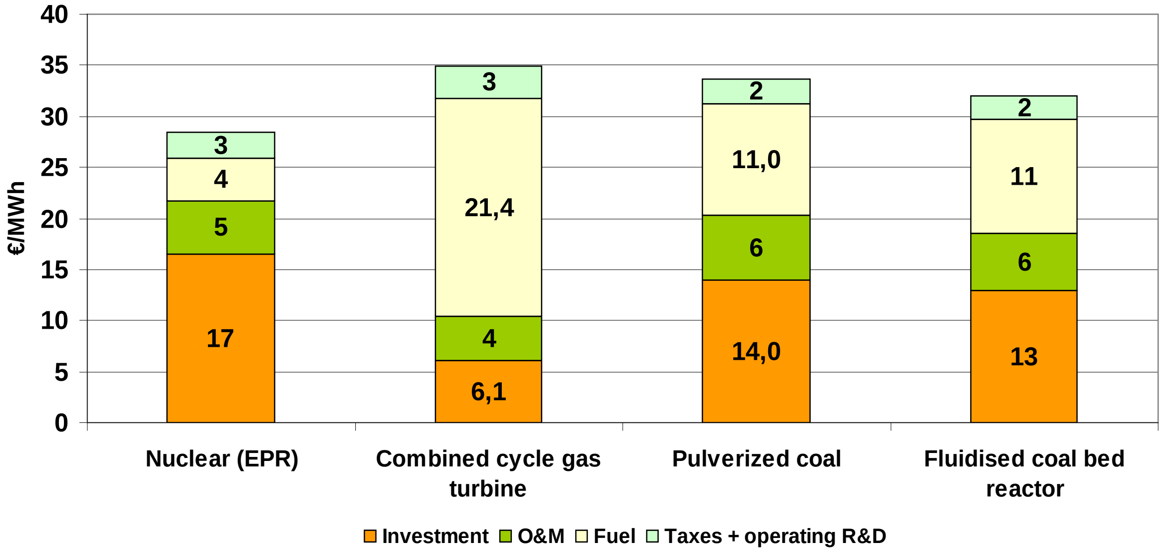
"External expenses" (ExternE), i.e. expenses borne neither by the operator, nor by the customers, are not taken into account by definition; however, the consequences of a cost equivalent to a CO_2 release permit have been analyzed.

All monetary values are expressed in real Euro 2001.

2c Main results:

Baseload levelized generation costs in 2015 expressed in €/MWh discounted at 8% and for a yearly operating time of 8000 hours (equivalent to a capacity factor of 91%) are shown in Figure 4 below.

Baseload levelized generation cost in 2015
Discount rate 8%



Reference: "Coûts de référence de la production électrique/DGEMP-DIDEME/3.07"

Figure 4

With a generation cost of about 29 €/MWh compared to 34.5 €/MWh for combined cycle gas turbine plants for a gas price of 3.3 US $/MBTu (8% discount rate), 33 €/MWh for pulverized coal plants and 32 €/MWh for fluidized coal bed plants, nuclear (EPR) is more competitive than the other production facilities.
This competitiveness is even better if the costs associated with greenhouse-gas (CO_2) emissions are taken into account when estimating the MWh cost price. Integrating the costs resulting from CO_2 emissions by non-nuclear fuels (gas, coal), which will be compulsory as of 2004 when the European directives are written into law, increases the total cost per MWh of these power generation methods as follows..
Considering two hypotheses in terms of CO_2 costs over the lifespan of oil and coal-fired power plants, i.e. €4/t CO_2 which is a very low assumption — it will be considerably higher in 2015 and beyond (post-Kyoto period) — and € 20/t CO_2, the overcost per MWh ranges between 1.4 and 7.1 € for the combined cycle gas turbine plants, 2.9 and 14.6 € for pulverized coal plants, and 3 and 15 € for fluidized coal bed plants.

Studies of sensitivity to the different parameters used to calculate generation costs were performed and showed that the economic risks associated with the various production technologies are very different.

Nuclear and coal are most sensitive to investment cost control; low discount rates favour nuclear, and high ones penalize it. Notwithstanding CO_2 penalties, combined-cycle gas turbine and circulating fluidized coal bed plants only become competitive with nuclear when discount rates exceed 11%.

The sensitivity of generation costs to fuel prices and the euro/dollar exchange rate have no effect on the order of competitiveness of the plants, but generation costs for combined cycle gas turbine plants are very sensitive to fuel costs and the rate of the dollar (over two-thirds of CCGT generation costs are accounted for by fuel). Gas prices therefore constitute a high uncertainty parameter for CCGT investors, especially since gas prices have always followed the trend in oil prices in the past.

As regards annual operating time, high capacity factors favour nuclear. Considering the size of the initial investment required, assessments show that for short annual plant operating times, the competitiveness of nuclear fades in favour of gas-fired power plants. More specifically, nuclear power becomes more competitive than gas (excluding external considerations such as greenhouse-gas overcosts) for operating periods of not less than 5000 hours per year (see Figure 5).

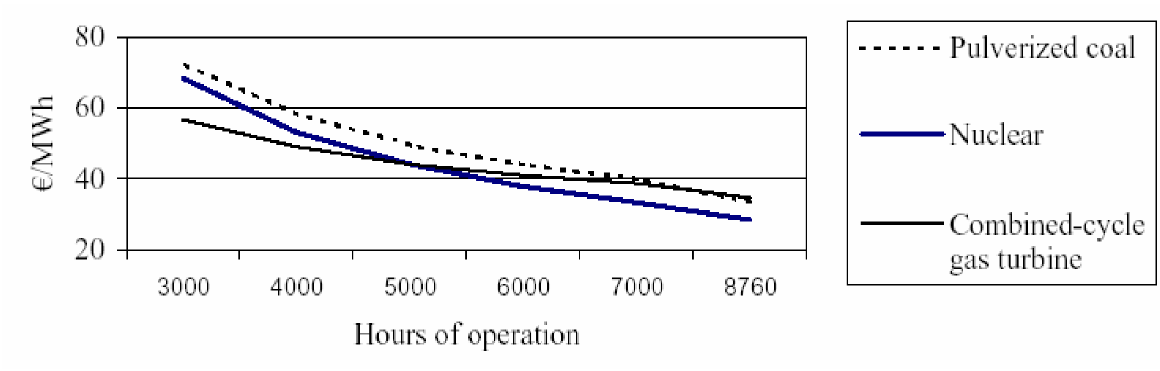


Figure 5

However, it should be noted that 5000 operating hours correspond to an availability factor of 57%, whereas almost all nuclear power plants currently in operation reach over 80%, and the EPR design features are such that the availability factor will be not less than 92%.

3. French energy policy:

A national debate on energy was organized between March and October 2003. Different documents were issued on this occasion, with many contributions from public and professional institutions, trade unions, associations, along with reports from Mr Besson, a Member of Parliament appointed for this debate, and from a committee of "wise men".

At the close of the debate, the Minister Delegate for Industry released a "white paper" describing the government's proposed energy policy. Three main lines of action were indicated:

-renewed control of energy consumption,

-diversification of production methods by developing renewable energies,

-preparation of "year 2020" as the starting date for the decommissioning of existing electronuclear plants and their replacement by new production units.

The government's desire to keep the nuclear option "open" was clearly stated, as was EDF's wish to build a French EPR pilot to be put into commercial operation during the period 2012-2015 in order to be able to launch an EPR series at the appropriate time; the possibility of including the schedule for the related investments in the draft law on energy policy was also envisaged.

This draft law on energy policy was presented to Parliament in May-June 2004 and was adopted at the end of June 2004.

The administrative process launched following this decision should lead to first concrete of a French EPR in 2007, thus ensuring continuity of the nuclear option policy for electricity generation in France.

4. Conclusions of the studies performed by Lappeenranta University of Technology in Finland

In a presentation made in 2000 at the 25th Annual Symposium of the Uranium Institute, Messrs Tarjanne and Rissanen presented a financial comparison of the new baseload power plant alternatives under Finnish conditions, as well as the current production cost of the existing Olkiluoto nuclear power plant based on an operating history of about 20 years.

The possible options considered for comparison were:

-a nuclear power plant built on an existing nuclear site (1250 MW capacity),

-a combined cycle gas turbine plant (400 MW capacity),

-a coal-fired condensing power plant (500 MW capacity),

-a fluidized peat bed condensing power plant (150 MW capacity).

A real interest rate of 5% per year and the fixed price reference level for 2000 were used.

The electricity generation costs of baseload alternatives at 8000 full-load operating hours are shown in Figure 6.

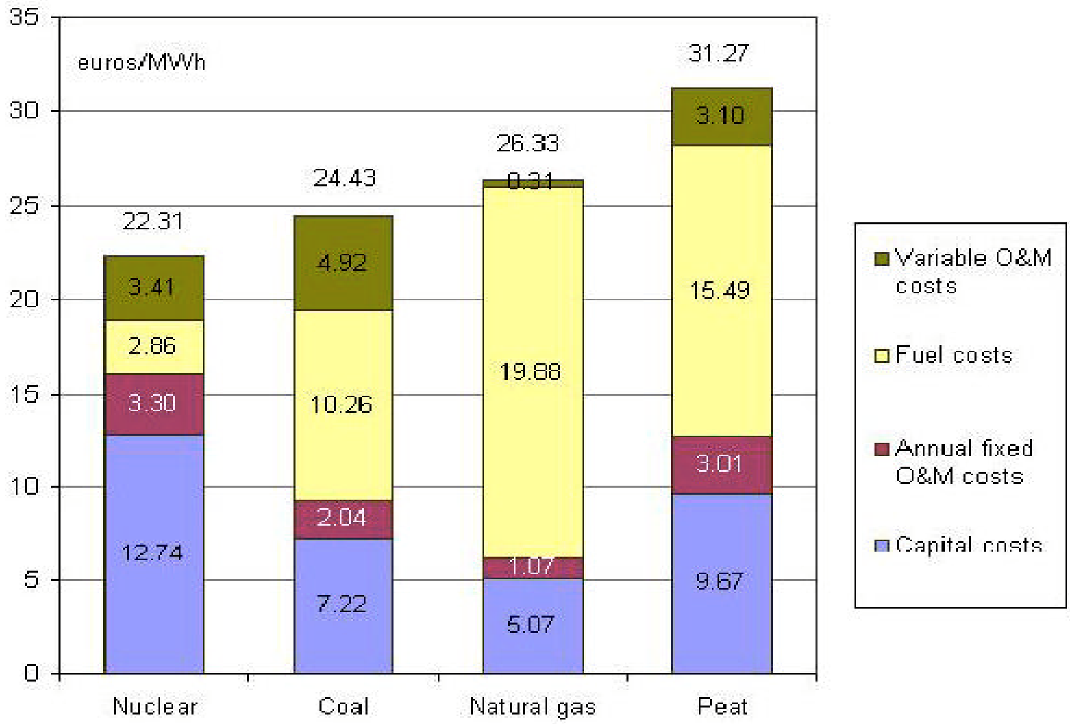


Figure 6

As for the DGEMP study, nuclear electricity was found to be the most competitive option at 22.3 €/MWh, ahead of coal-fired, combined cycle gas turbine and peat-fired generated electricity, with production costs of 24.4, 26.3 and 31.2 €/MWh respectively.

These calculations were updated in 2002, taking current fuel costs into account, but this did not change the leading position of nuclear generated electricity in terms of competitiveness.

Sensitivity studies led to the same conclusions as the DGEMP analysis:
-nuclear power is more sensitive to investment costs and changes in interest rates than coal and gas alternatives, but even a large increase of 10% in investment cost does not affect nuclear competitiveness; the impact of interest rate changes remains moderate for all alternatives and does not change the competitiveness ranking of the different options,
-nuclear power is quite insensitive to fuel costs, whereas a rise in fuel costs induces a major increase in the production cost of gas-fired plants,
-consistent with the DGEMP results, the nuclear power generation cost is the lowest for high annual operating times, i.e. in excess of about 5000 hours (consistent with DGEMP findings).

The conclusion of the authors of the comparative assessment of the different production plants was that from a purely Finnish point of view, both in terms of the economy and in terms of Finnish compliance with its Kyoto protocol commitments on greenhouse gas emission reductions (a 1250 MWe nuclear unit leads to savings of 8.3 million tonnes of carbon dioxide emissions annually compared to a coal-fired condensing power plant, and 3.7 million tonnes compared to a combined cycle gas turbine plant), the nuclear choice is by far the best alternative for a new baseload power capacity.

In the 2000 presentation, generation costs of the existing Olkiluoto nuclear power plant were also presented. TVO is a non-profit company, getting all its revenues through electricity sales to its shareholders. As generation of electricity was the TVO's only activity from the very beginning of Olkiluoto plant operations, it was possible to calculate the actual annual expenses of the two units commissioned in 1979 and 1981 respectively. The nominal interest rate used in the financial calculations was conservatively taken at 9% per year. The financial analysis was carried out by discounting all annual expenses and revenues to 1980 economic conditions.

The current operating license for the units extends to the end of 2018 under the condition that a complete safety assessment of the plant has to be made in 2008.

Figure 7 summarizes the conclusions of the analysis in terms of payback curves for the entire period between 1980 and 2018:

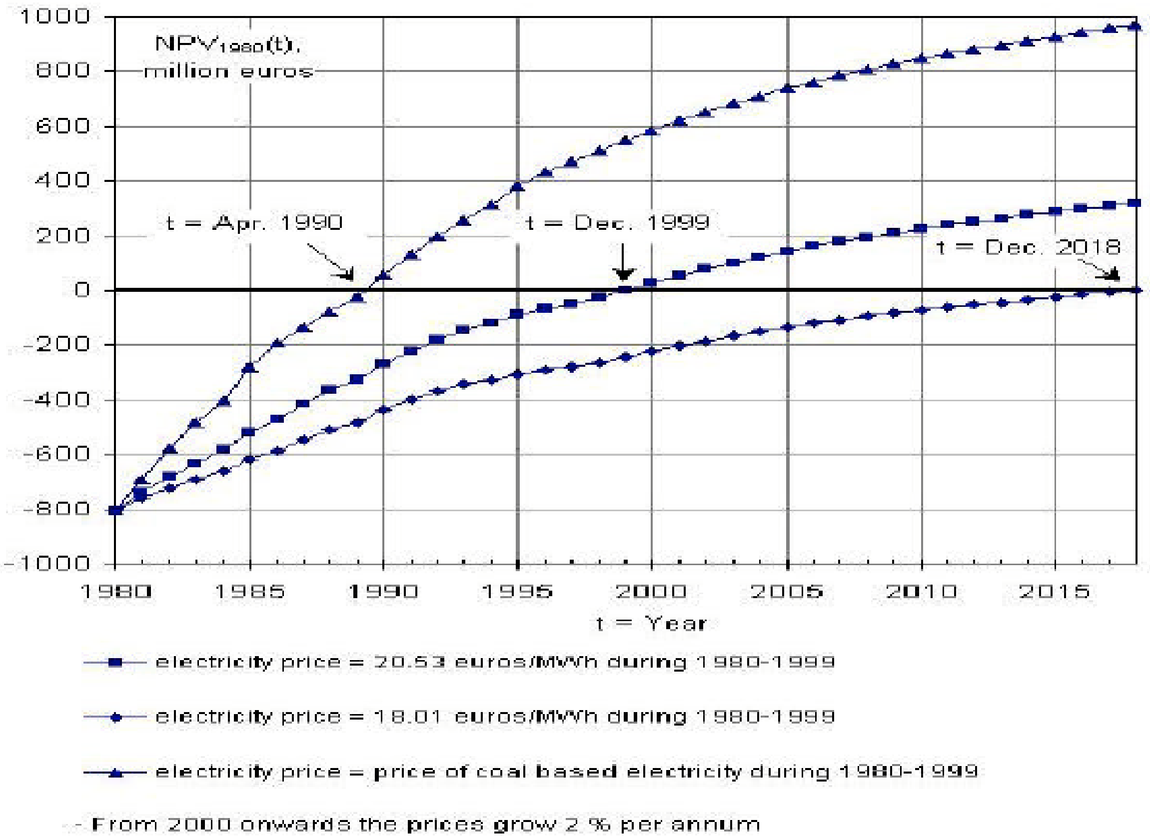


Figure 7

For an electricity price equal to that of coal during the 1981-1999 period (period of the study), the investment is paid back in April 1990 (after roughly 10 years of operation only!),
For an electricity price equal to 20.5 €/MWh, the payback time is the end of 1999.
For a payback time at the end of 2018 (current permitted operating limit), the resulting price of electricity is 18.0 €/MWh.

The outstanding conclusion of the authors was that the operating nuclear units at Olkiluoto had been highly profitable in the past, thus providing historical evidence that nuclear was the least-cost option for the new baseload capacity which was needed in Finland for the future.

5. The Okiluoto project

Following the conclusions of the experts, TVO submitted an application for a “Decision-in-Principle” to the Finnish Government in November 2000. The choice between a BWR and a PWR was left open, as were the site (Olkiluoto or Loviisa) and the possible range of the unit (from 1000 to 1600 MW).

This application was approved by the Government in January 2002, and by the Finnish Parliament in May of the same year.. The RFQ was issued in October 2002, and the proposals received in March 2003.

On October 15, 2003, TVO announced that the consortium led by AREVA-Framatome ANP with Siemens PG was the preferred bidder, and selected the EPR to be built on the Olkiluoto site.

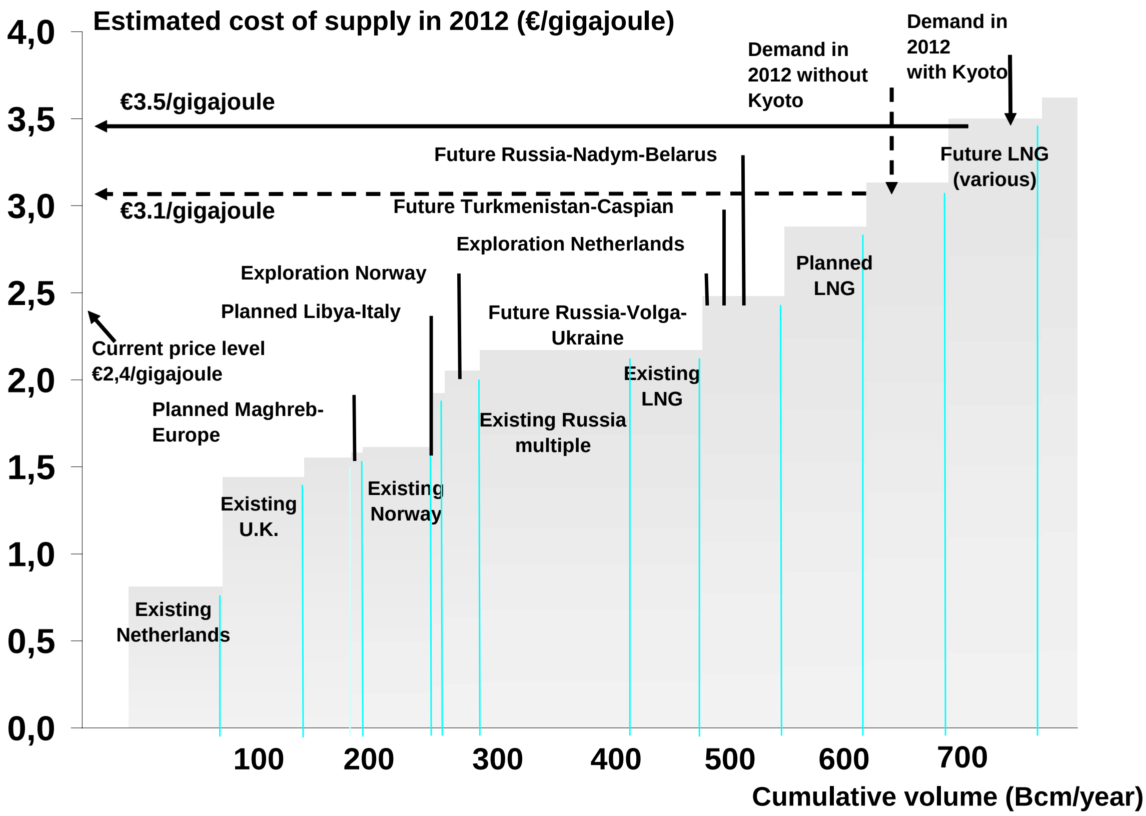
The contract effective date was January 1st, 2004. First concrete will be poured mid-2005 and the plant is expected to start commercial operation in 2009.

5. Conclusions

The main conclusion of the comparative assessments made by DGEMP and the Finnish experts at the Lappeenranta University is the same: nuclear energy generation is the most competitive for baseload operation. Nuclear benefits from a low marginal cost, which ensures connexion priority on the grid and a higher load factor. It secures market sales and long term cash flows.

The obstacles to the development of nuclear energy are the high investment cost/kW and public acceptance of nuclear energy, but once these difficulties have been overcome, nuclear energy generation has numerous advantages:
.the lowest generation cost compared to combined cycle gas turbine and coal-fired plants, thus ensuring a high profitability for investors in the long term,
.a low marginal generation cost,
.very low sensitivity to fuel costs,
.the only carbon dioxide-free baseload technology that makes it possible to match the Kyoto Protocol commitments in the medium term.

The combined cycle gas turbine method requires a lower investment cost/kW, but is highly sensitive to gas prices (which account for no less than 70% of the cost/MWh), which are set to increase continuously, according to most recent predictions (see Figure 8):



Gas prices in Europe in 2012 (Source: BCG report "keeping the lights on" May 2003)

Figure 8

Gas prices are highly volatile, which is a major risk for investors. This generation method will also be more and more penalizing in the future with respect to external costs associated with CO_2 emissions.

Moreover, from the investment standpoint, recent studies performed and compiled by AREVA experts (reference 5) show that for Liquefied Natural Gas (LNG), about 50% of the gas price results from the gas chain investments, and therefore should be considered as investment cost.

Coal-fired plants require high investment for clean coal, which nevertheless does not prevent this technology from having drawbacks with regard to CO_2 emissions and air pollution. In the longer term, clean coal with carbon capture and sequestration could perhaps be a competitive alternative option.

The results of the two studies described above were part of the decision process which led Finland to launch the construction of a fifth nuclear unit in Olkiluoto, and France to consider the construction of a first domestic EPR in order to keep the nuclear option open for renewal of the existing nuclear plants, starting in 2020.
Similar signs can be observed in the USA, in China which recently decided to duplicate its Ling Ao and Qinshan II plants and to launch the implementation of a generation 3 model, as well as in many other countries.

The renewal of nuclear electricity production thus appears to be a strong economic trend, which is likely to be amplified in the near future due to fluctuating fossil fuel prices.

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