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COMPARISON OF ELECTRICITY GENERATION COSTS

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ABSTRACT

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The economical competitiveness of various power plant alternatives is compared. The comparison comprises merely electricity producing power plants. Combined heat and power (CHP) producing power will cover part of the future power deficit in Finland, but also condensing power plants for base load production will be needed.

The following types of power plants are studied: nuclear power plant, combined cycle gas turbine plant, coal-fired condensing power plant, peat-fired condensing power plant, wood-fired condensing power plant and wind power plant.

The calculations are carried out by using the annuity method with a real interest rate of 5 % per annum and with a fixed price level as of January 2008. With the annual peak load utilization time of 8000 hours (corresponding to a load factor of 91,3 %) the production costs would be for nuclear electricity 35,0 €/MWh, for gas based electricity 59,2 €/MWh and for coal based electricity 64,4 €/MWh, when using a price of 23 €/tonCO2 for the carbon dioxide emission trading. Without emission trading the production cost of gas electricity is 51,2 €/MWh and that of coal electricity 45,7 €/MWh and nuclear remains the same (35,0 €/MWh)

In order to study the impact of changes in the input data, a sensitivity analysis has been carried out. It reveals that the advantage of the nuclear power is quite clear. E.g. the nuclear electricity is rather insensitive to the changes of nuclear fuel price, whereas for natural gas alternative the rising trend of gas price causes the greatest risk. Furthermore, increase of emission trading price improves the competitiveness of the nuclear alternative.

The competitiveness and payback of the nuclear power investment is studied also as such by using various electricity market prices for determining the revenues generated by the investment. The profitability of the investment is excellent, if the market price of electricity is 50 €/MWh or more.

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1 INTRODUCTION

The comparison of electricity production cost of various power plant alternatives forms the basis for preparation and decision making of new power plant investments. In this study the competitiveness comparison is carried out for merely electricity producing alternatives. The task is to find the most economical alternative for additional production of base load power. Combined heat and power (CHP) plants are not included in the comparison, because the breakdown of their production cost between electricity and heat can be made in many different manners. In good locations CHP plants are competitive, but the total potential of new applications is modest. Further construction of CHP plants will cover part of the future power supply deficit, but in addition new condensing power capacity will needed.

The following types of power plants are included in the study:
- nuclear power plant,
- combined cycle gas turbine plant,
- coal-fired condensing power plant
- peat-fired condensing power plant.
- wood-fired condensing power plant
- wind power plant

All the power plant alternatives represent today’s technology and their output capacities have been selected so big that the scale benefit of a big unit size can be utilized as much as possible. For peat and wood power plants the fuel supply restricts the unit size. Peat and wood fuel should be received within a distance of about 100 kilometers from the power plant site in order to avoid remarkable increase of fuel transport costs.

Fossil fuel and peat fired power plants produce carbon dioxide, which emissions should be restricted in accordance with the Finnish energy policy. In the calculations, the influence of the restriction of greenhouse gases is taken into account through the cost of the emission right.

The competitiveness and payback of the nuclear investment is also studied as such so that the incomes gained by the investment are calculated on the basis of several different electricity market prices.

2 PERFORMANCE AND COST DATA OF THE POWER PLANTS

The price level of power plant construction has risen remarkably during the recent years. The price increase has been caused by the growth of construction costs, the prices of metals (steel, copper and aluminum) and power plant components as well as the unbalance between demand and supply in the field of power plant construction. In addition, the fuel prices have rise rather strongly during the recent years. The general cost growth increases the operation and maintenance costs.

The price level of January 2008 has been used in the calculations. The investment costs do not include the value added taxes. The interests during construction and all owners costs are included in the investment costs. Thus, the investment cost equals the turnkey price of the complete power plant at the commercial commissioning date. For the nuclear power plant a construction time of six years has been used and for the other alternatives shorter times. The efficiency of electricity production is expressed as the annual efficiency corresponding to the whole year average. The possible state subsidies (such as investment subsidy) for wood and wind plants have not taken into account.

The nuclear power plant is a light water reactor plant (pressurized water reactor, PWR or boiling water reactor, BWR). The capacity of the plant has been fixed at 1500 MW representing the unit size category of the biggest available plants and consequently the investment cost per output capacity used in the calculations (euro per kilowatt, €/kW) utilizes the scale benefit in full. The initial uranium fuel loading of the reactor core is included in the investment, as well. In this study the nuclear investment cost is based on the case that the plant is constructed at a new site. The investment cost of the plant including the interests during construction equals 4125 million euro corresponding to 2750 €/kW.

All the expenses of nuclear waste treatment (including the final disposal of the spent fuel) and decommissioning of the plant are included in the operation and maintenance costs through the annual payments to the nuclear waste fund. The share of these payments is about one quarter of the operation and maintenance costs. The maintenance investments of the plant are also included in the operation and maintenance costs. The net efficiency of electricity production is 37 %.

The combined cycle gas turbine plant is assumed to locate near the existing natural gas network so that the connection fee to the existing gas network does not contribute much to the investment cost. The combined cycle gas turbine plant consists of a gas turbine, a waste heat boiler and a steam turbine. The output capacity of the plants is 400 MW and its efficiency 58 %. The investment cost of the combined cycle gas turbine plant is 280 million euro (700 €/kW).

The coal-fired power plant is based on pulverised coal combustion and the size of the plant is 500 MW. The coal plant would be located on the sea coast. The plant is equipped with SO_x and NO_x removal units. . The efficiency of the coal power plant equals to 42 %. The investment cost is 650 million euro (1300 €/kW).

The peat-fired power plant is based on fluidised bed combustion. The output capacity is 150 MW and the efficiency 40 %. Peat-fired power plant costs 225 million euro (1500 €/kW).

At present wood is used as power plant fuel only in combined heat and power (CHP) plants. Wood residual chips (forest chips) is the cheapest available wood fuel and it suits best as mixture with milled peat. There are no merely electricity producing wood power plants in Finland, because their electricity production cost is clearly higher than that of other power plants and higher than the market price of electricity. The available power plant concepts are based on small CHP plants with a power output capacity of 30 MW at maximum. If the CHP plants are used as a reference, the investment cost of a merely electricity producing power plant would be over 3000 €/kW and the efficiency only 33 %. It can be assumed that increasing demand of wood power plants would decrease prices to some extent. In this study the investment cost of a 30 MW wood power plant is assumed to be 81 million euro (2700 €/kW) and the efficiency 33 %.

The experiences of wind power plants in Finland are based on coastal (on-shore type) locations. The level of investment cost has been 1000 to 1100 €/kW since late 1990's to the recent years. The investment cost level depends on the market volume, competition situation, the project size and the local conditions of the site. The increased demand and the price increase of materials (steel and aluminium) and components have clearly raised the prices recently. In reference /3/ the investment cost of wind mills located on the coast is estimated at 1300 €/kW. Off-shore wind power plants at sea would cost 2000 €/kW. In this study the investment cost of a 3MW coastal wind power plant is assumed to be 3,9 million euro (1300 €/kW).

According to the production statistics of wind power the average peak load utilization time was 1789 hours per year in the year 2006 /2/. The best ten plants exceeded a peak load utilization time of 2400 hours. In the year 2005 with better wind conditions the respective average peak load utilization time was 2010 h/a and the best 20 plants exceeded 2400 a peak load utilization time of 2400 hours. In this study a peak load utilization time of 2200 hours per year is used. A life time of 25 years is used in the calculations.

Based on the operation experience of existing wind power plants the operation and maintenance costs vary between 10 and 15 €/MWh, of which advance maintenance and fault repair make major part. A bigger unit size and grouping of the plants in bigger wind power parks might decrease the operation and maintenance costs in the future. In this study a value of 11 €/MWh is used for the operation and maintenance costs.

The prices of fuels have risen recently quite strongly. The rise of the oil world market price is reflected clearly to the natural gas price, even if the influence mechanism has some delay. The price of coal has grown because of oil price increase and increased demand of coal. The price of nuclear fuel consists of the prices of natural uranium, enrichment work and fabrication of fuel elements. The increase of the natural uranium price has caused the biggest growth to the nuclear fuel costs. The following fuel prices have been used in this study: nuclear fuel 1,85 €/MWh, natural gas 23,2 €/MWh, coal 11,0 €/MWh, peat 8,90 €/MWh and wood chips 13,4 €/MWh /4/. It is to be noted that the price of nuclear fuel is only a small share of the price level of the other fuels and that the price of natural gas is clearly higher than that of coal, peat and wood.

The influence of greenhouse gas restrictions is realized through the emission price of the emission trading market. This contributes an addition to the production cost of gas, coal and peat power, but there is no additional cost for carbon dioxide free nuclear, wind and wood power. Future prices of emission rights have been valued at the electricity exchange market till year 2012. In the base case of the calculations the forward emission right price of 2012, 23 €/tonCO2, has been used. In one background study of the EU a forward price of almost 60 €/tonCO2 for period 2013-2020 has been estimated. In the calculations the electricity production costs has been calculated with emission prices of 0, 23 and 60 €/tonCO2.

The peak load utilization times of the Finnish nuclear power plants have on the average been over 8000 hours per year and reached even to 8400 hours. For the base case a peak load utilization time of 8000 hours per year corresponding to a load factor of 91,3 % has been used. The same value has been used also for the other power plant alternatives except for the wind power. In the reality the peak load utilization times for gas, coal, peat and wood plats would be shorter, but for equality the same value as for the nuclear power is used.

The economical lifetimes of power plants describe the time period during which the power plant investment should pay itself back. The technical lifetime is usually longer than this. The technical lifetime of a nuclear power plant is 60 years and an economical lifetime of 40 years is used in the calculations. The necessary annual maintenance investments for achieving this are included in the operation and maintenance costs the nuclear alternative. For the other power plants an economical lifetime of 25 years is used and their operation and maintenance costs do not include any special annual maintenance investments.

The economical profitability of the power plant investment depends on the market price of electricity. The emission restrictions and the emission price have clear impact on the future development of the electricity market price, which obviously increasing. The forward price of electricity for the year 2013 is 53 €/MWh and around year 2020 the price might well be of the order of 60-70 €/MWh. When calculating the payback and other profitability indicators of the nuclear power investment market prices 40 to 70 €/MWh have been used.

The performance and cost data of the power plant investments have been summarized in Table 1 and Appendix 1 presents the input data in graphically.

Table 1. Performance and costs data of the power plants, the price level of January 2008

PERFORMANCE AND COST DATA OF THE POWER PLANTS

INPUT DATA **January 2008 prices**

	NUCLEAR	GAS	COAL	PEAT	WOOD	WIND
ELECTRIC POWER [MW]	1500	400	500	150	30	3
NET EFFICIENCYRATE [%]	**37 %**	**58 %**	**42 %**	**40 %**	**33 %**	**-**
INVESTMENT COST [million €]	4125	280	650	225	81	3,9
SPECIFIC INVESTMENT COST [€/kW]	**2750**	**700**	**1300**	**1500**	**2700**	**1300**
FUEL PRICE [€/MWh]	**1,85**	**23,20**	**11,00**	**8,90**	**13,40**	**-**
FUEL COST OF ELECTRICITY PRODUCTION [€/MWh]	5,00	40,00	26,19	22,25	40,61	-
OPERATION AND MAINTENANCE COSTS, WHEN 8000 h/a [€/MWh]	**10,00**	**5,00**	**8,00**	**8,00**	**9,00**	**11,00**
SHARE OF VARIABLE O&M COSTS [%]	50 %	65 %	70 %	50 %	40 %	40 %
ECONOMIC LIFETIME [a]	**40**	**25**	**25**	**25**	**25**	**25**
REAL INTEREST RATE [%]	**5,00 %**	**5,00 %**	**5,00 %**	**5,00 %**	**5,00 %**	**5,00 %**
ANNUITY FACTOR [%]	5,83 %	7,10 %	7,10 %	7,10 %	7,10 %	7,10 %
EMISSION PRICE [t/CO2]	**23**	**23**	**23**	**23**	**23**	**23**
FULL LOAD UTILIZATION TIME [h/a]	**8000**	**8000**	**8000**	**8000**	**8000**	**2200**
CAPACITY FACTOR [%]	91,3 %	91,3 %	91,3 %	91,3 %	91,3 %	25,1 %

3 CALCULATION METHOD

An own-cost power production cost without any business profit and taxes is calculated for each power plant alternative. The annuity method is applied together with real interest rate and fixed price level. The principle of the annuity method is that the annual capital cost is calculated as equal installments for the economical lifetime of the investment. With these installments the investment and the interests will be paid back by the end of the economical lifetime. The real interest rate is approximately the nominal interest rate minus the inflation rate, if the inflation is small. On the basis of the nominal interests rates during this decennium the real interest rate has been of the order of 2-3 %.

In the base case a real interest rate of 5 % is used which is about two percents higher than the actual real interest rate. In case of 100 % debt financing this would make the capital costs higher than in the reality. Thus, the calculation is to some extent conservative. On the other hand, it is useful to have a small margin in the calculation interest rate which can compensate possible opposite changes in the input data. Alternatively, the margin of real interest rate corresponds to a mild business profit for the investment during its 40 year economical lifetime. In the base case the annuity factor is for nuclear power 5,83 % (5 %, 40 years) and 7,10 % for the other alternatives (5 %, 25 years).

The own-cost power production costs can be used for the competitiveness comparison between the various alternatives, but as such they do not express the profitability in the sense of business economy. The price difference between the electricity market price and the own-cost price during the whole economic lifetime will determine the business economy profitability.

The impact of changes in the input data has been studied in a sensitivity analysis by varying one of the input data at a time.

The profitability and payback of the nuclear investment is examined also alone so that various electricity market prices are used to calculate the incoming cash flow achieved by the investment. The results are presented as payback drawings and the payback time, the present value and the internal rate of return are calculated, as well.

4 RESULTS

4.1 Electricity generation costs without emission trading

The power production costs of the alternatives without emission trading are presented in Figure 1 and Table 2. The cost of nuclear power equals 35,0 €/MWh, which is the lowest of the alternatives studied. The cost of peat power is 43,6 €/MWh, that of coal power 45,7 €/MWh and that of gas power 51,2 €/MWh. Gas power is 16,2 €/MWh, coal power 10,7 €/MWh and peat power 8,6 €/MWh more expensive than nuclear power. The cost of wind electricity amounts to 52,9 €/MWh and that of wood power 73,6 €/MWh.

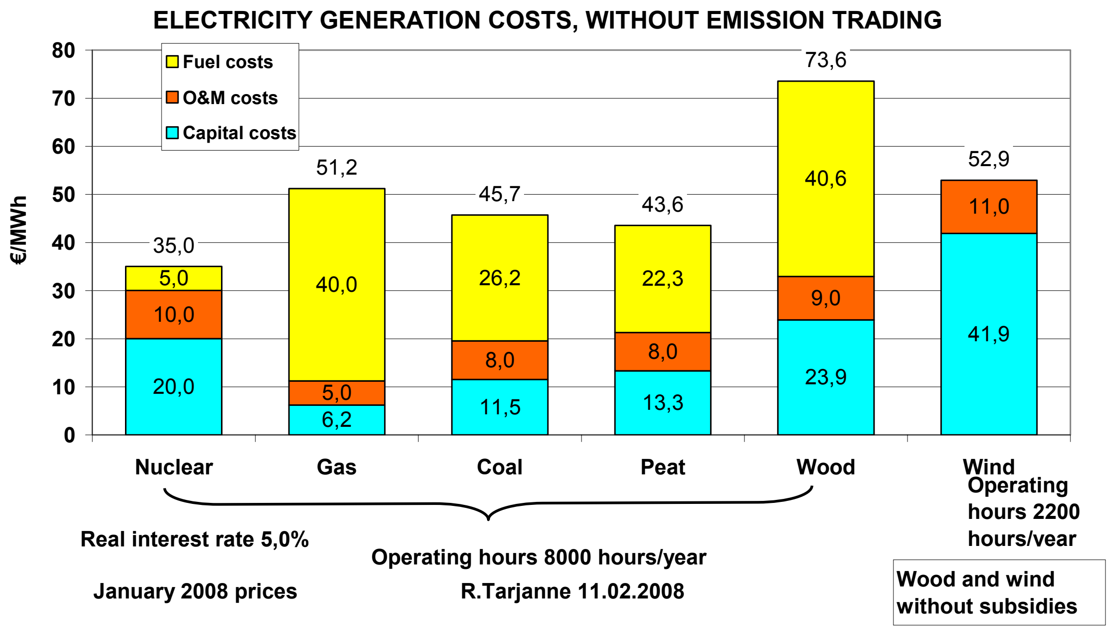

Figure 1. The electricity generation costs of the power plants, without emission trading.

The capital cost component is dominating in the nuclear and wind generation cost. The capital cost of wind power is about twice of that of nuclear power and for wood power it is to some extent higher than that of nuclear. For gas and wood the fuel cost component is remarkable – about 40 €/MWh, whereas for nuclear the fuel cost is very modest.

Because of the emission constraints, coal and peat suit badly for additional production of base load. According to the national climate and energy strategy of 2005 the use of coal should be restricted strongly. (The cost increase due to the emission trading as presented in the results below reveals concretely the decrease of the competitiveness of coal and peat.) Of the emission free alternatives the competitiveness of wood is weak (without the influence of the emission trading). The generation costs of low emission gas electricity and wind power are little over 50 €/MWh and thus over 15 €/MWh more expensive than nuclear power.

Table 2. The electricity generation costs of the power plants (€/MWh) without emission trading (5 % real interest rate).

COST ITEM	Nuclear	Gas	Coal	Peat	Wood	Wind
Capital cost	20,0	6,2	11,5	13,3	23,9	41,9
Operation and maintenance	10,0	5,0	8,0	8,0	9,0	11,0
Fuel	5,0	40,0	26,2	22,3	40,6	0,0
TOTAL	**35,0**	**51,2**	**45,7**	**43,6**	**73,6**	**52,9**

4.2 Electricity generation costs with emission trading

The power production costs with emission price of 23 €/tCO2 are presented in Figure 2 and Table 3. As a consequence of the emission trading the total electricity generation costs will grow to 59,2 €/MWh for gas-based electricity, to 64,4 €/MWh for coal-based electricity and to 65,5 €/MWh for peat-based electricity, whereas nuclear power generation costs remain at 35,0 €/MWh. Then gas power is almost 70 % and coal-based and peat-based power about 85 % more expensive than nuclear power.

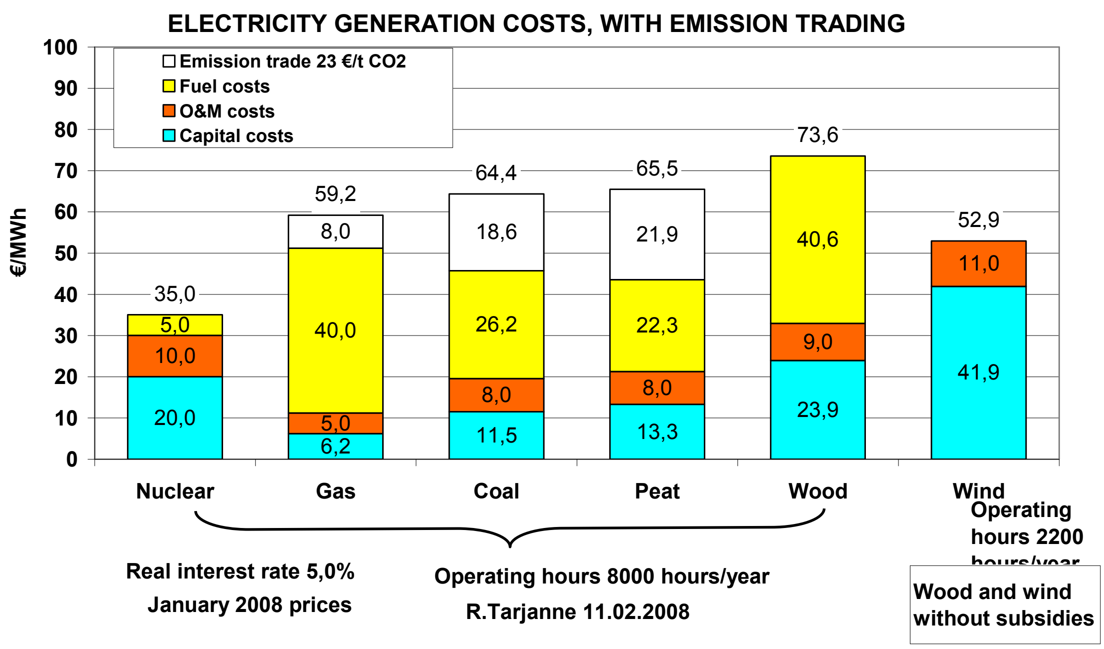

Figure 2. The electricity generation costs of the power plants with emission price of 23 €/tCO_2

Table 3. The electricity generation costs of the power plants (€/MWh) with emission price of 23 €/tCO_2 (5 % real interest rate).

COST ITEM	Nuclear	Gas	Coal	Peat	Wood	Wind
Capital cost	20,0	6,2	11,5	13,3	23,9	41,9
Operation and maintenance	10,0	5,0	8,0	8,0	9,0	11,0
Fuel	5,0	40,0	26,2	22,3	40,6	0,0
Emission trading	-	8,0	18,6	21,9	-	-
TOTAL	**35,0**	**59,2**	**64,4**	**65,5**	**73,6**	**52,9**

The power production costs with emission price of 60 €/tCO2 are presented in Figure 3. Then wood power becomes cheaper than peat and coal power and approximately equal with gas power.

The emission trading improves the competitiveness of emission free alternatives against fossil fuel and peat alternatives. The competitiveness of nuclear over gas, coal and peat increases.

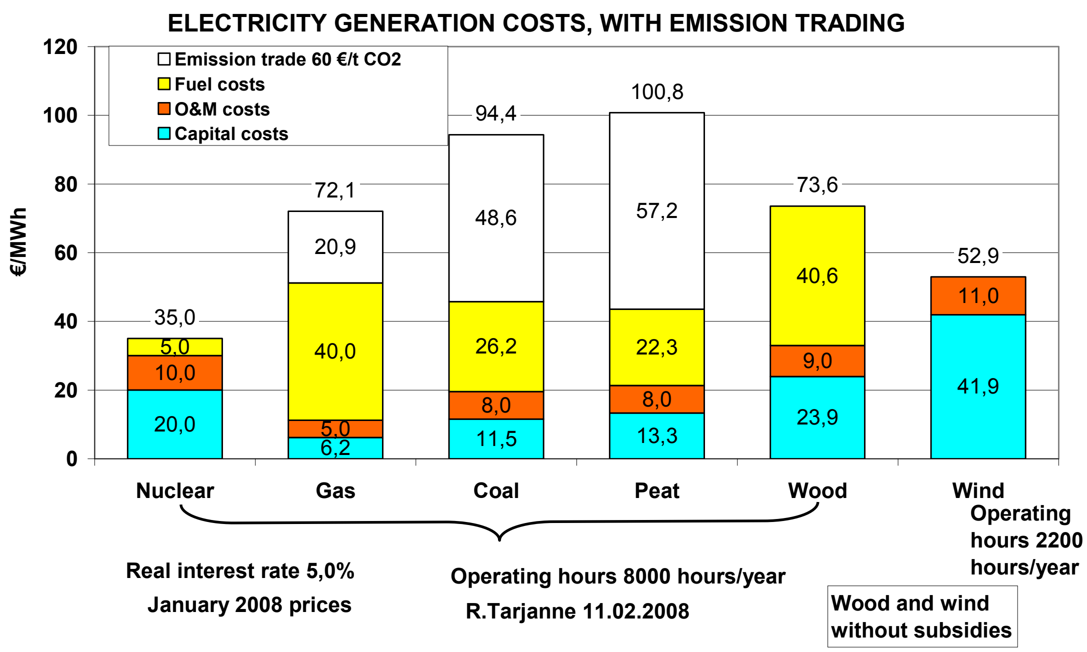

Figure 3. The electricity generation costs of the power plants with emission price of 60 €/tCO_2.

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5 SENSITIVITY ANALYSIS

The input data always contain to some extent uncertain or approximate values. Furthermore, the future involves own uncertainty factors. The impact of changes in the input data is studied in the sensitivity analysis.

In chapters 5.1 - 5.6 the impact of changes in the input data on the generation costs of the various alternatives are calculated. The following input values are varied: investment costs, fuel costs, carbon dioxide emission price, real interest rate, economic lifetime and annual full-capacity operating time.

The power generations costs with emission price of 23 €/tCO2 are used as the base case in the sensitivity analysis.

5.1 The impact of investment cost

The impact of investment cost on electricity generation cost is illustrated in figure 4. If the investment cost of the nuclear power would increase 20 %, the electricity generation costs would increase to 39,0 €/MWh. This is still clearly under the coal- and gas-based electricity generation costs and thus the impact on the competitiveness is small.

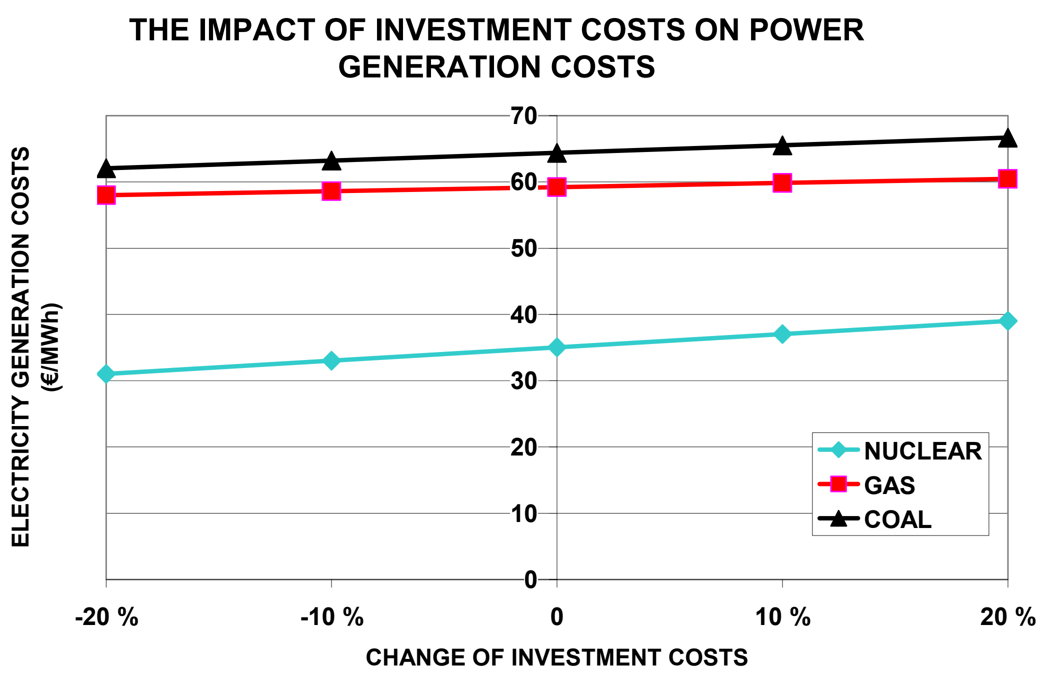
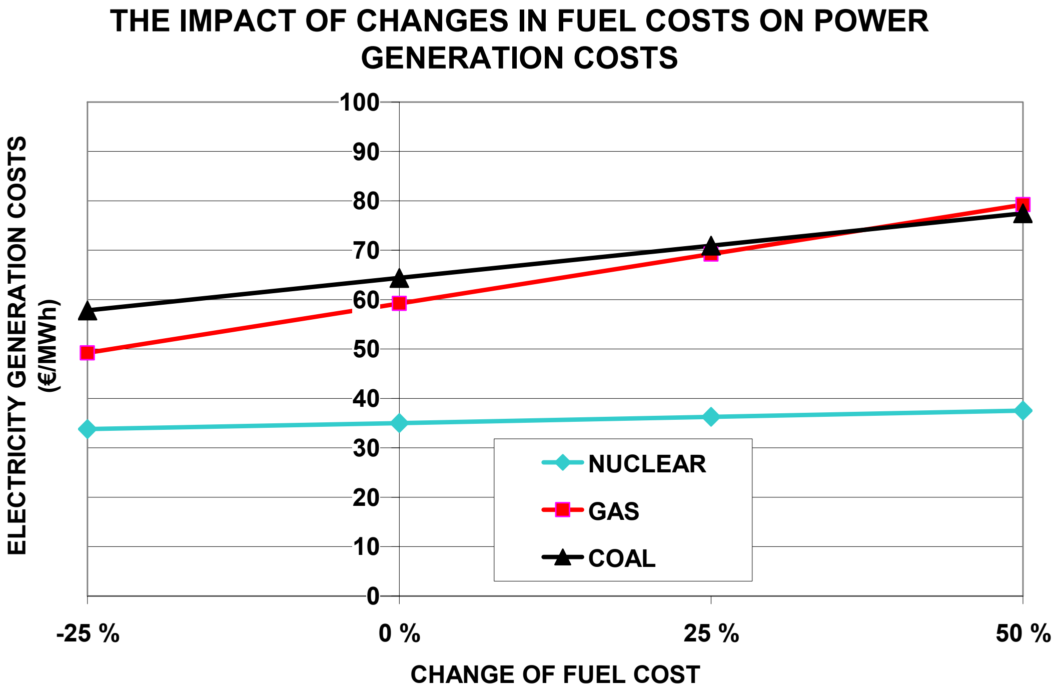


Figure 4. The impact of investment costs on power generation costs.

5.2 The impact of fuel cost

The impact of fuel cost on electricity generation cost is illustrated in Figure 5. If the fuel prices would increase 50 %, the cost of gas electricity would grow with 20 €/MWh and coal electricity with 13 €/MWh. But the increase of nuclear power would be only 2,5 €/MWh. The impact of increasing nuclear fuel cost is small, but the increase of the gas price causes a considerable increase of electricity generation cost.



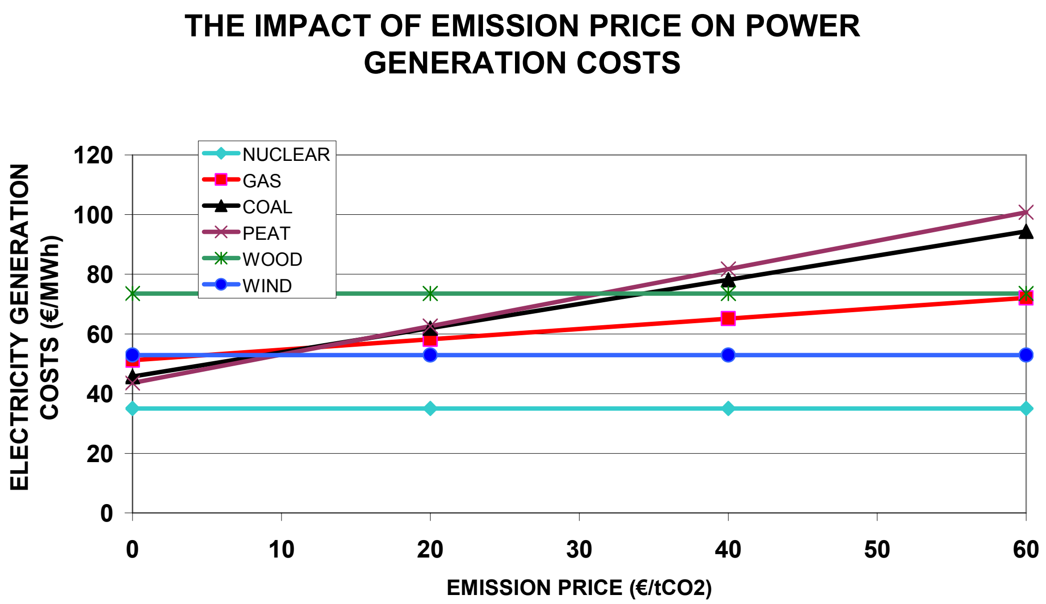
Kuva 5. The impact of fuel costs on power generation costs.

5.3 The impact of carbon dioxide emission price

Emission trading improves the competitiveness of carbon dioxide free power production alternatives compared to the fossil fuel based power plants. Nuclear, wood and wind power are carbon dioxide free.

Figure 6 illustrates the power production costs, when the cost of emission trade varies between 0 and 60 €/tCO_2. The values of power production costs presented in Figures 1, 2 and 3 with emission prices of 0, 23 ja 60 €/tCO2 can be read also from the lines of Figure 6. With high emission prices the changes of the competiveness of various power production means are remarkable.

Nuclear power is the most competitive production form already without emission trading, but its competitiveness compared to gas and coal power still increases with growing emission prices. If the emission price increases to value of 40 €/tCO2, the power generation costs of gas and coal power grows to values of 65,1 €/MWh and 78,2 €/MWh, respectively, while the production cost of nuclear remains at 35,0 €/MWh. As a carbon dioxide free production form also wind power becomes cheaper than gas, coal and peat power at the emission price of about 10 €/t. Wood power becomes cheaper than coal and peat power at the emission price of about 30 €/t.



Kuva 6. The impact of emission price on power generation costs.

5.4 The impact of real interest rate

The impact of real interest rate on electricity generation cost is illustrated in figure 7. The real interest rate varies in the range of 3 % to 15 %. The impact of the growth of the interest rate is greatest for the capital intensive production methods: nuclear, wind and wood power. When the real interest rate is below 15 % nuclear power is cheaper than all the other alternatives. At approximately 15 % nuclear power and gas power are equal.

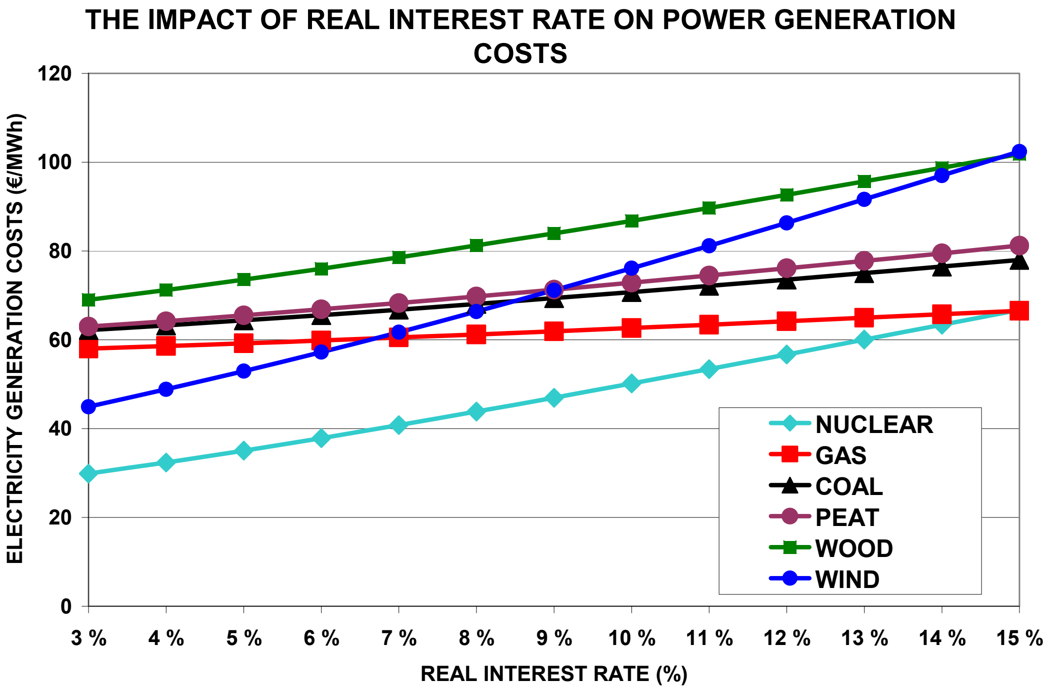


Figure 7. The impact of real interest rate on power generation costs.

5.5 The impact of economic lifetime

For the base case the economic lifetime was 40 years for nuclear power, and 25 years for the other alternatives. The impact of economic lifetime on electricity generation costs is presented in Figure 8. The economic lifetime varies in the range of 20 to 60 years.

If the economic lifetime is decreased from 40 years to 25 years, the production cost of nuclear power increases only with 4 €/MWh and nuclear power will still be the most economical option. For the other alternatives the increase of the lifetime from 25 years to 40 years does not have any essential impact on the results of the comparison.

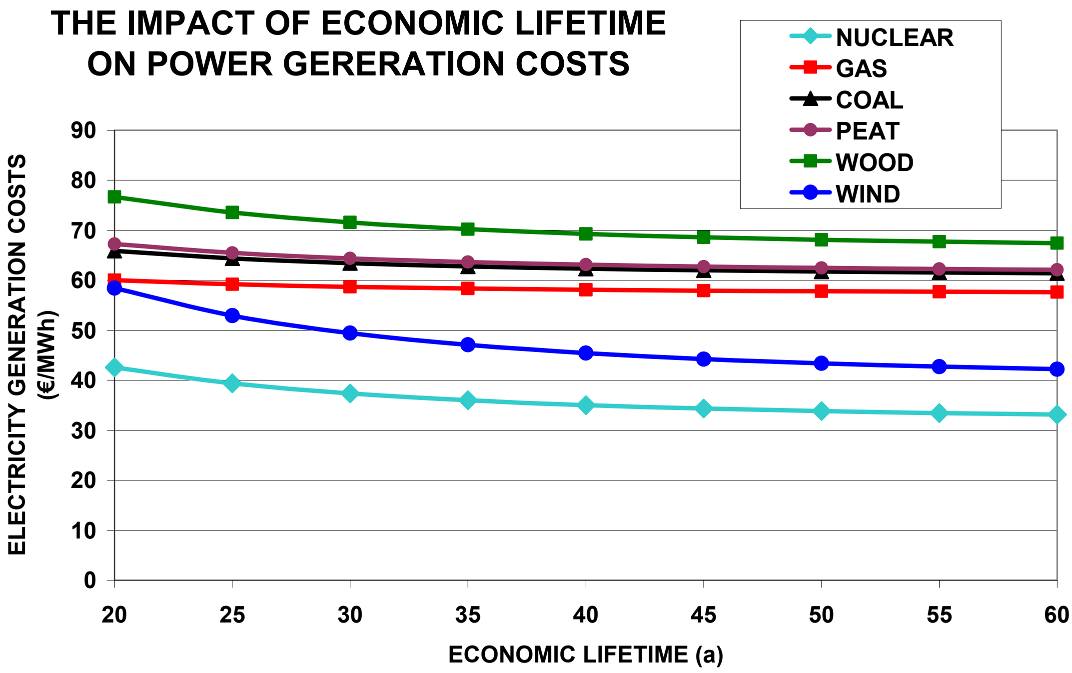


Figure 8. The impact of economic lifetime on power generation costs.

5.6 The impact of annual full-capacity operating hours

The impact of annual full-capacity operating hours on electricity generation cost is illustrated in figure 9. Wind power is not included, because its full-capacity operating hours cannot vary considerably.

The decrease of the full-capacity operating hours has the greatest impact on the capital intensive nuclear and wood power. When the full-capacity operating hours decreases from 8000 hours, the competitiveness of nuclear power compared to gas power remains good with medium class operating hours (around 5000 hours). Nuclear and gas power are equal at 3400 hours.

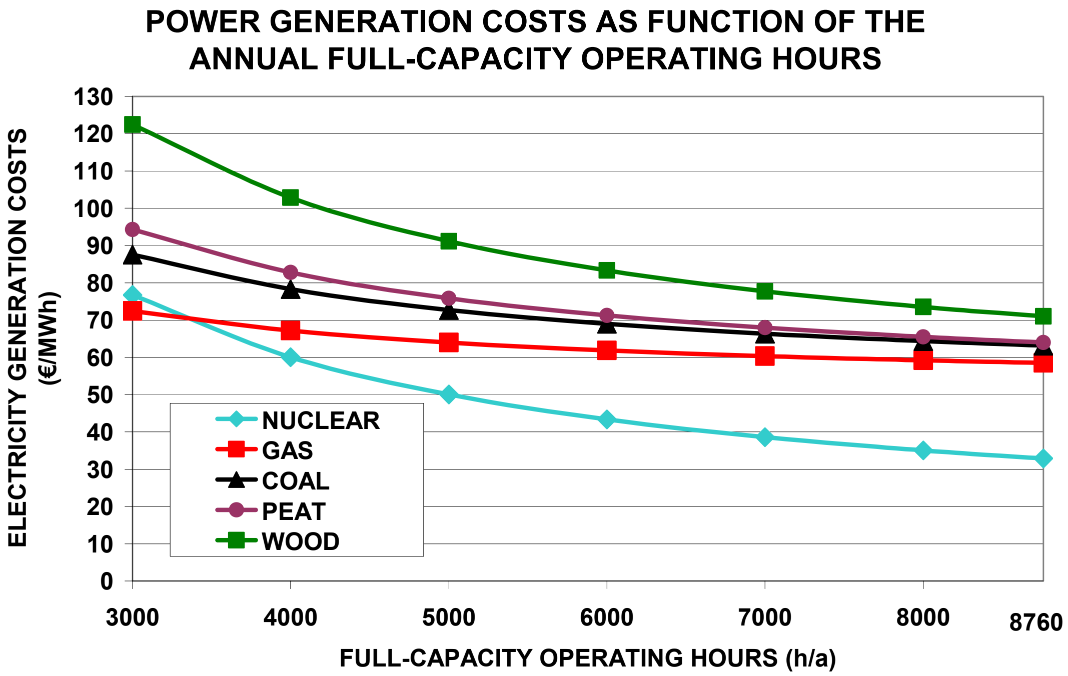


Figure 9. The impact of annual full-capacity operating hours on power generation costs.

6 PAYBACK OF NUCLEAR POWER INVESTMENT

In the competitiveness comparisons presented in the previous chapters the task was to find the most economical option for the additional production of the base load power. Nuclear power is by far the most economical choice in these comparisons. On the hand, it is possible to study the economy of the nuclear power investment alone so that the incomes earned by the investment are based on the market price of electricity.

The initial investment of the new 1500 MW nuclear power plant is 4125 million euro (2750 €/kW) and the economic lifetime 40 years. Excluded the capital costs, the annual costs of the plant comprise fuel costs (5 €/MWh) and operating and maintenance costs (10 €/MWh), which together make 15 €/MWh. The annual production of the plant is 12 TWh, which causes 180 million euro annual costs.

The incomes of the nuclear power plant originate from the electricity sales income. In the following the payback and other profitability indicators of the nuclear power investment are studied with various sales prices of electricity in the range of 35 to 70 €/MWh.

When the whole annual production of 12 TWh is sold at the own cost price of 35,03 €/MWh calculated in chapter 4 the annual sales income is 420,36 million euro. In that case the investment of 4125 million euro pays itself back in 40 years as shown in Figure 10.

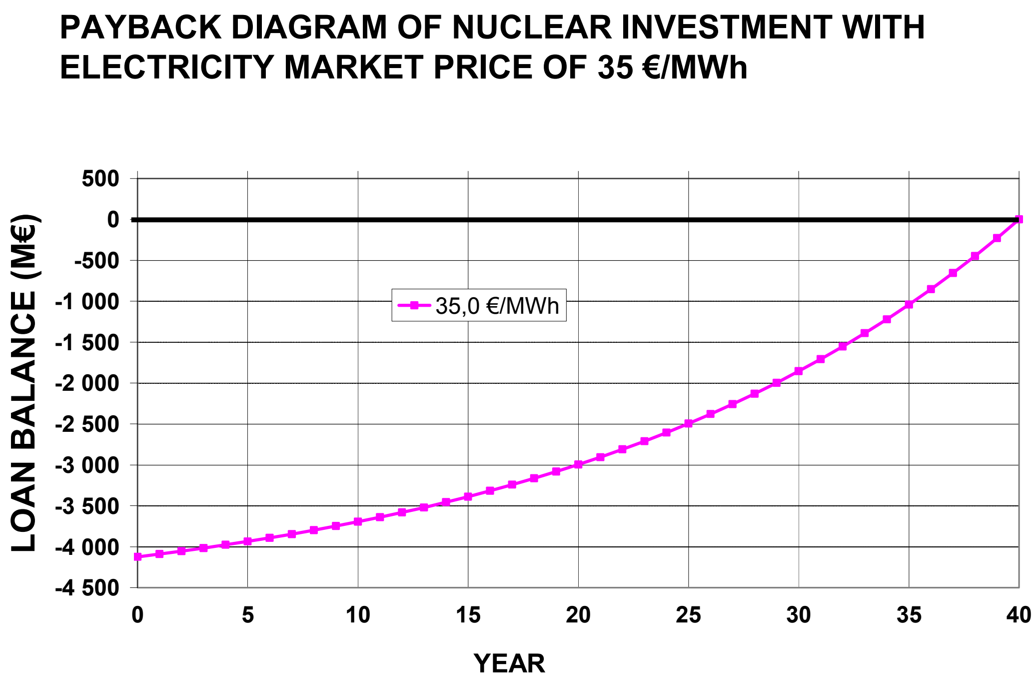


Figure 10. Payback diagram of the nuclear power plant investment at electricity sales price of 35,03 €/MWh (own cost price)

The market price of electricity is expected to be over 50 €/MWh in the future. In Figure 11 the payback diagrams of the nuclear power investment are presented at electricity sales prices of 35, 40, 45, 50 and 60 €/MWh. In Figure 12 the first 20 years period of Figure 11 is presented in a larger scale. The Figures show that the profitability of the investment is excellent at electricity sales prices of 50 ja 60 €/MWh. The respective payback times of the investment are 14 and 10 years.

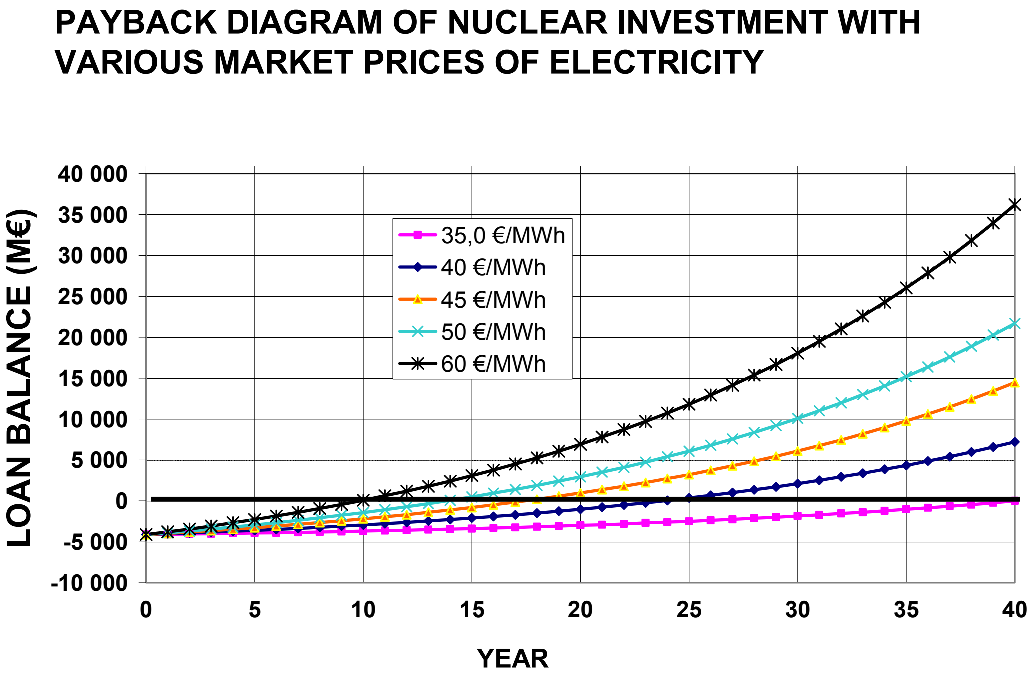


Figure 11. Payback diagrams of the nuclear power plant investment at electricity sales prices of 35, 40, 45, 50 and 60 €/MWh

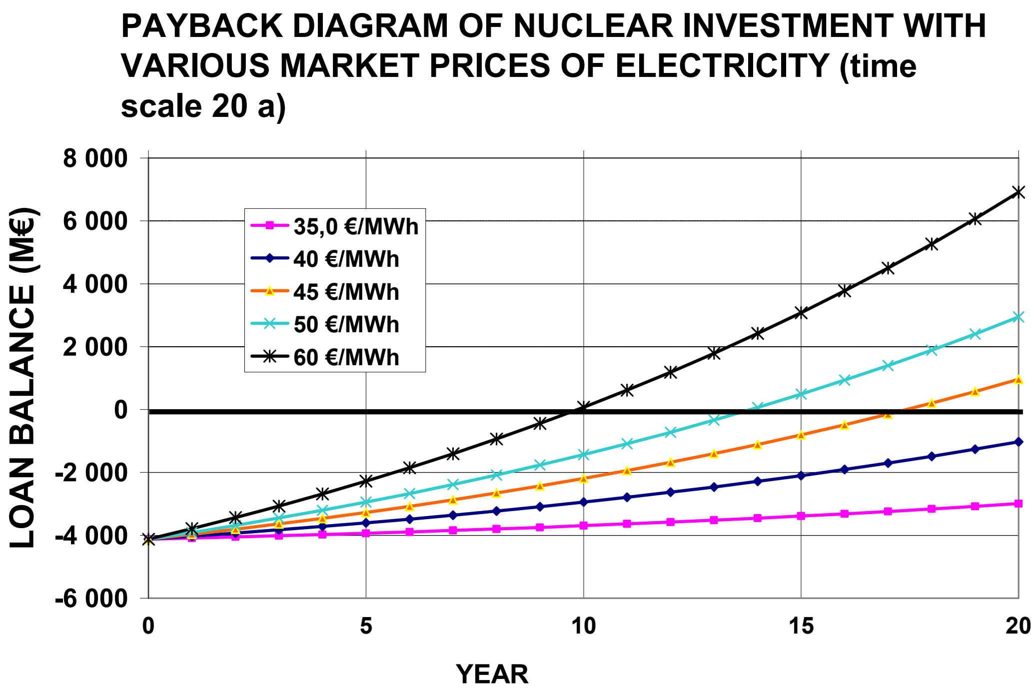


Figure 12. Payback diagrams of the nuclear power plant investment at electricity sales prices of 35, 40, 45, 50 and 60 €/MWh (time scale of 20 years)

Table 4. The profitability indicators of the nuclear power plant investment at various electricity sales prices

PROFITABILITY INDICATORS OF NUCLEAR INVESTMENT

OUTPUT CAPACITY	**1500**	**MW**
INVESTMENT =	**4125**	**M€**
STUDY PERIOD	**40**	**YEARS**

ELECTRICITY PRICE (€/MWh)	INTERNAL RATE OF RETURN	PRESENT VALUE (M€)	PAYBACK TIME (a)
35,03	5,00 %	0	40
40	6,74 %	1023	24
45	8,38 %	2052	17
50	9,95 %	3082	14
60	12,99 %	5141	10
70	15,96 %	7200	8

In addition, it is possible to calculate the internal rate of return and the the present value of the investment at various electricity sales prices. These results are summarized in Table 4. With electricity sales price of 50 €/MWh the internal rate of return of the investment is 10 % and with sales prices of 60 and 70 €/MWh as high as 13 and 16 %, respectively.

7 CONCLUSIONS

The electricity generation costs of the nuclear power plant with the annual full-load utilization time of 8000 h is 35,0 €/MWh, which is clearly the least cost option of all the electricity generation alternatives studied. With the emission price of 23 €/tCO2, the gas-based electricity would cost 59,2 €/MWh and the coal-based electricity 64,4 €/MWh. Peat and wood electricity are more expensive.

The electricity market price is expected to grow in the beginning of the 2010's to the range of 50 to 60 €/MWh and thereafter still higher. The restrictions of the carbon dioxide emissions and the emission price have raising impact on the electricity market price.

Electricity generation costs of the nuclear power are stable. The growth of the uranium price causes only a slight increase in the nuclear electricity cost, whereas the gas alternative is sensitive to the changes of the fuel price. The increasing use of gas in Europe causes a risk for considerable growth of the gas price which would lead to higher generation cost of the gas power. The impact of investment cost is greatest for the nuclear power. Gas based electricity is less sensitivity for the changes of the investment cost. However, even quite big increase of the investment cost does not change the competitiveness between nuclear and gas electricity.

The sensitivity analysis reveals that the nuclear power maintains well its competitiveness compared to the other electricity generation forms. Some changes in the input data, such as the growth of fuel prices and emission prices, make the competitiveness of the nuclear power even better. Emission trading will increase the electricity generation costs of gas-, coal- and peat-based power plants – perhaps even remarkably. The electricity market price will grow in the Nordic countries. Consequently, the advantage of nuclear power will still be improved.

When the profitability and payback of the nuclear investment is studied alone with various market prices of electricity, nuclear power turns out to be highly profitable. With the electricity sales price of 50 €/MWh the payback time of the investment is 14 years and the internal rate of return 10 %. With the sales price of 60 €/MWh the payback takes 10 years only and the internal rate of return is as high as 13 %.

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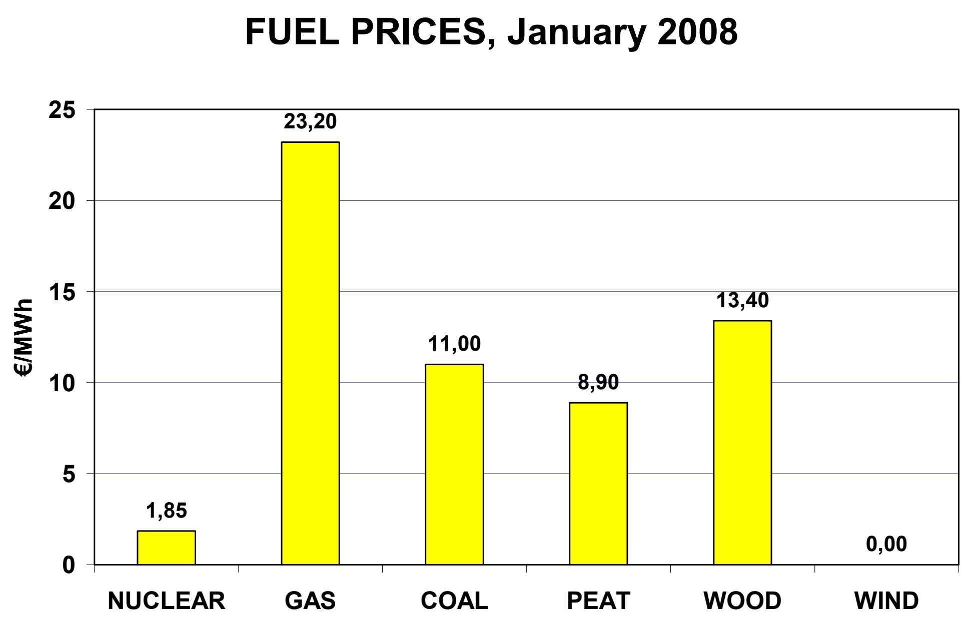
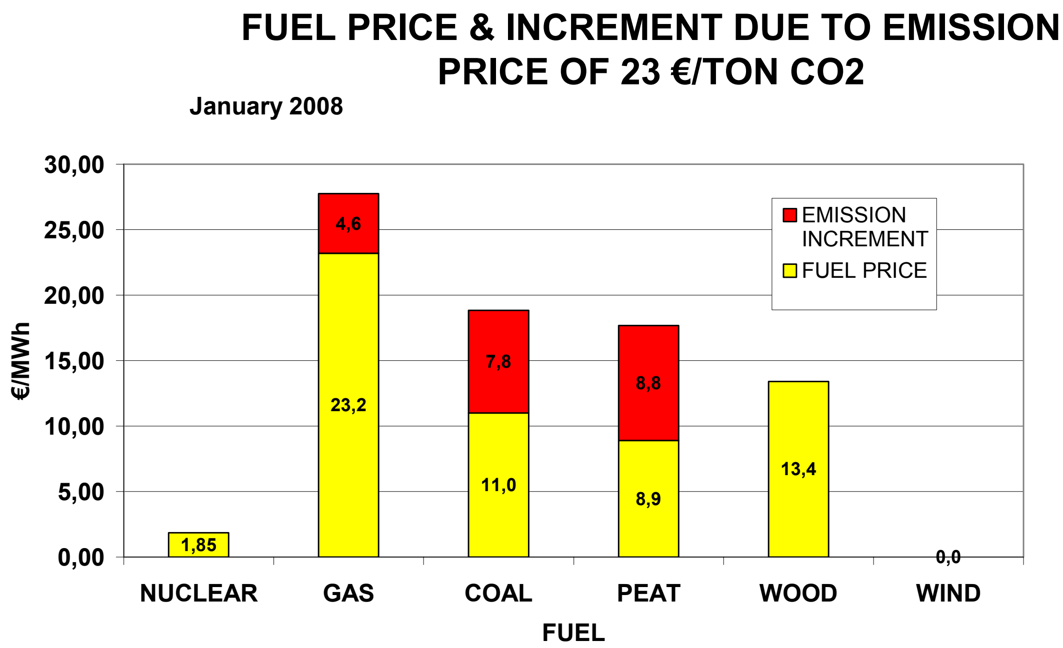
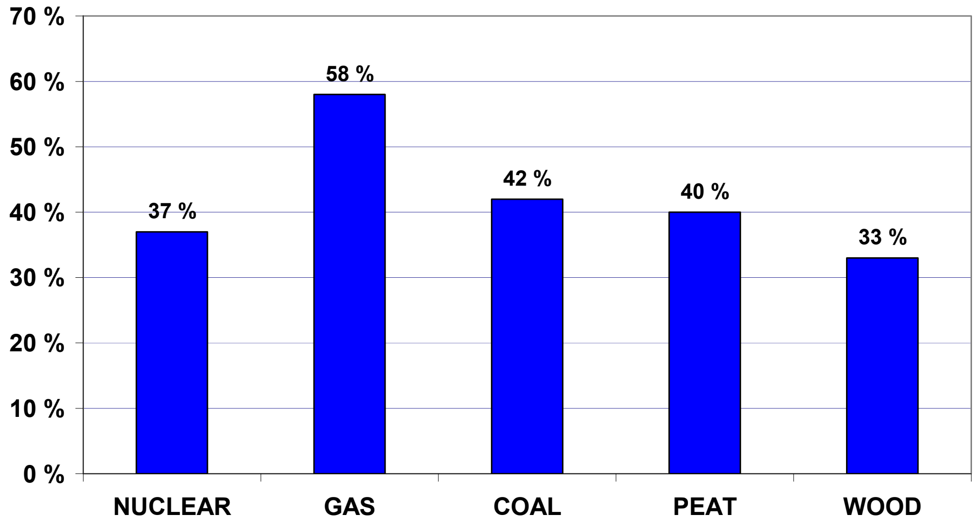
Appendix 1 The basic data of calculations





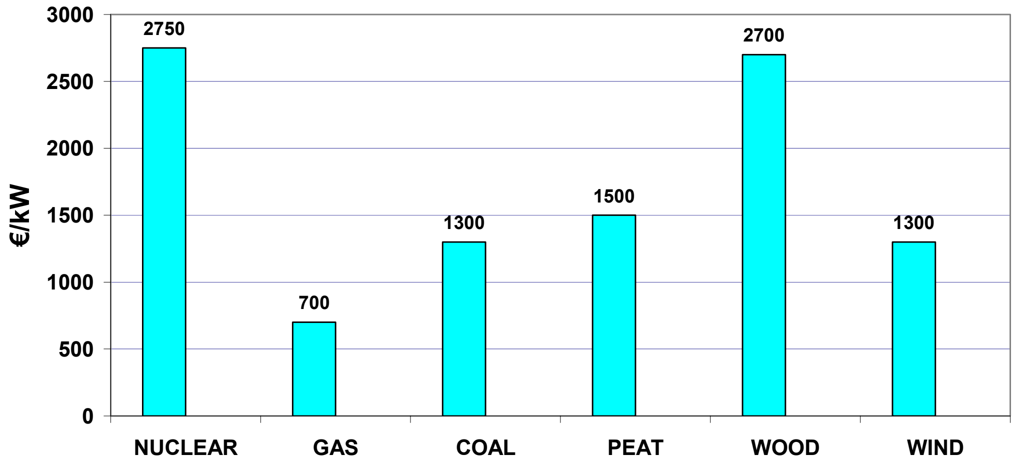
AVERAGE ANNUAL EFFICIENCIES OF POWER PLANTS



January 2008

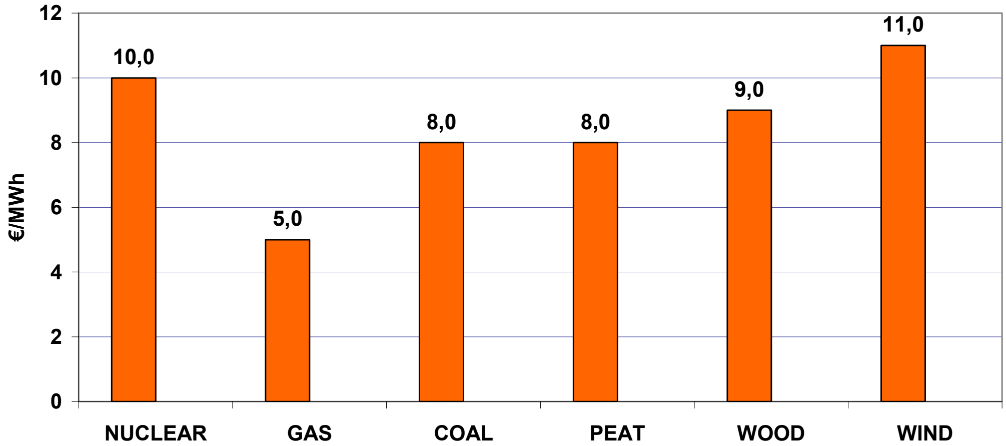
SPECIFIC INVESTMENT COSTS OF POWER PLANTS (€/kW)

(THE INTERESTS DURING CONSTRUCTION ARE INCLUDED IN THE INVESTMENTS)



OPERATION AND MAINTENANCE COSTS 1/2008

(NUCLEAR WASTE MANAGEMENT COSTS ARE INCLUDED IN THE O&M COSTS. THEIR SHARE OF O&M COSTS IS ABOUT 25 %. THEY COVER THE COSTS OF MANAGEMENT OF SPENT FUEL, DECOMMISSIONING OF NPP AND LOW AND MEDIUM ACTIVE WASTE.)



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