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DECISION MAKING PRINCIPLES FOR POWER PLANTS - ECONOMIC, ENVIRONMENTAL AND SOCIAL ASPECTS

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1. The markets for power in the European Union

1.1. The principle of competition

One of the basic principles of the European Union is to promote a common European market and have unrestricted trade of commodities and services between the member countries. When the internal market started most of the member countries had regulation in the market for electricity not compatible with open exchange. Basically in most member countries the supply of electricity was based on local or regional vertically integrated monopolies. In this regime investment in new equipment usually was not the problem because the cost of investment could be shifted easily towards customers.
With the beginning of a new regulation based on an open market the industry began with a high level of capacity by far enough to supply all the electricity needed and be able to cope with unforeseen situations on the supply side.
The regulatory regime allows customers to buy electricity from who ever they want. This regime has been introduced step-by-step and now it is near to completion. Such a regime completely changes the conditions of investment in this market.

1.2. Regulation of the power market

The European Commission has issued a number of directives in recent years that had to be translated into national law in order to create an internal market regulation for all member countries that somehow fits open markets and trade between countries. There is a strict separation between production of electricity, transport, distribution and supply and trade. Whereas transport and distribution are considered monopolistic in nature, they are subject to specific regulation regarding network access and pricing. Production, supply and trade are open markets where the forces of competition should influence the market behaviour of producers and consumers.
This being the basic principle on the other hand a lot of regulation also refers to production activities regarding the energy mix on the one hand and a number of physically conditions regarding production activities.

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1.3. Environmental Regulation

Environmental Regulation for power plants and power installations is part of the general regulation for environmental protection and in addition there are specific rules and regulations for power plant emissions, particularly airborne emissions.

In general every installation that may interfere with nature has to be analysed by a so-called "*Environmental Impact Analysis*" which is a kind of documenttation of expected effects if the installation is realised. In addition, certain interactions with nature have to be analysed on the basis of the directive on the conservation of natural habitats and of wild fauna and flora.

Specifically power plants have to fulfil a number of quality standards regarding emissions of sulphur dioxide, nitrogen oxide, dust and others. The operator has to prove that these standars will be fulfilled during operation. The necessary procedures are explained in more detail in chapter 4 in this paper.

Regarding the emission of greenhouse gases the European Union has started a scheme of special permits for the emission of greenhouse gases particularly carbon dioxide. Operators receive a certain amount of permits and at the end of the year have to prove that the quantity of carbon emitted corresponds to the quantity of permits that the company has available. The system is flexible in that permits can be bought and sold on a market that has been established in the meantime. This system of flexible mechanisms anticipates the procedures that have been envisaged in the Kyoto Protocol for all participating countries. This system will strongly influence the decision-making on the choice of fuel and plant in the future. In addition to the markets for fuel and plants the conditions of this additional market influences all strategic and operational decisions. The price in the market for emission certificates will determine decision making in the same way as the price for fuel or the power plant itself.

1.4. The role of Renewables and CHP

The European Union has set itself ambitious targets regarding the future structure of energy production and energy consumption in Europe in order to comply with greenhouse gas reduction goals on the one hand and goals to reduce the import of fossil fuels particularly oil and natural gas in the future. In order to reach these goals the share of renewable energy in the production of electricity, heat and in the transport sector needs to grow and there will be binding targets for all European Union member countries in the future. To increase energy efficiency it is intended to increase the share of power production in combined heat and power (CHP) mode. This may require additional infrastructure for heat distribution and may also conflict with the

aim of increasing the energy efficiency in buildings 'which in turn will reduce the demand for heat in the future.
In order to increase the share of renewable energy member countries use different instruments on a national level. At present, the Union is working on a directive to increase import and export of renewables between European countries and other countries. This however, requires a certain standardisation of instruments of promoting renewables. The outcome of this political process of negotiation between countries is presently uncertain.

1.5. The role of European rules for national decision making

The market and industry structure in the electricity industry in European countries have been quite different in the past. And also at present there are quite remarkable differences regarding market structure, ownership and the role of government in respect to this industry. National governments have basically the say regarding the energy mix in the power sector (e. g. the decision on nuclear power) whereas the European Union has successfully introduced a number of market rules that are now binding in all European countries. However, the monitoring of these rules is to a large extend with national governments so that there still are lots of differences regarding the implementation of these rules.
To summarize: the introduction of the open market model for the electricity sector has been introduced in Europe on the basis of European regulation and also quite a number of important energy policy measures particularly in the area of environmental regulation have been strongly influenced by European policy makers. On the other hand a lot of national differences remain partly because of socio-cultural differences on the one hand and historic differences in market and industries structure on the other hand. One important difference is for example the strong role of municipal utility companies in some countries like Germany and the much more centralised structure in Britain with private ownership and in France with state ownership.
The basic paradigms of running a utility company and particularly of making strategic and investment decisions for the future have considerably changed during the last ten years in Europe. In the following, we will go into more details of these changes and will explain them from a German perspective.

2. Decision making in the market place

In a market environment, a power plant can only run if the price on the market for a certain hour at least covers the marginal cost of running this plant in this hour[1]. If a sufficient number of other operators exist, the individual operator with his plant will act as a price taker. That is no individual alone can influence the price on the market. All operators have to adjust to the price resulting from all the production plants and the decisions of all operators. Thus, we would expect that the prices on the market follow the merit order of power plants as can be seen from figure 1.

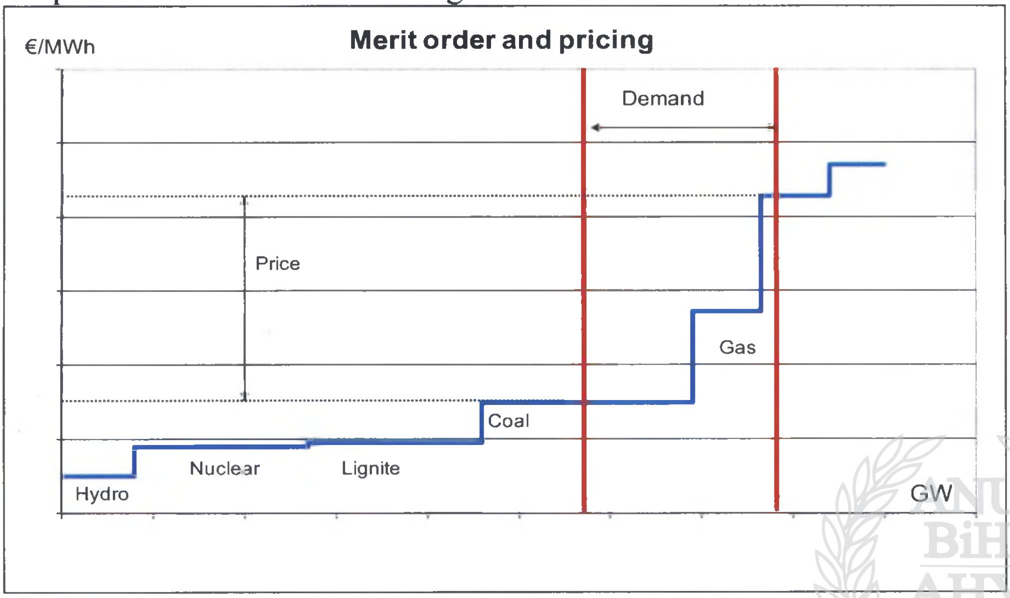


Figure 1: Merit order of power plants

As long as there is an abundance of capacity in the market, we can expect that prices will be largely determined by the short-term marginal cost of running different plants.

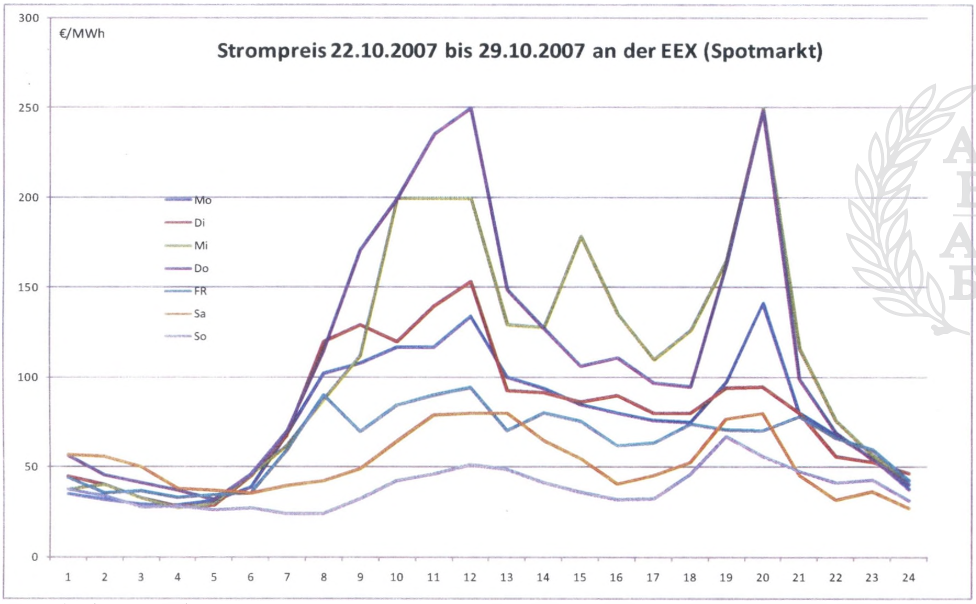
As we know however, this not a long-term solution because in the long run nobody can and will build power plants that do not cover total cost including fixed cost and all capital cost. When the introduction of the market model took place in Europe, there was in fact an abundance of power plant capacity. The newly created markets inherited a lot of capacity from the past constructed under completely different economic conditions. Formerly suppliers had a local or regional monopoly and could therefore plan investment without considering the market price of electricity set by competitors.

In the traditional model of organizing the electricity industry, a lot of the market risks are shifted towards the customer. In the new open market model, the division of risks between the market parties changes and the producer has to take some of the market risks particularly the risk of building power plants that might fail in the market because other competitors with a different cost

[1] The typical wholesale market time slice is one hour.

structure will set the market price in the future. There are of course also risks for the consumers: The consumer can choose between different products and particularly contracts for different periods of time. So there may be differences between the price development on the market on the one hand and the prices negotiated in the contracts on the other hand. Both of these risks however, are typical for market situations in all markets. We have to note however, that the long lifetime of assets in the power industry increases the risk of investment in this industry relative to other industries. Therefore, one of the crucial questions regarding the open market model in the electricity industry is whether under open market conditions there will be enough investment in the long run after the period of transformation from the former monopolistic model to the market model has been completed.

2.1. Price volatility



Price for all days of the week for 24h from October 22 to October 29, 2007, Source EEX

Figure 2: Wholesaleprice for power, EEX Spotmarkt, October 2007

It has been observed that in open electricity markets prices can become quite volatile from time to time that is at certain times prices move far away from marginal cost. This situation may only persist for a few hours but involves a great deal of risk for electricity traders. Figure 2 shows as an example the development of the spot market price for electricity at the European Power Exchange for a week in October 2007. The diagram shows the price curve for all days of the week over the 24 hour period.

As can be seen prices are almost the same for all days during off-peak hours during the night (between 22 h and 6 h in the morning). During the day peaks there are considerable differences between the week days particularly in this special week. There was a very strong price increase on Wednesday and Thursday. The explanation in this particularly case was that there was an unplanned outage of a large nuclear power plant during these days that ended on the Friday so that the price differences between the hours became much more moderate again.
This example shows that prices vary strongly depending on the short term availability of resources in the market. If resources are scarce for certain times we can expect strong price increases and there are examples where prices went up to 1,000 € per megawatt hour in the German spot market. Price peaks are beneficial for the producers because for certain hours they increase there income considerably above the level of marginal cost at the same hours. On the other hand such peaks occur at unexpected times and in unexpected intervals so it is difficult to plan for such income in order to make sure that the total cost of a plant can be met.

2.2. Investment decision in a market with volatile prices

In general an investment for a power plant is economically feasible if the plant can cover its total cost during operation. This is the case if there are sufficient hours during which the plant can achieve a positive margin above marginal cost that is sufficient to cover the fixed cost including the capital cost of the plant. In Figure 3 this is explained.

$$\sum_t (p_t - b_t) \geq C_{fix} \qquad \text{for all } t \text{ with } b_t \leq p_t$$

P = expected market price
b= expected variable cost
C_{fix}= fixed cost
t = time index (hour)
Plant can only run if marginal cost can be recovered
Plant has to recover fixed cost incl. of rate of return

Figure 3: Conditions for economic feasibility

Remember that for the plant to be successful two conditions have to be met:

1. A plant can only operate if marginal cost can be recovered, that is the price at a certain hour is greater or equal the marginal cost of this particular plant. This is the general principle, in real operations the problem is somewhat more complex because start up cost has to be considered as well.
2. On the other hand, the plant also has to achieve a surplus above marginal cost in a sufficient number of operating hours to also recover the fixed cost.

In order to analyse the conditions for a particular plant a so called price duration curve of the market is used. This is then compared to the conditions of the plant. The price duration curve itself is a listing of all prices achieved hour per hour in the market place ordered by its level. **Figure 4** now shows how we can find out about the economic feasibility of a plant in a situation with a given price duration curve. The marginal cost of an individual plant determines its potential hours of operation under given prices.

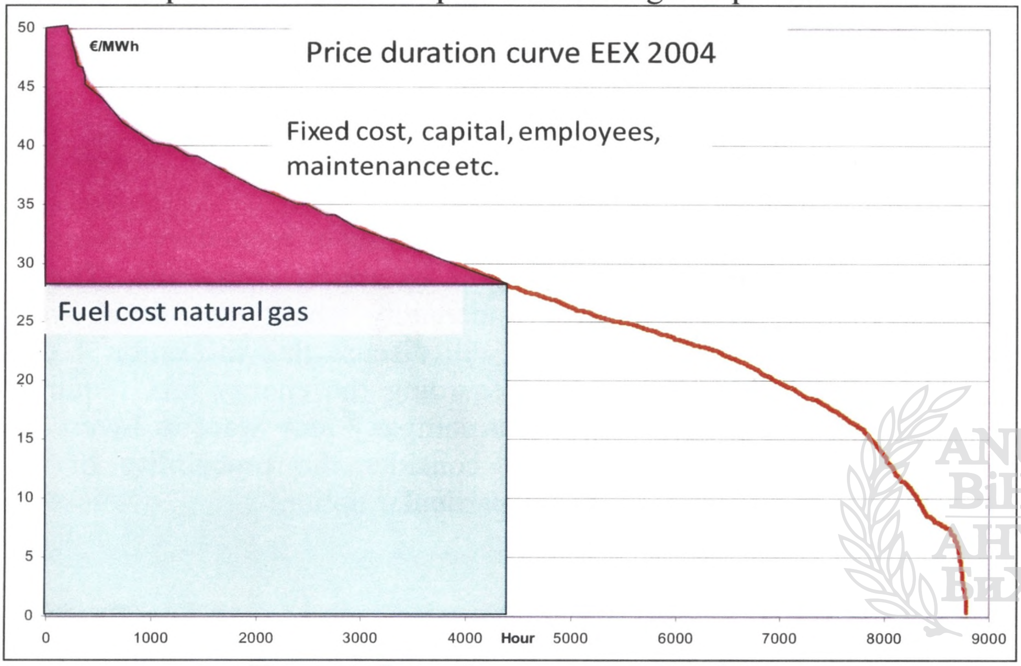


Figure 4: Price duration curve EEX 2004

The sum of all prices achieved during operating hours minus the marginal cost is the contribution of this plant to its fixed and capital cost. If the area above the marginal cost line is sufficient to cover the fixed cost, the plant can be run and investment is meaningful. If the area is too small and the fixed cost cannot be recovered from the market prices, then it does not make sense to invest in such a plant.

2.3. Market risks

There is, of course the problem of finding out about potential prices in the future. Under market conditions, the duration of contracts for power delivery is much smaller than the lifetime of power plants. Thus, market risks can not be reduced by simply having long term contracts. This problem is particularly relevant for highly capital intensive power plants like nuclear plants. There is an automatic tendency in the market mechanism to favour plants with low

capital intensity because the time required for the capital expenditure to flow back is much smaller. This is one of the explanations for the high share of natural gas plants in the United Kingdom, where the market model was introduced much earlier then in most other parts of Europe.
The market risks become smaller, if the number of players in the market gets smaller. An implicit coordination of investment plans can be more easily achieved than if the number of players is very large. To some extent there is a certain contradiction between competition wanted in order to have cost efficient prices and the long term problem of securing enough investment in order to reach the necessary security of supply.

2.4. Regulatory uncertainties

In addition to the market risks there are a number of regulatory uncertainties that may interfere with investment plans by utility companies. The most important one at present is the uncertainty about the future of the environmental regulatory regime. We will discuss this in section 4 of this paper. There are other uncertainties regarding the energy mix required by society or government If for instance a company may want to invest into a nuclear plant, it may also want to consider the probability of future government interference regarding this particular option.

2.5. Priority for Renewables

In order to promote the contribution of renewable energies to the production of electricity, producers of renewable electricity in Germany receive a special status. The production of renewable sources is given absolute priority in the network. Producers from others sources have to adjust their production to the amount of renewables available in the system at any time. With the high share of wind energy in the renewable portfolio and the erratic nature of wind energy the system has to adjust to a lot of short term changes caused by fluctuating inflows of power from wind energy plants. This increases investment uncertainties for potential investors for new plants. We will come back to this aspect in section 3 of this paper.

3. Network restrictions

3.1. Locational decisions and network

A location of a power plant depends on a number of factors like

- available infrastructure for transport of fuel and waste,

- availability of cooling water,
- availability of connection to power grid,
- availability of capacity in the grid to follow production plan for the plant.

Assuming that the physical requirements for a location (transport of fuels and waste, availability of cooling water) are met, in what way do network aspects influence the investment decision? From the point of view of system stability the network operator may have strong priorities for the location of plants in order to avoid network bottlenecks. These preferences must not coincide with the preferences by the producer who will prefer sites with good infrastructure availability plus low transport cost for the fuel. Theoretically, the potential network bottlenecks expressed in money terms should be balanced against the potential economic benefits of the producers in order to find the economic optimum. In practice however, the monetary value of network congestion may not be available and thus, decision making by plant investors may not fulfil the necessary conditions of the network.

In the German case in order to promote competition in the present legal situation plant operators have the right to be connected at any location of their choice and a certain priority will be given to new operators regarding the actual use of the network. This situation has caused a run towards locations with low transport costs for fuel (near the coast) where however, there is not sufficient power demand to use the potential output of these newly planned plants. Potentially there will be overproduction in certain regions and overdemand in other regions. Consequently, there may be bottlenecks in the network that require rescheduling of plants in general and may lead to much lower production in newly planned plants then the operator has envisaged. From this we can conclude that investment plans have to be coordinated with the network operator. The British system has developed solutions for this problem by applying different kinds of charges to newly connected power plants depending on the availability of network capacity. This will give an incentive to investors to plan production sites in conformity to the requirements of the grid.

3.2. National and international trade

As was mentioned in the introduction European policy strives for an open European electricity market where theoretically every customer in any member country can choose his supplier in any other member country. On the other hand there are network restrictions for international exchange of electricity between member countries. These restrictions are twofold:

- The conditions of network access may differ between countries so that the administrative procedures for trade activities are complicated

- Physical capacity may not be sufficient to allow international exchange in the volume required by customers.

Again here, we have a special optimization problem: to expand the network is meaningful as long as the extra network cost is lower than the cost differences for power between different regions. In Europe there are remarkable differences in production cost of electricity depending on the availability of certain cheap sources of energy (especially hydropower and nuclear). These sources are however restricted either by political factors or by natural/physical factors and therefore a re-allocation towards such cheaper sources in the longer run is only possible in a limited way. Yet international exchange of electricity within the given physical restrictions plays an important role between quite a numbers of European countries. The European Union is setting up regulation in order to cope with cross-border bottlenecks between countries.

Instead of exporting/importing power producers in the longer run can also think about setting up new power stations in regions where power prices are higher than in other regions. To give an example power shortages in the Netherlands lead to congestion in cross border transmission between the Netherlands and Germany. As a short-term solution, the transmission capacities are auctioned to interested parties. For a longer term solution German companies have decided to build power plants in the Netherlands.

Investment decisions for a new plant to mainly serve export purposes are not the case in Germany. For such a plant it may be necessary to build individual commercial power lines independent of the general grid in order to make sure that the export contract can be fulfilled without any restrictions from the ups and downs in the general grid. Such plans have been discussed but until now not realised.

4. Environmental regulation

Nowadays there is a very detailed regulation on all aspects of possible interference of power plants with the natural environment. For the erection of new plants or the change of existing plants permission is required. This permission is based on a number of administrative procedures. A potential investor of a new plant has to inform the authorities about a lot of aspects of his project. At a certain stage also a public hearing will take place so that the public can voice their concerns about any possible consequences of the investment planned. In this way the role of NGOs has been strengthened considerably. Often the concerns voiced by such organisations led to additional measures to be taken against unavoidable interference with natural structures that then have to be financed by the investor.

4.1. Command and control type regulation

The Federal Environmental Law (BImSchG) is the basis of all the administrative procedures. All power stations above a certain size are subject to the procedures for permission for building and running the plant. The strictest procedures apply to plants above a size of 50 MW but also smaller plants above 1 MW may need permits but procedures may be simplified. The aim of the law is to make sure that plants are built and operated in such a way that environmental quality can be maintained. In detail that implies:

1. There should be no damaging environmental effects or other dangers or other disadvantages for the general public and the neighbourhood.
2. Precautions should be taken against damaging environmental effects or other dangers or disadvantages especially taking measures corresponding to the state of the art.
3. Waste materials should be avoided, not avoidable waste material should be recycled and not recyclable waste should be deposited without interfering with general well-being.
4. Energy should be used in an efficient way.
5. In addition such plants have to be shut down in such a way that
6. There should be no damaging in environmental effects or other dangers or disadvantages for the general public and the neighbourhood.
7. Existing waste materials should be recycled in an orderly and undamaging way or should be deposited without interfering with general well-being.
8. The restoration of an orderly state of the area used should be granted (§ 5 BImSchG).

These general rules have been specified in great detail for different plants and there are several annexes to the law referring to power plants. These annexes contain detailed emission standards for power plants and the administrative procedures to monitor the actual emissions of plants after beginning of operation. In general measurements of emissions are continuous and just in time so that authorities can interfere immediately if emissions are above the standard. In addition standards may be increased above the values in the general law by local authorities if local conditions require higher standards.
These standards refer to nitrogen oxides, sulphur dioxide, metals like mercury, cadmium and many others, dioxin and similar substances and dust. The standards are defined as a maximum amount of substance per cubic metre of flue gas and are valid for the average of the day. In addition, there are also maximum values for half hour averages.
The introduction of these emission standards first for new plants and later also for all existing plants has led to a dramatic reduction of emissions of the substances mentioned.

4.2. Environmental impact analysis

For power stations also a general environmental impact analysis has to be carried out often in connection with the flora/fauna/habitat impact analysis. These instruments are used as precautionary measures against potential environmental effects of power plants. Therefore, the scope of this analysis is much wider than the emission standard regulation described above. Practically all natural factors that may be influenced by the building and operation of the plant have to be considered. Usually these analyses are carried out by expert institutes. Such an environmental impact analysis has to take care of the special conditions of any special location and therefore is independent of the particular power plant type. So, if the power plant of a certain type has been accepted by the authorities at location A this does not necessarily imply that it also will be accepted at location B.

Besides all the environmental factors possibly influenced by a power plant site, the availability of cooling water is a particularly important aspect. If water from rivers is used for this purpose the environmental impact analysis has to find out whether this could lead to a degradation of water quality in this particular river. This may necessitate the extra investment into a cooling tower or may lead to restricting the operation of the plant depending on the water temperature of the river arriving at the plant inflow. As was already mentioned the public is part of the procedure of an environmental impact analysis. The documentation of this analysis has to be published; afterwards there will be a public hearing. Interested parties can make statements on certain issues regarding the proposal which later on will be debated in a public hearing. At the end the authorities have to make a report also explaining their decisions regarding objections from the public. In this context, the principles laid down in the Federal Law for the protection of nature and landscape play an important role. According to this law, avoidable interference with nature and landscape should not take place. If interference cannot be avoided those causing the interference have to take measures to compensate for this interference. This compensation can take place by direct restitution on the one hand or by taking equivalent measures for instance in other areas. If, for instance for a new site for a power plant it is necessary to cut trees and the living conditions for animals in this untouched region will be changed, the investor will have to finance compensatory measures in another area. This could take the form of planting trees and making sure that the conditions for a wild life will be equivalent to the ones in the area where he wants to build his power plant. It is quite clear that with any project of a large kind negotiations on what kind of compensating measures will be adequate will start. In a densely populated country it will also be sometimes difficult to find adequate other territories where the compensation could take place. Protection of nature restricts the possible scope of industrial activity especially for new sites.

4.3. Energy taxes

Energy taxes depending on the way they are levied have an influence on decision making on power plants. In the German case energy taxes are mostly consumption taxes. With the so-called ecological tax reform in 1999 a tax on electricity was introduced, it has to be paid by the consumer. This tax is therefore neutral to the type of power plant orf fuel. In addition there are also taxes on certain fuels (but not coal); natural gas and oil are taxed and the tax party depends on the degree of efficiency in a particular plant. This is an incentive for higher efficiency possibly by using combined heat and power plants or using highly efficient combined cycle gas turbines.
In general the idea of taxing energy also is to give an incentive to consumers to reduce their consumption by increasing the efficiency of energy use. In the electricity industry in Germany this was not very successful until now because although more efficient equipment is being used continuously there are additional uses for electricity on the other hand so that consumption has risen to some extent. The rise has been relatively be small.

4.4. Regulation of Carbon emissions

As was already mentioned the European Union has introduced a carbon certificate scheme for all combustion units above a size of 20 MW. National governments have to set up a so-called *National Allocation Plan*, which lists the emission certificates granted to operators of energy combustion plants. The bulk of the certificates go to the electricity sector, mainly plants fired by coal or lignite. In the beginning the certificates were allocated free to operators. Although there was a surplus of certificates over emissions in the first period the price of the certificates rose considerably due to a lot of uncertainties with the beginning of the new system and also caused by some regional imbalances (Britain had to buy certificates in order to avoid running high price natural gas plants). In the present phase of the system the number of certificates allocated has been reduced so that the environment becomes a limiting factor for the enterprises. Present regulation in the European Union does not allow auctioning of all certificates to operators. In Germany the decision was made to sell a share of certificates to electricity operators by the government rather than allocating them for free. The price has presently settled at around 20 € / t CO_2 for the coming allocation period.

For the future the Eurolpean Commission now plans to sell all certificates in order to avoid negative distributional impacts that happened in the first phase (freely allocated certificates were considered as valuable assets by the enterprises and they increased their power prices accordingly).
The price of power has been influenced strongly by the new certificate system. As explained above the price of power depends on the marginal cost of the marginal plant at different times of consumption. As the diagram shows the marginal plants in Germany are either coal or natural gas plants, both subject to a price increase due to CO_2. The price for power from coal almost doubles and the price for natural gas increases less but natural gas in itself is much more expensive.

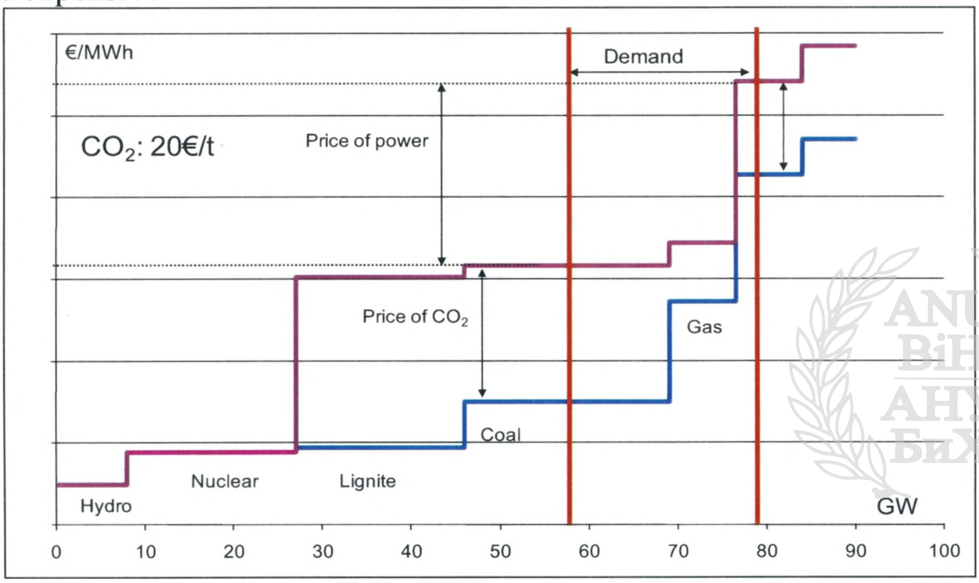


Figure 5: Merit order of power plants with a CO_2 price of 20€/t

It is one of the very important questions of present decision making on power plants on how the future regime for CO_2 certificates will influence investment behaviour. As was explained above the market price for power in the future is uncertain anyway because in liberalised markets the operator of the plant has to take a market risk. The uncertainty about the future price of CO_2 being responsible for about half of the cost of a power plant is a very important determinant of investment decision in the future.
There is a strong incentive in the carbon certificate system to invest into carbon free energy or alternatives with low carbon content. Whether the introduction of a CO_2 certificate system will lead to a revival of nuclear energy has led to controversial debates in recent years; there are also discussions on the possibility of extracting carbon from the flue gas and depositing it safely. However, there are no reliable technological concepts for this available yet.

4.5. Nuclear Energy

Nuclear Energy which accounts for about 30% of electricity produced in Germany is considered as a transitional energy and the parliament has passed legislation to gradually run down the nuclear plans within the next 12 years. The present legislation does not leave any room for new installations. Accordingly, there are no investment plans by German operators in Germany. German companies however, have announced that they might want to invest into nuclear plants in other European countries. The present political debate rather centers on the question whether it makes sense to close down the existing plants, which represent a very high technical standard long time before their lifetime ends. The legislator has decided that plants should not operate longer than the equivalent of 32 years. Permissions for the plant were originally granted for an unlimited life span as long as the plants fulfilled all the security criteria. The companies operating nuclear plants however, accepted the 32 year limit in a political bargaining process. There have been various proposals to change this legislation in order to be able to run the plants for a longer time but political parties are quite reluctant to changes this legislation because they fear repercussions in the public debate.

5. Social acceptance

The instruments described in this paper are instruments developed by parliamentary legislation and used by administrations at different levels. In addition, decision making on power plants may be influenced by social acceptance. Whether plants are accepted by the public or not depends on many criteria outside of the criteria we discussed until now in this paper. In the past it has been common practice for large energy companies to integrate local interests represented by regional stakeholders often in the form of special councils or bodies where regular meetings would inform regional stakeholders about the plans of the companies and the companies would listen to regional concerns. At the same time, it was quite common for companies holding a local or regional monopoly to finance or co finance public projects

This mechanism, which was quite successful in the past has lost a lot of its influence with the rise of grass root level local initiatives who voice their individual concerns directly. The forms of interaction in a democratic society change over time and thereby change the conditions of decision making for large investment.

On the one hand large projects in certain regions can lead to a lot of benefits and often investment wanted by regional bodies in order to attract value creating activities. There will be more jobs, there will be more income, there will be more taxes and all this can lead to an increase of the quality of life in that particular region. On the other hand, there may be regional disadvantages like environmental emissions, noise, additional transport activities etc. All these factors are analysed in the environmental instruments described in Chapter 4 but at the end this may not be convincing for certain interest groups in the region for the planned production site.

On the other hand the possible sites for power plants are quite limited, in Germany due to population density, availability of network connections, availability of access to cooling water etc.

In recent time there is a lot of opposition against new power plants even those replacing old ones on a regional level, particularly against coal fired power plants. The reasons are partly a strong emphasis on reducing greenhouse gases and partly resistance against possible environmental effects of such plants. In a society where the public wants stronger environmental controls than those represented by legislation the climate for investment becomes quite difficult.

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