# The Hard Coal-Fired Power Plant at Hamburg-Moorburg and Its Alternatives

**On behalf of**
**Bund für Umwelt und Naturschutz e. V.**

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## Summary

In the Hamburg suburb of Moorburg energy supplier Vattenfall plans to build a hard coal-fired power plant (HCPP). Generating an electric power of 1600 megawatts it would be one of the biggest power plants in Germany. What are the implications of such a huge power plant? This report examines the plan's ecological and economical sustainability and looks for an answer to the question if the Moorburg power plant is compatible to a sustainable energy scenario for Hamburg and Germany. Employing the eco-balance concept, the plans to build Moorburg power plant are analysed in terms of climate and environmental policy. Furthermore this report will explain how the market conditions for hard coal-fired power plants are changed by liberalisation of power markets and the increasing share of renewable energy in the power mix.

This report will show:

- the Moorburg power plant is far more climate-damaging than many other power plants
- the Moorburg power plant does not fit into the energy production scheme of an energy system based on energy effiency and renewable energy sources
- altogether it is debatable in ecological and economical terms and
- there are alternatives to Moorburg power plant that are more reasonable and – even from a costs point of view – more sustainable.

Potentials for renewable energies, power saving measures and cogeneration (cogen) in Hamburg are sufficient to cover the whole city's energy demand and costs of such an alternative are more advantageous both from a micro- as well as a macroeconomic perspective.

### *Environmental impacts of a hard coal-fired power plant*

**Industrialised countries will likely have need to reduce their greenhouse-gas emissions by some 80 per cent until 2050.**

Scientific findings indicating a humanly caused climate change condense. The objective of limiting global warming to a maximum of 2°C guides the EU's and G8's latest resolutions on energy and climate policy. It can be deduced from this objective that industrialised countries need to reduce their emissions of greenhouse gases by at least 80 per cent until 2050 – compared to the amount of emissions in 1990. If these targets for a long-term climate protection are taken seriously it is also possible to define targets for permitted amounts of emissions in separate sectors of the national economy. **Figure 1** shows the effects for a hypothetical emission reduction target of "-80%" in the year 2050. Due to a lack of other agreements it is assumed that the national target is evenly split up between the national economy's various sectors. This approach results in a remaining emission budget of about 85 mio. tons of $CO_2$ for the energy industry.

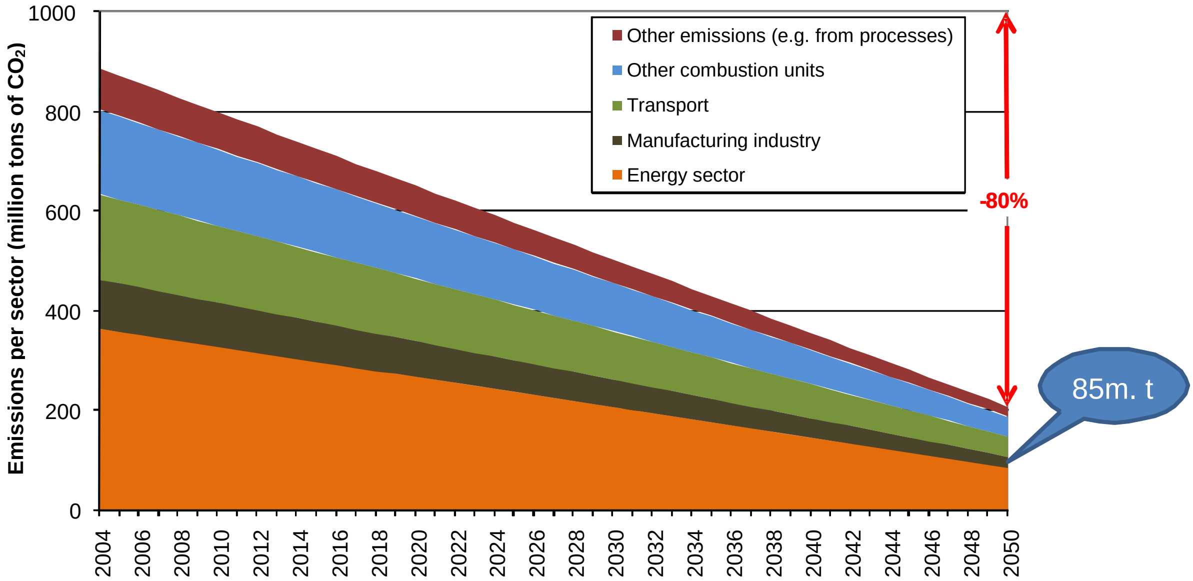


**Figure 1: The emission reduction target of "- 80 %" is evenly split up between the German national economy's various sectors (illustration based on own research)**

**Electricity generation in large-scale hard coal-fired condensation power plants is comparatively unefficient and causes significant amounts of greenhouse gases.**

In 2006, 136 TWh of electricity were produced in hard coal-fired power planthard coal-fired power plants (HCPPs). For that, hard coal with a heating value of 329 TWh was used. Accordingly, the average efficiency of HCPPs was 41 per cent. The energy consumption required by the power plant itself to maintain operation furthermore reduces the so-called net efficiency.

In most power plants a great deal of the generated waste heat is emitted into air or water without further utilisation. That implies that far more than half of the coal's energy is wasted without any benefit.

The high amounts of greenhouse gas emissions show up in the eco-balance (Figure 2), which considers all up- and downstream processes.. While a Moorburg type power plant emits greenhouse gases of 800 to 850 grams of $CO_2$-equivalents per kilowatt hour of electricity generated (depending on the share of cogeneration), the emissions of a modern natural gas-fired power plant (NGPP) make up a third of the amount. Even an optimised design utilising almost three times more waste heat for cogeneration than the value of 250 MW originally considered to be realistic, emissions do not drop substantially below 800 g/kWh. This is because such a power plant still emits nearly 40 per cent of the fuel energy without any utilisation: the power plant is too large to be able to use the better amount of waste heat.

Hence, Moorburg power plant is not the „most climate-friendly power plant in the world" as it is called in the report on its environmental impact assessment. **Rather, the old Wedel coal power plant is comparable concerning the greenhouse gas balance,** because it is smaller and fits better into the district heating network. As a result it can be stated that cogeneration in coal power plants reduces greenhouse gas emissions – but not to an extent that bridges the gap between the fuel types of coal and natural gas.

In contrast, most renewable energy sources produce only insignificantly low GHG emissions.

**What is Cogeneration?**

Cogeneration means waste heat inevitably produced during electricity generation is used to heat homes, warm swimming pools or provide process heat for industrial uses. This means the inherent energy of fuels is utilised both for power generation and for heating and warming. Cogeneration saves a huge amount of fuel and results in a considerable reduction of greenhouse-gas emissions. Basically every power plant can be turned into a combined "heat and power plant". However, this concept is particularly appropriate to decentral, smaller power plants because their heat can be used locally without long distance transport.

In Germany, 14 per cent of the electricity demand is covered by cogeneration power plants. A large part thereof comes from big power plants feeding in their waste heat to district heating systems, from industrial cogeneration and from steam turbine plants. But then also communal heat and power (CHP) plants – smaller and more compact plants for concurrent electricity and heat supply – contribute to that.

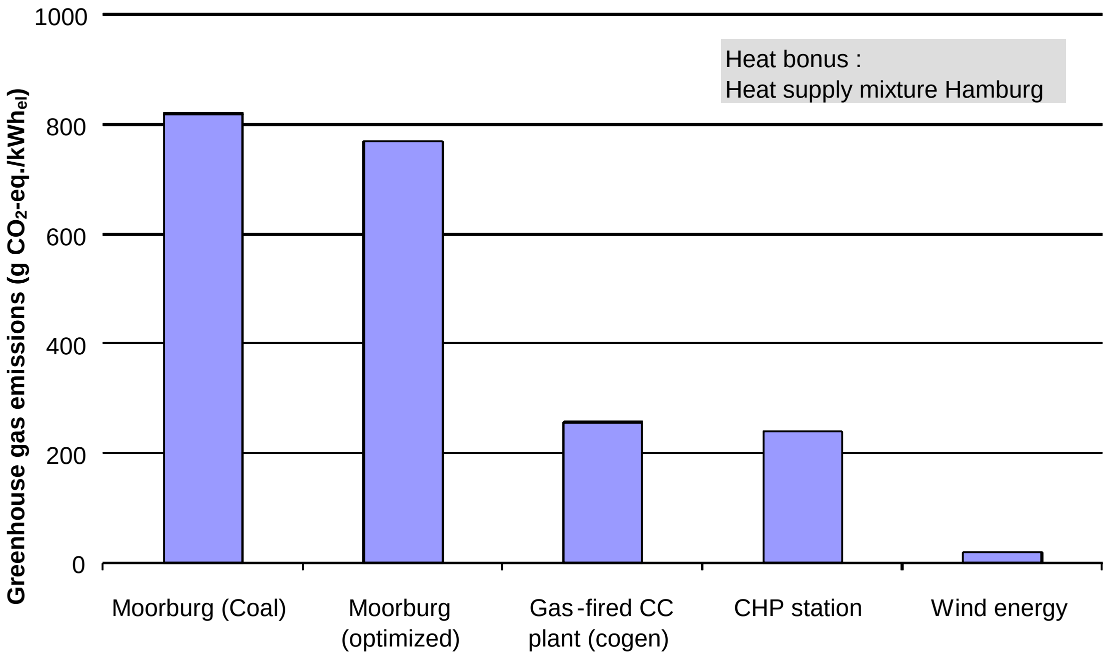


**Figure 2: Greenhouse-gas emissions along the lifecycle of selected electricity generation methods (Co-gen: cogeneration; CC: combined cycle (gas turbine); CHP: combined heat and power).**

In this context it has to be noticed that **power plants that are built today have a technical lifespan expected to be at least four decades and perpetuate the respective amount of greenhouse gas emissions for this period of time.** Thereby they compromise the achievement of long-term climate protection targets.

**The damage costs connected to greenhouse gases are immense.**

If we assume damage costs of 70 €/t $CO_2$ – as proposed by the German Federal Ministry for the Environment –, the Moorburg power plant would cause external costs of around 700 Mio. Euro per annum – just for its direct $CO_2$ emissions. The much discussed Carbon Capture and Storage (CSS) method is no solution for this type of power plant for a number of reasons – one of which is the lack of profitability. An upgrade to CSS – if at all technically feasible – would decrease the power plants efficiency factor by 10 to 15 percentage points.

There are numerous **additional ecological reasons** against a Moorburg type hard coal-fired power plant: Despite extensive exhaust filtering measures hard coal-fired power plants emit high amounts of **airborne pollutants**, e.g. nitrogen oxide and heavy metals.

**Coal-fired power plants seriously affect the aquatic ecosystem**, e.g. by withdrawing and warming huge amounts of water for cooling purposes. Furthermore coal mining causes **environmental impacts and social consequences in the producing countries**.

### *The Moorburg power plant in the energy market*

During the 1990s, the basic conditions for the power industry in Germany and Europe changed fundamentally. Until then, electricity was predominantly produced by regional monopolistic companies in Germany. Market prices for electrical power were the result of a mixed calculation. In this calculation, the electricity production costs of various power plant types were taken into account and an average value was computed on that basis. The respective power plant's electricity production costs were calculated from the sum of all costs which was divided by the amount of electricity produced. A moderate profit margin was added.

Along with the so-called **liberalisation** of electricity markets in Europe the pricing and profitability assessment for power plants changed fundamentally. Electric power is traded with on electricity exchanges – there is no guarantee of a certain price.

A popular method for answering the question, if an investment is advantageous, is the comparison of the average electricity production costs and gained revenues. One part of the electricity production costs is made up by the initial investment. Typically, specific investments for a hard coal-fired power plant have been between 1,000 and 1,200 € per kilowatt hour (€/kWh) so far. Only recently these figures rose by up to 40 per cent for new contracts according to accounts received – due to great demand and also due to steel prices rising sharply. A combined cycle gas turbine plant (CCGT) fuelled with natural gas has cost 500 to 600 €/kWh up to now. There, too, are reports on price increases of 25 per cent. These increases may well be temporary and as the Moorburg power plant is already contracted, the latest increases are of no relevance and will not be considered in the profitability assessment.

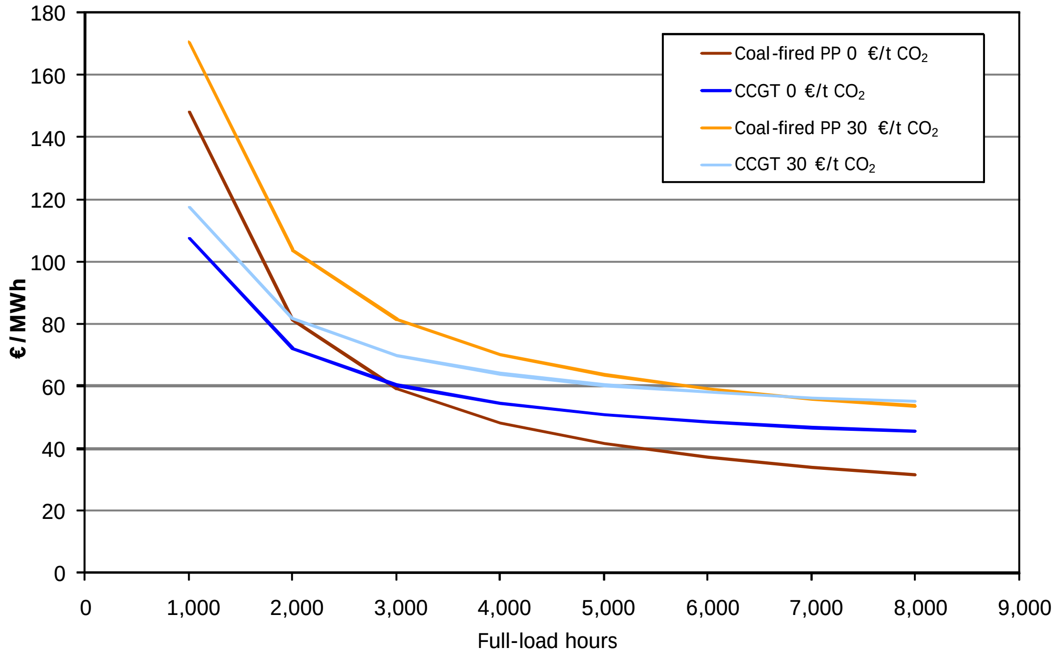


**Figure 3: If the $CO_2$ price is set to zero, coal-fired power plants are more cost-efficient than CCGTs from 3,000 hours of operation per annum. At a price of 30 Euros per ton of $CO_2$, coal-fired power plants are only more cost-efficient at over 7,000 hours of operation – compared to combined cycle gas turbine plants (PP: power plant; CCGT: Combined cycle gas turbine).**

At a medium or high utilisation (e.g. 6,000 full-load hours per annum) it is decisive in the comparison of costs, which costs have to be taken into account for the purchase of $CO_2$ emission allowances (Figure 3). If no price for emission allowances is considered, coal-fired power plants have a slight cost advantage . At a price of 30 Euros per ton of $CO_2$ the costs for electricity production by coal are considerably higher than the electricity production costs of gas-fired power plants. At the moment, the price for $CO_2$ emission allowances for the second committment period (2008 to 2012) is 22 €/t $CO_2$. For the time after 2012 a further tightening of climate protection targets has to be considered. By then, easily acessibile and cost-effective technical solutions for emission reduction may be exhausted and a further increase of $CO_2$ emission allowance prices has to be assumed.

The higher the degree of utilisation the greater the shift in favour of coal-fired power plants, with lessened full load hours natural gas-fired power plants become more and more attractive. The higher the price of $CO_2$ the more advantageous is the gas-fired power plant.

**Once the power plant is built, the operator tries to utilise it to capacity.**

Regarding the operation of a power plant, initial investment costs are of no further relevance. Since they are fixed costs, they are independent of the power plant's actual utilisation. From a short term perspective an operator will always try to utilise its power plant when the revenues from electricity sales exceed the plant's operational costs. Formerly, as a first approximation, operators calculated the ratio of fuel costs and efficiency (i.e. the marginal costs of production) and compared it to the market price for electricity. If the market price was higher than the marginal costs of production, the operator utilised its power plant.

Since the introduction of the EU Emission Trading Scheme there is another compound to be added to this calculation: Greenhouse gas emissions now have a price. Non-utilisation of a power plant means the respective emission allowances can be sold on the $CO_2$ market – even if they were allocated without any charge. When a power plant is utilised, these potential revenues are not realised and have to be regarded as **opportunity costs**. The operator will consequently only utilise its power plant when not only fuel costs but also the full $CO_2$ costs can be regained.

**How the wholesale electricity price is established: The “Merit Order” principle**

Each power plant operator has to place a bid for every hour of the next day, which is composed of a price and the capacity that can be delivered at that price. The price on offer is made up by addition of fuel and $CO_2$ costs.

As a general rule, the operator will place a bid for the maximum capacity at a price equalling the marginal costs. The respective electricity exchange collects all bids and ranks them by costs in an ascending order. This results in a list denominating the power plant’s operational succession or “merit order”.

Figure 4 shows an example of such a “merit order” for an artificial but nevertheless typical set of power plants. On the left hand side those power plants are to be found that have no or very low marginal costs – like hydroelectric, photovoltaic and wind energy. Cogeneration power plants partly benefiting from selling heat follow up. Next are nuclear power plants, then new and older coal-fired power plants. Rightmost the gas-fired power plants are found which do not need high investments but have high marginal costs.

The electricity exchange now accepts bids from those power plants with the lowest bids until the forecasted demand is satisfied. The bid of the last power plant whose bid is accepted determines the price for electricity that has to be paid for all energy delivery contracts. This means power plants are not paid the value of their own bid but according to the marginal power plant’s bid. This is not a specific feature of the electricity market but in fact a fundamental procedure on marketes in pure competition.

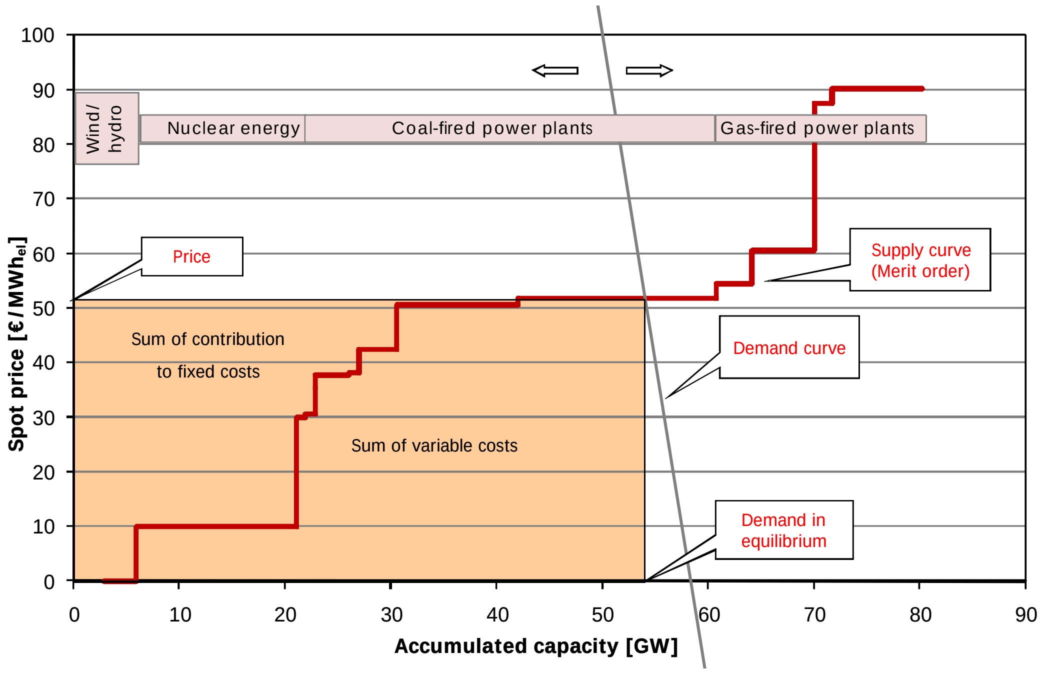


**Figure 4: Pricing mechanism at an electricity exchange**

The price of electricity is formed in the break-even point of supply and demand. In times of low demand the marginal power plant is usually – as in our example in **Figure 4** – a coal-fired power plant. With rising demand, the demand curve shifts to the right. It then meets the supply curve at a higher price. At a demand of circa 70 GW the marginal power plant in our example will be a gas-fired power plant.

The electricity price is not a result of a calculated average of all power plants' costs but equals the operational costs of the last power plant utilised to satisfy demand in electricity – the so-called "marginal power plant". If all power plants are not paid according to their own cost structure, but the marginal power plant's costs, this raises the question what happens with the difference. Economists describe this difference between revenues and operational costs as **contribution to fixed costs**. This contribution has to cover the power plants' fixed costs that have not been included in the electricity exchange's price calculation. In **Figure 4** the market value of electricity produced is marked by a pale red area. The supply curve divides the field into variable costs below and contribution to fixed costs above the curve. Consequently, a yardstick for the profitablility of an investment in a new power plant is that its contribution has to exceed its fixed costs.

In order to analyse the profitability of a projected power plant, a momentary assessment is not sufficient. Rather it has to be taken into account how the power plant will be utilised in every hour of a given year unter realistic preconditions. As we are analysing a new power plant and the set of power plants' composition will gradually change in the next years, we cannot use empirical values. That is why the analysis uses the **electricity market model** *deeco-s* which can simulate the behaviour of both a set of power plants and a single power plant. To simulate the electricity market the model uses data of all involved power plants, estimates on the demand of electricity and time series of available renewable energies like wind and solar radiation. The *deeco-s* model then calculates – for each hour in a year – those power plants that are necessary to supply the assumed electricity demand, the resulting spot market price and each power plant's electricity generation. With these results, it is possible to determine the power plants' revenues, the electricity production costs and the contribution to fixed costs.

As it is impossible to forecast the actual set of power plants in 23 years, different scenarios were analysed. Two scenarios of a specific national electricity generation mix were played through with two different energy price scenarios. For each combination of these four general parameters, four different versions of the Mooburg power plantwere simulated.

The electricity market modelling shows (Figure 5):

**None of the versions of a Moorburg-type hard coal-fired power plant evaluated can obtain enough contribution to fixed costs to pay off the investment, if the emission trading scheme will be shaped according to the climate protection targets.** These especially includes auctioning all emission allowances from 2013 onwards.

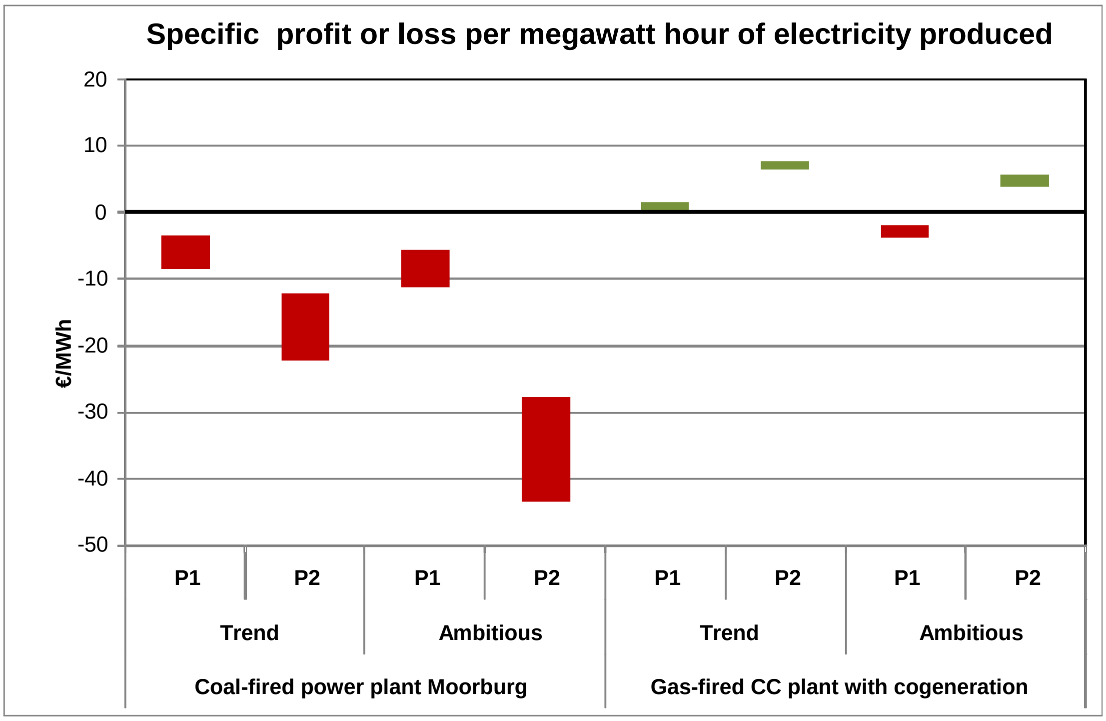


**Figure 5: Profits and losses of a hard coal-fired power plant and an alternative natural gas-fired power plant in different energy price- and energy market scenarios.**

"Trend": No conversion of national energy industry to a sustainable energy system; "Ambitious": Substantial efforts in improving energy efficiency, higher share of renewable energies. "P1": Moderate increases in fuel and $CO_2$ prices; "P2": Sharp increases.

Why then the Moorburg power plant was projected? An important reason certainly is the fact that its **investors until recently calculated with the assumption that after 2012 they will still get a good deal of the required $CO_2$ emission allowances free of charge.** Already small shares of free emission allowances would make the Moorburg version planned by Vattenfall profitable for the year 2015 – assuming a scenario with low fuel prices and low power plant (fixed) costs. If 30 per cent of all emission allowances would be allocated free of charge, in the "trend" scenario assuming low fuel costs all hard coal-fired power plant versions are profitable in the year 2015.

**This shows, that from a climate policy perspective a auction of the entire amount of emission allowances is an important strategy element in the future emission trading scheme.**

## There is an alternative: A national scenario for a sustainable energy industry

The above mentioned examination shows: Further extension of hard coal-fired power plants in Germany is ecologically critical, economically questionable and is not compatible to the achievement of German climate protection targets. This poses the question if there are alternatives. Is there – despite the withdrawal from the nuclear energy programme and without the controversial disposal of $CO_2$ – a way for an overall energy supply realising the radical reduction of CO2 emissions to a fifth the amount of 1990 until the year 2050?

This question was analysed in a study named "Ecologically optimised extension in the use of renewable energies" (German title: "Ökologisch optimierter Ausbau der Nutzung erneuerbarer Energien", conducted by DLR, IFEU, Wuppertal Institute, 2004) – and was affirmed. In various updates since then the scenario assumptions were held up-to-date and were especially adapted to the more rapidly rising oil price and also to slower efficiency development and demographic change. The consequence of these studies is a lead scenario called "**Leitszenario 2006**" which was employed in this study as a yardstick for a sustainable energy supply.

The basic prerequisite is an energy strategy that employs **renewable energies**, higher **conversion efficiency** – which especially means **cogeneration** – and an improved **energy efficiency on the demand side**. The share of renewables in the overall electricity production increases from 12 per cent in 2006 to 27 per cent in the year 2020 and 77 per cent in 2050. Due to economies of scale and technological progress in the domain of plants operated with renewable energy sources the electricity production costs will furthermore decrease – especially those technologies without fuel costs will profit from that. Along with that there will be a substantial structural shift in the power plant range: The share of decentral cogeneration plants considerably increases in this scenario. Hard coal-fired condensation power plants are not compatible with this flexible future set of power plants. Networks of adjustable plants based on renewable energy sources, load management, flexible gas-fired power plants, improved demand forecast methods, and energy reservoirs integrate the fluctuating energy sources.

Despite the increasing relevance of natural gas-fired power plants in a scenario characterised by increased efficiency and renewable energies the **overall gas consumption in this scenario decreases** to half of the present figure. The dependence on external supplies is, thus, mitigated.

The lead scenario's implementation would initially cause additional costs due to necessary investments in plants to utilise renewable energy. But in the long term perspective, when prices for fossile energy sources soar and the described costs of renewable energy power plants decrease simultaneously, the lead scenario proves beneficial even from the costs point of view. When and to which extent this effect will strike depends on the suppositions made concerning the price development paths.

Not included in this calculation of costs are the external costs avoided – climate damage costs, other environmental costs, endangered security of fuel supply etc. – which, should they be considered, would significantly earlier close the gap in costs.

### There is an alternative: Efficiency, renewables and cogeneration in Hamburg

The national perspective is important to gain an overview over the long term development of energy structures in Germany. At the same time, the local and regional potential for efficiency and renewable energies has to be evaluated to identify options for future local action.

The city of Hamburg set an ambitious short term target. Employing a whole bundle of measures in all sectors $CO_2$ emissions shall be reduced by 2m. tons per annum (t/a) until 2012 compared to the figure as of 2007. This corresponds to a reduction of 11 per cent within four years time. The construction of Moorburg power plant would – even if Hamburg's old Wedel-based power plant would be shut down – mean a plus in $CO_2$ emissions of net over 8m. t per annum – four times the amount that the Hamburg government plans to reduce annually until

2012. The construction of Moorburg power plant therefore is hardly compatible with the climate protection scheme's intentions.

But can the German national lead scenario be transferred onto the situation in Hamburg? An urban area has limited opportunities for the development of renewable energies – there are few areas for agriculture and forestry and limited potentials for wind energy. The high percentage of large scale industry in Hamburg's overall electricity consumption (Figure 6) furthermore complicates a reduction of electricity consumption.

More or less all national studies show the necessary emission reductions cannot be achieved just by a conversion of the energy supply system but also need substantial efforts concerning the reduction of end-user electricity consumption. Therefore, in a first step, the opportunities to reduce the current electricity consumption by measures to enhance energy efficiency until the year 2030 are examined. The second step is an analysis of renewable energy potentials – the perspective is widened to the Hamburg metropolitan region because the rural areas can make an important contribution to the general supply situation. As in 2030 natural gas will still play an essential role, it is scrutinised in a last step how this energy source can be utilised as efficient as possible by the use of cogeneration in Hamburg.

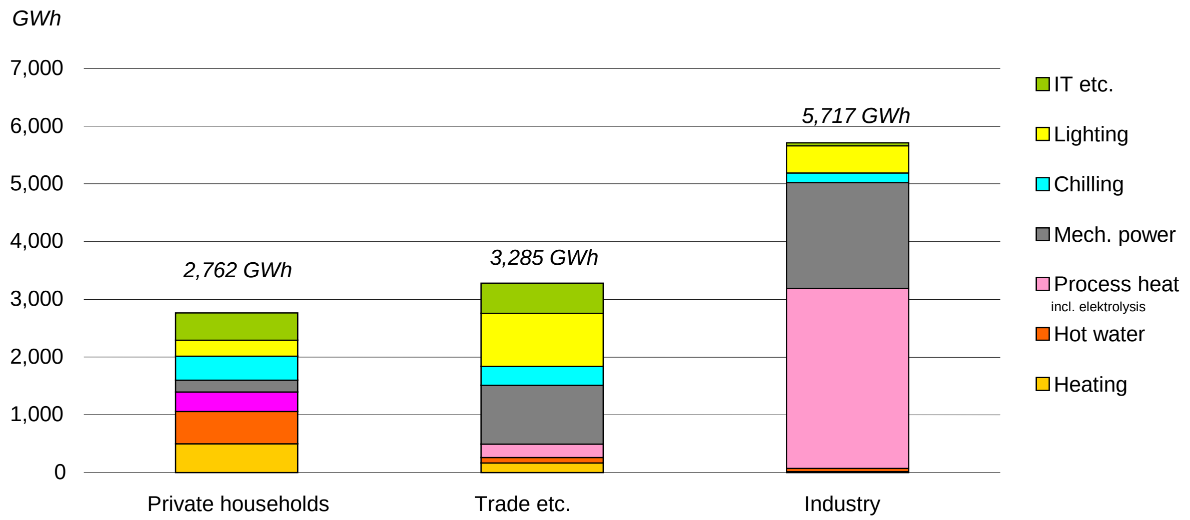


**Figure 6: End-user electricity consumption in Hamburg in 2004 by application and sector (public transport not included)**

## Efficiency

To determine the potential power savings the sectors private households, trade and industry are examined separately. It is calculated how much the electricity consumption can be reduced by efficiency measures – only economically viable measures are considered. Market penetration of efficiency technologies can be jeopardised by market failure for various reasons. Often, measures that are profitable themselves are only implemented as a reaction to motivation and information schemes and to additional incentives. Such schemes cause additional costs. These "transaction costs" are added to the cost calculation for a sustainable energy supply. Altogether with all sectors included, there are potential power savings of 30 per cent until 2030 – in contrast to the trend scenario, in which the efficiency enhancements are compensated by an increase in energy demand (Figure 7). The calculated potential power savings mean cost savings of 530m. Euros in today's prices. The relevant transaction costs amount to about 32m. Euros.

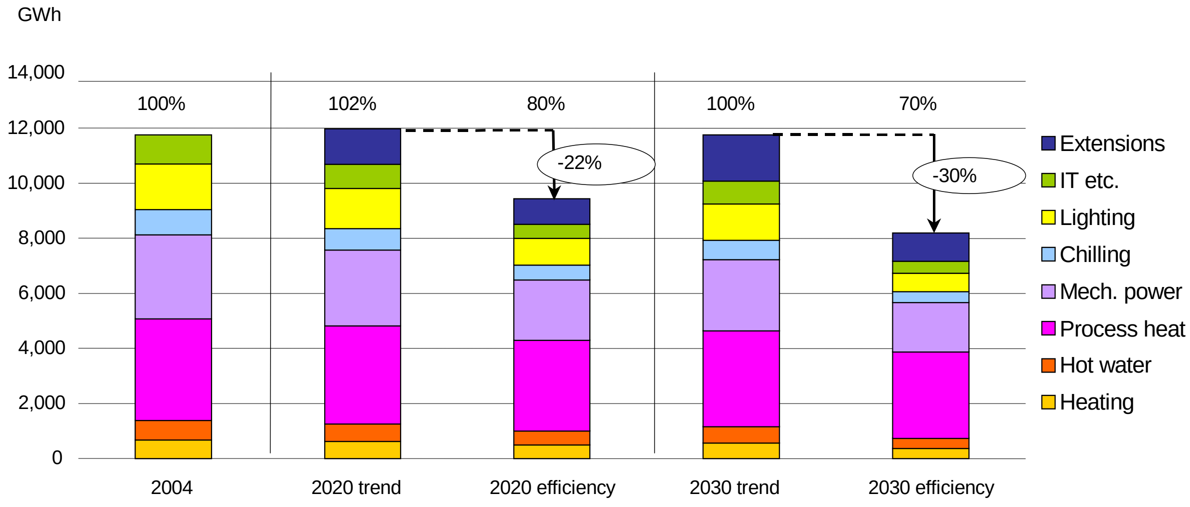


**Figure 7: Efficiency potentials in all sectors for Hamburg (by application) for the trend scenario and the efficiency scenario (in which all profitable measures are implemented).**

## Renewable energies in the Hamburg metropolitan region

The share of renewable energies in the Hamburg primary energy demand was 4.8 per cent in 2004 – predominantly due to contributions of biogenous waste and electricity from renewable energy sources purchased from outside Hamburg's boundaries. The production of electricity from renewable energy sources in Hamburg so far amounts to 57 wind power plants producing just under 34 MW, some biomass energy plants and sewage gas, landfill gas and biogenous fractions in waste incinerators respectively as well as some megawatts of photovoltaic and water power.

It is obvious that the northern German, sparsely wooded and urban Hamburg area only has restricted access to renewable energy sources – which is especially evident for the segments of biomass (due to few agricultural and forestry areas) and wind. For an assessment of wind and biomass potential the whole Hamburg metropolitan region was analysed and then the city itself was allocated with a share of the region's generation capacity correlating to its share of inhabitants. Potentials for solar power (photovoltaic) and the region's very limited opportunities to expand the use of water power were examined for the Hamburg city area only. Energy sources that cannot be allocated to a specific German region like offshore wind power and electricity imports from solar thermal power plants were allocated according to Hamburg's share in the German total population.

**Altogether a potential of 1.6 TWh/a can be stated for the production of electricity from renewable energy sources in Hamburg and its metropolitan region until 2030.**

Additional to that about 1.8 TWh/a from wind offshore power plants and regenerative power imports (produced outside Germany) have to be added according to the lead scenario and can be technically assigned to Hamburg due to Hamburg's share in German total population.

| Potential extensions 2030<br>Renewable energies | Hamburg city<br>Capacity [MW] | Full-load [hours] | Yield [GWh] | Hamburg MR (40 %)*<br>Yield energy [GWh] | Annotations |
|---|---|---|---|---|---|
| **Wind** | | | | | |
| On-shore | 90 | 1900 | 171 | 628 | Hamburg: 80 % of [1] HMR: [2] |
| **Photovoltaic** | 20.5 | 850 | 17 | | Hours of full-load: [3], extensions: [4] |
| **Biomass** | | | | | |
| Wood fuel | | | 67 | | 200,000 t/a; 50 % for electricity, eta el=0.3 |
| Biogas | | | 32 | 191 | Hamburg: organic waste HMR: liquid manure |
| Agricultural residues | | | | 51 | Steam turbine, eta el=0.2, 40 % of potential |
| Energy crop | | | | 430 | 10 % agricultural area; eta el=0.32 |
| **Water power** | 0.3 | 4500 | 1 | | |
| ***Total RE*** | | | ***289*** | ***1300*** | |
| ***Outside HMR:*** | | | | | |
| *Total PV potential* | | | *600-1100* | | 50 % of appropriate roof surface area |
| *Wind Off-shore* | | | *1480* | | Weighed share [5] |
| *Imp. solar thermal power* | | | *320* | | Weighed share [5] |

[1] Repowering and 3 newly designated areas. 80 % of potential extensions. Increasing hours of full-load due to hub height and technological progress. [2] see text [3] average 2002-2005 according to www.sfv.de
[4] Assumption: plus 700 kW p.a. [5] Share weighted according to population (2%) of extension till 2030
* 40 % of total potential of HMR (share of Hamburg city's population in total population) allocated to Hamburg city.
HMR: Hamburg metropolitan region

**Table 1: Renewable energies in the Hamburg metropolitan region: potential contributions in the year 2030**

## Potential of cogeneration

Hamburg as a city state has a very high habitat density and therefore offers ideal prerequisites for the utilisation of heat from cogeneration plants. This opportunity is already used to a great deal. A 770 km long distance heating network provides 405,000 Hamburg households with approximately 4 terawatt hours of heat. Till the year 2010, an additional 20,000 households are being connected to the network. Long distance heating is challenged by the fact that heat demand will decrease in existing circuit sections due to the existing buildings being energetically modernised. To compensate this decrease and develop new potentials, the network has to be densified and, at the same time, the network needs upgrading.

There are potentials for heat distribution in district heating as well as long distance heating and industrial cogeneration. **In the transition phase towards a higher regenerative share the Hamburg long distance heating network can be supplied by various plants operated with renewable energy sources as well as highly efficient combined cycle power plants – supplemented by decentral cogeneration plants supplying smaller district heating networks.** In the above stated sectors, a bare eight terawatt hours of electricity could be generated by cogeneration power plants.

## Hamburg's contribution to Germany's future energy system

Hamburg has a demand in electrical power of about 12 terawatt hours. Today, the city can use its influence, to develop and upgrade the energy system in terms of a sustainable energy supply. What these alternatives mean concretely concerning their costs and the greenhouse gas emissions, will be displayed in brief in a "flashlight picture" of the year 2030.

After an analysis of all potentials we recommend an energy mix as follows:

- Reducing the annual electricity consumption through efficiency measures by 3.5 terawatt hours;
- Utilise the potentials for renewable energies accessible until the year 2030 in the Hamburg metropolitan region: 1.6 terawatt hours per annum;
- Utilisation of offshore wind power and imported solar power amounting to 1.8 terawatt hours per annum;
- Construction of a 650 megawatts gas-fired combined cycle power plant with cogeneration features to produce 4 terawatt hours per annum;
- Construction of decentral gas-fired cogeneration (CHP) plants for smaller district heating networks and industrial heat supply with an electricity generation of 1 terawatt hour annually.

**Such a scenario based on energy efficiency and renewable energies for Hamburg is - in different price scenarios - more cost-efficient in the long run – by about a quarter up to nearly a half –, and already achieves the target to reduce $CO_2$ emissions to a fifth in 2030.**

In addition to that, such a scenario would generate savings concerning climate damage in nine-figure sums of Euros and also end-user electricity costs which are not calculated herein.

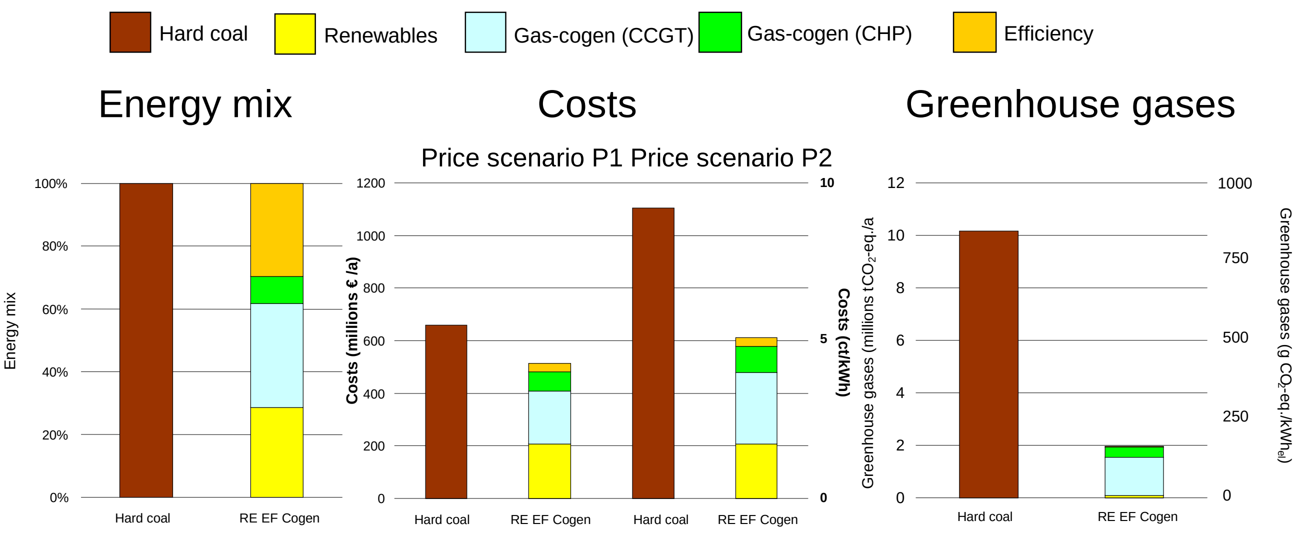


**Figure 8: Comparision of the energy mix, annual costs and the greenhouse gas emissions of electricity generation from hard coal (12 TWh) and equivalent generation/savings from renewable energies, efficiency measures and use of cogeneration in the year 2030.**

It is an ambitious scenario for Hamburg. It will come true, if national government, the federal states and local governments as well as private investors and end-users conceive an effective climate policy, renewable energies, energy efficiency and cogeneration as central strategic elements.