ACCEPTABILITY IN GERMANY FOR WIND POWER, SOLAR POWER AND FUEL CELLS AS ENERGY SUPPLY

BETTINA FRENZEL
VATTENFALL EUROPE AG (BERLIN, GERMANY)

Abstract
Essentially the ***energy reserves of fossil energy sources are limited on coal in Germany***. Furthermore, reserves of fossil energy sources are comparatively low in the ***25 EU countries***, amounting to ***only 3 percent*** including hydrocarbons. The pressure on reserves of fossil energy sources arises in relation to ***increasing demand*** (world-wide). ***Growing world market energy and raw material prices*** lead to efforts to become independent especially from gas and oil reserves also outside the electricity and heat sector.
In response to higher energy prices, ***new technologies*** and more efficient new systems are being developed and put into practice. This paper will present examples of ***energy solutions*** based on ***wind power, solar power and fuel cell technologies***. In areas with favourable weather conditions, the generation of wind and solar power exceeds consumption. How can the excess electricity be used to generate hydrogen for the traffic and industrial sectors in future? The respective developments and trends are to be discussed against the background of the potentials these technologies have and ***resultant difficulties***. Additional identifying alternatives to ***reduce the energy input and increase the energy efficiency***. The paper discusses the demand for energy in particular in the fields of electricity, heat and mobility.
Taking into consideration the ***net system security and supply security***, these new technologies provide an opportunity to ***reduce energy-induced CO2 emissions world-wide***. At the same time, businesses can gain competitive advantages by facing up to the special challenges and to operate jobs. Framework conditions must be designed in such a way as to widen rather than to narrow the options for a ***broad energy and technology mix***.

1 Introduction and objective

The German electricity generation market is dominated by large power plants (for coal, nuclear energy, gas). Stand-alone small plants which generate electricity from renewable sources have however experienced a relatively high growth. A comprehensive modernization and renewal of the power plant park (until 2020: 30.000 to 40.000 MW) is necessary due to the end of the technical life-cycle of fossil-fired power plants and the political decision to phase out the use of nuclear energy. Therefore the investors have to decide on the future energy mix.

The long-term goal of the German government is to increase the share of renewable energies in the total power supply to at least 12.5 percent by 2010 and to at least 20 percent by 2020. Renewable energies have been part of the normal electricity mix for some time. Renewable energies accounted for 3 percent of primary energy consumption in Germany (2003). These energy sources do not lead to ozone-depleting greenhouse gases. There are extensive support programs available to promote the use of renewable energies in electricity and heat production. The increase in electricity from renewable energies over the last few years is mainly based on the Renewable Energy Act (EEG) of 01.04.2000. 65 percent of the electricity generated from renewable energy sources receive support under this Act. To meet a fluctuating demand on the basis of fluctuating renewable energy sources is a major challenge for a sustainable energy supply.

2 Risks and opportunities of selected energy solutions in Germany

2.1 Wind power systems (WT)

2.1.1 Framework conditions and influence factors

Having harnessed most of its hydraulic power, Germany sees the biggest development potential in wind power until 2020. Remarkable 18.6 TWh (or 4/10 of renewable the energies) were generated from wind energy in 2003. This was an increase by 1.8 TWh compared to the previous year or a 9 percent growth. A total of 15,387 wind turbines were installed in Germany in 2003, a fivefold increase compared to 1998. WT achieved 2.000 full-load hours because of wind offers in 2003.

The development of wind power was greatly supported by wind funds financed by banks and capital investors during the last few years. The federal government budget allocates approximately € 150 million p.a in direct subsidies to support wind energy generation. The government provides also guarantees to a limited extent. Indirect support e.g. by low-interest credits amounted to approximately € 90 million in 2002. The EEG supports electricity based on wind power over a period of 20 years, providing however for a wide-range of differentiations, restrictions and digressions depending on the reference revenues of the system. Suitable onshore locations are meanwhile hard to find. The wind is stronger and more permanent at sea (offshore). A rapid development of offshore wind farms is promoted by high initial reimbursements of 9.1 cents per kWh over a period of 12 years in the 12 sea miles zone (the exclusive economic zone up to a water depth of 20m) provided the wind farm is commissioned not later than in 2010. This subsidy period increases for parks built far away off the coastline and in very deep waters. In order to avoid competing ecological requirements, such parks are only promoted if built outside of nature and bird reserves. The necessary grid development is currently financed by the use-of-system fees of the accept transmission system operator (TSO) without any charges levied on the other German system operators. Unlike the EU directive, the German EEG fails to make the input expressly subject to the proviso that the safety of the national electricity system must not be compromised. Thus, system security is weakened, while the risk of outages continues to grow.

German wind power development both onshore and offshore is expected to result in 23.000 MW by 2008. Installed offshore capacity in the North Sea and the Baltic Sea should reach 20.000 - 25.000 MW by the year 2030 in accordance with a strategy paper of the German government. (This corresponds to the capacity of 20 conventional power plant units.) The share of offshore wind power in electricity consumption will thus increase to at least 15 percent with about 87 TWh (total wind power share 25 percent) or half of the present-day nuclear power within the next three decades (average utilization of 3,500 hours annually). [1]

2.1.2 Selected project: Offshore wind farms

The generation of offshore wind turbines is envisaged to reach at least 1.500 MW i.e. by 2008, to be expanded to 6.800 MW in the medium term i.e. by 2012 [1]. To achieve this target, suitable locations for wind farms have been identified in the exclusive economic zone (beyond the 12 sea miles zone). In this area, there are no proprietors in the legal sense of the term. The development of offshore wind power utilisation is done gradually. Extensive research projects in the field of technology, environment and nature conservation have accompanied this development for quite some time. No experience exists so far worldwide with regard to the 40 projects envisaged to be erected in deep waters up to 40 meters far off the coastline. Nevertheless, 24 applications have been filed for wind farms in the North Sea and 6 for wind farms in the Baltic Sea. [2] The first research platform in North Sea started operation in a water depth of 28m in the autumn of 2003. It will provide clear answers as to wind conditions and the availability of suitable areas. The wind turbines must be connected to the grid by long sea cables. Energy yield is expected to be some 40 percent higher than on land [3]. Maintenance of offshore turbines poses a particular challenge in winter time. Offshore turbines with rotors over 5 MW are estimated to have a life span of 20 years. There is operational experience with onshore wind turbines extent only over a period of approximately 10 years in Germany.

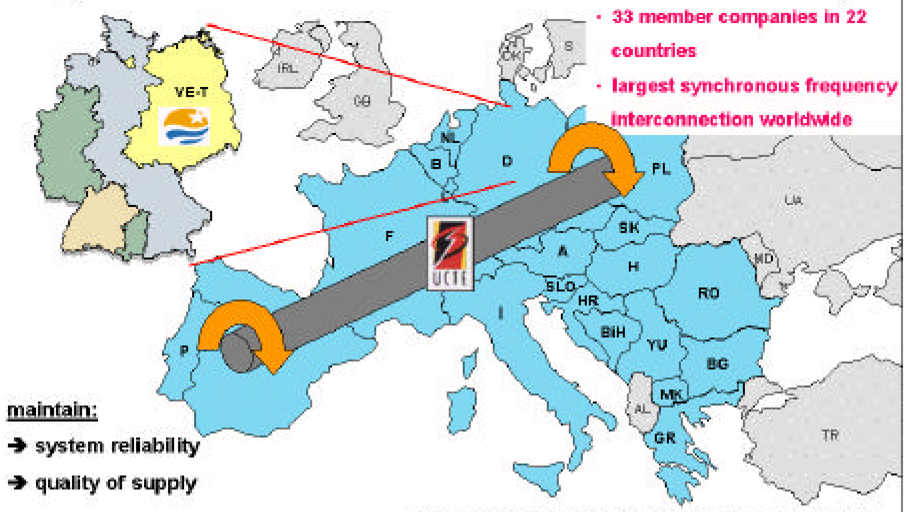
The fact that onshore and offshore wind farms are sustainable technologies, which are considered feasible, is borne out by the involvement of major energy supply companies (e.g. Eon) in different pilot projects. Potential investors expect a trial period of at least 3 years. At present, wind energy is used to generate electricity. There are however endeavours to use wind power for water desalination or for hydrogen production in the mid and long term (see chapter 2.3.2).

2.1.3 Effects and economic efficiency of wind turbines

Currently, offshore projects still entail major technical, economic and legal insecurities. The grid is designed for today's power plant and consumer locations (conurbations may be up to 500 km away from generation sites). To accommodate fluctuating onshore and offshore electricity inputs into the system, the thermal and dynamic restrictions of the grid must be identified and new capacities must be established. 1.500 km of high - and extra-high voltage lines must be established in the North of Germany by 2016. No targeted investment grants are offered for offshore network developments. Furthermore, any network expansion envisaged for 2015 must be planned already today since some of the necessary planning and permission procedures take up to 12 years. It makes sense to develop wind power and network expansion planning in parallel. For a transitional period, a reasonable generation management may help. New WT could add, if the wind inputs are temporary limited in relation to the net conditions. The four TSOs in Germany try to cope with the current situation by concluding contracts which foresee the option to switch off wind turbines when the network is overloaded.

For meteorological reasons it is not or only to a limited extent possible to control the time and amount of wind power available by load management and weather forecasts. In some regions, wind power can currently be predicted 24 hours in advance with 90 percent accuracy. However, forecasts sometimes deviate from the real situation by up to 50 percent of the installed wind capacity, e.g. if winds or storms turn out to be weak. Customer demand can only be influenced to a limited degree. Therefore, scheduled power plant reserves are usually based on fossil energy sources ("shadow power plants") must be available independent of the ability to forecast wind power capacities. Currently, each MW of wind power is met by 800 - 900 kW of reserve capacity. Today, it is hardly possible to store large quantities of electricity in an efficient way. In the long run, energy storages, e.g. made of hydrogen, may provide a solution. To make capacity reserves available in the short run would require considerable investments in the development of expensive conventional peak load power plants, e.g. gas-fired plants, which convert up to 60 percent of the energy into electricity. Large-scale interconnected systems with energy systems able to respond quickly (distributed power plants, see chapter 2.3.2) are another option to cope with a fluctuating power supply from wind farms. In that the TSO has to ensure a secure, reliable and efficient electricity system (EU directive), see figure I.

Figure I: UCTE – Union for the Co-ordination of Transmission of Electricity



Source: Vattenfall Europe Transmission GmbH (VE-T)

The current use of wind power in Germany leads to a reduction of CO_2 emissions by 20 million t per year, i.e. approximately 2 percent of total CO_2 emissions [2]. Wind farms do not discharge any sulphur dioxide or radioactivity. Our CO_2 emissions would reduce by 10 percent by the year 2025 [3]. On the other hand experts estimate that we “pay” for the reduction of each ton of CO_2 based on wind power by at least 200 kg of CO_2 from reserve power plants. Moreover, model calculations show that CO_2 emissions can be easier reduced by investments in a at quicker efficiency increase of the power plant park than by the development of wind energy. [4] The generation in energy-efficient and environmentally friendly cogeneration plants must be reduced to make room for EEG power fed into the system. The direct consequences of the changed scheduling of conventional power plants are a reduction of efficiency and higher specific fuel consumption leading to higher CO_2 emissions. Electricity consumers will have to pay higher electricity prices due to lower grid utilisation and higher maintenance costs (wear and tear increases, if plants are operated not in line with specifications).

In offshore area essential questions remain open as to conflicting uses e.g. shipping lines, fishing industry, gravel extraction, military exercise areas and environment and nature conservation. The type and extent of their impact depend strongly on the planning and the location of the wind turbines. Local authorities are responsible for the planning decisions. Some studies have shown that the impact, e.g. on migratory birds, is not as high as some may have feared. At newer installations, the threshold values (daily 30 minutes as well as 30 hours per year) are kept and the periodic shadows throw reduced by it. Light reflexes are reduced by weak tone of the installations largely as well as unreasonable noise annoyances are avoided by sufficient distances.

The stipulation of fixed prices under the EEG gives private investors in existing onshore projects high planning security. Major progresses led to a 55 percent price reductions for wind power since 1991. At average offshore wind speeds of 8 to 9 m/s at a height of 60m, the utilization period is 3.000 to 3.600 hours a year, i.e. an average capacity utilisation of 34 to 41 percent [3]. Taking into consideration the differing range of investment costs, the calculated electricity generation costs range from nearly 6 to 10 cents per kWh. Given a likely learning curve, electricity generation costs of less than 5 € ct/kWh seem possible in the longer run. Reputable finance providers point however to some unclear cost factors of offshore projects. For example, no calculation exists for a real offshore wind farm in a water depth of 30 m. Initial cost estimates arrived at over € 1bn per project which made the search for investors nearly impossible [5]. While offshore wind farms are only marginally more expensive than onshore farms, ancillary investment costs are much higher. For a wind farm located 30 km offshore, ancillary investment costs amount to 83 to 143 percent of the equipment costs. At a distance of 70 km, they would even reach 113 to 208 percent. These are 3 to 6 times the ancillary costs required for wind farms built on land. In addition to the equipment costs, there are annual operational costs (7.5 percent) and maintenance costs (35 percent). [6] Operators of wind power and solar systems are required to conclude a liability insurance. Insurance costs for onshore wind farms currently amount to 2 percent of annual revenues. The leader (Alliance) in the wind power insurance market has however declared that it is not prepared to insure offshore wind farms neither today nor in future [5].

Experience with existing offshore projects in Denmark and Sweden can be applied to German projects only to limited extent. The aim of the envisaged projects is to demonstrate the technological maturity and reliable permanent operation in order to encourage insurance companies and banks to participate in privately funded offshore projects.

Many industries benefit from the use of wind power in particular the local construction sector and local operators (maintenance and repair) of wind turbines. In addition, regional jobs are created in shipyards, steel companies and the shipbuilding industry. Currently, wind energy offers jobs to 46.000 people [3] also in less-favoured regions.

The so-called repowering, i.e. the substitution of small old plants by powerful modern state-of- the-art plants, could replace over 3.000 MW of old wind power capacities by 2030. [6] This technology lead could be further used. The erection of the discarded wind turbines alone would provide 6 million people (assume: minimum requirements 1,000 kWh per person [7] and 2,000 h utilization period) with access to modern forms of energy in developing countries. An adequate technology transfer of new wind turbines could further contribute to meeting the growing energy demand in developing and newly industrialized countries, thus helping to ensure world-wide a sustainable energy supply. Availabilities to meet the energy demand are much more independent so that the existence of energy reserves is not a must.

The world market for onshore and offshore WT is expected to show a positive trend with increases of the installed capacity from 7,700 MW (2004) to 11,000 MW (2008) and nearly 18,000 MW in 2012 . Today, Germany accounts for approximately one third of the capacity installed world-wide and half of the capacity installed in the EU. Wind power has experienc ed a clear upswing in Europe. Studies suggests that the non-European market will become dominant not before 2011. Manufacturers and project developers plan to open up foreign markets mainly by joint ventures or the establishment of subsidiaries. [1] The biggest obstacles to commitments are seen in insecure framework conditions for the energy sector in the countries of destination, an unstable political situation and specific funding risks.

2.2 Solar systems

2.2.1 Framework conditions and influence factors

Temperatures of 6.000° C prevail at the surface of the sun providing an inexhaustible source of energy. Solar energy can be used actively and passively. The active use includes the conversion of sunlight into heat in a solar thermal process. Another possibility is to convert the sunlight directly into electric energy in solar cells in a photovoltaic (PV) process. Passive uses include simple energy-saving measures in buildings, energy-efficient building equipment and improved construction methods adjusted to climatic conditions (see also chapter 3) to store the heat in the walls and ceilings of the buildings.

The development of solar technology has been promoted by different support programs in Germany. Some of them shall be briefly described here. Subsidies from the Renewable Energy Act have triggered a genuine boom of the solar industry. The EEG provides for a basic reimbursement of electricity from solar energy of 45.7 cents per kWh. Reimbursement rates increase depending on the place of installation (e.g. at a building facade) and the installed capacity [2]. In addition, there is the "Solarthermie2000plus" program which supports long-term research aimed at the thermal use of solar energy in low-temperature houses. In order to reduce the need for primary energy, trial projects have been carried out with the aim to use solar energy for hot water preparation and room heating, solar air-conditioning or process heat in industry. These are very important endeavours given that 1/3 of the entire primary energy used in Germany is used for heating and hot water preparation. Heating and hot water preparation accounts even for nearly 90 percent of the energy consumption of households. The building modernisation program launched by the Reconstruction Loan Corporation (KfW) bank group and the German government (so-called KfW program) supports in particular extensive modernization works in old buildings constructed in 1978 and earlier. It funds up to 100 percent of the investment costs including ancillary costs (up to a maximum amount of 250 € per cubic meter living space). Additionally, KfW and Deutsche Ausgleichsbank (DtA) offer low-interest investment loans for environmental and energy-saving measures by private households and manufacturing companies [8]. Energy utilities, municipalities, federal states and the European Union also offer different support programs for solar power installations.
With the aim to consolidate and develop Germany’s position as a production location for PV systems, the government provided € 27 million in grants for photovoltaic research projects in 2003. The different incentive programs have led to annual growth rates ranging from 30 to 40 percent of the solar industry since 1999. At

present, the installed capacity amounts to 400 MW or 1/7 of the installed wind power capacity [8]. The World Bank promotes solar projects world-wide especially in developing countries.

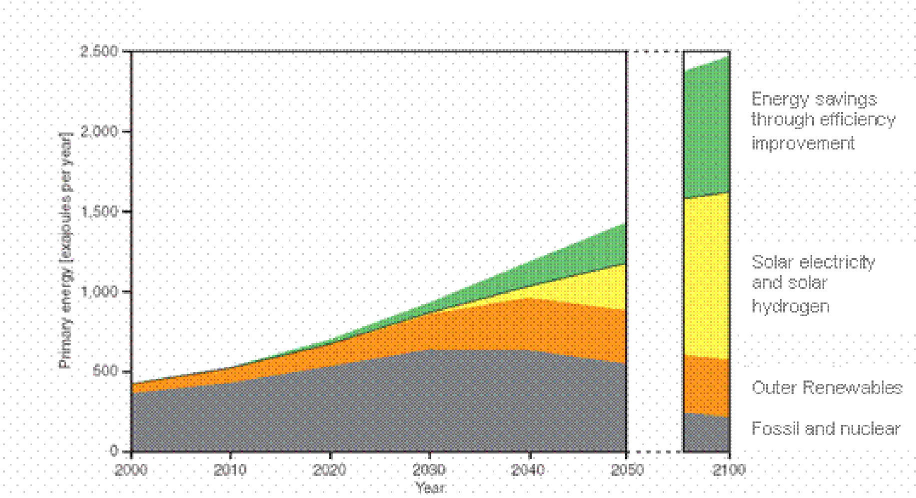
2.2.2 Selected project: large-scale solar thermal systems

A profitable operation of solar thermal installations is only possible between the 35th northern and southern degree of latitude. Germany is too northern. Nevertheless, this technology is presented here since German research institutions and companies make intensive efforts to develop the technology for the export market.

Besides heat, solar thermal power plants generate also electricity. A capacity of 1,000 MW requires an area by 20-50 km^2 depending on the climate and building situation. The conversion into electrical energy is done like in conventional combined heat and power plants. High operational temperatures necessitate sufficiently high direct insolation, thus limiting the number of suitable locations. Unlike fossil-based energy generation, solar thermal generation leads to generation gaps (e.g. at night). These gaps can be closed by fossil fuels and electricity generated from stored heat. Purely solar driven power plants currently use a downstream power plant unit for up to 2.500 hours full load operation per year [9]. A considerable increase would be possible, if the thermal energy of the solar field could be stored in a cost-efficient way (e.g. by molten salts). It would then be possible to add a second collector field of the same size to such a power plant and feed the collected solar energy into the storage. The power plant unit would use the energy stored in times of low insolation. An increase in the operating period could spare the investments for a second power plant unit provided the costs of the thermal energy storage are lower than the additional costs of a bigger power plant unit. Affordable thermal energy storage concepts are available. They can reduce electricity prime costs by up to 20 percent [9]. Used especially in peak load times, they can generate very high proceeds.

Solar thermal systems currently feed into the network an amount of energy similar to the total world-wide generation by PV systems (approximately 500 GWh per year). Installed electrical capacity based on solar energy is estimated to reach 40 GW worldwide by the year 2025 [9]. According to studies, about 30 percent (see figure II) of the world-wide electricity consumption may be covered by solar energy by the year 2050 – presented on figure II [2, 4]. A combination of solar thermal systems and biomass thermal systems is conceivable exclusively on the basis of renewable energies. Existing fossil-fired power plants could be supplemented by an additional solar thermal unit in high insolation areas in the short or medium term. Solar thermal cogeneration plants generate in addition to electrical energy e.g. drinking water from a sea water desalination plant (e.g. by thermal distillation processes). In co-generation plants, a solar efficiency of up to 85 percent is conceivable [4]. It is therefore necessary to develop and test large-scale solar thermal systems with the aim to increase the share of solar energy by combining water heating and support for room heating.

Figure II: Global primary energy portfolio



Source: World in Transition, WBGU 2003

2.2.3 Effects and profitability of solar systems

Solar resources are practically unlimited. Furthermore, solar energy is environmentally friendly and causes hardly any pollution. Based on a life-cycle analysis (manufacturing of components, construction, operation and disposal), a comparison of specific CO2 emissions per MWh of electric energy generated shows the following results: only 12 kg for thermal solar systems, 14 kg for hydraulic power plants, 17 kg for wind farms and as much as 110 kg for photovoltaic systems [10]. The production of semiconductor modules for PV systems requires a lot of energy and leads to high emissions.

Profitability depends strongly on the location: Electricity prime costs are almost linearly influenced by the available solar energy. Given the same insolation conditions, electricity generated in large-scale solar plants costs currently double the price of electricity from locations in wind intensive areas, but only half the price of electricity generated by photovoltaic cells. But since PV systems are able to produce electricity effectively also in dim daylight, they are suited for use in Central Europe. The energy return time are nearly 3 years with currently costs of 60 – 90 € ct/kWh. Energy companies are already today able to forecast seasonal fluctuations in insolation more precisely than local wind power availability. In winter, the availability of solar thermal electricity tends to go down, while wind power tends to be available in excess.

In the 80ies, different solar thermal prototypes and demonstration installations generated electricity at a price of 50 - 100 € ct/kWh. Later systems reached a price of 30 € ct/kWh. Technical improvements and developments have reduced the price to 12 - 15 €ct/kWh. [9] Therefore, the energy return time is nearly 5 months. Today, network-bound electricity generation must compete with conventional power plants in the liberalized German energy market (electricity prices of 4 € ct/kWh and below). Therefore, the market entry of suitable regenerative technologies (e.g. PV) is easier in decentralized markets. Renewable energies can only achieve a meaningful share of the energy market, if connected to the supply system. Future support measures for PV solutions should be more concentrated and focused. They should be based on government investment grants but not on permanent subsidies. German PV systems have been successful without support only in certain niche markets such as stand-alone systems. The biggest challenges are the increase of the efficiency of PV systems which is currently rather low and the reduction of specific investment costs. Automated serial production, growing reliability and thermal energy storage will help reduce costs further.

In 2002, the photovoltaic sector provided some 12,000 jobs in Germany. It expects a market growth of 50 percent in 2004 alone and intends to create 4,000 new jobs this year.

Flexible structures in the energy sector and strong incentives to enhance energy efficiency are essential prerequisites for the use of solar thermal systems. At a global level, it is of central importance to have international agreements on economic and ecological development and a stronger transfer of resources, technology and know-how. Energy could be transported in the form of hydrogen.

2.3 Fuel cells

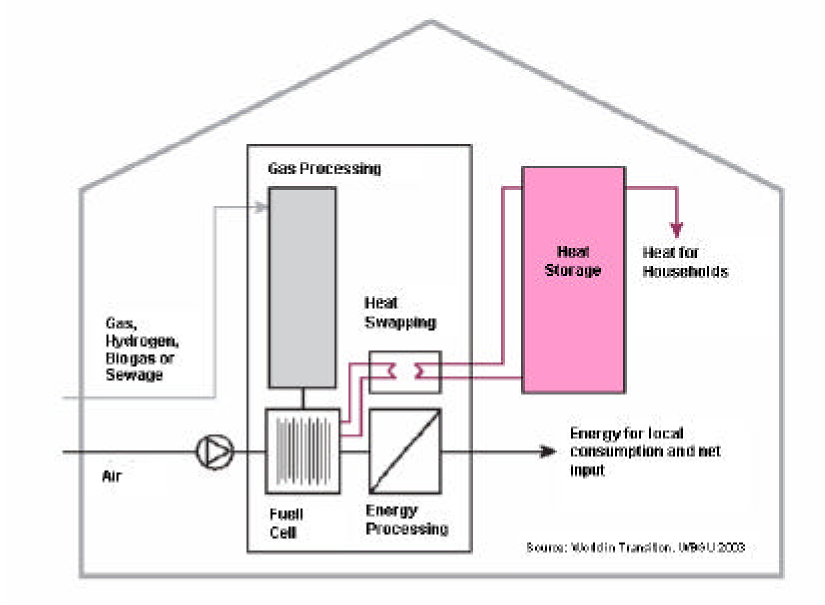
2.3.1 Framework conditions and influence factors

The biggest challenge for researchers and engineers is to be overcome the dependence on crude oil and other fuels and to search for new energy sources. As early as 1839, Sir William Grove, an English physicist, discovered the principle of the fuel cell. This small electro-chemical power plant generates electric energy from hydrogen. In stationary application, fuel cells can be used for the supply and utilisation of energy in electricity and heat generation units. In mobile application, fuel cells deliver energy to drive an electric engine. The German government supports individual projects by private companies. The aim is to obtain a 5 percent share of hydrogen in fuel volume sales by 2020 [11].

2.3.2 Selected projects: Housing energy supply and fuel cell-driven buses

Stationary fuel cells convert fuels (mainly natural gas, hydrogen, biogas and sewage gas) in electricity and heat in an efficiently non-polluting way. Tests are underway to use small stationary systems (1-5 kW) for housing energy supply and larger systems (250 kW) for electricity generation, co-generation, industrial process steam and direct current generation. The first interconnecting field test worldwide started in Germany in January 2004. It is to be completed in March 2005. The project connects and operates 31 fuel cell heaters which form a "virtual power plant". Each fuel cell supplies 4.6 kW_{el} and up to 11 kW_{th} [12]. The fuel cells have been installed in apartment blocks, small business parks and public facilities (see the house energy provision on figure III). The fuel cells installed in different cities are interconnected and centrally managed from one control centre located in university Duisburg/Essen building.

Figure III: House Energy Provision with Fuell Cell



Participants include heating equipment manufacturers, energy utilities and the University as well as associations and energy providers from Belgium, the Netherlands, Portugal, Spain and the United States. The European Commission contributes more than € 3 million to the total project costs of € 8.6 million. The aim is to examine whether centrally controlled fuel cell heaters connected to the public electricity network can help optimize the electricity generation of the public system in future. The sophisticated test runs carried out under practical conditions are to establish whether this technology can live up to customer requirements with regard to reliability, efficiency and CO2 emissions reduction. Successful tests and growing operational experience will allow to start the production of bigger series in 2006 [12]. Given a total electrical capacity of 142.6 kW, the present power plant park could theoretically be replaced by some 700.000 of these virtual power plants which could ensure electricity supply based on intelligent scheduling. Nevertheless, manufacturer and other parties involved assume that a wide-spread use will not make sense before 2010 since the equipment applied in field test is still too big, too expensive and too susceptible to failure.

Fuel-cell driven vehicles use a new drive technology and a new fuel. The electric engine receives electricity from a fuel cell which generates the electricity by electrolysis reversal. When hydrogen reacts with oxygen of the air to form water, electric energy and heat is released. This energy and heat is used to drive the vehicle. The only emission is pure steam. The fuel cell replaces the dynamo of the car since it supplies electricity to run the increasingly more sophisticated electronic control systems, the parking heater or the air-conditioning. Public transport operators in Europe (EU project Clean Urban Transport for Europe (CUTE)) are currently testing fuel cell-driven buses and the establishment of a hydrogen infrastructure. Certified green electricity from HEW (Vattenfall group) will be used for producing the hydrogen for filling station in Hamburg. [13] The commissioning of the buses will be followed by a test phase of two years. During this time, the suitability of the technology for every day use will be examined, while the manufacturer will continue to improve the buses and broaden their use.
In autumn 2004, another demonstration project will start in Berlin: a fleet of 16 hydrogen-driven vehicles and a public hydrogen filling station. The aim of the Clean Energy Partnership (public private partnership involving industry and the Germany government) is to test in Berlin whether hydrogen is a suitable fuel to be used routinely in special combustion engines and whether fuel cells are suitable for day-to-day use in private car, buses and commercial vehicles. The volume of hydrogen spent today amounts to approximately 1/5 of the world-wide natural gas consumption. There is no pure hydrogen in nature. For that project it is produced from renewable energy sources (of Vattenfall). The first public hydrogen filling station in Europe allows filling up cars with hydrogen, petrol or diesel. The project envisages is including customers as test drivers at a later stage in order to enhance the acceptance and attractiveness of hydrogen-powered vehicles. It is planned to expand the project to include commercial marketing starting in 2006. The business sector has provided funds totalling € 28m for the project, while the German government provided € 5 million for the necessary filling station infrastructure. [11]

2.3.3 Effects and economic efficiency of fuel cells

The use of stationary fuel cells helps avoid some 30 percent of CO2 emissions compared to the current separate generation of electricity and heat. Only 10 percent of the electricity supplied today in Germany is based on the co-generation principle. Over two million heating installations need to be modernised in Germany by 2010. This provides an ideal opportunity to expand the use of co-generation e.g. by installing fuel cells, especially since co-generation technologies make an essential contribution to improving the climate balance of the energy sector in the short run. A short-term increase of efficiency of up to 60 percent is seen as realistic, while an efficiency of 70 percent is considered achievable. [4] Pilot projects are underway to investigate the effects of integrating smaller, more local networks into the interconnected energy system. The development of modern information and communication technologies allows concentrating and coordinating small individual plants to form a so-called decentralized power plant. Germany will have to fundamentally renew its power plant park in the next few years. It has thus the opportunity to use the construction of new plants to change its spatial supply structures.

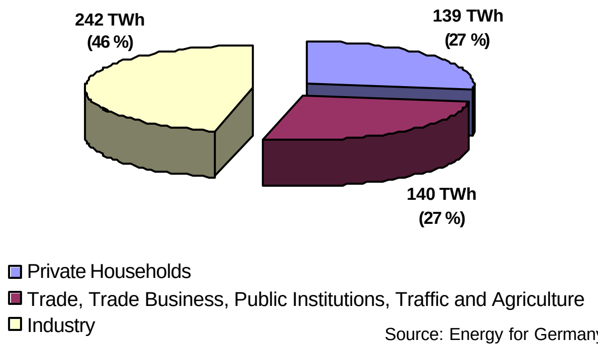
CO2 emissions of the transportation sector amounted to 169 million t in 2003, an increase of 6 percent compared to 1990 (159 million t) [14]. Fuel cells offer the most promising perspectives for the development of an environmentally friendly low-noise driving system since they offer double the efficiency of a combustion engine with no pollution. Given the rapidly growing traffic in our cities, an emission-free low-noise operation is a major benefit.

As a technology of the future the fuel cell is still in its development phase. A wide-spread use of hydrogen is currently restricted by the lack of capacities for low-cost hydrogen production, the lack of infrastructure and the lack of fuel cells available at competitive prices. Furthermore, its lifespan is still insufficient for wide-spread commercialisation. Currently the vehicles with alternative drive are 10 fold increase of the normal mass-produce vehicles. BMW has designed a car that can be run on both fuels for a transitional period. 20 percent of German vehicles were supplying with hydrogen by the planned offshore (70 – 85 TWh electric energy per year). Instead of pure hydrogen, synthetic liquid fuels from coal gasification, non-conventional oil reserves or biomass can be used temporarily. Hydrogen is already produced from fossil fuels by steam reformation in industrial facilities (efficiency of 70 to 80 percent) e.g. non-polluting production from steam and natural gas [4]. These synthetic fuels can use existing infrastructure. Synthetic liquid fuels may become the new price-determining source of energy. Given the increase of world-wide energy consumption especially in the area of mobility, crude oil is likely to keep its position in the world energy market in the near future besides new synthetic fuels and later hydrogen. The pilot projects are therefore important to gain first practical experience in order to be able to improve the technology in a more efficient and targeted manner.

3 Demand and potential efficiency

39 percent of the German primary energy consumption (489 million t of hard coal equivalents) was covered by domestic sources (including nuclear energy) in 2003. Households account for approximately 27 % percent of the German energy demand (see figure IV). Private households reduced their CO2 emissions to 122 million t. This is a 5 percent reduction compared to 1990 (129 million t). [14]

Figure IV: Net Power Consumption in Germany 521 TWh (without Net Losses and Power Plant Installation Consumption)



Source: Energy for Germany, DNK 2004

Nevertheless, electricity consumption has gone up continuously and the oil crises had no visible effect on electricity consumption. This is the result of the direct dependence of users on the electricity markets. Moreover, electricity prices have been relatively moderate and stable over a long period of time. 80 percent of German electric utilities offer or intend to offer specific ecological electricity products. This boom of the supply market is hardly met by consumer demand. While surveys show that about two thirds of the population want to protect the environment, less than one percent is prepared to pay more money for it. According to estimates, a 50 fold increase of the market volume is possible [15]. As a result, more and more consumers are supplied with energy generated in an environmentally friendly way (feed into the system under the EEG), while very few pay the higher ecological tariffs. The biggest problem of the electricity sector is the impossibility to directly allocate the electricity generated to individual suppliers (e.g. WT and PV). There is only one electricity system. As a result, electricity generated in an ecological way ends up in the same system like conventional electricity. Certificates and quality labels are used to demonstrate to electricity customers that ecological electricity comes from reliable and environmentally friendly sources. Existing labelling regulations are however inadequate since they fail to prescribe a uniform design. No information about the country of origin is required, instead a non-binding statement about environmental effects is considered sufficient. Furthermore, there is a lack of sufficient legal control. Since electricity is traded in international markets, cross border efficiency standards and labels should be introduced.

The mobility sector showed almost the same continuous development trend like the electricity market. Here, oil has bound consumers. Due to the buffer effect of high fixed costs (for transport and refining) and high taxes (up to 80 percent of the final price), the real end price paid for gasoline remained relatively stable despite growing oil prices. The mobility sector accounts for 60 percent of the entire oil consumption [14]. Synthetic liquid fuels are currently being tested under practical conditions as to whether the can provide an alternative to oil (see chapter 2.3.2). Given the still relatively low energy demand for mobility purposes in most of the developing countries, a rapid increase in demand is expected in the next few decades.

Unlike the mobility sector, the stationary use of fossil fuels (e.g. as heating energy for buildings and industrial processes) experiences a decline in energy consumption in each energy crisis [14], i.e. the consumption starts to decrease in stationary systems in industrialized countries, while world-wide consumption remains stable. The higher efficiency of energy conversion is one contributing factor. The motive behind the energy reduction may be either efforts to save money or enthusiasm for modern technologies/innovations or a deeply-felt responsibility for future generations. The additional benefit felt is an incentive to increase efficiency. Consumers may use energy more efficiently e.g. in buildings, machines, appliances, motor vehicles or transportation services. Examples are:

- Better insulation (e.g. vacuum insulation and windows improve insulation 10-fold compared to customary insulating material [4])
- Air-conditioning of buildings (automated complete solutions with controlled ventilation in combination with heat exchangers and heat or cold storages)
- Automatic breakers (in standby mode: to cut electric appliances from the mains)
- Load management to shift maximum electricity withdrawal to times of low demand (e.g. by variable tariffs and subsidies for storage technologies, or automatic control of household appliances according to the tariff situation)
- Energy consulting and contracting with regard to e.g. facility contracting saving measures on the basis of renewable energies or cogeneration.

Voluntary labelling and governmental minimum efficiency standards have been established to provide orientation. In the long run, it would be desirable to make cross-border labelling compulsory for energy-intensive consumer goods, buildings, industrial facilities and services and to update them in line with new developments. The EU is already planning to introduce energy labelling for buildings from 2006 onwards. As a result, the regulatory framework of the future may stipulate ambitious targets with regard to the use of heating and refrigeration energy and provide suitable support programs [15].

Energy strongly determines our quality of life: in industry, transportation, housing and leisure. The restricted reach of traditional energy sources can be countered by energy savings and efficiency increases in the conversion, distribution and use of energy. As a result, the net energy demand can be reduced by 30-35 percent. This will lead to a higher quality of life and more jobs. Furthermore the technical innovations contribute to sustainable energy supply.

4. Summary and outlook

The political target to strive for environmental compatibility of the energy sector is reflected by the use of renewable energy sources and the growing resort to cogeneration. The Renewable Energy Act laid the foundations for this development. Industry made this advance possible by remarkable technology leaps. Now further activities are needed to make these technologies world-wide applicable and to improve specific energy solutions. Despite intensive efforts it has not yet been possible to reduce the output of conventional power plants by promoting renewable energies. By coincidence, the increase of electricity consumption in Germany (8 TWh) was just as high as the expansion of renewable energies in 2003.

Large theoretical generation potentials of renewable energies have not yet been tapped because of technical, economic, political and ecological factors. Fossil energy sources and conventional power generation will continue to be the basis of electricity supply for a long time. Long-term scenarios forecast a doubling of the world-wide energy consumption by the year 2050 (to 27bn t of hard coal equivalents) compared to 15bn t in 2003 [14]. The investments necessary for the restructuring of the energy system will mainly come from private business. In a free market economy, the success of a company is mainly determined by the purchase behaviour of its consumers. Adequate framework conditions must allow for a broad and balanced energy mix involving all energy sources and available technologies while ensuring supply security.

The following developments and technologies will be of crucial importance in future:
- Increase of fuel efficiency in all types of power plants (e.g. large-scale use of CO2-free power plants will be possible from 2020 onwards), while replacing worldwide all coal-fired power plants older than 20 years; newer plants will allow to cut CO2 emissions by 1.4bn t p.a. which corresponds to a reduction of worldwide CO2 emissions by 6 percent
- Joint and coordinated concept of wind turbine manufacturers, project developers and operators, system operators (DSOs and TSOs), authorities and politicians to integrate large offshore wind capacities into the supply system (to examine the overall system behaviour, repercussions on system stability, reserve capacities of power plants)
- Solar backed heat systems and central heat storage systems and their combination with other non-polluting sources of heat (like biomass, geothermal heat, waste heat from highly efficient cogeneration plants) to ensure a largely CO2-free supply of heat since the use of sun energy provides the biggest potential in the long run.
- Large-scale interconnection of energy producers and consumers to transport electricity over long distances and to make use of statistical balancing effects e.g. between wind and solar energy converters and to adjust generation and demand
- Use of fuel cells in stationary cogeneration of electricity and heat or in vehicles as a bridge function to the hydrogen economy
- Use of hydrogen as an innovative storage and transportation medium of energy generated from renewable sources in consideration of safety, since hydrogen is highly explosive
- Reduction of the end energy consumption by measures aimed at implementing potential energy savings
- Technology transfer with regard to (renewable) energies and implementation support especially in regions where permanent supply security is not a major concern. This is a task to be tackled jointly by governments and the energy sector leading to far-reaching positive effects (such as flexibility, peace and security)

To achieve these goals, uniform framework conditions are important at the international level such as opening of markets and harmonization of international competition. Competitive distortions should be avoided and market barriers should be dismantled in national markets. This will lead to a functioning competition for energy services and furthermore to research, development and education programs.

Bibliography

[1] Wind Energy Study 2004: Assessment of the Energy Market until 2012, 2004 (http://www.hamburg-messe.de/Scripte/allgemein_Info/Bestellung_DEWI-Studie/Studie_WindEnergy_en.htm?Menu=Visitor)
[2] Bundesministerium für Umwelt, 2004 (www.bmu.de)
[3] Bundesverband Windenergie e.V. (BWE): Grundlagen der Windenergie, 2003 (www.windenergie.de)
[4] German Advisory Council on Global Change (WBGU): World in Transition – Towards Sustainable Energy Systems, 2003
[5] Boehmer-Beuth, U.: Energie aus Windkraft, 2003
[6] Deutsches Windenergie Institut (DEWI), Rehfeldt, K. et.al.: Weiterer Ausbau der Windenergienutzung im Hinblick auf den Klimaschutz, 2001
[7] World Energy Council (WEC): Energy for Tomorrow´s World – Acting Now!, 2000 (http://www.worldenergy.org/wec-geis/publications/reports/etwan/exec_summary/exec_summary.asp)
[8] Hug, R.: Herausforderungen 2004: Nachhaltigkeit und erneuerbare Energien, 2004 (www.solarserver.de/solarmagazin/artikeljanuar2004.html)
[9] Pitz-Paal, R.: Solarthermische Kraftwerke, 2004 (www.bine.info/pdf/infoplus/FachartikelPitzPaalDLR.pdf)
[10] Nitsch, J. et.al.: Schlüsseltechnologie regenerative Energien, 2003 (http://www2.dlr.de/TT/system/publications/HGF-Text_TeilA.pdf)
[11] Clean Energy Partnership (CEP): Mobil mit Wasserstoff – staying mobil with hydrogen 2004 (www.cep-berlin.de)
[12] Vaillant: Feldtest ”virtuelles Kraftwerk” mit Brennstoffzellenheizgeräten gestartet (www.vaillant.de/mod/netmedia_pdf/data/prmi01_04_virtuelles_kraftwerk.pdf)
[13] Graf, D.: Einführung von Wasserstoff als Energieträger: Rolle der Energiewirtschaft, 2004
[14] World Energy Council (DNK): Energie für Deutschland, 2004
[15] Wüstenhagen, R.: Ökostrom von der Nische zum Massenmarkt, 2000