Research for a Sustainable Energy Supply
Recommendations of the Scientific Advisory Board of VGB PowerTech e.V.
2007
Secure energy supply is of utmost importance to any modern economy, vital for the economic capacity and for securing appropriate conditions of living and the welfare of society.

Thus, energy is a paramount topic for future development. Energy has to be made available in an environmentally friendly and socially compatible way. Therefore, it is being recommended to spend energy economically in an ecologically sound manner in order to prolong the utilisation of limited resources. Substitutes are to be identified in due time for sources of energy that are petering out.

Research and development are the key for the solution of energy-related problems within the scope of overall concepts that also comprise increases in efficiency, protection of the environment and identification and development of new sources of energy. Research funds are not to be used in favour of or against any form of energy but are to be allocated evenly because it goes without saying that research results are not predictable.

The funds for energy research – public funds and industry budgets – and the related direct and indirect consequences, i.e. the number of junior researchers and students, are far from meeting the employment requirements of energy engineering. A close link between industry and universities in the field of energy engineering and natural sciences to support training and education is indispensable. Besides, social and scientific acceptance is often missing for this demanding and sophisticated technology.
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Executive Summary

In a period of rapid change in the European energy supply, new political strategies to develop sustainable energy technologies are required. Adequate funding of research provided by the EU and the EU member states is a precondition for industrial implementation, commercial use and export of technologies.

On this behalf, the Scientific Advisory Board of VGB PowerTech expresses its view of the situation, its concerns and suggestions. Thus, the members of the Advisory Board, representatives of a variety of technical disciplines and numerous European universities, intend to elucidate the university perspective and bring it into the discussion between politics and industry.

An intensive discussion on the following problems of future energy supply, and hence the energy research situation, is urgently needed. Facts and discussion points are

• how to ensure energy supply by sustainable use of all available primary energies,
• how to define a conclusive way to reduce CO₂ emissions,
• withdrawal of utilities and manufacturing companies from pre-competitive research activities,
• how to meet losses in public acceptance, resulting in insufficient numbers of students and junior staff,
• a far too low priority of energy research within the European Research Area,
• a decrease of specific national energy research.

From the Advisory Board’s point of view, an immediate RD&D consensus between politics and industry is regarded as necessary, taking into account all future possibilities and constraints of energy supply. This paper should also demonstrate contributions to be expected from university research.
1 Energy supply – status
The liberalisation of the energy market and, consequently the “unbundling” of the value adding chain, have already induced considerable business restructuring processes and extreme adaptations to utilities and plant manufacturers. The energy industry was very cautious under these circumstances. Thus, enormous investments – which were not made in the past – are required today to meet the increased and still increasing demand in energy, to cope with the changed generation structure and the aging of installed electricity generation and transport facilities. In some countries long delayed new power plant construction programmes were launched only recently. It is being estimated that in the next 20 years investments of nearly 1,000 billion Euro will be needed. The economies of the EU will have to accept this challenge. Practically all European states depend more or less on energy imports. In its Green Paper “Towards a European strategy for the security of energy supply” (published in November 2000), the European Commission emphasised this fact in its 2006 version. The degree of dependency on energy imports is expected to grow from some 50 to about 70 % in the next 20 years. This dependency is differing according to each source of energy. The evaluations will also have to take into account the circumstances in the supply countries. This situation is very striking for natural gas. It is expected that the import dependency of the EU on this source of energy will increase in the next two decades to more than 80 % and that Russia will extend its dominating role as the most important gas supplier for the EU member states. The worldwide energy demand will further increase. According to forecasts, it is assumed that the primary energy demand will increase by some 60 % in about three decades. This is particularly obvious in threshold countries like China and India. Annual economic growth rates partly reach double-digit numbers; they all require an increase in primary energy production of at least the same size. Today, these countries already need net imports of some primary sources of energy. Under these circumstances, the problems of resources of individual primary sources of energy will aggravate and a global competition will result. This problem can partly be alleviated by efficient energy application. The prices for energy – but also other raw materials – will increase. Natural gas and fuel oil prices have doubled in Europe within a few years and due to increasing demand the situation will not relax. This is connected with partly serious effects on some energy conversion processes where costs highly depend on the costs of the input energy (e.g. gas or coal).
For reasons of climate protection, the CO₂ emissions have to be decreased worldwide. With the ratification of the Kyoto Protocol reduction targets for greenhouse gases were fixed, although large polluter countries have not yet ratified the Protocol and are still not obliged to decrease emissions. Reduction targets beyond the scope of the Kyoto Protocol are being debated vigorously.

The EU committed itself to lead the way to the reduction of greenhouse gas emissions. An important instrument for meeting the Kyoto targets for parts of the energy industry is the implementation of emissions certificate trading. It is planned to extend this scheme to other energy businesses. For reasons of climate protection and to reduce its import dependency, the EU also wishes to increase the share of renewables. Not only for primary energy consumption, but also for individual areas like electricity generation or engine fuels, supply targets were agreed upon for 2010 that require a minimum share of renewables. The individual solutions are up to the member states and are dealt with differently. However, it is a fact that thanks to the increased application of renewables and nuclear power the consumption of fossil primary energy sources can be reduced and thus the resources can be saved, i.e. less CO₂ emissions are discharged.

There is consensus about the fact that energy efficiency has to be further increased on the generation as well as on the consumption side. Increased energy efficiency will in turn reduce consumption of primary energy, greenhouse gas emissions, its effect on the environment and import dependency. The questions in connection with zero-CO₂ primary sources of energy are considered differently. This applies to renewables and to a larger extent to nuclear energy. Besides, technologies are being developed to separate CO₂ in power plant processes and to store it for the long term in geological formations. These technologies will be able to contribute to emission reduction in the energy industry in about 20 years at the earliest.

2 The future of energy supply – predictions

In most forecasts of the future development of the EU, it is assumed that power consumption will increase faster than consumption of primary energy. Another assumption is that future power consumption will grow proportionally to the gross national product. Thus, power demand intensity will increase, whereas the intensity of primary energy demand — that is the value related to the gross national product — will decrease. IEA¹ is assuming annual growth rates of primary energy consumption until 2030 of 0.7 % for the EU and 1.7 % worldwide. Accordingly the increase in electricity generation amounts to 1.3 % for the EU and 2.5 % worldwide. The share of fossil primary sources of energy will even increase in the EU and worldwide. This is mainly due to the decreasing share of nuclear energy in some countries that is only partly made up by renewables.

Electricity demand can be covered by fossil fuels, nuclear energy or renewables. In 2002 the world gross electricity generation amounted to 16,074 TWh, 65.3 % of which were based on the fossil fuels coal, oil and gas, 16.5 % on nuclear energy, 16.2 % on hydro power and 2.0 % on other renewables. The corresponding data for the EU are 2,986 TWh with 54.4 % fossil fuels, 32.2 % nuclear energy, 10.1 % hydro power and 3.3 % other renewables. Fossil primary sources – mainly natural gas – of energy that are consumed in electricity generation will have higher growth rates. In total the share of fossil fuels spent for power generation will increase by 5 % worldwide and in the EU until 2030.

¹ Source: IEA World Energy Outlook 2004
Against this background, enormous endeavours have to be made to protect the climate. The reduction of CO\textsubscript{2} emissions – while energy consumption and the share of fossil fuels are increasing – will only be possible in exceptional cases. Thus, the increase of energy efficiency is most important in the short and medium term, both on the generation and consumption side.

3 European energy research policy – status

The “White Book” on renewables issued by the EU in November 1997 has set the target to double the use of renewables in the period 1990 to 2010. “An Energy Policy for Europe” of the EU from January 2007 requires a share of renewables of 20 % for the year 2020 as binding target. Today, the amount of renewables in electricity generation is less than 7 %. Even if this target will be met and the energy saving measures will be implemented successfully it will not be possible to cover the demand securely and sustainably with today’s technologies. Thus, research is required to strengthen the efforts in order to use existing sources of energy more efficiently and to develop new energy conversion technologies.

The European industry managed in the past to take a leadership role in the construction of energy conversion plants with high energy efficiency and high environmental standards. One of the most prominent events of these joint activities was the increase of the efficiency of coal-fired power plants in Europe by nearly 10 % points. Efficiencies of more than 45 % in coal-fired steam power plants and nearly 60 % in combined gas and steam power plants on natural gas basis demonstrate impressively the state of the art that is also being implemented in the new power plant construction programme.

As already mentioned, the European energy policy is coined by the achievement of the climate protection targets and the concern about the growing European dependency on energy imports. These problems were partly taken into account by the 7th Framework Programme of the “European Research Area (ERA)” for the years 2007 to 2013. In comparison to the 6th Framework Programme, where the development of energy conversion technology was only a sub-issue within the scope of “Sustainable development, global change and eco system” and thus not a primary target within the sense of the Green Paper, energy research is now enjoying a much higher significance.

The 7th Framework Programme mainly comprises four specific programmes (co-operation, ideas, people, and capacities).

Each of these specific programmes is connected to a certain purpose, an own structure and individual application conditions. Energy research now received an own emphasis within the scope of the specific programme “Co-operation”. It is the objective to adjust the energy industry that is mainly based on fossil fuels to a more sustainable supply based on a broad energy mix. The focus is on technologies with low or zero CO\textsubscript{2} emissions in connection with improved energy efficiency and rational energy utilisation in order to meet the challenges of supply security and climate change and to simultaneously increase the competitiveness of European companies.

Apart from hydrogen and fuel cells, research funding is concentrating on the production of fuels derived from renewables, renewables-based electricity generation, renewables for heating and refrigeration purposes, intelligent energy networks, knowledge and facts for political decision making, energy efficiency and energy savings and fortunately also CO\textsubscript{2} separation and storage for low-emission power generation as well as clean coal technologies.
In total it can be ascertained that the financial budget in the field of energy research – however commencing from a low level – was extended. Against the background of the importance of the topics energy and climate protection this positive development cannot be considered sufficient and calls for further intensification and action.

4 Education of engineers and junior research staff

By the end of the nineties energy and energy supply were of minor interest in the broad public perception. Energy was available and energy engineers were dealing with it in secrecy. That situation was particularly striking at universities, because the majority of students did not take any interest in engineering courses apart from “modern” fields like information and communication technology.

After a couple of years the broad public opinion has changed. Energy in general and its supply have become subjects that not only enjoy more attention but already cause interest and concern. That does not mean that more school leavers are seriously considering to study energy engineering, however, a turnaround of the public opinion is noticeable. What is the reason for that? Two fields of knowledge seem to be dominating: On the one hand the understanding about the finiteness of fossil fuels and on the other hand the burgeoning danger of climate changes due to the so far worldwide uncontrolled discharge of CO$_2$ emissions. These two findings were the main aspects in energy perception at the end of the past century and made energy a priority topic in broad discussions, i.e. even people so far not involved in these subjects started to discuss the issue. Also a paradigm shift could be observed: people who had a more critical attitude against nuclear energy considered it differently because of the climate danger caused by CO$_2$.

The electricity demand in EU 25 will increase from today 3,000 TWh/a to 4,400 TWh in 2020. Due to the age structure of the current power plant portfolio and the phase-out of nuclear power in Germany, a capacity gap of some 2,400 TWh will emerge. Thus, the question has to be answered how to close this gap. Anticipating a technically realisable mean utilisation factor of 7,500 full-load-h/a for thermal power plants and expected 3,000 full-load-h/a for wind power plants (onshore and offshore) we would require:
- 200 nuclear power units with a capacity of 1,600 MW each, or
- 320 lignite-fired units with a capacity of 1,000 MW each, or
- 530 hard coal-fired units with a capacity of 600 MW each, or
- 800 combined cycle gas-fired power plants with a capacity of 400 MW each, or
- 160,000 wind energy plants with 5 MW each (plus a backup capacity margin of 80 %, e.g. 425 hard coal-fired power plant units or 640 combined cycle power plants).

These figures alone demonstrate that also in future an energy mix will be required to secure electricity supply. But first and foremost these figures underline the enormous engineering capacity that is needed within the EU for the construction and operation of replacement power plants. So far no solution has been identified to cope with this issue, thus future energy supply will be facing more serious problems.

The VGB Scientific Advisory Board is aware of the problem and intends to increase the attractiveness of engineering university courses. Therefore, a curriculum was drafted as a first step towards a consecutive bachelor and master university course that is to meet the requirements of the world of labour.
5 Recommendations

5.1 General research objectives

Research for sustainable energy supply has to take into account the following facts:

• In the next 30 years, the worldwide consumption of fossil energy is expected to equal the world’s total consumption up to now.

• Fossil energy sources will continue to provide the majority of the energy supply.

• Renewables, which are to cover 20% of the energy demand by 2020 according to EU plans are expected to increase their contribution. However, their absolute share of energy supply will remain marginal.

• Nuclear energy is currently supplying 15% of the EU primary energy supply as largest CO₂-free energy conversion technology. It will be required in Europe and worldwide for the aforementioned reasons.

• Objectives of energy policy will have to correspond to the targets of the Kyoto Protocol and further agreements as well as to the Cleaner Coal Technology Recommendations.

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After liberalisation of the market, new research structures are required. They must not only take into account the general changes, but will determine the direction and speed of progress in the development of technologies for sustainable energy supply.

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For major research programmes it is necessary to build up research networks and to create centres of competence in order to accelerate the development in all areas of power plant engineering and to obtain optimum results.

Co-ordination becomes even more vital in cases where model demonstration plants have to be realised for central large power plant concepts, e.g. for supercritical steam conditions with temperatures exceeding 700 °C, for coal-based combined cycle power plants, or for integrating CO₂ separation and -sequestration into the process (“CO₂-free coal power plants”).

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In the USA and Japan, clearly structured and long-term energy development concepts have been initiated. In Europe, such concepts are badly needed. The approaches for such concepts in the form of technology platforms are formulated for the 7th Research Framework Programme of the EU. Now these approaches have to be implemented, however, the following aspects have to be taken into account for an overall concept of research policy:

• Analyses of complex systems for energy supply, the energy market and the use of energy, resulting in a clear political declaration of intention, have a key function.

• Because of their long lead times, new technologies for increasing the energy conversion efficiency have to be developed into demonstration plants as fast as possible. Processes for the years following 2010 have to be developed, tested and demonstrated now.

• At present, efficiencies of up to 50% for coal-fired power plants and of more than 60% for natural gas-fired power plants are realised. Higher efficiencies seem possible, but not yet feasible.

• In recent years, the European power plant industry has achieved a good position in the global market. Thus, supercritical and environmentally compatible units developed in Europe
can be successfully sold worldwide against competitors from America and Asia. Such exports will not succeed without a demonstration plant erected in the European home market.

- Within the scope of the “Clean Development Mechanisms” developed by the EU, “Cleaner Coal Technologies” which are particularly relevant not only for research, technical development and demonstration, but also for achieving the objectives of the Kyoto Protocol, must be given an outstanding position.
- Promotion and funding of research in the field of renewables and other future energy sources ought to be focussed on fundamental, pre-competitive and near-market topics.
- Nuclear safety and final waste disposal are of top priority.

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The effects of direct and indirect funding of research on the training of junior energy engineers must be taken into account.

- Preconditions for high-quality European university research (and highly qualified graduates) are adequately equipped research institutes funded by public means, project-related governmental funding of research work on a reliable scale allowing continuity, and additional case-by-case funding from the industry.
- Project-oriented public funding of basic research for university institutes is the best investment into European “human resources”.

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It is an important task in Europe to ensure that joint research (co-operative activities) of universities, manufacturing companies and energy suppliers is further supported. Research capacities can thus be pooled, making it more effective.

In agreement with industry, university representatives should also be included as advisors into the formulation of governmental energy research programmes at an early stage.

The industrial joint research of VGB PowerTech, the Technical Association for Power and Heat Generation, can become an integrating and co-ordinating element of the power plant-related research structure now under development in Europe. European energy technology will become more competitive thanks to contributions from the increasingly European orientation of VGB.

5.2 Objectives of research

Detailed research objectives can be derived from analysing the future energy demands and the subsequent requirements that have to be realised by technology.

The following list of tasks is to demonstrate the variety regarded necessary in the field of energy research. It has been set up without claims to completeness or priorities.
Survey of research tasks to be tackled:

Central generation units based on fossil, nuclear or hydro power
- steam power plants with maximum efficiency,
- coal-based combined cycle power plants with pressurised combustion (IGCC), more efficient gas turbines,
- advanced materials (metal, ceramics, plastics),
- advanced, safe, economical and low-waste nuclear reactors and reduction of the amounts of final deposits (e.g. through partitioning and transmutation),
- integration of energy supply (power/heat/low-temperature heat) with fuel production (syn-gas, poly generation),
- process monitoring and process diagnosis, optimum control algorithms, condition-based maintenance, life-cycle analyses,
- recording and optimisation of plant lifetime,
- high-temperature membrane technologies for gas separation,
- technologies for separation and sequestration of CO₂ (development and demonstration).

Decentralised energy conversion in plants based on combined heat and power plants with
- fuel cells,
- small-sized gas turbines and small-sized motor engines and
- their integration into decentralised generation units, e.g. by central control (virtual power plant).

Use of renewables on the basis of
- wind (e.g. generation and feeding in from offshore wind installations),
- hydro-power (e.g. environmentally compatible, more efficient hydro-power plants),
- solar energy (e.g. solar thermal power plants),
- biomass (combustion and gasification).

Waste disposal
- integration into energy supply,
- linking of waste disposal and electricity generation plants.

Hydrogen technology
Setting up of a secure (reliable) and economic technology for
- production,
- transport,
- storage and
- use in stationary plants.

Electrical grids
- topology and stability.

Materials research
- system-related materials research for implementation into process technology.
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