Clean and Sustainable Energy Supply – The European Approach

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1. Development and Status of the European Union

The European Union (E.U.) is a multinational and intergovernmental union, established in 1992 by the Treaty of Maastricht, The Netherlands, with the intention to promote the economical and political integration of the member states. The present union is the successor of the s.c. Common Market, the European Economic Community (E.E.C.), founded in 1957 as a supranational association with the purpose of enhancing the economic cooperation of the first 6 members Belgium, The Netherlands, Luxembourg, France, Italy and West Germany. In the following years this community became enlarged by new partners - Denmark, Ireland and Great Britain in 1973, Greece in 1981, Portugal and Spain in 1986 - forming the first E.U. of 12 member states in 1993. Ten more partners gained accession to the union in 2004 (Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia), followed by Bulgaria and Romania in 2007, which brought the total present number of member states to 27.

The E.U. represents a single market with no internal barriers, a common trade policy and an own currency adopted so far by already half of its members. Despite of still very strong and historically based gradients in industrial development and economy, in particular between the early partner countries in Western Europe and the more recent new member states of Centre and Eastern Europe, the economy in the European Union has grown steadily over the last decade, resulting in a total GDP increase of almost 48% since 1996. Thus, the E.U. has developed up to today into one of the largest economical and political units in the world.

In line with the economic growth in the E.U., the expected rise in gross energy consumption during the last decade was with 12,1% comparatively low, which – at a marginal population increase of about 2.3% – resulted in a reduction of the energy intensity of more than 11% [1]. This positive tendency is due to both savings in direct use of primary energy sources, and an increasing application of more efficient energy conversion processes and, thus, the specific consumption per inhabitant is – in comparison with similarly advanced regions of the world – much lower, for example less than half of that of the U.S.A.

In more detail, the gross inland consumption of energy in the E.U. is with more than 77% essentially based on fossil fuels (37.3% oil, 23.9% natural gas, 17.9% solid fuels), with only 14.6% nuclear energy and 6.3% renewable sources. Furthermore noteworthy is – as in most industrialized regions of the world – the remarkable move towards the conversion of primary energy into electricity as the most versatile form of usable energy. Between 1994 and today, the electricity generation in the E.U. increased by more than 25%, which is much in excess of the rise of the total energy consumption of 12.1% during the same period.

The above stated energy consumption is in contrast with an own total production of primary energy carriers which is insufficient to cover the demand. Therefore, there is today a dependence on energy imports of on average approximately 50%.

2. Expectations and Response

The above given data briefly characterize the present situation in the E.U. and underline the critical issues, some of which also apply to other regions of the world:

- The ongoing rise in demand for energy will continue; for the E.U. 1-2% per year is expected for the coming two decades with an even stronger need for electricity.
- For a foreseeable future the primary energy base in the E.U. will remain essentially similar to that of the previous decade: almost a third is based on nuclear power (its future utilization being under controversial discussion in various member states), about 10% is hydropower and (because of strong political support and subsidy schemes) a small but steadily growing part is provided by the utilization of biomass and, in particular, wind power of presently below 4%. Consequently, the major energy conversion is based on fuels of fossil origin with a predominant share of oil for the petrochemical sector and subsequent transport application whilst coals and – with rising tendency – also natural gas are used in stationary conversion processes.

- For natural reasons, the E.U. as a whole is short of primary energy resources; still available reserves are limited and/or not competitive to mine. As a consequence, the always existing dependence on primary energy imports, grown already to about 50%, is expected to increase to 65 or even 70% by 2030. Without any countermeasures, the reliance on imports of natural gas may rise to above 80%, of oil to above 90% [2]. Given such a strong dependency and an already experienced high fuel price volatility, the observable concentration of external fuel resources in the hands of a decreasing number of suppliers may imply the danger of economical risks and political uncertainties.
- In line with the profound opinion of many leading scientists of the world and supported by various extensive international studies, e.g. [3], [4], it is generally believed that our climate and a related "global warming" is negatively effected by anthropogenic activities, in particular the CO_2-emission from the conversion of fossil fuels, by more than 60% globally and even about 80% in the E.U. Despite the almost constant CO_2-emission in the E.U. during the previous decade, any projected rise of primary energy conversion will lead to additional emissions of CO_2 (as well as other s.c. greenhouse gases) which, in case of "business as usual", leaves the achievement of the targets of the Kyoto Protocol – and any more demanding goals already under discussion – highly questionable or impossible.

With these background issues, the European Union has adopted a long-term and coherent energy policy for balancing the three following challenging key objectives:

- Sustainable security of supply
- Environment protection
- Economical competitiveness

The first objective comprises essentially the two main goals of minimizing the energy utilization by improving the energy efficiency on one hand, and providing energy at necessary quantities and qualities for the consuming market. Numerous programmes were set up to support activities in areas such as:

- Saving energy by reducing / avoiding losses at the end-user, including the provision of measures for public convincement and incentives for the application of technological improvements;
- Increase of energy conversion processes for both mobile and stationary applications, including component improvement, retrofit of existing installations as well as replacement strategies for the rapidly aging fleet of European large scale industrial plants;
- Alleviation of the import dependence via improvement and further diversification of the already practiced energy mix, e.g. by supporting the rapid development of renewable power resources and their competitiveness as well as (re)vitalizing "dormant" energy reserves;
- Enhancement of external energy policy relations in order to ensure a safe, affordable and long-term provision of primary energy and, thus, to reduce the potential external of supply failures.

With regard to the second objective concerning the environment, any of the above areas with the intention to lower the use of fossil fuels will also be of immediate benefit to reducing CO_2-emissions. In addition, actions for CO_2-separation, capture and storage are initiated and supported.

Finally the third objective, competitiveness, covers topics such as the support of new and emerging energy- and environment-saving technologies, the stimulation of clean energy production and the further opening of the E.U.-internal market.

For the performance of the activities, policy measures were developed such as a recently distributed Green Paper on "A European Strategy for Sustainable, Competitive and Secure Energy" [5], which elaborates the priority areas for possible common actions and comes up with concrete proposals for immediate motions.

In order to path the future in Europe, and in line with the above challenges, the priorities of the ongoing research programme of the European Commission to support research, development and demonstration are the following:

- Energy savings
- Energy conversion efficiency
- Renewables in heating/cooling/electricity production
- Hydrogen/fuel cell technology
- Clean coal technologies
- CO_2 capture and storage technologies for zero emission power generation

Furthermore, most recently the European Union drastically tightened their already ambitious goals for reducing the influences on global climate by setting a target towards limiting the global temperature increase to a maximum of 2°C. For this, the strategic objective is a 20% reduction of green house gases by 2020 (and even 50% by 2050, provided that other regions of the world will follow), compared to 1990 by an "Energy Efficiency Action Plan" for three sectors, namely transport, buildings and electricity/heat generation. More precise, a mix of all primary energy sources is intended including 15% nuclear power (one third of electricity) and 20% renewables (with 10% bio fuels for transport).

3. Technological Advances

Within the carbon-free options, hydropower as one of the regenerative energy sources is already extensively used, and a substantial increase of its about 5 % share in Europe is unlikely. Other regenerative sources such as wind and solar energy are favoured by politics and by some part of our society and therefore, their utilisation is at present heavily subsidized in many European countries. However, area requirements, energy density, local availability of the natural energy source, local net considerations and investment costs may restrict their application. Still a limited contribution to the overall electricity supply will be provided by these sources even in regions of Europe with less beneficial natural boundary conditions.

Another alternative is the use of s.c. "CO_2-neutral" fuels like biomass (both grown or as by-products from various industrial processes). Europe is targeting for an increased utilisation of such sources from 3% in 1995 to almost 9% share in the energy market by 2010. The potential of such fuels as a part-replacement is remarkable considering the regional availability of such fuels, the positive effect of preservation of primary energy resources and of alleviating disposal problems, and the attraction of co-utilisation in existing fossil fuel fired plants as a technically feasible and cost-effective solution. Based upon the positive experience from industrial demonstration projects ongoing in the E.U. and numerous other activities, the additional use of biomass seems promising although comparatively limited in total capacity.

Therefore, the security of supply requires the energy efficiency of conventional fuel conversion based on fossil fuels to be raised considerably. One of the major ongoing research and development issues in Europe is dealing with the further improvement of the efficiency of the conventional supercritical power station concept with pulverized coal. This concept is entirely devoted to improving the fuel conversion process by testing advanced materials. At present, materials are under investigation for 700 °C application at 350 bar in a 500 MW_e boiler for the design of a next generation demonstration power station to be commissioned at about 2015 [6]. This process is aiming at overall efficiencies of above 47 % and thus, a considerable reduction of the specific CO_2-emission in comparison to the state-of-the-art. Because the present emission control technology complies with the European standards, no further development of flue gas treatment is required at this stage.

In addition, new concepts towards a Zero Emission Power Plant (ZEP) were started in recent years, in line with the Carbon Capture and Storage (CCS) initiative of the European Commission [7]. One of these concepts is the Post Combustion alternative, in which the CO_2 is separated from the flue gas by scrubbing with e.g. amines or other chemicals. This well-known technique is supposed to be economically applicable for power plants with already high efficiency and even for retrofit purposes at such plants. As this low temperature gas treatment needs an additional energy consuming, regeneration of the sorbents research is ongoing on this process and on alternative separation techniques in order to reduce the efficiency penalty as well as costs. However, as an interesting technology this process was investigated within an E.U.-supported research project and is at present considered to be tested on large scale by various utilities in Europe.

A second alternative is the Oxyfuel process, in which the fuel is burnt with O_2 resulting in an almost N_2-free flue gas from which the CO_2 can be separated from the H_2O by condensation. After several years of intense research on laboratory and pilot scale in Europe, the first 30 MW_{th} prototype is presently in the phase of start-up in Germany.

The third clean coal technology is essentially based on the above described IGCC process with O_2 input to the gasifier and a shift of the CO in the process gas to CO_2, hence resulting in a gas containing predominantly H_2 and CO_2. As this H_2 would be then available for either external use e.g. in high temperature fuel cells, or as fuel for a (future) H_2-gas turbine within the IGCC concept, this process is named Precombustion technology. In order to separate H_2 and CO_2, low temperature processes are available with the disadvantage of cooling the process gas and, thus, an energy loss prior to the turbine for which reheating of the gas is required. As an alternative solution, high temperature separation is desirable, for which ceramic and polymeric membranes are presently also under investigation. With regard to large scale application of the new IGCC process with CO_2 separation, a first demonstration plant with a capacity of 450 MW_e is in planning in Germany and is expected to be commissioned in 2014. This project will produce CO_2 for storage, the separation will be realized by a well experienced low temperature technique.

All the above activities with regard to CO_2 capture require CO_2 transport and final storage. Both are existing technologies and well experienced in particular in the gas and oil industry. Well known examples of CO_2 storage are the projects of raw natural gas separation at Sleipner since 1996, the most recent Snohvit field both in Norway and at In Salah, Algeria since 2004 as well as at Weyburn in Canada for enhanced oil recovery.

However, it is meanwhile well understood that the presently stored CO_2 volumes of the above projects are small in comparison with the expected volumes to be removed from power plants. Therefore, a considerably upscaling in transportation and storage is required. However, most critical is the definition of storage criteria, the selection of appropriate underground on– and off–shore storage sites and the preparation of the legal framework. All these are activities of high priority which are presently carried out in Europe at many institutions and member states with considerable support from local governments and from the E.U.

4. References

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Speaker’s Biography

Professor Dr.-Ing. Klaus R.G. Hein is Acting Director of the Institute of Combustion Technology at the University of Stuttgart, Germany. Previously he was Vice President of this University, Dean of the Faculty of Energy Technology, and Director of the Institute for Process Engineering and Power Plant Technology. He was formerly Chair for Energy Technology at the University of Delft, The Netherlands and head of the Research and Development Department at the German Utility RWE. Prof. Hein has been a member of various international specialists‘ organizations and expert delegations of the German Government as well as of the European Union. He received prestigious awards for his achievements related and has authored over 300 technical publications.