Towards a Sustainable European Energy System

Conclusions from the European Energy Conference 2012 - The European Forum for Energy Research.

About the European Energy Conference

The European Energy Conference E2C was held in Maastricht, April 17th to 20th. This international bi-annual conference, the first time organized in Barcelona in 2010, is supported by the European Science Foundation (ESF) and the two Learned Societies – the European Physical Society (EPS) and the European Material Research Society (E-MRS). More than 400 registered participants from 51 countries gathered in the Maastricht Expositie & Congres Centrum (MECC). The largest European delegation came from Germany; most of the Asian participants came from Taiwan. Prof. Harald Bolt from the Research Centre Jülich served as chairman of the Conference.
The European Energy Conference is open to all relevant topics related to energy. It brings together scientists and technicians in the various energy areas – from fossil energies to nuclear power and renewable energy technologies. In morning plenary sessions the participants had the chance to get understandable updates on the progress of all relevant energy areas. In the afternoon symposia, organized topically in parallel sessions, specialists presented their latest results. This truly interdisciplinary approach opened the energy field to all stakeholders - physicists, chemists or material scientists, economists, industry, science managers, and politicians. This approach allowed participation on the progress of the various fields, to learn about the status and potential of specific energy technologies, to recognize the impact of economic considerations, to note the conclusions and decisions industry takes, and to be informed about the European and international political structures developed to cope with this gigantic task - to supply mankind with sustainable energy. Better awareness of the global progress will also lead to a better appreciation of the scientific achievements in other energy related area and will contribute to a better understanding of those acting in the wide arena of energy research.
The E2C energy conference is managed by a Steering Committee composed of representatives of the three societies. They will define in near future the venue and the date of the next conference, E2C-2014.
This conference was a great success and met its mission and also the expectations Commissioner G. H. Oettinger had, when he offered his patronage to it.

Welcome from EU Commissioner Günther H. Oettinger, E2C Patron

It is my great pleasure to offer my patronage and support to the 2nd European Energy Conference. This conference is organised by the European Science Foundation, the European Physical Society and the European Materials Research

Society, which are three preeminent entities in the field of research and development. The world needs to invest in research to obtain solutions for the future. In the energy field this need is even more necessary, not only because of the exigent goals the European Union has committed itself to reach regarding CO_2 emission cuts and energy efficiency, but also because of the result of unpredictable events, such as the Fukushima accident, which imposed the review of safety standards. Counting on the participation of experts from various disciplines and sectors, this event will help in the definition of a common vision on the development of the European energy policy.
The energy challenges nowadays are far from being national or even regional. In a globalised world, there is the need to discuss and find the common best practices while paving the way to keep improving them. For all these reasons, I congratulate the organisers for this second "European Energy Conference" and I am sure that the contribution of both keynote presentations and the symposia will bring added value to the role of research and innovation for a more sustainable and efficient European energy policy.

Preface by the Conference Chair

Energy is vital to our society and economy. The future of the European energy system has to be sustainable in terms of environmental and climate impact and also in terms of supply, industrial viability and societal acceptance. A resolution of this dilemma is imperative.
The challenges encompass many levels of complexity, from natural science research and engineering to social sciences, systems solution and actions and agreements at the global political level. This question of global future energy supply has to be addressed with objectivity and competence, without ideological bias. The European scientific community has the potential to optimise the necessary interdisciplinary cooperation and communication in energy research, development and the support to industrial innovation.
The second European Energy Conference has taken place at a time for strategic decisions, bringing together over 400 researchers from x countries and all areas of science, it consolidated and communicated the vitally necessary synergy of scientific and technical competence with knowledge on environmental and social implications. Convened by three major European science associations, the European Science Foundation, the European Physical Society and the European Materials Research Society – it has become the forum to define the role of energy science and research in the transformation process towards the future sustainable European energy system.
This report summarises the key messages emerging out of the plenary discussions, the five symposia, the poster sessions, the discussions and brainstorming sessions. It illustrates the variety of voices, and the need to provide a forum that allows them to exchange expertise with each other and with stakeholders from industry and with policy-makers.
[Harald Bolt]

Key Issues Identified by the Scientific Community

Sustainable European Energy Systems

Rebuilding the energy system is a task requiring an integrated perspective guided by well-developed scenarios which must reconcile many aspects such as mitigation of climate change, environmental considerations, sustainability of resources, security of energy supply, social acceptance, and last but not least compliance with economic criteria. Energy supply is being increasingly influenced by contributions from fluctuating energy sources with uneven geographical distribution which adds further challenges. In a European context, liberalization of the energy market is as mandatory as consideration of worldwide competition. This will force energy policies and market partners to accept true competitiveness.

- Market decisions for energy technologies must be based on equitable cost attribution including external costs. The emission trading system is key to reflecting some of these cost elements in market prices and hence decisions. Its effectiveness, however, is compromised by political actions for exempting market sectors and for subsidizing specific technologies in the mass market.
- Greatly varying climate conditions and hence resources for renewable energies in different parts of Europe require a European energy policy approach. Enhancing qualitatively and quantitatively the European electricity transmission network is a precondition for optimizing electricity generation and storage capabilities. Generally, it is mandatory to move from present nationally dominated planning horizons towards a transnational European energy partnership interfacing also with regions beyond the EU.
- Consideration of availability of resources currently is too much constrained on fossil and nuclear fuels. Scarce and unevenly geographically distributed resources of materials such as rare earth elements, lithium and other metals may also have a strong impact.
- Optimizing energy demand implies, beyond technical measures for energy saving, changes in societal behavior towards energy consumption. A growing reflection of external cost in market prices for energy products will be a key driver for a transition towards a sustainable energy future.

[Hardo Bruhns]

Sciences for energy

Fuels. Leif Hammarström (keynote) presented development of solar fuels, primarily hydrogen, from photosynthesis,algae and bacteria. Solar fuels will eventually be important for the transport sector and can be used to balance intermittent energy. Produced hydrogen is difficult to handle and in contributed papers, ways of converting it to methane and methanol by the synthesis of hydrogen and CO_2 were presented.

Storage. One of the key problems for a future non-fossil-fuel dependent mobility and transport system is to find suitable storage possibilities. In this connection direct methanol fuel cells were discussed. The development of nanochemically-optimized materials for energy storage was presented by Robert Schlögl (keynote). The most popular storage device, the Li-ion cell was shown to profit from solid state electrolytes instead of liquid ones for better heat performance. As an example on ongoing improvements on energy efficiency, Edward Jobson (keynote) demonstrated the reduced fuel requirements for bus transport in recent years.
Electricity. Electricity generation can be improved by using high temperature materials. It was shown that high efficiency power plants, fossil or bio, well above 50% may be achieved by thermal barrier coated materials with strengthened ferritic alloys. In solar electricity generation, recent progress on how to achieve solar-to-electric efficiency well above 40% for multi-junction cells was discussed by one of the pioneers in the field, Frank Dimroth (keynote).
Nanotechnology. Many different applications of nano technology were presented. Some of these were nanostructured bulk material for efficient thermoelectric power generation, nanowire solar cells, hybrid solar cells based on nanostructured metal-oxides, nanostructured plasmonic back contacts for light trapping in thin film silicon and highly luminescent colloidal heteronanowires for solar energy harvesting.
New concept. A new concept of fluorescent wide bandgap silicon carbide semiconductors for white and infrared LEDs as well as silicon solar cells was presented by Mikael Syväjärvi. This is a new materials application which has not previously been explored.
General. Generally the focus of oral and poster presentations was on innovative materials and processes which have a future potential for energy applications.
[Sven Kullander]

Use and Conversion of Primary Energy Sources - Nuclear Fission and Fusion

Nuclear energy is an important factor in the European energy mix. It clearly remains a CO_2-free energy option. For these very reasons, nuclear energy has established a place in the European energy mix, it is economical and ecological but has difficulty to be socially accepted.
The nuclear session treated first the safety issue of the presently operating nuclear power plants. This was addressed of a comprehensive key note lecture given by Dr J.-M. Cavedon. The accident of Fukushima is the consequence of the Tsunami disaster but also of the lack of safety for the Fukushima reactors 1-4.
The situation in Europe and more especially in Switzerland is significantly different because safety during operation as well as during unexpected events has been upgraded since years. This increase in safety norms is also the case when passing from Generation II (GENII) to GENIII reactors which offer additionally passive safety measures. The deployment of GENIII reactors in Finland was the topic of the second talk with the vision of increasing nuclear power within liberalized energy markets. The GENIV and V programs concern High Temperature and Fusion systems; in this frame the European Integrated

Fusion Materials Programme was presented. It was also anticipated that in fusion plant energy efficiency may be the enhanced for example by polarizing the plasma of reagent nuclides. The security and sustainability issues were also treated by Pr.Ch.Poinssot suggesting sustainable nuclear energy with significantly shorter waste storage times by recycling the actinides and comparing once-through versus closed fuel cycle scenarios. However a last cycle is always expected and an option remains the Inert Matrix Fuel in thermal reactor that is investigated with European in-pile tests. The residual waste material must remain in a confined and safe from for the environment. This was the topic of the last presentation dealing with disposal of spent fuel, radionuclide release and secondary phases.
[Claude Degueldre]

Energy Networks and Storage

Energy networks are the enabler to bring energy to meet consumer needs. The networks present great challenges as they are crucial to pursue European climate targets as well as to guarantee security of supply and contribute to economic development. But networks need intelligence and capacity to store excess of production to match the offer to the society needs and this must be done in an integrated way either at economical and society level.
E2C presented the opportunity to discuss this challenge in a holistic way touching several hot topics. First towards a pan-European network by tackling the breakthroughs that are needed, on one hand to accommodate bulk energy production from renewables either off-shore wind or big solar plants from the South by raising and discussing technical, economical and regulation options to go ahead with this objective and on the other hand to overcome the bottlenecks to fully connect regional networks. At great deal of research is needed from the regulation side, from the reliability point of view and from ICT technologies now capable to manage the network on line in a secure and optimal way. The concept of virtual power plants must be developed and turned operational at European level.
Second, the discussion on new emergent energy carriers was brought to the agenda. The debate was concentrated on technical-economic issues regarding the implementation of hydrogen, shale gas or organic hydrogen production and distribution, considerations ranging from transport problems to storage at domestic level. A lot of effort has to be done at material level to bring down the costs of such technologies. Also, optimal integration of different carriers is a hot subject.
The third main topic related to issue of intelligent distribution grids. The discussion was open from the state of the art to the technical needs to put cities producing for their needs through high levels of quality of service while integrating in the buildings and transport new paradigms for the energy source. Bringing intelligence in an integrated and coordinated way to the distribution networks, by accommodating in optimized way already available technologies covered the center of debate. Smart cities and smart grids must work together.

[Teresa Ponce de Leao]

Overarching Themes

In contrast to corresponding North American events, the participants in the European Energy Conference shared a clear consensus on the greenhouse gas effect, with climate change being induced as a result of human activity, particularly the combustion of fossil fuels. Clearly elsewhere certain elements at least would deny this connection, more on ideological than on scientific grounds. This general consensus recognized in these environmental consequences a primary motivation for research, development and application directed towards a sustainable energy economy. There was therefore an overarching theme directed to a significant reduction of greenhouse gas emissions, both by engineering and biological processes. Energy efficiency, in improved systems and processes, can minimize but not eliminate this problem. In both cases carbon dioxide would be captured and sequestered, either as biomass or geologically. However while biology has sequestered carbon and yielded oxygen on geological time scales, it was recognised that artificial carbon capture is an extremely difficult technical challenge, taking account the required time scale, costs of a massive infrastructure, and safety considerations. It is not yet established that this approach can be technically, economically and politically implemented. Use of carbon dioxide may be a more promising approach, for example as a medium for enhanced oil and gas extraction, as well as a potential chemical feedstock. Reduction of carbon dioxide was mentioned, but of course it involves an energy input. It is in this context that the biological approach may be advantaged. First generation biofuels can be severely criticized, it being mentioned that the US bioalcohol programme uses about half of the national grain crop, and that even in the context of increasing food grain prices. A parallel criticism can be directed towards palm oil-sourced biodiesel. Cellulose and lignin feedstocks, being low cost, widely available and often even with a disposal cost as waste, do not attract any of these objections. There is a promising area for genetic engineering research, for example in the enhancement of enzymes for “biolysis” of these materials.

There was no overt orientation towards – or against – any particular energy technology, but given the current political circumstances the nuclear option received a rigorous analysis. There is of course the long-term aspiration of a fusion-based system, with endorsement of the ITER programme, but in the interval a significant ongoing contribution from fission to the electricity supply of Europe is a certainty. Attention focused on the safety and waste disposal aspects, of course; the spectacular reduction of the required confinement time if actinides are removed during fuel reprocessing was a welcome insight. The “once-through” fuel cycle implies use of only 0.7% of mined uranium, and is obviously not sustainable on that basis. Fuel reprocessing also permits disposal of plutonium, for example in MOX fuel.

The role of geology and geophysics in supporting diverse aspects of the energy economy will significantly develop, not only in the extractive industries of petroleum and natural gas, but as a fully renewable energy source in geothermics

and as a guarantee of security in sequestration of carbon dioxide, chemical toxics and radioactive materials. A full and detailed knowledge of "subsurface Europe" will become a key "overarching theme" for research and application in the future.
Two further overarching themes relate directly to the human dimension: education and training, and health and safety. It was mentioned that only 20% of third-level students are engaged in the physical, mathematical and engineering disciplines. It must be a priority for Europe to maintain its competence in all fields related to energy, and that requires not only an environment of encouragement and support at student level, but also a reasonable prospect of a stable and rewarding career for the competent professional. On health and safety, while renewables are attractive and have a momentum of sympathy at the present time, it must be recognised that every industrial process has its hazards, the energy-related industries no less than others. Indeed it could be suggested that the prime "overarching theme" of the Conference is that energy is not an end in itself, but rather a service required by society as a whole; a perspective of the energy landscape must provide for current human needs while maintaining the obligatory option for a sustainable future.
[Augustin McEvoy]

Science for Sustainable European Energy: Recommendations

Science is the process of acquisition of understanding, here that of materials and processes relevant to the production, use and management of energy. Consequently scientists are researchers and advisors, not deciders in the domains of energy policy. The decision makers are governments and investors, and the bases of their decisions are obviously economic and political. The role of science – and scientists – is guidance so that the decisions and investments are rational, ecological, and economical, with reliability and safety. In fulfilling this role communication is primordial.
The political and economic decisions can be implemented, in a democracy at least, on a basis of acceptance by society at large. A rational basis for that acceptance can be based only on widespread knowledge of the issues at stake. Here the role of press, television and the communications media generally is of key importance, as the message of the scientific community is often lost in the noise of populism and propagation of sectional interests. A cadre of well informed, committed and objective communicators in the media is a vital necessity. An example of the present situation is the frequent confusion of power and energy. For renewable technologies in particular, the yield of systems is often quoted in the media in watts, kW, MW etc., i.e. in terms of maximum rated power of an installation rather than the more relevant annual energy production, kWh/year etc. Such a presentation falsifies any comparison with convention thermal systems. Rigour and exactitude are the measure of a responsible press.
The educational requirements for the scientists and engineers of the future have already been mentioned, and the relatively small fraction of third-level students following the physical sciences and engineering. To recruit and motivate students to take up this challenge, inspiring and competent teachers at second level are irreplaceable.
On the more technical side, effective synergies between specialists must be stimulated. In the earth sciences, for example, the energy interest applies to evaluation of mineral resources,

mining and extraction, including recent innovations such as fracking for natural gas and unconventional petroleum production; geothermal energy sources; hydrology for hydroelectric development and exploitation; and seismic studies for plant siting and security, again for hydro and nuclear energy installations. So geology evolves as a cross-cutting energy technology inviting exactly the synergies mentioned; detailed knowledge of subsurface Europe, and indeed of undersea Europe can avoid unnecessary duplication of effort among the fields of action mentioned, avoiding conflict of interpretation and rational decision-making for sustainable planning and investment.

In a similar way a more consistent systems approach to energy technologies is imperative. Research often focuses, necessarily, on a single parameter or aspect, physical, chemical or material. However the result must be applied within an integrated system in which all the necessary parameters are optimized for efficiency. Again an example is illustrative. It has become a more common practice to evaluate the efficiency of a petroleum-based transport system on a well-to-wheel basis so that each step, extraction, refining, distribution, vehicle technology, emissions and environment all receive appropriate consideration. Loss of this perspective leads to inadequate analysis. Again in the transport field, electric and fuel cell vehicles are constantly promoted as pollution-free. This claim is defensible only when the electricity generation or hydrogen production are free of harmful emissions.

In summary, then, communications and understanding, education, synergy between specialists and a systems perspective were seen as essential components of a vigorous European energy scene.

[Augustin McEvoy]