EUROPEAN COMMISSION

Community research

ISSN 1018-5593

Further tasks for future European Energy R&D

A second set of recommendations for research and development by DG-RTD's Advisory Group on Energy

EUR 22395

Interested in European research?

RTD info is our quarterly magazine keeping you in touch with main developments (results, programmes, events, etc.).
It is available in English, French and German. A free sample copy or free subscription can be obtained from:

European Commission
Directorate-General for Research
Information and Communication Unit
BE-1049 Brussels
Fax +32-2-295 82 20
http://ec.europa.eu/research/rtdinfo

EUROPEAN COMMISSION

Directorate-General for Research
Directorate J – Energy
E-mail: rtd-energy@ec.europa.eu
Internet: http://ec.europa.eu/research/energy

Further tasks for future European Energy R&D

A second set of recommendations for research and development by DG-RTD's Advisory Group on Energy

2006

Directorate-General for Research
Sustainable Energy Systems

EUR 22395

The main report was written by Dr Derek Pooley and the annexes by Dr Niels Busch, Prof Gerhard Faninger and Dr Roger Ballay respectively, in collaboration with Mr Angelo Airaghi, Prof William d'Haeseleer, Dr Wolfgang Dönitz, Dr Cesar Dopazo Garcia, Dr Alain Gerard, Dr Heather Greer, Dr Gerd Eisenbeiss, Mr Frederick Mariën (EC), Dr Patrick Lederman, Prof Peter Lund, Mr Odisseas Panopoulos (EC), Prof Frantisek Pazdera, Mr Carlos Pimenta, Prof Erich Tenckhoff, and Prof Iacovos Vasalos. It was adopted by the Advisory Group on Energy (Chair: Prof Peter Lund) on 21st June, 2006.

Cataloguing data can be found at the end of this publication.

Luxembourg: Office for Official Publications of the European Communities, 2006

ISBN 92-79-02689-5

ISSN 1018-5593

Printed in Belgium

PRINTED ON WHITE CHLORINE-FREE PAPER

Table of Contents

Preface

In 2002 the Commission asked its DG-RTD Advisory Group on Energy (AGE) to develop a vision for energy R&D on a European scale, with emphasis on overcoming the barriers between advocates of different energy options and the consequent compartmentalisation of advice into unlinked recommendations about each from their enthusiastic advocates. The objective was to support decision-makers with wide and thorough analyses of the issues at stake, and of the potential of various technology options to provide Europe with sustainable energy supply and use.

In early 2005 AGE responded to the Commission's request by publishing two reports on work it had by then completed. These were:

- 'Key Tasks for future European Energy R&D' (EUR21352). Here AGE selected those technologies (biomass, cleaner use of coal, fuel cells, hydrogen, nuclear fission, nuclear fusion, solar photovoltaics and wind energy) that it considered likely to be the most important in changing the EU energy scene. AGE identified those improvements required in each technology and the research tasks that should be tackled at EU and Member States level to realise those improvements.

- 'Towards the European Energy Research Area' (EUR21353). Here AGE focussed on the analysis and assessment of the potential for more trans-EU collaboration and cooperation in various areas of energy research, together with practical recommendations to make ERA a reality in the energy field.

AGE therefore believes it has already identified those energy R&D tasks that have the best chance of allowing the EU to break its costly and worrying dependence on crude oil and natural gas supplies and also to reduce the extent to which it contributes to CO_2 emissions and hence to global climate change. This new report, which we have called **'Further Tasks for future European Energy R&D'**, is an extension of the earlier **'Key Tasks…'** work, looking this time at ways of improving the efficiency of energy use and also at another selection of low-carbon energy supply options, options almost certainly less important than those considered in 'Key Tasks' but significant none-the-less. In addition, this report looks at those so-called 'cross-cutting' or enabling technologies that have the potential for improving the energy scene although they are themselves neither energy-supply nor energy-use options.

The work reported here was carried out by three working sub-groups of AGE, in one or other of which most AGE members (listed in Annex 4) participated. The overall AGE chairman during the work was Peter Lund; the Energy Efficiency working group was chaired (and Annex 1 written) by Niels Busch; the additional renewables working group was chaired (and Annex 2 written) by Gerhard Faninger; the cross-cutting working group was chaired (and Annex 3 written) by Roger Ballay; the covering report and the overall integration/editing are by Derek Pooley.

This paper is entirely the responsibility of AGE and does not necessarily represent the views of the European Commission or of any national Government.

The challenges remain!

Since the work underlying our earlier reports was carried out, in 2003 and 2004, the issues that worried AGE then, namely **energy prices, energy security and environmental impact**, have become more threatening, as AGE predicted. Thus:

- The escalation of fossil fuel prices that had begun in the early years of the century has continued to worsen. When the work on which the 'Key Tasks' report was based was carried out oil prices were in the \$20 – \$30 per barrel range; now they are around \$70 per barrel. Gas prices have also risen dramatically.

- The threat of energy insecurity, which could easily come from our over-dependence on too few, potentially unreliable, suppliers of crude oil and natural gas, has become clearer. We have seen some problems, albeit temporary ones, arising for gas supply to the EU because of political differences between Russia and Ukraine. More recently, the problems over the security of oil supplies from Iraq have been compounded by other worries about potentially unreliable supplies from Iran, Colombia and more recently Bolivia.

- More and more evidence has come to light for the occurrence of substantial changes to the earth's climate over the last several decades. Although the causes of these changes are not yet absolutely certain, by far the most convincing explanation is that they derive to a significant extent from the anthropogenic increase in greenhouse gases in the atmosphere, especially of CO_2 from the combustion of fossil fuels.

The three main ways to mitigate these three problems were also considered by AGE in its earlier reports and remain essentially the only ways forward. We must either change our **lifestyle** so that we spend less of our wealth on energy consuming products and services, or we must increase the **efficiency** with which such products and services are supplied, so that less energy is used, or we must find **low carbon energy sources** that can continue to provide the energy we currently use but do not rely on crude oil and natural gas and do not release so much CO_2 into the atmosphere. We can, of course, gain some contribution from each of the three.

It is the opinion of AGE:

- That the EU or its member states governments could do more to influence the choices energy consumers make (their **lifestyle**), so that growth in demand for the many services that energy provides is lessened, possibly even reversed. This means persuading people not to live in houses much too big for their needs, not to drive Sports Utility Vehicles when ordinary family cars are adequate, not to take so many far flung holidays – and so on. It is clear that no-one has a magic recipe for doing this and AGE members have no special competence here; we are simply well-informed EU citizens. However, AGE believes that **most** people will **not** make substantial changes to their lifestyle before real and damaging impacts are felt, when it may already be too late, unless they benefit fairly directly from doing so earlier. Governments could, for example, move more taxation away from income, general sales etc. towards energy (especially gas and liquid fuels) and energy consuming facilities (houses, cars, aircraft etc.). AGE recognises that this is a difficult and unpleasant task for politicians as well damaging to already-energy-poor families. Moreover, governments have so far had almost no success in persuading the already-and-increasingly-well-off citizens of the EU not to use some of their new wealth on energy consuming possessions and activities. In poorer but fast-developing countries like China, where energy consumption per head is much less than in the EU, this simpler-lifestyle route to lower energy use is completely without promise.

- That **improved efficiency** of energy use, as AGE noted in an earlier report, relies on 'a mosaic of more-energy-efficient products and processes that are continually being invented, adopted, improved and eventually discarded for something better'. Few of the individual technologies in the mosaic have a high potential on their own, although collectively they are very important. Indeed, **all** AGE members judge that improved energy efficiency will, in aggregate, make the biggest contribution to reducing our demand for oil and gas and our emissions of CO_2. However, most developments here will occur **without the help of EU-wide R&D**, as industries develop better manufacturing processes to reduce costs and better products to improve their competitive edge, as consumers buy more efficient equipment to gain better performance or save fuel costs and improve the energy performance of their houses. Nevertheless, AGE has looked yet again at how it might be possible to speed up the process of improving the efficiency with which energy is used, via R&D initiatives taken at the European level. Our conclusions on energy efficiency are set out below and in more detail in Annex 1.

- That to rely on **lifestyle** changes and **efficiency** improvements alone would be too optimistic, and most informed observers of the energy scene agree on this. Lifestyle and efficiency have not in the past and may well not in the future achieve significant or even any reductions in energy consumption. AGE therefore concludes that the safest and most promising route to a more sustainable energy future is to replace oil and gas, as far as we can in the EU, with the so-called **low-carbon** or **carbon-neutral energy sources**. This approach is dismissed by some lifestyle and efficiency advocates as relying on the 'technological fix' but at least we can see a concrete way forward here. AGE believes that we should focus maximum effort on finding how best to continue to deliver to final users the electricity, gaseous and liquid fuels to which we are all now addicted in the EU (or provide some equally convenient substitutes) without using so much crude oil and natural gas and without releasing too much CO_2. The contributions that improved technology can make to bring low carbon energy sources into the market was the main subject of our 'Key Tasks' report (EUR21352). But our earlier report was not fully comprehensive and in this new report we look at another set of possibilities.

Improving Energy Efficiency

The World Energy Council report on *end-use* technologies estimates **potential** worldwide savings of as much as 25% by 2020 and over 40% by 2050, much of it achievable without further technological developments. AGE notes that these savings are similar to those achieved over the last 30 to 40 years and that the recent increases in energy prices make it more likely that we will realise the potential. Higher energy prices will drive both the take-up of existing best-practice and also of product innovation, at a greater rate than is normally driven by the industrial competition that now forces all manufacturers to develop improved products or lose their place in the global market place. But AGE believes it would be unwise for the EU and its Member States to rely only on market forces to drive such take-up and innovation. Experience shows that, without government regulations setting clear minimum energy efficiency standards and goals for further improvement, little may happen – and that rather slowly.

Because improved energy efficiency is achieved in so many different ways for different products and processes the role of EU strategic research in realising the potential is likely to be small. In its earlier 'Key Tasks' report AGE did highlight what it still believes to be the main area where multi-national strategic research could help the EU take big steps forward in the efficiency of energy use. This is in improving the efficiency of conversion of fossil fuels and other heat sources to electricity, using either heat engines or fuel-cells. But, even outside this area, the potential rewards from better efficiency are so large that AGE believes **some** more general EU-supported energy efficiency research is justified.

Hence, **AGE recommends**:

- A significant budget element in FP7 (e.g. € 200-300 million) for energy efficiency R&D.

- That this energy efficiency R&D programme should be broad in scope and not too tightly specified, with EU R&D programme managers having the delegated authority to support any group of EU scientists coming forward with novel and credible ideas for significant improvements in energy efficiency in any field important for the EU.

- That the funding of demonstration projects to prove and illustrate radical technology changes in industrial processes should also be considered.

- That energy systems analyses should be included as part of this energy efficiency work programme.

- And finally, that socio-psycho-cultural and socio-economic research – although not a central theme for an EU RTD program on energy efficiency technologies – should also be considered. It should provide insights that can help EU governments to influence lifestyle choices and hence maximise the take-up of improved energy use technologies.

However, AGE stresses that energy efficiency will not, by itself, solve the energy problems the world is facing. Increased energy efficiency certainly alleviates them and buys us time – quite probably in ways and to extents that we have only begun to appreciate – but new primary energy sources must also be developed. The world cannot simply save its way out of its energy difficulties.

More Renewable Energy Sources

In the earlier 'Key Tasks' report AGE considered the six low-carbon energy sources that it believed might make really large contributions to supplying the electricity, gaseous and liquid fuels on which we now rely so completely, without using increasingly-scarce crude oil and natural gas and without so much emission of CO_2. They were biomass, cleaner use of coal, nuclear fission, nuclear fusion, solar photovoltaics and wind, three of which are renewables. There is no doubt that collectively these six have the **technical potential** to supply all our energy needs, indeed some of them (especially fusion and solar photovoltaics) individually have essentially unlimited technical potential. They are generally electricity producers, but gaseous and liquid fuels can be derived from them via hydrogen and the hydrogenation of biomass or even CO_2.

The problem is that their technical potential can be achieved only if high costs and/or other problems can be dealt with. For this reason AGE believes that other low-carbon/renewable energy sources, usually with less overall potential than the first six, may still need to be kept in our sights because they may be easier to use when local circumstances are favourable. AGE thinks the more important of these are hydropower, geothermal energy, low-temperature solar heat collectors, high-temperature solar power systems and various ocean energy systems (waves, tides, marine currents and temperature and salinity gradients). AGE has now evaluated these in a similar way to the six dealt with in 'Key Tasks', again using the assessment criteria defined and used in the earlier report. The detailed assessments are attached as Annex 2 to this report but brief summaries are included below.

There are yet more renewable possibilities, in addition to this second tranche of technologies. Most are currently not much more than gleams in the eyes of their proponents, including the solar production of fuels and commodities, solar high-temperature industrial process heat, solar power chimneys and solar power from earth orbiting satellites. In this case, AGE has not carried out formal evaluations but notes that there are these possibilities that may become more attractive at some future time. Our comments on these are set out in Annex 3.

Hydropower

Worldwide, hydropower is definitely the most cost effective renewable energy source, currently providing over 80% of all renewable energy. It also plays an important role in electricity grid stabilisation and in levelling the demand on fossil and nuclear plant, thanks to its quick start-up times and large inter-seasonal storage capacity. One of the greatest opportunities for quick gains for the renewable energy portfolio is to maximize the energy produced from existing hydroelectric plants through modernization. Gains of 5 to 10% might not represent an excessive target for most hydropower owners and where there are significant numbers of dams without generation, the potential is higher.

AGE acknowledges that hydropower is a well-established, mature technology, but believes there are opportunities for further system integration and technical innovation, in order to enhance its development in the EU and globally; via efficiency upgrading, automated maintenance, dam life extension, impact analysis, system integration, remote-control and optimisation. The role of the EU should be to provide an adequate policy framework for these improvements, to help with public information and education (that should enable citizens to make a balanced assessment of risks and benefits of dams) and to support the development of appropriate codes and regulations and incentives. Also, the long-term impact of climate change on the European hydro-power resource needs to be addressed.

The greatest potential for new hydropower in Europe lies in small, run-of-the-river systems, where the technological know-how is currently widely dispersed in Europe. It is essential to co-ordinate that knowledge EU-wide to gain maximum benefit from it.

Geothermal Energy

Geothermal energy is already used in 71 countries, 24 of which use it to generate electricity. Total worldwide installed capacity for geothermal heat supply now stands 28 GW, providing some 73 TWh of heat per year, the low load factor reflecting the absence of heat demand for much of the year rather than any unreliability in the heat source. Worldwide geothermal electricity capacity is nearly 9 GWe, generating 57 TWh/year, that is a load factor of about 70%. The electricity supplied makes up 0.4% of global electricity production.

Objectives for additional geothermal R&D funding should include the following; better tools for exploration, resource confirmation and depletion management; better technology for well drilling, logging and completion; techniques for the development of deep (> 3,000 m) geothermal resources; optimisation of new projects by applying field experience from existing ones and providing system-demonstration projects at several different scales which should help reduce costs; the wider spread of the understanding and mitigation of environmental effects.

Solar, low-temperature heat collectors

A wide range of low-temperature, solar-heat collectors and systems, mostly for residential applications, have been available in the EU market for decades. These products are now fairly reliable, usually built to a high technical standard and in hot, sunny countries such as Cyprus they are already ubiquitous for domestic hot water supply. However, there are technical and economic barriers preventing their wider use in the EU and sales growth in most countries is still very dependent on public subsidies, not unlike the other renewable energy technologies.

New systems, for cooling and process heat, are now emerging onto the market. Solar assisted cooling is an especially attractive prospect in hot countries, since the peak cooling demand coincides with maximum solar radiation. A number of large-scale solar cooling systems have already been successfully demonstrated and it is now necessary to support their introduction into the market. Small-scale solar cooling systems could be ready within a decade, if some support for their development is provided.

Some EU R&D should be targeted on optical coatings and self-cleaning glazing materials, as well as on advanced thermal storage that could improve operational effectiveness and efficiencies of these systems. In general terms AGE supports the introduction of stronger policies to promote solar heating and cooling in EU-Member States.

Solar high-temperature, concentrating energy systems

Solar systems for producing high-temperature heat and for thermal electricity generation use concentrating collectors. Several systems for electricity production (350 MWe in total) have been used successfully since the mid-1980s to generate electric power in those regions of California with high direct radiation. The spread of the technology came to a halt in the early 1990s, following the withdrawal of tax credit support schemes, because costs were still too high to compete with low and declining fuel prices. Solar high-temperature technology is certainly yet another route to sustainable electricity production, but it requires costs to be reduced by a factor of 3-5 compared with the present. The research infrastructures needed for such development and testing pilot plant are costly and would benefit from a Europe-wide approach.

A new 50 MW plant is under construction in Nevada (USA) and one 50 MW plant will be started in Andalusia (Spain) in 2006, using molten salt storage systems. Two international requests for bids have recently been released for hybrid solar power plants (that is solar high-temperature plant with fossil-fuelled back up) in Morocco and Algeria and further projects are being planned in Iran, Israel, Egypt and Mexico. In the EU, Spain offers an incentive of about 22 cents/kWh for solar thermal electricity. The most mature technology today is the parabolic trough system that uses thermal oil as heat transfer fluid but experimental and demonstration units exist that avoid the intermediate heat exchange cycle or use solar tower technology.

AGE does not consider that there is any need for 'strong' EU-wide coordination in the solar high-temperature field, but there are R&D topics which would be well suited to the EERA concept. Most of the research should probably concentrate on the development of high temperature materials and on two-phase flow and heat transfer under extreme conditions.

Ocean Energy Systems

Some 71% of the Earth's surface is covered by water and the technical potential to harvest the abundant renewable energy sources that these oceans contain is vast, but practical realisation remains very difficult. Thus tidal power stations work well but their use is limited by high capital costs and by the relatively few high-quality sites that are available. In contrast, for salinity-gradient-based technologies many uncertainties remain and for ocean-thermal-conversion technology, exploiting ocean temperature gradients, development is lagging even further behind. Wave and marine-current technologies are probably somewhere in between these extremes.

For the EU, a focus on wave energy would probably be reasonable in the medium term, aiming at demonstrating the costs with greater confidence and testing the ability of devices to withstand the harsh ocean environment. Additional R&D funding would help to mitigate the substantial technical risk faced by device developers seeking to harness the ocean energy. Increasing R&D funds is critical to the development of practical ocean energy systems and will speed up the rate at which we determine their real promise, if any.

Other Concepts for Renewable Energy Technologies

The number of different ways that have been suggested for harnessing the natural energy flows deriving from the sun, earth and moon is very large, but AGE has still not completely exhausted them. We have, however, now considered several more-way-out possibilities and our comments on them are given in Annex 3.

Cross-cutting Technologies

In another section of its most recent work, AGE has sought to identify which so-called 'cross-cutting' issues have the greatest potential to improve energy technology in the EU. It has concluded they are materials, biotechnology, a good energy R&D infrastructure and an effective linkage between basic (or frontier) research and the energy industry. The detailed report of this work is attached as Annex 3.

Materials

Materials technology is the most important and obvious cross-cutting issue. Thus, in its earlier 'Key Tasks' report, AGE noted that better energy technologies frequently 'depend on having materials which can withstand more severe conditions. Boiler tubes or turbine blades must be sufficiently strong when very hot and also resistant to corrosion, abrasion and creep at high temperatures; coatings and the bonding of dissimilar materials are often crucial'. AGE believes that better materials are often valuable in many applications and that developing them is frequently beyond the capability of individual equipment manufacturers.

AGE therefore concludes that a part of FW7 should be assigned to materials development, supporting work that promises better structural integrity at high temperatures, better corrosion and abrasion resistance, better measurements of the key parameters in burning fuels etc.

Biotechnology

The production from non-fossil sources of gas and liquid energy carriers as well as electricity (which currently seems easier to generate without fossil fuels) is a long-term necessity if we are to provide transport fuels in the future. One very attractive option for doing this would be to modify natural biological processes, so that the direct production of fuels like hydrogen using sunlight as the energy source becomes possible. Biological processes have, after all, been responsible for the generation of our fossil resources over the past several million years. Equally attractive would be to modify current plant biology simply to increase biomass yields, or to use biological processes to convert conventional biomass such as wood into much more valuable liquids and gases with lower costs and energy inputs.

Unfortunately, only good ideas and/or promising, early-stage research is available up to now. AGE believes the EU should support a range of good ideas that have the potential to bring biology much more strongly into the energy scene than we have seen during the era of fossil and nuclear fuels. Because of its interdisciplinary character and its distance from marketable applications, this area has not been given sufficient attention nor sufficient funding so far. It deserves to be more systematically supported in a long-term programme with general goals such as the improvement of the efficiency and overall yield of photosynthesis, or good stability in basic biological processes.

Energy Research Infrastructures

AGE recognizes that common European R&D infrastructures can be very effective in building a European knowledge base that is world-class, with CERN and JET as two clear examples. As well as their positive impact on Europe's ability to tackle the most challenging tasks in science and technology, many of which are beyond even the larger member states to fund properly, they also promote better technical education, scientific excellence, the mobility of researchers and the dissemination of R&D results.

Given the success of common facilities in basic research, it seems to AGE very regrettable that, fusion research apart, there has been little attempt to establish a systematic European Energy R&D infrastructure. A strategic, vision for the infrastructure needed to support an energy ERA needs to be developed by ESFRI in consultation with the energy research community.

Links with Frontier Research

It is evident that the increased power of silicon-based computing, together with the discovery of modern, solid-state sensor technology, has led to major improvements in the control and efficiency of vehicle power units, improvements that the original researchers did not have in mind. To avoid unnecessary delays in making such key linkages the EU needs to ensure that European basic researchers are aware of the needs of the energy sector and that energy researchers are reasonably familiar of where potentially-relevant frontier research is heading.

AGE therefore welcomes the intention to allow proposals that include applied research within 'Cooperation', and frontier research within 'Ideas', since this should support cross-cutting proposals with both basic and applied research aspects. It is not clear how such proposals will be initiated or assessed, and further clarification from the Commission is needed on this.

Generally

Cross-cutting applied research has been given considerable prominence in the proposals for FP7. The Cooperation programme has provision for cross-cutting proposals that would receive funding across themes but, as in FP6, the adequacy of the proposals will only become clear in their implementation. A specific budget allocation for energy-related cross-cutting research in the other thematic strands of Cooperation would improve the chances that the necessary joint calls would be made.

Conclusions

Since the energy crises of the 1970s major progress has been made in improving the technology of both energy use and energy production from non-fossil energy sources. Thus, in many OECD countries, energy efficiency has roughly doubled over that period, with real GDPs twice those of 1970 and total energy demand the same or not much higher. In non-fossil sources, waste combustion for energy, windpower and solar water heating are now in widespread use where the circumstances are favourable; the solar photovoltaics industry is now quite mature, albeit with costs that are still too high for bulk use; Generation III nuclear power plant (such as EPR and AP1000) are available and the first EPR in Europe is under construction in Finland.

But much remains to be done! In energy efficiency, encouraging the take up of existing best practice is perhaps the key, though AGE believes the EU as a whole, as well as individual manufacturers, needs to be on the look out for new technical ideas to reduce the energy intensity of our economies. For low carbon and renewable energy sources the technologies almost all need still more improvement if their penetration of the energy market is to be as fast and extensive as circumstances require. The renewables, where the energy intensity of the basic sources is inevitably low, are in particular need of innovation aimed at reducing their costs. For nuclear fission the basic energy intensity is high and it is now economically competitive, but we still need to develop even better ways of ensuring safety under all circumstances and to prove and demonstrate beyond reasonable doubt the safety and effectiveness of geological waste disposal. Longer-term options such as hydrogen and fuel cells and nuclear fusion, also need to be pursued to see if their great promise can be realised.

AGE set down what it believed were the ‘key tasks’ for EU energy R&D in its earlier report (EUR21352) and has no reason to change the recommendations contained there. In this report we have extended our earlier work, recognising that the most important technologies for Europe as a whole will usually not exactly match the needs of individual countries, where there will often be niche markets for some particular technologies.

We are confident we know what R&D needs to be done. What is still missing are the funds to do it. AGE therefore repeats its earlier assertion that energy R&D funds in the EU are still not commensurate with the size and importance of the problems we face in energy.

Annex 1: Energy Efficiency

Background

Energy policy involves balancing four different, often conflicting aims: Security of supply, environmental sustainability, social cohesion and economic competitiveness. One tool furthers all four goals simultaneously; Energy efficiency (EE), an important concept in a world in which energy is becoming a limiting factor for the maintenance and development of peoples' welfare.

Energy policies at EU and national levels should set necessary goals for EE RTD, while political support is imperative for successful implementation of new EE measures. EU EE-actions have so far addressed specific issues, but a comprehensive European approach is missing, and efforts in the Member States are insufficient. In general, the demand for energy services has grown faster than efficiency has improved. DG TREN notes in a green paper that the rate of improvement has declined and mentions imperfect information, split incentives, absence of price-setting of externalities, and lack of transparency, knowledge and awareness as some of the reasons why EE-policies are difficult to implement.

AGE defines energy efficiency as efficiency in the conversion, transport and use of energy. AGE has chosen to associate EE with the '*end-use*' of energy, where by *end-use* we mean the service provided by the energy before it is dispersed in a way that makes it useless to other users.

AGE finds that, although increasing energy prices will drive the market place to make EE-innovations, it would be unwise of the EU and its Member States to rely too heavily on the market as concerns innovation. Nevertheless, it is obvious that the market forces should be exploited to the utmost in the applications of EE RTD. Improvements in EE will often be efficiently driven by industrial competition. The product development is almost always better left to the manufacturers, but experience shows that without regulation by standards and laws very often little happens – and slowly.

Although the role of strategic research in many EE-connections may be modest, the potential of energy efficiency is so tremendous that consideration is warranted of EU supported high-tech research in certain areas. The first SWOG report deals with the most obvious of these areas. The World Energy Council report on *end-use* technologies estimates potential worldwide savings of as much as 25% by 2020 and over 40% by 2050.

EE research is indeed cross-cutting and interdisciplinary. History shows that technological innovations have had substantial impacts on energy efficiency. Much of the background work has been 'basic' (i.e. pre-market) research. Material research, biotechnology, nanosciences, intelligent manufacturing and other cross-cutting themes provide interesting avenues for long-term RTD in energy efficiency.

Increases in the overall EE will primarily come from:

- Improvements contributed by innovations in ubiquitous energy-consuming products.
- And through'radical' changes of large-scale energy-consuming processes in the industrial sectors. By 'radical' efficiency improvements AGE means improvements of the order of 25% or more as opposed to the incremental 1-3% most usually achieved through efficiency gain measures.

Taking into account existing activities at EU and national levels, AGE:

- Recognizes the 'traditional' concept of EE among national administrations.

- Accepts the unavoidable fuzziness of the boundaries around EE.

- And wants to consider EE-aspects not included specifically elsewhere in AGE's work. Changing lifestyles and human behavior (work-leisure patterns, transport and communication patterns, household size, diet, etc.) are indeed essential for achievement of EE aims, but AGE finds that research in these areas may be better served in other programmatic contexts than technological R&D.

The key areas

In national EE RTD programs the following technology areas are mentioned as key areas for RTD&I activities:

- Direct, supplier-based demand-management systems, especially interactive supply & demand management systems that allow customers to manage their own energy consumption.

- Buildings (industrial, public, private; i.e. heating, cooling, lighting, appliances; including integration of local production of secondary energy).

- Transportation (i.e. improved petroleum based fuels and vehicles, alternative fuels and vehicles).

- Industry (i.e. processes, motors, steam systems, compressed air systems, sensors and controls).

- Infrastructures (i.e. information and communication technologies).

- Power industry (i.e. superconductivity, energy storage, demand-side management, distributed generation and use, heat pumping technologies).

AGE does not have access to energy-systems analyses that allow judgment on the technology areas, in which developments could be expected to make a difference. The issue of energy demand and energy efficiency is so complicated and controversial that it deserves to be looked into in detail. AGE recommends that a general study is undertaken under the next framework program. There is a regrettable absence of rigorous scenario-based analyses. Such scenarios could be useful for testing the elasticity of energy performance to the proposed measures and powerful means for planning and communication. Studies on specific aspects of EE RTD could be useful, even if in the end AGE may not be able to go much beyond a recommendation for significant funding of (unspecified) R&D on EE aspects where this could lead to significant reductions in energy/emissions. However such studies – especially studies that elucidate the added value of European level research – are not available.

Another problem that AGE faces is that substantial EE improvements (and indeed considerable energy savings) could be implemented without any RTD, if the political will existed, whereas promising EE technologies and innovations may be overlooked if it is not.

Recommendations

Hence, **AGE recommends**:

- A significant budget element (e.g. € 200-300 million) for EE R&D in FP7.

- That the European Union should keep the options open in a EE R&D program that will allow any group of scientists with novel ideas that may lead to improvement in EE in any field to apply and argue their case.

- That the WP for the EE R&D program should be broad in scope and general in specifications with priority given to innovations leading to major improvements in *end-use* efficiency.

- That systems analyses should form natural parts of the WP. The overall energy consumption should be addressed through studies of the effects of innovative EE-improving technologies.

- That socio-psycho-cultural and socio-economic research – although not a central theme for an EU RTD program on EE technologies – should be considered a valuable sources of knowledge for the implementation of these technologies.

- That the possibility of funding of demonstration projects in industrial processes (radical technology changes) should be considered.

AGE observes that successful European energy-efficiency policies will require coordinated efforts of all sectorial instruments (e.g. Cohesion Funds , Structural Funds, the EU Emission Trading System) and other fiscal means to tackle energy inequality within member states, and a 7th Framework Program reflecting the emphasis on energy efficiency in research.

Intellectual capacity building should be taken into account as a major factor in the success of energy-efficiency policies. Policy-makers and administrations tend to master supply-side policies, but have problems coming to terms with demand-side and its multiplicity of actors.

R&D in energy efficiency would certainly benefit from EU-level funding. The necessary emphasis on energy efficiency should translate into a significant share of the 7th FP for research, in order to speed up the development of energy efficient materials and appliances as well as innovative solutions for whole energy systems.

However, considerable progress is already possible with the existing technology. The main weakness of energy efficiency implementation is the lack of human capacities on this issue at all levels: EU governments and national administrations, local authorities, enterprises, etc. A key task of the European Commission should be to develop capacity building in co-operation with the national, regional and local authorities.

Finally, it should be born in mind that energy efficiency does not solve the energy problems the world is facing. Increased energy efficiency certainly alleviates them and buys us time – quite probably in ways and to extents that we have only begun to appreciate – but new primary energy sources must be developed. The world cannot save its way out of the energy sink.

Annex 2: Renewable Energies

Hydropower

Background

Hydropower is a mature, commercially competitive energy technology. Many projects built in the early decades of the 20th century are still operating today, though most have been rehabilitated, modernized or re-powered.

Controversial issues are associated with large hydropower plants, especially with dams. By 1950, governments, or in some countries the private sector, were building increasing numbers of dams as populations increased and national economies grew. At least 45,000 large dams have been built as a response to meet an energy or water need. Today nearly half of the world's rivers have at least one large dam. But the last 50 years have also highlighted the performance and the social and environmental impacts of large dams. They have fragmented and transformed the world's rivers, while global estimates suggest that 40-80 million people have been displaced by reservoirs.

The generic nature of the impacts of large dams on ecosystems, biodiversity and downstream livelihoods is increasingly well known. From the knowledge of 'World Commission on Dams' (WCD) it is clear that they have contributed to the loss of forests and wildlife habitat, the loss of species populations and the degradation of upstream catchments areas due to inundation of the reservoir area; the loss of aquatic biodiversity, of upstream and downstream fisheries, and of the services of downstream floodplains, wetlands, and riverside, estuarine and adjacent marine ecosystems; and cumulative impacts on water quality, natural flooding and species composition where a number of dams are sited on the same river.

Today, most large projects under construction or planned are located in China, India, Turkey, Canada and South America.

The competition with gas-fired power plants, faster to build and cheaper overall in an era of inexpensive and abundant hydrocarbons and of increased public environmental awareness, have lead a number of European countries to stop launching large hydro-projects. With increased pressure on fossil sources, this situation is likely to be reconsidered. Nevertheless, the drawbacks of large hydropower are the main barriers that have to be addressed. In the meantime, small hydropower should be promoted.

Small hydropower (≤ 10 kWe) has some untapped potential in Europe, which could be rapidly developed. Industry needs continuous support for innovation and technology to ensure that small hydropower maintains and enhances its contribution to the emission-free, indigenous electricity generation in Europe, and that hydropower facilities operate with no significant environmental impact.

Summarising, there is some potential for new (small) hydropower. There are also some possibilities to improve existing larger hydropower plant in EU-Member countries. Hydropower faces challenges, both in terms of public acceptance and economics, due in part to the long approvals and construction cycles, high initial cost and hence long payback period.

Market situation

The technical challenges associated with large hydropower are mostly covered by the few manufacturers of major equipment and the many suppliers of auxiliary components and technology. While no major breakthroughs have occurred in machinery, the advent of computers has led to many incremental improvements, inter alia in monitoring, diagnostics, protection and control technologies.

The technical challenges for small hydropower can be met both spin-off from the large hydropower industry and by the application of appropriate technology by small manufacturers, organisations and agencies. Perhaps the greatest difference between the technology status of large and small hydropower is the huge variability of designs, layouts, equipment types and material characteristics used in small hydropower. It can be said that there is no simple 'state of the art' in small hydropower, but rather a huge body of knowledge and experience in designing and building projects to fit the site and the resources of the developer.

Attractiveness of hydropower technologies

Worldwide, hydropower currently provides over 80% of renewable energy, and is not only considered the most cost effective renewable energy source but also plays a unique role in achieving grid stability and in load levelling, thanks to quick start up times and large inter-seasonal storage capacity.

One of the greatest opportunities for quick gains to the renewable energy portfolio is to maximize the energy produced from existing projects through modernization. Gains of 5 to 10% might not represent an excessive target for most hydropower owners and, where there are significant numbers of dams without generation, the numbers could be somewhat higher.

There is still a potential for new (small hydropower) and improved projects in EU Member States as well as in developing countries, but with barriers both in the financial and institutional/political areas. Where not already implemented, technology and performance improvements at existing projects have benefits that exceed costs by 2 to 5 times.

Priorities for augmented R&D

While acknowledging that hydropower is well established, and considered a mature technology, there might be some remaining opportunities for system integration and technical innovation in order to enhance its development globally.

Continuous improvements in technology are required. The hydropower industry needs to maximize the use of its existing resources and adopt collaborative approaches to developing new projects that meet sustainability guidelines.

Most of the development on hydropower technologies should be financed by private initiatives: efficiency upgrading, automated maintenance, dam life extension, impact analysis, system integration, tele-control and optimisation.

However, it is the role of the EU to address by adequate policy framework the following issues: public information and education for a balanced risk/benefits understanding, elaboration of a common European position on the above mentioned WCD report, and the development of appropriate codes and standards regulations and incentives as regards small hydropower systems. Also long term impact of the climate change on the European hydraulic resources has to be addressed.

Governments probably have the greatest role by supporting existing hydropower as and where it is sustainable and promoting and supporting the development of new projects that also meets sustainability guidelines.

Small-hydropower development requires the technological know-how that is widely dispersed in Europe. It is therefore essential to co-ordinate that knowledge, and to move over from a situation where know-how and results are dispersed, and necessarily incomplete, to one where work is systematic and co-ordinated.

Assessment of hydropower technologies

The results of the evaluation of hydropower technologies are listed in the following table.

Hydropower Systems against Evaluation Criteria

Criterion	Comments
Potential Economic Contribution	
at current energy prices	**small** – mostly used already
at 2 times current	**moderate** – at special areas
at 4 times current	**moderate** – at special areas
Health and Safety Impacts	
to work force	**very good** – installation and maintenance regulated by directives and standards
to public	**good** – but problems with high dams
Environment Friendliness	
locally	**fair** (large hydro), **good** (small hydro) – site depending
global warming	**excellent**
Input Sustainability	**excellent**
Security of supply	**excellent** – with sometimes seasonal differences
Compatibility with EU needs	**very good** – site depending
Deliverability	**very good** – subject to public acceptance – site depending
The need for EU-wide R&D	**low**
Secondary (spin-off) merits	**few too good** – export opportunities of turbines and engineering
Special factors	**site depending**

Recommendations

AGE-SWOG-1 believes that for further developments of hydropower technologies neither huge expenditures nor radical changes are necessary. What are required are continuous improvements in technology. The hydropower industry needs to maximize the use of its existing resources and adopt collaborative approaches to developing new projects that meet sustainability guidelines. However, it is necessary to show clearly how hydropower can be built and operated in a sustainable manner. Most of the effort on hydropower technologies should be financed by private initiatives: efficiency upgrades, automated maintenance, dam life extension, impact analysis, system integration, telecontrol and optimization.

On the other hand, it is the role of the EU to address by adequate policy framework the following issues: public information and education for a balanced risk/benefits understanding, elaboration of a common European position on the WCD report, and the development of appropriate codes and standards regulations and incentives as regards small hydro systems. Also long term impact of the climate change on the European hydraulic resources has to be addressed.

Small-hydropower development requires the integration of multidisciplinary technological know-how that is currently widely dispersed in Europe. It is therefore essential to co-ordinate small-hydropower activities, and to move over from a situation where know-how and results are dispersed, and necessarily incomplete, to one where work is systematic and co-ordinated, within framework of research programmes.

References

Niels Nielsen: Hydropower Technologies and R&D Programmes. Input to the IEA-Seminar 'Catching Up: Priorities for Augmented Renewable Energy R&D. March 3, 2005, Paris/IEA.

EUREC Agency, March 2005 (European Renewable Energy Centres Agency) FP7 Research Priorities for the Renewable Energy Sector.

Dams and Development: A New Framework for Decision-Making. The Report of the World Commission on Dams: An Overview – November 16, 2000 – http://www.dams.org

Geothermal Technologies

Background

Geothermal energy is the energy below the earth's surface in the form of hot water or rocks. It has been used since ancient times for heating and, for about 100 years, for electricity generation. Its potential is far under-exploited. Important limitations to expanding its use are economics as well as the geographic distribution of the resource. It is essential to distinguish between low enthalpy (LEG) and high enthalpy (HEG) geothermal energies. In general, the former is restricted to the first 3,000 m below the surface, while the latter extend beyond that depth.

Besides electric power generation, geothermal energy is today used for district heating, as well as for heating (and cooling) of individual buildings, including offices, shops, small residential houses, etc.

The largest geothermal district-heating systems within the EU can be found in the Paris area in France. But Austria, Germany, Hungary, Italy, Poland, Slovakia and others also have a substantial number of interesting geothermal district heating systems.

Sweden, Denmark, Germany and Austria are the leading countries in terms of the market for geothermal heat pumps (LEG) development within the EU.

In 2003, a total of approximately 2 Mtoe has been supplied (within EU 20) by geothermal heating alone; including ground-coupled heat pumps.

Market situation

Geothermal energy for electricity generation was first commercially used in 1913 in Tuscany, Italy. Geothermal energy has been used on a large-scale for both heat and electricity (> 100 MW) for over 45 years.

The geothermal sector is currently the fourth largest electrical power production sector using renewable energy sources, ranked behind hydraulic power, biomass and wind power.

Presently, geothermal energy is used in 71 countries, 24 of which use it to generate electricity. Over 80 countries have reported resource availability. Total worldwide installed capacity now stands at 8,902 MWe, generating 56.8 TWh/year, which is equivalent to 0.4% of global electricity production. Unique to geothermal is the added capability of using the heat in the separated hot water from power generation for direct-use applications, contributing significantly to the 2004 global installed capacity of geothermal heating of 27,825 MWth for direct utilization and total energy use of 261,418 TJ (72,622 GWh).

If the large regions of the world are considered, two main producers of geothermal electricity can be seen: America (3,921 MWe) and Asia (3,291 MWe). Europe comes next, with a total capacity of 1,123 MWe.

Applications in EU member states linked to exploitation of hot water for baths and swimming pools are 36.5% of total (752 MWth) followed by building heating (35.7% of total, 734 MWth). Heating greenhouses for agriculture (18.7% of the total; 386 MWth) and fish farming (6.1% of total, i.e. 126 MWth) are the other two big geothermal applications in the European Union. Other applications have also been developed to a lesser degree, such as the use of heat in industrial processes (0.65% of total, i.e. 13 MW), solar cooling (0.08%, i.e. 2 MW) and agricultural drying (0.03%).

In spite of the lack of sufficient accumulated experience current generation costs are estimated in the range of US$ 0.02-0.10/kWh and projected to come down to US$ 0.01-0.08/kWh. Capital costs vary widely, depending upon resource quality and generation size, and are currently valued in the range of US$ 1,150-2,300/kW installed capacity for high quality resources, down by about 50% over the last twenty years.

A large part of geothermal energy is used by geothermal heat pumps (LEG), under the heading of the so-called very low temperature applications. The European Union is one of the main regions of the world to have developed geothermal heat pump technology (ground-coupled heat pumps). The total number of geothermal heat pumps is estimated at more than 379,000 units, equivalent to 4,531 MWth 2004 (+30.5% with respect to 2003). The heat pump industry is by far the most dynamic of the three geothermal sectors.

Attractiveness of geothermal technologies

Production from geothermal sources is independent of weather and of daily and seasonal variations.

Geothermal energy could provide indigenous, affordable, environmentally friendly power (HEG) to areas now without power or where power is currently provided by oil. Increased efficiencies in power production would be expected from development of deeper, hotter geothermal resources and more effective use of resources could be made through co-generation and cascaded use.

Priorities for augmented R&D

With the long term objective of increasing electrical production (HEG) and parallel rapid growth in heat use (LEG), the main areas requiring improvement must be in cost-effectiveness in the marketplace, improved resource assessment, better public awareness and addressing environmental barriers.

Some of the current HEG R&D priorities being addressed are: Environmental impacts of geothermal energy; enhanced geothermal systems; deep geothermal resources; advanced geothermal drilling techniques; direct use of geothermal energy; sustainability of geothermal energy use; geothermal power generation cycles.

Though LEG is in many ways a mature technology, it now requires increased financial support to attain its ambitious goals, but not necessarily more R&D.

It is necessary to inform stakeholders of the benefits of LEG energy, encourage partnerships that allow benefits to flow back to the community and clear commitment on the part of national governments on the positive impact of new technologies towards mitigation of CO_2 emissions.

Some of the specific priorities for additional HEG R&D could include funding to expedite the completion of current priorities as well as new topics and include increased production and dissemination of information towards: development of better exploration and resource confirmation and management tools; verify the cost effectiveness of electricity production from enhanced geothermal systems; development of deep (> 3,000 m) geothermal resources; increased geothermal co-generation (power and heat); reduction of costs of geothermal well drilling, logging and completion; optimisation of ‘cascading use’ through experience and demonstration at different scales which can certainly help reduce costs for space/district heating; better understanding and mitigation of environmental effects. Man-induced seismicity can become a show-stopper, in particular for development of geothermal systems in densely populated (West European) areas that are not used to experiencing natural seismicity. In addition, dissemination of appropriate information to stakeholders is essential.

The exploration of ‘deep geothermal resources’ might greatly benefit from the use of oil-related technologies.

Assessment of geothermal technologies

The results of the evaluation of geothermal technologies are listed in the following table.

Geothermal Systems against Evaluation Criteria

Criterion	Comments
Potential Economic Contribution	
at current energy prices	**good for LEG, moderate for HEG** – at special areas with natural hot water source
at 2 times current	**possible large**
at 4 times current	**large**
Health and Safety Impacts	
to work force	**very good** – installation and maintenance regulated by directives and standards
to public	**very good**
Environment Friendliness	
locally	**unknown** (plate tectonics), H_2S smells
global warming	**very good**
Input Sustainability	**excellent**
Security of supply	**excellent**
Compatibility with EU needs	**very good** – in areas with geothermal sources
Deliverability	**good for LEG** – continuous energy production, **unknown for HEG**
The need for EU-wide R&D	**large for LEG, moderate for HEG** – big expensive projects with European visibility needed
Secondary (spin-off) merits	**moderate for HEG** – export opportunities
Special factors	**site depending**

Recommendations

AGE-SWOG-1 thinks that a few well-targeted lighthouse commercial projects might be enough to have a realistic appraisal of geothermal energy problems as well as to advance the technology and to prove the cost effectiveness.

More public funding for HEG R&D would support an extension of geothermal for power generation and direct heat use to areas far from tectonic plate boundaries and greatly increase the areas of utilization.

References

Ladislaus Rybach: Geothermal Energy for Electricity Generation. Input to the IEA-Seminar 'Catching Up: Priorities for Augmented Renewable Energy R&D'. March 3, 2005, Paris/IEA-International Energy Agency.

EUREC Agency, March 2005 (European Renewable Energy Centres Agency) FP7 Research Priorities for the Renewable Energy Sector.

EU and Worldwide Geothermal Energy, INVENTORY Barometre Geothermie, December 2005.

Solar Thermal Heating and Cooling Technologies

Background

The implementation of solar thermal technologies for low to medium-temperature applications as a source for heating and cooling in Europe and the development of a strong European solar thermal sector are important steps towards achieving the European policy goals of increased security of energy supply, reduction of greenhouse gases and sustainable development.

A major part of the energy use in the EU is related to applications in heating and cooling which operate at temperatures below 80°C. In this temperature range solar thermal technologies offer opportunities for replacing valuable fossil fuels by emission free solar solutions.

More than one third of the EU primary energy is used in buildings. This figure reflects the potential for solar thermal technologies as the main technology to replace traditional fuels used for heating and cooling.

Based on the present state of the technology, the perspectives for further technological developments and the combination with price developments for traditional fuels as a result of scarcity and environmental cost, a plausible assumption can be made that, over the next 25 years, energy needed for heating and cooling in the EU could be reduced around 50% through a mix of energy savings, energy efficiency and the use of solar thermal. In economic terms this implies that widespread use of solar thermal technologies in combination with other energy reduction measures could eliminate 15% or roughly €100 billion out of the EU energy bill in a few decades time.

The worldwide and European solar thermal markets have grown significantly over the recent years. The most dynamic markets for flat-plate and evacuated tube collectors worldwide are in China and in Europe. The average annual growth rate between 1999 and 2003 was 27% in China and 12% in Europe. At the beginning of 2005, the installed capacity of flat-plate and evacuated tube collectors in Europe was 10 GWth (14 million square meters of collector area).

Europe is leading in technological terms but in terms of manufacturing, 75% of the solar thermal collectors installed worldwide in 2003 were produced in China. Europe comes at second place, with just 10% of the world-wide production. In order to improve European competitiveness and to open new markets, a strong common European strategy for solar thermal technologies is needed.

Today, markets for solar thermal systems are domestic hot water preparation, solar heating and cooling of buildings, drying processes e.g. crop drying. New approaches for solar thermal applications are solar-combined heating systems, solar-supported district heating for housing estates and solar-supported process heat up to temperatures of 250ºC.

Market situation

A large variety of solar-thermal components and systems, mostly for residential applications, are available on the market. The products are reliable and show a high technical standard in the low temperature regime. However, there are technical and economic barriers and obstacles preventing the wider use of solar thermal components and systems. The market growth is not yet stable and still is very much dependent on public support (subsidies), not unlike the other renewable energy technologies.

Solar heating and cooling applications have a low penetration in most countries where business is carried out mainly by small and medium enterprises with partly manual fabrication and no established technical-scientific R&D expertise. There has been, however, a rapid market growth in recent years for small solar hot water systems (SDHW) in countries moving towards partly automatic or semi-automatic fabrication of solar-thermal components.

Over the past 20 years the specific costs of SDHW systems have decreased by a factor of two. Besides hot water supply in southern European countries, e.g. Greece, Cyprus, 'solar heat' is not yet seen as fully competitive with fossil alternatives. The relative competitiveness of solar thermal systems will naturally improve if oil and gas become more expensive.

The world-wide installed capacity of solar thermal systems is estimated to be around 98 GWth, corresponding to 141 million square meters of collector area by the end of year 2004. Of these 74 GWth were flat-plate and evacuated tube collectors, which are used to generate hot water and for space heating and 23 GWth by unglazed plastic collectors, which are used mainly to heat swimming pools. A capacity of 1.1 GWth air collectors was installed. These are used for drying agricultural products and to a lesser extent for space heating of houses and factories. The use of solar thermal energy greatly varies in the different countries, depending upon its economic development and societal habits. In North America (USA and Canada) swimming pool heating is dominant with an installed capacity of 19 GWth of unglazed plastic collectors, while in China and Taiwan (44 GWth), Europe (11 GWth) and Japan (5 GWth) flat-plate and evacuated tube collectors are mainly used to generate hot water and for space heating.

Based on the data available for the year 2005 at the date of publishing this report the total installed capacity worldwide of flat-plate and evacuated tube collectors can be expected to be 115 GWth (164 million square meters).

The annual collector yield of all solar thermal systems installed by the end of 2003 in the 35 recorded countries corresponds to an oil equivalent of 9.3 billion litres and an annual avoidance of 25.4 million tons of CO_2.

Attractiveness of solar thermal technologies

The energy need for heating and cooling as well as for crop drying and process heating is large and growing, the solar resource is large especially in southern latitudes, and the environmental advantages as well as the economic benefits are substantial.

Buildings using solar energy (active and passive) have remarkable advantages: they require less energy, cause less adverse environmental impacts, e.g. reduced CO_2 emissions, provide open sunlight, high quality space, improve building aesthetics, require no special architecture.

While solar water and space heating have been in the market for decades, new approaches for solar thermal applications – e.g. for cooling and process heat – are now emerging onto the market. Solar assisted cooling is an extremely promising technology, as peak cooling requirement coincides with peak solar radiation. A number of large-scale solar cooling systems have been successfully demonstrated: and it is now necessary to support wide market introduction. Small-scale solar cooling systems could be ready within a decade, if some support to its development is provided.

Summarising, solar thermal systems could replace more than 30% of the EU's oil imports.

Priorities for augmented R&D

The market deployment of the various solar heating and cooling technologies should be supported by appropriate EU policy measures, as this would facilitate their growing presence in the market and their associated environmental benefits. It is however important to emphasise that public R&D expenditures are not the main requirement for the development of a mature market for solar heating and cooling technologies. Market stimulation is an essential element. Policies, as well as economics and cultural aspects have a significant impact on the market development for solar thermal systems.

High performance and cost efficient materials for improved solar thermal systems might be borrowed from other existing technologies: cost-effective optical coatings on the surfaces interacting with the solar irradiation in order to reflect, transmit or absorb the light in a highly effective way; low-cost anti-reflective and self cleaning glazing materials (e.g. new synthetics, embossing of suitable micro-structures into the surfaces of panels and tubes). Plastic materials for collectors with high thermal and optical performance could significantly reduce the costs of solar thermal systems.

For the future development of solar thermal systems, advanced insulation materials are necessary and energy storage materials with a higher energy density than water need further development. Promising technologies are based on phase change materials or thermo-chemical storage processes (e.g. sorption).

With increasing demand for higher comfort levels in offices and houses, the market for cooling has been increasing constantly over the past years. The obvious solution to provide the energy for these cooling applications through solar thermal systems is still under development. In the small capacity range the component development of cooling equipment needs further R&D in order to come to higher performance, lower prices and to a more industrialized production.

In order to support the further development and market introduction of solar thermal systems, it is necessary to provide, as well as the technology itself, the appropriate boundary conditions. Among these are methods of testing and assessing the thermal performance, durability and reliability of systems and components. Tools and education packages for practicing architects are also needed. Furthermore, it is necessary to develop methods for assessing the environmental benefits from solar thermal systems and to include solar thermal in building standards and regulations such as the European Building Performance Directive.

Assessment of solar thermal technologies

The results of the evaluation of solar thermal technologies are listed in the following table.

Solar Thermal Systems against Evaluation Criteria

Criterion	Comments
Potential Economic Contribution at current energy prices at 2 times current at 4 times current	 **fair to good** – site depending **large** **very large**
Health and Safety Impacts to work force to public	 **excellent** **excellent**
Environment Friendliness locally global warming	 **excellent** **excellent**
Input Sustainability **Security of supply**	**excellent** **very good** – depending on weather
Compatibility with EU needs **Deliverability**	**very good** **excellent** – modular units can be installed to match demand
The need for EU-wide R&D **Secondary (spin-off) merits**	**fair to good** – advanced thermal storage, cooling systems **moderate** – export opportunities
Special factors	**excellent** – strong public support generally

Recommendations

AGE-SWOG-1 thinks that the deployment of solar thermal systems within buildings will have a real impact to the future energy supply at the EU scale. The objective should be to develop competitive advanced solar heating and cooling systems which are able to cover 5% – 10% of the overall low temperature heat demand of the EU-Member States by 2020.

Market penetration of solar thermal systems has to do more with public funding and legal measures than with Energy R&D Policy. The existing collectors available in the market place – both flat plate and evacuated tube collectors – are simple enough and mostly industrial innovation is needed. Some applied and well targeted research and development on optical coatings and self-cleaning glazing materials as well as advanced thermal storage design might improve efficiencies and operation. For faster market deployment system integration and testing are recommended.

AGE-SWOG-1 support the development of stronger policies to promote renewable heating and cooling in EU-Member States: EU Directive to promote heating and cooling from Renewables.

References

The IEA-Solar and Cooling Programme: www.iea-shc.org

Faninger, Gerhard: The Global Potential and Role of Solar Thermal Applications: A New Vision for Solar Heating and Cooling. IEA-Solar Heating and Cooling Programme. November 2004.

Weiss, Werner, Bergmann, Irene, Faninger, Gerhard. (2005): Solar Heating Worldwide, Markets and Contribution to the Energy Supply 2003, www.iea-shc.org

Michael Rantil: Research and Development Needs for Solar Heating and Cooling. Input to the IEA-Seminar 'Catching Up: Priorities for Augmented Renewable Energy R&D'. March 3, 2005, Paris/IEA-International Energy Agency.

FP7 Research Priorities for the Renewable Energy Sector EUREC Agency, March 2005 (European Renewable Energy Centres Agency).

European Renewable Energy Council, EREC, March 2005 For a European Directive to Promote Renewable Heating and Cooling.

ESTEP: European Solar Thermal Technology Platform: Position Paper for the Start of the European Solar Thermal Technology Platform, November 2005. Published by ESTIF and EUREC Agency (European Renewable Energy Centres Agency).

Solar High-Temperature Power Systems

Background

Solar systems for producing high-temperature heat are based on concentrating collectors. Such solar systems have been used successfully since the mid-1980s to generate electric power commercially in regions of California (USA) with high direct radiation. Further spread of this technology came to a halt in the early 1990s, because the costs were still too high to compete with declining fuel prices. Recently, greater urgency for climate protection and sustainable technologies and the volatility of fuel prices have led to new incentive programmes for solar power plants sponsored by national and European initiatives and by the World Bank.

Seven different technical concepts of concentrating solar thermal power technologies (CSP) are currently under promotion in Europe. Most of the systems are planned for Spain, which offers an incentive of about 22 €cents/kWh for solar thermal electricity. The most mature technology today is the parabolic trough system that uses thermal oil as heat transfer fluid. Several 50 MWe units using thermal energy storage based on molten salt are currently planned.

The potential of CSP in Europe (EU-15) is estimated to be more than 2000 TWh/year, mainly in Spain, Italy, Portugal and Greece – including Mediterranean islands. This figure has considered only unused, unprotected flat land area with no hydrographical or geomorphologic exclusion criteria with a direct radiation level above 1,800 kWh/m^{2}a.

The ECOSTAR evaluation estimates levelised electricity cost (LEC) of 17-18 €cents/kWh for these initial systems, assuming a load demand between 9:00 a.m. and 11:00 p.m. under southern European solar conditions. The other selected technology options are currently planned in significantly smaller pilot scale of up to 15 MWe. The LEC is significantly higher for these small systems ranging from 19 to 25 €cents/kWh. Assuming that several of the smaller systems are built at the same site to achieve a power level of 50 MW and take benefit of a similar O&M effort than the larger plants, LEC estimates of all of the systems also range between 16 and 18 €cents/kWh. The systems achieve a capacity factor of up to 30% under these conditions (depending on the availability of storage).

One significant exception is the integration of solar energy into a gas-fired combined-cycle plant, which at the current status of technology can only provide a solar capacity factor of 11% and needs significant fossil fuel (20 – 25% of the solar share depending on load curve) but offers LEC of below 8 €cents/kWh. Due to the low specific investment cost of the gas turbine/combined cycle together with a high efficiency, the system is specifically attractive for hybrid operation.

Based on current understanding of the issues associated with the various systems, cost reduction of 30 – 35% triggered by technical innovations appears feasible for most of the technologies. These figures do not include effects of volume production or scaling of the power size of the plants beyond 50 MW. For parabolic trough technology a cost reduction of 14 % for larger power blocks (400 MW) and 17% for volume production effects when installing 600 MW per year was estimated.

Market situation

The construction of the first plant has been started; several others are close to start construction. In Spain solar power plant installations of more that 500 MW have requested to be considered under the above-mentioned tariff scheme and should be installed by 2010.

A variety of projects are under operation in California for almost 20 years with 150MWe and there are some other ones in operation in the vicinity of Barstow in the Mojave Desert of similar outputs. Further developments and constructions are planned in the USA.

Two international requests for bidding have been released for hybrid solar power plants in Morocco, and Algeria, further projects are under preparation in Iran, Israel, Egypt and Mexico.

A global market initiative by the governments of 10 countries (Algeria, Egypt, Germany, Israel, Italy, Jordan, Morocco, Spain, Yemen) have agreed to establish the boundary conditions to generate a market of 5,000 MW of concentrating solar power plants needed to become fully commercial.

Market focuses are in the larger scale projects (80-300 MW), as well as in smaller systems (10-50 MW). The larger systems are thought to be appropriate for bulk power, and would be developed as fossil hybrids (generally natural gas). The smaller systems have a variety of potential sub-markets, including captive industrial power, distributed generation, or small independent grids. In some situations, these, too, would be hybrids. Electricity generation costs for these first plants are in the order of 15-20 €cents/kWh in Southern Europe for 50 MW size systems.

Low-cost thermal energy storage systems improve the revenues of a solar power plant significantly. Promising concepts are concrete storage for parabolic troughs or molten salt or packed beds for central receivers. Quartz sand may be a candidate for a future high temperature storage system for air receiver power towers.

In solar concentrating plants for process heating, heat at high-temperature level can be provided in receivers which have already been developed to a multi MW scale for high temperature heat generation: in central receiver systems at 500-1,000°C and in an experimental scale up to 2,000°C in parabolic dish concentrators and in solar furnaces. Thus it is useful to investigate whether such plants – as well as allowing solar thermal power production – could also be used effectively to produce chemical energy carriers like hydrogen or could help to meet the energy demand for the established high temperature processes in the primary industry.

For the near-term only niche industrial applications at high-temperature levels can be expected, such as detoxification of specific hazardous wastes or testing and treatment of materials. Whilst developing the first niche applications an intended effect is to establish specific know-how in solar chemical engineering and to collect those experiences which are required to carry out solar chemical bulk processes. At the same time further specific applications of solar radiation should be explored. The feasibility of a solar chemical technology has been demonstrated at engineering scale.

Attractiveness of solar high-temperature technologies

Solar thermal high-temperature technology would be an option for sustainable electricity production, if costs were reduced by a factor of 3-5 compared with the present. Research infrastructures and pilot plant development are costly and would benefit from a European approach.

Europe currently might have a leading role but this is in jeopardy from progress in the US and Japan. It is part of this vision that Europe should maintain its position as the world-leader of both the technological development and the commercial utilisation of solar thermal high-temperature applications. EU-funding is necessary in order to keep Europe in the lead in solar thermal high temperature technologies.

The chances for the companies of the industrialized world are twofold: solar chemical techniques could be employed directly at locations in the developed countries if there is enough sun (e.g. in Southern Europe, in the Southern States of the USA, in Israel, in Australia) or could be exported to non-industrialized or developing countries which have good solar conditions (e.g. North African countries, South Africa, Namibia, Arab countries, Mexico). In a future world economy these countries could export electricity or their fossil resources if they have them, taking benefit from the increasing world market prices, whereas a major part of their own increasing demand could be covered by renewable options.

Priorities for augmented R&D

Current development needs are concentrated in: Parabolic Trough Technology using direct steam generation; Central Receiver Systems (CRS) using molten salt storage or CRS using saturated steam; CRS using atmospheric air, and CRS using pressurized air receiver and dish steering systems.

Continuous demonstration of scaling steps of technology innovations are required to run down the cost curve.

Innovative approaches for further cost-reduction have partly proven their technical feasibility: Efficiency improvements for direct steam generation for parabolic troughs or hot air for gas turbines in power towers; cost reduction up to 25%; approaches in hybrid power conversion.

Low cost thermal energy storage systems improve the revenues of a solar power plant significantly. Promising is concrete storage for parabolic troughs or molten salt or packed beds for central receivers. Quartz sand may be a candidate for a future high temperature storage system for air receiver power towers.

The main objective of medium- to long-term R&D is to develop high efficient solar combined cycle (always in conjunction with gas) for power production. This will reduce total system costs significantly and reduce the need for cooling water thus increasing the potential solar power contributions significantly in Europe mainly South Europe.

Medium- to long-term research should also focus on thermal energy storage systems and the integration aspects of solar energy into larger more efficient power cycles. This development needs a number of scaling steps from the lab to the power plant thus demanding a longer development time and higher cost for the qualification of the concepts. Before starting such a development the consortium should be well aware on the medium to long term aspect of this research activity and the cost associated with it. It appears necessary to include demonstration activities in this development phase. In order to achieve a significant progress, much larger resources are needed for these developments than offered in public programs in the past.

Competition is essential for cost reduction. In order to stimulate competition it appears to be essential to give similar starting conditions to a number of options. This includes the support of pilot plant demonstrations in order to establish a technical reference that allows suppliers to create commercial projects in the future. In addition, there is a need for growth in the available expertise in several associated domains (glass, reflectors, light weight structures, storage and other).

R&D priorities for long term research in the field of solar fuel and commodity productions are: technology development of integrated receiver-reactors; windows for volumetric and direct absorption receiver-reactors; secondary concentrators; specific high temperature high flux measurement techniques; system evaluation of thermo chemical cycles and concepts; testing and demonstration of prototype units.

Further needs for improvements are: reduction of operation and maintenance costs; stimulation of mass production; development of advanced materials for high -temperature applications and for thermal energy storage.

Assessment of solar high-temperature technologies

The results of the evaluation of **solar high-temperature technologies** are listed in the following table.

Solar High-Temperature Systems against Evaluation Criteria

Criterion	Comments
Potential Economic Contribution at current energy prices at 2 times current at 4 times current	 **nil** for the forseeable future – only test facilities in operation **some possible** **fair to good**
Health and Safety Impacts to work force to public	 **very good** **very good**
Environment Friendliness locally global warming	 **excellent** **excellent**
Input Sustainability **Security of supply**	**excellent** **fair to good** – site depending
Compatibility with EU needs **Deliverability**	**good in South Europe** – only during direct sun shine hours **good** – modular units can be installed to match demand
The need for EU-wide R&D **Secondary (spin-off) merits**	**fair** – as soon as demonstration plants are in operation **fair to good** – HT materials, experiments on thermal shocks, export opportunities
Special factors	**site depending**

Recommendations

AGE-SWOG-1 recommendation is based on the vision that Europe should maintain its position as the world-leader of both the technological development and the commercial utilisation of solar thermal high-temperature applications. Only the support of medium- to long-term research will keep Europe competitive in solar thermal high temperature technologies, and that would not otherwise be carried out. Research infrastructures and pilot plant development are costly and would benefit from a European approach.

Interesting by-product technologies such as hazardous waste detoxification, water desalination as well as materials testing and treatment might be important short/medium term applications of this technology.

AGE-SWOG-1 thinks that there is not a current need for 'strong' coordination in the solar thermal field, but nonetheless there are topics which would be well suited to the EERA concept, including R&D to: increase efficiency and reduce costs (high temperature approach, light weight concentrators, and new reflector concepts); explore and develop high-temperature technologies for various purposes; reduce operation and maintenance costs and stimulate mass production; develop materials for high-temperature applications and for thermal energy storage. Most of the research should concentrate on the development of high temperature materials and, probably, two-phase flows and heat transfer under extreme conditions.

The SolLab Network is an important existing opportunity for collaboration and coordination. This should be extended to other members.

Materials research represents an opportunity for cross-cutting activities within the ERA.

References

European Commission, Directorate-General for Research: 'Towards the European Energy Research Area' Recommendation by the ERA Working Group of the Advisory Group on Energy AGE-ERWOG. Community Research: EUR 21353.

Robert Pitz-Paal: Concentrating Solar Power. Input to the IEA-Seminar 'Catching Up: Priorities for Augmented Renewable Energy R&D'. March 3, 2005, Paris/IEA-International Energy Agency.

EUREC Agency, March 2005 (European Renewable Energy Centres Agency) FP7 Research Priorities for the Renewable Energy Sector.

Ocean Energy Technologies

Background

Ocean energy includes potential and kinetic energy from the ocean. Several types of ocean energy sources with different origins exist and the sources are grouped into five principal categories: tidal, wave, marine current, thermal gradient and salinity gradient.

There is no commercially leading technology on ocean energy conversion systems at the present time. Nevertheless, there are commercially operated power installation based on tidal and wave power systems.

The most developed conversion systems concern tidal energy. Tides are generated by the rotation of the earth within the gravitational fields of the moon and the sun. The relative motions of these bodies cause the surface of the oceans to be raised and lowered periodically. Tidal energy is predictable in both its timing and magnitude. The locations where tidal power could be developed economically are relatively few, because a mean tidal range of five metres or more is needed for the cost of electricity to be competitive with conventional power plants. Additional requirements are a large reservoir, and a short and shallow dam closure.

The energy from ocean waves can be considered to be a concentrated form of solar energy. Winds are generated by the differential heating of the atmosphere and, as a result of their blowing over large areas of water; part of their energy is converted into waves. Near-shore and mainly at the shoreline the wave power level is in general smaller than offshore because of wave breaking in shallow waters. Other phenomena such as refraction, and diffraction in indented coastlines, can cause significant resource variations alongshore on a scale of 1 km or much less, especially at the shoreline. Power of waves has been recognised for millennia by its destructive capacity, the possibility of harnessing it has also been a challenge. More than one thousand patents of wave energy devices have been filed since the end of the 18th century, but it was only after the first oil crisis in 1973 that the research and development on wave energy appropriate scientific background started.

Many wave energy devices have been proposed but few have reached demonstration. Prototypes of onshore, near-shore and offshore Oscillating Water Column systems deployed since 1985 have proven this technology, which is still being developed. Various offshore wave energy devices are reaching the prototype stage as well as devices to exploit the energy resource that marine currents contain.

Different types of wave energy devices are now developed and planned to be built in the near future in the framework of international co-operation in the IEA Ocean Energy Systems Programme.

Marine currents, caused by thermally-driven circulation in addition to tidal effects, is kinetic energy from the sea which can be harnessed using techniques similar in principle to those for extracting energy from the wind, by using submarine converters similar to 'underwater windmills'. But this option is still relatively undeveloped. A number of studies have been completed on the energy potential of marine currents but there have been few on the engineering requirements for utilisation of this resource. The start up of the exploitation of the marine currents energy can make use of conventional engineering components and systems but development is required to achieve reliability and durability of the equipment at low operational and maintenance costs. The technique that has been mostly considered for the exploitation of marine currents is to use a turbine rotor, set normal to the flow direction that is mounted on the seabed or suspended from a floating platform. The development of technology for the exploitation of marine currents is also clearly processing: three prototypes are being tested now.

Salient gradient utilises the osmotic pressure difference arising between fresh water and sea water (Salinity Power). Large amounts of renewable energy can be extracted wherever freshwater from rivers and lakes meets the saltwater of the ocean. When freshwater and saltwater are separated by a suitable membrane the freshwater will spontaneously migrate through the membrane and dilute the saltwater in the process known as osmosis. The flux of water through the membrane can generate a hydrostatic pressure corresponding to a water head of 100 m or more which can be used to generate power in a hydropower turbine. Within osmosis power ocean salinity increases hydropower potential. This technology has an enormous unexploited power production potential world-wide. Estimates indicate a potential about 250 TWh per year in Europe and 2,000 TWh globally.

The main objective of the EU-co-funded Salinity Power project is the development of a cheap membrane with a long operating life in order to keep the cost for power down. Recent developments and results suggest that salinity power plant can be constructed with a very gentle environmental impact taking very good care of the local environment and biodiversity. Assuming realistic membrane performance and cost data it is expected that salinity power will be competitive with other emerging renewable energy sources such as off-shore wind power and biomass power generation when commercialised in about 5 to 10 years.

Ocean Thermal Conversion uses the thermal gradient between surface water heated by solar radiation and the cold deep water. Ocean thermal energy systems (Ocean Thermal Energy Conversion or OTEC) have been up to now only test prototypes. OTEC has no practical value for EU as its potential in EU is very small; it could be useful for other regions of the world.

Market situation

There are three tidal-power barrages around the world operated as commercial power plant, amounting to a worldwide total of 260 MWe of installed capacity. Tidal power systems are mature as the plant of La Rance rated at 240 MW (10 x 24 MW) has demonstrated. Commissioned 38 years ago, it has been operated in quite satisfactory technical and economical conditions (net productivity of 544 million kWh/year). The most critical problem was due to corrosion. It has been rapidly overcome. The main reported drawback is the negative impact on the ecosystem of the river. The latter has been severely damaged during the 3 years of construction when the connection sea-river was interrupted. It took more than 10 years to find a new equilibrium point with an even richer biodiversity with most of old species present and new ones adapted to the operation conditions.

In the case of wave power there are currently two installations operated as commercial-testing installations, cumulating around 750 kWel of peak power. The first commercial wave power plant is planned to be installed near Povoa de Varcim, off Portugal's northern cost, with a total capacity of 2.25 MW. Another 30 wave energy converters with an additional 20 MW will be signed and installed, if the results from the first plant will be positive. The private investor expects several hundred MW along the coast in this region.

As there are – besides of tidal energy plants – no purely commercial ocean energy plants operating, learning curves and cost figures do not rest on existing experience, but on estimates.

Attractiveness of ocean energy technologies

Around 71% of the Earth's surface is covered by sea and oceans, and the potential opportunities to harvest the abundant renewable energy sources that these contain is vast, but very uncertain concerning realisation.

Priorities for augmented R&D

Over the last twenty years, ocean energy developers received little public funding. For example, European Communities Framework Programme financed projects over that period for a total contribution of €23 million, equivalent to only 10% of the funding contributed towards photovoltaic projects.

Increasing R&D funds will speed up the rate of development. The effort and finance put forward in the United Kingdom is already showing an increase in technical progress. Several concepts are envisaging full-scale demonstration prototypes around the British coast.

There are a number of both technical and non-technical barriers that must be addressed. Technical barriers are specific to individual technologies and include: Wave energy systems (wave behaviour and hydrodynamics of wave absorption, reliability and survivability incorporated into the design, generic mooring techniques, power take-off systems and deployment methodologies); Tidal Stream Current Systems based on hydraulic turbines (basic knowledge of current speed along the water column, structure water tightness, cost efficiency and reliability, foundation and installation methods, as well as transfer of knowledge to underwater systems); Salinity Gradient (development of functioning and efficient membranes); Ocean Thermal Energy Conversion (thermal cycles, influence of the environment, floating systems and other).

Non-technical barriers include: Resource assessment; energy production forecasting and design tools; test and measurement standards; environmental impacts; arrays of farms of Ocean Energy Systems; dual-purpose plants that combine energy and other structures.

In the near term, ocean energy technologies will continue prototype deployments and investigation of multi-device large scale deployments. In the medium term, these technologies may become a significant contributor to those markets adjacent to the resource. In the longer term, when hydrocarbon scarcity becomes an increasing constraint and new forms of energy transmission are justified, ocean energy could become a much more important part of the world's energy portfolio.

Assessment of ocean energy technologies

The technologies to extract energy from the many ocean resources are early stage in comparison with other renewable energies. Also, it is not possible to assess all ocean energy systems in the same package. The results of the evaluation of **ocean energy technologies** are listed in the following table.

Ocean Energy Systems against Evaluation Criteria

Criterion	Comments
Potential Economic Contribution	
at current energy prices	**nil** – only test facilities in operation
at 2 times current	**some possible**
at 4 times current	**uncertain**
Health and Safety Impacts	
to work force	**uncertain**
to public	**good**
Environment Friendliness	
locally	**fair to good** – site depending
global warming	**excellent**
Input Sustainability	**excellent**
Security of supply	**excellent**
Compatibility with EU needs	**good**
Deliverability	**good** – site depending
The need for EU-wide R&D	**good**
Secondary (spin-off) merits	**fair to good** – export opportunities
Special factors	**site depending**

Recommendations

AGE-SWOG-1 thinks that the five ocean energy technologies have different maturity, strengths, risks and R&D needs. Tidal technologies work well; their use is limited by high investment cost strongly dependent on sites quality and availability. No dramatic changes are expected but incremental improvements along with experience curve could help reduce costs by something like 30%. On the contrary, for salinity-gradient based technologies many uncertainties remain. Ocean thermal conversion technology (OTEC) is lagging even further behind. Wave and marine currents technologies are probably somewhere in between. A focus on wave energy would probably be reasonable in a medium term approach aiming at demonstrating the economic viability conditions and the capacity of technology-ready devices to withstanding rough water conditions.

AGE-SWOG-1 thinks that ocean energy technologies must solve two major problems concurrently: proving the energy conversion potential and overcoming the very high technical risk of damage in the harsh environment. Additional R&D funding would help to mitigate the substantial technical risk faced by device developers daring to harness the energy of the marine environment. Increasing R&D funds will speed up the rate of development, and is critical to advancing the development and the future of ocean energy systems.

Following the realisation of successful projects during FP6, AGE-SWOG-1 recommends that further EU supported projects should focus on continued prototype development and move towards supporting projects that resolve the issues associated with optimising single unit deployment and pave the way for the deployment of demonstration multi-device farm projects. The main issue of available resources is the scarcity of good sites.

AGE-SWOG-1 emphasis collaboration between the European research actors in ensuring the necessary progress on shared issues such as test facilities and the development of common standards. Also training is required.

R&D on ocean energy devices can be carried forward using STREPs, with a small number of IPs perhaps being utilised for large-scale demonstration plant. Networking and joint planning has been carried out to date by the European Wave Energy Network (EWEN). Ongoing networking might be adequately addressed via Coordination Actions – the EU Ocean Energy Association (EU-OEA) is a good example. A NoE could also be of value in planning and implementing common infrastructure and research facilities. Use could be made of the Integrated Infrastructure Initiatives instrument for the development of research infrastructure such as European test facilities.

References

Katrina Polaski, Philippe Schild: R&D Priorities for Ocean Energy Systems. Input to the IEA-Seminar 'Catching Up: Priorities for Augmented Renewable Energy R&D'. March 3, 2005, Paris/IEA-International Energy Agency.

European Commission, Directorate-General for Research Towards the European Energy Research Area Recommendation by the ERA Working Group of the Advisory Group on Energy AGE-ERAWOG. Community Research: EUR 21353.

EUREC Agency, March 2005 (European Renewable Energy Centres Agency) FP7 Research Priorities for the Renewable Energy Sector.

IEA Implementing Agreement on Ocean Energy Systems: www.iea-oceans.org

Other Renewable Energy Concepts

Solar Production of Fuels and Commodities

The ultimate goal of solar chemistry is the chemical storage of solar energy, to make that energy source available regardless of time and location. In the long-term future the fossil fuels required as chemical feedstocks for the production of basic chemicals could be substituted by solar energy.

Compared to thermal energy storage, the conservation of solar energy in chemical form offers additional flexibility. Time and place of use are subject to significantly fewer constraints than for the grid-connected electricity. So seasonal adaptation of energy demand and supply is possible, and remote places without grid connection or mobile application can be individually served, which in many cases is not possible on the basis of electricity.

The fundamental question addressed in this research field is whether the chemical storage of solar energy or the production of solar fuels by concentrating solar technologies offers significant performance and cost benefits compared to other renewable alternatives. This has to be evaluated in the light of the experience gathered over the past twenty years by solar chemistry but also by other approaches (such as the nuclear high temperature thermo-chemical cycles).

One of the most-studied solar chemical processes is the reforming of natural gas to produce synthesis gas. The technical feasibility of solar reforming of methane has already been demonstrated at an engineering scale applying different reactor concepts. Presently the receiver concept is enhanced and industrial scale plants are modeled.

In addition new approaches for materials used in thermo-chemical cycles have been identified. Previous limitations, e.g. in the use of thermo-chemical cycles based on metal oxides, were due to the high dissociation temperature of the metal oxide (> 1,500 K), which appears to be difficult to control in terms of the material properties. Recent studies have identified a new group of metal oxides with a spinel structure as potential materials for a thermo-chemical cycle with dissociation temperatures below 1,200 K. These and other approaches appear to be a promising start for an efficient method of hydrogen production (compared to electrolysis with renewable electric power). However, much more renewable energy generating capacity must be built than that needed for this target before it makes sense to use wind or PV for electrolysis, for instance, or to gasify biomass to hydrogen. Given this situation, hydrogen will not be a prerequisite for de-carbonising the current energy system.

Solar High Temperature Industrial Process Heat

In solar thermal-concentrating plants process heat can be provided at high temperatures: in receivers which have already been developed in a multi-MW scale for high temperature heat generation in central receiver systems at 500-1,000ºC and in an experimental scale up to 2,000ºC, in parabolic dish concentrators and in solar furnaces even at more than 2,000ºC. Thus it is useful to investigate whether such plants – as well as solar thermal power production – could meet the energy demand for the established high temperature processes in the primary industry.

For the short to mid term future some market niches can already be identified today. These include the solar photo-chemical production of specialty chemicals and the solar detoxification of polluted water and hazardous wastes.

For the near-term future, the first industrial applications can be expected such as solar steam reforming of natural gas, photo-chemical production of specialities, detoxification of specific hazardous wastes, or testing and treatment of materials. Whilst developing the first applications an intended effect is to establish specific know how in solar chemical engineering and to collect the experiences which are required to carry out a larger range of solar chemical bulk processes. At the same time also further specific applications of solar radiation should be inspired.

Solar Chimney Technologies

Solar chimney technology is an electricity power generating method with the warm air of a large solar collector driven up through a tall chimney by convection. The earliest description of a solar chimney power station was written in 1931, and a model was built in 1982 in Manzanares, Spain, 150 km south of Madrid. The power plant operated for nearly 8 years. A heavy storm in January 1989 destroyed it. The experiment (50 kW power, tower 200 m high (steel)) was never meant to be economically viable but intended to demonstrate the physical concept. The calculations were proven by the performance.

A new approach uses a reinforced concrete structure with taller solar chimneys – up to 3,000 m height and 100 m internal diameter – and lighter structures: ‘Floating solar chimney technology’. Compared to the older concept, the efficiency of solar chimney power plants should be increased and the costs decreased. For the production of 50% of the present world energy demand for electricity a land of 130,000 km^2 (360 km x 360 km) is necessary. But in EU-Member States, appropriate areas for Floating Solar Chimney applications are very limited.

As no Floating Solar Chimney is in operation, learning curves and cost figures do not rest on existing experience, but on estimates. The costs of Floating Solar Chimney Technology are estimated to be much lower than that of a ‘concrete solar chimney power plant’ and thus become competitive with both comparable technologies, namely wind and PV but also with conventional power generation.

In a future ‘solar world’ a solar chimney could be a solution with some interesting features: no cooling water needed (it is a dry air cooling system in itself), intrinsic heat storage for power production after sunset and low tech characteristics that allows for cheap labour cost in constructing the large green house area around the tower. In the global solar belt there are many countries with plenty of such low cost labour force – Spain is of course to expensive. But serious reservations are to be made. Besides the evident siting difficulties which would drastically reduce the applications in Europe, structural integrity, durability of plastic components, process ability transport and assembling of huge components and maintainability are far beyond the foreseeable state-of-the-art.

Solar Power Satellites

At the end of 1970, the United States (Department of Energy and NASA) in co-operation with the European Space Agency (ESA, ESTEC) developed a concept for solar power satellites. The idea was to employ the much greater intensity of solar energy in space compared with that available at the earth's surface. A space transportation system carries materials and personnel to the construction base in the orbit. The assembled power satellite beams rf-radiation to a ground-based antenna which converts the radiation to electricity and delivers it to the grid.

A solar powered satellite is almost constantly illuminated throughout the year and the microwave beam transferring the energy to the ground is virtually unaffected by atmospheric conditions. Bearing in mind the loss in the microwave transmission system, which is estimated to be less than 40%, each square metre of solar cells in the solar power satellite will deliver approximately five times more energy to the electricity user than would be absorbed from terrestrial photovoltaic power plant. The 3-year assessment programme was finished 1981 with the result, that some proposed types of solar power satellites would be technically feasible – although the technical challenges are formidable – but the environmental, economic, social and international problems and uncertainties are to large for realisation. Summarising, the technical feasibility of the SSPS concept is not in doubt. The drawbacks are in the environmental impacts. Reducing the effects of the radio frequency beam on the living activities to an acceptable level seems quite difficult. Anyhow, it would lead to adopt a very low energy density transmission requiring huge antennas and ground footprint of the conversion facilities.

Annex 3: Cross-cutting Technologies

Preamble

Scope and working process

The cross-cutting working group (WOG4) has been commissioned by the AGE to explore the opportunities that might be offered by enhanced cross-cutting approaches in a limited number of areas and to look more particularly into the relation between basic research and energy technology development. The aim of this exercise is to maximize the efficiency of the innovation chain , bearing in mind that, underlying this specific mission , is the assumption that cross-cutting issues have the potential to be an accelerator of innovation and a source of potential breakthroughs for energy technology development. To realize this potential as fully as possible, the WOG4 proceeded in the following way:

- First it detected the most promising cross-cutting issues, in the perspective of contributing to achieving the strategic goals of the European energy policy.

- Then it looked at the way those issues have been addressed so far in terms of overall governance and operational management. In this respect, the typical aspects that have been more specifically considered were: stakeholders' awareness and mobilisation, financing mechanisms and level, connexion with adjacent processes (thematic issues management, basic research), instrument appropriateness, etc.

- Where a gap still exists and hurdles are clearly identified, recommendations for new schemes, novel approaches (or pursuing the current ones) that are meant able to overcome those barriers have been proposed.

The selection process

The role of a number of cross-cutting issues meant as 'horizontal' activities has already been fairly extensively dealt with as part of other work, in particular in SWOG (resources), ERAWOG (arising from socio-economic research) and in the reflection on strategic questions of the second stage of the AGE work (SQ 1: influencing factors, 4: barriers, and 6: international). Therefore the cross-cutting issues addressed in the group were chosen in a complementary manner, for they are meant, according to the expert group members experience, to have the highest potential impact on the energy RT&D results. These are: materials, biotechnologies, infrastructures and linkage with basic research.

Just like 'Energy', the 2 first ones are technology related issues taken out of the list of 9 thematic areas of the 'Cooperation' Specific Programme of FP7. They have been chosen for their unique potential of cross-fertilisation, in particular for the benefit of the energy sector. Evidence of that potential has been extensively given already by materials sciences. The subsequent question is about going faster and maximizing the spin-off for energy.

On the contrary, although underlying all life on Earth, up to now biotechnology is not currently widely used in commercial energy conversion. In a context of a 'post easy-energy era', learning how to mimic Nature might offer new opportunities in the longer term.

The last two subjects arise from a different nature since they are not directly technology oriented. In terms of instrument, the related priorities are part of the 'Capacities' and 'Ideas' Specific Programmes respectively. They address issues relating to organisation and research management, that are regarded as playing a critical role on the effectiveness of the S&T contribution to meeting the energy strategic objectives.

This choice may appear subjective. Other enabling technologies like IC&T, Power Electronics, Simulation techniques, Instrumentation & Control have been discussed as well from the energy perspective. The group recognized the significant role they have continuously played in optimising the design of equipment , in improving the performances, increasing the security and reducing the operating costs. However, they were not further analysed because the group considered they are less likely to make such a big change on energy technology as to deserve special recommendations beyond what the market is currently offering under more powerful drivers than the energy sector.

Materials for Energy Technologies

Past energy technology achievements from advanced materials and further challenges

Since the age of stone, materials have been the key that conditions the way products fulfil their requirements. In energy applications in particular, materials progress has allowed the design of equipment having higher energy densities, longer lives and being more environmental friendly, ultimately giving better value for money. This created affordable and widespread energy services and undoubtedly a better quality of life.

However, now that it is widely recognized that crude oil and natural gas production will peak sooner rather than later and that the atmospheric concentration of CO_2 should be contained as much as possible; a 'business as usual' scenario is certainly not an acceptable option. On the contrary, unprecedented pressure is now put on society in general and on energy stakeholders in particular to design innovative technology able to meet a rising demand from new sources of energy and/or with lower greenhouse gases discharges. The resulting requirements on the constituent materials of future equipment are going to be more stringent as the operating environments allowing higher energetic and environmental performance become more severe.

In order to illustrate this situation, examples can be found in the whole energy chain:

- **Electricity Generation**

Fossil: high temperature (typically up to 700°C for steam turbines in supercritical cycles and up to 1,400°C for gas turbines) resistant materials (metallic, metal-ceramic, ceramic) for the key components, especially the blade and vanes of the first row of the turbines have led to compact designs and spectacular energy efficiency increases in fossil-fuel fired power plants (almost doubling since the 1980's). Drastic reductions of NOx emissions have also been made possible with optimised burners. In the foreseeable future, as oil and natural gas are rapidly decreasing, coal will be the main energy source for transformation to heat and power. In many places, especially the developing countries, it will be the only affordable technology. Therefore, as coal conversion is currently a highly CO_2 emitter, further efficiency improvements by the development of even more advanced temperature resistant materials as well as CSS (Capture, Separation and Sequestration) of CO_2 is necessary to ensure the goals of cleaner use of coal are met. With respect to CSS of CO_2, the technological challenge, it is not meant to include critical materials issues. Instead, the questions of the economical, ecological, and social aspects of CSS first have to be answered.

Nuclear: the NPPs of generation 1 and 2 have seen their operating indicators steadily improved to reach the highest standards in terms of safety, reliability, availability and durability. This would not have been possible without significant improvements of their metallic components with respect to stress-strain corrosion and irradiation resistance.

For the NPPs of Generation 3 (now in design and construction) and Generation 4 (VHTR, FB, and High Performance-LWR) the overall goals of further improvements of safety, availability, commercial, and environmental acceptability requires further materials development with respect to higher operational temperatures and pressures, improved neutron irradiation behaviour, and even better corrosion resistance, and by this to contribute to the overall goal of a responsible energy provision.

As regards waste management, there are different strategies pursued in the different countries. They involve different concepts and technologies for storage and disposal of nuclear waste. There are ongoing related R&D programmes carried out under the responsibility of each country that includes materials development especially for the exploration of suitable storage and disposal sites.

As far as fusion technology is concerned, it has already been pointed out how important are the material issues. The need for facilities (IFMIF) aiming in particular to test the irradiation resistance of the first wall materials (14 MeV neutron radiation environment) has been recognized.

Wind generation: the quest for the economy of scale necessary to make wind power more competitive requires larger windmills with longer rotor blades. Again, better materials and production processes have allowed increased blade-tip speeds and centrifugal forces. The goal for further R&D is not the reduction of fabrication costs – this will be reached by industrial competition among the different vendors – but for the blades it is still vital to develop new materials, e.g. metal-plastic composites, which can withstand the increased static and dynamic stresses and strains due to the higher loads of increased rotor diameters.

PV: The challenges for a broad and world-wide market introduction of photovoltaic technology are manifold. With the exception of niche applications the biggest obstacles so far are the costs of the silicon-based technology. There are concepts to replace the silicon- based systems (expensive, limited efficiency, heavy, mechanically not flexible) by polymer semiconductors (cheaper substrate, more light weight, more flexible) or by organic dye sensitised solar cells (nano-technology). The goals are: a cheaper, weather resistant, long-term reliable mass product with higher efficiency than the silicon technology.

- **Distribution and Storage**

Superconductivity is a technology that has the potential to contribute significantly to higher energy efficiency. High Temperature Superconductors (HTS) that can operate at temperatures at or just below liquid nitrogen temperature opens a much better energy-conserving approach than the previous LTS materials. For low voltage applications, thin film technologies are already in application. For high voltage applications thicker, semi-finished products such as long strings, wires, and cables are still at an early experimental stage and many applications as switches, transformers, cables, generators etc. could be improved by HTS. Materials development has to be pushed forward with respect to increased critical current densities, required to be stable in a magnetic field at 77 K. Thicker semi-finished products are needed, which should be flexible, bendable, and weldable without loosing their properties.

Storage is potentially of high value in the energy chain. It enables a flexible energy use in time and sometimes in space, energy can be supplied when and where it is needed. Unfortunately, it is the weakest component of the chain already and will become more-and-more critical. In particular, we have no ready-to-use substitute for the time when filling a gasoline tank of our car will no longer be affordable. Electrochemical batteries do not provide a sufficient driving range so far and are very heavy. In the electric networks, electricity storage cannot be stored directly. For a short time, superconducting magnetic coils can help maintaining the power quality and sodium–sulphur batteries or redox flow systems may contribute to load levelling applications.

There is clearly a need for novel materials in those fields in addition to the prospects opened by hydrogen technologies. Concerning the latter, the challenge is to increase the energy density of the storage medium. The conventional storage technologies (gaseous under high pressure, liquid at -253ºC,) cannot provide the energy dense storage capacities as e.g. gasoline or diesel can. Other routes should be explored like high capacity hydrogen storage systems in solid-state materials (metal-hydrides, carbon nano-tubes, or nano-Magnesium or nano-Magnesium-Alanate with nano-Titanium as catalyst). The hydrogen storage is one of the key bottlenecks for the automotive application. Without major improvements, the 'hydrogen economy' would probably not happen.

• **Energy Use**

Energy saving and energy efficiency have a significant potential to reduce energy demand if we are able to make our society more conscious about the responsible use of energy. This issue is more particularly worked out in the midst of the WOG2 of AGE the outcomes of which are also reported in Annex 1 of this report. Our focus here is on the contribution of materials to implementing this policy.

Energy conservation improvement in buildings is a goal of high pay off. To achieve this goal, new insulation materials should be developed as well as the concept of 'Reflecting, Glazing, and Transparent Surfaces' made of low-cost multi layer thin film coatings, spectrally sensitive to their environment. In addition, organic Light Emitting Diodes are devices that can offer efficient lighting.

As regards, **heating**, fuel-cell-based CHP systems are promising but still need strong R&D support. Solid Oxide Fuel Cells in particular might provide the higher energy efficiency (60%) for stationary applications if we could remove major technological barriers to reach an acceptable price (today 4,000 €/KW, in comparison to a diesel system costs 3 to 10 times less) and durability target. For this purpose, better materials and cheap manufacturing processes should be designed in particular for of Membrane-Electrolyte Assembly (MEA), the ceramic electrolyte, the bipolar plate.

The transportation sector is a significant contributor to overall CO_2 discharges and is almost exclusively dependent on liquid fossil fuels, it will be the first hit by the tensions on the oil market. Alternative solutions should then be pursued. The PEM fuel cell technology, with hydrogen as a fuel (e.g. for city traffic) having the potential to achieve a 'tank-to-wheel' energy efficiency nearly double of conventional ICEs are excellent candidates. However, there remains a big gap in cost (today 3,000 €/KW in comparison a diesel engine costs 30 to 50 €/KW) and in durability. Bridging the gap will come through the use of membrane materials allowing higher temperature operation, to simplify the system, and MEAs using less and cheaper catalysts. In this perspective, the introduction of quite new polymer electrolyte membranes should be investigated.

S&T objectives and technology priorities

In the following paragraphs, we give examples of materials and research objectives that seem of particular relevance. From the above review of the needs in relation to strategic applications, two broad groups of materials can be considered. First, **structural materials allowing operating conditions going beyond the current industrial state-of-the-art**. The latter include high temperatures, mechanical loads, chemically aggressive environments and radiation. The complexity is increased when these conditions are combined because synergy effects may amplify the ageing phenomena. Such materials capable of meeting 'multi-criteria' specifications are key in the design of components working in extreme conditions like typically: turbo-machines, engines, combustion chambers, exchangers, core structure of nuclear reactors, filters, and membranes, just to name a few.

In order to expand the boundaries of current capacities, accurate knowledge of the temperature-dependence of the oxidation rate, together with a mechanistic description of the mode of scale loss, are important factors in developing a reliable prediction of lifetimes. In this perspective, oxide dispersion-strengthened alloys (ODS Fe, Ni or inter-metallic based), composite metallic or ceramic matrix materials, ternary super or ultra-super alloys are typical families of high-performance materials that would deserve to be studied.

Another significant challenge consists in designing materials with several often contradictory properties, such as ductile ceramics, as e.g. strain forgiving turbine blades . In case of particularly strict specifications, multi-material structures should be suggested, in which each material would fulfil a particular specification, as typically thermal barriers in nuclear reactors and SOFC stack assemblies. As regards the scientific approach, we should highlight the importance of developing numerical modelling for predicting these materials' behaviour. The structural complexity of these materials will require tools for multi-scale approaches including the atomic scale, and clear identification of all the necessary steps for the numerical methods. Such a predictive physical and numerical approach is necessary to implementing a true capacity for the design and production of new materials.

A second group is of **functional materials** for which the structural integrity is not the most critical issue. They play an essential role in the function of the component in which they are inserted. Interface and surface phenomena may be very important in the overall required performance. The properties which are typically required concern electronic conductivity involved in resistive losses minimisation, photo-electricity, thermo-electricity etc., ionic conductivity and facilitation of oxido-reduction reactions, catalytic reactions etc. There may be also additional requirements on physico-chemical properties in order to realize these properties, to create adequate conditions for the reactions (for instance degree hydration) and to keep a certain mechanical integrity along the load cycling applied. Thin film technology using polymers or ceramics compounds is very promising in this regard especially when created by nanometre-scale engineering techniques.

Nano-technology has the potential to be very effective in several segments of the energy sector: conversion, storage, distribution and use. In particular, they have a significant potential for bringing breakthroughs in the development of those technologies that could realize a strategy of lesser fossil fuel dependence in a sustainable way i.e. solar cells, super-conducting wires and tapes, thermo-electric devices, energy saving thanks to high thermal products, hydrogen storage, fuel cells, batteries, super-capacitors etc. For example, the cost reduction of PV systems can benefit from the strict control of particles at atomic scale, allowing thin layers of active materials to be deposited on cheap and light plastic substrates avoiding the use of glass which is currently a cost limiting factor. In the same way, fuel cells can benefit from electrodes and electrolytes with nano-structures and therefore enlarged thin films surface of nanometre thickness with increased catalytic performance at a much lower cost. Although some noteworthy developments of NNT have already impacted some applications, it is clear that additional efforts in R&D are still needed to fully exploit the potential of nano-materials and their particular relevance to the energy field.

Strength and weakness of material research in Europe

In a recent report (c.f. 'SWOT in energy research' report), experts concluded that Europe has built its competitiveness on mature materials technology but has been losing or is going to loose ground as compared to Japan and USA in nearly all fields of materials development for energy, i.e. for metals, ceramics, plastics, and/or any combination/composites of these. On the market side, the competitive position of the European industry is reportedly weakening. However, basic research and training are generally considered to be strong. This is the case in particular for nano-materials where good assets exist but with a too weak transfer rate of knowledge from research to product design. Some of the reasons for this are generic and linked to the deficiencies of the European innovation system: fragmentation, poor linkage public-industry and EC-MS, lack of application orientation, insufficient social status profile offered to researcher carriers, low SMEs involvement. The S&T existing assets in nano-sciences, provide a good basis for the creation of high added-value industrial organisations. To this end, integrated approaches are needed combining nano-sciences and production technologies on the one hand and nano-technologies interests arising from other sectors than energy on the other hand.

The EC shares this concern. Its direction G (Industrial technology) has 3 units dedicated to the management of materials and processes. They are in charge of the materials related priority 3 of FP6 (4 of FP7) and have funded a portfolio of projects of 1.5 G€ over the FP6. WOG4 appreciates that coordinated calls and joint calls have been launched for a better coordination of thematic priorities 3 and 6. It recommends evaluating their impact on the energy technology innovation and encourages further similar initiatives.

Recommendations

The examples discussed above provide abundant evidence that materials have demonstrated their key role in a broad range of application fields, especially in the energy sector, and that they remain major stumbling blocks for solving a number of energy challenges. It is the group's opinion that the materials priority should continue to be strongly supported by the EU programmes with a special attention that energy issues and related needs are integrated into the 'materials' R&D strategic agenda in a more systematic way.

Biotechnologies for new energy options

Background, motivation

The production of energy carriers from renewable energy sources is highly desirable in the long-term to replace fossil energy resources and to limit the CO_2 emissions to the atmosphere. One option could be to modify biological processes (which have been responsible for the generation of our fossil resources during several million years in the past) by high-tech methods and apparatus for the direct production of fuels like hydrogen using sunlight and/or biomass.

Unfortunately only good ideas and early promising results of research are available up to now. The technical basis is neither sufficient to assess the real application potential, nor are there proven concepts which would allow a stringent R&D process with milestones, quantified goals and data for commercial evaluation. However, this subject 'biotech' – according to experts – can enable industrial applications which are expected to have commercial promise in the long-term. In our case it can be used as an example of how promising ideas can be handled by basic research, in order to gain eventually innovative solutions for our pending energy problem in the long term.

Status of R&D for hydrogen production processes

Three types of hydrogen production paths through modified micro organisms are being investigated:

- Photolysis: direct production of hydrogen from water by artificial photosynthesis in sunlight.

- Photo-fermentation.

- Dark fermentation.

Mimicking photosynthesis for hydrogen production from water seems to be the most elegant solution with a theoretical potential of up to 40% efficiency. However, the present status of the laboratory work is characterized by efficiencies of some % only and – even more critical – a limited life time and yield due to the reaction of the oxygen radicals with the hydrogenase enzyme.

The fermentation processes mentioned above are much better developed. It has been indicated, that with further progress an alternative could be found, which at least is able to compete with the existing methane production processes (fermentation of biomass with subsequent conversion to hydrogen).

In general, a better understanding of the structure and mechanisms of function of the key bio-catalytic processes is essential for creating efficient hydrogenase enzymes and for controlling the involved chemical processes. Up to now, a COST action has been completed which involved a network of scientific research groups and institutions, collaborating in this field of basic technologies with a small funding by the EU covering only the transaction costs. In addition to that, two projects are currently funded in FP6: SOLARH and HYvolution.

However projects are isolated, not integrated within the H_2 platform, without a long-term perspective, and – compared to the US and Japan – with a lack of financing.

Recommendations

Our recommendations are:

- In order to promote promising basic solutions in the field of energy an adequate funding concept for basic research should be created. Not only paper work, but long-term-oriented, hardware-based scientific research at universities and institutions for selected schwerpunkte should be funded.

- We recognize that bio-hydrogen generation, using one or more of the diverse range of options could, in the long-term, offer a serious contributing potential to meeting the strategic goal of clean energy resources availability.

- Due to its interdisciplinary character, its distance from marketable applications and its long term perspectives, this area has not been given sufficient attention and sufficient funding so far.

- Therefore it deserves to be more systematically supported in a long-term approach with general goals like improvement of sunlight efficiency and overall yield as well as stability of basic processes.

- It is recommended that networks are strengthened but also that competition between research centers is encouraged, e.g. by awards for main breakthroughs. A stable trans-nationally-integrated research organization with a common European vision is to be created under the auspices of ERC.

- It seems unrealistic to expect major funding contributions from the industry during the early phase of basic research. But it is strongly recommended to organize regular meetings including experts from the industry for evaluating results and early decisions on potential practical applications of the new technologies.

- Closer links should be established with the European Technology Platforms dealing with Hydrogen/FC and with Bio-fuels. Stakeholders from the energy sector should be involved in a permanent dialogue with the basic research community.

References

'Energy Scientific and Technical Indicators and References', European Commission 2005, EUR 21611.

Strategic Research Agenda (SRA) of the European H2/FC Platform 2005.

Biotechnology for gaseous bio-fuels production. Presentation made by Pr Kornel Kovacs to AGE WOG4 on October 6, 2005.

'Biotechnology for energy' Assessment sheet by Pr Kovacs to WOG4.

'Architecture of the photosynthetic oxygen-evolving centre' by Jim Barber, Iwata &al in Science Journal.

European Research Infrastructures in Energy

Objectives

RTD in new energy systems is a long term, multidisciplinary, collective endeavour. Scientific and engineering research efforts must be coordinated and targeted in order to lead the way efficiently to technological development and demonstration which, in turn, will foster manufacturing and commercial activities. Research Infrastructures (RI) are appropriate tools with which to integrate multinational team work, to attract the world most talented investigators and to educate and train scientists and engineers for pioneering systematic RTD as well as for achieving significant breakthroughs. RI also permit launching high-risk energy-related RTD that industries otherwise would not undertake. The benefits of building RI must be evaluated in the far term but RI can be highly cost effective if and only if its definition, construction and operation are driven by oriented thematic goals with an industrial future application in sight.

State of the art

Large RI are usually associated with ‘big science’ (High Energy Physics Facilities, very large Telescopes, Synchrotron Radiation Sources, High-Flux Neutron Sources, large Fusion facilities, etc).

The US-DOE efficiently integrates the planning, coordinated functioning and significant funding of RI for basic/applied research, technological development and demonstration Projects in Energy (fusion/plasma sciences, materials research, combustion research, hydrogen storage, energy biosciences, global climate change, geosciences, engineering sciences, membrane and separation sciences). The US-DOE, and, in particular, its Office of Science (OS), integrates a nation-wide powerful network of 15 National Laboratories and over 280 University Research Groups/Centres, with energy related user Research Facilities located at both. There is a firm conviction that RI will enable energy breakthroughs that will fuel the US economy in the decades to come.

In Japan many RI are a part of Corporate Research Laboratories; on the other hand, the Science and Technology Agency (STA), part of the Prime Ministers Office, controls ‘big Projects’ outside Universities (National Aerospace Lab, National Research Lab for Metals, Japan Atomic Energy Research Institute, Institute of Physical and Chemical Research, Japan Information Centre of Science and Technology, Research Development Corporation of Japan,…); Monbusho funds many Universities, including the costs of teaching, research and infrastructure.

The EU has a significant number of RI in Energy, dispersed among EC Joint Research Centre locations, CERN and the various Member States (Max Planck, Julich, ZSW, CEA, CNRS, RISO, ECN, VTT,…), operated and funded under different criteria. Apart from a significant difference in the total level of funding between RI in the EU on one side and USA and Japan on the other, there is another obvious difference, a high degree of coordination and effort integration is evident in the USA and Japan, while the EU is marked by the dispersion of monetary and human resources.

SWOT Analysis

The European Strategy Forum on Research Infrastructures (ESFRI) has the role to support a coherent approach to policy-making on RI in Europe and to act as an incubator for international negotiations about concrete initiatives. In particular, ESFRI is preparing a European Roadmap for new RI of pan-European interest. The ESFRI Roadmap Working Groups (RWG) analyse topical issues. They seek independent scientific, technical or socio-economic advice using existing bodies; the RWG may also set up Expert Groups (EG). 15 EG have been appointed so far. The ESFRI Roadmap will be instrumental in helping to identify those Projects that are crucial for the scientific community in Europe. Projects may cost a few €10 M up to over a G€. Trans-national Access, Integration of Activities, Integrated Infrastructures Initiative, Coordination Actions, Communication Network Development, Design Studies, Construction of New Infrastructures and Accompanying Measures are among the tools to set in motion RI Projects funded under FP6 but all are rather remotely related to Energy.

In this context, the comparison with existing modes of organisation and management in the EU’s competitor countries lead us to conclude that more integration and better coordination should give enhanced performance in the EU Energy Research system.

- **Dilemma on RI for Science (basic research) and /or for Engineering/Industry (applied research and development).**

  In the US-DOE organisation, both fundamental and applied research, as well as technological development and demonstration projects are integrated. For example, the OS sponsors and coordinates a broad range of intellectual advances in applied mathematics that underpin programs in the physical, biological, and environmental sciences. This integration has been successful in terms of technology development and as well in the scientific excellence since the OS has funded the research of 35 Nobel Laureates since DOE’s inception in 1977, and a total of 79 Nobel Laureates have been associated with DOE and its predecessor agencies since 1934.

On the contrary, in the FP7 structure, Basic Research and Applied Research &Technology will be managed separately. As a consequence, the possible RI dedicated to Energy Research are likely not to be able to benefit from theoretical advanced cross-cutting knowledge developed in fundamental research-oriented RI. Therefore, AGE considers that some kind of liaison should be established between the basic and applied programmes in order to enhance their cross-fertilisation.

- **European RI are behind those of the USA and Japan, missing cutting-edge facilities.**

  The EU is lagging behind the USA and Japan in energy RI. It is not just a matter of our competitors spending more, but also of investing better. Thus there are no shared, cutting-edge European RI in this sector. Moreover, while the US-DOE seems to have well defined roadmaps, in Europe they are unclear. The USDOE, and particularly the OS, has a detailed high-quality database of research groups in energy-related topics within the USA and, in some instances, in the rest of the world. An EU-RTD Energy data base does not seem to exist or it is poorly used.

- **Difficulties to reach consensus on needed RI among MS. Competition vs Cooperation.**

  The US-DOE, integrating operation, budget and decision power and independence, is at a strong vantage position compared to the budgetary and topical dispersion among Programmes within the EC, among MS and among regions within MS. This situation calls for an effort to reduce fragmentation and develop a high degree of coordination rather than exacerbating conflicting interests.

- **Energy RI are absent from the Roadmap.**

  Up to now, energy research is an area that has been poorly integrated in the process of creating European RI. Since energy R&D itself is of such strategic importance and since key energy infrastructures are needed, henceforth it would be desirable that this be reflected in ESFRI's roadmap and work plan. In this perspective, the Energy community looks forward to participating in workshops where they are prepared to formulate their RI priorities.

Potential Research Infrastructures in Energy

Although the 'energy sector' should give a serious consideration to the possibility of having facilities targeted to oriented/applied research and technological development, the following needs for upgraded or new distributed RI on Energy could be anticipated:

- Materials for energy (several networks). Nano-scale Science for New Materials and Processes.
- Advanced processes (separation, gasification...). European IGCC Network (Puertollano & Buggenum).
- Nuclear fission (advanced reactors/transmutation; CEA leadership).
- Advanced Scientific Computing.
- Bio-hydrogen generation.

Conclusions and recommendations

WOG4 recognizes that the concept of common European Research Infrastructure (ERI) is an appropriate instrument for the European Research Area building. It has the potential to enhance S&T excellence as well as multi-disciplinary approaches and to foster education, training and researchers mobility. Hence it should be able to contribute significantly to tackle a number of challenges facing the energy research.

The examples of greater success given by organisations in the US and in Japan suggest that more coordination and integration are needed in the EU. They should develop in two directions:

- Horizontally between the existing national RI centres. Member States must overcome the present individualistic approach and join their funding and interests to build first class RI. For new ones, a cohesive top down vision, should be defined that should benefit from the existing Networks of Excellence as well as from Competence Centres already set up in several Member States. The activity's relevance could be ensured if the programmes are inspired by Strategic Research Agendas developed in the existing Technology Platforms.

- Vertically, down the innovation chain, the scopes of the RI should allow the functional integration of basic and applied research and technology development, through public-private partnerships and links between academia and industry. At the implementing stage, the ERI should be driven by thematic goals targeted on future industrial applications and a liaison should be established with possible Joint Technology Initiatives.

In order to fulfil the excellence and the cost effectiveness requirements of ERI, AGE WOG4 recommends that the qualification process be based on a strict evaluation of the S&T quality level of the laboratories and research teams involved. An EU RTD Energy Data Base mapping the EU-wide skills and capacities would be helpful in this regard.

In order to create momentum for the ERI deployment, ESFRI has a key role to play. WOG4 regrets that the 'Energy Sector' has not used the opportunities offered so far by the EU RI policy. In future, energy must be included among the top priorities and projects arising from the energy R&TD should be considered in the ESFRI roadmap under preparation. Symmetrically, the energy community should find ways of better collaboration with ESFRI, aiming at defining a strategic vision of its RI needs. For example, taking advantage from the reflections made on other cross-cutting issues, AGE could make preliminary proposals on Materials, Advanced Processes, Fission and Bio-hydrogen Generation.

Supporting cross-cutting and basic research

In this section, we analyse how effectively the existing organisation and instruments support research on cross-cutting issues and how it is likely to evolve in the FP7 context. The links with frontier research is also considered.

Adequacy of existing arrangements for cross-cutting issues

The work programme and instruments of FP6 addressed the need for energy-related cross-cutting research (basic and applied) and made provision for it. However, this is only part of the story. According to Commission contacts in the Energy Directorate, obtaining adequate funding from other thematic programmes (e.g. Materials) proved to be extremely difficult. The AGE's 2004 ERAWOG report recognised this and recommended a much closer coordination of energy with other thematic strands of the FP in order to facilitate cross-cutting research.

Cross-cutting applied research has been given considerable prominence in the proposals for FP7. The Cooperation programme has provision for cross-cutting proposals that would receive funding across themes. And the proposals for Materials and Biotechnology include specific mention of energy-related cross-cutting issues (adequate in the case of Materials and Biotechnology; less so in the case of ICT), with the possibilities of joint calls. However, as in FP6, the adequacy of the proposals will only become clear in the implementation.

A specific budget allocation for energy-related cross-cutting research in the other thematic strands of the Cooperation would improve the chances that the necessary joint calls would be made. Identifying the issues to be addressed in such a way that they lead to actual calls for proposals is perhaps more important, and the role of European Technology Platforms (ETPs) is critical here[1]. **The research priorities established by energy ETPs, having been independently verified, should be used to establish priorities for cross-cutting joint calls between energy and other strands in the Cooperation programme.**

[1] *As recognised in the proposal for e Council decision.*

Links with frontier research

The same applies to basic research (frontier research in the terminology of FP7). In FP7, frontier research will be addressed by the Ideas programme, the European Research Council playing a crucial prioritising role. The Scientific Council (one of the components of the ERC) '...will establish the overall scientific strategy [and] ensure the establishment of the work programme'[2]. The proposal for the Ideas programme also recognises the need for cross-cutting research, as in the Cooperation programme. **It is essential to ensure that energy ETPs, the Commission, research institutions and industry has an adequate input to the Scientific Council at an early stage.**

The creation and/or development of **research infrastructures** is covered by the Capacities programme within FP7. Based on a quick review, there is no specific mention of cross-cutting research issues in the proposal for the Capacities programme. However, equally there is no reason why cross-cutting infrastructures should not be developed in the same way as any other infrastructure – although such infrastructures are probably more difficult to envisage and establish. **Once again, the role of ETPs (and of resulting Joint Technology Initiatives) may be critical here; as pointed out elsewhere in this report, the ESFRI could also play a valuable role.**

Finally, proposals that include applied research within Cooperation, and frontier research within Ideas, are to be allowed, and this could include cross-cutting proposals with basic and applied research aspects. **It is not clear how such proposals will be initiated or assessed, and further clarification from the Commission is needed on this.**

[2] *Proposal for a Council decision, p23.*

Annex 4: AGE Members

Title	First Name	Surname	Country
Mr.	Angelo	AIRAGHI	Italy
Mr.	Roger	BALLAY	France
Dr.	Niels	BUSCH	Denmark
Mr.	Antonio	COLINO	Spain
Prof.	William Denis	D'HAESELEER	Belgium
Dr.	Wolfgang	DÖNITZ	Germany
Dr.	Cesar Manuel	DOPAZO GARCIA	Spain
Dr.	Gerd	EISENBEISS	Germany
Prof.	Gerhard	FANINGER	Austria
Prof.	Marcello	FONTANESI	Italy
Dr.	Alain	GERARD	France
Dr.	Heather	GREER	Ireland
Dr.	Sue	ION	UK
Mr.	Alessandro	LANZA	Italy
Dr.	Patrick	LEDERMANN	France
Mr.	Carlos	LOPEZ-CACICEDO	Spain
Prof.	Peter	LUND	Finland
Mr.	Frederick	MARIEN	EU Commission
Mr.	Peter	NYGARDS	Sweden
Dr.	Frantisek	PAZDERA	Czech Republic
Dr.	Peter	PEARSON	UK
Mr.	Carlos	PIMENTA	Portugal
Dr.	Derek	POOLEY	UK
Prof.	Erich	TENCKHOFF	Germany
Prof.	Iacovos	VASALOS	Greece
Mr.	André	VERSTEEGH	Netherlands
Prof.	Alfred	VOSS	Germany
Prof. Dr. Ir.	Margot	WEIJNEN	Netherlands
Mr	Frederick	MARIEN[1]	EU Commission
Mr	Odissefs	PANOPOULOS	EU Commission

[1] *Frederick Marien has been the secretary throughout the mandate of the current AGE, organising its activity.*

European Commission

Further tasks for future European Energy R&D

Luxembourg: Office for Official Publications of the European Communities

2006 – 50 pp. – 21.0 x 29.7 cm

ISBN 92-79-02689-5

ISSN 1018-5593

SALES AND SUBSCRIPTIONS

Publications for sale produced by the Office for Official Publications of the European Communities are available from our sales agents throughout the world.

You can find the list of sales agents on the Publications Office website (http://publications.europa.eu) or you can apply for it by fax (352) 29 29-42758.

Contact the sales agent of your choice and place your order.

KI-NA-22395-EN-C

Since the energy crises of the 1970s major progress has been made in improving both the efficiency of energy use and energy production from non-fossil sources. Thus overall EU energy efficiency has roughly doubled over that period, waste/biofuels combustion for energy, windpower and solar water heating have entered widespread use where the circumstances are favourable and improved nuclear power plant are becoming available. But accelerated progress to less carbon dioxide emission and less dependence on natural oil and gas is now essential.

Almost all low carbon and renewable energy technologies need further improvement if their penetration of the energy market is to be as fast and extensive as circumstances require. AGE therefore set down in an earlier report (EUR21352) what it believed were the 'Key Tasks' for EU energy R&D, aimed at making the technological improvements that are needed, and has no reason to change those recommendations. That work deliberately focused on what AGE judged the most important low-carbon technologies but in this report we have extended it to cover improved energy efficiency, several more renewable energy sources and those cross cutting technologies, such as high temperature materials, that could enable better energy supply and use technologies. The outcome is a 'further' set recommendations for EU R&D.

Publications Office
Publications.europa.eu

ISBN 92-79-02689-5
9 789279 026898