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Future Needs and Challenges for Non-Nuclear Energy Research in the European Union

Discussion Paper

Outcome of eight expert workshops

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Future Needs and Challenges for Non-Nuclear Energy Research in the European Union

Outcome of eight expert workshops

held in Brussels
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Report prepared by:

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Foreword

With the 5th EU RTD Framework Programme entering its final phase and the European Commission, Member States and Parliament currently discussing the format and content of the 6th RTD Framework Programme (2002-2006), the Energy Directorate of the Commission's Research DG considered it opportune to organise an informal expert review of the future needs and challenges for non-nuclear energy research in Europe.

For this purpose, the Commission organised, in November and December 2001, a series of eight workshops with invited external experts, selected to provide a broad representation of the research community, including industry. The objective of the workshops was to initiate a process of reflection, discussion and consultation on the priorities for energy research that will ultimately lead, *inter alia*, to the development of future Work Programmes for EU-funded RTD actions.

The subject areas selected for the workshops broadly reflected the proposals for the 6th Framework Programme and the content of its Specific Programmes, but did not exclude other areas of interest in the wider context of the European Research Area.

Between 15 and 20 experts were invited to each workshop, aiming at striking a reasonable balance between a representative coverage of the sector and the desire not to exceed a level of participation that would allow open, dynamic and creative discussions and interactions. Prior to participating in the workshops, each expert was asked to fill in a questionnaire prepared by the Commission Services in order to gather and summarise their views in advance of the discussions. At the workshops themselves, syntheses of the views expressed in the questionnaires were presented and provided the basis for the ensuing debates. The Commission chaired the workshops with the aim of arriving at coherent views amongst the participating experts.

This document summarises the outcome of the eight workshops, concentrating on three key aspects: rationale and objectives of RTD in the areas covered, RTD priorities and implementation modalities. With the new 6th RTD Framework Programme in mind, the experts were asked to consider in particular the possibilities for future Integrated Projects and Networks of Excellence, two important new instruments for future EU research.

The report is not intended to be anything more than a discussion document to inform the ongoing debate on priorities for non-nuclear energy research in the EU. As such, it can be regarded as an input, amongst others, for the preparation of Work Programmes for the energy part of the Priority "Sustainable development, global change and ecosystems" of the forthcoming 6th RTD Framework Programme.

Disclaimer:

This report summarises the outcome of eight workshops with independent experts, chaired by the Commission Services.

The contents do not necessarily represent the policy or views of the European Commission and do not engage it in any way.

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Commentary on the workshops

The eight workshops brought together some 150 invited experts, who welcomed the opportunity to discuss energy RTD priorities with the Commission and generally agreed that the format and content of the workshops were at the right level and the discussions worthwhile. Indeed, many participants would have welcomed additional time to delve even deeper into the complexities of the subject.

The outcome of each workshop is summarised in the following chapters. However, a number of points also emerged that were common to all workshops :

- Non-nuclear energy research is becoming increasingly important, particularly as regards the role it plays in support of a wide range of key EU policies (e.g. security and diversification of energy supply, combating climate change and air pollution, energy market liberalisation, sustainable development, industrial competitiveness, regional development and cohesion etc). There are opportunities for large and small-scale research in all sectors and technologies and all must contribute to a more sustainable energy future. The challenge for future EU-supported RTD activities will be in focussing on areas where the scale of ambition and the expected impact in terms of European added-value clearly justify intervention at the European level.

- Socio-economic aspects of research must be fully integrated into technology research actions and projects and can no longer be treated as a separate or minor additional aspect. Issues ranging from the public acceptability of renewable energy sources to the opportunities for consumer interaction with energy markets need to be tackled alongside more technical matters, such as improvements in the costs or efficiency of system components.

- Setting detailed quantifiable targets for energy RTD proved to be very difficult and little progress on this front was made during the workshops. Some of the difficulties encountered need further consideration, e.g. should cost or price targets be used, should regional differences be taken into account (e.g. for biomass energy costs), should components or systems be considered, what electricity costs should be used for comparisons etc. The type of general indicative targets (indicators) that could be used to help focus future RTD activities also needs further discussion.

- The new funding instruments proposed for the 6th RTD Framework Programme, Integrated Projects and Networks of Excellence, were not well known or understood by the workshop participants prior to the meetings. The Commission's intention to undertake a major information campaign on the new instruments was welcomed and it was recommended to pro-actively stimulate research actors to engage in the preparatory steps for developing proposals using the new instruments.

- The objective of the European Research Area of increased collaboration between EU and Member State funded research programmes is considered essential for closing the gap with the US and Japan that exists in many technologies and to maintain Europe's world lead in other technologies. A large potential was also perceived for collaboration with local, regional and national actions in validation, deployment and demonstration activities.

1. Hydrogen Technologies

1.1 Rationale and objectives for future RTD

Hydrogen could be a key element in the long term for a future sustainable energy economy. It provides a suitable pathway for gradually reducing today's dependency on fossil fuels and increasing the contribution of renewable energy sources. In the long term, renewable (and nuclear) energy will provide a significant share of energy supply, in which electricity is expected to become the dominant energy vector. However, the current share of electricity in the energy supply is only 20% and the remaining 80% comes in the form of fuels for transport and heating in buildings and industry. Moreover, electrical energy is difficult to store in large quantities; it can however be converted and stored as hydrogen. Hydrogen will therefore play a key role in adapting future energy supply to meet energy demand.

Hydrogen can be produced by electrolysis of water with electricity from cheap hydropower or from renewable energies such as wind, solar thermal and, in the longer term, photovoltaic electricity. It can also be produced from fossil fuels or nuclear energy. Hydrogen can be used in fuel cells for all end use applications, where it is highly efficient and intrinsically clean. Gas turbines can run on hydrogen, e.g. for small co-generation and medium to large scale electricity production. Hydrogen may also be used directly in internal combustion engines (ICE) or, more efficiently, in fuel cell electric drivelines.

An important objective is to reduce the cost of hydrogen production to make it competitive with currently used conventional fuels. EU RTD should pursue different hydrogen production pathways to achieve this objective:

- For the medium term, hydrogen from fossil fuels, particularly natural gas, could be the most likely route to achieve cost-effectiveness; the cost of small-scale hydrogen production from natural gas will have to be decreased by a factor 2-3. The drawback of CO_2 emissions will be addressed by CO_2 capture and sequestration, the benefit of which should be factored into costs.
- Production of hydrogen by electrolysis with cheap hydropower should also be explored, as well as with wind and solar thermal electricity which have a similar potential for hydrogen production.
- Nuclear power could also be investigated as a possible source of hydrogen production, either as provider of electricity for water electrolysis or as supplier of high-temperature heat for the thermo-chemical decomposition of water.

Cost-effective transport, distribution and storage of hydrogen are major issues. This, and the setting up of an appropriate infrastructure, could create a large market and open up new economic and employment development opportunities. RTD, and in particular pre-normative research, is a prerequisite here.

1.2 Future RTD priorities

To achieve the objectives mentioned above, the following **high** priority RTD activities and their time scales *(Short, Medium, Long term)* have been identified :

Basic materials research:
Electrochemical materials : e.g. catalysts, materials for reversible fuel cell/ electrolysers, hydrogen storage (e.g. carbon nano-structures, metal hydrides and

micro-porous materials, organic/non organic materials, carbides) and hydrogen separation *(SML)*.
Target : *cost reductions and improved performance of active materials.*

Hydrogen Storage:
A technology breakthrough is urgently needed, especially for on-board vehicle hydrogen storage. Development of cost-effective innovative hydrogen storage media and related pre-normative work to support standardisation, e.g. of interconnections, component specifications; evaluation/ development of large scale (e.g. underground) storage media for buffering RES; development of more energy efficient methods for H_2 liquefaction and compression *(SML).*
Target : *For transport applications: system cost 10€ /kWh stored; at least 7 wt%, with round trip (charge/discharge) energy costs of less than 15% and start-up time of less than 30sec to full discharge; targets for large stationary storage to be developed;*

Hydrogen Production:
Development, analysis and comparative assessment of candidate pathways for hydrogen production from :

⇒ fossil fuels (including CO_2 capture and sequestration) *(SM);*

⇒ electrolysis with cheap RES, e.g. hydropower, wind and solar thermal *(SML);*

⇒ biomass *(SM);*

⇒ nuclear energy/ thermo-chemical processes *(L).*

Effort should include development and demonstration of low cost electrolysers and fuel processors for fossil and bio-fuels, at scales for on-board vehicle, filling station, and large industrial scale.

Socio-economic aspects should also be considered, including comprehensive life cycle environmental impact assessment, safety analysis and cost-benefit analysis (including externalities).
Target: *Demonstrate technologies for hydrogen production at large scale (industrial) and small scale (filling station, vehicle and domestic), that in commercial use will produce hydrogen at prices competitive with conventional fossil-based fuels (currently around 10€ /GJ).*

Hydrogen Safety:
Application of risk assessment, FMEA, simulation, etc. to the complete fuel chain, systems and components, including hydrogen end-use, to identify safety critical events and to support regulation and safety standards at EU and global level; promotion of public awareness and understanding *(SML).*
Target: *establishment of hydrogen safety initiatives at EU and international level, linking with standards and regulatory bodies; reports on safety critical scenarios; manuals of best practice.*

Hydrogen Distribution:
Development and demonstration of strategies and technologies for hydrogen distribution networks and fuelling infrastructure, based on marine, land transport or pipeline technologies, including logistics, standards, regulation and safety assessment, cost effectiveness analysis and other socio-economic aspects, ensuring compatibility with trans-European networks *(SML)*.
Targets: *test/evaluate/prove alternative technology options for hydrogen distribution; define and compare (including socio-economic aspects) alternative scenarios for "growing" hydrogen fuelling networks - e.g. to penetrate 10/ 15% of filling stations by 2010 and 30/ 50% by 2020 – evolving from fuelling infrastructure for single fleets*

through networked urban fleets to pipeline distribution in the long term (compatible with EU transport networks); enhanced codes and standards; compilation of best practices for handling hydrogen.

Research in support of policies related to a Hydrogen Energy Economy:
Socio-economic research in support of policy decisions – e.g. cost-benefit analysis of scenarios for developing the hydrogen economy; co-ordination of environmental impact analysis (e.g. above fuel chain analysis); analysis of natural resource implications; science-society issues; analysis of human resource implications (e.g. education and training needs, mobility, social acceptability, etc) *(SM)*.
Target: *social, economic, energy and environment impact assessment of scenarios for a hydrogen economy; recommendations for transition strategies and GHG implications; analysis of human and financial resource implications.*

Hydrogen Combustion:
Development of highly efficient combustion systems for operation with hydrogen, or hydrogen / natural gas mixes (hythane), such as small, medium and large turbines for electricity production and co-generation *(SML)*.
Target: *adapt turbines to a hydrogen economy.*

1.3 Implementation modalities

Illustrative examples of possible topics for Networks of Excellence and Integrated Projects :

<u>Networks of Excellence</u>

- ***Hydrogen storage*:** Explore a wide range of hydrogen storage systems and concepts; materials research will be a key issue (e.g. nano technology, adsorption of hydrogen, etc.)
- ***Hydrogen production from unconventional technologies:*** RTD to explore the possibilities of hydrogen production from nuclear, thermo-chemical water splitting, biological and photochemical processes, etc.
- ***Hydrogen Education and Training Centre:*** the aim would be the establishment of accredited training and education, in all the above aspects of hydrogen; promotion of public awareness; forum for international exchange;
- ***Centre for Hydrogen Research and Safety:*** the aim would be to establish co-ordinated, linked activities in Member States, e.g. European Hydrogen Safety Agency, addressing above major issues; codes and standards interfaced to international activities;
- ***Research in support of policies, and on technical barriers, related to a hydrogen energy economy:*** Impact assessment of the policies aiming at the development of a hydrogen energy economy, focusing on the role of R&D and other non-technical energy sustainable development measures. This RTD will include an assessment of non-technical barriers for the introduction of hydrogen as an energy carrier.

Integrated Projects

- ***Cost-effective H_2 production from fossil fuels*** including fuel processor technologies, H_2 separation, CO_2 capture and storage;

- ***Cost effective H_2 production by electrolysis*** from wind energy , PV, hydropower etc (e.g. cost-effective electrolysers) and from biomass;

- ***Technologies for hydrogen handling, distribution, pipelines, storage and fuelling infrastructure***, pre-normative RTD; scenarios for developing a hydrogen fuelling network; transition strategies;

- ***Realisation of small self-sufficient local hydrogen economies*****,** i.e., hydrogen "villages" or "parks" which adapt energy supply from RES such as wind, PV and biomass, to the demand of heat and power in buildings, industry and transport fleets by means of hydrogen generation and storage and the use of (reversible) fuel-cells and electrolysers; strategies for replication.

As regards the other instruments that could also be appropriate for RTD in this area, the following topics have been identified :

Specific targeted research projects *:* focusing on materials/ component RTD :
- Catalysis for fuel processors;
- Critical hydrogen components – control valves, sensors, metering, safety systems;
- Hydrogen combustion in small / medium gas turbines for co-generation.

Co-ordination of national programmes : *Pathways to a European Hydrogen energy economy* – joint effort on scenarios and timelines for implementing a hydrogen energy economy and pathways to clean hydrogen production; develop co-ordinated approaches to cost-benefit analyses, technology mapping, benchmarking, impact assessment (e.g. contribution to GHG reduction) and scenario analysis; co-ordinated dissemination /communication strategies.

2. Fuel cells

2.1 Rationale and objectives for future RTD

Fuel cell are an emerging technology which are expected, in the medium and long term, to replace a large part of the current combustion systems in industry, buildings and road transport, as they have a higher efficiency, lower pollution levels and a potential for lower cost. In the long-term, fuel cells and hydrogen may be expected to form an integral part of a RES based energy supply, where hydrogen would be a major energy carrier. This could lead to a huge international market for fuel cells in transportation, stationary and portable power applications.

The fuel choice for fuel cells is an important issue. In the long term hydrogen from renewable sources is the ideal fuel which, in combination with fuel cells, is intrinsically clean. In the medium term, fuels for fuel cells will have to be derived from fossil fuels such as natural gas, biomass and possibly coal. The drawback of CO_2 emissions related to fossil fuels can be avoided by CO_2 capture and sequestration.

Interest in fuel cells world-wide is strongly increasing in electricity companies, equipment manufacturers and car manufacturers. More research is needed to reduce the cost of fuel cell systems (for transport applications and for stationary applications in buildings and decentralised electricity production) to enable them to become competitive with currently used conventional combustion technologies over a time horizon between 2010 and 2020.

In view of the huge potential market, the competitiveness of the EU industry is a major issue; currently US and Japanese fuel cell companies far exceed EU fuel cell manufacturers in number, size and years of experience. A much stronger research effort, integrated at the European level in the next FP, is a prerequisite for new EU companies to become competitive with US and Japanese manufacturers.

To make these perspectives achievable by 2010–2020, research must be accompanied by parallel complementary measures such as the definition and harmonisation of norms and standards, the training and education of engineers, scientist and researchers, increasing public awareness and acceptability, the setting up and implementation of legal and fiscal measures to ensure better market entry conditions to compete with well established conventional technologies. These measures should encourage a stronger presence of industry. Further to the research effort on materials, components, stacks and systems, the role of industry becomes progressively more and more essential to develop low cost and efficient manufacturing methods for pre-serial and mass production as well as in the process of encouraging the building and use of a hydrogen infrastructure.

The EU added value for the area of fuel cells is high as a consequence of the high and growing level of RTD activity in this field in many Member States. A reinforced co-operation between EU and Member State programmes will allow the achievement of critical mass and improved complementarity, increasing competitiveness and the potential for breakthroughs. There is a large potential for deployment and demonstration activities in combination with National and Regional programmes. Fuel choices, safety aspects and infrastructure require a common EU approach, which can be supported through pre-normative research.

2.2 Future RTD priorities

To achieve the objectives mentioned above, the following **high** priority RTD activities and their time scales *(Short, Medium, Long term)* have been identified :

	(1)	(2)	(3)	(4)	(5)
Stationary fuel cell systems					
High temperature FC for small size distributed co-generation and/or electricity generation in building and industry, including integrated systems with new and RES technologies (kW to 100s of kW scale)	*SML*	*SML*	*SM*	*SML*	*SM*
Low temperature FC for small size distributed co-generation and electricity generation in building and industry including integrated systems with new and RES technologies	*SML*	*SML*	*SM*	*SML*	*SM*
Low temperature FC for Uninterrupted Power Supply (UPS)	*SML*	*SML*	*SM*	*SML*	*SM*
High temperature FC for medium to large size power generation including hybrid design with turbines (up to MW scale)	*SML*	*SML*	*SM*	*SML*	*SM*
Mobile fuel cell systems					
FC for Auxiliary Power Units (APU)					*SM*
Low and high temperature FC systems for road LHVs & HDV, rail and marine transportation including hybrid designs	*SML*	*SML*	*SM*	*SML*	*SM*
Other horizontal issues					
Issues linked to the use of fuels other than hydrogen (fuel choice, multi fuel capability and flexibility)	*SML*	*SML*	*SML*	*SML*	*SML*
Socio-economic and pre-normative research accompanying policy and regulatory activities, facilitating the development of standards, in particular on safety related issues, as well as science-society issues (e.g. education and training needs, mobility, social acceptability, etc).				*SML*	*SML*

(1) *Basic material research;* ***(2)*** *Improvement of cells, stacks, fuel processors components;* ***(3)*** *Development of Balance of Plant inc. simplification and optimisation;* ***(4)*** *System integration;* ***(5)*** *Others (studies, networks, bench-marking, dissemination, etc).*

Fossil fuels and particularly natural gas will still be used for many years to come. A cleaner use of these fuels will be progressively enhanced in all fields of application with CO_2 capture/ sequestration, pollutant reduction and use of cleaner technologies such as fuel cells. In this context, HT-FC has a high potential to exploit fossil energy derived fuels and therefore is a key bridging technology for the transition period between today's fossil fuel based economy and a future hydrogen based economy.

CO_2 capture and sequestration in FC systems must be limited to very large power plant and therefore has a medium priority, although FC systems can intrinsically facilitate this process.

RTD to support APUs has a medium priority. The real benefit of APUs in transportation should first be proved before proposing large and costly projects.

Synergies of development between all types of applications, including RTD of a generic nature, need further clarification, although some are obvious, such as between PEMFC for the traction of heavy duty vehicles and for heat and power generation. Others such as operating FC vehicles as decentralised heat and power generators do not appear to show much promise. A more in-depth assessment of these potential synergies is recommended.

Industry has a key role to play in the further development of fuel cells and should start now to develop low cost and efficient manufacturing methods for pre-serial and mass production.

2.3 Implementation modalities

In the field of fuel cells, large Integrated Projects and Networks of Excellence will be justified to increase complementarity between National and European programmes and to reduce the gap with major competitors. These new concepts applied to problems with a large European dimension could contribute to real breakthroughs in the technology, as well as in accelerating the process towards the commercialisation of fuel cells.

The integration of co-operation with non-EU countries is also becoming increasingly necessary in the current context of the globalisation of markets and global climate change and should be further explored.

Illustrative examples of possible topics for Networks of Excellence and Integrated Projects :

Integrated projects

One important advantage of the fuel cell is its capability to be attractive for a very large range of stationary and mobile applications. Each type of fuel cell has specific intrinsic advantages, more or less adapted to certain applications. System oriented Integrated Projects could be envisaged in the following areas :

- ***Small and medium size (mainly low temperature) fuel cells for co-generation and air conditioning***, in particular in buildings and the urban habitat; including the adaptation of heat and electricity supply to demand, by integration with storage systems, heat pumps, electrolysers, etc.
- ***Large scale power generation,*** in particular high temperature fuel cells and systems; including the development of gas turbines suitable for use with high temperature fuel cells and of FC/ gas turbine hybrid systems. Main applications in the range of 0.5-5 MW are decentralised electricity production and co-generation in buildings and industry (integrated in electricity grids or as stand-alone systems).
- ***Development of Auxiliary Power Units*** for both transport and stationary applications;
- ***Fuel cell systems for small road vehicles,*** including vehicle concepts of fuel cell and fuel cell hybrid vehicles and problems related to fuelling infrastructure;
- ***Fuel cell systems for heavy duty road, marine and railway transportation***.
- ***Balance of plant and development of components*** for low and high temperature fuel cell systems, aiming at cost reduction and improved reliability (e.g. stacks, reformers, cost-effective inverters, storage systems, etc.).

Benchmarking of different types of fuel cell technology in each of these projects, including demonstration, might represent an incentive to highlight advantages and disadvantages between fuel cell types for similar applications, aiming to optimise the final choice of fuel cell.

Networks of Excellence

Networks of Excellence could exploit the synergies present in basic material research in areas where the EU already demonstrates a great potential to increase its lead over its main competitors. Networks of Excellence are also suitable for addressing socio-economic issues. Examples of Networks of Excellence are:

- ***High temperature PEMFC:*** developing PEMFC which operate at 120-140°C instead of 80°C could lead to major cost reductions, higher tolerance for CO in reformer fuels, improved co-generation, higher reliability, etc.
- ***Low temperature SOFC:*** a decrease in the SOFC operating temperature from 800-1000°C to 500°C could lead to major cost reductions due to the lower cost of materials and production processes.
- ***Socio-economic and pre-normative research*** accompanying policy and regulatory activities, facilitating the development of standards, in particular on safety related issues, as well as science-society issues (e.g. education and training needs, mobility, social acceptability, etc).

Another example would be the exploitation of synergy between the two main types of application (stationary and transport), e.g. between power modules for distributed generation and heavy duty vehicles.

3. Biomass and Bioenergy

3.1 Rationale and objectives for future RTD

Currently, Europe's energy supply is dominated by fossil resources such as oil, coal and natural gas, resulting in rapidly increasing CO_2 emissions and vulnerability for EU energy supply. RTD on RES (renewable energy sources) technologies has the long term objective to bring about a largely RES based energy supply which is intrinsically clean and guarantees a reliable EU domestic energy supply.

Biomass already contributes around 5% of the EU energy supply and 65% of the total primary renewable energy production, predominantly for heat and power applications. In the long term, the contribution of biomass to the EU energy supply has the potential to increase to 20%, subject to policies to be adopted by the Union in relation to agriculture, sustainability, security of energy supply and the Kyoto protocol.

Renewable energy systems predominantly produce electricity. However, currently only 20% of the EU energy supply is in the form of electricity – the remaining 80% being in the form of fuels for heating and transport. Of the RES technologies only biomass produces solid or liquid fuels which could be used as, or transformed into, fuels for heating (in buildings and industry) and transport. In addition, for transport applications, bio-fuels are one of the few options for a net CO_2-free system.

The EU bioenergy industry is considered a world-wide leader in several technical areas, such as combustion and gasification. Future RTD programmes will help industry, largely constituted by SMEs, to maintain this leading position and advance in other areas, such as liquid biofuels.

Collaboration between the EU and Member States' RTD programmes in the framework of the ERA will greatly contribute to achieving critical mass and avoiding wasteful overlaps, whilst simultaneously improving co-ordination and the targeting of limited resources. There is great potential in this area for deployment and demonstration activities, with national and regional co-operation. Within this framework, collaboration with the new Accession Countries, which account for a very large part of European biomass resources, should be further developed and enhanced.

Target : the principal objective for future EU RTD should be the development of cost-effective integrated approaches from biomass collection to fuel production and use, taking into account sustainable biomass procurement as well as market opportunities. Sustainable biomass procurement should be a basic requirement to be taken into account in any future approach proposed for development.

3.2 Future RTD priorities

To achieve the objectives mentioned above, the following **high** priority RTD activities and their time scales *(Short, Medium, Long term)* have been identified :

- RTD aimed at achieving the cost reduction potential for energy from biomass: 15-20% (heat, electricity) and 30-50% (liquid fuels). RDT projects should analyse the biomass potential and availability in particular markets, taking into account the different regulatory and legislative issues. Research dealing with the increase of biomass potential (e.g. yield of energy crops) should be coupled with the energy production technologies *(SML).*

- Reliable and cost-effective combustion technologies with innovative reduction of atmospheric pollutants. For large scale (>15-20 MW) development of combustion technologies capable of operating with multi-fuel resources (including co-firing). Special focus on corrosion, char combustion, aerosol and ash disposal as well as ash agglomeration and fouling problems related to difficult-to-burn biomass. Combustion and power units for small scale conversion (<1MW) using standardised feed-stocks should focus on self-running processes and new control and monitoring systems, including new management schemes for biomass use *(SML)*.
- Reliability and cost effectiveness of gasification systems for electricity generation via CHP and biomass gas co-firing *(SM)*. Exploration of routes to produce H_2-rich clean syngas *(ML)*. This is considered to be a key technology for efficient power, fuel and feedstock production.
- Cost effective production of biofuels for transport[1] (bio-ethanol, bio-methanol mixtures, DME and Fisher-Tropsch) from various feedstock and energy crop resources. RTD on optimisation of efficiency and pollutant emissions in combustion engines using biofuels. The research should take into account the fact that the main parameter determining the cost effectiveness of biofuels production is the cost of the raw material (60-80% of the total cost) *(SML).*
- R&D ***(i)*** accompanying EU and MS policy and regulatory activities *(to foster biomass and biofuels in large volumes)*, ***(ii)*** facilitating the development of standards and ***(iii)*** analysing socio-economic *(e.g. long-term assessments on the impact of CAP, regional infrastructures and the development of rural areas on biomass availability and use)* and science-society issues *(e.g. education and training needs, mobility, social acceptability) (SML)*. Wherever possible, such R&D actions should be fully integrated into other RTD activities, such as those described above.

3.3 Implementation modalities

Illustrative examples of possible topics for Networks of Excellence and Integrated Projects :

<u>Networks of excellence</u>

- ***Research into non-technical barriers related to biomass use for energy production.*** Assessment of the policies, regulatory activities and the socio-economic barriers having an impact on the availability and use of biomass energy sources, focusing on the role of R&D.
- ***Research in support of standardisation and on measuring techniques related to biomass utilisation for energy production.*** Assessment of the standardisation activities needed to promote biomass into the energy market; research activities facilitating the development of standards.
- ***R&D to explore the possibilities for the potential use of energy crops in the bioenergy chain.*** Technical barriers related to the increase of the yield of energy crops and to their utilisation for energy production purposes. Research on their potential and availability in particular markets taking into account the different regulatory and socio-economic issues.

[1] The production of biofuels from conventional raw materials and processes is not considered to be a relevant research subject.

Integrated projects

- ***Biofuel from lignocellulosic material.*** Development of cost effective and sustainable production methods for ethanol based on lignocellulosic waste materials or dedicated crops. Processes and novel technologies for lignocellulosic material pre-treatment and subsequent enzymatic hydrolysis steps.
- ***Co-firing.*** Development of technologies for biomass co-firing at high percentages in coal and natural gas fired plants and the removal of technical barriers, e.g. corrosion, char combustion, aerosol and ash disposal as well as ash agglomeration and fouling problems related to difficult-to-burn biomass.
- ***Biomass gasification gas cleaning.*** Product gas clean-up for biomass gasification systems with a significant gas conditioning requirement e.g. hot or warm fuel gases clean-up, biomass-based production of synthesis gases and biomass gasification to produce hydrogen for fuel cells.
- ***Energy from bio-waste.*** Innovative, low emission waste to energy concepts and technologies development. After analysing the raw material potential and availability in particular markets and taking into account different regulatory, legislative and socio-economic issues, the project would focus on the specific RTD needs of the whole “waste” to energy chain.

4. Photovoltaics

4.1 Rationale and objectives for future RTD

The promotion of renewable energy sources (RES) is a high priority for the European Union, in view of the commitments made to reduce greenhouse gases under the Kyoto Protocol and for reasons of security and diversification of energy supply. Another driver is the Council Resolution on renewable energies of May 1998, which aims at doubling the share of RES in the EU energy supply from 6% in 1998 to 12% in 2010. This objective will require increased efforts both at Community and Member State level.

As a renewable energy source, PV has the potential to be a clean, emission-free, reliable, consumer-friendly source, which can be deployed in a wide range of applications and in a "distributed" form. However, the current cost of PV electricity is still an order of magnitude higher than conventional electricity. Although costs have been dramatically reduced in the last decades, further cost reduction is indispensable for this technology to become competitive with conventional technologies, even if there already exist today niche markets where PV is competitive (e.g. stand-alone application in remote areas). Significant improvements are still possible in terms of cost reduction and improvement of efficiency; a strong RTD effort is the key to achieving these objectives.

RTD should be aimed at all issues which may contribute to cost reductions such as: materials, manufacturing, reliability and longer life, increase of efficiency, etc. In addition, actions are needed to strengthen the PV industrial base in Europe, such as strategic programming to increase promotion and use.

Today, the share of PV in EU electricity production is only 0.15%, but it has the potential to make a significant contribution in the next 20-30 years if the targets given below can be achieved. These long term targets are:

- Investment cost for PV systems of 1-1.5 €/Wp (module cost of 0.5–1.0 €/Wp);
- To improve reliability for PV systems and increase life from current 15-20 years to 30 years;
- To increase system efficiency from the current 10-15% to 20-30%;
- The above targets should, in the long term, lead to a PV electricity cost of 0.06 – 0.1 €/kWh.

4.2 Future RTD priorities

To achieve the objectives mentioned above, the following **high** priority RTD activities and their time scales *(Short, Medium, Long term)* have been identified :

- **Thin-Film PV** *(ML)*
- **Innovative concepts and fundamental materials research**
  The topic of innovative concepts for PV technologies when combined with that of fundamental materials could have the potential to lead to solar cell efficiencies of 40-60% in the long-term. Also other innovative concepts such as organic and hybrid solar cells should be explored. *(ML)*

- **Crystalline-Si PV Process Technologies**
  Improvement in the crystalline-Si PV process technologies is necessary to incrementally improve the current commercial workhorse of PV products. This should include RTD on materials usage and thin wafer processing *(SM).*
- **PV in Buildings**
  PV in buildings has an enormous potential, both for stand-alone and grid-connected systems. Dedicated PV modules and systems should be developed which can be easily fitted to roofs and facades (e.g. flexible PV sheets). Also the adaptation of energy supply to the demand for heat and electricity should be addressed *(SML)*.
- **PV components and systems – balance of systems**
  In order to achieve cost reductions, RTD should address the cost reduction and reliability of other system components and of complete PV systems, both for stand-alone and grid connected PV applications *(SML)*.
- **Norms and Standards**
  Norms and Standards need to be developed and improved by pre-normative research. Universal standards will greatly facilitate the market penetration of PV technologies *(SML)*.
- **Large PV Power Plants**
  Development of large scale MW size PV plants for production of electricity (and possibly hydrogen) and adaptation of electricity supply and demand by means of storage systems, fuel cells, electrolysers, etc. *(ML)*.
- **Socio-economic issues**
  Socio-economic issues such as non-technical barriers, environmental and health issues and science-society questions should, in general, be integrated into the above RTD actions *(SML)*.

4.3 Implementation modalities

Illustrative examples of possible topics for Networks of Excellence and Integrated Projects:

<u>Networks of Excellence</u>

- ***Thin film PV technology***
  This is a key area for the future of PV. This NoE would bring together major players for the various types of thin film PV technologies, such as tf-Si, CdTe, CIGS, DSC, to bring about synergies and critical mass. The aim would be to develop cost-effective PV cells and modules based on the thin film concept.
- ***Organic solar cells***
  Promising results have recently been obtained by EU researchers. This NoE would aim at networking activities in organic solar cells and allow researchers and industrial partners to gather knowledge and experience and carry out research in materials, photochemistry and manufacturing with the objective to achieve very low cost PV.
- ***PV Concentration***
  This NoE on PV concentration would bring about a synergy between the various EU activities in this area, in which the EU is already the world leader.

- ***Materials research and next generation PV***
  Fundamental materials research to improve the efficiency and reliability of PV systems. This would include fundamental research related to the development of third generation PV, which may achieve efficiencies of 40-60%. Also the development of long-term RTD roadmaps for PV development would form part of this network.
- ***Socio-economic issues***
  Barriers related to social acceptance, recyclability, risks associated with toxicity of materials, etc. should be addressed. Socio-economic research should also evaluate PV related policy and regulatory activities, promote the introduction of PV technologies and address science-society questions in general.

Integrated Projects

- ***Bulk solar cell technologies for thinner wafers and thin film crystalline-Si***
  A way to cope with the future silicon feedstock shortage and to reduce costs is to diminish its use in PV cells. This can be achieved by RTD aimed at the production of thinner wafers or thin films of silicon. This integrated project would bring together a large number of research groups working on this topic in the EU, in order to form a critical mass.
- ***Improved production methods for solar cells and modules, with an emphasis on automation and the handling of thinner wafers***
  The rapid increase of PV markets requires industry to adapt its production to achieve large production volumes by strongly increasing production speed whilst maintaining high yield and quality. This project would address issues such as design techniques for production processes, development of PV production equipment, low-cost crystalline PV processes, etc.
- ***Application of PV in buildings and habitat***
  This integrated project would develop PV modules for use on building roofs and facades (e.g. flexible PV modules, flexibility of modules in dimension and shape, rear contact module technology), aesthetic module and system design for buildings, integrated PV/solar air heating facades, etc. It would also address the adaptation of energy supply to the demand for heat and electricity, by means of storage systems, heat pumps, fuel cells/ electrolysers, etc. and their integration with PV systems.
- ***PV systems including large MW size PV plants***
  The development of other components and their integration in complete PV systems offers a large potential for cost reduction and increased overall quality. This integrated project would include RTD on PV system design techniques, cost-effective inverters, etc. It would also address the problem of intermittent electricity production and the adaptation of electricity supply and demand by means of storage systems, fuel cells, electrolysers, etc. Also new applications of PV in daily use would be explored.

5. Other renewable energy technologies

5.1 Rationale and objectives for future RTD

The renewable energy technologies covered by the workshop were Concentrated Solar Thermal Power (CSP), Wind, Geothermal and Ocean energies. These four technology areas have one common denominator – they are better suited for medium to large-scale applications from the MW range to hundreds of MW. The current minimum size for CSP and Geothermal plant is around 5 MWe. Offshore installations will always be "farms" of at least 10 MWe for either wind or ocean energy. All these renewable energies, apart from geothermal energy, have a seasonal and intermittent behaviour. For example, the most productive season for CSP is the summer and for ocean energies it is winter. Studies have shown that the energy potential for these renewable energies could be at least 35 TWh/y for CSP in Mediterranean regions, 600 TWh/y for wave power along the Atlantic coast, 800 TWh/y for geothermal (hot dry rock concept) and 1000 TWh/y for wind. It should be noted that the current overall annual EU electrical production is 2500 TWh. The long-term cost of electrical energy from these resources is expected to be between 0.03 and 0.05 €/kWh.

CSP has proven its technical feasibility by the operation in California for more than 20 years of a 254 MWe installation, but the electricity cost of 0.12 €/kWh is much higher than the cost of conventional electricity, which currently amounts to 0.04 €/kWh. Wind has demonstrated its reliability but also here the cost of 0.04 to 0.09 €/kWh is generally too high. For geothermal energy the Hot Dry Rock (HDR) concept has a large potential but its technical and economical feasibility still has to be demonstrated at a pre-commercial stage. Ocean energy is just beginning to present reliable results from a small number of prototype installations.

R&D is therefore needed to reduce costs, to improve availability and reliability and to increase performance. The actors are from both research centres and industry; industrial partners are increasingly taking the lead in becoming co-ordinators of EU-funded projects.

5.2 Future RTD priorities

Four RTD areas and a number of non-technical issues are considered to be important for all these technologies in the long-term.

Technical R&D Needs:

- RTD aiming at cost reduction by decreasing manufacturing and installation costs (simpler systems, lower cost components, easier installation procedures, etc.), increasing lifetime, reliability and safety and improving system efficiency; operation and maintenance issues should also be addressed. Specifically, for each of the four technologies, the needs are:

– ***Concentrated Solar Power (CSP)*:** development of more efficient and cost effective solar components and plant schemes, innovative storage systems and new solar-enhanced chemical applications.

– ***Ocean:*** development of cheaper and safer installation methods and production, better availability and predictability of deliverable energy and technically proven concepts for onshore and offshore systems.

– ***Wind*:** improvement of mechanical design *(e.g. aerodynamics, intelligent structures and materials, design methods and models, noise)* and electrical design *(e.g. power electronics and generators, control strategies, condition*

monitoring, wind farm integration), optimised logistics *(e.g. manufacturing/ assembly, transport, installation and operation and maintenance)* and elaboration of standards *(e.g. wind conditions, structural systems, materials, reliability)*.

– ***Geothermal (HDR):*** development of new reservoir management techniques, cheaper drilling technologies and more cost-effective power cycles.

- In many cases, the resource potential of these technologies was evaluated more than ten years ago and the tools available at the time often led to the potential to be underestimated. New assessment methods should be developed to take into account new developments and the constraints for installations (land use, legislation, etc.).
- As the technologies are coming closer to the market, codes and standards need to be developed.
- The environmental impact of these technologies also needs to be addressed. This is especially important for ocean and wind energy systems.

Socio-Economic Needs:

Socio-economic issues and non-technical barriers related to these technologies need to be addressed. There is also a need for education and training, both for the public and for professionals involved in these areas.

Generic Needs:

Some generic needs have also been identified; these are relevant for all four technologies. They are the standardisation of power purchase agreements within the EU, improvement of grid integration requirements, recycling of components and reduction of environmental impact.

5.3 Implementation modalities

Illustrative examples of possible topics for Networks of Excellence and Integrated Projects :

<u>Networks of Excellence</u>

- ***Concentrated Solar Power***: a network of EU facilities would provide the expertise and tools to sustain the technology development of various options for CSP.
- ***Ocean***: a network of test facilities (sea sites and laboratory sites) would provide the standardisation of testing methods and explore the potential for achieving technical and economic feasibility for existing and new concepts.
- ***Resource assessment for all RES technologies***: projection of the renewables potential in the medium-long term with quantitative and qualitative methodologies.
- ***Socio-economic RTD***: evaluation of the internal and external costs of all renewable technologies in comparison to conventional fuels in the EU and in the NAS countries, especially for electricity generation. Methods to promote the introduction of all RES technologies and address non-technical barriers.

<u>Integrated Projects</u>

- ***Concentrated Solar Power***: RTD aiming at the development of low cost production methods for components and solar modular systems.
- ***Wind***: RTD aiming at the improvement of aerodynamics and material research for new design and structures.
- ***Geothermal***: demonstrate the technical and economic feasibility of electricity production with the Hot Dry Rock concept.

6. Advanced power plants and CO_2 capture and sequestration

6.1 Rationale and objectives for future RTD

Global and EU energy supply is currently, and may for the foreseeable future (2020 - 2030), be dominated by fossil energy sources. However, their CO_2 emissions are a major drawback in the context of global climate change. The challenge is therefore to be able to use these fossil fuels while eliminating CO_2 and other polluting emissions (NOx, SOx and particulates) whilst at the same time maintaining EU industrial competitiveness in global markets.

Gas turbines with ever increasing efficiencies will contribute partially to the solution of this problem by allowing some fuel switching from coal to natural gas (to the extent that security of supply is not compromised). Cleaner coal technologies will continue to be necessary in this global picture, to allow the use of the most abundant fossil fuel reserves. Know-how in this sector is also critical to maintain the competitiveness of EU industry in developing markets such as China and India. The role of industry in these areas of highly competitive markets is expected to be crucial.

Cost effective CO_2 capture and sequestration is an essential element in reconciling fossil fuel usage with climate protection, by reducing CO_2 emissions to near zero, and needs to be addressed urgently as a high priority. The cost of one ton of CO_2 avoided should be reduced to below 30 € in the short to medium term and to below 20 € in the medium to long term, achieving reductions in emissions by capture of 90%.

6.2 Future RTD priorities

To achieve the above mentioned objectives, the following priority RTD areas and their timescales *(Short, Medium, Long term)* have been identified :

CO_2 capture and sequestration:

- Near-zero emission fossil fuel based concepts for large-scale energy conversion systems *(SML)*;
- CO_2 capture and storage technologies to achieve the cost and efficiency targets mentioned above :
  - ⇒ Capture options include: post-combustion, pre-combustion decarbonisation & oxyfuel combustion systems and other novel technologies for retrofit and new build *(SML)*;
  - ⇒ Most promising CO_2 storage options are geological (including enhanced oil recovery and enhanced coal bed methane). In the longer-term, chemical storage routes should also be explored *(ML)*.

Gas turbines:

- High efficiency gas turbines with reduced specific cost, reliability of 98%, availability of 95% and low emissions (NOx less than 9ppmv for natural gas) *(SML)*;
- Advanced high efficiency (above 65%) gas turbine cycles of above 100 MW (combined cycles, hybrid systems *(SML)*;
- Catalytic combustion systems with a reduction in the specific costs of plant equipment of 15%; high efficiency hydrogen driven gas turbines *(ML)*;

- Industrial gas turbines of high efficiency (above 45% for 5-50 MW, above 50% for 50-100 MW) *(SM)*;
- Distributed power generation with high efficiency (above 38%) gas turbine systems of below 5 MW including CHP; near-zero emission cycles based on gas turbines *(SML)*;
- Gas turbines using lower heating value fuels (below 25% of that of natural gas) such as biofuels and industrial gases, having emission levels below 20 ppm (NOx) *(SML)*.

Clean solid fuel power generation:

- Large-scale high efficiency low emission coal conversion systems *(SML)*;
- Coal-based near zero emission power plants *(SML)*;
- Systems for the co-utilisation of biomass with coal *(SML)*;
- Ultra-supercritical technology to achieve 55% efficiency by 2020 with more than 90% availability *(SML)*;
- IGCC enhancement *(L)*;
- Techno-economic appraisal of the various options in view of CO_2 capture and sequestration *(SML)*.

6.3 Implementation modalities

Illustrative examples of possible topics and issues to be addressed in Networks of Excellence, Integrated Projects and other instruments :

Networks of Excellence

- ***CO_2 post-combustion capture***. Comparison of post-combustion capture techniques; non-technical barriers to capture; legal and regulatory framework; suitability for subsequent storage options; trace elements in the CO_2.
- ***Pre-combustion CO_2 capture and oxyfuel systems***. Comparison of pre-combustion capture options and oxyfuel techniques; non-technical barriers to capture; legal and regulatory framework; suitability for subsequent storage options; trace elements in the CO_2; oxyfuel combustion; gas turbine combustion, materials and controls; applied chemistry.
- ***Geological storage of CO_2***. Comparison of the available options; saline aquifers; enhanced coal bed methane (ECBM) and enhanced oil recovery (EOR); public acceptance aspects; storage potential; legal implications; stability issues.
- ***Chemical storage of CO_2***. Comparison of the available options; magnesium, silicon and other carbonates; public acceptance; storage potential; transport and mining activities; applied chemistry; kinetics.

Integrated Projects

- ***Pre-combustion CO_2 capture***. System assessment studies; development of oxyfuel combustion and other routes; gas turbine based systems; development of hydrogen production and combustion; novel membranes and other separation techniques.
- ***Post-combustion CO_2 capture***. New and retrofit options, including for coal; development of new sorbents and solvents; cost reductions and process simplifications; integration with storage options; CO_2 purity.

- ***Geological storage of CO_2***. Reduction of the energy requirement; test of long-term stability (seismic); demonstration facilities both on land and off-shore; demonstration of enhanced oil recovery and enhanced coal bed methane options.

In the longer term, one or more comprehensive integrated projects could be envisaged on a full scale plant for the capture and storage of CO_2 incorporating the results of on-going RTD projects, such as SACS, GESTCO, NASCENT, ECBM, etc.

National programmes

Co-ordination activities could be expected, in particular in the fields of gas turbines and clean coal technologies, to accompany actions undertaken by industrial actors, as well as in the following specific topics related to CO_2 : CO_2 storage options, UK ZEPG for CO_2 capture/sequestration, CRUST (CO_2 reuse through underground storage) programme of the Netherlands, national attitudes towards sequestration of CO_2.

Specific targeted research projects

Coal, biomass/waste co-utilisation schemes; small-scale CHP based on gasified biofuel; aquifers and enhanced oil recovery - properties and potential; novel approaches to sequestrating CO_2 (e.g. chemical storage).

Co-ordination actions

Exchange of information via networks on topics such as cost reductions in small-scale, high efficiency, clean coal (zero emission) plants; low to zero emission power generation (ZEPG) from fossil fuels involving the full supply chain.

7. Novel concepts and systems for electricity storage, transport and distribution networks

7.1 Rationale and objectives for future RTD

By 2050, the World Energy Council envisions the global energy mix be made up of at least eight different sources (coal, oil, gas, nuclear, hydro, biomass, wind and solar), none of which is expected to have more than a 30% share of the market.

Electricity can make this diverse supply portfolio possible whilst simultaneously meeting global energy and environmental demands. In the coming decades, electricity's share of total energy is expected to continue to grow from 24% in 1970 to 40% in 2020 (IEA estimation for OECD countries), as more efficient and intelligent processes are introduced into industry, business, homes and transportation. Ultimately, the energy portfolio strategy is expected to result in an electricity/ hydrogen energy system capable of providing globally abundant, clean and affordable energy.

Today, a complex reorganisation of the electric power industry has started in Europe, encouraging competition at both the wholesale and retail ends of the EU electricity market. To facilitate the open European energy markets, an effective interconnection between Member States is needed. This should also include the New Accession States and neighbouring extra-European areas.

In the near future, utilities may still operate regulated distribution systems, but in a longer term the production, brokerage and sale of energy, as well as new services, are set to become competitive functions of the future unified energy market. This implies the need to transform the conventional electricity transmission and distribution grid into an *unified and interactive energy service network*. Major technological and regulatory changes needing substantial RTD effort will be the basis of this new open and unified energy service market. Removing the geographic constraints on the delivery of energy services will lead to increased competition and enhanced quality, reliability, security and safety against human errors, international attacks (saboteurs or cyber attacks) and natural threats.

Distributed Energy Resources (DER) will play a key role in this novel concept. They cover a broad range of technologies and provide small-scale power at sites close to the users. They also offer new market opportunities and enhanced industrial competitiveness. To pave the way to a sustainable energy future based on a large share of distributed generation, there is a clear need to prepare the European energy system for the large-scale integration of both renewable and distributed energy resources. To this end, the key enabling technologies should be developed, allowing a transition towards interconnected grids using common European planning and operation methods and systems.

Barriers related to finance, policies, technologies and technology standards need to be removed and actions aimed at the adaptation of technical grid infrastructures, the establishment of necessary institutions and the harmonisation of the related regulatory frameworks and market conditions should be carried out. The planning of the optimised unified grid should be accompanied by strategic studies on the impacts of such a system on (e.g.) cost-effectiveness and economic aspects, private, public and political commitments, CO_2 reduction targets, emissions trading schemes etc.

Above all, system reliability and power quality must be ensured despite vastly more complex operations, including huge volumes of hourly and daily transactions and far more participants in the movement of power from sources to users. Large investments in innovation and the installation of novel power delivery technologies will also be essential to achieve a broad and sustainable European energy service network, needed for the 21st century.

In this scenario, energy, and particularly electricity, has a new EU dimension and, in consequence, European energy RTD actions must anticipate and accompany these developments. To achieve this, two main medium to long-term targets are proposed:

- Full and effective integration of Distributed Energy Resources (DER) through an interconnected transmission grid ("New Unified European Energy Grid").
- Transformation of the traditional energy and power supply networks into an interactive (customers/ operators) service network.

7.2 Future RTD priorities

To achieve the above-mentioned targets, the following **high** priority RTD strategies have been identified, together with their timescales *(Short, Medium, Long term)*:

- Development of new concepts, systems and strategies for control and supervision to ensure secure operation of the *Unified European Energy Grid (ML)*

The expected results of the above-mentioned activity would ensure the proper utilisation of the increasingly complex grid structure with the new intermittent energy sources, such as wind and solar power. Also, the implementation of interactive service networks would require novel control and supervision schemes.

- Development of new systems, methods and tools for system planning, evaluation and integration of *distributed energy resources* (DER), in particular renewable energy sources (RES) *(ML).*

Many intermittent and grid-connected sources, such as wind and solar power, need new ways of securing energy services to the end-users. To this end, there is a need to develop new common planning methods that also take into account the interchangeable roles of energy producer and user. The future grid structure has to be able to handle situations where the user of the energy services becomes a producer when there is a surplus of local supply. This can include the small-scale production of e.g. wind and solar power, solar heat or CHP based on hydrogen and fuel cells.

- Development of key enabling technologies as well as the services to facilitate interactive energy networks with high power quality and security of service *(SML)*. Examples of key enabling technologies include :
  - ⇒ Power electronic devices (FACTS and HVDC) based on wide-bandgap semiconductor materials, such as silicon carbide, gallium nitride and thin-film diamond, should dramatically lower their costs.
  - ⇒ Large-scale High-Temperature Superconducting (HTS) materials and transmission applications to conduct up to three times as much as electricity within the existing conduit at half of the current costs.
  - ⇒ Energy Storage technologies, such as:

- Gel and AGM lead batteries using special alloys and designs. Further efforts are needed to improve the performance of lead acid batteries and the exploitation and management of the storage facility, including the assessment of the state of charge.
- Advanced Lithium-ion and lithium polymer batteries with high energy density. This technology has a 3 times higher energy density than lead acid batteries and a target lifetime of ten years.
- Reversible fuel cells and redox flow batteries are new technologies for storage. Besides the development of the electrochemical aspect, some controls to regulate the flow of the electrolyte and the appropriate inverter need to be considered for further development.

To build the new type of the grid structure, it is essential to develop and efficiently deploy low-cost enabling technologies. These technologies will help to bridge together local networks to form a truly European network with the capability to integrate a large share of DERs.

7.3 Implementation modalities

Illustrative examples of possible topics for Networks of Excellence, Integrated Projects and other instruments:

Networks of Excellence

- ***Joint socio-economic studies,*** including the development of common strategic roadmaps for energy service networks, aimed at harmonising regulations, safety, testing, certification, education and training.

- ***Advancing knowledge on 'enabling technologies',*** such as power electronic devices based on wide-bandgap semiconductor materials, electro-chemical storage technologies, new materials and chemicals for storage.

Integrated projects

- ***Plan, develop and test systems for the large-scale integration of DER in several EU regions.*** This includes techno-economic assessment, dynamic simulation of the interaction with the network, grid stability and control of power and energy exchange, the establishment of harmonised regulatory frameworks and market conditions, security and environmental assessments, training of operators for DG systems behaviour, etc. These very ambitious projects would necessitate full co-ordination with Member State and regional programmes.

- ***Develop de-localised, grid-connected energy storage technologies and systems,*** including research on new materials and chemicals.

- ***Implement and apply new information and communication technologies (ICT)*** to monitor, operate and control local distributed networks with a large amount of integrated DERs. This includes systems to mitigate the vulnerability of critical infrastructures, the development of a new generation of energy production and distribution infrastructures and analysis of the market opportunities and services for the "new utility" of the 21st century.

The following tasks could either be developed as specific targeted research projects or become sub-projects in larger Integrated Projects:

- To develop information and communication based systems for the integration of DER, utilising the electricity grid as a data transfer medium.
- To develop autonomous and self-adaptable control systems to manage distribution networks with DER.
- To assess security, risk and dynamic issues related to power systems with large amounts of DER.

Co-ordination activities at EU and international level

Several co-ordination activities have been proposed, which should ideally be included within the activities of the Networks of Excellence or Integrated Projects:

- Development of testing requirements and plans for the integration of DERs.
- Assessment of the impacts of DER on energy service networks.
- Development of communication and interconnection standards for DER systems connected to the Unified European Energy Grid.
- Development of guidelines and methods for system planning and operation.

National programmes

The following activities were considered as more suitable for mutually opened national programmes, co-ordinated at EU level:

- Demand Side Management (DSM) with system control.
- Quality of power supply.

8. Energy socio-economic research for European policy-making

8.1 Rationale and objectives for future RTD

European energy and environmental policy decisions need a sound scientific basis. Examples are the targets for the share of renewable electricity, energy taxation, quantified objectives for greenhouse gas emissions and subsidies for clean energies. For all these policies and measures an evaluation of the potential socio-economic impacts is needed by decision-makers.

European research plays a key role in developing and using socio-economic *tools* to provide a substantiated scientific background for the various energy related policies and measures and the resulting regulations.

In the area of *climate change*, researchers go beyond purely scientific problems and address energy issues related to the socio-economic impacts of policies and measures (e.g. what are the cheapest options to achieve the Kyoto targets, what are the consequences of greenhouse gas emissions trading, etc.).

European energy socio-economic research also tackles the evaluation of *external costs* or the monetary quantification of the socio-environmental damages provoked by energy production and consumption (e.g. what damages should be included, what methodology should be used, what policy could internalise these external costs, etc.).

With the advent of the *European Research Area* and the launching of the sixth Framework Programme, a more integrated and coherent approach for energy socio-economic research will bring greater benefits both in accompanying the development and application of regulatory measures and in the formulation of future energy and environment policies.

8.2 Future RTD priorities

To achieve the objectives mentioned above, the following priority RTD activities have been identified :

Forecasting methods, comparative and alternative scenarios

- Very-long term Energy-Economy-Environment modelling tools (2050-2100) dealing with issues such as resource depletion, climate change and radioactive waste management.
- Refinement in the models with a time horizon of 2020 – 2030 (*economic agents*, *territory* definition, *infrastructure changes*, the role *of technological innovation*). “Baselines” comparison, stochastic approach to model results and deriving scientific consensus-building on energy futures.

Integration of energy, economy and environment aspects

- Database improvement. Benchmarking of tools/ methods/ results. Extrapolating data versus generalising (and simplifying) methodologies. Data for energy policies and costs, greenhouse gases and external costs.
- Context dependency generalisation, transferability and representation: clustering techniques, reconciling bottom-up with top-down estimates. Instruments to represent the infrastructure issues (e.g. hydrogen, distributed power generation,

CHP), to calculate their costs and to optimise the options in energy, economy and environment terms.

Mastering and monitoring the policy issues

- *Ex-ante, in itinere* and *ex-post* evaluation of energy and environment policies, such as security of supply, the liberalisation of European energy markets and combined policies (fiscal, standards, etc).
- Kyoto flexible mechanisms related to energy and also addressing the inclusion of non-CO_2 greenhouse gases and sinks, transaction costs, market design and the "additionality" issue. The implications of enforcement and sanctions, permit market imperfections and the shaping of new Kyoto targets (2020-2050) should be studied.

Stakeholders involvement and citizen participation

- Transparency of scientific assumptions to facilitate the support of policy making processes. The involvement of "customers" in the definition of scenarios (strategic planning) and tackling non-technological and non-cost issues influencing decisions (behaviour, comfort factors, urban patterns, etc).
- Awareness raising, "learning by doing" and social acceptability for new and clean energy technologies, prototypes of Joint Implementation and Clean Development Mechanism projects ("empowerment of consumers") and deployment of sustainable policy/ legal framework best-practices.

Externalities evaluation

- External costs - consolidation of the basic principles, concepts and definitions. Refining, validating and improving the accuracy of models (dispersion, deposition…), the global warming issue, cost control methods, monetary valuation techniques, the aggregation of results at the EU-level, very long term effects (e.g. discount rates).
- Inclusion/ exclusion in the externalities evaluation of security of supply, accidents, benefits, jobs creation, depreciation of publicly funded infrastructure, additional burdens and impacts like ecosystem damage, land use/ land take, soil and water quality contamination. Case studies in the New Accession States.

8.3 Implementation modalities

Energy socio-economic research should, as far as possible, be systematically integrated into research carried out in the more "technological" areas, i.e. incorporated into the Integrated Projects and Networks of Excellence described in the previous chapters. However, there will also be a need for stand-alone socio-economic research to achieve specific horizontal/ generic objectives, such as those highlighted above.

The following are illustrative examples of possible topics for Networks of Excellence, Integrated Projects and specific targeted projects for energy socio-economic research :

<u>Networks of Excellence</u>

European and World energy modelling, including medium (2020-2030) and longer-term perspectives (2050-2100). Focussing on transparency of assumptions, baseline confrontations, developing countries and geopolitical risks. Attention to be paid to database quality, sustainability indicators and results transfer from modellers to

decision-makers. Scientific assessment “help-desk” for research and energy policies, including social acceptance.

Integrated projects

External costs, dealing with the issues of security of supply, ecosystem damage, sector comparisons (including electricity, transport and industry), aggregation of results, case studies in the EU (evolution of technologies) and New Accession States, stakeholders participation, practical internalisation mechanisms.

Specific targeted research projects (or co-ordination actions), which are also likely to be part of Integrated Projects and Networks of Excellence.

Socio-economic research tackling in a horizontal and comparable way the non-technological issues related to energy carriers (e.g. hydrogen), renewable energy technologies (e.g. PV, biomass) and CO_2 disposal (capture and sequestration) including the economic aspects (costs), citizen / consumer preferences (behaviour) and the impacts of private choices.

Annex

Alphabetical List of External Workshop Participants

Naim	AFGAN	IST	P
Gerry	AGNEW	ROLLS-ROYCE	UK
Peter	AHM	PA ENERGY A/S	DK
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Jörg	BAUMGÄRTNER	EEIG "Heat Mining"	D
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Joachim	BERG	VAILLANT	D
Ruggero	BERTANI	IGA Secretariat / ENEL/ERGA	I
Mike	BESS	ESD	UK
Achim	BÖCKELT	BMW AG	D
Rodolphe	BOUCHARD	TotalFinaElf	F
Tim	BRUTON	BP SOLAR	UK
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