FP7 Research Priorities for the Renewable Energy Sector

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Consolidated Input
from European Renewable Energy Research and Industry
to the European Commission Stakeholder Consultation
on Research Themes of the 7th Research and Development Framework Programme

EUREC Agency
European Renewable Energy Centres Agency

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INTRODUCTION

THE RENEWABLE ENERGY SECTOR'S RESEARCH PRIORITIES FOR THE SEVENTH EUROPEAN FRAMEWORK PROGRAMME FOR RESEARCH AND DEVELOPMENT (FP7)

After increasing its turnover tenfold from 1.5 billion EUR in 1990 to 15 billion EUR in 2004, the European renewable energy[1] sector has only just begun to reveal its enormous potential for growth. As its contribution to Europe's economy grows, so will its workforce, with 1 million expected to work in the sector by 2010. Technology-focused small- and medium-sized companies with an ability to assimilate and commercialise new scientific knowledge are the driving force behind the renewable energy industry's expansion.

Renewable energy research – an investment for a sustainable energy future

Europeans are clearly in favour of clean and sustainable energy production from renewables. Asked in a 2002 survey "In which of the following areas would you like to see more energy-related research in the European Union", they voted for renewables-related research far ahead of fossil and nuclear energy research[2]. There are many reasons for this positive public image, not least the sector's contribution towards fighting climate change by generating energy cleanly without causing net carbon dioxide emissions. At the same time, renewable energy can reduce our dependence on imported energy.

The renewable energy sector can make a substantial contribution towards a number of major EU policies:

- the 'Lisbon' and 'Barcelona' objectives, which describe a dynamic 'knowledge' economy based around research, development and innovation with a specific focus on the competitive key sector of environmental technology
- a weaker reliance on energy imports
- the development and use of renewable energy resources as laid down in the EC's renewable energy directives and 1997 White Paper
- the fulfilling of international obligations such as the Kyoto Protocol

The quantifiable environmental, economic and social benefits of the renewable sector are closely aligned with these key European objectives.

Given the high importance of these objectives, and the EU's aspirations for the renewable energy sector, the decline in public financial support for renewable energy research at EU and Member State level is a worrying trend that must be reversed. In recent years, EU funding has dropped from 400-450 million EUR in FP4 and FP5 to approximately 380-410 million EUR in FP6. Direct funding by the Member States of EU-15 slumped from 300 million EUR to 250 million EUR between the start and end of the 1990s, but has since shown evidence of rallying slightly. As an emerging industry, the renewable energy sector needs a supportive political and legal framework to reach its full potential, which includes strong public investment in research and development and better incentives for private-sector research spending.

The content of the following chapters is a first for the European renewable energy sector, for they describe the outcome of a joint discussion, in some cases conducted over as much as three years, between representatives from research and industry. The result is a collection of research priorities for each technology that could serve as useful input to the future FP7 work programme. The overall message is clear: there is much to do in each area, whether it is in bioenergy, solar thermal, photovoltaics, hydropower, wind energy, geothermal or any of the other areas we cover, such as the integration of the different technologies into our energy supply systems or "solar buildings", a topic that also includes aspects of energy efficiency.

Our discussions have led us to conclude that, as regards the Seventh Framework Programme, we need:

- **An average annual research budget for renewable energy of 250 million EUR**
- **A budget within FP7 exclusively for renewable energy technologies**

Also

- **Better tools and mechanisms to increase the take-up of research results by industry**
- **Changes to the implementation of the Framework Programme that encourage greater SME participation**

[1] In this document the phrase 'renewable energy' is used as it is defined in Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources.

[2] European Opinion Research Group 'Energy : Issues, Options and Technologies', December 2002

ECONOMIC, ENVIRONMENTAL AND OTHER SOCIETAL BENEFITS OF RENEWABLE ENERGY

Renewable energy – a high growth sector

The turnover of the European renewable energy industry grew tenfold from 1.5 billion EUR in 1990 to 15 billion EUR in 2004.

Wind

The turnover of Germany's wind industry (the world's number one market for installation) was 4.2 billion EUR in 2003. The industry has grown annually by an average of 35% since the late 1990s.

Photovoltaics

The photovoltaic industry has recorded even higher growth rates, closer to 45% per annum in the installed capacity in Europe since 1999. The value of the European PV market in 2004 was approximately 1 billion EUR.

Solar thermal heating and cooling

Between 1999 and 2004 the installed solar thermal capacity in the EU grew from 5,600 to 9,800 MW_{th} (14 million square metres of collector area). Over this period some countries, such as Germany, experienced years where their growth rates reached 20% and above.

Biomass

Europe leads the way in developing technologies to generate electricity from biomass. EU-15 accounted for 90% of the OECD countries' increase in electricity generated in this way between 1990 and 2002. Biomass now supplies about 4% of the EU's energy, mainly as fuel for heating and for CHP plants. It is the only renewable energy source that can be used to produce competitively-priced liquid fuels for transport.

Geothermal

The advantage of this renewable energy resource is that a single plant can provide power continuously for more than 30 years without a need for backup. In EU-15, around 5 TWh of electricity are produced this way each year. In recent years, new geothermal power plants have been built in areas previously thought to be unsuitable (see 'Success Stories').

The renewable energy industry is pushing European governments to commit to a target of 20% of the primary energy consumed in Europe to come from renewable energy sources by 2020. Between now and then, the global wind industry is capable of increasing its annual turnover to 80 billion EUR, while the worldwide PV industry could have a value of 60 billion EUR if this target is adopted and met. A continuous supportive political and legal framework for renewable energy development, coupled with public and private investment in renewable energy research will enable the sector to sustain its strong growth rates over the coming decades.

Strong job creation potential

The renewable energy sector provides employment to large numbers of people and will generate more jobs as it grows. They will range from highly-skilled, research-related jobs in the design and manufacture of renewable energy products to jobs requiring a lower level of skill, for instance in the maintenance of renewable energy systems, or the harvesting and transport of biomass.

Historical and current employment in renewable energy in Europe

The number of people employed both directly and indirectly in wind turbine manufacturing had reached 72,000 across Europe by 2002. The growth in Denmark over the 1990s was particularly impressive. The country's forward-looking public policy achieved an increase from 2,900 full-time work-places in 1991 to 21,000 in 2002. Europe now has 15,000 jobs dependent on the photovoltaic industry. It is estimated that the bioenergy sector provides employment to 450,000 people.

Forecasts predict there will be a total of 1 million jobs for the renewable energy sector by 2010. By 2020, this impressive number is set to double if the proposed 2020 renewable energy target is met[3].

A competitive environmental technology made in the EU

European companies lead the world in the performance, quality and durability of a number of renewable energy technologies, but this position is under serious threat from countries such as the US, Japan and China.

The export markets for renewable energy products and services are to be found both in industrialised and developing countries, with on-grid applications being more relevant for the first group, and off-grid applications for the second.

To maintain or increase European manufacturers' share of the world market in the face of strong international competition, further cost reductions and technical enhancements are needed. A greater R&D effort will help to deliver these, and in so doing, maintain the EU's competitive edge in the growth sector of environmental technologies.

Wind:

In 2003, almost 80% of the wind turbines sold worldwide were made by European companies

Solar thermal heating and cooling:

Europe installed 1 GW_{th} installed in 2003, but its share of the world market is far behind that of China, with 7 GW_{th}.

Photovoltaics:

In mid-2004, European companies supplied 26% of the world cell market. By 2005/6, from an assessment of the planned expansion in production capacities, this is forecast to drop to 23-24%. Over the same period, Japan will increase its market share from approximately 54% to 59%.

Carbon dioxide savings – a key environmental benefit

The renewable energy capacity installed in Europe currently saves in the order of 130 million tonnes of CO_2 annually (excluding electricity from large hydropower plants). The CO_2 reduction due to renewable energy source exploitation is forecast to reach 320 million tonnes per year by 2010, providing the target of the 1997 European Commission White Paper on renewable energy is met. This target is for 12% of the EU's primary energy consumption to come renewables by this date. By comparison, the amount of CO_2 reduction that EU-15 must make from 1990 levels to comply fully with its obligation under the Kyoto Protocol is 338 million tonnes per year by the same time.

External costs and subsidies in the energy sector

Conventional forms of energy, especially fossil fuels, are associated with pollution that damages the economy and ecosystems. The price of energy does not include the cost of repairing this damage. A recent EC-sponsored study, 'ExternE', has estimated the economic cost of this pollution by assessing its toll on human health, its damage to buildings and agriculture, and its contribution to global warming. It has shown renewable energy to have very low external costs.

The energy market's failure to internalise its external costs is exacerbated by the high level of subsidy provided to conventional energy production. A study from 2000[4] estimated that, in the USA, the nuclear industry received about 30 times more support per kWh output than wind power in the first 15 years of the industry's development. Over the same period, the wind industry produced 1.9 TWh electricity for the nuclear industry's 2.9 TWh, suggesting that renewable energy can provide a very good return on the public investment made in it.

[3] European Renewable Energy Council EREC: "Renewable Energy Target for Europe", January 2004, Brussels. See www.erec-renewables.org for details

[4] Goldberg, M. (2000), Federal energy subsidies: Not all technologies are created equal, REPP, July 2000

From 2001, the cumulative savings in external costs delivered by following the trajectory towards a 20% share of renewables in the EU's primary energy supply by 2020 will amount to 120 – 320 billion EUR. Furthermore, in EU-15, fuel savings of 120 billion EUR are expected.

European Environment Agency (2004) 'Energy subsidies in the European Union: A brief overview':
"The presence of each primary fuel in an energy portfolio with minimised risk has a real economic value, but this is currently disconnected from mainstream discussion on subsidy mechanisms, energy models and private sector investment decisions. [...] What is clear is that the role of technologies for exploiting renewable energy in diversifying energy price risk is not yet fully recognised by the market."

Billions saved in grid infrastructure investment in a renewable energy economy

The IEA has shown that 15% of the total cumulative investment required in electricity supply infrastructure may be saved between 2003 and 2030 if the world moved towards a decentralised, energy-efficient electricity supply system based around renewable energy technologies. For OECD countries, this sum amounts to approximately 800 billion EUR in total. This compares to a subsidy of just 5.5 billion EUR to the renewable energy industry in EU-15 in 2001. Even if this amount of annual subsidy were maintained at a vastly increased level for the next 25 years, the savings in grid infrastructure investment would still be tremendous.

RENEWABLE ENERGY, INTERNATIONAL COMPETITIVENESS, AND THE "KNOWLEDGE ECONOMY"

The conclusions of three European Councils in 2001 and 2002 illustrate how economic growth, job-creation and sustainable development have, together, become a high priority for EU policy-making. In a globalised economy, Europe's competitive advantage is to be found in its ability to develop and bring to market innovative products and services. For this reason, the importance of research has moved up the agenda as a means to achieve the "Lisbon target" (quoted below). Taken together, the logical conclusion of these different statements is to create conditions that encourage European economies to produce and export high-tech, innovative, environmental technologies.

Renewable energy and competitiveness

On January 28th 2004, the European Commission launched its **Environmental Technologies Action Plan**, which is "based on the recognition that there is significant untapped technological potential for improving the environment while contributing to competitiveness and growth." It continues, "investing in research, from both private and public sources, is vital for the EU economy, including eco-industries." These eco-industries include the renewable energy sector, as seen in the statements on the 'Lisbon agenda' presented below:

- **Lisbon European Council, 2001**: Member States agree that by 2010 Europe should be "the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion'"
- **Gothenburg European Council, 2001**: "The European Council agrees a strategy for sustainable development which completes the Union's political commitment to economic and social renewal, adds a third, environmental dimension to the Lisbon strategy and establishes a new approach to policy making."
- **Barcelona European Council, 2002**: "Overall spending on R&D in the EU should increase and approach 3 % of Gross Domestic Product (GDP) by 2010."
- '**Facing the Challenge', 2004** (a mid-term review of progress towards goal agreed in Lisbon): "The Lisbon strategy calls for addressing climate change [by] rapidly ratifying the Kyoto Protocol (2002), showing progress in delivering Kyoto targets (by 2005), meeting the target of 12 % of primary energy needs and 22 % of gross electricity consumption from renewable energy sources. [...] Taking care of the environment should remain an important dimension of the strategy as it can both constitute a source of competitive advantage in global markets and increase competitiveness."
- **European Commission's Strategic Objectives 2005-2009**: "A greater security of energy supply would be provided by a concentrated effort to reduce energy demand, [...] as well as by the vigorous promotion of renewable energies"

Explicit calls for more research money for renewable energy

During 2004, the Commission, the Member States, the European Parliament and the international community all made the case for more research funding specifically for renewable energy.

The **Transport, Telecommunications and Energy Council of the European Union of 29 November 2004** stressed the importance of increasing the competitiveness of renewable energy by focusing research and development. It was of the view that “as regards new long-term targets [...] adequate R&D must be provided”. This statement is valuable because it correctly links the possibility of 2020 targets for Europe with the fact that R&D is needed now to reach them. The 2000 Green Paper on Security of Supply COM(2000) 769, also offers a target for a 20% substitution from imported fuels by 2020.

In the **Communication from the Commission COM(2004) 366** dated 26 May 2004 on 'The Share of Renewable Energy in the EU', the Commission accepts that it is “necessary to [...] accelerate the pace of public support for research, technological development and demonstration in renewables in Europe.”

Before the international ‘Renewables 2004’ conference (1-4 June 2004, Bonn) the **European Parliament** passed a resolution stressing “the need to increase support for R&D and innovation in renewable energies”. The **political declaration of the conference** said, “Ministers and Government Representatives emphasise the need for additional targeted research and development, especially by developed countries,” while one of the **policy recommendations** was to “increase funding for renewable energy R&D.”

INVESTING 250 MILLION EUR A YEAR IN RENEWABLE ENERGY RESEARCH

250 M EUR should be the average annual expenditure on renewable energy research under the next Framework Programme. Raising the renewable energy research budget to this level is crucial to helping the sector sustain its high growth rate. However, care should be taken to provide this funding through instruments that are sufficiently simple and flexible, both in terms of procedures for participation and co-financing requirements, not to discourage SME participation.

Table 1 shows the average annual spend on renewable energy research from FP4 onwards (data before FP4 is not readily available). Without adjusting for inflation, the funding for renewable energy research under the Framework Programmes has declined by about 10% over the last ten years. Taking account of the effect of inflation, the decline is closer to a quarter.

Framework Programme	Funding Period	Average annual spend on renewable energy (M EUR or ECU)
FP4	1995-1998	110
FP5	1999-2002	estimated 100-110
FP6	2003-2006	estimated 90-100

Table 1 – Renewable energy funded by different European Framework Programmes

The International Energy Agency publishes statistics on direct public expenditure on renewable energy research by EU-15’s Member States. The chart below underestimates R&D spend because of gaps in some countries’ reporting of this data. However, it shows that spending has declined by approximately 150 million EUR a year since the early 1980s.

These downward trends are inconsistent with the EU’s aspirations for the renewable energy sector, as set out in key official documents like the White Paper on renewable energy of 1997 (COM(97) 599), the Green Paper on the security of Europe’s energy supply (COM(2000) 769), the Directive on the promotion of electricity from renewable energy sources (2001/77/EC) and the on promotion of biofuels (2003/30/EC).

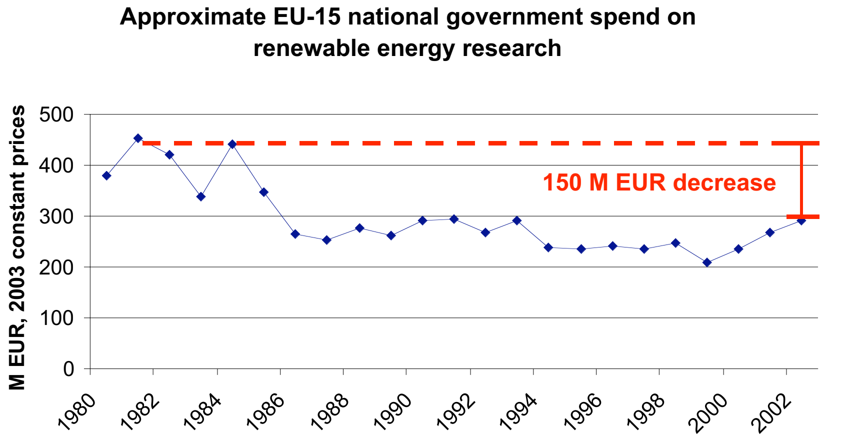


Figure 1: Source: International Energy Agency

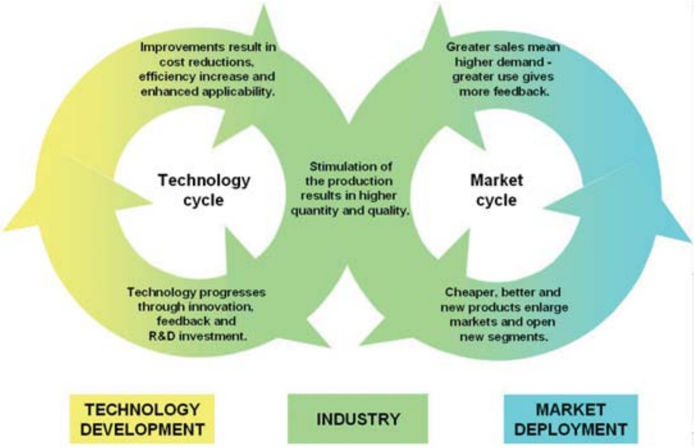
Early in the 1980s, at the time of the Second Oil Crisis, energy was at the top of the policy-making agenda in Europe purely as a result of concern over our degree of dependence on imported oil. Oil prices again hit record levels in the last few months and remain high. Meanwhile, Europe is steadily increasing its dependence on imported natural gas, making the security of Europe’s energy supply as much of an issue now as it was twenty years ago. Furthermore, in recent years we have come to appreciate much better how our consumption of fossil fuels is changing the climate and jeopardising our future well-being by damaging ecosystems across the world.

The exploitation of indigenous renewable energy sources and of opportunities to save energy should be our response to these problems. The quotations on the previous page demonstrate that the European institutions and the wider international community have recognised an increased spend on renewable energy research as important. The EU should put pressure on its Member States to increase their direct national funding for renewable energy research. It should lead by example and, as a first step, increase its renewables research budget from 100 M EUR / year on average to 250 M EUR to make up for the drop in Member State spending since the last time that energy was this high a political priority, in the early 1980s.

An increase to an average of 250 M EUR per year for EU-funded renewable energy R&D would help ensure that sectors that have received less attention in recent years are also able to undertake research important to the continuing development of their technology and thereby provide the EU with the scientific knowledge necessary to maintain its leading international position across the full spectrum of renewable energy technologies.

- More renewables research is required to increase the efficiency of existing technologies, fully develop emerging high-potential renewable technologies, and, overall, to drive down the cost for the production of heat, power and fuels from renewable energy sources.
- More renewables research projects will yield more results, and these will help European companies to maintain and increase their competitiveness and market share in the face of strong competition from Japan and the US.
- More renewables research will pave the way to a clean and healthy environment, and contribute to security of energy supply.

Virtuous Cycle in a Supportive Policy environment



Source: NET Nowak Energy & Technology Ltd., St.Ursen, Switzerland, www.netenergy.ch

An efficient use of public funds

European-level renewable energy and energy-efficiency research projects have translated quickly into better, more efficient technology solutions for our society. These have been accompanied by successful projects aiming at the integration of renewable energy.
Although it is difficult to establish an exact relationship between research spending and industry expansion, the evidence suggests that the sector's recent double-digit annual growth rates result from a technology push from R&D and a market pull that are mutually reinforcing (see illustration below), stimulated by a supportive policy framework.

A small selection of research success stories

Biomass — *FORENERGY NNE5/395/2000*

This project, co-ordinated by a Finnish company, developed a new kind of bundling technology, which helps make the timber resource more easily exploitable for energy purposes. It enables wood to be transported on standard trucks used already by the conventional timber industry. Since the project finished in early 2004, the process it developed has gone on to be used beyond Finland in Italy, Sweden, Spain, Switzerland and the Czech Republic.

Geothermal — *JOR3-CT98-0313*

This EU-funded experimental plant at Soultz-sous-Forêts is the first geothermal project in the world with three deep wells (each app. 5000 m) and the first to show that it is possible to create an underground heat exchange system using the "Hot-Fractured Rock" (HFR) approach. In the process, special monitoring equipment and seismic monitoring software were developed. The plant is expected to start producing power by the end of 2005, by which time it will have facilities that enable it to host researchers from all over the world. Geothermal power production cycles such as will be used at Soultz were installed in 2000 with EU-support in Austria (Altheim) and Iceland (Husavik), thereby increasing the range of usable geothermal resources within the EU. Newer plants, designed using the results of these projects, have come on stream in Austria and Germany, and others are under construction.

Marine energy — *LIMPET JOR3-98-0312*

In 1998 EC's Joule 3 research programme funded a full-scale 500 kW demonstration project of Oscillating Water Column (OWC) technology, which is now operating as a commercial plant connected to the electricity grid on the island of Islay in Scotland. A wide variety of different devices are being tested for their ability to extract energy from the sea whether from waves, tides or currents.

Small hydropower — *SEARCH LHT NNE5/247/2000*

The Small Efficient Axial Reliable Compact Hydro Low Head Turbine, is an FP5 project supported by the European Commission and

Switzerland. By using custom-made components, manufactured for the same cost as standard components, it has shown that for hydroelectric turbines of less than 1 MW capacity, new designs are possible that increase their efficiency (by between 5 and 10%) and lifetime. When installed at an existing plant in France, where one such turbine replaced another of an older design, the maximum power output of the plant increased from 260 kW to 320kW for the same flow of water.

Solar buildings

ECCO ENK6-CT-2002-00656

Already the results emerging from this project are providing a major step forward with regard to the combination of energy efficiency and user comfort in buildings: An intelligent shading controller has been is being built that optimises the energy performance of a building and at the same time adapts the performance its users' preferences. This kind of technology will lead to a much more widespread acceptance of eco-building concepts.

Solar thermal electricity

DISS JOR3-CT- 1995-0058 DISS JOR3-CT 1998-0277 INDITEP ENK5-CT-2001-00540

These projects established that it was possible to reduce the costs of electricity produced from solar thermal concentrating power by 10% by using a technique of direct steam production. A 5MW prototype plant is now being built.

EUROTROUGH II ERK6-CT-1999-00018

This project resulted in an efficiency improvement of 10% compared to the existing parabolic trough technology and will be used in Spain in the commercial concentrating solar power plants that are currently being planned.

Solar thermal heating and cooling

ASODECO NNE5/531/1999 SACE NNE5/2001/25

In several projects such as ASODECO the use of solar heat for thermally-driven cooling was successfully demonstrated. Thermally-driven cooling is set to become increasingly important in future years as demand for efficient cooling technologies grows. The SACE project compared existing solar cooling projects, identifying the most successful technologies, the typical performance of average systems and the potential for further improvements.

Solar photovoltaics

DOIT ENK6-CT-2000-00321

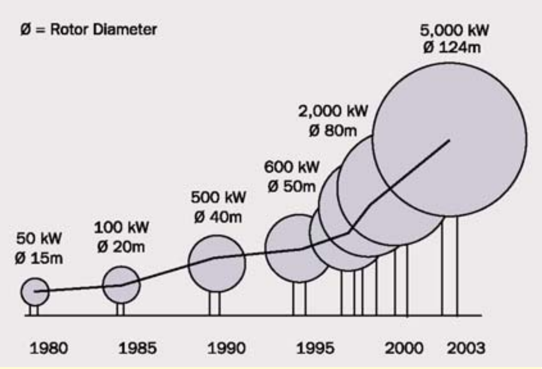
This project produced a successful prototype of a highly efficient amorphous- and microcrystalline-silicon tandem solar module on glass substrates.

FULLSPECTRUM 502-620

An efficiency > 34% at 300 suns was realised for monolithic triple junction concentrator cells on Germanium. It is expected that a 35%-milestone will be achieved in early 2005. The rapid evolution of III-V concentrator photovoltaic systems is expected to result in a successful market entry of the technology soon.

Wind

DISPOWER ENK5-CT-2001-00522



A mixture of taller turbines, improved components and better siting has resulted in an overall efficiency increase of 2-3 % annually over the last 15 years. As a rule of thumb, manufacturers expect the production cost of wind power to decline 3-5% with each new generation of wind turbine they add to their product portfolio. A cost reduction of over 50% in the last 15 years has been achieved for electricity from wind power.

Meanwhile, software has been developed to predict the output of wind farms better. As part of the DISPOWER project, artificial neural networks were trained to learn the relationship between variations in meteorological data and the wind power output of several UK wind farms. This resulted in improved power predictions: a 92% correlation with observed data versus about 90% correlation achieved through the easiest form of prediction, the “persistence model”.

Integration

Accommodating a high penetration of wind electricity in isolated networks, such as may exist on islands, poses many technical challenges. To operate these networks securely and economically, advanced tools are needed. The development of Energy Management Systems that integrate advanced modules for power unit scheduling, storage management and wind forecasting has allowed utilities to operate these isolated networks with wind penetration levels as high as 35 %.

Off-grid applications

The research programmes for off-grid applications have tended to focus on solar hybrid stand-alone systems capable of supplying villages that are cut off from a larger transmission and distribution network. The main results have been the development of advanced grid interfaces that can control the quality of power supply and increase the lifetime of storage devices like batteries. Such systems have a clear competitive advantage over conventional diesel-based systems for rural electrification.

A SPECIFIC FP7 BUDGET LINE FOR ALL RENEWABLE ENERGY TECHNOLOGIES

As in FP4, a fund exclusively for renewable energy technologies should be established in FP7. The "Sustainable Energy Systems" allocation under FP6 funds a wide variety of energy technologies. To increase the transparency with which the budget of the Framework Programme is managed and in order to give renewable energy researchers a clearer idea of how much they will receive over the duration of the Framework Programme, an effort must be made to define more precisely the amounts going towards each area, including renewable energy technologies and energy efficiency. In granting renewable energy its own budget, it will be easier to assess the impact that European public research funding has had on the sector.
All renewable energy technologies should receive funding under FP7. Each kind has its own intrinsic advantages and limitations. Combined intelligently, they can together form the backbone of a robust, environmentally-sound and secure energy supply system.

Better technology transfer to industry

One key way to use the knowledge generated by public research funds efficiently is to ensure it passes smoothly along a continuous technology development chain linking the laboratory to the marketplace. An increased R&D spend should go hand in hand with efforts to increase the take-up by industry of the results generated by publicly-funded research projects. EUREC Agency is keen to see new, improved ways to incentivise collaboration between public and private sector research. It would be desirable, for example, to create fora where public sector researchers, industrialists and other relevant actors may define a research agenda alongside an industrial policy for a particular industry. For photovoltaics, the Commission is already taking such an initiative through the establishment of the European Photovoltaic Technology Platform. We hope that the Commission will also support other renewable energy sectors choosing to organise themselves in this way such as the wind and bioenergy sectors.

Simpler procedures and flexible instruments

EUREC Agency, EREC and our members welcome the proposals of Professor Ramon Marimon[5] for simplifying the administration of the Framework Programme and for reducing the costs to proposers and participants. EUREC Agency also welcomes the rebalancing of the budget favour of Specific Targeted Research Projects and Integrated Projects with smaller consortia. These are both moves that will encourage more industry participation, in particular from SMEs.

Socio-economic research and education

While the following chapters of this booklet focus mainly on engineering-related research, the social and economic issues related to renewables should not be neglected. A better appreciation of these surrounding issues will likely improve the public's attitude towards renewable energy and therefore increase the rate at which such technologies penetrate the market. Similar attention must be paid to technical and economic education curricula in the field of renewable energy, as the current offer in the European education system is insufficient to support the market's expansion.

CONCLUSION

Renewable energy is a high-tech sector crucial to the emergence of the competitive, environmentally-benign, knowledge-based economy that Europe wants to establish. The text above describes the economic and environmental contribution of renewable energy and the rationale behind our two key demands: FP7 funding for renewable energy research in the order of 250 M EUR per year, and a budget line in FP7 dedicated exclusively to this area. There is much research in renewable energy that remains to be done across the full range of renewable energy technologies, aimed both at reducing costs and at developing new processes, techniques and products.
Public sector researchers (accounting for the majority of EUREC Agency's membership) and the renewable energy industry (represented by the European Renewable Energy Council and its members), have jointly defined the summaries of renewable energy research priorities contained in the following pages. The resulting document is a useful tool for policy-makers wanting to set up a programme for research that will have the support of industry and could serve as useful input for the definition of the future work programme for FP7.

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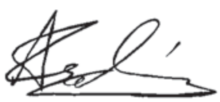


President EREC

[5] *'Evaluation of the effectiveness of the New Instruments of Framework Programme VI'– 21 June 2004*

FP7 Research Priorities for the Renewable Energy Sector

Scientific R&D Priorities for the Different Renewable Energy Technologies

BIOENERGY

Bioenergy is seen as one of the key options to mitigate greenhouse gas emissions and substitute fossil fuels. This is certainly evident in Europe, where a wealth of activities and programmes was and is executed for developing and stimulating bioenergy.
Over the past 10-15 years in the European Union, heat and electricity production from biomass increased with some 2% and 9% per year respectively between 1990 and 2000 and biofuel production, e.g. for transportation purposes increased about 8-fold in the same period.

Biomass contributed some two thirds of the total renewable energy production in the EU (2,000 Petajoule) or 4% of the total energy supply in 1999. Given the targets for heat, power and biofuels, this contribution should rise to some 10 % (6,000 Petajoule) in 2010.
Over time, the scale at which bioenergy is being used has increased considerably. This is true for electricity and CHP (Combined Heating Power) plants and how biomass markets are developing from purely regional to international markets, with increasing cross-border trade-flows.

R&D Targets for FP7

For the future, a more strongly coordinated European approach is desired. Europe needs more comprehensive R&D trajectories for key options as Biomass-fired integrated gasification combined cycle (BIG/CC) and advanced biofuel concepts, an international biomass market allowing for international trade and an integral policy approach for bioenergy incorporating energy, agricultural, forestry, waste and industrial policies. The Common Agricultural Policy (CAP) of the (extended) EU should fully incorporate bioenergy and perennial crops in particular.
In order to increase the share of biomass for energy production and thereby as much as possible developing the resources available within the European Union, which guarantees for availability for the decades to come, we have to develop all biogenic streams which are already there, which are not yet being used as well as developing new resources based on energy cropping. The materials to be used should serve both energy and feedstock supplying purposes.

To start from all possible available sources and develop the upstream technology generating a reduced set of fuel characteristics, while improving the downstream technology to accept an extended and more variable stream of inputs

The way to address this goal is to start from all possible available sources and develop the upstream technology generating a reduced set of fuel characteristics as well as improving the downstream technology such that it can more readily accept an extended and more variable stream of inputs.
The approach is thus to reduce the variability of the input while extending the availability and, at the same time creating greater technical acceptability in conversion technology.
In view of this R&D should focus on three main directions:

Photo: © ADEME

Feedstock Production

The aim is to develop the conditions for maximising the availability within the European Union of biomass and biomass related waste streams for production of energy as well as fossil input replacing feedstock for the industry. The input materials will be based on forestry, agricultural, food and beverage industry as well as newly to be developed activities as energy cropping and improved harvesting technology. The supply chain, logistics, separation and pre-treatment technology will have to be developed in such a way that more limited, well standardised and documented fuels in great quantity will emerge and will be adaptable to state of the art and newly developed conversion technologies. Obviously the economics will have to be addressed to guarantee market implementation.

- Production, collection and pre-processing of agricultural, forestry residues and biogenic municipal solid waste (MSW) fraction
- Demonstration of bioenergy chains from energy crops including harvesting, pre-treatment, logistics and end use. Improvement of energy crops spices
- Analysis of potential chances and bottlenecks regarding import of biomass from outside the EU
- Production and trade of standardized solid fuels
- Pre-normative research and standardization
- System studies on land use change and non-energy market competition.

Conversion Processes

The main aim is to optimise reliable, efficient and cost effective technologies (combustion, gasification, pyrolysis, etc.) focusing on reduction of pollutants, multifuel resources, and operational aspects relevant to both small and large-scale plants. Biorefinery for the integrated production of energy and other products must be enhanced. Emphasis must be given to the determination of the suitability of the conversion processes and biofuel energy chains based on the energy and environmental balances as well as on the energy production costs.

- New concepts of pre-treatment ensuring accommodation of biofuels into the present and future conversion chains (e.g. torrefaction)
- Maximising conversion of biomass and wastes with current fossil fuels based electricity generation: process improvement, ash properties and slagging, as well as reuse of the waste streams emerging from the co-firing process
- Utra low emission power plants, both on the basis of current combustion/steam cycle technology and less commercially developed technologies, as mentioned below
- Advanced gasification for power and hydrogen/ syngas production
- Production of fuels by thermal and/or catalytic processing of gasification products. Fisher Tropsch, Methanol etc.
- Ethanol from lignocellulosic materials
- Biochemical processes based on digestion and/or fermentation
- Fuels and chemicals integrated with energy production (biorefineries)
- Decentralised combustion and gasification technology for heat, power and combustion gases
- Improving the properties of bio oils such that these can be used in current state of the art downstream systems

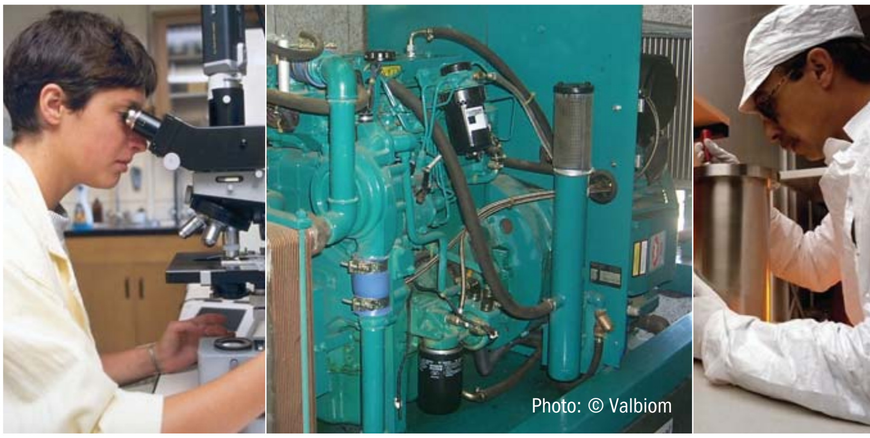


Photo: © Valbiom

- New conversion technologies like sub- and supercritical gasification and improving the catalytic function during the process, including hydrogen gas production from biomass
- Development of assessment tools and studies for the determination of energy balance, environmental balance, with emphasis on greenhouse gas (GHG) emissions, and costs of the bioenergy conversion processes and biofuels energy chains.

End Use Integration

The main aim is to enhance the integration of technological development with the end users needs and demand, involving the key stakeholders.

- Logistics and market development of the production chain of advanced biomass and waste derived fuels
- Adaptation of the fuels and end use technology for new advanced biomass related energy carriers
- Life cycle assessment and chain optimisation
- Socio economic aspects, legislation, permits and acceptability
- Distributed generation with biomass combined heat and power combined heating power (CHP) systems; focus on (positive and negative) impacts on grid integration of decentralised biopower
- Models for energy, environment and economic assessment based on market demand (heat, power, fuels) and feedstock availability (land use and material use competition)
- Accounting models for Kyoto-related benefits
- Education and promotion strategies and programmes
- Modelling/analysing interactions with planning and leading decision makers

Photo: © ADEME

GEOTHERMAL ENERGY

Geothermal energy is a renewable energy resource that can deliver heat and power 24 hours a day throughout the year, independent of external factors like weather and season. This permanent availability makes it an attractive complement to the energy supply mix. Besides, this energy resource is nearly infinite and available all over the world.

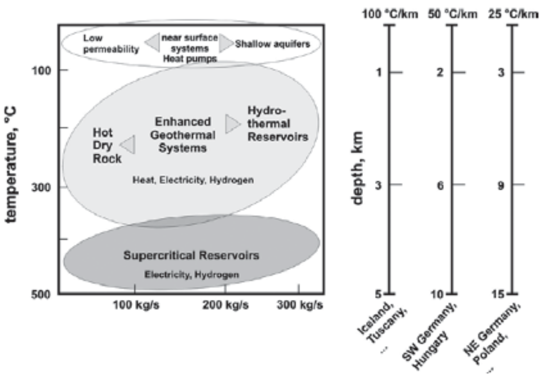
In EU-15 in 2002 more than 6 TWh of heat and approximately 5 TWh of electricity were produced. 2.3 TWh of these 6 TWh of heat were produced in Sweden using geothermal heat pumps.

Although geothermal energy has a longer research tradition, intense research, development and demonstration is required in many fields to speed up the progress of electricity generation and achieve considerable cost reductions. To reach a goal of 25 GW installed geothermal electrical capacity in the year 2030 we have to further invest in research. As geothermal energy has not yet reached full commercial competitiveness, the private sector companies and energy suppliers are still reluctant to invest. Hence the definite need for support by the European Commission. Only continuity in research can make geothermal energy a pillar of a sustainable and renewable energy solution in the near future.

The costs for the installation of geothermal plants can be reduced by at least a factor of three

The following list of research fields recommended for further investigation is limited to issues directly belonging to exploration and exploitation of geothermal resources. Other topics concerning the periphery or infrastructure, such as facilities for the conversion of heat into electricity (e.g. organic Rankine cycle, Kalina cycle, etc.), engines or heat pumps etc. are not mentioned but also need optimisations.

Geothermal energy can be used to produce heat and/or power. Geothermal use is dictated by the resource quality in terms of temperature and permeability available at economically drillable depths. The different domains of geothermal resources (low to medium temperature, medium to high temperature and supercritical reservoirs) are illustrated below. The permeability variations may change the exploitation conditions for each temperature domain. E.g. in the medium to high temperature zones hydrothermal reservoirs of poor permeability can be found.



R&D Targets for FP7

Low to Medium Temperature Zones

These zones can be exploited with heat pumps, which is a commonly used technology. Very good global energy efficiency can be achieved when geothermal heat pumps are combined with solar energy. This very promising distributed energy scheme will not be described here.

Medium to High Temperature Zones (Enhanced Geothermal Systems)

The ability to exploit the medium to high temperature zones is of particular importance for Europe. Geothermal power plants for heat and/or power generation can play a major role as base load in the energy supply system. An end user will accept geothermal energy if its consumer prize is competitive. The costs for the installation of geothermal plants can be reduced by at least a factor of three. Two thirds of the costs of geothermal plants are associated with drilling the wells, so great efforts must be made here. The main fields of costs reductions are: exploration, drilling and completion, reservoir stimulation, heat to power conversion. To achieve these goals the following technological research is needed:

Photo: © BESTEC

Geothermal Data Acquisition and Preliminary Investigations

Methodological and technological developments

- Re-interpretation of existing geophysical, geological and geochemical exploration data (surface, borehole) as well as additional laboratory experiments to identify statistical representative key values (mean squares, standard deviations) of physical rock properties
- Evaluation of technical and financial conditions for a further use of existing boreholes and mines for geothermal exploration
- Improvement of (geophysical, geological, geochemical) data acquisition and analysis
- Improvement and/or development of tools for geoscience's data acquisition and analysis.

Drilling, Stimulation and Reservoir Assessments

Methodological and technological developments in drilling

- Development of innovative drilling technology for exploration and preliminary reservoir assessment: e.g. micro drilling
- Drilling for reservoir development and exploitation: breakthrough methodologies (laser drilling, fusion drilling..)
- Direct drilling methods to connect converging boreholes
- Completion techniques: integration of fibre-optic cables, enhancement in heat transmissibility of cements (under laboratory and in-situ conditions) etc.
- Optimisation and development of in-situ measurement technologies
- Development of data interpretation methodologies: e.g. electrical borehole tomography.

In-situ analysis of reservoir properties, modelling of geothermal reservoir behaviour and management

- Optimisation and further development of numerical tools for systematic measurements of the thermal, chemical, hydraulic and mechanical long term behaviour of geothermal facilities (especially hydrothermal and EGS facilities)
- Development of numerical modelling tools to enable modelling of the long-term geothermal reservoir's behaviour (including economically viable options for reservoir management). Using recursion formula optimised tools would deliver improved (in-time) predictions by comparing in-situ data (drilling, pumping,.. results) with geophysical, geological, geochemical information
- Scale relevant experimental investigations of the principal processes dominating the geothermal reservoir behaviour under energy extraction in terms of optimisation of available resources.

Stimulation

The aim of the stimulation by fraccing is to increase the geothermal energy production by increasing the surface of the natural heat exchanger. Fraccing and production processes are hereby monitored by innovative monitoring techniques. This means control and management of the fracs' creation, maintenance and restoration of fracs as well as supervision of energy production.

Techniques/Contents:

- Optimisation of stimulation technologies: costs reduction for hydro fraccing; improvement of innovative stimulation methods (physical, chemical.)
- micro seismic / passive seismic, localisation and seismological assessment of cracks, determining of crack parameters
- resistivity monitoring, resistivity tomography, monitoring electrical potentials by kinetic and chemical processes
- developing a slim-line high temperature directive borehole radar to investigate structure and extend of geothermal usable strata
- development of sensors (physical parameters, chemical tracers' analysis) and data transmission techniques to be used in deep geothermal boreholes
- development of soft- and hardware (e.g. high temperature packers.....)

Exploitation, Economic, Environmental and Social Impacts

- Handling of heat-carrying fluids and direct vaporisation
- Development of holistic concepts for the management of geothermal resources: combination of funding and feed-in, combination of house heating and cooling
- Systems analysis: impacts on society when using geothermal energy (acceptance, availability, cost calculation, CO_2 reduction aspects, ..).

Risk Evaluation for the Development of Geothermal Energy

- Quantitative estimation of the risks (e.g. costs and capacity) by use of geothermal energy (EGS, hydrothermal, geothermal heat pumps) especially by involving technical quantities (e.g. rock specific drilling progress) analogue to methods in the oil industry.

Demonstration Plants

There is a special need for demonstration plants:

- Pilot plants: These plants will demonstrate the "normal" use of geothermal energy as reliable heat and/or power producer and should be implemented in the public heat and/or electricity net. They serve as test platform (e.g. for an energy supplier) and will deliver first of all operating data. Besides optimisations can be done under normal operating conditions
- Researchers test facility (or plant): There is a further need of these platforms for knowledge transfer to young scientists and for testing several new techniques e.g. new stimulation, operation and monitoring techniques etc.

Supercritical Zones in Geothermal Fields

The long-term evolution for geothermal resource exploitation concerns the supercritical zones of geothermal fields. Very high temperatures (up to 500°C) have been recorded at relatively shallow (< 4 km) depths in Italy, Iceland and Japan. Other systems are likely to exist at drillable depth in the West Indies, the Azores Islands and perhaps in Greece and Turkey. Such reservoirs could deliver very high enthalpy fluids with high flow rates due to the low viscosity of supercritical water. These supercritical geothermal fields hold very high risks concerning the physical controllability of these very high temperatures and pressures. Indeed the exploitation of these zones will open new fields in materials' research.

MARINE ENERGY

Around 71% of the Earth's land mass is covered by sea and oceans, and the potential opportunities to harvest the abundant renewable energy resources that these contain is vast, estimated at between 1 – 10 terawatts globally. The paper summarises EUREC's views on the marine energy FP7 research priorities. Wave and tidal devices face many similar technical challenges. Therefore common themes have been denoted that are applicable to both wave and tidal areas, as was done in FP6 OCEAN ENERGY Calls.

During the lifetime of FP6 the marine renewable sector has made significant progress. Deployment of, in some cases, grid connected full-scale prototypes in open water has demonstrated technological capability to harness marine renewable energy. These include the Archimedes Wave Swing and Pelamis wave power machines and StringRay, Seaflow and Hammerfest Strom AS tidal power devices. Additionally, the European Marine Energy Centre (EMEC) on Orkney has developed extensive infrastructure resulting in a dedicated Marine Renewable Open Sea Testing Laboratory. The diversity of deployed machines shows the sector is still relatively immature and at this stage it is not clear which technology types will gain market dominance.

R&D Targets for FP7

Despite many milestone achievements within the industry, the 'step' change of delivering financially viable technologies and power generation projects using marine renewables has not yet been achieved. Whilst the deployment of full size prototypes has demonstrated capability it also has focused attention on the issues that still need to be addressed in order for the commercial success and wide spread adoption of marine renewables. Following the realisation of single unit demonstration projects, it is recommended that the focus of FP7 aims to facilitate 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.

Electrical Network Integration

Given the intrinsic nature of marine energy sources the onshore distribution network must be able to cope with an intermittent power supply. Research into mitigating these impacts on local supply quality and network infrastructure determines onshore electrical infrastructure requirements. Also greater understanding of their mechanical and electrical controllability will assist network integration and deployment.

Energy Capture and Resource

Much work has been undertaken relating to establishing robust estimates of the total European marine resource assessment via programmes of activities such as The European Wave Energy Atlas (WERATLAS). Whilst total energy resource estimates are widely accepted within the Community, estimates as to the attainable and grid connectable resources are more subjective and mobile given the emergence of new technologies and increasingly detailed understanding of those in existence. Established methodologies that allow a greater understanding of the nature and magnitude of the recoverable, sustainable and deliverable marine energy resource would be very useful for the sectors development.

Environment

The environmental impact upon marine ecology of the wide scale implementation of marine renewables is not understood. Issues of noise and vibration due to piling, sediment disturbance due to cable laying, AC electrical signal interference, sediment transportation changes, fishing breeding ground interference and impact on mammal and bird life require further study.

Photo: © Ocean Power Delivery Ltd.

The FP7 should facilitate continued prototype development and pave the way for the deployment of demonstration multi device farm projects.

Photo: © Wavegen

Design Tools

Work to increase the reliability, functionality, accessibility and acceptance of new and existing design software would increase confidence in the performance of deployed prototype marine renewables. Software methodologies that increase the confidence of marine energy prediction and quality of design information will lead to better conceptual and physical designs, choice of materials, manufacturing processes and prototype and production devices. In particular the extension of performance prediction and modelling software into non-linear conditions will allow better assessment of reliability and survivability.

Testing Standards

In order to achieve successful and mature marine energy concepts it is necessary to develop 'products' via scaled prototyping. This results in initially building small model through to ultimately construction full-scale models for deployment in the sea. Therefore it is highly desirable to establish robust guidance procedures for the design, development and evaluation of marine renewables. This will result in advancements in the science of performance measurement, solving scaling problems and establishing improved testing protocols.

Economic Modelling

The creation and validation of robust lifetime economic models applicable for marine renewables will provide greater assurances and increased confidence in the investment community and assist the marine renewables towards commercial implementation.

Foundations and Mooring

Historically much work has been done in other marine sectors in respect to mooring. Considerable knowledge would be gained by adapting these systems to create generic models of both active and passive mooring systems for marine renewables. Also many proposed shallow water technologies make use of mono pile techniques to secure devices to the seabed. Scouring around seabed structures requires further investigation.

Operations & Maintenance

The realisation of demonstration farm projects presents a variety of issues associated with the safe and cost effective installation, operation and decommissioning of both floating and submerged structures in the marine environment. Given that access to remote marine installations is subject to climatic, time and cost restrictions, the design of marine renewable technologies must balance the costs of system reliability versus access for scheduled and emergency repair and maintenance. In addressing these issues there is an opportunity to examine the suitability of existing methods used in the oil and gas and offshore wind turbine industry so techniques and methodologies may be adapted to the specific needs of marine renewables.

Photo: © Ocean Power Delivery Ltd.

SMALL HYDROPOWER

Small hydro has important untapped renewable energy potential, which could be rapidly developed. Although small hydro is generally considered a mature technology, the industry needs continuous infusions of new ideas and technology to ensure that small hydro maintains and enhances its contributions to the emissions-free, indigenous electricity generation Europeans are seeking, and that hydro facilities operate in harmony with the environment.

The main challenge to the acceleration of its development consists in reconciling economy and ecology. It is therefore necessary to develop equipment, methods and mitigation measures which simultaneously satisfy the criteria of easy environmental integration, simplicity, efficiency, and reliability so as to lower the break even point, through better use of available resources, and the decrease of construction, operation, and maintenance costs.

Contrary to the generally accepted idea that hydropower is an old energy that has reached such an experience that it cannot be improved; small hydro has still a scope to evolve, especially in equipment and design practices.

Public funding is needed to support industry in its efforts to bring about a breakthrough in favour of this environmentally friendly technology for the following reasons:

- Hydro R&D is very expensive, especially in hydraulic-turbine laboratory development, and the construction of civil-engineering scaled physical models for testing the performances of the hydraulic structures
- Small-hydro development requires multidisciplinary R&D involving technological know-how that is widely dispersed in Europe
- Small-hydro R&D is consistent with the Commission's objectives for the rational use of energy, improvement of energy security, and reduction in the emission of CO_2 and other pollutants, and increase in industrial competitiveness.

Photo: © VA Tech

It is therefore essential to co-ordinate small-hydro R&D, 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 the framework of true research programmes.

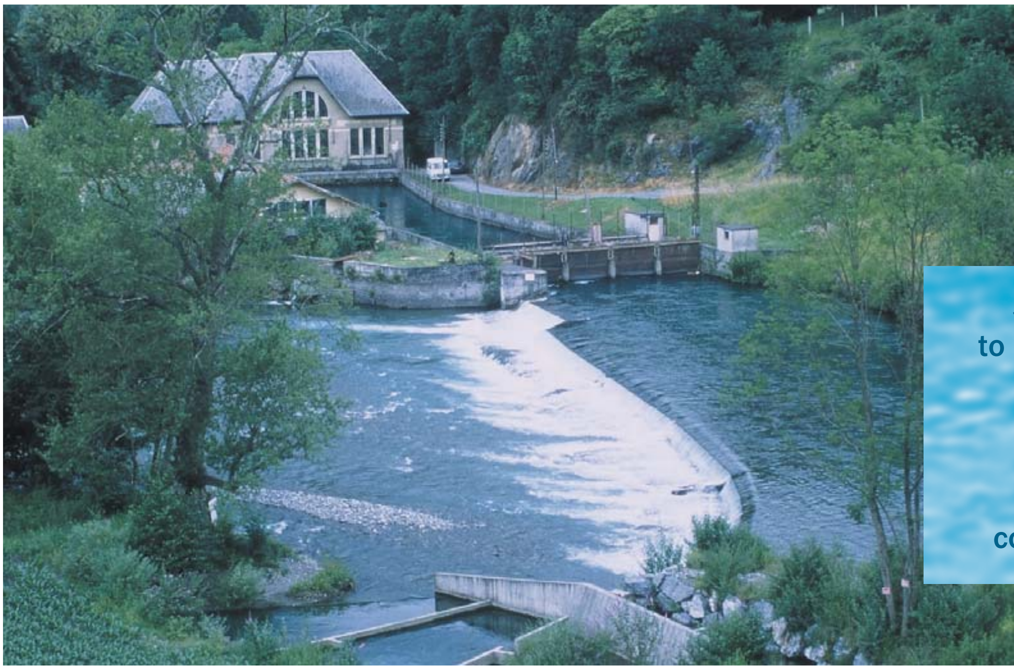


Photo: © ADEME

Small hydro still has a scope to evolve, especially in equipment and design practices. A further coordination and systematisation of European research programmes would contribute to reach these goals.

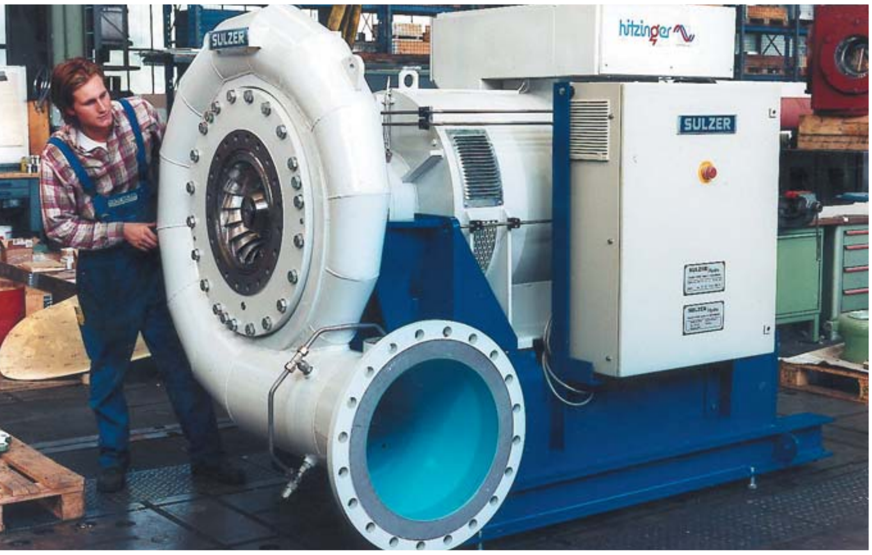


Photo: © VA Tech

R&D Targets for FP7

In the short and medium term:

- Development of good-practice design guidelines for developers and engineers (Develop a systematic project-development method, a preliminary-project design-software, etc.)
- Development of standards and control procedures dedicated to small hydro
- Awareness campaigns to assist in understanding the technology, and promote better acceptance of small hydro
- Awareness campaigns to support the development of multipurpose projects
- Development of software that allow a fast and efficient civil work design
- Adaptation of high pole permanent magnet excitation generators to small hydro
- Development of low speed generators (direct-drive low-speed generators for low heads)
- Development of standardised control and monitoring hardware packages
- Development of standardised control and monitoring software that can be easily customised for a site-specific use (graphical user interface, improved monitoring and data analysis, etc.)
- Development of submersible turbo-generators
- Development of compact equipment which require the laying of few, if any cofferdams
- Development of integrated design rules, taking environmental issues in consideration
- Development of specific bioengineering techniques in the field of SHP
- Further investigation on a strategy of handling trashrack material
- Guide on the design of power houses
- Development of a checklist on the environmental integration of existing plants
- Development of plant performance tests for existing small hydropower plants.

Photo: © VA Tech

In the long term:

- Improvement of hydrological assessment methods (development of low cost but efficient measurement techniques and hydrological site evaluation software)
- Definition of correct minimum residual flows and/or appropriate flow conditions (Compare existing methods, and, if necessary, develop new ones)
- Support integrated design (Development of a water-to-wire strategy)
- Development of standardised/systemised hydraulic structures
- Development of efficient desilters with high head intakes, of self-cleaning water intakes, and of trashracks
- Cost reduction in penstock set-up (R&D on assembly and laying-down techniques, as well as on materials)
- Development of head-enhancement techniques for very low heads

Photo: © Österreichischer Verein für Kleinwasserkraft

- Development of appropriate turbines design suitable to electrical output below 1MW (according to simplicity, reliability, operational and performance guarantees criteria)
- Tests of new construction material
- Development of variable-speed operation (Optimal use of low and variable heads sites)
- Development of screening systems for downstream and upstream migrating fish (fish passes, fish-guiding systems)
- Development of standard and objective methods for environmental-impact assessment
- Development of guidelines on how to optimise residual flow demands by means of river rehabilitation
- Integration of decentralised electricity production from small hydropower in the grid
- Research on networking strategies for clustering SHP plants management
- Flexible small hydro turbines for very low head (<5 m).

Solar Buildings

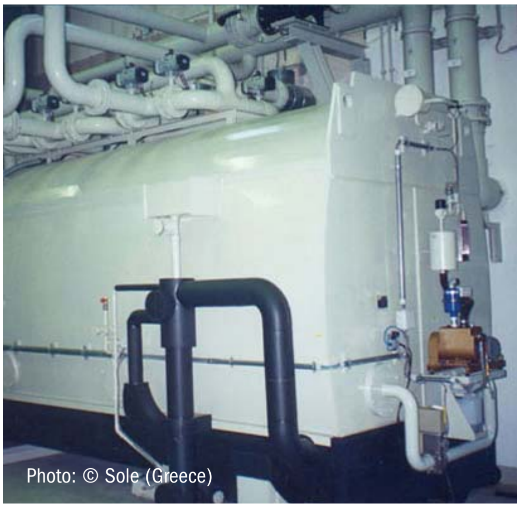


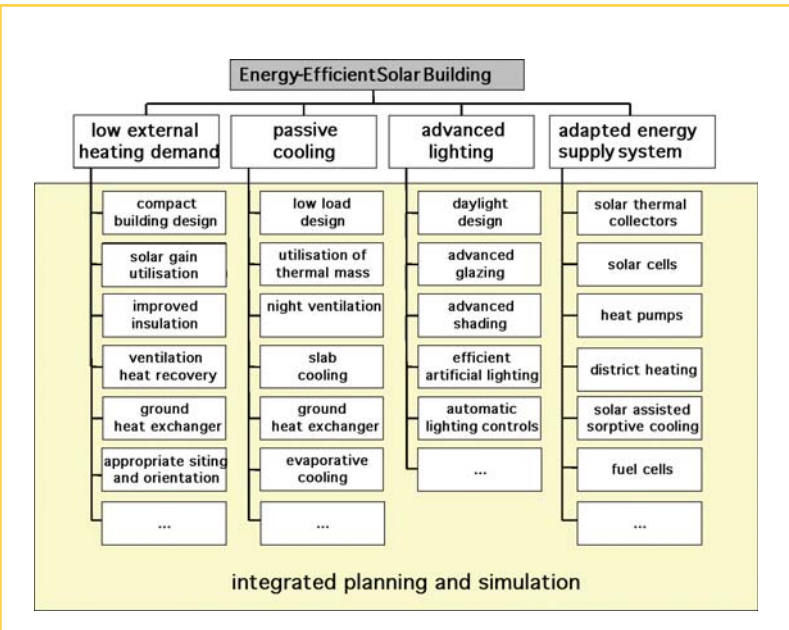
Photo: © Sole (Greece)

Despite the diversity of individual life styles in the EU member states, about a third or even more of the total final energy consumption in Europe is used to heat, cool and light buildings. To reduce the related high carbon dioxide emissions in the building sector a new class of buildings has been realised in the past decades. These *"solar buildings"* or *"lean buildings"* exploit naturally available energy sources in order to provide increased visual and thermal comfort for their inhabitants while at the same time reducing the energy demand.

Architects and their clients have a wide range of options to choose from when designing a solar energy building (see figure below). The result should be an innovative concept that follows a holistic approach, i.e. combining intelligent architectural approaches, energy efficiency measures, an advanced control of the incoming solar gains and solar assisted energy supply systems. The related R&D requirements can be divided into integrated design aspects, system technologies, and technological and conceptual improvements to the building envelope. All these tasks have a medium- to long-term R&D agenda associated with them, which should be accompanied by short- to medium-term demonstration programmes. For the latter, the special investment character of the building sector – i.e. investment decisions followed by a rather tight time schedule for design and construction – should be taken into account and increased flexibility ensured for the related contracts.

Further ambitious R&D and related legislation will help to make the following **roadmap** a reality:

- By 2010 new residential buildings in the EU will not need more than 60 kWh of external primary energy per year per square metre for heating, cooling, lighting and other building services. Office buildings will not need more than 100 kWh/year/m^2, and the target for retrofitted residential buildings will also be 100 kWh/year/m^2
- By 2020, 40% of all buildings in the EU will be below 100 kWh/year/m^2. This also implies an ambitious retrofitting rate for the existing building stock. The standard for new residential buildings in 2020 will be 45 kWh/year/m^2
- By 2050, new buildings in the EU will not use more than 30 kWh/year/m^2. At the same time, 50% of the existing building stock will reach values below 60 kWh/year/m^2.



R&D Targets for FP7

R&D on Integrated Design

Designers have important opportunities to closely integrate considerations of architecture, sustainability, solar gains and energy efficiency. These considerations include much more than just engineering systems that heat, cool and light the interior so that satisfactory indoor conditions are provided. In fact, the occupants, their living and recreation and working places, and the outdoor environment must be considered in an architecture which seeks to utilise ambient energy sources and seasonal and diurnal outdoor changes to reduce reliance on mechanical and electrical systems. The following R&D-fields are suggested:

District Heating, 90-Days' Central Heat Storage

As the energy consumption of buildings decreases, the question of how to optimally satisfy the remaining demand becomes important. Here, district heating systems make the application of particularly optimised energy supply systems possible. Further R&D is needed for example into both systems and control strategies as well as low temperature heating systems and long-term heat storage (see also "seasonal storage" below).

Improved Statistical Procedures for Solar Gains

Integrated design architecture and technical approaches such as nocturnal ventilation for cooling purposes are often termed "passive". This is misleading, however, as they do actively contribute solar gains to the energy balance of a building. It is important to develop better instruments to quantify and report these solar gains (e. g. through Eurostat) because these are widely underestimated and often even neglected.

Tools for Integrated Design and Urban Planning

To integrate consideration of the occupants and the outdoor environment in an architecture which uses ambient energy sources and seasonal and diurnal outdoor changes to reduce reliance on mechanical and electrical systems requires design support tools considerably more sophisticated and user-friendly than those currently considered. Furthermore, in order to follow a truly integrated approach, buildings and their surroundings must be designed so that each supports the other. Streets and neighbourhoods must also receive attention, including the reflections and glare from the buildings within them, insulation and shading, planning implications of single-sided housing layouts, and so on. As addressing mainstream construction and urban planning simultaneously remains a major challenge, R&D has a role in providing appropriate design tools.

Pre-Designed Buildings Elements

Ready-to-order, pre-designed building elements that include for example solar thermal or photovoltaic approaches would make it easier for architects and building designers to integrate such technology into the building concept. The development of such "solar construction elements" is thus proposed as a way to increase the solar fraction of a building's energy balance.

Healthy Indoor Environment

Warm, well ventilated, naturally lit "solar buildings" often provide healthier indoor environments than conventionally designed buildings and those who use them appreciate this advantage. The results of a rigorous assessment of the benefits of the indoor environment of "solar buildings" could increase their popularity with the public. Related research in this area should be accelerated.

Improved Strategies for Better Knowledge Transfer

The whole process from the start of design to the end of construction is shaped to a large extent by traditional practice and convention, with the adoption of new practices often only playing a role at the margin. The knowledge transfer between different stakeholder groups therefore needs to be improved, and related barriers and strategies should be investigated. In particular, there is a need for better demonstration programmes with an emphasis on replicability, post-occupancy evaluation and information dissemination.

Broad Life-Cycle Assessment Analyses, With a Special Emphasis on CO_2-Mitigation

For the foreseeable future climate protection will remain high on Europe's political agenda. At the same time, policy-makers are now increasingly interested in buildings that are in a broader sense 'green'. These considerations might relate to mains water use, construction materials, the health of the indoor environment or the health of the 'social connectedness' of the community of which it is a part. Each of these areas has a research agenda associated with it.

Passive energy house, © Austria Solar/Bramac Dachsysteme International

R&D on System Technologies

The performance of technical equipment is a determining factor in the overall energy consumption of both office buildings and residential houses. While improved efficiency is a key driving factor for improvements, other issues like technical equipment that is well-suited for reduced overall energy consumption are also very important. The related R&D priorities regarding solar heating and cooling technologies as well as building integrated photovoltaics (BIPV) are covered in separate papers. Further topics that are not covered by these headings are listed below:

Demand Side Management

Demand side management concepts help energy consumers choose the best moment to take energy from the electricity grid or gas distribution network in such a way as to stabilise the inflows and outflows of energy from these networks. With growing penetration of distributed, fluctuating generating capacity in the grid, the incorporation of such systems in building components is an area that must be developed further.

Novel HVAC (Heating, Ventilation, Air Conditioning) Concepts, Micro-CHP

Issues for further R&D into combined heat and power ("CHP") plants include novel HVAC technologies adapted to meet the remaining energy demand of low energy houses (e. g. compact ventilation units including small exhaust air heat pumps, Stirling engines, reciprocating engines, micro-gas turbines, fuel cells, small geothermal heat pumps) and their operation control strategies.

Optimised "Adaptive-" and "Predictive Control"

"Predictive control" is a mechanism that enables technical building equipment to anticipate future perturbations to the internal environment (such as changes in solar gain or room occupancy), while “adaptive control” stands for control systems that are able to progressively adapt themselves to the building, its users’ preferences, and the outdoor climate characteristics. Related control strategies must be further developed and integrated into embedded systems for building energy management systems (BEMS).

Advanced Seasonal Heat and Cold Storage Concepts

Solar district heating systems with a seasonal storage facility could cover 80% and more of today’s thermal energy. In this context, the term “seasonal” initially stood for a period of many months, while the decline of the energy needs of buildings has reduced the necessary time period to approximately 90 days. Thus, the development of this promising approach must continue to be an important area of research that also includes advanced sorption storage. The concept must be also extended to seasonal cold storages.

switchable optical transmission properties. Research and development efforts should focus on

- advanced switchable glazing concepts that reflect the light instead of absorbing it,
- angle selective coatings in the form of microstructures that show a high reflectivity of incident light at high solar altitudes and yet a high transmittance at near-horizon angles,
- multi-functional surfaces that modify the optical or adhesive properties of the treated surface to make it, for example, spectrally selective, minimally reflective and self-cleaning.

Multi-Functional Façades, Novel Shading Devices, and Advanced Day-Lighting Concepts

The control of heat flows and solar gains through windows is far from being the only issue regarding improved façade design. A few further examples from a wide range of advanced design aspects for which further R&D efforts are necessary include novel concepts for mechanical shading devices, better use of natural radiation for lighting, advanced ventilation concepts including air pre-heating, and building integration of PV and thermal elements which is the key to a widespread use of solar energy in buildings.

R&D on the Building Envelope

Improved building envelopes can generally contribute significantly to reduced energy consumption for both residential and non-residential buildings. The following points are recommended for further R&D:

High-Performance Insulation Technology

Novel thermal insulation systems can reduce thermal conductivities by more than ten times compared to conventional materials. Such systems based, for example, on second-generation vacuum panels should be further optimised under future R&D programmes.

New Thermal Storage Materials

The thermal mass of building structures is very important for an optimised energy performance. Microencapsulated phase change materials (“PCM”) and related slurries can be important for passive cooling and used for effective heat and cold transfer in buildings. Further R&D into these materials is necessary.

Advanced Windows

As windows are the components with the highest energy transfer in the building envelope, an improved management of the incoming solar gains is desirable. The focus of future developments must be turned to

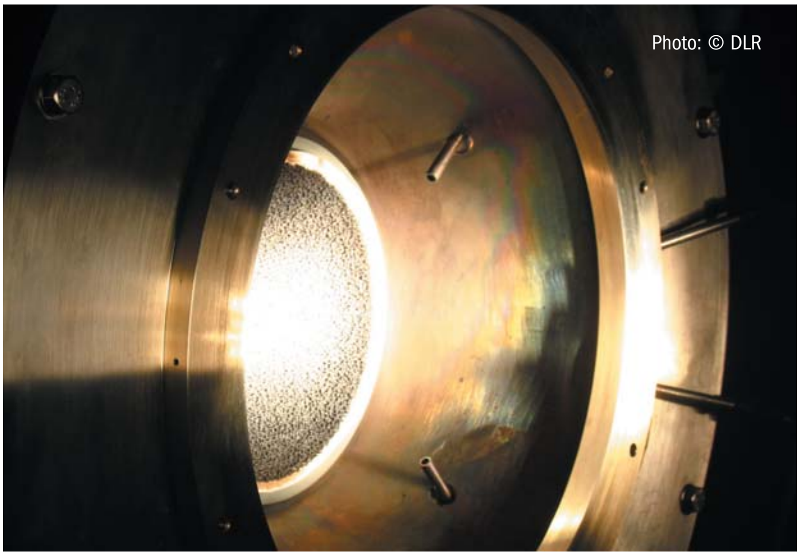
A holistic approach : combining intelligent architectural efforts, energy efficiency measures, an advanced control of the incoming solar gains and solar assisted energy supply systems

Fraunhofer-Gesellschaft's headquarters in Munich: the innovative double-skin façade developed by FhG ISE allows for natural ventilation and cooling without mechanical ventilation technology or a chiller. The concept includes an intelligent sun-shading approach and thermally activated ceilings.

SOLAR CHEMISTRY

The ultimate goal of solar chemistry is the chemical storage of solar energy to make this energy source available regardless of time and location. In the longer term, fossil fuels as required for the conversion of crude feedstock or 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. Seasonal adaptation of energy demand and supply is possible, and remote places without grid connection or mobile applications can be individually served, which in many cases is not possible on the basis of electricity. In addition, there is an inherent thermodynamic advantage of using concentrated solar power at high temperatures as the energy source of process heat to drive thermo-chemical reactions. High efficiency processes lead to economic competitiveness.
Additionally, for the short- to mid-term, there are potential niche applications for solar detoxification of polluted waters and hazardous wastes, for solar photochemical production of speciality chemicals, and for solar materials processing.



Aperture of receiver-reactor for the solar thermo-chemical splitting of water

R&D Targets for FP7

Production of Solar Fuels

Of special interest is the solar thermo-chemical production of hydrogen. Here, the main routes are thermolysis, thermo-chemical cycles, cracking, reforming, and gasification. The complete substitution of fossil fuels with hydrogen (H_2) is, evidently, a long-term goal. A viable mid-term strategy aims at the development of hybrid solar/fossil endothermic processes in which fossil fuels are used exclusively as the chemical feedstock for H_2 production and concentrated solar power is used exclusively as the source of process heat. Important examples are the endothermic reforming, cracking, and gasification of carbonaceous materials.

The integration of solar concentrating technologies with reaction systems capable to thermo-chemically split water at reasonable temperature levels can be of immense value and impact on the energy industry and economics worldwide

The most matured technology is the reforming of natural gas. Its technical feasibility has already been demonstrated at an engineering scale applying different reactor concepts.
Beyond that, promising technologies offer even now the potential for solar hydrogen production completely free of emissions and free of fossil fuel inputs. The integration of solar concentrating technologies with reaction systems capable of thermo-chemically splitting water at reasonable temperature levels can be of immense value and importance to the energy industry and economics worldwide. New approaches for technologies and materials used for solar operated thermo-chemical cycles need to be followed, in particular for cycles based on metal oxides and sulfur compounds. Economic analyses indicate that the solar thermo-chemical production of hydrogen can be competitive with the electrolysis of water using solar-generated electricity, and, under certain conditions might even become competitive with conventional fossil-fuel based processes at current fuel prices, especially if credits for CO_2 mitigation and pollution avoidance are taken into consideration.

Solar Detoxification

A promising field of application of non-concentrated sunlight is the detoxification of seriously contaminated water and gas streams that cannot be treated by conventional and simple means like biological digestion.
It is current practice to purify these toxic fluids using physico-chemical treatment processes like phase transfer technologies, i.e. stripping, extraction, adsorption, thermal treatment processes or advanced oxidation processes. Titanium dioxide and Fenton's reagent, combined with solar radiation are the best way to achieve complete detoxification using renewable energy.

Pilot plant for the photochemical synthesis of fine chemicals

Research should focus on cost reduction by developing cheaper and more efficient systems. This comprises the development of photocatalysts and sensitizers with larger solar efficiency and productivity and improvements in reactor technology. Further improvement is also necessary with respect to the combination with separation and other treatment technology to develop integration strategies of solar detoxification units as a part of a purification plant. Testing of new application areas, scale-up and demonstration studies are and will be necessary to facilitate market introduction.

Solar Photochemical Production of Chemicals

In solar photo-chemical processes, solar energy is used instead of lamp-operated processes. Studies have shown that operation and maintenance costs can be significantly lowered with solar photochemical processes, since drawbacks of the lamp technology, such as low lamp efficiency and short lamp life, can be avoided.
The most promising examples of fine chemicals production are the various applications of singlet oxygen that is obtained from normal oxygen by photochemical sensitization. Hundreds of compounds can be formed by means of singlet oxygen, including popular examples such as expensive fragrances like rose oxide, but also precursors for chemical commodities like pesticides, pharmaceuticals and other active compounds or ingredients for varnishes. Another highly efficient example is the photo-nitrosation of cycloalkanes that leads to direct precursors for nylons which are important technical polymers being produced every year at a multi-million ton scale.
Reactor technologies for such applications comprise concentrating technologies like troughs, dishes and solar furnaces but also non-concentrating reactors like double or triple skin sheets or tubes with or without compound parabolic concentrators. Several receiver materials have been tested.
In addition to improvements in receiver technology, e.g. for heterogeneous reactions, operational aspects have to be improved to reach higher efficiencies. Chemical aspects, like the systematic search for relevant applications, adaptation of known photochemical systems to solar conditions and the development of new photocatalysts and sensitizers are necessary to develop further this application field, which can deliver a valuable contribution to the current chemical research on renewable synthetic processes ('green chemistry').

Solar Materials Processing

Concentrating solar technologies can also be used beneficially for manufacturing, testing, and thermal treatment of materials. In solar thermal concentrating plants, process heat can be obtained at high temperature levels. For example, central receivers have already been developed in a multi MW scale for temperature in the range of 500-1000 °C and in an experimental scale for temperatures up to 2000 °C. In parabolic dish concentrators and in solar furnaces temperatures even higher than 2000 °C can be reached. It is thus useful to investigate whether such plants - in addition to solar thermal electricity production - may be used to combine power generation with the energy demand for the established high temperature processes in the primary industry or sea-water desalination. Regarding the production of raw materials and secondary raw materials, solar heated processes provide the combined advantages of lower fossil fuel consumption and drastically reduced amounts of exhaust gases, which may significantly reduce the overall investment costs. Investment cost for exhaust gas treatment may exceed 50 % of the total investment.

Outlook

For the near term future, first industrial applications of solar chemistry can be expected, such as solar steam reforming of natural gas, photo-chemical production of speciality chemicals, detoxification of specific hazardous wastes streams (e.g. polluted water), or testing and processing of materials. Some market niches relating to these applications have already been identified.
Mid- to long-term developments should aim at completely carbon-free technologies, in particular in the field of solar hydrogen. Further improvements and large-scale demonstration of promising routes for solar thermo-chemical splitting of water can open this path.
Required technological developments include improved receiver design and components, intelligent operation strategies, specific measurement techniques and, most importantly, cost reduction of hardware and products.
While developing the first applications, specific know-how in solar chemical engineering will also be established and experiences gained, which are required to carry out a wider range of solar chemical bulk processes.

SOLAR PHOTOVOLTAICS

In the photovoltaics sector, research priorities are set in the context of recent developments in Europe. The Commission initiated the process of establishing a Technology Platform by setting up the Photovoltaic Technology Research Advisory Council, which produced a booklet called *'A Vision for Photovoltaic Technology for 2030 and Beyond'* in the summer of 2004. EUREC Agency and EPIA responded to the consultation on this Vision, and the research priorities outlined below are in line with the Strategic Research Agenda and the technology targets presented in that document.

The implementation objectives and the route map for achieving these targets are contained in the Vision Report. These include the halving of electricity costs from PV in the 2010-2015 timeframe and a 3 GW_p installation target in Europe by 2010.
Over the last year, there has been an ongoing dialogue between EUREC-Agency, representing many of the major European PV research centres, and EPIA, the trade association for the European photovoltaic industry, in order to define a common research and development agenda to strengthen the European position both in the short and long term. Quantitative R&D targets, short, medium and long-term priorities, along with an overall budget can be found in the Annex.

Photovoltaics is a proven technology with a high potential for contributing to a clean, secure energy system for Europe. Over the last few years, it has shown a rapid growth rate at over 30% per annum in the worldwide market, in which European companies strongly participate. The technology is applicable to a wide range of system sizes, from milliwatts to multi-megawatts, although perhaps the most attractive short-medium term applications are for distributed generation of electricity on the kilowatt scale, both grid-connected and autonomous. However, an overall challenge to reduce costs of PV generated electricity substantially remains, and this requires research into cell materials and processes, module design and production, system components and all aspects of system implementation.

Research priorities relate to advancing existing technologies for cells, modules and systems in line with the medium term objectives of the Strategic Research Agenda to ensure progress along the whole supply chain

R&D Targets for FP7

Within the FP7programme, research priorities relate to advancing existing technologies for cells, modules and systems in line with the medium term objectives of the Strategic Research Agenda, together with some activities to develop the research base required to meet the longer-term targets. In all cases, the scope needs to encompass both development of techniques and of the equipment required to implement those techniques. The strategic programme needs to include both component development and the complementary systems development necessary to ensure progress along the whole supply chain.

Cell Technologies

Crystalline Silicon Technology

- Reduction of wafer thickness
- Designs for increased efficiency
- Module development (reduced material consumption, lifetime extension, recycling and waste minimization)
- Low cost, high throughput processing
- Developments in manufacturing – epitaxial processes, wafer equivalents

Photo: © Q-Cells

Thin Film Materials

- Processes and equipment for high yield, low cost manufacturing
- Large area modules, new module concepts
- Reduction of material consumption, replacement of sensitive materials (scarcity, environmental issues)
- Multijunction and increased efficiency concepts
- Transparent conducting oxides (low cost, tailored to device requirements)

New Cell Concepts

- Lifetime and efficiency advances for organic and polymer cells, together with targeted research on processing proof-of-concept
- High efficiency concepts such as III-V concentrator cells

Systems and Implementation

- Building integrated photovoltaics – product designs, concepts for multifunctionality, simplified installation procedures
- Inverters – extension of lifetime, cost reduction
- Energy management systems for both grid connected and stand-alone systems
- Grid connection issues – intermittency, control and stability

Photo: © RWE Schott

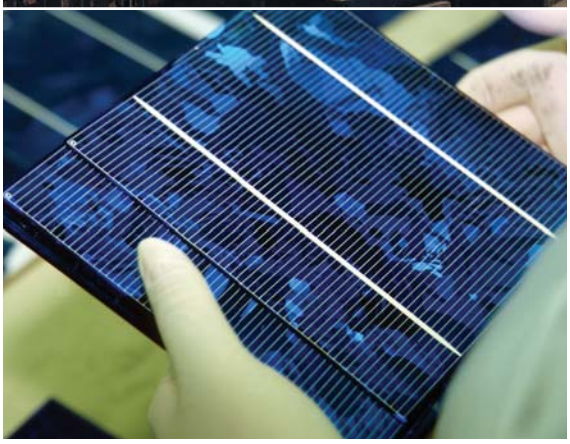


Photo: © Q-Cells

Photo: PV reaction chamber, © HMI

- Storage concepts with low cost, especially for short term storage in regard to grid connected systems and long term reliability for stand alone systems
- Concentrator systems – reduction of cost, reliable tracking systems, compact designs
- Hybrid systems and products – integrating PV with other energy technologies and services
- Socio-economic aspects e.g. regarding solar home systems in developing countries

Standards and Certification

- Both at the component (wafer, cell, module and BOS) and the system level, activities related to standardisation, certification and quality assurance (including training and maintenance issues)

Emerging Ideas

Whilst the list of topics above represent the priorities as decided by the EUREC/EPIA dialogue in PV Catapult, it should be recognised that in a rapidly developing field such as photovoltaics, new concepts and issues may arise within either the cells or systems area during the course of the FP7 period. It is recommended that part of the medium-long term budget be allocated to open tender proposals for relatively small projects, provided that they can demonstrate the potential for reaching the long term cost goals defined in the Vision Report. We notice that the German Federal Ministry of Education and Research, in its position on FP7 published on 26 November 2004, writes, "In order to be flexible enough to take up novel research areas and respond to new developments, a certain amount (about 10%) of the funds for each thematic priority area should be set aside for purposes to be defined later."

SOLAR THERMAL ELECTRICITY

Photo: © CIEMAT/PSA

Solar thermal power generation is in operation at nine Californian plants, based around huge fields of parabolic trough collectors. The plants were inaugurated 1986-1991 and have a combined maximum power output of 354 megawatts.

Strengthened by recent European R&D activities, the upcoming project opportunities are the first chance to move down the cost curve since the early commercial success in California. Due to the support in previous Framework Programmes, the European concentrating solar thermal power (CSP) industries are now in a world leading position to commercialise solar thermal electricity both within Europe and overseas.

CSP has the potential to provide large-scale solutions to global energy problems within a relatively short timeframe and to contribute substantially to carbon dioxide reduction efforts. Because of its relatively conventional technology, ease of scale-up and suitability for combined solar and conventional combustion operation, it can provide a major share of clean energy. If sufficient thermal storage capacity is installed, then these plants will be able to provide uninterrupted power to the customer without additional back-up plant capacity in the electricity grid.

The potential to provide electricity from CSP in Europe is concentrated on the Mediterranean area. With the available area suitable for CSP systems in southern Europe (Spain, Italy, Greece, France and Turkey) approximately 90% of the electricity requirements of EU-15's Member States can be satisfied. If electricity imported from Northern Africa is also considered, the potential is almost infinite compared to Europe's energy needs.

Different concentrator technologies have been realised:

Line-Focusing Collectors

In so-called parabolic trough systems, parabolic mirrors concentrate the direct sunlight onto absorber tubes to heat a heat transfer fluid (i.e. oil) which subsequently produces steam in a separate boiler; a more advanced option is to evaporate the water directly inside the absorber tubes. A conventional steam turbine is then powered by this high pressure steam at a turbine input temperature in the order of currently up to 400° C. Parabolic troughs systems are the only commercially proven technology today with installed collector fields of approximately 2.5 million m² and more than 15 years of operation experience..

Cost targeted innovation approaches appear to be a prerequisite to achieve competitiveness for concentrating solar power in the medium-to-long-term time frame.

The linear Fresnel collector is a special modification of the line-focusing technology. Here, the entire parabolic mirror is replaced by a large number of segmented flat mirror facets, which are suspended horizontally. As relatively inexpensive components can be used, this technology has the potential to provide competitive levelised electricity costs, despite higher geometric losses in comparison to parabolic trough collectors.

Solar Tower Systems

In these systems, sunlight is concentrated on a small area. The light is reflected to a central receiver on top of a tower by a large field of mirrors, so-called heliostats. Very high operation temperatures in excess of 1,000°C can be reached due to the high solar concentration factor. It is, therefore, possible to operate steam plants at elevated temperature or combined cycles (gas turbine plus steam turbine) to achieve very high efficiencies.

Parabolic Dish Systems

In this technology, direct solar radiation is also concentrated onto an absorber close to its focal point, but this time by a comparably small point-focusing reflector. Although a wide variety of thermodynamic processes can, in principle, be realised, systems using Stirling engines to produce electricity from the concentrated solar radiation are presently the most advanced. Parabolic dish systems are relatively small power generation units (5 to 50 kW_{el}), making stand-alone or other decentralised applications their most likely market.

With today's technology and component costs of CSP-systems, costs for bulk electricity production are projected to 15 - 20 cEUR/kWh for European irradiation conditions, and 10-15 cEUR/kWh for excellent sites, such as California. This competes at present with mid-load power from conventional power plants in the range of 4 - 5 cEUR/kWh, but these costs will undoubtedly increase in the forthcoming years due to increasing fuel costs and environmental requirements. Because of that, we may expect that a sustainable market integration of solar thermal electricity can be achieved, if the generation costs may be reduced in the next 10 to 15 years to

Photo: © DLR

a competitive cost level in the order of 8 cEUR/kWh. The European Union is convinced of the potential of this technology and currently supports the implementation of three demonstration solar thermal power plants in Europe (PS10, ANDASOL, SOLAR TRES) with a total sum of 15 million EUR.

The limitations of today's commercial solar thermal power plants are:

- For **parabolic trough** power plants the steam temperature is limited to 375°C due to the thermal stability of the required heat transfer medium, which limits the net power block efficiency to 35% (gross 38%) and the annual overall efficiency below 15%. Current R&D efforts have already demonstrated that direct steam generation can increase steam temperature and cycle efficiency and at the same time reduce costs.
- For **central receiver** systems higher temperatures may allow the combination with other highly efficient power cycles, such as combined cycles, and a better utilisation of heat storage. No commercial plant has yet verified the cost objectives projected for the solar components, above all the heliostats, since up to now there has been no experience with mass production. Current R&D efforts have prepared options to use the high-temperature potential with new generations of solar receivers. The first commercial central receiver plants currently erected in Spain will help to drive down costs by economies of scale and automated operation strategies.
- For **Dish Stirling** Systems "Mean-Time-between-Failure"-intervals achieved today are still considerably below the reliability figures needed for remote power applications. Current demonstration efforts present the first step to prepare autonomous operation.

In addition to continuous implementation of CSP power plants leading to cost-reduction by mass production and scaling-up effects, further substantial R&D activities are necessary to achieve the required overall cost reduction factor of 2 - 5. Cost-targeted, innovative approaches appear to be a prerequisite to achieve competitiveness for concentrating solar power in the medium- to long-term time frame.
The rate of development of CSP technology in Europe has, in the past, been held back by the inherent need of the technology for large-scale installations. Development and demonstration have to be performed in the Megawatt range, in order to obtain results with relevance for commercial application. Thus, a single development step requires large-scale test conditions and sufficient financial resources.

R&D Targets for FP7

The main goals for FP7 with regards to CSP technology should aim at the cost reduction of components and systems, through new developments and demonstration, with the target to reduce levelised electricity costs below 8 cEUR/kWh by 2015. Essential innovations for cost reduction are, for example:

Innovative Concepts for High Performance Light-weight Solar Concentrators

Approaches to be followed are: reduction of the specific concentrator weight using improved reflector materials and larger concentrator sizes, simplified line-focusing approaches (e.g. Fresnel-concentrators), factory prefabrication of elements without further alignment needs in the installation, more autonomous control schemes, cheaper mechanical drives, and a reduced number of tracking units per unit surface as well as micro-mechanical systems. Of additional importance are the development of more cost effective, durable reflector materials including composite and honeycomb structures, durable and highly reflective, long-lasting large-scale mirrors and also heat resistant secondary concentrators.

Innovative Low Cost Thermal Energy Storage Concepts

Low cost storage materials (like salt, quartz sand or concrete), high temperature phase change materials for heat storage at a constant operating temperature and new charging and discharging strategies are aspects which will influence the specific costs of thermal energy storage. Storage concepts for steam generated directly by solar collectors is required to exploit the cost reduction potential of the direct steam generation technology. Thermal energy storage in general increases the full-load capacity of the power plant and offers the capability to produce power on demand to increase the revenue.

Solar Receivers/ Absorbers

Receiver and absorber coatings for parabolic trough collectors are successfully introduced into the market for the presently exploited temperature range. To proceed with the trend to higher temperatures, further innovation is needed in the field of materials and surfaces to reduce thermal emissions and to withstand the higher loads at high temperatures in non-vacuum conditions specifically for central receiver systems.

Photo: © CIEMAT/PSA

Power Cycles

Large scale gas turbine power cycles operated by high temperature heat from power towers and using the waste heat in a steam cycle have the potential to double the annual performance of today's solar power plants. The combined heat and power approach may also significantly reduce the energy cost of these systems. The development of CO_2-free hybrid operation strategies (using biomass) offers greater flexibility and cost-reduction potential. The further development of Stirling-engine systems and their hybridisation are essential issues especially for dish systems. The automation of plant operation (including the solar field) is essential to reduce O&M costs. Direct steam generation with steam temperatures above 500°C is a promising cost-reduction approach for line-focusing collectors, offering integration in more efficient Rankine cycles. In addition, the adaptation of seawater desalination systems to the particular specifications of solar thermal waste heat (part load behaviour, optimised turbine outlet steam conditions, optimised operation strategies, etc.) would widen the scope of applications, significantly.
The combination of a steam producing solar collector and a conventional combined cycle plant should not necessarily be considered a better long-term solution than solar-only concepts that include thermal storage technologies. The reason for this is that the delicate balance between two combined-cycle sub-processes leads to extremely small solar shares when a steam producing solar collector is coupled to a conventional combined cycle plant.

SOLAR THERMAL HEATING & COOLING

The contribution of solar thermal heat to the world's energy supply has been strongly underestimated in the past. According to the IEA publication 'Solar Heating Worldwide' (2004) solar thermal collectors with an overall capacity of 70 GW_{th} were installed worldwide in the year 2001. The installed capacity in the EU-15 corresponded to approximately 10 GW_{th}.

Although a considerable capacity has been installed in recent years, most of the solar thermal systems are used for swimming pool heating, domestic hot water production and to some extent for space heating.
The use of solar thermal energy in large-scale residential buildings, for cooling and industrial applications or drying is currently insignificant.
The target set in the White Paper on renewable energy published by the European Commission in 1997 of installing 100 million square metres of solar collector area by 2010 will clearly not be reached, although solar thermal energy has the potential to meet the complete heating and cooling demand in the residential sector and to contribute significantly to the energy supply of the commercial sector.

Solar district heating, Schwarzenegger Stadion, Graz

Zero-emissions factory with 200 m^2 roof solar collectors

Low energy ski hut Masner, Tirol

R&D Targets for FP7

To reach the target mentioned above and maintain Europe's leading technological position in the field of solar thermal technology, an ambitious fundamental and applied R&D programme is needed, accompanied by demonstration. The main goals within FP7 should be to develop competitive advanced solar heating and cooling systems which are able to cover 5 -10% of the overall low temperature heat of the European Union in the medium term (2020).

The proposed research areas are divided in five main sections:

High Performance and Cost Efficient Materials for Improved Solar Thermal Systems

Fundamental and applied research is needed to develop:
- 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 glazing materials (e.g. new synthetics, embossing of suitable micro-structures into the surfaces of panels and tubes)

Material research is also needed on the thermal side of the solar thermal energy conversion:
- Materials and components to decrease the stagnation temperatures of solar thermal collectors without decreasing the efficiency in the temperature range needed
- Plastic materials for collectors with high thermal and optical performance that could significantly reduce the costs of solar thermal systems
- For the future development of solar thermal energy stores, advanced insulation materials are necessary and energy storage materials with a higher energy density than water have to be further developed. Promising technologies are based on phase change materials or thermo-chemical storage processes (e.g. sorption)

Advanced Solar Thermal Components: Collectors and Thermal Storages

- Advanced flat-plate collectors specifically designed for roof and façade integration
- New collectors for medium temperature applications up to a temperature level of approx. 250°C are necessary for new and challenging applications like solar cooling and solar heat for industrial processes.
- Photovoltaic-thermal (PVT) collectors
- Thermal storages

The potential for solar thermal applications in the housing sector and industry will increase drastically, once suitable technical solutions will be available to store the heat for the medium to longer (seasonal) term. Such advanced storage systems could utilise chemical and physical processes to reduce the total storage volume and the related costs.
The general aim should be to develop materials, components and systems that allow a reduction of storage volume by at least a factor of 3, compared to water.

Applications

Large-Scale Solar Combisystems for DHW and Space Heating

Solar heating systems for combined domestic hot water preparation and space heating, so called "solar combisystems", are increasing their market share in many European countries, but current designs are mainly focused on single-family houses. Therefore it is necessary to develop and to demonstrate solar combisystems of several hundred kW for multi-family houses. Also, large-scale applications for housing estates and solar-assisted district heating systems of several MW should be demonstrated.

Special focus should be on stagnation behaviour, net optimisation and net management with respect to solar thermal heat integration (reduction of the temperature levels in the supply and return pipe), optimised storage concepts (aquifer, bore holes, new materials...) as well as on the combination of solar thermal systems with central biomass heating plants and the integration into conventional district heating networks.

Development of cost efficient solar-only heating systems, covering 100% of the hot water and space heating demand of residential and commercial buildings

All solar combisystems for combined hot water and space heating on the market to date need a back up boiler. This leads to the fact that the additional cost of a solar combisystem can be compensated for only through fuel savings.

To reduce the cost of the overall heating system, it is necessary to develop solar-only heating systems. In combination with well-insulated houses and high energy density storage tanks, a solar thermal system will be able to provide 100% of the space heating demand of a building.

Solar Thermal Systems for Industrial Applications and Sea Water Desalination

The industrial sector has the biggest energy consumption in the EU countries at approximately 30%, followed closely by the transportation and household sectors. The major share of the energy, which is needed in commercial and industrial companies for production, processes and for heating of the production halls, is below 250°C. The unique features of these applications lie on the scale on which they are used. Appropriate system designs and controls are needed to meet industrial requirements. Furthermore design tools, medium temperature collectors and high performance storage tanks are needed for the efficient integration of the solar energy into industrial processes.

Cooling Applications

With increasing demand for higher comfort levels in offices and houses, the market for cooling has increased constantly over the past years. The obvious renewable energy response (providing the prime energy for these cooling applications through solar thermal systems) requires more R&D. In the small capacity range the component development of cooling equipment needs further R&D in order to a higher performance at lower prices using a more industrialised production. For all systems – small capacity for residential application and in small commercial buildings as well as in the large capacity range for large buildings and industrial applications – R&D is required in the following areas:

- cooling machines for low capacities and machines able to adjust to the solar thermal heat supply
- system design, integration and control
- providing best practice solutions with demonstration projects.

The main goals within FP7 should be to develop competitive advanced solar heating and cooling systems which are able to cover 5 - 10% of the overall low temperature heat of the EU in the medium term (2020).

Systems for Combined Space Heating and Cooling

The combination of solar space heating, hot water production and cooling has not been addressed so far. Such systems have a high market potential and, by extending the operational period of the collectors to the full year, they will dramatically increase the competitiveness of solar thermal technology through the combination of heating and cooling.

Building Integration

For a widespread market introduction of solar thermal systems, architectural aspects have to be taken into consideration. Solar thermal collectors have to become an integral part of the building, ideally becoming standard construction elements.

Furthermore, the impact of solar thermal systems on the building physics (i.e. façade collectors) and HVAC-systems are important factors and have to be investigated in more detail.

Standards, Regulations and Test Procedures

In order to support the further development and market introduction of solar thermal energy, it is necessary to provide, besides 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 practising architects are also needed. Furthermore, it is necessary to develop methods to assess the environmental benefits of solar thermal systems and to include solar thermal in today's building standards and legislation such as the European Energy Performance of Buildings Directive.

WIND ENERGY

Wind energy technology has made good progress in recent years, with wind turbine development now in the multi-megawatt range. The amount of installed annual capacity in Europe has grown at 22% annually for the last six years and total installed capacity now stands at over 34GW.

All of this is well documented, for example by the European Wind Energy Association (EWEA). Wind energy to date has achieved only a fraction of its potential, and is exploited chiefly in Germany, Denmark and Spain. The greatest challenges remain the rapid up-scaling of turbines and large-scale deployment, both on and offshore, in complex terrain, and in extreme environments. All pose great technological challenges. Moreover, the pressure to reduce risk in the output of wind farms necessitates improved wind resource assessment techniques and forecasting tools. An abridged listing of research and development priorities is provided below.

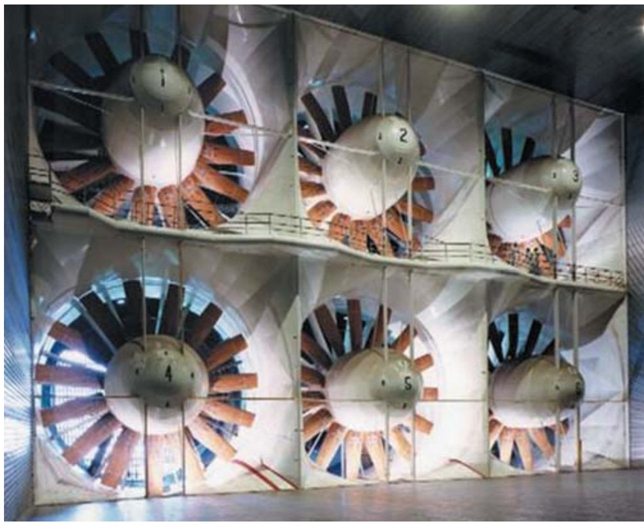


Photo: © Risoe/Hjuler

R&D Targets for FP7

Technological research and development under the Seventh Framework Programme should focus on the reduction of risks and uncertainties associated with up-scaling of individual turbines and wind farms, and the large scale deployment of wind energy to meet the target of 75,000 MW by 2010. With sufficient support for R&D, by 2010, wind turbines in the range of 8-10 MW may be developed, and individual wind “power stations” could measure in the Gigawatt scale. FP7 funding support is needed to ensure that the necessary design tools exist to develop such machines, to model very large wind farms, and to build understanding of the technical issues associated with their deployment, operation, maintenance and overall system integration.

> The greatest challenges remain the rapid up-scaling of turbines and large-scale deployment, both on and offshore, in complex terrain, and in extreme environments

EWEA has calculated that the R&D requirements of the wind industry far outweigh the existing funding opportunities of FP6. The wind industry looks towards FP7 for support of its vision for wind energy development up to 2030, and the fundamental R&D required realising its objectives.

The technological R&D requirements of the wind industry were identified over a 3-year consultation involving the key actors in Europe’s wind industry[1]. It should be noted that within each of the R&D themes, individual tasks are not listed in order of importance, nor in terms of the magnitude of funding required. This list concerns primarily technological and scientific research requirements for wind energy technology. While significant R&D is needed into the social and economic issues crucial for the development and deployment of wind technology, such issues are covered in less detail here. EWEA can provide more information upon request.

Wind Turbine and Component Technology

- Up-scaling of wind turbines
- Dedicated technology for low wind speed inland locations; high wind speed/ high turbulence locations; and for cold climates and offshore locations
- Aerodynamic and aeroelastic design, structural design
- Mechanical interfaces to alleviate dynamic loads
- Improved modelling of loads for safety and reliability
- New materials with higher strength to mass ratios, and higher internal damping
- Advanced manufacturing technologies for low cost production
- New concepts, e.g. flexible blades & hubs, offshore

Photo: © Vestas

[1] The European Wind Industry Strategic Plan for Research & Development – First Report: Creating the Knowledge Foundation for a Clean Energy Era, EWEA, Brussels, January 2004

O&M cost reductions through improved design
- Integration of demand side requirements in turbine design
- Modelling of O&M requirements for large turbines
- Testing and verification methods
- Energy management and storage systems for stand alone applications
- New electrical generator technologies, power electronics and control

Large Wind Farms and Integration into Electrical Systems

- Flow in and around very large wind farms
- Control of wind farms and wind farm clusters
- Short term power prediction
- Reliability models – particularly regarding offshore turbines
- Site-specific control of turbines to cope with variations in external conditions
- Scenarios for a redesigned EU grid system with high wind penetration
- Increased predictability of system output
- Increased power quality and consistency
- Early failure detection and condition monitoring systems
- Effective output forecasting methods for large turbines
- New storage and transmission technologies

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Photo: © NEG MICON

Long Term wind Resource Prediction and Site Estimation

- Electrical output prediction tools
- Increased accuracy of wind farm electricity output assessment prior to installation
- Long term fluctuations in wind resource, including effects of climate change
- Resource assessment in mountainous areas, and other complex terrain
- Resource assessment in cold and icing environments
- Offshore wind resource technology and assessment
- Extreme wind conditions

Offshore and Extreme Wind Farm Environments

- Drivers behind offshore operations and maintenance
- Condition monitoring and planned maintenance
- Offshore wind farm design
- New transportation techniques and O&M access and maintenance
- Systems and components for erection
- Offshore turbine design – multi megawatt, multi-rotor systems
- Alternative, and deep-water foundation structures
- Combined wind and wave loading
- Effects of very large wind farms on wind speed

Socio-Economic and Environmental Issues

- Environmental impact issues, particularly on and near shore
- Potential conflicts of interest: military and defence, fisheries, shipping, oil & gas exploration & pipelines, sand mining, etc.
- Legal research into offshore ownership in coastal waters, Exclusive Economic Zones, etc
- Development and certification of new standards for components, risk assessment, O&M, etc.
- Techniques for mitigation of visual, aero-acoustic noise, and electromagnetic impacts; cumulative impacts
- Life cycle analysis, and decommissioning alternatives

Distributed generation

Europe's integrated electricity network will be subject to substantial restructuring in the coming years as a direct consequence of the ongoing liberalisation of the energy market and the planned increase in the share of generation met from renewable energy sources to 21% by 2010 in EU-25. The present electricity supply infrastructure, which is characterised by large, centralised power stations, will evolve into a system comprising both centralised and decentralised electricity supplies. This process will place new demands on the engineering of these systems, including equipment specification and control. The anticipated rapid growth in the numbers of decentralised micro generators requires an advanced integration strategy to be developed, and alongside this more attention will need to be paid to demand side management.

In this changing environment, characterised by low reserve capacities on the one hand and increasing numbers of fluctuating generators on the other, securing network stability and supply reliability will be a significant challenge, and one critically dependent on achieving the right energy mix, complemented by bi-directional energy management, efficient communication structures and trading systems as well as novel grid deployment planning processes. All this must be based on advanced information and communications technologies.

Ultimately, power balancing and quality, energy demand and production forecasts, international energy trading via energy stock exchanges and much more will be handled by intelligent energy management systems that secure a cost effective and reliable supply and distribution of energy. Besides, the technical concepts for building up electricity grids with a high share of distributed generation (DG) will also depend on the progress made in the fields of energy storage as most of the renewable energy resources involved are of an intermittent nature.

These considerations are being considered by the DGnet project and by other related DG/renewable energy projects within the so-called IRED "Cluster" of DG projects. It is clear from these projects that in order for renewable and other sources of DG to make a major contribution to the European electricity network within the first quarter of this century, the following research issues must be addressed:

Photo: © Eurec

Intelligent energy management systems must secure a cost effective and reliable supply and distribution of energy

R&D Targets for FP7

Advanced Planning and Simulation Systems, Tools, and Methods are Required for Networks with Increasing Complexity

- To determine technical constraints of the network
- To test operation strategies
- For online decision support during network operation.

Development of Key Enabling Technologies

- Advanced power electronic devices to optimise power generation and distribution, improve power quality and reliability, minimise losses and costs
- Energy storage technologies to reduce pricing volatility, protect against power quality problems, and support intermittent power sources on the grid
- Advanced automation for electricity distribution systems
- Advanced CHP concepts

Development of Information, Automation and Communication Technologies

- Control and supervision of networks and generation units (making renewable energy sources as dispatchable as possible)
- Standardisation of interfaces and communication protocols and components
- "plug and play" communication solutions for DG/RES components

Additional Efforts on Network Related Issues

- Protection, security of supply, ancillary services, stability, power network management, reliability and quality of power supply
- Dynamic grid operation
  - dynamic setting of protection relays
  - dynamic dispatch
  - cooperative frequency and voltage control
- Support or recovery of network included black-starts
- Real-time risk management
  - to manage intermittent renewable generation
  - to appropriately reconfigure the grid in real time for enhanced security of supply

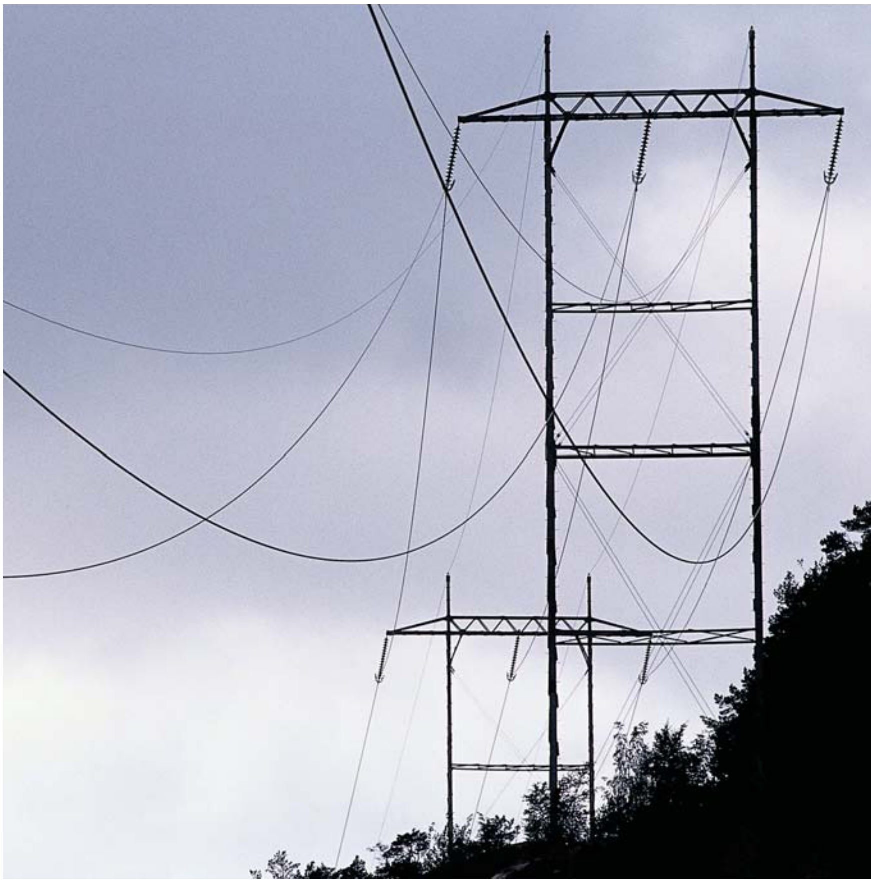


Photo: © Norsk Hydro

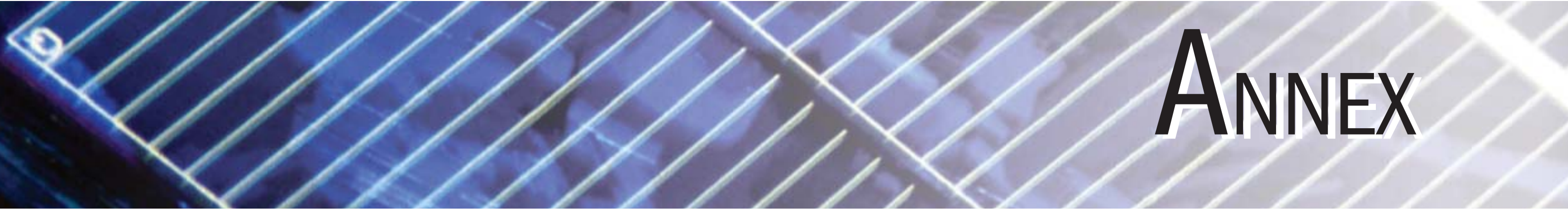
R&D on Energy Related Issues

- Forecasting systems with increased accuracy
- Decentralised energy management systems including:
  - optimisation of generation mix
  - storage management (heat and electricity)
  - interaction with existing supervisory systems
  - distributed real-time monitoring and control of distributed generators
  - real-time energy exchange, trading and billing of DG
  - evaluation of the contribution of ancillary services
  - electricity balancing market

R&D on Socio-Economic Issues

Common and harmonised tools to tackle complex social and economic issues:

- Development of common strategic roadmaps for energy service networks to harmonise regulations, safety, testing, certification, education and training
- External costs of energy, social issues, and ethics in energy
- Energy policy
  - improving the security of energy supplies in future energy markets
  - new regulations
  - support schemes (feed in tariffs, green certificate schemes, energy taxation, net metering)
  - Addressing the specific issues of implementation within the new EU Member States



PV Catapult workshop “Setting RTD priorities for FP 7”

In the frame of the EC project 'PV Catapult' (Contract no. 502775 (SES6-2004)), representatives from research and industry in the PV sector estimated the total public budget needed to achieve the research priorities detailed in the 'Solar Photovoltaic' section of this brochure. **This budget does not distinguish between European and national support**. The meeting at which the estimates were made took place on 4 November 2004 in Brussels and also involved members of the Photovoltaic Technology Research Advisory Council.

List of research activities and corresponding budget

Short to medium term priorities

Research Activity	Priority (High(H) ; Medium(M); Low(L))			Estimated Budget in Million Euros for 4 Years Budget (2007-2010)	
	Priority: R&D Priority	Impact on Market	Impact on EU-R&D-Industry	Handling Issues	Production Machines (Prototype)
1. c-Si: Feed-stock Silicon (high purity)	L	L	L	Ø	Ø
New silicon processes	H	H	H	10	10
Wafer thickness	H	H	H	50+	50+
Cell efficiency	H	H	H	50+	50+
Module	H	H	H	20+	20+
			Total :	130	130
2. Thin Film	10 … 15% 1 … 1.5 m2	3 … 5 m2 <50€/ m2	Priority		
a-Si/μ Si			H	30+	30+ (Gen. 7)
a-Si			H		
CIS			H	30+	30+
CTS			L	Ø	Ø
Thin (<10μ)Si/ Large deposition Area			M	5+	5+
			Thin Film modules Total:	65	65
3. Dye		L		Ø	Ø
4. Organic		L		Ø	Ø
5. BOS					
BIPV		H		5	5
Inverters		H		5	5
Energy management		M		2	2
Batteries		M		2	2
Stand alone		M		2	2
Hybrid		M		2	2
Concentrators		M		2	2
			Total :	215	215

Medium to long term priorities

Research Activity	Relative Priority (High; Medium; Low)	Estimated Budget in Million EUR for 2007-2010
New Process development for on C-Si manufacturing	High	80
Thin Film	High	60
Material replacement		
Multijunction		
TCO		
Storage		
Low cost per kwh - short term storage (i.e. 3 Eurocents/kWh)	High	30
Organic/polymer cell development (detail dependent on results from FP6 NoE)	Medium	20
Grid-connection (large scale) (Link with national programs)	Medium	10
Novel concepts (e.g. hot carriers, thermophotonics, very high efficiency approaches) – liable to be developed in several small projects	Low	20
Module design	Low	
Emerging areas in cells or systems – new initiatives arising during the period 2005-2008	N/A determined by topic)	10
Total		230 million EUR

Global budget (EU plus national funding)

	Short & Medium	Medium & Long	Total
Budget in Million €	430	230	660

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