Catching Up: Priorities for Augmented Renewable Energy R&D

Joint Seminar on Long-Term R&D Priorities

3 March 2005
Paris, France

Organised by
The International Energy Agency Renewable Energy Working Party (REWP) and
the related
Renewable Energy and Hydrogen Implementing Agreements (IA)

Blank page

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Catching Up: Priorities for Augmented Renewable Energy R&D
Joint Seminar on Long-Term R&D Priorities

Executive Summary

As a result of the growing interest on renewable energy worldwide as a possible component to the search for responses to the Kyoto Protocol requirements as well as the need for security of energy supplies, the IEA has undertaken a series of internal analyses and discussions culminating in a one-day seminar in order to firm up recommendations. The initial analyses reviewed a series of scenarios as to the possible contribution of renewable energy supplies over the next several decades. A number of these scenarios were considered, and ultimately, the IEA Renewable Energy Working Party tabled the vision for 50% of the world's total primary energy supplies to be obtained from sustainable renewable sources by the middle of this century. The one-day seminar convened in Paris on 3 March 2005, considered this vision and through presentations from all Renewable Energy Implementing Agreements as well as that for Hydrogen discussed how this could be achieved. The main conclusions are summarised here.

Renewable energy has made considerable progress over the last few decades. Through technology development, much carried out through international collaboration, many options have reached levels of maturity that allow broad market deployment and others find cost effective applications in niche markets. Globally, renewable energy sources account for 13.4% of the world's total primary energy. The phenomenal increase over the last few years of emerging renewables such as wind and solar PV, as well as modern bioenergy plants, are starting to show up in both the energy statistics as well as the economic activity with annual sales in the multibillion US$/y. As a result of this progress, and the potential for more to come, the European Union has set a target to increase electricity generation from renewable energy sources at 21% by 2010.

The conclusions of the Seminar point to the need for significantly higher RD&D budgets to help expedite developments. The principle priorities identified include:

- *Total electricity generation from renewable energy could account for 50% of total generation by 2050 under the scenario of accelerated technology development and the benefit of policies for CO_2 credits*
- *Cost reductions in order to improve market deployment potential. This can be achieved through technology advances but also through development of manufacturing and production processes,* – the learning cycle
- *Environmental and Social issues associated with public acceptance and capacity build-up*
- *Certain technologies face seasonal fluctuations and intermittency. It is necessary to address integration of new technologies to the grid including specific technologies on storage and grid management. These issues can be addressed perhaps through collaborative effort within the framework of the IEA.*
- *Demonstrations in most areas, such as in concentrating solar power, ocean energy, novel bioenergy technologies and other options to test new findings and as a precursor to market deployment*
- *Requirements for regulatory framework in areas addressing heating and cooling such as Bioenergy, Solar heating and Geothermal heat pumps*
- *R&D must lead to market related products and services. There has to be a clear distinction between wide ranging 'long term scientific research' and well focussed 'near market RD&D'.*

Finally, it is important to remember that each country has its own RD&D priorities based on their particular resource endowment, technology expertise and industrial strengths.

Background

As a result of the geopolitical and energy developments of the last few years, there is renewed interest in renewable energy worldwide. This renewed interest differs from that experienced a few decades ago because it is based on several contemporary factors as opposed to just the need for energy security of the 1970's. They include the adoption of the Kyoto Protocol providing clear evidence that the world community must use a plethora of sustainable energy options to meet the targets agreed. Second, the accumulated experience on renewable energy technologies over the last few decades has served to temper the enthusiasm of earlier times and helped professionals in the field to address issues in a more pragmatic way. Thirdly, through RD&D as well as market deployment of renewable energy during this period, many of these options have made significant advances and are now cost effective in many applications. Finally, through credible assessments of both the resources involved as well as the prospects for additional technology improvements, there is clear evidence that the future prospects of these sustainable energy options are brighter and hold the promise for much larger contribution to energy supplies. There is broad consensus that advanced renewable energy technologies can play a vital role in the search for sustainable energy in the decades to come but the RD&D will need to be accelerated.

Internal discussions within the International Energy Agency (IEA) have also been positive and according to a press release in 2004, 'Renewable energy shows great potential for contributing to the solution of some of today's energy security and environmental challenges, but more attention must be paid to what is really happening with renewable energy policies and markets, with particular consideration given to cost-effectiveness' (IEA Press release 1 June 2004). The press release goes on to state that 'Renewables could play a key role in the global energy mix with further commitment to research and development and technology innovation…' In terms of potential business opportunities, if renewable energy technologies succeed in accelerating their market acceptance through the technology and market cycles, it is conceivable that they could capture a significant share of the projected US$ 16 trillion for global energy supply infrastructure investments over the next three decades.

The IEA has been monitoring these developments and has undertaken over the last few months a series of reviews and assessments on the future role of renewable energy and the initiatives that need to be taken. Several studies undertaken within the OECD and elsewhere have pointed out that while there has indeed been significant progress in the cost effectiveness of renewable energy, there has been a corresponding trend towards leaner technology development budgets. In addition to the analyses, the Renewable Energy Working Party [1] and the Renewable Energy and Hydrogen Implementing Agreements of the IEA organized a one-day seminar on 'Priorities for Augmented Renewable Energy R&D' held in Paris on 3 March 2005. The conclusions of the effort are summarised in this report. It is hoped that they can help determine the level of support for Renewable Energy in member countries for both technology development as well as deployment. Ultimately, it is envisioned that these sustainable options can help member countries position themselves more strategically in their efforts to address the energy and environment challenges of the 21st century.

[1] The REWP IA include: Bioenergy, Geothermal, Hydrogen, Hydropower, Ocean Energy Systems, Photovoltaic Power Systems, Solar Heating and Cooling, Concentrating Solar Power and Chemical Energy Systems and Wind Energy Systems.

Status of Renewable Energy

The amount of renewable energy in the IEA countries, in the period 1970 – 2001, doubled in absolute terms from 141.5 Mtoe to 280.9 Mtoe but the share of renewable energy in total primary energy supply increased only from 4.6% in 1970 to 5.5% in 2001. Most of this increase occurred between 1970 and 1990, when renewables supply grew by 2.8% per year. Subsequently, from 1990 to 2001 some renewables, including hydropower and traditional bioenergy grew more slowly. As a result, the share of renewable energy generated electricity actually declined from 24% in 1970, to only 15% by 2001. The contribution of mature technologies such as hydro and geothermal power did not grow significantly over the period from 1990 to 2001. Nevertheless, hydropower remains the major source of renewable energy for electricity generation accounting for over 86% of the total contribution of renewables. At least six IEA countries derive over 50% of their electricity production from renewables – primarily hydro. They include Austria (70%), Canada (58%), New Zealand (63%), Norway (99.6%), Switzerland (60%) and Sweden (60%). The European Union has set a target to increase electricity generation from renewable energy sources at 21% by 2010[2].

The phenomenal increase over the last few years of emerging renewables such as wind and solar electricity generation, as well as modern bioenergy plants, are starting to show up in the statistics and currently account for about 2% of the total IEA electricity generation. The contribution of these emerging options in some IEA countries is becoming significant. In Denmark for example, the contribution of wind and to a lesser degree biomass to electrical generation has grown from about 0.1% in 1970 to 16% in 2001. Countries that have increased the commercialisation of solar and wind energy significantly include Denmark, Germany, Spain, the United States and Japan (IEA documents).

Globally, renewable energy sources account for 13.4% of the world's total primary energy supply[3], mainly in the form of traditional biomass for heating and cooking in rural areas, modern biomass combustion, and hydropower. In an energy future based to a large extent on renewable energy, a wide range of "new renewable technologies" would have to contribute a major and continuously growing share to the world's energy portfolio. According to past work by the IEA, without major technology and policy intervention, renewables would increase by only1.3% per year over the next thirty years while the global energy demand would grow by 1.7% per year.

[2] Directive 2001/77/EC
[3] Renewables Information 2004, OECD/IEA 2004

Lessons Learned

The principle lessons learned over the last thirty years are that the move towards sustainable renewable energy options depends on resource availability, technical maturity and finally a policy environment that is conducive to both technology improvements as well as commercialisation. Because of the diverse nature of renewable sources of energy, it is important that each country or region promote technologies and options that are well suited to specific resource availability. Unlike the current energy system based on fossil fuels, the transition to renewable sources will have to be based on heterogeneity of technologies and applications.

Technology improvements have been impressive over the last three decades and have resulted in significantly lower costs for delivered energy. There is clear understanding that environmental credits will play a role in deciding on new energy projects. There is already a market for greenhouse gas credits. With the ratification of the Kyoto Protocol, there is a parallel effort to establish public policies that will help societies achieve the shift to sustainability.

Another very important lesson on RD&D in renewables is the generally limited involvement of the private sector, despite the fact that RD&D is the driving force for innovation, cost reduction and market deployment opportunities[4]. Although there have been exceptions to this rule in some countries and by some large corporations in newer technologies such as photovoltaics and wind, the public sector has been the main funding source with the concomitant constraints of ownership of the resulting intellectual knowledge. It is well understood though that private sector companies are better suited to carry out applied research with internal resources because they would have a free hand in proceeding to commercialisation. Technology development and market experience are strongly linked and can function as a virtuous cycle in advancing technology improvements through market implementation lessons. A public policy environment to encourage more private sector involvement could enhance renewable energy technology development and commercialisation.

Support for RD&D

Support for technology development by IEA member countries has been significant over the last few decades but not always consistent. The recent IEA publication "Renewable Energy Market and Policy Trends in IEA Countries" highlighted a number of conclusions related to renewables RD&D. The findings of the study can be seen in Figures 1-4 and can be summarised as follows:

Total government energy research, development and demonstration (RD&D) budgets in IEA Member Countries increased sharply after the oil price shocks in the 1970s. Budgets declined to about half of their peak levels by 1987 and remained relatively stable to 2002. As a percentage of total RD&D funding, funding for renewables was higher from 1974 through 1986 than in the period since 1987.

[4] Renewable Energy Market and Policy Trends in IEA Countries, OECD/IEA 2004

Renewable energy technologies accounted for just 8.2% of total government energy RD&D funding from 1974 to 2001. Table 1 below presents shares of renewables in all energy RD&D in all IEA countries by technology in million USUS (2002 prices and exchange rates).

Table 1 - Shares of Renewables in all Energy RD&D spending by IEA countries

	1974-2001	1974-1986	1987-2001
Renewable Energy Total	8.2%	8.7%	7.6%
Solar Heating & Cooling	1.1%	1.4%	0.7%
Solar Photo-Electric	2.2%	1.8%	2.7%
Solar Thermal-Electric	0.9%	1.3%	0.5%
Wind	1.0%	1.0%	1.1%
Ocean	0.3%	0.4%	0.1%
Biomass	1.2%	0.9%	1.5%
Geothermal	1.5%	1.9%	0.9%
Large Hydro (>10 MW)	0.0%	0.0%	0.1%
Small Hydro (<10 MW)	0.0%	0.0%	0.0%

The United States, Japan and Germany accounted for 70.4% of IEA government renewable energy RD&D funding in the 1974 – 2002 period.

The decreasing share of public funding for energy RD&D allocated to renewable energy appears to be inconsistent with presumed political intentions in many IEA countries to increase the share of renewables in total primary energy supply (TPES).

RD&D spending on renewable energy by the private sector has been gradually and selectively growing over the last thirty years. This has been the case with RD&D in wind and solar photovoltaics. Still, renewable technologies such as solar heating and cooling and ocean energy are heavily dependant on public RD&D budgets.

Government RD&D expenditures towards energy technologies in IEA Member Countries were about US$ 291 billion (2002 prices and exchange rates from 1974 to 2002). Figure 1 shows government budget outlays for energy RD&D in this period. In 1974, total IEA government investment for energy RD&D was about US$ 6 billion, of which only US$ 60 million was for renewable energy. Budget outlays peaked in 1980 at US$ 15 billion, but then declined to about US$ 9 billion in 1987. From 1987 to 2002, funding was relatively stable, averaging about US$ 9 billion from 1987 to 1991 and US$ 7.5 to 8 billion in the 1990s. Total energy RD&D expenditures in 2002 were just under US$ 8 billion (49% of the 1980 value). Renewable energy RD&D expenditures in 2001, at US$ 696 million, were about 35% of the 1980 value.

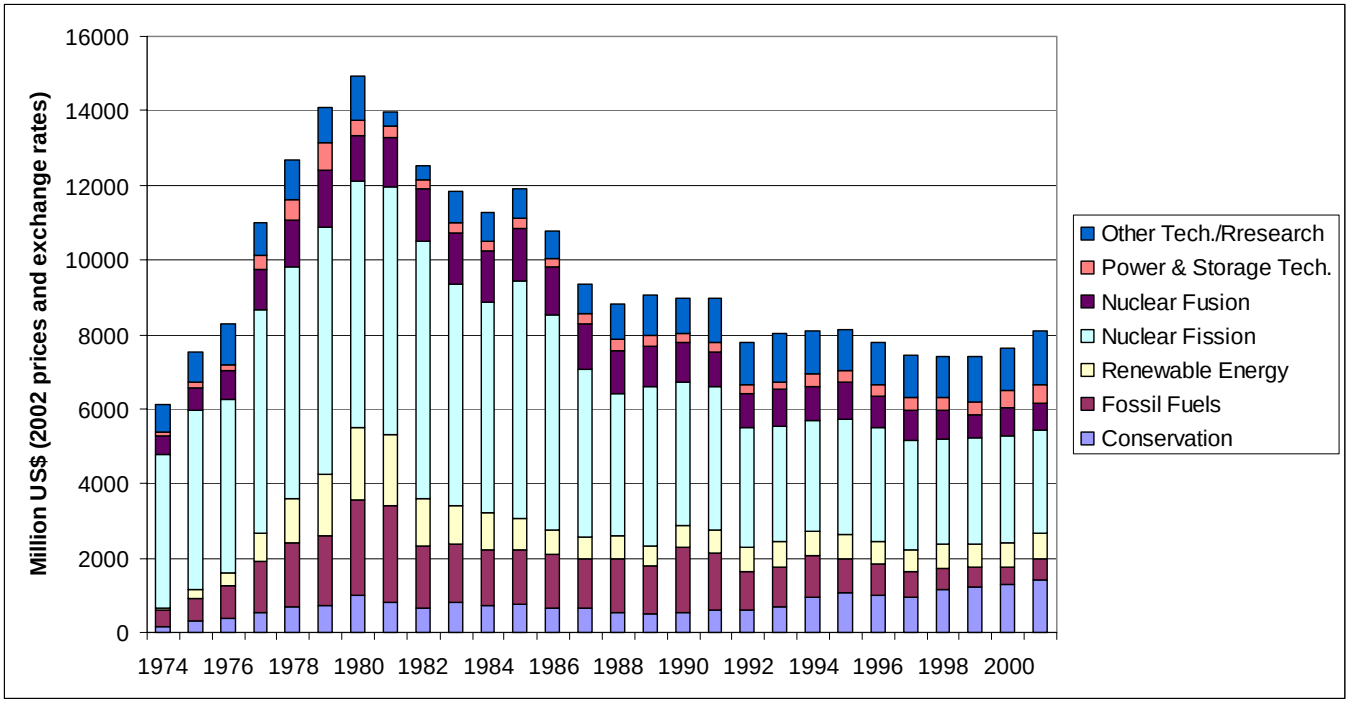

Figure 1. Government Energy RD&D Budgets in IEA Countries, 1974-2001
(Source: Renewable Energy Market & Policy Trends in IEA Countries, OECD/IEA 2004)

Aggregate IEA energy RD&D budget outlays for nuclear fission, fossil fuels and renewables decreased in the late 1980s and 1990s, while funding for nuclear fusion, conservation and power and storage technologies increased. RD&D investments in hydrogen and fuel cells (included in the "other technology" category) rose considerably in the 1990s and early 2000.

From 1974 to 2002, renewable energy RD&D budgets of the IEA countries totalled about US$ 23.55 billion, some 8% of total energy RD&D funding in the period. Expenditures for renewables RD&D grew rapidly in the late 1970s and peaked in 1980 at just under US$ 2 billion. Expenditures declined by about two-thirds in the early 1980s but have been relatively stable since the late 1980s, in the range of US$ 550 million to US$ 700 million. Annual expenditures on renewables RD&D for all IEA countries averaged about US$ 650 million from 1990 to 2001, 7.7% of total government energy RD&D budgets (Figure 2).

Germany, Japan and the United States accounted for about 66% of total renewables RD&D funding in the period 1990 to 2002. Italy, the Netherlands and Switzerland accounted for an additional 15%. These six countries combined invested US$ 531 million per year on average for renewable energy RD&D. The United States had the highest average renewables RD&D budget of US$ 236.9 million per year. The average annual budget in Japan was US$ 110.9 million and in Germany US$ 82.8 million between 1990 and 2002.

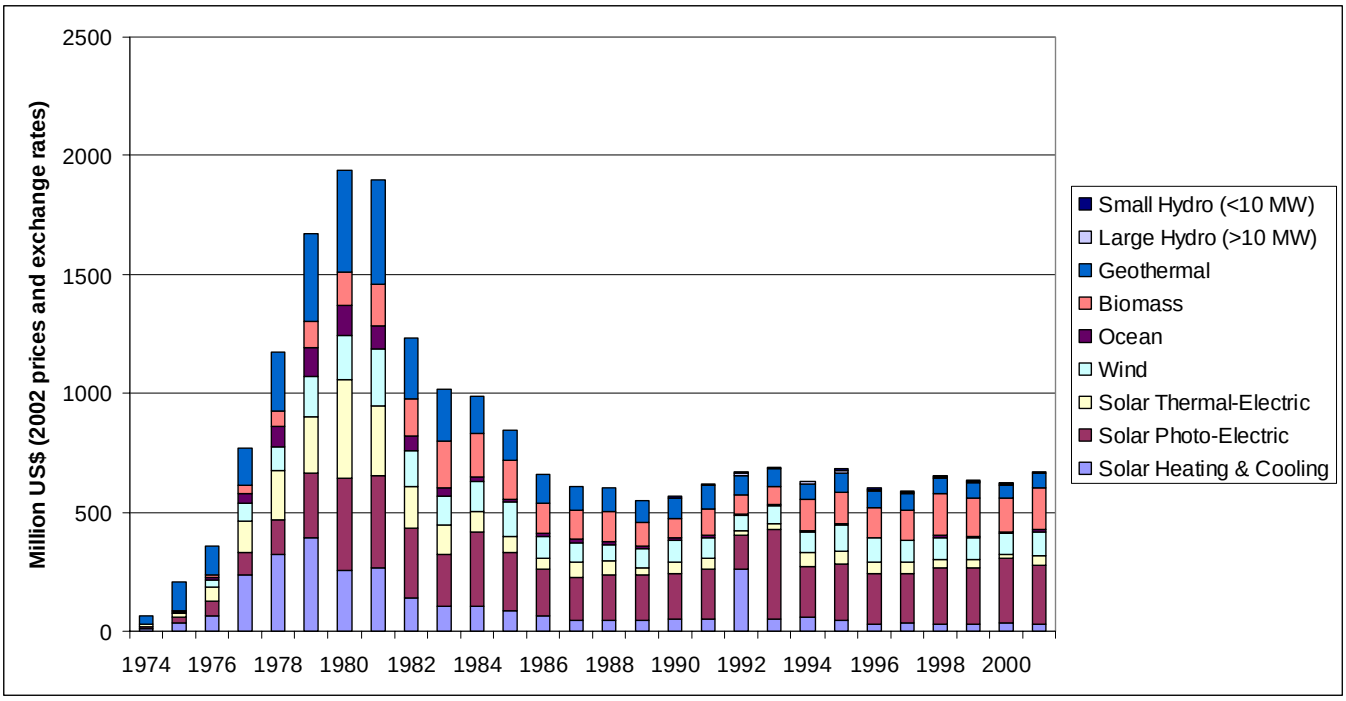

Figure 2. Government Renewable Energy RD&D Budgets for IEA Countries, 1974-2001 (Source: Renewable Energy Market & Policy Trends in IEA Countries, OECD/IEA 2004)

Renewable energy RD&D funding priorities usually reflect resource endowments. For example, New Zealand and Turkey have major geothermal resources, and 70% of RD&D funding in New Zealand and 45% in Turkey were for geothermal in the 1990-2002 period. Norway allocated 35% of its renewables RD&D to large hydropower. On average, biomass accounts for more than 40% of the renewables RD&D budgets in Austria, Canada, Finland, Hungary and Sweden. About 43% of renewables RD&D in Denmark and 37% in the United Kingdom went to wind energy. Both countries have significant wind energy potential. Natural resource endowments, however, do not always dictate renewable energy RD&D priorities. Potential industrial opportunities often play a role in resource allocation. Germany has limited solar resources, but its budget for solar PV represented 48% of its renewable energy RD&D budget from 1990 to 2002. RD&D budget priorities in the six IEA countries with the largest public sector outlays for renewable energy from 1990 to 2002 are outlined in Figure 3. The differentiation among technologies in other countries is indicated too.

With regard to the shares of renewable energy technology RD&D, funded through public funds, it can be seen in Figure 4, that geothermal, solar heating & cooling and solar thermal electric accounted for 84.9% of the total in 1974. However, the trend has been reversed since then. In 2002, predominant technologies were Solar Photo-Electric, Biomass and Wind, accounting for 76% of renewable energy RD&D, while only 20.5% went into the former leader technologies.

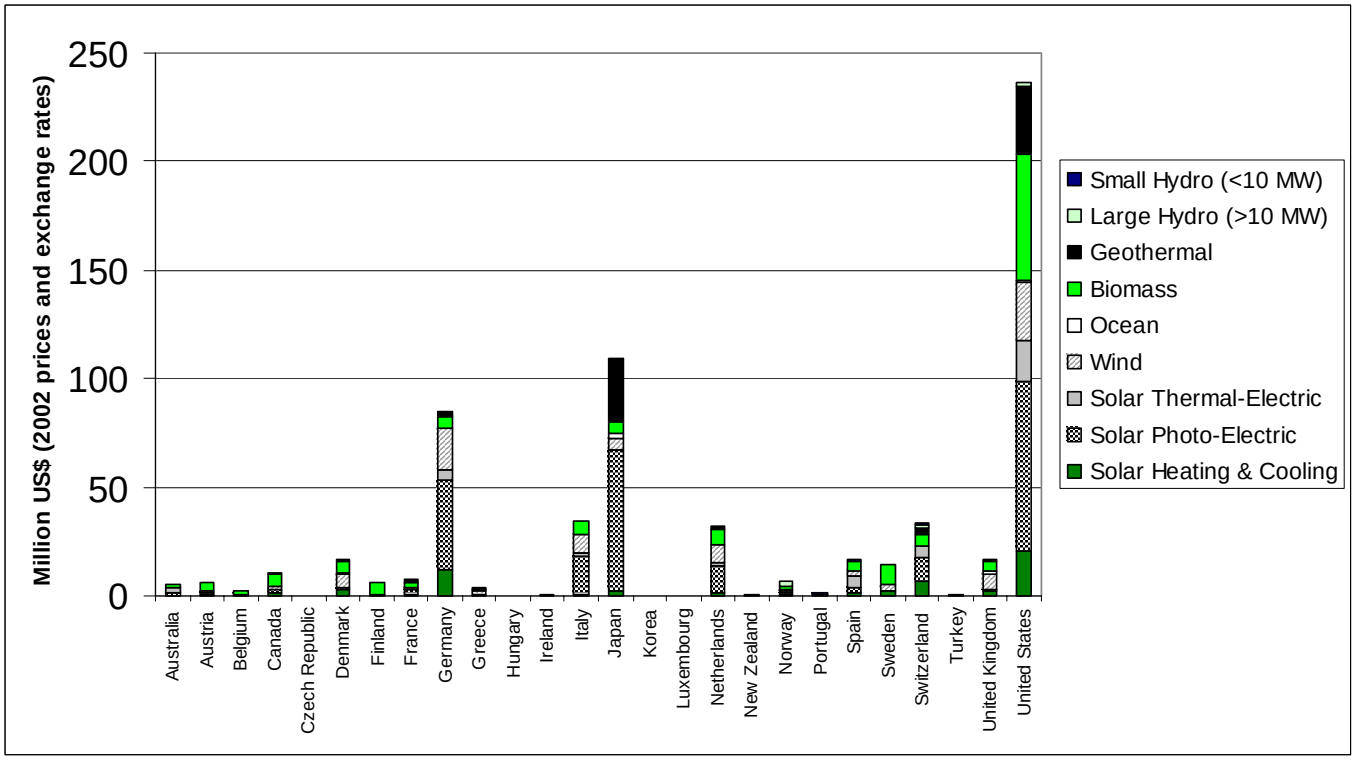

Figure 3. Average Annual Renewable RD&D Budgets in IEA Countries, 1990-2002 (Source: Renewable Energy Market & Policy Trends in IEA Countries, OECD/IEA 2004)

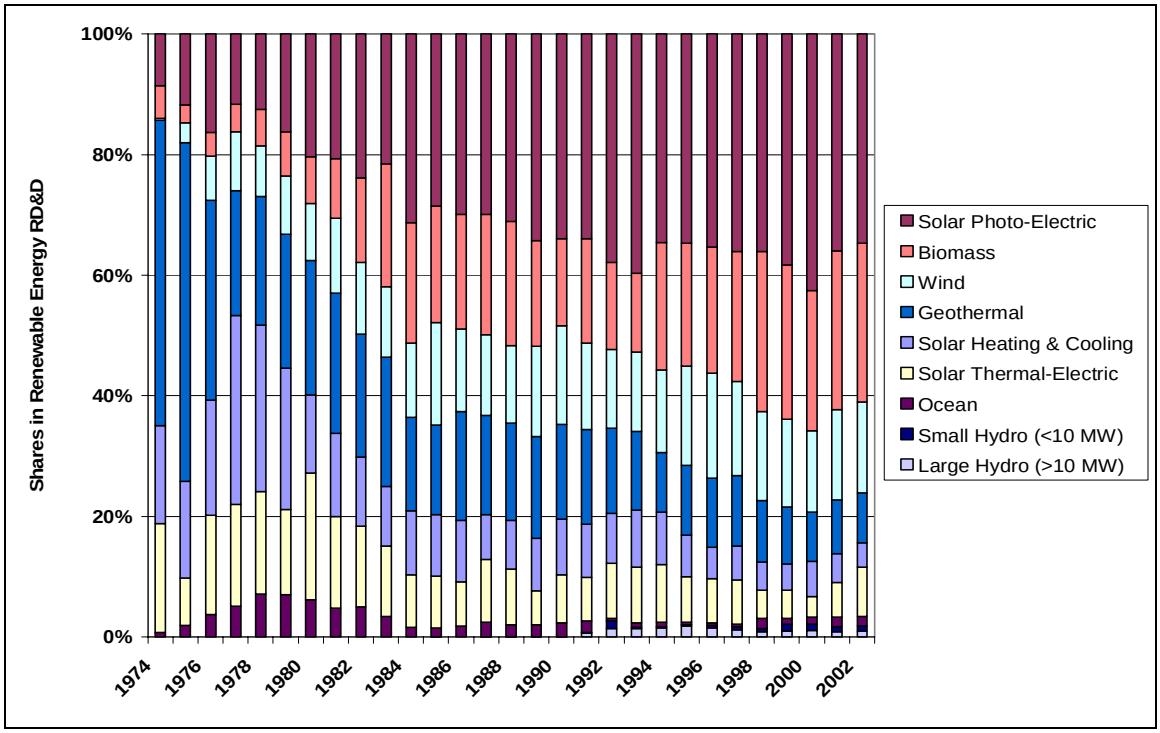

Figure 4. Shares of Renewable Energy Technology RD&D, 1974-2002 (Source: Renewable Energy Market & Policy Trends in IEA Countries, OECD/IEA 2004)

Despite the drop of total RD&D expenditures on Solar PV in the early 1980s from some US$ 400 million in 1980 to US$ 182 million in 1987, the relative importance of Solar PV in the renewable energy RD&D portfolio has been increasing steadily. While the share of Solar PV was at 8.6% in 1974, it was raised to 34.7% of the total reported renewable energy RD&D funding for 2002. The peak was reached in the year 2000, when 42.5% or some US$ 271 Million of the budget was attributed to Solar PV.

A similar observation can be made when looking at RD&D expenditures for biomass and wind technologies. While the actual budget on biomass RD&D shrank from some US$ 213 million in 1983 to only about US$ 76 million in 1993, the relative importance increased steadily from 5.4% to 26.3% in the period from 1974 to 2002. Wind power received only 0.3% of the total budget in 1974, but 15.1% in 2002. The relative attention paid to wind has been rather stable in the 1980s and 1990s, with shares varying between 11.9% (1981 value, when the total budget spent on Wind power actually peaked with some US$ 242 million) and 17.4% (1996 value).

Geothermal experienced a very significant drop of RD&D attention: its share in the total renewable RD&D budget decreased sharply from 33.1% attributed in 1974 to only 8.3% in 2002. Almost the entire budget came from the US and Japan, which together made up for some 80-90% of the geothermal RD&D budget throughout almost all the period.

Solar Thermal Electric technologies faced similar trends. While up to 21% (1980 value) of the renewable budget were attributed to them in the late 70s and early 80s, the trend changed through the lessons learned on the potential payoff of RD&D in this area. Resource allocations among technologies have changed, with the result that only about 3.4% of the total funding went to this technology in 2000. It has since then increased again to 8.2% in 2002.

Impact of Past Market and Policy Trends in Renewable Energy

The principle constraint in advancing renewable energy over the last few decades has been cost effectiveness. With the exception of large hydropower, combustible biomass (for heat) and larger geothermal projects (>30 MW_e), the average costs of renewable energy are generally not competitive with wholesale electricity and fossil fuel prices. For power generation technologies, this point is well summarised in Figure 5. On the other hand, for specific small-scale applications, there are several renewable energy options that compete in the marketplace. These include hot water from solar collectors and electricity from small hydro and other technologies.

The challenge facing renewable energy technologies is to advance the state of the art to the point where more renewable options can generate energy at costs that are competitive with conventional sources. With the worldwide adoption of stricter environmental standards and guidelines for greenhouse gas emissions, it is becoming clear that renewable energy systems will be credited for their inherent advantage in lowering emissions. These environmental credits will contribute towards making the delivered costs for renewable energy more attractive and they have already been the driving force in policy initiatives in many IEA countries. Nevertheless, substantial breakthroughs of technologies to improve their cost competitiveness will still be a priority.

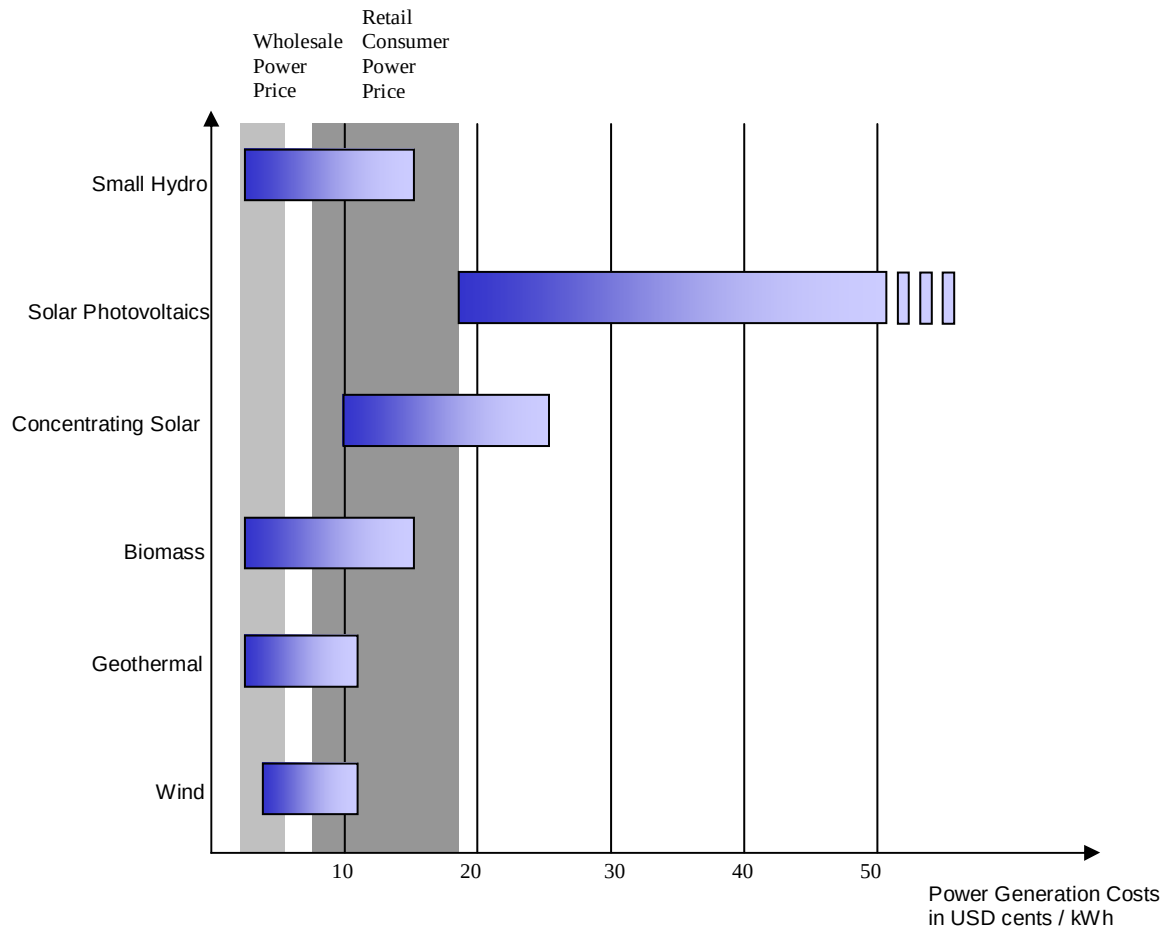

Figure 5. Cost Competitiveness of Selected Renewable Power Technologies (Source: Renewables for Power Generation, Status and Prospects, OECD/IEA 2003)

Past policy initiatives in support of renewable energy in many IEA countries, have concentrated on Research and Innovation, Market Deployment and Market-Based Energy. Although the purpose of the current initiative is to refocus the RD&D component of the above, there will be a need to ensure that the market oriented policies complement the technology initiatives. Based on the experience to date, the following observations can be made regarding deployment:

- *Significant market growth in renewable technologies has resulted from a combination of policies that address specific barriers and/or complement existing ones.*
- *Longevity and predictability of policy support is important to overall market success. A 'stop and go' policy environment does not provide a sound basis for private sector involvement.*
- *With the trend towards market liberalisation, early support policies for emerging renewable energy technologies must be tailored carefully to ensure against the impact of significant drop in overall energy prices.*

Scenarios of Global Energy Portfolio

The REWP vision is that scenarios produced by various institutions – against the background of significantly rising overall energy consumption – stipulate that renewable energy sources could grow from supplying 13.4 % of world's total primary supply today to 20% in 2030 and 50% in 2050.

For the objectives on renewable energy set out by governments to be reached, a clear strategy must be at the centre of every transformation path into a more renewable energy future. The strategy should include a significant acceleration in technical development of technologies. Although new and improved renewable energy technologies are currently being developed aiming at lower capital costs, improved reliability and higher conversion efficiencies, much more work will be needed over the next 50 years. Developments in R&D that will lead to dramatically improved and lower-cost technologies will be crucial.

The technologies that were close to competitiveness in 1973, such as large hydropower, biomass combustion, and geothermal, have plateaued at about 5% of TPES. Although they have still considerable potential for market penetration because of their attractive cost competitiveness, newer ones such as wind power, several forms of advanced bioenergy (e.g., anaerobic digestion) and to some degree photovoltaics, have advanced through the RD&D pipeline. Nevertheless, these newer technologies have not yet grown enough to propel renewables overall to higher penetration.

If national objectives for diverse and environmentally sustainable energy use are to be achieved, additional funding for renewables will be necessary to lower supply costs and make available to the market place a variety of technological options. Some renewable technologies are very far from competitive. With photovolatics, for example, industrial applications have long been cost-effective, and limited niches in high solar resource areas are close to economic. In addition to the space exploration and consumer products, it is now very common to observe PV powered signs in road construction sites, water pumping, lighting systems at recreation properties and many other, all planned and funded through market forces. These niches should be encouraged with market deployment support. But to achieve the mainstream, PV costs must come down substantially. More RD&D funding is needed to achieve the breakthroughs that will lead to large-scale markets.

Other renewable technologies have fallen out of the RD&D pipeline. Concentrating solar power, ocean energy, and advanced geothermal are all technologies that lost much of their RD&D funding some years ago. It is time to assess their potential in the context of the new imperatives that arise from the ratification of the Kyoto Protocol and perhaps refocus RD&D investments to bring these technologies to the market. Such refocusing may occur not necessarily by increasing overall funding levels, but rather either through reallocations or more imaginative ways of leveraging public funding with the private sector. Efficiency and effectiveness are called for in devising strategies to accomplish a wider spectrum of R&D priorities. This calls for imaginative approaches that include both public sector investments and the efforts of the private sector supporting potentially winning technologies that can subsequently be encouraged through policy initiatives towards commercialisation.

The Seminar Deliberations

In order to address the above issues and arrive at concrete recommendations on policy initiatives, The IEA REWP, and the Renewable Energy and Hydrogen Implementing

Agreements organised a Joint Seminar on Long-Term R&D Priorities on 3 March 2005 in Paris. A background Discussion Paper was prepared ahead of the seminar with input from all IAs concerned.

About 100 persons representing the cutting edge knowledge base of renewable energies attended the event, including the delegates to the IEA Committee on Energy Research and Technology (CERT) and the IEA Renewable Energy Working Party, representatives of governments, European Renewable Energy Council, members from all Renewable Energy and Hydrogen Implementing Agreements, international and national energy research institutes, international and national industry associations, IEA Secretariat and others. The conclusions of the Seminar will form the basis for a comprehensive report on the R&D priorities for renewable energy technologies.
The Seminar programme is attached as Appendix A and the list of participants shown in Appendix B.

The principal premise of the seminar was based on ***the IEA REWP vision for 50% of the world's total energy supplies (TPES) to be obtained from sustainable renewable sources by the middle of this century****. This vision was established following consideration of a series of sustainable energy scenarios proposed by several public and private sector analysis groups. These Scenarios produced against the background of significantly rising overall energy consumption stipulate that renewable energy sources could grow from supplying 13.4 % of world's total primary supply today to 20% in 2030 and 50% in 2050. Such targets could be achieved through a combination of policies that would reduce the cost of renewable energy sources and would need to allow for substantial CO_2 permit prices of the order of US$50/t for certain options. R&D investments could significantly reduce the need for deployment support.*

The key element towards the realisation of the REWP vision is the accelerated technological advancement and cost reduction of all the renewable technologies, combined with novel applications and deployment in the context of distributed generation, global production and trading of fuels (including hydrogen), and bulk transmission of renewables-generated electricity. ***The REWP and the related Renewable Energy and Hydrogen Implementing Agreements agreed to work together to define mid to long term R&D priorities for renewable energy to support the vision of the REWP.*** *It is expected that the conclusions of the Seminar will form the basis for a strategic report on the R&D priorities for renewable energy technologies.*

The Executive Director of the IEA, Mr Claude Mandil, opened the seminar and the Committee on Energy Research and Technology (CERT) and the Renewable Energy Working Party (REWP) Chairs provided introductory comments.

The Executive Director welcomed the participants to the seminar and set out the context of the event. Mr Mandil pointed out that based on the World Energy Outlook, the current thinking among energy planners is that the world needs more of all energy options at reasonable costs. Because of the broad concerns for the environmental impact of energy use, the world needs to promote sustainability through:

- *More energy efficiency,*
- *More renewable energy,*
- *More nuclear power, as well as*
- *Fossil fuels used in the most efficient manner.*

Through increased Research and Development in renewable energy technologies, nuclear energy, as well as in selected areas of fossil fuels such as the capture and sequestration of CO_2, there is indeed realistic expectation that the world will be able to meet energy demands in a cost effective manner while promoting sustainability.

Renewables are definitely among the technologies we need in order to reduce global warming and improve our security of supply. Yet the ***R&D budgets for renewable energy had indeed declined over the last few years*** *compared to those employed by IEA countries in the 1970's. While recognising the very significant progress made through technology development in many renewable energy options, it was important to point out that some early market deployment initiatives were premature. Since then however, technology development and market development have been streamlined.*

Based on recent analysis, and subsequent discussions within the IEA, ***there is broad consensus that R&D in renewable energy must be strengthened*** *with a caveat that priorities must be well selected in order to address policy externalities, especially as they relate to prospective cost effectiveness in the markets. Intelligent choice of such priorities will invariably facilitate market deployment of new and improved technologies.*

If national objectives for diverse and environmentally sustainable energy use are to be achieved, additional funding for renewables is necessary to lower the costs and make available to the market place a variety of technological options. Efficiency and effectiveness are called for in developing strategies to accomplish a wider spectrum of R&D priorities. This, in turn, requires new approaches to include both public sector investments and the efforts of the private sector.

The Executive Director stressed that the Seminar provided an excellent opportunity to consider those strategies and explore the options for the RD&D related to renewable energy. It constituted a very timely response to the proposals made several months earlier in Bonn. Mr Mandil encouraged participants to identify the most promising priorities in each of the renewable technologies involved, and to be prepared to table their findings to IEA ministers in justification of the request for additional budgets for R&D.

Similarly, the REWP and CERT chairs, Roberto Vigotti and Graham Campbell respectively, welcomed the seminar participants. Graham Campbell also reminded participants of the key perspectives of the CERT organisation. These include.

- *To promote innovative R&D*
- *To define tools and analysis*
- *To foster international cooperation, and*
- *To communicate results of collaboration,*

The keynote presentations in Session 1 were intended to set the context and the vision of the seminar. The first panel presentation by Fridtjof Unander of the IEA Energy Technology Office outlined the results of the World Energy Outlook 2004 and the IEA Energy Technology Perspectives Project. He pointed out that under the reference scenario, the contribution of renewables would grow from about 10 EJ or 19% of total electricity generation in 2000, to over 20EJ by 2030 but still within the same 19% contribution to the total because of growth in total electricity generation. Under the Alternative Policy Scenario which includes additional policies such as extension of Portfolio standards in the US, Green certificates in Japan as well as more R&D efforts, the future renewable energy contributions could grow to 24% by 2030 and 32% by 2050. Furthermore, the impact of CO_2 pricing at US$25/t and US$50/t, could boost the share of renewables in total electricity generation to as much as 49-53% by 2050.

The contribution of the various renewable energy technologies to generation would be different under the various scenarios. Under the reference scenario, the principal contribution would be made by hydro followed by biomass, wind and geothermal and only minimal amounts from solar technologies. On the other hand, under the alternative scenario

and with US$50/t pricing of CO_2, all technologies contribute significantly to total generation. Solar PV could be cost competitive by as early as 2030 under the scenarios of increased R&D and deployment strategies. On the other hand, Wind energy becomes competitive after 2030 under the reference scenario. An important finding of the analysis was that increased R&D investments might significantly reduce the need for deployment support.

Arthuros Zervos, President of the European Renewable Energy Council, spoke on 'Priorities for the Renewable Energy Research'. He pointed out that public support for strong R&D for Renewable Energy Sector (RES) is necessary to promote the associated emerging industries to reach their full potential. More research is required to increase the efficiency of existing technologies, develop new technologies, processes and products and to drive down significantly the production costs for heat, power and fuel for RES. Furthermore, increased R&D spending should be accompanied by increased involvement of the industry to ensure the market uptake of the generated results. Under a supportive scenario, the contribution of RES to the world energy supply could reach 47% by 2040. Professor Zervos showed that growth rates of new RES technologies such as wind and PV have been of the order of 25-30% per year during the past few years and projected that other emerging technologies could demonstrate similar growth rates once the important technical breakthroughs have been accomplished through increased R&D.

The strong message was repeated that R&D is needed for all RES technologies to develop their full potential. Technical priorities for each sector should be defined based on the maturity of the technology involved. To this end he proposed four generic groups:

- *Mature technologies such as Small Hydro and Geothermal where the main objective should be to increase efficiency and reduce costs*
- *Rapidly emerging technologies such as wind and PV where the objective should be to ensure large-scale technology development*
- *Existing technologies with promising potential such as Biomass and Solar Thermal where the objective should be to ensure market deployment and larger growth rates, and*
- *Technologies under development such as Marine energy where the objective should be to advance the state of the art in order to make them ready of market application*

Kaoru Yamaguchi of the Institute of Energy Economics of Japan made the last presentation of this session. He showed that there is a new policy environment influencing renewables. This environment contains both positive and negative impacts. On the positive side, he listed the New Vision for 50% sustainable energy sources by 2050, the Kyoto Protocol requiring stronger environmental constraints, the high energy prices and instability in the Middle East indirectly improving the competitive position of renewables. Recent events such as terrorism threats point to the advantages of distributed generation, and the emergence of new industries can contribute to economic growth. On the negative side there is increasing energy demand as a result of the growth in China and India, unknown factors of cost, infrastructure development and technology and finally changes in conventional energy frameworks.

Mr. Yamaguchi pointed out that there is a need to review the characteristics of policy instruments such as targeted R&D and regulatory framework encompassing incentives and quotas. Some have been successful such as the Japanese R&D subsidy for PV and PURPA in the US, yet for others it is too early to conclude. Some of the lessons learned point to the need for policy sustainability, integration of the cost of intermittency into the market, and the need to have R&D priced in terms of both monetary (US$) and physical market value (kWh). Implications of change in energy systems in the long-term encompass infrastructure for distributed systems with various types of resources and technologies and integration of energy systems with regional development, advancement of developing countries and global energy security. The policy framework in the new paradigm points to the need to advance

technologies through carefully chosen R&D projects and programs as well as market deployment. To convince policy makers on new initiatives, renewable energy supporters must be able to show benefits.

Presenters during Sessions 2 and 3 concentrated on the particular technologies covered by the Implementing Agreements. They covered Electricity from Renewables (Session 2) and Heat and Fuels (Session 3). Each of the Implementing Agreement leaders presented a summary of progress in their respective technologies and outlined the respective priorities arising from their work. Details of these priorities are included in Appendix C. The complete reports by each IA on the status of their technology and priorities suggested are available through the IEA.

Session 2 Electricity from Renewables, included presentations on Geothermal energy, Hydropower, Wind energy, Photovoltaics, Concentrating Solar Power, and Ocean energy.

In the case of Geothermal Energy, it was pointed out that the technical potential of this option is of the order of 5,000 EJ/y and it is available in 80 countries. Geothermal energy is being used in 71 countries with electricity generation capacity accounting for 8,900 MW_e. Costs of geothermal energy have come down by 50% in the last 20 years and are projected to come down to US$ 0.01 –0.08/kWh. The main challenges for this option are to reduce generation costs, increase geographical distribution of use, and improve technology for new and sustainable uses. If these challenges are met, geothermal energy could contribute 5% of Global electricity by 2020 and could make a higher contribution through significant government support for R&D, education and skills transfer and effective public/private cooperation. The main technology priorities are shown later on and include resource exploration, technology development and information dissemination.

The report on Hydropower served to remind participants that this option provided the world with safe, reliable and cost-effective electrical energy for more than 100 years. It still provides the lion's share of clean renewable energy worldwide and has the potential to be a significant contributor to the REWP vision for 2050. The key issues for hydropower include promoting hydro's value and sustainability, improving technologies, and integrating hydro with other renewables especially in the context of addressing intermittency. For the longer term, it will be necessary to improve public acceptance and advance innovative and cost effective technologies.

Among the emerging options, Wind Energy is advancing fast with global installed capacity estimated to have reached 46GW and growing. This growth has been achieved through significant reductions in the cost of delivered power over the last few years. Wind generated electricity can further come down in costs from about US$ 0.04/kWh now, to less than US$ 0.03/kWh within the next two decades. The key issues over the next few years include technology improvements, offshore wind issues, system integration and in particular intermittency, and environmental and societal issues.

The impressive advances in Solar Photovoltaics achieved during the last few decades, have helped enhance commercialisation of these technologies. Without any practical limit in resource potential, the key barrier to overcome is still cost effectiveness in the broad markets. There is a need to continue strong support of PV R&D in several areas including materials, cells and modules, system components, processes and manufacturing and cross-cutting issues such as network, storage, buildings applications and other.

The report on concentrating solar energy –Solar PACES- outlined that there are now nine commercial plants in the US operating since the late 80's and more pilot and prototype systems emerging worldwide. Generation costs can be as low as US$ 0.15-0.21/kWh for the

50 MW plants. Hybrid plants incorporating fossil fuels would lower cost further. There is need for additional R&D to stimulate competition and attract further competence while allowing for medium-to-long term developments that need scaling steps.

Ocean Energy Systems are still at the early stages of development. They encompass several types of technologies including Ocean wave, Tidal, Marine current, Salinity gradient and Ocean thermal. Technology development in these areas shows no evidence of convergence at this time. Nevertheless, the potential is almost unlimited and there is interest in several countries to advance the state of the art for important contributions in the longer term.

Following the presentations in Session 2, there were several key questions/comments raised, including:

- *How to we prioritize technologies*
- *It is too early to understand cost estimates on Ocean systems*
- *Intermittency and Integration are very important issues and there is a need to explore the technical and other options for managing these issues. The higher the wind energy penetration, the higher is the cost of integration because of intermittency*
- *There is a need to transform the grids to improve the absorption capacity of renewable energy*

Session 3 included presentations on Bioenergy, Hydrogen and Solar Heating and Cooling.

On Bioenergy, it was clarified that even though this topic is reported in Session 3, it is important to understand that 'Bioelectricity' accounts for more electricity generation currently than any other renewable energy option except Hydro. Bioenergy is a complex matrix of resources and technologies that can generate heat, electricity and transport fuels. It accounts for significant contribution to energy supplies in many countries and there is potential for growth through improved technologies and enhanced deployment policies. It has the potential to directly replace fossil fuels through technologies that are already cost effective in most cases. It was concluded that in the case of bioenergy, significant cost reductions have already been achieved and policy instruments for market deployment are currently important priorities.

Hydrogen in the energy system will serve as a clean energy carrier *with flexible production and use options. It is attractive in the context of renewable energy technologies because in the long run, it can be produced from a variety of these options and used to address some of the associated issues of intermittency, storage and integration to the grid.*

Solar Heating and Cooling technologies could easily be the successor of oil and gas heating and that technical improvements have broadened the cost effective applications for these options. R&D budgets for this technology have decreased substantially during the last two decades. Increased R&D funding is needed to further improve cost effectiveness and allow faster market deployment.

Key Questions/Comments made by Seminar participants at the end of this session (S3) clarified some of the arguments made and included:

- *The R&D budgets spent on Bioenergy per unit energy output is minimal compared to other renewable energy options.*
- *Geothermal energy can also be used for heating and cooling with or without a heat pump. It is already practiced in many countries*
- *Security and public acceptance of renewable energy is just as important as technology development*

- *Hydrogen deployment will take time*

Additional comments from audience on all sessions included:

- *The need for more information on adoption of R&D metrics to measure results*
- *The importance of Intermittency of energy supply by certain renewable sources*
- *The need for improved articulation of the technologies available now and what needs to be done to advance the state of the art*
- *In comparing the R&D allocations of the 1970's and the more recent ones, it was pointed out that the fear of 1970's type shortage of energy is not present now*
- *Prioritization can occur with proper criteria*
- *The need to relate RD&D in renewable energy to current social issues such as unemployment and other*
- *The reference scenario is unsustainable. We therefore need more Energy Efficiency as well as more Renewable Energy. R&D is a good investment to address the sustainable energy scenario.*

Overall Conclusions and Priorities Identified by Panel of Rapporteurs

The seminar provided for a series of rapporteurs at the end of the day to summarize each of the sessions and encourage further discussion. According to these summaries, Session 1 provided a context for the seminar. The speakers pointed out that Renewable Energy technologies could, under various scenarios or visions, provide very significant contribution to total energy supplies within the planning period under discussion. Under certain assumptions on alternative energy policies and pricing for CO_2 at US$50/t, the share of electricity generated from renewables could exceed 50% by 2050.

The roadmap towards the above targets needs to be fully defined but certain general principles must be accepted. R&D on renewables, for example, must be carried out in the context of integrated energy policies that take into consideration technology development as well as market deployment through fiscal or other means that leverage public support with the resources of the private sector. In addition, it was emphasised that R&D requires different levels of support depending on the maturity of technologies. Mature technologies *such as Small Hydro and Geothermal for example need to address increasing efficiency and reducing costs while* Rapidly emerging technologies *such as Wind and PV need to address the issues associated with large-scale technology development.* Existing technologies with promising potential *due to resource availability, such as Biomass and Solar thermal need to ensure market deployment and larger growth rates.*

R&D appears to be essential at the early stages to advance technical know how and to bring down costs and influence market penetration. In the longer term it facilitates cost effectiveness through more improvements in both the product as well as the manufacturing process.

In order to facilitate the request for increased financial support, several speakers and interveners pointed to the need to relate renewable energy R&D to the broader energy policy issues of cost effectiveness, security of supply, as well as environmental benefits. At the same time, it would be advantageous to refer to the potential industrial and economic benefits of new technologies.

On Session 2, it was concluded that each of the IA leaders supported strongly the technology they cover, stressing that their technology:

- *Can contribute substantially to electricity generation.*
- *There exists a huge potential for technological improvement and cost reductions*
- *As a consequence there is a need for more funds for R&D, especially since it is evident that budgets for Renewable energy have been reduced dramatically over the last two decades*
- *Cannot and must not concentrate efforts in a few technologies but rather support R&D in all areas*

Because technologies are at different levels of maturity, there is a need for different types of intervention. Nevertheless there are some common priorities such as:

- *Cost reductions in order to improve market deployment potential. This can be achieved through technology advances but also through development of manufacturing and production processes - themselves affected by targeted market deployment and active investments by the private sector – the learning cycle.*
- *Environmental issues, both real and perceived*
- *Social aspects such as public acceptance and capacity build-up*
- *Integration of new technologies to the grid, including specific technologies on storage and grid management. These issues can be addressed perhaps through a new IEA agreement or cooperation between implementing agreements*
- *Need demonstrations in certain areas, such as in concentrating solar power and ocean energy to test new findings and as a precursor to market deployment*

The main highlights of Session 3 included:

- *Requirements for regulatory framework in areas addressing heating and cooling such as Bioenergy, Solar heating and Geothermal heat pumps*
- *Both Bioenergy and Hydrogen contribute to fuels for transport and have an integral storage capability*
- *Intermittency is a real problem for the electricity sector and both Bioenergy and Hydrogen can help. The IEA REWP has already been helpful and plans for a new IA on grids would be positive*
- *The list of priorities for research and development were too numerous, especially in the context of declining resources. It is important to clarify what should be done at the international level as opposed to national and individual company level. There is a need for assessing the added value of international R&D. A follow-up observation to the above is the need for better – stronger management framework. This may include better metrics, regular reviews of priorities and regular refreshing of research team participants to reflect on new priorities*
- *R&D must lead to market related products and services. This link is particularly important in the context of justifying our work in political messages and requests for additional resources.*
- *There has to be a clear distinction between wide ranging 'long term scientific research' and well focussed 'near market RD&D'*
- *Finally, it is important to remember that each country has its own RD&D priorities based on their particular resource endowments and technology and industrial strengths.*

The Overall Conclusions of the Seminar were summarised by pointing out that important challenges for sustainable energy supply are not yet resolved. 3 Es+1 encompassing Economic Development, Energy Security and Environmental Sustainability while addressing Energy Poverty are still valid and call for action.

The key messages that can be derived from the seminar deliberations include:

- *Technology learning takes place through RD&D and international collaboration*
- *Policies to promote sustainable energy have an impact and thus are necessary*

- *Technologies have different time lines but similar potentials (Hydro/Wind/PV for example)*
- *RD&D coupled with technology deployment are needed to achieve the desired goals*
- *Differentiated approaches are necessary to address diverse problems of non uniform technical challenges*
- *Technology collaboration has provided proof that it contributes substantially to accelerate progress*
- *More needs to be done to advance the development and commercialisation of sustainable energy and can be done*

Implications for Policy

The seminar discussions reiterated the positive climate on renewable energy progress and elaborated on the potential for significantly higher energy contributions in future decades. There is broad and valid consensus that Renewable energy has made very significant progress over the last three decades. Through RD&D – much carried out through international collaboration – a number of sustainable technologies have advanced and are gaining a growing market share while contributing significantly to energy supply. The cost of delivered energy from renewables sources has come down dramatically through technology development and market feedback. The current cost of generating energy is comparable with conventional forms of energy in the case of hydro, many forms of bioenergy and geothermal, and in niche markets for many other technologies. Hydroelectricity provides almost 20% of global electrical generation while Bioenergy and Geothermal contribute significant amount of both electricity and heat. Newer technologies such as Wind and Photovoltaics are becoming important global industries with annual sales of several billion US$. Physical and technical potential of each and all technologies is very large to unlimited although there is geographic influence on the choice of option and technology, hence the need for flexibility on technology choice.

The experts attending the Seminar pointed out that the potential for renewable energy to significantly increase its contribution to global energy supplies is very strong. Drawing on the experience of the last few decades and the lessons learned, it is clear that renewable energy can play a very important role in sustainable energy supplies by the middle of this century. Based on recent IEA analysis, there is broad consensus that R&D in renewable energy must be strengthened with a caveat that priorities must be well selected in order to address policy objectives, especially as they relate to prospective cost effectiveness. Intelligent choice of such priorities will invariably facilitate market deployment of new and improved technologies. To this end, it will be necessary to refocus the renewable energy strategy towards three general directions as pointed out by the Executive Director Mr Mandil. They include:

- *Increased targeted renewables RD&D funding*
- *Improved strategy for market deployment and*
- *Inclusion of externalities in policy considerations – especially as they relate to cost effectiveness*

The goal towards cost effectiveness can be advanced through a determined effort in many directions. One important point that was clearly mentioned during the seminar was the need that R&D must lead to market related products and services. This link is particularly important in the context of justifying our work in political messages and requests for additional resources. There has to be a clear distinction between wide ranging 'long term scientific research' and well focused 'near market RD&D'. It was well recognized that cost

reductions through R&D can lessen the requirement for overly generous deployment incentives and hence they should be given top priority.

In addition to the above, there will be a need to address generic technology related issues such as the integration of renewable energy to the grid and related energy storage issues. This is particularly important for certain fast growing technologies such as wind and PV because of the intermittent nature of their energy contribution. It is an important global issue that could facilitate overall deployment of these emerging technologies while at the same time advancing the concepts of distributed generation. There was broad consensus that this issue may merit a new implementing agreement because of the benefits of international collaboration.

Other policy related priorities identified during the seminar and listed later on in Appendix C include the need for targeted demonstration of promising technologies and improvements in the regulatory framework affecting new energy options such as renewables.

Finally, it was concluded that both the search towards cost effectiveness and the addressing of practical issues such as integration to the grid could act as catalysts to improve the participation of the private sector in RD&D in renewable energy.

Selected References

1. *Energy to 2050 – Scenarios for a Sustainable Future, OECD/IEA 2003*
2. *Renewable Energy Market and Policy Trends in IEA Countries, OECD/IEA 2004*
3. *Renewables Information, OECD/IEA 2004*
4. *Renewables for Power Generation – Status & Prospects, OECD/IEA 2003*
5. *World Energy Investment Outlook, OECD/IEA 2003*

Appendix A

Programme of ***the Joint Seminar "Catching Up: Priorities for Augmented Renewable Energy R&D"***
3 March, 2005 – Paris, France

Welcome Address
Claude Mandil, Executive Director, International Energy Agency

Introduction and Objectives of the Seminar
Roberto Vigotti, REWP Chair, Italy
Committee on Energy Research and Technology – a Perspective
Graham Campbell, CERT Chair, Canada

Session 1
Setting the Context and the Vision
Moderator: Neil Hirst, Director, and International Energy Agency
Panellists:
Energy Technology Perspectives for Renewables – Fridtjof Unander, IEA
Priorities for the Renewable Energy Research– Arthouros Zervos, European Renewable Energy Council (EREC)
Policy Frameworks for Paradigm Shift – Kaoru Yamaguchi, Institute for Energy Economics, Japan
Rapporteur: Morgan Bazilian, REWP Delegate, Ireland

Session 2
Electricity from Renewables - Technology Path for Distributed and Decentralised Generation
Moderator: Ralph Sims, REWP Delegate, New Zealand
Panellists:
Geothermal – Ladislaus Rybach, Vice Chair Geothermal IA, Switzerland
Hydropower – Niels Nielsen, Executive Secretary Hydropower IA, Canada
Ocean Energy – Katrina Polaski, Chair Ocean Energy Systems IA, Portugal
Solar Photovoltaics – Stefan Nowak, Chair Photovoltaic Power Systems IA, Switzerland
Wind Energy – Peter Goldman, Chair, Wind Energy IA, United States
Rapporteur: Joachim Nick-Leptin, Ministry of Environment, Germany

Session 3
Heat and Fuels from Renewables - Technology Path for Production of Heat and Fuels, including Hydrogen
Moderator: Christophe Jurczak, REWP Vice Chair, France

Panellists:
Bioenergy – Kyriakos Maniatis, Chair Bioenergy IA, European Commission
Concentrating Solar Power and Chemical Energy Systems – Robert Pitz-Paal, Executive Secretary, SolarPACES IA
Hydrogen – Trygve Riis, Chair Hydrogen IA, Norway
Solar Heating and Cooling – Michael Rantil, Chair Solar Heating and Cooling IA, Sweden
Rapporteur:William Gillett, REWP Delegate, European Commission

Rapporteurs Panel
Moderator: Gilles Mercier, REWP Vice Chair, Canada

Rapporteur Session 1: Morgan Bazilian, REWP Delegate, Ireland
Rapporteur Session 2: Joachim Nick-Leptin, Ministry of Environment, Germany
Rapporteur Session 3: William Gillett, REWP Delegate, European Commission

Discussion
Moderator: Antonio Pflüger, Energy Technology Collaboration, International Energy Agency

Conclusions and Next Steps
Roberto Vigotti, REWP Chair, Italy

Appendix B List of Seminar Participants

AGERT	Carsten	Strategic Planning Fraunhofer Institute for Solar Energy Systems, Germany
ALISSE	Lily	Renewable Energy Unit, International Energy Agency, France
ANTTONEN	Mika	Senior Adviser, Energy Department, Ministry of Trade and Industry, Finland
BATAILLE	Michel	IT Manager, European Photovoltaic Industry Association, Belgium
BAZILIAN	Morgan	Head of Sustainable Energy Services, Sustainable Energy Ireland
BHUYAN	Gouri	Director, Civil Infrastructure & Alternative Energy Technologies, Powertech Labs Inc, Canada
BIERMANN	Andreas	Long Term Office, International Energy Agency, France
BILLSON	Matthew	Policy Adviser, Energy Technologies – International Team, Dept of Trade & Industry, UK
BLASCO	Manuel	CENER, Spain
BRUCHMANN	Ullrich	Federal Ministry for Environment, Nature Conservation & Nuclear Safety, Germany
CAMPBELL	Graham	CERT Chair. Director General, Office of Energy Research & Development Natura Resources Canada
DI CECCA	Antonio	Energy Statistics Division, International Energy Agency, France
ELEK	Janos	Senior Counsellor, Hungary
FALCAO	Antonio	Professor, Instituto Superior Tecnico, Portugal
FANINGER	Gerhard	University of Klagenfurt, Austria
FIORENTINO	Antonio	Ponte di Archimede Spa, Italy
FRANKL	Paolo	Ecobilancio Italia, Italy
FUKASAWA	Kazunori	Director, NEDO, France
GARCIA-CONDE	Antonio	National Institute for Aerospace Technology, Spain
GELLER	Laurie	Science Officer, International Council for Science, France
GESSANGER	Stefan	Secretary General, World Wind Energy Association, Germany
GILLETT	William	Directorate-General for Energy and Transport, European Commission, Belgium
GONCALVES	Helder	INETI, Portugal
GORISSEN	Norbert	Head of Division, Bundesministerium für Umwelt, Naturschutz und Reaktorsicherhei Germany
GRUNNE	Tore	Adviser, Ministry of Petroleum and Energy, Norway
HARA	Nobuyuki	Renewable Energy Unit, International Energy Agency, France
HERSLETH	Petter	Statkraft AS, Norway
HIRST	Neil	Director, Energy Technology Office, International Energy Agency, France
IKEGAMI	Yasuyuki	Deputy Director, Associate Professor, Institute of Ocean Energy, Saga University, Japan
JONES	David	Editor - Platts Renewable Energy Report, Platts, UK
JURCZAK	Christophe	REWP Vice Chair. Charge du bureau des énergies renouvelables et des technique nouvelles, Ministère de l'Economie, des Finances et de l'Industrie, France
JUSTUS	Debra	Climate Change Global and Structural Policies Division, Environment Directorate, OECD
LEWIS	Tony	Director, Hydraulics & Maritime Research Centre, University College Cork, Ireland
LOPEZ MARTINEZ	Cayateno	Director General Adjunto, CIEMAT, Spain
LYONS	Lorcan	Energy Statistics Division, International Energy Agency, France
MALYSHEV	Teresa	Renewable Energy Unit, International Energy Agency, France
MANDIL	Claude	Executive Director, International Energy Agency, France
MANITATIS	Kyriakos	Chair, Bioenergy IA. European Commission, Belgium
MARTINEZ-PLAZA	Diego	Ciemat-Plataforma Solar de Almeria, Spain
MENNA	Pietro	European Commission- DG TREN, Belgium
MERCIER	Gilles	REWP Vice Chair. Office of Energy Research & Development, Natural Resources Canada
MICHAUX	Gabriel	FPS Economy, Energy Policy Division, Belgium
MIGNONE	Alicia	CERT Vice Chair. ENEA, Italy
MILOW	Bernhard	Programme Directorate Energy, DLR, Germany
MOORER	Richard	Deputy Assistant Secretary, Technology Development, Energy Efficiency & Renewabl Energy, U.S. Department of Energy
MORITA	Hiroyasu	Deputy Director, Ministry of Economy, Trade & Industry, Agency of Natural Resources Energy, Japan

MUELLER-STEINHAGEN	Hans	Director, DLR Institute for Technical Thermodynamics, Germany
NALETTO	Simonetta	Enel Spa, Belgium
NICK-LEPTIN	Joachim	Head of Division of Research in the Field of Renewable Energies, Federal Ministry o Environment, Nature Conservation and Nuclear Safety, Germany
NIELSEN	Neils	Executive Secretary, Hydropower IA. Principal, Kator Research Services, Australia
NIELSEN	Kim	Rambøll, Denmark
NOWAK	Stefan	Chair, Photovoltaic Power Systems IA. Nowak Energy & Technology Ltd, Switzerland
OCHARAN	Enrique	Ministry of Industry, Tourism and Trade, Spain
PADILLA	Ana	Energy Statistics Division, International Energy Agency, France
PASSMORE	Rosemary	Australian Delegation to the OECD, Adviser for Industry, Tourism & Resources, France
PFLUGER	Antonio	Division Head, Energy Technology Office, International Energy Agency, France
PITZ-PAAL	Robert	Solar Research Division, DLR Institute of Technical Thermodynamics, Germany
PNEUMATICOS	Stelios	Orthologic Consulting, Ottawa, Canada
PONTES	Teresa	Chair, Ocean Energy Systems IA. INETI, Portugal
POTTINGER	Carrie	Energy Technology Office, International Energy Agency, France
RALDOW	Wiktor	Head of Unit, European Commission, Belgium
RANTIL	Michael	Chair, Solar Heating and Cooling IA. Swedish Research Council for Environmen Agricultural Science and Spatial Planning (FORMAS), Sweden
RIIS	Trygve	Chair, Hydrogen IA. Research Council of Norway
RIKHEIM	Harald	Adviser, Research Council of Norway
ROBINSON	Michael	Deputy Director, NREL's National Wind Technology Center, United States
ROGEAUX	Bernard	R&D advisor for strategic research and development, EDF-EPSI, France
ROHLIN	Peter	Swedish Energy Agency, Sweden
ROMERI	Valentino	Analysis, Research and Advisory, Rasfin, Italy
ROMERO ALVAREZ	Manuel	Director of Renewable Energy Division, Centro de Investigaciones Energetica Medioambientales y Tecnologicas, Spain
RYBACH	Ladislaus	Vice Chair, Geothermal IA. Managing Director, Geowatt AG, Switzerland
SANCHEZ SUDON	Fernando	CENER, Spain
SANGIOVANNI	Giuseppe	Long term Office, International Energy Agency, France
SCHNEIDER	Rainer	REWP Member, Forschungszentrum Jülich GmbH, Projektträger Jülich, Germany
SCHOU	Annette	Head of Sections, International Division, Danish Energy Authority, Denmark
SELLERS	Rick	Head, Renewable Energy Unit, International Energy Agency, France
SHAW	Suzanne	Scientific Officer, Joint Research Centre – Institute for Energy, The Netherlands
SHIMA	Masakazu	Permanent Delegation of Japan to the OECD, France
SIMS	Ralph	Sustainable Energy Centre for Energy Research, Massey University, New Zealand
SODERBAUM	John	Science and Technology Adviser, Department of Industry, Tourism and Resources, Australia
STENZEL	Till	Renewable Energy Unit, International Energy Agency, France
SUKER	Tadijica	Long Term Office, International Energy Agency, France
TAMME	Rainer	DLR-German Aerospace Center, Germany
TIMMER	Marc	Director General, EUFORES, Belgium
TIRIS	Mustafa	Institute Director, TUBITAK-MRC, Energy Institute, Turkey
TOMITA	Tetsuji	Senior Coordinator, The Institute of Energy Economics, Japan
TRONNINGSDAL	Jan	Long Term Office, International Energy Agency, France
TULEJ	Peter	Renewable Energy Unit, International Energy Agency, France
UNANDER	Fridtjof	Division Head, Energy Technology Office, International Energy Agency, France
VAN DUIN	Armande	ECN (Energy R&D benchmark for Dutch Ministry of Economic Affairs), The Netherlands
VIGOTTI	Roberto	REWP Chair. ENEL – Divisione Internationale, Italy
WEISS	Brigitte	Austrian Federal Ministry for Transport, Innovation and Technology, Austria
WITTE	Frank	Senter Novem, The Netherlands
WOODRUFF	Madeline	Energy Technology Office, International Energy Agency, France
YAMAGUCHI	Kaoru	Group Manager, The Institute of Energy Economics, Japan
ZERVOS	Arthouros	European Renewable Energy Research Council, Belgium

Appendix C Detailed Priorities by Technology

Generic Priorities Arising Out of the Seminar Discussions

- *Cost reductions in order to improve market deployment potential. This can be achieved through technology advances but also through development of manufacturing and production processes, themselves affected by targeted market deployment and active investments by the private sector – the learning cycle*
- *Intermittency is a real problem for certain technologies. It will be necessary to address integration of new technologies to the grid including specific technologies on storage and grid management. These issues can be addressed perhaps through a new IEA agreement or cooperation between implementing agreements*
- *Dedicated demonstrations in certain areas, such as in concentrating solar power, ocean energy to test new findings and as a precursor to market deployment, as well as large scale demonstrations at commercial scale are needed for all renewable energy technologies to improve market acceptance*
- *Environmental sustainability and Social issues associated with public acceptance and capacity build-up*
- *Requirements for regulatory framework in areas addressing heating and cooling related to Bioenergy, Solar heating and Geothermal heat pumps*
- *R&D must lead to market related products and services. This link is particularly important in the context of justifying our work in political messages and requests for additional resources. There has to be a clear distinction between wide ranging 'long term scientific research' and well focussed 'near market RD&D'*
- *Market penetration instruments such as standardisation, labelling and trade issues need to be developed further.*

Bioenergy

According to the strategic plan and the ongoing activities based on the twelve Tasks the R&D priorities for Bioenergy are presented on the basis of resources, conversion processes to energy vectors and integration of research themes along the value chain.

Sustainable Resources

Increase the availability of affordable feedstocks with attention to improved production processes of forest biomass and reliable large-scale supply chains to meet future demand by big market players. Further improve the yields of energy crops and short rotation forestry and develop the appropriate handling and logistic systems for the new types of feedstocks. Improve the handling of waste streams and recovery of resources and fuels from them that can be used with environmental responsibility for energy or fuels production.

Conversion Processes

All main conversion technologies should achieve cost reductions and increase the overall conversion efficiency with more emphasis of combined heat and power (CHP) applications. Combustion: *Improve the reliability and penetration of cofiring applications with fossil fuels and the environmental performance and automation of small scale –household- applications. Attention should be given to new systems such as organic Rankine cycles, with increased emphasis on multifuel operation for all applications. Demonstrate large (>300 MW_{th}) CHP industrial plants with dedicated feedstock supply systems. For incineration, increase the efficiency to power with materials of higher corrosion resistance properties and further decrease emissions of pollutants.*

Gasification: *Achieve market penetration of downdraft systems with reliable tar removal at the small scale (< 1 MW_e) while at the middle scale (1-5 MW_e) the effort should be on fluidized bed CHP applications based on catalytic tar conversion. Continue the development of Integrated Gasification Combined Cycle (IGCC) technologies in the industrial scale (25-50 MW_e) and achieve the production of clean synthesis gas that could be used for the production of synthetic liquid (such as Fischer-Tropsch) and gaseous (such as hydrogen) biofuels.*
Pyrolysis: *Demonstrate the production of bio-oil at industrial scale and its utilisation in CHP applications or in dedicated turbines and engines. Develop the production of chemicals from bio-oil and promote its value as means to increase the energy content of biomass per unit mass for transportation and subsequent unitisation in other conversion processes.*
Anaerobic digestion: *Further expand the resource basis by adapting technologies to operate with difficult waste streams and effluents and reduce the costs of biogas purification to biomethane for utilisation in transport applications, feed into natural gas pipelines or as a hydrogen carrier.*
Fermentation: *demonstrate at industrial scale the production of ethanol from lignocellulosic materials and reduce the costs of the processes and the enzymes used and further expand the resource basis. Demonstrate the advantages of ethanol/methanol as hydrogen carriers.*
Biorefineries: *Develop and demonstrate the concept for the production of chemicals, materials, fuels and energy with increased degree of utilisation of the available biomass resources and thus drive towards sustainable industrial systems.*

Integration of research themes
Socio-economic: *Improve the understanding of bioenergy's societal and economic aspects with attention to rural development and employment and promote its public acceptance by the citizen with attention to the farmers and foresters who will have to operate with new crops and unconventional production systems. Promote the citizen's choice principle for biofuels for transport and household-heating applications.*

Climate change: *Further improve the understanding of bioenergy's contribution to fighting climate change and provide the basis for selecting appropriate national strategies for GHG mitigation. Based on a full fuel-cycle basis compare bioenergy and fossil energy systems in terms of GHG balance and evaluate the tradeoffs between strategies of maximised carbon storage (afforestation, forest protection) and maximised fossil fuel substitution with biofuels.*
Trade: *Develop a sustainable functional international biofuels market*. *Analyse the options for integrating the production of biomass for energy and subsequent export into agricultural and agro-forestry systems especially in developing countries and countries in transition. Evaluate of the political, social, economic and ecological impact of biomass production and trade in these systems for the local people, for food production; also in relation to sustainability.*
Systems analysis: *Provide better understanding of the underlying policy issues that create barriers to the penetration of bioenergy systems into the energy markets and the interaction of the various policies that are affected by bioenergy such as energy, environment, agriculture, taxation etc. as well as the analysis of the interaction between different parts of the energy system (e.g. consumers, fuels producers, utilities) and the interaction of the energy system with other parts of society. Provide decision makers with scientifically sound and politically unbiased analyses and conclusions needed for strategic decisions related to research or policy issues.*

Concentrating Solar Power

Short to medium term research should focus on the improvements of modular components like concentrators, heliostats or modular receivers. These are essential cost drivers.

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

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

Geothermal

In addition to the current R&D work, it is necessary to inform stakeholders of the benefits of geothermal energy, encourage partnerships that allow benefits to flow back to the community and clear commitment on the part of national governments on the positive impact of new technologies towards mitigation of CO_2 emissions. Some of the specific priorities for additional R&D could include funding to expedite the completion of current priorities as well as investigate new topics and include increased production and dissemination of information directed towards:

- *Development of better exploration and resource confirmation and management tools*
- *Commercial development of enhanced geothermal systems*
- *Development of deep (>3,000 m) geothermal resources*
- *Increased geothermal co-generation (power and heat)*
- *Reduction of costs of geothermal well drilling, logging and completion*
- *Increased direct use of geothermal resources for space/district heating and multipurpose "cascading"*
- *Better understanding and mitigation of environmental effects. In addition, dissemination of appropriate information to stakeholders is essential.*

More general priorities being proposed include studies of:

- *Life cycle analysis of geothermal power generation and direct use systems*
- *Sustainable production from geothermal resources*
- *Power generation by improved conversion efficiency cycles*
- *Shallow geothermal resources for small-scale individual users*
- *Induced seismicity related to geothermal power generation (conventional and Enhanced Geothermal Systems)*

Hydrogen

The HIA Five year plan calls for additional work in collaborative R&D, Market Environment and Outreach, including:

- *Hydrogen production from renewable sources*

- *Advanced approaches to H2 production from C- materials, including decarbonisation and biomass to hydrogen processes*
- *Distributed hydrogen production*
- *On-board storage*
- *Infrastructure for stationary applications*
- *Databases of demos, systems and resources*
- *Enhanced information dissemination via web presence and E-publishing*
- *Growth and support of HIA through increased participation*

The HIA has identified the following global priorities in hydrogen production R&D

- *For all hydrogen production processes, significant improvement needs for increased plant efficiency, capital cost reduction, reliability and operating flexibility*
- *Small scale natural gas reformers*
- *Biomass to hydrogen processes*
- *Photoelectrolysis*
- *Biological processes*

Hydropower

There is significant opportunity to increase development of hydropower on a cost competitive basis as a foundation to meeting the REWP vision of 50% renewable energy by 2050. The highest priorities to focus new, additional R&D spending over the next 20 years can be classified under technical, economic and socio/environmental categories.

Technical priorities include

- *continuing equipment and materials development (by equipment manufacturers)*
- *improved performance of existing hydro plants*
- *innovative approaches to add generation to dams*
- *in-stream flow technologies (in conjunction with Ocean Energy IA)*
- *integration of wind into hydropower systems (in conjunction with Wind IA)*
- *development of hybrid systems for small hydro (in conjunction with Wind and Hydrogen IAs)*
- *training and education of professional and technical staff*

Economic priorities include

- *reducing O&M costs for existing and new hydro*
- *innovative financing for new hydro plants*
- *developing hydropower in developing countries*
- *improved risk management processes*
- *financial resources to upgrade existing projects in non OECD countries*

Socio-economic priorities include

- *increased public acceptance of hydropower*
- *auditable process to certify hydropower projects as sustainable*
- *safety and security of hydropower facilities*

To achieve the REWP's goals, the focus of RD&D funding for hydropower should be prioritized to cover the following key issues:

a) *provide approval mechanisms to ensure sustainable development that meets government and public acceptance*

b) *provide funding mechanisms for new projects in developing countries and existing low performing projects in non-OECD countries*
c) *Develop improvements in technology (systems, materials, manufacturing processes) and performance (systems and processes) for new and existing projects*
d) *develop/improve technologies for dams with power plants, and rivers with in-stream flow generation potential*
e) *work with other IA's (wind, hydrogen, ocean energy) to develop symbiotic benefits for overlapping renewable technologies*

Ocean Energy Systems

Ocean energy technologies must solve two major problems concurrently: proving the energy conversion potential and overcoming a very high technical risk from a harsh environment. Additional R&D funding would help to mitigate the substantial technical risk faced by device developers daring to harness the energy of the marine environment.

There are a number of both technical and non-technical barriers that must be addressed. The non- technical barriers include:

- *Resource assessment*
- *Energy production forecasting and design tools*
- *Test and measurement standards*
- *Environmental impacts*
- *Arrays of farms of Ocean Energy Systems and*
- *Dual-purpose plants that combine energy and other structures*

The technical barriers are specific to individual technologies and include:

- *Wave energy systems (wave behaviour and hydrodynamics of wave absorption, reliability and survivability incorporated into the design, generic mooring techniques, power take-off systems and deployment methodologies)*
- *Tidal Stream Current Systems based on underwater turbines (basic knowledge of current speed along the water column, structure water tightness, cost efficiency and reliability, foundation and installation methods, as well as transfer of knowledge to underwater systems)*
- *Salinity Gradient (development of functioning and efficient membranes)*
- *Ocean Thermal Energy Conversion (thermal cycles, influence of the environment, floating systems and other)*

Solar Heating and Cooling

A comprehensive and ambitious applied research, development and demonstration programme is needed to develop competitive advanced solar heating and cooling systems which are able to cost effectively provide 5 -10% of the overall low temperature heat demand of the IEA Member countries by 2020.

The proposed research priorities are outlined below:

1. Advanced Materials and Components
- *Advanced materials*
- *Advanced solar thermal collectors*
- *Advanced thermal energy storage*

2. Advanced Systems

- *Large-scale solar heating systems*
- *Solar industrial processes systems*
- *Solar cooling systems*
- *Combined solar heating and cooling systems*

3. Building Integration and Passive Solar

4. Standards, Regulations and Test Procedures

Solar Photovoltaics

There is a need for strengthened R&D efforts in several areas. The main issues being cost, efficiency and industrial products, R&D efforts are needed for

Materials
Examples: new materials for solar cells, window layers, encapsulation of solar modules

Solar cells and modules
Examples: improvement of existing solar cell technologies (crystalline silicon, thin film silicon and II-VI compound semiconductors), development of new solar cell technologies (organic solar cells), implementation in solar modules

System components and building integrated photovoltaics (BIPV)
Examples: advanced system components (inverters, battery chargers, cabling), hybrid systems, integrated products for BIPV, multifunctional components for building applications

Process and manufacturing
Examples: industrial production processes, feedstock materials, large scale manufacturing

Environmental aspects
Examples: improved energy payback, reduction of emissions, recycling

Quality assurance and standards
Examples: reliability of PV power systems, optimised energy yield, standards for new technologies and BIPV

Crosscutting issues
Examples: topics of relevance for PV and other (renewable) energy systems, grid interconnection issues, energy storage, energy production and use in buildings

Long-term R&D
Examples: basic materials' R&D involving nanotechnology, organic thin films, molecular chemistry, high-efficiency solar cell concepts through photon management

Wind Energy

R&D priorities in the mid- and long-term time frame in wind energy include:

Increase value and reduce uncertainties in areas such as:

- *Forecasting power performance*
- *Reduce uncertainties related to engineering integrity, improvement and validation of standards*

- *Storage techniques*

Continue cost reductions through:
- *Better models for aerodynamics/aeroelasticity*
- *New intelligent structures/materials and recycling*
- *More efficient generators, converters*
- *New concepts and specific challenges*
- Stand alone and hybrid systems

Enable large-scale use through:
- *Electric load flow control and adaptive loads*
- *Better power quality*

Minimise environmental impacts by addressing issues in:
- *Compatible use of land and aesthetic integration*
- *Noise studies*

Flora and fauna