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Towards the European Energy Research Area

Recommendations by the ERA Working Group of the Advisory Group on Energy

EUR 21353

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Towards the European Energy Research Area

Recommendations by the ERA Working Group of the Advisory Group on Energy

2005

Directorate-General for Research
Sustainable Energy Systems

EUR 21353

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PREFACE

In October 2002 the Commission asked its DG-RTD Advisory Group on Energy (AGE) to develop a strategic vision for energy R&D on a European scale, with an emphasis on overcoming existing barriers and on addressing the fragmentation that presently characterises much of energy R&D in Europe.

The objective was to support decision makers with wide-ranging and thorough analyses of the issues at stake, and of the potential of various technology options to provide Europe with sustainable energy supply and use.

The AGE embarked on a two-pronged approach by establishing two working groups:

- a Strategic Working Group (SWOG), to provide guidance on energy research priorities and strategies, at EU and Member States levels;
- a European Energy Research Area Working Group (ERAWOG), which focused on assessing the potential for greater coordination in various areas of energy research, together with practical recommendations to make ERA a reality in the energy field.

The analysis and recommendations put forward in this second report come from ERAWOG, and have been endorsed by AGE. They are important as the collective conclusions of many independent experts from very different backgrounds and specialisations although they do not, of course, commit the European Commission.

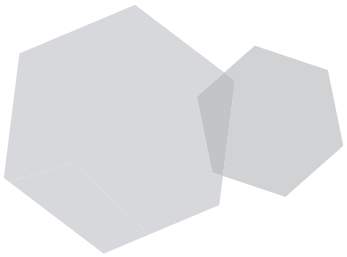
The ERAWOG members responsible for the thinking behind and the content of this report are Niels Busch, Gerd Eisenbeiss, Gerhard Faninger, Alain Gerard, Heather Greer (ERAWOG Chair/Rapporteur), Frantisek Pazdera, Peter Pearson and Iacovos Vasalos.

Other members of the AGE and of DG-RTD also contributed by making presentations to ERAWOG or by providing information and useful comment. They were William Borthwick, Hardo Bruhns, Martin Huemer, Peter Lund (AGE Chair), Frédérick Mariën (AGE and ERAWOG Secretary), Odissefs Panopoulos, Michel Poireau, Derek Pooley, Alfred Voss and Margot Weijnen. ERAWOG was also assisted throughout its work by Commission Services (DG RTD-Unit J).

ERAWOG believes that the creation of an ERA in energy (EERA) is an imperative if the effectiveness of European energy research is to increase, as is well demonstrated by the existing high level of integration of fusion oriented research, and that the EERA must be visionary and concern the deployment of complete technologies in the marketplace. Its creation will require the full commitment of Member States. ERAWOG has also identified critical issues for the creation of the EERA, regarding specifically the 7th Framework Programme.

In this first report, ERAWOG has identified eleven sets of organisational goals to be reached in corresponding technology fields, through actions to be undertaken by all public and private stakeholders. It has also identified a key role for the European Commission in terms of coordination, removal of researcher mobility barriers, implementation of administrative instruments for research, education, collaboration with third countries and ensuring flexibility in the face of ever-changing research requirements.

Paving the way towards an EERA will require attention to the issues analysed in this report, and to the strategic priorities and issues addressed by SWOG. Hence, the two reports should be regarded as complementary to one another.



I. MESSAGE TO POLICY-MAKERS

If society's future energy needs are to be met, a massive, long-term commitment of resources is needed. No single energy technology on its own will provide the solution, so research must be carried out across a wide range of technology options, which together could have a significant impact. Given the scale of the resources needed, we will continue to struggle to prioritise. Optimisation of the use of resources is essential.

Research across Europe is fragmented. Energy is no exception and, despite many years of co-operation, there is still little coordination of energy research programmes. The present approach to organisation is far from optimum: a great deal of energy research is carried out within regional and national programmes operating largely independently of one another and of the main European programmes. ERAWOG believes that the research problems in energy will be solved only by abandoning this costly and ineffective approach.

The Member States will be better able to tackle their energy problems if they do so together. The problems are shared, and shared solutions are needed across the Community. Some can only be addressed if Europe coordinates its participation in major international R&D projects. And it must also be recognised that achieving real effectiveness may involve the abandonment by some Member States of their own research programmes in some energy fields, in favour of a better coordinated European approach.

We can develop the new energy technologies we need, but we can only do so in time if energy research is far better organised than at present. It is ERAWOG's belief that energy research in Europe must be goal-directed, and that goals must be visionary and concern the deployment in the market place of complete technologies. This cannot happen without a well-coordinated approach across Europe, and a pooling of the resources available at regional and national levels. And the intellectual challenges are such that the best research brains in Europe must be shared at a European level.

Realising the European Research Area in energy – the European Energy Research Area – is thus not an option but an imperative. ERAWOG calls on the Member States to commit to the concept and principles for creating the EERA.

In this report, ERAWOG has identified 11 sets of organisational goals to be reached in 11 technology areas, through a series of actions which should be undertaken by all public and private stakeholders.

The Commission itself has a key role to play. It must:

- continue with top-down actions to stimulate a coordinated approach to planning and funding energy research;
- make sure that barriers to the mobility of researchers and the protection of intellectual property rights are addressed;
- implement the instruments at its disposal so as to achieve their goals of integration and coordination;
- allow for the necessary cross-cutting issues to be addressed – in materials, in education and training, in tackling societal problems associated with new energy technologies – including the age and gender imbalances that exist in many energy research fields;

- make sure that European energy research is carried out in collaboration with third countries;
- provide the flexibility needed to respond to changing requirements, in the development of future Framework Programmes.

But in addressing this agenda, the Commission will need the support of the Member States and all other stakeholders.

Time has been lost. The real work of creating the European Energy Research Area must start.

II. INCREASING THE EFFICIENCY AND EFFECTIVENESS OF EUROPEAN ENERGY RESEARCH

The demand for energy research is about to take off. This is largely due to the convergence of three critical factors: demand for energy itself is rising and will continue to rise[1]; fossil fuels are running out; and the need to start taking climate change seriously is becoming more and more clear. Our dominant energy technologies are unsustainable into even the near future, and there are research problems to be solved before alternative technologies can be as widely deployed as they must be. And some technologies will take decades to bring to the market. Arguably, the problems to be solved through energy research are among the most important facing society in the 21st century.

Supporting the necessary increase in energy research will take a substantial increase in financing[2]. But financing is not enough. It is undeniable that energy research programmes in the US or Japan are larger than those in the EU[3], but one of the important problems for Europe is that, despite many years of Framework Programmes, European energy research remains widely fragmented and uncoordinated. Each Member State – indeed, each region – independently plans and funds its energy research. In contrast, much of US and Japanese energy research is organised through large national programmes allowing for a concentration of financing on strategic priorities. Global markets for advanced sustainable energy technologies are huge and growing, and Europe is at risk of a serious loss of market share in key energy technology markets.

This report – of the ERA Working Group (ERAWOG) of the Commission's Advisory Group on Energy – focuses on increasing the efficiency and effectiveness of the organisation of energy R&D in Europe. Without a more rational use of resources (financial and intellectual); without access to world-class research facilities for European researchers; without a much more strategic approach to energy research in Europe – without all these it will be impossible to meet the enormous challenges faced by society in providing for its future energy needs in a sustainable way. It is such issues that the European Research Area will address.

The concept of a European Research Area was discussed in a European Commission Communication in January 2000. This Communication acknowledged the gap between Europe's expenditure on R&D compared with the much higher expenditures by the US and Japan, and recognised that the "fragmentation, isolation and compartmentalisation of national research efforts and systems, and the disparity (between) regulatory and administrative systems, only serve to compound the impact of lower (European) investment in knowledge"[4]. The European Research

1. **World energy, technology and climate change outlook 2030 – WETO**, *Brussels: European Commission Directorate-General for Research – Energy, EUR 20366, 2003.*
2. *The Strategy Working Group (SWOG) of the Commission's Advisory Group on Energy has recommended a fourfold increase in funding for European energy research. We endorse that recommendation. See* **A Vision for European Energy R&D: Recommendations for Research and Development by the Strategy Working Group of the Commission's Advisory Group on Energy, December** *2004.*
3. *"The United States of America and Japan account for over 65% of the energy RDD spending by IEA member governments", Antonio V del Rosario, Chairman, World Energy Council, 2003.*
4. **Towards a European Research Area**, *Brussels: European Commission Communication to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, COM (2000) 6, 18 January 2000..*

Area would aim to improve the coordination and integration of research in Europe. The Commission's Framework Programmes would help in creating the conditions needed for such integration, and the Member States would themselves participate in creating a 'single research market' in Europe through a voluntary process of self-coordination. The objective of creating the ERA was adopted by the European Council at Lisbon in March 2000[5].

Unhindered progress towards realising the ERA in energy is thus not an option but an imperative for European society, and hence also for European policy-makers and administrators.

5. Presidency Conclusions, Lisbon European Council, 23 and 24 March 2000. See http://europa.eu.int/comm/off/index_en.htm.

III. VISION OF A EUROPEAN ENERGY RESEARCH AREA (EERA)

The term 'European Energy Research Area' (EERA) is used throughout this report to denote our vision of the ERA as it develops within and across the field of energy R&D.

It is not an untilled field because, in some ways, the EERA exists already. For a long time industry and public research institutions have communicated and worked with one another in tackling shared problems, and previous Framework Programmes have led to a significant measure of co-operation and collaboration among key research actors. Research within industry is already largely organised on a European, and even a global, basis. Although this is far from a fully developed EERA, it nonetheless provides fertile ground for rapid progress, as the many energy-related initiatives since the start of FP6 have demonstrated (see Section D).

Our overall vision of the EERA does not differ markedly from that contained in numerous Commission documents. Above all, it is of a vibrant, world-leading single energy research market across Europe, with well-trained researchers able to pursue rewarding careers within that market. Such a market will serve both to retain European researchers and to attract good research staff from elsewhere in the world. Our vision of the EERA includes the coordination requirements, organisational approaches, and funding instruments outlined below.

We want European energy R&D to be a vigorous force behind securing a substantial share of the €16 trillion-plus[6] world market for energy technology between 2001 and 2030.

Many of the issues faced in developing the EERA are common to the ERA more generally. However, the need to pursue energy research across a broad agenda[7], the typically large funding needs and very long lead times involved in bringing energy technologies to the point of market deployment, and the consequent high level of risk involved[8] make the EERA all the more important. The specific needs of the EERA include the following:

- Political commitment to solving the environmental, economic and societal problems that energy research aims to address.
- A long-term commitment of resources such that R&D can be organised to address all of the research needed to deploy the technologies concerned in the market. The time horizon for each technology ranges from one to seven or more decades.
- Commitment of all actors – including industry – to a set of strategic research agendas that will determine and guide all R&D up to the point of market deployment.
- Access not only to public funding for expensive, high-risk, long-term projects, but also to additional private-sector risk capital.

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6. The International Energy Agency's estimate of the total world market for energy technology between 2001 and 2030. Note that this estimate does not include the **additional** *investment required if the OECD Alternative Policy Scenario drives research; additional investment would be required in (for example) carbon-sequestration technologies, widespread introduction of hydrogen fuel cells and advanced nuclear generation systems are included.* **World Energy Investment Outlook**, *Paris: International Energy Agency 2003.*

7. Since no one technology is likely to provide all of the answers.

8. The volatile nature of energy markets, exacerbated by factors such as security of supply issues, market liberalisation, and – in Europe – emissions trading, creates a high level of uncertainty about the conditions within which new energy technologies will have to function even in the near future.

- Availability of world-class energy research facilities at a European level.
- A pooling of energy research intellectual resources to solve the many problems shared across the Community.
- The ability to carry out the necessary cross-cutting research problems, especially in relation to the many materials problems that are central to so much energy research.

ERAWOG's conclusions concerning the organisation of the EERA reflect the above needs. However, they also reflect differences between specific energy technologies.

Coordination and organisational arrangements within the EERA

The coordination needs of a given research field depends on a number of factors of varying importance across the energy research area. Thus, different approaches to organisation will be employed within the EERA, as follows:

There are fields needing strong coordination in order to achieve the necessary progress, including a robust organisational approach to planning, coordination and monitoring. Organisational approaches based on the Technology Platform (TP) concept are likely to be adopted[9], if very expensive research infrastructure is needed, and/or if early standardisation requires consensus among many stakeholders. A TP can also help to generate consensus from stakeholders on how to channel support. Very strong industrial participation will be essential. Public support for R&D will be closely aligned with agreed research strategies having well-defined market deployment objectives. The need for massive funding in most cases will necessitate the close coordination of regional, national and European research programmes in these fields[10].

Other research fields can be organised adequately with more *moderate coordination*. Such fields should share a common vision and consensus on how to realise it[11]. Thus, the TP concept may still apply, but mainly for purposes of developing, gaining commitment to, and monitoring progress towards, a strategic vision and research strategy. The coordination needs of such fields might effectively be met through the appointment of an Advisory Council that is representative of the key interests in the field.

Finally, a limited number of energy research fields – especially where lead times and research costs are relatively low, and market deployment is relatively close – have *low coordination* needs. Indeed, competition issues could make coordination difficult to achieve in practice. Such fields will be much more loosely organised, and the main emphasis will be on networking and the selective sharing of information. Even these fields, however, will benefit from agreed research strategies and a closer coordination of regional, national and European funding than exists at present. We envisage that these needs will generally be met through bottom-up activities such as normal shared-cost projects, networks and other forms of communication and dialogue. R&D

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9. **Technology Platforms: from Definition to Implementation of a Common Research Agenda**. *Brussels: European Commission, 21 September 2004, EUR 21265.*

10. Because a given research field will not be a priority for all Member States, variable-geometry solutions (varying numbers of Member States participating in research in each field) will be needed.

11. Such a vision might, for example, be of market deployment of a nearly developed technology at acceptable cost, or of retaining an existing dominant market position via the achievement of further critical breakthroughs.

road maps can be developed within relatively short-term projects, and commitment gained via conferences, consultation processes and the like.

To ensure the most appropriate allocation of available funds to the different energy research fields, the EERA will also need coordination across all of the different fields, in the form of an agreed R&D strategy for the whole energy research area. In a fully developed EERA, such a strategy will assist in ensuring the availability of adequate funds from a multiplicity of sources.

An effective EERA will enjoy a high level of coordination of cross-cutting research, especially in the materials field[12]. There will also be a need for close linkages with social research and with activities aimed at improving education, training and mobility of researchers.

Instruments and financing within the EERA

All energy fields will use the full range of existing FP instruments[13]. We believe there will also be a need for instruments capable of providing higher levels of flexibility than is possible at present.

Effective use of the ERA-NET instrument will be critical in bringing about the levels of coordination and shared funding between regional, national and European administrations that are needed to realise the EERA, especially where strong coordination is needed. Our vision of the EERA includes a development of successful ERA-NETs into more durable forms of organisation.

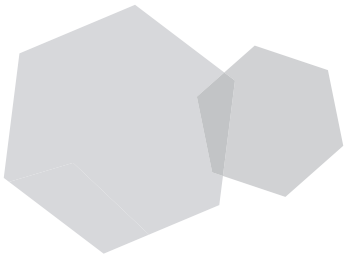
Most of the strategically important energy research fields will require significantly more funding in order to provide the solutions needed. As public budgets are always limited, more effective funding at a European level will be obtained by coordinating funds pooled from many sources, including:

- Larger levels of European research funding, primarily through the Framework Programmes.
- National and regional funding, possibly using Article 171 of the EU Treaty[14] to legitimise joint undertakings.
- Funding from private industry, mainly through co-funding shared-cost projects, as at present, together with substantial risk capital sourced from the EIB and other public and private sources. It is likely that major, long-term projects using finance from multiple sources will be organised as Joint Technology Initiatives.
- Utilisation of Structural Funds and other sources of funding for the development of major European energy research infrastructures at regional level.

12. Progress in many strategically critical fields of energy is dependent on breakthroughs in materials research: hydrogen storage, solar photovoltaics, solar thermal (high-temperature), super-critical steam, for example.

13. Integrated Projects (IPs), Networks of Excellence (NoEs), Specific Targeted Research Projects (STREPs), Coordination Actions (CAs), Specific Support Actions (SSAs), and infrastructure projects (I3).

14. Article 171: "The Community may set up joint undertakings or any other structure necessary for the efficient execution of Community research, technological development and demonstration programmes."



IV. A LOT DONE – MORE TO DO

Progress to date

Previous Framework Programmes have helped energy research organisations in the public and private sectors to learn more about one another. Collaborative research projects involving a wide range of institutions have deepened that knowledge. This long-term collaboration represents a foundation that is essential for building the EERA.

The European energy research community has responded positively to the concept of ERA and the New Instruments (NIs), in general the only limiting factor being the availability of funds to support an adequate number of actions at an adequate level[15]. It is too early to be able to draw conclusions on the ultimate value of these actions but, within energy, most are in key areas and all involve key research actors within the field. All of the energy fields addressed by the work programme for FP6 now include at least some Networks of Excellence and Integrated Projects, along with the more traditional instruments such as Specific Targeted Research Projects, Coordination Actions and Specific Support Actions – although in some specific topics and in some specific energy fields, gaps remain where adequate proposals have not yet been received.

The indications at present are that European Commission initiatives have generally been well designed from the point of view of advancing the ERA, even though there are aspects of FP6 and the NIs which will benefit from refinement[16], and although it is still too early to assess accurately the success or otherwise of these instruments, particularly NoEs[17]: ERAWOG notes the large size of some consortia, and shares the concerns expressed in the Marimon Report in relation to their size. Over and above the instruments of FP6, the Commission has taken the initiative on the related topics of hydrogen-related technologies and fuel cells: the formation of a High Level Group (HLG) has already led to the establishment of the TP on hydrogen/fuel cells. The Commission has also been essential in providing top-down support for TPs in other areas such as solar PV. More will be needed.

The above augurs well for the future. However, there is room for improvement. Sadly, there is little evidence so far of significant action by national or regional administrations. Although a number of ERA-NET actions are now under way in energy, these are relatively few and far

15. *In the first Calls in FP6, the number of approved projects has greatly exceeded the number that could be accepted, due to budgetary constraints; and there have been severe limits to the amounts of funding that could be provided for many accepted projects.*
16. *See, for example,* **Evaluation of the Effectiveness of the New Instruments of Framework Programme VI**, *Report of a High Level Expert Panel chaired by Professor Ramon Marimon, 25 June 2004; and the Commission responses –* **Communication from the Commission: responding to the observations and recommendations of the high-level panel of independent experts concerning the new instruments of the 6th Framework Programme**, *Brussels: COM(2004) 574 final, 27 August 2004, together with the Commission Working Paper SEC(2004) 1057, of the same date, accompanying the Communication.*
17. *NoEs have still to show their value. The principal purpose of this instrument is to encourage 'durable integration'. So far, it seems there are difficulties in creating consortia which are sufficiently focused on such an objective, and it is likely to be some years before an assessment can be made of the success of NoEs in this regard. Some categories of research institution (e.g. universities, industrial teams) may have special problems with the legal requirements for creating durable structures, and the Commission should identify and examine such problems.*

between[18]. There has been insufficient progress in opening and/or coordinating national/regional energy research programmes, and there is no real evidence that national administrations are taking steps to demonstrate the commitments made at Lisbon and subsequently, in relation to the ERA. This is as true for energy as it is for other research fields.

The concept and potential benefits of the ERA generally, and the EERA specifically, are little understood and even less valued by the research community. Given that the ERA is intended to create greatly enhanced career prospects for European scientists, a lack of understanding will hold back its development. We believe that a lack of understanding of – and more worryingly, a lack of commitment *to* – the ERA extends to regional and national administrations. This represents a barrier to progressing the related issues of improved coordination and greater concentration of resources.

Some lessons

The following lessons from the steps taken to date should be heeded if the overall project to advance the EERA is to succeed:

Real progress requires deep and ongoing political commitment. More specifically, it requires practical ways of translating that commitment into financial and organisational actions aimed at sharing resources. Furthermore, given the very long time frame needed for much energy research, there is a need for real *continuity* of political support over a long time period – measured in decades rather than in years. This is vitally important, and it should be pursued at the highest political level[19].

Continuing to encourage bottom-up planning and coordination actions will be vital to ensuring further advances towards realisation of the EERA. At the same time, top-down initiatives in some key areas will continue to be needed.

The new instruments are capable of working well, but their objectives with respect to the EERA must be used to guide the application of these instruments. The present budget is too small to allow the NIs to be used as fully as is needed.

There is no one 'ideal' solution: different research fields have different needs. This may mean different paths towards EERA; it may mean different destinations. It is necessary to adopt as flexible an approach as possible in order to accommodate differing sets of needs.

18. The fact that ERA-NETs are not permitted within Euratom is unfortunate because it hinders greater coordination of national R&D in this field.

19. The most effective level at which to pursue a translation of commitment into action on the part of the regional and national administrations may be the Council of Ministers. However, political commitment must be translated into administrative action.

V. GETTING THERE

1. CRITICAL ISSUES FOR FP7

The Seventh Framework Programme will run from 2007 to 2011. This is a critical period in the development of the ERA, and the whole project will fail unless FP7 provides the appropriate guidance and support. We see little point in looking further ahead than the end of FP7 for the purposes of planning the ERA in energy, even though some of the most important energy R&D initiatives that will be started during FP6 and FP7 will continue for many more years after the end of FP7. In this connection, we merely observe that the organisational arrangements made in the near future will require political, financial and other support for a long time ahead. This makes it all the more critical that the organisational arrangements put in place during FP6 and FP7 are as effective as possible. We have identified eight imperatives for the EERA which will need to be taken into account in designing FP7:

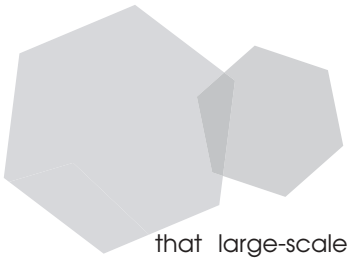
- Accelerate the coordination of regional and national research programmes
- Accelerate progress in strategically crucial fields of R&D
- Develop world-class facilities for European energy research
- Establish effective information and communication systems
- Develop human resources
- Ensure adequate international participation
- Build societal backing
- Ensure the necessary scientific basis in other research fields such as materials research and information and communications technologies

The remainder of this section deals with these issues, specifically with FP7 in mind. However, many of these apply equally to the remainder of the present Framework Programme.

Accelerate the coordination of regional and national research programmes

The availability of funds for European research is a critical issue in planning FP7: what can be achieved through even significantly increased funding via the Framework Programme budget alone will be very different from what can be achieved if other funds from national, regional and other sources are also available for European research from the start of FP7. Therefore, the importance of increasing the use of the Open Method of Coordination[20] – by whatever means – cannot be overemphasised; and whatever high-level political and other influence can be brought to bear on this during the remainder of FP6 should be mobilised without delay. It is likely

20. The Open Method of Coordination (OMC) is the approach agreed at Lisbon. It is essentially a voluntary approach to coordination involving the use of a range of tools such as networking, benchmarking of policies and programmes, sharing information, training, etc., in order to identify areas where coordination would be of benefit to the actors involved.



that large-scale funding from multiple sources will be required for specific major projects organised on a European basis, and it is for this kind of funding need that regional and national administrations should be preparing. Planning for FP7 should be based on an assumption of substantial progress in this regard before 2007.

There is a need for an increased number of ERA-NETs in the energy field. Some administrations may find it difficult or impossible to participate in ERA-NETs, due to a lack of resources or of the necessary organisational structures. Administrations should: a) ensure an adequate level of coordination of energy research programmes within their own boundaries, and b) allocate resources specifically for full participation in ERA-NETs and other OMC processes. The Commission might consider the establishment of an 'overarching' ERA-NET for the energy R&D field, whose functions would be to identify and remove any barriers to the coordination of energy R&D, and to provide additional top-level support for the OMC process.

The Scientific and Technical Research Committee (CREST) has a potentially valuable role to play in increasing the coordination of Member State energy research programmes. CREST has organised workshops, sponsored by the Commission, on the opening of national research programmes in the areas of marine sciences, chemistry and plant genomics. It would be desirable to see this extended to the energy area. A strengthening of the role of CREST, particularly in relation to the Open Method of Coordination (OMC), is needed[21].

Where relevant, regional and national administrations should be urged to include investment in energy research infrastructures in their plans for the use of Structural Funds. The Commission should ensure that appropriate mechanisms are in place to ensure that the role of Structural Funds in relation to research infrastructure is fully utilised.

Accelerate progress in strategically crucial fields of R&D

Within energy, progress in a number of fields requires substantial investment in the research needed for large-scale, long-term projects to pilot or demonstrate a new technology (e.g. zero-emission coal-based electricity generating plants; advanced nuclear fission reactors). In some cases, IPs will be adequate, but in some instances the scale will be larger than could be supported through IPs. The arrangements currently envisaged by the Commission – TPs leading to JTIs with multiple sources of private and public sector funding, invocation of Article 171, and the establishment of Quick Start projects with substantial loans from EIB, EBRD and perhaps from private sources also – are probably adequate. Many of these will need to be in place during the lifetimes of FP6 and FP7.

The timescales for some of the large projects foreseen in energy are measurable in decades rather than in years. Equally, the scientific and technical challenges are great. Hence, the level of risk is substantial. We note that the Commission is already considering the "potential multiplying effect that could be provided through the introduction of a European loan guarantee mechanism in the research area"[22] and we urge a solution to the issue of guarantees well before the commencement of FP7.

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21. It would be important to ensure that CREST's role is strengthened rather than diminished by the work of future High Level Groups.

22. Technology Platforms: from Definition to Implementation of a Common Research Agenda. Brussels: European Commission, 21 September 2004, p.21, EUR 21265.

There are other important issues which are not unique to energy research. These include the protection of intellectual property rights in large, long-term research programmes involving shared research across a number of sectors; and the provision of adequate arrangements to facilitate movement of research staff across the EU. Such issues lie outside the scope of ERAWOG's terms of reference.

Develop world-class facilities for European energy research

There is a need for world-class energy research facilities[23] operating at a European level in most topics. The new instruments, and Networks of Excellence in particular, should lead to the development of such facilities, and should be an effective instrument provided they are sufficiently focused on this objective, both in their design and deployment. The following may help to provide NoEs with the necessary focus and durability:

- encourage *existing* successful NoEs to focus on the creation of European Research Facilities;
- encourage *new* proposals primarily from small consortia whose primary objective is to create an ERF;
- ensure a strong weighting for the 'durable integration' and 'European added value' evaluation criteria;
- encourage greater use of Coordinated Actions for purposes of networking (and where the purpose is explicitly not to integrate the participating bodies), leaving NoEs for a smaller number of activities more focused on the development of ERFs.

The development of ERFs may require a measure of flexibility not currently available from the existing new instruments. Given that ERFs are likely to be directly concerned with critical research issues in one or more fields, it is easy to envisage a need for infrastructural development combined with a major research programme, for instance. There may well be other important EERA agendas not easily addressed with currently available instruments – for instance, some cross-cutting research, or some international projects. A new, flexible instrument, potentially allowing for a mix of infrastructure development, organisational structuring and actual research activities, would fill a gap in the existing range of instruments, and may be valuable in the mid to long term. The new flexible instrument envisaged would include elements of the existing IP/STREP, NoE, and I3 instruments.

Within energy, there will be a need for a relatively limited number of large, costly infrastructures designed to serve the research community at a European level (for example, large-bandwidth facilities such as GÉANT and GRIDS, to support networked R&D; concentrated solar energy test facilities such as *Plataforma Solar de Almería*; and hot laboratories to serve the needs of nuclear fission research). In general, such infrastructure could receive funding support via the specific

23. Such facilities are referred to in this report as European Research Facilities (ERFs). European energy research infrastructures are likely to be located within ERFs. ERFs are analogous to the concept of European Centres of Excellence, referred to by this title in many Commission documents. We believe that the use of the term "excellence" is unfortunate and should be avoided – thus, we also feel that NoEs should more properly be called "Networks of Integration" (though for clarity we continue to refer to them as "Networks of Excellence" throughout this report.

programme "Structuring the European Research Area – Support for Research Infrastructure". To date, no large-scale energy infrastructure projects have been concluded within FP6, although a significant number of smaller actions are under way. It is desirable to see a much greater mobilisation of the I3 instrument within FP7 for major energy infrastructure. We believe that closer coordination of the infrastructure and energy elements of FP7 is called for.

Establish effective information and communication systems

There is a need for reliable information on the main European energy research players and the ways they are structured. We hope that this will be delivered by the Synergy study currently being concluded for the Commission. If not, the Commission should initiate a process to provide this kind of information.

The SINAPSE e-network (Scientific Information for Policy Support in Europe) should be pursued vigorously since it will promote and facilitate communications among researchers across Europe. It is encouraging that the pilot phase will commence in 2005, and desirable to see the system in full operation before the start of FP7.

The ERA, in general, still appears to be little understood, even among the research community and among national and regional administrations (this is even more the case among the general public, which is addressed below). The Energy Directorate in the Commission should consider the possibilities for a more vigorous information campaign targeted at the energy research community – individual researchers, research bodies and national/regional administrations – with the primary focus being on explaining the aims and benefits of the EERA.

Develop human resources

Better utilisation of European human research talent is one of the primary aims of the ERA. A vibrant research sector in Europe, where scientists are able to pursue their careers across the EU, find interesting, world-leading work, and develop their talents, is likely to help in *retaining* European researchers and *attracting* talent from abroad. The need to attract and retain good research staff, to provide excellent and relevant education and training, to protect skills, to address age profiles in key fields (e.g. in nuclear fission there is an urgent need to retain relevant scientific skills and to ensure a flow of younger scientists into the field), and to address a gender imbalance where the vast bulk of existing energy research staff is male. are all important issues in energy[24].

ERFs and major research infrastructures will play an important role in the education and training of researchers. A close relationship between such establishments and the education sector will be important.

The linkage between the Marie Curie Fellowship scheme and the specific programme on energy is weaker in FP6 than it was in previous Framework Programmes, with no coordination activities for energy Fellows within FP6. Given the importance of education and training in the EERA, this linkage should be strengthened.

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24. NoEs have an important role to play in addressing such issues, and the Commission should ensure that existing and future NoEs focus adequately on them.

Ensure adequate international participation

Energy and emissions are global problems, and the international co-operation aspects of the EERA must not be overlooked since in the energy area there are issues of critical importance to the EU to be addressed. So far in FP6, there has been limited success in allocating the €600 million budgeted for international co-operation[25], and increased participation of third countries in energy R&D is needed. There is an urgent need to identify and remove the barriers to progress in this regard; lack of information is one barrier that could be removed relatively easily. We believe there is a political will in favour of third-country participation in the Framework Programmes, and the Commission should act to translate this will into action.

There will remain a need for specific instruments suited to specific situations and specific geographical locations. Large-scale projects should be open to countries outside of the EU (a model being the openness of the nuclear fusion ITER project). At the outset of any proposed major project, there should be a full examination of the scope for, and potential benefits from, the participation of both developed and developing third countries.

Build societal backing

Energy R&D in key strategic fields faces public opposition and lack of understanding of the issues or the science. Given the sensitive nature of the priority energy topics, an increased research concentration on these technologies may well be held back by this societal opposition. Society is even more distant from the *organisation and funding* of research: more specifically, we believe there is an almost complete lack of awareness of the ERA among the general public. Yet it is the general public who will provide the scientists of the future. And it is precisely to provide people with the opportunity of a rewarding career in a European-wide research market that the ERA – the EERA – is being developed.

The progress both of energy research and of the development of the EERA as an ongoing social process across Europe could thus be impeded by social factors. There is a need for an explicit focus on social research including barriers, education/promotion/awareness-raising, deliberative processes, etc. Within FP7, this could be achieved *both* by broadening the scope of socio-economic research within the thematic programme on energy, and *by* strengthening the link between energy and the Science and Society programme – with specific energy-related topics included in this programme, and an allocation of some funds specifically for energy-related social and cultural research.

25. For example, only 16% of the €285 million allocated to INCO within FP6 has been committed so far.

Ensure the necessary scientific basis in other research fields such as materials research and information and communications technologies

The technology assessments in the following section show that some of the most crucial energy research needs are concerned with cross-cutting issues such as materials problems or the development of ICT applications in the energy field. The present arrangements for energy-related cross-cutting research within FP6 are not satisfactory. For instance, given the importance of materials research in so many crucial energy R&D fields, there is a need for a much closer interface between energy and the cross-cutting elements of the Framework Programmes to ensure that important energy-related materials research is promoted, and that there is an adequate level of coordination with the energy programme.

2. THE NEEDS OF SPECIFIC TECHNOLOGIES

Introduction

The central element in the work of the ERA working group was an assessment of the organisational needs of the different fields within energy research. This assessment was conducted independently of the technical assessments carried out by the Strategy Working Group (SWOG): the ERA working group assessment focused *only* on the needs of each field for coordination and for the various instruments. Thus, our assessments were not in any way concerned with the relative strategic importance of each field although, of course, they were carried out against the context of the strategy working group assessments.

The starting point in selecting specific technologies for assessment was the selection made by SWOG which identified eight technologies for assessment[26]. All but one of these were included by ERAWOG – although discussed by ERAWOG, nuclear fusion was not included in the organisational assessment since it is already functioning in effect as a well-developed ERA. Four additional technology fields – grid integration, ocean energy, socio-economic research, and solar thermal (high-temperature) energy – were included in the ERAWOG assessment. These additional fields all have coordination needs at some level, and are therefore potential candidates for the EERA.

Each of the technologies considered were initially assessed against nine criteria, six of which referred to the *applicability* of the EERA concept, and the other three to their relative *readiness* for the EERA. The nine criteria were as follows:

Applicability to the EERA:

- Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?
- Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?
- Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?
- Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?
- Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?
- Is the field so costly/complex that significant research advances call for a shared approach?

26. Idem

Readiness for the EERA:

- Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well-coordinated research effort)?
- Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?
- To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/ collaboration?

The EERA working group also considered other documentation on the existing organisation of R&D in each of the technologies considered, before arriving at conclusions regarding their coordination and other organisational needs. The results are summarised below, and further information on the assessments is presented in Annex B of this report.

The specific technologies

The technologies considered by the ERA working group were as follows (in alphabetical order)[27]:

- Biomass energy
- Fuel cells
- Hydrogen-related technologies
- Integration of renewable energy sources and distributed generation into the grid
- Near-zero emission power generation based on fossil fuels (including pre- and post-combustion CO_2 separation and storage)
- Nuclear fission
- Ocean energy (wave; sea current)
- Socio-economic and policy-related research
- Solar photovoltaics
- Solar thermal (high-temperature)
- Wind energy

ERAWOG also considered nuclear fusion, and concluded that there was little to add in relation to its current organisation; nuclear fusion already functions as a more or less complete ERA. This is *not* intended to represent a full coverage of all energy technologies; ERAWOG was anxious to assess a wide *range* of technologies but, in the time available to the group, it was not feasible to address them all. In a second phase of ERAWOG's activities, energy technologies missing from this report

27. It should be noted that the ERA working group considered rather more technologies than did the strategy working group. The reason for this is that, although a field may be of relatively low strategic importance to Europe as a whole, it may nonetheless be a fruitful field for a coordinated approach by those working in it. Note also that although nuclear fusion was considered by the group, this field is already in effect functioning as a well-developed ERA.

may be assessed. Omission of a technology does not imply that they are unsuited to the EERA; 'deep' geothermal energy research, for example, is already well coordinated via a major ongoing IP-like project initiated in FP5.

Biomass energy

Vision

The overall objective is to expand the use of biomass, especially in the transport sector, in order to replace fossil fuels in the EU-25 by up to 30% by 2030. Technology and equipment must be developed to enable a higher energy contribution from biomass in the EU energy balance.

This goal will require new developments in the value chain for valorising biomass via new energy crops and their exploitation, with both thermochemical and bioconversion methods to produce biofuels, hydrogen and chemicals leading to cost-effective solutions.

Organisational and resource needs

Achieving the overall objective will involve a coordinated joint effort by stakeholders from the industrial and academic community – with expertise not only in energy, but also in agriculture, biotechnology, chemistry, and industrial processes.

The level of involvement of each stakeholder depends on the maturity of the technology for market use. Biomass use for electricity production via co-combustion is considered a rapidly maturing technology, while the generation of electricity via gasification requires further development. Cost-effective production of biofuels and hydrogen via the gasification route needs substantial improvement in biomass feedstocks, catalyst development and process integration. Bioconversion routes for the production of either biofuels or chemicals requires cross-cutting fundamental research in new crop production methods, biotechnology routes to the desired products, and cost-effective separation and utilisation of both biofuels and chemicals.

Another important need is the adoption of policies both at community and Member State level, in order to: a) introduce economic and regulatory instruments (including tax policies) to increase the commercial viability of biofuels; and b) develop standards for biofuels deployment (distribution and use).

Satisfying the needs

The level of coordination needed will be dictated by the resource and organisational needs, as well as the needs of the specific technology. ERAWOG believes these can be met by the use of existing and proposed instruments:

- Member States should become involved in the ERA-NET scheme which will be useful in developing a common policy aimed at encouraging the development of balanced growth, harvesting and distribution of biomass resources for both energy and non-energy use.
- Private enterprises, financing institutions and research organisations will be the prime movers in developing gasification technology for hydrogen and BTL fuels, using existing Framework

Programme instruments, including infrastructure development for a BTL demonstration plant using the I3 instrument.

- The use of bioconversion methods for the economic production of biofuels and chemicals will require a higher level of basic research, and hence a greater involvement of researchers in third-level institutions will be needed. Once again, the existing FP instruments should be adequate.
- Research organisations, universities and industry will be the prime movers in developing processes for the simultaneous production of biofuels, chemicals and energy, employing the proposed new flexible tool and developing European Research Facilities to be established for core technologies.

Fuel cells

Vision

Fuel cells are an excellent technology option for clean and highly efficient electricity production from natural gas, and later on from hydrogen, especially for mobile and local applications. A vision of the widespread use of fuel cells depends on the availability of abundant and cheaply produced hydrogen (of course, hydrogen can be used as an energy carrier in conjunction with conversion technologies *other* than fuel cells – such as internal combustion engines or gas turbines – and *fuel cells* can be employed using natural gas, for example, rather than hydrogen, as a transitional strategy). The successful development of fuel cells will change many industrial structures, and will create a new market opportunity where Europe should strive for a leading position.

ERAWOG sees fuel cells as a future strategic commodity on a global market. In order to gain a large share of this emerging market over the next ten years, Europe should join forces within the EERA and with the instruments introduced during FP6 and its predecessor programmes.

Organisational and resource needs

Although based on a very old idea, fuel cells still require expensive R&D because the costs of recently achieved solutions and demonstrations are still far too high to compete effectively in the market. The US and Japan currently invest large sums of public and private money in fuel cell research and product development. This is a challenge for Europe, where national strategies prevail over joint efforts, and the industrial groups actively developing these technologies are global (or at least transatlantic) players. European research on fuel cells will remain weak unless European programmes and the existing Technology Platform change the situation. There will be a need for close collaboration between industry and the leading European research institutions.

In the perspective of the EERA, it is important to choose the right level of coordination – especially bearing in mind competitive issues among Europe-based industrial players. Thus, the necessary coordination has to be of medium level – that is, applying the existing FP instruments. Special consideration should be given to developing the necessary norms and standards in order to prevent incompatibility within the market – for example, in grid connections, or with respect to fuel supply infrastructures.

As fuel cells still cannot compete on a cost basis in the market, there is an urgent need for more fundamental research in order to develop new approaches. Even in a perfect EERA, this research will need financial support without strong coordination – self-coordination by global scientific exchange, conferences, etc, should be sufficient.

Satisfying the needs

ERAWOG supports the European approach of a Technology Platform combining the fuel cell and hydrogen strategies, although both elements are not necessarily closely connected. When cheap hydrogen is widely available from environmentally benign primary energy sources, a much closer integration of research in the two fields will be necessary. In the meantime, ERAWOG recommends that the independence of both fields be carefully respected.

Other than this, ERAWOG has little to add to the strategy already being implemented: the establishment of a High Level Group on hydrogen/fuel cells, followed by the development of a Technology Platform. This coordination scheme will be strengthened by all existing tools such as ERA-NETS, NoEs, IPs, STREPs, etc.

There is strong international competition from other countries with high competence in fuel cell research, including the US, Canada, Japan, China and Korea. ERAWOG recommends a careful analysis of relative strengths before proceeding to a higher level of external co-operation.

Hydrogen-related technologies

Vision

The vision is of a highly efficient energy supply and service economy, supported by hydrogen as an energy carrier, along with electricity. Hydrogen is abundant in nature, but it will only help in meeting sustainability objectives if produced without CO2 as a by-product. Our vision therefore includes production of hydrogen by sustainable means – for example, using hydro, wind, wave/sea-current, high-temperature solar thermal, or photovoltaic energy. In the mobility and transport sector, hydrogen and synthetic hydrogen-rich fuels will play an important role in replenishing the energy economy.

Organisational and resource needs

Different needs exist for different aspects of hydrogen research, including hydrogen storage, sustainable production of hydrogen based on existing energy technologies, and development of novel methods of hydrogen production:

- The development of lightweight, compact **hydrogen storage systems** is critical for the ultimate success of hydrogen in the transport sector, and also in the marketing of portable devices replacing batteries. Although this is a crucial aspect of hydrogen R&D, strong coordination may not be appropriate since new ideas and approaches are still needed. What is needed in the EERA is a coordinated awareness of ongoing development so that the necessary norms and standards can be imposed as soon as market deployment begins in ten to 20 years.

- **Alternative hydrogen** production methods from many non-electric primary (and some secondary) energy carriers have to be developed and optimised. This must be coordinated with R&D in other fields – e.g. in nuclear and solar thermal development – in order to study thermochemical cycles for water splitting; or in the biomass sector, as one of the many possibilities of producing biomass fuels. With respect to the EERA, many strategies are of European dimension, interest and visibility, so adequate coordination is needed.
- **Fundamental research** is still needed to gain new ideas for hydrogen production (e.g. biological and photocatalytic methods), storage (e.g. in nanostructures) and applications (see fuel cells). This research will not need to be coordinated too closely – self-coordination by global scientific exchange, conferences, etc. is the most desirable approach.

Since a hydrogen system in transport will and must consist of a globally compatible infrastructure, research and development, as well as demonstration and deployment, have to be more and more strongly coordinated as market introduction comes closer.

Satisfying the needs

ERAWOG supports the existing organisational developments – the appointment of a High Level Group followed by a Technology Platform with the development of a common strategy within working groups on R&D and eventual deployment. This scheme of coordination will be strengthened by:

- An ERA-NET, in existence since October 2004, bringing together national and regional strategies on hydrogen technologies
- Application of all existing FP instruments
- Opening up European projects to important partners from other continents.

Integration of renewable energy sources and distributed generation into the grid

Vision

A European grid which is able to utilise energy supply from small as well as large generators using a wide range of energy technologies, including photovoltaics, wind energy, fuel cells, CHP and ocean energy.

Organisational and resource needs

There is a need for a range of R&D projects with the participation of all European Member States, utility companies, SMEs, and research organisations aimed at solving outstanding problems associated with the integration of renewables into the grid – including energy storage, power electronics, ICT technologies, etc.

There are policy and regulatory aspects of grid development and management which must be addressed in a coordinated manner.

Satisfying the needs

The arrangements established in FP5 – networks, clustering of existing projects – provide a good basis for advancing a coordinated approach in FP6. The ongoing RES-DG cluster of projects brings together seven major projects/networks with a total funding of €34 million.

Within FP6, the EU-DEEP project (total funding €30 million), which started in January 2004 and will run until mid-2009, will address market integration issues, regulation adaptation, connection technologies, grid impact of distributed generation, and Distributed Energy Resources (DER) systems.

Plans are already in place for extending existing coordination activities into FP7.

ERAWOG considers that substantial progress is being made in this field, in the direction of coordinated research efforts at a European level. It is desirable to continue to support existing activities, and to support any further initiatives to address additional research needs as they arise. ERAWOG considers that the existing range of instruments should be adequate to meet any such needs.

Near-zero emission power generation based on fossil fuels (including pre- and post-combustion CO_2 capture and sequestration/storage)

Vision

The long-term objective is the generation of electricity with fossil fuel combustion (in the very long term, coal) with near-zero CO_2 emissions. In the short to medium term, we envisage improvements in technology towards much greater efficiency in the use of all fossil fuels for electricity generation – including reduced emissions and the capture and sequestration/storage of CO_2. In the medium to long term, we expect the development of new combustion methods to make CO_2 separation easier, and the development of safe CO_2 transportation and sequestration methods.

Organisational and resource needs

The above-mentioned objective will be achieved through a coordinated effort by utility companies, equipment suppliers, and the academic community working together and drawing on resources from materials science, combustion engineering, equipment design, environmental and social sciences.

Incremental improvements in existing processes are possible with new materials and combustion modifications, resulting in a more concentrated CO_2 flue gas stream, and making CO_2 capture and sequestration/storage easier. There is a need for a range of focused R&D projects to achieve these improvements.

A near zero-emission fossil fuel (probably coal) based power plant will require developments in materials science, new combustion processes, CO_2 separation methods, and safe transportation and sequestration/storage of CO_2. Integration of all process steps for power generation (with and without hydrogen production for fuel cells) will be necessary for providing many of the options for reaching the final goal of a near zero-emission electricity generation

plant based on coal. There will be a need for some very large-scale projects to pilot and demonstrate the integrated technology. For CO_2 sequestration/storage, there will be a need for R&D to help the development of regulatory mechanisms to address long-term safety and sustainability issues.

Satisfying the needs

The coordination efforts required to reach the goals will become more and more demanding as the realisation of the near-zero emission objective becomes closer. The following actions are envisaged in increasing order of coordination needs:

Industry and research organisations will be the prime movers behind substantial improvements in energy efficiency, which can be achieved by incorporating new materials in traditional combustion systems. Existing FP instruments (IPs, STREPs) should be adequate for the development of the materials technology. Construction of a demonstration plant to test material components will involve a major project with multiple funding sources.

- Research organisations, universities and industry will develop sequestration/ storage-ready combustion systems, including the development of CO_2 separation methods. The new flexible instrument (see elsewhere in this report) is recommended for this area because of the need to integrate many different research topics, and many different branches of research, in order to achieve maximum energy efficiency.

- Industry, together with research organisations, will be the principal actors in the development of new methods of coal conversion (PFBC, IGCC) that will facilitate CO_2 separation. A pilot plant that will allow for evaluation of approaches will be needed, along with one to two demonstration plants in which the complete carbon management path will be demonstrated.

- Governments, industry, financing institutions, research organisations and universities will be involved in developing inter-related technology and policy options for promoting a near zero-emission fossil fuel-based power plant. A Technology Platform will be required to define an integrated approach; international co-operation will be essential. An initial step should be the establishment of a High Level Group to put forward a common vision, a strategic research agenda, and a deployment strategy towards a near zero-emission coal-based power plant.

Nuclear fission

Vision

The long-term objective is to develop technologies for nuclear fission energy generation that:

- guarantee the highest standards for safety, security and resistance to proliferation with essentially no risk to the workers, the general population and the natural environment – and, in particular, guarantee the safe management and disposal of the radiotoxic waste produced;
- optimise the use of natural resources (uranium, thorium) so as to make nuclear fission a sustainable source of energy for centuries, while minimising the production of toxic waste, especially high-level, long-lived radioactive waste;
- broaden the opportunities for the use of nuclear energy beyond electricity production, including use of process heat for various applications such as production of chemicals, hydrogen mass production, and sea-water desalination.

These are in essence the goals of the fourth generation of nuclear power systems and their associated fuel cycle. The current (second) generation has reached industrial maturity and competitiveness, although the question of safe final disposal of the radioactive waste remains to be validated at the industrial level. Third-generation systems, which are safer and more economic, have just started market deployment. Generation IV systems are expected to start penetrating the market around 2030-2040. Generation IV technology is of considerable importance in Europe since nuclear energy generation will still represent some 22% of electricity generation in Western Europe in 2020. There is also a large potential global market for European manufacturers, especially in Asian countries.

ERAWOG's vision is of a concerted effort by all of the research actors involved such that the long-term objective stated above is realised in as short a timescale as possible.

Significant advances are expected through continued research on second- and third-generation technology. In particular, Europe-wide accepted solutions to the management and disposal of high-level toxic waste have to be found well before Generation IV will be ready for market deployment. This also includes continued R&D aimed at maintaining and improving high levels of radiological protection, especially to resolve uncertainties concerning the effect of low and protracted doses of ionising radiation on human health. ERAWOG's opinion is that this topic pertains to medical studies rather than to nuclear fission energy technology per se. However, the studies in this field would certainly benefit from a better-coordinated organisational framework established for nuclear fission research at large.

Organisational and resource needs

The main need now is for major planning and coordination aimed at substantial European involvement in the development of a Generation IV nuclear plant. Given the major involvement of the US in such a project – particularly through the Generation IV International Forum – there is a need for a unified European effort. A joint undertaking among several Member States could be the objective.

Given the very high costs of research and the long lead time, there is a need for substantial ongoing public funding to cover R&D and infrastructure costs. European infrastructure is much needed, particularly in the provision of European hot lab facilities and new material test facilities.

Attention to education and training is required particularly in the field of nuclear fission, noting the need (at the least) to maintain expertise in this critical field.

There is a need for major cross-cutting materials research, particularly in relation to structural elements and fuel elements for reactors operating at high/very high temperatures.

Satisfying the needs

As regards Community-supported R&D, all of the existing Framework Programme instruments are needed in this field. Large infrastructures might be provided partly by projects undertaken as Integrated Infrastructure Initiatives (I3), or they could be an early and important element within a major European programmatic approach to nuclear fission research.

ERAWOG is supportive of initiatives that could lead to a Technology Platform in nuclear fission, addressing a much wider research agenda than is presently covered by FP6/Euratom. Such an initiative would deserve strong top-down support from the European Commission.

Ocean energy (wave/sea-current energy)

Vision

ERAWOG supports the IEA Implementing Agreement vision for ocean energy[28]: "to realise by 2020 the use of cost-competitive, environmentally sound ocean energy on a sustainable basis to provide a significant contribution to meeting future energy demands apart from other uses such as desalination". More specifically, we look forward to the emergence of a small number of dominant ocean wave and sea-current technologies, and of a significant deployment of these in appropriate locations around Europe.

Organisational and resource needs

Europe is currently a world leader in ocean energy R&D. Ocean energy research in Europe is currently dominated by SMEs, with support from public research bodies, universities and others. There are networking and coordination needs in advancing the research agenda already produced by the European Wave Energy Network, WaveNet. There is recognition among the WaveNet members that the considerable research work currently under way in Europe has been fragmented and conducted in isolation.

There are R&D needs in relation to first- and second-generation ocean energy devices, centred mainly on efficiency improvement, design refinement and cost reduction. There is a need for information exchange on matters of shared interest, and short-term R&D projects to address shared problems. Shared problems include knowledge gaps requiring a multi-disciplinary approach.

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28. See http://www.iea-oceans.org/about/vision/home.htm

There is a need to ensure adequate links with all actors involved in ocean-based technologies, especially offshore wind energy technology, to ensure that any possible synergies are pursued.

Satisfying the needs

The necessary R&D should be carried out in a coordinated way in Europe, and should utilise the existing IEA Implementing Agreement for carrying out ocean energy research in collaboration with international partners. We envisage collaboration between the European research actors in ensuring the necessary progress on shared issues such as test facilities, and the development of common standards. R&D on ocean energy devices could be carried forward with a series of STREPs addressing specific topics, or by means of an IP whose objectives encompass the whole research agenda established by WaveNet. An IP would represent a means of advancing ocean energy research in a well-coordinated way.

Networking and joint planning have been carried out to date by the European Wave Energy Network (WaveNet), a Thematic Network established in 2000 within FP5. CAs represent a suitable instrument for the continuation of networking.

WAVETRAIN – a Marie Curie Research Training Network established within FP6 – aims to advance topics such as device modelling, assessment of devices and components, and socio-economic assessment. This is a valuable network that deserves ongoing support.

Use could be made of the Integrated Infrastructure Initiatives (I3) instrument for the development of research infrastructure, such as a network of European test facilities, which may be large scale and costly.

Socio-economic and policy-related research

Vision

The vision is of a highly developed set of resources at a European level – comprising research actors from individual Member States collaborating on shared problems – and meeting European needs for energy, environmental and economic research. In addition, we envisage European-level research on societal drivers of and barriers to innovation in and the widespread utilisation of new and more sustainable energy technologies and infrastructures, and on the interactions between people and energy.

Organisational and resource needs

The main need is to ensure an adequate level of coordination of socio-economic and policy-related research by the Member States, to provide for shared approaches, knowledge and experience, wherever these are warranted. There is an ongoing need for the further development of socio-economic research methodologies capable of providing answers to policy and other questions relevant to innovation in energy technologies, and to energy production and use and its economic and environmental implications.

There are two broad sets of needs, one concerned with economic research and the development and use of economic models, and the other concerned more with policy-related and socio-cultural aspects of new energy technologies and infrastructures and demand-side issues.

- The former is quite well established in energy research, while the latter has mostly been addressed at national level to date. Thus, there are existing resources conducting socio-economic research focused on econometric modelling and the like, and there has been a measure of networking and coordination through previous FPs.
- The same cannot be said of energy-related social and policy-related research, and there is a need for both an increased level of research in this field, and for greater coordination. Although there is research within Member States, there has been relatively little shared activity across Member States to date, even though many of the challenges are shared.

Satisfying the needs

Specific socio-economic research challenges can be addressed by utilising existing FP instruments.

With regard to policy-related and social/cultural aspects of energy (including issues ranging from innovation policy and instruments to the acceptability of new energy technologies and infrastructures, end use and behavioural issues), the FP6 work programme already allows for proposals in these fields, and this would provide a basis for research proposals at a European level. There would be scope for a joint research effort on common issues, to be established by national energy bodies in collaboration with appropriate national level research institutions.

The Commission should encourage the establishment of an ERA-NET, with a view to bringing together national as well as European socio-economic and policy-related research and associated data. The aim should be to identify shared issues that would benefit from a coordinated approach at a European level. These issues could be advanced through specific projects using the existing Framework Programme instruments.

Solar photovoltaics

Vision

The overall objective is to expand the use of grid-connected PV systems in the electricity sector with a meaningful and growing penetration by PV in Europe by 2030, and a significant penetration in non-grid markets by 2020. Such an objective will require new developments in materials and manufacturing processes, linking the physics of PV devices to manufacturing process technologies.

Organisational and resource needs

Although photovoltaic technology has already been brought to some markets, there are significant barriers, some of them involving long-term research efforts – vital if PV is to achieve major penetration particularly in grid-connected applications. The time needed to advance

these satisfactorily is probably still quite considerable, although PV is an area where there is substantial market competition already.

Achieving the overall objective will involve a coordinated joint effort by stakeholders from the industrial and academic community. The level of involvement of each stakeholder depends on the maturity of the technology for market use.

Many R&D activities are under way, involving large consortia funded in FP5 and FP6, plus the Distributed Energy Resources cluster of activities which includes considerations of issues linked to large-scale PV grid connection.

Private enterprises, financing institutions and research organisations will be the prime movers in developing new PV technologies. In all areas of PV production, considerable R&D (both basic and applied) is necessary in materials and new production technology: research on PV, linking the physics of PV devices with manufacturing technology (more specifically, mass production of PV devices) and material research on promising PV technologies will benefit from a shared approach.

An important need is for the adoption of policies both at community and Member State level in order to provide resources for assessment and siting, environmental attributes, standards, testing and evaluation, marketing and financing mechanisms to expedite deployment, integration of PV systems especially in low-energy buildings, and energy storage in synergy with PV technologies.

Satisfying the needs

The main strategic opportunities for progressing the EERA in relation to PV technologies are the need, recognised in Europe, for much greater efforts to compete effectively with Japan and the US, and the need for a new generation of PV technologies, which must be closely linked to cheap manufacturing processes and products which are environmentally friendly.

ERAWOG believes these can be met by the use of existing and proposed instruments:

- Member States should become involved in the ERA-NET scheme, which will be useful in developing a common policy aimed at encouraging the development of balanced growth of PV systems for both rural electrification and remote sites, and grid-connected electricity in conjunction with distributed generation based on a range of RES-E sources.
- Research organisations, universities and private industry will be involved in the long-term efforts required for the economic production of solar cells and PV systems, using existing Framework Programme instruments. ERAWOG acknowledges, and is generally supportive of, the desire of European PV actors to establish a TP. However, it has to be recognised that the PV R&D activities are already well organised, so the establishment of a TP must be considered carefully. The existence of the PV Technology Research Advisory Council, PV TRAC, is welcome, and provides a useful starting point in identifying common research goals, and in progressing an agreed strategic research agenda for PV in Europe.

Solar thermal (high temperature)

Vision

The objective is to develop highly efficient solar combined cycle technologies (always in conjunction with gas) for power production as well as solar thermal production of hydrogen or other fuels. More specifically, the goal is to achieve cost reductions of a factor of 3-5, compared with present costs. This will allow a significant contribution to electricity supply in Europe (mainly Southern Europe).

Europe currently has a leading role in solar thermal high-temperature technologies, but this is in jeopardy from the US and Japan. It is part of this vision that Europe should maintain its position as the world leader of both the technological development and the commercial utilisation of solar thermal high-temperature applications.

ERAWOG's vision is one of a joint European effort that supports the strategic medium to long-term research necessary to keep Europe competitive in solar thermal high-temperature technologies.

Organisational and resource needs

Solar thermal high-temperature technology will be an option for sustainable electricity and fuel production. Research infrastructures and pilot plant development are costly and would benefit from a European approach.

ERAWOG concludes that the solar thermal field does not need to be strongly coordinated. Nonetheless, there are topics which would be well suited to the EERA concept, including R&D to:

- increase efficiency and reduce costs (high temperature approaches, lightweight concentrators, new reflector concepts);
- explore and develop high-temperature technologies for various purposes including solar thermal hydrogen/fuel production (solar thermal could represent the only technology to compete effectively with nuclear, for the production of hydrogen);
- reduce operation and maintenance costs, and stimulate mass production;
- develop materials for high-temperature applications and for thermal energy storage.

The SolLab Network is an important existing opportunity for collaboration and coordination. There is a need for such collaboration on a wider basis across Europe.

There is also a need for large-scale infrastructures, such as Plataforma Solar, but with general European access.

The achievement of such a significant contribution from solar thermal high-temperature technologies will not only require technological developments leading to cost reductions, but will also necessitate consideration of market development, grid integration, environmental impact, and socio-economic aspects.

Satisfying the needs

Initiatives should be taken that utilise all the instruments available through the Framework Programmes. A European Research Area in solar thermal high-temperature technologies that can support the sector through long-term generic and scientific R&D should be the ambition. R&D in high-temperature solar thermal energy should be included in the FP7 work programme.

There is a key role for IPs to form the basis for large-scale R&D, including the construction of pilot/demonstration plant. High-temperature aspects, along with other topics related to the production of hydrogen, should be included within the scope of the H_2/FC Technology Platform.

An effort should be made to extend the access to networks such as SolLab and infrastructures such as the Plataforma Solar.

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

Wind energy

Vision

The objective is to develop cost-effective technologies that will allow wind energy to contribute significantly to electricity supply in Europe, as well as worldwide, by 2020. It is foreseen that offshore wind turbines will produce much of this contribution. This makes R&D in offshore wind technology a priority area.

It is part of this vision that Europe should maintain its position as the world leader of both the technological development and the commercial utilisation of wind energy.

ERAWOG's vision is one of a joint European effort that supports the strategic medium to long-term research necessary to keep Europe competitive in wind energy – research that would not otherwise be carried out.

Organisational and resource needs

The achievement of such a significant contribution will not only require technological developments leading to cost reductions, higher degrees of exploitation of wind resources, and better and more stable operation of wind turbines, but also necessitate consideration of market development, grid integration, environmental impact, and socio-economic aspects.

There is need for open-knowledge networks among the European research institutes and industry dealing with long-term generic and more fundamental wind energy related R&D-activities. There is also a need for more and better-coordinated activities that can make knowledge available to EU companies at a cost comparable with that available to US and Japanese competitors.

This need for R&D covers such a broad spectrum of research areas in technology, earth and environmental sciences, and socio-economics that a strong measure of coordination is warranted in order to ensure that European resources – human as well as fiscal – are optimally exploited.

Satisfying the needs

Initiatives should be taken that utilise all the instruments available through the Framework Programmes. A European Research Area in wind energy that can support the sector through long-term generic and scientific R&D should be the ambition. A necessary basic element will be the inclusion of wind energy topics within FP7.

ERAWOG believes that offshore wind energy should be given high priority, and that the establishment of a Wind Energy Technology Platform should be pursued, as should the possibilities for multinational offshore R&D programmes.

Summary of instruments and approaches

The instruments and approaches suggested by ERAWOG are summarised in Table 1 on the following pages. Summaries of the more detailed technology assessments carried out by ERAWOG are presented in Annex 2.

Table 1: Technology visions — Organisational/coordination needs — Proposed approaches to addressing needs

	Vision	Organisational/coordination needs	Proposed approaches to addressing needs
Technology field Biomass energy	Expand the use of biomass in the transport and electricity sectors, replacing fossil fuels by up to 30% by 2030. A coordinated effort by stakeholders from energy, agriculture, biotechnology, chemistry and industrial processes. Establishment of the necessary economic and regulatory conditions for a viable European biofuels industry.	The need is to organise research and resources in: • Biomass crop development • Optimising design and operation of biomass pyrolysis and gasification, for hydrogen and/or BTL liquid fuels • Economic bioconversion of ligno-cellulose raw materials into ethanol • Develop viable approaches to simultaneous production of biofuels, chemicals and energy at an economic cost	• Member State involvement in the ERA-NET scheme, to (a) develop common policies to encourage balanced growth, harvesting and distribution of biomass resources; and (b) develop economic and regulatory incentives for biomass use • Use of existing FP instruments by industry and research organisations in the development of gasification technology for hydrogen and BTL fuels • Long-term collaboration by research organisations, universities and industry for (a) use of bioconversion methods to produce biofuels (IPs, STREPs, NoEs); and (b) simultaneous production of biofuels, chemicals and electrical and thermal energy
Fuel cells	A set of cost-effective devices replacing batteries in portable appliances, internal combustion engines in cars, and less effective alternatives in decentralised CHP plants in buildings and industry.	• A more unified approach to R&D, enabling Europe to compete effectively with the US and Japan • Close collaboration between industrial and public research laboratories • Although fuel cell and hydrogen R&D are linked, much of the research in each field is independent of the other, and this independence should be respected	• ERAWOG supports the initiatives already undertaken – establishment of a High Level Group, followed by a Technology Platform. The relative independence of hydrogen and fuel cell research should be respected carefully • A careful analysis is needed to provide a basis for European co-operation with other countries
Hydrogen-related technologies	A highly efficient energy supply and service economy whose quality may be supported by hydrogen.	• R&D on hydrogen storage systems, although vital, should not need strong coordination • Research on alternative hydrogen production methods must be coordinated with R&D in other fields – e.g. in nuclear and solar thermal development, and in the biomass sector. Adequate coordination across these fields is needed • Fundamental research is also needed; strong coordination is not needed for such research	• ERAWOG supports the initiatives already undertaken – establishment of a High Level Group followed by a Technology Platform. The relative independence of hydrogen and fuel cell research should be respected carefully • The ERA-NET already established is essential for coordinating national and regional strategies • All existing FP instruments should be utilised

Table 1: Technology visions — Organisational/coordination needs — Proposed approaches to addressing needs

	Vision	Organisational/coordination needs	Proposed approaches to addressing needs
Integration of RES and DG into the grid	A European grid which is able to utilise energy supply from small as well as large generators using a wide range of energy technologies, including photovoltaics, wind energy, fuel cells, CHP and ocean energy.	• A range of R&D activities with the participation of all European Member States, utility companies, SMEs and research organisations, aimed at solving outstanding problems associated with the integration of renewables into the grid – including energy storage, power electronics, ICT technologies, etc. • Policy and regulatory aspects of grid development and management must be addressed in a coordinated manner	• The arrangements already in place – networking and clustering of existing projects, and the major IP under way within FP6 – should provide an adequate means of organising research in this field • ERAWOG notes that arrangements are already being developed to extend coordination into FP7 • The existing range of instruments should be adequate to meet identified research needs
Near-zero emission power generation based on fossil fuels	• Short to medium term: improvements in technology towards much greater efficiency in the use of all fossil fuels for electricity generation – including reduced emissions and the separation and sequestration of CO_2. • Long term: the generation of electricity with coal combustion with near-zero CO_2 emissions.	• A coordinated effort by utility companies, equipment suppliers, and the academic community working together, and drawing on resources from materials science, combustion engineering, equipment design, environmental and social sciences • There will be a need for long-term projects for the development and construction of pilot and demonstration plants. This will need collaboration among a large number of major players, and adequate funding	• Use of all existing FP instruments will be needed, along with the new flexible instrument recommended in this report • There are substantial cross-cutting research problems – especially involving materials research – and the design of FP7 should facilitate this • ERAWOG believes that establishment of a Technology Platform will be needed in order to develop a long-term research strategy aimed at development and construction of near-zero emission power plants. A Joint Technology Initiative will probably be needed to put in place the necessary funding. The first step should be the establishment of a High Level Group
Nuclear fission	Develop sustainable nuclear fission energy technology, through European participation in the development of Generation IV systems – to start market deployment by around 2030-2040 (nuclear energy generation will represent some 22% of electricity generation in Western Europe in 2020).	• Major planning and coordination aimed at substantial European involvement in the development of a Generation IV nuclear plant • A joint undertaking by several European Member States in order to participate fully in the Generation IV International Forum • Address the need for education and training (at least to maintain expertise) • Major cross-cutting materials research (particularly for structural elements and fuel elements in high/very high temperature environments)	• Use of all FP6/7 instruments • Use of I3 instrument for infrastructures, or alternatively develop infrastructures as an early element in a major European programmatic approach to nuclear fission research • ERAWOG supports initiatives that could lead to the TP in nuclear fission, addressing a much wider research agenda than presently covered by FP6/Euratom • Strong top-down support from the European Commission

Table 1: Technology visions — Organisational/coordination needs — Proposed approaches to addressing needs

	Vision	Organisational/coordination needs	Proposed approaches to addressing needs
Ocean energy (wave/sea-current)	By 2020, the use of cost-competitive, environmentally sound ocean energy on a sustainable basis to provide a significant contribution to meeting future energy demands apart from other uses such as desalination. (Note: this corresponds to the vision adopted in the IEA Implementing Agreement.	• A much more coordinated approach to ocean energy R&D in Europe, to maintain Europe's current lead • Multi-disciplinary research to address problems particularly associated with fourth-generation devices • Adequate links with (for example) offshore wind energy and with the oil and gas and the power industries will be needed	• STREPs and IPs should carry forward the strategic research agenda already developed by actors in ocean energy. A major IP could advance ocean energy technologies in a well-coordinated way. Use of the I3 instrument may be desirable for development of needed European research infrastructure • Ongoing networking should be ensured; CAs should represent an adequate tool • The existing Marie Curie RTN is welcome, and deserves ongoing support
Socio-economic and policy-related research	• A highly developed set of resources at a European level – comprising research actors from individual Member States collaborating on shared problems – and meeting European needs for energy, environmental and economic research. • European-level research on societal drivers and barriers associated with new and more sustainable energy technologies and infrastructures, and on the interactions between people and energy (production and use).	• Further development of a European competence in socio-economic modelling, based on successful collaboration to date • An increase in the level of energy-related social and policy research, with far greater collaboration between Member States and regions than has been achieved to date	• Establishment of an ERA-NET to investigate the opportunities for a collaborative approach both to socio-economic research and to research into relevant social and policy issues • Use of STREPs, IPs and possibly NoEs • Care should be taken to include participants from the new Member States and from countries neighbouring the EU
Solar photovoltaics	Expand the use of PV systems in the electricity sector with some contribution to the grid by 2020, and a significant penetration in non-grid applications (the European Photovoltaic Industry Association does not envisage a major contribution by PV to the European grid before 2030; up to 20% might be possible by 2050). This will require new developments in materials and manufacturing processes, linking the physics of PV devices to manufacturing process technologies.	• Much closer coordination of all actors in PV research in Europe – public institutions, industry and financial institutions – and incorporating materials research and manufacturing processes for mass production • Policies are needed, at community and Member State level, to provide resources for assessment and siting, environmental attributes, standards, testing and evaluation, marketing and financing mechanisms to expedite deployment, integration of PV systems especially in low-energy buildings, and energy storage in synergy with PV technologies	• ERAWOG welcomes the establishment of the PV Technology Research Council (PV TRAC), and the proposal to establish a Technology Platform. However, caution is needed to ensure that the level of coordination within any TP is adequate – bearing in mind the continuing need for fundamental research and the existing level of coordination in the field • Cross-cutting materials research should be facilitated by the design of FP7 • Participation by the Member States and regions already established in the ERA-NET should be encouraged

Table 1: Technology visions — Organisational/coordination needs — Proposed approaches to addressing needs

	Vision	Organisational/coordination needs	Proposed approaches to addressing needs
Solar thermal (high temp)	Development of highly efficient solar combined cycle technologies (in conjunction with gas) for power production as well as solar thermal production of hydrogen or other fuels. This will allow a significant contribution (e.g. greater than 10% - in the longer term) to electricity supply in Europe (mainly Southern Europe). It is important to maintain Europe's existing lead in this field.	• This field does not need to be strongly coordinated, but research is needed at a European level on a wide range of topics • There is a need for wider European access to existing and new research infrastructures	• Use of all existing FP instruments, plus the possible use of the new flexible instrument recommended in this report. An IP(s) would be desirable for the construction of pilot/ demonstration plant • High-temperature aspects, along with other topics related to the production of hydrogen, should be included within the scope of the H_2/FC Technology Platform • An effort should be made to extend the access to networks such as SolLab and infrastructures such as the *Plataforma Solar.* • Materials research represents an opportunity for cross-cutting research within the ERA.
Wind energy	• Cost-effective technologies to allow wind energy to contribute significantly (e.g. greater than 10%) to the electricity supply in Europe and worldwide in 2020 (offshore wind turbines will produce much of this contribution). • Europe should maintain its position as the world leader both in wind technology and in commercial utilisation. • The vision is of a joint European effort to supports the necessary strategic medium- to long-term research to achieve the above.	• More and better-coordinated activities that can make knowledge available to EU companies at a cost comparable with that available to US and Japanese competitors • The R&D needed covers such a broad spectrum of research areas in technology, earth and environmental sciences, and socio-economics that a strong measure of central coordination is warranted in order to ensure that European resources – human as well as fiscal – are optimally exploited	• ERAWOG believes that offshore wind energy should be given high priority, and that the establishment of a Wind Energy Technology Platform should be pursued, as should the possibilities for multinational offshore R&D programmes • The market-oriented politico-socio-economics of wind energy should be addressed systematically • A stable investment climate for wind energy is necessary for large-scale exploitation of wind energy. More extensive use of Structural Funds for financing offshore wind projects should be considered in this context

VI. CONCLUSIONS AND RECOMMENDATIONS

We believe that good progress has been made in creating the EERA during the first years of FP6. This has been made possible partly as a result of earlier actions designed to bring key stakeholders together, in shared research, in networks and associations, and in developing and debating R&D road maps and strategies. Apart from this history of progressive co-operation, the success to date has been largely due to the mix of bottom-up initiatives taken at the level of the individual research establishment, and of top-down initiatives and support provided by the European Commission. This mix of initiatives is appropriate for the future development of the EERA.

Recommendation 1 – mix of bottom-up and top-down initiatives

The Commission should continue to progress the EERA through a mix of top-down initiatives and support, and through creating opportunities for bottom-up initiatives.

The requisite efficiency and effectiveness – and indeed the necessary concentration of resources – can only be achieved if substantial progress is made in increasing the coordination of regional, national and European programmes.

Recommendation 2 – increased concentration of resources

The Commission should:

- Promote the establishment of a greater number of ERA-NETs in the energy area.
- Identify and remove the barriers to regional or national coordination.
- Establish and maintain a web-based database of energy research actors and the ways they are structured.
- Strengthen the role of CREST with respect to use by Member States of the Open Method of Coordination.
- As early as possible in the development of TPs, identify opportunities for initiatives for Joint Technology Initiatives and the use of Article 171 of the EU Treaty. One or two should be 'fast-tracked' in order to establish the process, and to serve as examples for further initiatives.
- Consider separate programmes for very large/complex projects (e.g. construction of an advanced fission reactor, or a zero-emissions coal-fired plant/CO_2 sequestration).
- Advance its consideration of a Loan Guarantee Scheme. This is especially important in energy research.
- Encourage early use of the 'Support for Research Infrastructure' programme for the development of large-scale energy research infrastructures.

Recommendation 3: Member State responsibilities

Member states should:

- ensure that commitments made regarding research funding are translated into national and regional policies leading to action;
- provide the resources necessary for full participation in ERA-NETs within the energy research field;
- ensure an adequate level of coordination of energy research programmes within their own boundaries.

By the start of FP7, it is likely that a number of energy-related JTIs will be starting, and a number of European Research Facilities will be at an emergent stage. TPs will shape the research priorities in a number of energy research fields. Thus, the instruments available in FP7 will have to support this progression.

Recommendation 4 – instruments in FP7

Instruments proven to be successful in FP6 will be equally appropriate in FP7, and should be retained, bearing in mind the following:

- NoEs should be concentrated on the development of European Research Facilities (and NoEs should be re-titled 'Networks of Integration').
- Greater use should be made of Coordination Actions for larger networks whose main aim is 'coordination through networking'.
- A new flexible instrument should be considered to offer the possibility, within a single contract, of networking, development and implementation of a research work programme, and development of infrastructure.

ERAWOG is of the view that existing structures are inadequate with respect to the cross-cutting research needs of energy. While this is particularly the case for cross-cutting materials research, the observation also applies to other fields such as ICT and Science and Society.

Recommendation 5 – FP7: energy-related cross-cutting research

FP7 should:

- ensure even closer coordination of energy and the other elements of the Framework Programmes necessary for achieving energy research goals (the research needs of a particular topic should not be confined to the priorities of a thematic programme);
- consider the use of the new flexible instrument (recommended in 4 above) as a means of ensuring that important cross-cutting research needs are addressed.

Some needs for energy research infrastructures have been identified, and a number of the most important research priorities in energy involve the construction of large, costly pilot or demonstration plant – which in itself serves a similar purpose to infrastructures for energy researchers. Within FP7, there will be a need for some large energy infrastructures to be put in place (see technology assessments for specific suggestions). Structural Funds could play an important role in funding major energy research infrastructures at regional level.

Recommendation 6 – use of Structural Funds

Regional and national administrations should make greater use of Structural Funds for the creation of ERFs and energy research infrastructures.

It is essential that progress be made during FP7 towards increasing the utilisation and mobility of researchers. In addition, there is an urgent need to address the issues of age and gender profiles of energy researchers. There is also a need to ensure a close relationship between the development of the EERA and the provision of excellent education of relevance to energy research.

Recommendation 7 – FP7: education and training; age/gender profiles

The Commission should:

- **initiate a dialogue between the education sector and representatives of energy research;**
- **strengthen the linkage between the Marie Curie trainee scheme and the specific programme on energy;**
- **ensure that the training requirements in NoEs and IPs are taken seriously by consortia; development and implementation of training plans should be closely monitored;**
- **ensure that consortia take seriously their obligation to address resource imbalances in areas such as age and gender.**

The ERA is essentially a societal movement, serving social as well as economic aims. At heart, it concerns the creation of a healthy European employment market for scientists and engineers. But the aim of energy research (and hence the EERA) is to meet society's needs for sustainable energy. These aims mean that energy research in general, and the EERA in particular, must not be allowed to progress independently of the society in which they exist. We are convinced that the EERA is still little understood by energy researchers and policy-makers, and even less so by the general public. And future energy technology options are either unknown or distrusted by the public.

Recommendation 8 – FP7: broader societal issues

The Commission should:

- increase the emphasis on socio-economic research linked to energy technologies by broadening the scope of social research carried out within the energy programme, and strengthening the link between the energy programme and Science and Society;
- act to raise understanding and appreciation of the importance and benefits of the EERA to society.

International co-operation is of great importance in the energy field. There is a need for collaboration with the developed world in tackling shared problems. There are opportunities also for Europe to share its technologies for sustainable energy with the developing world, and there are massive commercial opportunities in this sector. Finally, there are good political and environmental reasons why the EU should co-operate actively with neighbouring countries. Instruments cannot be applied in the same way in all countries and areas, and there is a need for flexibility in order to maximise third-country participation.

Recommendation 9 – international co-operation

The Commission should:

- act to remove any barriers to participation by third countries in the Framework Programmes, in order to encourage a greater take-up of the funds available for international co-operation;
- ensure maximum flexibility in the application of instruments to third-country participation.

We have, in our assessments of specific energy technologies, reached conclusions as to the most appropriate ways of progressing the EERA for each field. This assessment reassures us that the mix of instruments recommended in this report should be adequate to meet the requirements of energy research in the mid term.

Recommendation 10 – specific energy technologies

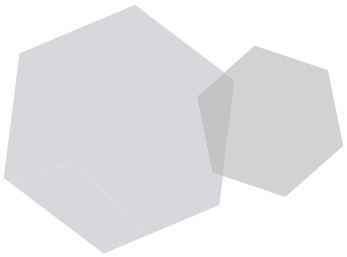
Our recommendations on the most appropriate approach to coordination, and the appropriate instruments to be employed, are summarised in Table 1 above.

Overall conclusion

On the basis of its assessments, ERAWOG is of the view that energy R&D in FP6 and FP7 will benefit from a rapid transition towards greater coordination, increased pooling of regional, national and European funding, and the adoption of ambitious, long-term goals for technology deployment. However, the level of coordination aimed for in any one field must be carefully tailored to the actual needs in that field, and the dangers of over-coordination must be borne in mind.

The current instruments, augmented by the new flexible instrument recommended in this report, should be capable of meeting the energy R&D needs in the short to mid term (although it remains too early to say with confidence that the new instruments of FP6 will be effective in furthering the aims of the EERA). Because so much energy research is complex and long term in nature, there will be a fairly widespread need for Technology Platforms and Joint Technology Initiatives with funding from diverse sources. Funding is needed not only for research, but also for coordination purposes.

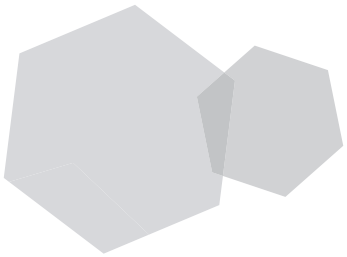
So far, energy R&D is on the appropriate course in FP6. What is needed now is a continuation on this course, accompanied by (a) ongoing monitoring of the effectiveness of the FP6 new instruments and their application, and (b) an accelerated effort to increase the involvement of the Member States at the European level.



ANNEX A

Glossary of Acronyms Used in the Report

Acronym	*Meaning*
CA	Coordination Action
CREST	Committee on Research Science and Technology
DER	Distributed Energy Resources
DG	Distributed Generation
EBRD	European Bank for Reconstruction and Development
EERA	European Energy Research Area
EIB	European Investment Bank
ERA	European Research Area
ERA-NET	FP6 instrument for coordination of Member State activities
ERAWOG	Advisory Group on Energy (AGE) Working Group on the ERA
ERF	European Research Facility (used in this report as an alternative to the more commonly employed "European Centre of Excellence)
FP	Framework Programme
HLG	High Level Group
I3	Integrated Infrastructure Initiative
ICT	Information and Communications Technologies
IEA	International Energy Agency
IGCC	Integrated Gasification Combined Cycle
IP	Integrated Project
JTI	Joint Technology Initiative
MS	Member State of the European Union
NIs	New Instruments introduced in FP6
NoE	Network of Excellence
OMC	Open Method of Coordination (see footnote 18, page 9)
PFBC	Pulverised Fluidised Bed Combustion
PV	Solar Photovoltaics
PV TRAC	Photovoltaics Technology Research Advisory Council
R&D	Research and Development
RDD	Research Development and Demonstration
RES	Renewable Energy Sources
RES-E	Electricity from Renewable Energy Sources
SME	Small and Medium-Sized Enterprise
SSA	Specific Support Action
STREP	Specific Targeted Research Project
SWOG	Advisory Group on Energy (AGE) Working Group on energy R&D strategy
TP	Technology Platform



ANNEX B

Summary Assessments of Selected Energy Technologies

Introduction

The following pages contain the summary technology assessment sheets for the technologies examined by ERAWOG:

- Biomass energy
- Fuel cells
- Hydrogen-related technologies
- Integration of renewable energy sources and distributed generation into the grid
- Near-zero emission power generation based on fossil fuels (including pre- and post-combustion CO_2 separation and storage)
- Nuclear fission
- Ocean energy (wave/sea current)
- Socio-economic research
- Solar photovoltaics
- Solar thermal (high temperature)
- Wind energy

The assessments entailed a consideration of an agreed set of questions which would be likely to impact upon the applicability of the EERA to the technology in question, and upon the readiness of the technology for early progress. Of course, these are not the only determining factors, but they provide a focus for the assessment. In addition to this consideration, ERAWOG members conducted a broader assessment based on their own knowledge of the technologies, on available information, on discussions with others where necessary, and, last but not least, on the technology assessments conducted by the SWOG.

The aim was not to conduct an exhaustive analysis, but rather to utilise an approach that would give indications of the extent to which the EERA would be likely to help in progressing the research agendas in each technology, and clues as to the likely value of the range of available instruments in the Framework Programmes; of the need for European infrastructures; of the need for cross-cutting research; and of the possibilities for progressing coordination via approaches such as Technology Platforms, Joint Technology Initiatives, use of Article 171, and so on.

Biomass Energy

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	Yes, for the following areas: • Design of plants optimised for energy use, looking for a better trade-off between high yield and limited environmental impact • Development and commercialisation of equipment which can reliably harvest woody crops • R&D on optimising the design and operation of more conventional Biomass to Liquids (BTL) processes (conversion of multiple biomass feedstocks to liquid fuels via gasification and Fischer Tropsch synthesis-Biomass to Liquids(BTL)) • Bioconversion methods for producing liquid fuels and hydrogen from ligno-cellulose parts of woody plants • Biomass use for the simultaneous production of biofuels, chemicals, and energy (biorefinery)
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	Yes, especially for: • Need to achieve the biofuels directives: –about 6% of transportation fuel by 2010 – 20% by 2020
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	Yes: • Current: global consumption 50 EJ/year • Global potential 450 EJ/year
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	Yes, examples include: • Establishment of biomass energy crops requires public support in terms of tax incentives • Need to reduce public resistance to genetically modified organisms to produce crops with improved yields and decreased cost
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	Yes, for topics listed in item 1 and the need to adopt European standards for biofuels utilisation
Is the field so costly/complex that significant research advances call for a shared approach?	Yes, because of: • Multi-fuel and multi-path exploitation of biomass resources, which necessitates a shared approach

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well coordinated research effort)?	Yes, specifically: • Biodiesel production established in some European countries (Germany, France, Austria, Italy) • Ethanol and its derivative ETBE used as fuel component in some countries (France, Spain, Sweden) • BTL liquids (Methanol, DME, Fischer-Tropsch) from biomass synthesis gas likely to be produced after 2010
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	Yes: • Many countries (e.g. Austria, Nordic countries) have an active programme on bioenergy
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	Yes, for example: • A NoE on Overcoming Barriers to Bioenergy • An IP aimed at introducing BTL production and utilisation • An IP aimed at biomass utilisation for hydrogen • Need to encourage biomass utilisation for concurrent production of electricity, heat and high-value chemicals (biorefinery)

Assessment of selected technology, based on the above

Vision

The overall objective is to expand the use of biomass, especially in the transport sector, in order to replace fossil fuels in the EU-25 by up to 30% by 2030. Technology and equipment must be developed to enable a higher energy contribution from biomass in the EU energy balance.

This goal will require new developments in the value chain for valorising biomass via new energy crops and their exploitation, with both thermochemical and bioconversion methods to produce biofuels, hydrogen and chemicals leading to cost-effective solutions.

Organisational and resource needs

Achieving the overall objective will involve a coordinated joint effort by stakeholders from the industrial and academic community – with expertise not only in energy, but also in agriculture, biotechnology, chemistry, and industrial processes.

The level of involvement of each stakeholder depends on the maturity of the technology for market use. Biomass use for electricity production via co-combustion is considered a rapidly maturing technology, while the generation of electricity via gasification requires further development. Cost-effective production of biofuels and hydrogen via the gasification route needs substantial improvement in biomass feedstocks, catalyst development and process integration. Bioconversion routes for the production of either biofuels or chemicals requires cross-cutting fundamental research in new crop production methods, biotechnology routes to the desired products, and cost-effective separation and utilisation of both biofuels and chemicals.

Another important need is the adoption of policies both at community and Member State level, in order to: a) introduce economic and regulatory instruments (including tax policies) to increase the commercial viability of biofuels and b) develop standards for biofuels deployment (distribution and use).

Satisfying the needs

The level of coordination needed will be dictated by the resource and organisational needs, as well as the needs of the specific technology. ERAWOG believes these can be met by the use of existing and proposed instruments:-

- Member States should become involved in the ERA-NET scheme, which will be useful in developing a common policy aimed at encouraging the development of balanced growth, harvesting and distribution of biomass resources for both energy and non-energy use.
- Private enterprises, financing institutions and research organisations will be the prime movers in developing gasification technology for hydrogen and BTL fuels, using existing Framework Programme instruments, including infrastructure development for a BTL demonstration plant using the I3 instrument.
- The use of bioconversion methods for the economic production of biofuels and chemicals will require a higher level of basic research, hence a greater involvement of researchers in third-level institutions will be needed. Once again, the existing Framework Programme instruments should be adequate.
- Research organisations, universities and industry will be the prime movers in developing processes for the simultaneous production of biofuels, chemicals and energy, employing the proposed new flexible tool and developing European Research Facilities to be established for core technologies.

Fuel Cells

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	• Although there is industrial involvement in FC research, many topics relevant for cost-effective fuel cells still require pre-competitive research (i.e. a long way from commercial application), including: materials and material systems, understanding of basic processes critical for good performance and degradation, and systems engineering with complex interaction of components
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	**Low** at **present** – will be high if costs come down, and when H_2 becomes cheaply available in quantity
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	• Provided cost effectiveness and fuel requirements are met: very large • Given the level of R&D in the US and elsewhere, Europe could lag seriously behind
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	**No**
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	• The necessary cost reductions in fuel cells are very high, and there is a need for many parallel research paths. Coordination should not restrict this. Given the high risk involved, the need for parallel research paths further increases the case for coordinated/supported activities • There is a need to ensure adequate communication between different research programmes working on similar topics • Need for collaboration on development of standards, testing, safety requirements, etc.
Is the field so costly/complex that significant research advances call for a shared approach?	• Can be dealt with within the frame of existing instruments such as IPs, NoEs, etc. • European FC R&D needs more funding than at present for lab work, prototypes and experimental small-scale production – and more will be needed for market introduction • However, the multi-stranded nature of research on fuel cells, and the need for parallel lines of research, means that some level of strategic planning of R&D would be beneficial

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well coordinated research effort)?	• Major global industrial players interested and currently engaged in projects
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	• Yes, in many Member States with an active involvement in all aspects of FC research • Good research institutions exist (and many are already involved) to carry out research projects together with partners in industry, universities and other research partners
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	• Many past and existing networks involving all key European players (e.g. ELEDRIVE, FCTESTnet, FHIRST, SOFCnet) • HLG and TP has brought together most interests and forms a promising basis for a more coordinated European approach

Assessment of selected technology, based on the above

Vision

Fuel cells are an excellent technology option for clean and highly efficient electricity production from natural gas, and later on from hydrogen, especially for mobile and local applications. A vision of the widespread use of fuel cells depends on the availability of abundant and cheaply produced hydrogen (of course, hydrogen can be used as an energy carrier in conjunction with conversion technologies other than fuel cells – such as internal combustion engines or gas turbines – and fuel cells can be employed using natural gas, for example, rather than hydrogen, as a transitional strategy). The successful development of fuel cells will change many industrial structures, and it will create a new market opportunity where Europe should strive for a leading position.

ERAWOG sees fuel cells as a future strategic commodity on a global market. In order to gain a large share of this emerging market over the next ten years, Europe should join forces within the EERA and with the instruments introduced during FP6 and its predecessor programmes.

Organisational and resource needs

Although based on a very old idea, fuel cells still require expensive R&D because the costs of recently achieved solutions and demonstrations are still far too high to compete effectively in the market. The US and Japan currently invest large sums of public and private money in fuel cell research and product development. This is a challenge for Europe, where national strategies prevail over joint efforts, and the industrial groups actively developing these technologies are global (or at least transatlantic) players. European research on fuel cells will remain weak unless

European programmes and the existing Technology Platform change the situation. There will be a need for close collaboration between industry and the leading European research institutions.

In the perspective of the EERA, it is important to choose the right level of coordination – especially bearing in mind competitive issues among Europe-based industrial players. Thus, the necessary coordination has to be of medium level – that is, applying the existing FP instruments. Special consideration should be given to developing the necessary norms and standards in order to prevent incompatibility within the market – for example, in grid connections, or with respect to fuel supply infrastructures.

As fuel cells still cannot compete on a cost basis in the market, there is an urgent need for more fundamental research in order to develop new approaches. Even in a perfect EERA, this research will need financial support without strong coordination; self-coordination by global scientific exchange, conferences, etc., should be sufficient.

Satisfying the needs

ERAWOG supports the European approach of a Technology Platform combining the fuel cell and hydrogen strategies, although both elements are not necessarily closely connected. When cheap hydrogen is widely available from environmentally benign primary energy sources, a much closer integration of research in the two fields will be necessary. In the meantime, ERAWOG recommends that the independence of both fields be carefully respected.

Other than this, ERAWOG has little to add to the strategy already being implemented: the establishment of a High Level Group on hydrogen/fuel cells, followed by the development of a Technology Platform. This scheme of coordination will be strengthened by all existing tools like ERA-NETS, NoEs, IPs, STREPs, etc.

There is strong international competition from other countries with high competence in fuel cell research, including the US, Canada, Japan, China and Korea. ERAWOG recommends a careful analysis of relative strengths before proceeding to a higher level of external co-operation.

Hydrogen-Related Technologies

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	**Overall yes, although:** • Many research topics are already near to the competitive stage (H_2 is already available to industry) • But H_2 from high-temperature electrolysis, thermochemical processes, etc., are pre-competitive • Pre-competitive elements of the H_2 strategy are fundamental research on novel/promising methods of production (e.g. biological systems), and H_2 storage with new materials and safety studies (a complex problem with no viable solutions to date)
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	• **Very much** so, since political decisions have already been taken by the EC as well as by the US (though it is unsure whether the US commitment to H_2 as a major energy carrier will remain in the longer term) to embark on a H_2 strategy • Its significance is high even if there are alternatives to the H_2 strategy
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	**Very large**, and given that the US is accelerating the development of H_2, it is vital that Europe should at least keep abreast of what may become a universal energy carrier. Note, however, that this is a long-term assessment
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	Yes, but this applies mainly to distribution and end use. International collaboration is not so important when it comes to H_2 production
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	• **Yes**, to the extent that it is important to ensure that technological solutions developed in Europe do not diverge • Harmonisation is vital in: infrastructure for fuelling systems; standards (safety, etc.); and to some extent H_2 handling, transport, storage and application projects
Is the field so costly/complex that significant research advances call for a shared approach?	• Yes, for building demo/pilot plants production technologies such as high-temperature electrolysis or thermochemical cycle • No, for other more conventional production technologies such as low-temperature electrolysis or reforming and POX – these are existing/competing technologies

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well coordinated research effort)?	**Yes**, but on a small scale, and confined to H_2 for industrial uses. No structure is available yet for commercial refuelling
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	• Yes, in some EU Member States, but not all • Existing programmes do not have a shared vision in relation to H_2
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	• Major global players are interested and engaged in projects • Most importantly, there have been major/ongoing discussions on a shared European approach, leading to the formation of a HLG (in 2003), and now the establishment of a H_2 Technology Platform and sub-structures

Assessment of selected technology, based on the above

Vision

The vision is of a highly efficient energy supply and service economy, supported by hydrogen as an energy carrier along with electricity. Hydrogen is abundant in nature, but it will only help in meeting sustainability objectives if produced without CO_2 as a by-product. Our vision, therefore, includes production of hydrogen by sustainable means – for example, using hydro, wind, wave/sea-current, high-temperature solar thermal, or photovoltaic energy. In the mobility and transport sector, hydrogen and synthetic hydrogen-rich fuels will play an important role in replenishing the energy economy.

Organisational and resource needs

Different needs exist for different aspects of hydrogen research, including hydrogen storage, sustainable production of hydrogen based on existing energy technologies, and development of novel methods of hydrogen production:

- The development of lightweight, compact hydrogen storage systems is critical for the ultimate success of hydrogen in the transport sector, and also in the marketing of portable devices replacing batteries. Although this is a crucial aspect of hydrogen R&D, strong coordination may not be appropriate, since new ideas and approaches are still needed. What is needed in the EERA is a coordinated awareness of ongoing development, so that the necessary norms and standards can be imposed as soon as market deployment begins in ten to 20 years.

- Alternative hydrogen production methods from many non-electric primary (and some secondary) energy carriers have to be developed and optimised. This must be coordinated with R&D in other fields – e.g. in nuclear and solar thermal development – in order to study thermochemical cycles for water splitting; or in the biomass sector, as one of the many possibilities of producing biomass fuels. With respect to the EERA, many strategies are of European dimension, interest and visibility, so that adequate coordination is needed.
- Fundamental research is still needed to gain new ideas for hydrogen production (e.g. biological and photocatalytic methods), storage (e.g. in nanostructures) and applications (see fuel cells). This research will not need to be coordinated too closely: self-coordination by global scientific exchange, conferences, etc. is the most desirable approach.

Since a hydrogen system in transport will and must consist of a globally compatible infrastructure, research and development as well as demonstration and deployment have to be more and more strongly coordinated, as market introduction comes closer.

Satisfying the needs

ERAWOG supports the existing organisational developments – the appointment of a High Level Group followed by a Technology Platform with the development of a common strategy within working groups on R&D and eventual deployment. This scheme of coordination will be strengthened by:

- An ERA-NET, in existence since October 2004, bringing together national and regional strategies on hydrogen technologies
- Application of all existing FP instruments
- Opening European projects to important partners from other continents.

Integration of Renewable Energy Sources and Distributed Generation into the Grid

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	**No:** close to use
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	**Yes:** essential for grid stability, and for further connection of multiple small-scale production sites
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	**Large global need for solutions** However, the main issues are to do with improving the European electricity situation
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	**No**
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	**Yes:** solutions must apply on a trans-European basis, and there is a need for shared standards and shared approaches to regulatory matters
Is the field so costly/complex that significant research advances call for a shared approach?	**No,** but the solutions affect the design and implementation of extremely costly energy infrastructures
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	Each Member State is concerned with research in this field, though with varying levels of research
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	Yes: there is a major cluster of projects and networks within FP5 focusing on various aspects of DG: • ENIRDGnet is a network of 37 partners from 15 Member States • SUSTELNET is a network focusing on policy and regulatory issues • A cluster of projects including CRISP (ICT technologies), INVESTIRE (storage), MICROGRIDS, DISPOWER (RES-E), DGFACTS (utilising power electronic techniques) • Within FP6, a CA led by ISET (France) is coordinating seven FP5 projects and will be extended to include coordination of FP7 projects/actions • An IP (EU-DEEP) with a total budget of 30M will run from Jan 2004 to June 2009, aimed at resolving outstanding problems

Assessment of selected technology, based on the above

Vision

A European grid which is able to utilise energy supply from small as well as large generators using a wide range of energy technologies, including photovoltaics, wind energy, fuel cells, CHP and ocean energy.

Organisational and resource needs

There is a need for a range of R&D projects with the participation of all European Member States, utility companies, SMEs, and research organisations, aimed at solving outstanding problems associated with the integration of renewables into the grid – including energy storage, power electronics, ICT technologies, etc.

There are policy and regulatory aspects of grid development and management which must be addressed in a coordinated manner.

Satisfying the needs

The set-ups established in FP5 – networks, clustering of existing projects – provide a good basis for advancing a coordinated approach in FP6. The ongoing RES-DG cluster of projects brings together seven major projects/networks with a total funding of €34M.

Within FP6, the EU-DEEP project (total funding €30M), which started in January 2004, will run until mid-2009 and will address market integration issues, regulation adaptation, connection technologies, grid impact of distributed generation, and Distributed Energy Resources (DER) systems.

Plans are already in place for extending existing coordination activities into FP7.

ERAWOG considers that substantial progress is being made in this field, in the direction of coordinated research efforts at a European level. It is desirable to continue to support both existing activities and any further initiatives to address additional research needs as they arise. ERAWOG considers that the existing range of instruments should be adequate to meet any such needs.

Near-Zero Emission Power Generation Based on Fossil Fuels[1] (Including Pre- and Post-Combustion CO_2 Separation and Storage)

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	**Yes**, especially: • Improved efficiency (high-temperature materials) • Inherently cleaner coal technologies (PFBC, IGCC) • Sequestration ready combustion systems • Affordable separation technologies • Storage technology for CO_2
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	**Yes** • Coal is the main fuel used for electricity generation in EU • Reduced dependence on energy imports • Need to stabilise liberalised energy markets
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	**Yes** There is a very large global market – many new coal-fired steam power plants will be built in non-EU countries • Real danger that Europe could lose lead to US/Japan
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	**Yes** (needs a unified European approach, and need for collaboration with other programmes) • Need to focus on EU lighthouse projects (very large project(s) similar to ITER) • EU should join US programme (FUTUREGEN) on zero-emission fossil fuel power plant
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	**Yes** • For example, the items listed in item 1 (and reduced R&D spending by utility companies in medium- and long-term R&D means public support is necessary) • EU-ETS (and possible extension to other gaseous pollutants) will lead to pressure for CO_2 savings from new/retrofitted fossil fuel power plants
Is the field so costly/complex that significant research advances call for a shared approach?	**Yes** – very costly indeed, and: • Complexity means that there is a need for cross-cutting research and concurrent research in several areas • Construction of prototype plant very costly and liberalised markets are not conducive to such developments

1. The principal focus of this assessment is on the cleaner use of coal.

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well coordinated research effort)?	**Yes** - for instance: • New generation of ultra supercritical boilers, e.g. Germany, Denmark • Existing IGCC plants in Bugenum (NL) and Puertollano (ES) • PFBC plants in Spain, Sweden, Germany Large-scale CFB in France, Poland, and Finland
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	**Yes** - for example: • National programmes dedicated to clean fossil power plants exist in the following countries: Germany, Italy, UK • Restricted activities exist in Denmark, France, Spain, Austria, Portugal, Greece • New Member States
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	**Yes** - for example: • FP5: TN:POWERCLEAN • FP5/6: CO_2NET/CO_2NET2 • FP6: ERANET/SSA (FENCO) • EU participation in CSLF

Assessment of selected technology, based on the above

Vision

The long-term objective is the generation of electricity with fossil fuel combustion (in the very long term, coal) with near-zero CO_2 emissions. In the short to medium term, we envisage improvements in technology towards much greater efficiency in the use of all fossil fuels for electricity generation – including reduced emissions and the capture and sequestration/storage of CO_2. In the medium to long term, we expect the development of new combustion methods to make CO_2 separation easier, and the development of safe CO_2 transportation and sequestration methods.

Organisational and resource needs

The above objective will be achieved through a coordinated effort by utility companies, equipment suppliers, and the academic community working together, and drawing on resources from materials science, combustion engineering, equipment design, environmental and social sciences. Incremental improvements in existing processes are possible with new materials and combustion modifications, resulting in a more concentrated CO_2 flue gas stream, and making CO_2 capture and sequestration/storage easier. There is a need for a range of focused R&D projects to achieve these improvements.

A near zero-emission fossil fuel (probably coal) based power plant will require developments in materials science, new combustion processes, CO_2 separation methods, and safe transportation and sequestration/storage of CO_2. Integration of all process steps for power generation (with and without hydrogen production for fuel cells) will be necessary for providing many of the options for reaching the final goal of a near zero-emission electricity generation plant based on coal. There will be a need for some very large-scale projects to pilot and demonstrate the integrated technology. For CO_2 sequestration/storage, there will be a need for R&D to help the development of regulatory mechanisms to address long-term safety and sustainability issues.

Satisfying the needs

The coordination efforts required to reach the goals will become more and more demanding as the realisation of the near-zero emission objective becomes closer. The following actions are envisaged in increasing order of coordination needs:

- Industry and research organisations will be the prime movers behind substantial improvements in energy efficiency, which can be achieved by incorporating new materials in traditional combustion systems. Existing FP instruments (IPs, STREPs) should be adequate for development of the materials technology. Construction of a demonstration plant to test material components will involve a major project with multiple funding sources.
- Research organisations, universities and industry will develop sequestration/ storage-ready combustion systems, including the development of CO_2 separation methods. The new flexible instrument (see elsewhere in this report) is recommended for this area because of the need to integrate many different research topics, and many different branches of research, in order to achieve maximum energy efficiency.
- Industry, together with research organisations, will be the principal actors in the development of new methods of coal conversion (PFBC, IGCC) which will facilitate CO_2 separation. A pilot plant that will allow for evaluation of approaches will be needed, along with one to two demonstration plants in which the complete carbon management path will be demonstrated.
- Governments, industry, financing institutions, research organisations and universities will be involved in developing inter-related technology and policy options for promoting a near zero-emission fossil fuel-based power plant. A Technology Platform will be required to define an integrated approach – international co-operation will be essential. An initial step should be the establishment of a High Level Group to put forward a common vision, a strategic research agenda, and a deployment strategy towards a near zero-emission coal-based power plant.

Nuclear Fission

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	• Second-generation technology is mature, in commercial exploitation for > 30 years • Waste disposal still needs industrial validation • Third generation is ready for industrial deployment; first units should be commissioned around 2010 • Fourth-generation technology is a long way from commercial exploitation (ca 2040)
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	• Yes! In the reference scenario, nuclear energy generation will still represent 22% of electricity generation in Western Europe in 2020 • Nuclear energy generation reduces EU dependence on imported oil and gas and improves security of supply for the EU
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	• Yes: there is a large global market for European manufacturers, mainly in Europe and Asia • European technology is presently competitive • But there is a risk of losing market share against the US, Japan, Russia and, in the long run, China
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	• Present collaboration with US, Japan, Russia and elsewhere is done at the national level. Hence, a European strategy is not essential for international collaboration • However, it would be highly desirable, since it would strengthen the position of European actors
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	• A broad European approach is needed for the development of design requirements and standards (European utilities are grouped in the European Utilities Requirement) • R&D would benefit from harmonisation and standardisation (e.g. reactor codes)
Is the field so costly/complex that significant research advances call for a shared approach?	• Yes: integration of research resources (teams and tools) is highly desirable to develop a mid-long-term vision for sustainable nuclear energy generation and the corresponding R&D • Infrastructures: existing heavy infrastructures (large hot facilities) should be shared, and new infrastructures should be designed and operated as European facilities

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well coordinated research effort)?	Yes: in Europe the nuclear industry (PP manufacture and fuel cycle) is already structured around (two major) large industrial players
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	• Yes: there are large research programmes in several EU Member States which could serve as a basis for further development • But the situation varies across the EU, depending on national policy towards nuclear fission • In general, national research policies are not oriented towards new developments (there are some exceptions, and the situation is changing)
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	• Yes: projects and networks in successive FPs allowed significant progress over a long period • NoEs, IPs and Integrated Infrastructure Initiatives within FP6 provide a basis for further development, particularly towards a Nuclear Fission Technology Platform

Assessment of selected technology, based on the above

Vision

The long-term objective is to develop technologies for nuclear fission energy generation that:

- guarantee the highest standards for safety, security and resistance to proliferation with essentially no risk to the general population or the natural environment;
- optimise the use of natural resources (uranium, thorium) so as to make nuclear fission a sustainable source of energy for centuries;
- broaden the opportunities for the use of nuclear energy beyond electricity production, including use of process heat for various applications such as production of chemicals, hydrogen mass production, and sea-water desalination.

These are in essence the goals of the fourth generation of nuclear power systems and their associated fuel cycle. The current (second) generation has reached industrial maturity and competitiveness, although the question of safe final disposal of the radioactive waste remains to be validated at the industrial level. Third-generation systems, which are safer and more economic, have just started market deployment. Generation IV systems are expected to start penetrating the market around 2030-2040. Generation IV technology is of considerable importance in Europe, since nuclear energy generation will still represent some 22% of electricity

generation in Western Europe in 2020. There is also a large potential global market for European manufacturers, especially in Asian countries. ERAWOG's vision is of a concerted effort by all of the research actors involved, such that the long-term objective stated above is realised in as short a timescale as possible.

Organisational and resource needs

The main need now is for major planning and coordination aimed at substantial European involvement in the development of a Generation IV nuclear plant. Given the major involvement of the US in such a project – particularly through the Generation IV International Forum – there is a need for a unified European effort. A joint undertaking among several Member States could be the objective.

Given the very high costs of research and the long lead time, there is a need for substantial ongoing public funding to cover R&D and infrastructure costs. European infrastructure is much needed, particularly in the provision of European hot lab facilities and new material test facilities.

Attention to education and training is required particularly in the field of nuclear fission, noting the need (at the very least) to maintain expertise in this critical field.

There is a need for major cross-cutting materials research, particularly in relation to structural elements and fuel elements for reactors operating at high/very high temperature.

Satisfying the needs

As regards Community-supported R&D, all of the existing Framework Programme instruments are needed in this field. Large infrastructures might be provided partly by projects undertaken as Integrated Infrastructure Initiatives (I3), or they could be an early and important element within a major European programmatic approach to nuclear fission research.

ERAWOG is supportive of initiatives that could lead to a Technology Platform in nuclear fission, addressing a much wider research agenda than is presently covered by FP6/Euratom. Such an initiative would deserve strong top-down support from the European Commission.

Ocean Energy[1]

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	**Yes**, although some devices are at the demo stage and some could come to commercial production in the mid term: commercial demo schemes of larger-scale devices in Ireland, Netherlands, Portugal, Sweden, UK. Wave Dragon has already supplied electricity to the grid, though on a very small and experimental scale
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	In theory, **yes** (e.g. estimates for Ireland alone give the practical OE resource as 15.8 TWh/a, compared with 16 TWh/a for wind (on- plus offshore)
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	**Yes** – very large global potential **Yes** – Europe is currently ahead of other competitors but some overseas companies are very active and may be first to have commercial schemes in operation. National programmes in Japan, China, India. Much private-sector involvement, both in Europe and the US
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	**No**
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	**In part –** e.g. common approaches are needed to the definition and measurement of capacity ratings, etc.
Is the field so costly/complex that significant research advances call for a shared approach?	**Yes** – test facilities are expensive and a European network of test centres across a range of environmental conditions is needed. Progress is being made in this direction.

1. Includes potential and kinetic energy from the ocean

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well coordinated research effort)?	**In part**: R&D is dominated by the private sector in Europe, with companies active in Denmark, Greece, Ireland, Netherlands, Portugal, Sweden and UK. A full supply structure is not yet in place but progress will be made as pilot/demo work progresses
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	**Yes, in part** – Denmark, Ireland, Portugal, UK have national programmes. However, national funding remains at a low level
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	**Yes** – European Wave Energy Network (Wavenet/EWEN), funded in FP5, has produced a comprehensive analysis and R&D road map for Europe – main players recognise need for further networking/communication/co-operation

Assessment of selected technology, based on the above

Vision

ERAWOG supports the IEA Implementing Agreement vision for ocean energy[29]: "to realise by 2020 the use of cost-competitive, environmentally sound ocean energy on a sustainable basis to provide a significant contribution to meeting future energy demands apart from other uses such as desalination". More specifically, we look forward to the emergence of a small number of dominant ocean wave and sea-current technologies, and to a significant deployment of these in appropriate locations around Europe.

Organisational and resource needs

Europe is currently a world leader in ocean energy R&D. Ocean energy research in Europe is currently dominated by SMEs, with support from public research bodies, universities and others. There are networking and coordination needs in advancing the research agenda already produced by the European Wave Energy Network, WaveNet. There is recognition among the WaveNet members that the considerable research work currently under way in Europe has been fragmented and conducted in isolation.

There are R&D needs in relation to first- and second-generation ocean energy devices, centred mainly on efficiency improvement, design refinement and cost reduction. There is a need for information exchange on matters of shared interest, and short-term R&D projects to address shared problems. Shared problems include knowledge gaps requiring a multi-disciplinary approach.

29. See http://www.iea-oceans.org/about/vision/home.htm.

There is a need to ensure adequate links with all actors involved in ocean-based technologies, especially offshore wind energy technology, to ensure that any possible synergies are pursued.

Satisfying the needs

The necessary R&D should be carried out in a coordinated way in Europe, and should utilise the existing IEA Implementing Agreement for carrying out ocean energy research in collaboration with international partners. We envisage collaboration between the European research actors in ensuring the necessary progress on shared issues such as test facilities and the development of common standards. R&D on ocean energy devices could be carried forward with a series of STREPs addressing specific topics, or by means of an IP whose objectives encompass the whole research agenda established by WaveNet. An IP would represent a means of advancing ocean energy research in a well-coordinated way.

Networking and joint planning have been carried out to date by the European Wave Energy Network (WaveNet), a Thematic Network established in 2000 within FP5. CAs represent a suitable instrument for the continuation of networking.

WAVETRAIN – a Marie Curie Research Training Network established within FP6 – aims to advance topics such as device modelling, assessment of devices and components, and socio-economic assessment. This is a valuable network that deserves ongoing support.

Use could be made of the Integrated Infrastructure Initiatives (I3) instrument for the development of research infrastructure, such as a network of European test facilities which may be large scale and costly.

Socio-Economic and Policy-Related Research

Criterion	Qualitative assessment
Potential applicability of EERA concept	
At a pre-competitive stage in research, a long way from commercial exploitation	**Not relevant**
Of (potential) importance to the overall European energy system	**Yes**, although indirectly. Socio-economic research is needed in some specific areas (e.g. DG), but the focus here is on more general socio-economic research. It is important in that it is required in order to guide, support and encourage energy R&D in all fields (including fields with little support from industry and/or the public). There are also major social issues concerning the acceptability of energy technologies, safety, planning, etc. which present potential barriers to funding and supporting key research. New issues concern 'deliberative' processes (how do you talk to the public; how people respond to new information). There is also a need for long-term (50-80 years time horizon) research.
Very large global market potential – danger that Europe could lag behind international competitors	**Not really relevant,** although it is important that Europe should stay at least abreast of the world, and is able to model the energy/environment field credibly for its own internal decision-making and for global forums
Needs unified European approach to collaborate with major R&D programmes elsewhere in the world	**Yes,** in that there is a need for projections and other outputs on a European basis, and these should be consistent with other non-European models
European approach needed in order to progress key research issues (e.g. harmonised European standards)	**Yes:** European policy decision-making requires an acceptable and accepted basis of socio-economic research
So costly/complex that rapid development necessitates a shared approach (e.g. in providing research infrastructure)	**No** (cost). **Yes** (complex – the issue here is not only one of complexity but of finding generally acceptable ways of dealing with that complexity)

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
An industrial/supply structure already in existence in Europe	**Yes,** in that Centres of Excellence exist in the EU which are capable of developing and maintaining socio-economic approaches on a par with anything in the world
Existing national/regional research programmes provide a basis for development of European policies/ programmes	**Yes:** most significant national/regional research programmes include socio-economic research as an essential element, and these resources already work together on a European level
Activities already undertaken (e.g. networks, associations, etc.) in information sharing and identifying possible areas for collaboration	Many major projects in previous FPs (for example, ATLAS, SENSER, PSI, modelling projects including ExternE, POLES, etc.) – with ongoing work both on the maintenance of models and on new modelling projects NEWEXT is an ongoing project with six partners (five Member States) aiming to improve the 'external costs' aspects of ExternE There is considerable networking and co-operation in this field

Assessment of selected technology, based on the above

Vision

The vision is of a highly developed set of resources at a European level – comprising research actors from individual Member States collaborating on shared problems – and meeting European needs for energy, environmental and economic research. In addition, we envisage European-level research on societal drivers of and barriers to innovation in and the widespread utilisation of new and more sustainable energy technologies and infrastructures, and on the interactions between people and energy.

Organisational and resource needs

The main need is to ensure an adequate level of coordination of socio-economic and policy-related research by the Member States, to provide for shared approaches, knowledge and experience, wherever these are warranted. There is an ongoing need for the further development of socio-economic research methodologies capable of providing answers to policy and other questions relevant to innovation in energy technologies and to energy production and use and its economic and environmental implications.

There are two broad sets of needs: one concerned with economic research and the development and use of economic models, and the other concerned more with policy-related and socio-cultural aspects of new energy technologies and infrastructures and demand-side issues.

- The former is quite well established in energy research, while the latter has mostly been addressed at national level to date. Thus, there are existing resources conducting socio-economic research focused on econometric modelling and the like, and there has been a measure of networking and coordination through previous FPs.
- The same cannot be said of energy-related social and policy-related research, and there is a need both for an increased level of research in this field, and for greater coordination. Although there is research within Member States, there has been relatively little shared activity across Member States to date, even though many of the challenges are shared.

Satisfying the needs

Specific socio-economic research challenges can be addressed by utilising existing FP instruments.

With regard to policy-related and social/cultural aspects of energy (including issues ranging from innovation policy and instruments to the acceptability of new energy technologies and infrastructures, end use and behavioural issues), the FP6 work programme already allows for proposals in these fields, and this would provide a basis for research proposals at a European level. There would be scope for a joint research effort on common issues, to be established by national energy bodies in collaboration with appropriate national level research institutions.

The Commission should encourage the establishment of an ERA-NET, with a view to bringing together national as well as European socio-economic and policy-related research and associated data. The aim should be to identify shared issues that would benefit from a coordinated approach at a European level. These issues could be advanced through specific projects using the existing Framework Programme instruments.

Solar Photovoltaic

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	• **In part, yes**: although PV has already been brought to some markets, there are significant barriers, some of them involving long-term research efforts, and vital if PV is to achieve major penetration, particularly in grid-connected applications: - Need for major cost reductions - Need for innovative new concepts – particularly in thin-film technologies - Need for mass production technologies • The time needed to advance these satisfactorily is probably still quite long, although PV is an area where there is substantial market competition already
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	**Yes**, provided technical and particularly economic problems can be overcome, there is potential for approximately 10% penetration by PV in Europe, with an expected upper limit of around 20%. Potential exists in: • Rural electrification and remote sites • Grid-connected electricity in conjunction with distributed generation based on a range of RES-E sources
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	**Yes (large global market potential):** although still embryonic, PV is reckoned to have huge potential in global markets, and major growth is expected in stand-alone applications worldwide **Yes (Europe could lag):** US and Japan have much bigger R&D programmes in PV than Europe
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	**No** (the effectiveness of European R&D in PV could be improved by greater coordination, but this is not needed for international collaboration)
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	**In general, no, with the following exceptions:** • Resource assessment and siting, environmental attributes, standards, testing and evaluation, marketing and financing mechanisms to expedite deployment, and integration of PV systems in especially low-energy buildings, and energy storage in synergy with PV technologies • Progress in materials and manufacturing processes (linking the physics of PV devices to manufacturing process technologies) would benefit from a shared approach (though this could be difficult to achieve)
Is the field so costly/complex that significant research advances call for a shared approach?	**Yes:** see topics listed under item 5 above

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well-coordinated research effort)?	**Partly**
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	**Yes,** although the situation is highly variable across Member States, a few have active R&D programmes in PV (national activities tend to focus on market deployment issues)
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	**Yes** • The PVNET and PVECNET activities funded within FP5 focus on developing R&D road maps for PV in Europe • The European PV Industry Assn. (EPIA) is active and a European road map is due for release at its conference in June 2004 • ASiNet is a European network focusing on amorphous silicon devices • Many other R&DI activities involving large consortia funded in FP5 and FP6, plus the distributed energy resources cluster of activities, which include consideration of issues linked to large-scale PV grid connection

Assessment of selected technology, based on the above

Vision

The overall objective is to expand the use of grid-connected PV systems in the electricity sector with a significant penetration by PV in Europe by 2020. Such an objective will require new developments in materials and manufacturing processes, linking the physics of PV devices to manufacturing process technologies.

Organisational and resource needs

Although photovoltaic technology has already been brought to some markets there are significant barriers, some of them involving long-term research efforts and vital if PV is to achieve major penetration particularly in grid-connected applications. The time needed to advance these satisfactorily is probably still quite considerable, although PV is an area where there is substantial market competition already. Achieving the overall objective will involve a coordinated joint effort by stakeholders from the industrial and academic community. The level of involvement of each stakeholder depends on the maturity of the technology for market use.

Many R&D activities are under way involving large consortia funded in FP5 and FP6, plus the Distributed Energy Resources cluster of activities which includes the consideration of issues linked to large-scale PV grid connection.

Private enterprises, financing institutions and research organisations will be the prime movers in developing new PV technologies. In all areas of PV production, considerable R&D (both basic and applied) is necessary in materials and new production technology: research on PV, linking the physics of PV devices with manufacturing technology (more specifically, mass production of PV devices) and material research on promising PV technologies will benefit from a shared approach.

An important need is for the adoption of policies both at community and Member State level in order to provide resources for assessment and siting, environmental attributes, standards, testing and evaluation, marketing and financing mechanisms to expedite deployment, integration of PV systems especially in low-energy buildings, and energy storage in synergy with PV technologies.

Satisfying the needs

The main strategic opportunities for progressing the EERA in relation to PV technologies are the need, recognised in Europe, for much greater efforts to compete effectively with Japan and the US, and the need for a new generation of PV technologies which must be closely linked to cheap manufacturing processes and products which are environmentally friendly.

ERAWOG believes these can be met by the use of existing and proposed instruments:

- Member States should become involved in the ERA-NET scheme which will be useful in developing a common policy aimed at encouraging the development of balanced growth of PV systems for both rural electrification and remote sites, and grid-connected electricity in conjunction with distributed generation based on a range of RES-E sources.
- Research organisations, universities and private industry will be involved in the long-term efforts required for the economic production of solar cells and PV systems, using existing Framework Programme instruments. ERAWOG acknowledges and is generally supportive of the desire of European PV actors to establish a TP. However, it has to be recognised that the PV R&D activities are already well organised, so the establishment of a TP must be considered carefully. The existence of the PV Technology Research Advisory Council, PV TRAC, is welcome, and provides a useful starting point in identifying common research goals, and in progressing an agreed strategic research agenda for PV in Europe.

Solar Thermal High Temperature

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	**Yes**, in particular: • High Efficient Solar Combined Cycle (always in conjunction with gas) for power production • Solar thermal production of hydrogen or other fuels from renewable sources
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	**Yes**, in the longer term, for: • RES-E (generated in S Europe or N Africa) • Production of low-cost fuels incl. hydrogen
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	• **Yes:** Europe currently has a leading role but this is in jeopardy from the US and Japan
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	**No**
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	**No,** but there may be a need for this in time, in connection with high-temperature applications
Is the field so costly/complex that significant research advances call for a shared approach?	**No,** although for large-scale components, research infrastructure and construction of prototypes, the cost may be such that a shared approach would facilitate progress

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well-coordinated research effort)?	**Yes** (and are working together already – the first prototype plants have been built in Spain and Italy). There are solar plant construction companies and component suppliers in Germany, Spain, Italy (ACS; Schott, Flabeg)
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	**Yes** (national programmes dedicated to solar high-temperature technology in Germany, Spain, France, Switzerland, Italy and Israel; and restricted activities exist in Denmark, Greece and Portugal
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	**Yes** – for example: • FP6: ECOSTAR (road map activity for solar thermal electricity) • FP6: INNOHYP CA (Coordination Action for hydrogen production on thermo-chemical cycles form nuclear or solar heat) • IEA SolarPACES Network • Sollab Network of Research Facilities for concentrating technologies from Germany, Spain, France and Switzerland for scientific exchange and optimised facility use

Assessment of selected technology, based on the above

Vision

The objective is to develop highly efficient solar combined cycle technologies (always in conjunction with gas) for power production, as well as solar thermal production of hydrogen or other fuels. More specifically, the goal is to achieve cost reductions of a factor of 3-5, compared with present costs. This will enable a significant contribution to electricity supply in Europe (mainly Southern Europe). Europe currently has a leading role in solar thermal high-temperature technologies, but this is in jeopardy from the US and Japan. It is part of this vision that Europe should maintain its position as the world leader of both the technological development and the commercial utilisation of solar thermal high-temperature applications. ERAWOG's vision is one of a joint European effort that supports the strategic medium- to long-term research necessary to keep Europe competitive in solar thermal high-temperature technologies.

Organisational and resource needs

Solar thermal high-temperature technology will be an option for sustainable electricity and fuel production. Research infrastructures and pilot plant development are costly and would benefit from a European approach.

ERAWOG concludes that the solar thermal field does not need to be strongly coordinated, but there are topics which would be well suited to the EERA concept, including R&D to:

- increase efficiency and reduce costs (high temperature approaches, lightweight concentrators, new reflector concepts);
- explore and develop high-temperature technologies for various purposes including solar thermal hydrogen/fuel production (solar thermal could represent the only technology to compete effectively with nuclear, for the production of hydrogen);
- reduce operation and maintenance costs, and stimulate mass production;
- develop materials for high-temperature applications and for thermal energy storage.

The SolLab Network is an important existing opportunity for collaboration and coordination. There is a need for such collaboration on a wider basis across Europe. There is a need for large-scale infrastructures such as Plataforma Solar, but with general European access.

The achievement of such a significant contribution from solar thermal high-temperature technologies will not only require technological developments leading to cost reductions, but will also necessitate consideration of market development, grid integration, environmental impact, and socio-economic aspects.

Satisfying the needs

Initiatives should be taken that utilise all the instruments available through the Framework Programmes. A European Research Area in solar thermal high-temperature technologies that can support the sector through long-term generic and scientific R&D should be the ambition. R&D in high-temperature solar thermal energy should be included in the FP7 work programme.

There is a key role for IPs to form the basis for large-scale R&D, including the construction of pilot/demonstration plant. High-temperature aspects, along with other topics related to the production of hydrogen, should be included within the scope of the H_2/FC Technology Platform. An effort should be made to extend the access to networks such as SolLab and infrastructures such as the Plataforma Solar.

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

Wind Energy

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is the technology still a long way from commercial exploitation (thus making collaboration more feasible)?	• The European WE industry is competitive but depends on frontline R&D for further improvements and essential cost reductions • The structure of the electric grids and their management must be developed to accommodate large-scale utilisation of wind energy • A long-term challenge is the development of radically new ('fourth generation') wind turbines that are still far from the market
Is the technology of importance to the overall European energy system (making coordination of research actors more likely)?	• Wind power is applicable only in suitable locations, but in such localities the potential is high in Europe and worldwide • Deregulation of the European energy markets and internalisation of the externalities into the pricing of the wind energy will create a situation in which wind energy has the potential to become a significant contributor to the electricity markets (10-20% or even higher, depending on storage options such as water pumping, hydrogen, etc.) • The distributed nature of wind energy will lead to a reduction in transmission losses and to more efficient utilisation of the electrical grid, but also to new investments in the high-voltage grid
Is there a large global market potential, with a danger that Europe could lag behind international competitors (making it more likely that European researchers would wish to co-operate via the EERA)?	• Yes, considerable; a realistic assumption is a global increase in wind power capacity of around 10 GW in 2004 alone • In 2003, European wind turbine manufacturers supplied 80% of the new wind energy capacity, so Europe is market leader at present, but runs the risk of losing market shares if joint efforts are not made in research areas such as short-term forecasting of power outputs, offshore environment and technology, wind-turbine technology (materials, computational fluid mechanics), and grid dynamics and integration
Does the field require a unified European approach in order to collaborate with major R&D programmes elsewhere in the world (making it more likely that researchers would seek a coordinated European approach)?	• No, not really, although international R&D co-operation may provide a valuable means of promoting new European wind technologies • However, there may be a need for a joint EU approach to technology foresight and scouting • Also, it is important to ensure that markets elsewhere do not develop in ways and directions that are incompatible with EU technology

Wind Energy (followed)

Criterion	Qualitative assessment
Potential applicability of EERA concept	
Is a European approach needed in order to progress key research issues (e.g. harmonised European standards)?	• The WE industry's own R&D efforts are short-term innovation activities with a trend towards becoming closed vis-à-vis competitors, R&D institutions and universities, which makes it difficult to sustain long-term research activities on a European level • Lack of European funding of R&D projects leads to deterioration of the European research networks in the wind sector and pushes the R&D back to fragmented national research programmes (compared with the US Wind Energy Program that exploits the research competences in the whole of the US and is coordinated by the National Renewable Laboratory in Bolder, Colorado) • So there is a need for medium- to long-term R&D that would be unlikely to happen unless supported by public initiatives at national/EU levels; such research is needed to maintain Europe's global lead and the momentum of wind technology • It is also necessary to develop European standards related to safety, testing, certification, environmental issues, inclusion of external costs, grid integration and management, etc.
Is the field so costly/complex that significant research advances call for a shared approach?	• See point 5 above

Criterion	Qualitative assessment
Readiness for early application of EERA concept	
Is there already an industrial/supply structure in existence in Europe (that is, is European industry ready to carry forward a well-coordinated research effort)?	• Yes, and well developed, but wind turbine manufacturing is still only significant in a limited number of European countries (Denmark, Germany, Spain, Greece, Portugal) • A European Wind Energy Association and a European Academy of Wind Energy exist
Are there existing national/regional research programmes in Europe that would provide a basis for the development of European policies/programmes?	• Wind energy has developed on the basis of a combination of industry efforts and national R&D programmes • Most EU Member States have wind energy as a component of their national R&D programmes, but national activities are focused on market deployment and on support of the industry, not on long-term R&D
To what extent have activities already been undertaken (e.g. networks, associations, joint research) in information sharing and identifying possible areas for coordination/collaboration?	• Publication of a European Wind Atlas (and development of a methodology followed by Member States in producing national wind atlases) demonstrates both the understanding of the importance of wind energy and the effectiveness of existing networks • European Wind Energy Association is very active and has many Industries as well as national R&D organisations and associations as members • The Thematic Network managed by EWEA presented a European R&D strategic plan to the Commission in January 2004

Assessment of selected technology, based on the above

Vision

The objective is to develop cost-effective technologies that will allow wind energy to contribute significantly to electricity supply in Europe, as well as worldwide, by 2020. It is foreseen that offshore wind turbines will produce much of this contribution. This makes R&D in offshore wind technology a priority area.

It is part of this vision that Europe should maintain its position as the world leader of both the technological development and the commercial utilisation of wind energy.

ERAWOG's vision is one of a joint European effort that supports the strategic medium- to long-term research necessary to keep Europe competitive in wind energy – research that would not otherwise be carried out.

Organisational and resource needs

The achievement of such a significant contribution will not only require technological developments leading to cost reductions, higher degrees of exploitation of wind resources, and better and more stable operation of wind turbines, but will also necessitate consideration of market development, grid integration, environmental impact, and socio-economic aspects.

There is need for open-knowledge networks among the European research institutes and industry dealing with long-term generic and more fundamental wind energy related R&D activities, and for more and better-coordinated activities that can make knowledge available to EU companies at a cost comparable with that available to US and Japanese competitors.

This need for R&D covers such a broad spectrum of research areas in technology, earth and environmental sciences, and socio-economics that a strong measure of coordination is warranted in order to ensure that European resources – human as well as fiscal – are optimally exploited.

Satisfying the needs

Initiatives should be taken that utilise all the instruments available through the Framework Programmes. A European Research Area in wind energy that can support the sector through long-term generic and scientific R&D should be the ambition. A necessary basic element will be the inclusion of wind energy topics within FP7.

ERAWOG believes that offshore wind energy should be given high priority, and that the establishment of a Wind Energy Technology Platform should be pursued, as should the possibilities for multinational offshore R&D programmes.

European Commission

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This report highlights the importance and the relevance of making full use of ERA related instruments to help energy RTD in Europe to adopt ambitious long-term goals for technology deployment. This would take place through greater coordination and increased pooling of regional, national and European funding, including appropriate use of article 171, of coordinated networks (ERANETS) in energy, of joint technology initiatives and of EU structural funds.

The report underlines a set of 10 practical recommendations to make ERA a reality in energy research.

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