INTERNATIONAL ENERGY AGENCY

REVIEWING R&D POLICIES

Guidance for IEA Review Teams

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The International Energy Agency (IEA) is an autonomous body which was established in November 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme.

It carries out a comprehensive programme of energy co-operation among twenty-six of the OECD thirty member countries. The basic aims of the IEA are:

- To maintain and improve systems for coping with oil supply disruptions.
- To promote rational energy policies in a global context through co-operative relations with non-member countries, industry and international organisations.
- To operate a permanent information system on the international oil market.
- To improve the world's energy supply and demand structure by developing alternative energy sources and increasing the efficiency of energy use.
- To assist in the integration of environmental and energy policies.

The IEA member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States. The Slovak Republic and Poland are likely to become member countries in 2007/2008. The European Commission also participates in the work of the IEA.

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of thirty democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Republic of Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, Turkey, United Kingdom and United States.
The European Commission takes part in the work of the OECD.

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FOREWORD

Energy security, environmental protection and economic prosperity all pose major challenges for today's energy decision makers. To meet these challenges, innovation, the adoption of new cost-effective technologies, and better use of existing energy-efficient technologies are key elements.

The world is not on course for a sustainable energy future – with security concerns and CO_2 emissions projected to more than double by 2050. But this alarming outlook can be changed. A recent major IEA analysis "Energy Technology Perspectives – Scenarios and Strategies to 2050" (IEA, 2006) demonstrate that by developing and employing technologies that already exist or are under development, the world could be brought onto a much more sustainable energy path.

The costs of achieving a more sustainable energy future are not disproportionate, but they will require substantial effort and investment by both the public and private sectors. There will be significant additional transitional costs related to RD&D and deployment programmes to commercialise many of the technologies over the next couple of decades.

Governments will continue to play a major role in energy technology R&D – in defining policies and funding them. How can IEA member country governments be sure they are making the right choices? One answer is by learning from the experience of others – through the use of peer reviews. The IEA version of the peer review – the in-depth review - is a well established tool used since the IEA was created more than 30 years ago. It provides for its members a framework to examine and compare experiences and discuss "best practices" in a host of energy policy areas, including research, development and technology policy.

Making the most of the in-depth review process, as well as recommendations emanating from it, offers the promise of better and more well-informed R&D policies – ultimately assisting the development of the new energy technologies that we so urgently need.

Claude Mandil
Executive Director
International Energy Agency

ACKNOWLEDGEMENTS

This book was conceived in response to requests from the Committee on Energy Research and Technology (CERT) for support to experts involved in the in-depth reviews (IDR) of IEA member countries' energy technology research and development (R&D) policies. The book seeks to thoroughly describe objectives and procedures and to provide guidelines and tools for the R&D in-depth reviews.

Jeppe Bjerg was the primary author and editor. Neil Hirst and Robert Dixon guided the work. Tom Kerr, Debra Justus, Carrie Pottinger, Jun Arima, Hisashi Yoshikawa, Andreas Biermann and Jolanka Fisher provided valuable input. Simone Luft and Diana Louis helped to prepare the manuscript. Production assistance was provided by the IEA Communication and Information Office: Rebecca Gaghen, Muriel Custodio, Corinne Hayworth, Loretta Ravera and Bertrand Sadin added significantly to the material presented.

The IEA Expert Group on R&D Priority Setting and Evaluation contributed to this project including definition of scope, drafting and reviewing. Input was gratefully received from the following members:

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Potential users of the book were consulted in the process to make sure that it is well understood and useful for reviewers. Constructive feedback and comments were received from members who have participated in IEA in-depth reviews in 2006:

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The IEA Energy Technology Office (ETO) expects that this book will assist team members, experts and desk officers in reviewing the energy technology R&D policies of IEA member countries.

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1. OBJECTIVE AND EXPECTED RESULTS

The objective of this book is to further strengthen in-depth reviews of IEA member countries' energy R&D policies and programmes by providing tools and guidance to review teams. The ultimate objective is to improve the recommendations to IEA member countries on improved energy technology and targeted R&D policies and programmes.

The book provides a framework for conducting R&D reviews and recommendations. It is not intended to be prescriptive, rather to serve as a consistent, logical and transparent process. Some of the expected results are:

- to improve the capacity of review team members, experts and desk officers to conduct R&D and technology policy reviews;
- to ensure more consistent and streamlined energy technology R&D reviews to facilitate cross country comparisons and general conclusions;
- to maximise the output from limited resources spent on R&D in-depth reviews.

The book contains a menu of tools, best practice examples and a list of questions for the review team. The menu does not cover all issues relevant to reviewing government R&D policies – issues not touched upon in this book could also be of relevance for the review.

Likewise not all issues are equally relevant in all countries. The menu is supposed to be a source for help, and not a check list where all issues should be covered in every in-depth review.

The primary target group is review team members, experts and desk officers participating in the in-depth reviews. But the information compiled and presented could be useful to others involved in reviews of technology policies and programmes.

The first two chapters describe the process and outputs of the IEA in-depth review process and provide details on the review of technology and R&D policies. The last six chapters provide further background, check lists, questions, good practice examples and other tools as support to the review of six core elements of coherent and effective energy technology R&D policies:

1. R&D strategy
2. R&D priority setting
3. R&D funding
4. R&D monitoring and evaluation
5. International R&D collaboration
6. Linking basic science and energy technology R&D

It is not possible to cover all subjects in detail and this book only provides a first tool box. Important issues – like linking energy R&D with deployment policies and commercialisation – will only be touched upon briefly, but will be further analysed in a forthcoming book from IEA on R&D policy.

2. IMPROVING ENERGY TECHNOLOGY POLICIES: LEARNING FROM PEERS

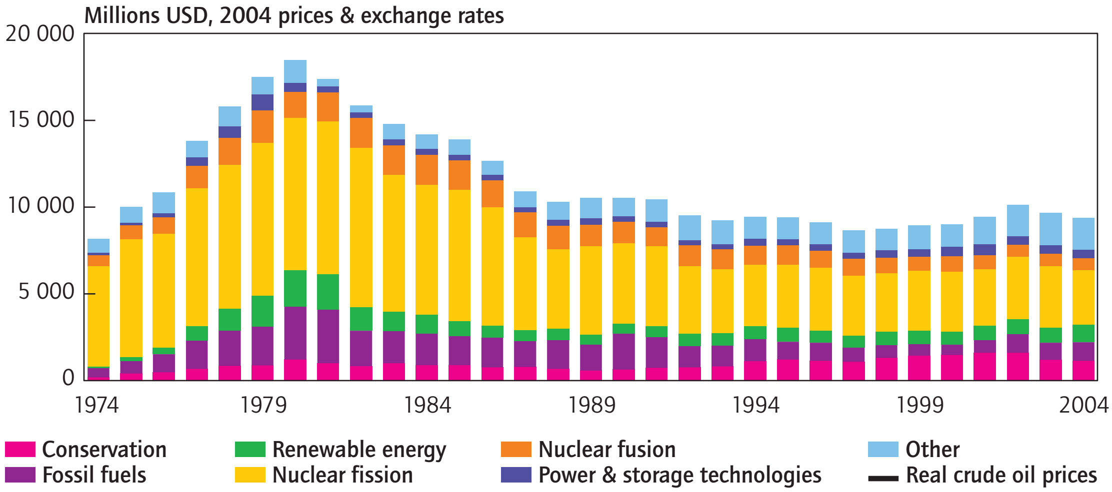
Outlook to 2050: the importance of energy technology policy

The IEA analysis "Energy Technology Perspectives – Scenarios and Strategies to 2050" (IEA, 2006) develops a number of technology development scenarios - The Accelerated Technology Scenarios (ACT). The scenarios show how energy-related CO_2 emissions can be returned to their current levels by 2050 and how the growth of oil demand can be moderated. Implementing the ACT scenarios will require a transformation in the way power is generated; in the way homes, offices and factories are built and used; and in the technologies used for transport.

In the end, it is the private sector that will have to deliver the changes required. But the market on its own will not always achieve the desired results in terms of technology development and technology uptake. A firm conclusion from the analysis is that governments have a major role to play in supporting innovative R&D and in helping new technologies to surmount some daunting barriers.

Meanwhile, the total government R&D spending of IEA member countries has declined over the last decades (Figure 1). Studies indicate that the decline in public budgets is not replaced by private R&D – in some countries private energy R&D is also decreasing. This is in sharp contrast to the recommendations from Ministers of IEA member countries, who have repeatedly called for strengthened energy R&D efforts. Current R&D spending levels probably remain far below what is necessary to tackle our energy challenges.

Figure 1. *R&D budgets for IEA member country governments 1974-2004*



Source: IEA, 2007.

IEA in-depth reviews: a tool to improve policies

The challenge of developing new energy technologies combined with the trend towards declining total IEA member country government spending on energy R&D makes it all the more important for governments to make the right choices in R&D policies, management and funding. This is where the peer review can be an important tool for developing and implementing more effective policies. A country seeking to improve the effectiveness of R&D policies and programmes can learn valuable lessons from its peers on what has worked and what has not. This can save time, and costly experimenting, in crafting the best policies for a particular country.

The in-depth reviews are the IEA version of a long-standing element of OECD practice – the peer review, namely, the systematic examination and assessment of the performance of a country by other countries. The ultimate goal is to help the reviewed country and other member countries improve their policy making, adopt best practices, and comply with established standards and principles. The multiple objectives of the in-depth review are:[1]

- to periodically check whether the energy policies of member countries are consistent with the IEA 1993 Shared Goals under their country specific context;
- to facilitate the reviewed countries in developing and implementing energy policies consistent with the Shared Goals through peer pressure by a neutral international organisation;
- to share updated information about the energy policies of member countries, which could provide useful input in policy formation;
- to provide basic input for other IEA activities;
- to give policy makers valuable opportunities for learning and observing good practices. This is a two-way process:
  - policy makers from member countries can learn lessons from reviewed countries through participation in review teams and/or discussions at the Standing Group for Long-Term Co-operation (SLT).
  - reviewed countries can learn lessons and different approaches from member countries through receiving peer review teams and discussions at the SLT.
- to broaden the network of energy policy experts among team members and officials of reviewed countries.

IEA shared goals and IEA ministers' guidance: review criteria

The review criteria for the in-depth reviews are the IEA Shared Goals adopted by IEA member country Ministers in 1993 (see Annexe 1 for full text).

According to the Shared Goals, the IEA member countries seek to create the conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA member countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants.

The IEA member countries aim to create an energy policy framework consistent with:

- diversity, efficiency and flexibility within the energy sector
- ability to respond to energy emergencies
- environmentally sustainable provision and use of energy
- environmentally acceptable energy sources

1. IEA, 2003. "Review Of The Country Review Process." Standing Group of Long-Term Co-operation. Note by the Secretariat. IEA/SLT(2003)10

- improved energy efficiency
- research, development and market deployment of new and improved energy technologies
- undistorted energy prices
- free and open trade
- co-operation among all energy market participants

On research, development and deployment the Shared Goals specify that:

"Continued research, development and market deployment of new and improved energy technologies make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged."

The in-depth reviews also check progress towards the commitments and guidance that Ministers of IEA Member countries agree to in the biennial IEA Governing Board meetings at Ministerial level (IEA Ministerial). At the recent IEA Ministerial, Ministers called for increased national efforts to support energy technology R&D:

- For a sustainable energy future, we need to accelerate the development and deployment of new technologies. We will work urgently to bring this about.
- We will encourage the strengthening of our R&D efforts to reduce the costs of new technologies such as advanced biofuels, solar, hydrogen fuel cells and electric vehicles.
- And we will enhance our energy technology collaboration with major emerging economies, bilaterally and through the IEA's technology network.

Coverage of reviews

The current in-depth review reports have comprehensive coverage of issues and sectors:

- energy market and energy policy
- energy security
- energy and environment
- energy efficiency
- oil
- coal
- natural gas
- electricity production and networks
- (nuclear for some countries)
- renewable
- energy R&D

The extensive coverage limits the resources available for individual issues like energy R&D. Time available for meetings with national technology and R&D experts is often limited and it is not always possible to include a technology and R&D policy expert in the team. However, R&D is now recognised as an increasingly important component of the review process.

IEA member countries are subject to in-depth reviews approximately once every four years. Review teams composed of member country experts and Secretariat staff visit the subject countries to meet energy policy makers, regulators, energy industries, energy consumers, and other stakeholders. These visits are followed by a report containing a comprehensive description of the energy situation and energy policies of the reviewed country with critiques and recommendations. This report is made public within the series "Energy Policies in IEA Countries".

Since there are significant diversities among member countries in terms of geographical settings, natural endowments, industrial structure, social background, and government organisations, recommendations are tailored to fit the unique situation of each country. See Annexe 2 for a description of the review procedure.

In order to have a sufficient basis for providing energy R&D policy recommendations, sufficient background documentation should be available for the review team and sufficient time dedicated for meetings with key R&D stakeholders in the country during the review. The team must have opportunity for in-depth discussions with those involved specifically in key decisions of R&D policy and management. This may necessitate a specialised programme of visits.

Thematic reviews versus traditional reviews

The IEA Governing Board reviewed the IDR procedure in 2005. It confirmed that in-depth reviews of IEA member countries should continue, with a comprehensive scope, and that a review cycle of no longer than 5 years should be maintained.

At the same time, the Governing Board also introduced the possibility for member countries to have a choice between "thematic review" and "traditional review".

In a thematic review, while maintaining comprehensive coverage, particular focus will be placed on a theme chosen by the reviewed country and a theme chosen by the Secretariat. In the 2006-2007 review cycle, energy efficiency has been given priority due to the Ministerial 2005 recommendations. Two of the 2007 reviews (United States and Finland) have Technology and R&D as a special theme.

3. IEA REVIEW OF TECHNOLOGY AND R&D POLICIES

This chapter will give an overview of the IEA's review of technology and R&D policies – the review criteria, the process and the outputs that are available for the review team and outline potential R&D issues to be described and discussed in IDRs.

What is good energy technology R&D policy?

Beyond the Shared Goals there are no explicit IEA definitions of good R&D technology policies. As a consequence, there are no agreed upon criteria guiding the review of countries' R&D policies. However, through the practice and experience of conducting in-depth reviews and through the recommendations of the Expert Group on R&D Priority Setting and Evaluation, the following set of elements and procedures are found to contribute to good and effective R&D policy making:

- a clear definition of government's role
- a national energy strategy (policy directions and goals)
- an accompanying technology and R&D strategy
- adequate and stable funding
- well defined and transparent R&D prioritisation and evaluation processes
- involvement of R&D stakeholders in priority setting and evaluation
- linkage with national science, research and innovation strategies
- linkage with policies for commercialisation and deployment
- public private partnerships
- strategy for international R&D collaboration

Reviewing a member country's R&D policy

As a team member engaged in in-depth reviews it is important to note that there is no explicit IEA definition of what constitutes effective R&D policy making. Additionally, there are no IEA R&D indicators by which to measure a country's performance in energy R&D policy. Each country will choose those energy technology policies that fulfil national priorities and achieve the fundamental common IEA goals.

There is no given level of R&D funding that the reviewed country must comply with. There is no technology that a country must engage in. Therefore, the team member reviewing a country's R&D policies should be looking for coherence and quality in decision making processes. This book seeks to provide the reviewer with a concrete set of issues to explore and questions to ask.

The IDR report is structured along the following lines:

- description
- critique
- recommendations

The issues and questions in this book will help team members describe the energy R&D policy in the particular country under review based on parameters believed by the IEA to be important. This description is the platform on which to found the critique. For example, if there is no coherence between overall energy strategy and actual funding of projects, this would be an obvious critique.

Other gaps, omissions and incoherencies should also be highlighted. The absence of coherence would naturally lead to recommendations asking the country under review to ensure / set up a system to ensure / investigate how to resolve these issues.

Potential R&D issues to be covered in IDRs

The IEA view as to what constitutes "key elements of a national energy R&D planning and prioritisation system" (previous page) logically focuses attention on a number of underlying issues and poses a number of questions to be discussed with countries under review. Below is a list of key issues to target in the review as well as a list of corresponding questions to explore these key issues to develop critique and recommendations.

A thorough description of the elements in the box below would be important as basis and preparation for the review – in particular for thematic reviews with focus on energy technology R&D. See Annexe 3 for the full list of energy R&D questions to be addressed by the reviewed country in the submission prior to the review visit.

Key technology and R&D elements to be described as part of the review

- The energy technology and R&D strategy
- Description of energy technology R&D programmes
- Description of energy R&D institutions and stakeholders
- Description of energy R&D funding and funding trends
- Description of energy R&D priority setting procedures
- Description of energy R&D programme evaluation procedures
- Description of link of energy R&D to basic science
- Description of link of energy R&D to deployment
- Description of international R&D collaboration and how this is prioritised
- Description of link to national research and innovation policies

Issues which could be discussed with the government during the review visit to develop critique and recommendations are listed below.

Key technology and R&D issues to be discussed with governments in an IEA in-depth review:

- Is there a national energy strategy?
- Is there an accompanying technology and R&D component?
- What analyses support portfolio development?
- How are investments prioritised and budgeted?
- Are there R&D evaluation methods?
- Are there independent management evaluations?
- What policies spur commercialisation, deployment?
- How are stakeholders involved in R&D policy formulation, priority setting and evaluation?
- How is public private partnership focused?
- How is international collaboration prioritised?

This list should be regarded as a menu of potential issues to be discussed. In the following chapters these issues are further explored and more detailed questions listed.

CERT contribution to the review

In 2003, the IEA member countries encouraged the IEA Secretariat to enhance the energy technology R&D component of the country in-depth review (IDR) (IEA, 2003). The Committee on Energy Research and Technology (CERT) and the Energy Technology Office (ETO) of the Secretariat were encouraged by the IEA Executive Director, Mr. Claude Mandil, to be more active in assessing and providing recommendations on R&D policies of IEA member countries through the IDRs.

The CERT and the ETO crafted a three-step approach to improve the recommendations to member countries. The three-step approach involves:

- encouraging technology experts to participate in review teams;
- identifying priority technology R&D issues to be addressed by each review team;
- identifying lessons learned and discuss implications for IEA work on technology policy issues.

Support from technology policy experts in the Secretariat

Country desk officers from LTO (Long-Term Co-operation and Policy Analysis) have overall responsibility for planning, implementing and drafting IDR reviews together with review teams. Technology R&D experts from the Energy Technology Office support the country desk officers by:

- providing input to planning the review visit and to the background briefing book for the team;
- reviewing country submissions;
- providing input to, and review of draft chapters;
- participating in selected in-depth reviews (1-2 visits per year);
- drafting the energy technology R&D chapters if an ETO expert has participated in the review visit.

It has been a practice that ETO staff participate as technology experts in about two in-depth reviews per year. Participation has focused on countries in which review of energy technology and R&D is given high priority, *e.g.*:

- countries in which energy technology R&D is on the forefront at international level, *e.g.* in terms of size of budget, key technologies, key policies;
- countries that have chosen a thematic review where R&D is one of the themes.

Key R&D resources available for the review team:

- Country submission on energy technology R&D
- CERT presentation from national technology R&D
- R&D priority issues identified by CERT
- IEA statistics on energy R&D
- R&D material collected by the Country Desk Officer in the briefing package
- Other relevant material provided by the country being reviewed
- Energy technology R&D Expertise Support from the Secretariat

4. R&D STRATEGY

Energy R&D is an important policy instrument to meet national energy policy objectives. Given the stringent budgetary conditions for government energy R&D programmes in many member countries, a coherent energy R&D strategy with clear prioritisation in line with national energy policy goals is essential. Transparency and involvement of major stakeholders in defining a national energy R&D strategy is of key importance.

An energy R&D strategy is not about "picking the winner" – a portfolio of technologies will be needed. There is no single technology – no «silver bullet» – that will solve all challenges for a clean, clever and competitive future.

R&D policy to support national policy objectives

The existence of a clear national energy policy is the most important precondition to formulate a stringent and target-oriented public energy R&D strategy. Even though the main goals for energy policy - like energy security, economic efficiency and emission reductions - are evident in most IEA member countries, the technologies and resources differ from country to country. As energy R&D is an instrument to achieve policy targets, a clear link between energy policy and energy R&D and other relevant policy areas (*e.g.* research, innovation, education and industrial policies) should be established in order to maximise efficiency of energy R&D.

Clear national energy R&D priorities should be documented and effectively communicated to key stakeholders in energy and research sectors. This is best done with development of a national energy R&D strategy with background documentation. Energy R&D strategy targets should be clear and quantified and preferably be categorised by short-, medium- and long-term objectives. A good example is illustrated below where long-term visions, scenarios and involvement of stakeholders have been important tools to develop a national R&D strategy on hydrogen.

Good example: Coherent R&D Planning using several tools and clearly communicating links with national priorities and basic science – Hydrogen Program example in United States. Detailed analysis and well described plans increase chances for effective R&D in support of national energy priorities.

Source: Marlay, 2006.

Government leadership in development of new energy technologies is possible with relatively low investments. Given a supportive policy framework, relatively small government investments in R&D can:

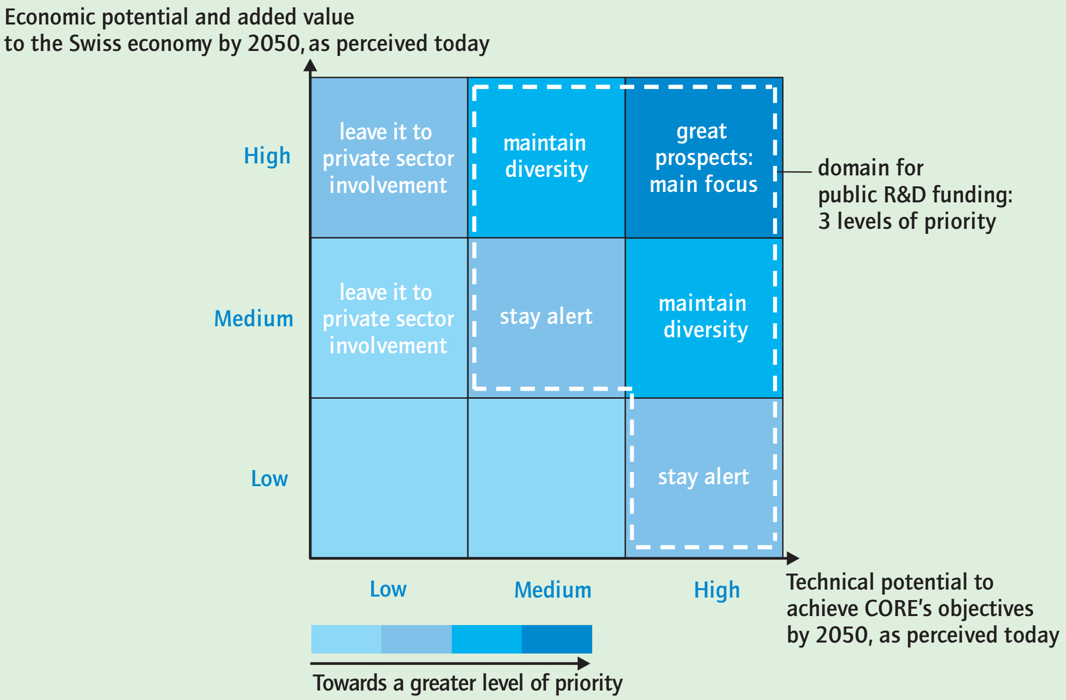
- signal government interest in broad policy goals;
- provide early leadership into technology frontiers;
- attract interest from potential participants;
- encourage private investment with early success;
- alter the course of technology development;
- result in strong public benefits over time.

Government R&D investment is usually targeted on areas with high-risk and long-term perspectives, whereas the private sector investment is targeted on the pre-competitive, short-term demonstration and commercialisation of energy technologies (see Figure 2).

Below is a good example of clear definition of areas in which government will provide support for R&D, and areas which are left to the private sector:

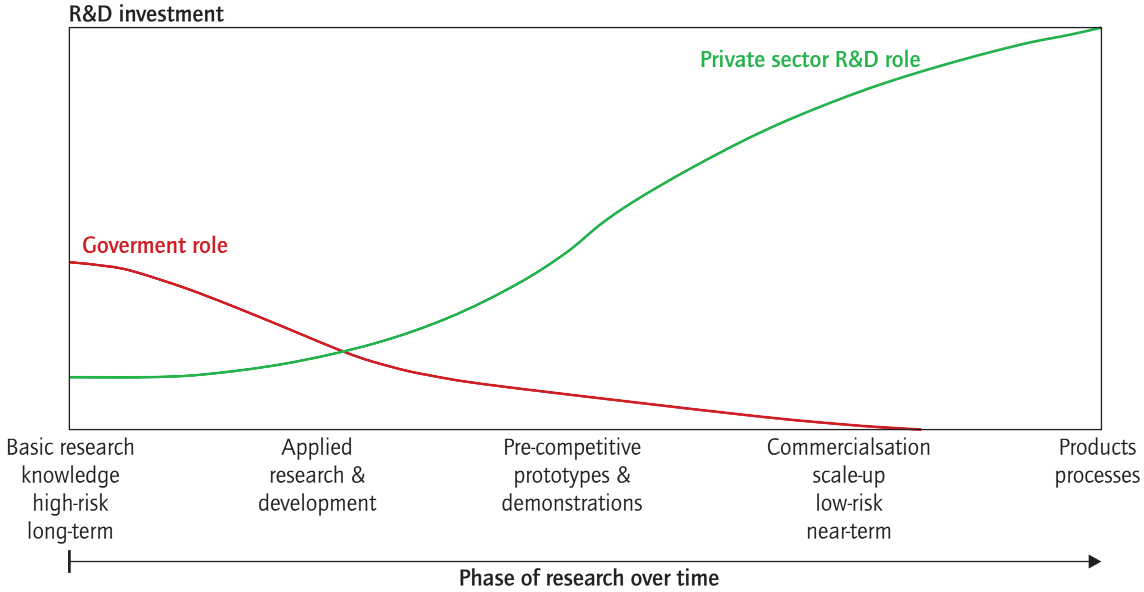
Good example: The matrix below is used to define the role of government-funded R&D in Switzerland. It is based on a long-term vision for development of the energy system and technology assessment. Three roles for government funding are identified:

- **Stay alert**
- **Maintain diversity, and**
- **Great prospectus – main focus**



Source: Gut, 2006.

Figure 2. ***Illustration of government and private sector R&D role in phases of research over time***



Another example of defining and communicating the strategic role of government funding in energy R&D is the Australian approach described in the box below.

Good example: The Energy Technology Assessment in the Australian White Paper 2004 takes a strategic approach and provides a guide to energy R&D innovation priority setting, recognising that Australia's relatively small size means that it cannot be a leader in all fields of technology, but must carefully consider its unique needs and capacities. The government assessed a broad range of energy-related technologies in this context. Accordingly, the White Paper has categorised energy technology into three broad fields – Market leader, Fast follower and Reserve – as outlined below.

Market leader	Fast follower	Reserve
Play a leading role in international R&D efforts	Strongly position Australia to follow international developments quickly	Position Australia to monitor international developments and follow as needed
Energy supply technologies		
Advanced brown coal Geosequestration Hot dry rocks Photovoltaic Remote area power systems Coal mining and extraction	Advanced black coal Natural gas Wind Biomass Wave Solar thermal	Hydrogen Tidal Large-scale hydro Nuclear
Energy demand technologies		
Solid oxide fuel cells	Intelligent transport systems Energy efficiency Advanced conventional vehicles Hybrid electric vehicles	Other fuel cells

Source: Securing Australia's Energy Future (The White Paper), 2004.

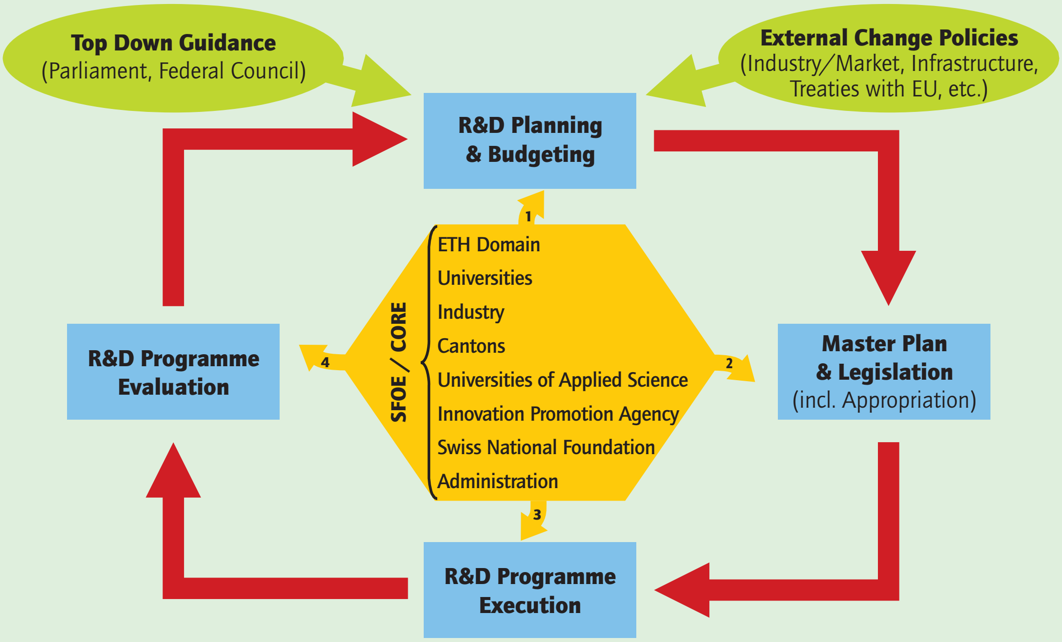
Long-term commitment and R&D portfolio management: the need to adapt and modify R&D programmes

When reviewing R&D programmes, it is important to recognise the significant changes in policy and other challenges that energy R&D programmes face. During the last decades there have been changes in: technological possibilities; expectations about energy supply, prices, and security; goals of energy administrations; national and international political environment; and the feasibility and accomplishments of various technological approaches and R&D performers.

A balanced R&D portfolio is particularly important since individual R&D projects may well fail to achieve their goals. Rather than viewing the failure of individual R&D projects as symptoms of overall programme failure, policy makers should recognise that project failures may generate considerable knowledge and that a well-designed R&D programme will inevitably include some failures. An R&D programme with no failures in individual research projects is pursuing an overly conservative portfolio.

The figure below illustrates an ongoing process that involves key stakeholders in defining a coherent national energy R&D strategy. Involvement of key energy R&D stakeholders in all aspects of energy R&D policy - strategic planning, priority setting implementation, and evaluation of programmes – is likely to increase chances for coherence and well-founded priorities.

Good example: Involvement of stakeholders in developing and using long-term visions for a coherent energy R&D Strategy in Switzerland.



A vision of a 2000 Watt Society

This vision serves as a long-term aim to direct R&D activities and the Swiss climate change strategy. "2000 Watt Society" is seeking to bring about the gradual introduction of a way of living and working that requires only one-third of current energy consumption but still delivers an improved quality of life. Using a phased approach, it will use the latest efficient technology and draw on experience from the world of economics, social sciences and politics."

Source: Gut, 2006.

List of questions for the review

Standard questions regarding national energy R&D strategy that could be applied during in-depth reviews are:

How is public energy R&D strategy developed?

- Which ministries are responsible for strategies and funding of energy R&D?
- How is coherence ensured?
- What is the role of the ministry in charge of energy?

Does the national energy policy include:

- Long-term vision of the role for new and advanced technology?
- Assessment of the potential contributions from technology?
- Strategy for technology development?
- Description of current priorities, on-going activities?
- Description of promising directions for future research?

- What are the national research objectives?
(Examples: strengthening the national research enterprise; supporting education and creating a technical trained workforce)
- What are the energy R&D objectives?
Short term (up to 5 years)?
Medium term (between 5 to 15 years)?
Long term (longer than 15 years)?
- How are R&D strategies developed? How are stakeholders of energy R&D (*e.g.* national and regional governments, universities, industry, research organisations) involved in the process of strategy development?
- What is the relationship between energy R&D objectives and national energy policy?
- What is the relationship between energy R&D objectives and national research objectives?
- Does the energy R&D portfolio support energy diversification/energy security? Give examples.
- Does the energy R&D portfolio support climate change mitigation? Give examples.
- Is there a comprehensive document that outlines future energy goals?
- How can energy R&D policy contribute to reach these goals?
- What – if any – are the major changes in energy R&D policy since the last IDR? How did the country respond to the recommendations of the last IDR?
- What is the role of public/private partnership – give examples of effective cooperation?

5. R&D PRIORITY SETTING

R&D priority setting is a process to help governments optimise national investments in R&D. There is no single methodology. Several tools can be applied in this process dependent on national circumstances such as energy policy goals, national energy technologies and national stakeholders.

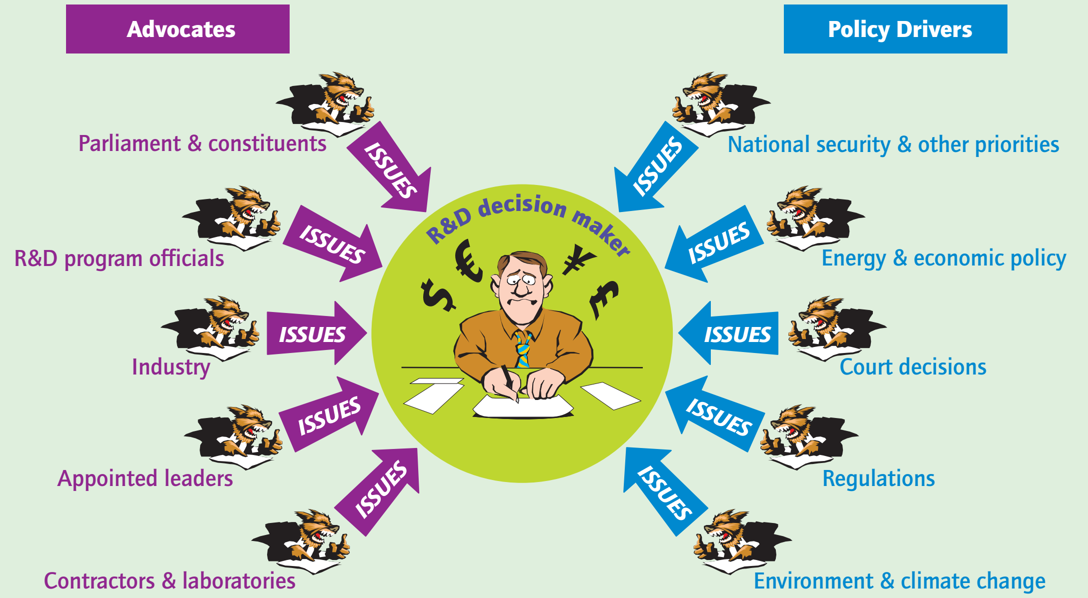
R&D priority setting is an ongoing process

As discussed in the previous chapter, R&D priorities should ideally support national energy policy goals and hence be closely related to overriding priorities and policies, *e.g.* environmental policies, national resources and general R&D strategy. A systematic process of priority setting to selecting projects and programmes has been found to be highly effective in many IEA member countries.

Priority setting involves the development of a consistent framework to compare the various technologies over a range of time frames and policy scenarios, with respect to their expected benefits and costs. This process of priority setting is most commonly based on an explicit or implicit vision of the long-term energy future, *e.g.* scenarios or visions.

A systematic process for priority setting for energy R&D programmes also involves engaging and communicating with stakeholders and a wider public. To the extent that procedures for prioritising and selecting are well described and transparent, a structured approach (methodology) to priority setting can increase acceptance for the outcome of the process by generating legitimacy in a process that involves conflicting interests.

Context for R&D priority setting



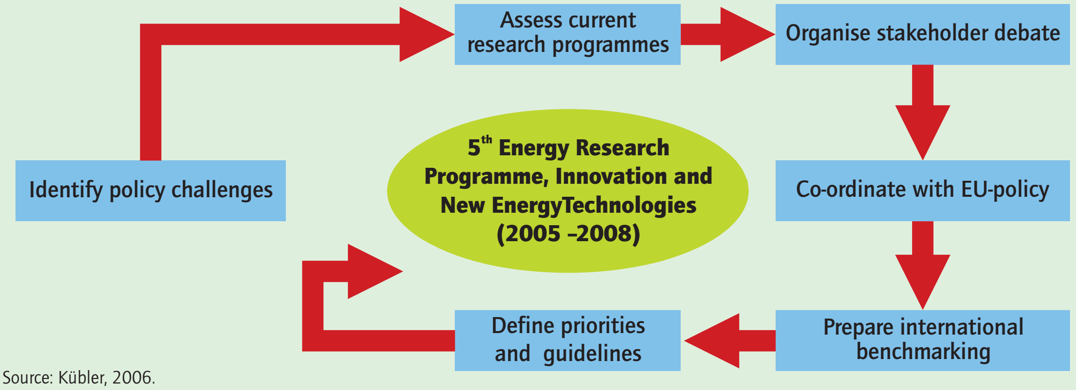
The figure illustrates the highly complex factors that influence R&D priority setting. Not all expectations can be met by the decision maker, yet they could not be done by computerised models.[2]

2. Adapted from illustration presented by Robert Marlay at the October 2005 workshop on R&D Priority Setting convened in Paris by the IEA Expert Group on R&D Priority Setting and Evaluation.

Priority setting is a continuous process. As national policies and strategic goals for technology development evolve, there is a recurring need for governments to review the R&D priorities and related investment portfolios. It is similarly necessary to continuously review and assess R&D programmes with respect to their potential roles and contributions to specific goals.

Below is illustrated the German process of developing a coherent national R&D programme involving different stakeholders in the process.

Good example: Six steps to develop the German Energy Research Programme



Source: Kübler, 2006.

Stability and long term horizons are key in obtaining results from public R&D investments. But the ability to adapt R&D programmes to change is just as important. Government funded technology R&D works over long time horizons, which result in many changes in the context in which the technology R&D priority setting systems must work, *e.g.*:

- changing governments and national priorities;
- research direction;
- modes of R&D management;
- "roller coaster" budgets;
- technology partnering and intellectual property;
- increased use of public R&D as policy tool.

Recent trends in IEA countries demonstrate that:

- large-scale demonstrations of energy technologies tend to be viewed sceptically;
- technology development projects are partnerships
  industry, academia, national laboratories, research institutions, consortia of R&D performers;
- extensive use of collaborative R&D planning and "technology road mapping" should include all stakeholders.

Advantages of clear public investment criteria for energy R&D

The combination of limited resources and a multitude of opportunities requires careful attention to funding priorities by R&D programmes. New programmes must demonstrate importance, consistency with national priorities, and likelihood of success. Existing programmes also need to be re-evaluated, modified, redirected or terminated, in keeping with energy policy needs and priorities. Ideally, energy R&D agencies should fund new, high-priority activities by reallocating resources from lower-priority or completed activities. However, the need to build and then maintain high-quality research teams must also be considered.

This calls for an R&D priority setting system which is flexible and can adjust to changing needs and opportunities. One way of ensuring this is through the development of explicit R&D investment criteria for government R&D. The use of clearly defined R&D investment criteria has several potential benefits, as it:

- allows policy makers to make decisions about programmes based on information beyond anecdotes, prior-year funding levels, and lobbying of special interests;
- improves the process for selecting, planning, and managing R&D programmes by increasing the productivity of the national R&D portfolio and the return on taxpayer investment;
- communicates government's expectations for proper programme management;
- sets standards for information to be provided in programme plans and budget justifications;
- improves public understanding of the possible benefits and effectiveness of the public investment in R&D.

However, it must be underlined that abrupt changes in priorities can be counterproductive. To achieve maximum results from articular technologies may require long time frames (*e.g.* fusion).

No single tool or methodology

There is no single tool or methodology to be used by governments for the priority setting process. However, the process often involves.

- Scenarios;
- Technology assessments;
- Road mapping.

Below are three examples from the European Commission, Japan and the United States.

Good example: A suite of quantitative and qualitative tools to support R&D priority setting within the European Framework Programme. Each tool has specific advantages and limitations in the priority setting exercise.

Quantitative tools

- World energy model: POLES
- European energy model: PRIMES
- European general equilibrium model: GEM-E3
- European econometric model: NEMESIS
- World and European optimization model: MARKAL (ETSAP)
- Analytical framework for RES: SAFIRE / GREEN-X
- Back-casting approach: VLEEM
- External costs accounting system: EXTERNE

Qualitative tools

- Delphi method for energy technologies (2030)
- Technology foresights
- Public opinion perception (Eurobarometer)
- Energy technology indicators
- **Participatory methods**
- **Experts networks (*e.g.* HLG-competitiveness, Energy Environment, AGE)**

Source: Perez-Sainz, 2006.

Good example: Technology Roadmap Development in Japan.

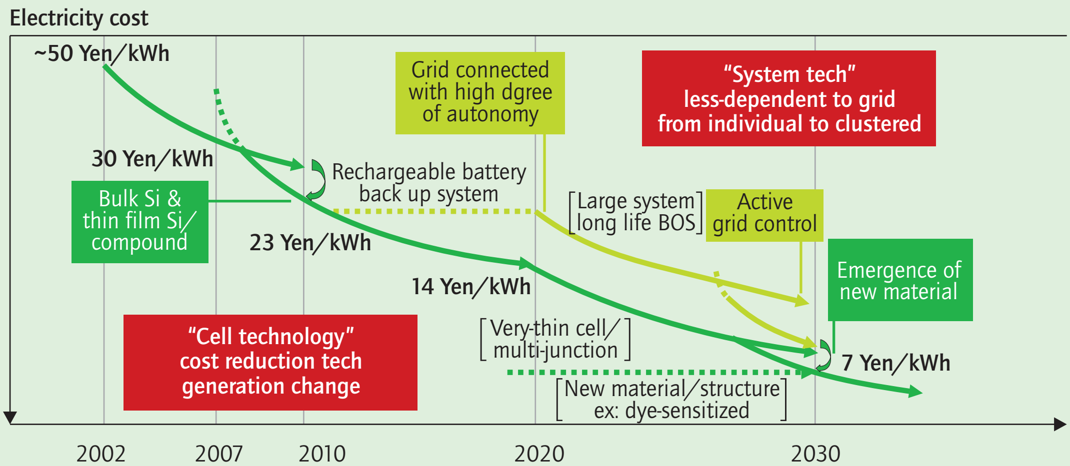
Objective of Technology Roadmap

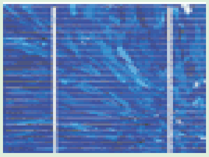
- Establish the basis for effective government R&D management
- Ensure PDCA cycle
- Serve as a communication tool for those who are engaged in R&D
- Share the long-term technology perspective with private sector
- Contribute to accountability

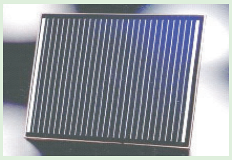
Activities and outcomes

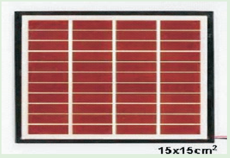
- Extract technology/technological challenges to meet policy targets
- Set technology spec/milestones and lay down road map toward 2030
- Clarify related policies for smooth commercialisation
- Undertake annual rolling process

Example of Technology Roadmap for Solar Power:









Source: Akai, 2007.

Good example: Overview of technologies and technology developments expected near-term, mid-term and long-term as the basis for identification of RD&D portfolio priorities.

US Climate Change Technology Programme

	Near-term	Mid-term	Long-term
Goal #1 Energy End-Use & Infrastructure	■ Hybrid & plug-in hybrid electric vehicles ■ Engineered urban designs ■ High-performance integrated homes ■ High efficiency appliances ■ High efficiency boilers & combustion systems ■ High-temperature superconductivity demonstrations	■ Fuel cell vehicles & H_2 fuels ■ Low emission aircraft ■ Solid-state lighting ■ Ultra-efficient HVACR ■ "Smart"buildings ■ Transformational technologies for energy-intensive industries ■ Energy storage for load leveling	■ Widespread use of engineered urban designs & regional planning ■ Energy managed communities ■ Integration of industrial heat, power, process & techniques ■ Superconducting transmission & equipment
Goal #2 Energy Supply	■ IGCC commercialisation ■ Stationary H_2 fuel cells ■ Cost-competitive solar PV ■ Demonstrations of cellulosic ethanol ■ Distributed electric generation ■ Advanced fission reactor & fuel Cycle Technology	■ FutureGen scale-up ■ H_2 co-production from coal/biomass ■ Low wind speed turbines ■ Advanced biorefineries ■ Community-scale solar ■ Gen IV nuclear plants ■ Fusion pilot plant demonstration	■ Zero-emission fossil energy ■ H_2 & electric economy ■ Widespread renewable energy ■ Bio-inspired energy & fuels ■ Widespread nuclear power ■ Fusion power plants
Goal #3 Capture, Storage & Sequestration	■ CSLF & CSRP ■ Post combustion capture ■ Oxy-fuel combustion ■ Enhanced hydrocarbon recovery ■ Geologic reservoir characterisation ■ Soils conservation ■ Dilution of direct injected CO_2	■ Geologic storage proven safe ■ CO_2 Transport infrastructure ■ Soils uptake & land use ■ Ocean CO_2 biological impacts addressed	■ Track record of successful CO_2 storage experience ■ Large-scale sequestration ■ Carbon & CO_2 based products & materials ■ Safe long-term ocean storage
Goal #4 Other Gases	■ Methane to markets ■ Precision agriculture ■ Advanced refrigeration technologies ■ PM control technologies for vehicles	■ Advanced landfill gas utilization ■ Soil microbial processes ■ Substitutes for SF_6 ■ Catalysts that reduce N_2O to elemental nitrogen in diesel engines	■ Integrated waste management system with automated sorting, processing & recycle ■ Zero-emission agriculture ■ Solid-state refrigeration/AC systems
Goal #5 Measure & Monitor	■ Low-cost sensors & communications	■ Large scale, secure data storage system ■ Direct measurement to replace proxies & estimators	■ Fully operational integrated MM systems architecture (sensors, indicators, data visualisation & storage, models)

Source: DOE, 2006.

List of questions for the review

Standard questions regarding R&D priority setting that could be applied during in-depth reviews are:

- How is energy R&D planning and coordination accomplished in your country? Is it supported by analyses including modelling? Is there a defined priority setting process?
- Is the process of priority setting primarily based on a bottom-up or a top-down approach?
- How are energy R&D priorities decided? How are stakeholders of energy R&D (*e.g.* national and regional governments, universities, industry, and research organisations) involved in the process of priority setting?
- Is there a specific energy R&D programme that reflects the priorities in your country? Give details about the R&D programme.
- Is there documentation for the process of setting energy R&D priorities? Please cite the website or publication.

6. R&D FUNDING

Funding of RD&D is critical to ensure development of energy technologies to solve mid- and longer term energy policy challenges. R&D statistics are an important tool to track R&D priorities and policies. R&D funding data is essential for designing new technology development policies.

Public R&D has fallen significantly in recent decades in IEA countries. Indications are that private sector R&D is also falling. The trend in R&D funding is a key indicator to discuss with member countries.

Declining public energy R&D budgets in IEA member countries

Energy technologies are expected to make a substantial contribution to mid- to long-term objectives of energy policy, namely, energy security, environmental protection and economic growth. The role of government energy R&D budgets is becoming more critical given that R&D activities in the private energy sector may be reduced as a result of competitive pressure under energy market liberalisation.

R&D statistics have proved to be valuable indicators of national energy policy and of technological change. R&D statistics are now an essential background element in many government programmes and provide an important tool for evaluating them.

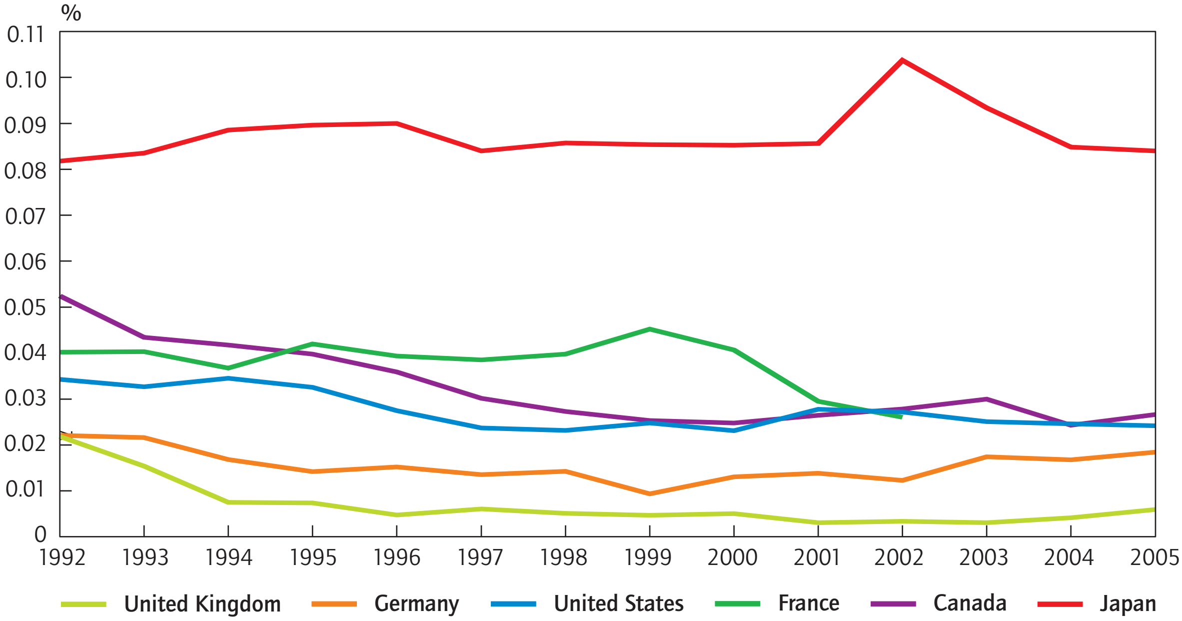
Government's energy budgets for energy R&D

Despite these critical roles, government energy R&D budgets in many member countries were reduced between the early 1980s and the 1990s. Total government expenditure of IEA member countries on energy R&D decreased from some USD 9.6 billion at 2005 prices in 1992 to USD 8.6 billion in 1998. This decline represents a continuation, albeit less dramatic, of the trend already established in the 1980s and is largely associated with the difficulties of the nuclear industry and, since 1985, with the decrease in oil prices. From 1998 the government expenditures have slightly recovered.

The development of energy R&D budgets as percentage of GDP for selected countries is illustrated in Figure 3 below. Only Japan has maintained a relatively high ratio, whereas the R&D budget relative to GDP has declined in the United States, Canada and in particular in several European countries. In Japan, the energy R&D represented 0.08% of GDP in 2005 but in most other IEA member countries it was below 0.03%. Most European IEA member countries have signed up to the Barcelona goal to increase total public and private research and development budgets to 3% of GDP by 2010.[3] There is a strong case that R&D budgets need to be re-built and sustained if governments are to achieve the objectives that they are setting for energy sustainability.

3. At the summit in Barcelona in 2002 the European Council set the goal of raising overall research investment in the EU from 1.9% of GDP to 3% by 2010.

Figure 3. *Nominal energy R&D budget as a percentage of nominal GDP for selected countries*



Source: IEA, 2007.

Government R&D budgets for individual energy technologies

Nuclear technologies still remain at the core of public R&D spending in some of the largest IEA member countries. But the relative share of nuclear technologies has decreased between 1992 and 2005. Government expenditure for fossil fuel research experienced the largest drop in share over the same period. Government budgets increased slightly for renewable energy and energy conservation, and grew significantly for hydrogen and fuel cells, for power and storage technologies, and for other technologies and research areas. Two countries (Japan and the United States) account for more than 70% of total R&D government budgets in IEA countries.

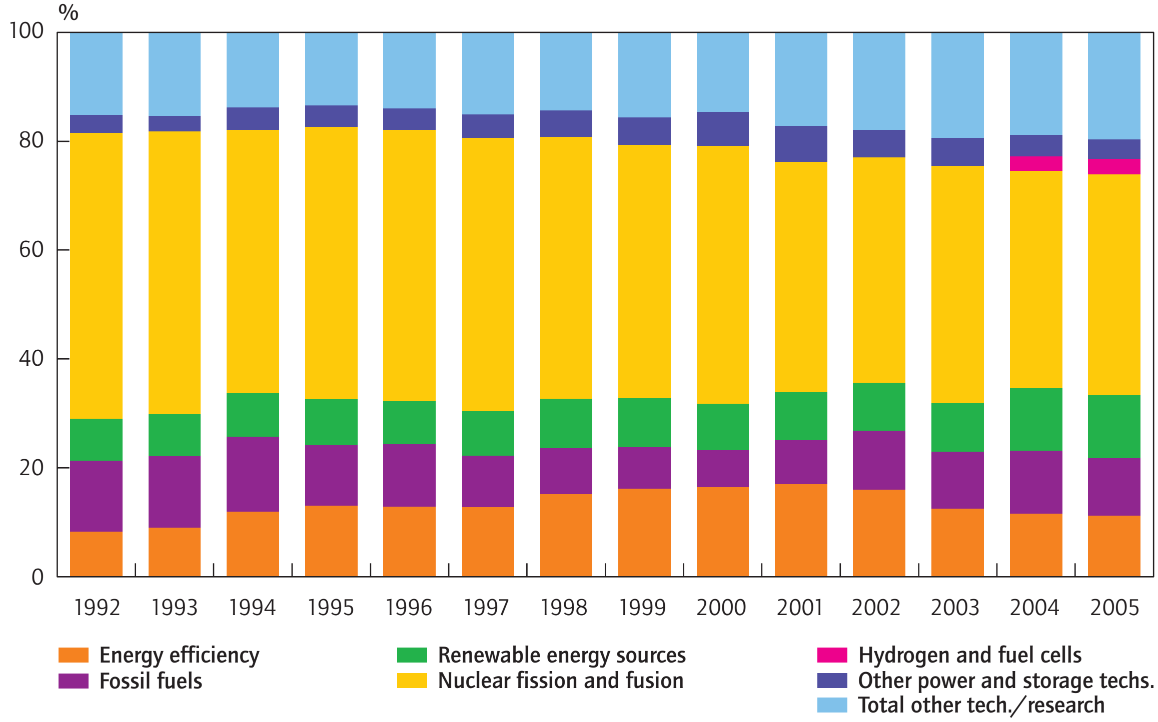
Private sector energy technology R&D

It is increasingly important to involve the private sector in R&D activities to accelerate technology development.

Very little information is publicly available on private industry R&D budgets for energy technologies. There is evidence that, following market liberalisation, many electric utilities have reduced their involvement in R&D. Research within the private energy technology industry, on the other hand, may still be important, but only in the most visionary cases does it look beyond a short-term horizon. In fact, as industry has increasingly focused on shorter-term R&D, government collaboration with industry has had the effect of shifting some government funding away from longer-term R&D and of focusing funds on the stage immediately before commercialisation.

Some member governments have encouraged private R&D spending through fiscal incentives (tax breaks, etc.), but these measures are not likely to induce a major shift towards longer-term research in industry. Although government energy R&D budgets have recently increased in the United States – and to a lesser extent in Europe – concerns remain as to whether insufficient resources have been allocated for medium- and long-term options to meet longer term energy policy objectives.

Figure 4. ***Government energy R&D budgets in IEA countries: technology shares***



Source: IEA, 2007.

Data on energy R&D funding

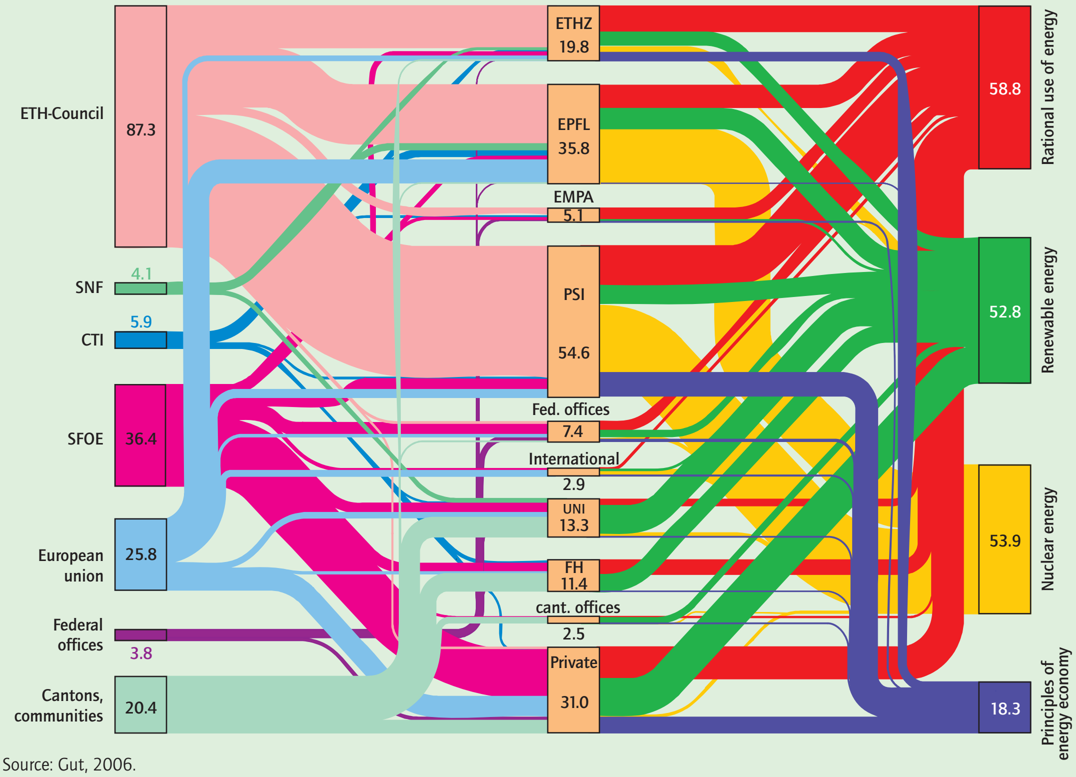
The actual funding of energy R&D is of high interest within IEA member countries. By comparing budgets in absolute and relative terms it shows the importance of a country's energy R&D as well as its competences. Data on energy R&D funding not only reveals current priorities but also the development of energy R&D over time. It also offers information on experiences with different approaches in energy R&D funding (*i.e.* general funds versus targeted R&D programmes).

Energy R&D funding cycles in the last 30 years for energy R&D in many IEA member countries closely mirrored geopolitical energy trends (oil prices and supply shortages primarily). To counter this phenomenon, effective R&D support for energy technologies should include a portfolio mix of both high risk (revolutionary) and lower risk (evolutionary) projects.

Funding schemes and the distribution of R&D budgets within the country under review are important as well as information about the distribution of budgets along basic science, research, development and demonstration.

The diagram below gives an excellent overview of the distribution of funds in the national R&D system in Switzerland. Examining the flow of R&D funding is a prerequisite for discussing and evaluating whether funding matches overall strategy and priorities, for the government and for the reviewer.

Good example: Funding sources, research institutions and technologies supported in Switzerland



Source: Gut, 2006.

List of questions for the review

Standard questions regarding energy R&D funding that could be applied during in-depth reviews are:

- What arrangements are in place to ensure an overview of the government's funding of energy R&D?
- What is the current status of government funding for energy R&D? Please present the breakdown based on the categories below and indicate if further information is available, *e.g.* reports, brochures, links.
  - a) Energy efficiency in industry, residential, commercial and transport sectors
  - b) Oil and gas
  - c) Coal
  - d) CO_2 capture and storage
  - e) Renewable energy sources
  - f) Nuclear fission
  - g) Nuclear fusion
  - h) Hydrogen and fuel cells
  - i) Other power and storage technologies
  - j) Other cross-cutting technologies or research, including R&D on energy system analysis and forecasting

- What is the funding of energy RD&D of different government ministries and institutions?
- What is the current level of RD&D funding from private sector – if possible split by technology?
- What is the current level of other public funding (regional, state level) of energy RD&D – if possible split by technology?
- Does the level and focus of R&D funding match up to the aims that the government is setting for the deployment of advanced energy technology?
- What is the present level of funding for basic science related to energy technology development?
- What is the future expected trend for energy RD&D funding?
- What is the level of funding of energy RD&D activities within international collaborative projects (bilaterals, multilaterals, EU-programmes, IEA Implementing Agreements)?

If these overviews are not available, discuss why they are not available and how coherence and added value is ensured. Discuss how lack of data influences R&D policy priority setting and evaluation opportunities.

7. R&D MONITORING AND EVALUATION

In addition to proper prioritisation, effective monitoring and evaluation of the performance of government-funded energy R&D are also crucial to maximise the cost-effectiveness of the R&D programme. New programmes must be justified demonstrating importance, consistency with national priorities, and likelihood of success. Existing programmes also need to be re-evaluated, modified, redirected or terminated, in keeping with energy policy needs and priorities.

Aiming for higher efficacy: the need for evaluation

When short of funds, governments tend to ask whether and how the efficiency of research can be increased. Within the last decade, evaluation of energy R&D has become standard practice in many IEA member countries. Due to low energy prices and an increased need to justify R&D budgets, the need for ex-post as well as ex-ante evaluation is on the rise.

The process and methodologies used should be evaluated against the major achievements of energy R&D. Methods for evaluation are diverse and include self-evaluation by programme managers or programme owners as well as evaluations by external experts. Most evaluations use statistical data and interviews with stakeholders to get a comprehensive view and to develop recommendations for future activities in energy R&D. Evaluation methods can be categorised as:

- continuum of Review Processes
  - pre-award
  - in-progress
  - post-award
- feedback
- independent reviews

One example of an ongoing evaluation process is the U.S. Program Assessment Rating Tool, or PART (described below).

Good example: The Program Assessment Rating Tool (PART)

PART has been tailored to monitor and assess US R&D programmes across agencies. These agencies use the criteria as broad guidelines that apply at all levels of federally funded R&D efforts, and use the PART as the instrument to periodically evaluate fulfillment of the criteria at the programme level. The R&D criteria have benefited from years of working with agencies, other stakeholders, and experts in assessment, to build on the best of existing R&D planning and assessment practices. The PART focuses on:

- **Programme purpose and design (20%)**
- **Strategic planning (10%)**
- **Programme management (20%)**
- **Programme results and accountability (50%)**

An example of independent reviews is found in Austria, where foreign experts evaluate energy R&D programmes (see below).

Good example: Independent evaluation by international experts of the Austrian energy R&D-concept.

In developing the Austrian Energy R&D-concept, a Swiss R&D policy expert – and chair of the CERT Expert Group on R&D Priority Setting and Evaluation - was invited to support the process as head of evaluators. This involvement helped to take into account new approaches and to question traditional priorities against the background of international developments.

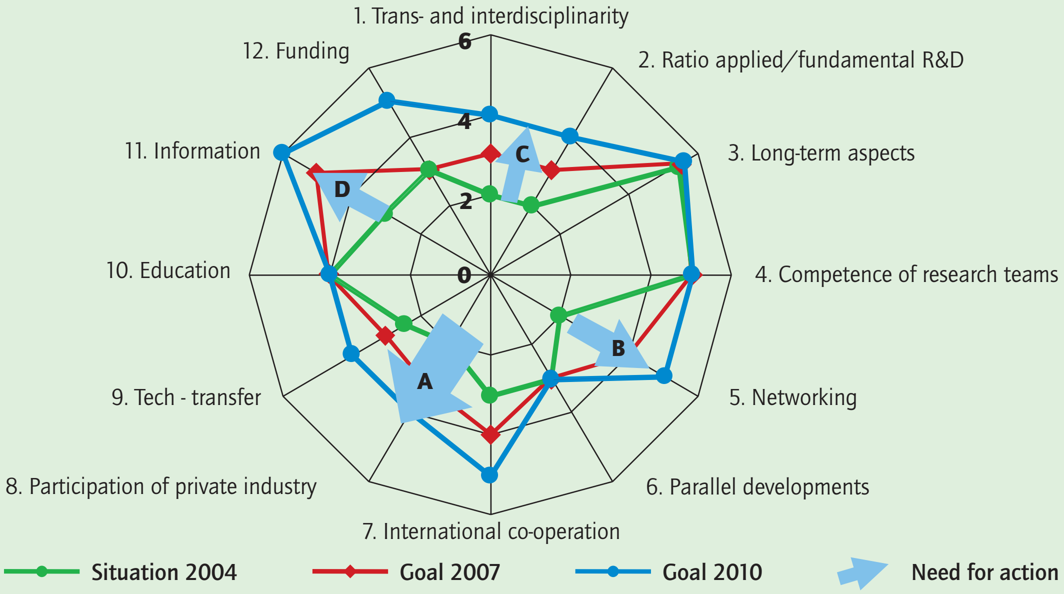
Based on this experience within the Austrian Programme on Technologies for Sustainable Development, all sub-programmes are now evaluated by international experts from Germany, Switzerland and the Netherlands as head of the evaluation team.

Foreign experts constitute at least one-third of the members of all evaluation panels.

Source: Greisberger, 2006.

Below is an example from Switzerland of support for evaluation of R&D programmes using the spidogram methodology. The spidogram provides an effective way to communicate and visualise profiles of different technologies. The important issue is to define parameters (in this case 12) to be improved over the lifetime of the programme, and to identify where action is needed.

Good example: Evaluation of R&D programmes based on 12 criteria.
Tool to identify and communicate the need for further action. Switzerland.



Source: Gut, 2006.

Assessment of energy technology policy

Measuring the performance of energy technology innovation is not a simple task. Energy technology innovation systems are driven by multiple goals, and the relative importance of these goals may change over time. Furthermore, emerging technologies (*e.g.* hydrogen and fuel cells) may take decades to transition from research to commercialisation, making end-results uncertain and difficult to measure. In particular, if technological innovation is expected to produce substantial public benefits, measurement becomes even more complicated. Nonetheless, in order to make sound R&D investment decisions, tools are needed to assess the performance of technology innovation systems. One example of an assessment framework is described below.

Good Example: Assessment framework for evaluating costs and benefits of R&D programmes.

An assessment framework was developed by the Board on Energy and Environmental Systems of the U.S. National Academies to evaluate the costs and benefits, both quantitative and qualitative, of a number of energy technology R&D programmes (NAS, 2001). The framework is designed to capture public benefits that the private sector cannot reap, and some benefits that may be realised even when a technology does not enter the market place immediately or to a significant degree. The framework identifies three types of benefits to energy research, development and innovation:

- economic benefits
- environmental benefits
- energy security benefits

It further distinguishes among three levels of benefit, reflecting different degrees of uncertainty about the commercialisation of research results:

- realised benefits are those resulting from full development and commercialisation of an innovation and that are certain with favourable economic and policy conditions;
- options benefits are those that accrue from successful development of a technology, even if it has not been fully commercialised due to unfavourable economic and policy conditions although opportunities exist for its future deployment should circumstances change;
- knowledge benefits, which reflect advances in scientific, technological and other knowledge that may aid in further innovation efforts.

List of questions for the review

Standard questions regarding energy R&D monitoring and evaluation that could be applied during in-depth reviews are:

Process

- Is there a regular process of evaluation of energy research progress/activities/programmes? How often will it take place and at which stage, (ex-ante, midterm, ex-post)
- Does it address compliance with management rules?
- Does it aim at assessing compliance with objectives set or achievements?
- Does it try to evaluate wider impacts? (like contribution to competitiveness)

Methodology

- Are evaluations mainly quantitative (statistical) or qualitative (interviews, meetings)?
- Which are the assessment tools used? Are there assessment indicators used (indicators for outputs and/or outcomes, measurement of progress made against baseline or against verifiable or quantifiable objectives)?
- Who carries out the different stages of the evaluations (in-house, peer-review, domestic or international)?
- Impact on programme implementation and on programme shaping
- How is the evaluation process, at various levels, embedded in programme management?
- Has the evaluation process led/is expected to lead to major reshaping of national activities or strategies?

- Should or could the evaluation process be improved?

Best practices

- Is there an example of successful approach which you would like to mention in the context of evaluation? Please describe the main characteristics of this approach.
- What are the most important achievements in the field of energy R&D since the last IDR? Please focus on the R&D content.

8. INTERNATIONAL ENERGY R&D COLLABORATION

International co-operation, on both a multilateral and a bilateral basis, is an instrumental means to maximise the benefit of energy R&D. Within a context of increasing globalisation and shifts of emphasis away from national R&D, such international collaborative efforts promise better returns on R&D investment through the sharing among participants of financial outlay, workload and results.

With R&D spending levels still way below what is needed, international collaboration to get more synergies becomes even more important. It should be considered to always make a recommendation on this issue during in-depth reviews, as it is a core area of IEA collaboration.

Potential benefits of international collaboration

Enormous R&D investments are needed to address the significant global energy challenges of security of energy supply and reduction of greenhouse gas emissions, while maintaining economic growth calls for international collaboration on R&D. There are at least three general benefits for international collaboration on R&D:

- International collaboration can reduce the need to expend national public funds on technology R&D that is redundant with activities under way in other countries and that is not essential for national competitiveness.
- International collaboration can make use of specialised expertise that resides in one country to the benefit of all countries involved.
- International collaboration can strengthen technology deployment by combining different kinds of national comparative advantages, such as the science and technology strengths of an industrialised country with lower labour costs for manufacturing in a developing country.

International R&D collaboration already plays a key role in most IEA member countries. Some countries have developed procedures for establishing an overview and prioritising this engagement. Below is an example of the vital role of international collaboration for Switzerland and an example of how to monitor international collaboration.

Good example: By asking researchers if the research is done with international co-operation, the Bundesamt für Energie (Switzerland) quantified the share of international co-operation in energy selective fields of RD&D in Switzerland.

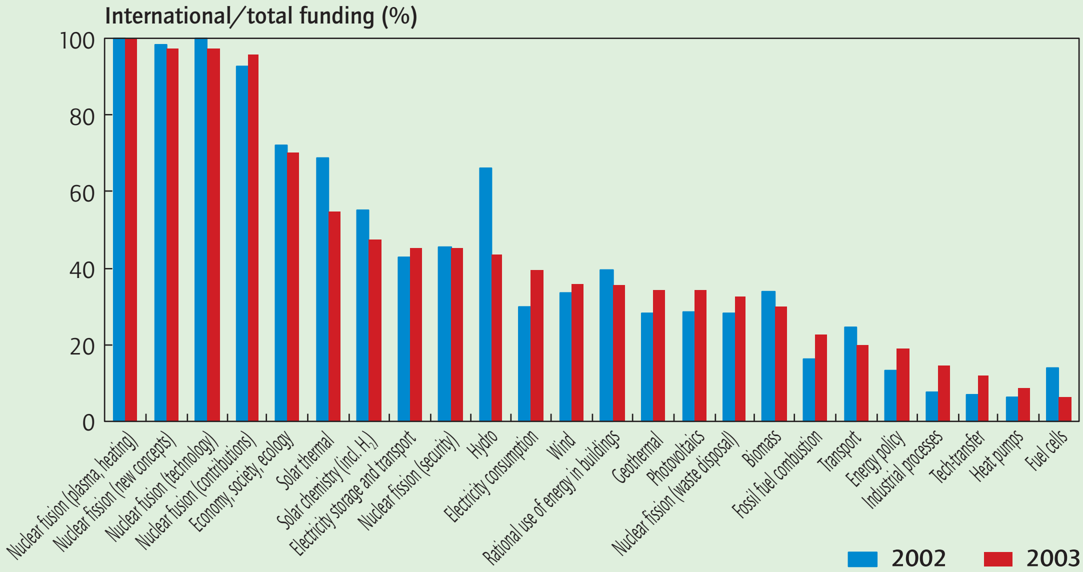


Figure: Public funding of projects with explicit direct international collaboration in relation to public funding of all projects in defined technology areas. As can be seen from the graph, international co-operation in Switzerland plays a vital role for nuclear-related and other long-term research, and plays an important role for many other areas, but less so for technologies nearing the commercialisation stages.

Source: Gut, 2006.

International co-operation already plays an important role for energy R&D but its contribution is difficult to quantify. Improved energy R&D statistics, as well as technological studies for specific areas, could help to formulate national energy R&D policy that incorporates international co-operation more proactively. Shown below is an example of prioritising international R&D collaboration as part of the national R&D priority setting process in the Netherlands.

Good example: Integrating national R&D priority setting and international R&D collaboration: Netherlands EOS.

Objectives:

- **Focus publicly funded energy research on a limited number of areas**
- **Optimise use of resources available**
- **Strengthen international co-operation**

Taking into consideration national strengths in knowledge and the contribution to a sustainable energy system, the Energy Research Policy Diagram has been developed to identify areas of high priority according to contribution to sustainable energy supply and the knowledge position. The matrix was also used to revise the Dutch engagement in international RD&D collaboration *e.g.* in the Implementing Agreements network. RD&D on technologies defined under "Key Priorities" and "R&D import themes" were subject to government support for international RD&D collaboration but with different objectives.

Source: Kool, 2006.

The EOS matrix

Examples of international technology collaboration

The International Energy Agency has a long history of facilitating international RD&D co-operation via its Implementing Agreements – see Annexe 5. There are numerous advantages in this scheme including:

- reduced cost and duplication of work
- greater project scale
- information sharing and networking
- linking IEA member countries and non-member countries
- linking research, industry and policy
- accelerated development and deployment
- harmonised technical standards
- strengthened national R&D capabilities

In addition, the IEA technology collaboration programme has a proven record of successful management that allows:

- flexibility
- intellectual property rights protection

An overview of participation in Implementing Agreements by individual countries can by found on www.iea.org by entering the "**By Country**" tab, clicking the individual country, and clicking "**all for this country**" under the headline "**Related Technology Agreements**". A snapshot of participation by country as of January 2007 is given in Annexe 8.

In addition to IEA Implementing Agreements, there are many other mechanisms by which IEA member countries seek and execute international co-operation in energy RD&D, including bilateral and multi-lateral agreements and activities via other international organisations. Below is an overview of types of R&D collaborative mechanisms used by IEA countries.

Bi-lateral Co-operation	International institutions
■ Bi-lateral Science and Technology Agreements	■ IEA - Implementing Agreements ■ OECD ■ UN ■ WMO ■ G8, G20
Multi-lateral co-operation	***Recent co-operation***
■ CSLF ■ IPHE ■ GEN IV ■ M2M ■ ITER	■ European Framework Programme ■ APEC ■ Nordic Energy Research

Examples of modi operandi of international energy technology collaboration in IEA countries

For European IEA member countries the collaboration through the European Commission Framework Programmes for R&D is of particular importance. An example of coordination amongst member states to create synergy and avoid duplication of work is the creation of ERA-nets. The example below describes the ERA-net on building technology programmes.

Good Example: ERA-net "ERABUILD"

ERA-net is a new instrument within the European Union aimed at better integration of national R&D programmes between member states. Within the ERABUILD program, owner and programme managers from eight countries are involved.

In addition to in-depth benchmark of national strategies, priorities, research goals and administrative procedures, the consortium aims to cluster expertise and to facilitate networking between researchers by joint workshops as well as other mechanisms. The consortium also tries to define common rules for Joint Calls for project R&D proposals and is organising pilots to learn from practical experience. The ultimate vision of ERABUILD is to open up national programmes and to accelerate technology development in the building sector.

Source: www.erabuild.net

List of questions for the review

Standard questions regarding international collaboration on energy R&D that could be applied during in-depth reviews are:

- **Is international collaboration on RD&D considered to be important?**
- **Is there a strategy for prioritising international RD&D collaboration vis à vis national RD&D?**
- **What types of international RD&D collaboration is your country participating in?**
  Which types of mechanisms?
  Which technologies?
- **What approaches exist for international co-operation in energy R&D?**
- **What topics and technologies are most relevant for international co-operation?**
- **What barriers exist for international co-operation in your country and are there attempts to overcome these barriers?**

9. LINKING BASIC SCIENCE AND ENERGY TECHNOLOGY R&D

Advances in basic science will be the foundation for progress on myriad energy technologies. Creating linkages between basic research and applied technology development will be crucial to ensuring the needed technology breakthroughs.

The need for energy technology breakthroughs: the need to link to basic science

The recent International Energy Agency publication *Energy Technology Perspectives: Scenarios & Strategies to 2050* described various pathways for achieving a clean energy future.[4] One of the key conclusions of the study was the need for urgent action to rapidly advance a portfolio of current - and breakthrough - technologies. The report urged policymakers, industry and academic institutions to expand budgets for research and development to advance scientific.

It is widely recognised that basic science research has the potential to help address society's energy challenges. Yet, there is a gap between the basic science and energy technology communities that hinders opportunities for collaboration, networking and accelerating scientific advances.

Policies to enhance the link with basic science

Basic research enables applied energy research and development (R&D) by providing a base of knowledge, skills and techniques for solving problems. However, there are a number of barriers preventing the linking of basic science and R&D. These include:

- **Different goals, incentives, and time horizons**. Basic science is concerned with advancing knowledge within disciplines broadly; applied energy R&D is substantially concerned with utility-producing devices, products and services that solve energy challenges.
- **Organisational issues**. Basic research and applied energy R&D functions are usually located in different organisational units, even within corporate and government energy R&D laboratories. This leads to different contact networks and peer groups, preventing opportunities for linkages.
- **Intellectual property issues**. Basic scientists and applied energy researchers relate to intellectual property rights (IPR) in different ways. Basic science tends to be very open in reporting results to the research community and communicating with peers. In contrast, as it approaches technology production, applied R&D becomes increasingly concerned with proprietary information and data related to the protection of IPR through patents, copyrights, and other mechanisms. These two approaches can sometimes be difficult to reconcile.

Establishing networks of basic science and energy R&D

Policymakers, private companies and researchers can point to many examples of successful collaboration between the basic science and applied energy R&D communities. Historically, linkages between basic science and applied R&D have been pursued in three ways:

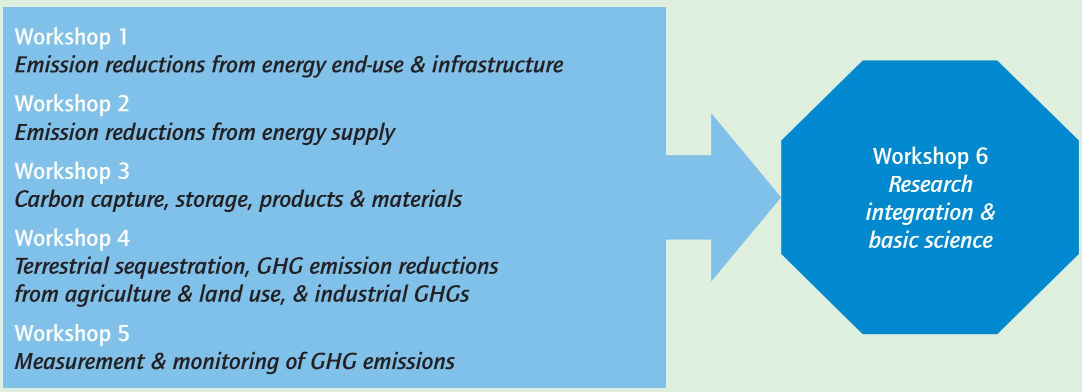
- "Mining" undirected basic research in key fields for useful findings.

4. International Energy Agency, "Energy Technology Perspectives: Scenarios & Strategies to 2050" (©OECD/IEA 2006).

- Shaping basic research agendas to address applied technology challenges.
- Increasing opportunities for interaction.

Below is an example of using portfolio analysis to identify gaps and R&D priorities including basic science. A series of workshops provided the basic science and the energy R&D community with an opportunity to meet and identify possible avenues for the breakthroughs. The example includes a structured methodology for the priority setting process.

Good example:
Portfolio analysis of Climate Change Technology Program

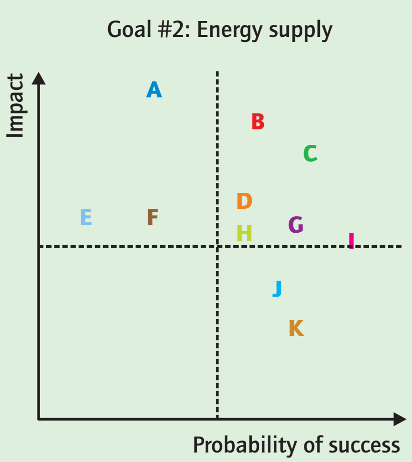


Experts participating in workshops using a structured methodology to be able for each CCTP Strategic Goal to:

- Assess Adequacy of the R&D Portfolio to Make Progress
- Identify Strengths, Weaknesses, Gaps & Opportunities
- Prioritize Gaps & Opportunities
- Make Selective Recommendations

Structured Methodology

1 = Identify portfolio gaps & opportunities; 2 = evaluate results (probability of success vs. impact, by time-frame); 3 = prioritise; 4 = add substance to key ideas

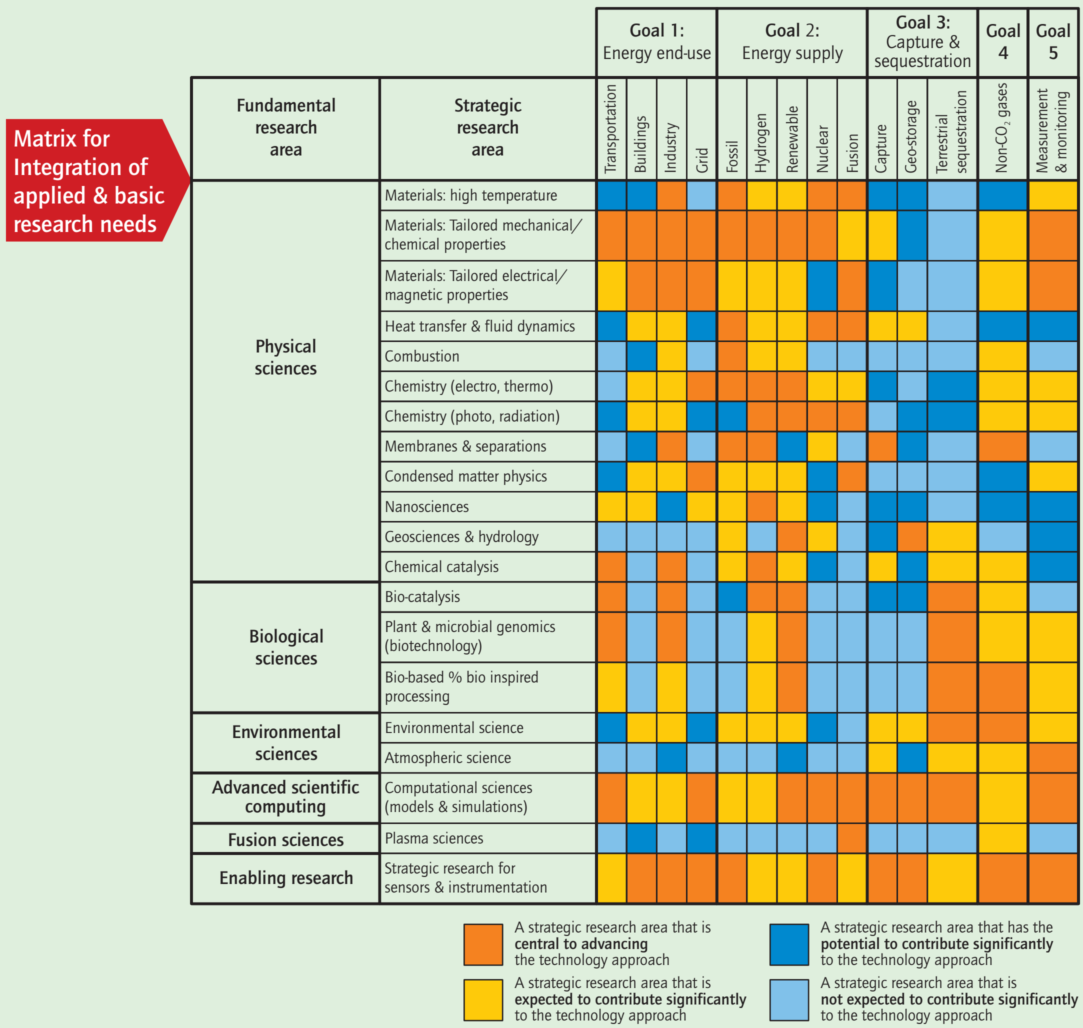


A	Artificial solar fuel photo-synthesis where you extract CO_2 from the atmosphere, using sun to reduce H_2O to H_2, then recycle carbon back to liquid fuel, use H_2 (long term)
B	Cheap energy storage to solve intermittency and other issues (chemical, solid state, thermal, H_2, etc.) (mid term)
C	Plug-in hybrid electric vehicles coupled with wind-discharge back to the grid – reduce intermittency (near term)
D	Nanotechnology for transmission and conversion of energy [mid term]
E	High altitude wind kite (turbine on kite, fly in stratosphere, energy extracted via cable) – takes advantage of higher intensity wind (long term)
F	Liquid photovoltaics (nano-structured liquids) homogeneous, detect-free liquids, maybe gels (long term)
G	Hi-temperature superconductive grid for electricity transmission in 2 directions (near term)
H	Nanotechnology for highly conducting superconductors and/or for generation, transmission, magnetic fusion
I	Integration of renewables with buildings –plug-in systems – vehicle plug-ins, thermo-electrics for certain spaces (near term)
J	Personalised power systems for home and work (something you wear).Personal-miniature space comfort systems (warming/cooling personal systems) (mid term)
K	Small-sized waste digestion (homes) for fuel/energy recovery – offset carbon from grid

Source: Marlay, 2006.

Below is another example of a tool used to identify strategic research priority links with basic science.

Good example: Matrix tool used to identify strategic research priorities, linking basic science in fundamental research areas with energy technology development needs. US Climate Change Technology Programme.



Source: DOE, 2006.

List of questions for the review

Standard questions regarding linking energy R&D with basic science that could be applied during in-depth reviews are:

- **How are government-funded energy technology research programmes designed to reflect and incorporate progress in basic science?**
- **How are government-funded basic science and energy RD&D programmes coordinated?**

ANNEXE 1. IEA SHARED GOALS

The 26 member countries of the International Energy Agency (IEA) seek to create the conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA member countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants.

In order to secure their objectives they aim to create a policy framework consistent with the following goals:

1. **Diversity, efficiency and flexibility within the energy sector** are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydro power, make a substantial contribution to the energy supply diversity of IEA member countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies**. In some cases this requires collective mechanisms and action: IEA member countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. **The environmentally sustainable provision and use of energy** is central to the achievement of these shared goals. Decision-makers should seek to minimise the adverse environmental impact of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should, where practicable, have regard to the Polluter Pays Principle.

4. **More environmentally acceptable energy sources** need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member coutries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. **Improved energy efficiency** can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. **Undistorted energy prices** enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent that it is necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. **Free and open trade** and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. **Co-operation among all energy market participants** helps to improve information and understanding, and encourage the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

The “Shared Goals” were adopted by IEA member country Ministers at their 4 June 1993 meeting in Paris.

ANNEXE 2. IEA IN-DEPTH REVIEW PROCEDURE

An indicative overview of the review cycle is shown in the table below:

Action	Timing in relation to team visit
Nomination of team members by SLT	Mid May
Selection of team members by SLT	Summer before (4-6 experts)
Country submission	2 months ahead of
Pre-visit by the country desk officer	1 month ahead of
Team visit	1 week to 10 day long visit
Drafting	2-3 months after
Presentation and discussion at SLT	5-6 months after
Publication and press conference	7-8 months after

Preparation for the team visit

The Secretariat keeps in close communication with the reviewed country and the team members to schedule and prepare the review. The Secretariat prepares briefing material, based on the information provided by the reviewed country and others, which is sent to the team members. For an efficient and productive discussion during team visit, team members are requested to study the possible issues for the reviewed country as fully as possible. Team members are encouraged to respond to the Secretariat proactively with their comments and suggestions to make the team visit fruitful.

Team visit

The team visit is a central event in the whole in-depth country review process. It usually takes a full working week. Following an internal meeting on Sunday evening, team visits usually start with meetings with the government. This is usually followed by a series of meetings with industry or other important organisations for energy policy. On the final day, the team presents its preliminary findings and recommendations and exchanges views with the government.

The team also holds several internal meetings in order to prepare the preliminary findings and recommendations to the reviewed government. For a successful team visit, it is essential that the team should have good discussions with the reviewed country as well as internally, to share a good understanding of the issues, the possible policy approaches, pros and cons of these approaches, necessary considerations, and so on.

Drafting the report

After the review visit, the country desk officer will prepare the draft, keeping contact with his/her counterparts in the reviewed country, and the team members as necessary, to ensure that the views of the team are adequately reflected in the draft. In some cases, country experts draft particular sections of the draft report. In this case, they will be required to submit their drafts within one month of the review visit so that the desk officer can incorporate them with other chapters in a cohesive manner.

When the desk officer finishes the first draft after consultation with the IEA Secretariat, he/she will circulate the draft to the team members for their comments. After incorporating the comments from team members, the draft will be sent to the reviewed country for their comments. Prior approval from the reviewed country will be sought as far as possible.

Discussion at SLT

The draft report is presented by the team leader at the SLT for discussion. Other team members are encouraged to join the meeting.

Publication of the report

The editing and printing process usually takes 3 to 4 months. A press conference may be held by a high level government representative together with the Executive Director of the IEA to release the report. The names of all team members will be listed in the published reports, as well as in the report entitled “Energy Policies of IEA Countries”.

Responsibilities of team members

Good preparation is one of the prerequisites of the review. Team members are encouraged to closely read the briefing package and be fully familiar with the reviewed country’s energy situation before the review visit.

It is the usual practice that each team member takes responsibility in certain areas (energy and environment, electricity, gas, energy efficiency, renewable, R&D, etc) according to his/her expertise. This “division of labour” is to be agreed at the kick-off meeting on Sunday. Each expert is expected to play an active role in “his/her areas” during the review visit through asking questions, gathering information and processing it into preliminary findings and recommendations.

Review team

Currently, the average size of the team is 7-8, composed of the team leader, two or three country experts, a Commission expert for EU countries, LTO Director or the Head of the Country Studies Division (CSD), country desk officer, another Secretariat staff (if necessary), a Nuclear Energy Agency (NEA) expert for countries with nuclear energy. In order to keep nature of the peer review, the majority of team members are supposed to come from member countries.

ANNEXE 3. R&D QUESTIONNAIRE FOR COUNTRY SUBMISSIONS

Below is section 11 from the "QUESTIONNAIRE FOR COUNTRY SUBMISSIONS FOR THE 2006/2007 SLT/CERT ANNUAL REVIEW OF ENERGY POLICIES" (IEA/SLT/CERT(2006)1) which includes the questions on Research, Development and Demonstration for country submissions to the in-depth review.

The country submission is available for the review team before the review visit.

11. RESEARCH, DEVELOPMENT AND DEMONSTRATION

a. Energy R&D Policy

- What are the energy R&D policy objectives? How are they related to national overall energy policy objectives and national research objectives? In particular, what is the status of energy R&D for energy diversification and climate change mitigation?
- What are the energy R&D priorities? How are they decided? How are long-term and short-term issues covered? What is the role of basic research and applied research?
- Who are the stakeholders of energy R&D (*e.g.* national and regional governments, universities, industry, research organisations)? How do they interact (*e.g.* public-private partnership, co-ordination among related institutions) under energy R&D policy formulation, implementation and evaluation procedure?
- What is the current status of funding (both in public and private sectors) and other government support including financial and tax incentives or regulatory measures for energy R&D? Please present the breakdown based on the categories (a) – (i), if available.
- How is the performance of already conducted energy R&D monitored and assessed?
- How do academic research and basic science contribute to innovation and introduction of new technologies?
- What are the key activities in international R&D collaboration and how are the results utilised?

b. Major research programmes

- Please describe research programmes of the following categories (a) – (i). Please indicate their major achievements, including cost reductions, if any. Please indicate if further information is available, *e.g.* reports, brochures, links.

a) Energy efficiency, including R&D on efficiency in industry, residential, commercial and transport sectors.

b) Oil and gas, including R&D on enhanced production, refining, transport and storage, non-conventional oil and gas production, combustion and conversion.

c) Coal, including R&D on coal production, preparation and transport, combustion, conversion (excluding IGCC) and other coal R&D.

d) CO_2 Capture and Storage, including R&D on CO_2 capture/separation, transport and storage.

e) Renewable energy sources, including R&D on solar energy (solar heating and cooling [including daylighting], photovoltaics, solar thermal power and high-temperature applications), wind energy, ocean energy and bio-energy (production of transport biofuels and other biomass-derived fuels, applications for heat and electricity), geothermal energy, hydropower (large & small) and other renewables.

f) Nuclear fission and fusion. Including R&D on nuclear fission light-water reactors (LWRs), other converter reactors, fuel cycle, nuclear supporting technologies, nuclear breeder, and R&D on nuclear fusion.

g) Hydrogen and fuel cells. Including R&D on hydrogen production, storage, transport, distribution and end use. Including R&D on fuel cells in stationary, mobile and other applications.

h) Other power and storage technologies, including R&D on electric power conversion, electricity transmission and distribution and energy storage.

i) Other cross-cutting technologies or research, including R&D on energy system analysis and forecasting as related to integration of intermittent resources.

c. Response to recommendations of last In-Depth Review:

Taking each R&D policy recommendation in turn, describe actions taken or planned.

Where no action has been taken, state this and (where appropriate) reasons for lack of action.

ANNEXE 4. GOOD PRACTICE EXAMPLES IN ENERGY TECHNOLOGY R&D POLICIES

Introduction

In the publication Energy Policies in IEA Countries 2005, the Secretariat highlighted some of the "good practices" in addressing common challenges. Most "good practices" have been taken from in-depth reviews over the previous four years, where such practices were commended. Other examples were also selected from recent IEA thematic works. In addition, recent developments reflecting the recommendations of a previous in-depth review or aimed at issues identified in other in-depth reviews have also been picked up from annual standard reviews, presentations at IEA workshops and other information sources.

Of course, each member country develops its energy policies in the context of its specific national circumstances; therefore, what is considered "good practice" in one country may not necessarily be applicable to all countries. In this context, the examples presented here should be understood as "good practices" rather than "best practices". It remains true that member countries learn from other countries' positive experiences and can draw on these experiences as a source of inspiration for their own policy development. It should be borne in mind that a list of good practices is not exclusive and that other positive examples exist elsewhere.

In the publication several good practices were identified under the following headlines:

- Consistency with national energy policy goals with clear prioritisation;
- Careful monitoring of the performance of government-funded R&D;
- Strong collaboration among various institutions dealing with energy-related R&D;
- Ensuring funding for government R&D;
- Public-private partnership;
- Multilateral and bi-lateral international co-operation.

Consistency with national energy policy goals with clear prioritisation

Given the stringent budgetary conditions for government energy R&D programmes in many member countries, a coherent energy R&D strategy with clear prioritisation in line with national energy policy goals is essential. Some good practices identified in previous in-depth reviews are presented below.

- In **Canada**, the Programme of Energy Research and Development (PERD) is planned and conducted with energy policy guidance from Natural Resources Canada, strategic directions from the Interdepartmental Panel on Energy R&D, and external advice from the National Advisory Board on Energy Science and Technology.
- **Norway**'s energy R&D is closely aligned with Norwegian energy policy objectives, with the majority of energy R&D spending going to the areas contributing most significantly to Norway's energy supply and wealth. Its OG21 (Oil and Gas in the 21st Century) is successfully delivering the research required to keep the Norwegian Continental Shelf an attractive exploration and production area.

- **Finland**'s energy R&D programmes are consistent with long-term national policies on industry, energy and technology. Priority is given to technologies that suit Finland's particular characteristics such as energy conservation and bioenergy. With such a focused approach, Finnish energy technology now accounts for 6-7% of all Finnish exports.
- Under **The Netherlands**' long-term strategy towards sustainable energy systems, two governmental groups reviewed the energy R&D programmes and priorities. The "energy transition group" undertook a large modelling exercise, running a range of technology scenarios to determine which technologies were the most dominant and robust in each scenario. A second "R&D group" undertook a major stakeholder consultation exercise. Starting from 63 potential technology R&D options as defined by stakeholders, the exercise ended up with 15-20 ranked priority topics based on two criteria: a) the contribution to a sustainable energy system in the light of 15 indicators and b) a leading position for The Netherlands in the field of the energy R&D in question. A technology gets priority if it has a high score in both criteria. A high score on a) but low on b) means that some knowledge is desirable, mainly to be imported from other countries. Financial support is given to the high priority areas and, to a limited degree, to "import options".
- **Australia** has clearly defined the role of energy R&D in its energy White Paper in June 2004. The Energy Technology Assessments in the White Paper provide a guideline for priority setting for energy R&D. Based on Australia's unique needs and capacities, it assessed a broad range of energy related technologies and grouped them into three categories: "market leader" where Australia can play a leading role in international R&D efforts, "fast follower" where Australia has a strong position in quickly following international developments and "reserve" where Australia monitors international developments and follows as needed.

Careful monitoring of the performance of government-funded R&D

In addition to proper prioritisation, effective monitoring and assessment of the performance of government-funded energy R&D are also crucial to maximise the cost-effectiveness of the R&D programme.

- **Canada** has been restructuring PERD to improve its efficiency, increase its focus on long-term activities and adapt to respond to climate change policies. The government has been reviewing one quarter of PERD's objectives each year and completed a full cycle over four years at the end of 2003.
- **Austria** invited foreign experts from Germany, Switzerland and The Netherlands to evaluate the sub-programmes of its Austrian Programme on Technologies for Sustainable Development.

Strong collaboration among various institutions dealing with energy-related R&D

When many organisations carry out energy-related R&D activities, appropriate collaboration is one of the prerequisites for the effectiveness of such activities. The increasing linkage between energy and other research areas further necessitates effective collaboration among research organisations.

- For example, Canada's PERD is governed by the Panel on Energy Research and Development composed of assistant deputy ministers and senior officials from the federal R&D departments and agencies which perform or manage energy R&D and which have a policy interest in science and technology.

- The Swiss Federal Office of Energy (SFOE) co-ordinates most federally directed energy R&D with advice from the CORE (Commission for Energy Research) composed of representatives from industry, research institutes, funding institutions and cantons. National Energy Research Conferences are held every 3-4 years in Switzerland to bring together industry leaders, representatives of the cantonal and federal agencies, politicians and energy experts to review national priorities and recommend corrections.

Ensuring funding for government R&D

Energy technologies are expected to make a substantial contribution to mid- to long-term solutions of energy policy challenges, namely, energy security, environmental protection and economic growth. Despite these critical roles, government energy R&D budgets in many member countries were reduced between the early 1980s and the 1990s. The role of government energy R&D budgets is becoming more critical given that R&D activities in the private energy sector tend to be reduced as a result of competitive pressure under market liberalisation. It is encouraging to observe a reversing trend in member countries in recent years.

- Canada's public R&D spending significantly increased between 2000 and 2003 from USD 200 million to USD 240 million, reversing the declining trend throughout the 1990s when the budget was cut from USD 272 million in 1991 to USD 169 million in 1999.
- In Spain, the public energy R&D budget was increased from EUR 34 million under the 3rd National Plan for Energy R&D Programme (2000-2003) to EUR 42-44 million under the 4th National Plan (2004-2007).
- Norway increased its R&D budget substantially from NOK 384 million in 2003 to NOK 441 million in 2004 after a period of sharp decline in the mid-1990s. This budget rose again by 15% in 2005.
- Belgium's 2003 energy R&D budget of EUR 76.7 million showed a large increase from EUR 54.6 million in 1999.

The in-depth reviews commended these developments. It is noteworthy that Japan (0.86%), Finland (0.50%), Switzerland (0.42%), Sweden (0.36%), the Netherlands (0.32%), the United States (0.27%), Canada (0.26%), Norway (0.26%) and France (0.26%) have relatively higher shares of government energy R&D per thousand units of GDP according to 2002 figures.

Public-private partnership

It is increasingly important to improve private sector R&D activities to facilitate the process of technology development and deployment. Furthermore, with market liberalisation where private sector R&D becomes more focused on short-term and applied research, governments also need to redefine their roles and improve their policy measures to stimulate private initiatives more effectively.

- The United States is conducting large scale public-private partnership initiatives such as the FreedomCAR Partnership (2002) and the Hydrogen Fuel Initiative (2003). Together, the extensive multi-year research efforts of these two initiatives are intended to facilitate a decision by industry to commercialise hydrogen-powered fuel cell vehicles by the year 2015.
- In Australia, the CRC (Co-operative Research Centres) Programme links researchers and research users in the public and private sectors, supporting both R&D and commercialisation/demonstration.

- The "Share Cost" scheme in Ireland engages the private and public sectors through sharing risks of short- to mid-term R&D. Typically, shared cost projects will qualify for support of up to 40% of eligible contract costs. The Green Paper on Sustainable Energy published in 1999 allocated 50% of the total energy R&D budget through the Share Cost scheme.
- The UK government supports collaboration between universities and companies on long-term solutions, in particular in the oil and gas industry. The R&D that receives support is recommended by PILOT, a joint industry/government body setting targets for future offshore production levels, capital investment and employment levels.
- Norway also has strong public-private partnerships. OG21 is a successful attempt to closely involve players in the management of research activities. Identifying nine key technologies with the Lead Parties, which have been selected among the most important oil companies on the NCS, is working well to ensure that R&D is carried out with a focus on results applicable to the industry. This has led to a high rate of additional spending by the oil industry on a rate of NOK 3-4 spent by industry for every NOK 1 spent by the government.

Multilateral and bilateral international co-operation

International co-operation, on both a multilateral and a bilateral basis, is an instrumental means to maximise the benefit of energy R&D. Within a context of increasing globalisation and shifts of emphasis away from national R&D, such international collaborative efforts promise better returns on R&D investment through the sharing among participants of financial outlay, workload and results.

- For example, in 2003, the United States initiated a ministerial meeting for the Carbon Sequestration Leadership Forum (CSLF) as a framework for international co-operation in research and development for the separation, capture, transportation and storage of carbon dioxide.

IEA Implementing Agreements can play a vital role in simplifying international co-operation between national entities, business and industry. Canada, Denmark, Finland, Japan, Norway, Sweden, the United Kingdom and the United States each participate in more than 20 Implementing Agreements of the IEA. In particular, compared with their respective total government budgets, the active participation of Nordic countries in these agreements is commendable.

ANNEXE 5. IMPLEMENTING AGREEMENTS

Managed by the Implementing Agreements themselves, these websites are the first source of comprehensive information about the present and past activities of each programme. They provide details of participation, access to reports, technical updates, policy analysis and other publications, as well as notification of upcoming events. Many Implementing Agreements organise regular conferences and workshops and their websites offer proceedings and working papers on the specialised topics. Large volumes of technical information and links to other relevant websites make these Implementing Agreement websites a valuable source of current information on technology status and R&D approaches in more than 40 energy technology domains. In addition, many of the Implementing Agreements publish easily downloadable newsletters.

More information about the energy technology collaboration under the IEA framework can be found on www.iea.org under "Technology Agreements".

Implementing Agreement	Website
ENERGY END-USE TECHNOLOGIES	
Buildings	
Buildings and Community Systems	www.ecbcs.org
District Heating and Cooling	www.iea-dhc.org
Energy Storage	www.iea-eces.org
Heat Pumping Technologies	www.heatpumpcentre.org
Electricity	
Demand-Side Management	http://dsm.iea.org
Electricity Networks Analysis, Research & Development	http://www.iea-enard.org/
High-Temperature Superconductivity Electric Power Sector	http://spider.iea.org/tech/scond/scond.htm
Industry	
Emissions Reduction in Combustion	www.ieacombustion.com
Industrial Energy-Related Technology Systems	www.iea-iets.org
Transport	
Advanced Fuel Cells	www.ieafuelcell.com
Advanced Materials for Transportation	http://www.iea-ia-amt.org
Advanced Motor Fuels	www.iea-amf.vtt.fi
Hybrid and Electric Vehicles	www.ieahev.org
FOSSIL FUELS	
Clean Coal Centre	www.iea-coal.org.uk
Clean Coal Sciences	http://iea-ccs.fossil.energy.gov
Enhanced Oil Recovery	www.iea.org/eor
Fluidized Bed Conversion	www.iea.org/tech/fbc/index.html
Greenhouse Gas R&D	www.ieagreen.org.uk
Multiphase Flow Sciences	www.etsu.com/ieampf
FUSION POWER	
Environmental, Safety, Economic Aspects Fusion Power	www.iea.org/techagr
Fusion Materials	www.iea.org/techagr
Large Tokamaks	www-jt60.naka.jaea.go.jp/

Nuclear Technology of Fusion Reactors	www.iea.org/techagr
Plasma Wall Interaction in TEXTOR	www.iea.org/techagr
Reversed Field Pinches	www.iea.org/techagr
Spherical Tori	www.iea.org/techagr
Stellarator Concept	www.iea.org/techagr
Toroidal Physics, Plasma Technologies of Tokamaks with	www.iea.org/techagr
Poloidal Field Divertors (ASDEX-Upgrade)	www.iea.org/techagr
RENEWABLE ENERGY TECHNOLOGIES	
Bioenergy	www.ieabioenergy.com
Deployment	www.iea-retd.org
Geothermal	www.iea-gia.org
Hydrogen	www.ieahia.org
Hydropower	www.ieahydro.org
Ocean Energy Systems	www.iea-oceans.org
Photovoltaic Power Systems	www.iea-pvps.org
Solar Heating and Cooling	www.iea-shc.org
SolarPACES	www.solarpaces.org
Wind Energy Systems	www.ieawind.org
CROSS-CUTTING ACTIVITIES	
Climate Technology Initiative	www.climatetech.net
Energy Technology Data Exchange	www.etde.org
Energy Technology Systems Analysis Programme	www.etsap.org

ANNEXE 6. IEA COMMITTEES INVOLVED IN TECHNOLOGY IN-DEPTH REVIEWS

Committees

The Standing Group on Long-Term Co-operation

The Standing Group on Long-Term Co-operation (SLT) encourages co-operation between IEA member countries to improve their collective Energy security, the economic Efficiency of their energy sector and the Environmental provision of energy services. To achieve these three E's, IEA governments in 1976 agreed to a programme for long-term co-operation in formulating and implementing national energy goals. One major driver of co-operation is the process of in-depth reviews of the energy policies of the member countries.

The SLT meets four or five times a year to provide guidance to the Secretariat, to undertake broad policy analysis, to share the results of the in-depth reviews and to provide a forum for the development of policies related to economic analysis of the energy sector, energy diversification and regulatory reforms, and climate-friendly energy use.

The Committee on Energy Research and Technology

The Committee on Energy Research and Technology (CERT) co-ordinates and promotes the development, demonstration and deployment of technologies to meet challenges in the energy sector.

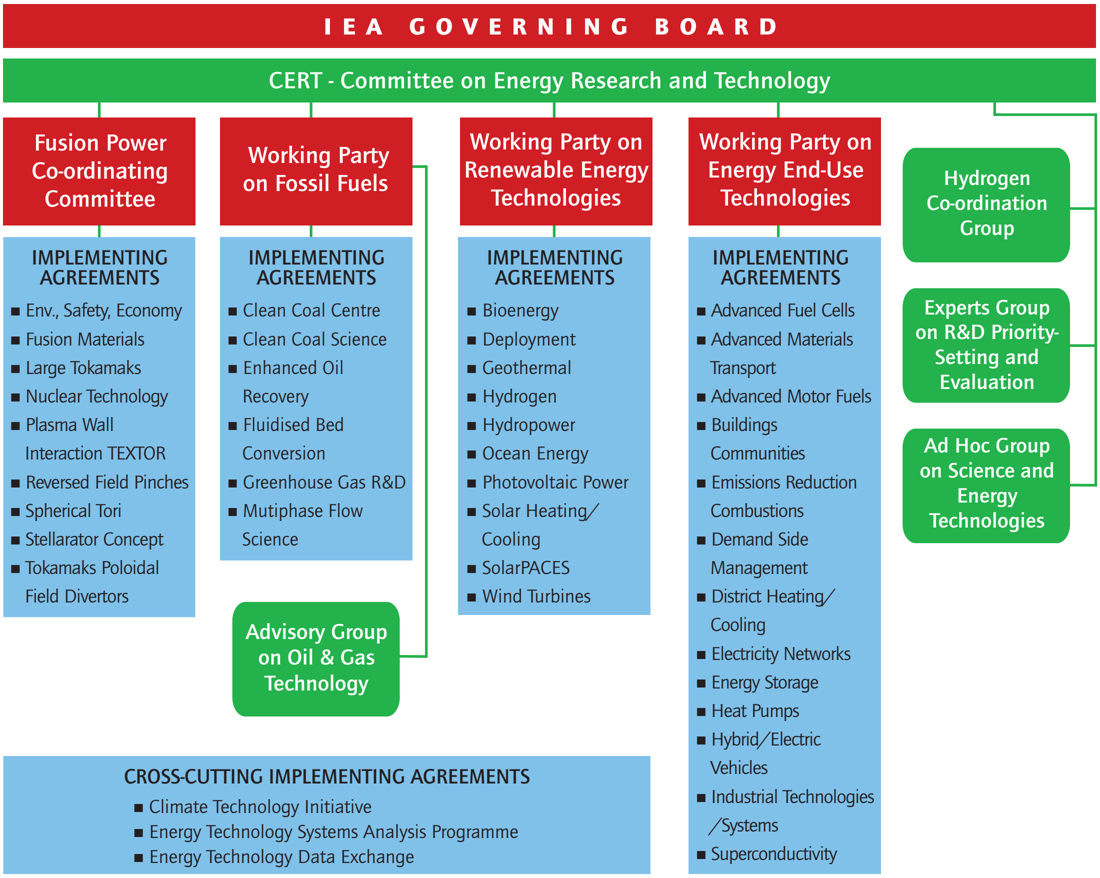
- Working Party on Energy End-Use Technologies (participating countries)
- Working Party on Fossil Fuels (participating countries)
- Working Party on Renewable Energy Technologies (participating countries)
- Fusion Power Co-ordinating Committee (participating countries).

In addition, expert groups have been established to advise on R&D priority setting and evaluation, on basic science and energy technology, and on oil and gas.

Implementing Agreements

The IEA provides a framework for more than 40 international collaborative energy research, development and demonstration projects known as Implementing Agreements (see figure below).

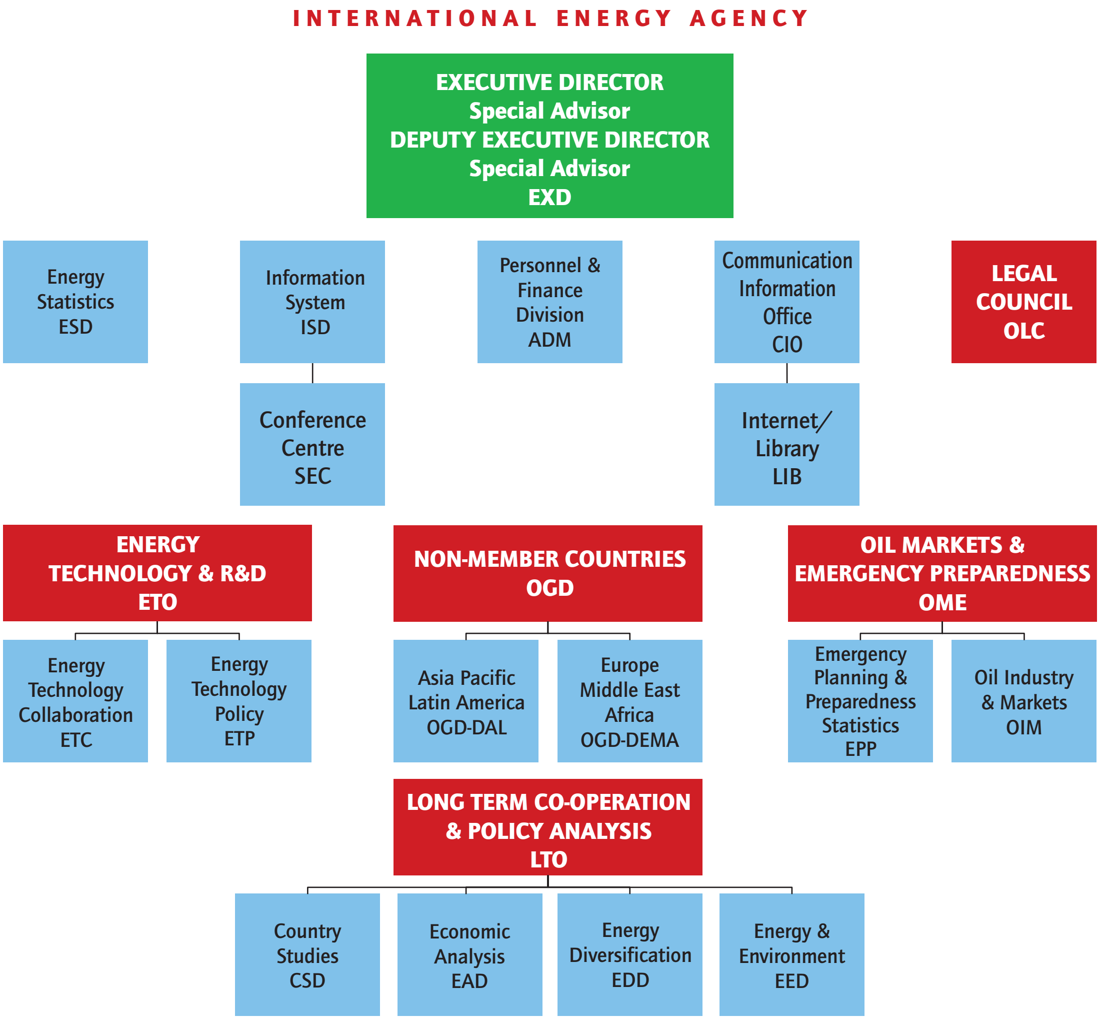
The IEA Energy Technology Network (as of 1 March 2007)



Below is an organigramme of the IEA Secretariat. Offices involved in the technology R&D in-depth reviews are the:

- Office of Long-term Co-Operation (LTO)
  Country Studies Division (CSD) – main division responsible for review
- Energy Technology and R&D Office (ETO)
  Energy Technology Policy Division (ETP) – co-ordination of input on technology and R&D policies
  Energy Technology Collaboration Division (ETC) – contribute with expertise on technology and R&D policies

Organigramme of the IEA



ANNEXE 7. ACRONYMS AND ABBREVIATIONS

ACT	Accelerated Technology Scenario in (IEA, 2006)
CERT	Committee on Energy Research & Technology
CSD	Country Studies Division
ERABUILD	European Research Area Network on Buildings
ERA-net	European Research Area network
ETC	Energy Technology Collaboration Division
ETP	Energy Technology Policy Division
ETO	Energy Technology Office
EU	European Union
IEA	International Energy Agency
IDR	In-Depth Review
LTO	Long-Term Co-Operation and Policy Analysis
NEA	Nuclear Energy Agency
NMC	Non-Member Countries (of IEA)
OECD	Organisation for Economic Co-Operation and Development
OGD	Office of Global Dialogue
OLIS	OECD's online committee information service
R&D	Research & Development
RD&D	Research, Development & Demonstration
RDD&D	Research, Development, Demonstration & Deployment
SLT	Standing Group for Long-Term Co-operation

ANNEXE 8. PARTICIPATION OF IEA MEMBER COUNTRIES IN IMPLEMENTING AGREEMENTS

Building Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Buildings & Community Systems	District Heating & Cooling	Energy Storage	Heat Pumps	TOTAL
Australia					**1**
Austria					**2**
Belgium					**2**
Canada					**4**
Czech Republic					**1**
Denmark					**3**
Finland					**3**
France					**3**
Germany					**3**
Greece					**1**
Ireland					
Italy					**2**
Japan					**3**
Korea					**1**
Netherlands					**3**
New Zealand					**1**
Norway					**4**
Portugal					**1**
Spain					**2**
Sweden					**4**
Switzerland					**2**
Turkey					**2**
United Kingdom					**3**
United States					**4**
IEA Total	**21**	**8**	**14**	**12**	**55**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Transport Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Advanced Fuel Cells	Advanced Materials Transportation	Advanced Motor Fuels	Hybrid and Electric Vehicles	TOTAL
Australia					**1**
Austria					**2**
Belgium					**4**
Canada					**3**
Czech Republic					
Denmark					**1**
Finland					**3**
France					**3**
Germany					**2**
Greece					
Ireland					
Italy					**3**
Japan					**2**
Korea					**2**
Netherlands					**2**
New Zealand					
Norway					**1**
Portugal					
Spain					**1**
Sweden					**4**
Switzerland					**3**
Turkey					
United Kingdom					**2**
United States					**4**
IEA Total	**17**	**5**	**11**	**10**	**43**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Electricity Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Demand Side Management	Electricity Networks, Analysis, R&D	High-Temperature Super-conductivity	TOTAL
Australia				**1**
Austria				**2**
Belgium				**3**
Canada				**2**
Czech Republic				
Denmark				**2**
Finland				**3**
France				**1**
Germany				**1**
Greece				**1**
Ireland				
Italy				**3**
Japan				**1**
Korea				**2**
Netherlands				**3**
New Zealand				
Norway				**3**
Portugal				
Spain				**1**
Sweden				**3**
Switzerland				**2**
Turkey				**0**
United Kingdom				**3**
United States				**2**
IEA Total	**16**	**10**	**13**	**39**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Industry Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Emissions Reduction in Combustion	Industrial Energy-Related Technologies & Systems	TOTAL
Australia			
Austria			
Belgium			**1**
Canada			**2**
Czech Republic			
Denmark			**1**
Finland			**2**
France			
Germany			**1**
Greece			
Ireland			
Italy			**1**
Japan			**1**
Korea			
Netherlands			**1**
New Zealand			
Norway			**2**
Portugal			**1**
Spain			
Sweden			**2**
Switzerland			**1**
Turkey			
United Kingdom			**1**
United States			**2**
IEA Total	**11**	**8**	**19**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Renewable Energy Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Bio-energy	Deploy-ment	Geo-thermal	Hydro-gen	Hydro-power	Photo-voltaic	Ocean Energy	Solar Heating & Cooling	Solar PACES	Wind	TOTAL
Australia	■		■	■		■		■	■	■	**7**
Austria	■					■		■		■	**4**
Belgium	■						■	■			**3**
Canada	■	■		■	■	■	■	■		■	**8**
Czech Republic											
Denmark	■	■		■		■	■	■		■	**7**
Finland	■			■	■			■		■	**5**
France	■	■	■	■	■	■		■	■		**8**
Germany	■	■	■	■		■	■	■	■	■	**9**
Greece										■	**1**
Ireland		■					■			■	**3**
Italy		■	■	■		■		■		■	**6**
Japan	■		■	■	■	■	■			■	**7**
Korea			■	■		■				■	**4**
Netherlands	■	■		■		■		■		■	**6**
New Zealand	■		■	■				■			**4**
Norway	■	■		■	■	■	■	■		■	**8**
Portugal						■	■	■		■	**4**
Spain				■		■		■	■	■	**5**
Sweden	■			■	■	■		■		■	**6**
Switzerland	■		■	■		■		■	■	■	**7**
Turkey				■		■					**2**
United Kingdom	■	■		■		■	■			■	**6**
United States	■		■	■		■	■	■	■	■	**8**
IEA Total	**16**	**9**	**9**	**18**	**6**	**18**	**10**	**17**	**6**	**19**	**128**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Fossil Fuels Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Clean Coal Centre	Clean Coal Science	Enhanced Oil Recovery	Fluidised Bed Conversion	Greenhouse Gas R&D	Multiphase Flow Sciences	TOTAL
Australia							**4**
Austria							**4**
Belgium							
Canada							**6**
Czech Republic							**1**
Denmark							**4**
Finland							**1**
France							**3**
Germany							**3**
Greece							**1**
Ireland							
Italy							**3**
Japan							**5**
Korea							**3**
Netherlands							**3**
New Zealand							**1**
Norway							**3**
Portugal							
Spain							**2**
Sweden							**3**
Switzerland							**1**
Turkey							
United Kingdom							**6**
United States							**5**
IEA Total	**10**	**10**	**9**	**12**	**16**	**5**	**62**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Fusion Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	ASDEX Up-grade	Environment, Safety, Economy	Fusion Materials	Large Tokamak	Nuclear Tech-nology	TEXTOR	Reversed Field Pinches	Spherical Tori	Stellarator Concept	TOTAL
Australia										**1**
Austria										
Belgium										
Canada										**4**
Czech Republic										
Denmark										
Finland										
France										
Germany										
Greece										
Ireland										
Italy										
Japan										**8**
Korea										**1**
Netherlands										
New Zealand										
Norway										
Portugal										
Spain										
Sweden										
Switzerland										**1**
Turkey										
United Kingdom										
United States										**9**
IEA Total	**2**	**3**	**4**	**2**	**3**	**3**	**2**	**2**	**3**	**24**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

Cross-Cutting Implementing Agreements

As of 31 March 2007. The table does not include participation of IEA non-member countries.

	Climate Technology Initiative	Energy Technology Data Exchange	Energy Technology Systems Analysis Programme	TOTAL
Australia				
Austria				**1**
Belgium				**1**
Canada				**3**
Czech Republic				
Denmark				**1**
Finland				**3**
France				
Germany				**3**
Greece				**1**
Ireland				
Italy				**1**
Japan				**2**
Korea				**2**
Netherlands				**1**
New Zealand				
Norway				**3**
Portugal				**1**
Spain				**1**
Sweden				**2**
Switzerland				**2**
Turkey				**1**
United Kingdom				**3**
United States				**3**
IEA Total	**9**	**11**	**15**	**35**

Source : IEA, 2007. Energy Technologies at the Cutting Edge.

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Governments will continue to play a major role in energy technology development – in defining policies to spur innovation and deployment, and in funding and prioritising research and development. But how can governments be sure they are making the right choices? One answer is by learning from the experience of others – through the use of peer reviews.

The IEA version of the peer review – the "in-depth review" - is a well established tool used since the Agency was created more than 30 years ago. It provides member countries with a framework to examine and compare experiences and discuss "best practices" in a host of energy policy areas, including research, development and technology policy.

Findings from IEA peer reviews show that effective R&D policy making requires:

- a clear definition of government's role
- a national energy strategy (policy directions and goals)
- an accompanying technology and R&D strategy
- adequate and stable funding
- well defined and transparent R&D prioritisation and evaluation processes
- involvement of R&D stakeholders in priority setting and evaluation
- linkage with national science, research and innovation strategies
- linkage with policies for commercialisation and deployment
- public private partnerships
- strategy for international R&D collaboration

The objective of this handbook is to further strengthen in-depth reviews of energy R&D policies and programmes by providing guidance, best practice examples and lists of questions for the review team.