SIXTH FRAMEWORK PROGRAMME
PRIORITY "ERA-NET"

Co-ordination of Research Activities

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Co-ordination Action to Establish a Hydrogen and Fuel Cell ERA-Net, Hydrogen Co-ordination

Work Package 3

Task 3.2, Deliverable D3.1

A study on Complementarities and Gaps between National H_2&FC RD&D Programmes and Analysis of New Opportunities (SWOT analysis)

List of Abbreviations

AFC	Alkaline Fuel Cell
CERN	The European Organization for Nuclear Research
CHP	Combined heat and power
CO_2	Carbon dioxide
CUTE	Clean Urban Transport for Europe
DMFC	Direct Methanol Fuel Cell
EC	European Community
ECTOS	Ecological City Transport System
ERA	European Research Area
ESA	European Space Agency
ESTO	The European Science and Technology Observatory
EU	European Union
FP	Framework Programme
GDP	Gross Domestic Production
HFP	The European Hydrogen and Fuel Cell Technology Platform
H_2	Hydrogen
H_2FC	Hydrogen and Fuel Cells
ICE	Internal combustion engine
IEA	International Energy Agency
MCFC	Molten Carbonate Fuel Cell
OECD	Organisation for Economic Cooperation and Development
PAFC	Phosphoric Acid Fuel Cell
PEM	Proton Exchange Membrane
PEMFC	Polymer Electrolyte Membrane Fuel Cell
R&D	Research and Development
RD&D	Research, Development and Demonstration
RTD	Research and Technological Development
RTDI	Research, Technological Development and Innovation
SFC	Solid oxide Fuel Cell
STEP	Sustainable Transport Energy Perth
SWOT	Strengths, Weaknesses, Opportunities and Threats
TAFTIE	The Association for Technology Implementation in Europe
WP	Work Package

Executive summary

The importance of hydrogen and fuel cell technology lies in its potential contribution to some of the major challenges facing the European Union today – enhancing security of energy supply, reducing green house gas emissions and strengthening European innovation and growth. Taking into consideration the financial commitments already made by the European Union and its Member Countries, the Europe has the potential to establish its leadership in the development of hydrogen and fuel cell technology.

Enhancing RD&D efforts in the field of hydrogen and fuel cell technology goes beyond increasing RD&D expenditures. One of the major barriers for realising the European potential in this field is a lack of coherency and collaboration between the national H_2&FC RD&D programmes of the European countries. One the most important means of enhancing RD&D efforts therefore lies in **increasing the openness** of national RD&D programmes to trans-national cooperation.

The overall aim of this report is to investigate the common strategic issues related to the hydrogen and full cell "community" in EU. The report has its main focus on archiving greater coordination and cooperation within hydrogen and fuel RD&D. More specifically, *the objectives of this study are*

- *to identify complementarities and gaps between national hydrogen and fuel cell programmes, and*
- *to analyse new opportunities for trans-national cooperation, including*
- *exploring possible mechanisms for opening up national RD&D programmes for other Member States.*

This study of RD&D programmes and similar efforts in 27 European countries reveals that although RD&D efforts differ significantly both in terms of institutional design, size of funding, level of ambition, technological portfolio, and international orientation, it is possible to identify **clear areas of overlap** that could potentially form the basis of trans-national cooperation. Such complementarities were identified both with regard to overall political priorities, in terms of technological portfolio and expertise of national RD&D programmes and in terms of research interests. In particular, **four** different research areas appear to be suited to for trans-national cooperation. Furthermore, HY-CO members have expressed interest in pursuing the possibilities strengthening trans-national cooperation within these four areas. The four areas are: hydrogen production, storage applications, fuel cell technology and to a certain extent social-economics.

The study indicates that there are **many opportunities for further trans-national cooperation** between European RD&D efforts in the field of hydrogen and fuel cell technology and that **great advantages could potentially be exploited**.

A number of benefits can be achieved from trans-national cooperation. Trans-national cooperation primarily gives the participants **access to a larger pool of different resources** as countries have different experiences and competencies within a number of areas. Furthermore, **trans-national cooperation facilitates knowledge and information sharing** between the different scientists involved in the RD&D programmes. Trans-national cooperation also increases the individual country's research capacity and opens up for research results that a single country could not have achieved.

A number of **barriers to trans-national cooperation must be overcome** or minimized in order for Europe to boost its trans-national activities. The identified barriers range from political barriers to inflexible legal structures and from funding shortages and excessive bureaucracy to a general lack of overview over the different opportunities for trans-national cooperation that exist.

The EU, national research agencies and regional authorities can all **play an active role** in furthering trans-national cooperation in Europe. In general, the EU is, based on its recent initiatives and activities, is perceived by the hydrogen and fuel cell community to do a good job in fostering more trans-national cooperation. However, the EU should be cautious not to go too far in setting rules and inflate bureaucracy. The envisioned **role of the EU** is as one structuring and facilitating trans-national cooperation and ensuring coordination of the process and objectives between the involved partners.

The new Member States are experiencing some difficulties in regards to participating in trans-national cooperation within hydrogen and fuel cells. While many of the old Member States already have well-developed research infrastructures within hydrogen and fuel cells and structures and mechanisms in place to support trans-national cooperation, this is not always the case in the new Member States. The new Member States are currently in the midst of building up their research infrastructures to EU standards. Furthermore, the new Member States suffer from a lack of funding and a lack of experience with applying for and participating in EU RD&D programmes. However, despite the problems, a number of opportunities within hydrogen and fuel cell research exist in the new Member States.

This study draws on a desk study of existing literature on the subject, a questionnaire survey among 18 hydrogen related experts across Europe and 21 interviews conducted with expert representatives of 18 countries in the field of hydrogen and fuel cell technology. Furthermore, it builds on a mapping and profiling of the national RD&D programmes of 27 European countries working in the field of hydrogen and fuel cell technology.

The study has thrived to set up a list of “best practices” and recommendable policy mechanisms of an “ideal partnership” for trans-national cooperation. See table below.

“Best practices” and recommendable policy mechanisms of an “ideal partnership” for trans-national cooperation.

Choosing the right partners

- In general, the success of trans-national cooperation depends crucially on choosing the right partners and organisations
- Partners need to share the same objectives and have similar priorities. Partners with too diverging priorities lead to unfocused and unsuccessful collaboration
- A degree of complementarity between the participating partners is important
- Trust building is essential in order to share knowledge and cooperate successfully. Building trust takes time
- The partnership should be between equal partners (a win-win situation)
- Partners must share a genuine will, motivation and desire to cooperate

Ensuring continuity

- Long-term partnerships and projects are preferred to shorter ones.
- It takes time to build a true commitment towards a partnership and a habit of engaging in trans-national cooperation
- A long-term partnership is necessary in order to build-up trust and common values between the involved partners. These are crucial preconditions for a successful and productive cooperation
- Long-term project planning is important, but a precondition for project planning is continuity
- Long-term financial stability is essential. Continuity of funding is often as important as the amount of funding given
- The sharing of knowledge is essential, but requires a high degree of mutual trust and commitment, which take time to build. Sharing of knowledge is thus a long-term process

Ensuring flexibility

- A high degree of flexibility in a RD&D project is desirable, because research and innovation are always characterized by uncertainty and risks
- Budgetary flexibility is important. It gives the researcher the financial autonomy needed to adapt to changes in the project or the scientific agenda
- A higher degree of trust should be given to qualified scientists. The EU should carefully check the candidates that apply for certain projects. But once a candidate has been proven 'worthy', plenty of room for manoeuvring should be given in the sense that the level of regulations, duties and formalities should be kept at a minimal

Minimising bureaucracy

- In general, requirements for reporting, monitoring and control should be kept at an absolute minimum. Despite various attempts to reduce bureaucracy, the administrative burdens are perceived as increasing
- Bureaucratic and administrative requirements imposed on the scientists take up valuable time for researching.
- The call and application procedures should be less bureaucratic, less complex, less costly and less time consuming

A supporting overall framework

- A higher degree of coordination between regional and national research agencies and the EU on topics such as RD&D programmes, priorities and objectives is desirable
- Awareness among research agencies, programme managers and scientists about the possibilities and advantages of trans-national cooperation is essential
- Scientists planning to engage in trans-national cooperation should be encouraged and supported by their national research agency, research organisation and programme manager

A SWOT analysis summarizes the findings in this study. See table below.

<table>
<tr><th colspan="2">Strengths, weaknesses, opportunities and threats for further trans-national cooperation on hydrogen and fuel cell RD&D in Europe</th></tr>
<tr><td>Strengths

• High level of adaptability among the new European Member States in East Europe
• World class RD&D within the hydrogen and fuel cell area
• World class basic research
• High level of funding for hydrogen and fuel cell RD&D activities (if the Quick initiative and FP7 are initiated)
• EU Member States have high and demanding ambitions within the hydrogen and fuel cell area
• Strong political backing for hydrogen and fuel cell technology and historical focus on the environment (demand-pull mechanism)
• Excellent framework conditions for environmental innovation
• Clear existing overlaps in terms of shared interest and technological expertise</td>
<td>Weaknesses

• Unawareness about shared interests and expertise
• Heterogeneity of RD&D programme design between the European countries within multiple areas (ex. technology, funding and support, legal frameworks and energy prioritization on a national scale)
• Intellectual property rights hampers collaboration as technology moves towards commercialization
• Weak at transforming research into commercial and competitive products in the market – the valley of death
• Low level of venture capital funding and lack of industrial involvement in agenda setting
• Low level of interaction between industry, government and scientists across national borders</td></tr>
<tr><td>Opportunities

• Gathering, coordination and sharing of information about European RD&D activities
• Identifying key parameters for matching common bi-lateral or tri-lateral interests
• Simplify and de-bureaucratize the call mechanisms and the control and evaluation procedures. Create greater project flexibility
• Improve and simplify private actors' access to public funds
• Establish a common institutional framework for trans-national cooperation
• Potential cooperation between countries with both similar and different climatic conditions
• Cooperation between countries with similar energy systems and priorities
• Cooperation between countries with similar industrial bases (ex. automotives)
• Establishment of long-term trans-national networks of cooperation
• The new Member States could benefit from working more closely together in areas of basic research
• Opportunity for designing specific and adapted RD&D projects in order to include the new Member States
• Further industry involvement in public RD&D agenda setting
• Greater interaction between scientists, the public sector and the industry</td>
<td>Threats

• Continued unawareness about shared interests and expertise
• Lack of will and ambition to firmly establish European leadership in the field of hydrogen and fuel cell technology
• Failure to set and implement common European RD&D priorities
• More bureaucracy and less flexibility resulting from the enlargement
• Strong and active international competitors within the hydrogen and fuel cell area
• Lack of synergy between the public sector and private RD&D
• Unawareness about RD&D activities outside national context
• Lack of continuity and failure to realise long-term benefits of trans-national cooperation</td></tr>
</table>

Introduction

Research into the area of hydrogen and fuel cell technology has, in recent years, become an increasingly important priority on the European research and development (R&D) agenda. Like in other fields of science and technology Europe also face competition from the USA and Japan and to a lesser extent Canada within the field of hydrogen and fuel cell technology[1]. These countries are making significant progress in all areas of hydrogen and fuel cell technology. The European Commission has noticed that although Europe has the skills and the potential to become a key player in the development of fuel cell and hydrogen technology, RD&D programmes are fragmented within and across the different countries[2]. Lack of trans-national coordination and collaboration of R&D programmes outside the EU-framework, has been identified as an important barrier to the competitiveness of the European innovation system[3]. To meet such challenges the European Commission has financed the project HY-CO. The goal of the project "HY-CO" is to network and integrate the national R&D activities by establishing a durable European Research Area (ERA-NET) in the area of hydrogen and fuel cells. Among the projects main objectives is to promote and develop a strong and coherent RTD policy on hydrogen and fuel cells in Europe, and stimulate the "*co-operation and co-ordination of national and regional research and innovation activities*". The vision behind it is to create an internal market in research and development. HY-CO started in October 2004 and is running for four years. The project is financed by the European Commission and has 21 participants from 16 countries. The HY-CO project consists of five work packages (WP). See figure 1.

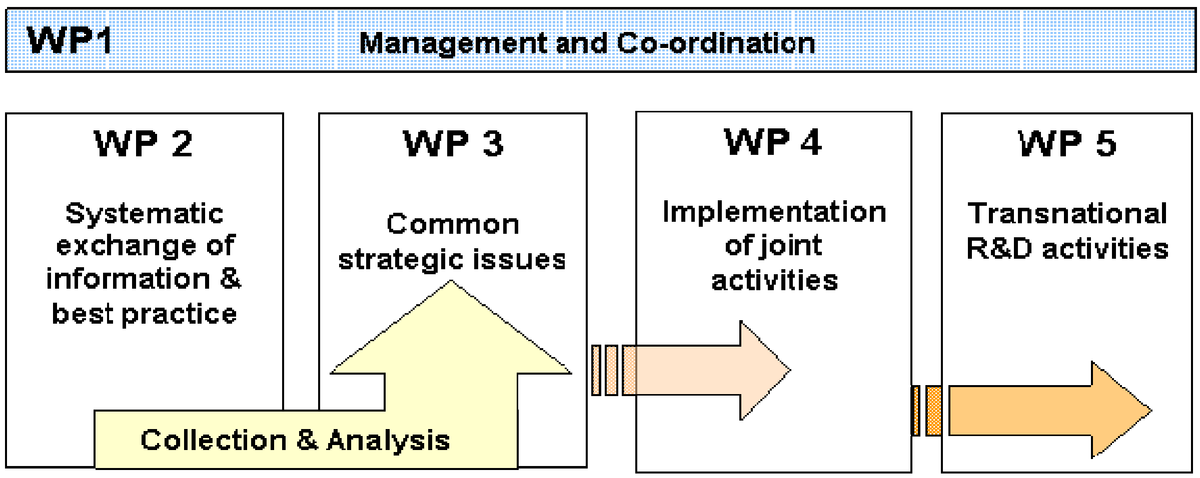

Figure 1: Overview of the HY-CO project.

This report covers the second main stage of the activities in WP3, namely the assessment and identification of complementarities and gaps between national hydrogen and fuel cell research programmes and an analysis of new opportunities in H2/FC-research.

The overall aim of this report (Task 3.2, Deliverable D3.1 in WP3) is to investigate the common strategic issues related to the hydrogen and full cell "community" in EU and has

[1] ESTO (2005)
[2] European Commission (2003a)
[3] European Commission (2005b)

its main focus on archiving greater coordination and cooperation within hydrogen and fuel RD&D. The objectives in WP3 are therefore to contribute to build a coherent EU strategy on research and development and explore possible mechanisms for achieving greater integration, including achieving a concerted European strategy for international cooperation.

More specifically, *the objectives of this study are*

- *to identify complementarities and gaps between national hydrogen and fuel cell programmes, and*
- *to analyse new opportunities for trans-national cooperation, including*
- *exploring possible mechanisms for opening up national RD&D programmes for other Member States*.

The report has 4 main parts:

- First, the report gives an account of the overall framework conditions of the European Union and its member countries. This includes an overview of competitiveness, innovation and RD&D expenditure, the current and future energy carriers and the main goals, drivers and priorities behind the RD&D policies of the EU Member States. This first part of the report is covered by Chapters 1 and 2.

- Second, the report in Chapter 3 gives an introduction to the research and innovation programmes policy instrument and to recent studies on trans-national cooperation on RD&D.

- Third, focus is turned to the identification of complementarities and gaps in national RD&D programs. The portfolio and focus of RD&D programmes are assessed along with the programme set-up, prioritisation, and stakeholder involvement. The programme implementation and beneficiaries are identified and the international orientation of the programmes is assessed. The third part of the report is covered by Chapter 4.

- Finally, focus is turned to the identification of opportunities for trans-national cooperation. Through a SWOT-analysis[4] the strengths and weaknesses of national RD&D programmes are identified along with the opportunities and threats in the environment regarding the building of the European Research Area in general and trans-national cooperation on RD&D programme level in particular. The fourth part of the report is covered by Chapter 5.

Empirical data for report comprise the following:

a) **Desk study** of existing data and information. Key documents include:

- Strategic Research Agenda report from the European Hydrogen and Fuel Cell Technology Platform
- Deployment Strategy from European Hydrogen and Fuel Cell Technology Platform
- Study on Priority Energy Technologies: SWOT analysis – Jitex/European Commission
- Non-Nuclear Energy Research in Europe – A Comparative study, EUR 21614/1

[4] SWOT stands for Strengths, Weaknesses, Opportunities and Threats.

- International Energy Agency, Reviews of R&D national programmes
- The ESTO-study, Assessing the international position of EU RTD on hydrogen and fuel cells - H_2FC
- Nordic Hydrogen Foresight Project, Summary Report
- ISI Essential Science Indicators on fuel cells - http://esi-topics.com/fuelcells/index.html

- Study on the design of national research programmes by Optimat VDI/VDE-Innovation + Technik GmbH
- Study by The Association for Technology Implementation in Europe (TAFTIE) on collaboration models between national research and technological development programmes

- To this material results from a **questionnaire survey** obtained in WP2 (HY-CO survey - response rate of 15 countries) has been added. The questionnaire based survey was sent to 18 hydrogen related experts across Europe. The questionnaire comprised 5 main sections: 1) General information on the EU Member States, 2) Opportunities for trans-national cooperation, including experiences from trans-national cooperation and expectations to future collaboration at EU level, 3) Governmental policy on RD&D priorities and current and future energy carriers, 4) Detailed description of RD&D programmes and supporting activities, including programme structure and budget figures, programme set-up, programme implementation, programme beneficiaries, programme monitoring and evaluation, commercialisation and access to venture capital, 5) Contact detail to main key RD&D actors from industry and science.

b) **Follow-up qualitative interviews** with key R&D managers, scientists and others, incl. representatives from the European Platform for Hydrogen and Fuel Cell Technologies, governmental officers etc. A total of 21 interviews were conducted with expert representatives of 18 countries in the field of hydrogen and fuel cell technology. The HY-CO Interview guide (see appendix II) was designed on the basis of the information obtained from the HY-CO questionnaire, allowing the interviewees to elaborate on some of the issues briefly touched upon by the HY-CO questionnaire. The first part of the interview questions covered current experiences with trans-national cooperation, allowing the respondents to describe partners involved, specify benefits, problems and the 'type' of cooperation. The latter part was prospective, covering future expectations to trans-national cooperation, allowing the respondents to elaborate on wishes, visions and perspectives for further development of trans-national cooperation. The HY-CO interview guide was sent to the HY-CO Executive Group for commenting before the interviews were conducted (see appendix I for a detailed list of the expert representatives interviewed and the interview guide itself).

These follow-up interviews provided the first assessment of opportunities for trans-national cooperation within RD&D, the experiences with trans-national cooperation and of legal and other barriers that prevented trans-national cooperation.

c) **The HY-CO Exploratory Workshop.** Inputs obtained from the different workshops, discussions and presentations held at the HY-CO Exploratory Workshop have been used in the report. The workshop was hosted by Nordic Energy Research and was held February 1-2, 2006. The expected results of the workshop were, among others, to obtain information on the ambitions for cooperation on H_2&FC among workshop participants and to identify research areas and research themes suited for trans-national cooperation. The preliminary version of this report was presented and discussed at the workshop.

The results of the desk studies, the HY-CO questionnaire, the follow-up interviews and the HY-CO explorative workshop form the basis for the report and the SWOT analysis. The SWOT analysis and the results from this report, task 3.2, will subsequently form the basis of a more thorough analysis and identification of barriers for trans-national cooperation.

This analysis will be carried out in task 3.3 by VTT Technology Studies in Finland. The research conducted in WP 3 and the workshops held will be the basis for the activities under WP 5, Trans-national R&D Activities.

The persons interviewed in this study were selected from the input received from the HY-CO questionnaires, the list of the Member States Mirror Group for European Hydrogen and Fuel Cell Technology Platform and from among other key persons within the hydrogen and fuel cell area. These include hydrogen and fuel cell scientists and programme managers from universities and research organisation across Europe, public officials from ministries and people from private companies and organisations. Furthermore, the list of people who had been chosen to participate was prior to the interviews send to the HY-CO Executive Group, VTT Technology Studies and Fraunhofer Institut für System- und Innovationsforschung for commenting.

The study has been carried out by Risø National Laboratory from August 2005 to December 2005 on behalf of Nordic Energy Research. Fraunhofer Institut für System- und Innovationsforschung (Ulrike Hasenauer) in Germany has carried out 10 interviews. Furthermore, inputs and comments to the process have been provided by VTT Technology Studies (Annele Eerola) in Finland and Nordic Energy Research (Birte Holst Jørgensen).

Chapter 1: Competitiveness, innovation and RD&D in the European Union

Since the enlargement in May 2004, the European Union now comprises 25 countries. In the Global Competitiveness Report 2005-2006, indicators of technological and macroeconomic performance are pared with the performance of key public institutions in an assessment of the competitiveness of 117 economies worldwide. Seven of the of the top-20 nations in the ranking of Growth Competitiveness are EU Member States (including the first place) as well as eight of the top-20 nations on the ranking of Business Competitiveness[5]. While confirming the position of some very competitive Member States, World Economic Forum also indicates the heterogeneity of competitive performance within the EU as a whole as shown on figure 1.1.

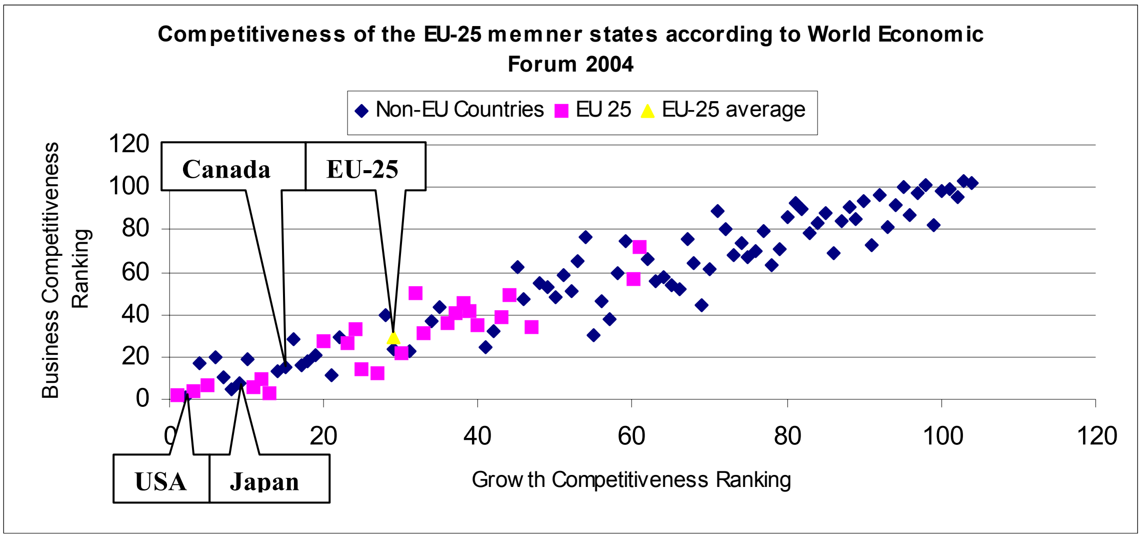

Figure 1.1: Competitiveness of the EU-25 Member States according to the World Economic Forum 2005

> **Box 1: Indicators of the Euro-Creativity Index**
>
> - Creative occupations as percent of total employment
> - Percent of population ages 25-64 with a BA or above
> - Researchers per thousand workers
> - R&D expenditure as percent of GDP
> - Patent applications per million people
> - High-tech patents per million people
> - Patens per million people
> - Percent of tolerant people (from Euro barometer)

Another measure of the competitiveness of the EU is the so-called Euro-Creativity Index. Florida et al. (2004) compares fourteen EU Member States to the USA. The aim of the index is to indicate the level of creativity and thereby estimate the innovative potential of these nations. The index is based on nine indicators (shown in box 1) covering three broad categories: tolerance, technology and talent.

Top performers in the Euro-Creativity Index are Sweden, USA, Finland and the Netherlands in that order. Looking at the nine indicators making up the Euro-Creativity Index, there is, however, significant variation as to why European nations perform as they do on the overall index[6].

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[5] World Economic Forum (2004)
[6] Florida et al. (2004)

The Euro-Creativity Index confirms the picture of the EU as a region with great competitive potential, but with quite differentiated performance across the individual member countries. These findings present both substantial challenges and opportunities for the Lisbon Targets agreed upon in 2000: to make the EU "*the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion by 2010*"[7]

1.1 Research and development in the European Union

On average, the EU-25 currently spends 1.95% of the GDP on research and development[8]. As illustrated in figure 1.2, both the USA and Japan spend significantly larger proportions of their GDP on RD&D compared to the EU-25. In March 2002, the European Council convened in Barcelona and agreed to increase current R&D spending to 3% of the GDP by 2010. This is an ambitious goal, yet realistic, taking into account the strong support given to the objective[9]. The Barcelona Targets are part of the wider EU strategy to meet the Lisbon targets mentioned above.

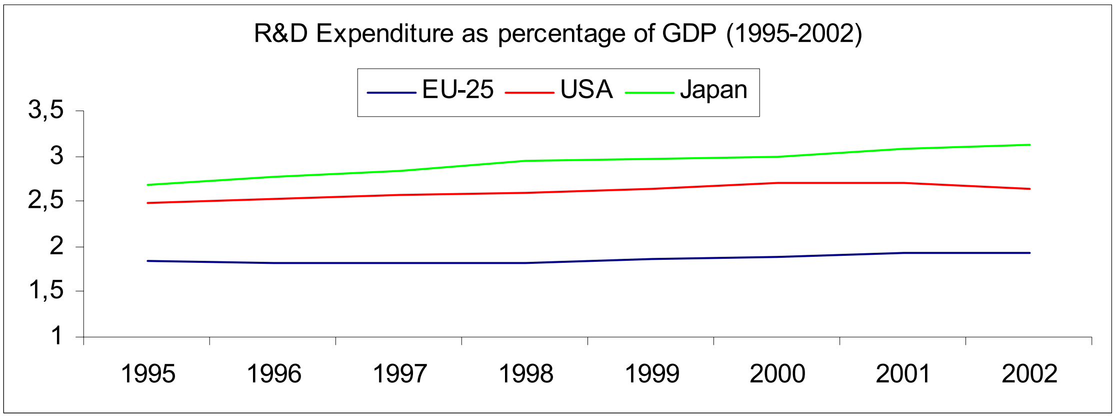

Figure 1.2: R&D spending as percentage of GDP. Source: Eurostat database

In terms of government funding of energy related R&D both the EU-15[10] and the USA have seen declining government R&D expenditures over the years as can be seen from figure 1.3. Japan has increased its spending and now spends over 40% of the total government funded R&D budget of the IEA countries. The USA and EU-15 spend about 33% and 20% respectively.

[7] European Commission (2005d)
[8] Eurostat database
[9] European Commission (2003b)
[10] Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Portugal, Sweden, Spain and UK

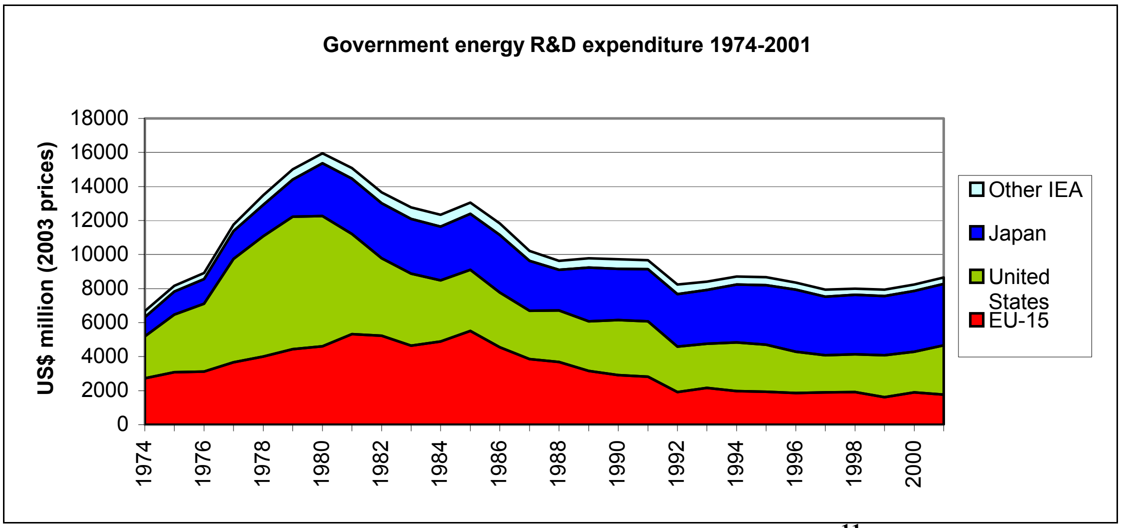

Figure 1.3: Government energy R&D expenditure 1974-2001[11]. Source: IEA R&D statistical website: http://www.iea.org/rdd/eng

The recently announced Quick Start Initiative with an indicative budget of €2.8 billion over a period of 10 years (this amount includes private funding) is an attempt to significantly increase RD&D in H_2FC and could pave the way for European leadership in the area[12].

In sum, the European Union has a good potential for research and development in general and in the field of hydrogen and fuel cell technology in particular. When taking the Barcelona targets, the Sixth and the Seventh Framework Programme and the Quick Start Initiative into account, the EU as a whole holds a relatively strong position in the development of hydrogen and fuel cell technology with respect to other countries[13].

However, **more than 80%** of EU research is financed at national level, with very little overall coordination[14], and much are to be gained from increased cooperation and coordination of trans-national R&D activities between the EU Member States.

[11] Data on energy research expenditures under the successive EU Framework Programmes are not included in the IEA statistics. The lack of EU data means that IEA statistics can at best provide only a limited view of the R&D funding landscape in Europe (European Commission 2005c).
[12] ESTO (2005)
[13] Ibid.
[14] European Commission (2002)

Chapter 2: Energy basics of the EU-25

A central driver in the development of hydrogen and fuel cell technology is the need for clean, efficient and secure energy. The European Union is the single largest fossil energy importing region in the world, representing 16% of the world energy market. Oil is the predominant energy source with a share of 38% by 2003, followed by natural gas and coal with a share of 23% and 18% respectively. Nuclear power has a share of 15%. The remaining energy sources are biomass and waste, and to a lesser extent, other renewables. The use of oil has declined since the 1970s along with the use of coal, which has declined sharply in both absolute and relative terms, while the share of gas has increased steadily[15]. Looking ahead, it is generally accepted that the two major challenges faced by the European energy system in the coming decades are increasing environmental effects of fossil energy sources and the uncertainty about continued access to cheap oil and natural gas.

The International Energy Agency (IEA) has outlined two scenarios for the development of the European energy system until 2030. It is important to note that these scenarios are not predictions of how the future *will* evolve, but likely projections of how it *could* evolve. The IEA has developed a reference scenario, which essentially assumes a continuation of current trends, and an alternative scenario, which includes a wider range of policy measures such as new measures in promoting renewables in power generation, in the transport sector and in buildings[16].

Both IEA-scenarios project significant changes in both the overall levels of energy demand and in the fuel mix in the EU-25 energy system over the coming decades.

Figure 2.1 illustrates the IEA's reference and alternative scenarios for the development of the primary energy demand for EU 25.

Under the assumptions of the reference scenario, the IEA projects that the overall energy demand will increase by 21% by 2030. The share of coal in the total primary energy demand is projected to decrease from 18% to in 2002 to 13% in 2030. Also the share of nuclear power is expected to decrease, from 15% in 2002 to 7% in 2030. The share of gas increases, from 4% in 2002 to 10% in 2030. Likewise, non-hydro renewables increases, from 4% in 2002 to 10% in 2030. In the reference scenario, the EU-25's dependence upon imported fossil fuel will increase substantially from 76% in 2002 to 94% in 2030 as domestic resources in the North Sea decline and the gab between gas production and demand continues to widen[17]. In the IEA reference scenario, CO_2 emissions will be 20% above the 2002 level. Power generation and the transport sector will account for 37% and 28% of the total CO_2 emissions respectively. This implies that the commitments made in the Kyoto Protocol, to cut greenhouse gas emissions to 8% below their 1990 level in the period 2008-2012, can only be met by buying emission credits from non-EU countries.

[15] International Energy Agency (2004) p. 252
[16] Ibid. p. 368- 371
[17] Ibid. s. 136

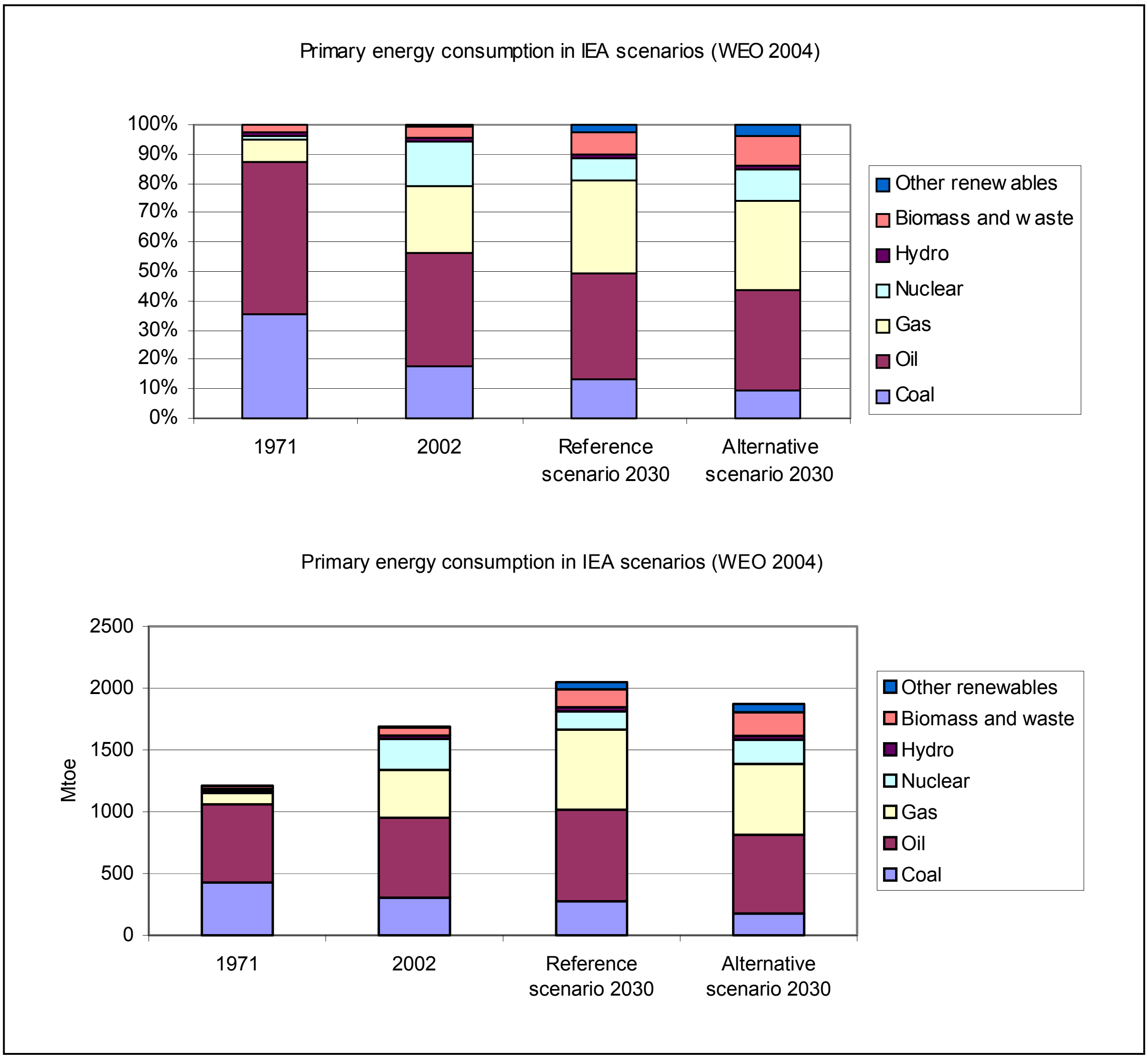

Figure 2.1: Overview of primary energy consumption in EU-25 in IEA reference and alternative scenarios for 2030. Source: IEA (2004).

Under the assumptions of the alternative scenario (see figure 2.1) the IEA projects that the overall primary energy demand will be about 9% lower than the reference scenario. Note that this is still an increase of 12% compared to 2003. A range of policy measures to reach the Kyoto commitment is included in the assumptions of this scenario. Fossil fuel therefore contributes only 71% to the total fuel mix compared to 81% in the reference scenario and coal is the major contributor to this decrease. Renewables are estimated to 16% and nuclear 10%. Under the assumptions of the alternative scenario, the demand for oil is cut by more than 14% compared to the reference scenario. CO_2 emissions will peak around 2020 and then begin to fall toward 2030 where it will be 19% lower than in the reference scenario[18]. In this scenario, both renewable energy and increased energy conservation and efficiency contribute significantly to reaching the Kyoto commitment and to lessen dependence on imported fuels.

[18] Ibid. p. 378

Both scenarios pose significant challenges to the development of the energy system both in terms of environmental performance and security of energy supply. The general picture of the energy situation of the EU-25 as it is presented by the IEA is confirmed by the European Commission's report 'Energy and Transport Scenarios on Key Drivers'[19]. The main findings are presented in figure 2.2.

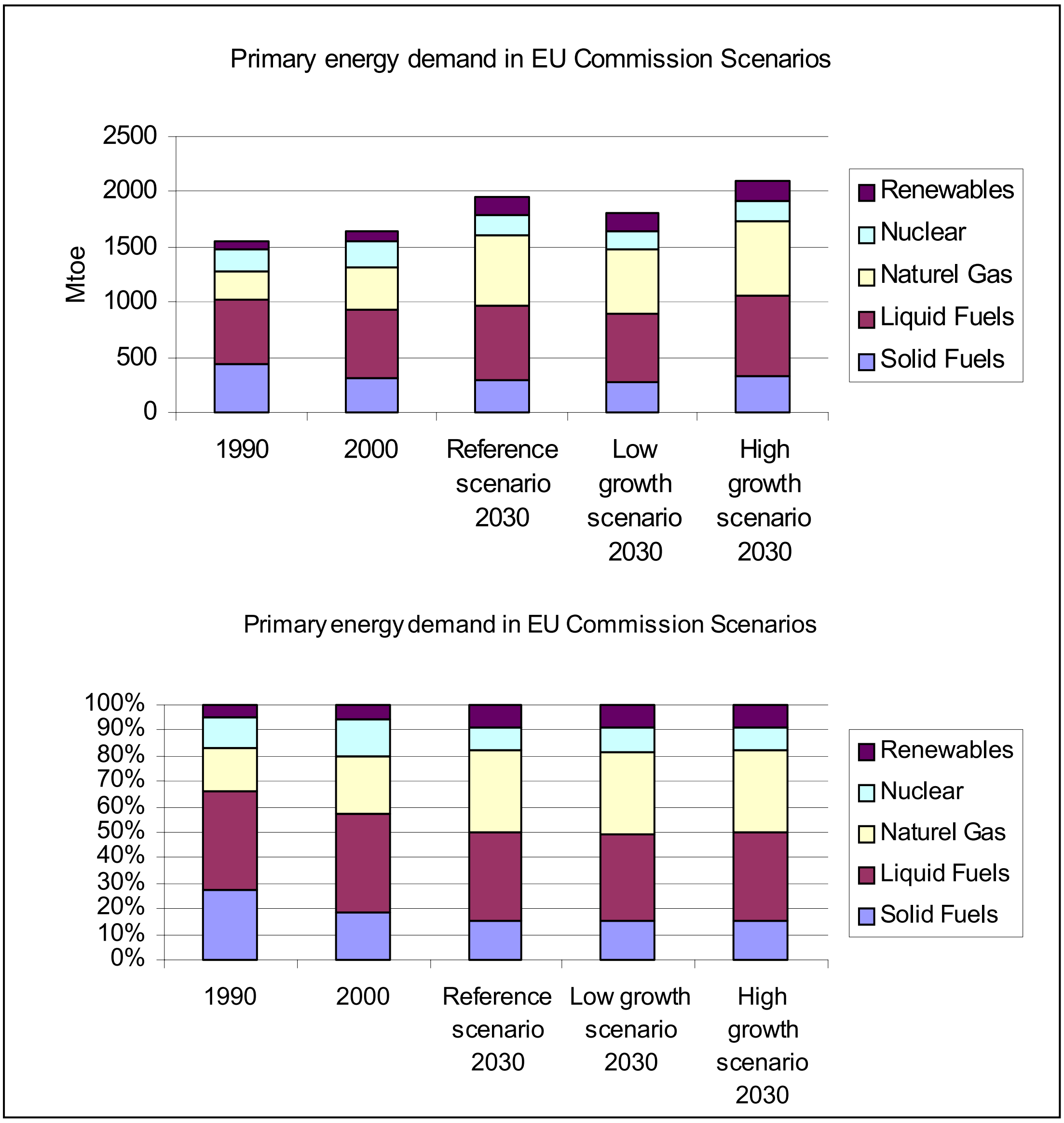

Figure 2.2: Overview of primary energy demand in the EU 25 in the Commission's reference, high and low growth scenarios for 2030. Source: European Commission (2004c).

The European Commission presents three scenarios for the development of primary energy demand in 2030 for the EU-25. The Reference scenario is based on the assumption of a continuation of current trends in the development of fuel prices and economic growth, while the Low growth scenario assumes slow economic growth and lower primary energy demand. In the High growth scenario these trends are reversed[20].

[19] European Commission (2004c)
[20] European Commission (2004c)

Regardless of which IEA or European Commission scenario is emphasised, the overall picture is one of relative decrease in the consumption of oil, coal and nuclear compared to today, while natural gas, renewables, biomass and waste are all on the raise.

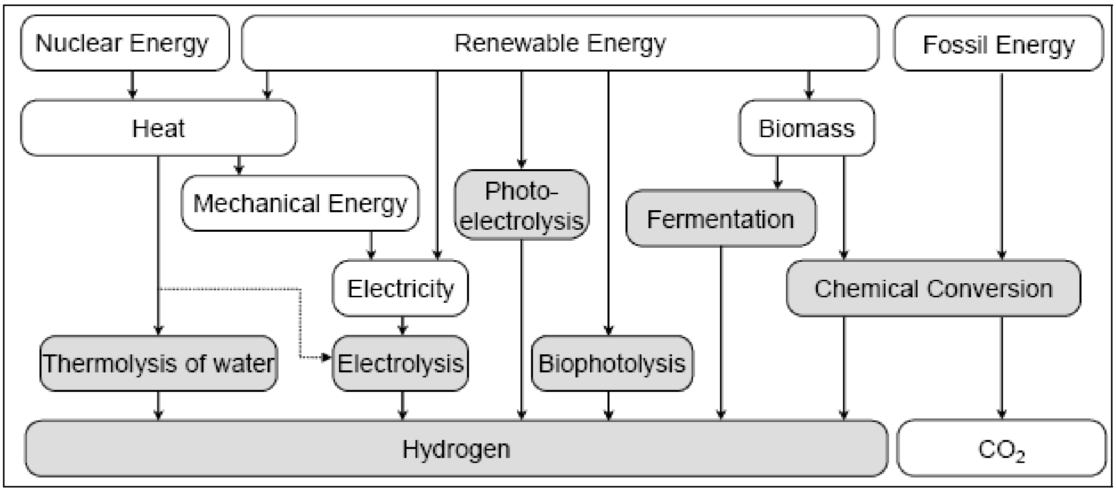

Figure 2.3: Hydrogen production pathways. Source: European hydrogen and fuel cell technology platform (2005) p. 19.

In principle, hydrogen can be produced from any primary energy source. And there are many ‘pathways’ by which various primary energy sources can be converted to hydrogen, see figure 2.3. The mix of available primary energy sources in the individual EU Member States will to a large extent determine which of these pathways become attractive. The general picture of the energy situation in the EU-25, as it is depicted in figure 2.1 and 2.2, covers significant variation between the energy situations of the individual EU-25 Member States[21]. As an example, Member States with large dependency of nuclear power, such as France, or natural gas such as the United Kingdom, or wind power, such as Denmark will have a special interest in particular hydrogen pathways allowing hydrogen production from these primary energy sources.

Another key element in the research and development of hydrogen production technology is the efficiency and cost-effectiveness of these pathways. This will to a large extent determine which primary energy sources become relevant for hydrogen production, and will therefore also determine the role of hydrogen in the overall energy system[22].

[21] European Commission (2005a)
[22] European hydrogen and fuel cell technology platform (2005)

Chapter 3: National RD&D programmes and trans-national co-operation

3.1 The research and innovation programme instrument

National research programmes is one of the later developments of the research systems. Over the second half of the 20th century, research systems have grown and become significantly more complex. While the institutionalisation and funding of public research prior to World War II by and large consisted solely in universities and other higher educational institutions and the basic governmental funding of these institutions, the number of types of institutions and funding functions has increased considerably thereafter[23]. The research councils were created in the period up until the late 1960's. One of the reasons for establishing research councils in the western countries was, originally, to ensure that direction, prioritisation and goal-setting of research were not only a matter of internal institutional strategies and prioritisation, but that some co-ordination across research institutions was happening and that influence from outside science on the direction and goal-setting of research was possible. Development of research should not only be a matter of internal institutional policy at the universities.

Research was increasingly considered an important element in the development of the welfare society and its economic growth. The role of research and innovation for societal development was promoted, for example, by supranational organisations such as OECD. During not least the 1970's, different ministries created a number of new public research institutions working specifically in areas of relevance to the working area of the ministry ('sector research'). For energy technology research this was reinforced by the oil embargoes in the early 1970's. That led to energy research programmes in many OECD countries and to establishment of the International Energy Agency in affiliation to OECD.

3.2 Systems of innovation and governance of research

As governmental research programmes not by themselves create technological innovation, the concept of the 'innovation system' is important in understanding how new technologies emerge and the forces that influence this process. An innovation system can be defined as "*the elements and relationships, which interact in the production, diffusion and use of new and economically useful knowledge*"[24]. The efficiency of an innovation system lies in its ability to serve the following <u>five primary functions</u>[25]: 1) To *create and diffuse 'new' knowledge*; 2) To *guide the direction of the search process* among users and suppliers of technology, i.e. influence the direction in which actors employ their resources; 3) To *supply resources*, including capital, competencies and other resources; 4) To *create positive external economies* through the exchange of information, knowledge and vision; 5) To *facilitate the formation of markets*.

The "new governance" approach considers governance in and by networks of actors. Focus it set on <u>interaction and co-ordination between actors</u> instead of having a hierarchical view on governance[26]. The new governance approach emphasise the importance of decentralised activities and the interplay between centralised and decentralised steering.

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[23] Guston, 2000; Grønbæk 2001
[24] Lundvall cited in Foxon et al. (2004)
[25] Foxon et al. (2004)
[26] March & Olsen (1995); Fuller (2000); Hackmann (2001)

3.3 Trans-national cooperation between national innovation systems

Governments can utilise a variety of policies to support the function of national innovation systems – trans-national cooperation being one with particular interest to the European research. Trans-national cooperation between national innovation systems in Europe has mainly taken place in the form of bilateral cooperation between just two countries in a field of common interest, while multi lateral cooperation between several countries is less common. Within the framework of the ERA-NET, the aim of trans-national cooperation moves somewhat beyond bi- or multi lateral cooperation and towards mutual opening of national RD&D programmes to support the development of a European Research Area[27].

The role of trans-national cooperation is directly related to the five primary functions of the national innovation system described in the beginning of this chapter. The aim of trans-national cooperation is to strengthen each of these functions through coordinated efforts between national innovation systems. TAFTIE (2005) identifies a number of ways in which trans-national cooperation can strengthen national innovation systems:

- To supplement own area of knowledge
- To supplement own R&D capacity
- To increase skilled R&D resources
- To ensure unbroken R&D activities within the value chain in international business processes
- To operate with R&D in the vicinity of production in international business processes
- To ensure the priority position in getting knowledge from becoming norm and standards, or even act in sketching contents for them
- To find partners for production and marketing
- To improve market position
- To learn about international operations
- To launch new products onto the markets
- To create business image

The ability of a national innovation system to reap these advantages is to a large extent determined by its international orientation. As we will be examining later in this report, a host of political, cultural, organisational, financial and technical problems can hinder the effective exchange of knowledge between national innovation systems. A range of instruments exists to overcome these barriers. Optimat identifies seven instruments for facilitating trans-national cooperation between national RD&D programmes[28]. See box 2.

For these instruments to work successfully, it is important that trans-national cooperation is clearly identified as a means to an end. Real need provides the basis for successful trans-national cooperation[29]. The success of trans-national RD&D efforts relies in no small part on real complementarities between the RD&D efforts of the national innovation systems, both in terms of overall objectives and practical expertise.

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[27] Optimat ltd. (2005) p. 2
[28] Optimat ltd. (2005) p. 2
[29] TAFTIE (2005) p 11

3.4 Trans-national cooperation on RD&D in Europe

Box 2. Instruments for facilitating trans-national cooperation between national RD&D programmes

1. Allowing national scientists to use programme budgets to participate in trans-national research
2. Allowing national scientists to use programme budgets to participate in cross-border technology transfer projects
3. Using programme budgets to support cross-border mobility or training of scientists
4. Using programme budgets to support participation in European or international committees or networks
5. Utilising research capacity and expertise from other countries by allowing foreign experts to participate in the national programme (with or without funding)
6. Utilising research capacity and expertise from other countries by allowing participants to use foreign experts as subcontractors
7. Using evaluators from other countries

Source: Optimat (2005)

Trans-national cooperation on RD&D takes place on three levels: Policy level, programme level and project level. During earlier European Framework Programmes (FP) solid experience has been gained on cooperation on project level. That is cooperation among universities, research centres and industry. But very little experience has been gained on programme level. FP6 first tackled this through three new initiatives[30]:

- the **CREST action on mutual opening of national programmes**
- the **ERA-NET scheme**
- use of the **Article 169** in the Treaty.

CREST is an advisory body whose function is to assist the Council and the Commission in performing the tasks incumbent on them in the sphere of research and technological development. After the informal ministerial meeting of Girona in early 2002, CREST launched in March 2002 a number of pilot actions for the mutual opening of national programmes in five areas (marine science, plant genomics, chemistry, astrophysics, complexity and complex systems). During 2003 CREST came to the conclusion that the ERA-NET Scheme is the most suitable mechanism to pursue this exercise.

The **ERA-NET Scheme** (European Research Area) is about the coordination and cooperation of national and regional programmes and as such, it aims at the national and regional (in the EU Member States and the Associated States) programme makers and managers. These are, in most countries, either working in the Ministries or working in national funding agencies, which implement programmes on behalf of their governments. The ERA-NET Scheme is implemented via open call for proposals. The Commission pays all additional costs related to the coordination up to 100%. One of the benefits of the ERA-NETs is that the cooperation, coordination and a free movement of knowledge and scientists enable the different national systems to take on RD&D tasks collectively that they would not have been able to tackle independently. HY-CO is one of these different ERA-NET programs, although it is still characterized by low trans-national cooperation.

Article 169 refers to the Article in the Treaty that enables the Community to participate in research programmes undertaken jointly by several Member States including participation in the structures created for the execution of national programmes. Even though Article 169

[30] European Commission, DG RTD (2004)

has not been used before FP6, a few important lessons have already been learned[31]. Among the lessons is that projects must have a clear political pertinence, good visibility and involve preferably a large number of Member States. Furthermore, the European added value must be clearly demonstrated. Finally, the experiences show that the time-consuming nature of the required co-decision procedure should not be underestimated.

Today, a number of examples of successful trans-national cooperation programmes exist in the EU. They range from programmes within the energy area to the space industry. The different programmes and schemes also vary in terms of how they are organised, funded and managed[32]. Furthermore, the time perspectives are very different. Given the variety of the programmes and schemes mentioned in this section, it is important to stress that a universal and all-encompassing model for how trans-national cooperation or other kinds of collaborative work should take place does not exist. The appropriate model for collaboration will be always context-specific and will thus depend on the circumstances and the character of the collaboration[33]. It is therefore difficult to be prescriptive on the most appropriate approach to trans-national cooperation for a country.

3.5 Models for financing trans-national cooperation in Europe

A number of financial models used in collaboration schemes between national programmes exist today. Some are most suited for long-term and continuous RD&D collaboration (for example the centralised common pot funding model used by the European Space Agency), whereas others are best suited for projects of more temporary nature. The different financing models identified by the TAFTIE study are listed in figure 3.1.

While the centralised common pot financing model is mainly suitable for collaboration activities in basic research and continuous schemes, it is less suited for time-limited RD&D projects, which includes the majority of trans-nations cooperation projects. Instead, TAFTIE points to *a decentralised common pot financing methods*, which appears to be best suited for industry-related strategic research, technological development and innovation collaboration schemes. It is particularly well-suited for financing of time-limited collaborative RD&D actions, which is often the category most trans-national cooperation agreements fall under. However, the widely used funding model in national RD&D programmes, the preferential access financing model, is actually **not** well-suited for collaborations between national programmes.

[31] European Commission, DG RTD (2004)
[32] TAFTIE (2005)
[33] TAFTIE (2005)

Models for financing trans-national cooperation in RD&D	Examples
a) Centralised Common Pot Requires a central organisation with a legal basis. Funds gathered by means of taxes, fees, etc. according to, for example, participants GNP or RTDI investment.	
aa) Centralised Common Pot - without guaranteed fair return ("juste retour")	• European RTD Framework Programmes • Research programmes of European Science Foundation (ESF) • RTDI programmes of Nordic Innovation Centre
ab) Centralised Common Pot - with adjustment of return	• Space science programmes ESA
b) Decentralised Common Pot - with mutual follow-up of separate national financings	• RTDI funding procedures of the French-Norwegian Foundation • The German–French programme Deufrako on land transport. • The EDCTP programme according to Art.169 of European Treaty
c) Simultaneous National Funding National authorities handle applications and make decisions according to commonly decided plans and schedules.	• The Finnish – Swedish – Norwegian collaborative ICT programme NORDITE • The Swedish-Israeli joint programme on telecom applications SIBED
d) Preferential Access Financing Not well suited for collaboration between national programmes.	• Used widely in national programmes

Table 3.1. Models for financing trans-national cooperation in RD&D. Source: TAFTIE (2005)

3.6 Best practices for trans-national cooperation

It has been pointed out during the interviews that valuable lessons can be learned by looking at how other countries organise trans-national cooperation. The HY-CO interviewees argue that Canada is a role model for organising trans-national cooperation. Canada has managed to become one of the key players within the field hydrogen and fuel cells and has large and ongoing RD&D efforts in the area. The EU could learn from how Canada utilises trans-national cooperation and partnerships. What is characteristic about Canada and its approach to trans-national cooperation is that the country is genuine interested in trans-national cooperation and very open towards setting up partnerships. An example of the Canadian approach to trans-national cooperation is the use of open seminars aimed at identifying and matching potential RD&D partners. Potential partners, including both Canadian scientists and foreign scientists, are invited to a focused two/three day open meeting with the purpose of identifying RD&D areas and topics where trans-national cooperation could be of mutual interest and benefit for the invited participants. Interested partners are subsequently grouped according to their interests and a shared technology and cooperation platform is created around the group.

It is interesting to note that Japan, another leading country with the hydrogen and fuel cell area, also invites its international partners to participate in its research calls.

The Canadian and Japanese experiences and the results of the HY-CO interviews strongly suggest that the facilitation of similarly open meeting processes and arrangements could be a key role for the EU. It could be a practical and non-bureaucratic way to foster trans-national cooperation. The role of the EU in boosting trans-national cooperation will be discussed in greater details in a later section.

Furthermore, best practice schemes derived from the experiences from other ERA-NET reports are presented in a recent study[34]. See table 3.2. In the table, a number of barriers to trans-national cooperation identified within other ERA-NETs are listed together with the suggestions on how to overcome these.

[34] Optima (2005)

	BARRIERS	ENABLERS		
		Ministries	Agencies/Councils	Programme Administrators
Policy level barriers	Policy to achieve national priorities through internal capacity building	Adopt a more open policy to encourage innovative trans-national approaches	Evaluate the potential and actual impact of European collaboration	Provide case study examples and success stories of trans-national projects
	The legal constitution forbids payments to non-residents	Remove legal restrictions	Clarify legal position and propose options to overcome restrictions	Ask for clear guidance on legal position
	Another organisation deals with international activities	Encourage inter-nationalisation of all national research funding organisations	Increase international networking activities	Take advantage of international networking opportunities
	No significant policy changes to encourage trans-national activities	Develop top-down strategy on coordination of national programmes	Review bottom-up experience of bilateral and multilateral cooperation	Provide case study examples and success stories of trans-national projects
	Inequality of investment makes it impractical to design joint programmes	Consider more integrated approaches to economic and technical cooperation	Encourage participation in multilateral programmes	Adopt flexible approach to 'a la carte' funding of trans-national projects
Programme level barriers	Sufficient volume of high quality applications from internal capacity	Provide additional, dedicated budgets for trans-national activities	Develop programmes or instruments that are trans-national by design	Highlight lost opportunities for trans-national value added
	No explicit criteria that encourage trans-national activities	Develop top-down strategy on coordination of national programmes	Use selection criteria to encourage trans-national projects	Ensure selection criteria does not discriminate against trans-national projects
	Source of funding does not allow use of funds for trans-national activities	Analyse reasons why source of funding does not allow funding non-residents	Identify and adopt innovative approaches from other countries	Highlight lost opportunities for trans-national value added
	Programme owner has limited experience of pan-European collaboration	Encourage internationalisation of all research programme designers and administrators	Encourage staff to be more involved in international networks	Increase involvement in pan-European collaborative programmes
	Different national rules and cycles make it impractical to collaborate	Identify priority areas for coordination and harmonise where appropriate	Provide a degree of flexibility in programmes to allow alignment	Establish coordination interface with related national programmes in other countries
	The programme is designed to address country-specific issues	Encourage inter-nationalisation of all research programme designers and administrators	Identify other countries with similar issues and identify areas for value adding cooperation	Identify programmes in other countries that are addressing the same issues
	Financial administration systems are not designed to cope with non-national contracts	Use agencies to administer any non-national contracts	Design systems to cope with non-national contracts and currencies	Allow participants to use subcontract option where appropriate
	Insufficient knowledge of similar national programmes	Encourage inter-nationalisation of all research programme designers and administrators	Allow programme administrators to travel to meetings, conferences, etc.	Develop links with peers in other countries through participation in networks and events
Project level barriers	National researchers not keen to see more budget used for trans-national activities	National researchers not keen to see more budget used for trans-national activities	Develop and promote policies for increased investment in trans-national activities	Use case studies to encourage more user interest in trans-national activities
	No demand from national applicants for inclusion of foreign partners	Encourage involvement of world class researchers by setting explicit allowable budgets	Design selection criteria to encourage more international consortia	Provide explicit rules on the options to use foreign experts
	Administration costs of trans-national projects outweigh the benefits	Provide infrastructural funding to facilitate more inter-nationalisation of national programmes	Develop internal processes to enable efficient administration of trans-national projects	Take advantage of multilateral facilitating frameworks to reduce administration costs

Table 3.2: Barriers and enablers. Source: Optimat VDI/VDE-Innovation + Technik GmbH (2005)

3.7 Cooperation frameworks within trans-national cooperation

The mere fact that any kind of cooperation between different groups of people will entail some coordination problems and costs, illustrates that cooperation will always be a time and resource demanding activity. In other words, trans-national collaboration always causes some "disturbance" to the usual practices of national programme management.[35] For the individual programme manager, trans-national cooperation can easily be perceived negatively due to the bureaucratic costs involved and the potential loss of human resources and funding. This is especially the case if the reasons or motivation for engaging in trans-national cooperation are not clearly stated from the beginning and the benefits of such cooperation are unclear. One must therefore expect that some sort of barriers will always exist for trans-national cooperation.

Overcoming these barriers or problems can be an issue of addressing structural problems, such as legal barriers (ex. that a RD&D programme is not open to foreign participation). More importantly, however, successful trans-national cooperation is also dependent on the motivation and commitment of the scientists, programme managers and other stakeholders involved. It is therefore important to address these barriers in order to be able to exploit potential opportunities for trans-national cooperation.

The work of TAFTIE concludes that a strong will and a real desire to engage in trans-national cooperation are prerequisites for any successful cooperation.[36] In order to motive scientists and programme managers to participate in trans-national cooperation, a perceived *need* for such cooperation must therefore exist. For the scientist or programme manager, the real or perceived benefits of engaging in trans-national cooperation must outweigh the real or perceived costs. It is unlikely that a top-down imposed initiative aimed at "forcing" scientist into trans-national cooperation will be truly successful, unless the preconditions mentioned above are met. A pragmatic and realist approach to trans-national cooperation and to the design of schemes for trans-national cooperation is therefore needed.

In order to minimize the inherent coordination problems and keep bureaucracy at an acceptable level, the model or organisational setup for collaboration should be kept as simple as possible. While the procedures for collaboration can be negotiated between two programme authorities fairly easier, it can become a problem between three parties where negotiations will be more difficult, but between more than three parties, negations over shared collaboration procedures will be even more difficult and perhaps impossible.[37] Furthermore, collaboration between programmes with similar cultural and institutional backgrounds and values is easiest. Based on these insights, TAFTIE (2005) concludes that collaborative actions should thus be built up from bi- or tri-lateral consortia. Furthermore, the resulting collaborative programme may contain many sub-themes which national (or regional) programmes can join. (see figure 3.1).

[35] TAFTIE (2005)
[36] ibid
[37] TAFTIE, Framing Collaboration Models between National Research and Technological Development Programmes, Final draft, July 2005

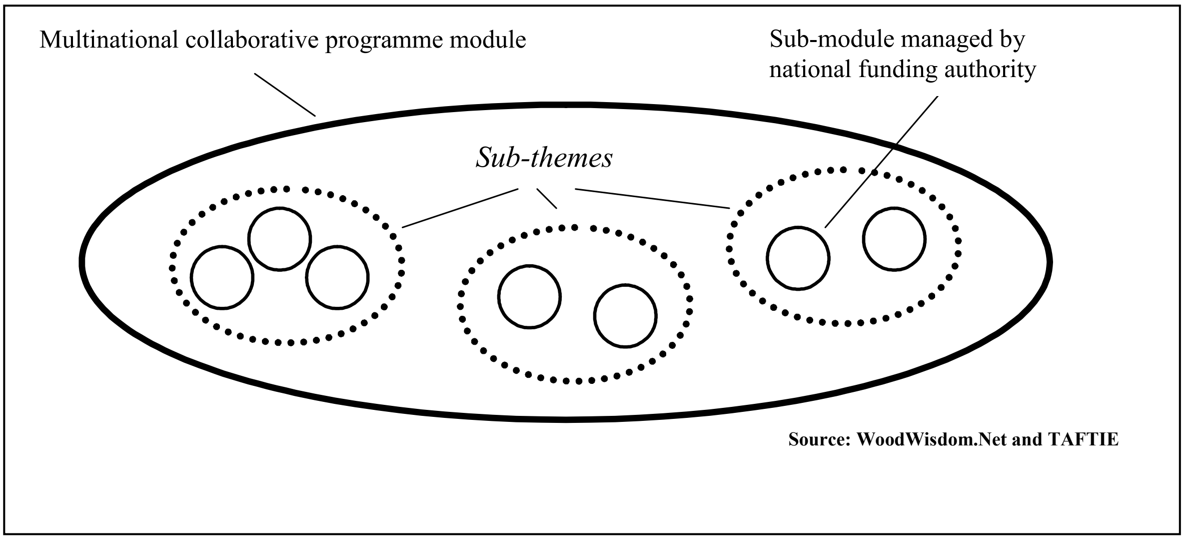

Figure 3.1 Multinational collaborative programme modules. Source: WoodWisdom.Net and TAFTIE (2005)

Chapter 4: Complementarities and gaps between the national H_2&FC RD&D programmes

Based on the information obtained during the study, it is clear that a wealth of RD&D activities is currently under way in Europe. It is also clear that few research programmes are alike. Research activities across Europe differ significantly with respect to the national goals and drivers that motivate them, the expertise they rely on, the technology they seek to develop and means of support and funding. Finally, they differ in the scope of their international orientation and the degree to which they involve foreign expertise. As already emphasised, complementarities between national strategic interests are essential if lasting trans-national cooperation is to be established and the benefits of such cooperation is to be realised.

This chapter aims to assess the complementarities and gaps between the national RD&D programmes of 27 European countries in the field of hydrogen and fuel cell technology. Complementarities and gaps between RD&D programmes are in themselves moving targets as motivations, priorities and expertise changes over time. The assessment of complementarities and gaps between RD&D programmes in Europe carried out within the scope of this report will aim at national priorities, technological portfolio, means of funding and level of international cooperation as they are reflected in national RD&D programmes in the countries studied.

4.1 Political goals and priorities

The goals for developing hydrogen and fuel cell technology are many. It is often very specific national priorities that are the main drivers behind hydrogen and fuel cell research. When asked about their general motivations for developing hydrogen and fuel cell technology, representatives from the respondent countries surveyed replied as shown in figure 4.1.

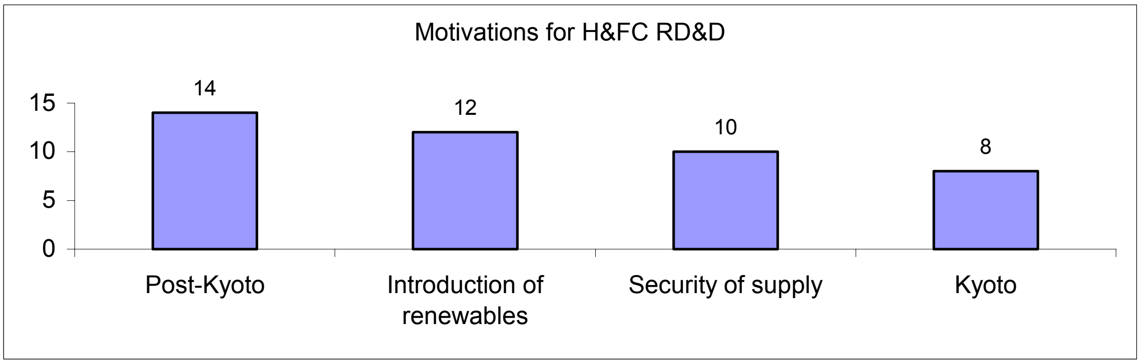

Figure 4.1: Motivations. Distribution of answers from 15 countries. Source: HY-CO survey.

Kyoto is generally the least motivating factor, while Post-Kyoto concerns are deemed significantly more important. Furthermore, among other important motivating factors indicated in the survey were issues like industrial competitiveness, economic growth and job creation, which underline Lisbon-agenda issues. This study has elaborated on this. The interview indicated that national automotive and energy related industries often are influential drivers for H_2&FC RD&D. See Table 4.1.

Security of supply	Economic	Environmental	Scientific	Automotive industry issues	Renewable industry issues	Nuclear energy issues
Austria Czech Denmark Finland France Germany Greece Iceland Spain Sweden United kingdom	Denmark Finland France Germany Greece Iceland Italy Portugal Spain Sweden United Kingdom	Belgium Denmark Luxembourg Netherlands Norway Portugal Spain Sweden United Kingdom	Czech Estonia Ireland Latvia Lithuania Poland Portugal Slovenia	Austria Italy Germany Sweden	Denmark	France

Table 4.1: Primary national motivations for H_2&FC RD&D.

As it can be seen, the three main overlapping motivations for conducting H_2&FC RD&D coincides with the broader EU objectives outlined in the European Hydrogen and Fuel Cell Technology Platform[38]: Security of supply, green house gas reduction and economic growth. This finding confirms the conclusions of the ESTO (2005). It is also clear that the majority of the New Member States are at this point primarily motivated by scientific interest rather than broader environmental or industrial objectives. In addition to the shared motivations of the majority of European countries it is worth noticing the special priorities of France and Denmark, showing the role of national industrial priorities in guiding H_2&FC efforts.

It is important to note that although these primary motivations can be identified, the specific national goals of each country vary both in terms of size of effort, level of ambition and time horizon. Political goals and priorities also differ in the way they are formulated and translated into action.

The majority of countries involved in hydrogen and fuel cell RD&D has made their main motivations and objectives explicit in a ‘hydrogen and fuel cell strategy’. The nature of this varies enormously from country to country. Among the most specific national hydrogen and fuel cell strategies are those based on a ‘national roadmap’ outlining expectations to future technological development at the national level.

[38] The European Hydrogen and Fuel Cell Technology Platform (2004), p. 16

Only a small number of the countries studied have one or more separate national programmes dedicated solely to hydrogen and fuel cell research. This can be summarised as shown on figure 4.2 below:

	Dedicated national H_2&FC programmes	Generic national H_2&FC programmes
National Roadmap	France, Denmark, Finland	Norway
No roadmap	Germany, Sweden, Italy	United Kingdom, Iceland, Czech, Austria, Estonia, Belgium, Greece, Latvia, Ireland, Portugal, Poland, Lithuania, Spain, Luxembourg, Netherlands

Figure 4.2: National RD&D programmes.

National RD&D programmes dedicated specifically to hydrogen and fuel cell technology are the exception in Europe. Usually national RD&D activities are conducted as part of generic research programmes directed at energy, environment, chemistry, materials or other broader research issues. In addition to the national generic and dedicated RD&D programmes, several regional governments in Germany, Spain and Belgium have dedicated RD&D programmes running parallel to those at the national level. As it can be seen, only four of the countries active in hydrogen and fuel cell RD&D have drawn up national roadmaps for guiding long-term efforts.

In conclusion, the goals and priorities behind RD&D efforts into the field of hydrogen and fuel cell technology are long-term and are meant to address problems beyond the immediate planning-horizon of national interest. This is perhaps the reason why goals and priorities within the field of hydrogen and fuel cell technology are often ambiguously formulated or not formulated at all. Amongst the countries that have – in one form or another – formulated national goals and priorities, there is a clear overlap between these and the overall objectives of the European Union. Furthermore, large national industries play a clear role in setting the national research agenda. One can conclude that there are clear overlaps of interest between the countries that have set objectives for H_2&FC RD&D in Europe. It should also be noted that a large group of countries have set no national objectives for H_2&FC technology and are primarily driven by scientific interest formulated by public research institutions. Opportunity to further clarify national RD&D objectives and the role of the trans-national cooperation in these countries is clearly present.

4.2 Technological portfolio and expertise

Hydrogen and fuel cell technology is in reality a broad range of very diverse technologies requiring an equally diverse range of skills to master. Also, research activities are conducted at various stages of technological development, from basic research to early commercialisation. This is reflected in the diversity of the technological portfolio and expertise of the individual European research activities.

As it can be seen from Figure 4.3 below, the type of research that national hydrogen and fuel cell research programmes are directed at, vary significantly between the European countries.

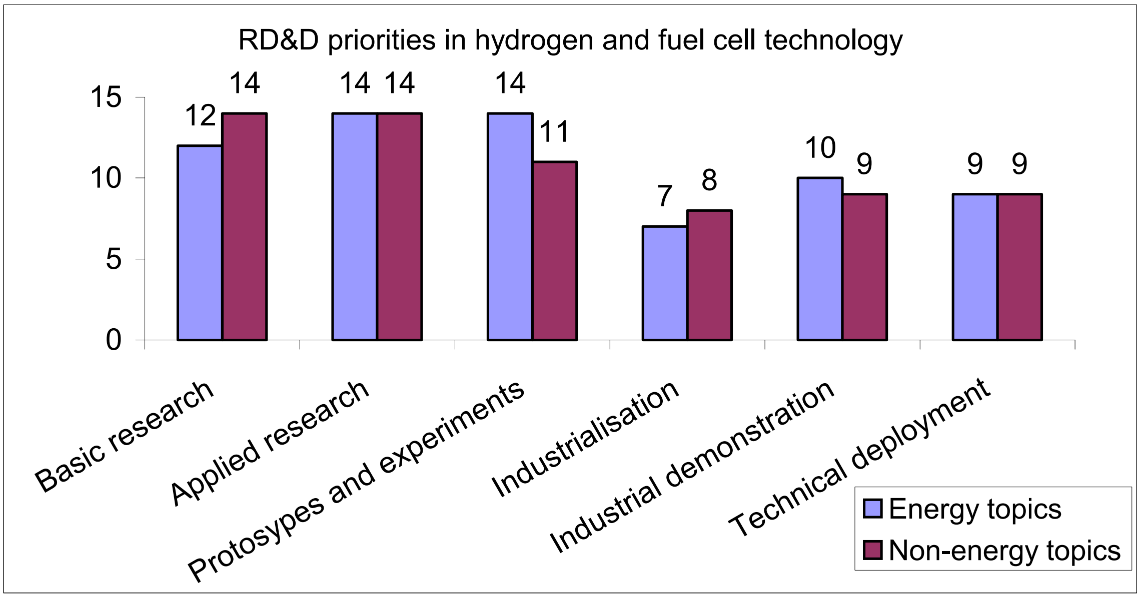

Figure 4.3: Priorities in national programmes. Distribution of answers from 15 countries. Source: HY-CO Survey.

Basic and applied research along with prototypes and experiments are prioritised areas in the development of hydrogen and fuel cell technology at this stage. Industrialisation and industrial demonstration, especially in terms of energy related technologies, has a slightly lower priority. That non-energy related technologies are generally prioritised higher in terms of industrialisation could be due to the fact that hydrogen is a bi-product from several chemical industries and are as such already in commercial use in other industrial processes. The countries deviating the most from the general picture of the European research priorities are Iceland, Luxembourg, Spain and Finland. In these countries, basic research plays only a minor role next to applied research, demonstration and deployment in cooperation with private industry[39]. This coincides with these countries' emphasis on economic growth and job-creation as illustrated in table 4.1 above. There is also a strong positive correlation between one-sided emphases on basic research and lack of clearly defined national RD&D objectives for hydrogen and fuel cell technology.

4.3 Hydrogen production

As indicated in Figure 4.1, hydrogen and fuel cell RD&D is often motivated by the introduction of renewable energy. This is especially true for countries with large existing shares of renewable energy contributing to the national energy system. The purest example

[39] HY-CO Survey

of this is Iceland's hydrogen and fuel cell strategy, which is based solely on hydrogen production from renewable energy sources. This is also true for a host of other countries, while a second group of countries emphasises natural gas as the main pathway for hydrogen production. A third group can be characterised as go-betweens, prioritising natural gas and renewable energy sources evenly. National RD&D priorities on hydrogen production is summarised in table 4.2.

Natural gas	Biomass	Solar Power	Geothermal	Hydro-power	Wind power	Nuclear power	Undetermined
Belgium Czech Denmark Germany Italy Netherlands Norway United Kingdom	Austria Czech Denmark Greece Sweden	Estonia Norway Spain Sweden	Iceland Italy	Iceland Norway	Denmark	France	Estonia Finland Ireland Latvia Lithuania Luxembourg Poland Slovenia Spain

Table 4.2. National RD&D priorities in H_2-production.

The categories shown are by no means exhaustive and have significant overlaps. Large countries with a broad range of RD&D activities, like Spain, France, Germany, Italy and the United Kingdom, or countries with very diverse energy systems such as Finland, generally has very broad or unspecified priorities for RD&D in hydrogen production. As it can be seen, a large group of countries have no particular RD&D priorities in this area.

Although hydrogen production from chemical industries is an important short-term priority in the European Hydrogen and Fuel Cell Platform, it is rarely mentioned in national RD&D priorities of the European countries. The most explicit example is the Air Liquide, which is a hydrogen pipeline/infrastructure established between chemical industries in France, Belgium and The Netherlands. Also, The Czech Republic explicitly mentions the importance of this source of hydrogen. Figure 4.4 illustrates the average importance given to techniques for hydrogen production in the 18 countries surveyed.

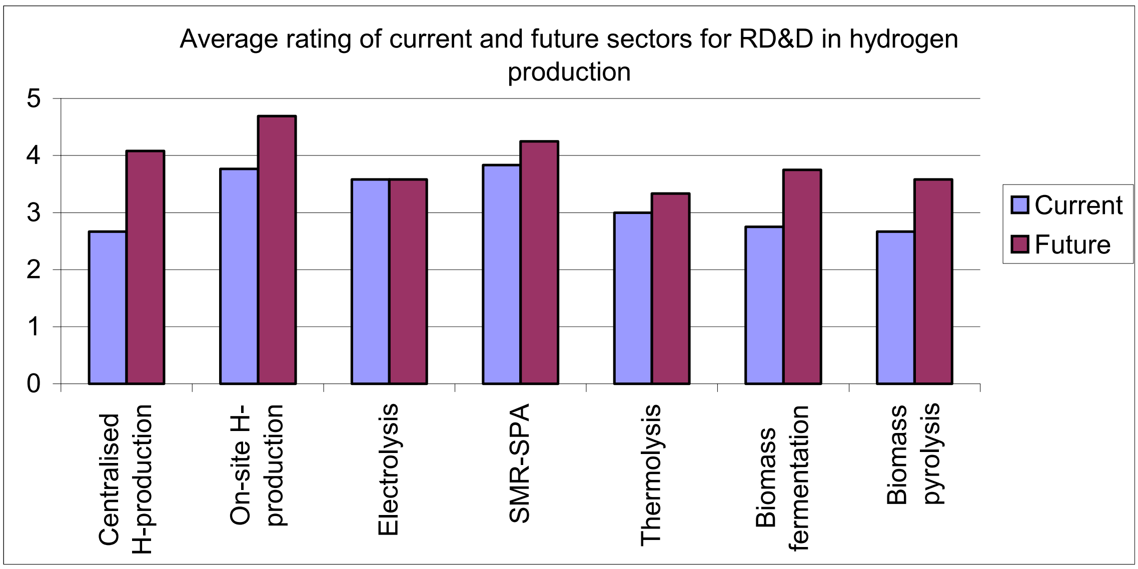

Figure 4.4: Average rating (1-6) of RD&D sector by importance. Source: HY-CO Survey.

In terms of hydrogen production methods, on-site distributed production is on average rated higher than centralised production both in the short and long-term. Among the hydrogen production technologies, reformation of natural gas (SMR-SPA) is the most highly rated technology and significant expectations are put on its importance in the future. Also electrolysis is highly rated but, as it can be seen, its importance is not expected to grow significantly in the future. Although the two biomass-technologies are not highly rated for their current importance, expectations for their future importance are high. In the medium term, the H_2&FC Platform foresees that: *"Most stationary applications will run on natural gas by 2020[40]"*

The national RD&D priorities of the European countries in terms of emphasis on RD&D in the area of hydrogen production technologies is summarised in table 4.3.

Electrolysis	**Steam reforming**	**Partial oxidation**	**Biomass fermen-tation**	**Artificial photo-synthesis**	**Thermolysis**	**Biomass pyrolysis**	**Un-determined**
Austria Belgium Denmark Germany Iceland Iceland Italy Lithuania Norway Spain UK	Belgium Denmark France Germany Italy Nether-lands Norway Spain UK	Denmark France Germany Italy Nether-lands UK	Austria Denmark Norway Spain UK	Estonia Sweden	France Greece	Finland Greece	Czech Ireland Latvia Luxem-bourg Poland Portugal Slovenia

Table 4.3: National RD&D priorities in H_2-production technology

The main emphasis is put on technologies corresponding to general national energy priorities as outlined in table 4.2. France, Spain and Sweden are noticeable in the sense that they have unique priorities in their national strategies. France emphasises hydrogen production from high temperature nuclear energy sources, while Spain mentions gasification of coal as an important possibility. In Sweden, artificial photosynthesis is a central part of the short-term goals of the national hydrogen and fuel cell strategy. Table 4.3 illustrates how the tables presented here can point to obvious areas for trans-national cooperation. Within artificial photosynthesis Sweden and Estonia are, for example, the only two identified HY-CO members that are active within this niche area. Similar observations can be done within the field of thermolysis where France and Greece are the only identified active countries within this specific area.

4.4 Hydrogen storage and distribution

Figure 4.5 shows that several storage and distribution options are being considered and prioritised in national RD&D programmes.

[40] European Hydrogen and Fuel Cell Platform (2004) p. 26

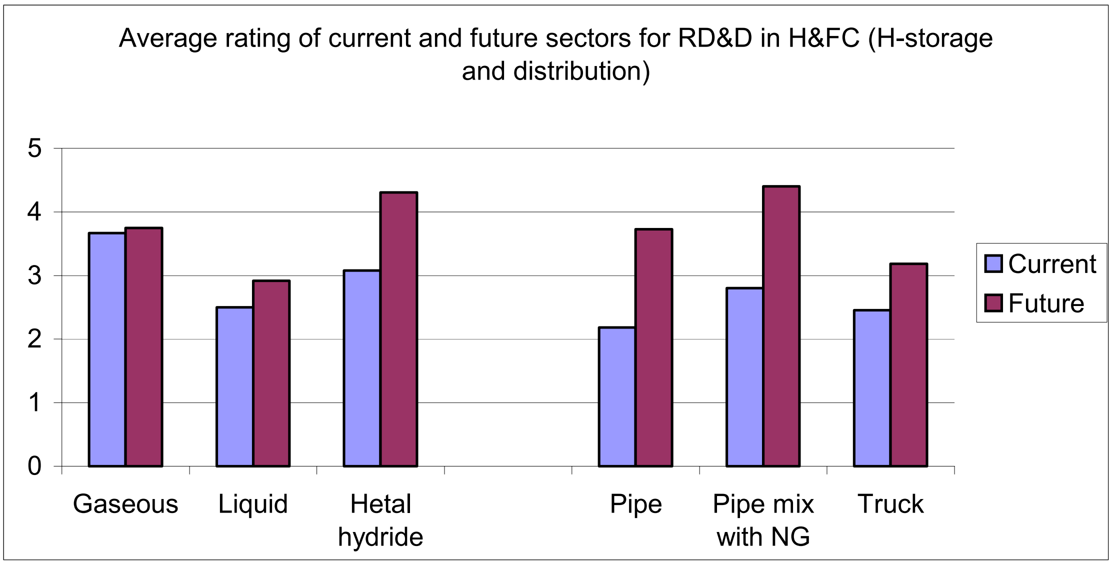

Figure 4.5: Average rating (1-6) of RD&D sector by importance. Source: HY-CO Survey.

Storage of hydrogen in gaseous form is on average the highest rated storage option in terms of current importance and it is expected to remain an important option for the future. Future expectations are also high for the option of hydrogen storage in metal hydrides, while, hydrogen storage in liquid form has the lowest average rating. When asked of additional technologies with particular importance the most frequently mentioned storage option is hydrogen storage in nano-materials.

In terms of hydrogen distribution methods, it is clear that the pipeline-based options are rated highly in terms of future importance. Especially pipeline distribution of mixed hydrogen and natural gas is highly rated both in terms of current and future importance. This is mainly due to the fact that several European countries already have extensive natural gas grids in place and that clear synergies between distribution of natural gas and hydrogen are envisaged.

In the broader view, the priorities placed on the individual storage options in national RD&D programmes are summarised in table 4.4.

Metal hydrides	H_2 Gas storage	Nano structures	H_2 Liquid storage	Undetermined
Austria Denmark Finland France Iceland Lithuania Norway Spain	Austria Belgium Czech Denmark France Germany	Austria Greece Italy Norway Spain	Austria Belgium Spain	Estonia Ireland Latvia Luxembourg Netherlands Poland Portugal Slovenia Sweden

Table 4.4: National RD&D priorities in H_2-storage technology

National RD&D priorities are distributed across the four general storage options. The largest overlap is to be found in the area of metal hydrides and storage of hydrogen gas. A number of countries are explicitly prioritising RD&D efforts in nanotechnology.

Returning to hydrogen distribution technology, the national priorities are summarised in table 4.5.

Shared NG and H_2 pipeline	Dedicated H_2 pipeline	Truck transport	Undetermined
Belgium Denmark Finland France Germany Greece Spain UK	Austria France Iceland Spain UK	Belgium Czech Iceland	Estonia Ireland Italy Latvia Lithuania Luxembourg Netherlands Norway Poland Portugal Slovenia Sweden

Table 4.5: National RD&D priorities in H_2-distribution technology

Priorities in hydrogen distribution technologies are closely connected to the role of natural gas in the national energy systems. The largest overlap in national RD&D priorities is on shared natural gas and hydrogen grids. Most of the countries prioritising this option have well-developed natural gas grids and places significant emphasis on natural gas, both in terms of its current applications and future role as a potential source of hydrogen production[41]. It is worth noticing that a large group of countries have no specified RD&D priorities in this area.

4.5 Hydrogen conversion – Fuel cells

The national RD&D priorities in fuel cell technology are summarised in table 4.6. By far the largest overlap between European research priorities can be found in the field of PEMFC technology closely followed by SOFC. Several countries have overlaps in more specialised efforts in other areas of fuel cell.

PEMFC	SOFC	DMFC	AFC/PAFC	MCFC	ICE	Un-determined
Austria Belgium Denmark Finland France Germany Greece Italy Netherlands Norway Slovenia Spain Sweden UK	Austria Denmark France Germany Italy Netherlands Norway Portugal Spain Sweden UK	Austria Finland Germany Portugal Sweden UK	Finland Germany UK	Germany Italy Netherlands Portugal	France Germany Spain	Estonia Iceland Ireland Latvia Lithuania Luxem- bourg Poland

Table 4.6: National RD&D priorities in H_2-usage technology

[41] International Energy Agency (IEA) – www.iea.org (last accessed 30/11/05)

The results presented in table 4.6 are consistent with the results obtained from the HY-CO explorative workshop in Oslo. In a workshop with the participation of Germany, Portugal, Italy, Belgium, Greece, Finland, Denmark, Spain, Czech Republic, Slovenia, representatives from these countries concluded that cooperation is most feasible for research for the PEFC and SOFC technology, while MCFC and DMFC are retained as options for cooperation.

The preferred research themes identified for cooperation within the areas of fuel cells by the participants are illustrated in table 4.7. The numbers in the table refer to the number of votes from the various countries represented in the workshop.

	PEFC	SOFC	MCFC	DMFC
Cell	5	5	1	3
Stack	4	6	1	2
System	5	5	2	2
Application	5	5	1	1

Table 4.7: Preferred research themes in fuel cells. Source: HY-CO Explorative Workshop

4.6 Application of hydrogen and fuel cell technology

In the survey stationary, transport, portable and socioeconomics were rated in terms of their current and future importance as research sectors. The 18 countries participating on the survey rated the issues on average as shown in figure 4.6.

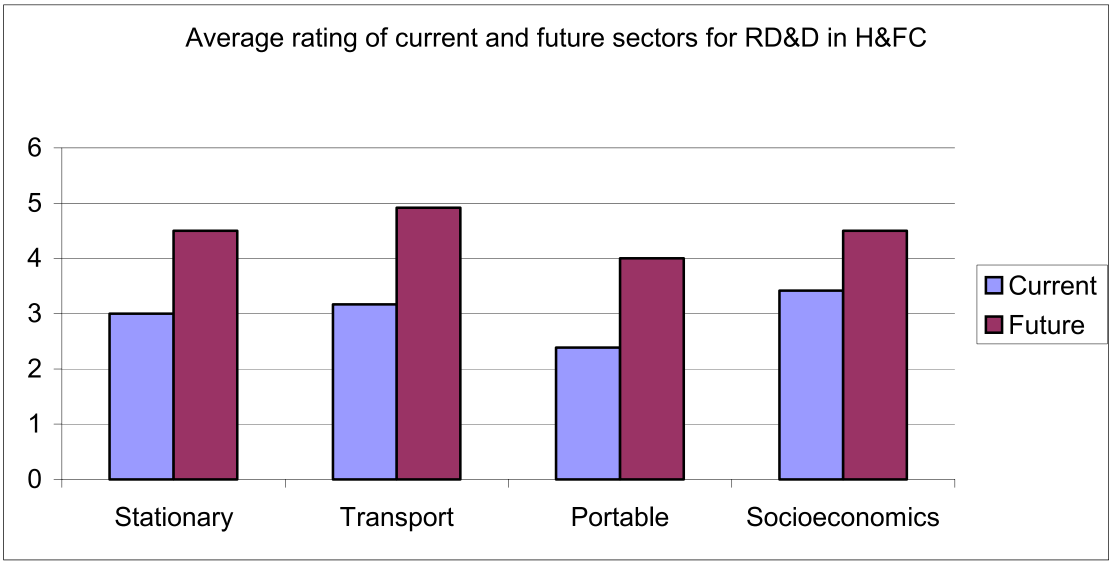

Figure 4.6: Average rating (1-6) of RD&D sector by importance. (Source: HY-CO Survey)

In terms of current importance, the study of the socioeconomics of hydrogen and fuel cell technology is rated the highest followed by transport applications. Portable applications are generally rated low in terms of both current and future importance. Expectations for future importance are generally high for all these possibilities, but RD&D in transport applications generally hold the highest expectations for its future importance. This should be seen in the light of the vision of the European Hydrogen and Fuel Cell Platform stating that: *"No significant contribution of hydrogen and fuel cell vehicles by 2020*[42]*"*

It is worth noting that the RD&D priorities of some countries differ significantly from the aggregated picture shown on Figure 4.5. The national RD&D priorities in application and hydrogen and fuel cell technology are summarised in table 4.8.

Stationary	**Transport**	**Portable**	**Hydrogen islands**	**Space**	**Undetermined**
Austria Belgium Denmark Finland France Germany Greece Netherlands Norway Portugal Spain Sweden UK	Austria France Germany Greece Iceland Italy Luxembourg Norway Portugal Spain Sweden UK	Austria Belgium Finland France Germany Lithuania	Greece Norway	France	Czech Estonia Ireland Latvia Poland Slovenia

Table 4.8: National RD&D priorities in area of application

Not surprisingly the largest overlap in European RD&D priorities are in stationary and transport applications. A significant group of countries have no particular RD&D priorities in terms of application of H_2&FC technology. This is primarily due to emphasis on basic research and lack of overall national application objectives (see table 4.1 and figure 4.2).

It is clear that although hydrogen and fuel cell RD&D activities conducted in Europe are highly diverse, there are clear overlaps in terms of technological portfolio and expertise. The main emphasis is on basic and applied research rather than demonstration and industrialisation. Technological portfolios in hydrogen production are to a large extent determined by national energy priorities. This is to some extent also true for distribution technologies, where existing natural gas infrastructure determines RD&D priorities. The technological portfolio in the area of storage technology is widely scattered over a wide spectrum of technologies. In addition, it was found that a broad group of countries have no particular emphasis or priorities on this area. In terms of conversion technology, overlaps exist in a broad range of fuel cell technologies and a small group of countries have competences in hydrogen conversion in internal combustion engine technology. Technological portfolio in application of hydrogen and fuel cell technology among the European countries has major overlaps, but also reveals interesting niches where trans-national cooperation could potentially contribute to developments. When looking at the technological portfolio and expertise of the European countries, there would seem to be a good match with the objectives envisaged in the European Hydrogen and Fuel Cell Platform.

A specific and quite obvious example of a potential trans-national cooperation agreement is between Norway and Greece within the application area. Both countries are pursuing the idea of so-called hydrogen islands, which gives a potential for establishing a collaboration scheme (see table 4.8). Norway and Greece are the only two identified countries that have

[42] The European Hydrogen and Fuel Cell Platform (2004) p. 27

national RD&D priorities within this area. It is likely that the two countries will face some of the same problems and challenges, which open up for co-developing some of the solutions. Furthermore, an opportunity to experiment with and test different H_2FC technologies in very different climates and energy systems exists, since these two countries have different energy infrastructures and resources.

4.7 Funding and means of support

With an estimated budget in excess of 300 million US$, the USA has the lead when it comes to government funding of hydrogen and fuel cell technology R&D. Also Japan is currently ahead of the EU with an estimated budget of more than $250 million, as indicated in figure 4.7.

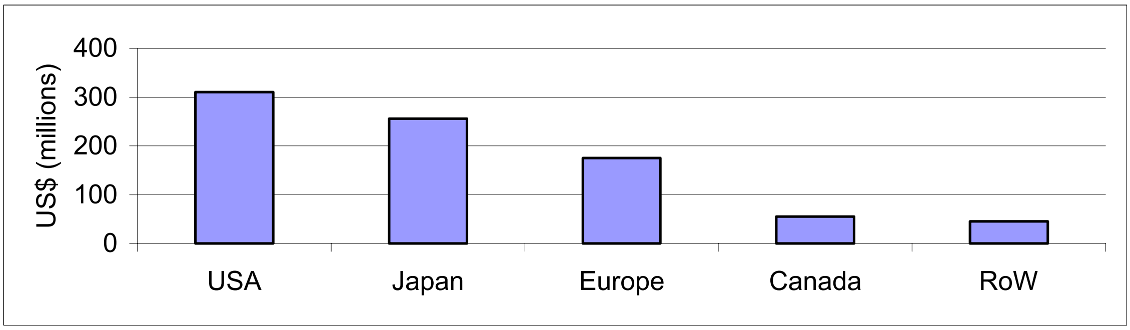

Figure 4.7: Government funding of hydrogen and fuel cell technology in 2003. Source: Cropper et al. 2003[43]

In Europe, as mentioned earlier and illustrated in figure 4.2, most hydrogen and fuel cell RD&D is conducted outside the research programmes dedicated to the purpose and is often funded as part of broader national research frameworks. In addition, many hydrogen and fuel cell projects are funded on a project-by-project basis as part of larger calls for research proposals in broader areas such as renewable energy, materials science or chemistry. The exact funding given per year per country is notoriously hard to estimate. Funding varies enormously between countries and from year to year, and figures obtained are rarely comparable between countries. These comparability-problems were evident in the survey results obtained under WP2 of the HY-CO project. A comprehensive overview of the funding of RD&D programmes in Europe could not be compiled based on these. Broad estimates of varying quality can be found in resent studied carried out on the subject:

- ESTO (2005) broadly estimates that the EU countries have more significant activities in monetary terms include Germany, The United Kingdom, France, the Nordic countries and Italy. ESTO confirms its finding with an estimate of the distribution of the current fuel cell industry based on number of people employed from Core Technology Ventures[44].

- Cropper et al (2003), estimates that the total government support given to hydrogen and fuel cell research activities in the Europe in 2003 to be around US$175 million

[43] These figures must be considered broad estimates, but are none the less the most adequate figures that could be obtained.

[44] ESTO (2005) p. 19 - 21

but does not specify the source of this finding nor a breakdown of this aggregated figure[45].

- OECD/IEA (2004) does not give an aggregated estimate of the funding, but does illustrate the comparability problem between means of funding by describing the diversity of 'budgets' for hydrogen and fuel cell RD&D in a number European countries[46].

Based on current knowledge, a comprehensive overview of the level of funding provided to H_2&FC RD&D in Europe cannot be obtained. Based on the information obtained during this study, our findings seem to support those of ESTO (2005) in its assessment of the countries with the most significant funding of RD&D activities in the H_2&FC field. These include:

- Germany
- United Kingdom
- France
- Nordic Countries

Although it is not possible to compare the size of funding in the European countries directly, it is possible to provide an overview of the types of government support given to hydrogen and fuel cell research.

4.8 International orientation of programmes

The extent to which the national RD&D programmes of the European countries are internationally oriented is not easy to measure concretely. However, most countries appear to be involved in hydrogen and fuel cell RD&D cooperate internationally at some level, although the role and the extent of international participation vary significantly. Figure 4.8 illustrates the schemes most commonly used to facilitate international cooperation in Europe in the countries surveyed.

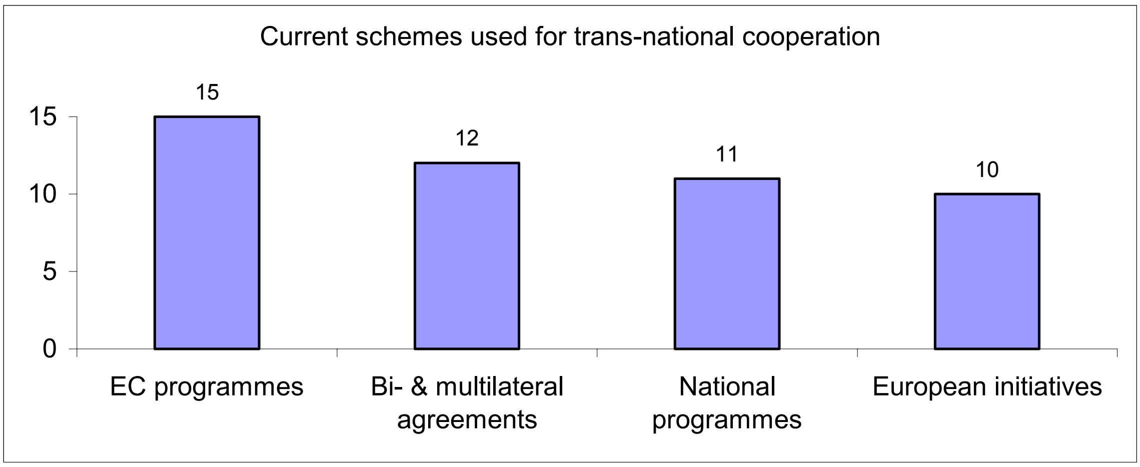

Figure 4.8: Current schemes for trans-national cooperation. Distribution of answers from 15 countries. Source: HY-CO Survey.

[45] Cropper et al (2003) p. 10
[46] OECD/IEA (2004) p. 105 - 194

European Community programmes are the most commonly used scheme for trans-national cooperation. Also bi- and multilateral agreements play an important role in this respect. It is worth noticing that more than half of the countries surveyed use national RD&D programmes to facilitate international cooperation. Figure 4.9 illustrates the level of foreign involvement and the possibility of funding trans-national research in national research programmes:

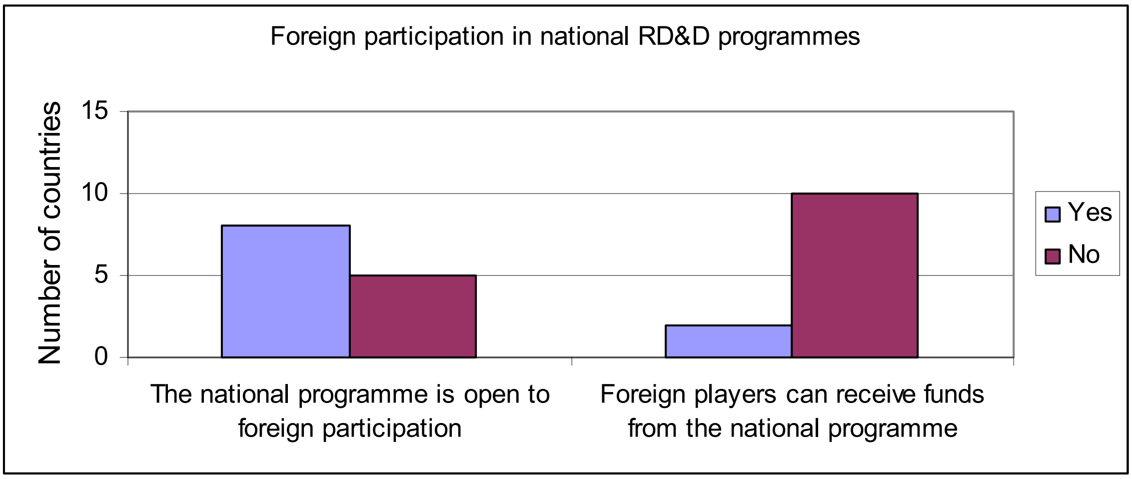

Figure 4.9: Foreign participation in national RD&D programmes. Distribution of answers from 13 (12) countries. Source: HY-CO Survey.

Figure 4.9 shows that 8 out of 13 programmes are open to foreign participation, but that only in a small share of these can foreign players receive funds from national programmes.

Figure 4.10 illustrates the role of foreign involvement in the national research programmes that are open to foreign participation.

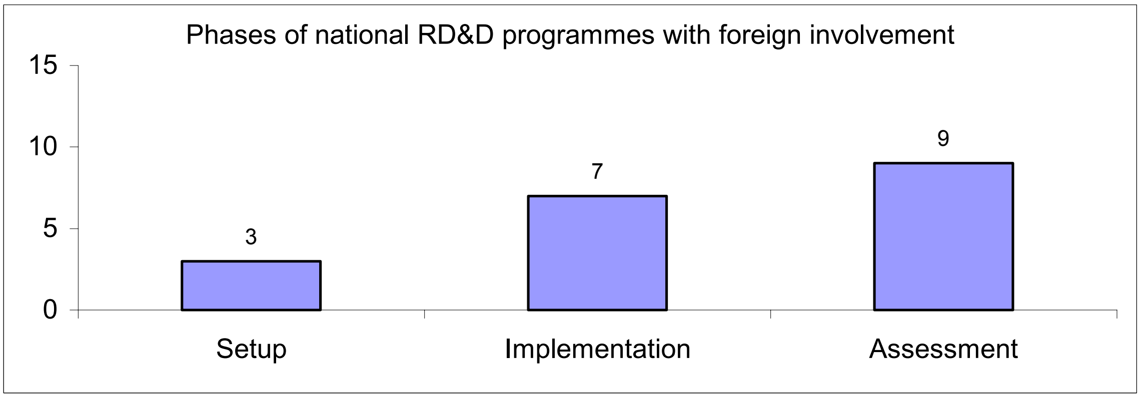

Figure 4.10. Foreign involvement in national RD&D programmes. Distribution of answers from 12 countries. Source: HY-CO Survey.

Foreign expertise is most commonly involved in the assessment and implementation phases of national research programmes. Other types of foreign involvement in national RD&D programmes included programme evaluation and involvement as third parties.

As it can be seen from figure 4.9 above, the EU Framework Programmes are by far the main instruments for facilitating trans-national cooperation. Outside the EU-Framework, only few long-standing examples of international cooperation in the field of hydrogen and fuel cell RD&D could be identified.

Based on the current level of international cooperation between the European countries, it is clear that the vision of the ERA-NET – to create a common European research area in the field of hydrogen and fuel cell technology – is still far from realised. To realise this vision and to reap the potential benefits of trans-national cooperation identified in Chapter 2, there is ample room to increase the level of international cooperation between the H_2&FC RD&D efforts of the European countries and to coordinate these according to common objectives.

4.9 Complementarities and gaps between European RD&D programmes

This chapter has focused on four major elements of RD&D efforts in the field of hydrogen and fuel cell RD&D in Europe. These included political goals and priorities, expertise and technological portfolio, funding and means of support and the level of international orientation. At every level, the diversity of European RD&D efforts is obvious and it is important to emphasise that this is both a potential strength and weakness.

The potential for reaping the benefits of trans-national cooperation between European countries is with a few noticeable exceptions present in all areas of hydrogen and fuel cell technology. To a large extent the European countries share common motivations for developing hydrogen and fuel cell technology and expertise and know-how in this field are primarily developed in parallel rather then in cooperation between European countries.

As we have seen, there are many potential areas of trans-national cooperation in hydrogen and fuel cell RD&D in Europe, but current activities are to a large extent characterised by lack of coordinated efforts between countries with otherwise complementary interests. This is most clearly visible in the small number of RD&D programmes explicitly aiming at utilising expertise from other European countries.

The following chapter will explore the opportunities for further trans-national cooperation in the field of hydrogen and fuel cell RD&D between the European countries.

Chapter 5: Opportunities for further trans-national cooperation in Europe

This chapter examines the opportunities for trans-nations cooperation in Europe. It looks at the benefits of trans-national cooperation and what the main barriers for increasing this kind of cooperation are. Furthermore, the role of the EU and the national research agencies in boosting trans-national cooperation is examined. An overview of the elements necessary for successful trans-national cooperation is also provided. The chapter is concluded by summarizing the findings of the entire report into a SWOT-analysis.

This chapter draws particularly on the data and experiences gathered from the interviews conducted during this study. In this way, the "real life" experiences of the HY-CO interviewees are given a **central** role as are the problems identified by these representatives and their suggestions on how to overcome the problems and create more opportunities for trans-national cooperation.

5.1 Experiences, benefits and barriers

The following sections look at the experiences the surveyed countries already have obtain from trans-national cooperation, both within energy-related areas and in other areas. Subsequently, the benefits from engaging in trans-national cooperation are, together with the identified barriers, examined in greater detail.

One precondition for increasing trans-national cooperation between countries within H_2FC RD&D programmes is that the countries, institutions and the involved scientists see some benefits by engaging in trans-national cooperation. Another precondition is that the overall framework for the trans-national cooperation does not pose any serious obstacles, problems or barriers, but instead enables and facilitates increased trans-nation cooperation.

In general, all the surveyed countries are currently involved in some sort of trans-national cooperation within the hydrogen and fuel cell area. Countries also have experiences with trans-national cooperation outside the energy-related areas. The vast majority of the countries have mentioned an array of different programmes and organisations through which they are cooperating trans-nationally within the non-energy area. Examples of such organisations and programmes are Eureka, European Space Agency, CERN and COST.

Trans-national cooperation within the hydrogen and fuel cell area also takes place through a number of different organisations and schemes. The different schemes and programmes are illustrated in figure 5.1. All countries point to use of different EU programmes for trans-national cooperation. The majority of the countries use other schemes simultaneously, for example bi- and multilateral agreements. Most countries are to some extent involved in a number of specific H_2FC programmes that entail trans-national cooperation, primarily in the context of EU programmes (under the FP5 & FP6 programmes). Furthermore, countries are involved in trans-national cooperation through programmes offered by International Energy Agency (ex. IEA Hydrogen Programme or IEA Advanced Fuel Cells) or through regional cooperation schemes (ex. in the Nordic region).

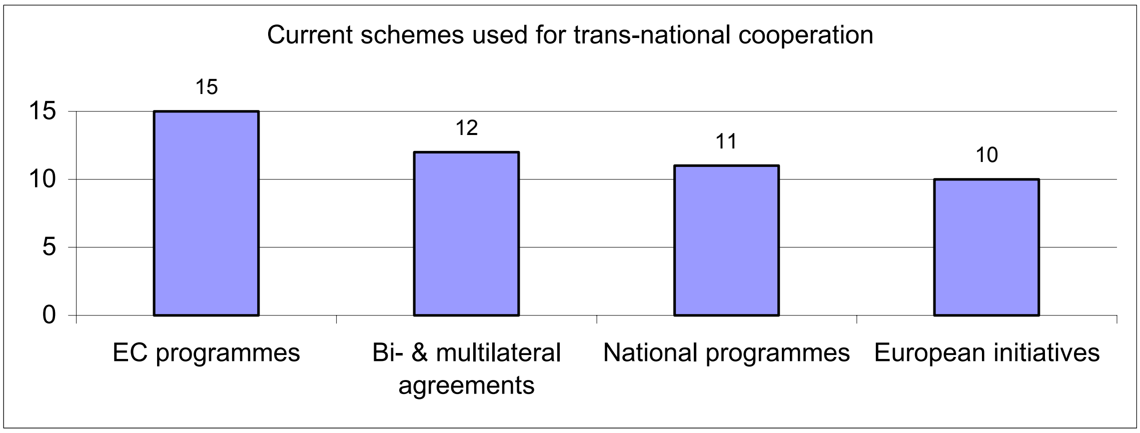

Figure 5.1: Current schemes for trans-national cooperation. Distribution of answers from 15 countries. Source: HY-CO Survey.

Benefits of trans-national cooperation within the hydrogen and fuel cell area
The current experiences with trans-national cooperation in the H_2FC areas are very positive (based on the countries participating in the HY-CO survey). The positive attitude towards trans-national cooperation may to some degree, however, be a result of the way the questionnaire for HY-CO survey has been designed. The respondents were only asked to list the *benefits* of trans-national cooperation, not the potential negative consequences.

The main benefits of trans-national cooperation listed by the HY-CO survey, the HY-CO interviewees and the representatives present at the HY-CO explorative workshop in Oslo can be summarized as follows:

- Achieving a critical mass within RD&D. Sharing of efforts and costs make it possible to archive results that a single country could not have archived.
- Access to new partners (ex. companies and research labs)
- Identifying common areas of interest and potential opportunities for future partnerships by building up formal and informal contacts to potential partners
- Better generation of new ideas and research areas
- Access to scientific facilities (ex: laboratories) and sharing of specific scientific tools, methods and techniques
- Sharing and co-development of best practices
- Harmonisation of codes and standards on a trans-national or international level.
- Better access to new knowledge, expertise and information
- Better access to new potential markets
- Avoid replication of research efforts and the reinvention of the wheel

- Enable new RD&D demonstration opportunities that could not have been achieved unilaterally

- Better utilization of existing and often specialized and expensive research infrastructure

- Achieving economies of scale by having a better coordination and guidance of national RD&D efforts

The wide range of advantages stated by the different HY-CO interviewees and the countries surveyed clearly illustrates why a higher level of trans-national cooperation in Europe would be beneficial. The main benefits of trans-national cooperation are the knowledge and information sharing that takes place between the different scientists involved in the RD&D programmes. Trans-national cooperation gives the participants a larger pool of different resources as countries have different experiences and competencies within a number of areas. Scientists can therefore obtain a deeper insight in their own areas, while at the same time being informed about the other relevant topics. The findings presented here are also in accordance with the results from the Optimat study[47]. Furthermore, the Optimat (2005) study illustrates that the result of countries tapping into external knowledge and engaging in collaboration with other countries with similar and non-competing interests was an increased research capacity and potentially higher quality results than a country could have achieved unilaterally.

The current lack of trans-national cooperation therefore appears counterproductive for the development and strengthening of the H_2FC RD&D community and the associated industry.

Trans-national cooperation appears to be especially important for smaller countries as it provides access to international scientific knowledge and the necessary critical mass in resource demanding areas[48]. However, larger countries can also benefit from the trans-national cooperation and may benefit from working with a small country. Iceland serves as an example of a small country with some unique natural sources of energy, a flexible administrative system and the necessary political support, which makes it an obvious country for carrying out hydrogen demonstration projects.

In sum, trans-national cooperation can be seen as a way to achieve more efficient and effective RD&D programmes, which could yield significant advances within H_2FC RD&D.

Problems and barriers for trans-national cooperation
The following section provides a short overview of the main barriers or problems for trans-national cooperation. The main section on barriers and problems preventing more trans-national cooperation and how these barriers could be overcome will be examined in greater detail in next task in WP3, Task 3.3.

Given the positive experiences and attitude towards trans-national cooperation expressed by the HY-CO members, combined with the obvious advantages of additional trans-national cooperation, the obvious question arises; why is trans-national cooperation within H_2FC RD&D still on a low level? As pointed out in table 3.1, barriers for trans-national

[47] Optimat (2005)
[48] Optimat (2005)

cooperation can be found on different levels (policy level, programme level and the project level) and they can vary in terms of their nature. A number of different reasons for the low level of trans-national cooperation can be listed. These range from political barriers to inflexible legal structures and from funding shortages to a general lack of overview over the different opportunities and problems that exist.

The main problems and barriers encountered today in trans-national cooperation are summarized in figure 5.2.

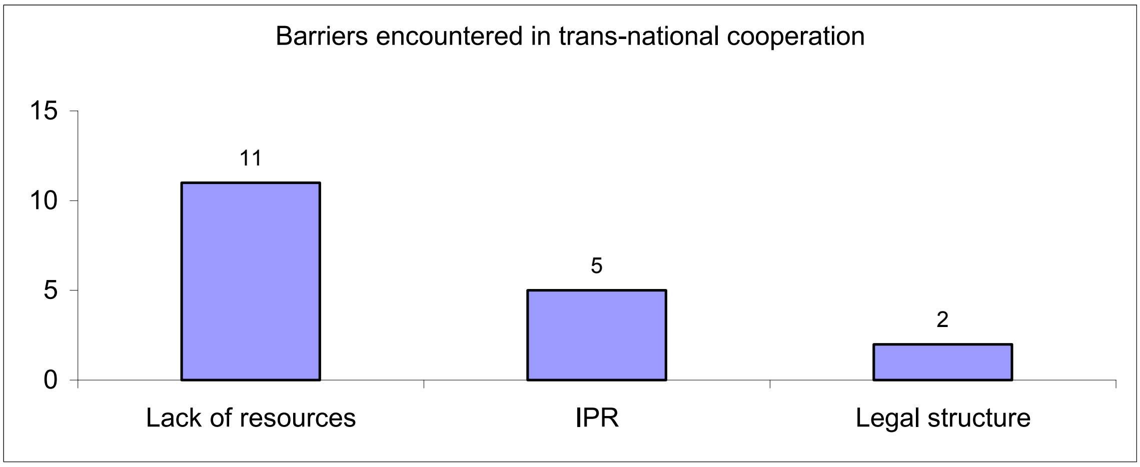

Figure 5.2. Barriers encountered in trans-national cooperation. Distribution of answers from 14 countries. Source: HY-CO survey.

It is possible to give a more detailed picture of the most common problems or barriers for trans-national cooperation by dividing them up into four categories:

A) Funding

Problems with funding within the H_2FC area should be divided up into two categories. A number of the interviewees may mention funding as a problem, but it is more in the sense that "*more funding would of course always be nice*". The lack of funding does, however, not seriously prevent them from conducting relevant research within the area. However, for a number of countries, primarily the new Member States, a lack of resources is a major problem that affects their research capacity and capabilities. In addition, problems with aligning financial resources and budget disputes over co-funding are mentioned by the interviewees as frequent problems when engaging in trans-national cooperation.

It is not only lack of funding that causes problems; a lack of budgetary flexibility can also be a serious hindrance in trans-national RD&D programmes. It is often difficult to change or alter the programme plan while the programme is still taking place. This can be a major problem, since research programs and priorities can change over time. The importance of ensuring the continuity of a RD&D programme should not be underestimated. According to the interviewees, long-term financial stability and a genuine commitment are important parts of a RD&D programme, because it takes time to establish trust and commitment. The continuity of funding can therefore be seen as equally important as the amount of funding given.

An important point when addressing funding issues are the possibilities for attracting co-funding for RD&D projects that involve industry/companies. Public co-funding can in the US be up to 80%, whereas public co-funding in Europe cannot be more than 40% and it is actually very seldom that co-financing is that high. In Canada the limits to public funding are lower – usually 33-50% (with an absolute axe of 75%).[49] This makes it harder to attract, motivate and involve companies in the EU, which otherwise is seen as an important way to bridge the gap between research and commercialization on the market.

B) Bureaucracy and coordination problems
One of the main problems mentioned by the interviewees regarding trans-national cooperation is bureaucracy. Given the fact that trans-national cooperation is often both a time- and resource demanding activity, it is crucial that bureaucracy is kept at an absolute minimum. The problems with bureaucracy can be found on a most programmes and funding schemes, but bureaucracy on an EU level is often mentioned. Despite various attempts to reduce the bureaucracy, the tendency of increased bureaucracy is perceived to continue. Bureaucracy starts with a complex and time consuming application procedure and once the project is approved, the requirements considering coordination, reporting and communication (meetings) require a lot of money and time that could be spent otherwise and better. According to the HY-CO interviewees, the more partners that are involved, the more inflexible and inefficient the whole project work becomes and research and contents fall behind. Bilateral cooperation is, on the other hand, often seen by the HY-CO interviewees to be somewhat easier and less bureaucratic.

C) Differences between RD&D programmes and standard procedures
Overall, the lack of coordination and incentives for trans-national cooperation are two of the main problems.

Divergences in rules and procedures in programme planning and implementation are some of the more practical barriers the interviewees have had to overcome. Variations from country to country exist within a large number of areas, including in the decision level for the initiation of a national/regional programme, programme design, programme duration, application procedures, contract negotiations, monitoring and evaluation of projects and programmes). In addition, different public financing mechanisms (vertical vs. horizontal grants, loans, tax reductions etc.) and different obligations with respect to auditing are also important problems that impede trans-national cooperation. The problem with differences in the different national RD&D programmes can be addressed on various levels with a number of different means as illustrated in table 3.1. A high degree of coordination and harmonization between the different national programmes and a high level of flexibility on the programme level can help to minimise the problems.

A more general problem regarding trans-national cooperation is the cultural differences and the general difficulties of working together in larger groups. Such problems can, however, be seen as an inherent part of trans-national cooperation and thus difficult to overcome. It is therefore important to find participants that can actually cooperate with each other when planning, setting-up and implementing the trans-national cooperation programmes. It is equally important to remember that successful trans-national cooperation, which always involves people from different countries, cultures and administrative systems, requires **trust** between the involved partners and that it takes **time** to build up the required level of trust. In other words, important elements in trans-national cooperation are 'learning by doing' and 'growing by doing'.

[49] ESTO (2005)

D) Human resources
It is not only a lack of financial resources that appears to hinder trans-national cooperation. The lack of human resources also plays a role in some of the countries. The problem is that trans-national cooperation always takes extra time and requires an extra workload, which often comes on top of the researcher's daily work. This is especially a problem for those countries, which have a lack of human resources and thus cannot spare any to trans-national cooperation.

The lack of human resources could be solved by building up research capacity within the area, for example by increasing the number of PhD students with the H_2FC area. This is of course a more long-term solution. Another way to solve the problem is to encourage scientists to participate more actively in mobility programs. Table 3.1 point to different ways on how to facilitate this. On the programme level, programme managers could, for example, inform scientists on case study examples and success stories of trans-national projects in order to motive them. Mobility programmes for both experienced scientists and for PhD students should not only be seen as a mean to foster more trans-national cooperation and cross-learning, but also build competencies in a country. A mobility programme could also be a way to overcome the problem of scientists and programme managers having insufficient knowledge of relevant RD&D programmes across Europe.

The HY-CO interviewees points to another barrier, namely the lack of discipline and commitment to trans-national cooperation that exists. Much of the collaboration has a strong voluntary character. There is no agreement of who does what and there are no instruments in place to force the speed of plans. In many projects a lack of priority of trans-national cooperation is evident, due to a much higher pressure from national policies.

In sum, a number of barriers to trans-national cooperation still exist today. A lack of resources is seen as a serious barrier as is the current intellectual property rights system. Furthermore, the current legal structures are also seen as a barrier for trans-national cooperation. Only two of the countries participating in the HY-CO survey have not experienced any barriers. This indicates that barriers do exist and that they in general are experienced as a problem for the HY-CO members. Besides the overall and widely acknowledge lack of funding and the bureaucratic problems encountered, the lack of guaranteed continuity in hydrogen and fuel cell RD&D programmes is also seen as a barrier, together with the problems of identifying of areas of common interest for trans-national cooperation within RD&D.

5.2 Facilitating more trans-national cooperation
The following sections will address and examine different ways to generate more trans-national cooperation. The role of the EU and national research agencies will, among other things, be addressed. The section will be concluded by a listing of important elements or "best practices" of an "ideal partnership" for trans-national cooperation.

One way to facilitate more trans-national cooperation within RD&D programmes and thus take advantage of the opportunities that exist within the H_2FC area is to focus on those stages of a RD&D programme that are *most suited* for trans-national cooperation. In this respect, it is important to distinguish between RD&D programmes and technologies that can be characterized as primarily being *basic research* and those that are more application and market oriented, often termed *applied research*. The distinguishing is important both in connection to trans-national cooperation within RD&D and collaboration in general. As illustrated in the HY-CO survey and confirmed by a number of the interviewees, intellectual property rights are seen as one of the most important problems when engaging in trans-national cooperation. TAFTIE (2005) points to the fact that intellectual property rights always cause different interpretations and presumptions, which can be difficult to accommodate within national RD&D activities. Furthermore, the difficulties associated with disputes and confusion over intellectual property rights appear to increase when RD&D activities are internationalised.

The problem that may arise from disputes and confusion over intellectual properties rights appears to be clearly related to the *nature* of the research undertaken. The problems with intellectual property rights increase as research or a technology is taken out of the laboratory (basic research) and moves closer to the application stage (applied research) and commercialisation on the market. As research comes closer to commercialization, information becomes more sensitive and thus more difficult to share freely among the scientists. Scientists involved in trans-national cooperation can for example find themselves under pressure by the industry to keep sensitive information from other competitors. On the other hand, intellectual property rights play a less important role within technological areas that are still seen as technological immature. The HY-CO interviewees point to cooperation within materials R&D as an example. Materials development is in this respect well-suited for trans-national cooperation, since it is often characterized by being basic research.

The intellectual property rights system is also often seen as a potential barrier for having more companies participating in joint RD&D cooperation programs. The involvement of companies is problematic because competitive concerns and rivalry among companies play an important role. Intellectual property rights are less problematic in basic science-related collaboration, because there is a presumption that significant results will be published in a number of scientific journals and the knowledge will thus be widely disseminated. Secondly, the technologies are often still in an experimental phase with no or only low value on the market. Companies are therefore less concerned with protecting knowledge and the competitive positioning and rivalry between companies TAFTIE (2005) concludes that science-oriented international collaboration is normally easier to arrange compared to industry-oriented collaboration. This may also explain why trans-national cooperation is perceived to be *easier* within for example hydrogen RD&D (characterized by basic research) than within fuel cells (characterized by applied research and closer to the marketplace) by a number of the HY-CO interviewees.

Despite the current problems with intellectual property rights, a number of the persons interviewed during this study were positive towards a greater interaction between scientists, public funding agencies and the hydrogen and fuel cell industry. It was suggested that the industry should be more involved in the planning of the R&D priorities, the topics and the design of the RD&D programmes. Influence on the RD&D programmes is seen as a motivation factor for the industry to participate and potentially co-fund RD&D programmes. A greater involvement of the industry is also seen as a potential way to close the gap between basic research and applied research.

In order to facilitate trans-national cooperation and minimize the potential disputes over intellectual property rights, TAFTIE (2005) suggests that collaboration between industry-oriented programmes can be best organised by selecting the most science-oriented parts from the programmes and collaborate on these programmes. Focusing on the most science-oriented parts is thus one way to reduce the potential difficulties that are associated with collaboration on industry-related RD&D activities. In addition to this, the industry should be engaged in industry-oriented RD&D programmes by planning its own RD&D programmes or modules, but integrating such programmes or modules into a broader collaborative framework with the participation of scientist and national authorities.

It is difficult to imagine how the overall problems and the difficulties associated with the current intellectual property system rights can be completely removed. However, measures can be taken to minimize the problems. According to the HY-CO interviewees, a more flexible intellectual property rights system and more flexible and less bureaucratic legal requirements and frameworks for trans-national cooperation is one way to spur more trans-national cooperation. In conclusion, trans-national cooperation is, in general, easiest within basic research and industry-oriented collaboration between industry-oriented programmes should be organised by focusing and collaborating on the most science-oriented parts. These experiences are supported by TAFTIE (2005) and their findings.

5.3 The role of the EU

The EU plays an important role in trans-national cooperation. Partly because it designs and implements different trans-national collaboration schemes and partly because of its funding role.

The HY-CO survey clearly illustrates that countries have widely different wishes and expectations to trans-national cooperation within H_2FC RD&D at the EU level. In general, countries naturally prefer to cooperate within areas of national importance to the specific country. A few countries also mention education and socio-economic analyses as potential areas for cooperation at EU level.

The same variety can be found in the countries' wishes for what kind of expertise and knowledge they would like to receive at the EU level. The wishes can be divided up into three broadly defined categories:

- Provide additional expertise, advice and facilitate information sharing for specific technology areas of national interest and of relevance to the national energy priorities

- Give advice on national policy implementation, input to the process of designing national hydrogen and fuel cell programs (for example advice on how to achieve a better coordination of RD&D in the different countries).

- Facilitate knowledge sharing, support the implementation of common standards and facilitate H_2FC demonstration projects across Europe.

The EU as a facilitator of trans-national cooperation

In general, the interviewees believe that the EU, based on its recent initiatives and activities, is doing a good job in fostering more trans-national cooperation. Examples of such initiatives include the ERA-net platform, the Joint Technology initiatives and the Hydrogen and Fuel Cell Technology Platform (HFP). The interviewees envision the role of the EU as one of structuring and facilitating trans-national cooperation. However, the EU should be cautious not to go too far in setting rules. Flexibility is important when a group of people are supposed to work together efficiently. The EU should adjust its influence on national/industrial activities to the budget it provides. In many cases, the EU requests disproportionate influence on the project proceedings and contents compared to its funding. This can make trans-national cooperation unattractive.

A number of the interviewees suggest that the EU focuses its efforts on 1) large trans-national demonstration projects and 2) on funding high-risk RD&D projects.

1) The EU role should be one of initiating and coordinating practice-oriented H_2FC demonstration projects across Europe and providing the funding necessary for such large-scale demonstration projects.

2) The role of the EU should be to finance *high-risk* H_2FC RD&D projects, primarily focused on *basic research* of materials for hydrogen technologies (ex. materials for transport and catalytic properties of electrolyte and electrode materials for fuel cells). However, the EU should not forget the value of small RD&D projects that only involve a small number of countries and not always focus its efforts on the very large, complicated and prestigious projects. Many resources are often spent on coordination and management in large projects compared to smaller and more flexible projects. Small projects with more moderate resource demands are also a good way to include countries in East Europe.

According to the interviewees, the EU should design its RD&D programmes and calls in a way where trans-national cooperation is actively encouraged. One way to generate more trans-national cooperation is by using funding schemes where a certain number of partners from certain countries must be involved in order to receive funding more extensively. This kind of EU funding schemes is seen by a number of the interviewees as a powerful collaborative force. In order words, EU should ensure that there is “a carrot” for trans-national cooperation. A similar funding mechanism could also be used in order to integrate the new Member States in the European RD&D programmes. EU calls and projects could for example be designed in such a way that RD&D consortiums are obliged to include partners from the new Member States in order to ensure that learning and development takes place across Europe and not just between a group of “lead” countries.

However, disagreement exists over the value of such schemes. Some of the interviewees point to a situation where the possibility to grip European money is in the foreground while the benefits in respect of content are more in the back. Thus partners are selected not due to a reasonable complementation of work, but in order to correspond to the framework conditions of the call.

Bureaucracy in the EU is mentioned by several interviewees as a problem for generating more trans-national cooperation. One suggestion to reduce the bureaucracy burdens is to give more freedom to those scientists that have been awarded EU funding. The EU should carefully check on the candidates that apply for specific RD&D projects, but once a candidate has proven 'worthy', plenty of rope in the sense that the level of regulations, duties and formalities should be reduced. Although this programme design is based on trust in the candidate, it is a practical way to optimize the actual time spent on conducting research and minimizing the administrative workload. At the same time, it would make trans-national cooperation more attractive for scientists and programme managers and thus ensure that the potential opportunities for trans-national cooperation are exploited.

A practical example of how the EU could act as a facilitator is the Canadian approach to trans-national cooperation mentioned previously. There is no reason why the EU should not be able to facilitate similarly open meeting processes within H_2FC RD&D.

5.4 The role of the national research agencies

National research agencies have a similarly important role to play in furthering trans-national cooperation. Given that the competence and responsibility of national RD&D activities will not be transferred completely to the EU, a very long time of coexistence of national and European programs will have to occur. It is therefore important to attempt to achieve a reasonably interlace and coordination of the different RD&D programs, ideally guided by clear targets and political aid from the single member countries. It is important to remember that trans-national cooperation can be conducted as an **extension** of existing national RD&D programmes.

For a national research agency there is always the question: Do we get as much funding back as we put across the border? Each country will obviously prefer to support its own national industry within the hydrogen and fuel cell area. Legal complications linked to trans-national cooperation can therefore impede trans-national cooperation if no appropriate funding structure is in place and if the national research programmes are not open for foreign participation. Funding foreign partners with national funds and the other way around can thus be quite difficult and often becomes a question of fairness instead of legal security.

Another opportunity for the national research agencies to boost trans-national cooperation is to address the awareness problem. According to the interviewees, there is often not enough awareness about the opportunities to engage in trans-national cooperation programmes and the advantages that potentially can be gained. This awareness problem appears to exist on both the programme level, but also on a governmental level and within the research agencies. The research agencies should address this awareness barrier. Furthermore, the overall concept of trans-national cooperation needs to be accepted at the governmental level and incorporated into the existing national RD&D programs.

The missing awareness about the opportunities and the advantages of trans-national cooperation appears to be correlated to the size of the country. According to the findings of the Optimat study[50], large economies (for example France, Germany and UK) in Europe appear to see less need for trans-national cooperation, primarily due to the fact that most of the infrastructure and expertise is available nationally. Furthermore, the influential decision makers in these countries appear not to see value of trans-national activity and there is little encouragement to allocate more of the budget in this area. In other words, because the well developed research infrastructures, trans-national activity is simply not a pressing necessity. Large country programmes are therefore also least likely to have explicit rules or instruments supporting trans-national activity, or financial systems designed to cope with non-national contracts or currencies[51]. Medium sized and small countries are, compared to large countries, more open and receptive to trans-national cooperation. However, small countries are especially interested in opening up towards foreign partners, often to compensate for the gaps in their own research programmes.

[50] Optimat (2005)
[51] Optimat (2005)

Funding agencies can also create more opportunities for trans-national cooperation by acting as a **facilitator** between different RD&D programmes or scientists in different countries. One possibility is to create and manage meeting- and discussion forums with other regions and nations (recently a discussion forum between the Netherlands and North-Rhine-Westfalen in Germany was, for example, established to discuss a closer cooperation within the ERA-net frame).

5.5 Problems with trans-national cooperation on a region level

The HY-CO study reveals that coordination problems also exist on a national and regional level. Currently, H_2FC programmes are spread across too many different departments and ministries in a number of the different HY-CO member state countries. This indicates that a need exists for a more **integrated** RD&D approach and an overarching framework, both on a national level and on a European level in order to prevent RD&D activities to be spread out between too many different organisations. The need for coordination and tight integration is especially relevant for countries (ex. Italy) with RD&D programmes on both national and regional level. In these cases extra attention to coordination between national and regional level is necessary in order to avoid overlapping activities and to steer RD&D towards common national as well as European objectives.

Another measure that could be taken to ensure coordination and integration of the RD&D programmes is the appointment of a liaison person, which is assigned to the H_2FC area. The liaison person can be located in the relevant governmental department, agency or research organisation. The liaison person should be responsible and capable of making the link between research organisations and the industry and the link to other countries in order to facilitate and exploit the opportunities for trans-national cooperation.

5.6 Country and application specific opportunities for trans-national cooperation

In general, the HY-CO survey and the phone interviews illustrated that neither scientists nor government officials have a detailed and complete picture of the different RD&D projects within the H_2FC area. It is therefore not possible to do an exact matching of which RD&D programmes, organisations or even scientists in different countries that should work together. A detailed mapping of RD&D programmes would also become incorrect over time, since RD&D programmes change and evolve. Furthermore, attempting to conduct a strict and too detailed top-down matching of the specific RD&D programmes would be contrary to the nature of trans-national cooperation and the findings found in the TAFTIE (2005) report. However, the development and implementation of a top-down strategy on the overall coordination of national RD&D programmes is a useful initiative on the policy level. The development of a top-down strategy can be used as a point of departure for an interactive process and fruitful discussion between the three different levels specified in table 3.1 (policy level, programme level and the project level).

However, as illustrated and elaborated on in chapter 4 it is possible to do an **overall** matching based on the different countries' energy system, RD&D priorities and objective and application areas and technologies. The matching of the different countries conducted in chapter 4 illustrated that countries have a number of common and overlapping priorities and interests within a wide range of different research areas and technologies. In order words, possibilities for trans-national cooperation exist within each of these different research areas.

The opportunities for trans-national cooperation presented in this report where discussed and elaborated upon during the workshop in Oslo hosted by Nordic Energy Research in February 2006. At the workshop, representatives from the participating HY-CO members (a total of 16 was represented) were asked to identify the three areas of RD&D that were **most** suited for trans-national cooperation for the specific HY-CO member. Table 5.1 illustrates the results of this exercise. The workshop confirmed the overall picture of the study presented in this report, namely that possibilities for trans-national cooperation within H_2FC RD&D do exist within a range of research areas. The workshop also illustrated that there is still additional research and development needed on all of the different steps involved in the "hydrogen value chain".

Area of Research, Development and Demonstration	Areas most suited for trans-national cooperation
H_2 production	Norway, Slovenia, United Kingdoms, Belgium (Walloon), Belgium (Flanders), Greece, Romania, Germany, Basque Region, Italy, Iceland, France
Storage applications	Portugal, Belgium (Walloon), Slovenia, Norway, Greece, United Kingdoms, Romania, Germany, Iceland, Denmark, France
H_2 distribution and supply	France, The Netherlands
Stationary applications	France, Denmark, Finland
Transportation and propulsion systems	France, Belgium (Flanders)
Portable applications	Portugal, France, Finland
FC technology	Belgium (Walloon), Germany, France, Belgium (Flanders), Greece, Romania, Basque Region, Italy, Finland, Denmark
Socio-economics	The Netherlands, Norway, United Kingdoms, Slovenia, Iceland, Portugal, France
CO_2 capture and storage	The Netherlands, France, Italy

Table 5.1. Areas for trans-national cooperation in H_2FC. Source: HY-CO Explorative Workshop, February 1-2, 2006.

In particular, **four** different areas were singled out by the representatives present at the workshop. The four areas were: Hydrogen production, storage applications, fuel cell technology and to a certain extent social-economics. These expressions of interest by the representatives lead to the creation of four different groups at the workshop. In other words, one group for each of the four identified areas of RD&D. These four groups can be seen as point of departures in the process of setting-up up future schemes for trans-national cooperation. Future steps should include the invitation and integration of other interested public programme representatives into the different groups.

It is, however, very important to stress that those areas of research that only a limited number of countries expressed interest in (e.g. portable applications or transportation and propulsion systems) should **not** be forgotten or overlooked. A limited, yet dedicated, number of countries working within a specific area of research may achieve significant results. The process of establishing a trans-national cooperation scheme involves establishing contacts and networks, building trust and slowly intensifying the cooperation. This may be easier to achieve in practice when only a small number of countries are involved. Once again, it is important to stress that trans-national cooperation is often a slow and stepwise process of "learning by doing" and "growing by doing".

The importance of gradually building up trans-national cooperation schemes was also reflected in the work carried out in the workshop in Oslo. The four groups identified were asked to discuss what kind of level of cooperation that would be feasible and which finance model would be most appropriate for collation between the different national RD&D programmes. The groups were asked to use the classification for the level of cooperation presented in box 3 and the financing models presented in table 3.1 when structuring their discussions.

Box 3: Classification of the level of cooperation

1) Knowledge and information exchange
2) Joint project implementation: Cooperation on a single project
3) Project clustering: Cooperation on a cluster of projects
4) Joint programming: Design a programme together, but run it nationally (decentralised)
5) Integrated programming: Design a programme together, and run it bi-, tri-, or multilaterally

Source: HY-CO Explorative Workshop, February 1-2, 2006

In terms of what level of cooperation would be realistic, the different groups identified "Joint project implementation" and "Project clustering" as the most appropriate and feasible level of cooperation in the short run. There was a consensus of opinions in the four groups that the most basic level of cooperation (knowledge and information exchange) had already been passed. However, the more advanced forms of cooperation (joint programming and integrated programming) were regarding as unrealistic in the short and medium term. In the long term, such forms of cooperation were regarded as feasible and desired end-goals. An important overall conclusion is that cooperation should start as early as possible in the process, so that it may develop and grow over time and slowly become more extensive and formal.

Given the current level of cooperation, simultaneous national funding was seen as the most appropriate financial model. The importance of obtaining future commitment from the budget owners and other stakeholders involved was stressed. It was suggested that the establishment of a formal contact person at the level of the budget owners (can be national ministries, research organisations, regional authorities etc) is an important next step.

5.7 The new Member States – an opportunity for increased trans-national cooperation

There is a long tradition of bilateral or multilateral cooperation between many of the "old" EU members and a number of these countries already have different structures and mechanisms in place to support such trans-national cooperation. On the other hand, the new EU Member States are in the midst of a process of building their research infrastructures up to EU standards. The new Member States are therefore often reliant on existing EU Members States for support and guidance on how to build up such an infrastructure and on how EU RD&D calls and projects work.

The new Member States are therefore in a potentially difficult situation in regards to participating in trans-national cooperation. The HY-CO interviewees from the new Member States point to problems with the European mechanisms of launching new calls and the requirements for joining EU projects. This is especially a problem in connection to the large and integrated RD&D EU projects. The cost of applying and responding to a call is mentioned to amount to approximately 5.000 € pr. call. This is often perceived to be too expensive and too bureaucratic. One explanation for the problems faced by the new Member States is a lack of experience with applications for EU programmes and the formal side of participating in calls and projects. Another explanation is the funding available in these countries. EU projects are seen as large, bureaucratic and complicated, which means that it takes resources for apply for them and to actually participate in them. Furthermore, the HY-CO interviewees from the new Member States mention that RD&D calls and EU projects are often fitted to conditions present in the old Member States, and do not suit the facilities or possibilities currently found in the countries in East Europe.

However, despite the problems, a number of opportunities exist. The new Member States share a number of characteristics that could open up for an increased trans-national cooperation between them within H_2FC RD&D. They are all in a radically new situation due to the economic and political transitions they have undergone, they shared to a large extent the same energy infrastructure and the same overall level of expertise within RD&D. Equally important, they share the same problems of operating under EU RD&D programmes and operating in the EU in general. The new Member States also have a historic tradition of working together, which would make a more extensive collaboration within hydrogen and fuel cells easier.

As shown in chapter 4, a larger number of the new Member States were categorized as being "undetermined" in terms of national RD&D priorities within most of the different categories (for example hydrogen distribution technology or storage technology). This implies that the majority of these countries have too a lesser extent "locked" themselves into a particular technological trajectory within the H_2FC area. Their current energy system naturally influences the future choices, but many of the new Member States countries can, in cooperation with the old EU Member States, pursue different research areas more freely. This could lead to more opportunities for generating trans-national cooperation.

The interviewees point to the existence of an awareness problem with regards to integrating the new EU Member States in the research agenda and RD&D programmes of the old Member States. Scientists in the old Member States have, in general, only a limited overview of hydrogen and fuel cell activities in the new Member States and visa versa. A better overview of the hydrogen and fuel cells RD&D activities would therefore be desirable and a first step towards more trans-national cooperation between the old and the new Member States. The overview of potential opportunities for trans-national cooperation with the countries in the new Member States will most likely also improve over time. A number of the new Member States countries are still in the early start-up phases regarding their hydrogen and fuel cell strategies and implementation plans and are often also slowed down by having a severe lack of resources. As these issues are gradually solved, the new Member States will become more active within the H_2FC area. However, the duration of such a process can be shorten by integrating these countries more tightly into the EU RD&D projects, which would create opportunities for more trans-national cooperation.

5.8 Elements of an "ideal partnership" for trans-national cooperation

The process of facilitating trans-national cooperation or setting up a partnership formed under a trans-national collaboration scheme is made up by a number of phases. The process can more specifically be divided up into four different phases. For each phase a number of threats have been identified. A number of opportunities or solutions have in the same way been identified.

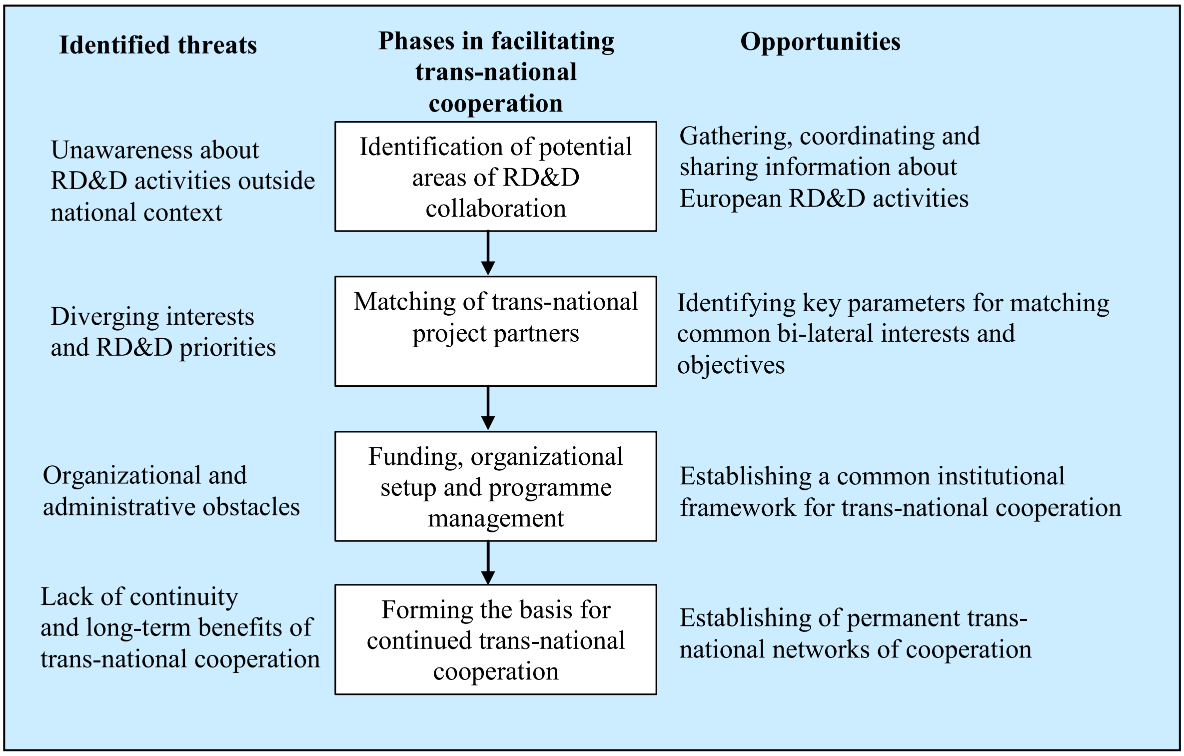

Figure 5.3: The different phases in setting up trans-national cooperation

Taking into account these four phases in facilitating trans-national cooperation and supplementing them with the experiences of the HY-CO interviewees, the findings of the Optimat, TAFTIE (2005) and Optimat/VDI/VDE reports, it is possible to point to some of the important elements or "best practices" of an "ideal partnership" for trans-national cooperation.

Choosing the right partners

- In general, the success of trans-national cooperation depends crucially on choosing the right partners and organisations
- Partners need to share the same objectives and have similar priorities. Partners with too diverging priorities lead to unfocused and unsuccessful collaboration
- A degree of complementarity between the participating partners is important
- Trust building is essential in order to share knowledge and cooperate successfully. Building trust takes time
- The partnership should be between equal partners (a win-win situation)
- Partners must share a genuine will, motivation and desire to cooperate

Ensuring continuity

- Long-term partnerships and projects are preferred to shorter ones.
- It takes time to build a true commitment towards a partnership and a habit of engaging in trans-national cooperation
- A long-term partnership is necessary in order to build-up trust and common values between the involved partners. These are crucial preconditions for a successful and productive cooperation
- Long-term project planning is important, but a precondition for project planning is continuity

- Long-term financial stability is essential. Continuity of funding is often as important as the amount of funding given
- The sharing of knowledge is essential, but requires a high degree of mutual trust and commitment, which take time to build. Sharing of knowledge is thus a long-term process

Ensuring flexibility
- A high degree of flexibility in a RD&D project is desirable, because research and innovation are always characterized by uncertainty and risks
- Budgetary flexibility is important. It gives the researcher the financial autonomy needed to adapt to changes in the project or the scientific agenda
- A higher degree of trust should be given to qualified scientists. The EU should carefully check the candidates that apply for certain projects. But once a candidate has been proven 'worthy', plenty of room for manoeuvring should be given in the sense that the level of regulations, duties and formalities should be kept at a minimal

Minimising bureaucracy
- In general, requirements for reporting, monitoring and control should be kept at an absolute minimum. Despite various attempts to reduce bureaucracy, the administrative burdens are perceived as increasing
- Bureaucratic and administrative requirements imposed on the scientists take up valuable time for researching.
- The call and application procedures should be less bureaucratic, less complex, less costly and less time consuming

A supporting overall framework
- A higher degree of coordination between regional and national research agencies and the EU on topics such as RD&D programmes, priorities and objectives is desirable
- Awareness among research agencies, programme managers and scientists about the possibilities and advantages of trans-national cooperation is essential
- Scientists planning to engage in trans-national cooperation should be encouraged and supported by their national research agency, research organisation and programme manager

5.9 Analysis of the strengths, weaknesses, opportunities and threats (SWOT)

The SWOT analysis summarizes the findings in this report and lists the strengths, weaknesses, opportunities and threats that have been identified. It draws on a desk study of existing literature on the subject, a survey of 18 hydrogen related experts across Europe and 21 interviews conducted with expert representatives of 18 countries in the field of hydrogen and fuel cell technology. Furthermore, it builds on a mapping and profiling of the national RD&D programmes of 27 European countries working in the field of hydrogen and fuel cell technology.

Strengths	Weaknesses
• High level of adaptability among the new European Member States in East Europe • World class RD&D within the hydrogen and fuel cell area • World class basic research • High level of funding for hydrogen and fuel cell RD&D activities (if the Quick initiative and FP7 are initiated) • EU Member States have high and demanding ambitions within the hydrogen and fuel cell area • Strong political backing for hydrogen and fuel cell technology and historical focus on the environment (demand-pull mechanism) • Excellent framework conditions for environmental innovation • Clear existing overlaps in terms of shared interest and technological expertise	• Unawareness about shared interests and expertise • Heterogeneity of RD&D programme design between the European countries within multiple areas (ex. technology, funding and support, legal frameworks and energy prioritization on a national scale) • Intellectual property rights hampers collaboration as technology moves towards commercialization • Weak at transforming research into commercial and competitive products in the market – the valley of death • Low level of venture capital funding and lack of industrial involvement in agenda setting • Low level of interaction between industry, government and scientists across national borders

Opportunities	**Threats**
• Gathering, coordination and sharing of information about European RD&D activities • Identifying key parameters for matching common bi-lateral or tri-lateral interests • Simplify and de-bureaucratize the call mechanisms and the control and evaluation procedures. Create greater project flexibility • Improve and simplify private actors' access to public funds • Establish a common institutional framework for trans-national cooperation • Potential cooperation between countries with both similar and different climatic conditions • Cooperation between countries with similar energy systems and priorities • Cooperation between countries with similar industrial bases (ex. automotives) • Establishment of long-term trans-national networks of cooperation • The new Member States could benefit from working more closely together in areas of basic research • Opportunity for designing specific and adapted RD&D projects in order to include the new Member States • Further industry involvement in public RD&D agenda setting • Greater interaction between scientists, the public sector and the industry	• Continued unawareness about shared interests and expertise • Lack of will and ambition to firmly establish European leadership in the field of hydrogen and fuel cell technology • Failure to set and implement common European RD&D priorities • More bureaucracy and less flexibility resulting from the enlargement • Strong and active international competitors within the hydrogen and fuel cell area • Lack of synergy between the public sector and private RD&D • Unawareness about RD&D activities outside national context • Lack of continuity and failure to realise long-term benefits of trans-national cooperation

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Appendix I: List over conducted phone interviews and interview guide

List over conducted phone interviews with HY-CO interviewees

Country	Respondent	Organisation
Austria	Theodor Zillner	Federal Ministry of Transport, Innovation and Technology
Belgium	Bart Laethem	Ministry of Flanders - Science and Innovation Administration
Czech Republic	Stepan Benes	Czech Energy Agency
Denmark	Aksel Mortensgaard	Danish Energy Authority
Finland	Rolf Rosenberg	VTT Technical Research Centre of Finland
France	Daniel Clement	The French agency for environment and energy management
Germany	Peter Malinowski	Research Centre Jülich
Germany	Helmut Geipel	Federal Ministry of Economics and Labour
Greece	Nicolas Lymberopoulos	Centre for Renewable Energy
Iceland	María Hildur Maack	Icelandic New Energy
Italy	Gaetano Cacciola	The CNR-TAE institute
Italy	Angelo Moreno	Italian National Agency for New Technologies, Energy and the Environment
Lithuania	Darius Milcius	Lithuanian Energy Institute, material Testing and Research Laboratory
Netherlands	Arie Bertus Stuij	SenterNovem
Norway	Jan-Erik Karlsen	Rogaland Research/University of Stavanger
Poland	Janina Molenda	Polish Hydrogen and Fuel Cell Association / AGH University of Science and Technology
Portugal	Rei Fernandes	Technical University of Lisbon, Research Group on Energy and Sustainable Development (IST)
Spain	Mónica Aguado Alonso	National Renewable Energy centre (CENER)
Sweden	Peter Lindblad	Uppsala university
United Kingdom	Ray Eaton	Department of trade and industry, Energy Innovation and Business Unit
United Kingdom	Bronwen Northmore	Department of trade and industry, Emerging Energy Technologies

Appendix II – The HY-CO interview guide

HY-CO Interview Guide

HY - CO

Co-ordination action to establish a hydrogen and fuel cell ERA-NET

ERA-NET

Vision

To be the driving force for public research programmes and to initiate joint coordinated programmes in hydrogen and fuel-cell technology in Europe

Mission

To provide the basis for and to set up a durable ERA-Net for the implementation of hydrogen and fuel cell technology in Europe

Your experience with trans-national cooperation in RD&D programmes

1. What are your **general experiences** with trans-national cooperation in RD&D programmes (other than hydrogen and fuel cells RD&D programmes) in [country]?

   - In which specific RD&D programmes did you experience trans-national cooperation?

   - Which countries were involved?

   - What kind of cooperation took place?

   - Is trans-national cooperation the general rule or the rare exception?

2. What are your **specific experiences** with trans-national cooperation within hydrogen and fuel cell RD&D in [country]?

   - In which specific RD&D programmes did you experience trans-national cooperation?

   - Which countries were involved?

   - What kind of cooperation took place?

3. Did the involved RD&D programmes in question **benefit** significantly from such trans-national cooperation?

   - If yes, what kind of benefits could be drawn?

4. Did you encounter any **problems or barriers** to trans-national cooperation in the programmes in question?

   - If yes, which ones? (e.g. coordination problems, legal complications in relation to contracts etc., divergent work routines, financial difficulties, lack of discipline, language barriers, heterogeneous expectations to quality and results)

Your expectations concerning trans-national cooperation in RD&D programmes

5. Do you think that (other) national hydrogen and fuel cell RD&D programmes could benefit as well from (further) trans-national cooperation, in terms of added value? (compared to H&FC activities in EC or FP's and (inter-)national initiatives like EURIKA, COST, HEP, IEA, IPHE)

   - If yes, what programmes in particular?
   - How?

6. What European countries do you see as obvious candidates for trans-national cooperation in your national research programmes and why (e.g. share of special expertise or other complementarities between different national RD&D programmes)?

7. What are the main barriers for further trans-national cooperation and how could these barriers be overcome?

How to boost trans-national cooperation in RD&D programmes

8. What should be the role of the EU in boosting trans-national cooperation in the field of hydrogen and fuel cell RD&D?

9. What could be done by the [country] government/ funding agency to boost trans-national cooperation in hydrogen and fuel cell RD/D programmes?

10. Do you expect national hydrogen and fuel cell RD&D programmes in [country] to benefit significantly from the HY-CO Mobility Programme? (If in doubt, see short description here: http://www.hy-co-era.net/Workpackage4)

11. If yes, in what way?