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A. Programmes on Energy Research and Technologies of the Federal Government

1. HYDROGEN

1.1 Past activities and Lessons Learned

In Germany, R&D on hydrogen technologies has been for a long time one of the key areas of the "Programmes on Energy Research and Technologies" of the Federal Government.

Until the middle of the 1980's, the thermochemical production of hydrogen from nuclear energy using the high temperature reactor was researched on. Another technology under investigation was the high temperature electrolysis (HOT ELLY). The public funds amounted to 2 – 3 M€ annually.

These activities have been stopped due to material problems and the interruption of the development of the high temperature reactor.

In 1988, an Ad-hoc Commission called up by the Federal Ministry of Research and Technology advised that there is no direct need for action with respect to a solar hydrogen economy. With respect to the precautionary principle, however, research policy should identify barriers to a hydrogen economy and initiate measures to overcome them.

Therefore, intensive R&D took place between **1988 and 1995** with public funds of about 5 – 7 M€ per year. R&D concentrated on the development of specific technologies (production – electrolysis – storage etc.) as well as on larger projects to demonstrate the whole supply chain. HYSOLAR and BAYSOLAR are the two major projects:

- Solar Wasserstoff Bayern (SWB, or BAYSOLAR) from 1986 to 1999
- Co-operation Project HYSOLAR with Saudi-Arabia from 1985 to 1995

In addition, a demonstration project on solar hydrogen was funded by the State of North-Rhine-Westphalia, the PHOEBUS project at the Research Centre Jülich.

A resume of these activities made in **1995** led to the following conclusions:

- the major precondition for a hydrogen economy is the production of CO2-free hydrogen
- major components needed for a hydrogen economy have been developed and work well
- "clean" hydrogen from renewables will not be competitive for a long time due to the high price of electricity from renewables (especially from solar)
- Electricity from renewables can better be used directly instead of using it for electrolysis. The "storage capacity" of the European power grid is sufficient for a long time. Using hydrogen as an energy storage option makes sense only if the storage capacity of the grid will not be sufficient to use the electricity produced from renewables
- No further large-scale demonstration projects on solar hydrogen are necessary
- An economic relevance of hydrogen as an energy carrier is not expected before 30 to 50 years, if no other cost-effective energy sources for the production of hydrogen are available before that time period
- The R&D programme should be focused on the development of fuel cells

1.2 Summary Description of National Programmes

Although hydrogen is a topic of the currently running "4th Programme on Energy Research and Technologies" of the Federal Government. However, there are currently no projects funded as a consequence of the conclusions from 1995.

The "Programme on Investment into the Future" (German abbreviation ZIP) started in 2001 to accelerate the development and deployment of key technologies, including fuel cells. Some projects specifically related to hydrogen technologies are currently funded under the ZIP-Programme. Projects include the demonstration of infrastructure for fuel cell busses.

In the meantime, another option to generate hydrogen from fossil fuels with CO2 capture and storage is part of the German COORETEC research concept developed during 2002/3. In June 2003, this new research concept COORETEC covering research on CO2 capture and storage has been published by the Federal Ministry of Economics and Labour. First projects on these topics will be funded in 2004 or 2005. More information: www.cooretec.de

Hydrogen production from biomass is being investigated as part of the bioenergy research programme.

A new vision on hydrogen technologies is currently drawn up on the initiative of the Federal Ministry of Economics and Labour (BMWA), involving the Federal Ministry of Transport (BMVBW), the Federal Ministry of Environment (BMU), several Ministries from the Federal States (Bundesländer) and representatives from industry and research. A report with recommendations on hydrogen technology development is expected to be released in the second half of 2004.

German companies, research institutes and universities are actively participating in the 6th Framework Programme of the European Commission.

2. FUEL CELLS

2.1 Past activities and Lessons Learned

Fuel cell R&D started with the first Federal programme on energy research **in 1974**. Intensive R&D of fuel cells has been performed in Germany **over the past ten years**. Fuel cells are a major focus of the subsequent "Programmes on Energy Research and Technologies" of the Federal Government.

R&D and testing efforts have concentrated on new materials, improved components and system integration. Therefore, fuel cells have become an option for a broad application in stationary and automotive applications. However, investment costs still exceed 10,000 €/kW. This is an improvement compared to the situation some years ago (50,000 €/kW), but the current state of development still does not allow an immediate commercialisation. Today, fuel cells do not compete with other power generation technologies.

Apart from the high cost, technical development has not yet guaranteed a lifetime of fuel cells which is sufficiently high. Major effort is needed to overcome this barrier.

Further R&D and demonstration is a prerequisite for a deployment programme.

2.2 Summary Description of National Programme

The "4th Programme on Energy Research and Technologies" of the Federal Government has the following general objectives:

- Development of technology options to reduce significantly the burden on environment and the climate caused by the use of energy carriers.
- Saving of scarce resources (primary energy carriers).
- Contribution to modernize our economy and to save our image as a technology nation. Improving export chances, providing new jobs.

Due to their high efficiency of electricity generation and their extremely low pollutant emissions, fuel cells are a top candidate to serve these objectives.

Current R&D activities under the **4th Programme** are concentrated on:

- Development of high temperature fuel cells (MCFC, SOFC) for stationary applications (block power plants, 100 – 300 kW_{el}).
- Development of a MCFC system
- Tube concept for SOFC
- Planar SOFC concept
- Development of a fuel cell system for house applications with components made in Germany.

Public funding for fuel cell activities amounts to 8 – 10 M€ annually. Projects are cost-shared with the private sector and therefore this corresponds to an overall budget of 16 – 20 M€ annually.

Fuel cells are additionally funded by the **"Program on Investment into the Future"** (German abbreviation **ZIP**) of the Federal Government. In the ZIP program, demonstration plays a major role. The ZIP program 2001-2005 has a volume of about 120 M€ and concentrates on:

- Further development and demonstration of 250 kW_{el} block power plants
- Demonstration of the SOFC tube concept in block power plants
- Development and demonstration of fuel cells for house applications (2 – 5 kW_{el}). PEMFC are preferred for this application
- Other applications of PEM (auxiliary power units, APU; portable applications)
- Education, technical training
- Further development of components for automotive applications
- Norms and standards
- On-board reforming of fuels
- Demonstration of fuel cell busses

In addition, German companies and research centres participate successfully in the Framework Programmes of the European Commission.

Recommendations for future R&D

In comparison to other countries Germany has a high standard in the development of fuel cells due to the strong concentration on stationary, mobile and portable applications for PEMFC, DMFC, MCFC and SOFC. Nevertheless, further R&D is recommended:

- Each of the fuel cell types PEMFC, DMFC, MCFC, SOFC has a high potential and shall be further supported by funded projects
- Enhanced funding for small and medium sized enterprises. A positive effect on job creation is assumed
- Process chains from fuel production to fuel cell application shall be investigated
- Further support of institutes and industrial companies for the further development of low-cost materials, components and systems.
- Restriction on most important fuel cell types (PEMFC, DMFC, MCFC, SOFC).
- First, concentration on stationary applications like block power plants and house applications. Second , mobile applications. Third, portable applications.

Targets for the next 8 – 10 years

In summary, the following targets are set for the next 8 to 10 years:

- Development of mature and complete fuel cell systems.
- Competitive costs of 1,000 – 1,500 €/kW_{el} in stationary applications and 50 €/kW in mobile applications.
- Proved lifetime with only minor degradation of 40,000 h for stationary and 5,000 h for mobile applications
- Full capacity to compete with other technologies

From today's point of view, there are no criteria which make it impossible to reach these targets.

B. Programmes of the Federal States (Bundesländer)

In the Federal States of North-Rhine-Westphalia, Baden Württemberg and Bavaria, substantial State (Bundesländer) programmes on hydrogen research are in place. They are summarised in the Annex.

(Note: It is difficult to distinguish between hydrogen and fuel cell activities in the programmes of the Federal States and the assignment of the Federal States programmes to "hydrogen" and "fuel cells" is somewhat arbitrary. In addition, there are hydrogen and fuel cell related programmes in other Federal States, in Hesse, Lower Saxony, Mecklenburg-Vorpommern and Saarland.)

C. Expectations from the IPHE

Germany is currently elaborating a new vision and strategy on hydrogen technologies. A report is expected to be released in the second half of 2004.

This report will investigate and evaluate the national programme priorities and the involvement in European and international activities. With the IEA Hydrogen Co-ordination Group HCG, the IPHE and the European Hydrogen and Fuel Cells Technology Platform being established and negotiated at about the same time, it is difficult to recommend at this point in time which priority will be given to activities and projects under the IPHE. In any case, good and efficient coordination of the international initiatives is one of the priorities.

In general, Germany supports actively the ongoing definition of concrete and meaningful activities and projects within the IPHE and the identification of priority areas for collaboration under the IPHE

Participation in European and international programmes will be constantly evaluated according to the following criteria:

- A transition to a hydrogen economy will only be successful in international cooperation, with a consensus on the road map or road maps. All aspects of policy need to be considered: technology and R&D policy, economic policy, industry policy, energy policy, environmental policy, … … . To introduce new technologies into the markets, public and private efforts and investments are needed. Will European and international cooperation help to minimise those efforts and investments; help to make use of the available investments most efficiently?
- Cooperation in IPHE R&D projects on hydrogen technologies has to reduce national R&D funding, and make the use of national R&D funding more effective. Real task sharing of important work packages is a pre-requisite (are the projects on the forefront of research and development?), as well as clear rules on intellectual property rights. Participation should be driven and steered by public and private sector views and requirements.
- Cooperation on Codes, Standards, Regulations and Safety of hydrogen technology should facilitate the international consensus and accelerate the introduction into the market.
- Close links between the different European and international initiatives regarding a future hydrogen economy should produce effective synergies and avoid duplication and unnecessary and inefficient management.

A more precise and comprehensive list of criteria is expected from the mentioned strategy report on hydrogen technology.

Annex

Fuel Cell Technology RD&D Activities and related Budget

4th Programme on Energy Research and Technologies and ZIP

Note 1: In the table below, budgets include Federal public budgets and private funds.
Note 2: The table does not include State Programmes and funding from EC Framework Programmes.
Note 3: Private sector R&D and demonstration without contribution from public funding surpass the amount of public funding and is not included in the budget table.

TECHNOLOGY AREAS	**BUDGET**	
FUEL CELLS	**R&D**	**DEMO (ZIP, 2001-2005)**
Basic R&D • National Research Centres	50 M€ (1990-2002)	
FCs for Stationary Applications • Distributed power applications (MCFC/SOFC) • CHP co-generation applications (PEM, SOFC)	120 M€ (from 1990-2003) 20 M€ (from 2000-2003)	38 M€ 44 M€
FCs for Automotive Applications • PEMFC/DMFC	105 M€ (1994-2002)	20 M€
Education and Normative Research		14 M€

Programmes of the Bundesländer

Note:
It is difficult to distinguish between hydrogen and fuel cell activities in the programmes of the Federal States and the assignment of the Federal States programmes to "hydrogen" and "fuel cells" is somewhat arbitrary. In addition, there are hydrogen and fuel cell related programmes in other Federal States, in Hesse, Lower Saxony, Mecklenburg-Vorpommern and Saarland.

North-Rhine Westphalia	
Competence Network Fuel Cells North-Rhine Westphalia	
Objectives	Funding of hydrogen and fuel cells: ➢ Information and communication with about 300 members of the Network from industry, science and society ➢ R&D and demonstration (application development; components development; material development; infrastructure measures; PEFC technology) ➢
Total Budget	48 M€ public funding of a total of 96 M€ for 47 projects, most of them FC projects

Time Period	Since 2000
Contact Persons	Prof. D. Stolten, Research Centre Juelich
web	www.brennstoffzelle-nrw.de

Bavaria	
Hydrogen Initiative Bavaria (WiBa)	
Objectives	Funding of hydrogen and fuel cells: ➢ H2 storage ➢ Infrastructure (1st refuelling station world wide) ➢ Portable DMFC systems ➢ Public awareness (exhibition at Deutsches Museum Munich)
Total Budget	75 M€ for 30 projects, most of them FC projects
Time Period	Since 1996
Contact Persons	Prof. U. Wagner, Technical University of Munich
web	www.ffe.de

Baden Württemberg	
Research Alliance Fuel Cells	
Objectives	Funding of hydrogen and fuel cells: ➢ PEMFC and SOFC ➢ House energy supply ➢ Bus demonstration ➢ Education and training
Total Budget	About 5 to 6 M€ per year
Time Period	Since 1990
Contact Persons	Br. W. Lehnert, ZSW Ulm and Stuttgart
web	http://www.forum-brennstoffzelle.de