Bundesministerium für Verkehr, Bau und Stadtentwicklung

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Technologie

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National Hydrogen and Fuel Cell Technology Innovation Programme

I. Background

Economic development and prosperity, seen in the context of the need to protect our local and global environment, are political priorities in Germany, Europe and the world in general. In order to foster economic growth without harming the environment we require a secure and increasingly clean supply of energy to our industry as well as to the transport and housing sectors. At the same time, we must stimulate knowledge-intensive industries since they create a reliable foundation for global competitiveness and secure jobs.

Hydrogen as a source of energy and **fuel cells** can help us make a significant step towards these goals. Throughout the last three decades, the German government has been actively promoting research on and the development of hydrogen and fuel cell technology. These R&D activities resulted in state-of-the-art technology that is setting international standards, as well as in findings that are valuable for future development efforts. Hydrogen emerged as an option for future energy production, provided that it can be produced in a cost-effective, environmentally viable manner.
We must now focus our efforts on the next steps. Promoting the emerging hydrogen and fuel cell industry in a targeted manner gives us a unique opportunity to influence this process and to speed up **commercialization**, which is important for Germany as a business location. This will require a **targeted multi-annual innovation programme (cover-**

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ing the entire process from basic research to preparing the launch on the market) for transport, stationary and portable applications.

The National Hydrogen and Fuel Cell Technology Innovation Programme **puts flesh on the bones of the coalition agreement.** At the same time, it is a further module in the implementation and evolution of the government's **Fuel Strategy**.

The programme will serve to coordinate current government activities that are going to continue (such as R&D at the Ministry of Economics and the Ministry of Finance within the 5th Energy Research Programme[1]) with the entire range of new measures, such as the preparations for commercialization carried out by the Ministry of Transport.

II. Challenges

Germany's cutting-edge position on the hydrogen and fuel cell technology market[2]

Hydrogen energy and fuel cell technology are highly relevant when it comes to producing energy for the transport sector as well as for stationary and portable plant and equipment.

German R&D on **stationary fuel cell systems** for domestic and industrial electricity and heating supply has reached a very high level. German fuel cell manufacturers, their German suppliers and the German research community are still among the leading players on the global market for stationary fuel cell systems. Last year, their research projects received a total of approximately € 30 m in funding from the Federal Ministry of Economics and Technology and the Federal Ministry of Education and Research.
Of Europe's major heating system manufacturers, four are German, as are two of the world's leading developers of combined heat and power fuel cell plant for industrial use. All of this means that this industry is of major importance for Germany. Integrating sta-

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1 5th Energy Research Programme of the Federal Government, "Innovation and New Energy Technologies", July 2005: http://www.bmwi.de/English/Navigation/Service/publications,did=74976.html

2 See paper „Vorreitermärkte Brennstoffzellentechnologie" ("Fuel cell technology – cutting edge markets") by the Innovation Initiative working group (subgroup on the public sector as a factor of innovation), January 2006

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tionary fuel cell systems into the infrastructure is proving unproblematic, since the existing natural gas pipeline network can be used. Manufacturers of stationary fuel cells are currently considering whether to invest in mass production facilities. Since this technology is not yet competitive due to its high cost, commercializing it will require financial back-up by the public sector.

Just as with stationary applications, Germany is in the vanguard with regard to **fuel cells for transport purposes**. However, the **fuel cells** for use in vehicles are so far only **produced outside of Europe**.

The automotive industry is of enormous importance for the German economy. More than 770,000 people are directly employed by it[3]. Economic analyses[4] have lead to the following conclusion for the transport sector: Provided there is a high uptake of cars equipped with fuel cells and Germany can export as many of them as it does conventional cars, there will be a positive impact on employment and the economy in general, when compared to a scenario without fuel cell cars. If, however, the majority of future fuel cell cars were to be manufactured abroad and imported by Germany, Germany would not only lose its drivetrain production, but sooner or later also its automotive industry in general to manufacturers abroad. The “conventional” parts of a car alone (especially the body) account for roughly two thirds of the value added in the production process. If the latter scenario were to come true, this could result in significant harm to the national economy. For example, if 20% of the cars used in Germany were fuel cell cars manufactured abroad, Germany would stand to lose as many as 250,000 jobs.

What this means is that Germany not only risks losing technological expertise and value added, but also its standing as an automotive manufacturer.

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3 Figures provided by the Association of the German Automotive Industry (VDA), 2005

4 HyWays: http://www.hyways.de (Integrated project with financial support by the EU that brings together a number of European industry representatives, representatives of the German federal states and of research institutions.)

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Keeping the lead in technology

Currently, Germany is in the lead in Europe with regard to hydrogen and fuel cell applications. For example, the Clean Energy Partnership (CEP) Project in Berlin is the largest and technologically most advanced transport sector hydrogen demonstration project in Europe.[5]

If you look at some recent studies on Germany's vanguard potential in fuel cell technology, however, the result is a mixed bag and some deficits manifest themselves – on the one hand, Germany is poised to take the lead in Europe, on the other hand, it is lagging behind major international competitors that are doing everything in their power to snatch the lead in technology away from it (see figure 1).

USA FreedomCAR Hydrogen Fuel Initiative	• Long-term programme/strategy 2003-2015 (DOE, 100% funded) • Commercialization by 2015 • $ 1.7 bn in the first 5 years for hydrogen infrastructure and fuel cells ($ 1.2 bn for R&D on H2&FC, $ 0.5 bn for hybrid and vehicle technologies) • 2006: $ 59.6 m for PEM fuel cells (R&D on fuel cell stacks, transport and stationary applications, fuel production) • Hydrogen storage: $ 150 m for 5 years
Japan WE-NET	• Long-term programme/strategy (100% funded; NEDO/METI) • 2005: ¥ 35.5 bn (approx. € 250 m) • Commercialization: 1 m fuel cell cars by 2015 • Strategic background: $ 52 m per year for R&D on PEM fuel cells (including stationary systems), regulations, codes & standards $ 32 m p.a., hydrogen utilization $ 38 m p.a.)
EU FP6/CUTE FP7/JTI	• 2003-2006: € 46 m • Starting in 2007 (envisaged): FP7 and JTI marketing programme: €1.5 bn, 50% co-financed by the member states
Germany General energy research/ CEP demonstration project	• Evolution and implementation of a comprehensive, long-term hydrogen and fuel cell technology strategy • 1974-2003: approx. € 200 m in funding (including approx. € 60 m from the Programme of Investments for the Future) • CEP: run as a PPP (2003-2007); funding: € 5 m (government funding for hydrogen infrastructure, excluding vehicles); total budget € 33 m.

Figure. 1: Hydrogen and fuel cell activities (selection)

[5] Project duration: 2004-2007; total budget: € 33 m, € 5 m of which are public funds (www.cep-berlin.de)

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In a worldwide context, indicators such as the number of patent applications filed (see figure 2) show that the US, Japan and Canada are in the process of gaining a competitive edge over Germany in some fields.

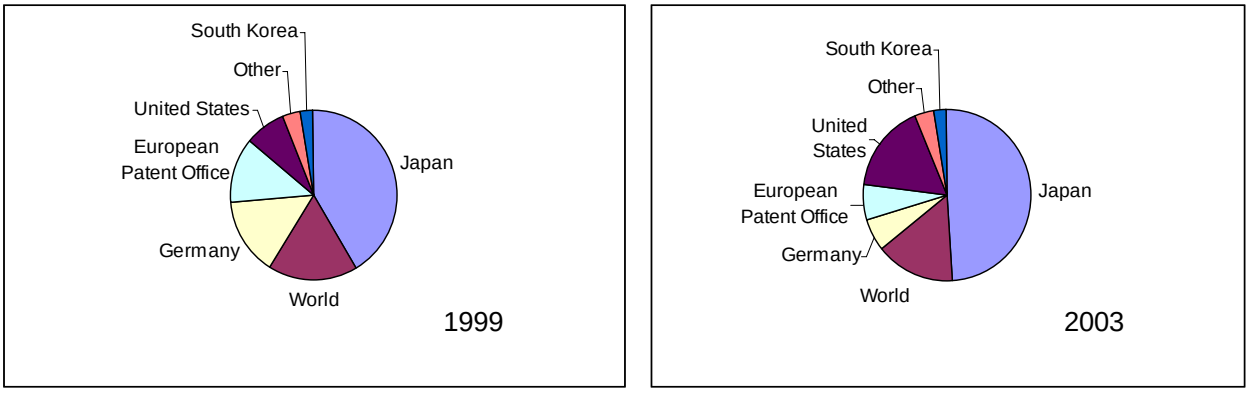

Figure 2: The number of fuel cell patent applications filed in selected countries and industry trends (Source: Thomson Scientific Ltd (2004): *The Hydrogen Revolution – An evaluation of patent trends in the fuel cell industry*)[6]

In the past, the Federal Government has made substantial funding available for hydrogen and fuel cell R&D (see figure 3). Starting in 1986, government support was significantly extended when the world's first large-scale projects demonstrating the full extent of a "solar" hydrogen chain were launched. After the successful conclusion of these activities the Federal Government, supported by the industry, began in 1995 to push the development of fuel cells as key elements of sustainable energy supply. The Programme of Investments for the Future, launched in 2001, facilitated further significant expansion of fuel cell development. Funding from this programme not only helped to establish state-of-the-art research infrastructure – activities under the programme played an important part in bringing German research in this field up to its current high level.

[6] Please note that these figures do not take the multinational character of the companies involved into account. According to the same source, the worldwide number of fuel cell basic patent applications rose from just under 1,000 in 1999 to 4,000 in 2003. Moreover, in 1999 there were still two German companies among the top five with regard to patent applications. In 2003, none was left.

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Federal Government funding for research in hydrogen and fuel cell technologies:

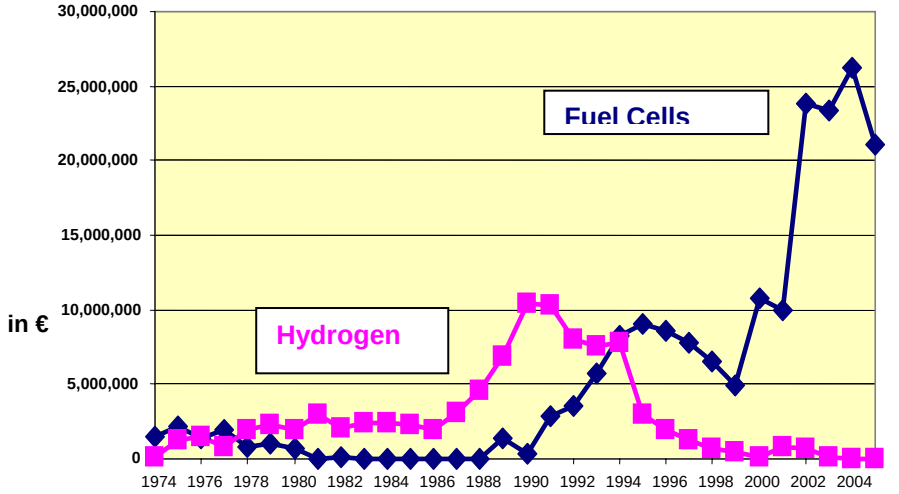

Figure 3: Annual funding 1974-2004

In future, in order to maintain and further improve the high level of R&D in Germany and to apply the findings to commercialization, a significant rise in funding will be required (especially for hydrogen and fuel cell technology development programmes).

From the point of view of economics, this is the importance of **Germany's current role** as a cutting-edge market for hydrogen and fuel cell technologies:

- There is a certain amount of risk involved in investing in R&D, demonstration projects and infrastructure because hydrogen and fuel cell technologies might not catch on to the extent that is currently expected. However, this risk is offset by the likely loss of jobs and value added that would follow if the fuel cell came to dominate the market without the German industry playing a leading role in transport and stationary applications and the establishment of infrastructure. This is the situation Germany needs to consider, and there is a strong case for bolstering its leadership in a targeted manner.
- Germany has no time to waste because it has some serious competitors that are putting all their efforts into fuel cell development. In addition, it will take years or even decades to anchor fuel cells firmly on the market (especially in the transport sector, where the necessary infrastructure will first have to be built). The scarcity of energy resources and climate change further narrow our window of opportunity.

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Germany's strength lies in its scientific and industrial expertise in the development and production of hydrogen and fuel cell technologies. The analyses conducted so far have shown that it might be dangerous for Germany to adopt a wait-and-see strategy because of the economic fallout for the automotive industry, its suppliers and the infrastructure providers. There is a danger that Germany might – as has already happened in other fields of research such as nanotechnology – remain in the lead with regard to basic research, while lagging behind with regard to industrial application.

Securing the supply of energy, improving energy efficiency, tackling climate change

The conservation of natural resources and energy has developed into a major political issue. Our societies can only function if affordable transport and housing are available. 90% of today's transport, to take just one example, depends on oil. The interrelationship of transport, security of energy supply and the prevention of climate change is of crucial importance for the future development of Germany and Europe in general as places to do business. We must significantly reduce our dependence on fossil fuels, especially oil and gas. This is the main reason why we need to look for alternative forms of energy.

Efficient new energy technologies play a key role in ensuring a secure and sustainable supply of energy. **Fuel cell technologies and hydrogen produced without generating carbon dioxide are an additional option for producing tomorrow's supply of environmentally friendly and efficient energy for our transport services and our homes.**

In 2004, an interdisciplinary working group convened by the Ministry of Economics proposed that a coherent strategy be drafted, covering both the supply and the demand side of energy, i.e. the procurement of fuels, their transport, distribution and conversion to energy, including the role of power engineering and the individual end users.[7] According to the members of the working group, the objective of a strategy like this for the short and

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[7] Source: Federal Ministry of Economics and Labour, Research Report No. 546: Strategy Report on Research Needs in the Field of Hydrogen Energy Technology, January 2005.

medium term would have to be to increase energy efficiency and make more use of renewable sources of energy.
Further developing hydrogen-based systems for the transport sector and for the power supply industry, for industrial use and for use in private households opens up an opportunity to harness an efficient and sustainable alternative to conventional fuels.

III. National Hydrogen and Fuel Cell Technology Innovation Programme

1. Acting on the commitments in the coalition agreement and on the decisions of the coalition cabinet meeting at Genshagen

The coalition partners have agreed to make an additional € 6 bn available for especially promising fields. Due to the challenges described above, a **national innovation programme for hydrogen technologies (including fuel cells)** is to be launched, among other measures (chapter 5.5 of the coalition agreement). The National Hydrogen and Fuel Cell Technology Innovation Programme is to be one module of Germany's **High-Tech Strategy** and is to focus on linking the business and science communities by way of a modern cluster policy.

Industry commitment and financial support of the programme in order to strengthen Germany's technology sector in the face of global competition are a vital prerequisite for this.

2. Objective

The objective of a **national innovation programme** in that field must be to preserve and bolster Germany's leadership in hydrogen and fuel cell technology by providing a substantial financial boost to hydrogen and fuel cell research in Germany.

The individual ministries' strategy determination efforts, basic research activities and development programmes, such as

- basic research and **portable** fuel cell R&D at the Federal Ministry of Education and Research,
- R&D[8] and demonstration/lighthouse projects as well as commercialization programmes for **stationary** hydrogen/fuel cell applications at the Federal Ministry of Economics and Technology (if appropriate, in coordination with the Federal Ministry of Transport, Building and Urban Affairs),
- demonstration and lighthouse projects for **transport** applications and commercialization planning for **hydrogen as a fuel** at the Federal Ministry of Transport, Building and Urban Affairs

are to be coordinated in a manner that prevents overlap and duplication of funding. Moreover, they are to result in a clear schedule for the industry that will have to contribute its share to the financing of the programme. The schedule should lay down how fuel cells and the hydrogen economy are to be developed in Germany, leading to an energy supply situation where hydrogen accounts for a considerable share of the market alongside other primary and secondary sources of energy.

It is chiefly the existing European initiatives in this field that are to provide guidance for the National Hydrogen and Fuel Cell Technology Innovation Programme. The European Commission – represented mainly by the Directorates-General for Research and Energy/Transport – promotes and coordinates hydrogen and fuel cell technology programmes at the European level. In January 2004 the Commission established the European Hydrogen and Fuel Cells Technology Platform (HFP) in order to create a focal point for the entire range of European R&D activities and accelerate the commercialization of hydrogen and fuel cell technologies. Among other things, this platform has since brought together industry and research community in outlining a European “vision” for the future use of hydrogen (see figure below).

8 For example, the 5th Energy Research Programme of the Federal Government (“Innovation and New Energy Technologies”, July 2005) contains comprehensive R&D and demonstration activities by the Federal Ministries of Economics and Technology and Education and Research.

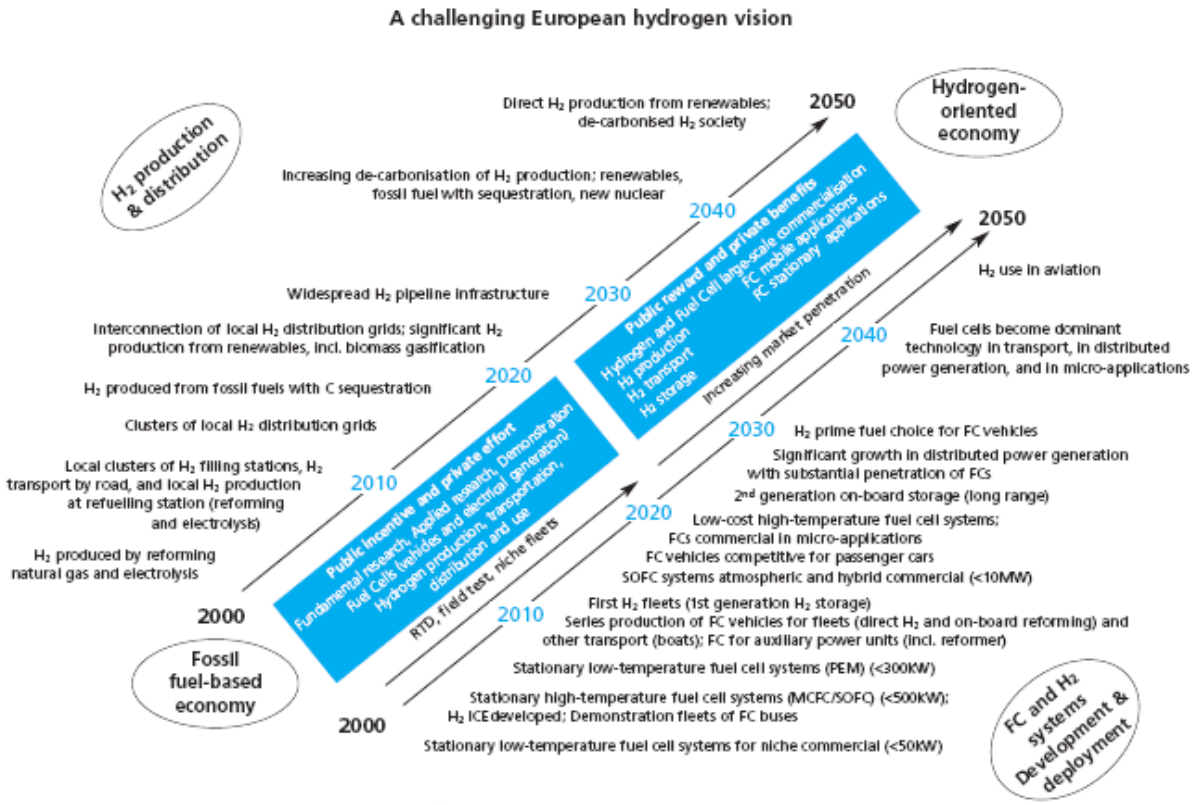

Figure 4: Skeleton proposal for European hydrogen and fuel cell roadmap

3. Prerequisites for a National Fuel Cell and Hydrogen Technology Innovation Programme

- The programme has evolved from the **Federal Government's Fuel Strategy** as a specific programme for the transport sector. (Objective: security of energy supply; reduction of carbon dioxide emissions) Aside from promoting the commercialization of hydrogen and fuel cell transport technologies it serves to fund the commercialization of stationary and portable applications as well as a range of R&D activities;
- The programme proposal is based upon a wide range of activities that have already taken place in Germany and Europe. It brings together the key recommendations resulting from them (most notably from the Transport Energy Strategy (VES), the Ministry of Economics strategy paper on required research in the field of hydrogen energy technologies [2004], the National Hydrogen and Fuel Cell Strategy Council and HFP) and takes up an issue that was highlighted in the coalition agreement – the need to get the private sector to agree to boost its investment in research on and the commercialization of energy technologies, too (PPP concept).

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- The proposal was shaped to resemble the strategic programmes of Germany's major competitors, Japan and the US (long-term programmes with high state funding for R&D; package funding for hydrogen and fuel cell technologies).
- One of the main tenets of the proposal is the focusing of the comprehensive **expertise of the German business and scientific communities (pooling existing centres of excellence)**. New projects with industry require programme and project structures that are authorized and able to take speedy decisions on substantive and operational issues.
- The proposal makes use of existing structures (notably the National Hydrogen and Fuel Cell Strategy Council and the National Hydrogen and Fuel Cells Coordination Centre at Jülich [NKJ]) and builds upon them in a targeted manner.

4. Core elements of the Hydrogen and Fuel Cell Technology Innovation Programme

a) Programme of work:
⇨ R&D – Continue and expand R&D, ranging from basic research to demonstration projects (drawing up a **National Hydrogen and Fuel Cell Research Agenda).**
⇨ Commercialization: Establish and expand **demonstration and lighthouse projects.**

b) Budget:
⇨ Additional federal funding – **€ 500 m for 10 years** for R&D, focus on commercialization

c) Organisation and structure
⇨ Form a professional programme and project management team for new projects with industry. Use existing R&D infrastructure in combination with an extended brief where appropriate.
⇨ Handle the individual activities in line with the existing funding guidelines[9] (e.g. R&D funding guidelines of the Federal Ministry of Economics and Technology).
⇨ Coordinate the individual projects at the National Hydrogen and Fuel Cell Strategy Council.

Objective: **Launching the National Hydrogen and Fuel Cell Technology Programme by the summer of 2006**

[9] Richtlinien zur Förderung von Forschung und Entwicklung im Bereich „Rationelle Energieverwendung, Umwandlungs- und Verbrennungstechnik", 24 February 2006, published in *Bundesanzeiger* No. 47 of 8 March 2006 (p. 1501).

a) Programme of work

It will be the task of the National Hydrogen and Fuel Cell Strategy Council to propose a detailed 10-year programme by the summer of 2006 on the basis of this draft.[10]

The basic objectives envisaged are

- giving a significant boost to hydrogen and fuel cell R&D aimed at the development of applications for the transport and building sectors;
- conducting a set of coordinated studies to arrive at a comprehensive analysis of the individual stages of a hydrogen economy roadmap (hydrogen and fuel cell roadmap) for the transport and building sectors, including an analysis of their economic and ecological viability;
- based on this set of studies, developing a hydrogen and fuel cell roadmap for Germany;
- financially supporting the implementation of the roadmap (follow-on industry projects that are closely coordinated);
- continuing and expanding current national pilot projects, notably the Berlin Clean Energy Partnership (CEP; runs until 2007) and the HafenCity project in Hamburg, as commercialization projects, if possible with a view to the European market, and providing financial support for the necessary investment in infrastructure and hydrogen vehicles.[11]

Action is required in the following fields:

Determination of strategy, especially
Drawing up a hydrogen and fuel cell technology roadmap (transition – markets – long-term prospects, quantities, infrastructure, economic effect, environmental impact, security of energy supply)

Research and development
R&D activities must be significantly intensified to enhance competitiveness.
- Improving hydrogen production processes, hydrogen storage and infrastructure,

[10] To this end, the ministries involved will present to the National Hydrogen and Fuel Cell Strategy Council an initial draft programme and budget outline for discussion and elaboration.

[11] **Note**: This is the way it was done in the US and Japan, among other countries. Their approach resulted in German fuel cell vehicles being used in demonstration projects in these countries, while there are still none available for German projects.

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- Further developing applications such as fuel cells and internal combustion engines, including hybrid engines (esp. materials development/development of components, production processes),
- Reducing costs along the entire value-added chain,
- Conducting system analyses alongside the process; assessing the process in a holistic manner

Ensuring an unambiguous regulatory framework for developers, producers and investors, for example by providing for

- Speedy adoption and implementation of international legislation
- Vocational and further training (in the trades)

A large share of the budget (65%) will be used for demonstration projects (lighthouse projects) designed to systematically prepare components and systems for full-scale commercialization in terms of reliability and suitability for everyday use (focus on transport applications).
To this end, PPP lighthouse projects with the following objectives are required (examples):

- More industry commitment through spreading of risks;
- Furnishing proof of technological feasibility;
- Seeing how it works in practice and evaluating the experience;
- Increasing take-up of the technology by providing objective information;
- Promoting cooperation at the national, European and international levels;
- Laying the foundations for Germany's future hydrogen economy.

Lighthouse projects

- Lighthouse projects bridge the gap between today's prototypes and full-scale commercialization (integration of new technologies into the system);
- They are based on a wealth of experience from individual regions and make use of existing projects (e.g. expansion of the CEP – Leuna pipeline system – HafenCity Hamburg – North-Rhine Westphalia);
- In the beginning, the focus will be on a few sites (clusters). Later on, activities will be broadened and then linked up with those in other European regions;
- A wide range of companies will be cooperating here, including all CEP partners, HDW/Blohm+Voss, MTU, Vaillant, Siemens, Airbus and numerous SMEs.

Selected project modules

- Expanding the hydrogen fleet (there are currently 15 vehicles in Berlin) to reach a total of several hundred state-of-the-art vehicles (passenger cars, buses and coaches);
- Establishing the necessary hydrogen infrastructure (filling station corridor);
- New hydrogen applications in shipping, aviation and the building sector;
- Optimizing the hydrogen production process and hydrogen storage (e.g. electrolysis, off-shore wind farms)
- Standardizing regulations, safety requirements as well as basic and further training.

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b) Budget

The German government has consulted with representatives of the industry and the scientific community meeting in the National Hydrogen and Fuel Cell Strategy Council and has taken into account the way Japan and the US are currently promoting the technology. In the light of all of this, the government has reached the conclusion that the national hydrogen and fuel cell innovation programme would require a total of € 1 bn in funding for a period of ten years (PPP approach). The programme is to be structured in a way that will allow parts of it to be linked up with European initiatives at a later stage.

The 2006 financial year is to be the initial phase of the National Hydrogen and Fuel Cell Innovation Programme. (Coordination of the programme of work with the National Hydrogen and Fuel Cell Strategy Council, putting the organisational structure and programme management into place, drafting of business plan and financial monitoring, securing industry commitment.) From 2007 onwards, funding levels for the individual activities under the programme will be sustained through commitment appropriations in the budgets of the ministries involved.

c) Organization and programme management

Due to the national scale of the programme, the complexity of the tasks and the number of project partners, bringing together German expertise will not be enough. Therefore, a **professional programme and financial management team** will have to be set up, something that is of particular importance with regard to the new activities that are to be launched in cooperation with industry.

What professional programme and financial management would have to deliver (examples):

- Secretarial tasks, coordination and management;
- Communications/PR (e.g. using the Internet);
- Contracting (legal and commercial skills);
- Financial control;
- Expertise in hydrogen and fuel cell technologies;

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- R&D project management (including PPP consortia), coordination of national R&D programmes
- Acceptance by industry and the scientific community.

A small share of the budget (5% max) will be earmarked for the establishment of a decision-making and coordination structure (programme management) that can handle the complex tasks involved.

4. The next steps

- (By the summer of 2006): Put the matter before the National Hydrogen and Fuel Cell Strategy Council and coordinate activities with it; draw up the overall programme of work/programme packages, especially
  - ⇨ establish a national hydrogen and fuel cell roadmap (analyses to be conducted, among others: WtW, infrastructure, energy market and emissions, country and sector profiles).
  - ⇨ draft and implement proposals for lighthouse projects (commercialization) for portable, stationary and transport applications;
- (By the autumn of 2006): Draw up an implementation plan/business plan
- (By the autumn of 2006): Secure industry and third-party commitments (e.g. based on consortium agreements similar to the one used in the CEP model).