

NIP – The German National Innovation Programme Hydrogen and Fuel Cell Technology

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NIP – The German National Innovation Programme Hydrogen and Fuel Cell Technology

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Summary

Mobility and energy supply are essential elements of modern societies. Participation in social and cultural life, commuting to work, the transportation of goods, and provision of power and heat for houses – all this will only be possible in the future with modern emission-free and efficient technologies. Similarly, economies will only be globally competitive through market leadership in these areas. Hydrogen and fuel cells play a key role in the mobility and energy supply of tomorrow.

The NIP – the National Innovation Programme for Hydrogen and Fuel Cell Technology – was launched in 2007 to accelerate market preparation for these technologies in Germany. Since then, projects with federal funding of almost €255 million for R&D as well as demonstration activities have been started, showing that industry is committed to developing future-oriented products deploying hydrogen and fuel cell technologies.

Looking at application areas, automotive manufacturers are preparing for market entry of series production passenger cars starting around 2015. This does not begin with hundreds of thousands of cars per year, but with a gradual ramp-up. Hydrogen infrastructure must be simultaneously established nationwide with special attention to carbon dioxide-free production pathways. In the stationary application area, industrial combined heat and power systems and residential power supply systems are expected to complete their market preparation phase within the next five years, in order to then be introduced as commercial products to the market. Special markets such as back-up power systems or specialty vehicles are also assuming an important role. They represent early market opportunities as well as pioneering sales potential for suppliers.

1 Introduction

Hydrogen and fuel cell technologies will play an essential role in the future of mobility and energy supply. In 2006, government, industry and science initiated the German National Innovation Programme Hydrogen and Fuel Cell Technology (NIP) as a strategic alliance. The NIP is intended to speed up the process of market preparation for products based on these future-oriented technologies. The total budget of the NIP to fund individual projects over a period of ten years (2007-2016) amounts to €1.4 billion. The Federal Ministry of Transport, Building and Urban Development (BMVBS) has dedicated €500 million for demonstration activities and the Federal Ministry of Economy and Technology (BMWi) will provide at least €20 million over the ten-year period. In total, this represents half of the overall budget, with the other half contributed by participating industry. Figure 1 shows the annual federal funding

in Germany since 2008 for those projects within the NIP that were approved by January 2010, adding up to almost €255 million (BMVBS: €169,276 million; BMWi: €85,679 million).

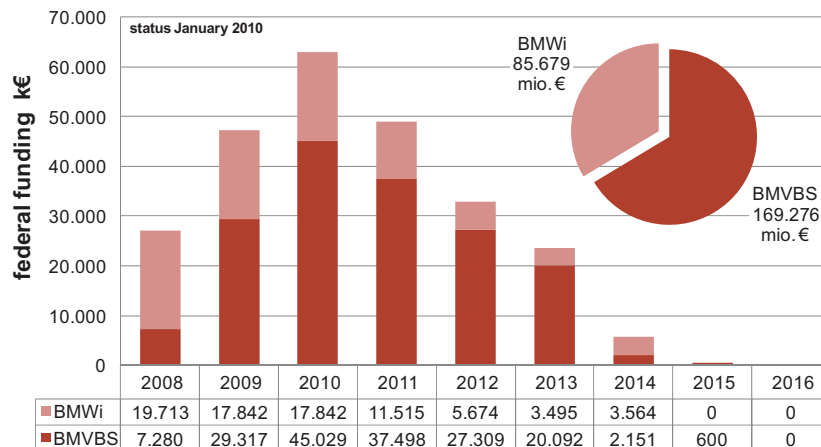


Figure 1: Approved NIP-projects (demonstration (BMVBS) and R&D (BMWi)).

The large-scale demonstration projects within the NIP are grouped into comprehensive lighthouse projects and take place under real-life conditions. Project partners thus work together efficiently on issues and challenges which they otherwise would have to face alone and with considerably higher individual effort.

The NIP is divided into three programme areas in order to advance numerous hydrogen and fuel cell technology product and application options in equal measure, and to address the application-specific challenges of market preparation in a targeted way. The particular programme areas are: »Transport and Hydrogen Infrastructure«, »Stationary Energy Supply«, and »Special Markets«. With an eye to series production of components, an explicit focus in all programme areas is also on strengthening the supply industry.

2 Transport and Hydrogen Infrastructure

The challenges for transportation are constantly increasing with regard to:

- Security of supply (decreasing oil dependency through diversification of the fuel portfolio, use of domestic energy carriers like synthetic fuels, electricity, and hydrogen)
- Environmental sustainability of supply (climate and environmental protection through increasing usage of renewable energies and more efficient drive train technologies)
- Affordability of supply (through decreased fuel consumption, cost effective fuels and moderate costs for purchase)

Incumbent technologies currently in the markets will be further optimised, but these improvements are insufficient to reach global climate targets. For example, in the European transport sector, an 80% reduction in greenhouse gas emissions by 2050, which is necessary to remain within the 2 degree target, requires maximum permissible emissions in new vehicles (passenger cars and light duty vehicles) of approximately 80g CO₂ per km by the year 2020. By 2030, this figure must be reduced even further to less than 60g CO₂ per km [1]. The optimisation of today's fuels and power drive technologies needed to meet these goals will in all probability not be achievable. It is therefore crucial that renewable energy sources and more efficient drive train technologies are implemented to enable the transport sector to meet its environmental targets. The development and embedding of new technologies for improved efficiency and sustainability will bring about a paradigm shift away from oil to a range of solutions taking regional considerations into account. An area offering vast potential in this context is hydrogen with fuel cell technology.

Leading OEMs like Daimler, Ford, GM/Opel, Honda, Hyundai, Kia Motors, Nissan/Renault and Toyota publicly announced in September 2009 that they strongly anticipate that a significant number of fuel cell vehicles could be commercialized from 2015 onwards. This number is expected to be as high as a few hundred thousand units over the life cycle on a worldwide basis. The announcement identified Germany as the lead market in Europe, where hydrogen vehicles are to hit the road first, and where the built-up of substantial numbers of filling stations is to commence.

The parallel step comprises the further development and tailored build up of the hydrogen fuelling infrastructure. These activities are promoted by *H2 Mobility*, a public private partnership that focuses specifically on developing the business case for an area wide hydrogen infrastructure in Germany during Phase I, which will run until 2011. *H2 Mobility* was launched in September 2009 with the signing of a "Memorandum of Understanding" between Daimler, EnBW, Linde, OMV, Shell, Total, Vattenfall and NOW. Since then, Air Liquide and Air Products have also joined the initiative. Taking Germany as a lead market and starting point will also help with infrastructure development in the whole of Europe.

To support and to accelerate the market preparation of technologies in the field of road transportation, the NIP focuses on deploying and demonstrating hydrogen vehicles and the associated infrastructure within its lighthouse project *Clean Energy Partnership (CEP)*.

2.1 Clean Energy Partnership (CEP)

The *CEP* was launched in 2002 as an international corporate partnership. Its aim is to demonstrate the every-day suitability of hydrogen as a fuel for vehicles and to test the infrastructure for refuelling such vehicles. In September 2008, the *CEP* embarked on its second phase. Since then, 48% of *CEP* funding contributions comes from the NIP. Currently, the *CEP* concentrates on the key regions of Berlin and Hamburg, with North Rhine-Westphalia added as a CEP-region in May 2010. CEP is the largest undertaking of its kind in Europe. More than 30 passenger cars are in daily use, and the expansion of this fleet continues. Furthermore, Berlin and Hamburg continue to boast operating fleets of public buses. As these fleets grow, the associated hydrogen infrastructure will mature accordingly. The CEP partners - vehicle manufacturers (BMW, Daimler, Ford, GM/Opel, Toyota and

Volkswagen), oil companies (Shell and Total), energy providers (Vattenfall), the gas industry (Linde) and public transport providers (BVG and Hochbahn) cluster their activities in the super ordinate modules to ensure a unified CEP voice. These common tasks include: coordination and management, project representation, knowledge and information management and public relations.

Opening the new hydrogen fuelling station in Berlin's Holzmarktstrasse in May 2010 marked an important milestone for the CEP on its way to expanding the infrastructure for hydrogen refuelling. At this station, project partners TOTAL, Linde and Statoil deployed innovative technologies to compress and store the gaseous hydrogen to up to 1,000 bars. The planned station at Sachsendamm in Berlin from Shell addresses large-scale validation of a scalable hydrogen fuelling station concept on the basis of liquid hydrogen transfers and a 900 bar cryopump. Subterranean installation of plant technology in order to reduce its footprint will also be demonstrated. Also in Hamburg a new hydrogen fuelling station is to be constructed by Vattenfall and Shell. The fuelling station in the HafenCity will serve to supply public city buses and private vehicles. Besides gathering practical experience in handling hydrogen safely, a further focus lies in energy balance optimisation. Incorporation of an innovative compressor and electrolyser aims to accomplish this goal. The use of power from regenerative sources of energy is the guarantee for a sustainable form of individual mobility. Operating experiences with regard to the hydrogen infrastructure for cars and busses will be gathered throughout these projects as a basis for the establishment of a future hydrogen station network.

In addition to the demonstration activities within the CEP, supporting R&D covers the optimisation of specific fuel cell components like a mass-producible gas diffusion layer, an electric turbo charger for the air supply or next generation passenger car and bus fuel cell system development and validation.

2.2 Hydrogen production

Next to electricity, hydrogen is considered to be the energy carrier of the future. It can be made from various energy sources, can be easily stored, is highly efficient in the operation of fuel cells and produces virtually no emissions. Its use opens up new perspectives for energy supply especially when it comes to transportation fuels.

Studies have shown that large scale hydrogen production via wind power, biomass and coal (with CCS in the longer term) as well as via natural gas and from industrial by-products (in the initial phase) are feasible from a technical and economic point of view. The same applies for the necessary infrastructure, distribution and storage technology so that the complete hydrogen value chain is ready for implementation in the coming years.

According to the study GermanHy [2] hydrogen could, depending on the scenario, cover between 23% and 40% of the energy requirements in the transport sector in 2050 and thereby supply up to 70% of passenger cars and light commercial vehicles. To generate hydrogen, a mixture of different primary energies will be used, amongst which wind energy is likely to be the most significant long-term option in Germany. From a cost perspective following the launch phase, hydrogen costs range between 3 and 4 €/t/km. Carbon dioxide

emissions from transport will drop by up to 80% in the longer term, and the share of renewable energies in the production of hydrogen could increase by over 60% by 2050.

Within the NIP, specific demonstration projects address the production of hydrogen based on renewable primary energy sources. This includes innovative gasification processes using biomass as well as electrolyser-based systems powered by wind energy. Besides technical aspects, questions regarding the integration of such devices in the overall energy market considering fluctuating energy supply from renewable power sources are being addressed.

If hydrogen technology represents a large share in Germany's future transportation systems, it will significantly contribute to Germany's future security of energy supply, and the fulfilment of EU climate change targets. Moreover hydrogen paves the way for new possibilities in the area of cutting edge technology, innovation, and as a result, global competitiveness.

The existing barriers to the market introduction of hydrogen as a fuel and respective vehicles are threefold. Firstly, the cost of the technology needs to be reduced over the entire value chain, but primarily in the vehicle and the hydrogen distribution and refuelling infrastructure. Secondly, hydrogen production needs to reduce its CO₂ footprint and thirdly, investment schemes for setting up the hydrogen refuelling infrastructure need to be identified.

The NIP addresses cost reduction of fuel cells as well as hydrogen production and refueling technologies in various projects. One example with regard to automotive fuel cell system cost shows that reductions of more than 90% were achieved from one generation to the next through integration of components, optimized manufacturing processes, use of new materials and technologies, and economies of scale (figure 2).

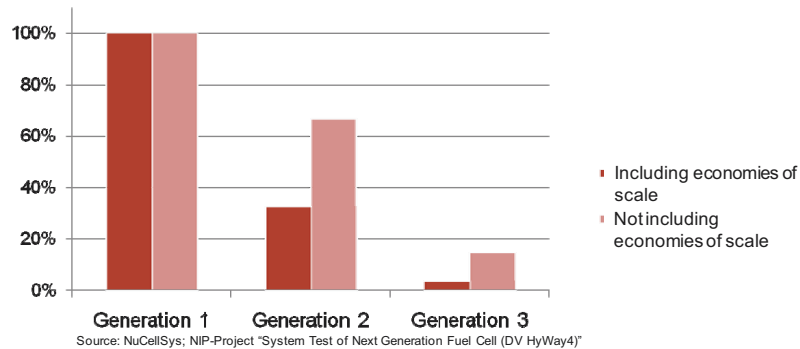


Figure 2: Cost reduction of fuel cell system (not including the stack).

3 Stationary Energy Supply

Stationary fuel cell systems provide power, heat and refrigeration in residential buildings and on ships, as well as for commerce and industry. They are expected to be ready for widespread use before the decade is out after a further testing phase. New, highly efficient

technologies make a significant contribution to climate protection. Around two thirds of the overall energy demand is associated with electrical power, heating, cooling and hot water. Due to their high electrical efficiency as well as their co-generation capability (combined heat and power systems) fuel cells significantly reduce energy consumption and related emissions. Using biogenic fuels such as biogas, a virtually CO₂-free energy supply is possible.

Highly efficient high temperature fuel cell systems powered by gas from sewage plants and biogas facilities are the focus of the NIP lighthouse project *NEEDS* (New Ecologic Energy Decentrally Supplied). Demonstrating the production of CO₂-neutral power, heat and refrigeration fuel cell power stations will supply energy to hospitals, factories, office buildings and indoor pools.

Within the framework of NIP, other lighthouse projects in stationary power supply are *Callux* and *e4ships*.

3.1 Callux – fuel cells in residential co-generation systems

Fuel cell heating systems convert hydrogen to power and heat via an electrochemical process. This makes them ideal for environmentally friendly implementation in buildings. In contrast to conventional systems where mechanical energy is converted to electricity, these innovative small combined heat and power systems are highly efficient. They boast vast effectiveness and guarantee low emissions thanks to their direct conversion of energy. A reformer produces hydrogen from natural gas directly on site. And thanks to the existing infrastructure, this is easily available — even as biogas.

The lighthouse project *Callux* intends to test fuel cell-based combined heat and power systems in residential applications so that they can be deployed for mass use within the coming decade. The Latin terms »calor« and »lux« mean »warmth« and »light«. Together they form the expressive name »Cal-lux« chosen for this comprehensive lighthouse project within the NIP. With the purchase, installation and operation of up to 800 fuel cell heating systems, the initiative represents Germany's largest field trial for fuel cells in homes. The goal of *Callux* is to pave the way for the market introduction of natural gas-powered fuel cell heating systems, enabling such systems to be reliably implemented in the future for daily use. The project began in September 2008 and is scheduled to run for seven years. The demonstration activities within *Callux* are supported by focused R&D addressing performance enhancement as well as cost reductions.

Callux partners are the energy firms EnBW, E.ON Ruhrgas, EWE, MVV Energie and VNG Verbundnetz Gas, the system manufacturers Baxi Innotech, Hexis and Vaillant, and the Centre for Solar Energy and Hydrogen Research — ZSW (Zentrum für Sonnenenergie- und Wasserstoff-Forschung). ZSW coordinates the cooperation between partners on the project level. Besides evaluating specific projects in this context, NOW handles the aligned knowledge management and paves the way for international cooperation.

The energy supply firms negotiate long-term contracts with equipment manufacturers independently of one another to examine and test the technology in practice. They procure cutting-edge fuel cell heating equipment, which they put at the disposal of interested households. To be in a position to obtain verifiable, scientific results, the same targets and

guidelines apply to all involved. In May 2010, fifty systems — regionally bundled — were installed across 13 German states. This number is set to increase to around 800 within the next several years.

The fuel cell equipment is especially designed for the basic needs of detached and semi-detached houses. Their thermal performance is rated at 2kW and electrical at approximately 1kW. Regarding the fuel cell technology itself, depending on the manufacturer either low-temperature PEM, high-temperature PEM or SOFC systems are being deployed. A natural gas burner ensures coverage during peak demand periods, if required. Meanwhile, a central control unit manages the entire system. In contrast to electricity production in central (off-site) power plants and separate heating in a boiler or furnace, up to 30% of primary energy can be saved.

Besides addressing technical issues, the *Callux* partners endeavour to minimise potential barriers to market entry. To achieve this goal, diverse and in part interdisciplinary issues are being addressed. Market partners and tradesmen in the sanitary-heating-climate field must, for example, be trained in time and be prepared for their future work on the new equipment through continuing, practical education measures. Joint communications activities by the consortium will ensure the public is informed about the new technologies and that interest among potential customers is fostered. Simultaneously, market and customer requirements must be clearly defined. For this purpose, the parties will conduct extensive market research. Interfaces must also be standardised to enable communication between the fuel cell heating equipment and household energy management systems.

Through binding orders of larger quantities, along with sophisticated concepts for supply structures, delivery chains will be established and finally costs reduced. All *Callux* activities are designed to promote and introduce the new technologies of fuel cell heating equipment as an efficient, climate friendly and cost saving form of energy supply for buildings, promoting added value in Germany.

3.2 e4ships – fuel cells in maritime applications

Whether a cruise ship, research craft, merchant vessel, ferry or yacht: in the future, highly-efficient, quiet and low emission power and heating will be brought on board through fuel cells. Initiated in July 2009 and operating until 2016, *e4ships* is the lighthouse project within the NIP in which well-known German dockyards and shipping lines, leading fuel cell manufacturers and classification societies will be testing the functionality of fuel cells as an onboard supply of energy under rugged maritime conditions. Current partners are: AIDA Cruises, CMT, DNV, Flensburger Schiffbau- Gesellschaft, Lürssen, Germanischer Lloyd GL, hySOLUTIONS, HAW Hamburg, Helmut-Schmidt-Universität, Imtech, INVEN Engineering, MEYER WERFT, MTU Onsite Energy, Öl-Wärme-Institut (ÖWI), Reederei Rörd Braren, Proton Motor, ThyssenKrupp MS, VSM and ZBT.

e4ships is divided into several projects to demonstrate innovative technologies. A high-temperature fuel cell is to be tested on board a cruise ship as a modular energy supply system that is run by natural gas. Following testing, the system will be optimised to ensure that the decentralised combined heat and power concept is further developed for passenger ships. In another part of the project, consortium partners will work on a fuel cell system that is

suitable for use on the high seas. To compensate for possible differences in the dynamics of fuel cells and onboard power supply networks, the energy supply will be buffered via a lithium-ion battery. Resource-saving sulphur-free diesel or second-generation synthetic fuels will be used to power the fuel cell equipment.

Besides purely technical challenges, overarching issues concerning ecological, technical and economic assessments of the application of fuel cells in ships will be addressed by *e4ships*. The involved parties work to uniform technical standards for system variations and performance classes. As soon as technical and regulatory hurdles to market maturity have been overcome, *e4ships* will be in the position to make a decisive contribution to the competitiveness of German dockyards and shipping lines through the provision of the necessary innovative and highly efficient technologies.

4 Fuel Cells in Special Markets

Before new technologies capture mass markets, they are often used in special applications that can showcase their merits particularly well. Under the NIP, this area is known as »Special Markets«. Fuel cell applications in these special markets stand out because of their greater proximity to market readiness compared to other application areas, their highly diverse applications — from micro fuel cells and critical power supply, to leisure and camping products — as well as a multitude of innovation-focused small to medium sized businesses involved. Critical power supply in various applications and industry fields (see Figure 2), conveyor technology, and vehicles such as forklifts and airport tow tractors, electric light vehicles like cargo bikes and boats, onboard power supply for the leisure and camping market, as well as small applications such as power supply for RFID systems (Radio Frequency Identification in logistics) on the basis of micro fuel cells, are just some of the diverse areas where this technology can be applied.



Figure 3: Fuel cells in critical power supply/ back-up power.

Following the NIP approach of clustering individual projects to enhance learning and communication among both academic and industry stakeholders, further lighthouse projects in the application areas of critical power supply and material handling are being prepared. In February 2010, for example, the *Bodensee* lighthouse project was started.

4.1 Bodensee Lighthouse Project

As a regional and thematic grouping for leisure applications of fuel cells, the *Bodensee* lighthouse project provides ideal conditions for the market preparation of fuel cell technology. By including operators (of e.g. boats and light vehicles), the public is offered a hands-on experience with fuel cell technology. Not only will the everyday suitability of sustainable and efficient products be tested, but public acceptance of new technologies will also be strengthened. That is why the *Bodensee* lighthouse project is particularly attractive for tourist-oriented regions, cities and communities, as well as for innovative institutions and businesses from the tourist, environmental and energy industries. Demonstrations will be focused initially in the Bodensee region, in Freiburg im Breisgau, and in the Danube city of Ulm.

Within the *Bodensee* project, the onboard power supply of camping vehicles (camper vans, mobile homes) and the power drive of leisure vehicles (boats, light vehicles) using fuel cell systems will be tested under everyday conditions. The goal is increased publicity, made especially feasible through fuel cell applications in this sector. The implementation of the *Bodensee* lighthouse project will be supported for a duration of one year by the state of Baden-Württemberg as a key partner. Various projects funded in the context of the NIP are part of the *Bodensee* lighthouse project. STEP is a project, where elcomax, SFC Smart Fuel Cell and Truma Gerätetechnik are developing and field-testing a new generation of membrane electrode assemblies (MEAs) for DMFC (direct methanol fuel cells) and HT PEM (polymer electrolyte membrane) fuel cells. Within the project »DMFC systems for light electric vehicles«, project partners Clean Mobile and SFC Smart Fuel Cell are developing a DMFC system platform tailored to the demands of the LEV (light electric vehicles) market segment. Optimisation and efficiency of the overall system of electric energy supply are at the forefront, as well as the demonstration of various LEV vehicle types in everyday use. A reformer fuel cell system will be further developed by Truma Gerätetechnik under the »Onboard power supply for leisure vehicles« project. The system will be subjected to a market-oriented practical test and deployed in the main independent onboard energy supply (auxiliary power unit) of leisure vehicles. The everyday testing is carried out by selected end customers and vehicle manufacturers.

The special markets area paves the way for fuel cell technology towards mass application. Here they demonstrate their reliable operation and the technological advantages of a future-oriented, sustainable, and cost conscious technology.

5 Conclusions

Hydrogen and fuel cell technologies will be key elements in future sustainable energy systems including transportation. Global efforts continue to introduce commercially viable products in this field as part of a broader portfolio of technological solutions.

Since the NIP began in 2008, more than 70 individual projects with more than 160 partners from industry and from academia were established in Germany addressing all industry sectors and markets in which hydrogen and fuel cell technologies have the potential to significantly reduce carbon dioxide emissions. The NIP combines focused R&D with comprehensive demonstration activities preparing the markets for all public and private stakeholders involved not only to address environmental issues, but also to strengthen their capability to remain at the forefront of innovations.

The structure to coordinate and manage the NIP with *NOW GmbH National Organisation Hydrogen and Fuel Cell Technology* as a strategic alliance involving public bodies (Government) and private organizations has proven to be efficient. Combining individually funded projects to form networks working commonly on overarching tasks, coherent communication, and fruitful international cooperation all help to leverage public funding and avoid doubling of private investments in the context of successful market preparation for hydrogen and fuel cell technologies.

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