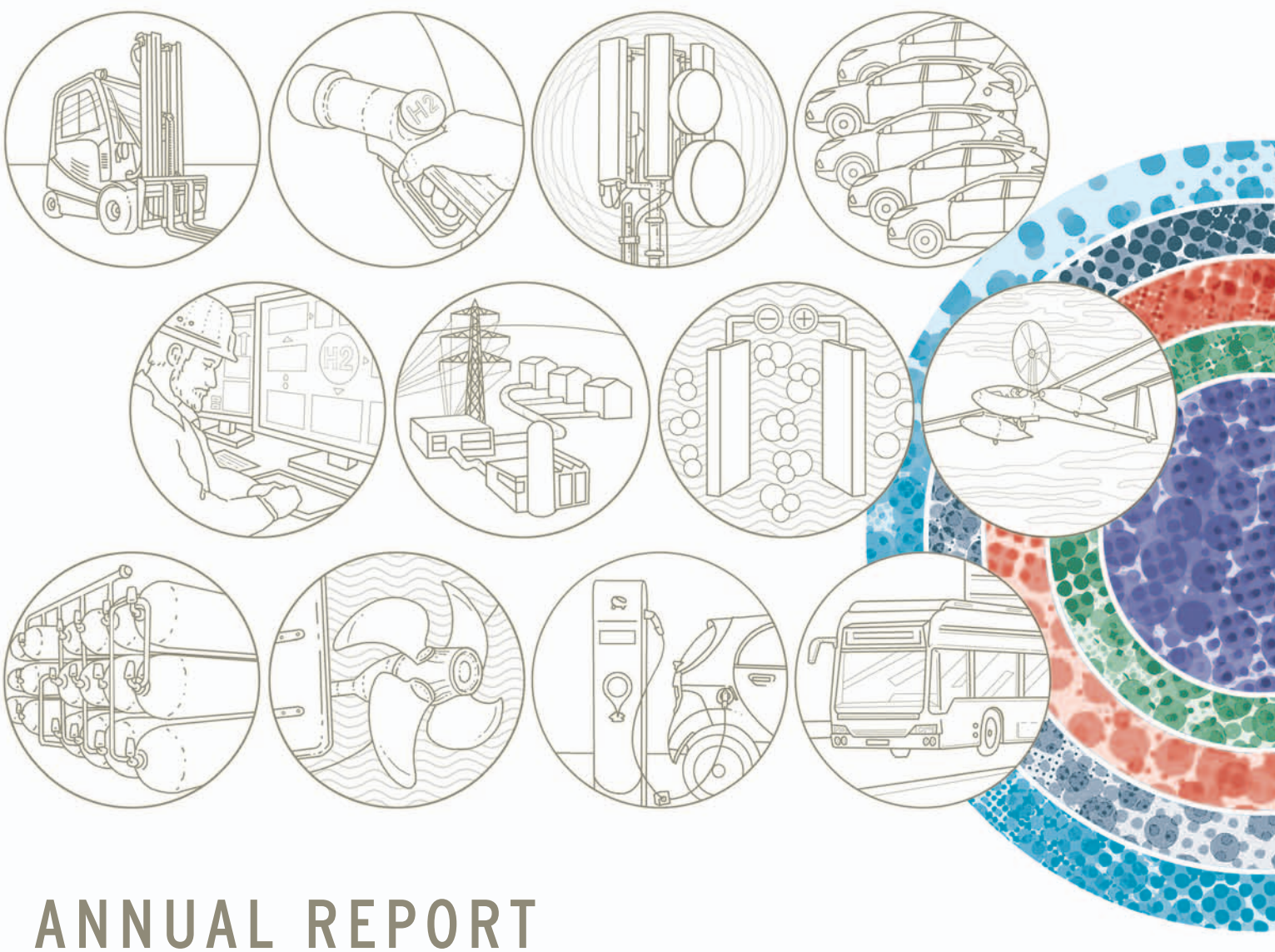
NOW
National Organisation Hydrogen and Fuel Cell Technology



# ANNUAL REPORT

# 2015

NOW coordinates the National Innovation Programme Hydrogen and Fuel Cell Technology of the federal government and the Electromobility Model Regions of the BMVI.

The following provides detailed information of projects newly approved in 2015 as well as those concluding in 2015.

Federal Ministry
for Economic Affairs
and Energy

## THE FOLLOWING BMWi NIP PROJECTS WERE APPROVED IN 2015:

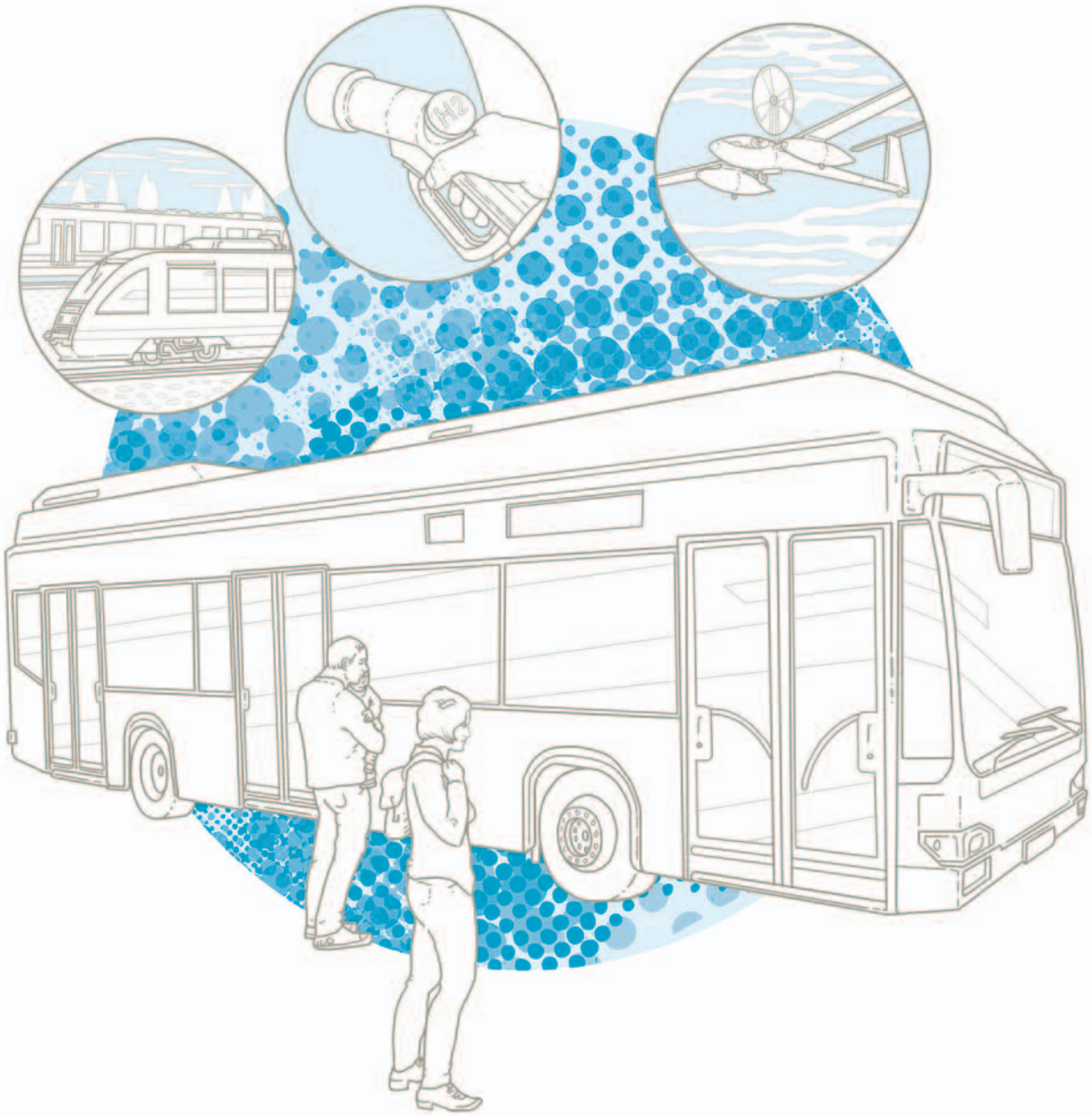
| PROJECT | COMMENCEMENT | CONCLUSION |
|---|---|---|
| METHAPEM | 01 May 2015 | 30 April 2017 |
| METHAPEM | 01 May 2015 | 30 April 2017 |
| METHAPEM | 01 May 2015 | 30 April 2017 |
| METHAPEM | 01 May 2015 | 30 April 2017 |
| QUALIFIX | 01 May 2015 | 30 April 2018 |
| QUALIFIX | 01 May 2015 | 30 April 2018 |
| QUALIFIX | 01 May 2015 | 30 April 2018 |
| QUALIFIX | 01 May 2015 | 30 April 2018 |
| NEST PeI | 01 May 2015 | 30 April 2018 |
| NEST PeI | 01 May 2015 | 30 April 2018 |
| NEST PeI | 01 May 2015 | 30 April 2018 |
| DruHEly | 01 May 2015 | 30 April 2018 |
| Green$H_2$ | 01 June 2015 | 31 May 2018 |
| SeFoG | 08 July 2015 | 31 July 2018 |
| Alterung SoHMuSDaSS | 01 August 2015 | 30 July 2018 |
| Alterung SoHMuSDaSS | 01 August 2015 | 31 July 2018 |
| Alterung SoHMuSDaSS | 01 August 2015 | 30 July 2018 |
| Alterung SoHMuSDaSS | 01 August 2015 | 31 July 2018 |
| SmartII | 01 September 2015 | 31 August 2018 |
| SmartII | 01 September 2015 | 31 August 2018 |
| SmartII | 01 September 2015 | 31 August 2018 |
| SmartII | 01 September 2015 | 31 August 2018 |
| SmartII | 01 September 2015 | 31 August 2018 |
| SmartII | 01 September 2015 | 31 August 2018 |
| Luftmo | 01 October 2015 | 28 February 2017 |
| BigPPsBip | 01 November 2015 | 31 March 2019 |
| BigPPsBip | 01 November 2015 | 31 March 2019 |
| BigPPsBip | 01 November 2015 | 31 March 2019 |

| PARTNER | FUNDING RATIO [%] | FUNDING BUDGET [€] |
|---|---|---|
| Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) | 100 | 284,583 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 80 | 69,703 |
| Wieland-Werke Aktiengesellschaft | 48 | 92,010 |
| SFC Energy AG | 48 | 97,831 |
| EWE – Forschungszentrum für Energietechnologie e. V. | 90 | 1,343,711 |
| Eisenhuth GmbH & Co. KG | 40 | 441,968 |
| fischer eco solutions GmbH | 40 | 441,758 |
| FuMA-Tech Gesellschaft für funktionelle Membranen und Anlagentechnologie mbH | 40 | 377,395 |
| Forschungszentrum Jülich GmbH | 100 | 710,324 |
| GKN Sinter Metals Engineering GmbH | 40 | 144,456 |
| Siemens Aktiengesellschaft | 40 | 94,999 |
| Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) | 100 | 599,351 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 100 | 2,865,139 |
| Forschungszentrum Jülich GmbH | 100 | 996,900 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 77 | 1,165,509 |
| Zentrum für Brennstoffzellen-Technik GmbH | 100 | 736,384 |
| Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) | 100 | 710,633 |
| Bosch Engineering GmbH | 50 | 84,214 |
| ElfER Europäisches Institut für Energieforschung EDF-KIT EWIV | 50 | 181,101 |
| Forschungszentrum Jülich GmbH | 100 | 787,095 |
| ElringKlinger AG | 40 | 2,327,556 |
| CeramTec GmbH | 40 | 632,490 |
| Karlsruher Institut für Technologie (KIT) | 100 | 581,288 |
| Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) | 76 | 396,981 |
| PROTON MOTOR Fuel Cell GmbH | 50 | 118,574 |
| Zentrum für Brennstoffzellen-Technik GmbH | 100 | 673,109 |
| fischer eco solutions GmbH | 50 | 241,502 |
| Dr. Schneider Kunststoffwerke GmbH | 50 | 252,319 |

| COMMENCEMENT | COMMENCEMENT | CONCLUSION |
|---|---|---|
| ecoPtG | 01 November 2015 | 31 October 2018 |
| ecoPtG | 01 November 2015 | 31 October 2018 |
| ecoPtG | 01 November 2015 | 31 October 2018 |
| ecoPtG | 01 November 2015 | 31 October 2018 |
| DESS2020+ | 01 November 2015 | 31 October 2018 |
| DESS2020+ | 01 November 2015 | 31 October 2018 |
| $H_2$-Neo-Kat | 01 December 2015 | 31 May 2017 |

| PARTNER | FUNDING RATIO [%] | FUNDING BUDGET [€] |
|---|---|---|
| IAV GmbH Ingenieurgesellschaft Auto und Verkehr | 50 | 1,068,026 |
| Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) | 100 | 1,227,555 |
| WASSERELEKTROLYSE HYDROTECHNIK GmbH | 60 | 238,504 |
| Reiner Lemoine Institut gGmbH | 90 | 840,225 |
| Robert Bosch Gesellschaft mit beschränkter Haftung | 40 | 1,571,227 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 82 | 1,054,156 |
| neoxid GmbH | 50 | 97,581 |

# NIP – TRANSPORT AND INFRASTRUCTURE



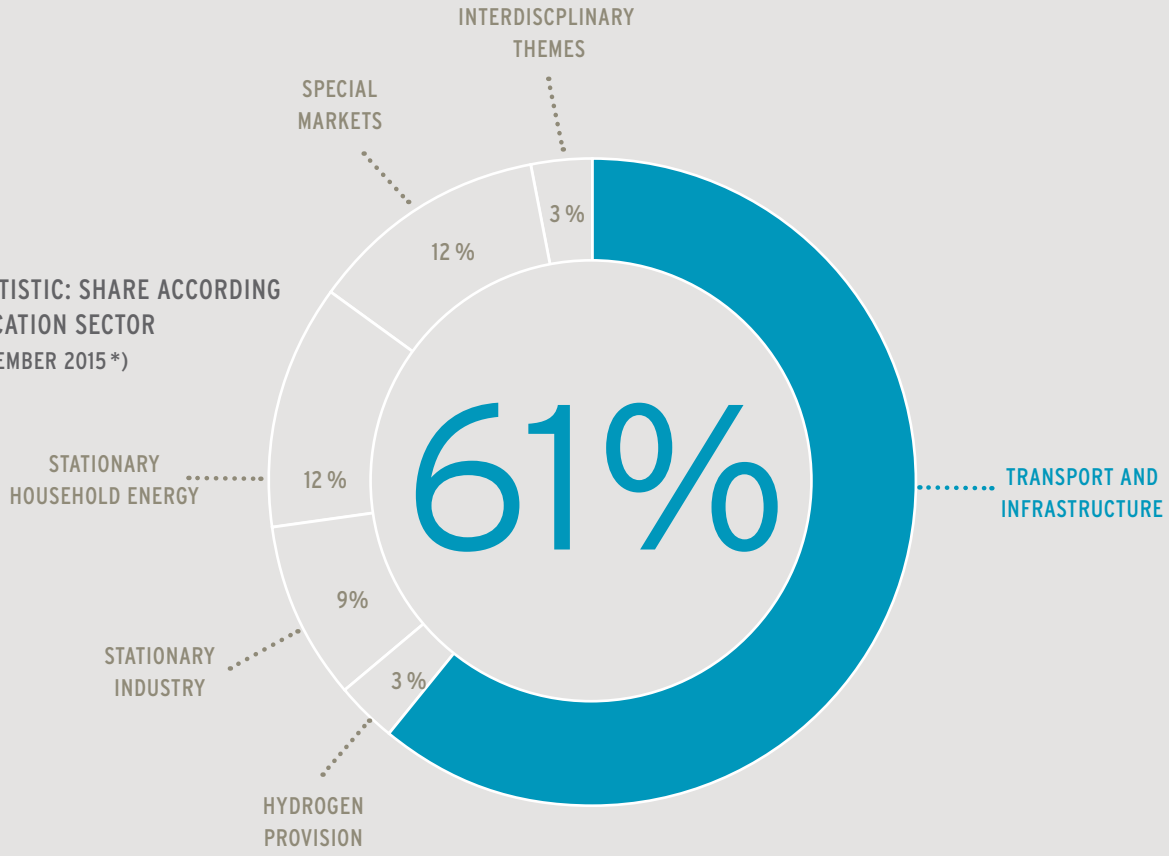

THE PROJECTS ARE LISTED I / 01 – I / 26 ON THE FOLLOWING PAGES,
COMPLETED PROJECTS ARE MARKED WITH 🏁 .

# NIP – TRANSPORT AND INFRASTRUCTURE

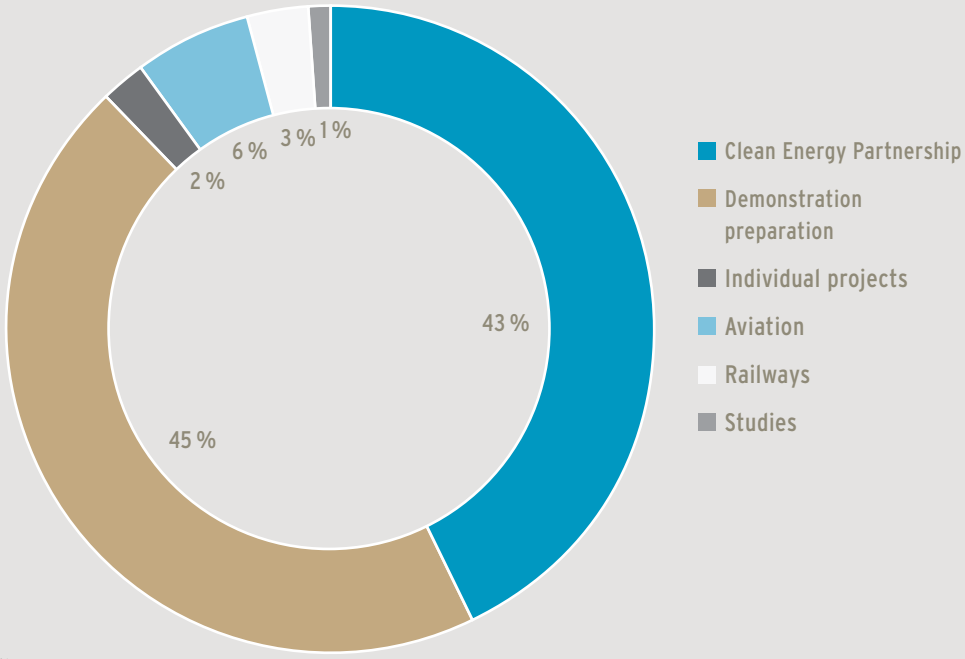
The Transport and Infrastructure programme area focuses on research and development along with demonstration activities in the areas of drive technologies and hydrogen infrastructure. Entire drive systems and key components such as polymer electrolyte fuel cells (PEMFC) and hydrogen storage are being closely examined throughout the research and development activities. A main focus is placed on reducing costs and weight, increasing service life and performance as well as enhancing reliability in day-to-day operations. In addition, efforts to improve the development of production processes of fuel cell systems are being stepped up in order to establish and enhance manufacturing expertise. In terms of infrastructure, cost reductions and improved reliability are similarly a key area of focus in the various projects and work is also continuing on the introduction of technological standards for hydrogen refuelling stations. The programme area is also examining potential areas of off road fuel cell application, such as for the supply of onboard power in aircraft or for drivetrains in rail transportation.

The demonstration projects are an important aspect of the Transport and Infrastructure programme area as they help validate the implemented technology under everyday conditions and also assist in preparing the market by increasing user acceptance. Comprehensive accompanying research activities in these areas is initiated and coordinated by NOW. Furthermore, hydrogen-based fuel cell vehicles are being tested in comprehensive collaborative projects spanning both personal transportation as well as local public transport. The expansion of hydrogen infrastructure is also being promoted within the framework of the 50 Refuelling Stations programme, coordinated by NOW, in order to provide a basic national supply network of hydrogen refuelling stations.

## NIP – STATISTIC: SHARE ACCORDING TO APPLICATION SECTOR
(AS AT DECEMBER 2015 *)



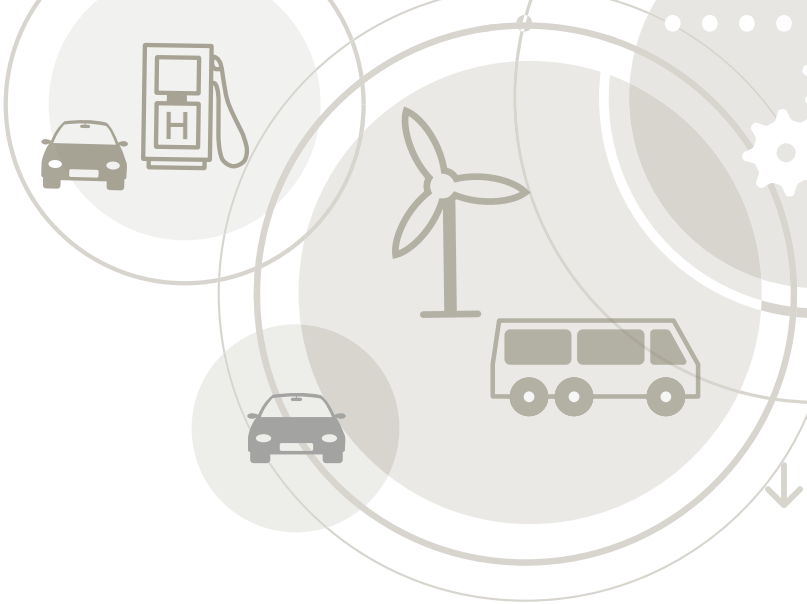

## NIP – TRANSPORT AND INFRASTRUCTURE: ALLOCATION BY APPLICATION AREA
(AS AT DECEMBER 2015)




* The diagram incorporates projects at planning stage at NOW, being processed by PtJ, LOI (Letter of Intent) as well as those approved.


# »Clean Mobility with Hydrogen and Fuel Cells.«


CRUISE CENTER
OF PM 130
GG HY 422



# CLEAN ENERGY PARTNERSHIP – MOBILITY WITH HYDROGEN

**Following to the Climate Change Conference of Paris (COP 21), the energy turnaround has more than ever become the most decisive project of our times. Germany has made an international commitment to reduce its $CO_2$ emissions. This entails deploying less fossil fuels than is currently the case and instead making increased use of renewable sources of energy for the generation of power, heat and for mobility.**

**Established in December 2002 under the auspices of the Federal Ministry of Transport and Digital Infrastructure (BMVI – Bundesministeriums für Verkehr und digitale Infrastruktur) as a joint government and industry initiative, the goal of the CEP is to test the system capability of hydrogen in the area of mobility. The CEP is a flagship project of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP), which is implemented by the National Organisation for Hydrogen and Fuel Cell Technology (NOW).**

**The CEP is in its third and final project phase, running until the end of 2016. From 2017 onwards, the CEP is to be successively transferred into a self-sustaining market.**

## VEHICLES IN THE CEP

Mobility with hydrogen and fuel cells was given fresh momentum in autumn 2015 with the introduction of the Toyota Mirai in the European market. BMW presented a new model in summer, which is equipped with a fuel cell and a new type of fuelling technology comprising cold and high pressure (cryo compression technology). The fuel cell is also deployed for bus operations, currently implemented in scheduled bus services at the public transport providers Hamburg Hochbahn and Stuttgarter Strassenbahnen. Besides four Citaro Fuel Cell Hybrid models from Daimler Buses, Hamburg Hochbahn also boasts two battery-powered buses from Solaris with fuel cell range extenders, which ply the newly introduced, so-called innovation route in Hamburg. The route is used to test the viability of buses in practice that are assessed by the company as having relevant drivetrains. As such, around 150 fuel cell cars and buses are in test operation. They have proven their technical maturity and performance over a total combined distance exceeding four million kilometres.

## GROWTH IN THE NUMBER OF HYDROGEN FILLING STATIONS

There are currently 20 publically accessible hydrogen filling stations in Germany and concerted efforts are underway to further expand this number. A total of 50 hydrogen filling stations are to be established, which are necessary for answering research and development questions such as those regarding calibration of pump volume and other issues regarding standardisation. An existing CEP partner, $H_2$ Mobility, will conduct the further subsequent expansion of the hydrogen filling station network with a goal of achieving regional coverage by 2018.

New stations were opened in Berlin, Hamburg and Stuttgart in 2015. The development of the so-called southern corridor made particularly good progress. State Secretary Dorothee Bär attended the inauguration of Germany's first motorway hydrogen filling station, the Total Motorway Service Station at Geiselwind on the A3 in Lower Franconia. »The nearly one million euros of funding spent on the construction of this filling station is money well invested as good infrastructure is a prerequisite for this new form of mobility to really catch on,« commented the State Secretary.

At the Total $H_2$ station in Munich's Detmoldstrasse, a second hydrogen pump featuring the innovative cryo compression technology was added to the existing standard 700 bar gaseous hydrogen pump. Following this modification to the filling station, fuel cell vehicles are now capable of commuting between the cities of Stuttgart, Frankfurt and Munich in the south of Germany.

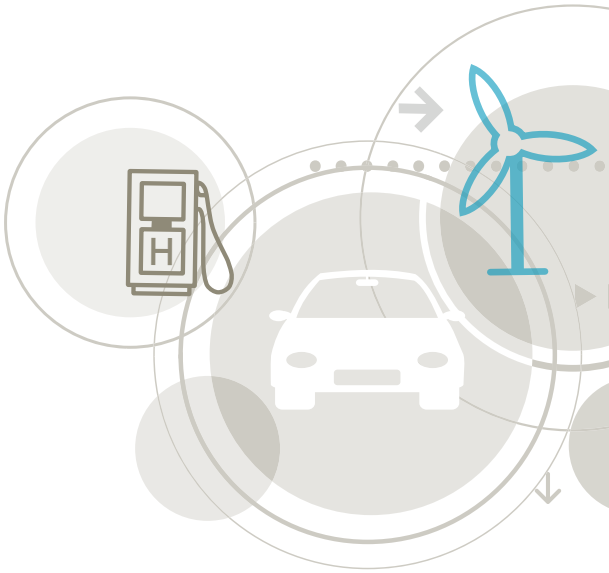
Of strategic importance for integration with the European hydrogen network is the project of OMV. In addition to the existing hydrogen stations in Stuttgart, OMV is planning three additional hydrogen filling stations in the southern German region. The Brenner motorway is also in focus as it is one of the most important corridors from Germany to Austria and then on to Italy.

## SUCCESSFUL CONTINUATION OF EVENT FORMATS

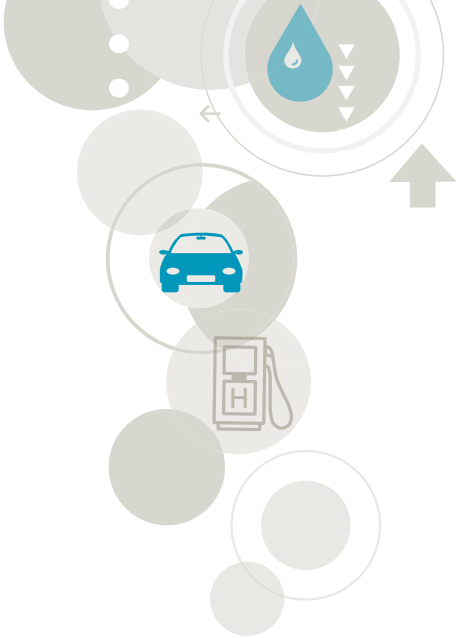
The CEP was once again represented at numerous events in 2015. Armed with fuel cell vehicles and latest innovations from hydrogen and fuel cell technology research, the CEP visited higher education institutions in Chemnitz, Bremen and Aachen, thereby continuing the successful »Campus Days« concept from 2014.

At the Hannover Messe 2015, the CEP could present several innovations from the area of fuel cell mobility. In the Ride & Drive area, CEP partner Toyota presented its mass production Mirai model to the German public for the first time. Another German premiere came from Volkswagen. Also in the CEP Ride & Drive area, the Wolfsburg-based manufacturer made its fuel cell version of the US Passat model available for the first time, on an outdoor exhibition area spanning some 15,000m².

Many other visitors could also learn more about the latest developments in hydrogen mobility during the Long Night of Science as well as the Open Days of the various ministries in Berlin.



More information:
www.cleanenergypartnership.de



$H_2$ MOBILITY
WASSERSTOFF TANKEN

## MISSION:
## HYDROGEN INFRASTRUCTURE

**Over the past few years, hydrogen refuelling stations and hydrogen vehicles have both proven their viability for day-to-day use in the Clean Energy Partnership (CEP) demonstration project. Now, the first vehicle manufacturers are bringing series-production fuel cell vehicles to the market and others will follow over the coming years. The carmakers are demanding that a comprehensive network of hydrogen refuelling stations is developed, along with additional measures to support the successful commercial introduction of hydrogen as a fuel.**

**This is one of the reasons why Air Liquide, Daimler, Linde, OMV, Shell and TOTAL established the $H_2$ MOBILITY Deutschland GmbH & Co.KG superordinate joint venture as an operational company. It is the result of a long process that already commenced in 2009 with the drafting of an action plan. With its entry in the commercial register and the appointment of Frank Sreball as Managing Director, $H_2$ MOBILITY took up operations in February 2015. Its task: the fast, efficient and comprehensive development of a hydrogen infrastructure for fuel cell vehicles.**

### $H_2$ MOBILITY Roadmap

The first phase involves the construction of 60 new hydrogen refuelling stations. By 2018/2019, Germany may already possess the world's largest hydrogen refuelling station network with approximately 100 stations operated by the $H_2$ MOBILITY joint venture. Up to 10 hydrogen stations will be established in each of the six urban regions of Berlin, Hamburg, Frankfurt, Munich, Rhine-Ruhr and Stuttgart. Further stations along major arterial roads and motorways will ensure a comprehensive supply network extending to the border regions of Austria, Switzerland, France, Belgium, Denmark and the Netherlands. In a second phase of development until approximately 2023, $H_2$ MOBILITY plans to operate up to 400 hydrogen refuelling stations. While the expansion in the second phase is coupled with the increasing number of fuel cell vehicles on the roads, the first 60 stations will be realised irrespective of actual vehicle registrations.

The undertaking by $H_2$ MOBILITY Deutschland GmbH & Co.KG represents the first time that a company is coordinating, planning, constructing and operating hydrogen refuelling stations as an overall national project with an estimated investment volume totalling some 350 million euros. To this day, there is no comparable initiative anywhere else in the world.

Wherever possible, the hydrogen stations will be integrated at existing service station sites. The systems feature a compact, space-saving design and are mainly comprised of standardised components for hydrogen storage, compression and pumps at 700 bar. The pure construction time is scheduled for just four to eight weeks. In addition, $H_2$ MOBILITY is also responsible for network planning as well as the procurement of hydrogen. The goal is to obtain the highest possible share made with renewable energy and make this available nationwide.

Through the partnership of the six companies from the gas, petroleum and automobile industries, the members not only minimise their individual risks, they also bundle their competencies. This leads to accelerated standardisation on both national and international levels, ensures that funding support is better used and thereby also makes a significant contribution towards the comprehensive expansion of infrastructure, paving the way to a $CO_2$-free mobility future. To ensure the advances are made in coordination with the automobile industry, BMW, Honda, Intelligent Energy, Toyota and Volkswagen also accompany the initiative as associated partners. The National Organisation for Hydrogen and Fuel Cell Technology (NOW) provides consultative support to the company in regard to policy issues.

More information (in German) at:
**www.h2-mobility.de**


LUFTDRUCK PRESSURE PRESSION PRESIÓN
zero emi


Linde Gas
Linde
HYDROGEN
REFRIGERATED
LIQUID


Linde

I / 01

## » DEVELOPMENT OF ASSEMBLY TECHNOLOGY AND AUTOMATION CONCEPTS FOR THE MANUFACTURE OF FUEL CELL STACKS «

In the MontaBS project an automation concept will be developed and assembly technology implemented for the manufacture of FC stacks based on metallic and graphite bipolar plates in a scalable prototype test plant, taking account of output and degree of automation. The development tasks deal with the processes and plant engineering for fuel cell manufacture as well as the production-oriented design of products and built-in components. The prototypical test plant allows the developed technology to be qualified and validated. Stacks of different formats and performance classes will be constructed and tested in the process.

Furthermore a stack technology based on experiences with stack NM5 will be developed, which addresses the demands of use in the automotive context. In particular investigations of water balance with different cell components will be undertaken to work out CCM/GDL/Flowfield configurations, which for example, allow reduction in humidification, and the appropriate operating concepts to be developed.

The development of manufacturing and cell/stack technology will be coordinated with each other, where the product development focuses on production-oriented design in particular.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| ElringKlinger AG | 3,719,598 | 1,636,623 |
| USK Karl Utz Sondermaschinen GmbH | 1,861,652 | 893,593 |
| J. Schmalz GmbH | 344,340 | 165,283 |

COMMENCEMENT: 01 January 2015
CONCLUSION: 31 December 2016

» A stack technology based on experiences with stack NM5 will be developed, which addresses the demands of use in the automotive context. «

# »With the help of the study, the necessary requirements for the integration of hydrogen infrastructure in the existing rail infrastructure will be outlined.«

I / 02

## »HYDROGEN INFRASTRUCTURE FOR RAIL«

The study will examine the use of fuel cell rail cars in Germany. The framework conditions will be analysed for the setting up of a hydrogen infrastructure in regional rail transport. As accompanying research for the »BetHy« project, the study focuses on the technical, legal and economic framework conditions.

As a first step, the operational requirements from rail systems will be analysed. Refuelling, deployment planning, maintenance and liability issues play a major role here. Parallel to this the technical requirements such as hydrogen sources and provision logistics will be defined. This includes identifying the hydrogen sources on the routes in question in Germany. Another focus is the legal framework conditions such as regulatory approval, energy economy and procurement. Up to now no legal framework has existed.

As a second step the study discusses which financing and operator structures can be achieved on the basis of information gained. The aim is to identify suitable operator concepts and opportunities for distribution among the actors. Furthermore a launch campaign with different publicity activities will be developed within an acceptance management initiative.

With the help of the study, the necessary requirements for the integration of hydrogen infrastructure in the existing rail infrastructure will be outlined and perspectives for commissioning authorities, transport companies and potential supply infrastructure providers will be highlighted.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Ernst & Young GmbH accounting firm in cooperation with Ludwig-Bölkow-Systemtechnik GmbH, TÜV SÜD Rail GmbH, SIGNON Deutschland GmbH, Becker Büttner Held, IFOK GmbH | 377,281 | 377,281 |

COMMENCEMENT: 01 October 2015
CONCLUSION: 30 April 2016


D
OF H 3

I / 03

## » CLEAN ENERGY PARTNERSHIP (CEP): ›HYNINE‹ – DEVELOPMENT, CONSTRUCTION AND OPERATION OF NINE HYDROGEN REFUELLING STATIONS «

Air Liquide, world market leader in gases, technology and services for industry and health sectors, has completed more than 60 hydrogen refuelling station projects throughout the world. Since 2012, Air Liquide has operated a hydrogen refuelling station in Germany located in Düsseldorf. As part of the BMVI's 50 refuelling stations programme, Air Liquide is constructing and will operate a further nine stations across Germany. In this way, Air Liquide is making a significant contribution to the establishment of a comprehensive national hydrogen infrastructure. The hydrogen refuelling stations will be set up in convenient transport locations either as stand-alone solutions or integrated in existing public service stations.

Besides the expansion of the refuelling network and the advancement of refuelling technology, the main research aims of the project also include the development and testing of various operational and supply concepts. In addition, Air Liquide has set the goal of investigating customer acceptance in order to ascertain whether any conclusions can be drawn from the results that may help to further optimise the technology. With its »Blue Hydrogen« initiative, Air Liquide undertakes to produce at least 50 % of the hydrogen it generates for energy applications without the release of any additional carbon dioxide by 2020. Upon this backdrop, Air Liquide will also develop strategies and concepts to increase the supply of green-certified hydrogen within the scope of this project. To this end, among the aspects to be examined will be the production of green-certified hydrogen via water electrolysis.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| AIR LIQUIDE Advanced Technologies GmbH | 19,841,822 | 9,524,075 |

COMMENCEMENT: 01 August 2014
CONCLUSION: 31 December 2016


Air Liquide hydrogen refuelling station in Düsseldorf

I / 04

## » SMARTFUEL® FOR HAMBURG: DEVELOPMENT AND DEMONSTRATION OF AN OPERATIONALLY OPTIMISED HYDROGEN REFUELLING STATION IN HAMBURG «

The joint project SmartFuel® for Hamburg comprises the development and expansion of a public hydrogen refuelling station as well as its safe and reliable operation suitable for everyday use over a time period of up to 24 months. A modular refuelling station design is being used (storage system, compressor, refuelling system), which will be developed and tested with the aim of increasing the overall reliability of hydrogen refuelling stations and reducing operational costs. By recourse to a new, SAE-compliant back-up system to refuel 700 bar vehicles according to A35 refuelling protocols, refuelling station availability to the customer will be increased. The design of the facility relies on a modular system that with increasing hydrogen demand facilitates inexpensive expansion of the refuelling station capacity. Control of the system will be designed according to SAE J2601: 2014 for 700 bar refuelling as well as 350 bar refuelling. In addition the SmartFuel® system will be prepared for operation and delivery logistics with 500 bar.

The complete system technology will be supplied by Air Products GmbH. Because the components and structural elements of the system (piston compressor, high-pressure storage cylinder, coolant heat exchanger, ventilation unit, system control) were developed and designed for the licensing requirements of the US market, part of the project is to adapt and further develop the technology in terms of international standardisation and with regard to the projects licensed in Germany.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Total Deutschland GmbH | 1,439,919 | 691,163 |
| Air Products GmbH | 572,250 | 274,680 |

COMMENCEMENT: 01 September 2014
CONCLUSION: 31 December 2016

» A modular refuelling station design is being used (storage system, compressor, refuelling system), which will be developed and tested with the aim of increasing the overall reliability of hydrogen refuelling. «

I / 05

## » OPERATION AND RELIABILITY OF A FUEL CELL SYSTEM «

Aim of the BeZel joint project is an improvement in operation and reliability of fuel cell-powered aircraft systems. A significant aspect includes the provision of hydrogen including on-board storage and the necessary refuelling infrastructure at the airport. Also playing important roles are the auxiliary units such as airworthy hydrogen sensors, electronic power controllers for the control of a high performance ventilation fan and exhaust gas treatment for fire extinction. Optimised and ready to integrate operational models are to be constructed in order to test these under real conditions. A third significant aspect regards boosting the service life of the systems and the individual fuel cell stacks. The accompanying examination shall identify and evaluate the critical operating conditions during airborne deployment. With laboratory tests, the effects are to be examined and the impact of individual parameters understood in greater detail. With these results, strategies will then be able to be developed that will help to avoid or minimise certain conditions or effects.

The following subgoals are to be achieved:

↗ Depiction of an economic supply of hydrogen in aircraft

↗ Examination of the service life of a fuel cell under flight conditions

↗ Manufacture of an airworthy sensor for the detection of hydrogen

↗ Development of a fire retardation system using inert gas

↗ Provision of a compact DC/DC voltage converter

↗ Development of the HVDC power electronics for a cooling fan

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Airbus Operations GmbH | 1,732,090 | 831,403 |
| Deutsches Zentrum für Luft- und Raumfahrt e. V. (DLR) | 1,700,263 | 816,126 |
| Airbus Defence and Space GmbH | 905,567 | 434,672 |
| ZAL Zentrum für Angewandte Luftfahrtforschung GmbH* | 248,971 | 119,506 |
| Apparatebau Gauting Gesellschaft GmbH | 1,122,168 | 538,640 |
| Nord-Micro GmbH & Co. OHG | 702,492 | 337,196 |
| Parker Hannifin Manufacturing Germany GmbH & Co. KG* | 713,584 | 342,520 |

COMMENCEMENT: 01 December 2014/* 01 January 2015
CONCLUSION: 01 December 2016

» Aim of the BeZel joint project is an improvement in operation and reliability of fuel cell-powered aircraft systems. «


Depiction of the installation of the fire extinguishing system in the cargo hold of a Airbus aircaft.

$H_2$ refueling station at BER airport

I / 06

## » H2BER DEVELOPMENT, TESTING AND ASSESSMENT OF INTELLIGENT OPERATIONAL STRATEGIES FOR THE VARIOUS COMPONENTS AND OVERALL CONTROL OF THE HYDROGEN REFUELLING STATION AT THE FUTURE BERLIN BRANDENBURG (BER) AIRPORT. «

In this project, the Reiner Lemoine Institute is investigating the hydrogen refuelling station at the future BER airport near Berlin. Goal of the project is to enhance the economic efficiency of hydrogen refuelling stations with on-site electrolysis by developing and testing intelligent operational strategies. Besides optimal operation of plant components, these strategies also enable the consideration of various power supply options (renewable energy as well as energy and balancing energy markets) and usage paths (refuelling of vehicles, reconversion, generation of heat, supply to industrial customers). A simulation model will be developed with which operational strategies for the control of all relevant refuelling station components (e.g. solid state storage, pressure storage, electrolyser) can be examined and optimised. The identified operational strategies will subsequently be tested and evaluated at the hydrogen refuelling station at the future BER airport. It is anticipated that the results will make a significant contribution to lowering operational costs in future hydrogen refuelling stations. The research project complements the current »H2BER Tankstelle« project (project reference no. 03BV232 »Construction and operation of a wind hydrogen production plant and the attached world's first $CO_2$ neutral refuelling station«).

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Reiner Lemoine Institut gGmbH | 605,399 | 290,591 |

COMMENCEMENT: 01 January 2015
CONCLUSION: 31 December 2016

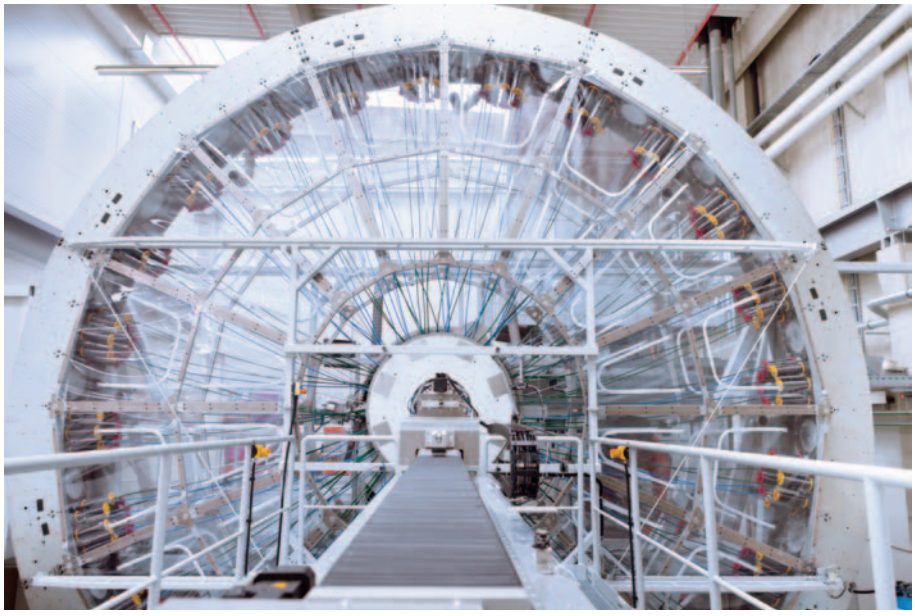
I / 07

## » HYLOAD: INTEGRATED HYDROGEN TANK STRENGTHENS VEHICLE BODY «

Within the scope of a publically funded research project, cooperation partners BMW AG, REHAU AG + Co and MAXIMATOR GmbH are working on the development of a new type of hydrogen tank that can be implemented as a load-bearing body part. The deployment of such an innovative pressure tank in vehicles also promises to result in lower weight and therefore less energy consumption and a longer range for fuel cell vehicles. The research partnership is led by BMW AG.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| BMW AG | 2,629,323 | 1,262,075 |
| Maximator GmbH | 403,724 | 193,788 |
| REHAU AG + Co | 1,644,677 | 789,445 |

COMMENCEMENT: 01 January 2015
CONCLUSION: 31 December 2016



Radial braider used for the manufacture of carbon fibre reinforced hydrogen pressure tanks in the REHAU lightweight construction technical centre in Viechtach, Germany

» The deployment of such an innovative pressure tank in vehicles promises to result a longer range for fuel cell vehicles. «

I / 08

## » HYLIGHT – DESIGN, CONSTRUCTION, SETTING UP AS WELL AS TESTING AND DEMONSTRATION OF AN EMISSION-FREE, ROADWORTHY HYDROGEN FUEL CELL CONCEPT VEHICLE IN PURPOSE DESIGN LIGHTWEIGHT CONSTRUCTION «

Under the publicly-funded research project »HyLIGHT«, the BMW Group are building and testing a highly innovative hydrogen fuel cell concept vehicle with long distance ability and excellent dynamics. The vehicle concept and the vehicle architecture are optimally designed for hydrogen fuel cell technology. The vehicle will be built as a »Purpose design« concept.

The concept vehicle will be constructed by the BMW Group as a test vehicle, which makes the potential of hydrogen fuel cell technology tangible through its lightweight construction and intelligent integration of all components.

As an elementary component of the architecture, a fully load-bearing hydrogen cryo-compression tank will be integrated for the first time in the floor assembly of the concept vehicle, in order to achieve the range goal of 650 km. The BMW Group is developing and validating the main components of the fuel cell system and the fuel cell system software itself.

Through the expected driving performance, high range and short refuelling time, combined with an original progressive design, the BMW Group will be able to inspire its customers with its new, future-oriented technology.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| BMW Group | 12,325,229 | 5,916,110 |

COMMENCEMENT: 01 January 2015
CONCLUSION: 31 December 2016

» The concept vehicle will be constructed by the BMW Group as a test vehicle, which makes the potential of hydrogen fuel cell technology tangible through its lightweight construction and intelligent integration of all components. «

I / 09

## » HYDROGEN SYSTEMS «

As a leading company and pioneer of hydrogen refuelling technologies as well as a hydrogen producer and supplier, Linde AG is actively working on increased expansion of hydrogen infrastructure. From the technological and particularly the economic point of view, the introduction of hydrogen as a fuel is a large undertaking.

Linde AG is active in this regard primarily in terms of new development and the necessary standardisation of the technological components. Depending on the relevant customer requirements, two alternative paths will be examined for hydrogen high pressure refuelling: the first path is the infrastructural chain for gaseous hydrogen, the second path is an infrastructural chain for liquid hydrogen. The overall goal of the »Hydrogen systems« project is to adapt hydrogen technologies to current and future market requirements for both paths.

The main elements of the project are the development of new cryo-pump and ionic compressor technologies. The research and development work commissioned focuses on market-ready system performance and prices for different target applications and advancing new developments. Furthermore the formulation and further development of national and international standards will be supported.

Through collaboration in international committees such as ISO TC197 and EN TC268, practical experiences from construction and operation of already existing $H_2$ refuelling stations will be incorporated into the standards. Cost and space optimisation concepts will be optimised and standardised, taking the requirements of facility safety into account. Other standardisation issues are sensible determinations in the area of the vehicle-refuelling station interface, $H_2$ quality, refuelling protocol and type of refuelling port.

The Linde technologies for hydrogen refuelling each have distinctive strengths depending on the operating conditions of the chosen $H_2$ supply. Synergic effects in developing common components used should be maximised, like for example, high pressure tanks, flow measurements or thermal management systems.

One of the interim results of the project is the newly-developed standard refuelling station with cryo-pump. The refuelling station has a new type of pump drive, an improved storage concept, and minimised operational costs with reduced space requirement. The concept is currently undergoing comprehensive tests to comply with specific performance parameters under all operational modes at a test refuelling station at Linde AG in Unterschleißheim near Munich.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Linde AG | 2,594,649 | 1,043,049 |

COMMENCEMENT: 01 March 2015
CONCLUSION: 31 December 2016

I / 10

## » DEVELOPMENT OF A 4TH GENERATION FC HYBRID CITY BUS «

Hydrogen-operated fuel cell buses have proven in small fleets that they already fulfil the operational requirements of transport services to a great extent. Building on the knowledge gained, an innovative successor vehicle generation will be developed. This FC bus concept will enable the local emission-free drive of solo city buses as well as articulated buses. Through interlinking energy and thermal management of the whole vehicle, synergies will be optimally used and thus efficiency considerably increased with the FC drive system.

At the same time the aim is to significantly reduce the cost of components and considerably increase the reliability/robustness of the FC drive train and thus keep the service investment low.

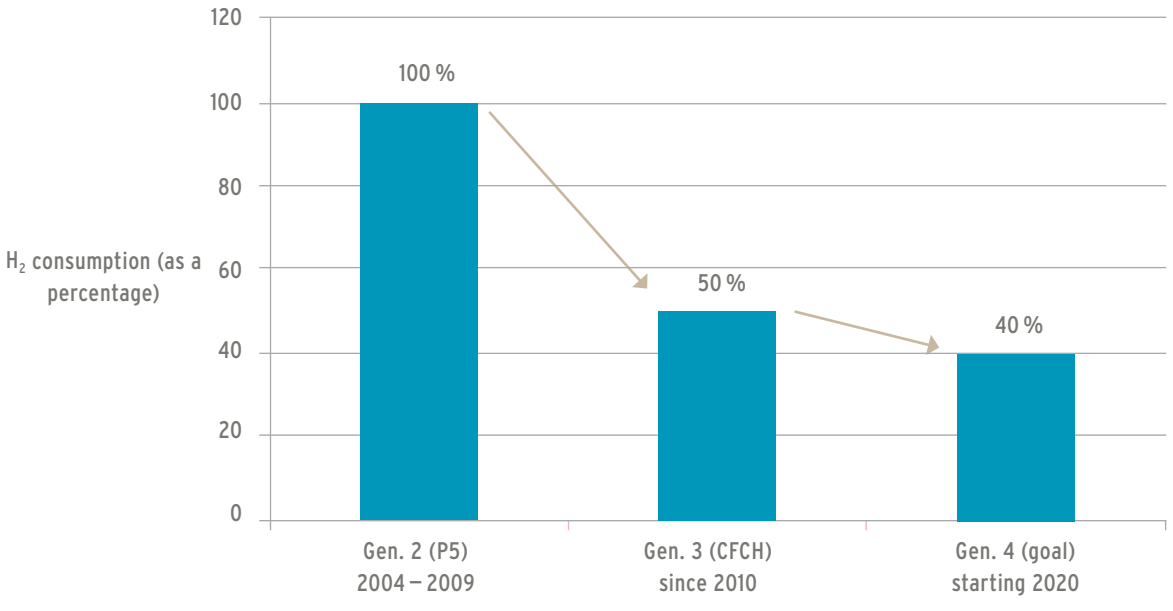
Despite the advancements already achieved by previous projects, the availability of the vehicles must be increased from today's 60 – 70 % to at least 90 %.

For environmentally-friendly product development, ecological results will accompany development for the components of the FC system and $H_2$ refuelling station. Through these R&D activities, another step will be taken towards achieving the technical and economic goals of a competitive, emission-free drive train for integration in a city bus in solo and articulated form.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| NuCellSys GmbH | 3,946,618 | 1,815,444 |
| EvoBus GmbH | 2,797,193 | 1,258,737 |

COMMENCEMENT: 01 March 2015
CONCLUSION: 31 December 2016

COMPARISON $H_2$ CONSUMPTION: GENERATION 2 TO 4




$H_2$ consumptions of different FC bus generations


OMV refuelling station at Stuttgart airport

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## » CLEAN ENERGY PARTNERSHIP (CEP) – PROJECT MODULE: NEW BUILD OF 3 HYDROGEN REFUELLING STATIONS AS WELL AS UPGRADING AND FURTHER OPERATION OF THE STUTTGART AIRPORT HYDROGEN REFUELLING STATION «

As part of the »50 refuelling stations programme«, OMV Deutschland GmbH in cooperation with Linde AG intends to build discharge points at existing OMV refuelling stations in Metzingen, Nürnberg (Gleiwitzer Str. 220) and at Munich airport. Furthermore the hydrogen refuelling station opened in 2009 at OMV Stuttgart airport will be upgraded according to the requirements of the Clean Energy Partnership (CEP) and so will be prepared for the upcoming market entry of hydrogen as a fuel. The research work planned in the project serves to optimise the technology – all four hydrogen discharge points will be incorporated in the accompanying research of the 50 refuelling stations programme – and helps develop associated processes under less than ideal starting conditions (market entry phase), and will contribute to demonstrating the potential of the technology also on an international scale.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| OMV Deutschland GmbH | 1,772,002 | 850,561 |

COMMENCEMENT: 01 March 2015
CONCLUSION: 31 December 2016

I / 12

## » FURTHER OPERATION OF THE HYDROGEN REFUELLING STATION AT HÖCHST INDUSTRIAL PARK «

Infraserv operates the hydrogen refuelling station at Höchst industrial park close to Frankfurt am Main airport. It was opened in November 2006 and is currently the only public hydrogen refuelling station in Hesse. It is rated as »CEP ready« and thus fully complies with the requirements of the CEP. It is the only public refuelling station at which hydrogen as a by-product is made available for motor vehicles via a 1.7 km-long pipeline. The hydrogen used is a by-product of the chemical industry located in Höchst industrial park, whose chlorine production yields around 30 million standard cubic metres of hydrogen per year. The existing hydrogen refuelling stations will continue to be operated and be incorporated to a large extent in the research and evaluation programme of the CEP as well as the accompanying research programme of the 50 refuelling stations programme of the federal government. Because of availability problems in the past, the issue of reliability in the operational phase will be given special attention. The operational testing and further development of the facility is planned in cooperation with the technology providers. The aim is to guarantee the operation, high availability of the facility and thus reliable supply in the region throughout the project's lifespan as well as to contribute to further reducing the general development and operational costs of hydrogen refuelling stations.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Infraserv GmbH & Co. Höchst KG | 284,806 | 136,707 |

COMMENCEMENT: 01 April 2015
CONCLUSION: 31 December 2016

» The existing hydrogen refuelling stations will continue to be operated and be incorporated to a large extent in the research and evaluation programme of the CEP as well as the accompanying research programme of the 50 refuelling stations programme of the federal government. «


Both fuel cell buses (350 bar) and cars (700 bar) can be refuelled at the hydrogen filling station located in close proximity to Höchst Industrial Park.


A hydrogen filling station will be installed and integrated on the grounds of the Westfalen filling station in Münster-Amelsbüren, within the scope of this project.

I / 13

## » CONSTRUCTION AND OPERATION OF THE MÜNSTER-AMELSBÜREN HYDROGEN REFUELLING STATION AND INTEGRATION OF A HYDROGEN CLEANING SYSTEM «

The start of construction of the first hydrogen refuelling station of CEP member Westfalen AG is planned for May 2016, and completion and commissioning for November 2016. The hydrogen refuelling station is located on the premises of the new multi-award-winning Westfalen large-scale station in Münster-Amelsbüren.

Both of the hydrogen pumps will be housed under the roof of the truck refuelling station, which was specially extended for this purpose. One pump in 700 bar technology for cars and another in 350 bar technology will be made, each with a hose for buses and cars. Stadtwerke Münster (Münster municipal utilities) intend on acquiring hydrogen buses and refuelling them daily at the end of their service at the Westfalen station.

The hydrogen will be delivered by trailer from Westfalen AG's nearby hydrogen production in Salzbergen. The gaseous hydrogen will be stored in a 21 metre-high container on the refuelling station premises. Then the hydrogen will run through a purification system, which improves the gas quality from 3.0 (99.9 volume per cent) to 5.0 (99.999 volume per cent) purity. Finally it will be compressed and the hydrogen fed through to the pumps.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Westfalen AG, Münster | 3,223,406 | 1,547,235 |

COMMENCEMENT: 01 April 2015
CONCLUSION: 31 December 2016

» The hydrogen refuelling station is located on the premises of the new multi-award-winning Westfalen large-scale station in Münster-Amelsbüren. «

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## » SYSTEMATIC OPTIMISATION OF PLANTS AND OVERCOMING EXISTING OBSTACLES THROUGH THE CONSTRUCTION AND OPERATION OF SEVEN HYDROGEN REFUELLING STATIONS WITHIN THE SCOPE OF THE CEP, ON THE PATH TO MARKET INTRODUCTION «

In February 2015, the joint venture $H_2$ MOBILITY Deutschland GmbH & Co.KG together with Air Liquide, Daimler, Linde, OMV, Shell and TOTAL took up operations with the goal of significantly accelerating the expansion of hydrogen infrastructure development in Germany. In an initial phase, $H_2$ MOBILITY will construct up to 60 hydrogen stations in Germany's large urban regions of Berlin, Hamburg, Frankfurt, Munich, Rhine-Ruhr and Stuttgart, along with further stations on arterial roads and motorways to ensure comprehensive coverage by 2018/2019.

Part of this first phase includes the building of seven hydrogen refuelling stations within the scope to the 50 Refuelling Station programme, as an R&D project with the intention of hereby acquiring knowledge through the stations' construction and operation to thereby remove existing obstacles on the path toward the market introduction of hydrogen as a fuel.

The hydrogen refuelling stations will be integrated in conventional filling stations at various locations of the partner companies Shell, TOTAL and OMV. $H_2$ MOBILITY plans, coordinates and operates the seven plants from three different technology suppliers: Air Liquide, $H_2$Logic and Linde.

**Research and development goals:**
1. Standardisation of plant design and installation planning taking technical, economic and regulatory aspects into account
2. Development of an optimised $H_2$ supply concept with the goal of increasing the portion of green hydrogen
3. Expansion and optimisation of plant operations to enable significantly increased filling station reliability and availability
4. Employee training/quality assurance
5. Enhancement of customer acceptance
6. Involvement in the accompanying research for the 50 Refuelling Stations programme

**Locations:**
Wuppertal/Shell/Linde
Geisingen/Shell/Linde
Frankfurt/Main/Shell/Air Liquide
Wendlingen/Shell/Air Liquide
Pentling/OMV/Linde
Rostock/TOTAL/$H_2$Logic
Werneck/TOTAL/Air Liquide

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| $H_2$ MOBILITY GmbH & Co.KG | 10,399,272 | 4,991,650 |

COMMENCEMENT: 01 April 2015
CONCLUSION: 31 December 2016

Partners of $H_2$ Mobility Deutschland GmbH & Co. KG have the goal of accelerating the expansion of the hydrogen infrastructure in Germany over the coming years.

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## » DEVELOPMENT OF A ROBUST, AUTOMOBILE-COMPATIBLE $H_2$ SENSOR TO MEASURE LEAKAGES OF ESCAPING HYDROGEN IN ORDER TO ELIMINATE SAFETY RISKS «

As part of the NIP project, neoxid GmbH is developing an automobile-compatible $H_2$ sensor to measure leakages of escaping hydrogen. Especially in the use of hydrogen-run vehicles, there is great potential danger should hydrogen escape through leakages. While hydrogen vehicles are today equipped with leakage sensors, these are difficult to produce and do not comply with the customary automobile industry demands and standards placed on vehicle components. In addition, they are costly, not very robust and their response times are excessive.

The aims of the approved NIP project include developing a Schottky diode hydrogen sensor with a nanostructured titanium oxide/metal boundary surfaces boasting a sensitivity to hydrogen smaller than 0.1 Vol.% (danger of explosion of hydrogen at more than 4.4 Vol.%) and without any cross-sensitivity to other gases. For this to be achieved, corresponding diodes and their manufacturing process must first be developed. Only sensors with integrated electronics will be manufactured using these diodes, which can then be fitted in the vehicles as a complete sensor system.

The development of this groundbreaking new sensor technology paves the way for hydrogen-run vehicles, as it represents the first time that a sensor is being made available that not only boasts high measurement quality but that simultaneously meets the demands of automobile technology. As such, a further building block is being put in place towards firmly establishing hydrogen as an environmentally friendly source of energy for the mobility sector.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| neoxid GmbH | 523,495 | 251,277 |

COMMENCEMENT: 01 April 2015
CONCLUSION: 30 September 2016

» The development of this groundbreaking new sensor technology paves the way for hydrogen-run vehicles. «

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## » F-CELL-PREP INVESTIGATION, DEVELOPMENT AND EVALUATION OF EFFICIENT CONCEPTS, NEW MATERIALS AND INNOVATIVE OPERATING STRATEGIES FOR FUEL CELL AND TANK SYSTEM COMPONENTS «

The supply of environmentally friendly, reliable and affordable energy is certainly one of the biggest challenges we face this century. With innovative concepts and technological advances, this challenge can be met. In the future, fuel cell technology with its high efficiency and hydrogen as a climate-neutral secondary energy carrier will represent the foundation for the sustainable supply of emission-free energy and mobility.

The aim of the project is to use the potentials identified in preceding projects and to incorporate them in the areas of fuel cell system components and $H_2$ tank system components. The main areas of focus are:

↗ Continuing research and development into suitable substances and materials for membranes of the fuel cell humidifier along with seal materials for the valves of the $H_2$ tank system.

↗ Examinations to lay the foundations for the system concept, particularly taking into account water management as well as the operating strategy and its effect on the design of affected system components.

↗ Development of system component solutions and production-focused product designs that were previously not available or too costly/complex until now.

↗ Development of testing standards and methods to ensure and safeguard the quality of system components.

With the listed measures, it is anticipated that a further critical contribution will be made to promote the maturity of fuel cell and $H_2$ tank system components along with guaranteeing production feasibility.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| NuCellSys GmbH | 6,344,278 | 1,801,775 |

COMMENCEMENT: 01 July 2015
CONCLUSION: 31 December 2016

» The aim of the project is to use the potentials identified in preceding projects and to incorporate them in the areas of fuel cell system components and $H_2$ tank system components. «

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## » HRS-MONI: MONITORING OF THE FREIBURG HYDROGEN REFUELLING STATION FOR THE ACCOMPANYING 50 REFUELLING STATION PROJECT «

The Freiburg hydrogen refuelling station was opened in 2012 by Fraunhofer ISE, equipped to »CEP ready« standard in 2013 and since then is part of the refuelling station network in Germany to establish hydrogen mobility. It will become a part of the 50 refuelling station programme of the NIP in the coming years and forms an important grid point in the South-West, also as a connecting point to HRS infrastructure in Switzerland and France.

Through the commissioned project, participation in the accompanying research of the 50 refuelling station programme will be facilitated, in order to gain crucial knowledge as a typical corridor refuelling station. The subject of the accompanying research is user behaviour and acceptance in mains operation, the development of logistics concepts, knowledge for further scenario development, optimisation of maintenance and repair, as well as minimisation of energy demand. To this end the operating results of the refuelling station will be monitored and made available to the CEP accompanying programme. In addition findings from the operation of the refuelling station so far will be translated into practice to improve operational management (adjustment of control unit, field testing of new components, monitoring the quality of the grid at the on-site hydrogen generation). Fraunhofer ISE is making the findings of this CEP project available in order to support the creation of a database that is as broad as possible for the further development and market preparation of sustainable hydrogen mobility.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Fraunhofer ISE | 209,998 | 100,798 |

COMMENCEMENT: 01 July 2015
CONCLUSION: 31 December 2016

» Through the commissioned project, participation in the accompanying research of the 50 refuelling station programme will be facilitated, in order to gain crucial knowledge as a typical corridor refuelling station. «

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## » ZEROE: DEPLOYMENT OF FUEL CELL CARS AS FLEETS IN HAMBURG AND MUNICH «

As a member of the Clean Energy Partnership (CEP), Toyota is convinced there is no one single pathway to the development of the sustainable drive technologies of the future. Toyota is pursuing a broad developmental approach in which fuel cell vehicles play a key role – especially for long-distance requirements.

Toyota has been working on fuel cell vehicles since 1992. In 2015, it was the first vehicle manufacturer to bring a mass production fuel cell car onto the market, with the Mirai.

The focus of the ZeroE project is on the testing of the Mirai in fleets with high annual mileages, as it is in this area that greater environmental effects can be expected to be achieved in terms of a reduction in $CO_2$ and other pollutants. The goal is to make a contribution towards commencing the process of a systematic changeover in fleets with high mileage demands to environmentally friendly technologies.

As part of the project, vehicle data is collected and evaluated. The collected data and analyses enable important conclusions to be drawn for the further deployment of the vehicles, their technical optimisation as well as for the continued rollout of the technology. Also being examined are aspects of whether the requirements can be met for commercial fleets with high mileage demands (such as range per day, reliability, user acceptance, etc.). Furthermore, the data and results will be made available to the joint expert working groups in the federal ministries active in the area of electromobility, enabling these to also be transferred to other cities.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Toyota Kreditbank GmbH | 976,470 | 390,588 |

COMMENCEMENT: 01 October 2015
CONCLUSION: 30 September 2016

» The focus of the ZeroE project is on the testing of the Mirai in fleets with high annual mileages. «

I / 19

## » ETUDE: PROJECT ON PROFESSIONAL AND ENGINEERING FURTHER EDUCATION AND TRAINING THROUGH DISSEMINATION OF INFORMATION AND LEARNING CONTENT ON THE PATH FROM CONVENTIONAL VEHICLE TO FUEL CELL BATTERY HYBRID VEHICLE «

ETUDE is the main further education and training project in the National Innovation Programme for Hydrogen and Fuel Cell Technology (NIP). In total three learning products have been developed since January 2012 for practically-oriented youth development and for further education and training by the participating partner companies Heliocentris, H-TEC, Spilett and ModernLearning:

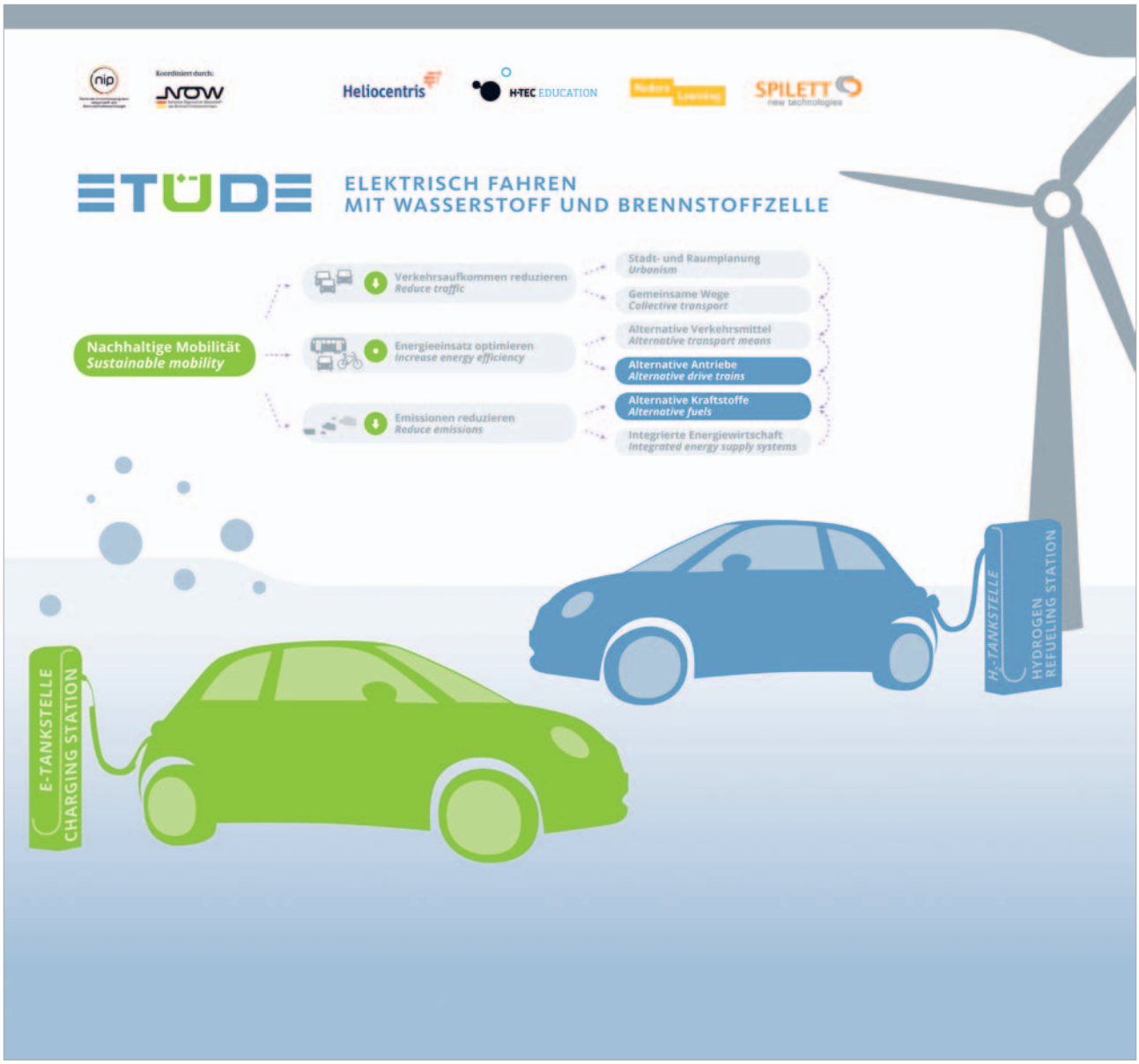
↗ The learning and information software »Mobile with hydrogen« (Subproject A) provides an insight into the technology and world of ideas of hydrogen mobility. A particular focus is on the societal context, the motivation to change and the challenges of societal and technological system changeover in the transport area.

↗ The training system »HyDrive« (Subproject B) facilitates a practically-oriented insight into the energy management of electric drives. A model vehicle equipped with fuel cell stack and supercap and the associated test stand captures the energy flows associated with driving situations and energy system designs where the parameters can be adjusted and presents these in a related software environment specified for use in teaching or study.

↗ The drive train model (Subproject C) enables realistic »fuel to wheel« analyses for different technological concepts of electromobility. The university-level educational tool can be adapted for battery-electric operation and also for a fuel cell battery hybrid. The integrated software models have adjustable parameters, in order to simulate different vehicles and driving situations.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Heliocentris Academie GmbH* | 1,443,720 | 692,986 |
| Spilett New Technologies GmbH | 152,327 | 73,117 |
| H-TEC Wasserstoff-Energie-Systeme GmbH | 204,171 | 98,002 |
| Modern Learning GmbH Bildung mit neuen Medien | 145,327 | 69,757 |

COMMENCEMENT: 01 January 2012
CONCLUSION: 31 March 2015/* to 30 June 2016




Three learning products for training and further education are being developed in the ETUDE project.

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## » PRODUCTION PROCESS DEVELOPMENT FOR FUEL CELL SYSTEMS «

The technology of the fuel cell, with its high degree of efficiency, and hydrogen, as a climate-neutral secondary energy source, forms one of the most important pillars in achieving the ambitious climate goals of the federal government.

Everyday practicability has already been successfully proven in field and fleet tests. The challenge of the future is to demonstrate the technology in the appropriate quantities for market entry and to reduce the costs of the techno-logy itself.

With the development of a holistic production process for fuel cell systems including quality assurance, logistics and information technology, as well as the required system technology and facilities, this project has laid crucial foundations for a medium-term scenario.

A focus of the project was the development of a production-oriented product design, supported through studies and analyses in the areas of components and system design in the very early development phase. The potential for improvement identified was successfully implemented, validated and utilised to a large extent and thus made a decisive contribution to reducing costs. Furthermore the requirements in terms of mountability, test viability, electrostatics, as well as the handling of hydrogen and high voltage were very important. Overall significant improvements regarding process reliability, assembly effort and product quality were achieved.

With the manufacture of a wide range of latest generation fuel cell systems, the prototypes production line which emerged from the development process with integrated testing concept, was tested and validated.

The leading position of NuCellSys GmbH as developer and manufacturer of fuel cell systems for application in cars was further strengthened through the project, in order to compete internationally against the ambitious plans of the large automotive manufacturers from Japan, Korea, USA and China.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| NuCellSys GmbH | 7,768,290 | 3,728,779 |

COMMENCEMENT: 1 January 2011
CONCLUSION: 31 March 2015

» With the manufacture of a wide range of latest generation fuel cell systems, the prototypes production line which emerged from the development process with integrated testing concept, was tested and validated. «


Prototypes production line

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## »DEMONSTRATION MERCEDES-BENZ B-CLASS F-CELL FLEET IN HAMBURG«

20 B-Class F-CELL vehicles were operated by customers in Hamburg as part of this project and thereby made the technology visible and capable of being experienced. The project could prove the suitability of fuel cell vehicles for everyday use as well as their technological viability in the market. Details of the technology could be conveyed through numerous lectures and events at universities and other educational institutions. Workers at the Mercedes-Benz Service workshop in Hamburg were also qualified to conduct repair and service tasks on the vehicles. As part of the Clean Energy Partnership, the standardisation of the technology could also make tremendous progress.

The vehicles travelled a total of more than 650,000km over the course of the project. One vehicle alone recorded a mileage of 325,000km and therefore contributed especially to gaining insights for the continued development of the technology. The vehicle was also distinguished with the »f-cell award 2014« innovation prize.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Daimler AG | 9,602,822 | 4,435,857 |

VEHICLES: 20 B-Class F-CELL vehicles

COMMENCEMENT: 01 May 2009
CONCLUSION: 31 January 2015

» As part of the Clean Energy Partnership, the standardisation of the technology could also make tremendous progress. «

## » F-CELL LUK: SIMULATION OF THE SUPPLIER LANDSCAPE FOR THE DEVELOPMENT OF COST-OPTIMISED COMPONENTS FOR FUEL CELL SYSTEMS) «

The provision of climate-friendly, reliable and affordable energy is one of the greatest challenges of the 21st century. It can be met through innovative concepts and technological advancement. Fuel cell technology, with its high level of efficiency, and hydrogen, as a climate-neutral secondary energy source, will form the basis for sustainable and low-emission energy supply and mobility in the future.

The aim of this project is to strengthen the leading position of German suppliers and engineering service providers and to gain additional suppliers for future-oriented fuel cell technology, to best position them for global competition. Furthermore the main components of the fuel cell system will be optimised and supplied for integration in a fuel cell system through many technological innovations, like for example, the adoption of additional, over-arching functions, new and alternative materials and new manufacturing methods and processes for cost-effective, financially viable manufacturing in large quantities. This will be undertaken in close cooperation with the supplier industry and service providers. With the development of new concepts in the areas of hydrogen recirculation, new simulation models to describe and characterise fuel cell system components and hydrogen monitoring, vital contributions will be made for future production in large quantities.

As one of the world's leading companies in the development and production of fuel cell systems, NuCellSys undertakes every effort to meet the demand for pollutant-free, sustainable mobility.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| NuCellSys GmbH | 16,262,095 | 7,805,806 |

COMMENCEMENT: 01 January 2013
CONCLUSION: 31 December 2015

» As one of the world's leading companies in the development and production of fuel cell systems, NuCellSys undertakes every effort to meet the demand for pollutant-free, sustainable mobility. «

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## » EPOWERSYS – POWER ELECTRONICS SYSTEMS FOR FUEL CELL VEHICLES «

Fuel cell vehicles are electric vehicles that also have a traction battery on board in addition to the fuel cell. DC/DC convertors are required to regulate the electrical current on board. These are bidirectional voltage transformers that adjust the various voltages of the battery and fuel cell to a common level, and that can also be deployed in pure battery or hybrid vehicles.

The identification of potentials for synergies in the power electronics of electric vehicles with batteries and fuel cells is necessary for further development and will provide cost reduction potentials due to economies of scale, to give electric mobility a further push forward.

Aim of the project was the analysis and evaluation of the performance electronics in terms of a modular design in order to flexibly implement them in electric drive concepts, for which automotive development methods were applied. The BOSCH-designed electronics were being tested under realistic conditions at Daimler AG according to the demands of Mercedes-Benz fuel cell aggregates. A key component was a newly developed high performance coil module (HPCM) from SUMIDA Components & Modules GmbH. New magnetic materials and innovative system combinations were researched.

The project results include highly efficient power electronics that achieved 98 % efficiency in a close-to-serial production OEM trial.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Robert Bosch GmbH | 9,796,668 | 4,702,401 |
| SUMIDA Components & Modules GmbH | 2,680,523 | 1,286,651 |
| Daimler AG | 412,396 | 197,950 |

COMMENCEMENT: 01 October 2010
CONCLUSION: 30 September 2015

» Aim of the project was the analysis and evaluation of the performance electronics in terms of a modular design in order to flexibly implement them in electric drive concepts. «

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## » DEMONSTRATION MERCEDES-BENZ B-CLASS F-CELL FLEET IN STUTTGART AND FRANKFURT «

30 B-Class F-CELL vehicles were operated by customers in Stuttgart and Frankfurt as part of this project and thereby made the technology visible and capable of being experienced. The vehicles travelled a total of more than 1,000,000km over the course of the project. The project could prove the suitability of fuel cell vehicles for everyday use as well as their technological viability in the market. Details of the technology could be conveyed through numerous lectures and events at universities and other educational institutions. Workers at the Mercedes-Benz Service workshops in Stuttgart and Frankfurt were also qualified to conduct repair and service tasks on the vehicles. As part of the Clean Energy Partnership, the standardisation of the technology could also make tremendous progress.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Daimler AG | 13,179,140 | 5,864,611 |

VEHICLES: 30 B-Class F-CELL vehicles

COMMENCEMENT: 01 November 2011
CONCLUSION: 30 June 2015

» The project could prove the suitability of fuel cell vehicles for everyday use as well as their technological viability in the market. «

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## » CLEAN ENERGY PARTNERSHIP – CEP PHASE II CONTINUED OPERATION OF FOUR BUSES WITH HYDROGEN COMBUSTION ENGINES «

With a view to protecting the climate, hydrogen is being produced from renewable energies. The Berliner Verkehrsbetriebe (Berlin public transport company) is continuing operation of a fleet of four buses with hydrogen combustion engines under the Clean Energy Partnership initiative – CEP Phase II over a period of five years. By the end of the project, a total operation time of 8.5 years will have been achieved. Together with the preceding project, the hydrogen buses had thus achieved an operation time comparable to diesel buses at the end of their deployment time within the BVG. Throughout the entire project period, the activities planned in the work packages were able to be implemented as anticipated.

The $H_2$ buses were mostly deployed on the express line X49 and consumed around 20 kg of hydrogen over 100km. The hydrogen buses were used primarily in early service to cover rush hour and for the afternoon shift. They took over regular tasks of the line service, normally carried out by diesel buses.

The first relevant problems with the drive train arose in 2012, because the vehicle manufacturer could no longer supply the spare parts needed and they had to be made by subcontractors. By developing comprehensive know-how in hydrogen technology at BVG, the operational readiness of hydrogen bus fleets in the existing $H_2$ garage will be guaranteed until the end of the project.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Berliner Verkehrsbetriebe AöR | 2,940,410 | 1,411,397 |

COMMENCEMENT: 1 February 2010
CONCLUSION: 31 January 2015

VEHICLES: 4 MAN low-floor buses Lion's City with hydrogen combustion engine
INFRASTRUCTURE: $H_2$ garage at the BVG premises

» The hydrogen buses were used primarily in early service to cover rush hour and for the afternoon shift. They took over regular tasks of the line service, normally carried out by diesel buses. «


Hydrogen bus of the X49 route at the depot.


BMW 5er GT FCEV

I / 26

## » CRYOFUEL – VISION VEHICLE FOR EMISSION-FREE PREMIUM LONG-DISTANCE MOBILITY «

Electric drives are a part of the future of emission-free mobility. For short distances in urban operation, electrical energy is best stored in a high-voltage battery. For long distances and short refuelling times, chemical storage in the form of hydrogen and subsequent conversion to electrical current in a fuel cell on board the vehicle is preferred.

Today the state of technology and the mainstream for the next few years is the storing of hydrogen in the vehicle in 700 bar pressure tanks at ambient temperature ($CGH_2$).

To increase vehicle range, BMW are currently researching a tank system which increases the energy density of a 700 bar storage system by more than 50 %. This is done through refuelling and storing of cryogenic gaseous hydrogen in a cryo-compressed storage system at up to 350 bar ($CcH_2$).

In addition the cooling of the fuel cell drive is improved by the cold energy stored in the cryo-compressed tank and so provides a higher continuous output.

In the CryoFuel project, test vehicles with high-performance fuel cell electric drives and hydrogen cryo-compressed storage systems were researched, developed and built upon in order to test the everyday practicability of cryo-compression technology in terms of storage, refuelling and performance.

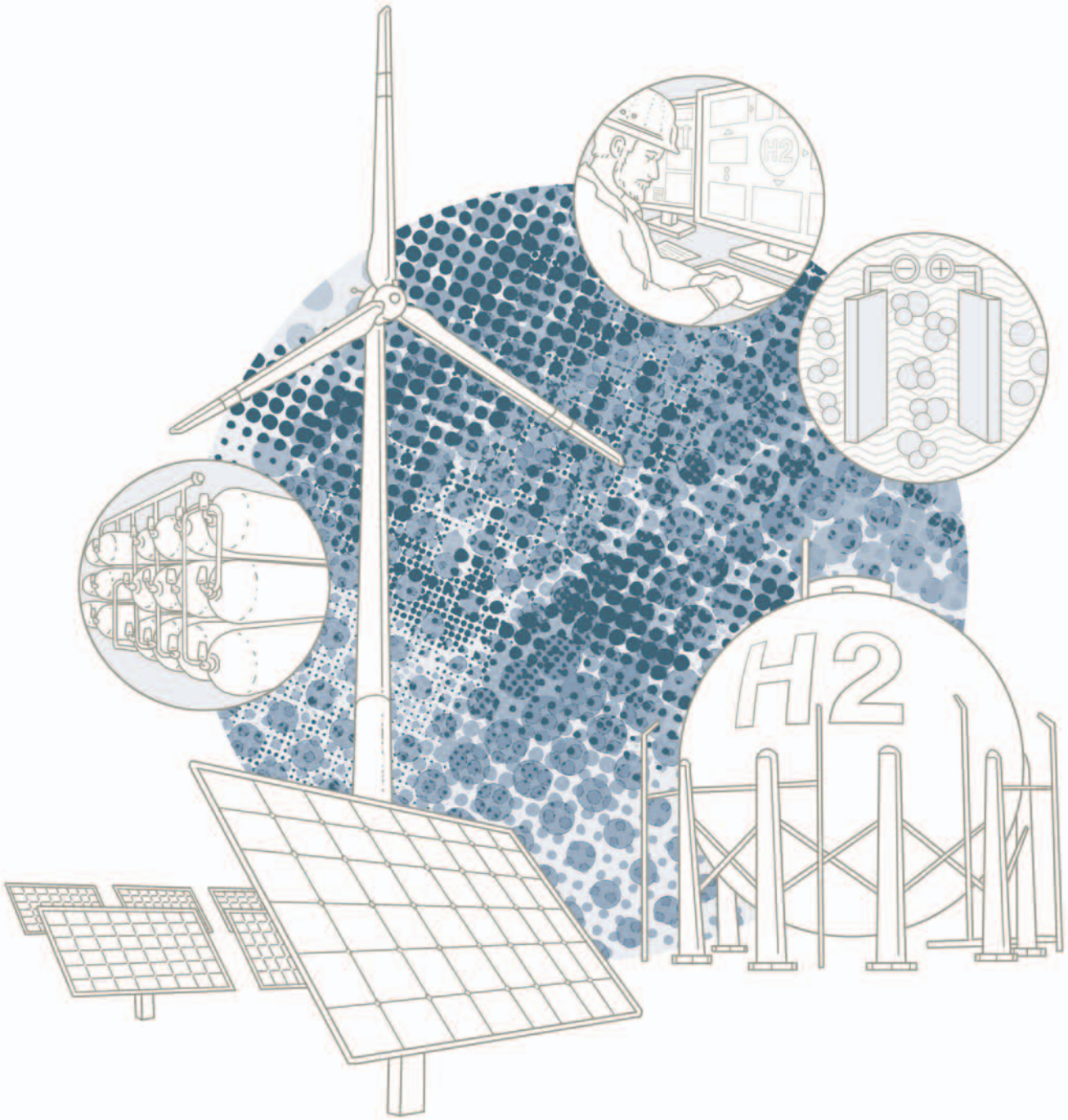
The project showed that also for larger cars, a higher performance class of everyday emission-free driving is possible with dynamic power delivery and driving comfort typical for this car category, at longer ranges and with faster refuelling.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| BMW AG | 20,534,271 | 9,856,450 |

COMMENCEMENT: 01 January 2013
CONCLUSION: 31 August 2015

» In the project, test vehicles with high-performance fuel cell electric drives and hydrogen cryo-compressed storage systems were researched, developed and built upon in order to test the everyday practicability of cryo-compression technology in terms of storage, refuelling and performance. «

# NIP – HYDROGEN PROVISION




THE PROJECTS ARE LISTED I / 01 ON THE FOLLOWING PAGES,
COMPLETED PROJECTS ARE MARKED WITH 🏁 .

# NIP – HYDROGEN PROVISION

Demonstration projects and studies on the production, storage and distribution of hydrogen are conducted within the Hydrogen Provision programme area in the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP). In line with the goals of the federal government's energy concept, the hydrogen is primarily produced using renewable energy – wind, solar and biomass. The hydrogen is used to power fuel cell vehicles and as a storage medium for large amounts of fluctuating renewable energy. Specific areas of application also include stationary reconversion, the feeding-in into the natural gas network as well as for use as a climate neutral industrial gas.

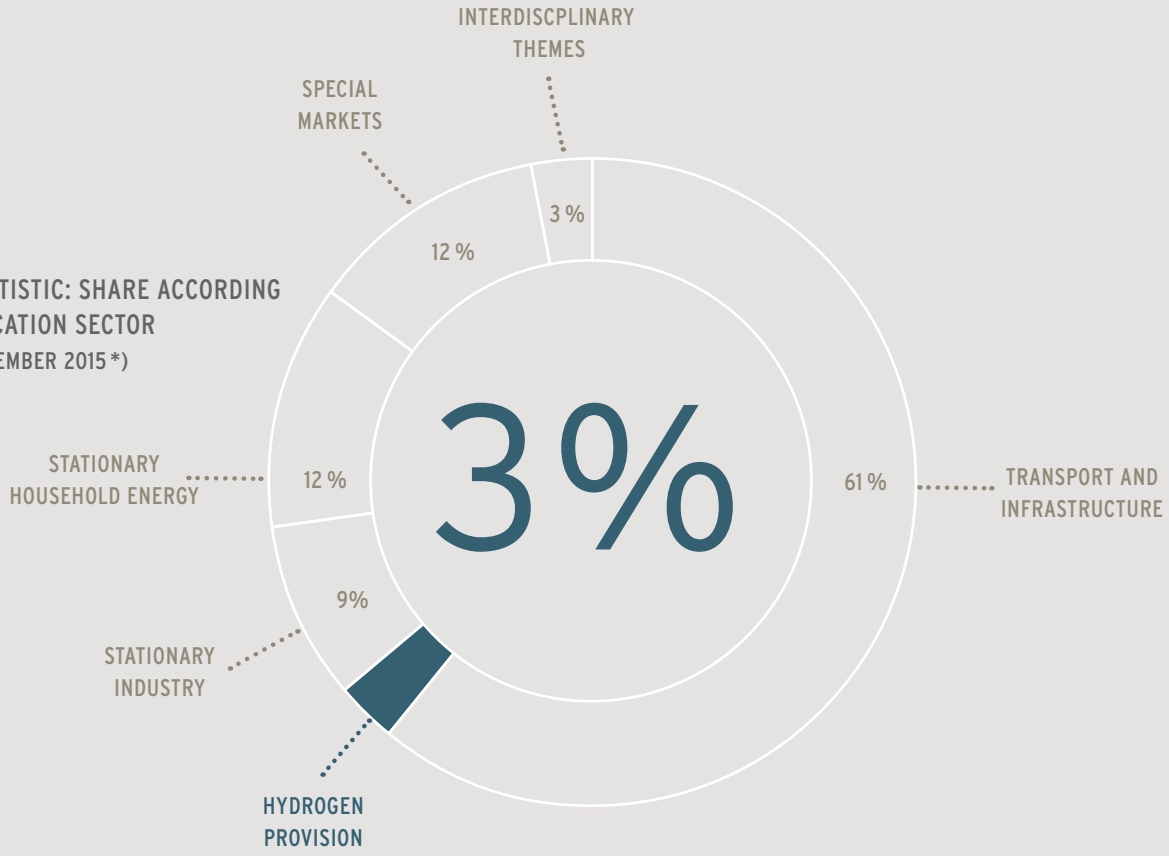
The use of regenerative hydrogen can make a significant contribution to the goals of the so-called energy turnaround. Not only does it accelerate the switch from fossil-based fuels to renewable sources of energy in the transportation and energy sector – as set out in the energy concept – it also creates energy storage capacities, which are urgently required for the energy turnaround to succeed. The special economic appeal of hydrogen as a fuel enables a lead market to be established, which can pave the way for the storage of energy and other applications.

Hydrogen production via the highly efficient water electrolysis method, chiefly from excess wind energy, is at the core of the programme area. Water electrolysis is regarded as a key technology for the integration of renewable energy in the areas of transportation and energy. New and growing markets for hydrogen lay the foundation for exploiting the significant development potential that is inherent in all electrolysis technologies.

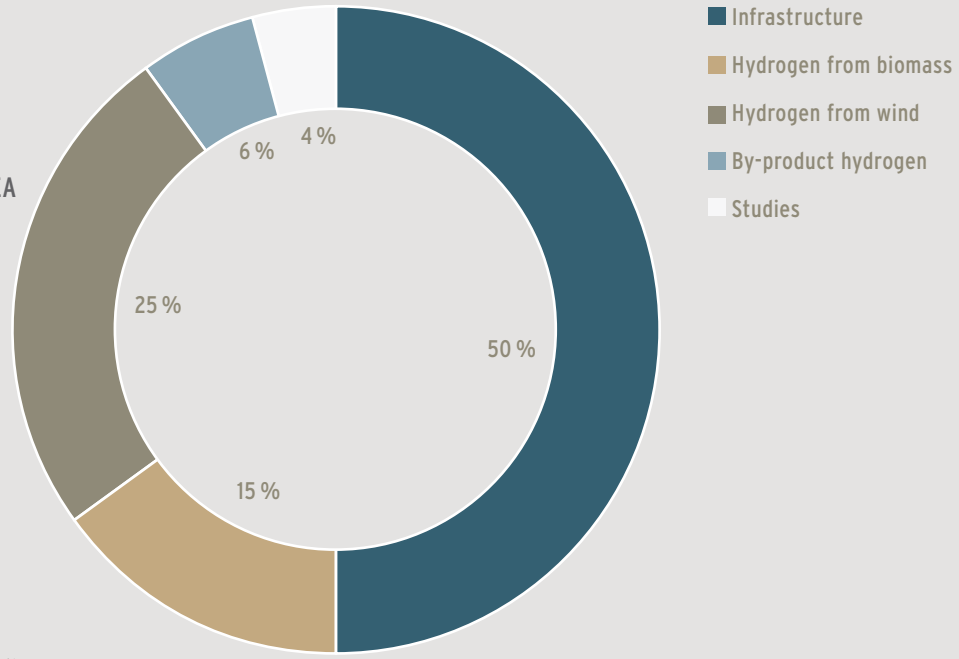
While the tried and tested alkaline electrolysis method may today still be the most common method of producing hydrogen electrolytically, the newer PEM electrolysis method is markedly gaining in importance. Demonstration projects using both technologies are being supported within the programme area.

The role of hydrogen in the energy and transportation sectors is also being examined on a cross-sector level in the programme area (see following article). The potentials of hydrogen and fuel cell technologies to reach the goals set out for the energy turnaround are issues being thoroughly discussed in numerous studies and analyses. The results also serve to classify the projects and other NIP activities, or their effect, in terms of how they can support the energy turnaround.

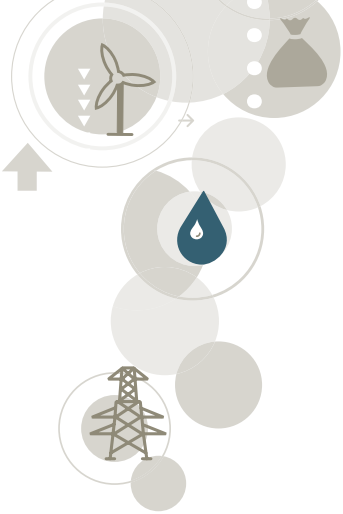
## NIP – STATISTIC: SHARE ACCORDING TO APPLICATION SECTOR
(AS AT DECEMBER 2015 *)




## NIP – HYDROGEN PROVISION: ALLOCATION BY APPLICATION AREA
(AS AT DECEMBER 2015)




* The diagram incorporates projects at planning stage at NOW, being processed by PtJ, LOI (Letter of Intent) as well as those approved.



## DWV EXPERT COMMISSION PERFORMING ENERGY COMMITTED TO BRINGING ABOUT AN ECONOMICALLY FEASIBLE, FUTURE-ORIENTED ENERGY TURNAROUND

**The performing energy initiative, which was amalgamated in 2015 into the German Hydrogen and Fuel Cell Commission (DWW – Deutscher Wasserstoff- und Brennstoffzellen-Verband) as an Expert Commission is committed to an efficient and economically feasible energy turnaround. Members from leading industrial enterprises, research institutes and organisations from the areas of environment and the promotion of technology are convinced that the energy turnaround can only succeed from an economic perspective with an integrated comprehensive concept spanning all three energy sectors. The focus is on developing regulatory proposals to create the prerequisites for the timely and economical market introduction of »green hydrogen«, or subsequent products such as synthetic fuels or renewable energy power-to-gas.**

With Commission spokesperson Werner Diwald at the helm, there are now 18 member companies and institutions pursuing the goal of an energy turnaround worthy of its name: after all, the renewable energies reform law (EEG – Eneuerbare Energie Gesetz) alone is not sufficient to achieve the energy policy objectives of supply reliability of renewable energy, economically. The regulations and policies of the EEG represent a change in energy and not an energy turnaround. The performing energy Expert Commission is therefore promoting an integrated energy concept (IEK 1.0) in which green hydrogen produced through renewable energy may serve as an interim solution for emission-free mobility.

$CO_2$ values have actually risen in Germany's transport sector over the past year by 1.7 percent. Without a strategic transformation process in the direction of $CO_2$-free mobility, the set targets cannot be met. The changeover to sustainable fuels and more efficient vehicles is necessary to achieve this. In the area of fuels, hydrogen produced using renewable energy can immediately improve the $CO_2$ balance of fuels used for transport. In the medium term, hydrogen-run vehicles will need to adopt a firm place in the mobility mix of the future to enable greater overall energy efficiency in the area of transport. Specialists consider the fuel cell as an important complement to pure-electric vehicles. In addition, in contrast to the battery, hydrogen as a source of energy provides the options for flexibility that are required to deal with the volatility inherent in renewable energy power plants.

On a European level, the course to the introduction of electric power-based fuels was set in September 2015. With its delegated legislation in the Federal Immission Control Act (BimSchG – Bundes-Immissionsschutzgesetz), the government set a strong signal for the market introduction of power-to-fuel. In the interests of German industry, business and citizens, the federal government is now called upon to enact policy changes in 2016 for the market introduction of power-based fuels.

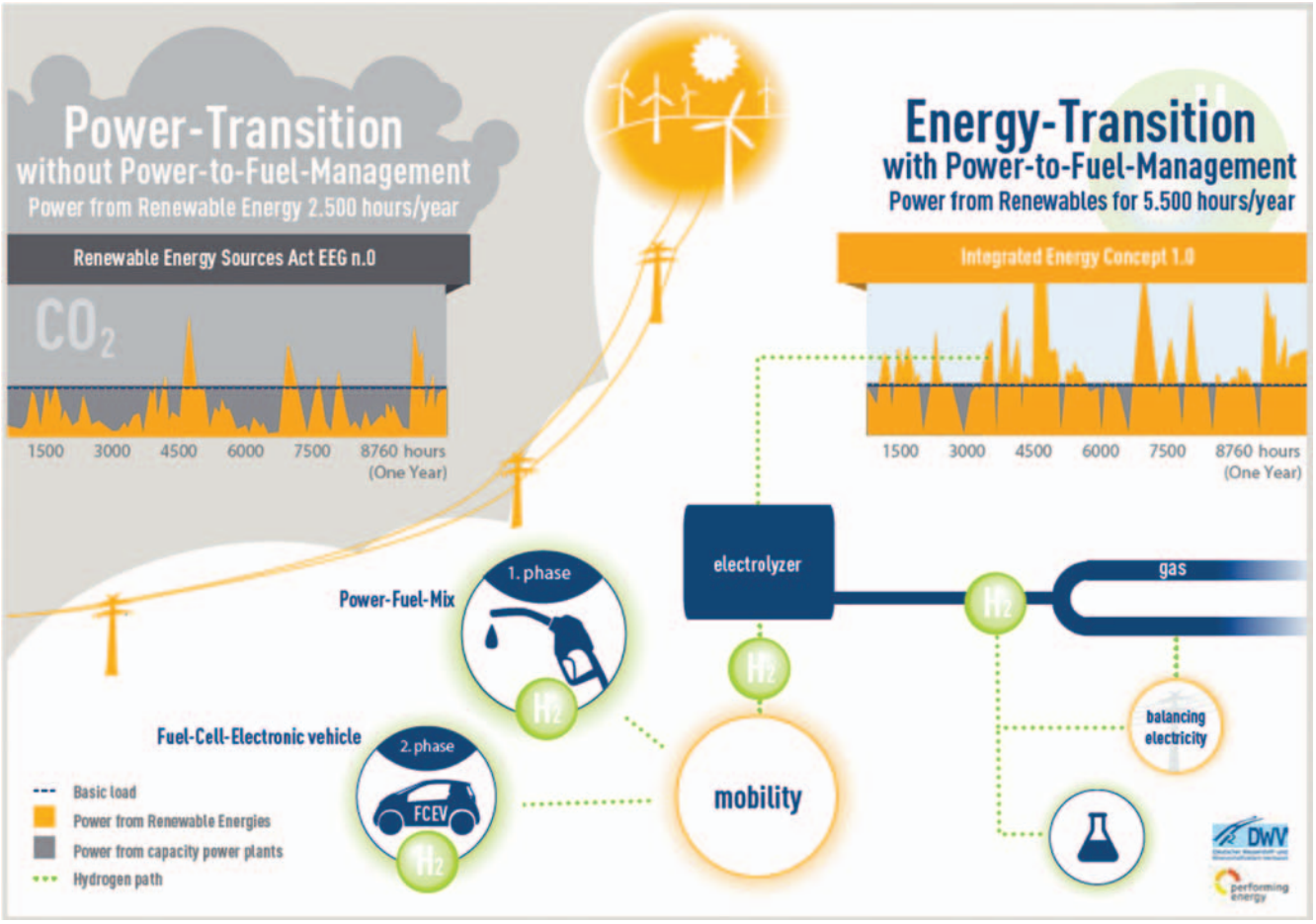

↗ Werner Diwald, Speaker of the DWV Expert Commission performing energy, together with BMVI State Secretary Norbert Barthle

In this regard, the performing energy Expert Commission developed the following key policy demands:

↗ The near-term introduction of the obligation that 0.5 % of the GHG (greenhouse gas) reductions from mobility must come through the use of bio fuels of the 2nd generation (advanced biofuels).

↗ Hydrogen or methane produced using renewable energy is to be credited to the GHG reduction amount. In this context, specifically hydrogen or methane in §37a of the Federal Immission Control Act (BimSchG).

↗ Tax concessions must be extended to include power-based fuels produced with renewable energy, irrespec-




tive of whether the hydrogen is brought into the transportation sector directly or chemically bound in gaseous or liquid fuels.

↗ Legal clarification of the characteristics of power-to-X as power cost-intensive plants is mandatory for successful market introduction. Whereby the classification of the applicable plants should be confirmed for a period spanning several years by the Federal Office for Economic Affairs and Export Control (BAFA – Bundesamt für Wirtschaft und Ausfuhrkontrolle).

↗ Technology-oriented start-up financing should also be taken into consideration for the market introduction phase.

↗ The take-up of power-to-X projects in a special loan programme of the KfW bank with concessional interest rates and corresponding maturity dates of at least 15 years in order to remove obstacles on the capital markets side.

**Performing energy members:**

↗ BeBa Energie GmbH & Co. KG
↗ Brandenburgische Technische Universität
↗ DBI Gas- und Umwelttechnik GmbH
↗ DENA
↗ Deutsche Umwelthilfe e.V
↗ Deutsches Zentrum für Luft- und Raumfahrt e.V.
↗ ENERTRAG AG
↗ Fraunhofer-Institut für Solare Energiesysteme
↗ Hamburger Wasserstoffgesellschaft
↗ hySOLUTIONS GmbH
↗ IVG Immobilien AG
↗ Linde AG
↗ McPhy Deutschland GmbH
↗ NOW GmbH – National Organisation Hydrogen and Fuel Cell Technology
↗ Siemens AG
↗ TOYOTA AG
↗ Total Deutschland GmbH
↗ Vattenfall Europe Innovation GmbH
↗ ZSW

With its work, the performing energy Expert Commission provides the federal government with a concept for a successful energy turnaround, new jobs and an approach to reduce energy imports. The proposals made by the Expert Commission enable a reduction of the renewable energy act levy (EEG-Umlage) and network charges. In addition, climate goals in the area of mobility can thereby be achieved without additional costs to citizens and business.

↗ Information on performing energy membership can be obtained via email from:
**presse@performing-energy.de.**

↗ Further information on the Expert Commission activities can be found at the new DWV internet site:
**www.dwv-info.de.**

## PREVIEW OF RESULTS FROM THE »META-STUDY TO EXAMINE THE POTENTIALS OF HYDROGEN FOR THE INTEGRATION OF THE TRANSPORTATION AND ENERGY ECONOMY«

**Over the past few years, hydrogen produced using renewable energy has gained in significance across several business sectors. In the automobile and fuel sector such renewable hydrogen is primarily considered as a fuel for fuel cell vehicles while for the natural gas industry, the feeding in of the gas into the grid is a key application option – including all other associated deployment possibilities (heating market, reconversion, gas mobility). The respective sectors follow different technological and business strategies, which to date have not been examined comparatively or in view of potential common utilisation perspectives. For this reason, the German Technical and Scientific Association for Gas and Water (DVGW – Deutsche Verein des Gas- und Wassersfaches) and NOW GmbH jointly resolved to commission an examination for the parallel use of hydrogen as a fuel and for feeding hydrogen into the natural gas network.**

The »Meta-study to Examine the Potentials of Hydrogen for the Integration of the Transportation and Energy Economy« analyses the value-added chain, technical conditions and development needs along with economic perspectives of both fields of application. At its heart is the comparative analysis of two key DVGW and NOW studies on Power-to-Gas and Wind Hydrogen. The identification of synergy potentials leading to approaches for the optimisation of cost efficiency through the combined usage of electrolytically produced hydrogen as a fuel and additive gas is an important material outcome. The examination was chiefly conducted by the DBI Gas- und Umwelttechnik research institute and also drew on the expertise of the MW-quadrat planning office. The study was jointly financed by NOW and DVGW with 20,000 euros (net) each and primarily completed between end 2014 and mid 2015. Preliminary results were discussed in an expert's workshop and the publication of final results is scheduled for the not too distant future.

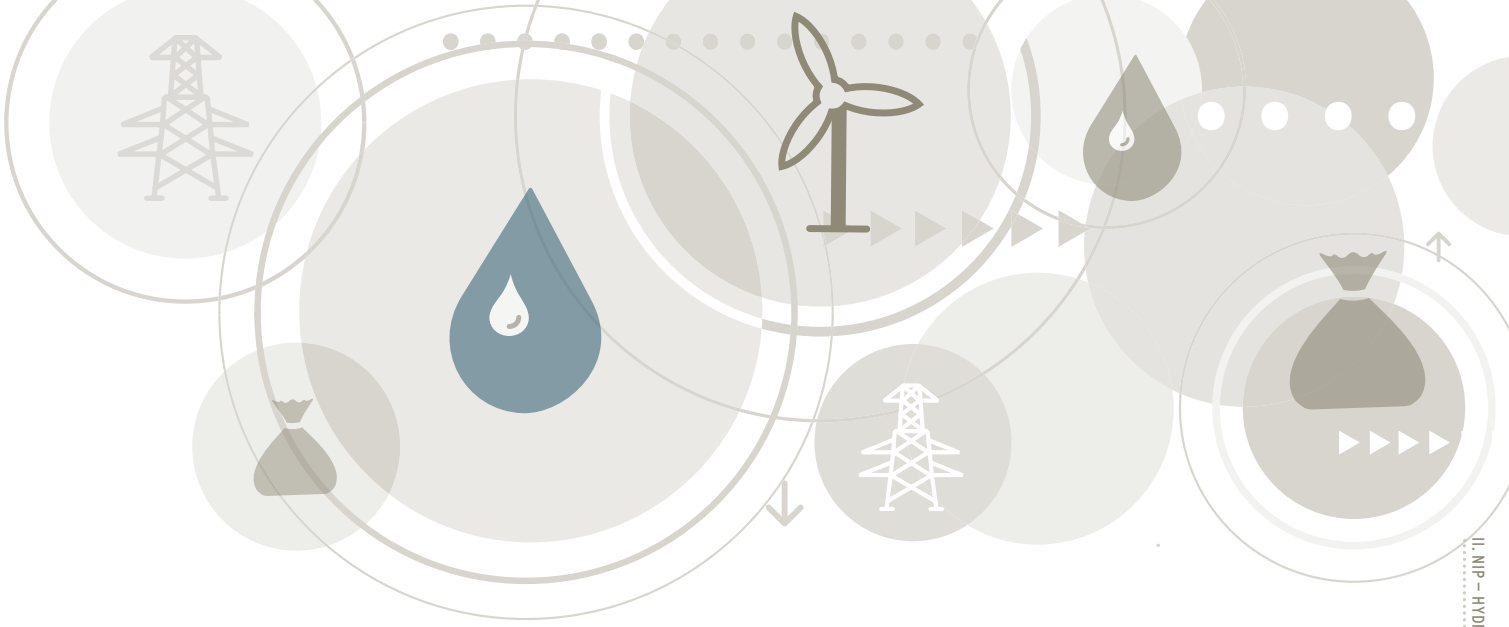
The meta-study incorporates the following work packages: WP 0: Study comparison; WP 1: Comparison of value-added chains; WP 2: Establishment of the research and development requirements; WP 3: Ideas for the instigation of future demonstration projects. This preview of results will present contents and outcomes from work packages WP 0 and WP 1. The detailed and complete presentation of all four work packages will occur upon the publication of final results as referred to above.

The studies to be compared in WP 0, »Integration von Wind-Wasserstoff-Systemen in das Energiesystem« (Integration of Wind Hydrogen Systems in the Energy System) from NOW [1] and »Entwicklung von modularen Konzepten zur Erzeugung, Speicherung und Einspeisung von Wasserstoff und Methan ins Erdgasnetz« (Development of Modular Concepts for the Production, Storage and Feeding in of Hydrogen and Methane in the Natural Gas Grid) from the DVGW [2] each examine the possible uses of renewable hydrogen. They are similar in their general orientation but are punctuated by several differences when examined in detail.



↗ Published in March 2014 (221 pages), left

↗ Published in February 2013 (249 pages), right





The utilisation concepts of the respective studies feature fundamental differences yet complement each other in their approaches. The usage concept followed by the NOW study puts its focus on the sale of renewable hydrogen as a fuel, for reconversion and for participation in the balancing energy market (electricity). In contrast, the DVGW study focuses on hydrogen being fed in to the gas network and its subsequent use as a fuel. Besides the usage concepts, the system concepts are also complementary. The DVGW examines power-to-gas plants with low to mid electrolysis performance of 0.9 $MW_{(el)}$ to 144 $MW_{(el)}$, while the NOW study focuses on a system with a nominal performance of 500 $MW_{(el)}$. The usage concepts are supplemented in the system concept of the NOW study with underground storage in a cavern, a gas and steam turbine power plant and a filling station for trailers with 100 parking spaces.

The studies examine both the availability of power from renewable production for deployment in electrolysis as well as the amounts of surplus power. When looked at in detail, however, clear differences can be seen. The DVGW study predicts the available power amounts at network hubs for the production of hydrogen for the year 2020, while the NOW study, with regard to the overall power generation capacities in Germany and differentiated according to zones (northwest, northeast and rest of Germany), for the year 2030.

For the calculation of feasibility, various different approaches are used. The NOW study calculated the costs and revenues to optimise the use of the plant, whereas the DVGW study undertakes a prime cost calculation. Both studies examine numerous system and plant management types of which the meta-study only examines selected cases for the sake of greater clarity. Despite the various system concepts and nominal power dimensions of the electrolysis, the volume of specific investment costs is at a similar scale: namely 1,106 EUR/$kW_{(el)}$; ELY with the NOW study and 1,033 EUR/$kW_{(el)}$; ELY with the DVGW study (144 $MW_{(el)}$; ELY).

Both studies consistently show that the variable operating costs are largely determined by the power costs for the operation of the electrolysis. Despite the large differences in the performance classes across the studies, the level of fixed operating costs are at a similar level at approximately: 29 – 57 EUR/$kW_{(el)}$; ELY (DVGW study) and 38 EUR/$kW_{(el)}$; ELY (NOW study).

Due to the differences outlined, a methodological comparison of prime costs, or the required revenues respectively, is only possible to a limited extent. Similarities can nevertheless still be derived. The prime costs range between 3.70 – 5.12 EUR/$kg_{(H2)}$ (DVGW study; with the exception of the smallest unit; 4,000 full load hours (FLH)) and 5.00 EUR/$kg_{(H2)}$ (NOW study; 3,052 FLH) at power procurement costs of 40 EUR/$MW_{(el)}$.

Based on the results from WP 0, in WP 1 specific value-added chains for hydrogen usage were identified as well as considerations to deployment possibilities made. For this, singular usages were considered in the first step (single models), corresponding value-added chains developed and prime costs for hydrogen calculated. Combination models of usage possibilities were then subsequently analysed. In regard to the single model observation, it was noticed that in comparison to the current (today's) reference revenue for other energy sources, the calculated future prime costs for hydrogen are not competitive. In must be noted here, however, that the environmental advantages of »green hydrogen« are not taken into account in today's financial market mechanisms, resulting in a systemic disadvantage.

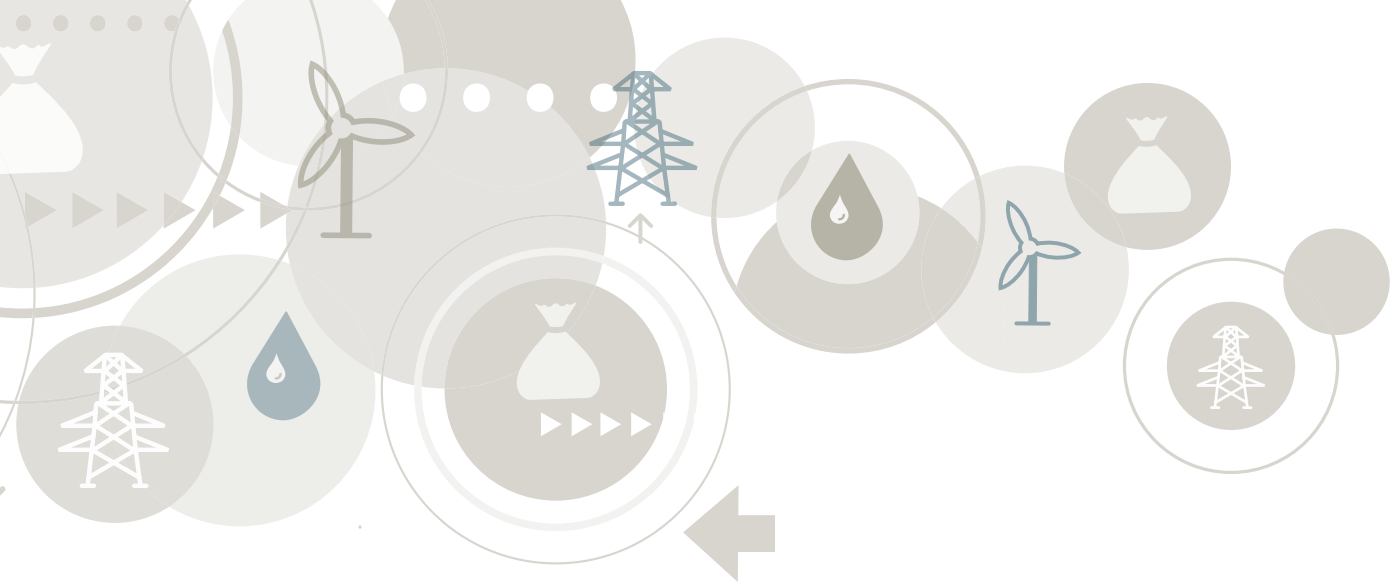
Considering the economic efficiency cannot currently be presented, combination models of various usage types were created and examined with a special view towards potential synergies and in regard to technical and economic benefits. Combination models technically unify several value-added chains together. The investment outlay for main and auxiliary systems as well as revenue technologies (fuel cell, CHP plants, refuelling stations, etc.), which makes up a considerable share of costs in single models, can thereby be shared among several us-

age paths – ultimately reducing the prime costs. Furthermore, the electrical performance of the electrolysis can be significantly increased in comparison to a single model, whereby synergy effects can be exploited so that the specific investment and operating costs can be reduced. A further benefit realised in the combination models is that already existing systems (e.g. underground storage, measuring technology, grid injection systems, etc.) can be utilised in all single models.

The hydrogen prime costs were calculated for three combination models (industry, mobility and gas network) and assessed in detail. To calculate the prime costs, the insights gained from both basic studies were used and verified or adjusted in liaison with the project partners. In addition, manufacturer information on prices for system components was also integrated. Two approaches were taken to assess the prime costs. In the first approach, capital, personnel, maintenance, disposal and consumption costs were taken into account in the prime costs (approach equivalent to the single model observation). The cost for the procurement of power for electrolysis and auxiliary systems was set in the calculation at 20 EUR/$kW_{(el)}$ with a life of 2,000 or 4,000 FLH, respectively. With the second approach, only the consumption costs (power for electrolysis and auxiliary systems) were included for the calculation in order to determine the marginal costs for the procurement of power. The capital, personnel, maintenance and disposal costs remained unconsidered in this approach. Taxes, network charges or levies were also not taken into account in the calculations.

The result of the cost breakdown to the investment shows that the electrolysis technology is the largest cost factor in all combination models. Depending on the combination model, this accounts for more than half of overall costs. Further substantial cost factors included the network connection (transformer, rectifier, substation), the revenue technologies (fuel cell, CHP plant, refuelling station, etc.) as well as provisions for contingencies and costs for the planning and approval of the system. In regard to the last two cost items, these can be reduced through the construction of further pilot plants and standardisation measures. Following the calculation and comparison of the prime costs of single and combination models, it can be stated that the prime costs of combination models are significantly lower than those of single models due to the inherent combinations of use. In part, with the exploitation of synergies in combined usage, reductions of over 30 % could be achieved. The industry combination model achieved the lowest hydrogen prime costs of 7.47 EUR/$kg_{(H2)}$ (corresponds to 7.47 EUR/100 km at a consumption level of 1 $kg_{(H2)}$/100 km in mobility), under the defined assumptions (2,000 FLH; power procurement costs of 20 EUR/$MW_{(el)}$). The prime costs of the other combination models lie in a similar scale. In comparison, while only slightly higher at 8.05 EUR/$kg_{(H2)}$, the mobility combination model boasted the highest prime costs. This occurs due to scaling effects in investments being the most pronounced for a performance range of <1 to 10 $MW_{(el)}$ (electrolysis), according to currently available information. A validation or further determination of degression rates can only be made in the course of demonstration projects.

Economic efficiency emerges in comparison to the available revenue possibilities at 4,000 FLH and power procurement costs of 20 EUR/$MW_{(el)}$ in the mobility area. The additional usage areas of industry and gas network exhibit prime costs that in comparison to single use observations are approaching economic efficiency. The economic appeal of the mobility usage area can be explained by the significantly higher prices that may be attained here in comparison to other markets.





The second observation approach (establishment of marginal costs for existing systems) shows the results that even with relatively high power procurement costs of up to 88 EUR/$MW_{(el)}$, economically viable revenues can be achieved in the area of mobility. For reconversion with fuel cells the tolerable power procurement costs are at 47 EUR/$MW_{(el)}$. For industry, a maximum power procurement cost of 31 EUR/$MW_{(el)}$ can be applied as the reference costs for hydrogen from reforming plants are relatively low and competitive pressure accordingly high. At 20 EUR/$MW_{(el)}$ the gas network value-added chain exhibits a very low tolerable power procurement maximum level due to the low comparative price of natural gas. It should be noted that the examination conducted on the prime and marginal costs was undertaken according to today's regulatory framework conditions along with current applicable investment and reference costs. It is difficult to predict the future development of regulations, technologies and costs – and cannot be reliably quantified in the present day. The environmental benefits of gases produced using renewable energy have not yet been quantified and taken into account either. Notwithstanding this, the evaluation of the framework conditions is outside the scope of this examination.

To evaluate the results, a sensitivity analysis was conducted in conclusion. Besides variations in power prices and the number of FLH, this also took into account potential price reduction of individual components (electrolysis, underground storage, grid injection systems, etc.) and technological developments (efficiency rates). It was shown that the power price and the number of FLH have the largest influence on the prime costs. The influence of cost reduction through additional and revenue technologies (underground storage, CHP plant, fuel cell, etc.) is, however, dependent on the power capacity incorporated in the value-added chain and therefore very varied.

**↗ Preview of results from authors**

Marco Henel, Anja Wehling, Martin Weiße, Oliver Ehret

**↗ Sources**

[1] Stolzenburg, K.; Acht, A.; Crotogino, F.; Donadei, S.; Genoese, F.; Hamelmann, R.; Horvath, P.L.; Krause, S.; Lehmann. J.; Michaelis, J.; Miege, A.; Sponholz, C. und Wietschel, M.; in Abstimmung mit der Nationalen Organisation Wasserstoff und Brennstoffzellentechnologie, »Integration von Wind-Wasserstoff-Systemen in das Energiesystem: Abschlussbericht«, 2014.

[2] G. Müller-Syring, M. Henel, W. Köppel, H. Mlaker, M. Sterner und T. Höcher, »Entwicklung von modularen Konzepten zur Erzeugung, Speicherung und Einspeisung von Wasserstoff und Methan ins Erdgasnetz,« 2013.

Completed energy storage facility incldуing production, compression, storage and reconversion.

## » NATIONAL INNOVATION PROGRAMME FOR HYDROGEN AND FUEL CELL TECHNOLOGY (NIP): DEMONSTRATION AND INNOVATION PROJECT RH2-WERDER/KESSIN/ALTENTREPTOW – DEVELOPMENT AND IMPLEMENTATION OF A WIND-HYDROGEN SYSTEM FOR $CO_2$-FREE STORAGE AND DEMAND-DRIVEN PROVISION OF WIND ENERGY «

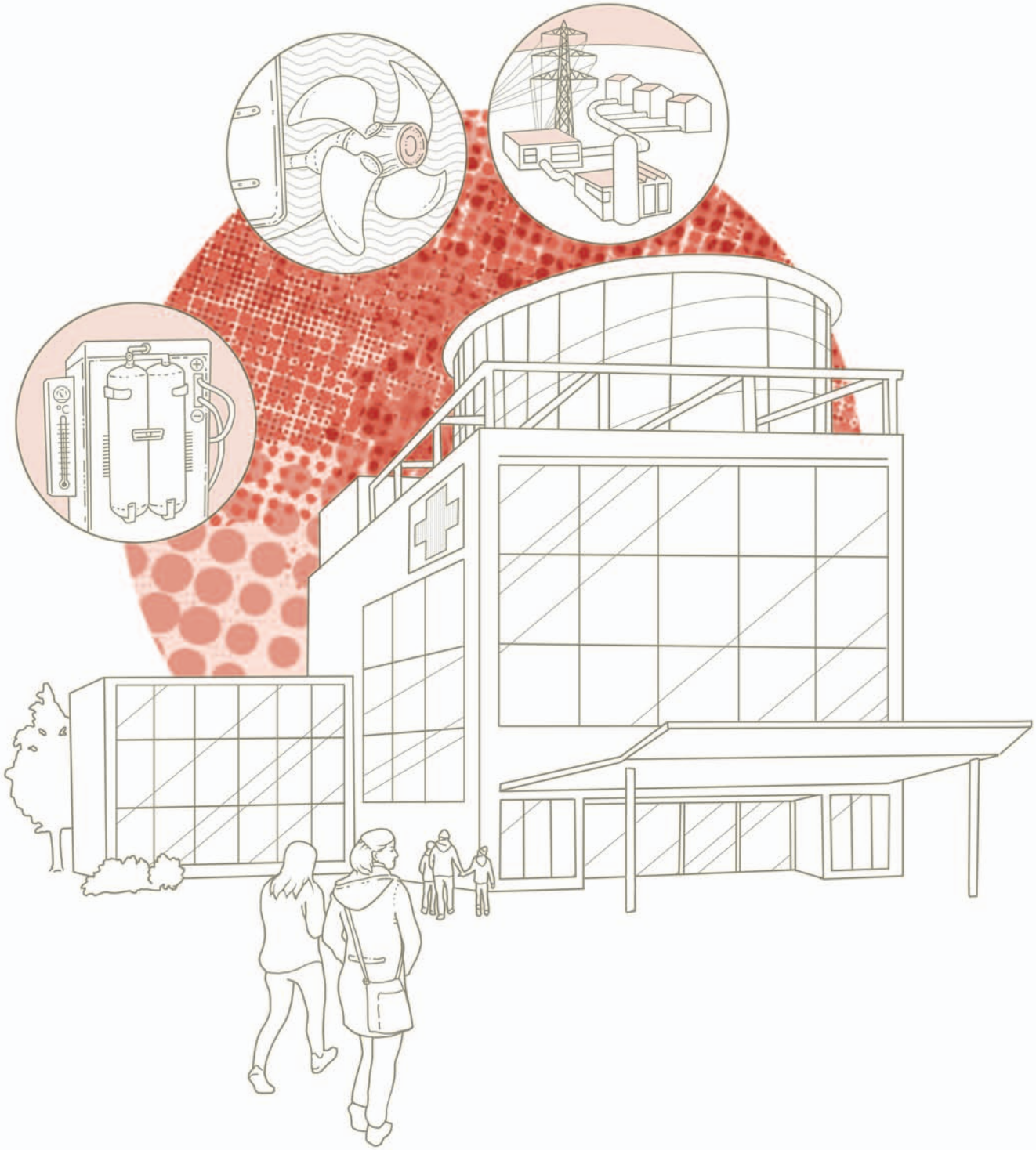
Supported by the Federal Ministry of Transport and Digital Infrastructure following a decision of the German Bundestag, the demonstration and innovation project facilitated the development and testing of wind-hydrogen systems. This $CO_2$-free energy storage system has made it possible to sustainably supply demand-driven wind electricity at any time. The energy storage facility is directly integrated in a wind park with a total output of approx. 140 MW. The circuit includes the production (210 $Nm^3/h$), compression (310 bar), storage (approx. 3,300 $Nm^3$) as well as reconversion (250 $kW_{(el)}$ in combined heat and power units) of pure hydrogen. The final energy forms used are power and heat. In addition the gaseous hydrogen can be extracted from the storage circuit. The two hydrogen CHP units have two different power settings. This facilitates an optimised operation mode and thus high electrical efficiency. The system uses a combined heat and power process for economic and ecological reasons. The project enabled experience to be obtained in approval processes and the operation of wind-hydrogen systems, filling and emptying characteristics of the hydrogen storage system and also allowed the regulation and control behaviour of the wind-hydrogen system with different operational modes to be tested. Operational and maintenance costs could also be determined.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| WIND-WASSERSTOFF-projekt GmbH & Co. KG | 6,787,336 | 3,257,921 |

COMMENCEMENT: 01 October 2009
CONCLUSION: 31 July 2015


Symbolic ground-breaking ceremony on 7 July 2011.

# NIP – STATIONARY ENERGY SUPPLY





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COMPLETED PROJECTS ARE MARKED WITH 🏁 .

# NIP – STATIONARY ENERGY SUPPLY

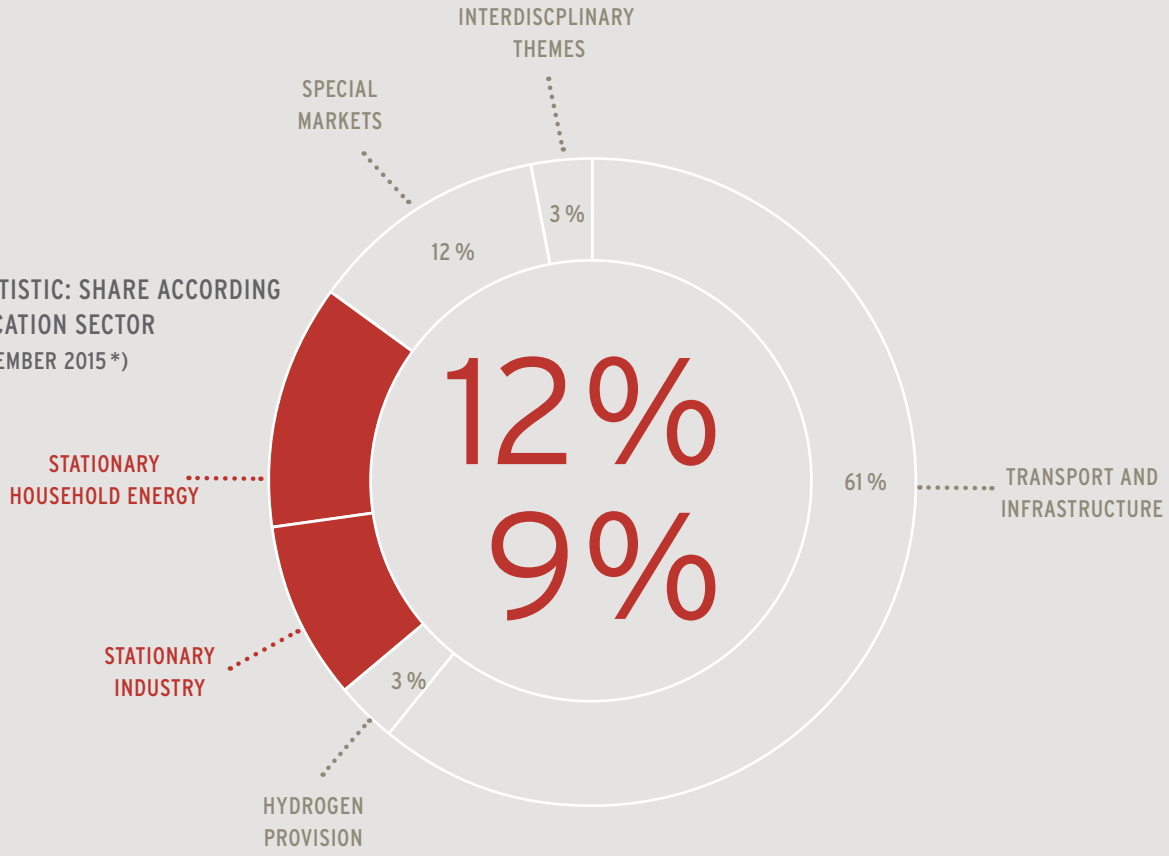
The Stationary Energy Supply programme area includes systems from an electrical capacity range of several hundred watts up to five kilowatts for household energy, and extends up to plants with some ten kilowatts to several megawatts in industrial use. The simultaneous generation of heat and power via fuel cells facilitates high overall efficiency rates of more than 85 percent. This enables $CO_2$ savings of between 25 and 35 percent compared with modern conventional supply systems.

The systems in household energy supply work on the principle of combined heat and power and operate using natural gas from existing supply networks. In the medium term, biogas and fluid renewable energies that are fed into the natural gas network will also be used. Fuel cell devices for household energy thus have the advantage of being directly usable without requiring investment in the surrounding infrastructure. Low to high-temperature polymer electrolyte membrane fuel cells (PEMFCs) and solid oxide fuel cells (SOFCs) will be used in this area.

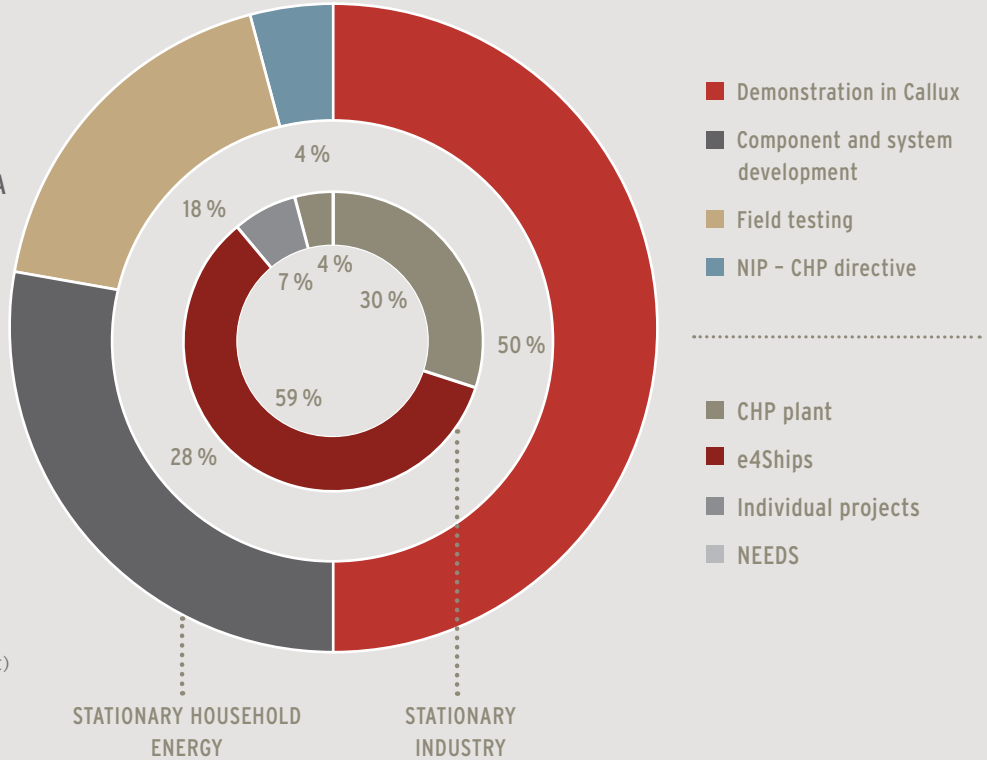
For fuel cell facilities in the industrial and shipping areas, SOFC and MCFC (Molten Carbonate Fuel Cell) technologies are mainly implemented.

In total there are several hundred fuel cell combined heat and power plants with a power capacity of 100 kilowatts and above in use worldwide.

## NIP – STATISTIC: SHARE ACCORDING TO APPLICATION SECTOR
(AS AT DECEMBER 2015 *)




## NIP – STATIONARY APPLICATIONS: ALLOCATION BY APPLICATION AREA
(AS AT DECEMBER 2015)




* The diagram incorporates projects at planning stage at NOW, being processed by PtJ, LOI (Letter of Intent) as well as those approved.

callux (nip)
Fuel cell field tests for the home

# CALLUX, PRACTICAL TEST OF HOUSEHOLD FUEL CELL HEATING SYSTEMS

## ON THE HOME STRAIGHT

**With the closing event of Callux being held 26 November 2015 in the Erich-Klausener Hall of the Federal Ministry of Transport and Digital Infrastructure (BMVI), the practical test of fuel cell systems in the home concluded just at the phase of market introduction. The overall result of the practical test that boasts almost 500 installed devices and over five million hours operation is nothing short of impressive. Besides the operation and optimisation of the fuel cell systems, various work packages serving to promote market preparation were also on the agenda.**

### FROM PRACTICAL TEST TO THE MARKET

The fuel cell heating systems could be optimised step-by-step throughout the installation period that spanned a total of three system generations. The improvements included a reduction in plant size, enhanced installation ease as well as an increase of availability to an average of 96 percent. With a power utilisation factor of over 30 percent, the fuel cell heating systems generated more than three million kilowatts of electricity that was either used on site of fed into the electricity grid. The system centrepiece, the stack, achieved run times exceeding 20,000 hours within one system generation. The overall efficiency rate of the plants amounted to 90 percent. Reductions of up to 1.9 tons of $CO_2$ annually per plant could be proven. Service and maintenance costs could be reduced by 90 percent throughout the course of the test and the costs of the system were reduced by 60 percent during the field trial, thereby making the purchase of fuel cell heating systems, with continued funding support, competitive with other high-efficiency systems.

### THE KEY TO SUCCESS: MARKET PREPARATION

Preparing the market for the imminent introduction in the market included many facets such as the development of infrastructure, vocational training and market research. As part of this, the Callux Box was developed in Callux, which serves as a remote controller and maintenance module and also enables a shared database for the plants and is additionally an important prerequisite for the operation of virtual power plants. Networked control of the system was tested within the scope of the trial and so-called timetable operations of over 50,000 hours were successfully conducted.

In addition, Callux was involved in vocational training, market research and communication. The qualification of specialist partners was aspired to via various instruments. A fuel cell heating system information programme that was available for either online use or for download, provided the possibility to approach the subject of fuel cells for household heating and power supply in a fun and contemporary manner. Numerous specialist lectures were made available to vocational schools, which were individually approached so that the teaching materials could be deployed. Callux also regularly gave updates on the current project status to all interested parties via webinars. Relevant target groups involved with fuel cell heating systems such as multipliers, marketing intermediaries, test customers and potential customers were surveyed by market research institute GfK. More than half the responding tradespersons perceived the fuel cell to have good chances of market success. Moreover, almost half the potential customers would take the purchase of such a system into consideration. And eight out of ten customers that already had experience with this innovative technology would recommend the plant to friends and acquaintances.

### CALLUX: A TRANSPARENT AND SUCCESSFUL PROJECT

With its transparent and professional approach, the Callux field test successfully conveyed the current status of the technology, which is now ready for market. Every individual project was registered in an online database and visible in the internet. Now, with the conclusion of the project, the Fuel Cell Initiative (IBZ – Initiative Brennstoffzelle) is urging for further market-related activities in 2016. Among the companies that have been involved in Callux are: Baxi Innotech, EnBW Energie Baden-Württem-

berg, E.ON, EWE, Hexis, MVV Energie, Vaillant VNG Verbundnetz Gas as well as the Centre for Solar Energy and Hydrogen Research (ZSW – Zentrum für Sonnenenergie- und Wasserstoff-Forschung) as project coordinator.

↗ The Callux project concluded with a closing event at the BMVI and on the backdrop of the impending market introduction in 2016

More information:
www.callux.net

## READY FOR THE MARKET:
## FUEL CELLS FOR HOUSEHOLD ENERGY SUPPLY

**Fuel cell-based systems for the combined production of heat and power let various demands be met for both existing and newly constructed buildings. The nine involved providers of the Fuel Cell Initiative (Initiative Brennstoffzelle) have systems in their range that can complement existing heating systems – so-called add-on devices – as well as full heating systems designed for various fields of application. For example, homeowners can combine the fuel cell with their existing boiler and thereby become a power producer. Among the prerequisites for this is the installation of buffer storage, which can store the continually produced heat from the fuel cell system. With full heating systems, the fuel cell provides the base heating load and a condensing boiler is automatically activated to flexibly cover any peaks, if necessary. In this way it is assured that the production of power can occur in a manner that is as continuous and effective as possible. The performance of the condensing boiler can be individually configured to the heating requirements of the particular building. Compact heating systems incorporate the entire technology in a modularly designed enclosure.**

### HEATING TURNAROUND WITH FUEL CELLS IS POSSIBLE IN GERMANY

With a choice of either the add-on or complete refurbishment approach, owners of existing buildings have two possibilities for deploying a fuel cell system. Considering the high average age of existing heating systems and the widespread availability of mains gas connections, there are good prospects in Germany for a modernisation market leading to a »heating turnaround« that is also linked with an improved $CO_2$ balance in household energy usage. The average age of heating boilers in Germany is 17.6 years. One third of all units have been in operation for more than 20 years. With the introduction of efficiency labels in existing dwellings, old systems will only be certified with the efficiency classes C, D or even E. In contrast, and depending on the specific model, fuel cell systems can be classified with the best rating of A++.


| Manufacturer | Buderus | Elcore | HEXIS | Junkers | SenerTec | SOLIDpower | SOLIDpower | Vaillant | Viessmann |
|---|---|---|---|---|---|---|---|---|---|
| Type | SOFC | HT-PEM | SOFC | SOFC | NT-PEM | SOFC | SOFC | SOFC | NT-PEM |
| Model description | Logapower FC10 | Elcore 2400 | Galileo 1000 N | Cerapower FC10 | Dachs Innogen | EnGen-2500 | BlueGEN | G6 | Vitovalor 300-P |
| Power output (el/th) | 0.7/0.62 kW | 0.3/0.7 kW | 1.0/1.8 kW | 0.7/0.62 kW | 0.7/0.96 kW modulating unit | 2.5/2 kW | 1.5/0.61 kW | 0.8/1.5 kW | 0.75/1 kW |
| Thermal output of auxiliary burner | 7.3 – 24 kW | Package solutions: 2.8 – 19.5 kW/ 7.8 – 33.2 kW, or external, individually selectable | 7 – 21 kW | 7.3 – 21.8 kW | 5.2 – 21.8 kW | external, individually selectable | external, individually selectable | 5.8 – 27 kW | 5.5 – 19 kW |
| Storage | Hot water storage 75 l, buffer storage 135 l | Package solutions: 500 l, or external, individually selectable | external, individually selectable | Hot water storage 75 l, buffer storage 135 l | Buffer storage with fresh water station 300 l | 300 l, optional | external, individually selectable | external, individually selectable | Hot water storag 46 l, Drinking water storage optional expandable to 300 l, buffer storage |
| Electrical efficiency | 45 % | 32 % | 35 % | 45 % | 37 % Full load | 50 % | up to 60 % | 33 % | 37 % |
| Overall efficiency | 85 % | 104 % | 95 % | 85 % | 90 % | 90 % | up to 85 % | 92 % | 90 % |
| Dimensions (W x D x H) | 1200 x 600 x 1800 | 600 x 550 x 1050 | 620 x 580 x 1650 | 1200 x 600 x 1800 | Fuel cell unit: 453 x 728 x 1054 System componentry: 655 x 1065 x 1800 | 630 x 830 x 1700 | 600 x 660 x 1100 | 599 x 693 x 1640 | 1085 x 595 x 1998 |
| Weight in kg | Entire system 304 kg in modular construction, max. module weight 112 kg | 115 | 210 | Entire system 304 kg, in modular construction, max. module weight 112 kg | 115 kg Fuel cell module | 350 | ca. 200 | 150 | 290 (fuel cell module 125, peak load module 165) |
| Field tests, cooperations, demonstration projects | ene.field (EU), small series in cooperation with energy suppliers | ene.field (EU ), ene.field (EU), various partners from the energy sector and construction | Callux (DE), Pharos (CH), ene.field (EU) | ene.field (EU) | enefield (EU), Callux (DE) | ene.field (EU) | Completed | Field test in Callux (DE), small series in ene.field (EU) | January 2013 pretest; July 2013 to March 2014 large field test |
| Market introduction | 2016 | 2014 | End 2013 | 2016 | 2016 | 2016/2017 | (2012) | 2016/2017 | April 2014 |
| Contact | www.buderus.de | www.elcore.com | www.hexis.com | www.junkers.com | www.derdachs.de | www.solidpower.com | www.solidpower.com | www.vaillant.de | www.viessmann.com |

Fuel cells for household energy supply are available to suit diverse individual requirements

## FUEL CELL: EFFICIENCY FOR NEW BUILDINGS

For new buildings, the fuel cell represents a highly efficient heating system based on natural gas that is an alternative, for example, to a heat pump combined with a photovoltaic system. Fuel cell heating systems fulfil the demands of the German Renewable Energies Heat Act, which outlines the possible applications of heating systems in new buildings.

## GOOD PROSPECTS IN THE HEATING MARKET

In view of the heating market and its average number of approximately 700,000 system installations annually, the prospects for the innovative fuel cell technology are good. Around 70 percent of the systems sold are installed in existing housing stock, 30 percent in new buildings. Overall, the share of gas heating systems is about 75 percent. Virtually every old system connected to the natural gas network can be replaced with more efficient fuel cell technology.

## BROAD RANGE OF SYSTEMS AVAILABLE

Besides the specific demands the building has for heating, the number of persons in the household is an important measure when planning for the installation of a new system. This is, for example, significant for dimensioning the hot water requirements. Also needing to be considered is the question of whether the power can be used in the household itself or is to be rather fed into the network. The different devices are characterised by varying electric and thermal performance attributes, which need to be taken into account when choosing a suitable model. The technology deployed for the fuel cell stack will generally play a subordinate role in the selection of a model.

e4ships (nip)
Brennstoffzellen im maritimen Einsatz
Ein Projekt im Nationalen Innovationsprogramm Wasserstoff- und Brennstoffzellentechnologie

## NIP LIGHTHOUSE PROJECT
## E4SHIPS

**The deployment of fuel cell systems in shipping, especially for the supply of on-board electricity, heat and in some cases cooling on large vessels represents a promising market and is receiving intense focus as part of the e4ships lighthouse project, from shipyards, shipping companies, fuel cell manufacturers, suppliers and classification organisations. Besides technical developmental efforts, issues of economic feasibility, standards of safety, market introduction strategies and the effects on climate protection are being examined.**

Aim of the e4ships lighthouse project is the targeted development of fuel cell systems for maritime deployment and tests on board of seafaring vessels. High temperature fuel cells (SOFC and HT-PEM) are used for this purpose. Fuels employed may include methanol, natural gas (CNG, LNG) or diesel.

Parallel to testing on the ships, the prerequisites for the approval of fuel cells on ships including the mentioned fuels at all international harbours are being developed within the scope of the International Maritime Organisation (IMO). On board, fuel cells can provide an optimal alternative to the often cost-critical shore-side power supply and also make an important contribution to reducing air pollution in harbour cities. This applies just as much to the main drive systems of ferries or river cruise ships.

Besides the systematic implementation on various vessel types and integration in the energy supply systems, the major technical challenges include deriving the technical standards for system types and performance classes for the shipping industry. Moreover, the path must be prepared towards higher performance systems in the future. Two demonstration projects for fuel cell applications on board ships are being conducted within the e4ships lighthouse project.

↗ The ***Pa-X-ell*** project involves the testing of high-temperature PEM fuel cells in a passenger ship and is led by the Meyer Werft shipyard in association with further project partners. The system is based on standardised modules that can be scaled up to any performance range by interconnecting them. Fuel cell modules, currently with a total of 60 kW, are now being tested on land and will be taken on board a passenger ship (MS Mariella/Viking Line) in summer 2016 and run parallel to the conventional energy supply. The system will initially be run on methanol via internal reforming. A natural gas reformer will be developed in a further step, which can later be deployed on gas-run ships to supply the fuel cell plant.

↗ The ***SchIBZ*** project is being conducted by a consortium led by ThyssenKrupp Marine Systems. At the core of activities is the development and testing of an integrated fuel cell system with a performance level of 500 kW for seafaring ships that in the middle term is intended to be able to comprise the main energy source for the supply of power on all types of oceangoing vessels. Following the completion of the tests of reformer and fuel cell module, further 25 kW modules were produced. Two of these modules, with a combined performance of 50 kW, will be installed in spring 2016 as a demonstration unit on board a cargo ship of the Rörd Braren shipping company. Here it will provide a significant part of the required on-board power for the duration of the test.

With the planned continuation of work, both concepts are to be developed further whereby similar tasks are to be tackled jointly.

More information:
wwww.e4ships.de

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## » RIVERCELL – CONCEPT AND DEVELOPMENT OF A FUEL CELL HYBRID SYSTEM FOR A RIVERBOAT (CRUISE SHIPS AND PUSH BOATS) «

The RiverCell project deals with the concept and development of a hybrid energy and drive system for riverboats. The aim is to significantly improve the efficiency and sustainability of ship powertrains in comparison to the conventional diesel motor-based powertrain technology.

To enable this and to supply the required overall electrical and thermal energy, a system featuring fuel cells in combination with innovative engine technology, photovoltaic, heat recovery and batter-based energy storage is being conceived. A modular energy system is being developed on the basis of a river cruise ship and its transferability to other ships with similar power requirements is being examined. An important aspect of the RiverCell project will include the optimisation of the fuel cell for deployment on board of ships. On the same token, the storage of suitable alternative fuels on board will also be examined and the regulatory framework for the development of guidelines defined.

An additional subproject will examine the deployment of pure electric powertrains for use on ships for the transportation of freight on inland waterways. The design and concept will be based on the analysis of operational and load profiles of conventional inland waterway freight ships, to help in the development of an innovative energy supply system for such vessels. In regional operation, the necessary energy will be provided to all consumers on board via accumulators. To supply energy consumers on longer, trans-regional trips, an additional hydrogen-operated fuel cell will also be on board. This project shows that innovative concepts for powertrains and energy supply not only have great environmental benefits compared to conventionally operated inland waterway freight ships, but they can also be economically competitive.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| MEYER WERFT GmbH & Co. KG, | 1,192,158 | 572,236 |
| NEPTUN WERFT GmbH & Co. KG | 349,490 | 167,755 |
| Viking Technical GmbH | 247,232 | 118,671 |
| Serenergy A/S | 1,846,552 | 886,345 |
| fischer eco solutions GmbH | 144,101 | 69,168 |
| HADAG Seetouristik und Fährdienst AG | 81,230 | 38,990 |
| FSG Flensburger Schiffbaugesellschaft mbH & Co. KG | 108,346 | 52,006 |
| hySOLUTIONS GmbH | 78,667 | 37,760 |
| TUB Technische Universität Berlin* | 294,870 | 141,538 |
| BEHALA Berliner Hafen und Lagerhausgesellschaft mbH* | 125,558 | 60,267 |

COMMENCEMENT: 01 January 2015/*01 July 2015
CONCLUSION: 31 December 2016

River cruise ship »VIKING FREYA«

» The project improves the competitiveness of SOFC systems, because if successful, a media module will be available that can be produced inexpensively and in large quantities. «

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## » MEMO: HIGHLY INTEGRATED MEDIA MODULE «

The focus of the project is the development of a highly integrated media module suitable for series production, which can connect a solid oxide fuel cell stack (SOFC) from ElringKlinger AG with a system from new enerday GmbH. The system delivers electricity from propane gas for the off-grid energy supply of any applications of between 200 and 700 W. The main functions of the media module are the distribution of combustible gas and air from the stack and the bundling of operating media in the exhaust gas system. Challenges include the reduction of manufacturing costs, weight and volume, automated series manufacture and the integration of a reformer, a recycling unit and avoiding return flow of exhaust gas. The development will be planned and controlled with the aid of production development methods of the Karlsruhe Institute for Product Development (KIT-IPEK). At the same time the existing methods for SOFC technology will be developed further and thus subsequent developments will be made available. The project improves the competitiveness of SOFC systems, because if successful, a media module will be available that can be produced inexpensively and in large quantities.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| ElringKlinger AG | 2,105,743 | 1,010,756 |
| Karlsruher Institut für Technologie (KIT) | 104,566 | 50,192 |

COMMENCEMENT: 01 May 2015
CONCLUSION: 31 December 2016

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## » HYBRID FUEL CELL HOME ENERGY SYSTEM FOR AUTONOMOUS SUPPLY FROM RENEWABLE ENERGY SOURCES «

The project comprises the development of the first generation of a new type of energy-autarchic and hybrid fuel cell home energy system with integrated combined heat and power and energy storage based fully on renewable energy – as well as the first installation and commissioning of 4 demonstration systems with test customers. The system is based on primary energy generation from PV (photovoltaics) and/or wind energy at home and a hybrid energy storage system, from which the entire electrical and thermal energy can be provided the whole year round with batteries, hydrogen storage systems and thermal storage systems. Through the use of a hydrogen storage system, fuel cells and an electrolyser, surpluses and deficits in the solar energy provision will be compensated for on a daily and annual basis. Through the proprietary, combined heat and power and energy storage optimised over the whole year, a very high overall efficiency of the system will also be achieved. The energy manager acts as central intelligence, ensuring that energy supply is guaranteed all year round at any time. Therefore in future, emission-free, autarchic home energy solutions can be achieved for customers on the one hand, and on the other the hybrid storage system can be integrated in the electrical grid via an externally controlled energy manager, creating a buffer capacity in the integrated network, that can be used by energy suppliers and enables the integration of renewable energies.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| HPS Home Power Solutions GmbH | 2,726,422 | 1,308,681 |
| Heliocentris Fuel Cell Solutions GmbH | 17,572 | 440,435 |

COMMENCEMENT: 01 June 2015
CONCLUSION: 31 December 2016

An intelligent energy management system ensures the supply of energy via a renewable energy-based hybrid fuel cell system.

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## » SOFC QA: SERIES PRODUCTION-READY QUALITY ASSURANCE OF INDUSTRIAL SOFC STACK PRODUCTION, SUBPROJECTS A/B «

The final goal of the planned project is the development and implementation of measuring and testing equipment ensuring specific quality criteria of key components of industrial fuel cell stack production, as well as the fuel cell stack end product itself.

Concretely, the testing of the mechanical integrity of electrolytes/fuel cells will be improved to the effect that all previously damaged test items will be reliably recognised and the test stress in the stack resembles reality very closely.

This requires the development of a new type of concept for series production-ready testing (higher output, reliable error detection, less manual effort).

Machine-aided measurement of metallic basic units represents another focus. The existing mechanical measuring apparatus (coordinate measuring machine) to determine flatness is not suitable for series production because of the long measuring time. Thus only selected areas of the unit can be included for technical measurement.

Aside from the quick execution of the measuring task, laser and/or camera-based systems also offer the possibility of expanding the actual measuring task (because of shorter measuring time). On the basis of the measuring data thus generated, statistically reliable figures for the stack components measured can be calculated.

Of equal importance is the replacement of the almost 100% manual visual inspection of electrolytes and fuel cells through automated optical error recognition by means of laser and camera. This will on the one hand, eliminate subjective errors by human testers, and on the other, increase the output of the tested components many times over. The comprehensive data generated facilitate a statistically reliable evaluation of the tested stack components.

The subject of analysis in a fourth work package is the development of guidelines for the design of packaging, so that transport stresses arising in practice don't lead to stack or ISM (integrated stack module) damage like, for example, leakages as a result of the tearing of the glass solder seal, induced fracture in FC, contact break of thermal elements.

In this way the stresses resulting from the transport of the FC stacks to the end customer (last mile) will be identified in cooperation with the manufacturer of the end unit by means of appropriate sensors (e.g. for vibrations). In addition the real stresses during transport to the system manufacturer will be demonstrated through simulation as well as experimental simulation in the laboratory at a test institute.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| sunfire GmbH | 426,338 | 204,642 |
| KERAFOL GmbH | 92,345 | 44,325 |

COMMENCEMENT: 01 June 2015
CONCLUSION: 31 December 2016

» Development of a new type of concept for series production-ready testing. «

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## » DEVELOPMENT PROJECT ELCORE 2.5 KW «

With this project, Elcore GmbH is pursuing the goal of expanding its own product range of efficient micro CHP (combined heat and power) units. Besides the successful Elcore 2400 micro CHP unit that was developed for deployment in single-family homes, the company wishes to also provide units with greater performance suitable for multi-family dwellings and commercial premises.

To enable the deployment of CHP units in this area, certifiable 2.5 kW modules based on the durable and inexpensive HTPEM fuel cell technology are being developed within the scope of this project. The pioneering new units incorporating key Elcore GmbH technologies such as the innovative HTPEM fuel cell stack, the efficient gas process for converting natural gas to hydrogen as well as the unique heat and water management, will need to be redesigned from the ground up for this purpose.

At the same time, the power and heat make-up of the cogeneration system for multi-family dwellings must be precisely determined in order to achieve high levels of efficiency and a maximum service life. It is here where fuel cell technology with its high efficiency has a decisive advantage over conventional units, leading to significantly increased cost efficiency and climate friendliness.

To achieve this, fundamental tasks and tests are necessary in this project in order to determine an exact make-up and level of power and heat production. The possibility for the subsequent continued development of even larger modules is to already be taken into account on a conceptual level within this project.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Elcore GmbH | 9,432,431 | 4,527,567 |

COMMENCEMENT: 01 March 2015
CONCLUSION: 31 December 2016

» It is here where fuel cell technology with its high efficiency has a decisive advantage over conventional units, leading to significantly increased cost efficiency and climate friendliness. «

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## » LEONARDO II «

Under the project names »Leonardo« and »Leonardo II«, Viessmann Werke and HEXIS are developing a fuel cell heating system which will expand the existing range of fuel cell-based micro CHP systems. One of the overall goals is the reduction of series model investment and operating costs of the fuel cell-based micro CHP systems already available today. Viessmann's systems engineering know-how gained from the fuel cell heating unit Vitovalor 300-P in particular is incorporated here.

The basis of the new fuel cell heating system is the high temperature fuel cell technology (SOFC) of the fuel cell heating unit Galileo 1000 N from HEXIS. While retaining the stack architecture, a new version was developed in the »Leonardo« project, the manufacturing costs of which will be considerably lower compared to now. A prototype version of this fuel cell heating system is currently in the practical test phase.

The focus of »Leonardo II« is the development and verification of the manufacturing and production processes as well as quality assurance at Viessmann, Hexis and their suppliers for the advanced fuel cell heating unit in the project. The pre-series units built in the project will demonstrate their practicability in laboratory and field tests.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Viessmann Werke GmbH & Co. KG | 4,227,342 | 1,225,929 |

COMMENCEMENT: 01 July 2015
CONCLUSION: 31 December 2016

» The focus of »Leonardo II« is the development and verification of the manufacturing and production processes as well as quality assurance. «

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## » FUELCELL@HOME PHASE 1 – MORE EFFICIENCY FOR YOUR HOME «

From 2010 to 2015 the energy service provider EWE VERTRIEB GmbH (EWE), together with the Australian-German manufacturer Ceramic Fuel Cells (CFC) and Gebrüder Bruns Heiztechnik (Bruns) tested fuel cell heating units in north-west Germany. The aim of both phases of the field test is to prove the technological maturity of highly efficient micro CHP systems based on fuel cell technology and to prepare for their introduction to the market.

A total of 74 fuel cell heating units of different generations were installed and operated over the duration of the project. With EWE, CFC/Bruns and the participating regional installers cooperating closely, the phases of installation preparation, actual installation in single-family homes, commissioning and operation of the systems were carried out successfully. Important findings regarding ease of installation were acquired and approaches were determined for practice-oriented optimisation going forward to the second project phase. In this way the further development of the technology was advanced and market introduction was prepared as planned.

In total more than 1 million operating hours were achieved in the operational phase by the middle of 2015. The fuel cell heating units thus generated around 1.4 million kilowatt hours of electricity. The availability of the systems was at more than 90%. The long-term stability of the fuel cell stack was examined and some improvements were made across the different generations. Overall the technical project goals were achieved. As planned, the necessary further development of the technology, taking account of the total costs, continued in a second project phase from the summer of 2012.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| EWE VERTRIEB GmbH | 5,226,041 | 2,508,500 |

COMMENCEMENT: 01 October 2010
CONCLUSION: 30 June 2015

» FuelCell@Home makes a major contribution to increasing energy efficiency in home energy supply. «


EWE field test facility in the project FuelCell@Home Phase 1

# NIP – SPECIAL MARKETS

THE PROJECTS ARE LISTED IV / 01 – IV / 04 THE FOLLOWING PAGES,
COMPLETED PROJECTS ARE MARKED WITH 🏁 .

# NIP – SPECIAL MARKETS

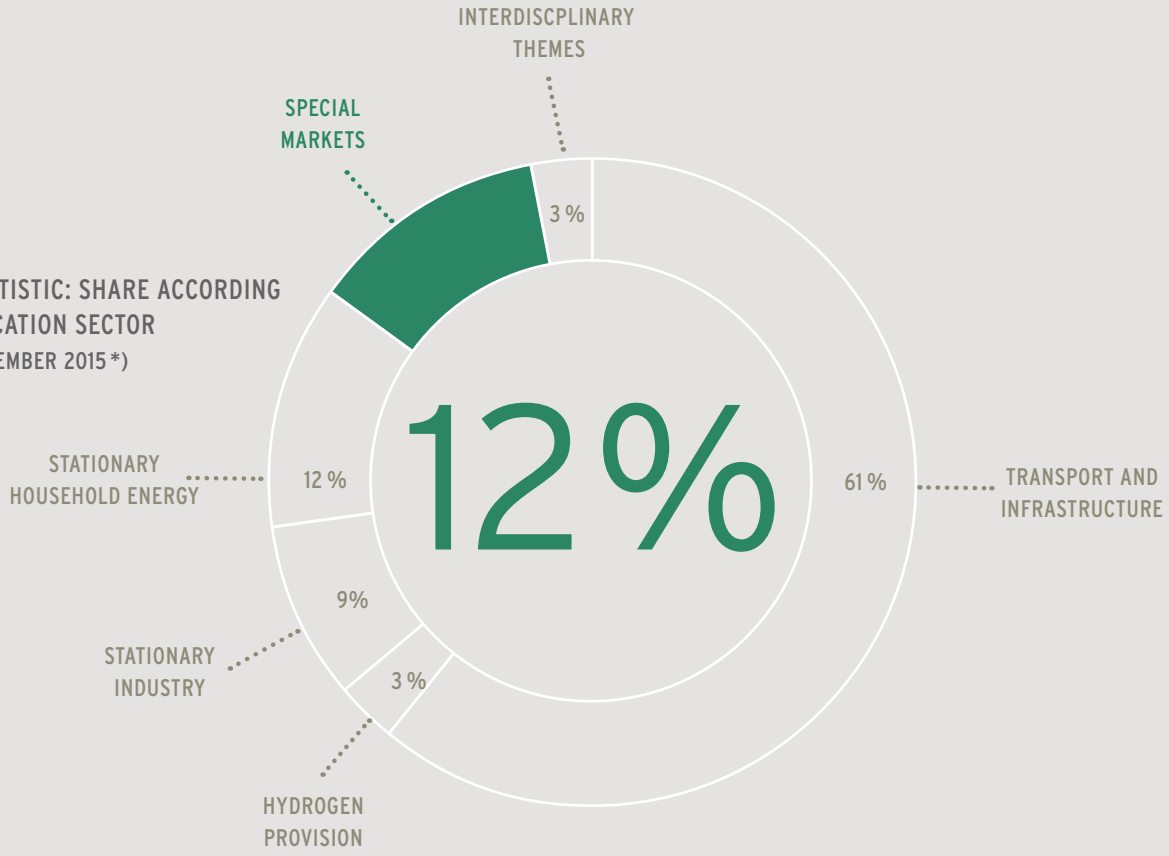
The Special Markets programme area of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP) incorporates a broad spectrum of applications. Likewise, the scope of power ranges deployed in the Special Markets is large, as are the diverse types of implemented fuels and fuel cell technologies.

The Special Markets also utilise many of the components that are also deployed in fuel cells for vehicles and stationary applications. The power range of applications in the Special Markets extends from several 100 watts for on-board power supplies, up to several ten kilowatts for uninterruptible power supplies and for special vehicle applications. Hydrogen, methanol, ethanol, bioethanol and LPG (propane, butane) in conjunction with a reformer, are employed as fuels. Various systems are in use for the supply of hydrogen, including gas cylinders and cartridges with metal hydrides or hydrogen generators based on chemical hydrides. In addition, the development of small hydrogen refuelling stations is also envisaged. For methanol-based systems, an existing infrastructure with distribution logistics is already in place. In terms of fuel cell technologies, the spectrum covers polymer electrolyte membrane fuel cells (PEMFC), high temperature polymer electrolyte membrane fuel cells (HT-PEM), direct methanol fuel cells (DMFC) and solid oxide fuel cells (SOFC).

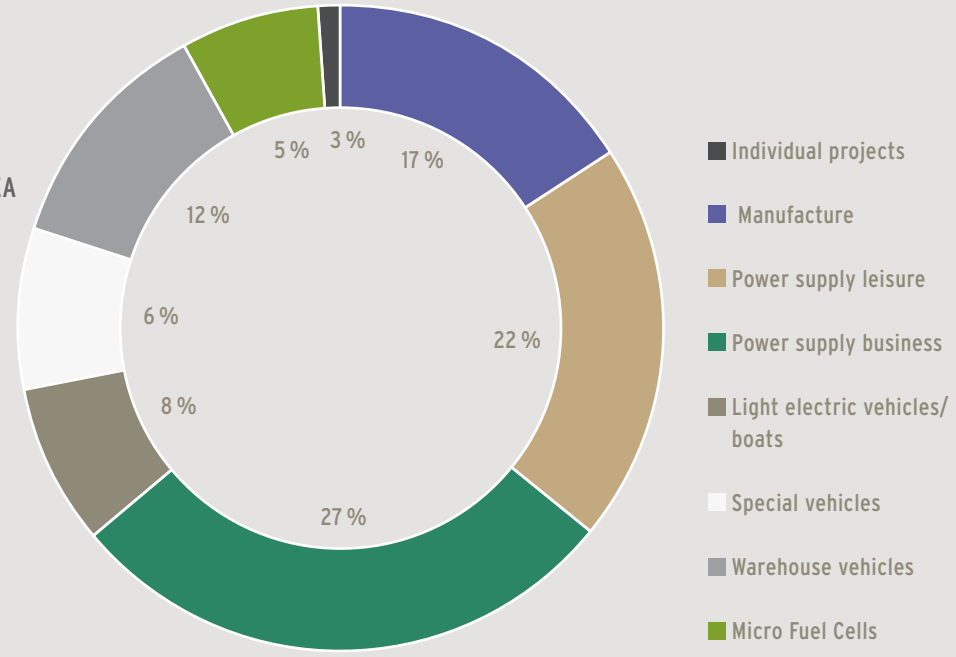
Special Markets incorporates the following areas of application:

- Power supply for business (emergency power supply, UPS, off-grid power supply, autonomous/hybrid power supply, emergency power systems, e.g. in the areas of telecommunications, IT and traffic control systems)
- Power supply for leisure (on-board power supply (auxiliary power units), caravans, camping, mountain cabins, boats)
- Warehouse vehicles (forklifts, haulers, tuggers, cargo tractors, conveyor belt cars, baggage tractors at airports, etc.)
- Special vehicles (service vehicles, municipal/street cleaning vehicles, refuse collection vehicles, small trucks with fuel cell range extenders)
- Electric light vehicles/boats (bicycles, cargo bikes, golf buggies, light boat (drives), fuel cell scooters, wheelchairs)
- Micro fuel cells (industrial sensors, small device supply)

## NIP – STATISTIC: SHARE ACCORDING TO APPLICATION SECTOR
(AS AT DECEMBER 2015 *)




## NIP – SPECIAL MARKETS: ALLOCATION BY APPLICATION AREA
(AS AT DECEMBER 2015)




* The diagram incorporates projects at planning stage at NOW, being processed by PtJ, LOI (Letter of Intent) as well as those approved.

clean power net (nip)
Fuel Cells in Industry and Business

## LIGHTHOUSE PROJECT EMERGENCY POWER SUPPLY/UPS (CLEAN POWER NET)

**The development phase of the lighthouse project commenced with 12 firms in 2010, with financial support from the Bavarian state government. Clean Power Net has been an NIP lighthouse project since 1 July 2013.**

The key challenges for the Clean Power Net (CPN) companies continue to be: the diversity of the markets and intended applications; the heterogeneity of the CPN partners themselves; the fact that the German market alone is too small; and the subsequent joint opportunity for CPN partners of internationalisation.

Numerous activities have been undertaken in order to promote market preparation and introduction of fuel cells in the supply of power, including:

↗ Public affairs at BMWi (Federal Ministry for Economic Affairs and Energy), to push for the establishment of an export fund at the corresponding development banks. A fact sheet was developed for this purpose entitled »Autonomous Energy Supply with Fuel Cells – The Export Potential of 'Made in Germany' Applications« (Autarke Energie-Versorgung mit Brennstoffzellen – Das Exportpotential von Anwendungen »Made in Germany«).

↗ **Arbeitskreis Wasserstoff** (Hydrogen Working Group) investigating alternative solutions for hydrogen infrastructure, logistics and suppliers.

↗ Meeting with **Arbeitskreis Sonstige Brennstoffe** (Working Group »Other Fuels«). Among other things, work commenced on the establishment of a benchmark for operators/user in terms of the issue of costs (Capex/Opex/TCO) for various sources of energy including hydrogen.

↗ **5th CPN General Assembly** with 39 participants in the Representation of the State of North Rhine-Westphalia in Berlin. Potential fuel cell users and multipliers were also in attendance as guests – a great benefit for the event and all CPN partners. The CPN partners had celebrated their 5th anniversary with 21 participants on the preceding night.

↗ Discussions with representatives from the Federal Office of Civil Protection and Disaster Assistance in Bonn; KRITIS risk management department, KRITIS protection concepts/cultural asset protection under the Hague Convention; and Section II – emergency prevention, critical infrastructure, international affairs.

↗ Project identification discussion with representatives of Deutsche Bahn (German Railways) and the Innovation Centre for Mobility and Societal Change (InnoZ) in Berlin.

↗ Presentation of the Clean Power Net (CPN) as well as the fuel cell manufacturer and performance profiles of 10 CPN partners at a workshop of the European Telecommunications Network Operators' Association (ETNO) in Berlin.

↗ Organisation of the export workshop "Potential applications of German fuel cells in the emerging markets" to support industry internationalisation efforts, in the Representation of the State of Baden-Württemberg in Berlin. Speakers from the following renowned export financing organisations could be acquired for the workshop:

- ↗ European Investment Bank EIB
- ↗ Euler Hermes Deutschland AG
- ↗ Germany Trade & Invest (GTAI)
- ↗ Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

**Membership structure:**

**New members:**

- ↗ AdKor GmbH
- ↗ Hydrogenics GmbH
- ↗ Siqens GmbH
- ↗ Leopold Kostal GmbH & Co. KG
- ↗ DB Bahnbau Gruppe GmbH

**Leaving members:**

FCPower Fuel Cell Power Systems GmbH and b+w Electronic Systems GmbH & Co. KG due to financial difficulties.

**Membership changes:**

↗ Elring Klinger AG has assumed a majority stake in New Enerday GmbH.
↗ Heliocentris Energy Solutions AG acquired and integrated FutureE GmbH.

More information:
www.cleanpowernet.de

## FUEL CELL SYSTEMS IN LOGISTICS

Like the entire transport industry, the logistics sector is facing the significant challenge of needing to fulfil environmental protection and emission targets. At the same time, the factor of cost efficiency, which has an even higher priority in logistics than in other areas of transport, must be taken into account. Among the areas of deployment that have proven to be particularly promising for the use of fuel cell-based systems and vehicles in logistics are: intralogistics in production halls and manufacturing facilities; cargo handling using industrial trucks; and vehicles on airport aprons. As such, forklifts have been developed and tested over the last few years within the scope of various demonstration and funding projects that have been supported with funds from the NIP. As part of these projects, important experiences were gathered during operation under real conditions that have been fed back into the further development of the technology and the markets. NOW works closely together with the Materials Handling and Intralogistics Trade Association of the German Engineering Federation (VDMA – Verband Deutscher Maschinen- und Anlagenbau e.V.).

With the explicit goal of gaining interest from several German airports for fuel cell demonstration and fleet projects or establishing cooperation between individual airports, NOW commenced with initial exploratory talks in 2010 with representatives from Hamburg, Frankfurt and Berlin Brandenburg airports as well as with the German Airports Association ADV. The fuel cell initiatives from the German states were also incorporated. Arising from these efforts was the **»Hydrogen, Fuel Cell and E-Mobility at Airports« Working Group** (Arbeitskreis »Wasserstoff, Brennstoffzellen und E-Mobilität an Flughäfen«). A part of its task is the examination of fuel cell-powered baggage tractors and other so-called ground power units with fuel cells. The Working Group also looks into the development and establishment of (mobile) hydrogen refuelling stations at airports.

Today, the members of the Working Group include the airports Hamburg, Berlin, Dresden, Leipzig, Munich, Stuttgart, Frankfurt (Main), Cologne/Bonn and Düsseldorf. AIRBUS Operations GmbH is also involved as a company from the aviation industry and the Center of Applied Aeronautical Research (ZAL – Zentrum für angewandte Luftfahrtforschung GmbH) is also a member from the area of research. In addition, the fuel cell state initiatives Initiative Sachsen, e-mobil Baden-Württemberg GmbH, $H_2$BZ-Initiative Hessen, hySOLUTIONS GmbH, Fuel Cell and Hydrogen Network NRW (Netzwerk Brennstoffzelle und Wasserstoff NRW) are involved along with the German Airports Association (ADV – Arbeitsgemeinschaft Deutscher Verkehrsflughäfen) and the Union of Service Providers at German Airports (VDF – Vereinigung der Dienstleister an Deutschen Flughäfen e.V.).

IV / 01

## »HOME BACK-UP SOLUTIONS FOR PRIVATE AND INDUSTRIAL APPLICATIONS WITH UNSTABLE POWER SUPPLY«

Fuel cells are normally understood to be components of a system and must be integrated into an energy supply solution by the user. In addition relevant specialist knowledge is required, and fear of new technologies and new fuels often represent obstacles impossible for many users to overcome, making market entry of fuel cells more difficult.

This is the starting point of the project: The DMFC fuel cell will be designed, further developed and established as a prototype power supply solution through technological further development and a high level of integration. In this way portable solutions for easy power supply will be developed for potential users, which will deliver electricity in the required form at the push of a button. Operation should also be simple, and interaction made possible via a wireless interface.

Also in this project the DMFC fuel cell (the energy producer) will be integrated with the lithium-ion battery (the energy storage system) and an energy converter into one component. This makes it easy for the fuel cell to be used in existing applications for private as well as for commercial users. Different device configurations will be developed as a prototype, in order to cover privately used applications right up to safety-critical applications in the public service area, like for example facilitating the safeguarding of digital infrastructure.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| SFC Energy AG | 2,134,885 | 821,930 |

COMMENCEMENT: 01 July 2015
CONCLUSION: 31 December 2016

» Different device configurations will be developed as a prototype, in order to cover privately used applications right up to safety-critical applications in the public service area. «

IV / 02

## » SOFC ON BOARD ENERGY SUPPLY SYSTEM «

Aim of the project was the development and testing of compact, efficient on-board power supply generators up to 500 W electrical power output based on an SOFC (Solid Oxide Fuel Cell) fuel cell and the logistically available fuel, liquid gas. The system's selected power range of at least 500 W based on propane gas clearly distinguishes itself from competing fuel cell technologies, thereby closing a gap in the energy range of up to 12 kWh/day, which is currently being predominantly covered by diesel generators from 4 KW performance upwards.

Areas of application were to initially be on-board networks in leisure craft in the marine field (sailing and motor yachts) as well as motor homes and caravans. Project partner Fischer Panda GmbH from Paderborn has well-established access and many years of experience in these markets. Within the cooperation, market-specific demands could be determined and implemented in corresponding application developments. Within the scope of the cooperation and through joint customer contact, further market applications were identified and tapped into, such as the supply of power at self-sufficient locations.

Systems were tried and tested under real conditions in numerous field test installations, where further valuable experience was gathered, which in turn could be used in subsequent developmental adjustments.

The project itself brought about certain issues being brought to light in the first place, thereby leading to significant steps for the product development.

On the basis of the fuel cell modules developed as part of the project, new enerday developed a new product line of turnkey power generators bearing the descriptions PowerTrailer and PowerBox.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| new enerday GmbH | 1,891,532 | 907,935 |
| Fischer Panda GmbH | 665,346 | 319,366 |

COMMENCEMENT: 01 June 2012
CONCLUSION 31 May 2015

As part of the project, a turnkey fuel cell-based power generator (PowerTrailer) was developed.

IV / 03

## » H2 INTRADRIVE – USING A HYDROGEN-OPERATED INDUSTRIAL TRUCK FLEET UNDER PRODUCTION CONDITIONS «

The aim of the research project H2IntraDrive was to research resource costs of hydrogen-operated forklifts and tug trains in an innovative production location as well as the associated real operating conditions. Furthermore it was to be established to what extent the use of hydrogen-operated industrial trucks is sensible with regard to energy efficiency, reliability, life duration as well as sustainability.

For the testing of industrial trucks, the BMW i body shop at the BMW Group plant in Leipzig was chosen. There the BMW Group built the first officially authorised German hydrogen refuelling infrastructure in the production hall. In parallel Linde Material Handling converted six tug trains and five forklifts with battery drives for use with fuel cell systems. The resulting findings from the user point of view was recorded by Lehrstuhl fml in a guide to using hydrogen-operated industrial trucks and published. Aside from testing, a technological comparison with conventional battery-operated industrial trucks was carried out and the ecological and economic sustainability of hydrogen-operated industrial trucks was evaluated.

Finally different framework conditions for German and North-American industrial trucks were identified with the aid of a benchmark.

Publications, presentations and further information can be found at **www.h2intradrive.de.**

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| BMW Group* | 2,954,767 | 1,418,288 |
| Linde Material Handling GmbH* | 2,302,405 | 1,105,154 |
| Technische Universität München – Lehrstuhl für Fördertechnik Materialfluss Logistik (fml) | 244,576 | 117,396 |

COMMENCEMENT: 01 December 2012
CONCLUSION: 31 October 2015/* to 30 April 2016

VEHICLES: Six tug trains and five forklifts (Linde Material Handling)
INFRASTRUCTURE: Ionic compressor up to 450 bar

Hydrogen storage and refuelling facility: H2IntraDrive at BMW Group Plant Leipzig


Hydrogen refuelling of a fuel cell-operated forklift


Energy supply solution with integrated DMFC fuel cells and 124 kWh energy supply


Functional model of a 500 Watt DMFC fuel cell

IV / 04

## » INDUSTRY DMFC MODULE FOR EMERGENCY POWER APPLICATIONS AND OFF-GRID ENERGY SUPPLY OF CRITICAL INFRASTRUCTURE «

Existing DMFC fuel cell products are used today in an output range of up to 500 W. Because of the rising energy requirements in many industrial applications, considerable market potential is opening up for DMFC systems with the output increase developed in this project. The increase in output of a DFMC module to 500 W and the development of cascaded systems facilitate the use of DMFC for energy supply solutions of up to 5 kW.

A DMFC fuel cell solution in the lower kW area bridges the gap between the output range of hydrogen fuel cells and previous DMFC systems. The benefits of the liquid fuel methanol – uncomplicated logistics, secure handling and long shelf-life – could simplify the market entry of fuel cells in many industrial applications. While there are comparatively high purchase costs for DMFC systems, logistics costs for the liquid energy source, methanol, are low. In this way DMFC systems are competitive against comparable technologies and generator solutions and can achieve considerable cost savings in total cost calculation while running, and significant advantages in practical handling through easy-to-handle methanol fuel.

Through the excellent efficiency of a DMFC in generating energy from fuel to direct current, the DMFC can even compete with the fuel costs of classic generators, with the added benefit of minimal noise levels and the advantages of several maintenance-free years.

By integrating fuel cells in a standard body housing, SFC Energy provides the customer with not just a technology, but with a standardised solution.

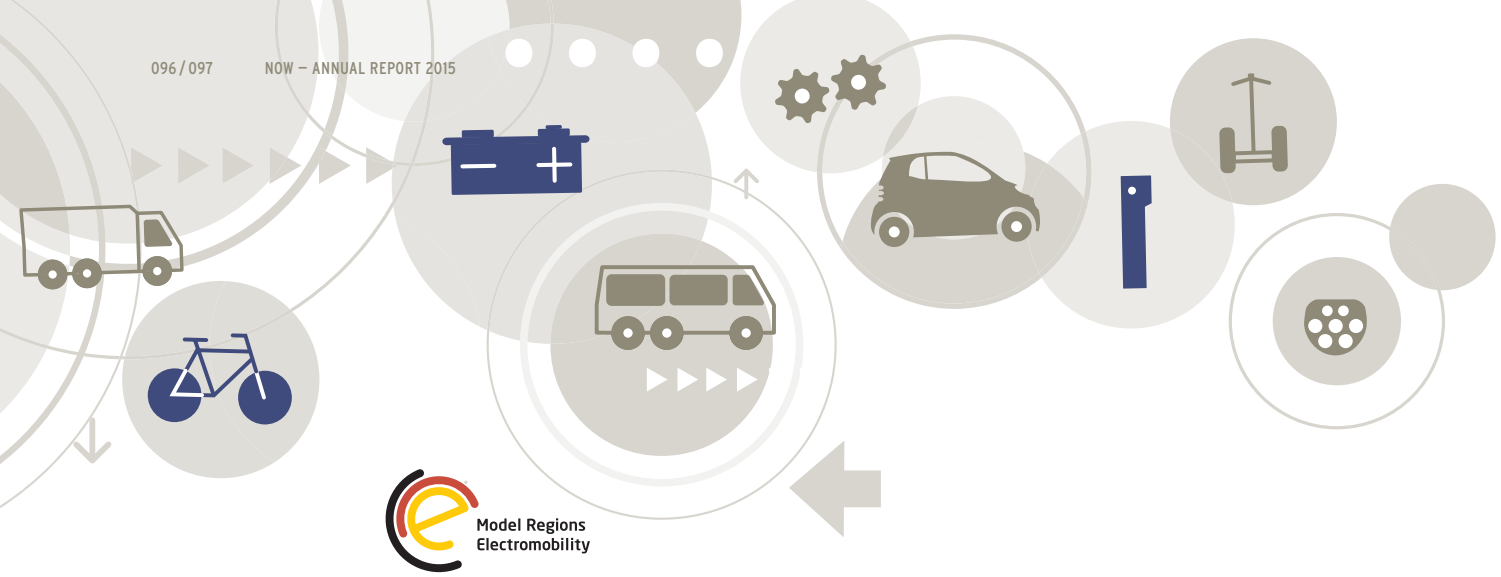
| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| SFC Energy AG | 1,814,746 | 871,078 |

COMMENCEMENT: 01 May 2013
CONCLUSION: 31 December 2015

» The benefits of the liquid fuel methanol – uncomplicated logistics, secure handling and long shelf-life – could simplify the market entry of fuel cells. «

# BMVI – ELECTROMOBILITY MODEL REGIONS

THE PROJECTS ARE LISTED V / 01 – V / 18 ON THE FOLLOWING PAGES,
COMPLETED PROJECTS ARE MARKED WITH 🏁 .



Model Regions Electromobility

# ELECTROMOBILITY AS A PART OF THE ENERGY TURNAROUND

## FUNDING PRIORITY ELECTROMOBILITY

The federal government supports research and development into alternative drive concepts and is open to all technology types and transport modes. Supported are plug-in hybrid, battery and fuel cell drive-based models, for road, rail, ship or air transport. With the National Development Plan Electromobility, the federal government set itself the goal to develop Germany into a lead market and leading supplier in the area of electromobility. Through the electrification of the transport sector, future mobility is to become more climate and environmentally friendly and less reliant on fossil fuels. The expansion of electromobility is therefore an essential supporting pillar for the realisation of the government's mobility and fuel strategy (MKS – Mobilitäts- und Kraftstoffstrategie).

## ELECTROMOBILITY MODEL REGIONS

The Electromobility Model Regions were established in 2009 by the Federal Ministry of Transport and Digital Infrastructure (BMVI – Bundesministerium für Verkehr und digitale Infrastruktur) formerly the Federal Ministry of Transport, Building and Urban Development (BMVBS – Bundesministerium für Verkehr, Bau und Stadtentwicklung), using funds stemming from the second economic stimulus package (Konjunkturpaket II). The strategic approach of the Model Regions is divided into two main areas: the demonstration and examination of the suitability of electromobility under everyday conditions in the regional projects as well as overarching accompanying scientific research. Through the cooperation between partners from industry, research and the public sector, local networks are being established. The work of the BMVI Model Regions aims to prepare the market by testing the technology under everyday conditions. Experiences made and results achieved are dealt with as key issues within the scope of the accompanying overarching scientific research. The goal here is to ensure that all involved companies and organisations can jointly learn from the experiences made and to also prime new players to be in a position to enter into the area of electromobility. The focus of the accompanying research is on the subject areas infrastructure, innovative drives & vehicles, fleet management, safety, user perspectives, regulatory framework as well as spatial/urban and transport planning.

## IMPLEMENTING ORGANISATIONAL STRUCTURE

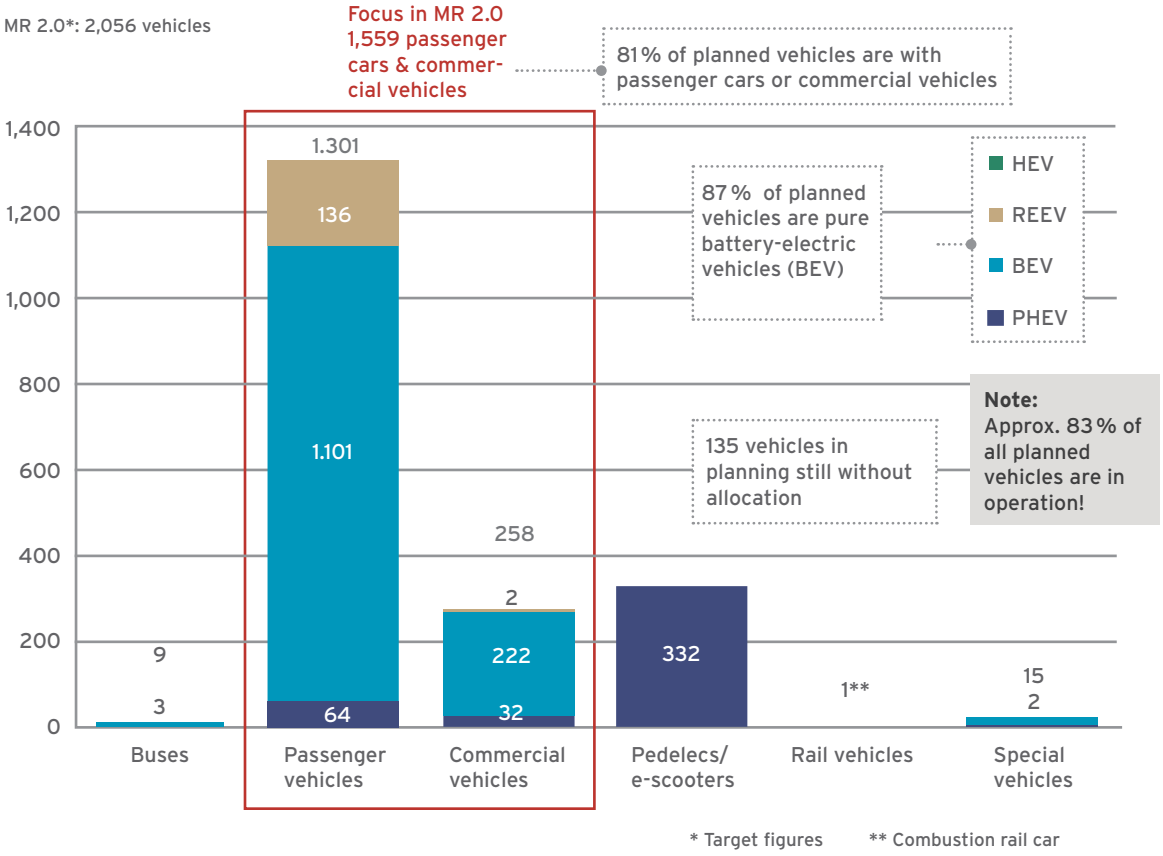
The BMVI Electromobility Model Regions are implemented and coordinated by NOW. Its key duties involve the definition and selection of programmatic areas of focus in conjunction with the BMVI, the coordination of the accompanying scientific research along with the management of individual projects.

The BMVI ensures the contents are aligned in a political context and together with the federal government is responsible for determining the focus of content in the area of electromobility.

Projektträger Jülich (PtJ) is responsible for project administration and supports the programme with legal advice on public funding. Regional coordination is conducted by the project headquarters (PLS – Projektleitstellen), comprised of regionally based players from the areas of business development, public utilities, energy agencies and from other public-private partnerships. They also ensure exchange takes place between project partners and thereby promote local and regional participation in the programme.

Cross-regional exchange is conducted in the Strategy Group. It provides the platform in which representatives from the Model Region project headquarters, players from the accompanying research as well as BMVI, NOW and PtJ can discuss all aspects of programme activities. The Electromobility Showcases (Berlin/Potsdam, Stuttgart, Bavaria/Saxony) as will as the accompanying research and impact studies of Showcases are also involved in the Strategy Group.

**OVERALL DISTRIBUTION OF VEHICLES IN THE MODEL REGIONS**
(Distribution according to segments & technology, only support phase II): focus in the area of passenger vehicles & commercial vehicles (BEV)




## SUPPORT OF ELECTROMOBILITY IN THE MODEL REGIONS

A diverse project landscape characterises the activities in the Model Regions. Over the past years, many areas of focus were set, providing a broad framework for future projects to be pursued. Some examples include:

↗ Integration of electromobility in the regional local public transport network

↗ Focus on commercial transport and urban courier services

↗ Intermodality and linked e-carsharing services (mobility chain)

↗ Interlinking the place of living with electromobility via neighbourhood-based projects

↗ Hybridisation in regional rail transportation

↗ Special vehicle applications at airports and for municipal deployment

↗ Fleet applications in municipal and commercial areas

On the basis of the funding guidelines of June 2011, around 80 project alliances with more than 250 partners and a total funding volume of approx. 140 million euros were implemented. The specific figures from the projects in regard to the progress of infrastructure and number of deployed vehicles are collected each quarter. At the end of 2014, around 78 percent of vehicles and 82 percent of recharging stations that were planned in the projects were in operation. As such, about 2,000 vehicles are in use and 1,200 recharging points were established through the projects and are now in operation.

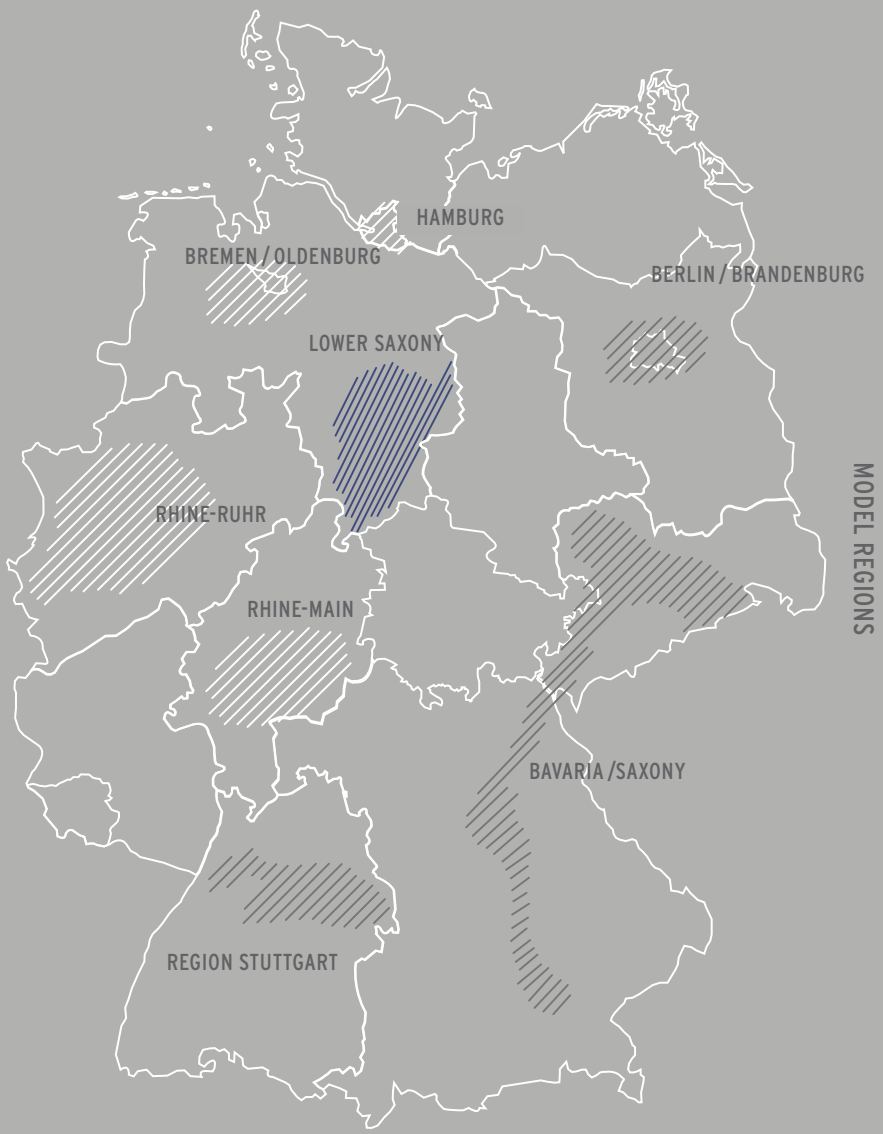
A data monitoring system is used by NOW as a central tool to coordinate the collection of the comprehensive data on current vehicle and infrastructure figures from the ongoing projects in the Model Regions. The diagram on the following page depicts the situation at the end of 2015 in the area of vehicles. In accordance with the aims of the federal government, at more than an 80 percent share of the overall fleet, the focus of application is on passenger and commercial vehicles.

In 2009 and 2010, German car manufacturers had no commercially available electric vehicles in their product range that could cover the demand for vehicles in the Model Regions and associated projects. As such, it was often required to make use of foreign products or undertake special modifications. Spurred on by the support programmes, German manufacturers are now supplying suitable vehicles – a total of 29 models from German manufacturers were available at the end of 2015.

JOINT STRATEGY GROUP

ACCOMPANYING RESEARCH

- USER PERSPECTIVES
- FLEET MANAGEMENT
- INNOVATIVE DRIVES & VEHICLES
- SAFETY
- INFRASTRUCTURE
- SPATIAL/URBAN & TRANSPORT PLANNING
- REGULATORY FRAME-WORK




MODEL REGIONS

CENTRAL DATA MONITORING

- MODEL REGIONS
- SHOWCASES/PREVIOUS MODEL REGIONS
- SHOWCASES

## NEW ELECTROMOBILITY FUNDING GUIDELINE OF THE BMVI

The federal government supports the area of electromobility with comprehensive funding support activities. The overall goal is to make the transport sector more energy efficient as well as more climate and environmentally compatible. At the same time, new sources of renewable energy are to be tapped into, especially for road transportation, to thereby reduce the dependency on fossil fuels. Since 2009, regional demonstration projects such as the »Electromobility Model Regions« programme of the Federal Ministry for Transport and Digital Infrastructure (BMVI – Bundesministerium für Verkehr und Digitale Infrastruktur) as well as the federal »Showcase Electromobility« have had a significant impact on the development of electromobility on a regional level in Germany. To enable this, cities and municipalities defined the framework and will continue to play a key role in the future for the further development of electromobility. The task is now to spread the insights gained throughout the projects and to support the commencing market introduction of vehicles with electric drivetrains and the corresponding infrastructure.

With the Electromobility Funding Guideline, which was published in June 2015, the BMVI supports the procurement of electric vehicles with the goal to increase the numbers of such vehicles on the roads, particularly in municipal fleets. It simultaneously aims to extend the recharging infrastructure including the linkages between vehicles and the power network in combination with the expansion of renewable energy for the transport sector on the municipal level. Immense potential exists here for the market launch of electromobility. Assuming that municipalities, on the one hand, operate vehicle fleets themselves, and on the other, are responsible for local mobility planning, the measures on a municipal level have a high diffusion rate.

A second area of focus of this guideline is on the support of application-oriented research and development measures with the goal of reducing costs of the technologies, components and systems required by electromobility. Besides private and public transport, this also includes promoting electrification in the areas of rail, freight and special transportation as well as for maritime applications. Programmatic, cross-project accompanying research enables a target group-specific amalgamation of results. During the first approvals phase in 2015 of the new guideline, more than 20 project outlines were submitted. Following the approvals process, they are now being implemented. A funding programme volume of 60 million euros is available until 2019.

## PROCUREMENT PROJECTS SUPPORT MARKET INTRODUCTION

The various projects approved within the framework of the BMVI Electromobility Funding Guidelines contribute to supporting market introduction. A focus is on the procurement of electric vehicles (cars, commercial vehicles and electric buses) within the scope of commercial fleets along with the necessary establishment and expansion of associated recharging infrastructure in public and private areas.

For operators of private and municipal fleets, the use of electric vehicles is worthwhile from a number of perspectives. Through the successive integration of electric vehicles in their own fleets, fleet emissions in terms of $CO_2$ and noise can be sustainably reduced. As the daily deployment profile of vehicles is already predefined in many cases, electric vehicles can be implemented in those specifically targeted instances where distances are calculable and/or intermediate recharging is possible. In addition, recharging facilities and the servicing of vehicles must be changed over to the requirements of electromobility. This is being examined as part of the research projects of the cities of Regensburg, Dresden and Flensburg as well as the regions of Ostwestfalen-Lippe, Weserbergland, norhern Sauerland and Steinfurt, as well as of private facilities such as Autoservice Frank Demmler or DSV Road GmbH. To also reduce fine dust pollution as well as $CO_2$ and noise emissions in cities, not only electric cars are being demonstrated within the scope of the funding programme but also electric commercial vehicles such as in the projects of TEDI Logistik as well as the companies Henkel, Elektro Obernauer and Transgourmet. As part of the supported projects in the cities of Freiburg im Breisgau and Detmold, public service staff has the possibility to use the electric vehicles of the municipal fleets privately within the scope of a carsharing model. This lets these employees experience electric vehicles in both a business and private context and also helps to reduce their emissions balance. In addition, the overall costs are reduced as the vehicles are better exploited.

Urban bus transportation companies providing local and regional public transport services can procure batter-electric buses within the scope of the funding project and test these in scheduled operations. Particular attention is placed on the experiences made during operations of services on challenging topography. In this regard, cities such as Bad Neustadt an der Saale, Bonn or the islands of Borkum and Sylt are planning to replace their diesel buses with battery-electric buses. Three battery-electric buses are also being deployed in Trier, within the scope of the funding project.

As a result of the expansion of recharging infrastructure, the regional energy suppliers, network operators and public utilities companies that are involved in many of the projects intend to primarily use renewable energy and also investigate the effect recharging procedures have on the local electricity network. This is the focus, for example, in the projects of Westfalen Weser Netz and Stadtwerke Trier public utilities company.

In addition, feasibility studies such as those planned in Dresden and Ingelheim will be undertaken to analyse and scientifically accompany the procurement and operation of electric vehicles along with the corresponding expansion of recharging infrastructure.

# SUBJECT AREAS OF THE SUPPLEMENTARY SCIENTIFIC RESEARCH

## SUBJECT AREA
## PASSENGER AND COMMERCIAL VEHICLES WG

Aim of the Passenger and Commercial Vehicles WG (AG PKW & Nfz) is the evaluation of the technological status of currently available electric vehicles, their potential for continued technological development as well as the determination of the environmental impact associated with electric mobility. The regular meetings of the working group (WG) serve to engage in an exchange of experiences and information between the projects of the Electromobility Model Regions. The individual projects thereby have the opportunity to present their current results and to also benefit from the experiences made by other participants. Furthermore, the user data arising from the projects and accompanying research are analysed in their entirety and the vehicles' suitability for use in practice along with their performance capacities are evaluated under real-life conditions. The second area of focus is the evaluation of the environmental impact of electric mobility under specific user profiles (private vehicle, carsharing, company fleet, etc.). The approaches taken by the various project segments can hereby be methodically harmonised through the Environmental Balance Working Group (Arbeitskreis Ökobilanz).

Significant progress was made in the area of gathering the user data – both in terms of the development of methodical approaches as well as the promotion of technical solutions. A comprehensive pool of data with 740 vehicles was established including BEV and PHEV and covering numerous vehicle segments and deployment contexts. Key aspects such as mileage driven and energy consumption could be looked into more closely on the basis of this data. With the simultaneous collection of recharging data, the application of electromobility could be evaluated in further detail and, for example, the important variable of charge losses further investigated.

Through the connection of the user data to developed generic environmental balance models, the environmental profiles of real user concepts in electromobility could be evaluated. A classification of the environmental impact in comparison to conventional vehicles was also conducted as well as the mapping of potential future and market introduction scenarios from an ecological perspective. A focus here was primarily on the key factors of the provision of energy – which, of course, should be sourced from renewable energy – as well as the vehicle's battery capacity. Due to the high-tech materials used, the latter has a particularly significant effect on the environmental profile of electric vehicles and should therefore be selected on the basis of the specifically intended application.

**List of publications:**


↗ BMVI Fachkonferenz 2015: Graf, R. (2015). Fahrzeugbewertung nach Einsatzmuster – Nutzung und Ökobilanz (Presentation). Offenbach am Main 2015.

↗ Graf R., et al. (2015): Bewertung der Praxistauglichkeit und Umweltwirkungen von Elektrofahrzeugen – Zwischenbericht. Bundesministerium für Verkehr und digitale Infrastruktur (BMVI) (ed.). Berlin 2015.

↗ Symposium Elektromobilität 2015: Eckert. Einsatz von Elektrofahrzeugen in der Praxis – Nutzungsanalyse und ökologische Bewertung nach Fahrzeugtyp und Einsatzkontext (Presentation). Esslingen 2015.

↗ LCA XV: Graf, R. (2015). Beyond the Lab – Environmental Performance of Electromobility (Presentation). Vancouver 2015.


**Contacts:**


↗ Roberta Graf, Fraunhofer Institute for Building Physics, Department of Life Cycle Engineering
↗ Dr. Stefan Eckert, thinkstep AG


Lufthansa
Airbus A380-800
Frankfurt am Main
MA
KALMAR
Lufthansa LEOS
19 795
08


Deployment of hybrid and electric drive technology reduces emissions of ground-based transport services at Frankfurt Airport.

## SUBJECT AREA
## SAFETY (FOCUS: BATTERY SAFETY)

The safety of batteries in electric vehicles (passenger vehicles) is a necessary prerequisite for the success of electromobility. The entire battery lifecycle must be considered, from its manufacture and actual usage, through to its recycling. Subjects such as storage, transportation, service and accidents must also be taken into account. In many areas there are already firmly defined safety-related activities and regulations, but in others there is partly a backlog such as in transport, storage and recycling of batteries or in their recovery from electric vehicles involved in accidents.

Aim of the project, in an initial step, was to identify and assess the potential risks of batteries in electric vehicles. It was examined whether existing regulations were sufficient to ensure battery safety in all segments of their lifecycle. With the involvement of recognised experts, the following areas of the battery lifecycle were considered: material and cell; battery and battery in vehicle; storage and transport; usage; and recycling. Overarching this, the additional important subject of damage limitation was analysed. From the review of the existing documents and regulations, a comprehensive database was developed, which will be made publically accessible following completion of the project.

In a second step, recommendations for action were developed for existing measures that had been deemed as being insufficient. These recommendations for action are aimed to contribute in improving the safety of batteries in electric vehicles even further.

It can be summarised that electric vehicles are safe. The study makes recommendations for action to further reduce any residual risks that are mainly in the framework conditions. The development of Li-ion batteries is in constant progress. For this reason, safety will remain in permanent focus in new developments and is to be guaranteed even beyond the completion of this study.

The results of the study are to provide a comprehensive point of reference for all players in the field of electromobility. Together with representatives from ministries, industrial companies and relevant organisations (VDA, ZVEI), the Lithium-ion Battery Competence Network (KLiB – Kompetenznetzwerk Lithium-Ionen-Batterien) is involved in steering the project via the project advisory council.

Contact

↗ **Dr. Alexander Kabza, Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW – Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg)**

## SUBJECT AREA FLEET MANAGEMENT

**Participants:**
The Fleet Management subject area is composed of more than 200 representatives from research, business and the public sector. Around 30 different players participated at each of the various subject area network meetings.

**Core focus/issues:**
The accompanying research in the Fleet Management subject area in 2015 is concerned with issues surrounding (e-) carsharing. A particular focus is on the following areas:

↗ Which potentials does the connection of carsharing and electromobility have in terms of sustainable mobility under various framework conditions?

↗ Which established and new forms of (e-) carsharing offers exist? According to which criteria can these offers be characterised?

↗ How must (e-) carsharing systems be designed under different framework conditions (e.g. under differing spatial contexts)?

↗ Which success factors and what obstacles influence the success of a(n) (e-) carsharing offer? Which of these success factors and potential obstacles can be directly influenced on the provider side and which are largely subject to external framework conditions?

**Subjects/projects/content 2015:**
In coordination with the project headquarters, scientific accompanying research institutions and the BMVI, the substantive areas of focus were derived. One subject area meeting comprised the opportunity to exchange experiences among participants and to build networks among players from research and practice. Another workshop assessed the potentials for e-carsharing and further developed a system to characterise e-carsharing offers. A broadly based study on existing (e-) carsharing offers enabled the establishment of a comprehensive pool of data. Various evaluations of the status quo of (e-) carsharing in Germany could be undertaken upon this basis. In addition, 14 in-depth interviews with (e-) carsharing operators were conducted and with six representatives of various municipalities. The challenges as well as the approaches to applied solutions during the introduction and operation of electric vehicles in carsharing business models were examined in detail during these interviews. The results of the accompanying research in the Fleet Management subject area are being prepared in a practically oriented brochure entitled »Elektromobilität im Carsharing – Status quo, Potenziale, Erfolgsfaktoren« (Electromobility in Carsharing – Status quo, potentials and factors for success). The guideline is aimed at all stakeholders of carsharing offers and provides detailed information on (e-) carsharing in Germany along with assistance in the important issues regarding the integration of electric vehicles in carsharing fleets. The main target groups to be addressed in the subject of sustainable (electro-) mobility are relevant players in administration as well as those in organisations or institutions wishing to reorganise their mobility management and thereby also planning to implement (e-) carsharing.

**Publications:**
↗ BMVI – Bundesministerium für Verkehr und digitale Infrastruktur (ed.) (2015): Elektromobilität in Flotten – Handlungsleitfaden

↗ BMVI – Bundesministerium für Verkehr und digitale Infrastruktur (ed.) (2016): Elektromobilität im Carsharing – Status quo, Potenziale, Erfolgsfaktoren

**Contact at the accompanying research institute:**
↗ Gerhard Parzinger
Erfurt University of Applied Sciences


POWER

## SUBJECT AREA
## USER PERSPECTIVES

The preparation of two brochures concluded the work in the User Perspectives subject area. These brochures chiefly provide the results of the survey of 2,304 users of electric vehicles. The already published brochure on electromobility in households and in fleets arrives at the conclusion for private users that: while potential limitations to the independence of individuals in the use of vehicles play a large role in terms of acceptance, this is assessed differently in regard to electric vehicles. For the acceptance of commercial users, safety and reliability are of major significance. In commercial fleets, there are usually also conventional replacement vehicles available for journeys exceeding the range of electric vehicles, making the short-term deployment of electric vehicles easier. The results for (car) sharing concepts indicate that it is predominantly younger men with a comparably lower affinity to cars that make use of these offers.



**Publications:**

↗ BMVI – Federal Ministry of Transport and Digital Infrastructure ed. (2015):
Elektromobile Sharing-Angebote: Wer nutzt sie und wie werden sie bewertet?

↗ BMVI – Federal Ministry of Transport and Digital Infrastructure ed. (2015):
Elektromobilität in Haushalten und Flotten:
Was beeinflusst die Kauf- und Nutzungsbereitschaft?

**Contact:**
↗ Dr. Elisabeth Dütschke, Fraunhofer Institute Systems and Innovation Research ISI

## SUBJECT AREA
## INNOVATIVE DRIVES AND VEHICLES

Buses with environmentally and climate friendly drives are being tested in practice by a growing number of German transport operators. To enable the exchange of experiences and a harmonised evaluation of the deployed drive technologies, the Federal Ministries of Transport and Digital Infrastructure (BMVI) and Environment, Nature Conservation and Nuclear Safety (BMUB) initiated the »Innovative Drives Bus« Working Group (WG). Participants of this WG are transportation companies, industry representatives (vehicle manufacturers and suppliers), the Association of German Transport Companies (VDV – Verband der Deutschen Verkehrsunternehmen), research institutes and consulting firms as well as ministry representatives. The previous practical experiences made and the respective concepts are jointly evaluated for their technical maturity and feasibility for practical use along with their attainable environmental and climate benefits.

Fundamentally open to all technology types, the focus of the WG is on the evaluation of diesel hybrid, plug-in hybrid and battery-electric drives including the associated storage and recharging technologies. The more intensive examination of further alternative drives, such as fuel cell or trolley buses, is earmarked for the continuation of the project.

For the accompanying research, a pool of data currently comprising some 22 million km from 154 hybrid and 49 diesel buses is available (data since January 2013). With a mileage of 210,000 km, the amount of experience with the 16 battery-electric buses is currently still limited. With the increasing number of battery-electric buses and the growing timeframe of testing, the conditions for a more in-depth evaluation are being created and continuously improved.

The availability of all diesel-hybrid buses has continued to improve over the past year: depending on the drive technology being considered, this was up to 92 %, with an average availability of 83 % among all hybrid buses. At around 75 % availability, battery buses are somewhat lower, yet individual vehicles are already showing availability rates clearly exceeding 80 %.

The fuel savings of diesel-hybrid buses compared with comparable conventional diesel buses depends on the type of hybrid bus and the characteristics of the route on which the hybrid bus was put into service. The topography proves to have a significant impact in this regard. For example, hybrid solo buses show that fuel savings of 20 % or more are possible. Potentials for improvement not only exist in the powertrain but also in auxiliary consumers such as in the passenger heating systems of serial articulated buses.

The passenger heating system energy requirements are of particularly great significance for battery-electric buses: in winter, the energy demands may be on par with that required for propulsion. Therefore, in the case of electric heating systems, the maximum range is correspondingly reduced or recharging times increased. This dependency as well as the influence, for example, of the topography on energy consumption needs to be investigated in greater detail using a broader pool of data.

The ecological benefits of the innovative drives can be shown, for example, by the amount of avoided greenhouse gas emissions, which arise from the amount of fuel saved: since the beginning of 2013 the buses being examined within the Innovative Drive Bus WG saved the equivalent of around 3,000t $CO_2$ (1 million litres of diesel fuel, respectively). With battery buses, first exemplary analyses illustrate the strong dependency of the attainable savings potential on energy usage and the greenhouse gas intensity of the power used. With use of power from renewable energy, a reduction potential of 80% and more exists over diesel buses. Buses with innovative drives also reduce local emissions of pollutants and noise. While battery-electric buses are fundamentally free of local pollutant emissions and are

quiet, hybrid buses – depending on their drive concept – also drive purely electric at times and thereby contribute to improving air quality and reducing traffic-related noise emissions. In some individual hybrid bus types, the motor is off for more than half of the operating time. Hybrid buses compared to diesel buses again also substantially reduce pollutant emissions. In comparison to both EURO V and EURO VI vehicles, the hybrid can record a reduction of 40 – 92 % in NOx emissions. Measurements of pure-electric accelerations from bus stops by hybrid buses also result in a reduction in noise emissions of up to two-thirds compared with a conventional diesel bus.

From an economic perspective, the deployment of innovative technologies continues to lead to greater costs. The actual additional costs were calculated using the example of a diesel hybrid bus. While including environmental costs into the equation reduced these additional costs, the economy gap cannot be completely closed – especially when one considers that such avoided environmental costs are not compensated for, such as through the public authorities.

Further issues to be examined have already been identified for the continuation of the Bus WG and the evaluation of alternative drives for city buses. Among these in regard to electric buses are, for example: conceptual issues for the supply of energy enroute or in the depot; the transferability of experiences made on single routes onto route bundles or even to entire route networks; and the potential effects of deploying electric buses on operating productivity and flexibility. In this way, the prerequisites for the selection of the optimal concept for the respective routes or networks and the assessment of resulting economic and operational effects can be significantly improved.

Contacts:
↗ Dr. Michael Faltenbacher, thinkstep AG
↗ Heinrich Klingenberg, hySOLUTIONS

A = Articulated
S = Solo
M = Mini-/Midi-
Suffix E = Electro
Suffix FC = Fuel cell
Suffix P = Plug-in hybrid

31 projects/34 operators
179 diesel hybrid buses
» 97 solo buses
» 82 articulated buses
25 electric buses
12 FC buses

FUNDING:
BMVI
BMUB
BMWi
BMBF

AS AT: 27 NOVEMBER 2014

05
Hybrid buses in Hanover
üstra (10 A)

Emission-free local transport for Hanover
üstra (3 SE)

04
Hub Osnabrück
Stadtwerke Osnabrück AG (2 ME)

06
EMIL
Braunschweiger Verkehrs-AG (1 SE, 4 GE)

EFBEL
Verkehrsverbund Rhein Ruhr
» Krefeld – SWK Mobil (4 A)
» Hagener Straßenbahn (2 S, 2 A)
» Dortmund – TRD Reisen (2 S)
» Bochum – Bogestra (5 A)
RVK
$H_2$ Busse (2 S BZ, 2 A BZ)

02
Hybrid buses for an environmentally friendly public transport system
Stadtverkehr Lübeck (5 S, 5 A)

VB Hamburg-Holstein (10 S)
eBTO
Hamburger Hochbahn (5 A)
ErPaD
Hamburger Hochbahn (5 S, 15 A)
Held
Hamburger Hochbahn (3 SP, 3 SE)
SaHyb
Jasper (24 S), Südelbe Bus (10 S)
NaBuZ demo
Hamburger Hochbahn (4 S BZ, 2 A BZ)


RegioHybrid
» Regiobus Mittelsachsen (10 S)
» Dresden – DVB (3 S, 3 A)
» Leipzig – LVB (3 A)
» 5 Further operators (11 S)
Sax Hybrid
» Dresden – DVB (10 A)
» Leipzig – LVB (10 A)
Sax Hybrid Plus
FhG IVI (1 PA)
SEB-Edda-Bus
FhG IVI (1 SE)
Linie 79
Dresden – DVB (1 SE)
Pilotlinie 64
Dresden – DVB (1 A)
eBus Batterfly
Leipzig – LVB (2 SE)
eBus Skorpion
Leipzig – LVB

13
Hybrid bus testing
Münchener Verkehrsgesellschaft (MVG) (1 S, 2 A)

03
Inmod
Mecklenburg-Vorpommern
GBB/Nahbus (1 ME), BBW (1 S), AVG (1 S)

07
Hybridbus Wolfsburg
Wolfsburger Verkehrsgesellschaft (3 S)

08
E-bus Berlin
BVG (4 SE)

14
Hybrid buses for Ingolstadt
Stadtbus Ingolstadt (3 S)

12
Elvo Drive
Voith AG (1 S)

09
Free
Kassel – Regionalmanagement Nordhessen (1 ME)

10
Primove Mannheim
Mannheim – RNV GmbH (2 SE)

11
Hyline S
Stuttgart – SSB (5 G + 5 AP)
S presso
Stuttgart – SSB (4 S BZ)


DB
Alcatel·Lucent
HaCon
inno
Schneider Electric
Zukunftsbahnhof
Berlin Südkreuz


JAFFESTRASSE
ELECTRIC CAR SHARING
NOW
Nationale Organisation Wasserstoff- und Brennstoffzellentechnologie
NOTSTROMVERSORGUNG
ELECTRIC CAR SHARING


WÄRME
STROM
zero
emission
Mercedes-Benz

V / 01

## » NO LIMITS – NEW ECONOMIC DEVELOPMENTS FROM MODELS FOR INNOVATIVE INTELLIGENT TRANSPORT SYSTEMS «

The fundamental aim of No LimITS is to bring about a positive change in the area of electromobility through the smart deployment of communication technology. It will make an important contribution in addressing the government's energy and climate policy goals within the scope of the energy turnaround. Technically, the focus is on developing an intelligent integrated system. On this basis, existing services in the mobility area can be better combined with each other and thereby enable new business models to be developed. Electromobility is to be made ITS-capable. No LimITS takes a combined view of economic and technical roles in order to define adequate institutional roles in the general area of electromobility, and to then apply these aspects in new ITS role models. The application scenarios are to demonstrate that through the provision of a technology-overarching system as well as the linking of existing and new communications solutions, it is possible to make improvements to mobility. With the connection of technological and economic components, a reciprocal optimisation of transport systems in the directions of cost efficiency, environmental sustainability and performance is to be initiated. The overriding idea is that infrastructure solutions that have proven their value in one region can also be transferred to another. The spread of electromobility is to be promoted through an improved interlinking of existing mobility offers.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Siemens AG | 974,789 | 487,394 |
| Deutsches Forschungszentrum für Künstliche Intelligenz GmbH | 382,389 | 344,150 |
| Hochschule für Technik und Wirtschaft des Saarlandes | 762,618 | 762,618 |
| Schulz – Institute for Economic Research and Consulting GmbH | 147,482 | 117,985 |

VEHICLES: Electric-drive vehicles: Internal project, made available by project partners
INFRASTRUCTURE: Mobile communications (ETSI ITS-G5), ITS Roadside Station, Parking space with recharging infrastructure, components for service (e.g. servicing recharging columns)

COMMENCEMENT: 01 January 2015
CONCLUSION: 30 June 2017

» With the connection of technological and economic components, a reciprocal optimisation of transport systems in the directions of cost efficiency, environmental sustainability and performance is to be initiated. «

V / 02

## » SYNCFUEL «

Electromobility will only be able to assert itself in the market once the recharging procedure can be conducted comfortably and reliably, at virtually any electrical socket without the need to install any additional equipment and can be paid for via a user-friendly billing system. At the same time, it is obligatory that energy for electromobility only comes from regenerative sources – only then can the targeted emission reductions be achieved. A recharging procedure where the feeding in from PV plants is synchronised with the consumption at a remote power socket provides the possibility to directly use the produced renewable energy for private consumption in order to recharge an electric vehicle. The resulting potential to reduce the electricity procurement cost at the remote power socket provides the leverage for the refinancing of the electric vehicle and the recharging infrastructure. This provides an approach for business models in various areas of electromobility. To examine this, a synchronised mobile Smart Meter (SyncMeter) is to be developed and deployed within this project, representing the technical vehicle to enable the synchronisation of the drawing of power at a remote electrical socket. At the same time, it is to ensure correct billing. Within the project, the following application scenarios will be examined where the vehicle is to be recharged remotely from the PV plant via either a (1) Schuko plug, (2) wallbox, (3) public recharging infrastructure, or (4) in a more distributed recharging infrastructure situation. A field test that included electric vehicles from the city of Dortmund municipal fleet, took place at selected locations at Klinikum Westfalen GmbH in conjunction with municipal locations in Dortmund and, as needed, private households. The area of application of the field test is in the Electromobility Model Region Rhine-Ruhr. To depict the vehicle-charging interface in accordance with standardised practice, the technology and testing platform for interoperable electromobility, infrastructure and networks at the Technical University of Dortmund was used. Here Smart Home situations and infrastructures as well as network topographies are depicted, which while not part of the field test must nevertheless be analysed for, e.g., the derivation and potential transfer of any business models. Besides the scientific-technical work conducted in the project, top-level stakeholder dialogues with representatives from federal politics, ministries, accompanying organisations and business are being pursued to produce feasible recommendations for action for the ongoing development of the regulatory framework of electromobility.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Technische Universität Dortmund | 1,154,499 | 1,154,499 |
| Klinikum Westfalen GmbH | 110,359 | 44,144 |
| Westfälische Hochschule Gelsenkirchen | 276,532 | 276,532 |
| HSAG Heidelberger Services AG | 397,500 | 198,750 |
| Stadt Dortmund | 231,714 | 185,371 |

**ASSOCIATED PARTNER:**
DEW21 GmbH

VEHICLES: Developmental activities and field tests conducted within the project are conducted with the vehicle fleet of the city of Dortmund. INFRASTRUCTURE: Required infrastructure for the project (recharging stations and mobile metering devices with synchronised consumption measurement, as well as ICT and billing system) is developed within the research project and tested in the field tests.

COMMENCEMENT: 01 January 2015
CONCLUSION: 31 December 2017

V / 03

## » HEVYBAT «

The development project »Hevybat« (heavy duty battery for vehicle hybridisation) includes the concrete objective of contributing to emission reduction and protecting resources. The aim is to develop inexpensive, electro-chemical energy storage systems and use them for hybrid drives of rail, road and inland waterway transport modes.

The focus of the project is the development of a new type of electro-chemical storage system for the hybridisation towards fuel cell electric drives with hydrogen and battery electric drive technologies for heavy loads. The development of the core component: a battery on the basis of a new kind of LTO technology is carried out right up to test and functional models with subsequent transfer of development findings to reference projects such as RiverCell2 and Ecotrain for evaluating practicability of electromobility. The goal is to expand the e-vehicle fleets in the area of heavy loads and goods transport with an emphasis on battery-electric mobility (incl. hybrid applications).

One of the focuses of the project is the material selection for the electro-chemical storage system. As already described, this should be anodically titanate-based, justified by the many benefits of a non-formation of a solid-electrolyte interphase. Through the combination of different titanate anodes with different cathode materials and electrolytes, a Heavy Duty application of an adapted cell solution should be found from the project. In addition a study will be carried out and the best variants of their results will form the basis for building and testing model cells. The know-how yielded from this will be applied in the selection of titantate cells already on the market. Furthermore the cell chemistry developed by Hoppecke through contract manufacture of prototype cells with higher capacity of 5 to 20AH is to be verified.

The results obtained from the project in the area of cell chemical development are to be incorporated in new kinds of laboratory cells and validated. Through future contract manufacture via a selected cell producer, the availability of these advanced cells will be assured.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| HOPPECKE Advanced Battery Technology GmbH | 4,267,933 | 1,740,463 |

COMMENCEMENT: 01 January 2015
CONCLUSION: 31 December 2017

» The goal is to expand the e-vehicle fleets in the area of heavy loads and goods transport with an emphasis on battery-electric mobility (incl. hybrid applications). «

V / 04

## » PRIMOVE MANNHEIM «

Mannheim is reinventing electromobility in local public transport: Over the course of the PRIMOVE research project, electric buses will be recharged as passengers board and alight at regular bus stops and thus can be employed for everyday service operation also on longer routes. In close cooperation between the municipal transport companies Rhein-Neckar-Verkehr GmbH (RNV), the city of Mannheim, Bombardier Transportation GmbH, as well as the Karlsruhe Institute of Technology (KIT), the use of two inductively-charged electric buses is planned over a time period of 12 months on regular service of the RNV 63 bus line, as well as deployment of an electric service vehicle in the transport region of RNV GmbH. The aim of the project is to prove the practicability of a technology transfer in the interest of further optimising a low-emission, public transport system. The investigation of the potential for cost reduction in reliable everyday operation subject to the framework conditions examined is also a focus. The experiences recorded in the PRIMOVE Mannheim project in terms of technology, public resonance and profitability will serve to prepare for the deployment of PRIMOVE technology in future for the entire transport region of the RNV.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Rhein-Neckar-Verkehr GmbH* | 4,601,089 | 2,254,533 |
| Stadt Mannheim | 101,025 | 50,512 |
| Bombardier Transportation GmbH | 1,554,120 | 699,354 |
| Karlsruher Institut für Technologie* (KIT) | 361,210 | 361,210 |

VEHICLES: 2 fully electric 12 metre buses; 1 electric delivery vehicle
INFRASTRUCTURE: Induction charging by means of PRIMOVE technology

COMMENCEMENT: 01 October 2012
CONCLUSION: 31 December 2015/* 30 June 2016

» The aim of the project is to prove the practicability of a technology transfer in the interest of further optimising a low-emission, public transport system. «

V / 05

## » SOCIAL-SCIENTIFIC AND ECOLOGICAL ACCOMPANYING RESEARCH IN THE ELECTROMOBILITY MODEL REGION RHINE-MAIN «

The results of the SÖB project make it clear that successes can indeed already be achieved in the area of electric mobility, but that diverse challenges still lie ahead. Already today, wise areas of application and target groups can be identified. Sharing systems and fleets have great potential for the deployment of electric vehicles from social, ecological and economic perspectives, and also enhance visibility of the technology among the general public. Important for a sustainable introduction and smooth operation of electric fleets are, however, targeted operator and usage models.

Various surveys, focus groups, workshops and interviews showed that from a user perspective, electric mobility is already in the awareness of many people and seen positively, especially among those who have already been behind the wheel of such an electric drive or supported vehicle. To reduce remaining prejudices against the technology (e.g. range, purchase price, public recharging infrastructure), municipalities can provide incentives and by taking up electric mobility early on in action strategies and in regulation can set the course towards more sustainable mobility in the future.

Clear too, however, was that electric mobility can only be considered as an environmentally friendly transport alternative under certain conditions. Decisive for the ecological perspective are the environmental factors throughout the entire vehicle lifecycle. Furthermore, not only should the electric car be taken into account, electric bicycles (pedelecs) in particular and other vehicle types also harbour immense ecological and economic opportunities.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Frankfurt University of Applied Sciences | 431,697 | 431,697 |
| Johann Wolfgang Goethe-Universität Frankfurt am Main | 450,434 | 450,434 |
| e-hoch-3 GbR | 213,010 | 170,408 |

COMMENCEMENT: 01 May 2012
CONCLUSION: 31 July 2015

» Sharing systems and fleets have great potential for the deployment of electric vehicles from social, ecological and economic perspectives, and also enhance visibility of the technology among the general public. «

V / 06

## » AMPERE – GENERAL PRACTICAL TEST FOR ELECTRIC VEHICLES WITH EXTENDED RANGE E-REV

Electromobility is making inroads in urban mobility concepts. As part of a joint project of Adam Opel AG, Vattenfall Europe Innovation GmbH and the Chair of Naturalistic Driving Observation for Energetic Optimisation at the Technical University of Berlin, 1,721 drivers of electric vehicles with range extenders were surveyed and data from 56 vehicles recorded.

The deployed Opel Ampera is ideal for the project requirements. It features an electric range of 40 – 80km and can utilise the onboard combustion engine as a generator for longer driving distances.

The Ampere project is the first project that records data from vehicles with range extenders that belong to private customers. Previous studies primarily based their data on testers that had received a vehicle for test purposes for a limited timeframe.

The focus of this project was on observing and understanding the driving behaviour of real customers over a longer period. The differences between assessments made by the customer and real measured driving data were also compiled.

In this regard, more than 62,000 single trips were recorded in a 12-month period, corresponding to a total distance exceeding 700,000km.

With a measuring technique that was specifically developed for the project, it was possible to record data transregionally – allowing testers to participate from anywhere in Germany and even from Austria and Switzerland.

The project was scheduled to run for three years, commencing 1 January 2013. Due to the immense amount of data and the resulting possibilities for data evaluation, the project was extended for a further nine months for the Technical University of Berlin.

Project homepage: **www.projekt-ampere.de**

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Adam Opel AG | 521,400 | 260,700 |
| Vattenfall Europe Innovation GmbH | 65,695 | 32,848 |
| Technische Universität Berlin* | 405,559 | 405,559 |

VEHICLES: Opel Ampera

COMMENCEMENT: 01 January 2013
CONCLUSION: 31 December 2015/*30 September 2016

» The Ampere project is the first project that records data from vehicles with range extenders that belong to private customers. «


SUMITOMO


CHAdeMO
BB-4629-0

V / 07

## »ELMO – ELECTROMOBILE URBAN COMMERCIAL TRANSPORT«

The »ELMO – Elektromobile Urbane Wirtschaftsverkehre« (Electromobile Urban Commercial Transport) project counts as one of the first that examined electromobility in an urban commercial transportation context. Among its areas of focus were the reliability and feasibility of electric commercial vehicles. Data was collected and evaluated in field tests covering some 150,000km travelled, 100,00kWh traction current drawn and 13,000 driving hours. Among the key insights were:

↗ A first major obstacle for electric goods transportation is the lack of available of suitable electric trucks. Especially from 7.5 t upwards, series models are not available. In some isolated instances, medium-sized vehicle manufacturers may offer converted diesel vehicles that are many times more expensive than the original vehicle.

↗ A second hurdle is the lack of a national service network resulting in prolonged periods of vehicle downtime in instances of repairs.

↗ In commercial use, establishment and operation of recharging infrastructure or the acceptance of drivers represent no major hindrances to electromobility.

↗ Wisely deployed, electric trucks can save 60 – 65 % of fuel costs in comparison to diesel vehicles.

↗ Economic deployment of electric trucks is currently only given in niche areas.

↗ Due to the lack of local emissions and their quiet operation, electric trucks may be feasible in the area of quiet, sustainable logistics. But for this the legal framework is not in place, such as with a »Quiet logisitics« certification similar to PIEK (Netherlands).

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Fraunhofer-Institut für Materialfluss und Logistik | 396,261 | 356,635 |
| Busch Jaeger Elektro GmbH | 105,497 | 52,749 |
| CWS-boco Deutschland GmbH | 765,953 | 382,977 |
| TEDi Logistik GmbH & Co. KG | 758,359 | 379,180 |
| United Parcel Service Deutschland Inc. & Co. OHG | 519,917 | 259,959 |
| Wirtschaftsförderung Dortmund | 92,588 | 46,294 |

VEHICLES: 30 vehicles procured/15 in operation
INFRASTRUCTURE: 1x Wallbox, 6x Schuko

COMMENCEMENT: 01 September 2011
CONCLUSION: 30 June 2015

» Due to the lack of local emissions and their quiet operation, electric trucks may be feasible in the area of quiet, sustainable logistics. «


Electric vehicle from CWS-boco in operation.

V / 08

## » COLOGNE-MOBIL II – ELECTROMOBILITY SOLUTIONS FOR NRW «

"From the runway to the Cologne Cathedral, intermodal electric mobility!« – was the vision of colognE-mobil. 13 partners examined the subject from a holistic perspective and investigated the suitability of electromobility for everyday use in the metropolitan region of Cologne. Besides the deployment of five types of vehicle models across various areas of use – including commercial use, carsharing and for taxi operations –all relevant aspects of electromobility in metropolitan regions were explored. Among these aspects were the optimisation of the recharging infrastructure, an analysis of customer and user behaviour, various electric mobility and intermodal concepts as well as examining the storage of renewable energy via solar carports and its use by electric vehicles.

At the core of the activities was the 56-vehicle-strong project fleet with which, for example, economic feasibility, noise emissions, environmental effects as well as a large number of technical aspects were investigated. The vehicles were recharged with 100% renewable energy at the 120 recharging columns that were set up, or at the three solar carports.

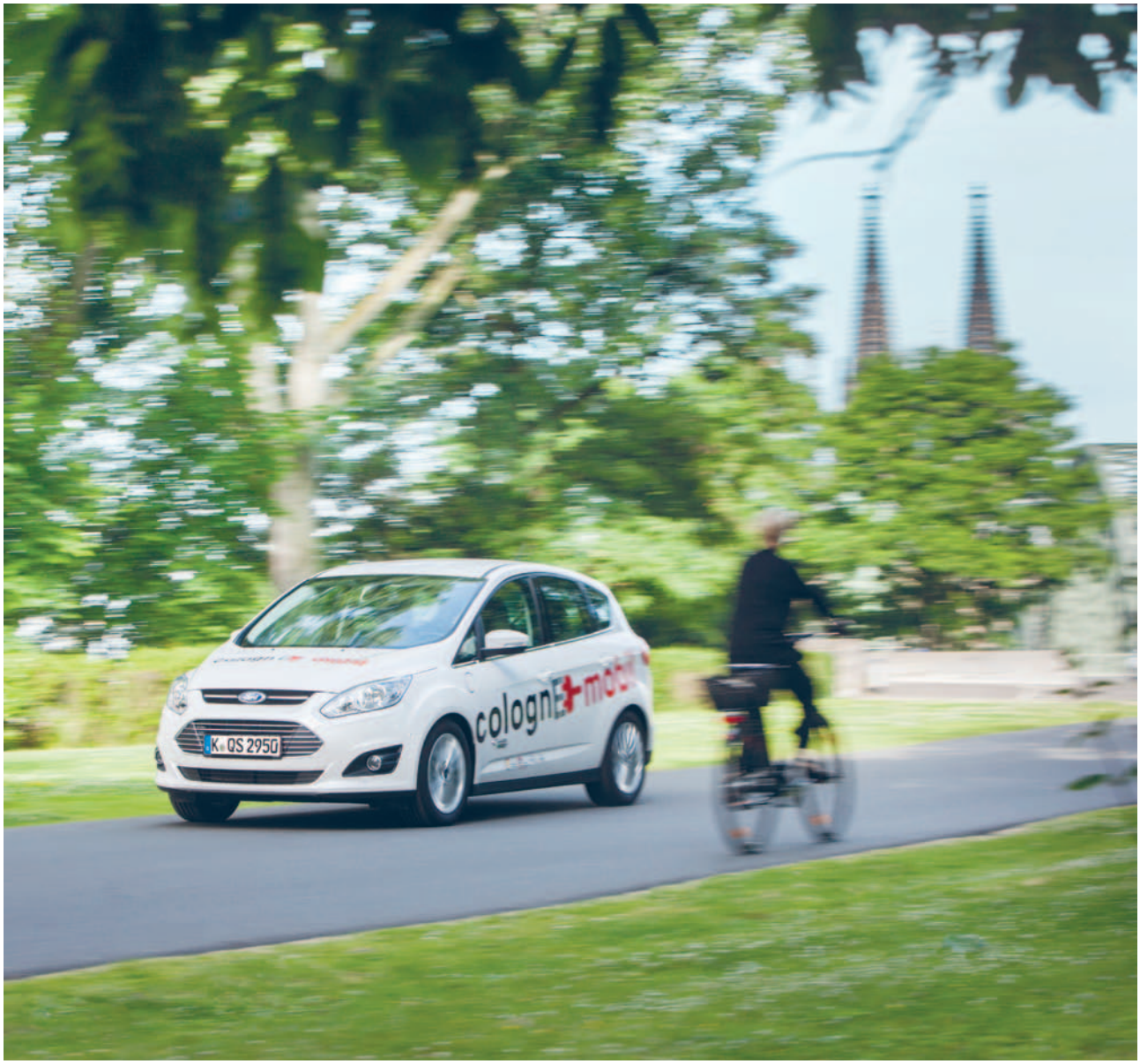
A further area of focus was the examination of user behaviour of pure battery-electric vehicles in comparison to plug-in electric vehicles. This was conducted both via an analysis of the recorded vehicle data and well as through user surveys. Thanks to newly developed IT systems, users were provided with information on how intermodal mobility chains could be optimised or shown new areas of deployment for electric vehicles.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| RheinEnergie AG | 4,824,069 | 2,412,034 |
| Ford-Werke GmbH | 4,039,038 | 2,019,519 |
| Universität Duisburg-Essen | 1,563,848 | 1,563,848 |
| Flughafen Köln/Bonn Gesellschaft mbH | 363,018 | 181,509 |
| DB Rent GmbH | 573,540 | 286,770 |
| Energiebau Solarstromsysteme GmbH | 292,717 | 146,358 |
| Regionalverkehr Köln Gesellschaft mbH (RVK) | 114,300 | 57,150 |
| TÜV Rheinland Kraftfahrt GmbH | 384,766 | 192,383 |
| TRC Transportation Research and Consulting GmbH | 278,275 | 166,965 |
| Auto-Strunk GmbH | 283,302 | 141,651 |

**ASSOCIATED PARTNER:**
Kölner Verkehrsbetriebe AG

VEHICLES: Ford Transit Electric, Ford Transit Connect Electric, Ford Focus Electric, Ford C-MAX Energi and Ford Fusion Energi
INFRASTRUCTURE: 120 recharging stations with 207 charging points at 80 locations 4 solar carports with a total of 14 spaces


cologne-Mobil-Ford C-Max Energi




cologneE-Mobil Ford C-Max Energi


cologneE-mobil fleet on the tarmac at Cologne Bonn Airport

V / 09

## » EMERGE – PATHWAYS TOWARDS THE INTEGRATION OF ENERGY, VEHICLE AND TRANSPORT DEMANDS «

Based on an holistic approach, the eMERGE project evaluated and developed usage, charging and marketing models of electromobility based on real customer data from the Rhine-Ruhr and Berlin regions. The goal: to promote innovative electric vehicles, create greater acceptance for business models and thereby secure the long-term market success of electric vehicles in the market. The data provided an integrated observation of all involved sectors in terms of influence and effect of the four domains of user, vehicle, traffic and energy. In a fleet test with 146 vehicles (smart fortwo electric drive) in the two application scenarios of end-user and company fleet, the project partners developed business models as well as new, sustainable business approaches.

eMERGE not only examined the technical aspects of electric vehicles, but also intelligent recharging systems to improve the utilisation of power supply. Various pricing systems were also used and evaluated in terms of customer acceptance. Based on transport models, the demands for the recharging infrastructure were examined as well as the need for a publicly available recharging infrastructure along with applicable regulation options. With the results, new business models for the optimisation of electromobility were developed.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Daimler AG | 4,050,063 | 2,025,031 |
| Technische Universität Berlin | 270,955 | 270,955 |
| PTV Planung Transport Verkehr AG | 464,520 | 232,260 |
| Universität Siegen | 224,898 | 224,898 |
| RWE Effizienz GmbH | 2,023,994 | 1,011,997 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 652,000 | 586,800 |
| Rheinisch-Westfälische Technische Hochschule Aachen | 198,586 | 198,586 |

VEHICLES: 146 smart fortwo electric drive
INFRASTRUCTURE: 11 intelligent wallboxes installed, 20 recharging columns converted for Plug&Charge

COMMENCEMENT: 01 July 2012
CONCLUSION: 30 June 2015

» eMERGE not only examined the technical aspects of electric vehicles, but also intelligent recharging systems to improve the utilisation of power supply. «

## »PRIMO2 – DEVELOPMENT OF MODULAR, DISTRIBUTED ENERGY STORAGE SYSTEMS AND COST-OPTIMISED MANUFACTURING PROCESSES FOR USE IN THE AREA OF LOCAL PUBLIC TRANSPORT«

The PRIMO project involves the development of innovative, distributed energy storage solutions which can be ideally used for flexible, customised dimensioning in the area of local public transport. In prismatic lithium ion cells available on the market which are used in electromobility, an electro-chemical characterisation and examinations on the relevant cell features were carried out in the light of suitability for existing local public transport applications. The preparation and analysis of the legal and normative requirements was used as the basis for the development and construction of a basic module. In the process the analysis of typical driving profiles of buses to determine cell chemistry and the requirements in terms of electrical components and thermal management were considered in particular.

Another work packet deals with the development of new kinds of charging strategies for these distributed energy storage systems and the installation of innovative charging technology. Aside from the development of these distributed modular energy storage systems, new types of innovative production and process technologies are developed to prove economic feasibility. The planned development is very closely connected to the project carried out in the Model Region of Saxony »SaxHybrid – serial hybrid busses with partially pure electric drive train«, which examines the prerequisite for externally rechargeable hybrid vehicles in different traffic and topographical areas of use as well as concrete customer requirements for rail-based local public transport vehicles.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| HOPPECKE Advanced Battery Technology GmbH | 6,345,204 | 3,172,602 |

COMMENCEMENT: 01 January 2012
CONCLUSION: 31 October 2015

» Aside from the development of these distributed modular energy storage systems, new types of innovative production and process technologies are developed to prove economic feasibility. «

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## »ELENA II – ELECTRIC DRIVE CONVERSION KITS FOR DIESEL DELIVERY VEHICLES«

A retrofittable electric drive for diesel delivery vehicles is being developed for small series production in the »EleNa II« project. In particular, the conversion kit is to enable small and medium-sized firms to move quickly and inexpensively towards electric mobility.

During the first project phase, a driveable test vehicle was developed and tested. In the second project phase, the conversion kit was further developed and six vehicles were set up for broader testing. On this basis, small series approval has now been granted and further reductions in price towards the preparation for market entry achieved.

The six converted Mercedes-Benz Sprinters are now being deployed in extensive test operations. Drivers can select from four operating modes in which either the combustion or electric motors operate independently or together on the drivetrain. While the electric motor is uncoupled in Combustion Mode, it can be activated in Hybrid Mode. In the Pure Electric Mode, the 40kW (80kW peak) electric motor with 16.8kWh battery capacity a top speed of 90km/h and a range of approximately 50km. Finally, in Recharging Mode, the electric motor runs as a generator and feeds energy back into the vehicle battery. The retrofitting components are designed in such way that they can be completely removed again, if required, and therefore make it possible for them to also be potentially used on leased vehicles. A cooperating alliance of medium-sized firms and research institutes teamed up for the development and testing of this conversion solution.

Email: **info@elena-phev.com**
Web: **www.elena-phev.com**

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Hochschule Esslingen | 577,657 | 577,657 |
| ARADEX AG | 927,696 | 463,848 |
| WS Engineering GmbH & Co. KG | 68,900 | 34,450 |
| Lauer & Weiss GmbH | 647,916 | 323,958 |
| Huber Automotive AG | 1,739,383 | 827,599 |
| Forschungsinstitut für Kraftfahrwesen und Fahrzeugmotoren Stuttgart (FKFS) | 274,043 | 246,639 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 302,659 | 272,393 |

VEHICLES: Conversion of 6 Mercedes-Benz Sprinters to plug-in hybrid electric vehicles (PHEV)

COMMENCEMENT: 01 March 2013
CONCLUSION: 30 September 2015

» On this basis, small series approval has now been granted and further reductions in price towards the preparation for market entry achieved. «


EleNa Sprinter – six transporters were equipped with the conversion kit within the project.


Intermodel public transport with electric buses and electric bicycles.

## » INMOD, INTERMODAL PUBLIC TRANSPORTATION IN REGIONAL AREAS BASED ON ELECTROMOBILITY COMPONENTS «

The aim of the inmod project involved the development and evaluation of concrete, realistic designs for feasible multimodal local public transport models of electromobility.

Throughout the project, electric buses quickly and frequently plied routes between base and middle centres. The side routes into small surrounding villages were eliminated, resulting in reduced distances and travel times made by the buses per trip, thereby allowing a greater frequency of services to be offered overall.

Electric bicycles in parking boxes were provided to make the so-called feeder services to the main bus line – thereby essentially becoming a part of the local public transport chain.

The resulting »inmod principal« arising from the project redefined bus services in rural regions: local public transport in structurally weak rural regions is always a multimodal, decentralised system. It is comprised of a fast bus service and an integrated feeder. The district undertakes the provision of the bus transportation, and the feeder is the responsibility of the local municipality, which is allotted funds for this precise purpose.

The project demonstrated that the electric bicycle can bridge long distances quickly and comfortably and is therefore very well suited for deployment as a feeder in local public transport services. The high price tag as well as the cost-intensive and inflexible parking/recharging boxes still represent residual problematic issues. Electric bicycles that can be provided without the necessity for the boxes represent a viable alternative for the future.

Tourists use the electric bicycles for the purpose of excursions rather than as a feeder service to the bus. A linkage of local public transport and tourism could therefore potentially enhance usage rates and improve financial feasibility.

During the project, one electric bus and two hybrid buses were deployed. The buses operated virtually without failure. The electric bus is ideally suited for deployment in rural areas. The hybrid buses could only recuperate limited braking energy as it is often not necessary to brake frequently on cross-regional routes. This means that the hybrid buses did not operate as efficiently as they could as perhaps in other scenarios, meaning an amortisation of the additional investment would appear as being unlikely.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Hochschule Wismar | 3,402,091 | 3,402,901 |

VEHICLES: 1 electric bus, 2 hybrid buses, 270 electric bicycles
INFRASTRUCTURE: Parking and recharging boxes for the bicycles, inmod-Manager software for user identification and for box handling

COMMENCEMENT: 01 November 2009
CONCLUSION: 31 May 2015

» The project demonstrated that the electric bicycle can bridge long distances quickly and comfortably and is therefore very well suited for deployment as a feeder in local public transport services. «


Berlin Süd
S


BAHN
Call a Bike

# International Cooperation

In order to create the relevant long-term and sustainable conditions for electromobility development in Europe, the transnational funding initiative Electromobility+ was launched, with the participation of public funding programmes from eleven countries: France, Germany, the Netherlands, Austria, Finland, Norway, Sweden, Denmark, Poland, Belgium and Italy.

Through the opening up of these regional and national programmes for transnational cooperation, their research activities were networked in order to thus generate a European added value.

In addition to the total of 15 million euros from national funding, the EU is providing up to 7.3 million euros for the subsidised programmes in the framework of the ERA-NET Plus programme.

Funding areas include research projects on political and regulatory aspects of electromobility as well as technology-based and experimental research.

The project funding within Germany is undertaken by the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur – BMVI) and the Federal Ministry of Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie – BMWi). TÜV Rheinland is responsible for the overall coordination of the transnational Electromobility+ initiative.

A cooperation agreement in the area of electromobility has existed between the Federal Ministry of Transport and Digital Infrastructure (BMVI) and the Chinese Ministry of Science and Technology (MoST) since 2011.

In three Model Region partnerships between Bremen/Oldenburg and Dalian, Rhine-Ruhr and Wuhan, as well as between Hamburg and Shenzhen, cooperation projects with German and Chinese partners are examining various aspects of electromobility.

## » DABREM: INNOVATIVE MOBILITY CONCEPTS FOR THE CITY OF THE FUTURE «

In the DaBrEM (Dalian – Electromobility Bremen) joint project the Robotics Innovation Centre of the German Research Centre for Artificial Intelligence (DFKI) and the Fraunhofer Institute for Manufacturing Technology and Advanced Materials (IFAM) closely cooperated with Bremen's partner city Dalian, the Chinese government and the Technical University of Dalian, in order to test innovative mobility concepts for the urban area on the basis of comprehensive data collection.

For the survey of vehicle data and user behaviour, the intelligent on-board unit developed at the DFKI and a fleet of up to 70 electric vehicles were used. The Chinese partners investigated electric buses, which were deployed as service buses in Dalian, in order to record principally technical data.

To test the innovative electric vehicle technologies, the DFKI integrated semi-automatic functions in several MIA electric vehicles, in order to facilitate automatic driving in succession in so-called »road trains«. The EO smart connecting car e-vehicle developed here also was used as a test vehicle. The Fraunhofer IFAM carried out comprehensive technology testing of electric vehicle components, which were developed by the Chinese partners among others for the DaBrEM project. With the help of the test results, IFAM were able to give recommendations for European licensing of the components. In addition they supported partners in planning e-vehicle charging infrastructure in the Dalian urban area.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Deutschen Forschungszentrums für Künstliche Intelligenz (DFKI) | 1,148,196 | 1,033,376 |
| Fraunhofer Institut für Fertigungstechnik und Angewandte Materialforschung (IFAM) | 435,853 | 392,268 |
| VEHICLES: different vehicle types (passenger vehicle-class), Research platform E02 | COMMENCEMENT: 01 July 2013<br>CONCLUSION 31 December 2015 | |


The EO smart connecting car 2.

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## » NRWMEETSNL «

Aim of the project was to develop a long-term partnership in the area of electromobility between the neighbouring regions of NRW and the Netherlands. To achieve this, cooperation with relevant institutions in the Netherlands was actively sought out during demonstration and R&D projects.

As a first step towards common measures, a dialogue forum was established as a platform for the exchange of experiences concerning electric vehicles, concepts for recharging infrastructure, vehicle and battery safety as well as transport and mobility concepts.

In addition – and based on the result of preliminary talks – a series of specialist workshops was conceived and organised between the partners in order to deal with targeted questions as well as issues of mutual interest and thereby lay the foundation for further collaborative projects.

A further building block was the realisation of cross-border mobility with electric vehicles, which throughout the study was worked on along four different routes from NRW to the Netherlands.

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| ee energy engineers GmbH | 755,376 | 679,839 |

INFRASTRUCTURE: 4 recharging points

COMMENCEMENT: 01 November 2012
CONCLUSION: 31 December 2015


Online at the concluding event of NRWmeetsNL

## »EMAP, ELECTROMOBILITY – SCENARIO BASED MARKET POTENTIAL, ASSESSMENT AND POLICY OPTIONS«

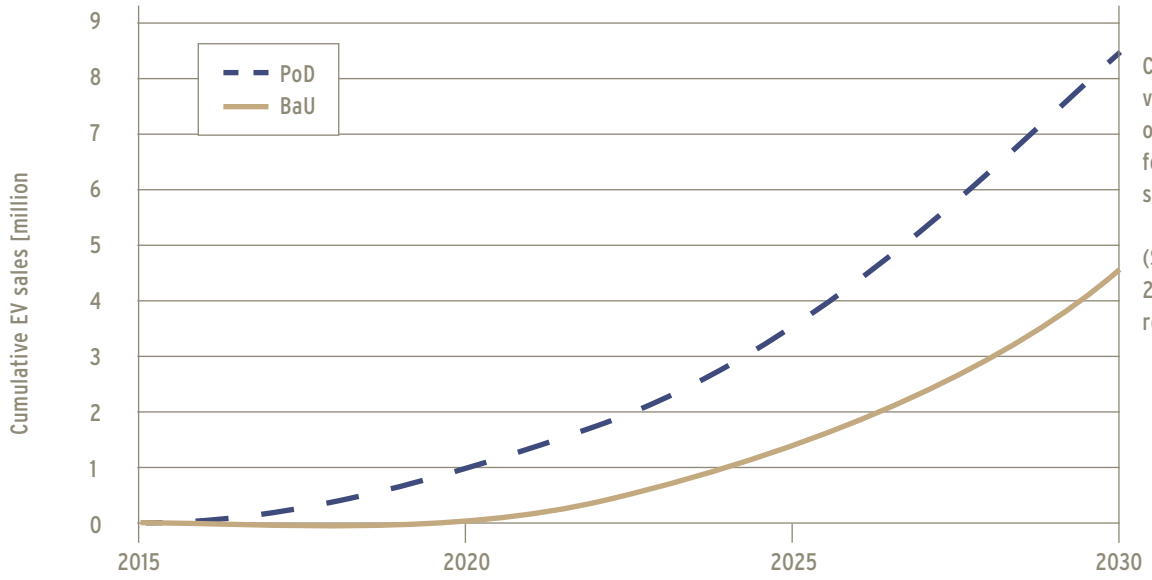
The focus of the eMAP research project (www.project-emap.eu) was the examination and determination of the market penetration of electric vehicles and associated economic effects. The market penetration of electric vehicles was estimated for a time horizon until 2030 using a scenario-based market model, for the three partner countries Germany, Poland and Finland as well as on an EU level. In order to investigate the potential of future development scenarios for electric vehicles, three scenarios were developed: a Business-as-Usual scenario (BaU) as the reference scenario, a Technology scenario (TeD) that assumed an accelerated technological development of electric vehicles, along with a Policy scenario (PoD) which was separately defined for each of the three partner countries and EU level. In the PoD scenario, a stricter $CO_2$ regulation (60g/km instead of 75g/km in 2030) was assumed for the EU, which when compared to the BaU scenario led to an increased market share of newly purchased electric vehicles of approximately 38 % in 2030 in the EU. In the PoD scenario defined for Germany it could be shown, for example, that taking into account four different policy funding measures (€1,500 purchasing rebate, exemption of the recharging electricity from the EEG levy, greater availability of recharging infrastructure, and greater awareness of the benefits of electromobility), that the »1 million electric vehicles on the roads by 2020« goal can still be achieved.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Bundesanstalt für Straßenwesen (BASt) supported by KE-Consult and the Institut für angewandte Sozialwissenschaft GmbH (infas) | 458,554 | 458,554 |
| Deutsches Zentrum für Luft- und Raumfahrt (DLR) | 198,927 | 179,034 |

**FURTHER PARTNERS:**
Technical Research Centre of Finland (VTT)
Motor Transport Institute Warszawa (ITS)

VEHICLES: No actual vehicles were deployed in the project. The focus was on model calculations on the passenger vehicle market.
INFRASTRUCTURE: No actual infrastructure was examined in the project. The focus was on model calculation on recharging infrastructure.

COMMENCEMENT: 01 June 2012/* 01 January 2013
CONCLUSION: 31 May 2015




Cumulative new vehicle registrations of EV in Germany for the BaU and PoD scenarios

(Source: Kugler et al. 2015 eMAP Scenario report, D6.2)

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## » SELECT – SUITABLE ELECTROMOBILITY FOR COMMERCIAL TRANSPORT «

Within the SELECT project, project partners from science and industry are examining to what extent electric vehicles can provide an environmentally-friendly alternative to conventional vehicles in commercial transport. Over the course of the project national transport surveys were analysed, user requirements and settings compiled and fleet driving patterns on the basis of GPS were evaluated. The project was funded by the European Commission as well as national funding providers in Austria, Denmark and Germany under the ERA-NET Plus Initiative Electromobility+.

A high potential for an electrification was identified in the trade, transport and logistics branches as well as in health and social services. Records of GPS data over the course of several weeks from care service providers confirmed the high potential for the use of electric vehicles based on the current state of technology. Investigations showed that around 30% of all care service and pharmaceutical logistics providers could already today convert all transport to electric vehicles – and do so on an economically viable basis. Furthermore it appears that fleet operators in commercial transport have great interest in electromobility, however are rather uncertain over costs. Thus it is recommended that companies offer the opportunity to become more familiar with electric vehicles, provide information on the cost benefits of electric vehicles and through the reorganisation of vehicle operation increase the potential for electric vehicles.

Further Informationen in the brochure Electromobility+ (2010 – 2015). Download at:
**http://electromobility-plus.eu/wp-content/uploads/E-_Brochure2015_low.pdf**

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| DLR Institut für Verkehrsforschung | 577,339 | 519,605 |

FURTHER PARTNERS:
AIT Austrian Institute of Technology GmbH, Mobility Department
DTU Technical University of Denmark, Department of Transport
Reffcon GmbH, Austria
Consilio Information Management GmbH, Austria
CLEVER A/S, Denmark

COMMENCEMENT: 30 July 2012
CONCLUSION: 30 June 2015

» Investigations showed that around 30 % of all care service and pharmaceutical logistics providers could already today convert all transport to electric vehicles – and do so on an economically viable basis.«

## » SCELECTRA: SCENARIOS FOR THE ELECTRIFICATION OF TRANSPORTS «

The »Scenarios for the electrification of transports« (SCelecTRA) project concluded on 30 June 2015. Its aim was the identification and analysis of policy measures to promote electromobility in Europe until 2030. Various policy scenarios were analysed for this purpose in terms of their economic efficiency (cost-benefit analysis based on a pan-European country-specific optimisation model of the power and transport sector) and their environmental impact (environmental footprint as well as costs for society or so-called »external costs«). Factors deemed as being electromobility-relevant were, in particular, differences in the energy mix across European countries and the effect of policy actions (variations in $CO_2$ reduction goals, scrapping premiums, fuel taxes and subsidies) and these were taken into account.

Both the analysis of the private and the overall societal costs showed that policy measures only lead to an enhancement in the spread of electromobility in the passenger vehicle segment up to the year 2030 under certain prerequisites.

The project, in which five partners from France, Austria and Germany were involved, ran over three years and was supported within the scope of the ERA NET Plus Electromobility+ Programme.

The project reports are available on the following website: **https://admin-prisme-internet.ifpen.fr/Projet/jcms/xnt_79184/fr/scelectra-publications**

| PARTNER: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| ElfER Europäisches Institut für Energieforschung | 37,347 | 33,515 |

**FURTHER PARTNERS:**
IFP Energies nouvelles, France
PE CEE Nachhaltigkeitsberatung & Softwarevertriebs GmbH, Austria
Institut Français des Sciences et Technologies des Transports de l'Aménagement et des Réseaux, France
KANLO Consultants SARL, France

COMMENCEMENT: 30 July 2012
CONCLUSION: 30 June 2015

VEHICLES: Various passenger vehicles including plug-in hybrid-electric vehicles and battery-electric vehicles

» Aim of the project was the identification and analysis of policy measures to promote electromobility in Europe until 2030. «

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## » CACTUS – MODELS AND METHODS FOR THE EVALUATION AND OPTIMISATION OF BATTERY CHARGING AND CHANGING TECHNOLOGIES FOR ELECTRIC BUSES «

Various technical, operational, economic and ecological models for the operation of fully-electric buses in local public transport are the result of the CACTUS project. Among the variables mapped by the models were: the routes including elevation and speed profiles; bus mass, seating and standing space parameters. Also: the bus' electrical consumers; energy storage; and recharging technologies and strategies implemented (charging at bus stops, while driving, or a change of battery). And furthermore: the investments and operational costs as well as emissions and pollutants. Based on the resulting models, methods could be developed to address various aspects. For example, with the help of the simulation it is possible to check for each of the various recharging infrastructure scenarios whether the vehicle deployment plan is feasible under particular conditions (outside temperature, vehicle occupancy). With this information, the optimal spatial layout of recharging infrastructure can be determined at minimal cost for a given vehicle deployment plan. All models and methods were implemented and integrated in a software tool and also obtained a graphical user interface. Various German and Polish transportation companies applied the methods. First the energy demands of the routes were assessed upon which basis the optimal infrastructure for the various recharging strategies could be calculated for the particular vehicle deployment plan.

| PARTNERS: | PROJECT BUDGET/€: | PROJECT FUNDING/€: |
|---|---|---|
| Institut für Automation und Kommunikation (ifak) e. V. Magedburg | 335,451 | 301,906 |
| Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e. V. | 312,453 | 281,208 |

**FURTHER PARTNERS:**
Silesian University of Technology, Poland

COMMENCEMENT: 1 June 2012
CONCLUSION: 31 May 2015

» With this information, the optimal spatial layout of recharging infrastructure can be determined at minimal cost for a given vehicle deployment plan. «


Battery-electric bus in regular scheduled local public transport service.

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