Electric Mobility with Hydrogen and Fuel Cells

State of development and market introduction in the area of passenger vehicles in Germany

NOW
National Organisation
Hydrogen and Fuel Cell Technology

Electric Mobility with Hydrogen and Fuel Cells

Demonstration vehicles with fuel cell electric drives at the Federal Ministry of Transport and Digital Infrastructure in Berlin.
Image rights: NOW | Philipp Plum

»With electric mobility and automated, networked driving, we are standing at the threshold to the biggest mobility revolution since the invention of the automobile.

The fuel cell is a key technology of this development. We have provided funding for innovations in this area for ten years already and support the market preparation of products.

Now we are continuing the successful government programme. We are therefore actively shaping a thrilling element in the powertrain transition towards electric mobility.«

Alexander Dobrindt, Federal Minister of Transport and Digital Infrastructure

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Support of hydrogen and fuel cell technologies for implementation in mobility

The German government supports the research and development of alternative drives, open to all types of technology and across all modes of transport. Powertrain types ranging from plug-in hybrid to battery and fuel cell, on the roads, on rail or on water as well as in the air. The federal government set itself the goal of developing Germany to the leading market and leading provider in the area of electric mobility. The electrification of the transport sector serves to achieve the goal of helping to ensure that the mobility of the future becomes more energy efficient, climate-friendly and free of emissions while reducing the dependency on fossil fuels. The expansion of electric mobility thereby represents a key pillar for the implementation of the government's Mobility and Fuel Strategy (MKS – Mobilitäts- und Kraftstoffstrategie).

With the **funding guideline for battery-electric mobility**, which runs until 2019, the Federal Ministry of Transport and Digital Infrastructure (BMVI – Bundesministerium für Verkehr und digitale Infrastruktur) provides targeted support for municipal players in the local establishment of electric mobility across all modes of transport. Building on the Electromobility Model Regions funding programme, the market launch of electric drive vehicles including the necessary associated infrastructure is thereby advanced in the strategic field of local mobility and logistics.

»Germany has the aspiration to become the leading market and leading provider in the area of electric mobility.«

Norbert Barthle, Parliamentary State Secretary BMVI

Electric Mobility with Hydrogen and Fuel Cells

Just as important as research into battery-electric cars is the development of fuel cell vehicles that are run with hydrogen. The German government has supported hydrogen and fuel cell technology for 10 years through the National Innovation Programme (NIP). A total of 1.4 billion euros have been invested by government and industry from 2007 to 2016 in hydrogen and fuel cell projects for mobile and stationary applications.

Upon the backdrop of the foreseeable market launch, the federal cabinet adopted the government hydrogen and fuel cell technology programme for the period 2016 to 2026, thereby continuing its support. The Federal Ministry of Transport and Digital Infrastructure alone is allocating nearly 250 million euros for this purpose.

NOW GmbH (National Organisation Hydrogen and Fuel Cell Technology) coordinates the overall programme. Over the past years, the German government has supported the development of alternative drives with funds totalling more than two billion euros.

Further information on the mobility initiatives of the federal ministry: www.bmvi.de/en

Federal Ministry of Transport and Digital Infrastructure

The core message:
Hydrogen and fuel cells are key technologies

Hydrogen and fuel cells are key technologies for the energy transition, including the accompanying mobility transition. This was among the conclusions that were clearly made within the scope of two high-level conferences held in the Federal Ministry of Transport and Digital Infrastructure in April and December of 2016.

Both industry and government emphasised that fuel cell-electric vehicles using hydrogen as a fuel represent a significant component for the realisation and breakthrough of electric mobility in the mass market.

The implementation of hydrogen produced by renewable energy not only brings about a reduction in CO_2 emissions resulting from transportation. Hydrogen can also connect the power, heating and transport energy sectors, and upon the backdrop of climate protection and the expansion of renewable energy also represents an efficient, sustainable and integrated energy system of the future.

CEP Fleet. Image Clean Energy Partnership

Fuel cells in cars are coming! Hydrogen refuelling stations will be established – nationwide! Industry, research and policy all pulling in one direction!

In a nutshell, this is the main message of hydrogen and fuel cell mobility. The clarity of the message should not, however, mask the fact that the path to achieving this is still long. Nevertheless, this path has now been defined and the finishing line has come to within striking distance.

Not only do affordable fuel cell vehicles need to be brought to market, the existing refuelling infrastructure must also be simultaneously expanded. The energy system is also to be newly aligned with the help of electricity-based fuels. This all demands time and requires that the various interests of politics, business and society are taken into account.

Nowadays there is no one who fundamentally questions that hydrogen mobility can be successful. Agreement exists in the involved industries and sectors along with the associated ministries, associations and non-government organisations that the future sustainability of the transport sector is dependent on electric mobility and on electricity-based fuels that are produced from renewable sources. The positive perception prevailing in Germany on the technology is strongly contingent on the power, heat and transport sectors being able to be integrated via hydrogen as an energy carrier, and through the efficient integration of demands in these sectors being capable of achieving further overall energy sector benefits.

Parliamentary representatives along with the federal and state ministries have reasserted the necessity for hydrogen and fuel cells in the area of mobility and for the energy system, especially in connection with climate protection and Germany's competitiveness on the international stage. There is agreement among the representatives from the automotive and energy supply industries along with the relevant associations in the goal of wishing to create an electric mobility transport sector in which, naturally, hydrogen-run fuel cell vehicles belong.

National Innovation Programme Hydrogen and Fuel Cell Technology (short: NIP)

The significance of hydrogen and fuel cell technology will continue to grow as a sustainable, low emission supply of energy will demand a shift from fossil fuels in the long term. In order to accelerate the development of hydrogen and fuel cell technologies to market maturity in various application areas, government, industry and research initiated the 10-year National Innovation Programme Hydrogen and Fuel Cell Technology (NIP) in 2007, which encompassed a funding volume totalling 1.4 billion euros. In the period until 2016, half of this amount was provided by the Federal Ministry of Transport and Digital Infrastructure (BMVI – Bundesministerium für Verkehr und digitale Infrastruktur) and the Federal Ministry for Economic Affairs and Energy (BMWi – Bundesministerium für Wirtschaft und Energie), and the other half from the involved industry partners. To date, the programme has made a successful contribution towards creating technological standards, reducing costs and making the technology suitable for general day-to-day deployment – such as by increasing service life as well as reducing the size and the weight of the fuel cell.

The goals:

Accelerating market development through targeted networking, support and funding of the hydrogen and fuel cell sectors in the mobile, stationary and portable areas.

Establishing value-creation chains and ensuring a share of value-creation in Germany.

Ensuring technology leadership and implementation of the technology in Germany.

Making products that are technologically mature competitive, and developing the hydrogen infrastructure, e.g. expanding the number of refuelling stations.

In late September 2016, the federal cabinet adopted the hydrogen and fuel cell technology government programme for the period 2016 to 2026. The continuation of the interdepartmental NIP firstly secures continuity for research and development, and secondly addresses the issue of necessary support of initial products for the purpose of market activation. The NIP is implemented through the relevant actions of the participating federal ministries. The Federal Ministry of Transport and Digital Infrastructure (BMVI) is initially allocating 250 million euros to the support of hydrogen and fuel cell technology until 2019. The Federal Ministry for Economic Affairs and Energy (BMWi) is continuing its funding of hydrogen and fuel cell technology in the area of applied research and development within the 6th Energy Research Programme with around 25 million euros annually. In addition, the BMWi has set up a funding programme under the National Action Plan on Energy Efficiency (NAPE) for the purchase of fuel cell heating devices for private customers. The NIP continues to be supported by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) as well as the Federal Ministry of Education and Research (BMBF), within the structures of NOW.

Driving societal forces:
Climate protection. Energy supply security. Growth

NOW – National Organisation Hydrogen and Fuel Cell Technology

NOW GmbH, National Organisation Hydrogen and Fuel Cell Technology, is a programme management association of the federal government for sustainable mobility and energy. It is responsible for the coordination and management of the National Innovation Programme Hydrogen and Fuel Cell Technology (NIP), the Local Electric Mobility Funding Programme (Förderprogramm Elektromobilität vor Ort) and the Recharging Infrastructure Funding Guideline (Förderrichtlinie Ladeinfrastruktur) of the Federal Ministry of Transport and Digital Infrastructure (BMVI). All three programmes were initiated for market preparation or for accompanying the market introduction of the technologies. Research, development and primarily demonstration activities are supported along with procurement initiatives for the purpose of market activation. The primary task of NOW involves initiating and/or evaluating projects and bundling these in such a manner that synergy effects can be exploited. NOW also undertakes so-called cross-sectional tasks, which include international collaborations, communication at the interface of politics, industry and science as well as public relations in order to raise overall awareness of the technologies and products. On behalf of the BMVI, NOW also supports the further development of the Mobility and Fuel Strategy (MKS – Mobilitäts- und Kraftstoffstrategie).

NOW
National Organisation
Hydrogen and Fuel Cell Technology

»Within the scope of NIP-supported projects, the costs of fuel cell systems for mobility applications could be reduced by around 75 percent, the figure for hydrogen refuelling stations was approximately 50 percent. Above a range of 300 to 350 kilometres, hybridised fuel cells in vehicles could demonstrate cost advantages over battery vehicles.«

Dr. Klaus Bonhoff, NOW

Further information about NOW:
www.now-gmbh.de/en

Seizing opportunities

Following the COP 21 Paris Climate Conference in December 2015, it is not only the governments of the industrial countries but those worldwide that now see it as their duty to ensure that the climate goals agreed upon are actually met. The Paris agreement stipulates, among other things, that the world must become greenhouse gas neutral by the second half of the century in order to limit the increase of global temperatures to a maximum of 2°C compared with preindustrial times. Climate protection therefore initially involves a drastic reduction in greenhouse gasses, which arise through the burning of fossil-based fuels such as oil, coal and gas. It is in this context that the term **»decarbonisation«** has established itself in the discourse. At the same time, increasing numbers of countries and regions are striving to reduce their dependence on fossil fuel imports and to secure their energy supply through the expansion of renewable energy. Besides its political impact, the departure from fossil raw materials also has significant economic effects. As climate protection and the secure supply of energy cannot be at the expense of economic prosperity, governmental policy is looking towards developing innovative and smart energy technologies, which will create new jobs and growth.

»On the one hand, we have regions in the world with growing mobility markets. And on the other, we must reduce emissions.«

Oliver Bishop, General Manager Hydrogen, Shell New Fuels

Targets and figures[1]

Climate protection **Global responsibility for future generations** **Raising efficiency in all energy sectors**	Raising efficiency in all energy sectors: In Germany: 20 percent by 2020 and 50 percent by 2050 Throughout EU: 20 percent by 2020 and 27 percent by 2030 Achieve climate protection targets – reduce greenhouse gas emissions: In Germany: minus 40 percent by 2020 and minus 85-90 percent by 2050 (status 2015: 26 percent) Throughout EU: minus 20 percent by 2020 and minus 40 percent by 2030 (all figures compared with 1990) Decarbonise transport sector Throughout EU: Transport greenhouse gas emissions minus 20 percent by 2030 (compared to 2008) and minus 60 percent by 2050 (compared to 1990)
Energy supply security **Less dependency on fossil-based fuels**	Reduce the dependency on the import of fossil fuels such as oil and gas Germany currently imports around 70 percent of its primary energy Increase the share of renewable energy Balancing the volatile production volume of renewable energy Electricity supply security during so-called dark phases
Growth **Secure prosperity through economic growth**	Create future jobs and export opportunities and develop national and European value-added chains Develop market leadership in energy technologies through innovation

»The right decisions need to be taken today to set the course for the future. The wheels are in motion – joint efforts and cooperation between all stakeholders are necessary.«

Dr. Johan van Zyl, Toyota Motor Europe

[1] Federal Ministry for Economic Affairs and Energy: www.bmwi.de;
Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety: www.bmub.bund.de;
European Commission: www.ec.europa.eu

The climate goals of the transport sector

Germany already committed itself in 2007 to reduce its greenhouse gas emissions by 40 percent until 2020 compared to 1990 levels. In November 2016, the Climate Protection Plan 2050 (Klimaschutzplan 2050), which outlines the path to a largely greenhouse gas-neutral Germany by 2050, was approved by the German cabinet. In order to achieve the long-term climate protection targets, besides having to reduce fossil fuels by up to 85 percent, the share of nationally produced renewable energy must reach a minimum of 95 percent. For 2030, the plan reiterates the overall goal of a greenhouse gas reduction of at least 55 percent compared with 1990.

Paramount is the transformation of the energy sector. The measures associated with the climate goals inevitably lead to electricity from renewable sources having to become the main energy carrier of the future. This applies especially for the heating and transport energy sectors, through the option of electricity-based fuels.

Transport facts[2]

The transport sector in Germany today accounts for approx. **25 percent of final energy consumption.**

Transportation produces around 1640 million tonnes of CO_2 emissions, which represents more than **18 percent of total CO_2 emissions** in Germany.

More than **90 percent of fuels used are still petroleum based** – biofuels and electricity continue to only play a minor role.

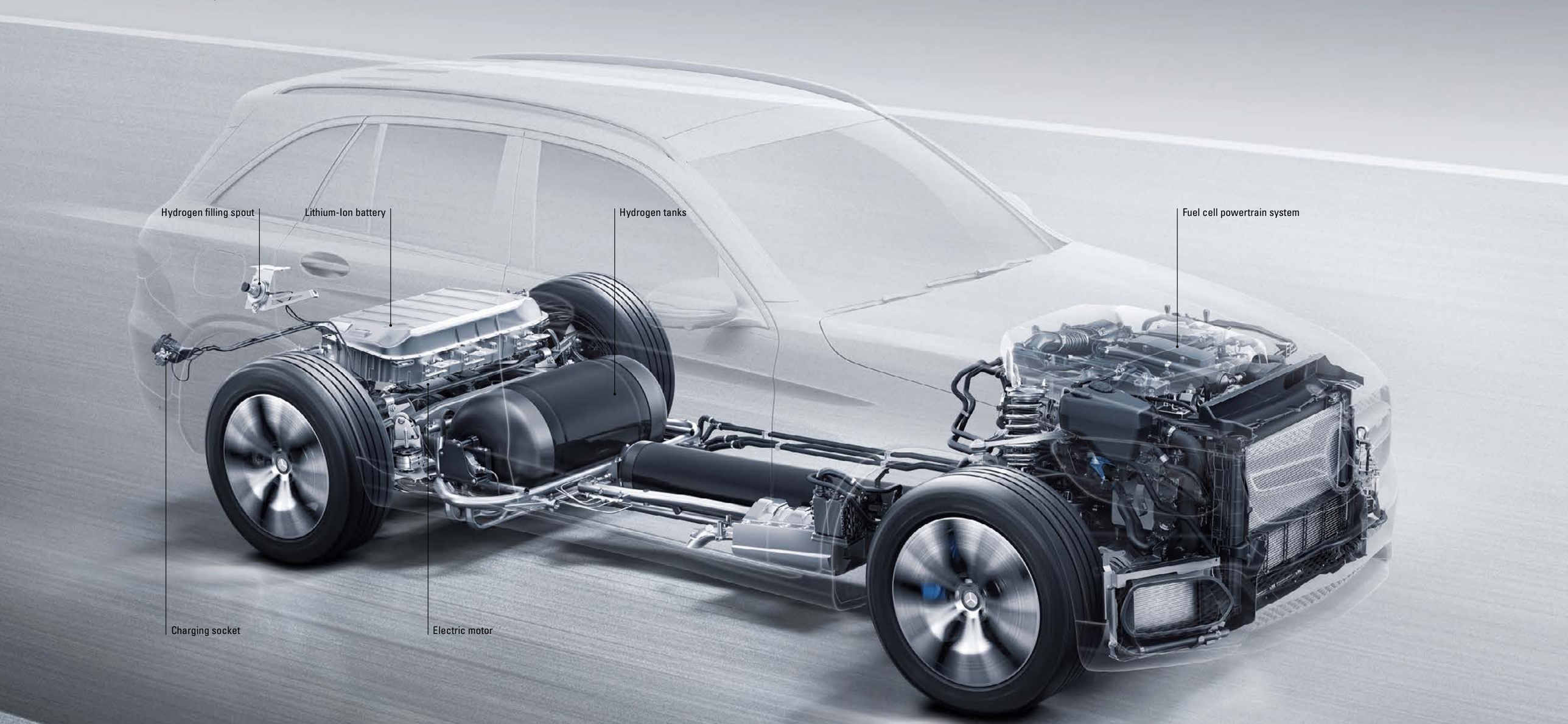
In other words: the share of **renewable energy** in the transport sector is just **5.6 percent (as at 2014)**, of which **0.5 percent** are accountable to **renewable electricity**.

[2] See German Environment Agency (Bundesumweltamt): www.umweltbundesamt.de;
Agency for Renewable Energies (Agentur für erneuerbare Energien): www.unendlich-viel-energie.de;
Federal Ministry for Economic Affairs and Energy: www.bmwi.de;
Federal Ministry for Environment, Nature Conservation, Building and Nuclear Safety: www.bmub.bund.de

»Battery and fuel cell technology combined in a fully electric plug-in hybrid vehicle – to date this is unique worldwide.«

Prof. Dr. Christian Mohrdieck, Director Fuel Cell for Daimler AG

Fuel cell powertrains in vehicles: Industry prepares itself



Mercedes-Benz GLC-F-CELL fuel cell powertrain system. Press photo: Daimler. Daimler is involved in the Clean Energy Partnership and H2 MOBILITY.

Mobility and Fuels Strategy represents the foundation for the future direction of transport

As demanded in the climate protection plan, the transport sector will contribute to the 2030 climate goal with 40 to 42 percent. The key requirement for achieving these goals is the diversification of the transport sector's energy with alternative fuels paired with innovative drive technologies together with the optimisation of traffic flows.

To enable the attainment of these targets, in 2012 the Federal Ministry of Transport and Digital Infrastructure (BMWi) developed the Mobility and Fuels Strategy (MKS – Mobilitäts- und Kraftstoffstrategie) on behalf of the federal government. A »learning strategy«, the MKS is regularly evaluated and adjusted. It represents the foundation for the development and future direction of the transport sector, taking special account of economic, ecological and social aspects.

Hydrogen refuelling station
Press photo Linde AG
Linde AG is involved in the Clean Energy Partnership, H2 MOBILITY and Performing Energy – the Alliance for Wind Hydrogen.

Hydrogen mobility with fuel cell vehicles

Following the presentation of many prototypes in the 1990s and 2000s, over the past years micro fleets of fuel cell vehicles (passenger vehicles, buses and light commercial vehicles) have been established throughout the world in diverse demonstration projects and tested under everyday conditions by various user groups. Now, fuel cell vehicles are being produced in small-series of several thousand units per model by various car manufacturers.

The manufacturers today offer these fuel cell vehicles to commercial and private customers, usually via leasing. Hyundai, Honda and Toyota have commenced market introduction in South Korea, Japan and the USA, and are preparing market introduction in Germany. Daimler will follow in 2017. Other large car manufacturers (VW/Audi, BMW, GM) are also working on the mass production suitability of fuel cell vehicles.

»Innovations are crucial and are a key factor in overcoming the challenges that lay before us, including those regarding climate protection. Germany is well positioned in global competition for fuel cell mobility.«

Bernd Eulitz, Member of the Board, Linde AG

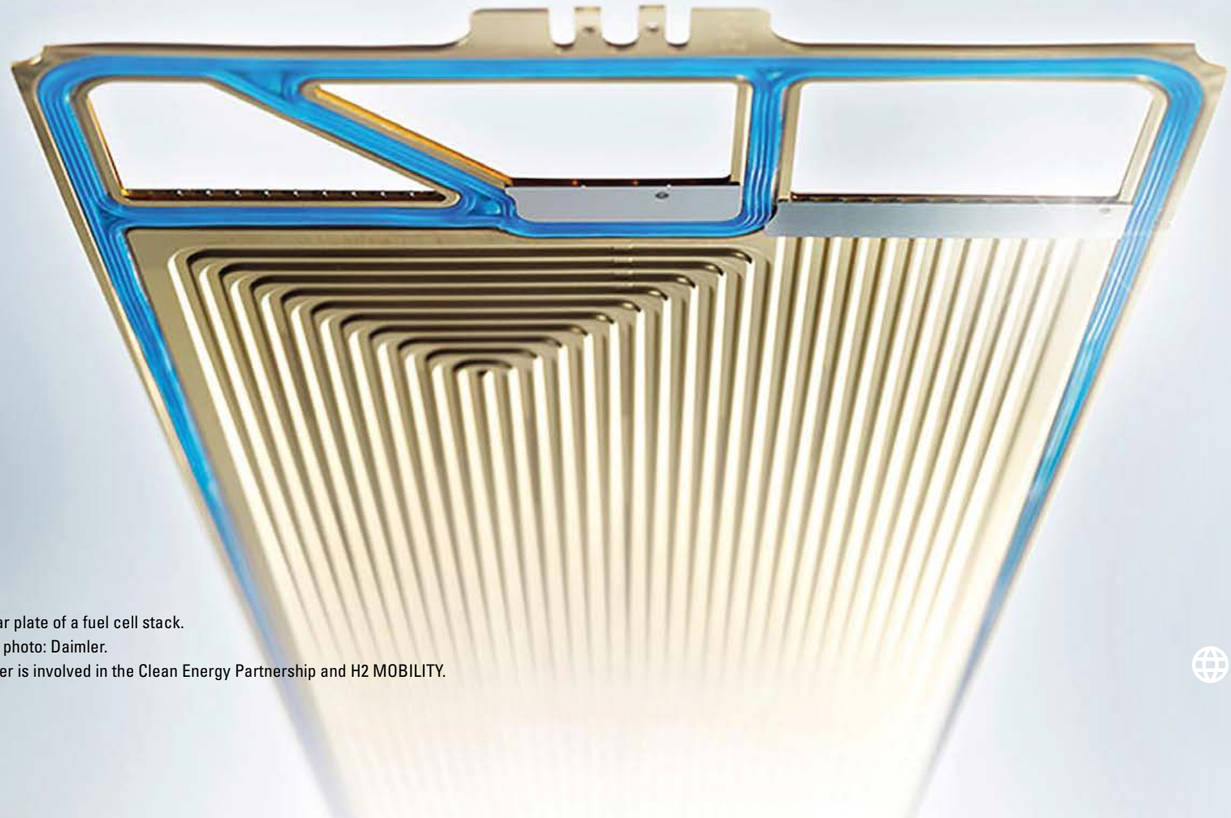
German industry prepares for series production of fuel cells

With the »Autostack-Industrie« initiative, which was announced mid 2017, the German automotive and supplier industry aims to ensure the preconditions exist for the commercial introduction of fuel cell vehicles in Germany and Europe by 2020. Eleven partners are working together to bring hydrogen technology to the point of industrial maturity. The goal is to establish competitive series production of fuel cells, while taking the high-quality demands of the German automotive industry into account. Inexpensive processes for the manufacture of stacks are to be developed along with the associated technical components that will allow for mass production later down the track. Until now, stacks have been imported from abroad by the automotive industry. Besides strengthening the expertise of the German manufacturing and supplier industry in regard to a key component that is required for the energy transition, the project also aims to ensure that value creation in the area of fuel cell technology is expanded in Germany and that the jobs associated with it are secured.

Fuel cell stack. Press photo: ElringKlinger.

»The activities in the automotive area were decisive for the development of hydrogen and fuel cell technology throughout the world.«

Tim Karlsson, IPHE



Bipolar plate of a fuel cell stack.
Press photo: Daimler.
Daimler is involved in the Clean Energy Partnership and H2 MOBILITY.

Clean Energy Partnership CEP

The Clean Energy Partnership goes mobile

The CEP, an association of leading technology, petroleum and energy companies along with the bulk of major automobile manufacturers works towards the vision of establishing hydrogen as a key element of the mobility and energy transition.

The partner companies address the challenges associated with the National Climate Protection Plan 2050 (Nationalen Klimaschutzplan 2050) and work with concerted efforts towards timely market penetration with new drives, storage media and climate-neutral fuels.

As a lighthouse project of the NIP, the CEP has successfully demonstrated over the past years that hydrogen can be a key pillar of the energy transition: with the sustainable production of hydrogen, CO^2 emissions can be reduced to a minimum, which is why the CEP focuses on “green” hydrogen. The hydrogen provided at refuelling stations comprises at least 50 percent from sustainable production methods. The first series production models of passenger vehicles are now also on the roads and clearly demonstrate that hydrogen-run fuel cell vehicles can be safely and reliably deployed.

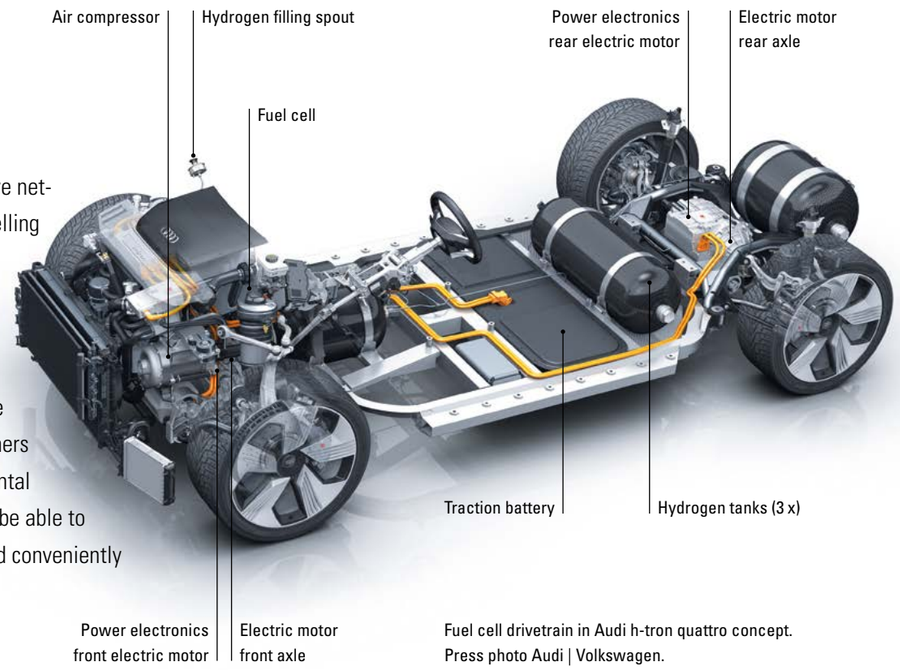
Further information at: www.cleanenergypartnership.de/en

Audi A7 h-tron
Press photo: Audi | Volkswagen
Volkswagen is involved in the Clean Energy Partnership and is an H2 MOBILITY associated partner.

Powertrain diversity and a growing level of electrification

The transition towards electric powertrains with batteries and fuel cells involves that there will be no singular powertrain type alone over the coming decades. Depending on the demands in regard to vehicle size, powertrain performance and the required range, and subject to environmental regulations or applicable emissions standards in the global automobile markets, consumers will choose either a vehicle with combustion engine (with petrol, diesel or gas as fuel), a pure electric car (with a battery or fuel cell system with hydrogen), or a mix of various powertrains (hybrid or plug-in hybrid, range extender concepts).

The necessary regulatory framework ensures the achievement of the societal objectives. The decisive factor, however, for market success of electric mobility is ultimately the consumer who must accept the technology and purchase the respective vehicles. Within the scope of the commercialisation of hydrogen and fuel cell technology in the mobility sector, it is imperative to ensure a comprehensive network of hydrogen refuelling stations. After all, fuel cell vehicles must not only be attractive and affordable as products in their own right while also convincing customers due to their environmental merits, they must also be able to be refuelled swiftly and conveniently at many locations.



Fuel cell drivetrain in Audi h-tron quattro concept.
Press photo Audi | Volkswagen.
Volkswagen is involved in the Clean Energy Partnership and is an H2 MOBILITY associated partner.

Expanding the hydrogen refuelling station network: Implementation in Germany, Europe and the world

Hydrogen refuelling station.
Press photo Linde AG.
Linde AG is involved in the Clean Energy Partnership, H2 MOBILITY and Performing Energy – the Alliance for Wind Hydrogen.

Joint initiatives

To promote market success of electric mobility with hydrogen and fuel cells, car manufacturers and petroleum companies have joined with the gas industry and energy suppliers in order to establish a refuelling station network for fuel cell vehicles, in the interest of all.

This is not least due to the realisation that it represents a lucrative new field of business for the future. Yet because of the high initial investment costs and combined with low utilisation rates in the market ramp-up phase, the refuelling station is not profitable in the first years of operation. For this reason, decisions must already be made today along with the creation of framework conditions for a functioning electric mobility market, to ensure future market success.

Policymakers are therefore striving to develop suitable, investment friendly framework conditions that help make the economic risks predictable. Industry is thereby supported in maing investments towards a sustainable mobility system.

Emerging from the Joint H2 Mobility Initiative, industry founded H2 MOBILITY and resolved to establish up to 400 hydrogen refuelling station over the coming years. The first 50 of these are being funded within the framework of the NIP. In this way, the proverbial chicken-or-the-egg conundrum – what comes first: the fuel cell vehicle or the hydrogen refuelling stations – was solved in Germany.

»From a European perspective, Germany is a very important country with its hydrogen and fuel cell activities. The expansion of hydrogen refuelling stations in Europe is occurring through various national programmes along the lines of the H2 MOBILITY plans in Germany along the TEN-T corridors[4].«

Jorge Chatzimarkakis, Hydrogen Europe

[4] The Trans-European Networks (short TEN) comprise transport networks (TEN-T for transport), energy networks (TEN-E) and telecommunication networks (eTEN).

H2 MOBILITY Deutschland

Industry partners working on the establishment of a hydrogen refuelling network for fuel cell vehicles

The companies Air Liquide, Daimler, Linde, OMV, Shell and TOTAL established H2 MOBILITY Deutschland GmbH & Co. KG in 2014. Its primary task is the fast and efficient establishment of a comprehensive nationwide hydrogen infrastructure for fuel cell vehicles in Germany by 2023.

The H2 MOBILITY roadmap specifies that the first 100 refuelling stations are to be constructed in a first project phase by 2018/2019, irrespective of the actual number of vehicle sales. A focus is on the eight main urban regions of Hamburg, Berlin, Rhine-Ruhr, Frankfurt, Stuttgart, Munich, Nuremberg and Leipzig/Halle as well as so-called hydrogen corridors along the connecting highways. Further stations on arterial roads and motorways will ensure a comprehensive supply infrastructure right up to the border regions of Austria, Switzerland, France, Belgium, the Netherlands and Denmark.

The second project phase will orient itself on the number of fuel cell vehicle registrations. Up to 400 hydrogen refuelling stations are to ensure the development of a complete national hydrogen infrastructure network in Germany by 2023. H2 MOBILITY will take on all operational tasks including network planning, authorisation, procurement, construction and the operation of the stations incl. payment systems and knowledge management. Moreover, H2 MOBILITY will procure hydrogen chiefly produced from renewable resources.

The initiative is accompanied by the associated partners BMW, Honda, Hyundai, Intelligent Energy, Toyota and Volkswagen as well as the National Organisation Hydrogen and Fuel Cell Technology (NOW). Support for the majority of the first 100 stations will, among others, come from the National Innovation Programme Hydrogen and Fuel Cell Technology or the European Commission in the Fuel Cells and Hydrogen Joint Undertaking (FCH-JU).

Further information at: www.h2-mobility.de/en

Hydrogen mobility means refuelling with hydrogen

The practical everyday use of fuel cell vehicles assumes that a network of hydrogen refuelling stations is in place. Subsequently, the expansion of a hydrogen refuelling infrastructure takes on an important role. Not only in Germany but also around Europe, industry initiatives exist and expansion plans are being made for hydrogen refuelling stations to enable pan-European transport with fuel cell vehicles.

The USA, South Korea and Japan have also set the path for the development of a comprehensive hydrogen refuelling station network to enable unrestricted driving with fuel cell vehicles.

Today, hydrogen can be refuelled in a matter of minutes, just like conventional fuels (diesel, petrol, LPG). Vehicles can store the hydrogen, which is usually in a gaseous form, at a pressure of 350 or 700 bar. In the passenger vehicle segment, 700 bar technology has generally become established as a standard due to the issue of range.

The refuelling facilities are correspondingly equipped with 700 bar supply nozzles. Fuel station components and the process of hydrogen filling including the refuelling coupling are already internationally standardised, thereby substantially simplifying the development of an expansive refuelling network as well as the interface to the fuel cell vehicles. This means that already today, a construction time of only four to eight weeks is necessary from the first turning of the spade until the hydrogen refuelling station can be in operation.

Currently, the biggest challenge in the expansion of hydrogen refuelling stations is no longer the system technology nor the construction, but rather the approvals process. However, timely and improved coordination between the applicant and the relevant authorities is to reduce this lead time in the future.

»Two goals for the immediate future:
1. *Market development of fuel cell vehicles through hydrogen refuelling stations*
2. *Sustainable cost reductions.«*

Guillaume Larroque, Total

Refuelling hydrogen
Images rights: NOW | Philipp Plum

Approval guidelines for hydrogen refuelling stations

NOW already published a guideline in 2013, which outlined matters needing to be considered in the hydrogen refuelling station approval process. The guideline builds on the experiences made in past approval processes. The brochure details the individual process and planning steps, and provides assistance in finding the correct contact persons to ensure the approval process is conducted smoothly and efficiently.

Download at: www.now-gmbh.de/de/service/publikationen
(in German only)

H2 MOBILITY Initiative: Action plan for the establishment of a hydrogen refuelling station network in Germany by 2023

Today there are already several hundred hydrogen refuelling stations in operation throughout the world. Within the scope of the NIP, 50 hydrogen refuelling stations have been established throughout Germany in the metropolitan regions of Berlin, Hamburg, Rhine-Ruhr, Frankfurt, Stuttgart, Munich, Nuremberg and Leipzig/Halle as well as along connecting motorways. This has laid the groundwork for 100 hydrogen refuelling stations under the stewardship of H2 MOBILITY to be in operation by 2018/2019. As such, a basic supply infrastructure to flank the market entry of the first fuel cell vehicles is in place.

~400 stations

is what Germany's public hydrogen refuelling station network will boast by 2023.

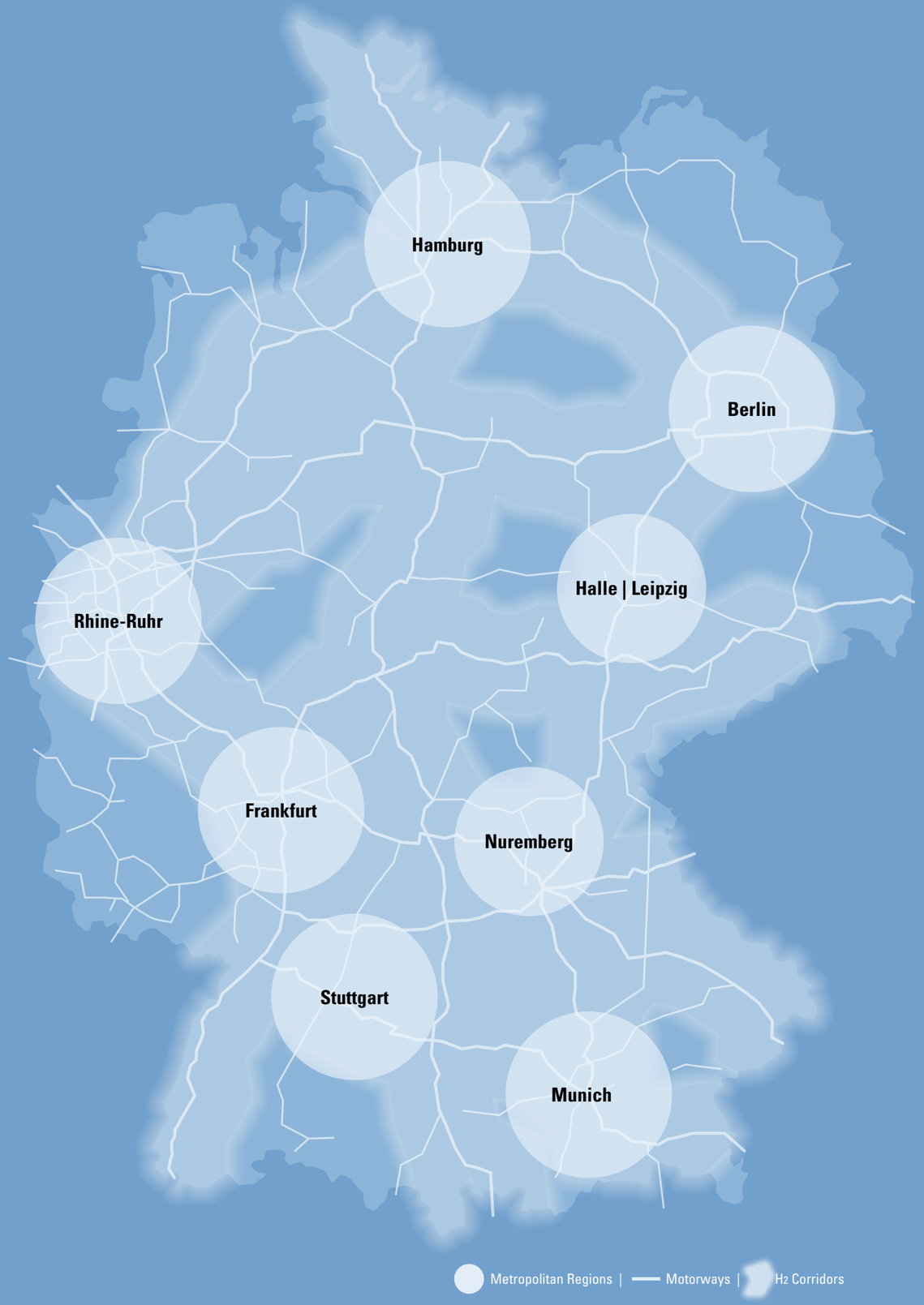
~90 kilometres

will then be the distance between the individual hydrogen refuelling stations on motorways around the urban regions.

>10 hydrogen refuelling stations

will be available in each of the metropolitan regions in 2023.

Further information at: www.now-gmbh.de/en/national-innovation-programme/aufbau-wasserstoff-tankstellennetz



Integrated energy system: Unifying energy sectors with electricity-based fuels

»The energy transition must take all sectors – power, heat, transport – into account.«

Dr. Oliver Weinmann, Vattenfall

Overhead power lines. Press photo: Vattenfall. Vattenfall is involved in the Clean Energy Partnership and Performing Energy – the Alliance for Wind Hydrogen.

Objective: Integrated energy system

The energy supply of the past has spawned today's energy system, which is divided in various energy sectors (power, heating for buildings/industry, fuel for transport) that each have their own transmission and distribution networks (power, gas and heating networks). Until now, there was little integration of the sectors. Production, provision and consumption are aligned with the respective consumer demands in the individual sectors.

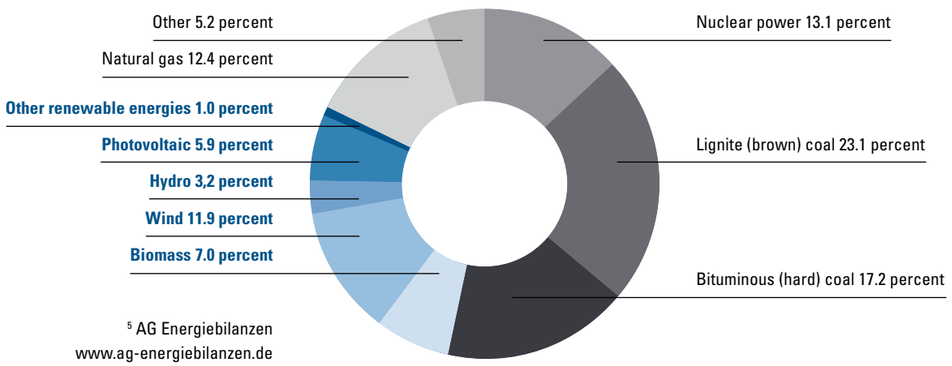
The continued expansion of renewable energy and the subsequent rapidly growing share of energy supply leads to the situation that renewable power must be integrated as the primary energy carrier in all energy sectors. With electricity-based fuels, the previously isolated energy sectors can be coupled with each other (keyword: integrated energy).

So that electricity can actually advance to become a cross-sectoral energy source and the benefits in terms of climate protection, energy security and growth transpire, various changes and adjustments to existing market structures and framework conditions are necessary. Specifically, the technical and regulatory prerequisites must be created in order to integrate the sectors.

Facts: Power production[5]

Total power production in Germany 2016: **648 billion kilowatt hours (kWh)**

Structure of power production in Germany 2016.
Overall share of renewable energies: **31.7 percent**



[5] AG Energiebilanzen
www.ag-energiebilanzen.de

Expansion of renewable energy and its integration in the energy system

The absurd situation that power from renewable sources can't be fed into the electricity network is nowadays becoming increasingly prevalent. This occurs on sunny days with brisk winds resulting in amounts of electricity being generated by the installed wind and solar energy facilities that exceed the capacity that can be transported by the existing electricity networks. These renewable energy plants must then be switched off. Power that is not produced due to capacity problems is called excess power. According to the opinion of experts[6], the amount of excess power is expected to already reach around 17 terawatt hours in 2020, and may even reach annual levels of approx. 20 to 40 terawatt hours by the year 2050.

From an economic and commercial business perspective, innovative technologies and solutions are required to make the energy system more flexible and subsequently enable these large amounts of clean energy to be used or stored for later consumption. Besides further adjustments to the energy system such as the expansion of electricity networks and intelligent load management (keyword »smart grid«), so-called flexibility solutions allowing the short-term storage or conversion of large amounts of electricity are gaining in significance.

[6] See forschung-energiespeicher.info and German Association for Gas & Water www.dvgw-innovation.de

Facts: Power consumption

Share of renewable energy of gross power consumption 2016: **31.7 percent**
of which **wind: 13.0 percent**; **solar: 6.4 percent**

Forecasts for **share of renewable energy** in consumed energy

By 2020: **47 percent**[7]

By 2035: **55-60 percent**[8]

Target by 2050: **at least 80 percent**[9]

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[7] Forecast of German Renewable Energy Federation www.bee.de and Agency for Renewable Energies www.undendlich-viel-energie.de

[8] Forecast Federal Ministry of Economic Affairs and Energy (BMWi), www.bmwi.de

[9] Federal government target

Hydrogen as an electricity-based fuel expands the energy systems and integrates energy sectors

The production of hydrogen via electrolysis using electricity generated via renewable sources offers an outstanding flexibility option for the supply of energy in the future. In contrast to electricity, it can be stored long-term (seasonally) and in large volumes. Moreover, through the production via electrolysis, it is possible to balance the electricity network loads in the case of any oversupply of renewable electricity. This also applies in the opposite direction, when hydrogen is reconverted to electricity via fuel cells and is fed back into the network. As an energy carrier, hydrogen can create new interfaces in the energy system both in a centralised and decentralised sense, and thereby enhance flexibility in an overall system with a high share of volatile renewable energy. This versatile use of hydrogen and associated technologies are nowadays summarised by the terms Power-to-Gas, Power-to-Fuel, Power-to-Heat or simply Power-to-X. They are discussed as a component of integrated energy concepts and are already being successfully tested in demonstration projects being conducted in the megawatt range.

From the year 2030/2035[10], when the share of renewable energy consumed in Germany will be at around 50 percent, hydrogen will become increasingly important as an energy storage medium. A reliable and stable supply of energy in periods of low renewable energy amounts must then be secured and provided through large amounts of stored energy. With the current state of scientific knowledge, hydrogen is the only medium capable of storing the vast volumes required. Hydrogen (storage) technologies are, however, not profitable under today's electricity market framework conditions. The deployment of electrolysis hydrogen in transport (directly as a fuel or indirectly as a raw material for the production of conventional fuels as well as synthetic hydrocarbons) could however open an early new field of business for industry, allowing the investments in a future-oriented energy system to be financed.

[10] According to the Ministry of Economic Affairs and Energy (BMWi), 40 to 45 percent of power consumed in Germany is to be produced from renewable sources by 2025. This figure is to rise to 55 to 60 percent by 2035 and to as high as 80 percent by 2050. (Status 2016: 30 percent)

»Power-to-X is not an end consumer technology – it's a transformation technology.«

René Schoof, Uniper

The potential of hydrogen in the various sectors

In the transport sector, hydrogen can be used as an alternative fuel in fuel cell vehicles.

In the supply of power, excess electricity can be stored in the form of hydrogen in large volumes and over long periods.

In the sector of buildings and industry, hydrogen can be deployed as a component of natural gas for heating. Hydrogen that is directly fed into the natural gas network or that is used for the production of synthetic methane, can be efficiently reconverted to electricity or turned to heat using fuel cell heaters or combined heat and power plant (cogeneration units).

Furthermore, hydrogen produced using renewable energy can be deployed in many additional industrial processes (refineries, chemical industry). To date, large amounts of hydrogen are extracted exclusively through the reformation of natural gas in this segment.

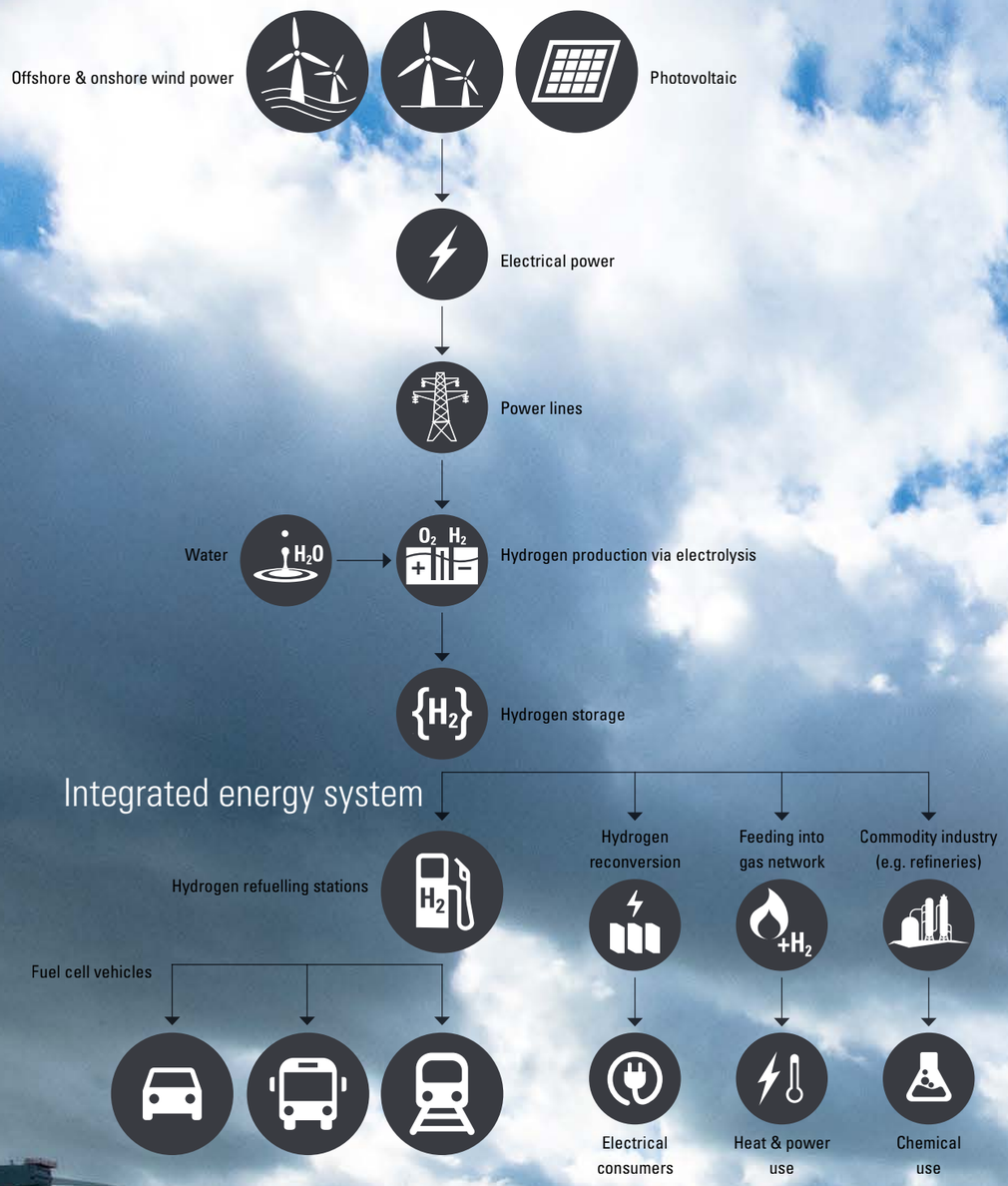

Diagram: Integrated energy system.
Icons adapted and modified; Publication BP Technology Outlook.
BP is involved in the initiative Performing Energy – the Alliance for Wind Hydrogen.

Performing Energy – the Alliance for Wind Hydrogen.

Fachkommission des DWV e.V.
Power-to-Fuel
performing energy

Representatives of leading manufacturers, research institutes and organisations from the areas of environment and technology founded performing energy – the alliance for wind hydrogen, in 2011.
The alliance was amalgamated in 2015 into the German Hydrogen and Fuel Cell Association (deutschen Wasserstoff- und Brennstoff-zellen-Verband) as an expert commission. The performing energy initiative is supported by the federal states of Brandenburg, Schleswig-Holstein and the city of Hamburg.

Aims: The companies and organisations involved work to promote wind hydrogen systems by highlighting the economic benefits of the integration of renewable energy with wind hydrogen systems.
The main concern is the strategic integration of renewable energy into the three energy sectors of power, heat and transport.

Further information at: www.dwv-info.de/performing-energy

Offshore wind park.
Press photo: Vattenfall.
Vattenfall is involved in the Clean Energy Partnership and Performing Energy – the Alliance for Wind Hydrogen.

Time for the transition

Refuelling with hydrogen
Image rights: NOW | Philipp Plum

Time for the transition

Declarations made by government and the activities of industry clearly indicate that the establishment of a mobility market with fuel cell vehicles is only a matter of time.

Yet the pace at which fuel cell electric vehicles will assert themselves in the mass market is highly contingent on how fast hydrogen is used as a source of energy besides electricity in the various energy sectors, and how quickly it can establish itself as an element of an integrated energy system.

The deployment of electricity-based fuels such as hydrogen in the transport sector represents a fresh field of business and can thereby contribute to initiating the necessary investment in the other sectors.

Throughout the many market-oriented demonstration projects of the NIP on Power-to-X, it was proven that highly efficient fuel cell systems and hydrogen from renewable energy can unify the energy sectors. This building block is essential for ensuring the supply of energy in Germany is oriented in a sustainable, climate-friendly, efficient and economical manner.

»Hydrogen and fuel cell technology was significantly developed further within the NIP through more than 650 individual projects and diverse industry networking initiatives.«

»Today, a sector comprising more than 500 companies and research institutions exists in Germany, which is not least attributable to the stable framework provided by the NIP.«

»Together with the USA, Japan and South Korea, Germany is leading in the development and market preparation of hydrogen and fuel cell technologies – not only in the area of mobility.«

»The NIP has successfully contributed towards creating technological standards, reducing costs and making the technology suitable for everyday use. The service life of fuel cells could be increased, the weight and size reduced.«

»Within the scope of the CEP, industry has committed itself to produce hydrogen with 50 percent renewable energy.»

»The NIP lighthouse projects helped to further develop hydrogen and fuel cells on a technological level while also raising its visibility and acceptance among the general public.«

»Close cooperation and co-financing exists in the NIP with government, business and research. This has enabled the technology and the market to come together and subsequently allowed cross-industry cooperation to take place along the entire value-added chain.«

Statements from the 2016 NIP final conference

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