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VOLKSWAGEN GROUP • SHAPING THE FUTURE OF MOBILITY

NO 06
June 2010

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# Intelligent Electricity

## New Directions in Energy Supply

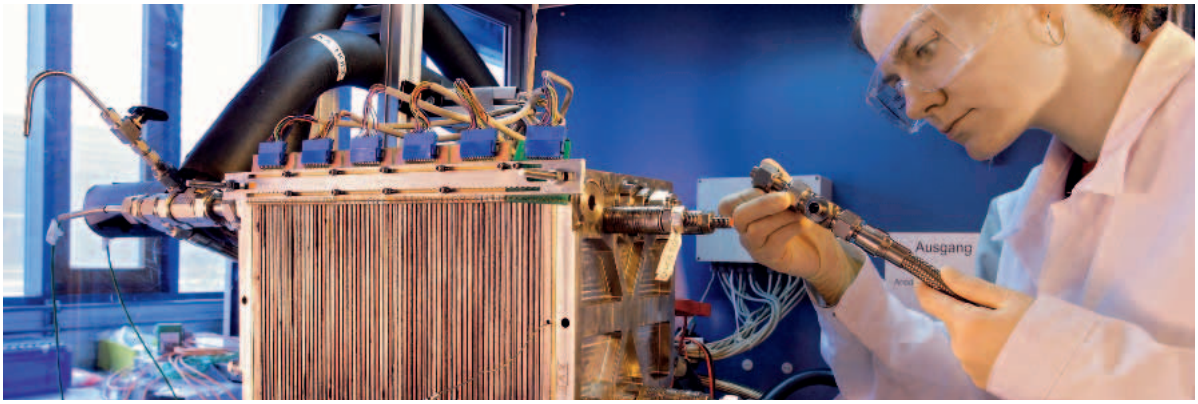
Picture: DDP/Jochen Luebke

**Two thirds of**
**Germany's energy is generated using fossil fuels.**

**In 2009,**
**238,000,000,000 kilowatt hours of energy came from renewable sources.**

# A Clean Solution?

## The Advantages and Disadvantages of Fuel Cells




The global automobile fleet is continuously growing; this is why it is important to further optimize combustion engines as well as to promote the development of new drive systems . One alternative that has been the topic of much discussion is the e-car. It can be powered by either battery or fuel cell – however, both drive systems are currently too expensive for the mass market. One advantage of fuel cell engines is their comparatively long range. Additionally, fuel cell propelled cars do not produce $CO_2$ – if the hydrogen for the engine is obtained from renewable energy sources.

### Pros

+ No local $CO_2$ emissions: the exhaust emits only steam.
+ Environmental friendly fuel. If the hydrogen is produced using renewable energy sources, no $CO_2$ is generated using this process.
+ High degree of efficiency. The degree of efficiency of a fuel cell engine is between 45 and 60 percent, whilst that of Otto engines is only 20 to 30 percent.
+ Long range: a distance of up to 500 kilometers using just one 6.4 kilogram tank of hydrogen – roughly equivalent to the range of a car with a combustion engine. Cost: currently approximately 51 euros.

### Cons

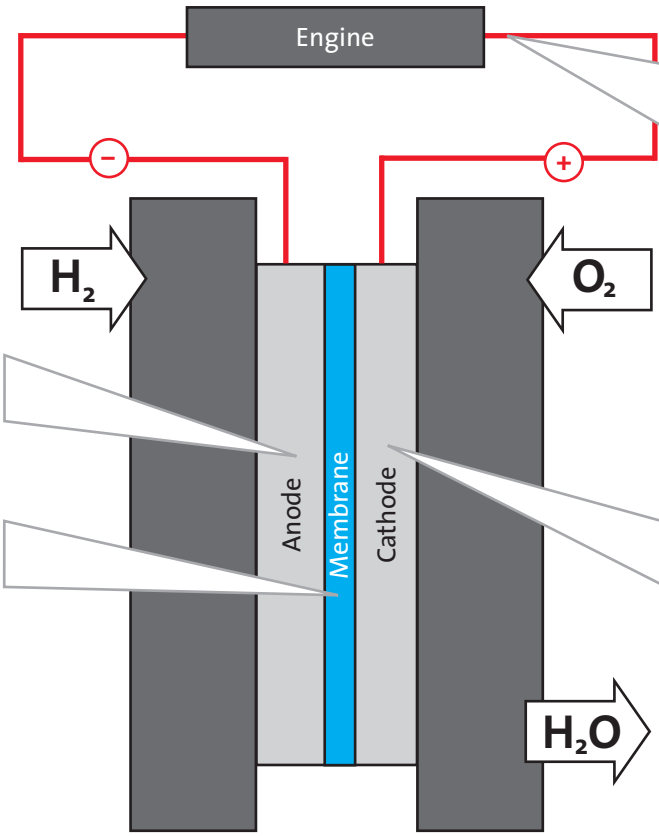
– High production cost. At the moment, the production of a fuel cell car prototype costs one million euros.
– Production of hydrogen. Hydrogen can also be obtained by using energy from fossil fuels, significantly inflating the car's $CO_2$ footprint.
– Short life span: the continuous-service capacity of a fuel cell is currently between 2,000 and 3,000 hours, compared to about 5,000 hours for a combustion engine.
– Insufficient infrastructure. Currently there are only 25 publicly accessible hydrogen gas stations in Germany. Ten more are planned.

Sources: Ludwig-Bölkow-Systemtechnik; Paul Scherrer Institut; Volkswagen AG

# The Functionality of Fuel Cells

① At the positively charged electrode, called the anode, hydrogen from the tank of the car is split into ions and electrons. The positively charged hydrogen ions move through the membrane to the cathode.

② Because the membrane is impassable for negatively charged electrons, they instead take a detour from anode to cathode via a cable.




③ The current flowing between anode and cathode powers the car's electric engine.

④ At the cathode, ions react with inflowing oxygen and electrons, producing water as a by-product, which then escapes through the exhaust.

➔ A single fuel cell produces a voltage of approximately one volt. To power an electric engine, 300 to 400 of the roughly two millimeter thick fuel cells are bundled together into a "stack".

Sources: Forschungszentrum Jülich; Volkswagen AG

**Hydrogen as an Energy Source**

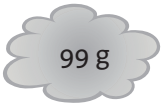
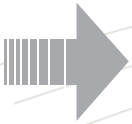
Hydrogen is a secondary energy source that can be produced from many different primary energy sources: from the electrolysis of water, which requires a current that can come from many different sources, to so-called ethanol reformation, as well as natural gas, through to coal or biomass gasification. In the event of major fossil fuel scarcity, hydrogen could provide around 50 percent of the energy required by the transport sector.

Sources: German Energy Agency; HyWays/European Commission

# How Far, How Clean, How Expensive?

## Drive Systems Compared

Every engine has its advantages and disadvantages. Range, $CO_2$ emissions, fuel consumption and cost depend on many factors, such as the model of car, driving style and road quality. An efficient gasoline engine does not necessarily produce more carbon dioxide than an electric or fuel cell car – it always depends on the source of the particular energy being used. Locally arising emissions (tank-to-wheel) are generally differentiated from total emissions – that is from energy supply to car (well-to-wheel). According to the Federal Environment Ministry, the e-car emits, if powered using the German energy mix, 115 grams of carbon dioxide per kilometer: compared to emissions of zero grams with renewable energies. The following table provides examples, comparing specific Volkswagen models with different engines.

| | **Range** per tank contents | **Local $CO_2$ emissions** per kilometer | **tank cost** per 100 kilometers |
|---|---|---|---|
|  **Gasoline engine** Golf 1.2 TSI BlueMotion Technology [1] |  1057 km |  121 g | € 7 euros |
|  **Diesel engine** Golf 1.6 TDI BlueMotion [2] |  1447 km |  99 g | € 4.40 euros |
|  **E-car** Golf blue-e-motion [3] |  150 km | 0 g | € 4 euros |
|  **Fuel cell car** Golf comparable car [4] |  400 km | 0 g | € 8 euros |

[1] 5.2 liter per 100 kilometers, 1.35 euros per liter. [2] 3.8 liter per 100 kilometers, 1.15 euros per liter. [3] Based on a battery with 26.5 kilowatt and the current electricity tariff price for households (end customer) of about 0.23 euros per kilowatt hour. [4] Based on a consumption of 1.28 liters per 100 kilometers and a hydrogen price of eight euros per kilogram.

Sources: German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety; German Federal Ministry of Economics an Technology; Volkswagen AG

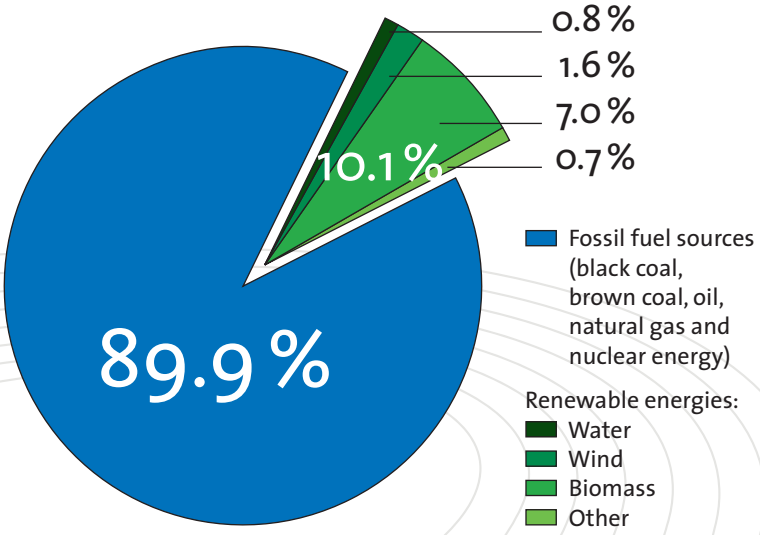
# Green Source

## Energy from Renewable Sources

Economic growth and a growing world population will, according to current estimates, see global energy demand almost double by 2030. At the same time, fossil fuel sources like coal, gas and oil will not be available limitlessly. Given this background, the need for sustainable environmental and climatic protection, renewable energy sources have become of increasing importance.

- ➔ Today, two thirds of energy supply in Germany is based on fossil fuel sources like coal, oil and gas.
- ➔ The current government wants to meet energy demands "almost exclusively" by alternative energy sources by 2050.
- ➔ The biggest problem with alternative energy sources like wind or solar is that although they are inexhaustible in principle, they are not constantly and consistently available everywhere.

Sources: German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety; Siemens




*So far the development of renewable energy sources in Germany has been a success story: their share of total energy supply (electricity, heat, fuel) has increased from 3.8 percent in the year 2000 to approximately 10 percent in 2009.*

Source: German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety

### Renewable energy in Germany (2009)

**238,000,000,000**
In 2009, 238,000,000,000 kilowatt hours of energy came from renewable sources.

**10.1 %**
Share of energy consumption.

**16.1 %**
Share of total electricity consumption.

**8.4 %**
Share of total heat energy consumption.

**5.5 %**
Share of total fuel consumption.

**109,000,000**
Metric tons $CO_2$ emissions avoided.

**300,500**
Employees in the renewable energy sector.

Sources: Arbeitsgemeinschaft Energiebilanzen; German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety

# Well Supplied

## Intelligent Grids

The development of renewable energy is changing the shape of the electricity grid. More and more small and decentralized facilities which are feeding wind or solar energy into the grid are supplementing the core large power plants that are essential today. The amount of energy fed in is however dependent on the appearance of sun or wind, for instance. This leads to fluctuations which today's grid is not designed to manage. The grid of the future must therefore be able to intelligently coordinate the actions of all its interconnected participants – producers, consumers and storage facilities – in order to guarantee a reliable and continuous supply of energy. In the future, so called smart grids – intelligent computer controlled grid networks – will connect and coordinate all participants using modern communication technologies.

Quellen: HEAG Südhessische Energie AG; Smart Grids Austria

### Wind power/Onshore

Wind power plants utilize the kinetic wind energy which is generated by differing air pressure ratios near the earth's surface.

- 21,164 wind power plants with an electric output of 25,777 megawatts had been installed in Germany by the end of 2009.
- In the year 2009, the use of wind energy saved 30 million metric tons of $CO_2$ emissions in Germany.

### Nuclear power

In Germany 17 nuclear plants are connected to the grid with a net output of 20,457 megawatts.

- About a 22.1 percent share of German energy supplies.

### Home plants

So called block heating stations, which have been developed by the energy provider LichtBlick in cooperation with Volkswagen, are to be installed in the basements of many large residential buildings in order to generate heat and electricity. At the same time, these generators are designed to feed tremendous amounts of energy into the public grid. Thousands of home plants are to be connected "within one minute" to form a large virtual generator. The so called swarm electricity is designed to fill in energy supply gaps. The energy will be released from the basements of thousands of block heating stations owners when no wind blows.

- Up to 100,000 households are scheduled to be equipped with these mini-plants and they will make at least two nuclear or coal plants obsolete.

### Caption

The watt hour is the unit by which energy conversion is measured. One watt hour equates to the energy that a machine with an output of one watt absorbs or emits in one hour. For example, 1,000 watt hours can power a vacuum cleaner for 25 minutes or let you watch television for seven hours.

| | |
|---|---|
| Kilowatt hour (kWh) | = 1,000 Watt hours |
| Megawatt hour (MWh) | = 1,000 Kilowatt hours |
| Gigawatt hour (GWh) | = 1,000 Megawatt hours |
| Terawatt hour (TWh) | = 1,000 Gigawatt hours |

Sources: alpha ventus; atw - international magazine for nuclear energy; German Federal Ministry for the Environment, Nature Conversation and Nuclear Safety; German Federal Ministry of Economics an Technology; Der Spiegel; Die Zeit; LichtBlick; Nationaler Entwicklungsplan Elektromobilität der Bundesregierung; Wirtschaftswoche

## Solar energy

Photovoltaic plants transform sunlight straight into electricity.

- Currently, photovoltaic provides approximately 0.7 percent of gross energy demand in Germany.
- About eleven million square kilometers of photovoltaic panels are currently installed in Germany. Roughly four terawatt hours of electricity have been generated by them thus far.

## Wind power/Offshore

The first offshore wind power plants started feeding energy into the German grid in August 2009. Twelve wind power plants with an output of 60 megawatts will be installed at the test field alpha ventus located north of the island Borkum – enough to provide for the electricity needs of about 50,000 households.

## Pump storage power plants

More electrical storage capacity is essential to the energy mix of the future, in order to supply energy as and when it is needed. At the moment, the most cost effective option for electrical storage is pump storage power plants in which electric pumps move water from low to high tanks, when power production exceeds demand. When demand begins to exceed production, the water stored in the high tanks is channeled down pipes , driving turbines which generate electricity. In Germany there are about 30 such storage plants, with an output of 7.5 terawatt hours.

## Households

Companies and private households now not only consume electricity but actually produce a growing proportion of energy themselves, using photovoltaic or geothermal plants which they can even sell when they do not need it themselves. Depending on demand, energy can be either fed into the grid or taken from it.

## Biomass

Biomass is the most important and versatile source of renewable energy in Germany. It is used for both heat and electricity production and to fabricate bio-fuels.

- 27 terawatt hours of electricity were produced from biomass in 2008. This equates to 4.5 percent of the total gross electricity needs of Germany.
- In 2009, about 69 percent of all energy generated from renewable energy sources was generated using various different sources of biomass.

## Water power

Water power is responsible (second only to the traditional use of biomass) for the biggest share of renewable energy.

- In 2008, 21.3 terawatt hours of electricity which is about 3.4 percent of German energy production from renewable sources were produced using water power.

## Geothermal energy

Geothermal energy is a virtually inexhaustible energy source which utilizes the natural heat of the earth.

- 0.018 terawatt hours of electricity were produced by geothermal plants in 2008.

# Electricity for E-Cars

According to the Federal Office of Statistics, there are currently 1,500 electric cars on German roads. This is to be changed. One million electric cars by 2020 is the declared goal of the German government. More e-cars also means more demand for power: experts calculate two terawatt hours are required for one million pure e-cars. This roughly equates to 0.3 percent of the total energy consumption of Germany – a level that the current grid could provide without requiring further sources. If, at some point, a larger proportion of transport users drove electrically powered vehicles, then an intelligent electricity management system will need to be deployed.

## 1,000,000 e-cars = 2 TWh electricity

*One million e-cars need approximately two terawatt hours of electricity. This is the same amount a small City with 40,000 inhabitants consumes in one whole year.*

- E-cars could potentially be consumers of electricity in an intelligent grid and so help avoid peaks in household energy consumption; thus contributing to the efficiency of power plants.
- The batteries of e-cars could serve as storage for excess electricity from renewable energy sources which cannot be transported and allocated due to current capacity limits.
- It is possible in principle that these batteries could even re-feed electricity back into the grid. Research on that subject is being done under the phrase "vehicle to grid". E-cars, however, can store only a limited amount of energy. Assuming that we are dealing with a ten kilowatt hour battery, and, based on the estimated one million e-cars that are expected to be on the roads by 2020, this amounts to a total storage capacity of ten gigawatt hours – little more than the storage performance of just one pump storage plant.

Sources: Institute for Energy and Environmental Research Heidelberg; Nationaler Entwicklungsplan Elektromobilität der Bundesregierung; Wuppertal Institute for Climate, Environment and Energy


## Imprint

**www.viavision.org.uk, www.viavision.org**

**Edited by**
Volkswagen Aktiengesellschaft
Konzern Kommunikation
Brieffach 1972, 38436 Wolfsburg
Phone: 05361/9-77604, Fax: 05361/9-74629

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**Published by**
Verlag Rommerskirchen GmbH & Co. KG
Mainzer Straße 16 -18, 53424 Rolandseck
Phone: 02228/931- 0, Fax: 02228/931-149
www.rommerskirchen.com

**Printed by**
L.N. Schaffrath GmbH
Marktweg 42-50, 47608 Geldern