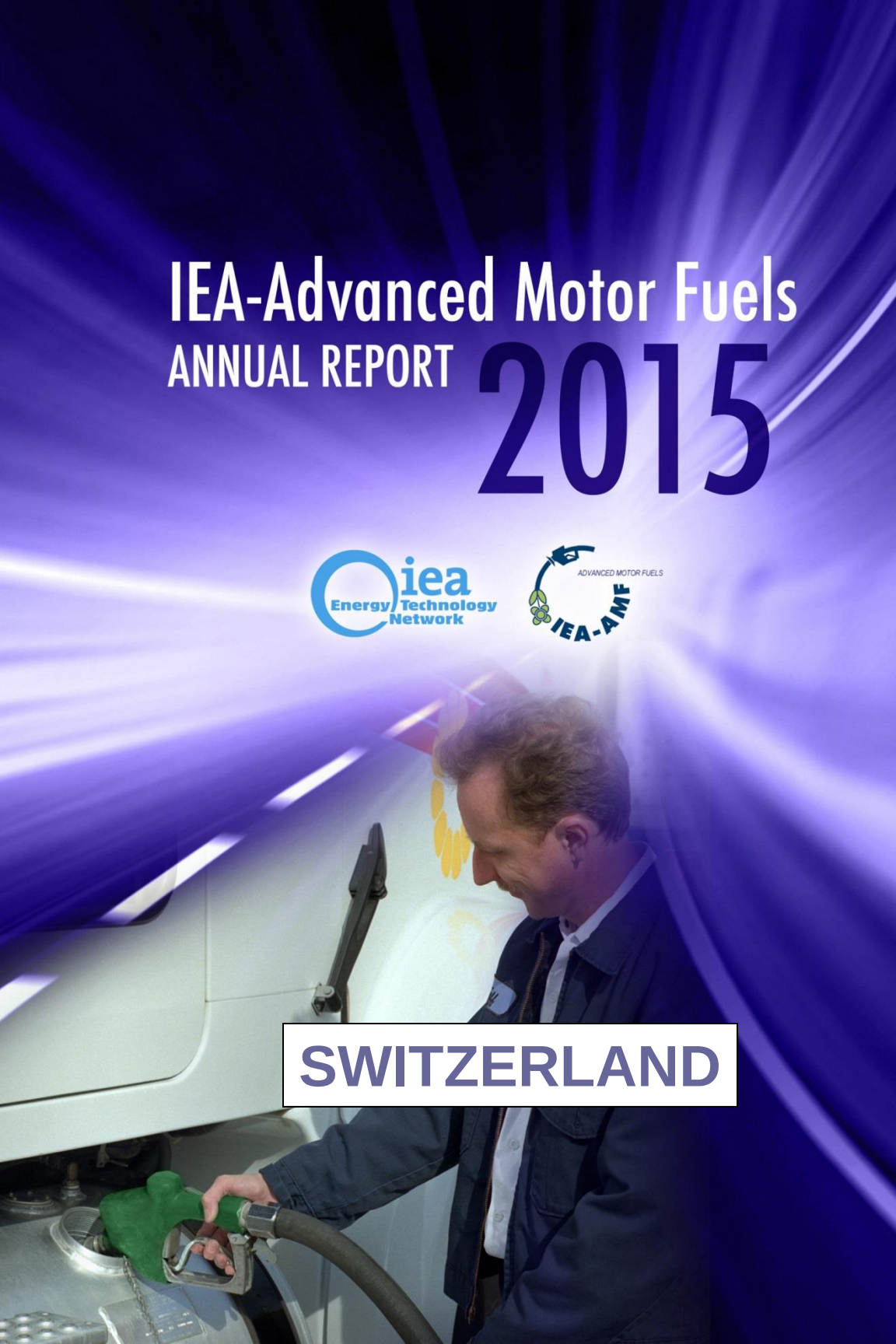
# IEA-Advanced Motor Fuels
# ANNUAL REPORT 2015



## SWITZERLAND

## Switzerland

### *Introduction*

Final total energy consumption in Switzerland in 2014[1] amounted to 825,770 terajoules (TJ), of which 36% was transport fuels [1]. Compared to 2013, transport fuel consumption lightly decreased by 0.4%. There were some changes in specific applications: diesel +2.5%, gasoline −4.0%, and aviation fuels +0.7%. All fossil fuels were imported. Figure 1 shows shares of energy sources in energy consumption for all kinds of transportation. With regard to aviation fuel, 10% is used for domestic flights [2]. Electricity is used for railroad transportation only.

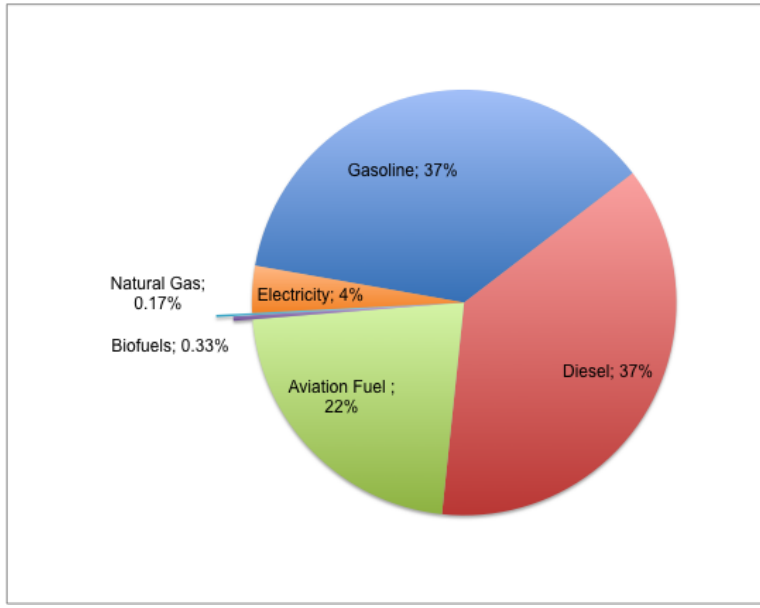



Fig. 1 Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland in 2014 [1]

Despite a large increase in biofuels used for transportation, from 640 TJ in 2013 to 1,017 TJ in 2014 (+59%), the share of total transport fuels remains very small (0.33%). The increase was mainly due to higher sales of biodiesel and bioethanol.

[1] At the time this report was prepared, only data from 2014 were available for Switzerland.

A total of 396,588 motor vehicles were newly registered in 2014 [3]. This represented a drop of −1.4% in the total amount of 5,784,084. Of passenger cars, 304,083 are newly registered, and with 4,384,490 units in total, these cars represent the most important share (75%). Of all passenger cars, 73% had gasoline engines, and 26% had diesel engines, of which 67% had a diesel particulate filter. The percentage represented by other propulsion systems was 1.4% (41,158 hybrid, 4,439 electric, and 13,507 other) [3].

Within the last 10 years (through 2014), the consumption of transport fuels (minus aviation fuel) increased by only 1.1%. In the same period, the number of cars (all types) increased by 15%. The average fuel consumption per car dropped significantly, and there was an important change in the kind of motor fuel used. The use of gasoline decreased by 25%, and the use of diesel increased by 56%. The consumption of biofuels rose by 335% in this 10-year time frame, but it represents a very low percentage of the overall motor fuel demand, increasing from 0.12% to 0.33%. Figure 2 shows the development in gasoline and diesel consumption by motor vehicles in 2005–2014.

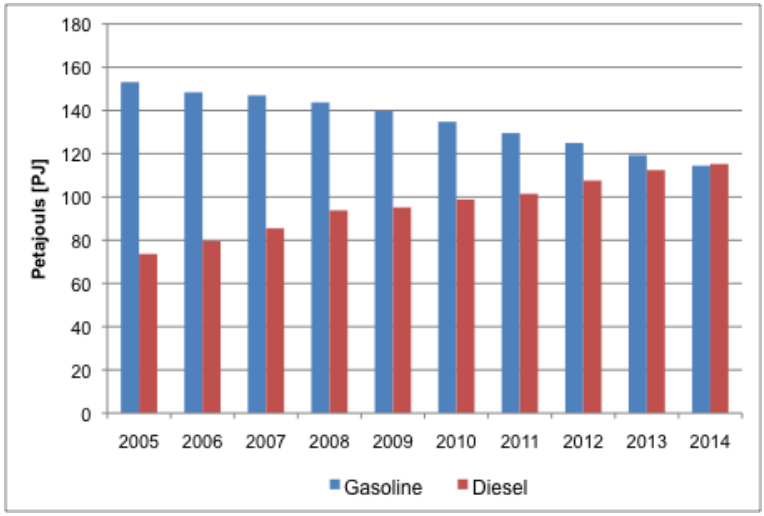



Fig. 2 Development in Gasoline and Diesel Consumption by Motor Vehicles in Switzerland, 2005–2014 [1]

Unlike other countries, in Switzerland, firms marketing motor fuels are not under any obligation for blending. This could be a reason for the rather low share of biofuels in the total amount of motor fuels.
Different cantons (Swiss member states) give vehicle tax reductions or even exemptions for purchasing environmentally friendly and energy-efficient

vehicles, but there is still scepticism about alternative propulsion systems because of their higher capital costs and reduced ranges.

## *Policies and Legislation*

### Energy Strategy 2050

In 2011, the Federal Council decided that Switzerland would withdraw from the use of nuclear energy on a step-by-step basis without increasing carbon dioxide ($CO_2$) emissions [4]. The five existing nuclear power plants, which provide 40% of the electricity in Switzerland, will be decommissioned when they reach the end of their safe service life and will not be replaced by new ones. The first nuclear power plant will be switched off in 2019, and the last probably in 2034.

To ensure a secure supply of energy, the Federal Council is emphasizing increased energy savings (energy efficiency); the expansion of hydropower and new renewable energy sources; and, if necessary, fossil-fuel-based electricity production (cogeneration facilities, gas-fired combined-cycle power plants) and imports. To achieve these targets, the Swiss energy system will need to be successively restructured during the time period up to 2050. In view of this, the Federal Council developed a long-term energy policy — Energy Strategy 2050. In September 2013, the Council launched an initial package of measures aimed at securing the country's energy supply over the long term [5]. This package will be supported by a fundamental revision of the 1998 Energy Act. In 2014, the Parliament started the debate. The final decision is expected in 2016. Important measures related to motor fuels are to (1) reduce $CO_2$ emissions, (2) increase energy efficiency, (3) increase the use of renewable energy sources including biomass, and (4) strengthen energy research.

### $CO_2$ Emission Regulations for Cars

Like the European Union (EU), Switzerland has introduced $CO_2$ emission regulations for new cars. Swiss importers are required to reduce the level of $CO_2$ emissions from passenger cars registered for the first time in Switzerland to an average of 130 grams (g) of $CO_2$ per kilometer (km) by 2015 [6]. In 2014, 80% of the newly registered passenger cars had to fulfil this target. Car importers missed that target and had to pay a penalty of 1.7 million CHF. The average $CO_2$ emission of passenger cars was 142 g $CO_2$/km, and the average fuel consumption was 6.11 liters (L)/100 km [7]. Along with introducing the new Energy Act, the Federal Council aims to align with the EU Commission's legislative proposal to tighten $CO_2$ regulations on cars. By the end of 2020, the average $CO_2$ emissions from passenger cars have to be reduced to 95 g $CO_2$/km. A law for light commercial vehicles (vans up to 3.5 metric tons [t]) similar to the one for

new passenger cars is awaiting formal adoption. For new vans sold in Switzerland, the targets are a fleet average of 175 g $CO_2$/km by 2017 and 147 g $CO_2$/km by 2020 [5]. In 2012, the average was 180.2 g $CO_2$/km.

### $CO_2$ Emissions Compensation: Motor Fuels

All importers of fossil motor fuels are required to use domestic measures to compensate for 10% of the $CO_2$ emissions caused by the entire transportation sector by 2020 [8]. The compensation rate started in 2014 at 2% and will be raised in three subsequent steps to the level of 10% in 2020. Importers of fossil motor fuels may carry out their own projects or acquire attestations (i.e., certificates). They may group together to form compensation pools. In response to this, the Swiss Petroleum Association established the Foundation for Climate Protection and Carbon Offset (KliK), a nonprofit organization. It operates as a carbon offset group and launches and subsidizes projects and measures to reduce $CO_2$ emission in different fields such as transportation, industry, buildings, and agriculture.

Another measure to reduce $CO_2$ emission is to blend fossil fuels with biofuels. This is the reason for the steep upswing in the amounts of biodiesel and ethanol in 2014.

### Energy Label for Motor Vehicles and Tiers

The energy label for motor vehicles is intended to support efforts aimed at reducing the average fuel consumption of motor cars. It provides information about the kind of motor fuel, fuel consumption (L/100 km), and $CO_2$ emissions (g/km) in relation to the curb weight of the vehicle. It increases transparency and helps individuals considering purchasing a new car decide which model to buy. In 2014, Switzerland introduced a label for tiers. It classifies, among other qualities, the rolling resistance of the tier and, with this, its energy efficiency [9].

### Mineral Oil Tax (Petroleum Tax)

The mineral oil tax is an excise tax that varies heavily depending on the product and its use (engine fuel, heating fuel, and technical purposes). For instance, the tax per liter is:

- 0.73 CHF for unleaded petrol,
- 0.76 CHF for diesel oil, and
- 0.003 CHF for extra light heating oil.

Tax reductions are provided for engine fuels used in agriculture, forestry, professional fishing, licensed transport companies, and other industries.

### Mineral Oil Tax Reduction for Natural Gas

To support Switzerland's target for $CO_2$ emissions, a reduction or even an exemption for environmentally friendly motor fuels came into effect on July 1, 2008, with the amendment to the Mineral Oil Tax Act. The tax for natural gas used as a motor fuel was reduced to 0.22 CHF/kg [10].

#### Mineral Oil Tax Exemption for Biofuels

Switzerland is the first country in the world to introduce sustainability criteria, such as minimum ecological and social requirements for the production of biofuels, into its legal framework. To promote the use of biofuels (e.g., biogas, bioethanol, biodiesel, and vegetable and animal oils) that satisfy minimum environmental and social standards, those biofuels are completely or partially relieved from the mineral oil tax. As a result, the tax reduction for biofuels is up to 0.72 CHF/L, in comparison with fossil fuels.

To obtain a tax exemption, the following criteria, which apply to both the cultivation and utilization of fuels, have to be fulfilled:

- Emissions of greenhouse gases from the biofuels must be at least 40% lower than emissions from fossil fuels.
- The environmental impact may not be greater than that from fossil fuels.
- The protection of rain forests and biodiversity must not be endangered.
- The biofuels must be obtained from raw materials that were produced in accordance with local social standards.

## *Implementation: Use of Advanced Motor Fuels*

#### Use of Biofuels as Motor Fuels

The share of biofuels within total transport fuels remains very small (0.33%). The most important biofuel is biodiesel, and in 2014, the amount almost doubled compared to previous years, and the use of bioethanol increased more than twice. The use of upgraded biogas remains at a low level, and the use of pure vegetable oil (PVO) as fuel has almost ceased. Figure 3 shows the development of biofuel consumption in motor vehicles over the last 10 years.

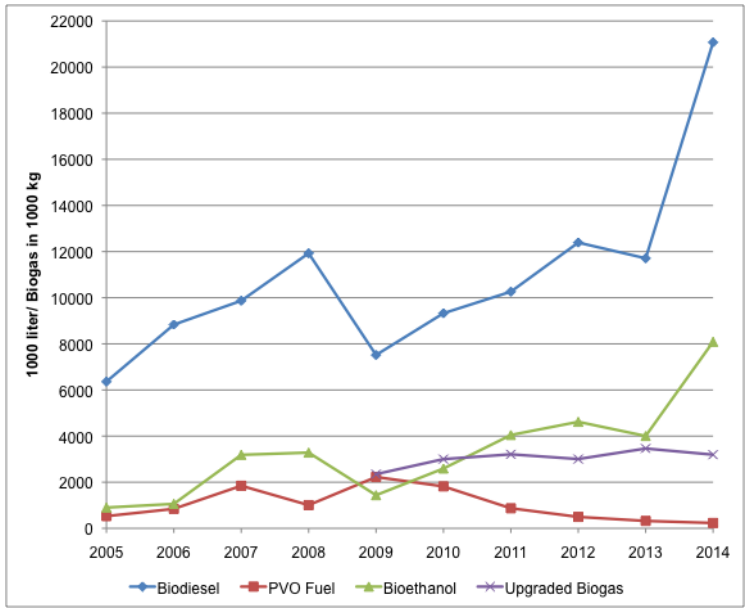



Fig. 3 Trends in Biofuel Consumption by Motor Vehicles in Switzerland, 2005–2014

### Biodiesel and PVO Fuel

The consumption of biodiesel fuel in Switzerland amounted to about 21.1 million L in 2014 (Table 1). Compared to 2013, this is an increase of 80%. This substantial gain can be contributed to the legal carbon offset obligation for $CO_2$ emissions that came into effect in 2014. Importers of fossil motor fuel had to compensate in a first step of 2% of $CO_2$ emissions. They did this partly by blending diesel fuel with biodiesel, resulting in B5.

In the 10 years up through 2014, consumption of biodiesel increased by 230%. Compared to consumption of diesel fuel, however, the amount was still very low, representing a share of 0.66%. Then in 2014, the consumption of PVO fuel dropped to a very low level. After reaching a maximum of 2.2 million L in 2009, consumption of PVO decreased to 0.23 million L in 2014. Biodiesel B100 and PVO fuel are used only in some local diesel fleets (mostly in agriculture) [12].

Table 1 Consumption of Biodiesel and PVO Fuel in Switzerland, 2005–2014 (in 1,000 L/yr) [11, 13]

| Year | Biodiesel (1,000 L) | PVO Fuel (1,000 L) |
|---|---|---|

| | National Production | Imports | Total | National Production | Imports | Total |
|---|---|---|---|---|---|---|
| 2005 | 6,180 | 181 | 6,361 | 529 | 0 | 529 |
| 2006 | 8,717 | 116 | 8,833 | 845 | 0 | 845 |
| 2007 | 9,756 | 113 | 9,869 | 1,846 | 0 | 1,846 |
| 2008 | 11,915 | 12 | 11,927 | 849 | 158 | 1,007 |
| 2009 | 6,837 | 679 | 7,516 | 808 | 1,418 | 2,226 |
| 2010 | 6,945 | 2,380 | 9,325 | 869 | 950 | 1,819 |
| 2011 | 7,161 | 3,101 | 10,262 | 641 | 229 | 870 |
| 2012 | 7,797 | 4,594 | 12,391 | 496 | 0 | 496 |
| 2013 | 5,633 | 6,076 | 11,709 | 293 | 29 | 322 |
| 2014 | 5,872 | 15,200 | 21,072 | 232 | 0 | 232 |

**Bioethanol**

In 2014, the consumption of bioethanol as a motor fuel amounted to about 8.1 million L (Table 2). Compared to the amount in 2013 (4.0 million L), this was an increase of 102%. The reason for this steep upswing was the same as for biodiesel — the petroleum industry's obligation to compensate 2% of $CO_2$ emissions. It partly fulfilled this target by blending gasoline with ethanol to E5 and E85.

The use of bioethanol as a motor fuel started in Switzerland in 2005. Until 2008, the whole volume was produced in Switzerland by Borregaard Schweiz. The closing down of bioethanol production in Switzerland in 2008 affected consumption in 2009; only Alcosuisse (a Profit Center of the Swiss Alcohol Board) was allowed to import and sell ethanol. There was a large drop in consumption in 2009. The Government resigned its activities related to the trade of bioethanol and opened the market to the private economy in the autumn of 2010. Since then, the whole volume of bioethanol is imported from Norway, The Netherlands, and Germany.

Table 2 Consumption of Bioethanol Fuel in Switzerland, 2005–2014[a] (in 1,000 L/yr) [1, 11]

| Year | National Production | Imports | Total |
|---|---|---|---|
| 2005 | 901 | 0 | 901 |

| | | | |
|---|---|---|---|
| 2006 | 1,060 | 0 | 1,060 |
| 2007 | 3,188 | 0 | 3,188 |
| 2008 | 3,284 | 0 | 3,284 |
| 2009 | 0 | 1,438 | 1,438 |
| 2010 | 0 | 2,593 | 2,593 |
| 2011 | 0 | 4,047 | 4,047 |
| 2012 | 0 | 4,619 | 4,619 |
| 2013 | 0 | 4,004 | 4,004 |
| 2014 | 0 | 8,089 | 8,089 |

[a] No bioethanol was used as a motor fuel before 2005.

### Biogas and Natural Gas

In 2014, the total use of gaseous motor fuels remained at roughly the same level as it was in the previous 5 years (Table 3). Data have been available since 2009. The share of biogas used as a motor fuel in the total amount of gaseous motor fuels decreased slightly, from 23% to 22%. The total amount of upgraded biogas fed into the natural gas grid increased from 9,981 to 15,063 t (+51%), but its use as a motor fuel remained much lower (3,194 t). This is because not all the upgraded biogas could be sold for use in vehicles, and there is an increasing demand for biogas delivered by the gas grid for heating purposes.

However, the total amount of biogas produced in Switzerland in 2014 was much higher (94,070 t) than the amount that has been upgraded and fed into the natural gas grid and used as a motor fuel, as mentioned previously. Most of the biogas is directly used on site for heat and power generation.

Table 3 Use of Biogas and Natural Gas as Motor Fuels (via the gas grid and directly at the fuel pump) in Switzerland, 2009–2014 (in 1,000 kg/yr) [14]

| Year | Upgraded Biogas Used as Feed in Gas Grid | Upgraded Biogas Used as Motor Fuel in Cars | Upgraded Biogas: Other Uses | Natural Gas Used as Motor Fuel in Cars | Total Gaseous Motor Fuels Used in Cars | Share of Biogas in Total Amount of Gaseous Motor Fuels |
|---|---|---|---|---|---|---|
| 2009 | 3,152 | 2,349 | 803 | 10,373 | 12,722 | 19% |
| 2010 | 4,505 | 3,002 | 1,503 | 12,080 | 15,082 | 20% |
| 2011 | 6,350 | 3,210 | 3,140 | 12,051 | 15,711 | 20% |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2012 | 6,915 | 3,005 | 3,910 | 11,830 | 14,835 | 20% |
| 2013 | 9,981 | 3,461 | 6,520 | 11,599 | 15,060 | 23% |
| 2014 | 15,063 | 3,194 | 11,869 | 11,394 | 14,588 | 22% |

### Energy Research

The Swiss Government supports energy research in the amount of 200 million CHF each year. From this amount, only a small part is dedicated to research in the field of advanced motor fuels. In support of Energy Strategy 2050, the Swiss Parliament in 2011 decided to increase subsidies for pilot and demonstration projects from a yearly amount of 5 million CHF to 35 million CHF in 2014. A second important decision that increased energy-related research activities and competencies in Switzerland was for a grant of an additional 200 million CHF for the period 2013 to 2016. The target was to launch and build the capacity of seven Swiss Competence Centers for Energy Research (SCCERs). Two SCCERs are important with regard to advanced motor fuels: SCCER BIOSWEET (Biomass for Swiss Energy Future) [15] and SCCER Mobility (Efficient Technologies and Systems for Mobility) [16].

The targets of energy research are described in *Energy Concept 2013–2016* [17]. It is published by the Federal Energy Research Commission (CORE), which acts as a consultative body for the Federal Council. On the basis of this publication, the Swiss Federal Office of Energy (SFOE) published a detailed research plan [18] covering 20 topical areas. The following paragraphs give some examples of ongoing research projects related to advanced motor fuels.

### Examples of Ongoing Research Projects

**Metal-nanoparticles and other nonlegislated emissions from cars with blended gasoline and alcohol fuels [19].** Metal-nanoparticles (including those in sizes below 20 nanometers [nm]) from gasoline cars are being investigated for different engine technologies (12 cars). The investigations focus on the composition and potential of secondary aerosols. Supplementary research is being conducted on nanoparticles at cold start, gaseous nonlimited components (especially nitrogen dioxide [$NO_2$], ammonia [$NH_3$], and aldehydes), and operation with alcohols. The project, led by the Laboratory for IC (Internal Combustion) Engines and Exhaust Control (AFHB) at the University of Applied Science Biel/Biennne, is a collaboration with the Paul Scherrer Institute (PSI) and the Swiss Federal Laboratories for Materials Science and Technology (Empa) (Figure 4).

Fig. 4 Test Facility at the Laboratory for IC Engines and Exhaust Control (AFHB)

**Effects of gasoline-butanol blend fuels on emissions and combustion in spark ignition (Sl) engines.** With different butanol blends (BuXX), basic combustion research is being performed on a SI-engine dynamometer with accesses for engine parameterization and pressure indication. In the second part of the project, two vehicles, one with older technology and the other with newer technology, are being investigated on a chassis dynamometer with special consideration of nonlegislated emission components.

**Hydrogen-enriched natural gas/biogas in passenger cars — potential by adaptation of the engine control system.** Hydrogen-enriched natural gas/biogas is being investigated in a field test of delivery vehicles of Mobility Solutions (Figure 5). It could be shown that an efficiency increase is already occurring without adapting the engine control system. In this project, the impact of adapting the ignition map for constant center of combustion on efficiency is being investigated.

Fig. 5 Euro 4 Passenger Car with 2.0-L Engine and Conventional Three-Way-Catalyst Being Tested with 15% and 25% Vol $H_2$ in CNG

**Characterization of high boiling point/synthetic fuels for homogenous charge compression ignition (HCCI) and partially stratified diesel engine combustion.** In this project, partially synthetic high boiling point fuels (Figure 6) are being investigated experimentally in fully homogenous (HCCI) and partially stratified combustion in optically accessible test rigs; corresponding global/reduced reaction models are being developed. Particular emphasis is on the development of a numerical index that accurately characterizes the ignition propensity of these fuels, thus providing guidance on the engine development process.

| | Original Fuels | | | Surrogate Fuels | | |
|---|---|---|---|---|---|---|
| | **Low CN (≈38)** | **Mid CN (≈50-55)** | **High CN (≈70)** | **Low CN (≈38)** | **Mid CN (≈50-55)** | **High CN (≈70)** |
| Non-Oxygenated | CN 39.6<br>57.5%$_{Vol}$ DK B0 +<br>42.5%$_{Vol}$ Eurosuper | CN 55.6<br>DK B0-1 | CN>74.6<br>HVO | **PRF41** (CN 39.6 )<br>41%$_{Vol}$ iso-Octane +<br>59%$_{Vol}$ n-Heptane) | **n-Heptane**<br>(CN 55.28) | **n-Decane**<br>(CN 76) |
| | - | CN 55.8<br>DK B0-2 + EHN | - | - | **TRF 7.3** (CN 51.42)<br>92.7%$_{Vol}$ n-Heptane +<br>7.3%$_{Vol}$ Toluene | - |
| Oxygenated | CN 36.5<br>66.5%$_{Vol}$ DK B0 +<br>33.5%$_{Vol}$ ETBE<br>(4.4%$_{Mass}$ $O_2$ content) | CN 55.2<br>64%$_{Vol}$ DK B0 +<br>36%$_{Vol}$ RME<br>(4.2%$_{Mass}$ $O_2$ content) | - | **BVP 31.8** (CN 37.8)<br>68.2%$_{Vol}$ n-Heptane +<br>31.8%$_{Vol}$ n-Butanol<br>(7.67%$_{Mass}$ $O_2$ content) | **BVP 9.1** (CN 50.05)<br>90.9%$_{Vol}$ n-Heptane +<br>9.1%$_{Vol}$ n-Butanol<br>(2.29%$_{Mass}$ $O_2$ content) | - |

Fig. 6 Original Fuels (left) and Corresponding Surrogate Fuels (right) Being Investigated for HCCI and Partially Stratified Diesel Engine Combustion

**Investigation of diesel and "dual-fuel" combustion processes at engine-relevant conditions with laser-based optical measurement techniques.** The advancement of dual-fuel engines is an attractive solution for both compliance with future emissions standards with optimized efficiency and for increasing fuel flexibility. However, the fundamental in-cylinder

phenomena at engine-relevant conditions need to be better understood. Advanced laser-based optical techniques at experimental test rigs for investigations at challenging high pressure and temperature conditions will be implemented (Figure 7).


Fig. 7 Large Engine Research Facility at Paul Scherrer Institute (PSI) in Switzerland with a Test Rig for a 1.2-MW Mechanical Output Diesel Engine

## *Outlook*

The doubling of the use of biodiesel and ethanol in 2014 is a promising signal for an increasing share of biofuels in the total amount of motor fuels. An important driver is the obligation of the petrol industry to compensate 10% of $CO_2$ emissions via domestic measures. Constraints on increasing the use of renewable motor fuels might be caused by the high requirements for tax relief for and a lack of regulations on blending fossil fuel with biodiesel or ethanol. Other than the support for tax exemptions and tax reductions, there is currently no strong political support for using biofuels in the transportation sector in Switzerland.

Food production has priority over fuel production in Switzerland because the country's areas for agricultural production are limited. Waste is thus preferred for the production of biofuels for ecological reasons. The barriers to introducing natural gas and biogas into the market are even higher — the need of special engines for bi-fuel use and building up a filling station infrastructure.

The target of Swiss Energy Strategy 2050, however, is to increase the amount of renewable energy and reduce $CO_2$ emissions. Drivers for increasing the amount of advanced and sustainable motor fuels could be the regulations as foreseen in Energy Strategy 2050. But they are also drivers for hybrid and electric vehicles. Additional grants for energy research will encourage much research related to the production and use of advanced motor fuels. Important fields of research are wood methanation, power-to-gas,[2] and flexible fuel combustion. [19]

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**Major Changes**

[2] "Power to gas" is a pathway envisioned to balance electricity production and demand by converting electric power to gaseous fuel, through electrolysis production of hydrogen and oxygen.

The consumption of biodiesel and ethanol almost doubled compared to 2013. A driver for this significant increase is the requirement that motor fuels importers compensate 2% of $CO_2$ emissions. This requirement will increase up to 10% by 2020.