IEA-Advanced Motor Fuels
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Switzerland

Technology Collaboration Programme
by iea

Switzerland

Drivers and Policies

The key basis of Swiss energy policy is the article on energy enshrined in the Federal Constitution since 1990. The Energy Act, the CO_2 Act, the Climate and Innovation Act, and the Electricity Supply Act all build on this article and together form the body of legislation on which Switzerland's sustainable and modern energy policy is based.

In 2017, the Swiss public voted in favour of the revised Energy Act.[1] This act was the first step in implementing the 2050 Energy Strategy, which contains the following objectives:

- Increase energy efficiency;
- Promote renewable energy in Switzerland; and
- Phase out nuclear power.

While existing nuclear power plants can remain in operation as long as they are safe, Switzerland has banned construction of new nuclear power plants.

At the end of 2020, the Federal Department of the Environment, Transport, Energy and Communications (DETEC) published its Energy Perspectives 2050+.[2] This document further develops the 2050 Energy Strategy by identifying technological paths in a series of scenarios, which outline the objectives of both energy policy (a secure and largely renewable energy supply by 2050) and climate policy (net zero emissions by 2050).

Laws are periodically adapted to address new boundary conditions or strengthened to reflect recent developments. New or revised acts are subject to an optional referendum and can be rejected by the public, as happened to the revised CO_2 Act,[3] which was rejected in June 2021. On March 15, 2024, an amended version of the revised CO_2 Act was passed by Parliament and brought into force.

Based on an initiative submitted in November 2019, the Federal Council adopted a Federal Act on Climate Protection Goals, Innovation and Strengthening Energy Security.[4] After the Act passed the parliament in June 2022, opponents successfully filed a referendum against it. But in June 2023, the Swiss public voted (with 59.1%) in favor of this new Federal Act, which creates a framework for Swiss climate policy and sets interim targets for reducing greenhouse gas (GHG) emissions by 2050.

The draft Federal Act on a Secure Electricity Supply from Renewable Energy Sources[5] was approved by the Federal Council in June 2021. The draft Act is based on the conclusions of Energy Perspectives 2050+ and results from a revision of the Energy Act and Electricity Supply Act. The key aim is to strengthen Switzerland's security of supply, particularly in the winter months, by expanding domestic renewable electricity production and setting binding expansion targets and energy consumption reduction targets. The bill was passed by Parliament in September 2023. Because a referendum was successfully filed against it, a public vote was held in June 2024. The revision of the Acts was accepted with 68.7% approval.

CO_2 Emission Regulations for Cars

Carbon dioxide (CO_2) emissions regulations for new cars apply in Switzerland just as they do in the European Union (EU). Until 2020, the measurement procedure and limit values of the New European Driving Cycle (NEDC) applied. Since 2021, the CO_2 emissions of vehicles have been determined according to the WLTP (World Harmonized Light-Duty Vehicles Test Procedure). The average CO_2 emissions of newly registered passenger cars must not exceed 118 g CO_2/km. This target decreases to 93.6 g CO_2/km in 2025 and to 49.5 g CO_2/km in 2030. A CO_2 target regulation for heavy-duty vehicles (HDVs) will also come into force for the first time in 2025. Importers of new HDVs must reduce average emissions by 15% compared with the reference values set out in the EU regulation and by 30%

1 Fedlex, Energy Law SR 730.0, https://www.fedlex.admin.ch/eli/cc/1999/27/de
2 Swiss Federal Office of Energy (SFOE), "Energy perspectives 2050+," https://www.bfe.admin.ch/bfe/en/home/policy/energy-perspectives-2050-plus.html/.
3 Fedlex, 641.71: Federal Act on the Reduction of CO_2 Emissions, https://www.fedlex.admin.ch/eli/cc/2012/855/en.
4 Federal Act on Climate Protection Goals, 2022, "Innovation and Strengthening Energy Security."
5 SFOE, 2021, "Federal Act on a Secure Electricity Supply from Renewable Energy Sources."

beginning in 2030. Each importer's vehicle fleet must comply with an individual target based on these values. If the target is exceeded, the importer will pay a penalty.

The average CO_2 emissions of all cars in 2023 amounted to around 112.7 g CO_2/km — more than 8 grams lower than in 2022 (120.9 g CO_2/km) and, for the first time, well below the target value of 118 g CO_2/km (Figure 1). This emissions reduction had a positive effect on the penalty, which dropped from EUR 16.4 million (USD 17.2 million) in 2022 to EUR 1.82 million (USD 1.97 million) in 2023.[6] This reduction is attributable to the further electrification of the Swiss new passenger car fleet. The proportion of new electric (20.7%) and new hybrid passenger cars (36.7%) amounted to 57.4% in 2023.

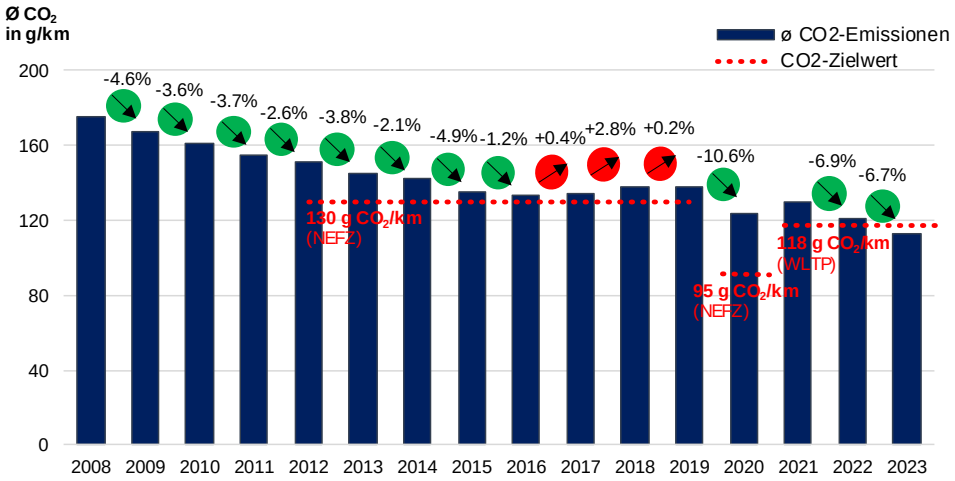

Figure 1. Average annual CO_2 emissions of passenger cars registered for the first time and reduction rates from 2008–2023. The arrows and percentages show the change compared with the previous year.

CO_2 Emissions Compensation: Motor Fuels

Importers of fossil motor fuels are required to compensate a certain amount of the CO_2 emissions (regulated by the CO_2 ordinance per year) caused by transport. They may conduct their own projects or acquire certificates. The compensation rate in 2023 was 20%; the rate increased to 23% in 2024.[7] A minimum of 15% must be compensated by domestic measures. The Swiss Petroleum Association established the Foundation for Climate Protection and Carbon Offset (KliK), which launches and subsidizes projects to reduce CO_2 emissions in fields such as transportation, industry, buildings, and agriculture. Another measure to reduce CO_2 emissions is to blend fossil fuels with biofuels. Because Switzerland is under no legal obligation to blend fossil fuels, emissions compensation is the only driver for blends.

Mineral Oil Tax Reduction for Natural Gas and Biofuels

To support the target for CO_2 emissions, a reduction — or even an exemption — for environmentally friendly motor fuels was enacted in 2008. Biofuels that satisfy minimum environmental and social requirements are completely or partially exempt from the mineral oil tax. As a result, the tax reduction for biofuels is up to EUR 0.77 (USD 0.83) per liter, compared with fossil fuels. The mineral oil tax reduction is valid until the end of 2030.[8] To offset the loss of tax revenue from this tax cut, the fossil fuel tax will be gradually increased until 2037.

6 SFOE, 2024, "Vollzug der CO_2-Emissionsvorschriften 2023."
7 FOEN (Federal Office for the Environment), https://www.bafu.admin.ch/bafu/en/home/topics/climate/info-specialists/reduction-measures/compensation/motor-fuels.html.
8 Mineralölsteuergesetz (MinöStG), Stand: March 15, 2024.

Advanced Motor Fuels Statistics

The following numbers and statements are based on 2023 statistics.

Energy and Fuels

Final total energy consumption in Switzerland in 2023 amounted to 767,450 terajoules (TJ), which represents a small increase of 0.3% compared with the previous year. The 5-year comparison (2019 vs. 2023) shows a decrease in Switzerland's total energy consumption of 8.7%, which corresponds to 66 TJ. The decline was mainly caused by reduced use of petroleum products and natural gas (minus 70.1 TJ or 15.7 %). In the case of petroleum products, there was a decrease of 9.7% in use of motor fuels and 27% in use of heating oil. The decline in natural gas use was 21%. The climatic differences between 2019 and 2023 (calculated using the heating degree index [HDD]) show a lower heating demand of 7.8%. In summary, the climate-adjusted consumption of fossil fuels has fallen by approximately 15%. Electricity consumption increased only slightly, by 4.1 TJ or 2.0%, during this period.

Gasoline and diesel consumption increased by a total of 0.3% (gasoline +3.3%, diesel -2.1%). Sales of aviation fuels rose by 15.9% compared with 2022 — but were still 13.8% lower than in 2019. Overall, fuel consumption was 4.7% higher than in 2022. Transport fuels account for 35% of total Swiss energy consumption; all fossil fuels were imported (Figure 2).

When importers of fossil motor fuels began blending fossil fuels with biofuels in 2014, the use of liquid biofuels rose from 29.4 million liters in 2014 to 251.3 million in 2023.

In 2023, 152.4 million liters of biodiesel and 98.7 million liters of bioethanol were used (see Figure 3). Hydrotreated vegetable oil (HVO) has been used in Switzerland only since 2016, achieving a maximum in 2018 with 34.1 million liters and dropping to 5,000 liters in 2022. In 2023 we see a slight increase to 185,000 liters. Pure vegetable oil fuel use is almost negligible (24,000 liters). Upgraded biogas as a transport fuel remained at a low level (2.4 million kg).[9]

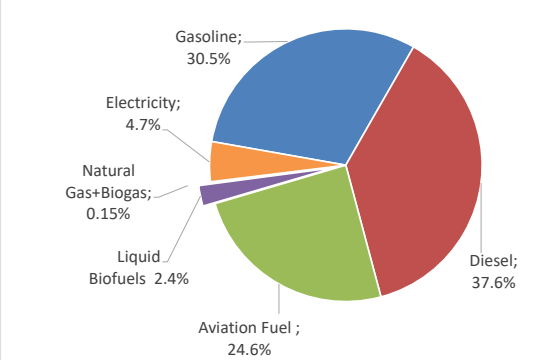

Figure 2. Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland, 2023[10]

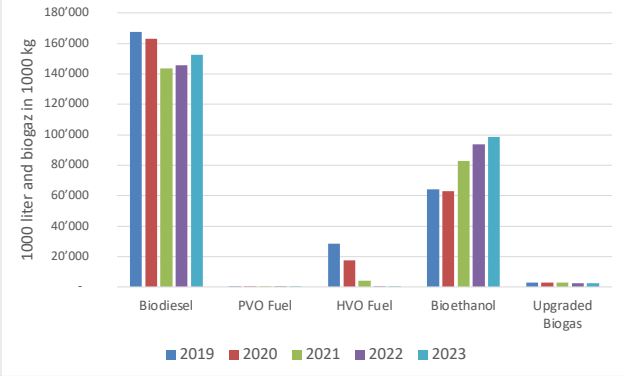

Figure 3. Use of Biofuels as Motor Fuels in Switzerland, 2019–2023

Only 14.5 million liters of biodiesel were produced in Switzerland; the remaining 137.9 million liters were imported (Germany, 65.2%; China, 11.9%; Austria, 10.1%; France, 8.2%; Japan, 4.0%; Greece, 0.2%;). All bioethanol is imported (Poland, 35.7%; Germany, 15.8%; Italy, 15.1%; Sweden, 11.4%; The Netherlands, 9.9; Norway, 4.9%; United States, 4.6%; Ukraine, 2.6%).[11] The small amount of HVO used in Switzerland is imported from Austria and Finland.

9 SFOE, 2024, "Schweizerische Statistik erneuerbarer Energien 2023."
10 SFOE, 2024, "Gesamtenergiestatistik 2023."
11 Swiss Custom Administration, 2024, "T2.8 Biogene Treibstoffe 2023."

The total amount of biogas produced and used in Switzerland in 2023 was 134.0 million kg. Only 33.3 million kg has been upgraded and fed into the natural gas grid. Of this, 2.4 million kg has been sold as biogas for cars, and the remainder (92.8%) was used for heating residential buildings or in industry. Compared with the amount produced, demand for biogas as a motor fuel is very low. A total of 6.9 million kg of natural gas was used as fuel — 28.2% less than in 2019 (Figure 4).

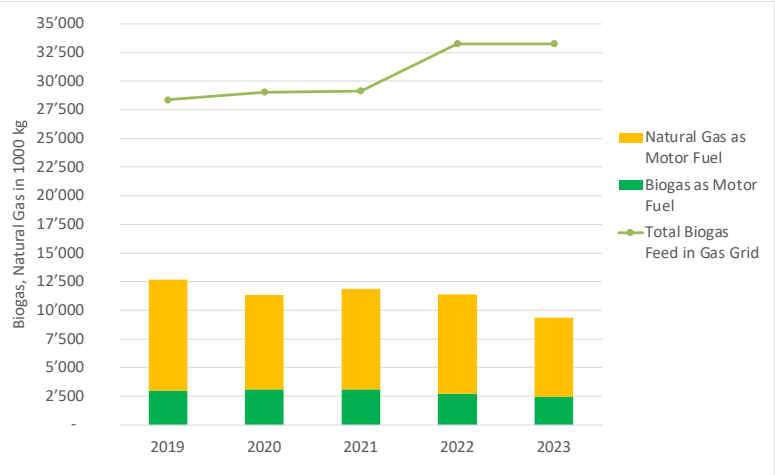

Figure 4. Development of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

Motor Vehicles

In 2023, 356,538 motor vehicles were newly registered in Switzerland, representing an increase of 10.6% over 2022 and a decrease of 12.9% compared with 2019. New registrations of passenger cars increased by 11.6%. The number of newly registered hybrid cars rose 23.7%, and electric car registrations increased by 30.7%. Sales of gasoline-fueled cars decreased slightly (by 1.2%), and sales of diesel-fueled cars dropped by 10.0%. Compared with 2019 totals, sales of cars powered only by fossil fuels declined by 59.8%. In contrast, sales of hybrid vehicles rose by 256%, and sales of electric vehicles increased by 302% in the same period (Figure 5).

Despite the steep rise in sales of electric and hybrid passenger cars, their share of the total (4,760,948) is still very small. Figure 6 illustrates this fact, using passenger cars as an example. Hybrid vehicles have a share of 7.6% of the total passenger car fleet, whereas the share of electric vehicles amounts to 3.3%. Most of the electricity used in the transport sector (85%) is for railroad transportation (Figure 2).

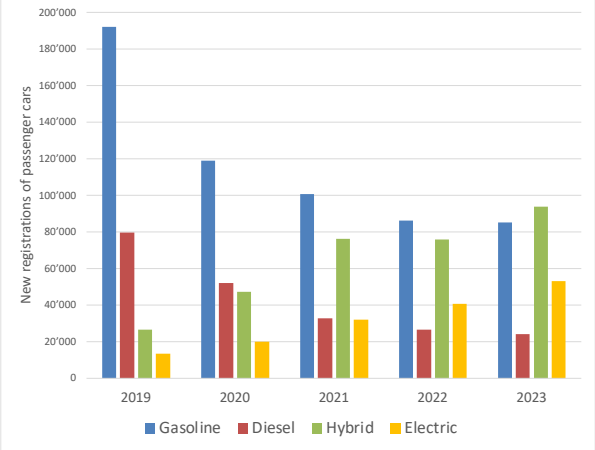

Figure 5. New Registrations of Passenger Cars by Fuel

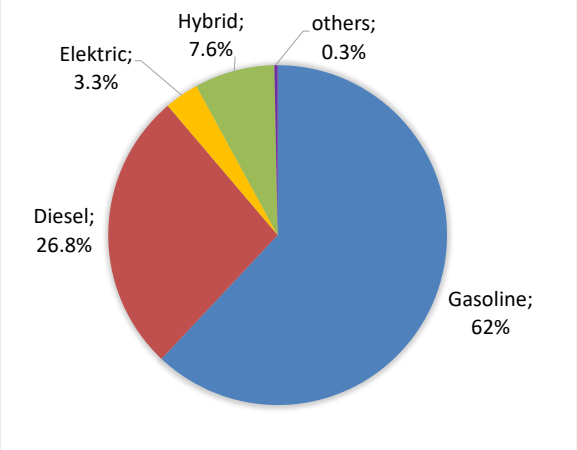

Figure 6. Passenger Car Share by Fuel, 2023 (Total Number is 4,760,948)

Research and Demonstration Focus

The SFOE has three funding schemes for subsidiary support of energy-related projects.

- The main focus of the Energy Research Programme is on development and application.
- The Pilot and Demonstration Programme promotes the testing and implementation of new technologies, solutions, and concepts.
- The purpose of the SWEET ("**SW**iss **E**nergy research for the **E**nergy **T**ransition") Programme is to accelerate innovations that are key to implementing Switzerland's Energy Strategy 2050 and achieving the country's climate targets.[12]

The overarching goals of all funded projects are to foster energy security, energy efficiency, decarbonization, and renewable energies.

The federal government's planned cost-cutting measures will reduce the budget for energy research and cut the program for pilot and demonstration projects. These cuts particularly affect combustion research, which also includes advanced motor fuels.

According to Scenario ZERO Basis (of the Swiss Energy Perspectives 2050+), after 2050, the transport sector should be operated without fossil fuel. That means reductions from 197.3 PJ gasoline, diesel, and natural gas plus 7.2 PJ biofuels and 13.7 PJ electricity in 2023 to 71.9 PJ renewable fuels and 60.7 PJ electricity in 2050 (data without fuels for aviation, which totaled 71.2 PJ in 2023). Figure 7 displays final energy demand.

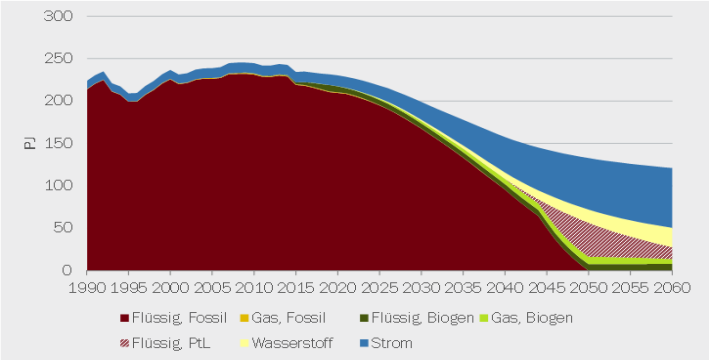

Figure 7. Final Energy Demand of Domestic Transport (Scenario ZERO Basis, Excluding International Aviation)[13]

Therefore, in the transport sector, the priority is electrification of passenger cars, public transport, the municipal sector, and freight transport and the use of non-fossil fuels for the rest. The projects mentioned below cover the production, storage, and distribution of the fuels, as well as their highly efficient use in internal combustion (IC) engines and exhaust gas after-treatment. The combustion and engine-relevant properties of biogas, hydrogen (H_2), methanol (MeOH), dimethyl ether (DME), and ammonia (NH_3) are also investigated.

SWEET refuel.ch: Renewable Fuels and Chemicals for Switzerland (2023–2030)[14]

To comply with the ambitious timeline of Swiss renewable energy and GHG emission targets, accelerated market development of sustainable fuels and platform chemicals is necessary. While first-generation technology is available to initiate a ramp-up, this is not the case for policies, laws, regulations, and markets (non-technical aspects). A first aim of the SWEET reFuel.ch project to investigate how investment security can be improved by closing this knowledge gap. A second aim is to strengthen innovative technologies currently at low technology readiness levels (TRLs). This goal will be achieved by focusing on green methanol pathways and other technologies with breakthrough potential for sustainable fuel and platform chemical production.

12 SFOE, "Energy Strategy 2050," https://www.bfe.admin.ch/bfe/de/home/politik/energiestrategie-2050.html.
13 SFOE, 2022, *Energy Perspectives 2050+*, Technical Report.
14 Swiss Federal Office of Energy, "SWEET: reFuel.ch," https://www.sweet-refuel.ch/.

NH_3 ICE ammonia combustion engine (2023–2027)
Ammonia is primarily considered for powering large marine engines. In this project, currently being conducted by Liebherr Machine Bulle SA, ammonia will be used for medium- to high-speed engines for mining machinery, smaller marine vessels, or cogeneration. A Liebherr prototype ammonia/ hydrogen 4-stroke engine — fully equipped with sensors, fuel injection system, and open electronic control unit — was installed at the experimental facilities of R&D Moteurs in France. The research team will quantify ammonia slip and nitrous oxide (N_2O) emissions and perform emission measurements of secondary and particulate formations.

E-Methanol compression-ignition combustion (2023–2027)[15]
Renewable methanol is a technically and economically promising solution to achieve net-zero CO_2-free IC engines for applications that cannot be electrified. The novelty, compared with existing methanol engines, is the use of a compression-ignition process (quasi "methanol diesel engine") to achieve the highest efficiency and power density. The researchers will evaluate the feasibility and limitations of e-methanol using an optically accessible test bench to investigate the underlying mechanisms under relevant pressure, temperature, and flow conditions, as well as different injection strategies. In addition, researchers will evaluate ignition-promotion concepts that could be required.

Exhaust analytics for low GHG impact fuels (2023–2025)[16]
This project will investigate the exhaust gas emissions of different combustion processes using (renewable) low-GHG fuels. A flexible engine test facility is used to examine the application of such fuels (i.e., methanol, ammonia) under engine-relevant pressure, temperature, and flow conditions, as well as varying combustion processes. The research team is assessing the use of appropriate exhaust gas analytical instrumentation to ensure that the emissions data obtained during engine development can be validated. The project will provide a coordinated input to the regulatory and standardization debate so that the IC engine industry can recommend emission analysis technologies to the regulatory authorities.

Combustion system with alternative pre-chamber fuels (2024–2026)[17]
The need to make IC engines more efficient, while reducing emissions and improving their ability to operate reliably with new synthetic fuels, has led to the development of a new, advanced combustion process: Spark-Assisted Compression-Ignition (SACI). Combined with an active pre-chamber, SACI can reliably control the auto-ignition of the premixed cylinder charge, resulting in an efficient combustion process suitable for new, difficult-to-burn synthetic fuels or very lean air-fuel mixtures. The aim of this project is to investigate the influence of the reactivity of the pre-chamber fuel on the hot reactive jets and the subsequent (partial) auto-ignition of the main chamber charge. Hydrogen is used for high reactivity and ammonia for low reactivity in the pre-chamber.

N_2O Exhaust Gas Treatment in Ammonia Engines II (2024–2027)[18]
NH_3 is considered a promising fuel for large engines and, in particular, for international shipping applications, because no CO_2 is produced from its combustion. However, high concentrations of the pollutants NOx, NH_3, and N_2O have been measured on prototypical large engine setups. The aim of this continuation project is to follow up on analysis and understanding of catalyst behavior in the complex exhaust gas containing these components, allowing researchers to propose recommendations to reduce pollutant emissions from prospective NH_3-fueled engines. Researchers are studying catalysts based on Fe-exchanged zeolites by analyzing the influence of acidic properties on catalytic activity, as well as by exploring the effects of hydrothermal and chemical aging. In addition, the exhaust gas composition of real NH_3 engines is considered, for example by including other pollutants such as hydrocarbons in the model gas investigations in the laboratory.

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15 FHNW ITFE (University of Applied Sciences Northwestern Switzerland, Institute of Thermal and Fluid Engineering), "EMOCION – E-Methanol Compression Ignition Combustion," project 502699 in ARAMIS (Administration Research Actions Management Information System), https://www.aramis.admin.ch/Texte/?ProjectID=53959.

16 FHNW ITFE, "EXHALE – Exhaust Analytics for Low GHG Impact Fuels," project SI/502712 in ARAMIS, https://www.aramis.admin.ch/Texte/?ProjectID=54053.

17 FHNW ITFE "SACI II – Combustion system with alternative pre-chamber fuels," project 502840 in ARAMIS, https://www.aramis.admin.ch/Texte/?ProjectID=55940.

18 PSI (Paul Scherrer Institute), "N_2Ooff II – N_2O exhaust gas treatment in ammonia engines – II," project SI/502902 in ARAMIS, https://www.aramis.admin.ch/Texte/?ProjectID=56158.

Outlook

The share of electric or plug-in hybrid cars in Switzerland continues to rise: their sales share was 28.0% in 2024. The demand for large electric vehicles for municipal use, local public transport, and freight transportation is also increasing. The demand for fossil fuels will therefore further decrease, and electricity consumption will increase. The number of charging stations for electric vehicles is growing commensurably with the growing fleet of electric vehicles.

For the remaining transport systems powered by combustion engines (still part of long-distance transport, maritime transport, various off-road applications, and combined heat and power), research institutes and industry are looking for the most suitable solutions using renewable fuels. The focus here is primarily on H_2, but also on NH_3, methanol, and DME. The challenge is that it is not yet clear which of these fuels is the most suitable and will prevail.

Cooperative research and development around renewable fuels and their use in combustion systems is therefore important. Just as for electromobility, the systems for supplying renewable fuels must also be set up in good time and, where possible, the existing ones must be converted. The production and procurement of non-fossil fuels are also of great importance here.

Major changes
In June 2024, the Swiss public voted in favour of the new Act on a Secure Electricity Supply from Renewable Energy Sources.

In 2023, sales of motor vehicles increased by 10.6% compared with 2022. Sales of gasoline- and diesel-fueled passenger cars declined by 3.3%; sales of hybrid cars rose by 23.7%; and 30.7% more electric passenger cars were sold. A total of 255,900 passenger cars were sold in 2023. Of these, 42.6% were gasoline- and diesel-fueled vehicles, 36.7% were hybrid vehicles, and 20.7% were electric vehicles. These sales had a positive effect on the average CO_2 emissions from newly registered passenger cars, which at 112.7 g CO_2/km were below the target value of 118 g CO_2/km for the first time!

Sales of biofuels increased slightly but remain low (3.5%) compared with the consumption of diesel and gasoline.

Benefits of participation in AMF
The future of IC engines depends, among other things, on the successful market introduction of reduced-CO_2 fuels. The AMF TCP is a pioneer in researching and describing novel fuels and their application, benefits, and effects in terms of efficiency and emissions. AMF is a unique source of information and a platform for international exchange of experience and cooperation.