IEA-Advanced Motor Fuels
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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 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.

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 passing the parliament in June 2022, opponents successfully filed a referendum against it. But in June 2023, the Swiss public voted in favour 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 Act also includes incentives to encourage the replacement of fossil-fuel heating systems with climate-friendly ones and the replacement of electric heating systems that still consume a lot of power in winter. All these measures contribute to Switzerland's energy security. In addition, the Climate and Innovation Act supports businesses that invest in innovative, climate-friendly technologies within a given timeframe.

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 will be held in June 2024.

CO_2 Emission Regulations for Cars

Carbon dioxide (CO_2) emissions regulations for new cars apply in Switzerland just as they do in the remainder of the European Union (EU). For the first time, in 2021, under the World Harmonised Light-Duty Vehicles Test Procedure (WLTP), the average level of emissions from cars registered in Switzerland could not exceed 118 g CO_2/km, while the maximum level of CO_2 emissions from delivery and light articulated vehicles (collectively referred to as *light commercial vehicles)* was 186 g CO_2/km.

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1 Fedlex, Energy Law SR 730.0, https://www.fedlex.admin.ch/eli/cc/1999/27/de

2 Swiss Federal Office of Energy, "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 Law on Climate Protection Goals, Innovation and Strengthening Energy Security, 2022.

5 SFOE (Swiss Federal Office of Energy), 2021, Federal Act on a Secure Electricity Supply from Renewable Energy Sources.

These targets correspond to those previously applied based on the New European Driving Cycle (NEDC) measurement procedure of 95 g CO_2/km for new cars and 147 g CO_2/km for new light commercial vehicles. 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. In 2022, the average CO_2 emissions from passenger cars were 120.9 gCO_2/km, exceeding the target value by only 2.9 g CO_2/km and decreasing by 8.9 gCO_2/km compared with 2021 levels (129.8 g CO_2/km) (Figure 1). This emissions reduction had a positive effect on the penalty, which dropped from EUR 26.0 million (USD 30.7 million) in 2021 to EUR 16.4 million (USD 17.2 million) in 2022.[6] The narrowing of the gap between the target maximum CO_2 emissions and the emissions of newly registered vehicles was influenced primarily by a significant decline in sales of gasoline and diesel vehicles and a marked increase in hybrid and electric vehicle sales.

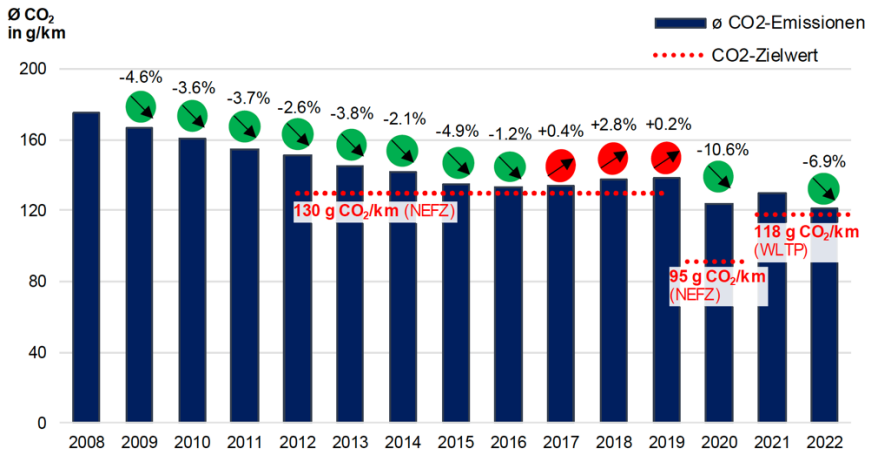

Figure 1. Average annual CO_2 emissions of passenger cars registered for the first time and reduction rates from 2008–2022. The arrows and percentages show the change compared with the previous year.

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 2021 was 12%, which will rise to 23% in 2024.[7] In 2022 and beyond, 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 now EUR 0.69 (USD 0.82) per liter, compared with fossil fuels. The mineral oil tax reduction is valid until the end of 2024.[8] To offset the loss of tax revenue from this tax cut, the fossil fuel tax will be gradually increased until 2028. These measures will be continued with the revision of the CO_2 Act.

6 SFOE, 2022, "Vollzug der CO_2-Emissionsvorschriften 2021."

7 BAFU (Bundesamt für Umwelt) (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: January 1, 2022.

Advanced Motor Fuels Statistics

The following numbers and statements are based on 2022 statistics.

Energy and Fuels

Final total energy consumption in Switzerland in 2022 amounted to 765,070 terajoules, which represents a decrease of 3.9% compared with the previous year. Consumption was impacted by the Russian invasion of Ukraine on 24 February 2022, which led to major uncertainties in Switzerland's energy supply and government calls for savings. Warmer weather also played a role. Compared with the previous year, the heating degree day index (HDD index) was 18.4 % lower, which resulted in a correspondingly lower heating energy requirement: heating oil: -19.5%, natural gas: -17.0%.

Gasoline and diesel consumption decreased by a total of 1.4% (gasoline -2.9%, diesel -0.2%). Sales of aviation fuels increased markedly — by 76.1% — but were still 26.2% lower than in 2019 (i.e., before the coronavirus pandemic). Overall, fuel consumption was 9.9% higher than in 2021. Transport fuels account for 33.5% of total Swiss energy consumption; all fossil fuels were imported (Figure 2).

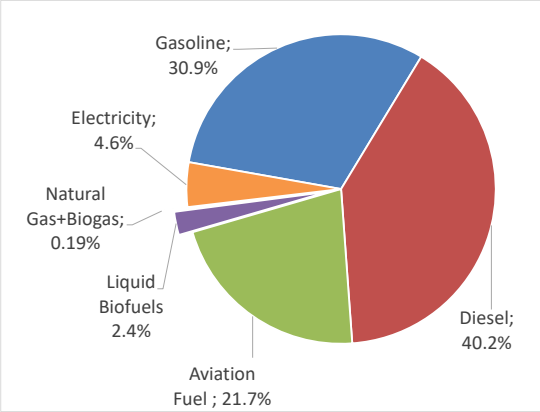

Figure 2. Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland, 2022[9]

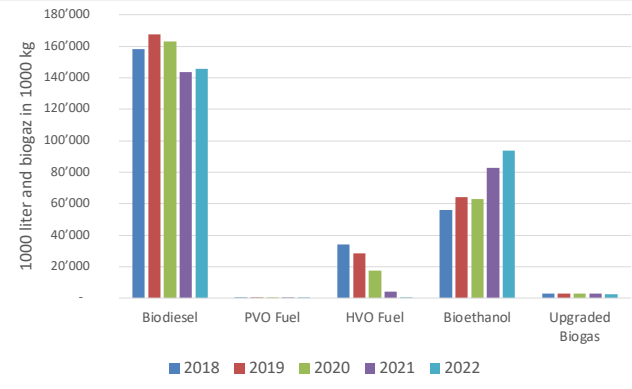

Figure 3. Use of Biofuels as Motor Fuels in Switzerland, 2016–2020

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 239.5 million in 2022.

In 2022, 145.6 million liters of biodiesel and 93.6 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. Pure vegetable oil fuel use is also almost negligible (39,000 liters). Upgraded biogas as a transport fuel remained at a low level (2.7 million kg).[10]

Only 14.1 million liters of biodiesel were produced in Switzerland; the remaining 131.5 million liters were imported (Germany, 71.8%; France, 14.6%; Austria, 7.9%; Japan, 3.9%; Greece, 1.1%; China, 0.7%;). All bioethanol is imported (Poland, 31.0%; The Netherlands, 18.5; Germany, 11.7%; Italy, 15.1%; Sweden, 12.0%; Norway, 4.8%; United States, 3.1%; Austria, 2.6%; Belgium, 1.2%).[11] The small amount of hydrotreated vegetable oil used in Switzerland is imported from Sweden.

The total amount of biogas produced and used in Switzerland in 2022 was 134.0 million kg. Only 33.3 million kg has been upgraded and fed into the natural gas grid. Of this, 2.7 million kg has been sold as biogas for cars, and the rest for heating. Almost all biogas used as motor fuel in cars is upgraded biogas fed into the natural gas grid. Figure 3 shows the development of the use of biogas and natural gas as motor fuels in cars. Despite an increasing amount of biogas fed into the natural gas grid, the demand for it as a motor fuel remains low: 91.9% of biogas is used for residential heating.[12]

9 SFOE, 2022, "Gesamtenergiestatistik 2021."
10 SFOE, 2022, "Schweizerische Statistik erneuerbarer Energien 2021."
11 Swiss Custom Administration, 2022, "T2.8 Biogene Treibstoffe 2021."
12 Association of the Swiss Gas Industry, 2022, "VSG-Jahresstatistik."

Motor Vehicles

In 2022, 322,387 motor vehicles were newly registered in Switzerland, representing a decrease of 7.8% over 2021 and 21.1% less than in 2019. New registrations of passenger cars decreased by 5.2%. The number of newly registered hybrid cars was almost the same (-0.5%) and electric cars (+26.5%) rose again. Sales of gasoline-fueled cars dropped by 14.4%, and sales of diesel-fueled cars dropped by 18.5%. Compared to 2019 totals, sales of those cars declined by 58.5% (Figure 4).

Despite the steep rise in sales of electric and hybrid passenger cars, their share of the total (4,721,280) is still very small. Figure 5 illustrates this fact, using passenger cars as an example. Hybrid vehicles have a share of 6.0% of the total passenger car fleet, whereas the share of electric vehicles amounts to 2.3%. Most of the electricity used in the transport sector is for railroad transportation.

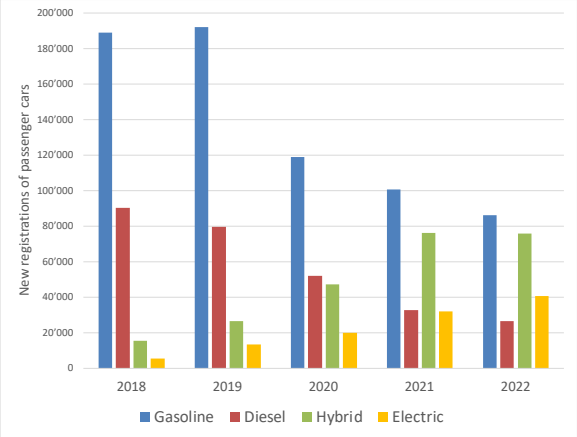

Figure 4. New Registrations of Passenger Cars by Fuel

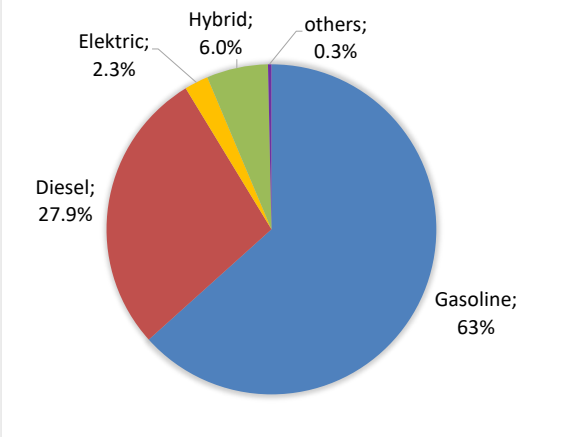

Figure 5. Passenger Car Share by Fuel, 2022. Total Number is 4,721,280

Research and Demonstration Focus

The Swiss Federal Office of Energy (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.[13]

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

According to Scenario ZERO Basis (of the Swiss Energy Perspectives 2050+), after 2050, the transport sector should be operated without fossil fuel. That means a reduction from 196.8 petajoules (PJ) gasoline, diesel, and natural gas plus 6.9 PJ biofuels and 12.8 PJ electricity in 2022 to 71.9 PJ renewable fuels and 60.7 PJ electricity in 2050 (data without fuels for aviation, which totaled 59.9 PJ in 2022). Figure 6 displays final energy demand.

13 SFOE, "Energy Strategy 2050," https://www.bfe.admin.ch/bfe/de/home/politik/energiestrategie-2050.html.

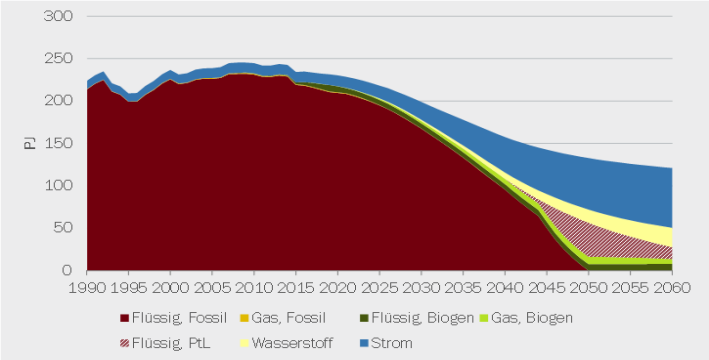

Figure 6. Final Energy Demand of Domestic Transport (Scenario ZERO Basis, Excluding International Aviation)[14]

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 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 investigated.

Sustainable Chemical Transport Fuels for Switzerland (2021–2024)[15]
This project investigates the role and perspectives of sustainable chemical transportation fuels within a net-zero Swiss energy system. It includes a techno-economic, environmental, and social life-cycle assessment of a comprehensive portfolio of chemical fuels — including hydrogen, biogenic, sun-to-liquid, and power-to-gas/liquid fuels. The results will be integrated into a scenario-driven energy system analysis. Because there are few sustainable primary energy resources for such fuel production in Switzerland, the analysis will be performed on a global level to identify plausible sources and locations for fuel production and import pathways.

E-Fuels: International Exchange of Research Findings and Activities (2021–2024)[16]
This project comprises an international exchange on the topic of e-fuels for transportation. Researchers will identify both the needs of the participating countries and their expertise. The exchange should enable individual countries to fill the knowledge gaps of other countries with their expertise and, conversely, benefit from the expertise of other countries. One goal of this project for Switzerland is to gain knowledge about e-fuels through the exchange at both the national and international level. This will enable Switzerland to get a picture of the state of development of e-fuels on a global level and identify research gaps. The products of this project are a compilation of previous findings from Switzerland and coordination of the international exchange of information. The project contributes to IEA AMF Task 64.

Recording and allocation of emission data in real road traffic using RES[17]
Remote emission sensing (RES) measures exhaust emissions by absorption spectroscopy in the wake of passing vehicles without interfering with traffic. This project focused on the numerical simulation of the distribution of exhaust gas components in the vehicle wake (Figure 7). Extensive numerical simulations have shown that the emission formation is contained in the 0.5- to 3-m downstream of the vehicle, independent of driving or environmental parameters. Further downstream, the dilution is too strong. This is an important requirement for the measurement frequency of the RES instruments. The project demonstrated the potential of hybrid large eddy simulation (LES)/Reynolds-averaged Navier–Stokes (RANS) simulations to improve the accuracy of exhaust cloud dispersion prediction. A direct correlation between the exhaust concentration measured by RES and the actual vehicle emission is

14 SFOE, 2022, Energy Perspectives 2050+, Technical Report
15 PSI Paul Scherrer Institute, “Sheltered – Sustainable chemical fuels for Switzerland,” https://www.aramis.admin.ch/Texte/?ProjectID=49507.
16 OST Ostschweizer Fachhochschule, “E-Fuels: International Exchange of Research Findings and Activities,” https://www.aramis.admin.ch/Texte/?ProjectID=49314.
17 Empa, “Collection and allocation of emission data in real road traffic using remote emission sensing,” https://www.aramis.admin.ch/Texte/?ProjectID=47374.

subject to larger uncertainties due to the instantaneous nature of the RES measurement and the measurement uncertainty of the instruments themselves. Experiments indicate a lack of coverage of truck exhaust clouds. The project contributes to IEA AMF Task 61.

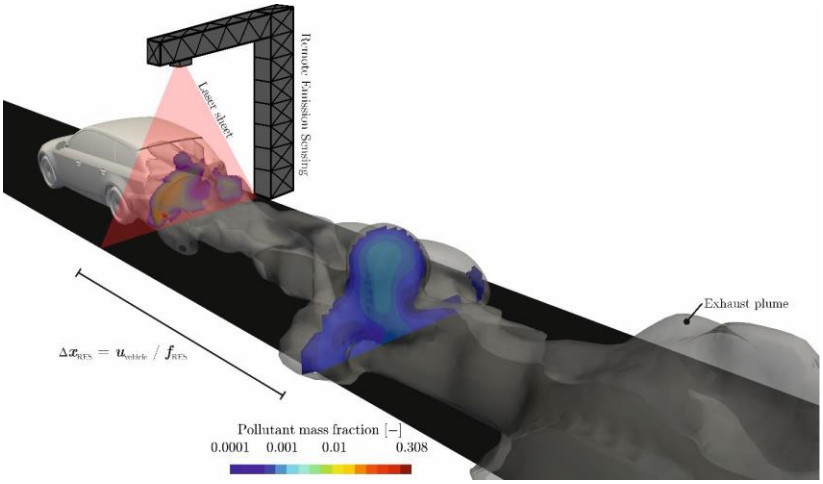

Figure 7. Measuring system and pollutant distribution behind the vehicle (J. Plogmann, Empa 2023)

SWEET refuel.ch: Renewable Fuels and Chemicals for Switzerland (2023-2030)[18]
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 (Renewable Fuels and Chemicals for Switzerland 23023–2030) project to investigate how investment security can be improved by closing this knowledge gap. reFuel.ch will develop robust and practical pathways for introducing sustainable fuels and platform chemicals to markets and the Swiss energy system using an inter- and transdisciplinary approach. This development will include inputs from social sciences (sociology, law, economics, and political science), natural sciences, and engineering, as well as dialogue with relevant stakeholders (i.e., policy makers, regulators, market actors, and end users). 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.

Efficient part-load operation of heavy duty DME engines (2022–2023)[19]
This project complements the investigations carried out in a previous project,[20,21] in which mainly high load conditions — typical for the operation of heavy-duty vehicles — were investigated with excellent results. At lower loads, difficulties arise due to the low temperature dosing limit of the exhaust gas after-treatment system. To solve this problem, researchers investigated partially premixed charge and compression ignition (PCCI) operation with late start of injection (SOI) and high exhaust gas recirculation (EGR) rates. The chosen strategy clearly shows that a high EGR in combination with a late SOI enables significantly lower fuel consumption losses than conventional exhaust gas flap operation. Lower NO_x emissions at the engine outlet also mean lower tailpipe emissions during the warm-up phase until the selective catalytic reduction (SCR) system is activated. Finally, the higher outside temperatures of the engine enable the dosing of the reducing agent for the SCR (w/AdBlue), so that Euro 7 and Tier 5 regulations can be achieved using a Euro 6-like aftertreatment system.

18 Swiss Federal Office of Energy, "SWEET: Sustainable Fuels," https://www.bfe.admin.ch/bfe/en/home/research-and-cleantech/funding-program-sweet/calls-for-proposals-overview/sweet-call-2-2022.html.
19 Empa, "HDV-DME-Part Load Efficient part-load operation of heavy duty DME engines," https://www.aramis.admin.ch/Texte/?ProjectID=51282.
20 FTP, "Efficient Diesel – Combustion chamber insulation for improved Diesel engine efficiency," https://www.aramis.admin.ch/Texte/?ProjectID=40682.
21 FPT, "HDV-DME – Investigation of the suitability of DME as an alternative fuel in HDV," https://www.aramis.admin.ch/Texte/?ProjectID=41773.

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 — is installed at the experimental facilities of the University of Nottingham. The research team will quantify ammonia slip and nitrous oxide (N_2O) emissions and perform emission measurements of secondary and particulate formations.

N_2O Exhaust Gas Treatment in Ammonia Engines (2022–2025)[22]
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 NO_x, NH_3, and N_2O can be released. This project aims to develop recommendations for exhaust after-treatment systems that reduce pollutant emissions from NH_3-fueled engines. Catalytic experiments will be performed in a wide range of pollutant concentrations and other feed components (e.g., O_2, H_2O) as well as temperatures in order to provide recommendations for after-treatment setups and catalyst compositions depending on these operating conditions. The project will include a general screening of suitable catalysts, but currently Fe-exchanged zeolites "seem most promising to remove N_2O and NO_x from exhaust gases with the help of NH_3".

E-Methanol Compression Ignition Combustion ("EMOCION") (2023-2027)[23]
Renewable methanol is a technically and economically promising solution for net-zero CO_2-free internal combustion 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. Feasibility and limitations need to be evaluated. An optically accessible test bench will be used to investigate the underlying mechanisms under relevant pressure, temperature, and flow conditions, as well as different injection strategies. In addition, researchers will evaluate possibly required ignition-promotion concepts.

Outlook

Sales of electric or plug-in hybrid cars are expected to account for at least 50% of new registrations as early as 2025. The demand for large electric vehicles for municipal use, local public transport, and freight transportation is also increasing. The demand for fuels will therefore decrease, and electricity consumption will increase. This poses an additional challenge for the renewable electricity supply in Switzerland, which will have to be greatly expanded anyway because of the planned gradual phase-out of nuclear energy. In addition, a large increase in the number of charging stations for electric vehicles is required.

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 clear which of these fuels is the most suitable and will prevail.

Cooperation between the 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 of great importance here.

[22] ETHZ ESC, "VADER – Value of sustainable fuels for the decarbonisation of Switzerland," https://www.aramis.admin.ch/Texte/?ProjectID=51133.
[23] AFHB, "Usage of LBG (Liquefied Biogas) for Heavy Duty Transport in Switzerland," https://www.aramis.admin.ch/Texte/?ProjectID=53959

Major changes
In June 2023, the Swiss public voted in favour of the new Act on Climate Protection Goals, Innovation and Strengthening Energy Security.

In 2022, sales of motor vehicles dropped by 7.9% compared with 2021. Sales of gasoline- and diesel-fueled passenger cars declined by 15.4%; hybrid remained the same; and 26.5% more electric passenger cars were sold. The share of gasoline and diesel vehicles sold in 2022 decreased to 49.2%, while hybrid vehicles accounted for 33.1%, and electric vehicles for 17.7%. These sales had a positive effect on the average CO_2 emissions from newly registered passenger cars, which exceeded the target value by 11.8 g CO_2/km and was 58.7% lower than in 2020 (28.6 g CO_2/km).

Sales of biofuels dropped slightly and remain at a very low level (3.3%) compared with the consumption of diesel and gasoline.

Benefits of participation in AMF
The future of internal combustion 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.