IEA-Advanced Motor Fuels

ANNUAL REPORT 2021

Technology Collaboration Programme

by IEA

Chairperson’s Message

Jesper Schramm, Chair of the AMF TCP

The Technology Collaboration Programme on Advanced Motor Fuels (AMF TCP) aims to reduce greenhouse gas (GHG) emissions and local air pollutant emissions from the transport sector while ensuring availability and affordability of transport fuels. The AMF TCP serves to inform and advise, with updated knowledge and information about transport fuels. Our activities consist mainly of creating collaboration tasks, where member countries combine their activities and skills to advance mutual goals. Our newsletters further this objective with short updates on the global and local situation.

In 2021, the International Energy Association (IEA) launched the report “Net Zero by 2050,” which is a roadmap for the global energy sector to reach zero emissions in 2050. For the transport sector, implementation of electric vehicles (EVs) is an important way forward. The global sales of new EVs was about 5% in 2020. According to the NZE scenario, this must increase to 60% in 2030. In 2035, sales of new internal combustion engine equipped vehicles (ICEs) will be zero and 50% of the heavy trucks will be EVs. In 2040, 50% of aviation fuels will need to be low-emission fuels.

The AMF group understands that EVs is a very essential element in the transition to a zero emission future. It is said in the report that the NZE scenario is only one example of a solution. There could be other solutions. It is quite clear that today the production of EVs is associated with higher CO_2 emissions than similar ICEs. If the future ICE vehicles operate on a CO_2 neutral fuel like biofuels or e-fuels, it is hard for me to see why this solution, which is at least close to the most climate-friendly solution, should not be part of the future road vehicle solution. It would be a natural activity for AMF to shed more light on this in our future work.

Important conclusions of the “Net Zero by 2050” report is that the future will rely on technology that has not been developed yet and it will require intensified international collaboration. Research and collaboration across TCPs have always been essential for AMF, and I am sure that the good spirit among people in AMF will enhance this further. I would like at this point to thank all participants in the AMF group for the good work that has been carried out in 2021 as well as in previous years.

Quite in line with the NZE report, AMF has initiated in 2021 the new tasks: “E-fuels and End-Use Perspectives” and “Sustainable Aviation Fuels.” Furthermore, the new task “Wear in engines using alternative fuels” was initiated in order to give a status on the experiences so far on engine wear issues associated with application of relevant alternative fuels for transportation.

Four tasks were reported and closed during 2021:

- Task 56: Methanol as a Motor Fuel – Review
- Task 57: Heavy Duty Vehicle Performance Evaluation
- Task 58: Transport Decarbonization
- Task 59: Lessons Learned from Alternative Fuels Experience

These tasks have all given important insight in fuels and emissions perspectives for transportation. I would like to highlight the conclusion from Task 58: “Bringing the GHG emissions of the road transport sector down to zero by 2050 cannot be achieved by one measure alone. Countries that deploy a set of different measures, such as reducing transport demand, improving vehicle efficiency, and adding renewable energy carriers such as biofuels, e-fuels, renewable electricity and renewable hydrogen have the best chances to meet ambitious decarbonization goals”.

The AMF work is moving somewhat from road transportation towards marine transport and aviation as a natural consequence of the electrification of road transportation. However, the way to reduce emissions from existing vehicles, which will be dominant for still quite some years, is through development of new fuels and ICE vehicle technology. Heavy trucks, ships and aircrafts will be depending heavily on new fuels if a zero emission future is to be reached. The AMF TCP will continue to provide sound scientific information and technology assessments facilitating informed and science-based decisions regarding advanced motor fuels on all levels of decision-making. We will evaluate the real-world performance of new fuel and technology platforms.

The Transport Coordination Group of IEA's Working Party on End-Use Technologies (EUWP) has proposed that all involved TCPs work on updating Argonne National Laboratory´s GREET (The Greenhouse Gases, Regulated Emissions, and Energy use in Technologies) model and expand it to further regions. AMF has identified one contribution on data on HDVs in Europe and one on marine fuels used in Europe. I very much foresee this to be an excellent way to progress in mutual TCP collaboration and "getting to know each other." So far, collaboration with the Combustion TCP, Bioenergy TCP and HEV TCP is an obvious and positive consequence.

AMF TCP's online seminars and workshops have become increasingly important since 2020 due to the COVID-19 pandemic. Going forward, I hope we will be able to have physical Executive Committee meetings and project seminars since this will maintain and encourage the good working environment that we have always had in AMF.

Vision

Advanced motor fuels, applicable to all modes of transport, significantly contribute to a sustainable society around the globe.

Mission

The mission of AMF is to advance the understanding and appreciation of the potential of advanced motor fuels toward transport sustainability. We provide sound scientific information and technology assessments facilitating informed and science-based decisions regarding advanced motor fuels on all levels of decision-making.

Highlights of Advanced Motor Fuels

Kim Winther, Subcommittee Strategy & Technology Chair

In the year 2021, the world was once again hit by Covid-19 variants. This put a major strain on international travel, which is good news in terms of reducing greenhouse gas emissions but bad news in terms of hosting in-person meetings. Within Advanced Motor Fuels (AMF), all physical meetings in 2021 were replaced by virtual meetings. Regardless, members discussed significant trends from around the world and they are highlighted here.

A major global milestone in 2021 was the launch of a global Carbon Intensity rating for larger marine vessels introduced by the International Maritime Organization (IMO) in line with the previously adopted main strategy to reduce GHG from shipping by 40% by 2030. This is one of many signs that the international marine industry is actively stepping up to the challenge of ship decarbonization.

One of the world's largest shipping companies, Maersk, announced in 2021 a build order for eight large, ocean-going vessels that will operate on methanol dual-fuel engines. This is a strong indication that the global marine industry believes in methanol as an advanced motor fuel for the future.

Ammonia engines are still in the test and development phase. In early summer 2021, the technology innovation company Wärtsilä initiated the world's first full-scale testing of ammonia as a fuel in a marine four-stroke engine. Later that year, a Norwegian shipowner agreed to retrofit a Wärtsilä ammonia engine to an offshore service vessel by early 2022. Other marine engine suppliers, such as MAN, are also working intensively on launching even larger two-stroke ammonia engines by 2024.

In July 2021, The European Union presented its "Fit-for-55" package, which is a broad package of climate-related legislative initiatives. The FuelEU Maritime regulation is one of these. However, the Fit-for-55 package also proposes binding targets for hydrogen refueling points, electric charging for stationary aircraft at airports and on-shore power supply for ships in ports. It also contains provisions for EU Member States to ensure coverage of refueling points for liquefied natural gas (LNG) dedicated to heavy-duty vehicles and LNG refueling points in maritime ports.

The United States announced in 2021 that the GHG impact of corn ethanol dropped by 23% from 2005 to 2019 due to both more efficient farming and ethanol production. This could put ethanol back in the game as a top candidate among low carbon fuels.

The AMF continues to monitor developments across the globe in search of the best advanced fuel topics to address in the coming years.

Annual Report 2021 Production Notes

This Annual Report was produced by Kevin A. Brown (project coordination/management), Kristen Mally Dean (lead editor), Lorenza Salinas (document production) and Mike Holik (cover design) of Argonne National Laboratory. Printing was done by Argonne Creative Services.

Contributions were made by a team of authors from the Technology Collaboration Programme on Advanced Motor Fuels, as listed below.

Country reports were delivered by the Contracting Parties:

Austria	Austrian Federal Ministry of Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK)
Canada	Natural Resources Canada
China	China Automotive Technology and Research Center (CATARC)
Denmark	Technical University of Denmark (DTU)
Finland	The Technical Research Centre of Finland (VTT)
Germany	Agency for Renewable Resources (FNR)
India	Ministry of Petroleum and Natural Gas
Japan	• National Institute of Advanced Industrial Science and Technology (AIST) • Organization for the Promotion of Low Emission Vehicles (LEVO) • National Traffic Safety and Environment Laboratory (NTSEL)
Republic of Korea	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Spain	Institute for Diversification and Saving of Energy (IDAE)
Sweden	Swedish Transport Administration (STA)
Switzerland	Swiss Federal Office of Energy (SFOE)
USA	U.S. Department of Energy (DOE)

Task reports were delivered by the respective Task Managers and Responsible Experts:

Task 28	Information Service and AMF Website	Dina Bacovsky
Task 57	Heavy Duty Vehicle Performance Evaluation	Petri Söderena
Task 58	Transport Decarbonization	Dina Bacovsky
Task 59	Lessons Learned from Alternative Fuel Experiences	Andrea Sonnleitner
Task 60	The Progress of Advanced Marine Fuels	Kim Winther
Task 61	Remote Emission Sensing	Åke Sjödin

Currency values in the Country and Task reports rely on the exchange rate at time of print publication, with the exception of Switzerland’s Country report, which uses the mean value of the FTA (Swiss Federal Tax Administration) that is valid in the reporting period.

Other sections of this report were delivered by the Chair, the Head of the Strategy & Technology Subcommittee and the Secretary:

Jesper Schramm	Technical University of Denmark (DTU)	Executive Committee Chair
Kim Winther	Danish Technological Institute (DTI)	Subcommittee Strategy & Technology Chair
Dina Bacovsky	BEST – Bioenergy and Sustainable Technologies GmbH	Secretary

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1 Technology Collaboration Programme on Advanced Motor Fuels (AMF TCP)

The Need for Advanced Motor Fuels
Because internal combustion engines will be the prime movers for the transport of goods and passengers for many years to come, there is a clear need for fuels that:

- Emit lower levels of greenhouse gases (GHGs),
- Cause less local pollution,
- Deliver enhanced efficiency, and
- Offer a wider supply base for transportation fuels.

It is also necessary that we understand the full impact of alternative energy solutions from a well-to-wheel perspective and use solid data for decision-making.

Our Approach
The AMF TCP has established a strong international network that fosters collaborative research and development (R&D) and deployment and provides unbiased information on clean, energy-efficient, and sustainable fuels and related vehicle technologies. We intend to:

- Build on this network and continue its fruitful contributions to R&D,
- Strengthen collaborations with other closely related (in terms of topics) Technology Collaboration Programmes (TCPs), and
- Do a better job of involving industry in our work.

By verifying existing data and generating new data, the AMF TCP is able to provide decision makers at all levels with a solid foundation for "turning mobility toward sustainability."

Benefits
The AMF TCP brings stakeholders from different continents together to pool and leverage their knowledge of and research capabilities in advanced and sustainable transportation fuels. Our cooperation enables the exchange of best practices. With our broad geographical representation, we are able to take regional and local conditions into consideration when facilitating the deployment of new fuel and vehicle technologies.

About the AMF TCP
The AMF TCP is one of the International Energy Agency´s (IEA's) Technology Collaboration Programmes. These are international groups of experts who enable governments and industries from around the world to lead programs and projects on a wide range of energy technologies and related issues (see also Section 4a). TCP activities and programs are managed and financed by the participants, which are usually governments. The work program and information exchange, however, are designed and carried out by experts from the participating countries.

Currently, 15 contracting parties from 13 countries participate in the AMF TCP (Japan has designated three contracting parties):

- Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) (Austria)
- Natural Resources Canada (Canada)
- China Automotive Technology and Research Center (China)
- Technical University of Denmark (Denmark)
- The Technical Research Centre of Finland (Finland)
- Agency for Renewable Resources FNR (Germany)
- Ministry of Petroleum and Natural Gas (India)
- National Institute of Advanced Industrial Science and Technology (Japan)
- Organization for the Promotion of Low Emission Vehicles (Japan)

- National Traffic Safety and Environment Laboratory (Japan)
- Korea Institute of Energy Technology Evaluation and Planning (Republic of Korea)
- Institute for Diversification and Saving of Energy (Spain)
- Swedish Transport Administration (Sweden)
- Swiss Federal Office of Energy (Switzerland)
- United States Department of Energy (USA)

AMF TCP Management

The AMF TCP is managed by the **Executive Committee**, which consists of one delegate and one alternate from each contracting party. These delegates assess the potential interest of national stakeholders, foster collaboration between country experts and AMF TCP members, and help shape AMF TCP work according to their own country´s interests and priorities.

The AMF TCP work program is carried out through **Tasks**, which are projects with defined objectives, a defined work scope, and defined starting and ending dates. These projects can be Task shared, cost shared, or a combination of Task shared and cost shared. Work in specific Tasks is led by Task Managers. Task Managers participate in Executive Committee meetings to present updates on the progress of work in the Task. They are also responsible for pulling together individual contributions and producing the final report.

To support the work of the Executive Committee and to enable discussions in smaller groups, two **subcommittees** were installed, with a focus on (1) strategy and technology and (2) outreach. The subcommittees regularly review and, as needed, develop and revise the AMF TCP's strategy, provide new stimuli to encourage technology development, and encourage the participation of new members. Each subcommittee is headed by one of the experts within the AMF Executive Committee, who leads discussions in the subcommittee and coordinates the activities of its members.

The **Chair of the AMF Executive Committee** takes the lead in all AMF-related work, chairs the Executive Committee meetings, and represents the AMF TCP at conferences, workshops, and IEA-related meetings. Several vice-chairs assist the Executive Committee chair with her/his duties and represent the major regions of AMF contracting parties; currently, these are Asia, the Americas, and Europe.

The AMF **Secretary** takes care of the daily management of the AMF TCP, organizes Executive Committee meetings, and serves as the main point of contact for Task Managers and for new members.

How to Establish Work Priorities

Work priorities for the AMF TCP are established according to the needs of the contracting parties. Meetings of the Executive Committee, the Strategy Subcommittee, and the Technology Subcommittee serve to discuss new developments and to identify knowledge gaps and implementation barriers. All delegates are encouraged to propose topics for new Tasks. Whenever three or more contracting parties support a proposal and sufficient funding is raised, a new Task can be established. This system allows for flexible adaptation of the annual work program, for continuous development of AMF's scope, and for reacting to any technology gaps or market barriers that have been identified.

Current Work Program

In 2021, six projects were ongoing:
- Task 28: Information Service and AMF Website
- Task 57: Heavy Duty Vehicle Performance Evaluation
- Task 58: Transport Decarbonization
- Task 59: Lessons Learned from Alternative Fuel Experiences
- Task 60: The Progress of Advanced Marine Fuels
- Task 61: Remote Emission Sensing

Cooperation with Other TCPs

The transport-related TCPs are organized in the Transport Contact Group. These are:
- Advanced Motor Fuels
- Advanced Materials in Transportation

- Advanced Fuel Cells
- Combustion
- Hybrid and Electric Vehicles
- Hydrogen
- Bioenergy

AMF actively seeks cooperation with these TCPs. Information exchange is fostered not only through participation in Transport Contact Group meetings, but also by attending each other's Executive Committee meetings, identifying fields of common interest, and participating in projects of other TCPs. Currently, the AMF TCP cooperates with the Hybrid and Electric Vehicles TCP in Task 57, and is involved in a joint project together with IEA Bioenergy in Task 58.

2

Ongoing AMF TCP Tasks

2.a
Overview of Tasks

Ongoing Tasks in 2021

Task Number	Title	Task Manager
28	Information Service and AMF Website	Dina Bacovsky
57	Heavy-Duty Vehicle Performance Evaluation	Petri Söderena
58	Transport Decarbonization	Dina Bacovsky
59	Lessons Learned from Alternative Fuel Experiences	Andrea Sonnleitner
60	The Progress of Advanced Marine Fuels	Kim Winther
61	Remote Emission Sensing	Åke Sjödin

Tasks 57, 58, and 59 concluded in 2021. The final reports and key messages for these Tasks are available on the AMF TCP website, https://iea-amf.org/. Tasks 28, 60, and 61 will continue in 2022.

Three new Tasks started in 2022. They will be reported within the AMF Annual Report 2022. In the meantime, all information is available on the AMF TCP website (https://iea-amf.org)

Task Number	Title	Task Manager
62	Wear in engines using alternative fuels	Jesper Schramm
63	Sustainable Aviation Fuels	Doris Matschegg
64	E-fuels and end-use perspectives	Zoe Stadler

2.b
Task Reports

Task 28: Information Service and AMF Website

Project Duration	January 28, 2004 – Continuous
Participants **Task Sharing** **Cost Sharing**	 None All contracting parties: Austria, Canada, China, Denmark, Finland, Germany, India, Japan, South Korea, Spain, Sweden, Switzerland, United States
Total Budget	EUR 55,000 (USD 61,000) for 2021
Task Manager	Dina Bacovsky BEST – Bioenergy and Sustainable Technologies GmbH Email: dina.bacovsky@best-research.eu
Website	https://iea-amf.org/content/projects/map_projects/28

Purpose, Objectives and Key Question

The purpose of Task 28 is to collate information in the field of advanced motor fuels and make it available to a targeted audience of experts in a concise manner.

Activities

- Review relevant sources of news on advanced motor fuels, vehicles, and energy and environmental issues in general. News articles are provided by experts in the Americas, Asia, and Europe.
- Publish three electronic newsletters per year (on average) on the AMF TCP website, and use an email alert system to disseminate information about the latest issues.
    - Issue No.1 / July 2021
    - Issue No.2 / October 2021
    - Issue No.3 / December 2021
- Prepare an Alternative Fuels Information System that provides concise information on alternative fuels and their use for transport. The system covers information on the performance of cars, effects of fuels on exhaust emissions, and compatibility of fuels with the needs of the transportation infrastructure.
- Update the AMF TCP website to provide information on issues related to transportation fuels, especially those associated with the work being done under the AMF TCP. The website, in addition to providing public information, has a password-protected area that is used for storing and distributing internal information for Delegates, Alternates, and Task Managers on various topics (e.g., strategies, proposals, decisions, and Executive Committee meetings of the AMF TCP).
- Since 2020, additional activities also include distributing news on social media. Follow AMF TCP on LinkedIn and Twitter.

Raw material	Conversion technology	Engine aspects
Paraffinic diesel	Oils and fats – Hydrotreatment Biomass – Gasification, Fischer-Tropsch H_2 + CO_2 – electro-fuel synthesis (P2X)	Diesel engines.
FAME biodiesel	Oils/fats + methanol – Transesterification	Diesel engines. Restricted blending of FAME for modern diesel engines.
Methane	Biomass – Anaerobic digestion Biomass – Gasification H_2 + CO_2 – electro-fuel synthesis (P2X)	Gas engines.
Methanol, ethanol, ethers (DME, OME), hydrogen	Biomass – Fermentation of sugars Biomass – Gasification and synthesis H_2 + CO_2 – electro-fuel synthesis (P2X) Methanol-to-gasoline (MTG)	Special engines.
Bio-oil	Biomass, plastics – Pyrolysis	Not compatible with high-speed diesel engines.

Fig. 1. Overview of biofuel production pathways

Key Findings

The AMF website and newsletters provide a wealth of information on transportation fuels to experts and interested laypersons.

The website covers background information on the AMF TCP and its participants, access to all AMF publications, details on AMF Tasks, and information on fuels and their use in vehicles.

- Delegates to the AMF Executive Committee and Task Managers of AMF Tasks are listed on the website with full contact details and portraits.
- AMF Tasks are briefly described and — where available — final reports and brief key messages are presented. Project descriptions and reports date back to the beginning of AMF in 1984.
- Other publications include AMF annual reports, country reports, newsletters, and brochures.
- Information on specific fuel topics can be found either by searching in the Fuel Information System (see figure above) or by identifying a relevant Task and checking the related report. Knowledge gained through AMF Tasks is frequently added to the Fuel Information System, which thus serves as a reference book for experts and laypersons alike.

Newsletters typically are around 12 pages and are provided electronically (subscription is possible via the website). Topics covered are:

- Demonstration/Implementation/Markets
- Policy/Legislation/Mandates/Standards
- Spotlights on Aviation, Shipping, and Asia
- IEA and IEA-AMF News
- Publications
- Events

The use of social media such as Twitter and LinkedIn is relatively new for AMF. Currently, every week one item is posted both on Twitter and LinkedIn. Items focus on statements from AMF Task reports and Task key messages, and they also promote the AMF newsletter.

Publications

In 2021, three electronic newsletters were published on the AMF TCP website and distributed through the national networks of the AMF delegates.

The Alternative Fuels Information System is available on the AMF TCP website. A new section on GHG emissions has been published, and findings from Tasks 51 and 54 have been included in the sections on methane and ethanol, respectively. The AMF TCP website is updated frequently with information from Tasks and Executive Committee meetings.

Task 57: Heavy Duty Vehicle Performance Evaluation

Project Duration	October 2018 - May 2021, and Webinar in October 2021
Participants **Task sharing** **Cost sharing**	 Canada, Chile, Finland, Japan (LEVO), Republic of Korea, Sweden Japan (LEVO) and Sweden
Total Budget	~EUR 610,000 (~USD 671,000)
Task Manager	Petri Söderena VTT Technical Research Centre of Finland Email: petri.soderena@vtt.fi
Website	https://www.iea-amf.org/content/projects/map_projects/57

Purpose, Objectives and Key Question

This project aims to demonstrate and predict the progress in energy efficiency of heavy-duty vehicles (HDVs), thus generating information to be used by transport companies, those procuring transport services and those forming transport policy. The project will encompass the newest diesel technologies on different markets, but also alternative fueled vehicles and advanced powertrain configurations tested on chassis dynamometer and on-road.

The proposed overall activity will cover three time dimensions:

- Legacy vehicles and a reference backwards through completed AMF Tasks
- Current performance of the best-available-technology HDVs using conventional and alternative fuels
- A projection of how energy efficiency and emissions can develop, using input from the Combustion TCP as well as modeling by the AMF TCP for estimating the effects of alternative vehicle and powertrain configurations
- Cooperation with the IEA's Hybrid Electric Vehicle (HEV) TCP offers insight to how different HDV powertrain and fuel (fossil and renewable) options perform against the CO_2 emission regulations, from a 2025 and a 2030 perspective.

Activities

Test Programs

Participating countries – Canada, Chile, Finland, Japan, Republic of Korea and Sweden – conducted tests and shared results in 2021.

Canada

The Canadian test program includes Class 7 and Class 5 trucks, which were tested both in-lab on a chassis dynamometer and on-road under real driving conditions using a portable emissions measurement system (PEMS).

The vehicles were tested with different loadings representing gross weight vehicle rating (GWVR), 50% payload, and 90% payload. Both vehicles were recent model years and included emission controls such as exhaust gas recirculation (EGR), diesel oxidation catalyst (DOC), diesel particulate filter (DPF), and selective catalytic reduction (SCR). Both were tested with U.S. certification diesel fuel; the Class 7 truck was tested with a B20 blend.

Chile

The Chilean test program included three Euro V diesel trucks in the weight category under 10 tons (GVW) and all of them tested in the Heavy-Duty Emission Laboratory of the Vehicle Control and Certification Center (3CV). The test program in Chile covers fuel consumption and PM emission measurements in chassis dynamometer according to the aggregated World Harmonized Vehicle Cycle (WHVC). Testing fuel is commercial diesel that meets Euro 5 specifications.

Finland
The Finnish test program includes six different heavy-duty trucks, all in the N3 category: Two spark-ignited (SI) and fueled with methane (CNG and LNG), two diesel-fueled, one ED95, and one dual-fuel (DF) diesel-methane. Spark-ignited and ED95 trucks were type approved to Euro VI step C. Diesels and DF trucks were type approved for Euro VI step D. Each truck was tested on a chassis dynamometer; the SI-LNG, diesel and DF trucks were also tested on-road with PEMS.

Republic of Korea
Starting in 2020, CO_2 emission monitoring of HDVs began in Korea. Vehicle manufacturers report CO_2 emissions of their HDVs by using HES (Heavy-duty vehicle Emission Simulator), a Korean HDV CO_2 and fuel consumption simulation tool. Based on the monitoring results, CO_2 emission standards will be set. Mandatory CO_2 regulation of HDVs will begin between 2023 and 2025.

The HES program has been released three times and teams are now working on bug fixes. The program calculates tank-to-wheel CO_2 emission and fuel consumption based on longitudinal vehicle dynamics. A fuel consumption map, air drag coefficient, rolling resistance coefficient, and vehicle weight are the main input data of the simulation program. The error rate between HES results and the chassis dynamometer test results is about 5%. Correlation analysis between HES and VECTO for 21 cases of vehicle data were simulated. The same input data was used for both programs. The coefficients of linear regression and determination are 0.9845 and 0.9932.

Sweden
The Swedish test program includes nine individual heavy-duty trucks (N3): Three CNG, two LNG (dual fuel) and four conventional diesel engines fueled with Swedish environmental class 1 diesel fuel (EN590 artic class). The trucks were tested both in chassis dynamometer and with PEMS.

Webinar
In October 2021, a webinar, "Heavy Duty Vehicles - Recent and Future Options with Regard to Energy Consumption and Pollutant Emissions," was held to disseminate Task results but also to cover other energy efficiency and CO_2 emissions reduction measures for HDVs. Recent findings from work done in AMF TCP Task 57 "Heavy duty vehicle performance evaluation" were presented. The Task Manager presented an overview, which was followed by related findings of the HEV TCP and case studies from Switzerland and Finland.

The following topics were covered:

- Energy Efficiency and Emissions of Heavy-Duty Vehicles
  Petri Söderena, AMF TCP Task 57 Leader, VTT, Finland
- Electrification of Heavy-Duty Vehicles
  Özcan Deniz, HEV TCP Task 41 Leader, German Aerospace Center (DLR), Germany
- Liquefied Biomethane in HDV Transportation in Switzerland
  Elimar Frank, Eastern Switzerland University of Applied Sciences, Switzerland
- High Capacity Transport in Finland
  Otto Lahti, Finnish Transport and Communication agency, Traficom

Main Conclusions

The main conclusion is that the current diesel heavy-duty trucks are rather energy efficient (on average close to 46 % BTE on typical long-haul mission) and, independent of the fuel and combustion method, they have low regulated emissions. Furthermore, the HDV CO_2 regulations that focus on tailpipe emissions constitute a barrier for further development of alternative fueled trucks. This could result in a halt in development of clean and efficient engines for dedicated alternative fuels, resulting in a preference to use drop-in fuel in the legacy fleet and electrification for new trucks entering the market. This type of legislation will have an impact on the possibility of using sustainably produced fuels in the future.

Energy consumption-wise, independent of fuel, the concepts based on compression ignition (diesel proves), including HPDI dual-fuel, deliver rather high efficiency. Spark-ignited methane engines, on an average, have close to 30% higher energy consumption compared to compression ignition engines of the same size and power. Considering CO_2 emissions, HPDI dual-fuel delivers on average close to 20% lower CO_2 emissions compared to diesel. Renewable diesel and ED95 reduce tailpipe CO_2 emissions about 5% compared to fossil diesel. This stems from small differences in the fuel hydrogen/carbon ratio. Spark-ignition (SI) methane engines deliver tailpipe CO_2 emissions equivalent or slightly lower to those of diesel engines. No high methane slip was observed for the methane-fueled trucks independent of the combustion method. Current Euro VI/US 2010 trucks have gaseous (for diesel, all emissions) regulated emissions below the legislative limit values, independent of the fuel. Regarding the SI methane trucks which were not equipped with particulate filters, PN emissions can be substantially higher than in a diesel truck.

Energy consumption-wise, and in efforts to reduce CO_2 emissions from trucking operations, the impacts of vehicle size and relative loading are often dismissed. The simulations carried out within Task 57 demonstrated that increasing gross vehicle weight rating (GVWR) from 60 to 90 tons could reduce CO_2 emissions per ton-kilometer of cargo by up to 40%. For example, currently Finland and Sweden are allowing heavy combinations: 76 tons in Finland and 74 tons in Sweden.

Also, some adjustments to vehicle CO_2 regulations and likely some mandates for renewable fuels are needed in order to keep ICE vehicles running on renewable fuels on the road in the future. Electrification is progressing rapidly, but heavy-duty long-haul trucks are not the optimum target for electrification.

Schedule

Task 57 was reported in AMF TCP ExCo meeting 61 in May 2021.

Task 58: Transport Decarbonization

Project Duration	January 01, 2019 – October 31, 2021
Participants **Task Sharing** **Cost Sharing**	 China, Finland, Germany, Japan (LEVO), Sweden, USA; AMF Task 28, AMF Task 59; Brazil, through IEA Bioenergy TCP European Commission
Total Budget	~EUR 150,230 (~USD 165,000)
Operating Agent	Eric Fee and Kyriakos Maniatis European Commission Email: eric.fee@ec.europa.eu
Task Manager	Dina Bacovsky BEST – Bioenergy and Sustainable Technologies GmbH Email: dina.bacovsky@best-research.eu
Website	https://www.iea-amf.org/content/projects/map_projects/58

Purpose, Objectives and Key Question

The purpose of the project is to draw the big picture of how advanced renewable transport fuels (i.e., advanced biofuels and renewable liquid and gaseous transport fuels of non-biological origin) can contribute to the decarbonization of the transport sector.

The key question is:

- How much can advanced renewable transport fuels contribute to the decarbonization of the transport sector?

The audience is policy makers.

Activities

The activities include the following work packages:

- **Key strategies in selected countries**
  Task participants from Brazil, China, Finland, Germany, Japan, Sweden and the United States provided detailed descriptions of GHG emissions from their road transport sectors and shared scenarios of how their countries intend to reduce these emissions.
- **Fuel production technologies and costs**
  A number of experts from within the IEA Bioenergy TCP and the AMF TCP networks provided descriptions of biomass feedstock availability, technology status, biofuel production costs, future feedstock costs, future fuels GHG emissions, the role of policy, and engine and fuel compatibility.
- **Country assessments**
  Experts of VTT assessed the possible future development of vehicle stocks of all kinds for Brazil, Germany and Sweden and calculated the future energy demand and associated GHG emissions. Scenarios were developed to show the effect of pushing the use of biofuels and electrofuels to the limits. This was compared to the national targets for GHG emissions from the transport sector.
- **Implementation barriers**
  Results from AMF Task 59 regarding implementation barriers for advanced biofuels are summarized.
- **Recommendations to policy makers**
  This section is still under development. It will draw conclusions from the project and provide actionable recommendations to policy makers.

Key Findings

The figure on the next page shows clearly the results for Germany.

The lines depict CO_2 emissions from road transport as calculated as tailpipe emissions (with biofuels and the use of electricity accounting for zero tailpipe emissions). The current policy is depicted in the base case scenario (light green line). If maximizing biofuel utilization, CO_2 emissions can be further reduced (dark green line). The effect of electrification alone is about as large as the effect of the current moderate biofuels utilization. With the maximum use of biofuels and electrification together, full decarbonization can almost be reached by 2050. Germany's target for 2030 of reducing CO_2 emissions to around 30 to 40 million tons per year will be missed by far.

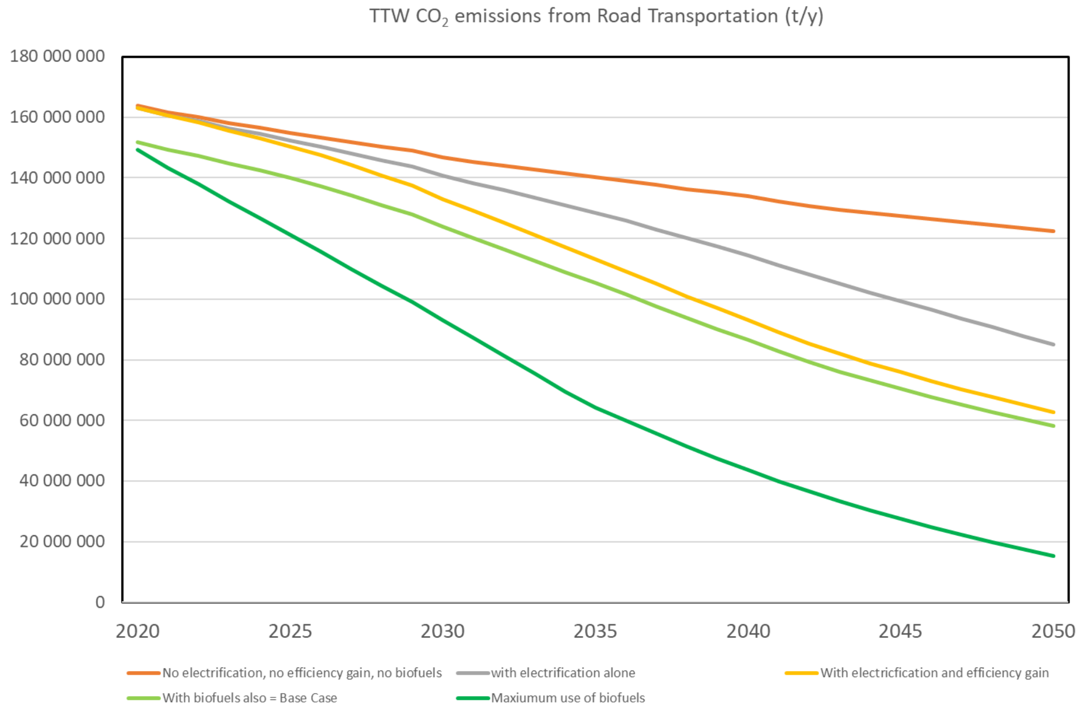


Fig. 1. Scenarios of CO_2 Emissions from Road Transportation for Germany

Main Conclusions

Bringing the GHG emissions of the road transport sector down to zero by 2050 cannot be achieved by one measure alone.

Countries that deploy a set of different measures such as reducing transport demand, improving vehicle efficiency, and adding renewable energy carriers such as biofuels, e-fuels, renewable electricity and renewable hydrogen have the best chances to meet ambitious decarbonization goals.

Our assessment shows that biofuels contribute most to decarbonization now and up to 2030, 2040, or even 2050, depending on the country. In Germany and in the USA, efficiency gains become the main contributor after 2030. In Finland and Sweden, the impact of biofuels remains largest until around 2040 when the use of electric vehicles takes over. In Brazil, biofuels remain the largest contributor until 2050.

Publications

The findings of this project have been presented in a webinar and published in four distinct parts and together with a summary document:

- Summary Report
- Key Strategies in Selected Countries
- Production Technologies and Costs
- Scenarios and Contributions in Selected Countries
- Deployment Barriers and Policy Recommendations

All reports as well as the webinar presentations are available for download at https://iea-amf.org/content/projects/map_projects/58.

Task 59: Lessons Learned from Alternative Fuels Experience

Project Duration	April 2019 – June 2021
Participants **Task sharing** **Cost sharing**	 Austria, China, Finland, Japan (LEVO), Sweden, United States None
Total Budget	~EUR 151,500 (~USD 184,000)
Task Manager	Andrea Sonnleitner BEST - Bioenergy and Sustainable Technologies GmbH Email: andrea.sonnleitner@best-research.eu
Website	https://www.iea-amf.org/content/projects/map_projects/59

Purpose, Objectives and Key Question

Decarbonizing the transport sector is one of the key objectives of national and international climate change mitigation policies. Alternative fuels and propulsion systems are of particular importance in reducing GHG emissions from this area. Many countries are actively seeking to increase the share of renewable energy sources in the transport sector.

However, experience with various attempts to introduce alternative fuels and vehicles to the market has shown that this is not always successful. Several participants in the AMF TCP have therefore proposed this project on lessons learned from market launch attempts.

The key questions that this project should answer are:

- Which factors determine whether the market launch of alternative fuels and vehicles will succeed or not?
- Can success factors and pitfalls, lessons, and recommendations for better action be deduced from the experiences of different countries in the last decades?
- How can people involved in the development of market introduction measures be supported?

Activities

Task 59 analyzed particular case studies that take into account the specific framework conditions for each country. The first step was to identify relevant case studies for each participating country.

Task participants from Austria, China, Finland, Japan, Sweden and the United States collected data and information on past market introduction case studies and described these according to the developed template. In addition to the descriptions, representatives from different stakeholder groups like ministries/authorities, automotive industry, fuel manufacturers and advocacy groups/organizations in the participating countries were interviewed on prior market introduction attempts and their insights were collected.

The case studies' drivers for market implementation, country-specific circumstances, measures taken, and stakeholders involved were checked against the result of the market implementation as part of the analysis. Success factors and show-stoppers as identified in the case study descriptions were supplemented with the results from analysis by the Task team.

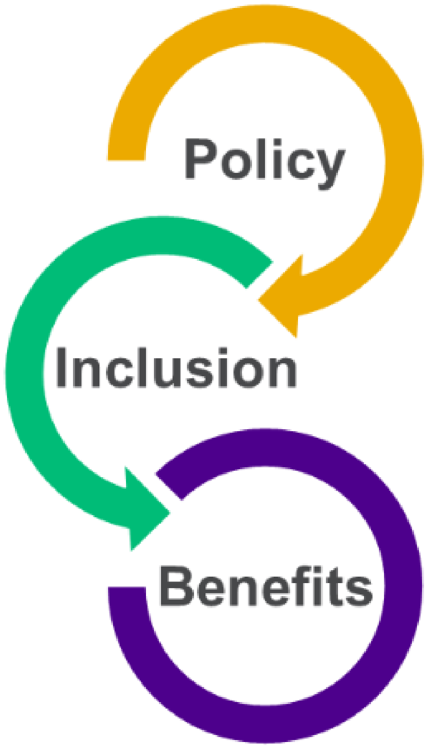
Results and findings from the respective case studies were discussed in an expert workshop with experts from the AMF TCP and external experts. Based on the results and discussions of the expert workshop, the Task determined the final lessons learned and recommendations, as described in the final report and summarized in the key messages.

Key Findings

The findings of the project led to the definition of three important pillars for a successful market introduction of alternative fuels: policy, inclusion and benefits.

Policy

Policy is a very important instrument for transitioning the future transport system. There is the need for long-term national and international policies with a comprehensive strategy. This includes a package of measures with financial and non-financial incentives. The coordination of government, academia, and industry within the implementation is important.



Inclusion

The involvement of all groups of stakeholders along the value chain is necessary. The perception of the general public on alternative or new fuels needs to be improved. Additionally, the future transport system should include different types of alternative drive systems and fuels, suitable for different applications. Existing infrastructure should be used with increased share of renewable drop-in fuels. New fuels and drive systems can complement drop-in fuels.

Benefits

Policy and inclusion should lead to benefits. It is essential that there are visible benefits or cost benefits for all groups of stakeholders to make the alternative fuel or propulsion system attractive.

Main Conclusions

Consistent policies and integration of all stakeholders are both necessary to overcome barriers for a successful market implementation of alternative fuels and propulsion systems.

There is the need for long-term and comprehensive policies, on national and international level, which include markets, stakeholders and different technologies to gain benefits for all types of stakeholders along the value chain of the transportation system.

Publications

Presentations from the AMF Task 59 Expert Workshop on Lessons Learned from Alternative Fuels Experience (Oct. 30, 2020, virtually)

AMF Task 59 Lessons Learned from Alternative Fuels Experience – Final Report (June 2021): https://iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Task_59.pdf

AMF Task 59 Lessons Learned from Alternative Fuels Experience – Key Messages (June 2021): https://iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Task_59_%20Key_Messages.pdf

Task 60: The Progress of Advanced Marine Fuels

Project Duration	November 2019 – November 2022
Participants **Task sharing** **Cost sharing**	 Austria, Canada, China, Denmark, Finland, Korea, Sweden, Switzerland, and USA Methanol Institute, USA
Total Budget	€1,795,000 ($2,161,000 US)
Task Manager	Kim Winther Danish Technological Institute Email: kwi@dti.dk
Website	https://www.iea-amf.org/content/projects/map_projects/60

Purpose, Objectives and Key Question

In 2013, AMF released its first Task report on marine fuels (Task 41). This report highlighted the fact that no alternative fuel option existed without significant added cost or other serious impediments. The preferred fuel, HFO, was soon to be banned or restricted due to the high Sulphur and fossil carbon content. Recent developments, however, have highlighted several new fuel options which should be assessed.

Task 60 seeks to answer the key question: How can new forms of advanced marine fuels contribute to carbon neutral shipping in the future?

Activities

Four virtual meetings were held during 2021. Denmark, Canada, Sweden and Switzerland were the main presenters at the meetings.

	Q4 2019	Q1 2020	Q2 2020	Q3 2020	Q4 2020	Q1 2021	Q2 2021	Q3 2021	Q4 2021	Q1 2022	Q2 2022	Q3 2022	Q4 2022
Formal Task Documents	DK												
Work presentation			FI	-	DK	CA	SE CH		US KR	CN			
Final report contribution								SE FI	US DK	CA KR	CH CN		Final

DONE

Fig. 1. Timeline of Task 60 efforts to study the progress of Advanced Marine Fuels. Key: Denmark (DK), Finland (FI), Canada (CA), China (CN, Sweden (SE), Switzerland (CH) and Korea (KR).

Austria joined as a new participant in 2021.

Key Findings

Following are highlights of the four main presentations held in 2021:

- **Denmark** finished work on the 2 MW methanol engine in 2021 and is about to commercialize the concept. Tests on ammonia were initiated on a 20 kW engine at Technical University of Denmark (DTU). Denmark also did a special study on emission reduction on coastal ferries.
- **Canada** did a study on marine black carbon and particulate matter emission factors. Four-stroke engines were found to emit more black carbon than two-strokes per kg of fuel. Low engine load

was found to produce more black carbon per kg of fuel than high load. Scrubbers were found to be ineffective towards black carbon but effective toward Sulphur and PM.

- **Sweden** did a study to compare technologies for short sea shipping and inland waterways. Included initially were seven fuels: HVO, Biogas, Ethanol, Methanol, Hydrogen, Ammonia, and electricity (Batteries). The number of fuels was later reduced to four: Biogas, Methanol, Hydrogen, and batteries. Technology readiness is highest for HVO, biogas and battery, and it is lowest for Ammonia. All alternatives will generate higher fuel cost. HVO is almost three times the cost of reference fuel. Biogas and electricity were found to be the cheapest low-carbon options.
- **Switzerland** made an experimental setup to emulate a large two-stroke marine engine – the Flex-OeCoS – which allows optical combustion analysis and Particle Image Velocimetry (PIV).

Publications

A final report of Task 60 will be available in late 2022 and can then be downloaded on the AMF TCP website: https://www.iea-amf.org/content/projects/map_projects/60.

Task 61: Remote Emission Sensing

Project Duration	May 2020 – October 2023
Participants **Task sharing** **Cost sharing**	 China, Denmark, Finland, Sweden, Switzerland None
Total Budget	EUR 210,000 (USD 254,000)
Task Manager	Åke Sjödin IVL Swedish Environmental Research Institute Email: ake.sjodin@ivl.se
Website	https://www.iea-amf.org/content/projects/map_projects/61

Purpose, Objectives and Key Question

The objective of this task is to evaluate and propose how remote emission sensing (RES) can be used—for policy purposes as well as for direct enforcement—to detect high-emitting/ gross-polluting vehicles in real-world traffic.

The project will comprise all vehicle categories (i.e., passenger cars, light-duty commercial vehicles, heavy-duty trucks, buses and motorcycles) running on commonly used combustion fuels (i.e., petrol, diesel and CNG/LNG) designed to meet all adopted legislative emission limits (e.g., Euro 1/I – Euro 6/VI). However, special attention will be paid to high-emitting vehicles designed to meet the most recent emission standards, such as Euro 6. Target pollutants will be NO_x and PM.

The project aims to evaluate and compare the performance and applicability of the following main types of RES technologies to identify high-emitting vehicles:

- Conventional RES (Type 1 RES): This is in practice the technologies that are already offered to the market by commercial providers for emission measurement services.
- Point sampling RES (Type 2 RES): In terms of measurement strategy Type 2 RES is quite similar to Type 1/conventional RES, but it is still under development (i.e., not yet commercialized), and it demonstrates the best advantage for measuring PM emissions, both number and mass.
- Plume chasing RES (Type 3 RES): From a measurement strategy, this perspective is rather different than Type 1 and 2. Not as many vehicles can be measured per time unit, but the measurements on each vehicle have longer duration than those measured with Type 1 and 2. As a result, this RES is more useful to pinpoint high-emitters.

The project will make use of existing RES datasets in Europe and China, as well as new datasets from upcoming RES measurement campaigns until early 2023.

The general outcome of Task 61 will be an independent comparison and evaluation of the performance of various RES technologies, with a focus on their ability and usefulness to detect excess-emitting vehicles for direct enforcement as well as emission legislation and air pollution policy purposes. The project will provide proposals on how RES can be practically applied for these purposes covering both existing and future in-use fleets. The project's final report will include:

- An "up-to-date" view of the real-world emission performance of European and Chinese in-use fleets, demonstrating the impact of current emission legislation on the real-world emissions of different vehicle categories grouped by emission standard, vehicle manufacturer, engine family, etc., to reveal eventual gaps between on-road emissions and legislative emission limits.
- A comparison and evaluation of the performance of different RES technologies to accurately measure on-road emissions, and particularly to accurately pinpoint high- or excess-emitting vehicles on an individual vehicle level and on vehicle model or engine family level.
- Proposals on how RES can be practically used to detect high-emitting vehicles for direct enforcement purposes as well as to monitor real-world emissions for emission legislation and air pollution policy purposes.

Activities

WP 1: Collection and consolidation of existing data

In 2021, the RES datasets available for the work of Task 61 increased substantially. For example:

- The number of Type 1 RES records in the European CONOX database increased to more than 1,500,000 records, due to new data coming from Switzerland (Zürich), Germany (Berlin) and Belgium (Flanders). The Flanders data are the first in the CONOX database collected with the HEAT EDAR instrument (https://www.heatremotesensing.com/edar).
- In Europe, approximately 80,000 new Type 2 RES records were collected in the first two city demonstration measurement campaigns in Italy (Milan) and Poland (Krakow). The pollutants measured were PN (particle number) and BC (black carbon).
- In China, a cost-effective roadside sensor platform, including the use of electrochemical NO sensors and commercial instruments (CO_2, PN), was experimented on a road track. This pilot study indicates the cost-effective roadside sensor plat is capable of identifying high emitters.
- During the past five years, particularly 2019-2021, measurements with Type 3 RES on heavy-duty trucks have been carried out in several European countries (Austria, Denmark, Germany and Sweden). Data are available in already published or soon-to-be published reports. In some of the studies, trucks have been pulled over to the roadside for inspections of potential emission tampering (mainly SCR Adblue tampering).
- Through Tsinghua University, nearly 10,000 vehicles were measured using plume chasing. These tested vehicles contribute to the multiple-year measurements in several megacities for assessing emission control benefits (Chengdu, Shenzhen).
- VTT will release real driving emission (RDE) data from previous onboard PEMS tests when they are available.

WP 2: Comparison and evaluation of the performance of different RES technologies

The following are highlights of 2021:

- The CARES RES characterization measurements campaign at the RDW test track in the Netherlands during one week in June. RES Type 1-3 instruments were deployed to measure the emissions from PEMS-equipped gasoline and diesel light-duty vehicles, a heavy-duty truck and two motorcycles.
- The CARES city demonstration campaign in Milan. The RES Type 1 HEAT EDAR instrument and the CARES Type 2 PN, BC and NO_x sensors were deployed, and a few PEMS-equipped light-duty vehicles repeatedly passed the measurement sites.
- Tsinghua University: Plume chasing (RES3) measurements were validated to annual inspection (simplified dynamometer) and remote on-board monitoring data. The results reveal good correlations on manufacturer or fleet-average levels for China V and VI heavy-duty diesel vehicles.
- EMPA: A high-fidelity hybrid RANS-LES solver was developed for an accurate description of the plume dispersion by keeping the computational cost considerably low (testing/validation is in progress). Additionally, an extensive parameter study using the validated but less accurate RANS model was carried out, which led to a conference paper for 22nd Stuttgart International Symposium.

WP 3: Evaluation of using RES to detect individual high-emitting vehicles for enforcement

See some of the activities listed under WP1 and WP2 (relevant for high-emitter detection).

WP 4: Evaluation of using RES for emission legislation and air pollution policy purposes

See some of the activities listed under WP1 and WP2 (relevant for RES policy applications).

WP 5: Project coordination & management, synthesis, reporting and dissemination

In 2021, Task 61 made its first contribution to the IEA-AMF Annual Report. Activities and progress were reported in the Executive Committee meetings 61 and 62. Three Task 61 work meetings were arranged in 2021. A MS Sharepoint for Task 61 was prepared in 2021 to support the storage and exchange of internal work documents as well as reports and publications.

Key Findings

- In the first RES Type 1 campaign carried out in Flanders (in 2019), the HEAT EDAR instrument accurately detected deliberately SCR-tampered (high NO_x -emitting) heavy-duty trucks on the

motorway in 6 out of 7 trucks pulled over for a roadside inspection. This is a detection rate of 86%. When trucks were pulled over by random, the SCR tampering rate was only about 10%.
- Preliminary results and experience indicate that the new RES Type 2 sensors – developed and demonstrated for the first time in the CARES project (in Milan and Krakow, respectively) in 2021 – could be important tools for learning more about real-world PN and BC emissions in general, and about high-emitters of these pollutants in particular.
- The 2021 results from the CARES RES characterization measurements at a test track, to be published in early spring 2022, will improved understanding of the three different RES types' ability to identify high-emitters and how they compare to PEMS measurements.
- The plume chasing data (RES3), in line with the trends represented by dynamometer and on-board monitoring results, indicated that China VI HDDVs have much lower NO_x and PM emissions than previous counterparts. For China V HDDVs, the results also showed that vehicles with newer (post-2018) model years could be more effective in reducing NO_x emissions than the earlier China V HDDVs. These benefits have been well captured by the reductions in fleet-average emissions and road concentrations (NO_x) both in Shenzhen and Chengdu. Furthermore, the updated version of the national emission inventory guidebook (to be released by the Ministry of Ecology and Environment of China) has been enriched by the plume chasing results.
- A clear relation between the momentary emissions caused by driver-to-driver differences was found from RDE-tests conducted in the Helsinki metropolitan area. The effect on CO, NO_x and PN formation was found to be especially strong in aggressive versus smooth driving styles, as rapid acceleration and high peaks in engine power typically cause a rapid rise in NO_x emissions. Furthermore, the PEMS tests demonstrated that the variation in emissions caused by different types of vehicles may be significant, especially over different Euro 6 emission standards.
- The EMPA parameter study found that the most crucial volume that RES must capture is the core exhaust plume, which lies within the first 1.5 m behind the vehicle. The location of the pollutant concentration peak (PCP) as well as the core exhaust plume shape are mainly influenced by the pipe position. The vehicle acceleration causes the PCP to shift towards the vehicle. Additionally, the simulations show that wind has no significant influence on the core exhaust plume. With regards to RES, an independence of the width of the street is found.

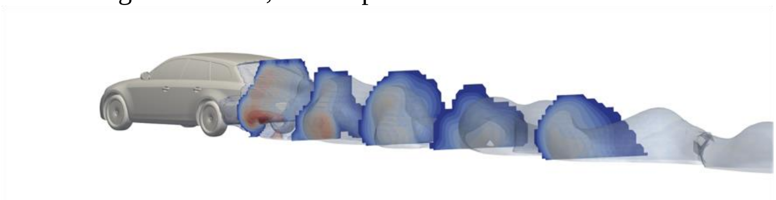


Fig. 1 The EMPA parameter study found that the most crucial volume RES must capture is the core exhaust plume, within 1.5 m behind the vehicle.

Main Conclusions

- The collection of new RES and RDE data resumed and was substantially enhanced in 2021 after more than a year of Covid-19 restrictions that hindered many planned field experiments in both Europe and China.
- A good agreement between RES and PEMS was observed in different field studies in both Europe and China.
- Recent RDE-tests demonstrated the big impact driver-to-driver differences have on emissions of NO_x and small particles. They also demonstrated the large variation in emissions that may occur between different types of vehicles.
- Further development of plume dispersion models and subsequent modelling exercises can be used for pinpointing advice on how RES capture of the plume can be optimized.

Publications

- Jerksjö, M., Sjödin, Å., Merelli, L., Varella, R., Sandström-Dahl, C. (2021) Remote emission sensing compared with other methods to measure in-service conformity of light-duty vehicles. IVL Report C620. https://www.ivl.se/english/ivl/publications/.

- Shen, Y., Zhang, Q., Wang, D., et al. (2021) Evaluation of a cost-effective roadside sensor platform for identifying high emitters. Science of the Total Environment, in press
- Xiang, S., Zhang, S., Wang, H., et al. (2021) Mobile Measurements of Carbonaceous Aerosol in Microenvironments to Discern Contributions from Traffic and Solid Fuel Burning. Environmental Science & Technology Letters, 8(10), 867-872
- Plogmann, J., Gubser, A., Dimopoulos Eggenschwiler, P. Remote Sensing Measurements and Simulations for Real Driving Emission Characterization of Vehicles, 22nd Stuttgart International Symposium (2022), accepted and available from April 2022.

- Further upcoming project reports will be available for download on the website: https://www.iea-amf.org/content/projects/map_projects/61.

3 The Global Situation for Advanced Motor Fuels

Country Reports

Countries participating in the AMF TCP have prepared reports to highlight the production and use of advanced motor fuels in their respective countries, as well as the existing policies associated with those fuels.

Austria

Drivers and Policies

Transport GHG Emissions Share and Increase

The transport sector, being the strongest emitting sector not covered by the European emissions trading system, emitted about 30% of GHG in 2019. Passenger and freight kilometers increase continuously, which is the main reason why GHG emissions in transport have seen an increase of 76% since 1990. Due to reduced economic activities and lock-down restrictions applied as a result of the COVID-19 virus, a significant drop of 9.2% in GHG emissions in the combined energy and transport sector took place from 2019 to 2020. A significant part of this reduction stems from a -11.2% lower consumption of diesel and a drop of gasoline consumption by 17.1%. Due to the starting economic recovery in 2021, fuel consumption increased by 4.4% for diesel and 5.3% for gasoline, according to a market assessment by the Association of the Mineral Oil Industry (FVMI). Therefore, a lasting change of the long-term tendency due to behavioral changes or structural changes during the pandemic year cannot be identified.

Politics – Recent activities and developments

Austria is committed to carbon neutrality by 2040. This goal requires substantially increased decarbonization efforts across all energy sectors. Especially in the transport sector, a radical turnaround is needed to contribute to the political aim. Austria, therefore, has adopted a number of measures such as a newly designed taxation system, which puts a price on ecologically destructive activities. In 2021, a new taxation system came into force, which introduces a CO_2 pricing system with a continuously increasing price path from EUR 30 (USD 34.2) per ton CO_2 (2022) up to EUR 55 (USD 62.7) per ton CO_2 (2025). From 2026 onwards, an EU-wide CO_2 emissions trading system will replace national fixed price rates. In addition, an obligatory procurement of zero-emission vehicles by the public sector is taking effect. Other measures already put in place are an increased NoVA tax and the “Right to Plug.” which alleviates previous legal approval hurdles for the installation of charging stations for apartment owners at their vehicle parking space in a multi-apartment building.

National strategies in the area of transport have been developed, such as the Mobility Master Plan and the corresponding RDI Mobility 2030 Strategy. Complementary strategic plans for Freight Transport and Hydrogen are just being completed. Despite significant efforts, a consistent overarching activity document listing measures, their expected contributions and corresponding KPIs (fully describing the path to climate neutrality in 2040) is not available. An updated Austrian National Energy and Climate Plan reflecting the ambitious European Green Deal targets in the *Fit for 55* package (reduction of greenhouse gas emissions by 55% by 2030) might be the nucleus for an aggregation of all planned measures and their expected impact.

Austrian Integrated National Energy and Climate Plan (NECP)

The integrated NECP is a planning and monitoring instrument of the EU and its Member States. It is intended to contribute to improved coordination of European energy and climate policy and is the central instrument for implementing the EU’s renewable energy and energy efficiency targets for 2030. For Austria, the NECP main instruments are (1) to increase the share of renewable energy sources in the fuel sector, whereby in Austria the biogenic share in relation to the energy content of diesel is about 6.3%, and for petrol currently about 3.4%, and (2) the Normverbrauchsabgabe (NoVA) tax, in which a bonus/penalty system for CO_2 emissions is levied when passenger cars are first placed on the domestic market (new car purchase or private import), which provides incentives to purchase vehicles with low CO_2 emissions.

Taxes and Incentives

Starting in July 2008, the NoVA tax was introduced for taxing the acquisition of new vehicles. As of March 2014, new cars that emit less than 87 g of CO_2/km are exempt from NoVA. Further reduction steps of 5 g of CO_2/km per year are planned until 2024. Each additional gram results in a financial penalty of EUR 80 (USD 91) on the purchase price of a passenger vehicle. Pure biofuels are exempt from the mineral oil tax. CNG is exempt from the mineral oil tax as well but is subject to the lower natural gas tax.

Advanced Motor Fuels Statistics

Fleet Distribution and Number of Vehicles in Austria

According to provisional figures, for the second time in history, the total fleet of motor vehicles registered in Austria passed seven million, with 7.21 million registered motor vehicles. That is an increase by 1.64% or 116,156 vehicles compared to 2020. Passenger vehicles, the most numerous type of vehicle (share: 71.2%), showed an increase by 0.8% to 5.13 million vehicles (Table 1).

Fleet numbers indicate a continuous trend toward advanced alternative propulsion systems, especially toward BEVs and HEVs (Figure 1). For instance, there were 76,539 BEVs and 107,111 HEVs in Austria in 2021, which shows a continuing positive trend from previous years, and which follows an exponential trajectory. The number of vehicles powered by compressed natural gas (CNG) and liquefied petroleum gas (LPG), including bivalent ones, shows a stable, but very moderate fleet level of 5,787 vehicles (2020: 6,063). There is a continuing slow decrease of bivalent vehicles to 3,132 (2020: 3,308; 2019: 3,474) while the CNG vehicles fleet stays stable with 2,654 (2020: 2,753; 2019: 2,602). With 55 (2020: 45) vehicles, the fuel cell electric vehicle (FCEV) fleet is still negligible.

Table 1. Austrian Fleet Distribution of Passenger Vehicles by Drivetrain, 2016–2021

Drivetrain	2016	2017	2018	2019	2020	2021
Gasoline	2,031,816	2,074,442	2,133,473	2,173,772	2,190,388	2,192,128
Diesel	2,749,038	2,770,470	2,776,333	2,772,854	2,762,273	2,717,475
Electric	9,071	14,618	20,831	29,523	44,507	76,539
LPG	1	2	2	2	2	1
CNG	2,456	2,433	2,365	2,602	2,753	2,654
H2	13	19	24	41	45	55
Bivalent gasoline/ ethanol (E85)	6,165	5,992	5,769	5,770	5,190	4,878
Bivalent gasoline/ LPG	341	335	333	330	330	331
Bivalent gasoline/ CNG	2,574	2,773	3,177	3,143	2,978	2,801
Hybrid gasoline/ electric	18,696	26,039	34,086	45,645	68,983	108,978
Hybrid diesel/ electric	1,337	1,455	2,463	6,172	14,378	27,996
Total	4,821,508	4,898,578	4,978,856	5,039,854	5,091,827	5,133,836

Source: Statistik Austria

New registrations of alternatively powered passenger cars rise again despite overall trend

In 2021, 239,803 new passenger cars were registered, 3.6% less compared to 2020. Thus new passenger car registrations are 27.2% below the level of the pre-crisis year 2019 and have reached the lowest level in 37 years. The decline is linked to a continuation of the significant decrease in petrol and diesel-fueled passenger cars registrations. The number of petrol-powered passenger cars also fell to 91,478, corresponding to a share of 38.1%, and the number of diesel-powered passenger cars fell to 58,263, corresponding to a share of 35.9%.

Despite the overall trend, at 90,062 cars, the share of all alternatively powered passenger cars increased to 37.6%, thus showing an impressive 17.5 percentage points increase within a year. In absolute numbers, the numbers are even more impressive with an increase of 79.9% compared to 2020's 50,060 cars. Among alternatively powered drives, petrol-hybrid passenger cars (43,051) have an 18.0% share, BEV passenger cars (33,366) have a 13.9% share and diesel-hybrid passenger cars (13,545) have a 5.6% share. Yet the number of newly registered BEVs still do not match the increase in the total fleet number.

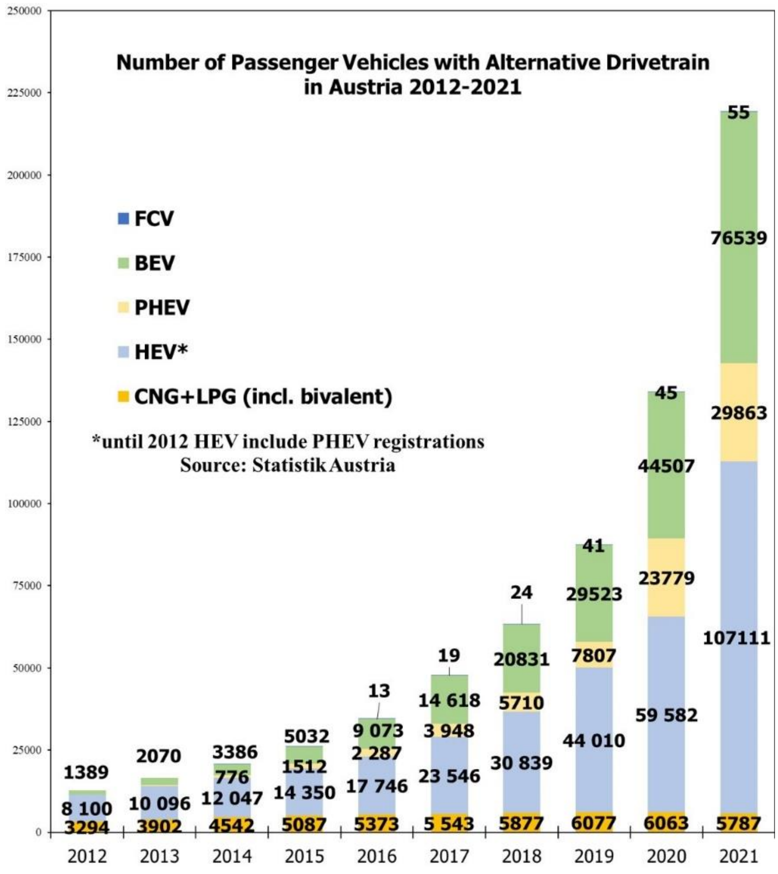


Fig. 1. Trends for vehicles with alternative drivetrains in Austria, 2012-2021
Source: Statistik Austria

Average CO_2 Emissions of Passenger Cars

In 2021, the average CO_2-emissions of newly registered passenger cars amounted to 135 g/km, based on the Worldwide Harmonised Light Vehicles Test Procedure (WLTP). (All-electric and hydrogen vehicles were taken into account). The number drops to 116 g/km if electric and hydrogen vehicles are included. The average number for petrol-powered M1 vehicles is 139 g/km (2020: 143 g/km), and diesel-powered passenger vehicles show an average of 150 g/km (2020: 156 g/km).

Development of Filling Stations

By the end of 2020, Austria had 2,733 publicly accessible filling stations. As an annual average for 2021, the price of gasoline for private use at a filling station was EUR 1.281 (USD 1.46) and the correlating price of diesel was EUR 1,237 (USD 1.34) per liter. With 125 public CNG stations in 2021, the number of public CNG filling stations has continuously decreased in recent years (2020: 149). For LPG, 39 filling stations are available (2020: 37). In addition, three public LNG filling stations in Ennshafen (Upper Austria), Feldkirchen (Styria) and Vienna are in operation.

Austria has seven hydrogen fueling stations (HFSs), of which five are publicly accessible. For one, access is limited to companies, commercial enterprises, and municipalities; another is dedicated to hydrogen research. Except for the latter, all HFSs support a pressure of 70 MPa.

Research and Demonstration Focus

Energy Model Region

As part of the "Energy Model Region" initiative, made-in-Austria energy technologies are developed and demonstrated in large-scale, real-world applications with international visibility. In the coming years, the Austrian Climate and Energy Fund (KLIEN) invests up to EUR 120 million (USD 131 million) in three Energy Model Regions. One such region—WIVA P&G— demonstrates the transition of the Austrian economy and energy production to an energy system based strongly on hydrogen. Particular emphasis is given toward the development of hydrogen transport applications like in the HyTruck – Hydrogen Truck Austria project. The WIVA P&G Energy Model Region forms part of the Mission Innovation Hydrogen Valley family.

klimaaktiv mobil Program

Austria's national action program for mobility management, called klimaaktiv mobil, supports the development and implementation of mobility projects and transport initiatives that aim to reduce CO_2 emissions. Since 2004, 21,000 climate friendly mobility projects have been funded. The klimaaktiv mobil website offers a map with details of each project. Total financial support amounted to EUR 167.5 million (USD 181 million) until the end of 2021.

Energy Research Program

The Energy Research Program provides research and innovation funding for the introduction and implementation of climate-relevant and sustainable measures and energy technologies. The strategic research focus is on sectors contributing significantly to GHG emissions, such as the transport sector. In addition, funding is dedicated to the participation of Austrian stakeholders in international organizations like the IEA TCPs.

R&I Mobility Strategy 2030

The R&I Mobility Strategy 2030 provides financial support for R&I projects and R&I activities on fundamental issues of sustainable passenger and freight transport within the context of the four mission areas: Cities, Regions, Digitalization and Technology. The annual budget is between EUR 15 million and EUR 20 million (USD 16.3 million and USD 21.7 million). A project database is available online.

ERA-NET Bioenergy

In the European Research Area (ERA-NET) Bioenergy, Austria cooperates with Germany, Poland and Switzerland in funding transnational bioenergy research and innovation projects. Austria's contribution to the recent 14th ERA-NET Bioenergy Joint Call amounts to EUR 0.8 million (USD 0.9 million).

Outlook

Austria is committed to reaching carbon neutrality by 2040, 10 years earlier than the EU. The supporting Government Program identifies alternative fuels as indispensable for reaching this ambitious goal. Advanced motor fuels play a crucial role in the Austrian Climate and Energy Strategy and are considered an important element for a successful Austrian transition toward sustainable mobility.

The areas of deployment, though, depend on the use case. Electrification is the preferred option for use cases with limited energy requirements, such as passenger cars or light duty vehicles with limited mileage. For the latter RDI funding, schemes are not directed at improving ICE drivetrains any more. Funding programs therefore focus on biofuel and synthetic fuel topics for use cases with high energy density demands, such as aviation or waterborne applications.

At the moment, Alternative Fuels Infrastructure Regulation (AFIR) is being discussed, which will set out the future framework for the deployment of charging and refueling infrastructure across the European Union. The document will include mandatory targets for member states, instead of today's indicative targets.

Additional Information Sources

- Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, http://www.bmk.gv.at/

Canada

Drivers and Policies

Clean Fuel Regulations (CFR)

Canada is developing regulations for cleaner fuels. When finalized, the proposed Clean Fuel Regulations would require liquid fossil fuel producers and importers to reduce the carbon intensity (CI) of the gasoline and diesel they produce in and import into Canada. The proposed regulations would also establish a credit market whereby the annual CI reduction requirement could be met via three main categories of credit-creating actions: GHG emission reduction projects that reduce the CI of liquid fossil fuels, supply of low-carbon fuels, and the fueling of advanced vehicle technologies. Parties that complete these actions (e.g., low-carbon fuel producers and importers) can participate in the credit market as voluntary credit creators. The proposed regulations would require that CI be reduced by 14 grams of carbon dioxide equivalent per unit of energy by 2030. Final Clean Fuel Regulations are targeted for the spring of 2022.

Renewable Fuels Regulations (RFRs)[1]

The federal RFRs require fuel producers and importers to have an average renewable content of (1) at least 5% based on the volume of gasoline and (2) at least 2% based on the volume of diesel fuel and heating distillate oil that they produce or import into Canada. The regulations include provisions that govern the creation of compliance units, allow trading of these units, and also require recordkeeping and reporting to ensure compliance. When *Clean Fuel Regulations* is published, these volumetric requirements will be incorporated into those regulations and *Renewable Fuel Regulations* will be repealed. Alongside the federal policy, Canada has a variety of provincial renewable fuel policies which prescribe specific renewable fuels volumes. Ontario, Canada's most populous province, has a minimum 4% bio-based content in diesel and 10% bio-based content in gasoline, moving towards 15% in 2030.[2]

Renewable-fuels-related Standards

The Canadian General Standards Board (CGSB) is responsible for developing fuel and renewable fuel quality standards, via consensus by public and private sectors (see Table 1).

Table 1. CGSB Renewable Fuel-quality-related Standards[3]

Fuel Standards	Number
Oxygenated automotive gasoline containing ethanol (E1–E10)	CAN/CGSB 3.511
Automotive ethanol fuel (E50–E85 and E20–E25)	CAN/CGSB 3.512
Denatured fuel ethanol for use in automotive spark ignition fuels	CAN/CGSB 3.516
Diesel fuel containing low levels of biodiesel (B1–B5)	CAN/CGSB 3.520
Diesel fuel containing biodiesel (B6–B20)	CAN/CGSB 3.522
Biodiesel (B100) for blending in middle distillate fuels	CAN/CGSB 3.524

Greenhouse Gas Emission Regulations

In 2014, the second phase of action on light-duty vehicles (LDVs) for model years 2017 to 2025, with increasingly stringent GHG standards, was initiated. Under these published regulations, *Passenger Car and Light Truck GHG Emission Regulations*, the average GHG emissions performance of new light duty vehicles decreased from about 302 g/mi in 2011 to about 245 g/mi in 2019, a reduction of about 19%. Canada completed a mid-term evaluation of the appropriateness of its standards for model years 2022 to 2025, concluding that the U.S. standards established in 2020 that increased by roughly 1.5% per year were not stringent enough to meet Canada's climate goals. Canada will work with both the U.S. and California to develop future LDV GHG regulations while intending to align with the most stringent LDV GHG tailpipe regulations in the U.S., be they at the federal or state level.

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1 https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=103l
2 https://www.ontario.ca/laws/regulation/r20663
3 http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html

In 2018, the *Regulations Amending the Heavy-Duty Vehicle (HDV) and Engine Greenhouse Gas Emission Regulations* were published. The amendments established more stringent GHG emission standards for heavy-duty vehicles and their engines, starting with the 2021 model year. Consideration to the amendments introducing new GHG emission standards that apply to trailers hauled by on-road transport tractors are being assessed. Amendments are estimated to result in cumulative fuel savings of 27.7 billion liters with respect to the portion of the lifetime operation of model years 2020 to 2029 that occurs between 2020 and 2050.

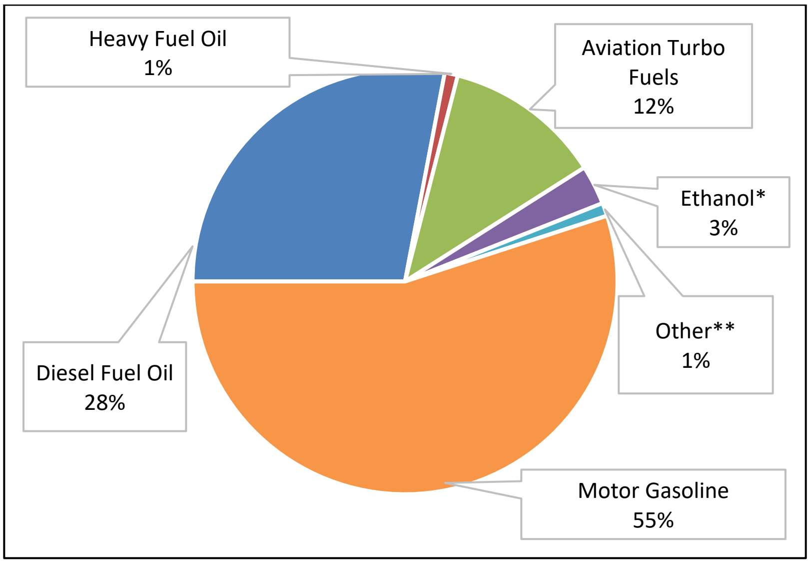
In December 2020, the Government of Canada announced its plan, A Healthy Environment and a Healthy Economy," with a commitment to further improve the efficiency of heavy-duty vehicles standards for post-2025 by aligning with the most stringent standards in North America—whether at the U.S. federal or state level. The Government of Canada has recently launched discussions on a commitment to require 100% of medium- and heavy-duty vehicles sales to be zero emission by 2040, where feasible.

Pan-Canadian Framework on Clean Growth and Climate Change (PCF)

The Pan-Canadian Framework is the federal, provincial, and territorial plan to grow the economy, reduce GHG emissions, and build resilience in the face of a changing climate. The PCF includes more than 50 concrete actions that cover all sectors of the Canadian economy and puts Canada on a path toward meeting Canada's Paris Agreement GHG-emissions-reduction target of 30% below 2005 levels by 2030.

Advanced Motor Fuels Statistics[4]

Figure 1 shows energy use by fuel type in 2018 for transportation in Canada and Table 2 shows the supply of and demand for ethanol and biodiesel.



* Ethanol proportion is estimated on the basis of production data.
** The "Other" fuel type includes electricity, natural gas, aviation gasoline and propane.

Fig. 1. Fuel Mix of the Canadian Transportation Sector 2018

Table 2. Canadian Supply and Demand of Biofuels in 2019 (in millions of liters)

Parameter	Ethanol	Biodiesel
Canadian production	1,891	359
Imports	1,219	725
Exports	0	417
Domestic use	3,094	665

[4] https://www.nrcan.gc.ca/sites/nrcan/files/energy/energy_fact/2021-2022/PDF/2021_Energy-factbook_december23_EN_accessible.pdf

Research and Demonstration Focus

ecoTECHNOLOGY for Vehicles (eTV) Program

Transport Canada's eTV Program is an initiative that conducts in-depth safety and environmental performance testing on a range of new and emerging advanced passenger car and truck technologies. The program investigates the performance of alternative-fueled vehicles, including renewable fuels, hybrid and electric, CNG, and hydrogen fuel cell vehicles.

Program of Energy Research and Development (PERD)

The Natural Resources Canada (NRCan) program PERD supports energy R&D conducted by the federal government and is designed to ensure a sustainable energy future for Canada. Key research areas focus on knowledge and technology that will help reduce the carbon footprint of fuels and emissions from transportation sources.

Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (EVAFIDI)

NRCan continued to invest in the expansion of the network of electric vehicle (EV) charging and alternative refueling stations across Canada through EVAFIDI. Funding will establish a coast-to-coast network of fast-charging stations along the national highway systems, natural gas refueling stations along key freight corridors and hydrogen refueling stations in major metropolitan areas.

Zero-Emissions Charging Station[5]

As of April 2021, NRCan has approved projects that will build 1,089 electric vehicle, 22 natural gas stations and 15 hydrogen stations. Almost half of these stations are already open to the public. Investments are also made to support the development of enabling codes and standards for vehicles and charging and refueling infrastructure.

Energy Innovation Program (EIP)

NRCan's EIP supports clean energy innovation both internally within government and externally with industry. Accelerating clean technology R&D is a key component of Canada's approach to promoting sustainable economic growth, reducing emissions including GHGs, and supporting Canada's 2050 clean growth targets.

Clean Transportation System-Research and Development Program (CTS-RD)

Transport Canada established the CTS-RD to support projects that help improve the environmental performance of Canada's transportation system, specifically in the rail, marine and aviation sectors. The program looks to advance new clean technology innovations, practices or research.

Canada's Action Plan to Reduce GHG Emissions from Aviation

Canada's Action Plan to Reduce GHG Emissions from Aviation includes research and development to support the future use of sustainable aviation fuel. Within this plan, the Green Aviation R&D Network has several on-going projects focusing on bio-derived jet fuel applications for Canada.

Memorandum of understanding between the California Air Resources Board and Environment and Climate Change Canada

In 2019, California, the U.S. state with the strictest emissions regulations, and Canada signed a cooperation agreement to advance clean transportation. The memorandum of understanding commits to working together on respective regulations to reduce GHG pollution from vehicles, promote the uptake of cleaner vehicles, and share best practices related to cleaner fuels.

Clean Growth Program (CGP)

NRCan's Clean Growth Program is providing CAN 155 million (USD 123 million) investment in clean technology R&D and demonstration projects in three Canadian sectors: energy, mining and forestry.

Strategic Innovation Fund (SIF)

The SIF, managed by Innovation, Science and Economic Development Canada, is provided to support Canadian businesses investing in innovation. The program helps offset costs related to researching and implementing new technologies, including the automotive sector.

[5] Zero-emission vehicle charging stations (canada.ca)

Net Zero Accelerator Initiative (NZAI)[6]
Within the SIF, the NZAI will provide up to CAN 8 billion in support of projects that will enable Canada to reduce its domestic GHGs through projects that promote the decarbonization of large emitters, clean technology and industrial transformation and the development of a Canadian batteries ecosystem.

Incentives for Zero Emissions Vehicles Program[7]
Canada's accelerated zero-emission vehicle sales target will support the new 2030 climate reduction targets, which are 40-45% below 2005 levels. With light-duty vehicles remaining in service for about 15 years, requiring 100 percent of vehicles to be zero-emission by 2035 will also help put Canada on a path to achieving its long-term goal of net zero emissions by 2050. To help achieve these targets, Canada introduced a suite of new policy measures, including a federal purchase incentive program for eligible ZEVs.

Electric Vehicle Infrastructure Demonstration (EVID) Program
NRCan's EVID program supports the demonstration of next-generation and innovative ZEV charging and hydrogen refueling infrastructure. Over 20 demonstration projects are addressing key technical and non-technical barriers in a range of applications focusing on challenges to the implementation of EV charging infrastructure, such as bi-directional charging combined with energy storage, fast charging performance in the North and interoperability of electric bus charging infrastructure.

Outlook

As depicted in Table 3, the Canadian transportation sector is comprised of several distinct subsectors. Each subsector exhibits different trends during the projected period. GHG emissions from cars, trucks, and motorcycles are projected to decrease by 20 Mt between 2005 and 2030, while those for heavy-duty trucks and rail are projected to increase by14 Mt.

Table 3. Transportation: GHG Emissions (Mt CO_2-eq)[8]

Transportation Subsector	2005	2020	2030	Δ 2005 to 2030
Passenger Transport	**90**	**88**	**70**	**-20**
Cars, light trucks, and motorcycles	82	79	61*	-21
Bus, rail, and domestic aviation	8	9	9	1
Freight Transport	**62**	**73**	**73**	**11**
Heavy-duty trucks, rail	54	68	68	14
Domestic aviation and marine	8	5	5	-3
Other: recreational, commercial, and residential	**10**	**9**	**10**	**0**
Total	**162**	**170**	**153**	**-9**

* These projections are based upon the current emissions standards, which are in place for model years 2017 to 2025.

6 Net Zero Accelerator Initiative - Strategic Innovation Fund
7 Building a green economy: Government of Canada to require 100% of car and passenger truck sales be zero-emission by 2035 in Canada - Canada.ca
8 https://unfccc.int/sites/default/files/resource/br4_final_en.pdf

China

Drivers and Policies

China will strive to achieve the goal of carbon neutrality, realizing the peak of carbon dioxide emissions before 2030, and carbon neutrality before 2060. China will further implement the national strategy for the development of new energy vehicles (battery electric vehicles, plug-in hybrid electric vehicles and fuel cell electric vehicles). A development plan for the New Energy Vehicle Industry (2021-2035) has been put forward: by 2025, the sales of new energy vehicles will reach around 20% of the total sales of new vehicles; by 2035, battery electric vehicles will become the mainstream of new vehicles; public vehicles will be fully electrified; fuel cell electric vehicles will be commercialized; and the hydrogen fuel supply system will be steadily advancing; which will effectively promote energy conservation and emission reduction and improve the efficiency of social operations.

Peak Carbon Dioxide Emissions Action Program Pre-2030

In October 2021, the State Council printed and distributed the Peak Carbon Dioxide Emissions Action Program Pre-2030 (“the Program”). Centering on the implementation and execution of the Central Committee of the Communist Party of China’s and the State Council’s important strategic decisions on peak carbon dioxide emissions and carbon neutrality, and focusing on peak carbon dioxide emissions target pre-2030, the Program makes overall deployment of peak carbon dioxide emissions in accordance with the State’s work requirements regarding complete, accurate and comprehensive implementation of the new development concept and optimization of peak carbon dioxide emissions and carbon neutrality work.

The Program proposes to implement peak carbon dioxide emissions work throughout all aspects of economic and social development, and focus on the implementation of “top 10 peak carbon dioxide emissions actions,” such as green low-carbon energy transformation action, energy saving, carbon reduction and efficiency enhancement action, peak carbon dioxide emissions action in industrial fields, peak carbon dioxide emissions action for urban and rural development, green low-carbon action in the transport field, carbon reduction action through cyclic economy assistance, green low-carbon science and technology innovation action, carbon sink capacity consolidation and enhancement action, green low-carbon action by all people and orderly cascade peak carbon dioxide emissions action in all regions.

In regard to the green low-carbon action in the transport field, it is proposed to actively expand the application of new energy and clean energy such as electricity, hydrogen energy, natural gas and advanced liquid biological fuel in the field of transport. China will energetically promote new energy vehicles and gradually reduce the proportion of traditional fuel vehicles to new vehicle production and sales as well as vehicle ownership. By 2030, the proportion of newly added vehicles using new energy and clean energy for propulsion should reach approximately 40%. China will speed up the construction of green traffic infrastructure and orderly propel the construction of infrastructure such as charging pillars, auxiliary power grids, fuel (gas) filling stations and hydrogen filling stations to enhance the level of urban public transport infrastructure.

The White Book of Policies and Actions of China for Addressing Climate Change

In October 2021, the State Council Information Office published the White Book of Policies and Actions of China for Addressing Climate Change.

The White Book emphasizes that climate change is a common challenge for all mankind. Addressing climate change is related to the sustainable development of the Chinese nation and the future and destiny of mankind. The White Book introduces the progress of China in addressing climate change from four major sections of “new concept of China regarding addressing climate change,” “implementation of national strategy to actively address climate change,” “historical changes of China for addressing climate change” and “joint development of fair, reasonable and win-win global climate governance system,” shares practices and experiences of China on addressing climate change, and enhances international understanding.

As a responsible country, China will actively promote the joint development of a fair, reasonable and win-win global climate governance system and contribute the wisdom and strength of China for addressing climate change. Facing the serious challenges of climate change, China is willing to make joint efforts and move forward hand-in-hand with the international community to promote stable, long-range implementation of the Paris Agreement and to make greater contribution to global efforts for addressing climate change.

Existing National Standards on Alternative Motor Fuels

- GB/T 23510-2009, “Fuel methanol for motor vehicles” was released on April 8, 2009, and implemented on November 1, 2009.
- GB/T 23799-2009, “Methanol gasoline (M85) for motor vehicles” was released on May 18, 2009, and implemented on December 1, 2009.
- GB/T 23799-2021, “Methanol gasoline (M85)” for motor vehicles was released on October 11, 2021, and will be implemented on May 1, 2022.
- GB/T 34548-2017, “The additive of methanol gasoline for vehicles” was released on October 14, 2017 and implemented on May 1, 2018.
- GB/T 31776-2015, “Determination method of methanol content in methanol gasoline for motor vehicles” was released on July 3, 2015 and implemented on October 1, 2015.
- GB/T 26127-2010, “Compressed coalbed methane as vehicle fuel” was released on January 14, 2011, and implemented on June 1, 2011.
- GB/T 26605-2011, “Dimethyl ether for motor vehicle fuel” was released on June 16, 2011, and implemented on November 1, 2011.
- GB 19159-2012, “Automotive liquefied petroleum gases” was released on November 5, 2012, and implemented on April 1, 2013.
- GB/T 20828 2015, “Biodiesel blend stock (BD100) for diesel engine fuels” was released and implemented on May 8, 2015.
- GB 25199-2017, “B5 diesel fuels” was released and implemented on September 7, 2017.
- GB 18351-2017, “Ethanol gasoline for motor vehicles (E10)” was released and implemented on September 7, 2017.
- GB/T 22030-2017, “Blendstocks of ethanol gasoline for motor vehicles” was released and implemented on September 7, 2017.
- GB 35793-2018, “Ethanol gasoline for motor vehicles E85” was released on February 6, 2018, and implemented on September 1, 2018.
- GB 18047-2017, “Compressed natural gas as vehicle fuel” was released on September 7, 2017, and implemented on April 1, 2018.
- GB/T 40510-2021, “Bio-natural gas as vehicle fuel” was released on August 20, 2021, and will be implemented on March 1, 2022.
- GB/T 34537-2017, “Hydrogen and compressed natural gas (HCNG) blended as vehicle fuel was released on October 14, 2017 and implemented on May 1, 2018.
- GB/T 37178-2018, “Coal-based synthetic natural gas for vehicle” was released on December 28, 2018, and implemented on July 1, 2019.
- GB/T 37244-2018, “Fuel specification for proton exchange membrane fuel cell vehicles—Hydrogen” was released on December 28, 2018 and implemented on July 1, 2019.

Advanced Motor Fuels Statistics

In 2021, 198.98 million tons of crude oil were produced in China, an increase of 2.4% year-on-year; 703.55 million tons of crude oil were processed, an increase of 4.3% year-on-year. Meanwhile, 512.98 million tons of crude oil were imported, a decline of 5.4% year-on-year.

In 2021, China produced 205.3 billion cubic meters (m3) of natural gas, an increase of 8.2% year-on-year. China imported 121.36 million tons of natural gas, an increase of 19.9% year-on-year.

In 2021, China’s auto production and sales were 26.082 million vehicles and 26.275 million vehicles respectively, with a year-on-year increase of 3.4% for production and 3.8% for sales.

The production and sales of new energy vehicles were 3.545 million units and 3.521 million units, both showing a year-on-year increase of 160%, accounting for 13.4% of the market share. The production and sales of fuel cell electric vehicles were both 2,000 units.

In 2021, the sales volume of commercial natural gas vehicles was 86,936 units and the top five provinces by sales were Xinjiang, Shanxi, Shaanxi, Hebei and Sichuan.

Research and Demonstration Focus

Promotion of Methanol Gasoline Pilot Project

In 2019, the Ministry of Industry and Information Technology and other relevant departments jointly issued the "Guiding Opinions on the Application of Methanol Vehicles in Some Areas." According to the principles of adapting measures to local conditions, being proactive and prudent, and being safe and controllable, the focus is on areas with better resources and experiences in operating methanol vehicles, such as Shanxi, Shaanxi, Guizhou, and Gansu, to accelerate the application of M100 methanol vehicles. The use of methanol vehicles for official cars, taxis, and short-distance passenger buses in suitable areas is encouraged. The use of methanol commercial vehicles in the fields of public service vehicles and dedicated logistics in suitable areas is encouraged.

By the end of 2022, Shanxi will make efforts to operate three to five methanol vehicles demonstration projects or routes, promote more than 20,000 units of M100 methanol vehicles and build more than 200 methanol refueling stations.

Guizhou has established a complete methanol vehicle production, sales, service system and methanol fuel transportation and distribution supply guarantee system. As of September 2021, Guizhou had promoted 16,400 methanol vehicles, with a total operating mileage of more than 6.5 billion kilometers and a maximum single-vehicle operating mileage of more than 950,000 kilometers. More than 50 methanol fuel filling stations have been put into operation in the province.

Gansu strives to have more than 10,000 methanol vehicles in the province by the end of 2025. At the same time, the use of methanol vehicles will be encouraged in the fields of urban buses, public services vehicles, and government vehicles. The use of methanol commercial vehicles will be encouraged in the field of infrastructure construction, and the use of heavy-duty methanol commercial vehicles will be encouraged in the field of resource mining. In addition, areas such as taxis and driving training will be encouraged to use methanol vehicles when adding and updating vehicles, and gradually household use of methanol vehicles will be promoted.

Promotion of Fuel Cell Electric Vehicles Pilot Project

In September 2020, the Ministry of Finance, MIIT, Ministry of Science and Technology, National Development and Reform Commission and National Energy Administration jointly issued the Notice on Developing Demonstrative Application of Fuel Cell Vehicles. Incentive funds will be allocated to the pilot city groups promoting fuel cell electric vehicles.

In September 2021, the first batch of three fuel cell vehicle demonstration city groups was announced and the three city groups are led respectively by Beijing, Shanghai and Foshan of Guangdong Province. During the demonstration period from 2022 to 2025, the five ministries and commissions will conduct integral assessments on the promotion and application of fuel cell vehicles, the R&D industrialization of key components, and the supply of hydrogen energy.

The Beijing-Tianjin-Hebei Demonstration City Group will rely on the demonstration projects of the 2022 Winter Olympics to promote the hydrogen energy industry chain. Zhangjiakou and Yanqing will respectively introduce 625 and 212 fuel cell electric vehicles for the Winter Olympics. In four years, the Beijing-Tianjin-Hebei area will achieve technological breakthroughs in core parts and components, and the number of fuel cell electric vehicles will be no less than 5,300.

The Guangdong Demonstration City Group aims to promote more than 10,000 units of fuel cell electric vehicles and build more than 200 hydrogen refueling stations.

Shanghai will cooperate with Suzhou, Nantong, Jiaxing, Zibo, and Ordos to complete the task of promoting 5,000 fuel cell electric vehicles.

Outlook

Driven by the goal of carbon neutrality, China will promote new energy and clean energy. China will actively develop renewable energy resources, such as wind energy, solar energy, biomass energy and hydrogen energy.

In order to fulfill the goal set in “Development Plan for the New Energy Vehicle Industry (2021-2035),” the new energy vehicles will develop quickly. Fuel cell electric vehicles are expected to realize commercialization by 2035.

Meanwhile, China will promote natural gas vehicles and methanol vehicles in areas where there are resources.

Additional Information Sources

- National Development and Reform Commission, https://www.ndrc.gov.cn
- China Association of Automobile Manufacturers (CAAM), http://www.caam.org.cn/
- China Society of Automotive Engineers (China-SAE), http://www.sae-china.org/
- China Automotive Technology and Research Center Co., Ltd. (CATARC), http://www.catarc.ac.cn
- Asia Pacific Natural Gas Vehicles Association (ANGVA), http://www.angva.org/
- Ministry of Industry and Information Technology (MIIT), http://www.miit.gov.cn/

Denmark

Drivers and Policies

In December 2019, Denmark approved a new Climate Act that will include a legally binding target to reduce GHGs by 70% by 2030 (relative to 1990 level), to reach net zero emissions by 2050 at the latest, and to set milestone targets based on a five-year cycle. In the political understanding, “A fair direction for Denmark,” it says that a reduction target by 70% by 2030 is a very ambitious goal, and that it will be particularly difficult to realize the last part of the goal (i.e., from 65% to 70%). Meeting the target will require currently unknown methods and, therefore, a close collaboration with the Danish Council on Climate Change and other experts. The Climate Act will be followed by climate action plans, which will contribute to ensuring that national reduction targets are met. The Climate Action Plan in 2020 included sector strategies and indicators at a minimum for central sectors such as agriculture, transport, energy, construction and industry. Moreover, Denmark has already taken the first steps toward establishing a professional and efficient energy sector as the basis for the transition to a sustainable green society. In June 2018, all parties of the Danish Parliament reached a political Energy Agreement to further build Denmark’s international positions of strength with a focus on renewable energy, energy efficiency improvements, research and development, and energy regulation. The measures and policies decided in the agreement are now in the process of being implemented.

Advanced Motor Fuels Statistics

General Energy Data

Gross energy consumption has been relatively constant since 1990, with falling consumption of coal and increasing consumption of renewable energy (see Fig. 1). Gross energy consumption peaked in 2007 at 873 PetaJoule (PJ) and has since followed a downward trend. Gross energy consumption is expected to drop annually by 1.2% until 2020, after which it will rise slightly to 778 PJ in 2030, corresponding to amounts in 2017. Coal consumption will fall considerably by 14% annually until 2030, due in particular to the expected stop in the use of coal in large-scale Combined Heat and Power (CHP) production. In 2030, only the power station Fynsværket and the cement industry will consume large amounts of coal. However, some plants will retain the option for coal operation, although actual use is assumed to be limited.

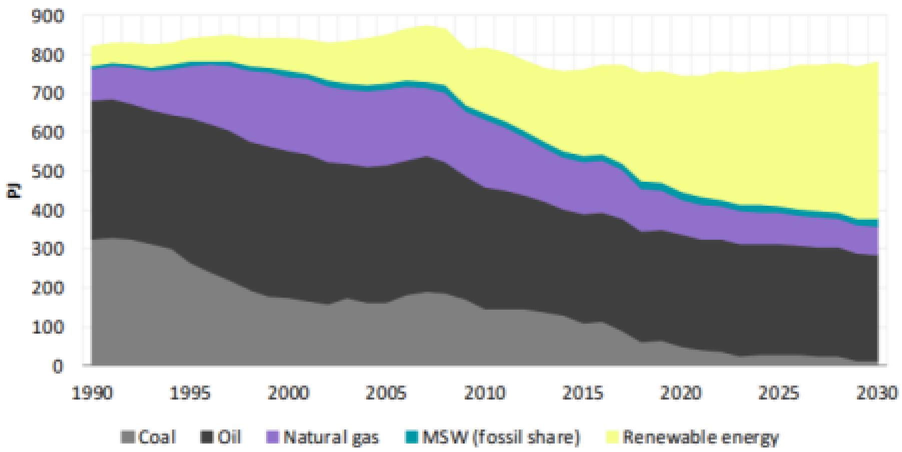


Fig. 1. Gross energy consumption (PJ) by type of energy, 1990-2030. The calculation for 1990-2017 has been adjusted for outdoor temperature/degree days relative to normal years (climate-adjusted) and electricity trade with other countries.

Figure 2 shows the total share of renewables (RES) as well as renewables shares for transport (RES-T), electricity consumption (RES-E), heating and cooling (RES-H&C), and district heating (RES-DH), respectively, calculated on the basis of the method described in the EU Renewable Energy Directive (RED) (EU, 2009; Eurostat 2018).

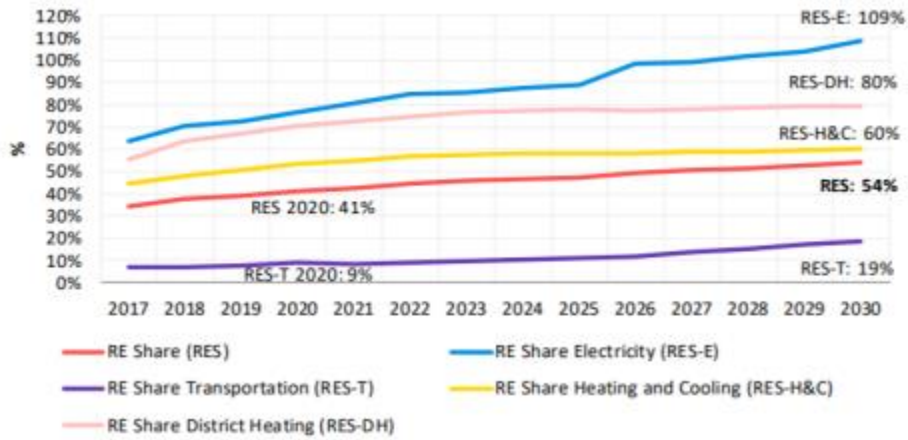


Fig. 2. Renewables shares 2017-2030 [%]. The renewables shares is calculated as defined in RED (Eurostat, 2018).

The RES and RES-T are subject to binding national EU targets in 2020. The EU RED also sets out a 2030 target for 27% renewables for EU countries together, but this target has not been implemented as national obligations. Instead, EU Member States are obligated to account for their contributions to reaching the common EU target in their National Energy and Climate Plans. The projections show that the RES is expected to be 41% in 2020, whereby Denmark will have met, and exceeded, its EU obligation for a 30% renewables share by 2020. The RES-T will reach 9% in 2020, whereby there will be a shortfall of 1 percentage point compared with the RED obligation of 10% in 2020. The overall RES will increase up to 2030, when it will reach 54%. The trend depends on the deployment of offshore wind, onshore wind and solar PV, and on the conversion of CHP plants to biomass, while energy-efficiency improvements in transport, industry, services and households will contribute to a lesser extent. The rate of renewables deployment in electricity supply is expected to exceed the rate of increase in electricity consumption, and Denmark's production of electricity from renewables is expected to exceed Denmark's electricity consumption from 2028. The RES-E is expected to increase to 109% in 2030. This trend is particularly contingent upon the offshore wind farms included in the 2018 Energy Agreement being commissioned by 2030.

There are also updated expectations regarding deployment of commercial solar PV (ground mounted solar farms) and expectations regarding replacement of older onshore wind turbines with fewer, more efficient turbines. The projection of onshore wind and solar PV deployment depends on the development in electricity prices; maintenance of the level for tender prices achieved in the 2018 technology neutral tendering round; voluntary renewable energy targets from large consumers and the market for PPA/guarantees of origin. A high percentage of RES-E affects calculation of the RES-T because the RED uses a multiplication factor of four for the renewables share of electric road transport and a multiplication factor of 1.5 for the renewables share of electric rail transport. With this background, RES-T increases to 19% in 2030, contingent on the number of electrified passenger cars and vans increasing to around 9% of the total number in 2030, and an increased use of electricity in rail transport. Greater use of bio-natural gas in transport will only contribute to a very limited extent. The blending ratio of biofuels in petrol and diesel is expected to be maintained at the current level in the absence of new measures. Fuel consumption for domestic air traffic is included in the calculation of the renewables share. The aviation sector has announced ambitious plans for biofuel blending, but as these announcements are neither binding nor reflect a profitable development pathway for companies in the absence of new measures, the plans have not been included in a renewables contribution from this sector.

Measured in relation to final energy consumption, the share of fossil fuels in the transport sector will fall from 95% in 2017 to 92% in 2030. This is due to a combination of electrification of the rail and road transport sectors as well as improved energy efficiency for conventional vehicles. Fossil fuel consumption by road transport is expected to amount to 73% of total fossil fuel consumption by the transport sector in the absence of any new measures.

Details on Advanced Motor Fuels
Renewables share increasingly consists of electricity produced from renewable energy sources (see Fig. 3). In 2030, the RES-E by the transport sector will correspond to the consumption of first generation biofuels; consumption of second generation biofuels will constitute a smaller share.

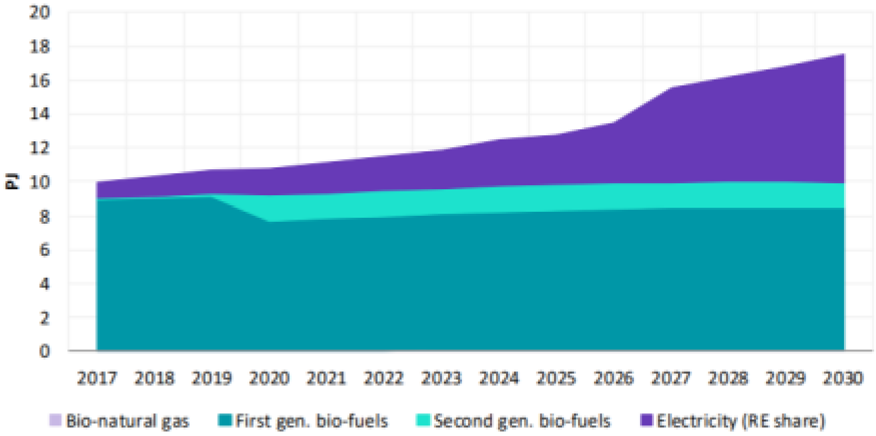


Fig. 3. Renewable energy consumption by the transport sector 2017-2030 [PJ].

The projections show that electric vehicles and PHEVs, in the absence of new measures, are expected to account for 22% of sales and almost 9% of the total number of passenger cars and vans on the road in 2030. This corresponds to approximately 300,000 electrified passenger cars and vans in 2030 (see Fig. 4).

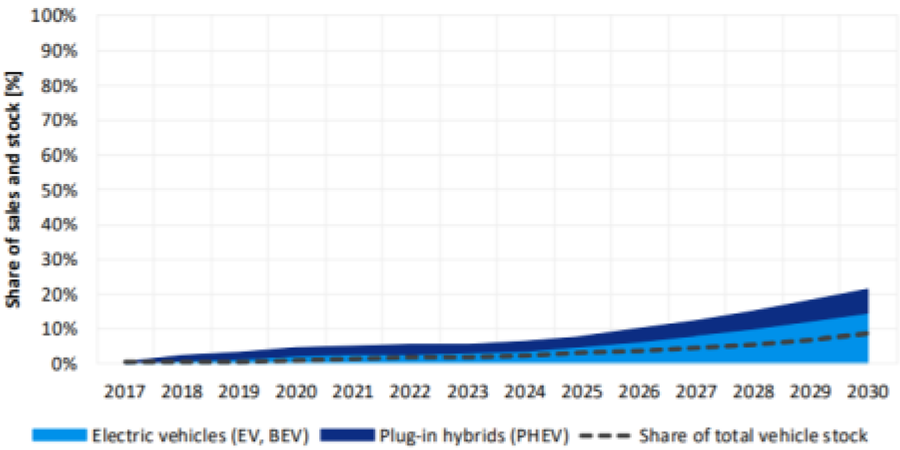


Fig. 4. Electrified vehicles' share of sales of new vehicles and share of total number of passenger cars and vans on the road 2017-2030 [%].

Research and Demonstration Focus

Research and Demonstration in Denmark are focused on electric vehicles and fuel cell vehicles for passenger cars. Several demonstration projects have been initiated. For HDVs, biofuels are the most obvious solution. However, liquid and gaseous electrofuels, which can store a surplus of wind turbine electricity, appear to be gaining attention. Research supporting analysis of common energy and transport fuels production systems also has high priority.

Outlook

In Denmark, the transportation sector is still almost entirely dependent on oil. By 2050, the government aims to meet all Danish energy supply by renewable energy, including that required by the transportation sector. In 2012, a broad majority in Parliament reached an energy agreement defining initiatives covering crucial energy policy areas for the period 2012-2020, and agreed to discuss additional initiatives for the period after 2020. The analysis from 2012 indicates that by 2020 and beyond, electricity, biogas, and natural gas could become especially attractive as alternatives to petrol and diesel in the transportation sector. Electricity is the most energy-efficient alternative because of high efficiency in the engine and an increase in the share of wind-generated electricity supply.

Energy Islands

The world's first energy islands will be constructed in Denmark, exploiting our immense wind resources in the North and Baltic seas. The energy islands will serve as hubs that can create better connections between energy generated from offshore wind and the energy systems in the region around the two seas.

In the North Sea, an artificial island will be established, which will be a hub for 3 GW offshore wind farms and with the possibility of 10 GW wind farms in the long term, and will thus be able to cover the consumption of 10 million households. The wind turbines that will supply power to the island are expected to be larger than they are today, and will go further out to sea than before. The technical equipment for energy distribution will be located on the island. It will not be possible to see the turbines from land. The energy islands are part of the development of the energy systems of the future, and it is part of the political agreements that electricity from the energy islands should be converted into new forms of energy (e.g., Power-to-X). This means that the green power will contribute to the phasing out of fossil fuels in both Denmark and Europe.

In the Baltic Sea, the technical equipment for energy distribution will be located on Bornholm, where electricity from offshore wind farms will be transported to the electricity grid on Zealand and neighboring countries. The offshore wind farms will stand approximately 20 km south-southwest of the coast and will be visible but not dominant on the horizon.

The parks at Bornholm must have a capacity of 2 GW corresponding to the electricity consumption of two million households. Like the island in the North Sea, the ambition is for electricity from the offshore wind farms to be able to be converted into other forms of energy, for example Power-to-X.

Additional Information Sources

- Danish Energy Agency, 2019, *Danish Energy and Climate Outlook 2019*, https://ens.dk/sites/ens.dk/files/Analyser/deco19.pdf
- Energistyrelsen, www.ens.dk.

Finland

Drivers and Policies

The 2016 energy and climate strategy calls for a 50% reduction of CO_2 emissions from transport by 2030, the reference year being 2005.[9] The 2019 Government Programme sets a new upper level: Finland will achieve carbon neutrality by 2035, and aim to be the world's first fossil-free welfare society.

In May 2021, the Ministry of Transport and Communications of Finland published a roadmap for fossil-free transport with the goal of halving GHG emissions from transport by 2030, using 2005 as the base year, and to achieve zero emissions by 2045. Measures of the roadmap include actions to support the procurement of electric and gas-powered vehicles, the distribution infrastructure, pedestrian and bicycle traffic, and public transport. Additionally, assessments cover the impacts of a stricter obligation to distribute renewable fuels, as well as the impacts of remote work, new transport services and combined transports in freight traffic.[10]

The current biofuels obligation (liquid biofuels) calls for 18% biofuels in 2021. In spring 2019, the biofuels obligation was revised, and the pathway toward 2030 was set. The biofuel target for 2029 and beyond is 30%, and this time the target reflects actual energy contribution without double counting. This explains the lower obligation for 2021 compared to 2020 (20%). There is also a separate sub target for advanced biofuels following the RED II directive: 2% between 2021 and 2023. In 2021, Finland passed a law amending gaseous and liquefied biogas in the transport biofuels obligation beginning January 1, 2022, and passed a law amending electrofuels in the biofuels obligation beginning January 1, 2023.[11,12] In addition, a separate biofuels obligation is set for non-road machinery diesel fuels. The current level is 3%, and it will increase on a yearly basis up to 10% in 2030.

As of 2011, the fuel tax system consists of an energy component, a CO_2 component and a bonus for reduced local emissions. The system favors the best of biofuels, but it is still transparent and technology neutral, and it can be used in combination with the obligation for liquid biofuels. Passenger car taxation (purchase tax and annual tax) has been CO_2-based (tailpipe) since 2008, providing substantial incentives for BEVs and PHEVs.[13]

In May 2021, the Ministry of Transport and Communications of Finland published a roadmap for fossil-free transport with the goal of halving GHG emissions from transport by 2030, using 2005 as the base year, and to achieve zero emissions by 2045. Measures of the roadmap include actions to support the procurement of electric and gas-powered vehicles, the distribution infrastructure, pedestrian and bicycle traffic, and public transport. Additionally, assessments cover the impacts of a stricter obligation to distribute renewable fuels, as well as the impacts of remote work, new transport services and combined transports in freight traffic.[14]

Advanced Motor Fuels Statistics

In 2020, the energy consumption in domestic transport (all modes together) was 166 PJ, and energy consumption in road transport was 152 PJ or 3.6 Mtoe (Table 1). Relative to the total final consumption of 1,018 PJ in 2020,[15] the figures were 16.3% and 14.9%, respectively.[16] In 2020, total CO_2-eq emissions were 47.1 Mt. The emissions from transport were 10.3 Mt (all modes together) and 9.8 Mt (road), which are 22.0% and 21.0%, respectively.[17,18]

[9] https://tem.fi/en/energy-and-climate-strategy-2016
[10] https://www.lvm.fi/en/-/transport-emissions-can-be-halved-by-2030-through-national-and-eu-measures-1641099
[11] https://www.edilex.fi/verohallinnon_ohjeet/2020_1116.html
[12] https://tem.fi/-/biopolttoaineet-jakeluvelvoitteeseen
[13] Parkkonen, L. (2013). Taxation of petroleum products and vehicles in Finland. CEN/TC 19 Conference. Helsinki, May 27, 2013.
[14] https://www.lvm.fi/en/-/transport-emissions-can-be-halved-by-2030-through-national-and-eu-measures-1641099
[15] pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehk/statfin_ehk_pxt_12sz.px/
[16] http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ymp__khki/statfin_khki_pxt_111k.px/
[17] http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ymp__khki/statfin_khki_pxt_111k.px/
[18] http://lipasto.vtt.fi/en/liisa/index.htm

Table 1. Energy in road transport in 2020

	PJ	ktoe	Share of fuels (%)	Share of bio (%)
Petrol (fossil)	47.2	1127	31.0	
Biocomp. petrol	3.8	90	2.5	7.4 of petrol
Diesel (fossil)	87.9	2100	57.7	
Biocomp. diesel	12.6	301	8.3	12.5 of diesel
Natural gas	0.35	8.4	0.23	
Biomethane	0.40	9.6	0.26	53.3 of gas
∑ fuels	152.3	3638		11.0 of fuels
	PJ	**ktoe**	**Share of total (%)**	
Electricity	0.41	9.8	0.3	
∑ fuels	152.3	3638	99.7	
Total	**152.7**	**3,648**		

Source: pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehk/statfin_ehk_pxt_12sz.px/

In terms of energy, the contribution of biofuels relative to the total amount of actual fuels is 11.0%, varying from 7.4% in petrol (mostly ethanol and some ETBE but also bio-naphtha; the statistics do not give details on this) to 53% in methane. The actual amount was 402 ktoe or 11.0% of the liquid fuels, meaning that the greater part of the biofuels used was eligible for double counting.

The four major Finnish players in biofuels are Neste (being the world's biggest producer of HVO), UPM, St1 and Gasum. The total production capacity of biofuels in Finland is some 540 ktoe.[19] Compared to the Finnish consumption of biofuels in 2020, Finland is more than self-sufficient in the production of biofuels. However, it should be noted that Neste relies mainly on imported feedstocks, whereas UPM, St1 and Gasum use indigenous feedstocks. All Finnish biofuel producers have announced major increases in capacity either in Finland or abroad.

Table 2 presents the vehicle fleet in use at the end of 2021 (without two- and three-wheelers and light four-wheelers). Table 3 presents the sales figures for new passenger cars in 2015-2020 (revised).

[19] https://valtioneuvosto.fi/artikkeli/-/asset_publisher/10616/selvitys-biopolttoaineiden-kustannustehokkaat-toteutuspolut-vuoteen-2030

Table 2. Vehicle fleet in use at the end of 2021 (without two- and three-wheelers and light four-wheelers)[20]

Fuel	Cars	Vans	Trucks	Buses	Special vehicles
Petrol	18,84698	9,440	2,145	20	20
FFV / ethanol	4,486	4,486	4,486	4,486	4,486
Diesel	751,779	751,779	751,779	751,779	751,779
Methane	6,351	6,351	6,351	6,351	6,351
Methane bi-fuel	8,025	8,025	8,025	8,025	8,025
BEV	22,921	22,921	22,921	22,921	22,921
PHEV petrol	72,363	72,363	72,363	72,363	72,363
PHEV diesel	4,626	4,626	4,626	4,626	0
Other	42	42	42	42	42
Total	2,755,349	2,755,349	2,755,349	2,755,349	2,755,349
Fuel	**Cars (%)**	**Vans (%)**	**Trucks (%)**	**Buses (%)**	**Special vehicles (%)**
Petrol	68.4	2.7	2.3	2.3	2.3
FFV / ethanol	0.2	0.2	0.2	0.2	0.2
Diesel	27.3	96.7	97.1	96.6	84.1
Methane	0.2	0.2	0.2	0.5	0.0
Methane bi-fuel	0.3	0.1	0.1	0.0	0.0
BEV	0.8	0.2	0.0	2.6	0.0
PHEV petrol	2.6	0.0	0.0	0.0	0.0
PHEV diesel	0.2	0.0	0.0	0.0	0.0
Other	0.0	0.0	0.1	0.0	0.0

Table 3. Sales of new passenger cars in 2015 - 2021[21]

Year	Petrol	FFV	CNG	Diesel	HEV P	HEV D	PHEV P	PHEV D	BEV
2015	66,248	105	158	38,797	2,817	29	400	15	243
2016	7,3251	14	165	39,451	4,668	11	1115	93	223
2017	70,520	1	433	36,060	8,512	2	2,401	152	502
2018	73,065	0	1,161	28,710	11,631	224	4,797	135	776
2019	67,751	0	2,142	20,871	14,582	990	5,807	159	1,897
2020	45,589	0	1,841	14,133	17,371	1,354	12,797	435	4,245
2021	30,757	12	909	8,397	25,871	2,235	19,519	620	10,152

The share of alternative fuel vehicles (PHEVs, HEVs, NGVs, FFVs) ranges from 18.0% (cars) to 0% (special vehicles). Among passenger cars, HEVs form the largest alternative vehicle group.

From 2019 to 2020, petrol increased and diesel dropped, whereas registrations of BEVs and hybrid vehicles, including HEVs and PHEVs, increased. There are some 400 alternative-fueled trucks, including FFVs and bi-fuel vehicles. The numbers for these two categories are explained by the fact that some heavy pick-up trucks and vans are registered as trucks. With the development of LNG refueling infrastructure and increased offerings of heavy gas trucks, trucks fueled by LNG have entered Finnish roads. The number of trucks fuelled by LNG grew from 134 in 2020 to 214 in 2021. In the case of buses, the number of battery electric buses has surpassed the number of CNG buses.

[20] https://www.traficom.fi/fi/tilastot/ajoneuvokannan-tilastot
[21] https://www.aut.fi/tilastot/ensirekisteroinnit/ensirekisteroinnit_kayttovoimittain/henkiloautojen_kayttovoimatilastot

Research and Demonstration Focus

In 2020, a new project on liquid electrofuels was granted funding by Business Finland. The E-Fuel project (2021-2022) aims to develop integration of hydrogen production through high-temperature electrolysis with CO_2 sequestration and Fischer-Tropsch fuel synthesis, and the project also includes research on end-use.

The BIOFLEX project (2020-2022) explores how suitable fuel oils made from biomass and waste plastics are for power plants and ship diesel engines. Development of production processes as well as measurements of the emissions when using new biofuels in marine engines are studied.

Between 2018 and 2021, VTT coordinated IEA AMF Task 57 “Heavy Duty Vehicle Evaluation,” which concentrated on energy efficiency, CO_2 and pollutant emissions of state-of-the-art HDVs among the AMF member countries[22]. The project covered a broad range of fuel options, including diesel, HVO, B20, ED95, LNG, CNG and different combustion modes. Independent of fuel type, the concepts based on compression ignition (diesel process), including HPDI dual-fuel, deliver rather high efficiency. In regards to tailpipe (TTW) CO_2 emissions, HPDI dual-fuel delivers on average close to 20% lower emissions than diesel. In addition, latest Euro VI trucks are capable of regulated emissions clearly below the legislative target values. Combined with state-of-the-art HDV powertrains, renewable fuels provide an effective measure for reducing GHG emissions in well-to-wheel (WTW) bases. Hence, HDV CO_2 regulations that focus only on tailpipe emissions constitute a barrier for further development of alternative-fueled trucks. This could halt development of clean and efficient engines for dedicated alternative fuels, resulting in a preference to use drop-in fuel in the legacy fleet and electrification for new trucks entering the market. The project also studied the impacts of vehicle size and relative loading, which are often dismissed. Increasing high capacity transportation (HCT) with a gross vehicle weight rating (GVWR) higher than the typical European 42-ton truck would be a cost-effective way for reducing CO_2 emissions per ton-km transported goods.

The MARANDA project (2017-2021), a hydrogen-related project examining hydrogen-fueled fuel cell-based hybrid powertrain system for marine applications, is still active. The H2020 (2019-2022) Flagsip project will install a total of 1 MW hydrogen-powered fuel cells on two vessels located in France and Norway; the ships will operate commercially for 18 months during the project.

From 2017-2021, Business Finland ran a program called “Smart Energy Finland.” The program brought together the services for technical development and exports and aimed to grant €100 million to smart energy solution innovations. The program also granted support for the international expansion of growth-oriented companies that possess growth potential and feature renewable energy and smart energy solutions in their product portfolio. The scope of the program was quite wide, and transport-related issues were only a minor part of the program. However, one subtheme of the program was “sustainable bioenergy solutions,” covering both biogas and advanced liquid biofuels. Another subtheme was dealing with batteries, thus having couplings to the transport sector.

The Clean Propulsion Project (2021-2023), funded by Business Finland, is focusing on development of maritime and non-road engine technologies for better efficiency and renewable fuels. The project has four focus areas. The first focus area includes developing a roadmap for sustainable shipping. The second focus area includes investigation and development of multiple power source propulsion systems, including hybrid technology demonstration. The third focus area covers novel combustion concepts and exhaust gas after-treatment technologies close to zero emissions. Different fuel options are investigated including hydrogen in non-road applications. The fourth focus area covers the development of virtual sensor and control algorithm for increased powertrain efficiency and full deployment of renewable fuels.

Outlook

Finland has to reduce its CO_2 in the non-ETS sector by 39% by 2030. This puts pressure on emission reductions in transport. Biofuels—or, in more general terms, renewable fuels—are seen as a very important element in emission reductions in transport. With its new liquid biofuels mandate written into law in spring 2019, Finland is one of the few countries with a fixed biofuels policy all the way to

[22] https://www.iea-amf.org/content/projects/map_projects/57

2030. In parallel with increasing the amount of biofuels, energy efficiency and electrification in transport are promoted as well.

In the newest government program, much attention is given to circular economy and biogas, so there is a political will to promote the use of biomethane in transport. Opening up of the gas market (gas transmission and sales separated[23]) as of 2020, a new pipeline connector to Estonia, and terminals for LNG import open up new possibilities for methane in stationary applications as well as in mobile applications on land and at sea. Currently, the Finnish LNG vessel fleet encompasses some 10 LNG-fueled ships, including passenger and cargo ships, as well as one icebreaker and one border patrol vessel. At the end of 2020, biogas obligation for transport and heating gas was proposed. If passed as law, it would require that future biogas be mixed in the national gas grid.

The Finnish energy companies have a record of being active in the field of biofuels. New capacity is to be expected within the borders of Finland and abroad.

Major changes
Energy and climate strategy in Finland calls for a 50% reduction of CO_2 emissions from transport by 2030, and a new upper level target for Finland is set to be CO_2 neutral by 2035. A liquid biofuels obligation law calls for 30% biofuels (actual energy share) in 2030. There is also a separate sub target of 10% for advanced biofuels. This means that Finland is implementing one of the most progressive biofuels policies in the world. Additionally, the government emphasizes a circular economy and the development of biogas.

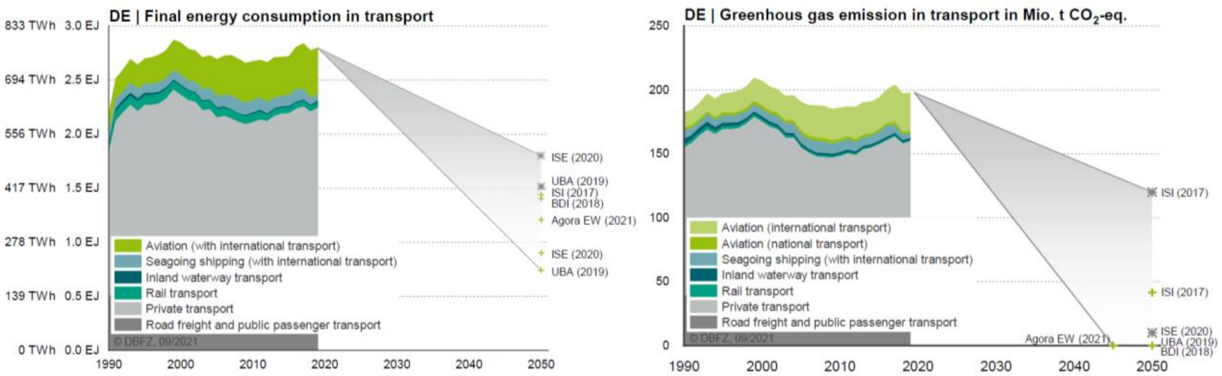
[23] https://figas.fi/en/gas-market

Germany

Drivers and Policies

Germany has set significant targets to reduce GHG emissions on the EU and national levels (e.g., European Green Deal and Federal Climate Change Act); the transition towards decarbonization is ongoing. Importantly, Germany's transport sector continues to be strongly affected by the COVID-19 pandemic in 2021. The Climate Change Act was amended in 2021, resulting in more ambitious climate targets for the years to come. In sum, Germany set binding target savings of at least 65% of GHG emission by 2030, compared to 1990, and aims to reach the ambitious goal of becoming carbon neutral by 2045.[24] The permissible annual emission budget for the transport sector is 85 Mt CO_2-eq in 2030.

While national and sector-wide GHG emission reduction targets for 2030 are in line with the German long-term strategy, they are not always reflected in sector-specific national contributions (i.e., EU energy efficiency target) and policies and measures (e.g., in the transport sector). These measures are specified in the Climate Action Programme 2030. These measures are only contributing a reduction of 41-42% GHG emissions in the transport sector by 2030[25]. This translates to 98 to 95 Mt CO_2-eq. GHG emissions in transport by 2030[26] Although Germany has already taken comprehensive climate measures, further efforts are required to achieve the set goal of CO_2 savings formulated in the Climate Change Act.[27] Figure 1 illustrates the massive gap between trends and targets in the transport sector; highlighting that significant action has to be taken quickly to reach the GHG emission target of 85 Mt CO_2-eq. by 2030.



Source DBFZ.

Fig. 1. The massive gap between trends and targets in transport 1990-2050

The main public drivers regarding policy in the transport sector remain the revised EU Renewable Energy Directive (RED II) and the Fuel Quality Directive (FQD), which are implemented by the Federal Emissions Control Act (BImSchG §37) and the GHG mitigation quota. The FQD is defined by EU Member States to implement GHG reduction targets for fuels placed on the market. By 2020, target reduction was set for 6% through renewable fuels, including the crediting of up to 1.2% upstream emission reductions per UER 2018. Fuel suppliers are obliged to report GHG emissions for the fuels they have placed on the market.[28] RED II formally became national law in September 2021 by continuing the GHG mitigation quota and increasing this quota incrementally from 7% in 2022 to 25% by 2030.[29] A summary is given in Table 2. The requirements outlined in the RED on sustainability and balancing GHG emissions are transposed into national law by the biofuel sustainability ordinance (Biokraft-NachV)).

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[24] https://www.bundesregierung.de/breg-de/themen/klimaschutz/climate-change-act-2021-1936846
[25] https://www.bundesregierung.de/breg-en/issues/climate-action/klimaschutzprogramm-2030-1674080
[26] https://www.bundesregierung.de/resource/blob/974430/1679914/e01d6bd855f09bf05cf7498e06d0a3ff/2019-10-09-klima-massnahmen-data.pdf?download=1
[27] https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-44
[28] https://www.dbfz.de/fileadmin/user_upload/Referenzen/Statements/Hintergrundpapier_Weiterentwicklung_THG-Quote.pdf
[29] https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&start=//*[@attr_id=%27bgbl121s4458.pdf%27]#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl121s4458.pdf%27%5D__1646058705951

Table 2. Summary GHG mitigation quota until 2030 and compliance options in Germany.

	Explanation
Quota	
GHG mitigation quota	Minimum share of GHG mitigation (yearly increase): 7% in 2022 up to 25% in 2030
Advanced biofuels in road transport (RED II Annex IX A)	Minimum share of energy (yearly increase): 0.2% in 2022 up to 2.6% in 2030
PTL jet fuel in aviation	Minimum share of jet fuel energy: 0.5% by 2026, 1% by 2028 and 2% by 2030
Compliance Options	
Advanced biofuels (RED II Annex IX A)	Amounts above minimum share with two-fold counting for amount above minimum share
Biofuels from UCO and animal fats (RED II Annex IX B)	Maximum share of energy: 1.9%
Conventional biofuels from resources also relevant for food and feed	Maximum share of energy: 4.4% and from 2023 onwards opt out of palm oil
Green hydrogen and resulting products (PTX/e-fuels, RFNBO)	Use in refineries and as fuel with two-fold counting
Electricity	Three-fold counting, adjustment mechanism factor 0.5 to 1.5
Upstream Emission Reduction (UER)	GHG mitigation through UER with max. 1.2% until 2026

The number of electric vehicles and plug-ins has significantly increased since 2017 (see Advanced Motor Fuels Statistics below); today, 25% of newly purchased vehicles are either electric or plug-in.[30] Nevertheless, the restructuring of the transport sector continues to be very slow. It is predicted that 40 million vehicles with combustion engine will be used in 2030, and that by 2045 there will be a remainder of combustion engines, due to the difficulty of electrifying certain areas of transport.[31]

Germany's public debate has been focusing on electric mobility, battery-powered vehicles, PtX and hydrogen in recent years. To decarbonize the transport sector, high priority has recently been given not only to e-mobility for short-distance traffic and passenger cars, but also to the enforcement of hydrogen and liquefied natural gas (LNG) infrastructure along the most important middle- and long-distance road networks. The federal government strongly supported the use of liquefied natural gas (LNG) for heavy-duty transport and waterborne application in recent years.[32] At the same time, methane as CNG/LNG is discussed as controversial in expert groups such as the federal government-convened National Platform Future of Mobility (NPM). The application of hydrogen as transport fuel is one of the main strategies to reach GHG quotas, as outlined in the National Hydrogen Strategy from June 2020.

The federal government believes that e-mobility is an integral part of climate-friendly mobility, having supported measures since 2016.[33] As of February 2022, there are 70 electric vehicle models from German manufacturers on the market[34] which are charged with electricity at circa 47.111 "normal" and 8.094 high-speed publicly accessible charging points.[35] In order to make electric vehicles more attractive, the federal government has decided to provide additional impetus for e-mobility. The overall package consists of temporary purchase incentives until the end of 2025, additional funds for the expansion of the charging infrastructure, and additional efforts in the public procurement of electric vehicles and tax measures.[36] In 2020, the federal government decided to increase the incentive, making a clear commitment to strengthening national e-mobility.

30 https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-44
31 Ibid.
32 https://www.bundesfinanzministerium.de/Monatsberichte/2017/12/Inhalte/Kapitel-3-Analysen/3-5-Novellierung-Energie-Stromsteuergesetzes.html
33 https://www.bmwi.de/Redaktion/DE/Artikel/Industrie/rahmenbedingungen-und-anreize-fuer-elektrofahrzeuge.html
34 https://www.adac.de/rund-ums-fahrzeug/elektromobilitaet/kaufen/elektroautos-uebersicht/
35 https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehmen_Institutionen/E-Mobilitaet/start.html
36 https://www.bundesregierung.de/breg-de/themen/energiewende/kaufpraemie-fuer-elektroautos-erhoeht-369482

The PtL-Roadmap was published in May 2021. The roadmap outlines Germany's efforts to expand the production of sustainable aviation fuel from renewable energy sources.[37] The federal government, federal states and industry representatives agreed in particular that electricity-based, power-to-liquid (PtL) kerosene from renewable energy sources plays a key role in making the aviation sector carbon-neutral and sustainable. A minimum of 200,000 tonnes of PtL kerosene used in German aviation by 2030 is for a goal; the target is linked to the National Hydrogen Strategy.[38] The target is intended to be reached by technological development, establishing uniform sustainability criteria and supporting the market ramp-up.

The election and formation of a new federal government in September/December 2021 was the most significant political change in recent years.[39] Importantly, the Green Party gained control over various key ministries focusing on climate action (Federal Ministry of Food and Agriculture; Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection; Federal Ministry for Economic Affairs and Climate Action). Whilst Germany will continue to commit to reaching EU and global climate change goals, the newly elected government announced that they would commit even further to climate mitigation with their 2030 targets.[40] For instance, the new federal government aims that 80% of the power supply will come from renewable resources. Additionally, Germany aims to have 15 million electric vehicles on the road. The new federal government continues to prioritize electricity and hydrogen for the transport sector. This is outlined in the Coalition Treaty of the new government from Dec. 10, 2021.[41]

Advanced Motor Fuels Statistics

The consumption of biofuels in Germany totaled 3.4 Mt in 2020,[42] primarily low-level blends of biodiesel, HVO, bioethanol and biomethane. See Figure 2. Moreover, to a minor extent, biomethane is used for CNG. Due to lacking incentives, there is no market demand for E85 and pure biodiesel. Overall, energy crops and their use as fuel are limited and need to be expanded in order to meet the climate goals.

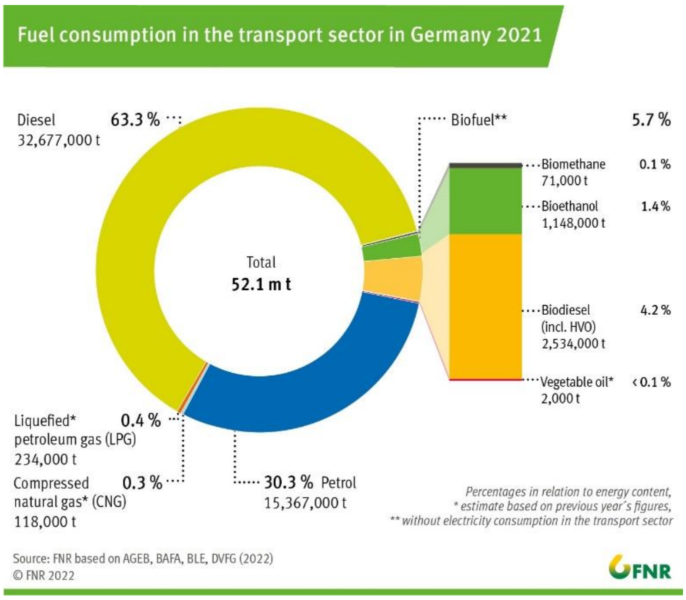

Fig. 2. Fuel Consumption in the Transport Sector in Germany in 2021 [43]

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[37] https://www.bmvi.de/SharedDocs/DE/Anlage/G/ptl-roadmap-englisch.pdf?__blob=publicationFile

[38] Ibid.

[39] https://www.bundesregierung.de/breg-en/news/federal-chancellor-election-1989862

[40] https://www.bundeskanzler.de/bk-en/news/government-statement-1991614

[41] https://www.bundesregierung.de/resource/blob/974430/1990812/04221173eef9a6720059cc353d759a2b/2021-12-10-koav2021-data.pdf?download=1

[42] https://mediathek.fnr.de/grafiken/daten-und-fakten/bioenergie/biokraftstoffe/biokraftstoffe-in-deutschland.html

[43] Federal Office for Economic Affairs and Export Control; BAFA et al. (Federal Statistics Office [Destatis], DVFG [German LPG Association], the Federal Ministry of Finance [or BMF], Agency for Renewable Resources [Fachagentur Nachwachsende Rohstoffe e.V., or FNR]), 2021.

Tables 1 and 2 show the 2013-21 trends for biofuels and biofuel blends. The overall savings in GHG emissions of all biofuels (pure) was 83% compared to fossil fuels and the prediction is that number will remain at this high level.[44] The increasing GHG savings of biofuels demonstrate that the physical demand for biofuels to comply with the GHG quota decreased.

Table 1. Trends in German Biodiesel (FAME, HVO, FT-BtL) Sales, 2013–2021, in Mt[45]

Sale	2013	2014	2015	2016	2017	2018	2019	2020	2021
Blend	1.741	1.970	1.978	1.987	2.183	2.296	2.301	3.025	2.347
Pure biodiesel	0.030	0.005	0.003	0.001	n/a	n/a	n/a	n/a	n/a
Total	1.772	1.975	1.981	1.988	2.183	2.296	2.301	3.025	2.347

Table 2. Trends in German Bioethanol Sales, 2013–2021, in Mt[46]

Sale	2013	2014	2015	2016	2017	2018	2019	2020	2021
E85	0.014	0.010	0.007	n/a	n/a	n/a	n/a	n/a	n/a
Ethanol	1.041	1.082	1.049	1.047	1.045	1.077	1.055	0.972	0.906
ETBE	0.154	0.139	0.119	0.129	0.111	0.110	0.088	0.126	0.147
Total	1.209	1.231	1.177	1.176	1.156	1.187	1.177	1.098	1.053

Table 3 shows the number of passenger cars in Germany by fuel type for 2016-21. A total of 59 million vehicles, including 4.7 million motor bikes, were registered in Germany as of January 1, 2021, along with 48.2 million passenger cars, 3.4 million trucks, 2.3 million towing vehicles and 75,548 buses.[47] At a share of 0.2%, 83,067 CNG-powered cars were registered. Another 346,765 LPG-powered cars were registered, which is a share of 0.6%. The number of hydrogen-powered cars increased from 507 (2010) to 808 (+59.4%).

Table 3. Number of Passenger Cars in Germany by Fuel Type on January 1, 2016–2021

Year	Gasoline	Diesel	LPG	CNG	EV	Hybrid	Plug-in
2016	29,825,223	14,532,426	475,711	80,300	25,502	130,365	X
2017	29,978,635	15,089,392	448,025	77,187	34,022	165,405	20,975
2018	30,451,268	15,225,296	421,283	75,459	53,861	236,710	44,419
2019	31,031,021	15,153,364	395,592	80,776	83,175	341,411	66,997
2020	31,464,680	15,111,382	371,472	82,198	136,617	539,383	102,175
2021	31,435.340	15,060,124	346,765	83,067	309,083	1,004,089	279,861

LPG = liquefied petroleum gas according to European fuel quality standard EN 589.
CNG = compressed natural gas according to German fuel quality standard DIN 51624.
EV = electric vehicle. X = values not comparable *Source: KBA 2021*[48]

Research and Demonstration Focus

Public funding for alternative motor fuels on the national scale is supported by the Federal Ministry for Digital and Transport (BMDV, previously BMVI) in the areas of National Innovation Programme Hydrogen and Fuel Cell Technology, NIPII, infrastructure, e-mobility, LNG, CNG, and jet fuel. Likewise, the Federal Ministry of Education and Research (BMBF) funds research through the

44 https://www.ble.de/SharedDocs/Downloads/DE/Klima-Energie/Nachhaltige-Biomasseherstellung/Evaluationsbericht_2019.pdf?__blob=publicationFile&v=4
45 Bafa Official Mineral Oil Data, November 2021 https://www.bafa.de/SiteGlobals/Forms/Suche/Infothek/Infothek_Formular.html?nn=8064038&submit=Senden&resultsPerPage=100&documentType_=type_statistic&templateQueryString=Amtliche+Daten+Mineral%C3%B6ldaten&sortOrder=dateOfIssue_dt+desc
46 Ibid.
47 https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Jahrebilanz_Bestand/fz_b_jahresbilanz_node.html
48 https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Umwelt/2021/2021_b_umwelt_zeitreihen.html?nn=3525028&fromStatistic=3525028&yearFilter=2021&fromStatistic=3525028&yearFilter=2021

"Kopernikus Projects" (P2X and SynErgie).[49] The Federal Ministry for Economic Affairs and Climate Action (BMWK) focuses on eFuels in the "Energiewende im Verkehr" program, including a total funding of EUR 130 million (USD 141 million). As a central measure, "real laboratories of energy transition" were established; in 2022, a roadmap will be presented.[50]

The BMDV launched a new supporting program for renewable fuels in 2021, with EUR 1.54 billion (USD 1.67 billion) available for 2021-24, consisting of resources from the Energy and Climate Fund (EKF) and the National Hydrogen Strategy.[51] Importantly, EUR 640 Million (USD 695 million)[52] will be used for R&D projects. This funding program scope also includes advanced biofuels. Due to a challenging European and German framework for biomass-based fuels, the biofuel share in activities to be funded is uncertain.

Outlook

Renewable fuels are important for achieving the future climate targets in transport. Those are required, especially for shipping and aviation, but also for road transport. Electric mobility is in the fast lane, but reaching climate and energy targets will not be possible without the use of all available options, including hydrogen, eFuels, market-introduced biofuels and advanced biofuels. With the new federal government, a stronger focus on climate mitigation can be expected. Overall, further R&D activities, such as reducing the GHG emissions of biofuels to make them compatible with the RED II limits, are needed to meet persistent challenges for the near future.

Additional Information Sources

- Bundesverband der deutschen Bioethanolwirtschaft, https://www.bdbe.de
- Bundesverband Regenerative Mobilität, www.brm-ev.de/en
- Verband der Deutschen Biokraftstoffindustrie, www.biokraftstoffverband.de
- Fachagentur Nachwachsende Rohstoffe e.V., https://biokraftstoffe.fnr.de/
- Deutsches Biomasse Forschungszentrum, www.dbfz.de[53]

Major changes

- The national Climate Change Act was amended; Germany aims for a 65% GHG emissions reduction by 2030 and carbon neutrality by 2045. For transport, emissions have to be reduced to max. 85 MMT CO_2-eq by 2030.
- The GHG mitigation quota will be continued from 7% in 2022, to 25% by 2030 to be realized by different compliance options.
- A new federal government was elected at the end of 2021; more and faster climate action with reference to their coalition agreement can be expected.
- The PtL-Roadmap for the aviation sector was introduced in May 2021, with a target of 200,000 t introduced kerosene in 2030.
- Increased political interest in hydrogen continues.
- New research & innovation funding scheme started in 2021, to help bring renewable fuels to market.

Benefits of participation in AMF

Access to global information and expertise with regard to advanced transport fuels; exchange of experience on implementation of solutions in AMF member countries.

[49] https://www.bmbf.de/bmbf/shareddocs/pressemitteilungen/de/2021/10/111021-Ariadne.html
[50] https://www.energieforschung.de/forschung-und-innovation/energiewende-im-verkehr
[51] https://www.bmvi.de/DE/Themen/Mobilitaet/Klimaschutz-im-Verkehr/Alternative-Kraftstoffe/alternative-kraftstoffe.html
[52] https://www.bmvi.de/SharedDocs/DE/Pressemitteilungen/2021/045-scheuer-fr-entwicklung-erneuerbarer-kraftstoffe.html
[53] https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-44

India

Drivers & Policies

India is home to around 18% of the world's population and uses 6% of the world's primary energy, which is projected to increase to 11% by 2040. It is the third largest oil consumer in the world after the United States and China, however, per capita energy consumption is amongst the lowest in the world at 0.6 tons of oil equivalent (toe) as compared to the global average of 1.79 toe per capita, or one-third of the world average. India's energy consumption growth is projected to be the highest among major economies during 2017 to 2040. India's primary energy consumption fell by 5.9% in 2020, the first fall in consumption this century due to the Covid-19 pandemic. Primary energy grows strongly in all scenarios, more than doubling the energy consumed between 2018 and 2050. Average growth per year is in the band of 2.5%-3.0%. As result of strong growth, India accounts for 35% of the increase in global primary energy consumption, 2018-2050, in the Business-as-usual (BAU) scenario.

An initiative started in 2016 to provide universal clean energy access to every household led to approximately 69% increase in LPG consumption in 2021, as compared to 2014. India is also targeting an increased share of gas in its primary energy mix from the current 6% to 15%.

Currently, India imports approximately 85% of its petroleum product requirement. Growing concern about the import dependence for fuel requirement in tandem with environmental pollution issues has driven the need for alternative fuels. India plans to reduce import dependency in the oil and gas sectors by adopting a five-pronged strategy, which includes increasing domestic production, adopting biofuels and renewables, energy efficiency norms, improving refinery processes and demand substitution.

Since 2014, the Indian government has undertaken multiple interventions to promote biofuels through structured programs such as the Ethanol Blended Petrol (EBP) program, Biodiesel Blending in diesel, and SATAT (Sustainable Alternative Towards Affordable Transport), an initiative for promotion of Compressed Biogas (CBG). India introduced a National Policy on Biofuels-2018 in June 2018 which envisages achieving 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel by 2030. However, the government has decided to ramp up ethanol production to achieve the ambitious target of 20% blending of ethanol in petrol by 2025 itself.

The major feature of the policy is categorization of biofuels as "basic biofuels" (e.g., first generation "1G" ethanol, biodiesel, etc.) and "advanced biofuels" (e.g., 2G ethanol, drop-in fuels, etc.) to expand the scope of raw material for ethanol production.

Advanced Motor Fuels Statistics

India's primary energy mix is dominated by fossil fuels and that will continue to be the case in the near future. Presently, oil and gas account for around 35% of India's energy consumption; this is expected to come down to 31% by 2040. However, from existing levels, absolute consumption is expected to double for oil and triple for gas. Energy demand across the transport sector is the highest across major sectors in terms of end usage.

The Indian government has been promoting and encouraging use of advanced motor fuels in the transport sector. In this endeavor, the blending of biofuels, which are sustainable and have lesser emissions as compared to fossil fuels, is being promoted in petrol, diesel and natural gas. Loans for construction of oil extraction/processing units for production of bio-fuels, their storage and distribution infrastructure and loans to entrepreneurs for setting up CBG plants were classified under priority sector lending by India's Central Bank on September 4, 2020.

Ethanol Blended Petrol (EBP) Program

Under the Ethanol Blended Petrol (EBP) program, oil marketing companies (OMCs) sell petrol blended up to 10% ethanol (E10) depending upon its availability. In order to augment the supply of ethanol for EBP, the Government decided to administer ethanol prices. This, combined with a slew of other measures, such as easing restrictions on the movement of ethanol between states; allowing more sources of feedstocks for production of ethanol, including sugar, sugar cane, sugar syrup, damaged food grain, maize, etc.; addressing state specific issues, and attractive ethanol prices and availability of molasses in the ecosystem facilitated improvement in the supply of ethanol from 154 million liters during Ethanol supply year (ESY) 2012-13 to around 3.02 billion liters during ESY 2020-21, thereby achieving average blending of 8.1% in petrol during ESY 2020-21. In order to promote the establishment of distilleries in states deficit in ethanol, OMCshave entered into long term off-take agreements with upcoming dedicated ethanol plants in such states. This will help avoid transportation of ethanol over long distances and supply fluctuations to meet the blending requirements.

Table 1. Trend in ethanol procurement under EBP program

Ethanol Blending Petrol Program					
Particulars	Ethanol Supply Year (Dec to Nov)				
	2016-17	2017-18	2018-19	2019-20	2020-21
Ethanol procured by PSU OMCs* (in million liters)	665	1505	1886	1730	3023
National average blending (in percentage)	2.0%	4.2%	5.0%	5.0%	8.1%

* Public Sector OMCs, i.e. Indian Oil Corporation Ltd. (IOCL), Bharat Petroleum Corporation Ltd. (BPCL) and Hindustan Petroleum Corporation Ltd. (HPCL)

2G Ethanol Program

The government of India has notified the “Pradhan Mantri JI-VAN (Jaiv Indhan-Vatavaran Anukoolfasalawashesh Nivaran) Yojana,” which will provide financial assistance of approximately USD 300 million for the period from 2018-19 to 2023-24 for supporting commercial projects as well as demonstration projects for 2G ethanol projects. India’s government has allowed procurement of ethanol produced from other non-food feedstock besides molasses, like cellulosic and lignocellulosic materials. The 2G feedstocks include agri-residues such as rice and wheat straw, cane trash, corn cobs and stover, cotton stalk, bagasse, and empty fruit bunches (EFB). In furtherance of this decision, oil public sector units (PSU) have planned to set up 2G ethanol bio-refineries in various parts of the country. Projects at Bhatinda (Punjab), Panipat (Haryana), Bargarh (Odisha) and Numaligarh (Assam) are in advance stages of construction and are likely to be made operational in 2022 and 2023.

Biodiesel

In June 2017, the government allowed direct sale of biodiesel (B-100) for blending with high speed diesel to all consumers, in accordance with the specified blending limits and the standards specified by the Bureau of Indian Standards. “Guidelines for sale of Biodiesel for blending with High Speed Diesel for transportation purposes 2019” were notified on May 1 2019. To augment the supplies of biodiesel and tap potential sources of biodiesel produced from used cooking oil (UCO), public sector OMCs, under guidance of Ministry of Petroleum and Natural Gas (MoPNG), are regularly floating Expression of Interest (EoI) for procurement of Biodiesel produced from Used Cooking Oil (UCO) to meet biodiesel requirements for blending.

Compressed Biogas (CBG)

As part of an initiative under the National Policy on Biofuels 2018, the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative was launched in October 2018 for promoting use of CBG along with Natural Gas. Under this initiative, oil and gas marketing companies (OGMCs) are inviting EoIs from potential investors/entrepreneurs to procure CBG for further selling to automotive and commercial customers.

Under this initiative, various enablers have been provided for development of the CBG sector. Compressed Biogas projects have been included under Priority Sector Lending by Reserve Bank of India. MoPNG has issued policy guidelines for the co-mingling of CBG with Natural Gas in the City Gas Distribution (CGD) network.

As of January 2022, OGMCs have issued 3,134 LoIs to potential entrepreneurs. Supply of CBG has been initiated from 17 CBG plants through 27 Retail Outlets. Compressed Biogas is also being supplied to industrial customers, and CBG injection in the CGD network has begun.

Research and Demonstration Focus

The Centre for High Technology (CHT), PSU OMC's research and development units under MoPNG, Department of Biotechnology (DBT) and the Council of Scientific and Industrial Research – Indian Institute of Petroleum (CSIR-IIP), Dehradun are working on a program to support R&D pertaining to energy biosciences in the country through various schemes and with major emphasis on advanced biofuels. The DBT-ICT center based in Mumbai has developed lignocelluloses technology that is demonstrated at demo scale and is now being used for establishment of commercial plants.

India is undertaking several initiatives with respect to the greater use of hydrogen in the energy mix. The first pilot of using H-CNG (Hydrogen fuel mixed with Compressed Natural Gas) as transportation fuel was started at Rajghat Bus Depot, New Delhi. Under this pilot, 50 buses in Delhi operated on a blended H-CNG mixture. The results were encouraging in fuel economy improvement and emission reductions. The MoPNG has further directed the OGMCs to introduce Green Hydrogen in the refineries at various locations as a feedstock. The pilot projects for setting up Green Hydrogen plants in the refineries are being planned.

An ambitious R&D project under the aegis of MoPNG is being done by Indian Oil Corporation Limited (IOCL) at a cost of USD 18.3 million. It is the first scientific project in India to address all aspects of the value chain of hydrogen-based mobility. IOCL R&D will use 15 indigenously manufactured/integrated hydrogen fuel cell buses to conduct a 20,000 kms field trial in Delhi NCR. Four demo units of hydrogen production units amounting to 1 ton per day will also be set up. Of these, three plants will be based on renewable sources (biomass gasification, reforming CBG and solar PV-based electrolysis) to produce green hydrogen. Trial of the first set of two fuel buses using this Green Hydrogen is expected to begin by the end of year 2022.An anaerobic gas fermentation technology will convert CO_2 into acetic acid, and aerobic fermentation technology will convert acetic acid into highly valuable Omega 3-fatty acids (DHAs) and bio-diesel. This value chain makes the overall process economically feasible. Studies are in advanced stages at the IOCL R&D center to install the world's first pilot plant with capacity of 10 kg/day CO_2. IOCL is also setting up an ethanol production plant to produce around 128 KL per day of ethanol using gas fermentation technology from pressure swing absorption off gases at Panipat Refinery.

In aviation, the first flight using 25% biojet fuel between Dehradun to Delhi was operated by Spice Jet on August 27, 2018. Biojet fuel used in the flight was developed by laboratory in CSIR-IIP,Dehradun, using Jatropha seeds. After the flight's success, the Government of India decided to set up demonstration plants for the future growth of Bio-ATF in the country.

Currently, efforts are focused on the development of cost-effective and efficient enzymes for 2G bioethanol refineries, development of value-added products by lignin valorization, commercial production of biojet fuel, compressed biogas from biomass, foodwaste and municipal solid waste, and cost effective biofuels from industrial waste gases.

Outlook

The outlook for biofuels in India will remain promising considering the thrust of the Government on promoting biofuels and advanced biofuels as "environment friendly" fuels.

Ethanol procurement by PSU OMCs reached 3,023 million liters of ethanol in ESY 2020-21.OMCs achieved a blending percentage of 8.1% during ESY 2020-21. As the demand for petrol rises, the demand for ethanol is bound to increase, year on year, with projected requirement for 10% blending, or 3.11 MMTPA (approximately 4 billion liters annually). Retailing of E100 fuel has commenced on a pilot basis at three retail outlets in Pune, Maharashtra. Based on the response of these pilot retail outlets, further expansion is planned.

The SATAT initiative will help reduce India's dependence on fossil fuels and increase the share of gas in primary energy consumption. This initiative will help integrate the vast retail network of companies with upcoming CBG projects. It has the potential to replace more than 50% of gas imports.

These highlighted initiatives have already started creating impact in the biofuel industry in India. Major developments in the advanced biofuel sector in terms of deployment in transport sector, investments, project establishment and enhanced R&D are expected in the coming years.

Additional Information Sources

- www.ppac.org.in for data on fossil fuels production, consumption, Import & Export
- www.mnre.gov.in for data on R&D projects
- https://www.siamindia.com for data on automotive industry
- www.dbtindia.nic.in
- www.iocl.com for data on R&D projects
- 1-BP Outlook 2020, India.

Japan

Drivers and Policies

The Government of Japan formulates the Strategic Energy Plan to show the direction of Japan's energy policy under the Basic Act on Energy Policy, which was enacted in June 2002 for the purpose of ensuring the steady implementation of energy policy.

On October 22, 2021, the Cabinet approved the Sixth Strategic Energy Plan for submission to the Diet,[54] which includes two key themes: (1) showing the approach to an energy policy of achieving carbon neutrality by 2050 announced October 2020, with the GHG emission reduction target of greenhouse gas emissions by 46% in FY 2030 from its FY 2013 levels, while continuing strenuous efforts in its challenge to meet the lofty goal of cutting its emission by 50%, as announced in April 2021; and (2) presenting initiatives to ensure stable supply and reduce energy costs based on the major premise of ensuring safety, in order to solve challenges facing Japan's energy supply and demand structure while taking action against climate change.

In order to decarbonize the transportation sector, Japan will promote reduction of CO_2 emissions through the production, use, and disposal of automobiles; improvement of energy efficiency in the logistics sector; and the decarbonization of fuel itself.[55,56]

For passenger cars, comprehensive measures such as expanding the introduction of electrified vehicles and infrastructures, and reinforcing technologies related to electrified vehicles such as batteries, supply chain, and value chain will be taken to achieve 100% electrified vehicle sales by 2035.

As for commercial vehicles, electrification targets were set as follows[57]:

- Aim for electrified vehicles to account for 20-30% of new light vehicles sales by 2030, and electrified vehicles and decarbonized fuel vehicles to account for 100% by 2040
- Aim for an advanced introduction of 5,000 heavy vehicles in the 2020s and set a target by 2030 for 2040 electrified vehicle penetration.

Advanced Motor Fuels Statistics

Figure 1 shows the energy sources used in the transportation sector in Japan.[58] Oil related energy accounts for 97.8% of total usage. The market for alternative fuels is very small in Japan, as is the number of alternative fuel vehicles owned (Table 1). Methanol, CNG, hybrid, EVs, and FCVs currently constitute the environmentally friendly vehicles.

The number of hybrid vehicles is rather large, owing to the number of passenger hybrid vehicles. CNG vehicles currently account for the largest number of vehicles in the low-emission truck category. The penetration of FCVs in the market has expanded; Japan has 5,278 FCVs.

[54] Agency for Natural Resources and Energy, "Cabinet Decision on the Sixth Strategic Energy Plan," https://www.meti.go.jp/english/press/2021/1022_002.html

[55] Agency for Natural Resources and Energy, October 2021, "Outline of Strategic Energy Plan," https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf

[56] Agency for Natural Resources and Energy, October 2021 (in Japanese), "Strategic Energy Plan," https://www.enecho.meti.go.jp/category/others/basic_plan/pdf/20211022_01.pdf

[57] https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/pdf/05_automobile.pdf

[58] Energy White Paper 2021, Agency for Natural Resources and Energy, June 2021 (in Japanese)

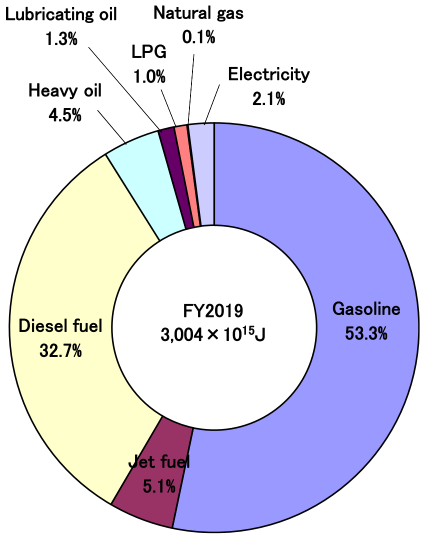

Fig. 1. Energy Sources Used in the Transportation Sector in Japan in 2019

Table 1. Current Penetration of Environmentally Friendly Vehicles Owned in Japan

<table>
<tr><th>Vehicle Type</th><th>Methanol[59,60]</th><th>CNG[5,6]</th><th>Hybrid[61]</th><th>EV[7]</th><th>FCV[7]</th><th>Vehicle Registration[62]</th></tr>
<tr><td>Passenger vehicles</td><td>2</td><td>11</td><td>9,711,746
(PHV:151,241)</td><td>123,706</td><td>5,170</td><td>39,185,711</td></tr>
<tr><td>Light, mid, and heavy-duty trucks</td><td>1</td><td>4,874</td><td rowspan="3">58,115</td><td rowspan="3">1,871</td><td>NA</td><td>5,948,364</td></tr>
<tr><td>Buses</td><td>0</td><td>172</td><td>NA</td><td>219,660</td></tr>
<tr><td>Special vehicles</td><td>2</td><td>1,529</td><td>NA</td><td>1,628,799</td></tr>
<tr><td>Small vehicles</td><td>1</td><td>1,816</td><td>1,896,381</td><td>4,532</td><td>NA</td><td>31,454,086</td></tr>
<tr><td>Total</td><td>6</td><td>8,402</td><td>11,666,242</td><td>130,109</td><td>5,170</td><td>78,436,620</td></tr>
</table>

Research and Demonstration Focus

Hydrogen

"Green Growth Strategy Through Achieving Carbon Neutrality in 2050" was updated June 18, 2021.[8] With regard to the use of hydrogen in mobility, support is being provided for the spread of fuel cell vehicles and the development of hydrogen stations. In addition, commercial vehicles such as trucks are one of the areas where hydrogen utilization is expected in the transportation field; trucks need to transport goods daily over long distances, which is difficult for EVs to apply. In the future, the spread of fuel cell vehicles and the systematic development of hydrogen refueling stations will be accelerated. In particular, the cumulative number of fuel cell trucks installed is expected to be up to 15 million units by 2050, amounting to approximately USD 2.7 trillion. In terms of refueling infrastructure, approximately 1,000 hydrogen stations will be installed in optimal locations by 2030, in anticipation of the widespread use of fuel cell vehicles, fuel cell buses, and fuel cell trucks.

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59 Automobile Inspection and Registration Information Association, as of March 2021 (in Japanese), https://www.airia.or.jp/publish/file/r5c6pv000000wkqt-att/r5c6pv000000wkr8.pdf

60 Japan Light Motor Vehicle and Motorcycle Association, as of March 2021 (in Japanese), https://www.keikenkyo.or.jp/information/attached/0000028680.pdf

61 Next Generation Vehicle Promotion Center (NeV), as of March 2021 (in Japanese), http://www.cev-pc.or.jp/tokei/hanbai.html

62 The Ministry of Economy, Trade and Industry, "Green Growth Strategy Through Achieving Carbon Neutrality in 2050" Formulated, June 2021, https://www.meti.go.jp/english/press/2021/0618_002.html

Hydrogen stations for fuel cell vehicles were operating in 157 locations nationwide as of January 2022.[63]

In response to such actions, the NEDO HySTRA pilot project involving the marine transportation and unloading of liquid hydrogen produced in Australia to Japan was initiated in May 2021 as part of the activities of the CO_2-free Hydrogen Energy Supply-chain Technology Research Association.[64]

Hydrogen engines can leverage well-established internal combustion engine technologies. Therefore, they are seen as having high potential for commercialization at lower cost. Activity in the Japanese industrial sector in 2020 featured the announcement of joint research on a single-cylinder hydrogen engine with a 5-liter stroke volume aimed at large engines conducted by Mitsubishi Heavy Industries Engine & Turbocharger (MHIET) of the Mitsubishi Heavy Industries Group and the National Institute of Advanced Industrial Science and Technology (AIST).[65]

In other news, Toyota Motor Corporation entered the 24-hour endurance race in May 2021 with a vehicle equipped with a 3-cylinder, 6-liter engine using hydrogen as a fuel, completing all 358 laps.[66]

Natural Gas

Approximately half of the natural gas vehicles (NGVs) in Japan are commercial vehicles, such as trucks, buses, or garbage trucks. Of the trucks, the majority are light- to medium-duty vehicles designed for short- or medium-distance transportation. In this context, Isuzu Motors Limited announced the Giga CNG in December 2015.[67] The introduction to the market of this heavy-duty CNG truck is expected to increase the use of NGVs for long-distance transportation. Aiming to further extend the running range, Isuzu Motors Limited released heavy-duty LNG trucks in FY 2022.[68] The LNG trucks have a running range of more than 1,000 km and CO_2 emissions from the LNG trucks are reduced by about 10%, compared to the latest diesel trucks.

Biofuel

With respect to initiatives aiming to encourage the use of biofuels in Japan, sales of gasoline blended with Ethyl tert-butyl ether (ETBE) in 2020 again achieved the target defined in the Act on Sophisticated Methods of Energy Supply Structures (500,000 kL (crude oil equivalent) of bioethanol and 1.94 million kL of bio-ETBE each year).[69] According to trade statistics, approximately 54,000 tons of ethanol were imported (mainly from Brazil) in 2020 as raw material for ETBE (equivalent to roughly 124,000 kL of ETBE).[70]

E-fuel

In order to achieve a cost lower than the price of gasoline for synthetic fuels in 2050, the commercialization of synthetic fuels will be worked out. In addition to improving the efficiency of existing technologies (reverse shift reaction plus FT synthesis process) and designing and developing production facilities, innovative new technologies and processes (e.g., co-electrolysis, Direct-FT) will be developed in order to establish an integrated production process for synthetic fuels. The Green Growth Strategy aims to establish high-efficiency and large-scale production technology by 2030, expand the introduction and reduce costs in the 2030s, and achieve independent commercialization by 2040 by intensively developing and demonstrating technologies for such synthetic fuels over the next 10 years.[8]

Outlook

In a “Green Growth Strategy towards 2050 Carbon Neutrality,” the electrification of automobiles will be promoted. Comprehensive measures will be taken to achieve 100% electrified vehicles (electric vehicles, fuel cell vehicles, plug-in hybrid vehicles, hybrid vehicles) in new passenger car sales by the

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63 Next Generation Vehicle Promotion Center (in Japanese), http://www.cev-pc.or.jp/suiso_station/index.html
64 CO_2-free Hydrogen Energy Supply-chain Technology Research Association, https://www.hystra.or.jp/en/project/
65 Mitsubishi Heavy Industries Ltd. (in Japanese), https://www.mhi.com/jp/news/210121.html
66 Toyota Times News (in Japanese), https://toyotatimes.jp/insidetoyota/137.html
67 Isuzu Motors Limited (in Japanese), http://www.isuzu.co.jp/product/giga/cng/
68 Isuzu Motors Limited (in Japanese), https://www.isuzu.co.jp/newsroom/details/20211028_01.html
69 Japan Biofuels Supply LLP (in Japanese), http://www.jbsl.jp/effort/index.html
70 Japan Alcohol Association (in Japanese), http://www.alcohol.jp/statis/import.pdf

mid-2030s at the latest. Furthermore, through efforts to neutralize energy such as e-fuel, Japan aims to achieve net emission through the production, use, and disposal of automobiles in 2050.

Additional Information Sources

- The Ministry of Economy, Trade and Industry, Overview of Japan's Green Growth Strategy Through Achieving Carbon Neutrality in 2050, January 2021, https://www.meti.go.jp/english/press/2020/pdf/1225_001a.pdf
- Green Growth Strategy Through Achieving Carbon Neutrality in 2050, https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html

Benefits of Participation in the AMF TCP
Participation in the AMF TCP makes it possible to obtain the latest information on advanced motor fuels for stakeholders, policy makers, and industry in the world. AMF TCP activities facilitate an international network on advanced motor fuels.

Republic of Korea

Drivers and Policies

The Korean government established the fifth basic plan for the development and use of new and renewable energy technologies in December 2020. This basic plan aims to increase the share of new and renewable energy among final energy by 2034, and plans to increase the supply of energy for transportation from 700,000 TOE in 2019 to 1.3 million TOE in 2034.

Korea implemented the RFS (Renewable Fuel Standard) program in July 2015. Accordingly, it is mandatory to mix and supply biodiesel to diesel fuel, and petroleum refiners and petroleum exporters and importers must mix and sell according to a set ratio. The mixing ratio of biodiesel to diesel fuel is shown in Table 1. The annual blending obligation ratio will be reviewed every three years as of July 31, 2015, taking into account the technology development level of new and renewable energy and the fuel supply and demand situation.

Table 1. Ratio of New and Renewable Energy Fuel Blending Ratio to Transportation Fuel

Year	Blending Ratio
2015	0.025
2016	0.025
2017	0.025
2018	0.03
2019	0.03
2020	0.03
Jan. 2021 – Jun. 2021	0.03
Jul. 2021 – Dec. 2021	0.035
2022	0.035
2023	0.035
2024	0.04
2025	0.04
2026	0.04
2027	0.045
2028	0.045
2029	0.045
After 2030	0.05

Note: To determine the compulsory blending amount by year, multiply the compulsory blending ratio by year times the domestic sales volume of transportation fuel, including mixed renewable energy fuels.

From January 1, 2018, the mixing ratio was changed to 3%. In 2020, policy makers considered changing the mixing ratio from 3% to 3.5%, but they decided to maintain the existing mixing ratio of 3%. In 2021, the amended RFS program announced that the blending ratio will be raised to 0.05, step by step, by 2030. In the future, an improved system to provide flexibility in fulfillment of obligations (e.g., deposit and deferral) is expected to be introduced.

In the case of bioethanol for use in gasoline vehicles, empirical studies have been conducted along with biobutanol, but the timing of introduction is not clear as the exact pilot operation plan or supply plan has not been confirmed. In the case of ship fuels, beginning January 1, 2020, the sulfur content was limited to 0.5% or less due to introduction of the Convention on the Prevention of Marine Pollution (MARPOL). However, on January 1, 2021, the Korean government announced enforcement decree No. 42 of the Marine Environment Management Act, which changed the standard for the sulfur content of the fuel of ships sailing in Korea to less than 0.5%.

In addition, as of September 1, 2020, the Special Act on Air Quality Improvement in Port Areas has been enforced. Accordingly, for large ports such as Incheon, Pyeongtaek, Dangjin, Busan, Ulsan, Yeosu, and Gwangyang, from September 1, 2020, the sulfur content of ships moored at the ports must be used with fuel of 0.1% or less. However, if an emission gas reduction device (desulfurization facility) is installed on the ship and the emission of sulfur compounds is within the standard value, there are no restrictions on the use of fuel.

Aviation, through the International Civil Aviation Organization (ICAO), which is a subsidiary of the United Nations, is regulated to reduce GHG emissions for international flights. On September 23, 2016, the Korean government declared that it would participate in the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA) system, and is considering introducing a GHG reduction/management system in 2021. The Korean government is promoting technical support for eco-friendly aircraft and the development of fuel to replace the existing aviation fuel.

Advanced Motor Fuels Statistics

Table 2 shows the number and ratio of vehicles registered in Korea by year and by fuel from 2014 to 2021.

Table 2. Vehicles Registered in Korea, 2014-2021

Fuel	2014	2015	2016	2017	2018	2019	2020	2021
Total	20,117,955	20,989,885	21,803,351	22,528,295	23,202,555	23,677,366	24,365,979	24,911,101
Gasoline	9,587,351	9,808,633	10,092,399	10,369,752	10,629,296	10,960,779	11,410,484	11,759,565
	(47.66%)	(46.73%)	(46.29%)	(46.03%)	(45.81%)	(46.29%)	(46.83%)	(47.21%)
Diesel	7,938,627	8,622,179	9,170,456	9,576,395	9,929,537	9,957,543	9,992,124	9,871,951
	(39.46%)	(41.08%)	(42.06%)	(42.52%)	(42.80%)	(42.06%)	(41.01%)	(39.63%)
LPG	2,336,656	2,257,447	2,167,094	2,104,675	2,035,403	2,004,730	1,979,407	1,945,674
	(11.61%)	(10.75%)	(9.94%)	(9.34%)	(8.77%)	(8.77%)	(8.12%)	(7.81%)
HEV	137,522	174,620	233,216	313,856	405,084	506,047	674,461	908,240
	(0.68%)	(0.83%)	(1.07%)	(1.39%)	(1.75%)	(2.14%)	(2.77%)	(3.65%)
CNG	40,457	39.777	38,880	38.918	38,934	38,147	36,940	35,208
	(0.20%)	(0.19%)	(0.18%)	(0.17%)	(0.17%)	(0.16%)	(0.15%)	(0.14%)
EV	2,775	5,712	10,855	25.108	55,756	89,918	134,962	231,443
	(0.01%)	(0.03%)	(0.05%)	(0.11%)	(0.24%)	(0.38%)	(0.55%)	(0.93%)
H2	-	29	87	170	893	5,083	10,906	19,404
		(0.00%)	(0.00%)	(0.00%)	(0.00%)	(0.02%)	(0.04%)	(0.08%)
ETC*	74,567	81,488	90,364	99,421	107,652	115,119	126,695	139,616
	(0.37%)	(0.39%)	(0.41%)	(0.44%)	(0.46%)	(0.49%)	(0.52%)	(0.56%)

*ETC: Other fuels (kerosene, alcohol, solar, LNG) and towed vehicles (trailers, etc.)

In 2021, new car sales reached 1.75 million units due to high demand for individual car purchases due to the COVID-19 pandemic, but the number of deregistration vehicles reached 1.2 million units, a net increase of 545,000 units.

Specifically, for internal combustion engine vehicles, the number of gasoline vehicles registered increased by about 3% compared to the previous year, and in the case of LPG, it increased, as civilians were able to purchase LPG vehicles due to the revision of related laws.

However, diesel vehicles decreased by about 1.2% due to the strengthening of emission regulations and fine dust problems, and the number of registered eco-friendly vehicles is steadily increasing due to the reduction in exemption for the supply of eco-friendly vehicles and the support of individual consumption tax to revitalize domestic sales.

In 2020, the share of domestic sales of eco-friendly vehicles accounted for about 12% of the total, exceeding 10% for the first time in history. In 2021, more eco-friendly vehicles are registered. In particular, the increasing rate of HEV, EV and hydrogen vehicles are considerable. By car type, hybrid cars increased by about 34%, electric cars by about 71%, and hydrogen cars by about 78%.
In the case of hydrogen vehicles, the number of vehicles supplied has increased by 11 times since 18 years ago, and from 2019 to 2020, the number of hydrogen vehicles was maintained as the number one in the world.

Figure 1 is Hyundai Motors' Nexo FCEV, which is produced in Korea and exported abroad. Figure 2 shows ELEC CITY, a hydrogen city bus of Hyundai Motors.

Fig. 1. Hyundai FCEV Nexo

Fig. 2. Hyundai FCEV ELEC CITY

Research and Demonstration Focus

Marine Fuel

Marine fuel is limited to 0.5% m/m or less in sulfur content as of January 1, 2020 due to the enactment of the amendment to MARPOL. To prepare for this, the establishment of a desulfurization facility, expansion of the supply of low-sulfur fuel, and the use of LNG were promoted.

In Korea, technology development and private investment in low-sulfur oil production and emission reduction technologies (e.g., scrubber) have been increased in line with these regulations.

In April 2020, SK Energy started operating the Residual Oil Desulfurization Facility (VRDS), an eco-friendly low-sulfur fuel production facility that started construction in November 2017. S-OIL also began supplying low-sulfur oil through facility expansion.

Jet Fuel

In order to prepare for the introduction of bio aviation fuel in the aviation sector, studies on the synthesis and empirical evaluation of bio aviation fuel using non-petroleum-based raw materials were conducted by various industries, academia, and research institutes such as the Next Generation Biomass Research Center and the Advanced Technology Research Institute. In particular, since December 2016, the Agency of Defense Development has conducted the research on applying bio-aircraft oil derived from vegetable oil to jet engines by applying domestic technology.

In November 2017, Korean Air flew about 14 hours from Chicago's airport in the United States with a fuel mixed with 5% plant-derived bio-jet fuel for the first time in Korea.

Bioethanol

In the case of bioethanol, an empirical study for supply was conducted from May 2016, and the manufacturing, supply, infrastructure, and applicability of fuel were verified by April 30, 2019.

One gas station was selected, and equipment and storage problems were checked for 365 days by season, and after endurance driving up to about 45,000 km through four demonstration vehicles, exhaust gas and vehicle conditions were checked.

In addition, a feasibility review study for expanding the introduction of biofuels in the domestic transportation field was conducted from December 2019 to August 2020, and through this, it was determined that more careful review is necessary for the future introduction of bioethanol.

Hydrogen and Electricity

Korea accumulated about 231,000 electric vehicles in 2021 and aims to increase the proportion of eco-friendly vehicles among new vehicles produced in Korea to 33% by 2030. It aims to electrify all types of vehicles, from sedans to SUVs, and medium-sized trucks of 5 tons or more. Specifically, the goal is to increase the mileage of a single charge over 600 km and the charging speed three times that of the current one.

Through the next-generation hydrogen fuel system development project, the government is pushing to increase the fuel efficiency of hydrogen vehicles by more than 30% by investing USD 24 million by 2024.

In addition, Korea gained experience operating 13 pilot vehicles for city buses since 2019, and mass production began in July 2020. Based on this experience, it plans to expand the application to long-distance buses and supply 4,000 hydrogen electric buses by 2025.

Outlook

For marine oil, the amendment to MARPOL has been reflected and the sulfur content in Korea has been regulated to 0.5% since 2021, and to 0.1% in some large ports. For jet fuel, there are plans to establish a foundation for utilizing domestic bio jet fuel, such as reforming laws, systems, and infrastructure, to implement CORSIA.

Additional Information Sources

- K-Petro, www.kpetro.or.kr
- Korea Register, www.krs.co.kr
- Ministry of Trade, Industry and Energy, www.motie.go.kr
- Korea Automobile Manufacturers Association, www.kama.or.kr

Spain

Drivers and Policies

The main policy instrument aimed at fostering the consumption of advanced motor fuels in Spain is the biofuel quota obligation. Wholesale and retail operators of fuels, as well as consumers of fuels not supplied by wholesale or retail operators, are obliged to sell/consume a minimal quota of biofuels. Each obligated subject has to present a number of certificates to a national certification entity to prove compliance. The Ministry for Ecological Transition and Demographic Challenge is the certification entity. Certificates have a value of 1 TOE. They can be carried over to the following year (up to 30% of the annual obligation) and can also be traded. In case of non-compliance with the targets, a penalty fee applies (in 2021 the fee was updated and a value of EUR 1,623/certificate was established). In case of over-compliance (some parties selling or consuming more than they are obliged to), the amounts collected from the penalty fees are redistributed by the certification entity proportionally to the subjects that sold/consumed biofuels exceeding their set quota obligation. Mandatory targets for sale or consumption were established in Royal Decree 1085/2015, on the promotion of biofuels. The target (in energy content) for 2021 was 9.5%. In 2019, double counting of some biofuels entered into force. In this sense, the National Markets and Competition Commission (CNMC) published in 2020 a document including the list of feedstocks which can be used to produce biofuels that can be accounted for the obligation. The list specifies whether a feedstock will be single counted or double counted as well as the information requirements regarding the mandatory sustainability criteria that operators have to meet.

Royal Decree 1085/2015 was modified in 2021 in order to introduce new requirements to be fulfilled by obligated parties. For 2021, a maximum limit of 7.2% for biofuels produced from food and feed crops was established as well as an indicative target of 0.1% for advanced biofuels (according to the definition included in the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources).

In 2020, the Spanish Government approved the "Hydrogen Roadmap: a commitment to renewable hydrogen." It is intended to identify the challenges and opportunities for the full development of renewable hydrogen in Spain, providing a series of measures aimed at boosting investment action, taking advantage of the European consensus on the role that this energy vector should play in the context of green recovery. The Roadmap provides a Vision 2030 and 2050, establishing ambitious country targets in 2030. In particular, regarding transport, the following milestones are envisaged by 2030:

- A fleet of at +-least 150 to 200 buses with renewable hydrogen fuel cells.
- At least 5,000 to 7,500 light and heavy hydrogen fuel cell vehicles for the transport of goods.
- A network of at least 100 to 150 hydrogen stations distributed all over the country with a maximum distance of 250 km between them.
- Use of hydrogen-powered trains on a continuous basis on at least two commercial medium- and long-distance routes on lines that are not currently electrified.
- Introduction of handling machinery using renewable hydrogen fuel cells and supply points at the top five ports and airports by volume of goods and passengers.

Furthermore, the Spanish Alternative Energy Vehicle Incentive Strategy 2014-2020 is the framework for programs intended to promote the purchase of electric, liquefied petroleum gas (LPG), natural gas, and bifuel vehicles.

Advanced Motor Fuels Statistics

Biofuels account for the largest part of alternative transportation fuel in Spain. The main contribution corresponds to biodiesel (FAME), the second most used biofuel is HVO and the third one is bioethanol. Other alternative fuels consumed in Spain are natural gas and LPG. Figure 1 shows the share (in energy content) of fuels consumed for road transport in 2021.

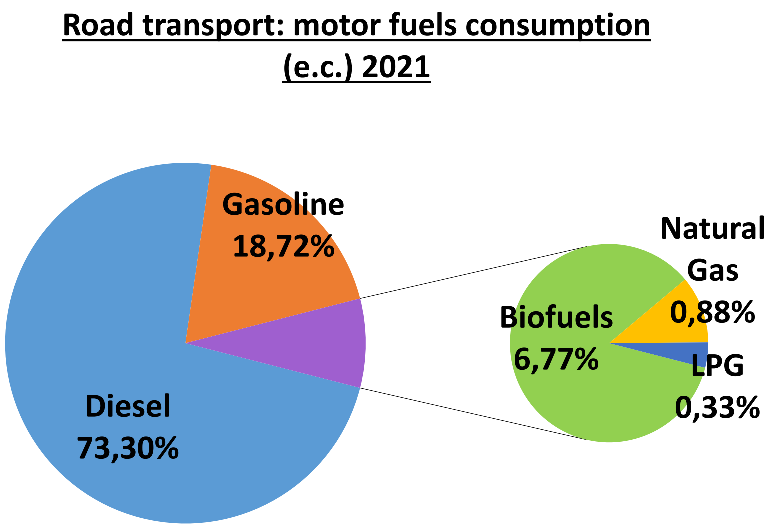

Fig. 1. Fuel Consumption (share in energy content) in Spain in 2021. *Sources: CORES, GASNAM.*

In Figure 2, the alternative fuels consumption in 2021 is shown.

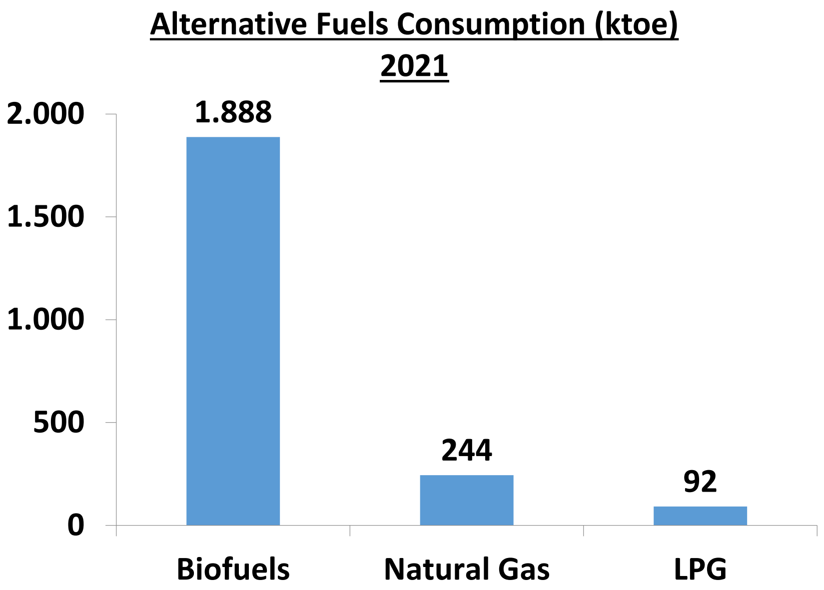

Fig. 2. Alternative Fuel Consumption (ktoe) in Spain in 2021. *Sources: CORES, GASNAM.*

Regarding distribution, Table 1 shows the number of public filling stations with alternative fuels.

Table 1. Filling Stations for Alternative Fuels in Spain

Alternative Fuel		Number of Filling Stations
Biodiesel blends	B20 or lower	35
	B30 or higher	3
Bioethanol blends	E15 or lower	1
	E85	4
LPG		780
Natural gas	CNG	103
	LNG	72

Sources: MITECO (Geoportal).

Research and Demonstration Focus

The Spanish State Scientific and Technical Research and Innovation Plan 2017-2020 is the main instrument for developing and achieving the objectives set in the Spanish Strategy for Science and Technology and Innovation 2013-2020, as well as those set in the Europe 2020 Strategy. Within the plan, eight major challenges for Spain were identified. The energy sector, including transport, is specifically addressed in the following ones: "Safe, efficient, and clean energy," "Bioeconomy: sustainability of primary and forestry production systems, food safety and quality, marine and maritime research, and bio-products" and "Sustainable, intelligent, connected, and integrated transport." The plan includes actions and funding mechanisms aimed at promoting research, development and innovation (RDI) activities which are in line with the Strategic Energy Technology Plan (SET Plan). Regarding advanced motor fuels, research and innovation projects within this State Plan shall address the priority activities included in the SET Plan Action 8 for Bioenergy and Renewable Fuels for Sustainable Transport.

The National Action Framework for Alternative Energies in Transport supports RDI by means of specific programs related to creation of clusters for innovation, incentives, cooperation through technology platforms, and support to research centers.

The integrated National Energy and Climate Plan 2021-2030 (NECP), submitted to the European Commission under the Regulation on the governance of the energy union and climate action (EU/2018/1999), addresses general RDI areas, the development of advanced biofuels among them.

There are two National Technology Platforms dealing with topics related to advanced motor fuels. Bioplat is the Spanish Biomass Technology Platform. It brings together companies, research entities, universities and other organizations in Spain to develop and promote sustainable commercial development of biomass technology. It addresses tasks related to biomass resources, production processes and final uses (e.g., biofuels for transport, biogas and biomass for electricity generation and thermal uses, bioproducts). It also carries out activities regarding sustainability, regulatory framework, and social, environmental and economic impacts, including rural development, bioeconomy, circular economy and climate change mitigation. The Spanish Hydrogen Technology Platform (PTE-HPC) aims primarily at facilitating and accelerating the development and use in Spain of systems based on hydrogen and fuel cells for different applications, transport among them.

Outlook

The Directive (EU) 2018/2011, on the promotion of energy from renewable sources, sets a specific target for the transport sector. Member States must require fuel suppliers to supply a minimum of 14% of the energy consumed in road and rail transport by 2030 as renewable energy. The contribution of biofuels produced from food and feed crops is limited up to a maximum 7%. Within that 14%, there is a dedicated sub-target for advanced biofuels (which are produced from feedstocks listed in Part A of Annex IX of the directive). These fuels must be supplied at a minimum of 0.2% of transport energy in

2022, 1% in 2025 and increasing to at least 3.5% by 2030. A specific methodology for the calculation of such shares (including different multipliers for some technologies) is provided in the directive. According to the integrated National Energy and Climate Plan (NECP), in 2030 the share of renewable energy in transport in Spain will be 28%, well above the target established in the directive. The contribution of biofuels from food and feed crops will be 6.8% and advanced biofuels will reach 3.69%.

The main trends included in the NECP for energy consumption in transport over the next decade are the following:

- There is a relevant decrease in final energy consumption due to increased efficiency and modal shift policies.
- There is a very significant decrease in the consumption of oil products and natural gas as well as a sharp growth of electricity use in vehicles.

The NECP includes a specific measure for the promotion of biofuels in transport. It consists of several actions aimed at supporting biofuels production and consumption, inter alia, mandatory targets, aid programs for advanced biofuels facilities and consumption objectives for aviation biofuels. In this regard, the Law on Climate Change and Energy Transition also contains provisions on the establishment of a quota obligation for sustainable fuels, including aviation fuels.

Additional Information Sources

- Bioplat: Spanish Biomass Technology Platform, www.bioplat.org
- CNMC: National Markets and Competition Commission (in Spanish), http://www.cnmc.es/
- CORES: Corporación de Reservas Estratégicas (Oil Stockholding Agency) (in Spanish), http://www.cores.es
- GASNAM: Spanish Association of Natural Gas for Mobility (in Spanish), www.gasnam.es
- Geoportal (MITERD): Filling Stations (in Spanish), www.geoportalgasolineras.es
- IDAE: Instituto para la Diversificación y Ahorro de la Energía (Institute for Energy Diversification and Saving) (in Spanish), https://www.idae.es/
- MITECO: Ministry for Ecological Transition and Demographic Challenge (in Spanish), www.miteco.gob.es
- PTE-HPC: Spanish Hydrogen Technology Platform (in Spanish), http://www.ptehpc.org/

Major changes

Royal Decree 1085/2015 was modified in 2021to respond to the needs to implement the measures and achieve the ambitious objectives established in the integrated National Energy and Climate Plan 2021-2030, in accordance with its Objective Scenario and with the share of renewable energy in transport for the year 2030 established by the Directive (EU) 2018/2001. New mandatory targets for biofuels (in energy content and including double counting for some biofuels) were established (9.5% in 2021) and new requirements to be fulfilled by obligated parties were introduced. A maximum limit of 7.2% for biofuels produced from food and feed crops as well as an indicative target of 0.1% for advanced biofuels are established.

Ministerial Order ITC/2877/2008 was modified in 2021 in order to update the penalty fee applied in case of non-compliance with the biofuels mandatory targets (a fee of EUR 1,623/certificate was established, where certificates have a value of 1 TOE).

Benefits of participation in AMF

Membership in the AMF TCP provides wider and easier access to information on advanced motor fuels, as well as helpful analyses that can be used to guide national policies and programs.

Sweden

Drivers and Policies

The overall goal of Sweden's environmental policy is to be able to pass on to the next generation a society in which major environmental problems have been solved, without increasing environmental and health problems beyond the country's borders. Sweden aims to become one of the world's first fossil-free welfare countries. In order to achieve this, the fossil-fuel dependency of the transport sector needs to be broken. Several measures are needed, such as reducing the total energy demand of the transport sector and ensuring that the remaining energy is both renewable and sustainable.

In 2017, a new climate policy framework was approved. The long-term climate goal means that by 2045, at the latest, Sweden will have no net emissions of GHG. In more precise terms, the long-term climate goal means that emissions from activities on Swedish territory will be cut by at least 85% compared with emissions in 1990. To achieve net zero emissions, flexibility measures are included. For the transport sector, a reduction in emissions (not including domestic air travel) of at least 70% by 2030, compared with 2010, has also been adopted.

In mid-2018, the Swedish government introduced what is known as a bonus-malus system, whereby environmentally adapted vehicles with relatively low CO_2 emissions are awarded a bonus at the time of purchase, and vehicles with relatively high CO_2 emissions (above 90 g/km as of April 1, 2021) are subject to a higher tax (malus) during the first three years. The system includes cars, light buses, and light trucks. The bonus is limited to a maximum of SEK 70,000 (USD 8,400).

Another important measure introduced in mid-2018 is the reduction obligation, which entails an obligation for fuel suppliers to reduce GHG emissions from sold volumes of petrol and diesel fuels by incorporating biofuels. In 2022, the reduction obligation is 7.8 % for petrol and 30.5 for diesel. In 2030, the levels are 28% for petrol and 66% for diesel. The biofuels included in the reduction obligation system are subject to the same energy and CO_2 taxation as fossil fuels. Biofuels outside the reduction obligation scheme have reduced taxes. Fuels for aviation are also subject to reduction obligation as of July 1, 2021. The reduction obligation in 2022 is 1.7 %.

Advanced Motor Fuels Statistics

Since 1990, the number of passenger cars has increased from approximately 3.5 million vehicles to 4.9 million vehicles. At the same time, GHG emissions from passenger cars were rather stable at around 13 million tons from 1990 to 2007. However, since 2007, emissions have been reduced significantly and were about 9.5 million tons in 2020. The main reason for the reduction is the increased energy efficiency of new vehicles and renewable motor fuels.

During the same time period, the increase in the number of vehicles other than petrol- and diesel-fueled has been moderate. The fleet of alternative-fueled vehicles was around 340,000 at the end of 2020 (see Fig. 1). In addition, there is an increasing share of conventional diesel vehicles which have been approved by the manufacturers to be fueled with HVO100. However, currently there are no available statistics on how large this share is.

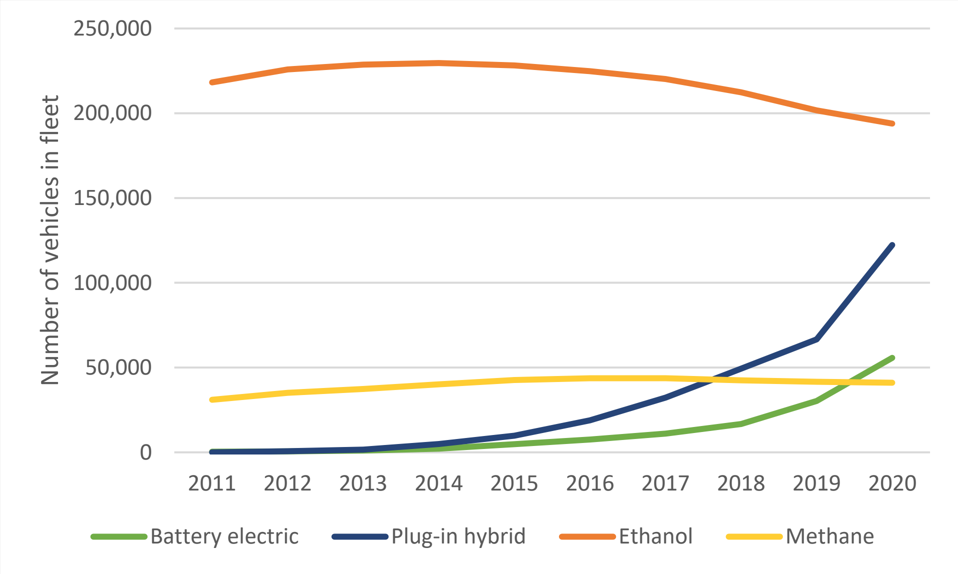

Fig. 1. Number of Advanced Motor Fuel Passenger Cars in the Fleet, 2011 – 2020

The alternative-fueled vehicles correspond to 8% of the total fleet of passenger cars (excluding diesel cars that can be fueled with HVO100). For light commercial vehicles and heavy-duty vehicles, the corresponding numbers are 3% and 2%, respectively. However, for buses, the share of vehicles registered as other than petrol- or diesel-fueled is around 27% of the fleet. The use of HVO100 in diesel-registered buses is extensive.

Although flex fuel ethanol vehicles are the most common type of alternative fuel vehicle in Sweden, the ethanol fuel (E85) sold during 2019 only corresponded to less than 1% of the energy content of transportation fuels sold. To a very high extent, flex fuel vehicles are fueled with petrol. The number of methane-fueled vehicles has stagnated at around 40,000 vehicles, which corresponds to approximately 1% of the fleet. The number of chargeable vehicles has increased substantially during the past few years.

The use of renewable biofuels and electricity for transport in Sweden amounted to 19 terawatt hours (TWh), or 26% of the transportation fuels sold during 2021 (see Fig. 2). Around 80% of the renewable fuel used in Sweden during 2021 was hydrotreated vegetable oil (HVO) and fatty acid methyl ester (FAME).

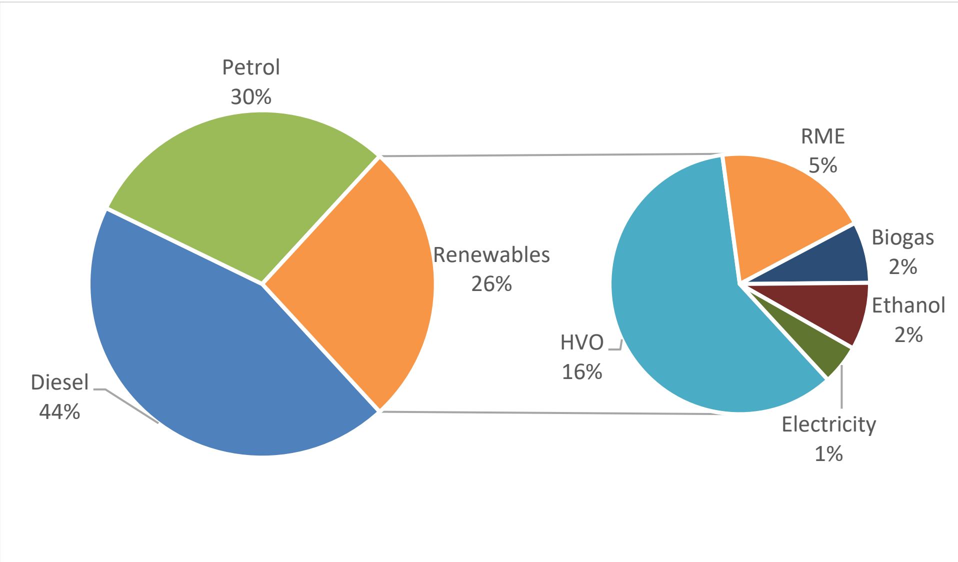

Fig. 2. Fuel Consumption in TWh within the Road Transport Sector during 2021, preliminary statistics

When HVO was introduced on the Swedish market, it was produced from crude tall oil from Sweden, Finland, and the United States. As the demand for HVO increased, the number of feedstocks and countries of origin increased. In 2020, the raw materials were to a large extent (72%) slaughterhouse wastes. The remaining shares were crude tall oil, corn oil, palm oil and palm fatty acid distillate in descending order. The majority of feedstock for HVO is imported, as shown in Figure 3. The average GHG emissions from HVO use in Sweden during 2020 corresponded to around 10 g CO_2-eq per megajoule (MJ).

FAME is primarily produced from rapeseed oil. Rapeseed oil is a preferred feedstock because its cold climate properties (i.e., cloud point) are more suitable for the Nordic climate compared with many other vegetable oils.

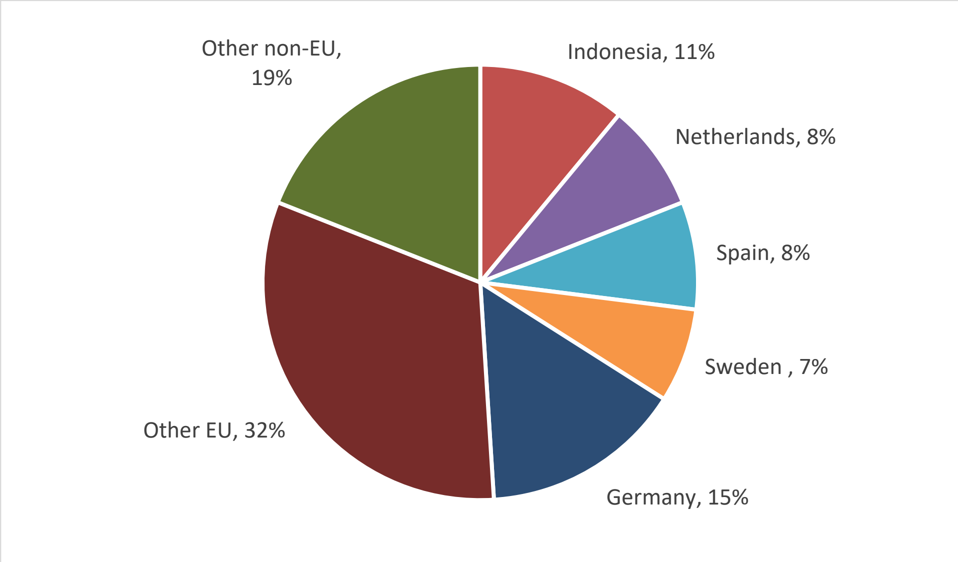

Fig. 3. Country of Feedstock Origin for HVO Consumed in Sweden in 2020

Research and Demonstration Focus

The Swedish Energy Agency has several energy-related research, development, and demonstration programs:

- Energy and environment. This program is focused on automotive-related research, innovation, and development activities in the areas of increased energy efficiency, transition to renewable fuels, reduction of local/regional environmental impacts, and areas with potential to strengthen the Swedish and English automotive industries' competitiveness in a global perspective.
- Research program for transport-efficient society, 2018-2023, on a system level. The call does not accept projects that focus on technology development of vehicle or engine technologies.
- Energy-efficient vehicles, 2015-2021. Both road vehicles and non-road mobile machinery are covered, as well as advanced motor fuels.
- Biofuels programs, thermochemical processes, and biochemical methods.
- Renewable fuels and systems, 2018-2021. The renewable fuels research program is a collaborative program between the Swedish Energy Agency and the Swedish Knowledge Centre for Renewable Transportation Fuels.
- Three Competence Centres in internal combustion engine research and one Competence Centre for catalysis research. The Competence Centre is a collaboration among the automotive industry, universities, and the Swedish Energy Agency. Each party finances one-third of the cost.
- The Swedish Gasification Centre. This center is focused on large-scale biomass gasification for biofuels production, but it also covers other applications of biomass gasification.
- A pilot and demonstration program that covers all types of technologies.

Outlook

The goal is set high in Sweden, with a reduction in GHG emissions of 70% in 2030 compared with 2010, and no net CO_2 emissions by 2045. Considering the rate of turnover of the vehicle fleet, advanced motor fuels play an important role for reaching these targets.

Additional Information Sources

- Swedish Energy Agency, http://www.energimyndigheten.se/en/
- The Swedish Knowledge Centre for Renewable Transportation Fuels, http://www.f3centre.se/

Major Changes

In 2017, the Swedish Parliament adopted a new climate law with the following targets:

- No later than 2045, Sweden shall have no net emissions of GHGs to the atmosphere.
- Emissions from domestic transport (excluding aviation) shall be reduced by at least 70% by 2030, compared with 2010.

Benefits of Participation in the AMF TCP

Sustainable and clean energy for transport is necessary to achieve national and international targets. The AMF TCP gives us an arena where we can cooperate with countries worldwide to develop unbiased reports on the effects of various advanced motor fuels.

Switzerland

Drivers and Policies

In September 2020, Swiss Parliament passed a revised CO_2-Act as a measure to achieve the climate targets of the Paris Agreement and to meet the goal of the Federal Council to reduce Switzerland's net carbon emissions to zero by 2050. An optional referendum came to pass, and the voters rejected it in June 2021. It was rejected because it caused too many costly measures, such as an increase in CO_2-tax on fossil fuel for heating up to EUR 200 per ton CO_2 (USD 217), a ban of fossil-fueled heating systems in new buildings, additional tax on fuel price, an air-ticket levy and more. Now, the parliament will elaborate a more moderate revision of the CO_2-Act. However, in alignment with the European Union Commission, in Switzerland step-by-step reduced CO_2 emission regulations apply for new passenger cars and for light and heavy-duty vehicles. Importers of fuels have to compensate for an increasing share of CO_2 emissions. One can observe a strong increase in sales of electric vehicles and heat pumps and a rise in electricity demand. This challenges the aims of the energy law in force since 2017[71], which stipulates a gradual phase-out of nuclear energy and which today covers about 35% of electricity demand in Switzerland. The increase of electricity demand can therefore only be achieved by reducing electricity demand in other areas, and through an expansion of hydropower and new, renewable energy sources like photovoltaics and wind. Increasing imports of renewable chemical energy sources, such as hydrogen or synthetic fuels, are being discussed politically. A procedure for importing certain biogenic aviation fuels into Switzerland has been established since July 2021. An initial delivery of 460 metric tons has been imported in the same month and blended with fossil kerosene in existing tank farms.

CO_2 Emission Regulations for Cars

In 2020, a new CO_2 emissions regulation came into force for new cars. The new limit is 95 g CO_2/km for passenger cars (previously 130 g CO_2/km) and 147 g CO_2/km for light commercial vehicles (vans up to 3.5 metric tons). The limit values are measured with the new World Harmonized Light-Duty Vehicles Test Procedure (WLTP). As a result of the tightening of the target value in 2020, average CO_2 emissions fell by 10.5%, from 138.1 g CO_2/km in 2019 to 123.6 g CO_2/km in 2020. However, the average emissions were well above the new target value of 95 g CO_2/km. Swiss car importers must pay a penalty if their average emissions exceed the limit value. Eased provisions after the introduction of the new limits apply until 2022. Nevertheless, the penalty rose from EUR 81.4 million (USD 95.5 million) in 2020 to EUR 122.6 million (USD 144.0 million) in 2021.[72]

CO_2 Emissions Compensation: Motor Fuels

Since 2014, importers of fossil motor fuels must use domestic measures to compensate for CO_2 emissions generated by the entire transportation sector.[73] The compensation rate was established at 2% in 2014, and was raised to 12% in 2021. Importers of fossil motor fuels may carry out their own projects or acquire certificates. The Swiss Petroleum Association established the Foundation for Climate Protection and Carbon Offset (KliK). It 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. This has led to a sharp increase in sales of liquid biofuels.

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 0.69 (USD 0.82) per liter (L) in comparison with fossil fuels. The mineral oil tax reduction was initially valid until 2020 and has now been extended until 2023.[74] To offset the loss of tax revenue from this tax cut, the fossil fuel tax will be gradually increased until 2028.

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[71] The Federal Council, 2017, "730.0 Energiegesetz (EnG)"
[72] SFOE, 2020, "Vollzug der CO_2-Emissionsvorschriften 2020"
[73] FOEN, 2012, "CO_2 emission compensation: motor fuels"
[74] Mineralölsteuergesetz (MinöStG), Stand: July 1, 2020

Advanced Motor Fuels Statistics

The following numbers and statements are all based on 2020 statistics. This therefore represents the impact of the Covid-19 pandemic in 2020.

Final total energy consumption in Switzerland in 2020 amounted to 747,400 terajoules. This represents a reduction of 10.6% compared to the previous year. The impact of the pandemic on energy consumption is particularly evident in transport fuels. Gasoline and diesel consumption fell by a total of 8.1% (gasoline -11.4%, diesel -5.2%). Sales of aviation fuels slumped by -62.2%. Overall, fuel consumption was thus 22.6 % lower than in 2019, which represents a historic slump. Transport fuels account for 22% of total Swiss energy consumption. All fossil fuels were imported. See Figure 1.[75]

In 2020, 336,841 motor vehicles were newly registered in Switzerland, which is the lowest level in 24 years and a decrease of 17.8% compared with 2019. New registrations of passenger cars fell by as much as 23.7%. Despite this record drop, the number of hybrid (+78.9%) and electric cars (+49.8%) that were newly registered rose again. Sales of gasoline cars dropped by 38.1% and sales of diesel cars dropped by 34.7%.

The fall in new registrations due to COVID-19 did not prevent the overall vehicle stock from growing by 1.3% to 6,241,141 engine driven vehicles. Despite the steep rise in sales of electric and hybrid vehicles, their share of the total is still very small. Figure 2 shows this, using passenger cars as an example. Hybrid vehicles have a share of 3% of the total passenger car fleet whereas the share of electric vehicles amounts to 1%. Most of the electricity used in the transport sector is for railroad transportation.

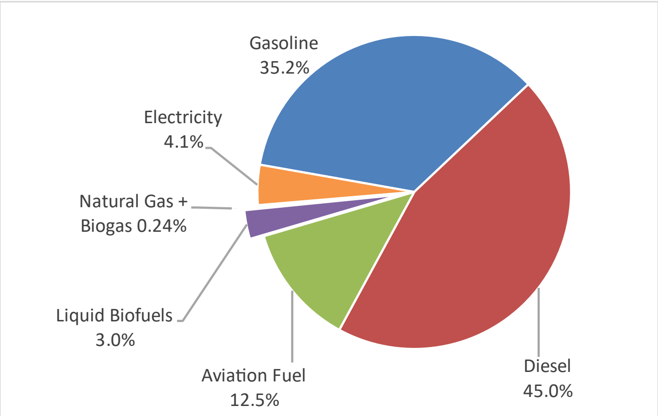

Fig. 1. Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland, 2020[76]

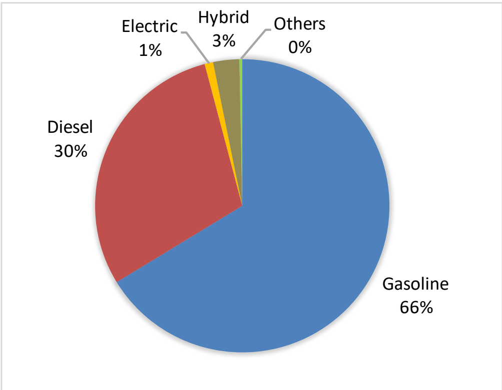

Fig. 2. Passenger car share by fuel, 2020. Total amount is 4,658,335[76]

As mentioned, importers of fossil motor fuels started blending fossil fuels with biofuels in 2014, due to the obligation to reduce CO_2 emissions. In the last five years, the use of liquid biofuels rose from 72.5 million L to 243.7 million L. In 2020, 163.1 million L biodiesel and 63.2 million L bioethanol were used. See Figure 3. Hydrotreated vegetable oil has only been used in Switzerland since 2016 (2020: 17.4 million L). Pure vegetable oil fuel is almost negligible (0.040 million L). Upgraded biogas as a transport fuel remained at a low level of 3.1 million kg.[77]

[75] SFOE, 2020, “Gesamtenergiestatistik 2019”
[76] Swiss Federal Statistical Office (BFS), 2020, “Mobility and Traffic”
[77] SFOE, 2020, “Schweizerische Statistik erneuerbarer Energien 2020”

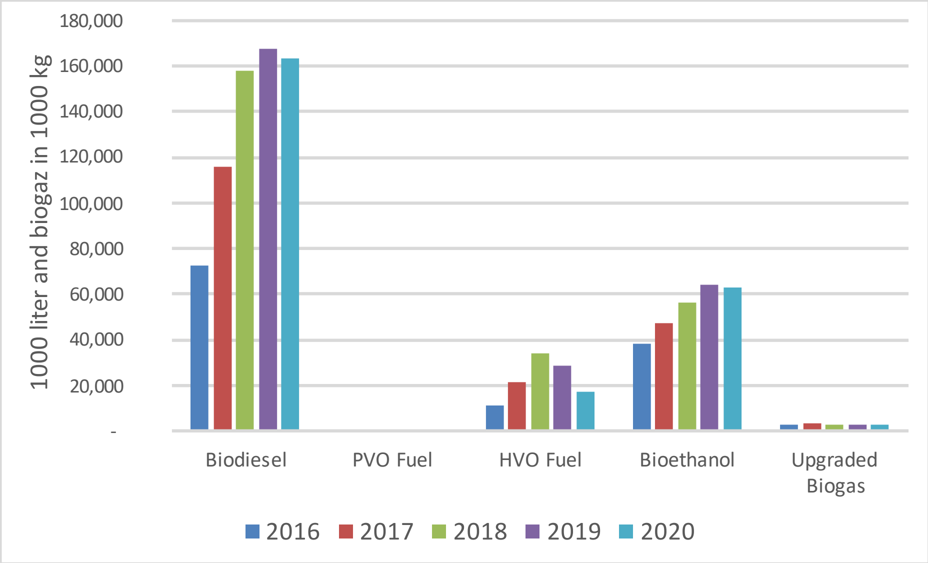

Fig. 3. Development of the Use of Biofuels as Motor Fuels in Switzerland, 2016–2020

Only 13.0 million L of biodiesel were produced in Switzerland. The other 154.5 million L were imported (Germany, 37.9%; Japan, 32.3%; France, 17.1%; China 9.9%). All bioethanol is imported (Poland, 30.7%; Sweden, 22.2%; Norway, 17.3%; Germany, 12.1%; Italy, 7.0%; and the rest from three other countries).[78] Hydrotreated vegetable oil is imported from the United States, 98.4%; and China, 0.2%.

The total amount of biogas produced and used in Switzerland in 2020 was 113 million kg. Only 29 million kg has been upgraded and fed into the natural gas grid. From this, a small amount (3.1 million kg) has been sold as biogas for cars, and the rest for heating. All biogas used as motor fuel in cars is upgraded biogas fed into the natural gas grid. Therefore, cars need no special requirements for biogas as a fuel. Figure 4 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 grid, the demand for it as a motor fuel remains at a low level while 89% of biogas is used for residential heating.[79]

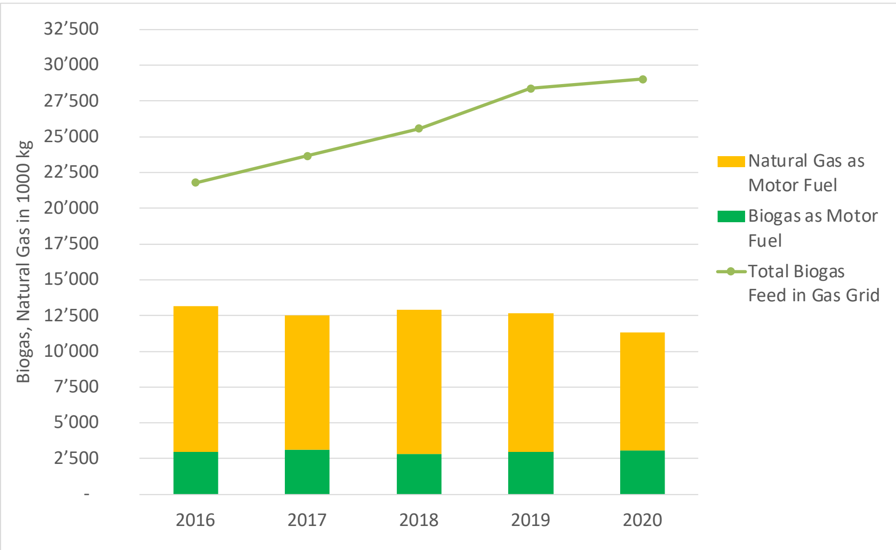

Fig. 4. Development of the Use of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

[78] Swiss Custom Administration, 2020, “T2.8 Biogene Treibstoffe 2020”
[79] Association of the Swiss Gas Industry, 2021, “VSG-Jahresstatistik”

Research and Demonstration Focus

In the research, development, and demonstration funding framework of the Swiss Federal Office of Energy, three programs - bioenergy, combustion, and mobility - support AMF research activities.[80] In the transport sector, the bioenergy and combustion programs almost exclusively fund alternative fuels projects in the industry and at universities. The combustion and engine-relevant properties of biogas, hydrogen (H_2), dimethyl ether (DME), polyoxymethylene dimethyl ether (OME) and ammonia (NH_3) are investigated. The mobility program has its research focus on electromobility. Demonstration projects with fuel cells in commercial vehicles are also funded. The following are examples of ongoing projects:

Carbon reduced Dual-fuel combustion in marine engines[81]

The adoption of LNG as marine fuel is a very important step to reduce GHG-Emission. In this project, a next step in the direction of sustainable fuels generated through synthesis on the basis of renewable energy is investigated. Synthetic fuels are associated with a price penalty that is clearly depending on the level of refinement, i.e. the number and complexity of processing steps involved. In consequence, gaseous synfuels must be expected to be the most realistic option for marine applications. These include specifically H_2, NH_3 and synthetic methane. The latter can be considered a classical drop-in fuel whereas the physical and combustion properties of H_2 and NH_3 are clearly distinct from the LNG used today on Dual Fuel engines. Therefore, the combustion relevant properties of pure and blended synfuels are investigated at a novel "optical engine" test facility (see Figure 5) in order to predict their impact on large Dual Fuel engines. This is specifically important for the initial phase of the introduction of such fuels, when they will not be available worldwide and in large quantities, such that engines will need to be able to operate on multiple fuels and also mixtures of them.

Fig. 5. The Flex-OeCoS – a novel optically accessible test rig for the investigation of advanced combustion processes under engine-like conditions
Source: ITFE FHNW, WIN-GD, CFS 2020-2023; contributes to AMF Task 60

Hydrogen Direct Injection Combustion Process[82]

This project focuses on hydrogen internal combustion engines (ICE) for heavy-duty, off-road applications, which have advantages over PEM fuel cells concerning service life, investment costs, thermal management and fuel flexibility (H2/CH4 admixtures). The aim is fuel conversion predominantly in a stratified, jet-guided mode; enabling combustion at λ=1 with nearly zero emissions and without the knock limitations of conventional combustion processes, especially at high loads.[83]

New combustion process for hydrogen engine in heavy duty and off road application[84]

In contrast to the aforementioned project, very lean hydrogen combustion will be investigated here. For this purpose, a special injection and ignition system is being developed that enables very lean hydrogen

[80] www.bfe.admin.ch
[81] https://www.aramis.admin.ch/Grunddaten/?ProjectID=47512
[82] https://www.aramis.admin.ch/Grunddaten/?ProjectID=48410
[83] Empa, ETHZ, IFS Uni Stuttgart, 2021 – 2023
[84] https://www.aramis.admin.ch/Grunddaten/?ProjectID=44967

mixtures up to λ =3 to be ignited. The goal is to achieve very low engine-out NO_x emissions that meet EURO 7 standards without exhaust after-treatment system. See Figure 6.

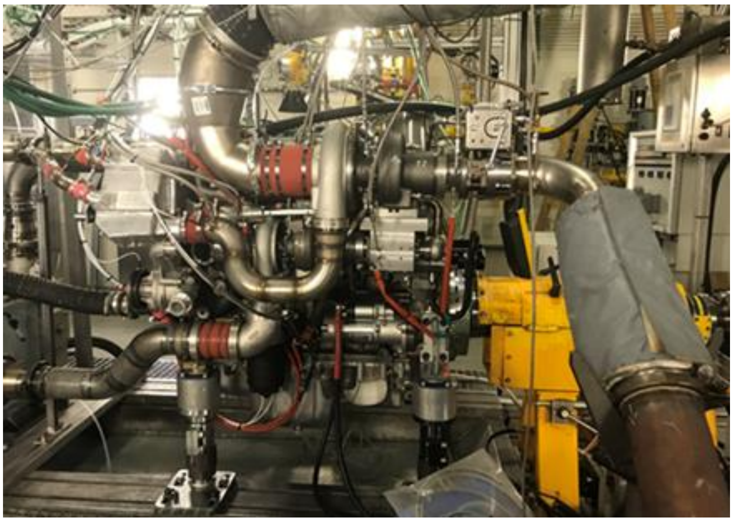

Fig. 6. Hydrogen Fueled Engine in the test bench
Source: Liebherr Machines Bulles SA

Flexible engine platform with new combustion concepts for renewable fuels[85]
The type of renewable chemical energy sources can vary greatly from region to region (methane/DME or methanol, biodiesel, HVO, etc). The availability of efficient, affordable and flexible energy converters for mobile heavy-duty applications is therefore important in order to be able to react to market conditions and thus promote the use of renewable energy. This project considers a flexible engine platform capable of efficiently converting high- or low-reactivity fuels. This is achieved by a novel fully variable valve train (see Figure 7) that allows flexible control of gas exchange and exhaust gas recirculation in combination with optimized combustion chambers and new combustion modes.

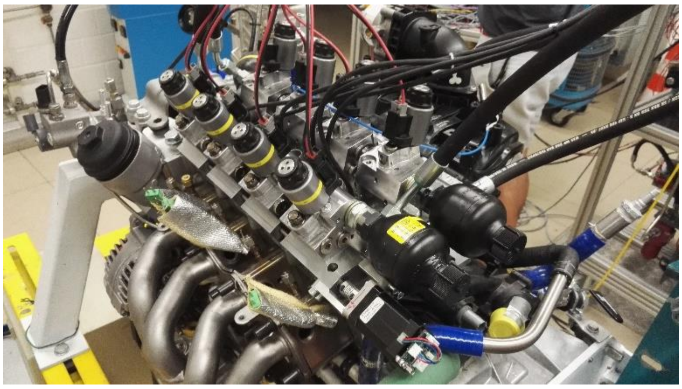

Fig. 7. Novel electro-hydraulic valvetrain on 4-Cylinder Engine
Source: Empa, FPT Motorenforschung AG, IDSC ETHZ, Etavalve; 2021 - 2023

Outlook

Sales of passenger cars with electric drive systems will continue to grow strongly. The expanded range of vehicles on the market, the massive expansion of electric charging stations and tax relief all contribute to this. Demand for large electric vehicles will be mainly confined to the municipal sector and to public transport. Trucks with fuel cells are also being tested, and power-to-gas plants are being built to supply them with hydrogen. The engine industry and research institutes are developing and testing combustion and engine concepts for the use of different fuels with a low GHG footprint. The focus is especially on H_2, but also on NH_3, DME, and OME. The engines developed for these fuels are intended for long-distance transport, marine transport, and different off-road applications.

[85] https://www.aramis.admin.ch/Grunddaten/?ProjectID=49517

Major changes
Swiss Parliament passed in September 2020 a revised CO_2-Act. It was rejected by an optional referendum in June 2021.

Swiss car importers must pay a penalty if the average new passenger car fleet exceeds 95g CO_2/km. With an average of 123.6 g CO_2/km in 2020, they had to pay EUR 122.6 million (USD 144.0 million). Total Swiss energy consumption dropped by 10.6%; fuel consumption was 22.6% lower than in 2019. Sales of gasoline and diesel passenger cars dropped and sales of hybrid and electric cars rose.

Benefits of participation in AMF
The future of internal combustion engines depends, among other things, on the successful market introduction of CO_2-reduced fuels. The TCP AMF 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.

United States

Drivers and Policies

The Biden Administration seeks to reduce U.S. greenhouse gas (GHG) emissions to net-zero on an economy-wide basis by 2050. Transportation, as the largest contributing sector to U.S. GHG emissions, plays a critical role. At the same time, consumer utility and affordability must be maintained, especially as the administration focuses on the redress of historical inequities. This monumental effort is seen as a vital response to the climate crisis.

The Energy Policy Act of 1992 (EPAct) requires certain centrally fueled fleets (federal, state, and alternative fuel provider fleets, such as those used by utility companies) to acquire light-duty alternative fuel vehicles (AFVs) as most of their new vehicle acquisitions. AFVs are promoted for their benefits on emission reductions, energy diversification, and low operating costs.

The U.S. Department of Energy (DOE) Technology Integration Program (formerly the Clean Cities Program) is a government-industry partnership that supports local decisions to reduce petroleum use and GHGs in the transportation sector through the use of alternative fuels, hybrid and electric-drive vehicles, idle reduction technologies, smarter driving practices, and improved fuel economy measures. The most recent data from the Technology Integration Program are for 2019 and show that the program saved 1.0 billion gasoline gallons equivalent (GGE), including 666 million GGE from alternative fuels/vehicles and 74 million GGE from electric and hybrid vehicles.

The transportation sector continues to use a large amount of renewable fuels. The primary driver of renewable fuel use in the U.S. is the Renewable Fuel Standard (RFS), which was adopted in 2005 and expanded in 2007 (RFS2). It requires increasing the volume of renewable fuel to be used in motor fuels. On December 7, 2021, the EPA proposed to retroactively reduce 2020 total renewable fuel volumes from 20.1 billion gallons to 17.1 billion gallons, as the previous value was set before the pandemic.[86] In 2020, U.S. gasoline consumption was 20% lower than in 2019. In addition, the EPA proposed the 2020 and 2022 volumes be set to 18.5 billion gallons and 20.8 billion gallons, respectively. Both the 2020 and 2021 proposed values represent a reduction from the pre-pandemic 2019 volume, 19.9 billion gallons, while the 2022 proposal marks a slight increase. The 2022 proposed value is significantly lower than the original target of 36 billion gallons in the RFS legislation, which envisioned much more robust growth in cellulosic fuel production than has materialized.

The cellulosic biofuel category was created largely with cellulosic ethanol in mind. However, renewable natural gas from landfills and anaerobic digesters, treated as cellulosic biofuel by the EPA through rulemakings in 2013 and 2014, has dwarfed liquid fuels in that category. Biomass-based diesel is mainly traditional biodiesel, derived from soy, corn oil, canola, and other vegetable and animal fats and oils. These categories are nested into the category of advanced biofuels, which also includes renewable diesel, biogas, renewable heating oil, and renewable fuels co-processed in petroleum refining. Finally, the broad category “Renewable Fuel” includes all of these categories combined with starch- and sugar-based ethanol.

The State of California developed the Low-Carbon Fuel Standard (LCFS) to reduce the average carbon intensity of its transportation fuels by 10% from 2010 to 2020. In 2019, California extended the LCFS to 2030 with reduced carbon intensities for transportation fuels by additional 10% reduction. Using life-cycle analysis, different carbon intensities were developed for different fuels, including alternative fuels and biofuels. With both the RFS and LCFS, a significant volume of biofuels — about 2.0 billion GGE — was used in California in 2020, although this value was about 6% lower than 2019.

In 2021, the U.S. Congress enacted the Bipartisan Infrastructure Law (BIL)[87]. The law establishes aggressive goals of transportation electrification and decarbonization with significant federal government investments in battery electric vehicles, charging stations, hydrogen fuel cell vehicles, and hydrogen production deployment. Under the law, the federal government will develop partnerships and provide financial assistance through competitive grants to state governments and industry to meet these goals.

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[86] EPA, 2021, EPA Proposes Comprehensive Set of Biofuels Program Updates and Improvements, December 7, 2021.
[87] The White House, Building a Better America, www.build.gov

Advanced Motor Fuels Statistics

The U.S. Energy Information Administration (EIA) estimated that total U.S. transportation energy consumption for 2021 was 26,935 trillion British thermal units (Btu), 9% higher than the same period in 2020.[88] More than 90% of this consumption is petroleum-based fuels (gasoline and diesel), with most of the remainder being ethanol blended into gasoline at 10%. Biomass accounted for 1,477 trillion Btu during 2021, natural gas for 1,095 trillion Btu, electricity for 66 trillion Btu, and propane for 7 trillion Btu.[89]

Biofuels

The best biofuel use data come from the EPA's recording of Renewable Identification Numbers (RINs) filed by refiner/marketers of liquid transportation fuels, as shown in Figure 1.[90] Each RIN is equivalent to 1 gallon of ethanol by Btu content; RINs are generated when a motor fuel refiner/blender blends or sells the renewable fuel or fuel blend. Renewable fuel volumes grew from 16.6 billion gallons in 2020 to 18.0 billion gallons in 2021, as fuel consumption rebounded after the first year of the pandemic.

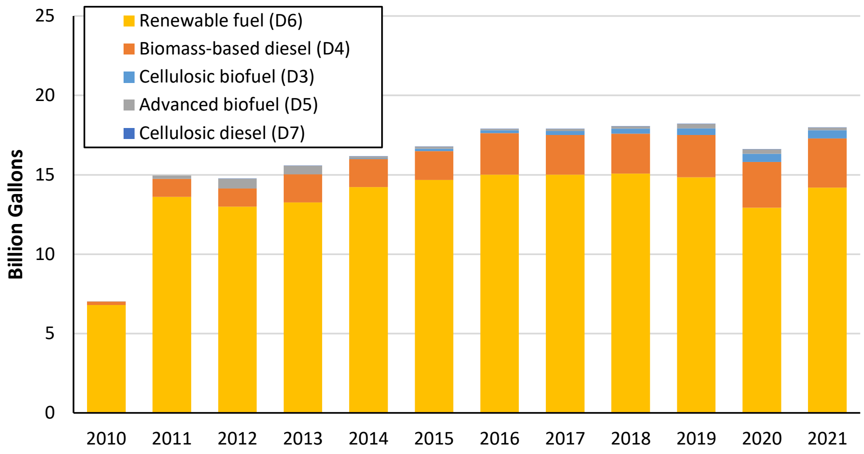

Fig. 1. Renewable Fuel Volumes Resulting from U.S. Renewable Fuel Standard

Electric Vehicles

Sales of plug-in hybrid electric vehicles (PHEVs) and battery electric vehicles (BEVs) in 2021, totaling 607,567, resulted in the largest sales year in U.S. history by far. For comparison, sales stagnated at about 320,000 per year from 2018 to 2020.[91] Similarly, hybrid electric vehicles (non-plug in) had record sales in 2021, totaling 800,381, up from 454,890 in 2020.[92] Available plug-in models totaled 185 as of February 2022, up slightly from 129 in February 2021.[93]

Alternative Fuel Infrastructure

The DOE's Alternative Fuels Data Center provides the number of alternative fuel refueling stations in the U.S.[94] As seen in Table 1, exclusive of electric recharging stations, the total number of alternative fueling stations in the U.S. increased by 40% between 2012 and 2021. However, the number of compressed natural gas (CNG) and liquefied petroleum gas (LPG) stations decreased slightly in 2021. The total number of public and private nonresidential electric vehicle recharging outlets jumped by over 800% over this same 10-year period, with a 20% gain in 2020 as well.

[88] *EIA Monthly Energy Review*, March 2022.
[89] Ibid.
[90] EPA, 2022, EPA Moderated Transaction System, February 2022.
[91] Argonne National Laboratory, 2022, "Light Duty Electric Drive Vehicles Monthly Sales Updates"
[92] Ibid.
[93] DOE, 2022, Alternative Fuels Data Center, "Availability of Hybrid and Plug-In Electric Vehicles"
[94] DOE, 2022, "Alternative Fueling Station Counts by State"

Table 1. U.S. Alternative Fuel Refueling Stations by Type, 2012–2021 (including public and private stations)

Year	B20	CNG	E85	Electric Outlets[a]	H2	LNG	LPG	Total	Total Non-electric
2012	675	1,107	2,553	13,392	58	59	2,654	20,498	7,106
2013	757	1,263	2,639	19,410	53	81	2,956	27,159	7,749
2014	784	1,489	2,780	25,511	51	102	2,916	33,633	8,122
2015	721	1,563	2,990	30,945	39	111	3,594	39,963	9,018
2016	718	1,703	3,147	46,886	59	139	3,658	56,310	9,424
2017	704	1,671	3,399	53,141	63	136	3,478	62,592	9,451
2018	670	1,574	3,632	67,957	64	114	3,328	77,339	9,382
2019	614	1,583	3,837	87,457	64	116	3,118	96,789	9,332
2020	703	1,549	3,949	108,190	64	103	2,967	117,525	9,335
2021	1102	1,506	4,378	130,241	67	103	2,804	140,201	9,960

[a] Total number of recharging outlets, not sites.

Research and Demonstration Focus

The DOE's Vehicle Technologies Office (VTO) sponsors research in fuels and advanced combustion engines for the purpose of displacing petroleum-derived fuels, matching engines and fuel characteristics better, and increasing engine and vehicle efficiencies. This research covers a very broad range of fuel, engine, and vehicle technologies. The summary provided here focuses on fuels and fuel effects and is based on an annual program report.[95]

Beginning in 2016, the Co-Optimization of Fuels and Engines (Co-Optima) initiative was led jointly by DOE's VTO and Bioenergy Technology Office (BETO). The goal of Co-Optima was to identify and evaluate technology options for the introduction of high-performance, sustainable, affordable, and scalable co-optimized fuels and engines. For example, researchers assessed 14 mixing-controlled compression ignition (MCCI) blendstocks that revealed strong potential for most to meet production and operational cost requirements, while seven demonstrated the ability to cut GHG emissions by more than 60%. Co-Optima included both spark ignition and compression ignition.

Identified metrics include:

- Enable additional 10% fuel efficiency in light-duty engines.
- Reduce criteria pollutant emissions by 50% in heavy-duty engines.
- Accelerate deployment of 15 billion advanced biofuel gallons/year.
- Enable an additional 9% to 14% fleet GHG reduction by 2040.

Research under the Co-Optima initiative concluded in September 2021 with final results to be published over the next several months.

Looking forward, VTO research and development in engines and fuels will focus exclusively on off-road applications, including rail, marine, aviation, and off-road equipment for agriculture, mining, construction, and forestry. While it is recognized that engines will continue to be used in on-road transportation for years, VTO powertrain research for such applications will focus on battery electrification and hydrogen fuel cell powered vehicles.

In addition, BETO will continue to promote the development of new fuels from initial concepts, laboratory research and development, and pilot and demonstration plant phases. Research areas include feedstocks, algae, biochemical conversion, and thermochemical conversion for aviation and marine fuels and high-value chemicals.

The DOE has begun to make significant investments in sustainable aviation fuels (SAF) to help decarbonize the U.S. aviation sector. The U.S. federal government has established a SAF Grand

[95] DOE, 2021, *Co-Optimization of Fuels & Engines FY20 Year in Review*, DOE/EE-2055, June 2021.

Challenge with a goal of 3 billion gallons of SAF by 2030 and 35 billion gallons by 2050.[96] The DOE, the Department of Transportation, and the Department of Agriculture are leading the grand challenge to develop a comprehensive strategy for scaling up new technologies to produce SAF on a commercial scale.

Outlook

The EIA's *Annual Energy Outlook 2022* projects increasing on-road transportation energy use from 2021 through 2023 as the U.S. rebounds from the pandemic and then decreasing energy use from 2024 to 2037, due to mandated increases in fuel efficiency. However, growth in travel demand will outpace these benefits and energy use will increase from 2038 to 2050.[97] The new GHG emission standard for light-duty vehicles proposed by the EPA will incentivize introduction of efficient vehicle technologies and electrified vehicles including PHEVs, BEVs, and FCEVs. The federal government and the auto industry anticipate electrification of the US LDV fleet by 2050. Low-carbon fuels in internal combustion engines can help decarbonize long-haul trucks, the aviation sector, and the marine sector.

Additional Information Sources

- Oak Ridge National Laboratory, "Transportation Energy Data Book" tedb.ornl.gov/
- DOE, Federal and State Laws and Incentives afdc.energy.gov/laws/
- EIA, *Monthly Energy Review*, Energy Information Administration eia.gov/totalenergy/data/monthly/
- DOE Technology Integration Program www.cleancities.energy.gov/
- DOE BETO program energy.gov/eere/bioenergy/

96 DOE, 2021, www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge
97 Energy Information Administration, Annual Energy Outlook 2021, eia.gov/outlooks/aeo/

4 Further Information

4.a
About the International Energy Agency

Established in 1974, the International Energy Agency (IEA) carries out a comprehensive program of energy cooperation for its 30 member and eight association countries and beyond by examining the full spectrum of energy issues and advocating policies that will enhance energy security, economic development, and environmental awareness and engagement worldwide. The IEA is governed by the IEA Governing Board, which is supported through a number of specialized standing groups and committees. For more information on the IEA, visit www.iea.org.

The IEA Energy Technology Network

The IEA Energy Technology Network (ETN) is composed of 6,000 experts participating in governing bodies and international groups managing technology programs. The Committee on Energy Research and Technology (CERT), which consists of senior experts from IEA member governments, considers effective energy technology and policies to improve energy security, encourage environmental protection, and maintain economic growth.

Four specialized Working Parties support the CERT:

- Working Party on Energy End-use Technologies (EUWP): technologies and processes to improve efficiency in the buildings, electricity, industry, and transport sectors
- Working Party on Fossil Fuels (WPFF): cleaner use of coal, improvements in gas/oil exploration, and carbon capture and storage
- Fusion Power Coordinating Committee (FPCC): fusion devices, technologies, materials, and physics phenomena
- Working Party on Renewable Energy Technology (REWP): technologies, socioeconomic issues, and deployment policies.

Each Working Party coordinates the research activities of relevant IEA TCPs. The CERT directly oversees TCPs of a cross-cutting nature.

The IEA Technology Collaboration Programmes

The IEA TCPs consist of international groups of experts who enable governments and industries from around the world to lead programs and projects on a wide range of energy technologies and related issues, from building pilot plants to providing policy guidance in support of energy security, economic growth, and environmental protection. Since creation of the first TCP in 1975, participants have examined close to 2,000 topics. Today, TCP participants represent more than 300 public- and private-sector organizations from more than 50 countries. TCPs are governed by a flexible and effective framework and are organized through an Implementing Agreement. TCP activities and programs are managed and financed by the participants. To learn more about the TCPs, please consult the IEA website.

4.b
AMF TCP Contact Information

4.b.i
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[a] Alphabetical order by country name

If you are interested in contributing to AMF work and your country is already a member, please contact your respective Executive Committee (ExCo) representative.

4.b.ii Task Managers[a]

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[a] Numerical order by Task

If you have specific questions about a Task, please contact the Task Managers as given above.

4.b.iii Chairs and Secretariat

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The AMF Secretary serves as the main point of contact. However, you may also address one of the Executive Committee chairs or heads of subcommittees with more specific questions.

4.c
AMF TCP Publications in 2021

Task 57: Heavy Duty Vehicle Performance Evaluation

This project aimed to demonstrate and predict the progress in energy efficiency of heavy-duty (HD) vehicles, thus generating information to be used by transport companies, those procuring transport services and those forming transport policy. The project encompassed newest diesel technologies on different markets, but also alternative fueled vehicles and advanced powertrain configurations tested on chassis dyno and on-road.

The Task was closed by holding a Web Seminar in which the findings from work done in this Task were presented. An overview provided by the Task Manager was followed by related findings of the Hybrid and Electric Vehicles (HEV) TCP and case studies from Switzerland and Finland.
Details can be found on the AMF Website.

Key Messages – May 2021
Final Report – May 2021

Task 58: Transport Decarbonization

This report assesses the contribution that renewable fuels can make to decarbonizing road transport. Bringing the GHG emissions of the road transport sector down to zero by 2050 cannot be achieved by one measure alone. Countries that deploy a set of different measures, such as reducing transport demand, improving vehicle efficiency, and adding renewable energy carriers such as biofuels, e-fuels, renewable electricity and renewable hydrogen, have the best chances to meet ambitious decarbonization goals.

Our assessment shows that biofuels contribute most to decarbonization now and up to 2030, 2040, or even 2050, depending on the country. In Germany and in the USA, efficiency gains become the main contributor after 2030, and in Finland and Sweden the impact of biofuels remains largest until around 2040, when the use of electric vehicles takes over. In Brazil, biofuels remain the largest contributor until 2050.

Key Messages – April 2021

The Final Reports, including the Summary, were published in 2020 and can be found on the AMF **website**

Task 59: Lessons Learned from Alternative Fuel Experiences

Consistent policies and integration of all stakeholders are both necessary to overcome barriers for a successful market implementation of alternative fuels and propulsion systems. There is need for long-term and comprehensive policies, on national and international level, which include markets, stakeholders and different technologies to gain benefits for all types of stakeholders along the value chain of the transportation system.

Final Report, June 2021
Key Messages, June 2021

4.d How to Join the Technology Collaboration Programme on Advanced Motor Fuels

Participation in the multilateral technology initiative AMF TCP is based on the mutual benefits it can bring to the TCP and the interested newcomer.

If you are interested in joining the AMF TCP, please contact the AMF Secretary, Dina Bacovsky.

The Secretary will provide you with details on the AMF TCP and invite you to attend an Executive Committee meeting as an observer. By attending or even hosting an Executive Committee meeting, you will become familiar with the TCP.

Contracting parties to the AMF TCP are usually governments. Therefore, you need to seek support from your government to join the TCP. The government will later appoint a delegate and an alternate to represent the contracting party in the Executive Committee.

Financial obligations of membership include:

- An annual membership fee, currently EUR 10,250 (USD 11,190)
- Funding for an ExCo delegate to attend two annual meetings
- Cost-sharing contributions to Tasks in which you wish to participate; cost shares range from EUR 10,000 to EUR 100,000 (USD 10,920 to USD 109,190).

Participation in Tasks can take place through cost sharing and/or task sharing. The institution participating in a Task does not necessarily need to be the institution of the Executive Committee delegate.

The AMF TCP Secretary and IEA Secretariat will guide you through the formalities of joining the Technology Collaboration Programme on Advanced Motor Fuels.

4.e
Partnerships

Collaboration with the International Transport Forum (ITF)

The International Transport Forum at the OECD is an intergovernmental organization with 63 member countries. It acts as a think tank for transport policy and organizes an annual summit of transport ministers. The ITF is the only global body that covers all transport modes. Administratively, the ITF is integrated with the OECD but it is politically autonomous.

The ITF works to establish transport policies that improve peoples' lives. Its mission is to foster a deeper understanding of the role of transport in economic growth, environmental sustainability and social inclusion, and to raise the public profile of transport policy.

The ITF organizes global dialogue for better transport. It acts as a platform for discussion and pre-negotiation of policy issues across all transport modes and it analyzes trends, shares knowledge and promotes exchange among transport decision-makers and civil society. The ITF's Annual Summit is the world's largest gathering of transport ministers and the leading global platform for dialogue on transport policy.

The collaboration of the ITF with the AMF TCP brings constructive inputs to the activities of the TCP and also helps give greater visibility to the outputs of the AMF TCP.

This closer relationship facilitates inputs and contributions for the AMF TCP and its members to support the development of transport-related policy instruments that are at the core of the ITF's work, strengthening the impact of the work of the AMF TCP. The cooperation enables an exchange of best practices.

Glossary

Advanced Motor Fuels (AMF)

The Technology Collaboration Programme on Advanced Motor Fuels (AMF TCP) is one of the multilateral technology initiatives supported by the International Energy Agency (IEA). Formally, these are also known as Implementing Agreements. The AMF TCP promotes more advanced vehicle technologies, along with cleaner and more-efficient fuels. Transportation is responsible for approximately 20%–30% of all the energy consumed and is considered to be the main producer of harmful emissions. Although the transportation sector is still highly dependent upon crude oil, advances are being made to allow for domestically made biofuels and other forms of energy.

Biofuels

Biofuels (for transport) are liquid or gaseous fuels produced from biomass, with the purpose of using them for the propulsion of vehicles (cars, trucks, buses, trains, ships, planes). Feedstocks include food and feed crops, energy crops, agricultural residues, forest and forest industry residues, industrial residues, and organic waste fractions.

Dual Fuel (DF)

DF is a fueling strategy currently being researched in diesel engines. A fuel resistant to auto-ignition, such as gasoline, is delivered to the combustion chamber through port fuel injection. A fuel that has a propensity to auto-ignite, such as diesel, is injected directly into the combustion chamber. This charge of diesel fuel is used to ignite the air-fuel mixture. Preliminary results show that by using diesel dual-fuel strategies, spark-ignited engine emission levels can be achieved along with the high thermal efficiencies of diesel engines.

Dimethyl Ether (DME)

DME is a fuel created from natural gas, coal, or biomass, which is noted for producing low levels of NO_x emissions and low smoke levels when compared to petroleum-derived diesel fuels. DME does not have some of the transportation issues associated with other alternative fuels, such as ethanol, which causes corrosion in pipelines. Because DME is a gas at room temperature, it must be put under pressure in large tanks for transportation and storage, unlike ethanol.

Electrofuel

Electrofuel is made by storing electrical energy from renewable sources in the chemical bonds of liquid or gas fuels. Butanol, biodiesel and hydrogen are the primary targets but methane and butane are also options for this class of fuel.

E85

E85 is composed of 85% ethanol and 15% gasoline by volume. This type of fuel is used in flex-fuel vehicles, which are compatible with pump gasoline and available alternative fuels. Consequent fuels, such as E0, E5, and E20, contain a certain vol% of ethanol, denoted by the number in their name, with the rest of the mixture being gasoline.

Ethanol (C_2H_5OH)

An alcohol fuel derived from plant matter (commonly feed corn), ethanol is blended into pump gasoline as an oxygenate. Changes to the engine and exhaust systems have to be made in order to run a higher ethanol blend. Ethanol is a popular alternative fuel because of its propensity to increase an engine’s thermal efficiency. Ethanol is also popular because it can be domestically produced, despite discussions of its impact on food supplies. By law, ethanol must be denatured by using gasoline to prevent human consumption.

Ethyl Tertiary-Butyl Ether (ETBE)

ETBE is an additive introduced into gasoline during the production process. As an additive, ETBE can be used to create some of the emission benefits that are inherent with oxygenates. ETBE can be derived from ethanol, which allows it to be included as a biofuel.

Fatty Acid Methyl Ester (FAME)
FAME is a form of biodiesel derived from waste biomass, such as animal fats, recycled vegetable oils, and virgin oils. Pure biodiesel, B100, must meet standards before it can be blended into diesel fuels. In the United States, different blends of biodiesel can be found across the nation, ranging from 5% to 20% biodiesel. Manufacturers are now creating engines compatible with biodiesel blends up to B20. Under European standards, the terms FAME and biodiesel are used synonymously. B100 may be used as a pure fuel as well, with only minor adaptations to vehicles.

Flex-Fuel Vehicle (FFV)
FFVs are capable of safely handling various fuels, ranging from gasoline to high-ethanol-content blends. The fuel system in an FFV vehicle is dedicated to handle the flow of ethanol, which would harm a normal vehicle. General Motors is a major producer of FFVs. These vehicles do see a loss in fuel economy when running on alternative fuels, due to the lower energy content of ethanol.

Fuel Cell Vehicle (FCV)
An FCV is a type of hybrid that uses a hydrogen-powered fuel cell to produce electrical energy, which then powers electric motors that drive the vehicle. FCVs have the potential to lower harmful emissions in comparison to internal combustion engines.

Green Hydrogen
Green Hydrogen is produced from renewable energy sources. The most discussed production pathway is splitting water by electrolysis, driven by electricity from renewable energy sources such as solar or wind. There are also a number of other pathways that exist which are based on biomass.

Greenhouse Gas (GHG)
GHGs are emissions that increase the harmful greenhouse effect in the Earth's atmosphere. The emission of carbon dioxide, a common GHG, is a direct product of combustion. GHGs are responsible for trapping heat in the Earth's atmosphere. Methane, another powerful GHG, can remain in the atmosphere for longer than a decade and is at least 20 times more effective than carbon dioxide at trapping heat. GHGs have been a topic of great debate concerning global climate change in years past.

Hydro-treated Vegetable Oil (HVO)
HVO is a bio-based diesel fuel that is derived through the hydrotreatment (a reaction with hydrogen) of vegetable oils. HVO can be used as a renewable diesel fuel, and it can be blended with regular diesel to create varying blends on a volume basis.

Internal Combustion Engine (ICE)
An ICE is a device that uses stored chemical energy in a fuel to produce a mechanical work output. There are more than 600 million ICEs in existence today, used for transportation and stationary purposes. Typical peak efficiencies for gasoline, diesel, and stationary engines are 37%, 42%, and 50%, respectively. Efficiencies of transportation gasoline and diesel engines are lower than their peak efficiencies, because they do not operate in the peak range.

Liquefied Natural Gas (LNG)
LNG is produced through the liquefaction process of natural gas, which can be used to power heavy-duty vehicles, such as transit buses. LNG is composed primarily of methane (CH_4), with impurities being removed during the liquefaction process.

Liquefied Petroleum Gas (LPG)
LPG is composed of propane (C_3H_{10}) and butane (C_4H_{10}), with its exact composition varying by region. This clean-burning fossil fuel can be used, with modification, to power current vehicles equipped with internal combustion engines, as an alternative to gasoline. LPG can also be produced domestically.

Natural Gas

Natural gas is a gas primarily consisting of methane (CH_4), which can be used as a fuel, after a refining process. This fossil fuel is extracted from the ground and burns relatively clean. Natural gas is not only less expensive than gasoline, but it also contributes to lower greenhouse gas emissions and smog-forming pollutants. Current gasoline and diesel vehicles can be converted to run on natural gas.

Natural Gas Vehicle (NGV)

NGVs are alternative fuel vehicles that use compressed or liquid natural gas, which are much cleaner-burning than traditional fuels. Current vehicles can be converted to run on natural gas, and such conversion is a popular trend among fleet vehicles. The only new original equipment manufacturer (OEM) NGV available in the U.S. market is the Honda Civic GX compressed natural gas car; in years past, by comparison, multiple vehicles were available. Countries in Europe and Asia offer a much wider selection of OEM NGVs.

Nitrogen Oxides (NO_x)

Nitrogen oxides are composed of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is formed from the nitrogen and oxygen molecules in the air and is a product of high combustion temperatures. NO_x is responsible for the formation of acid rain and smog. The three-way catalyst, which operates most efficiently at stoichiometric air-fuel ratios, has tremendously reduced NO_x emissions in spark-ignited engines. A lean-burn after-treatment system is needed for compression-ignition engines, because they do not operate at stoichiometric conditions.

Particulate Matter (PM)

PM is an emission produced through the combustion process. PM less than 10 micrometers in diameter can cause serious health issues, because it can be inhaled and trapped in a person's lungs. With the advent of diesel particulate filters, PM emissions have been tremendously reduced.

Plug-in Hybrid Electric Vehicle (PHEV)

A PHEV is a type of hybrid electric vehicle equipped with an internal battery pack, which can be charged by plugging the vehicle into an outlet and drawing power from the electrical grid. These vehicles are becoming popular, because the vehicle itself produces very low emission levels.

Port Fuel Injection (PFI)

PFI is a type of fuel delivery system in which fuel is injected into the intake manifold before the intake valve. This method of fuel injection is being replaced in newer vehicles by direct fuel injection. PFI is typically found in spark ignition engines.

Scrubber

A gas scrubber is used to filter particulates and liquid hydrocarbons from natural gas products. This improves the purity of the natural gas product and reduces sulfur content and NO_x. Scrubbers use particle filters, coalescers, mesh pads, and other devices to remove pollutants from the gas stream.

Selective Catalytic Reduction (SCR)

By using a catalyst such as ammonia, selective catalytic reduction converts nitrogen oxides into nitrogen and water to improve emissions control. Retrofit solutions for older diesel cars and machinery are increasingly available, making such machines gentler to the environment.

Well-to-Wheel (WTW)

The well-to-wheel concept takes into account all of the emissions created from the initial energy source to the end system for the desired mode of transport. For instance, an electric vehicle will create lower greenhouse gas emissions than a gasoline-powered vehicle. If the electricity used to charge the electric vehicle came from a combustion power plant and if other transmissions of power were taken into account, the electric-vehicle-related emissions could, in fact, exceed the emissions of the gasoline counterpart.

Notation and Units of Measure

1G	First Generation
2G	Second Generation
AFV	Alternative Fuel Vehicle
AMFI	Advanced Motor Fuels Website
B20	Biodiesel
BDC	Business Development Bank of Canada
BESC	Breakthrough Energy Solutions Canada
BEST	Bioenergy and Sustainable Technologies GmbH
BETO	Bioenergy Technology Office (US)
BEV	Battery Electric Vehicle
BMBF	Federal Ministry of Education and Research (Germany)
BMDV	Federal Ministry for Digital and Transport (Germany)
BMEL	Federal Ministry of Food and Agriculture (Germany)
BMWi	Ministry of Economic Affairs and Energy (Germany)
CBG	Compressed Biogas
CERT	Committee on Energy Research and Technology (IEA)
CFR	Clean Fuel Regulations (Canada)
CGP	Clean Growth Program (Canada)
CGSB	Canadian General Standards Board
CHP	Combined Heat and Power
CHT	Centre for High Technology (India)
CI	Carbon Intensity
CNG	Compressed Natural Gas
CNMC	National Markets and Competition Commission (Spain)
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
CORSIA	Carbon Offsetting and Reduction Scheme for International Aviation
COVID-19	Coronavirus
CSIR-IIP	Council of Scientific and Industrial Research – Indian Institute of Petroleum
CTS-RD	Clean Transportation System-Research and Development Program (Canada)
DBT	Department of Biotechnology (India)
DF	Dual Fuel
DHAs	Omega 3-fatty acids (India)
DME	Methanol/Dimethyl Ether
DOC	Diesel Oxidation Catalyst
DOE	U.S. Department of Energy
DPF	Diesel Particulate Filter
E85	85% Ethanol in Gasoline Fuel
E100	Pure Anhydrous Ethanol
EBP	Ethanol Blended Petrol
EFB	Empty Fruit Bunches (India)
EGR	Exhaust Gas Recirculation
EIA	U.S. Energy Information Administration
EIP	Energy Innovation Program (Canada)
EKF	Energy and Climate Fund (Germany)
EOI	Expression of Interest
EPA	U.S. Environmental Protection Agency

EPAct	Energy Policy Act of 1992 (U.S.)
ERA-NET	European Research Area Bioenergy
ESR	Effort Sharing Regulation (Germany)
ESY	Ethanol Supply Year
ETBE	Ethyl Tertiary-Butyl Ether
ETN	Energy Technology Network (IEA)
ETS	E*missions Trading System* (EU)
eTV	ecoTechnology for Vehicles (Canada)
EU	European Union
EV	Electric Vehicle
EVAFID	Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (Canada)
EVID	Electric Vehicle Infrastructure Demonstration Program (Canada)
FAME	Fatty Acid Methyl Ester
FCI	Food Corporation of India
FCV	Fuel Cell Vehicle
FFV	Flex-Fuel Vehicle
FNR	Fachagentur Nachwachsende Rohstoffe
FQD	Fuel Quality Directive (Germany)
FVMI	Association of the Mineral Oil Industry (Austria)
FY	Fiscal Year
GDI	Gas Direct Injection
GHG	Greenhouse Gas
GPF	Gasoline Particulate Filter
GWVR	Gross Weight Vehicle Rating
HC	Hydrocarbons
HD	Heavy Duty
HDV	Heavy-Duty Vehicle
HEFA	Hydrotreated and Esterified Fatty Acids
HEV	Hybrid Electric Vehicle
HFS	Hydrogen Fueling Station
HRS	Hydrogen Refueling Station (Japan)
HTL	Hydrothermal Liquefaction
HVO	Hydrotreated Vegetable Oil
ICAO	International Civil Aviation Organization
ICCT	International Council on Clean Transportation
ICE	Internal Combustion Engine
IEA	International Energy Agency
IMO	International Maritime Organization
IOCL	Indian Oil Corporation Limited
JRC	Joint Research Centre of the European Commission
KLIEN	Austrian Climate and Energy Fund
KliK	Foundation for Climate Protection and Carbon Offset (Switzerland)
LBG	Liquefied Biogas
LCFS	Low-Carbon Fuel Standard (US)
LDV	Light-Duty Vehicle
LES	Large Eddy Simulation
LEVO	Organization for the Promotion of Low Emission Vehicles (Japan)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
M15	85% gasoline with 15% methanol
MARPOL	International Maritime Pollution Prevention Convention

METI	Ministry of Economy, Trade and Industry (Japan)
MIIT	Ministry of Industry and Information Technology (China)
MLIT	Ministry of Land, Infrastructure, Transport and Tourism (Japan)
MoPNG	Ministry of Petroleum and Natural Gas (India)
NCP	National Climate Plan (Germany)
NECP	National Energy and Climate Plan
NEDC	New European Driving Cycle
NEV	New Energy Vehicle
NGV	Natural Gas Vehicle
NIP	National Innovation Programme Hydrogen and Fuel Cell Technology (Germany)
NO_x	Nitrogen Oxide(s)
NoVA	Normverbrauchsabgabe (Austria)
NPM	National Platform Future of Mobility (Germany)
NRCan	Natural Resources Canada
OMC	Oil Marketing Company
OME	Polyoxymethylene-dimethylether
PAH	Polycyclic aromatic hydrocarbon
PCF	Pan-Canadian Framework on Clean Growth and Climate Change
PEMS	Portable Emission Measuring System
PERD	Program of Energy Research and Development (Canada)
PFAD	Palm Fatty Acid Distillate
PFI	Port Fuel Injection
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PN	Particle Number
PSU	Public Sector Units
PTE-HPC	Spanish Hydrogen Technology Platform
PtL	Power to Liquid
PtX/P2X	Power to X (Germany)
PV	Ground mounted solar farm
R&D	Research and Development
RANS	Reynolds Averaged Navier Stokes equations
RD&D	Research, Development, and Demonstration
RDE	Real Driving Emission
RED	Renewable Energy Directive
RED II	Renewable Energy Directive II
RES	Renewables, total share of (Denmark)
RIN	Renewable Identification Numbers (US)
RFR	Renewable Fuels Regulations (Canada)
RFS	Renewable Fuel Standard (Korea, US)
SATAT	Sustainable Alternative Towards Affordable Transport (India)
SCR	Selective Catalytic Reduction
SET Plan	Strategic Energy Technology Plan (Spain)
SI	Spark Ignition
SIF	Strategic Innovation Fund (Canada)
SOA	Secondary Organic Aerosol
SynBioPTx	Synergies Combining Biomass and Power Technologies
TAEE	Tertiary-Amyl Ethyl Ether
TCP	Technical Collaboration Program (IEA)
UCO	Used Cooking Oil
UER	Upstream Emissions Reductions (Germany)
UN	United Nations

VPT	Vehicle Propulsion Technologies Program (Canada)
VRDS	Residual Oil Desulfurization Facility (Korea)
VTO	Vehicle Technologies Office (US)
WLTP	Worldwide Harmonized Light Vehicle Test Procedure
WP	Work Project
ZEV	Zero Emissions Vehicles

Units of Measure

Btu	British thermal unit(s)
g	gram(s)
gge	gasoline gallon(s) equivalent
g/km	gram(s) per kilometer(s)
kL	kiloliter(s)
km	kilometer(s)
ktoe	kiloton(s) of oil equivalent
MJ	megajoule (s)
MPa	megapascal(s)
Mtoe	megaton(s) of oil equivalent
PJ	petajoule(s)
T	Ton
TJ	terajoule(s)
TOE	tons of oil equivalent
TWh	terawatt hour(s)
W	watt(s)