IEA-Advanced Motor Fuels
ANNUAL REPORT 2020

Technology Collaboration Programme
by IEA

IEA Technology Collaboration Programme on

Advanced Motor Fuels Annual Report 2020

Rainbow Spine: The colors used for the spines of Advanced Motor Fuels Annual Reports follow the colors of the rainbow. Using colors allows readers to easily distinguish among the different editions of the annual report. This year's edition has a violet spine, indicating high class and dedication. AMF has recently concluded several excellent projects, which provide information on the use of methanol as a motor fuel, assess the role of renewable transport fuels in decarbonizing road transport, and evaluate new concepts for heavy-duty vehicles.

Cover: We are featuring a biogas fueling station on this year's cover to highlight the importance of gaseous and liquid biofuels to achieve GHG emission reductions. Biofuels can be distributed through existing infrastructure and applied in the legacy fleet. Thus, they provide GHG emission reductions already, while other components of our future transport system – such as electric vehicles – need to gain a larger share of the fleet before they will be able to make a significant contribution to GHG emission reductions. We firmly believe that all options are direly needed to decarbonize quickly and reach ambitious climate targets.

URL: http://www.iea-amf.org/annualreport

Photo credit: Image of cars at the biogas filling station — carbon neutral transportation concept by Shutterstock/Scharfsinn Photographer

Cover Design: Kate Thomas

Chairperson's Message

Jesper Schramm, Chair of the AMF TCP

The Advanced Motor Fuels Technology Collaboration Programme (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 annexes, where member countries combine their activities and skills to advance mutual goals. Our newsletter furthers this objective with short updates on the global and local situation. AMF TCP's online seminars and workshops have become increasingly important in 2020 due to the COVID-19 pandemic.

In recent years, electric vehicles have become an important technological solution to lower GHG emissions from transportation. However, it is most likely that some transport sectors cannot rely on electrification. Heavy duty vehicles, marine transport and aviation must still be fed by liquid or gaseous fuels in order to operate for many years to come. Therefore, still more efforts are foreseen for AMF TCP in these areas. Until electric vehicles can compete with traditional vehicles regarding operating range and price, the reduction of emissions from passenger cars will rely on the development of cleaner and more efficient vehicles, operating on traditional fuels. Therefore, for decades to come, fuels and engine technology for these vehicles will be the focus of AMF TCP's attention.

The strength of the International Energy Association (IEA) lies in the fact that IEA is a neutral organization. It was established in 1974 to coordinate and secure the energy supply of the Organisation for Economic Co-operation and Development (OECD) countries, and not to promote individual interests. Those reading our AMF TCP reports and newsletters should pay attention to the work, knowing that we report and advise in this spirit. Therefore, an important feature of all information coming from IEA and the AMF TCP remains objective information about energy matters.

The various TCPs of the IEA actually deal with competing technologies. For example, the Hybrid Electric Vehicles (HEV) TCP deals with electric vehicle technology, whereas AMF mostly deals with combustion engine technology – two clearly competing technologies. It is with great satisfaction that I see these two TCPs working together to deliver vehicle performance data in this year's Annex 57, "Heavy Duty Vehicle Evaluation."

In general, collaboration between TCPs is important in order to gain a broader evaluation of energy perspectives. For example, the decarbonization of transport is an important issue for the near future and it requires broad study and understanding. The issue is addressed in close collaboration with the Bioenergy TCP. Results from this study, "The Role of Advanced Renewable Transport Fuels in Decarbonising the Transport Sector in 2030 and beyond" were reported recently. Additionally, collaboration between AMF TCP, the Hydrogen TCP and the Combustion TCP has been discussed and those involved will most likely intensify this discussion in coming years.

The AMF TCP has a truly worldwide engagement. Geographic coverage is broad, with the contracting parties of the AMF TCP representing almost 50% of the world's population. However, we strive to include still more members, especially in economies with a growing transport sector and/or engagement in the supply and end-use of advanced motor fuels.

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. In the end, we know you will not get what you expect — you will get what you inspect!

Finally, a personal issue that I need to mention. Steven Goughen, one of the former chairs of AMF, passed away in 2020. He was a dedicated chairman and a personal friend to me and to other people of the AMF community. May he rest in peace.

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, Chairman of Strategy & Technology Subcommittee

In the year 2020, the world nearly shut down due to the Covid-19 virus. International travel was almost nonexistent throughout the year. This impacted the transport industry severely, especially in aviation, but certainly also in shipping and private vehicle use. Within Advanced Motor Fuels (AMF), all physical meetings in 2020 were replaced by virtual meetings.

A major global milestone in 2020 was the launch of the IMO 2020 Sulphur Cap which will ensure much cleaner marine fuels in the future. There is still a long way to go for shipping fuel to become entirely sustainable. However, one must remember that the remarkable progress of diesel cars and trucks throughout the last couple of decades began with the regulation and removal of Sulphur from road diesel fuel. Without this crucial first step, indispensable emission reduction technologies such as SCR and DPF would not have been possible. This is due to the simple fact that Sulphur is the enemy of catalysts.

For the first time ever, a country instated completely free public transportation. This happened in Luxemburg, a small non-EU state in Western Europe. Whether this will effectively reduce road traffic shall be interesting to watch.

As an overall trend, the global number of ICE cars continued to rise throughout 2020. Electric vehicles did take up some of the market growth but not enough to see actual decline in the sales of fuel powered vehicles.

Lots of PHEVs were sold in 2020. Sadly, none of them are biofuel compliant. Even though these cars are externally rechargeable, real-world fuel economy numbers suggest that owners often skip the recharging. As a result, PHEVs really post no benefit to the environment.

Trucks and SUVs are increasingly popular, particularly in the USA. The average weight of new vehicles is therefore still increasing. The average horsepower of new vehicles is also rising noticeably.

Despite these facts, fuel economy of new vehicles is improving. This is mainly due to new technologies implemented on the engine and transmission sides of design.

One technological highlight is the Freevalve engine introduced by Koenigsegg (“Tiny Friendly Giant”), which produces unprecedented power and fuel economy figures. This engine is also completely biofuel compliant, which is something we hope will become mainstream for all ICE vehicles in the near future.

DOR Chemical Group in Israel converted an Iveco Truck to methanol in 2020 in the wake of a similar effort by Chinese Geely, who introduced a methanol truck the year before. As low GHG methanol becomes more and more available, we can hope that this initiative too will be followed by others.

German sports car maker Porsche announced in 2020 a project to produce biosynthetic gasoline primarily for use in vintage Porsche cars.

Despite all efforts, reducing GHG from transport fuels remains difficult. Global biofuel production dropped by 11.6% in 2020. Flex-fuel vehicles are still absent from the mainstream vehicle market, which means that alcohol content in gasoline is effectively capped at 10% for most markets.

The EU decided to phase out palm-based transport fuels because the production of such oil was deemed not sustainable. This puts another strain on the availability of sustainable fuels for the diesel segment. This is particularly challenging because the diesel segment is also the hardest to electrify.

Synthetic liquid biofuels seem to be trending for road and aviation while synthetic alcohols and hydrothermal liquid biofuels are trending in the shipping world. Sustainable Aviation Fuel (SAF) was also high on the agenda in 2020 but production and availability are nowhere near the scale of the demand. Ammonia ship engines have been announced for the market in 2024-2025.

The AMF continues to monitor developments across the globe in search of the best advanced fuel topics to address in the coming years. Most likely, ammonia, SAF and electro-fuels will be among those topics.

IEA Technology Collaboration
Programme for International Energy Agency

Advanced Motor Fuels
Annual Report 2020

This Annual Report was produced by Kevin A. Brown (project coordination/management), Kristen Mally Dean (lead editor), Vicki Skonicki (document production), and John Schneider (printing) of Argonne National Laboratory. The cover was designed by Kate Thomas, also of Argonne National Laboratory.

Contributions were made by a team of authors from the Advanced Motor Fuels Technology Collaboration Programme, 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
Chile	Ministry of Energy
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
Israel	Ministry of Energy
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)

Annex reports were delivered by the respective Operating Agents and Responsible Experts:

Annex 28	Information Service and AMF Website	Dina Bacovsky
Annex 56	Methanol as Motor Fuel	Gideon Goldwine, Päivi Aakko-Saksa and Wibke Baumgarten
Annex 57	Heavy Duty Vehicle Performance Evaluation	Petri Söderena
Annex 58	Transport Decarbonization	Dina Bacovsky Eric Fee and Kyriakos Maniatis
Annex 59	Lessons Learned from Alternative Fuel Experiences	Andrea Sonnleitner
Annex 60	The Progress of Advanced Marine Fuels	Kim Winther
Annex 61	Remote Emission Sensing	Åke Sjödin

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)	Strategy & Technology Subcommittee Head
Dina Bacovsky	BEST – Bioenergy and Sustainable Technologies GmbH	Secretary

Contents

Technology Collaboration Programme for 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, AMF 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, 17 contracting parties from 15 countries participate in AMF (Japan has designated three contracting parties):

- Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (BMK) (Austria)
- Natural Resources Canada (Canada)
- Ministry of Energy (Chile)
- 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)
- Ministry of Energy and Water Resources (Israel)

- 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 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 members, and help shape AMF work according to their own country´s interests and priorities.

The AMF TCP work program is carried out through **Annexes**, which are projects with defined objectives, a defined work scope, and defined starting and ending dates. Annexes can be task shared, cost shared, or a combination of task shared and cost shared. Work in specific annexes is led by Operating Agents. The representatives of Operating Agents participate in Executive Committee meetings to present updates on the progress of work in the annex. 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 AMF'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 Operating Agents and for new members.

How to Establish Work Priorities

Work priorities for AMF 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 annexes. Whenever three or more contracting parties support a proposal and sufficient funding is raised, a new annex 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 2020, seven projects were ongoing:

- Annex 28: Information Service and AMF Website
- Annex 56: Methanol as Motor Fuel
- Annex 57: Heavy Duty Vehicle Performance Evaluation
- Annex 58: Transport Decarbonization
- Annex 59: Lessons Learned from Alternative Fuel Experiences
- Annex 60: The Progress of Advanced Marine Fuels
- Annex 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, there is cooperation with the Hybrid and Electric Vehicles TCP in Annex 57, and Annex 58 is a joint project together with IEA Bioenergy.

2 Ongoing AMF TCP Annexes

2.a
Overview of Annexes

Ongoing Annexes in 2020

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
56	Methanol as Motor Fuel	Gideon Goldwine, Päivi Aakko-Saksa, Wibke Baumgarten
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

Most of the annexes are continuing in 2021. Annex 56, however, concluded in 2020. The final report and key messages for this annex are available on the AMF TCP website, https://iea-amf.org/.

2.b
Annex Reports

Annex 28: Information Service and AMF Website

Project Duration	January 28, 2004 – Continuous
Participants **Task Sharing** **Cost Sharing**	 None All contracting parties: Austria, Canada, Chile, China, Denmark, Finland, Germany, India, Israel, Japan, South Korea, Spain, Sweden, Switzerland, United States
Total Budget	€50,000 ($58,880 US) for 2020 €55,000 ($64,768 US) for 2021
Operating Agent	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 Annex 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 / June 2020
  - Issue No.2 / December 2020
  - Issue No.3 / February 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 special password-protected area that is used for storing and distributing internal information for Delegates, Alternates, and Operating Agents on various topics (e.g., strategies, proposals, decisions, and Executive Committee meetings of the AMF TCP).
- In 2020, additional activities included providing a section on the compatibility of biofuels and vehicles to AMF Annex 58 and taking first steps in social media (LinkedIn and Twitter).

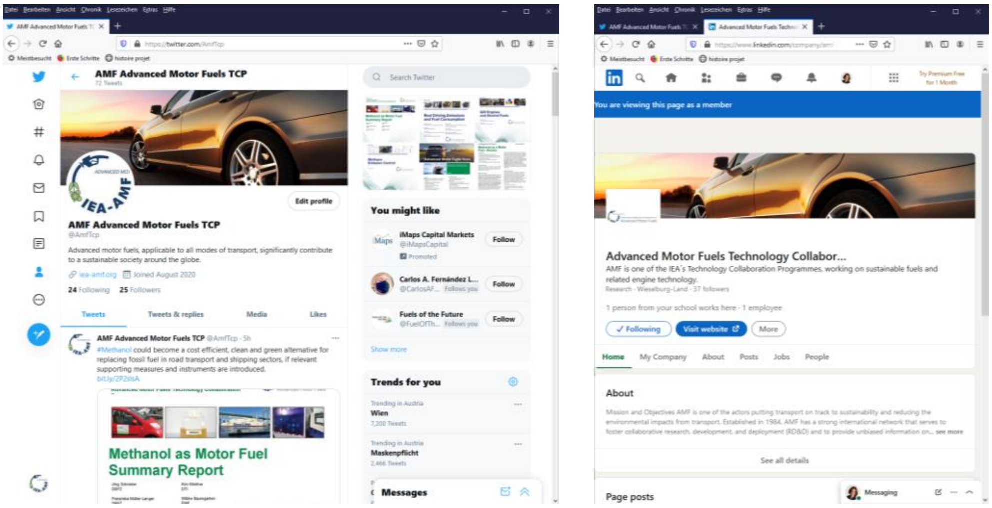


Fig. 1. AMF on Twitter and LinkedIn

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 projects (annexes), and information on fuels and their use in vehicles.

- Delegates to the AMF Executive Committee and Operating Agents of AMF annexes are listed on the website with full contact details and portraits.
- AMF projects 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 or by identifying a relevant project (annex) and checking the related report. Knowledge gained through AMF projects 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 annex reports and annex key messages, and also promote the AMF newsletter.

Publications

In 2020, three electronic newsletters were published on the AMF TCP website.

The Alternative Fuels Information System is available on the AMF TCP website. New sections on ammonia and hydrogen have been posted and one section on GHG emissions is under review. The AMF TCP website is updated frequently with information from annexes and Executive Committee meetings.

Annex 56: Methanol as Motor Fuel

Project Duration	November 2018 – June 2020
Participants **Task sharing** **Cost sharing** **Sponsor**	 Denmark, Finland, Germany, Israel, and Sweden Swedish Transport Administration | Trafikverket, Sweden Methanol Institute, USA | Belgium
Total Budget	€ 277,000 ($335,000 US)
Operating Agents	Gideon Goldwine Technion Email: gidi.goldwine@gmail.com Päivi Aakko-Saksa VTT – The Technical Research Centre of Finland (co-sharing) Email: paivi.aakko-saksa@vtt.fi Wibke Baumgarten FNR – Agency for Renewable Resources (co-sharing) Email: w.baumgarten@fnr.de
Website	https://www.iea-amf.org/content/projects/map_projects/56

Purpose, Objectives and Key Question

The purpose of this annex was to explore the potential of methanol to act as motor fuel and to meet global challenges on economy, energy security and climate change. Possibilities to produce methanol economically today create markets for tomorrow's renewable methanol produced using renewable sources. Different transport sectors were covered, including light-duty and heavy-duty road vehicles, as well as ships. In transport, also in the marine sector, there are ambitious current and anticipated regulations on greenhouse gases (GHG) and other emissions. The annex identified barriers for commercialization of methanol with suggestions to overcome these barriers.

Activities

Annex 56 was finalized with a joint Methanol Institute-AMF online seminar on October 26, 2020, and was formally closed on November 5, 2020 on the occasion of the ExCo 60 (held virtually due to COVID-19 pandemic). Activities were divided in four work packages (WP). In addition, reporting was handled as a separate task. The following work packages were implemented:

WP1 General issues on methanol as motor fuel, FNR supported by DBFZ, Germany

- Needs for methanol use in participating countries
- Production of methanol from fossil and renewable sources
- General aspects of methanol/biomethanol as motor fuel, including fuel properties
- Synthesis of the sector-dependent reports
- Analysis on barriers for methanol entering the fuel market earlier
- GHG aspects of methanol/biomethanol
- Cost evaluations

WP2 Sector-dependent evaluations

- Light-duty sector, DTI, Denmark. The fuels to be considered include M15, M56, M85, M100, MTBE, and GEM fuels.
- Heavy-duty sector, FNR supported by DBFZ, Germany. The fuels to be considered include MD95 and M100.
- Ships, VTT, Finland. The fuels to be considered include diesel/methanol dual fuel and other ship engine developments.

WP2 handled sector-dependent issues on methanol. For example, the review of the heavy-duty sector includes aspects according to infrastructure, material compatibility, and exhaust emissions. Cost of operation and methanol R&D projects in the participating countries are handled individually. Assessment was made in comparison to conventional fuels, mainly diesel.

WP3 Future high-efficiency engine for methanol, Lund University, Sweden

- Fundamental combustion research to achieve high efficiency methanol engines, next generation engines for alcohols

WP4 Barriers to commercialization, DTI, Denmark

- Special contribution in this work was prepared by Nordic Green, Denmark

Reporting

The final summary report and key messages were compiled by DBFZ, Germany and VTT, Finland with support of all other Annex 56 partners. The report consists of a short summary of all WPs, and the individual task share contributions, which are added as appendices.

Key Findings

- Methanol is a multipurpose fuel as it could be used straight or as blending component in fuels, for the production of fuel additives or for fuel cell application.
- Several concepts for internal combustion engines (ICEs) are available for using methanol in passenger cars, light-duty and heavy-duty engines as well as in ships.
- Straight methanol burns with very low particle and NO_X emissions in refitted engines. A further reduction of pollutants could be expected for future high efficiency combustion engines.
- Methanol could significantly increase the engine efficiency in dedicated engines. Therefore, additional research and development is needed to realize this potential – also from an OEM perspective.
- The existing fuel infrastructure requires no adjustments for low level methanol blends. For higher methanol blends and straight methanol, the adjustments of the existing fuel infrastructure are well known. With regard to material compatibility and safety, methanol has to be handled appropriately (e.g., by manufacturers) depending on the foreseen purpose and transport mode.
- In order to support GHG mitigation in transport, production capacity of sustainable renewable methanol has to increase from the current level of less than 1 million tons per year to cover a part of the transport sector. Today, methanol is mainly produced from fossil resources at the global production capacity of about 125 million tons.
- Production costs and GHG reduction potentials of renewable methanol produced on an industrial scale can be competitive to established renewable fuels, if using suitable resources like waste wood and cultivated wood.
- Supporting elements on strategic, regulatory, technical and communicative level are of overarching importance similar to any alternative fuel in transport.

Main Conclusions

Methanol as motor fuel was demonstrated in large vehicle fleets during the 1980s and ’90s. Despite technical success, methanol was not a commercial success. Recently, there is again increasing interest in methanol as fuel. Prominent examples are China, the largest user of methanol for automotive fuel, and Europe, where methanol is being considered as marine fuel or as energy for fuel cell electric vehicles. Internal combustion engines using methanol as fuel could be further developed for high efficiency to gain maximum energy and pollutant savings. However, if methanol will be applied as automotive fuel with higher blending rates or as pure fuel, technical adjustments of the existing fuel infrastructure are required (e.g., modifications of some fuel-carrying materials and safety measures).

Publications

The final summary report, corresponding appendices and key messages are available on https://iea-amf.org/content/projects/map_projects/56.

Annex 57: Heavy Duty Vehicle Performance Evaluation

Project Duration	October 2018 – May 2021
Participants **Task sharing** **Cost sharing**	 Canada, Chile, Finland, Japan, Republic of Korea, Sweden Japan and Sweden None
Total Budget	~€610,000 (~$671,000 US)
Operating Agent	Petri Söderena VTT – The 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 (HD) vehicles, thus generating information that can be used by transport companies, those procuring transport services and those forming transport policy. The project will encompass newest diesel technologies on different markets, but also alternative fueled vehicles and advanced powertrain configurations tested on a chassis dynamometer and on-road.

The proposed overall activity will cover three time dimensions:

- Legacy vehicles and a reference backwards through completed AMF Annexes
- Current performance of the best-available-technology HD vehicles (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 modelling by the AMF TCP for estimating the effects of alternative vehicle and powertrain configurations
- Cooperation with Hybrid Electric Vehicle (HEV) TCP brings insight to how different HDV powertrain and fuel (fossil and renewable) options perform against the CO_2 emission regulations of 2025 and 2030.

Activities

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 Chile test program included three Euro V diesel trucks in weight category under 10 tons (GVW), 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 the 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 will begin in Korea. Vehicle manufacturers have to 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 tailpipe 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 between HES results and the chassis dynamometer test results is about 5%. Correlation analysis between HES and VECTO for 21 cases of vehicle data was performed. 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.

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 for electrification for new trucks entering the market. This type of legislation will have an impact on the possibility to use sustainable produced fuels in the future.

In terms of energy consumption, 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 to or slightly lower than 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 truck not equipped with particulate filters, PN emissions can be substantially higher than in the diesel truck.

Regarding energy consumption and 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 Annex 57 demonstrated that increasing GVWR from some 60 up 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.

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

Schedule

Annex 57 will be reported in IEA-AMF Executive Committee meeting 61 in May 2021. Details will be available on https://iea-amf.org/content/projects/map_projects/57.

Annex 58: Transport Decarbonization

Project Duration	January 01, 2019 – December 31, 2020
Participants **Task Sharing** **Cost Sharing**	 China, Finland, Germany, Japan, Sweden, USA; AMF Annex 28, AMF Annex 59; Brazil, through IEA Bioenergy TCP European Commission
Total Budget	~€150,230 (~$165,000 US)
Operating Agent	Eric Fee and Kyriakos Maniatis European Commission Email: eric.fee@ec.europa.eu
Project Leader	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 aim 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**
  Annex 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 Annex 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. While 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.

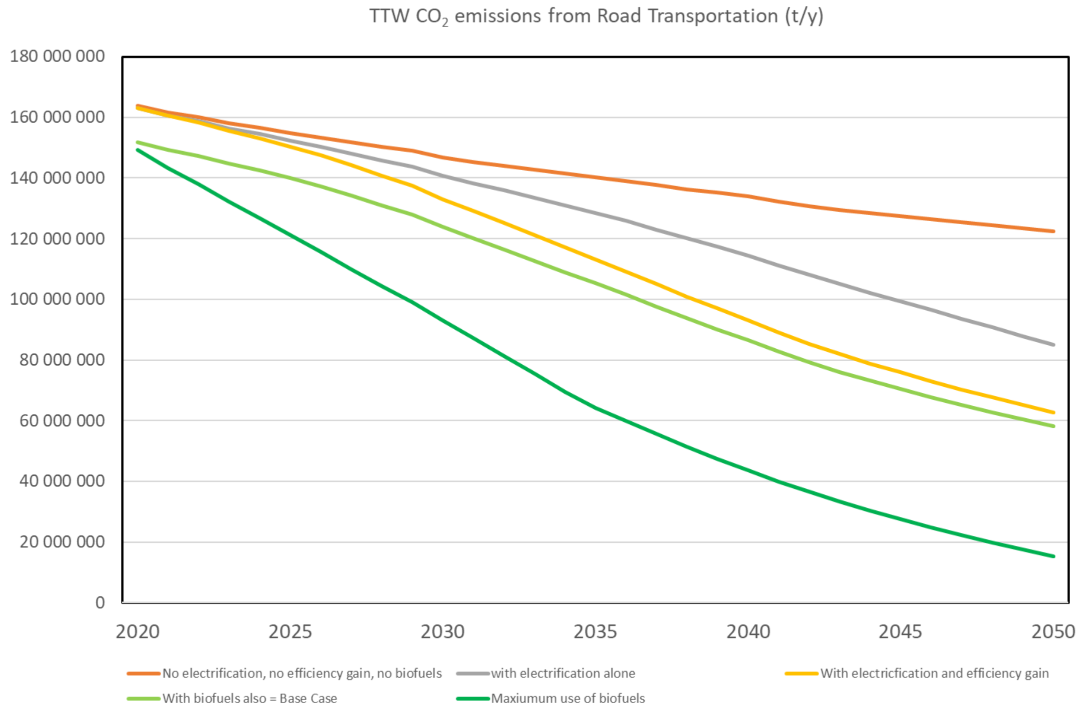


Fig. 1. Scenarios of CO_2 Emissions from Road Transportation for Germany

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, 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.

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.

Annex 59: Lessons Learned from Alternative Fuels Experience

Project Duration	April 2019 – December 2020
Participants **Task sharing** **Cost sharing**	 Austria, China, Finland, Japan (LEVO), Sweden, United States None
Total Budget	~€ 151,500 (~$184,000 US)
Operating Agent	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 goals 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 an annex on lessons learned from market launch attempts.

The 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

To answer these questions, Annex 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.

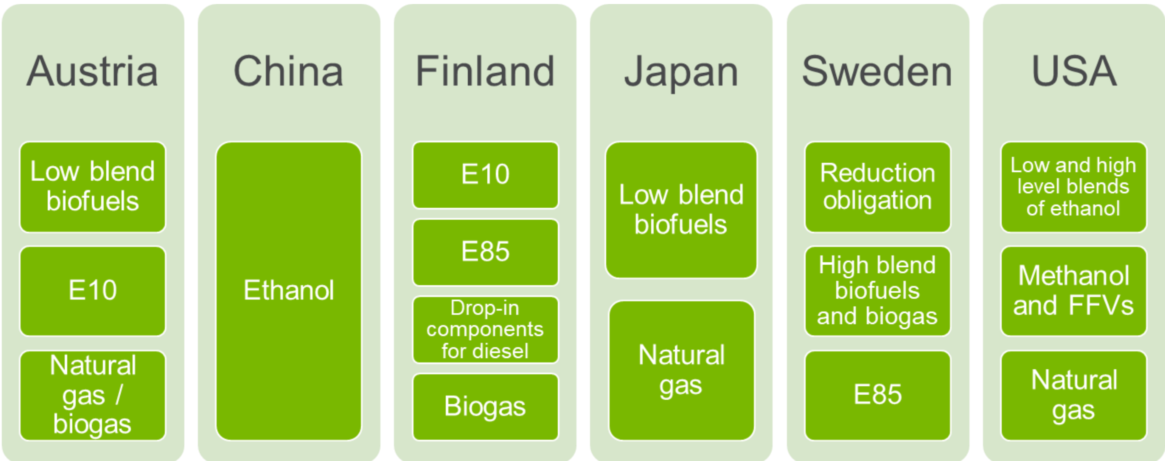


Fig. 1. Overview of the defined specific case studies

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, relevant stakeholders were interviewed 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 annex.

The findings from different cases in the participating countries were presented in an expert workshop and results were discussed with experts inside the AMF TCP as well as with external experts. The lessons learned and recommendations derived from our project were discussed with the workshop participants to verify the findings. Based on the results and discussions of the expert workshop, the annex determined the final lessons learned and recommendations, as well as policy briefs and key messages.

Key Findings

The key findings within this project can be divided into three important pillars for a successful market introduction of alternative fuels:

Policy

Policy is a very important instrument for transitioning the future transport system. A constant political driver is necessary to overcome the peak of implementation barriers. There is the need for long-term policies with a comprehensive strategy. This includes a package of measures with financial and non-financial incentives. Another policy aspect is the coordination of government, academia, and industry within the implementation process.

Inclusion

The involvement of all groups of stakeholders along the value chain is necessary. The different groups of stakeholders include automotive industry, motor fuels industry, fuel and vehicle marketers, customers, government and advocates. The perception of the general public on alternative or new fuels is often very bad and needs to be improved. Larger markets — or even the international market — need to be included. This is particularly important for small countries with low domestic biofuel production. Inclusion also means that the future transport system should be built up by a broad mix of alternative systems and fuels. All technologies are needed for the transition.

Benefits

Policy and inclusion should lead to benefits. It is essential that there are visible benefits or even cost benefits for all groups of stakeholders to make the alternative fuel or propulsion system attractive. At the moment, alternative fuels are not price competitive with fossil fuels because the costs do not include all points, there are no costs for GHG emissions or other climate relevant effects.

Main Conclusions

For the successful implementation of alternative fuels and vehicles in the transport system there is the need for long-term and comprehensive policies which include markets, stakeholders and different technologies to gain benefits for all types of stakeholders along the value chain.

Publications

Andrea Sonnleitner, "Lessons Learned from Alternative Fuels Experience," Presentation at the CEBC Central European Biomass Conference, Jan. 24, 2020, Graz, Austria.

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

- Lessons Learned from the Austrian Case Studies - Andrea Sonnleitner, BEST Bioenergy and Sustainable Technologies
- Lessons Learned from the Chinese Case Study - Ye Wu, Tsinghua University
- Lessons Learned from the Finnish Case Studies - Nils-Olof Nylund, VTT Technical Research Centre of Finland

Lessons Learned from the Japanese Case Studies - Masayuki Kobayashi, Organization for the Promotion of Low Emission Vehicles (LEVO)
Lessons Learned from the Swedish Case Studies - Magnus Lindgren, Swedish Transport Administration
Lessons Learned from the U.S. Case Studies - Michael Wang, Argonne National Laboratory

AMF Annex 59 Lessons learned on alternative fuels experiences – End Report (2021, in preparation), will be available on https://www.iea-amf.org/content/projects/map_projects/59.

Annex 60: The Progress of Advanced Marine Fuels

Project Duration	November 7, 2019 – November 7, 2022
Participants **Task sharing** **Cost sharing**	 Canada, China, Denmark, Finland, Korea, Sweden, Switzerland, USA Methanol Institute, USA | Belgium
Total Budget	€ 1,795,000 ($2,161,000 US)
Operating Agent	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 annex report on marine fuels (Annex 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.

Key Question: How can the new forms of advanced marine fuels contribute to carbon neutral shipping in the future?

Activities

The activities are distributed per country to reflect a broad range of technologies.

- Canada: Low Sulphur marine diesel fuel, engines and scrubber technology
- China: Methanol for fishing vessels and watercraft
- Denmark: Methanol flex-fuel, Ammonia for CI, DPF and SCR for coastal shipping
- Finland: Methanol and LBG
- Korea: LNG/LPG mixture technology, ammonia for small SI-engines
- Switzerland: Dual fuel for 2-stroke, methane-mixtures (e.g., with H_2)
- Sweden: Fuels for smaller marine engines on inland waterways
- USA: LNG and other alternative fuels

Two virtual meetings were held during 2020.

Key Findings

Some results are summarized below.

Finland

Finland performed fuel efficiency modelling in the advance fuel project (EU) http://advancefuel.aalto.fi/. Finland also studied HP direct injection of methanol in dual fuel (DF) engine, ethane and hydrogen enrichment of methane and straight methanol with ignition improver. Finland applied internal EGR for ignition improvement in methanol diesel engine with good results.

Canada

Canada is currently conducting a literature search focusing on black carbon and particulate matter emission factors used in marine emission inventories. Additional aspects that will be investigated include: different types of marine fuels (heavy fuel oil, marine diesel oil and very low-sulfur fuel oil), operating conditions, type of marine engine used (2-stroke, 4-stroke) and emission control technologies (i.e. scrubbers).

Denmark
Denmark ran a unit injector flex fuel concept with diesel and methanol mix at standard compression ratio 1:16.

China
China is focused on work on several levels: commercial vessel; barges handled by ministry of transportation; fishing boats handled by ministry of agriculture; methanol bunkering special issue due to low FP; looking into different vessels sizes; harbor crafts; pilot trials commencing in 2021, and transportation of methanol from the northwest to coastal regions versus importing methanol. China also has two marine engines type: high speed 200-400 kW for 1,000 tDW, and medium speed up to 1 MW for 10,000 tDW. China has no low-speed engine, no 2-strokes, and no solid work on glow plugs. China uses DMCC concept (port injected methanol) for smaller marine vessels. The first fishing vessel was put in service in December 2018. The first container barge went in service May 2019. Diesel replacement is 30-40%. Geely has methanol engines for cars and trucks, with 20,000 vehicles running. DMCC runs in 160 heavy vehicles, mine trucks, loaders, and locomotives. NO_x-soot tradeoff is significantly improved. No SCR is needed. Material compatibility is ensured by anti-corrosion treatment of components.

Korea
Korea (KSEO) built a NG/PG mixture supply equipment for engine test, and the test will be started at the end of 2020 on 1.5 MW 4-stroke medium speed engine. An investigation of NG/PG mixture combustion characteristics and performance will be conducted compared with conventional DF engine (NG). At KIER, ammonia fuel was investigated to replace gasoline through the conversion of a conventional gasoline engine with ammonia fuel system. Though the flame speed of ammonia is five times lower than gasoline, the ammonia-gasoline dual fuel shows enhanced combustion characteristics because gasoline acts as a combustion promoter and brings about faster combustion of all the cylinder charge. For this study, an ammonia-gasoline dual fuel system was constructed, and a programmable engine controller was also developed to make both ammonia and gasoline injected separately into the intake manifold in liquid phases. As a result, ammonia was used as the main fuel to replace 70% of gasoline and the same amount of carbon emission, such as CO_2, CO, and THC, reduced emissions in the engine.

Switzerland
Switzerland was initially delayed but is still on track. Two-strokes are in focus. A review will be delivered later. Switzerland is investigating the fundamentals of gas mixtures combustion. Optical and laser-optical techniques are used. There is good synergy with the work of Aalto Finland.

Sweden
Sweden used a consultant to investigate small marine engines for inland waterways and coastal shipping. Results on system review are expected by February 2021.

United States
USA will present a status update in Q3 of 2021.

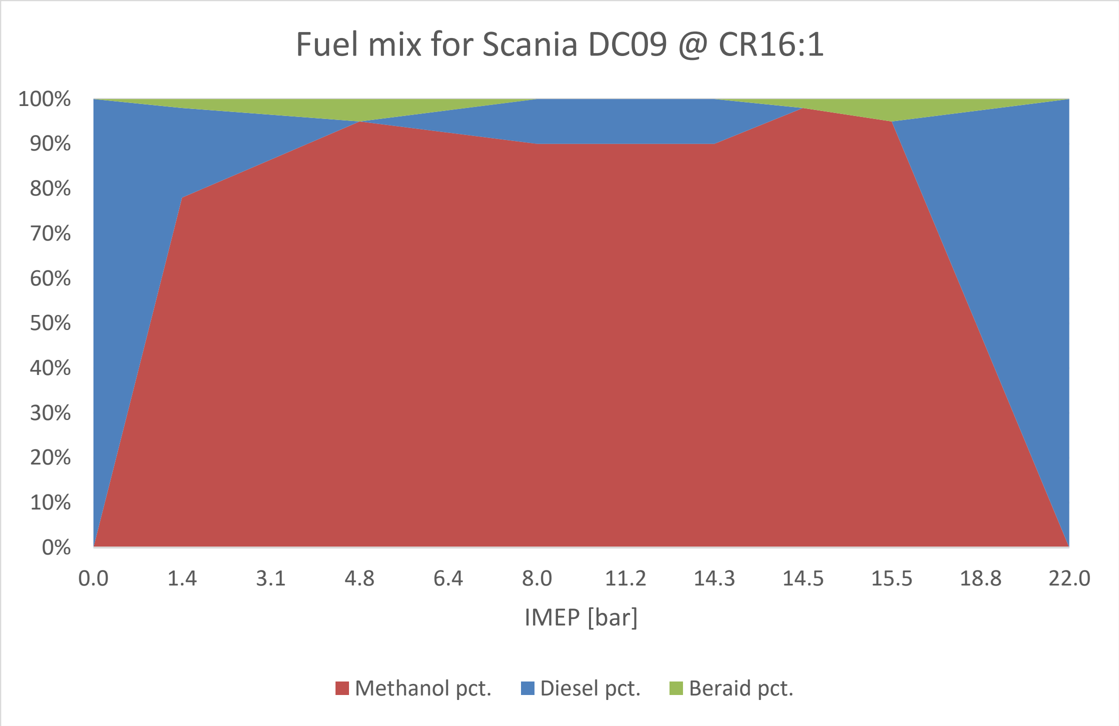


Fig. 8. Mixtures of methanol, diesel and additives are usable as fuel for standard marine engines if preheated combustion air is supplied (Result from Denmark).

Publications

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

Annex 61: Remote Emission Sensing

Project Duration	May 2020 – October 2023
Participants **Task sharing** **Cost sharing**	 China, Denmark, Finland, Sweden, Switzerland No cost sharing
Total Budget	€ 210,000 ($254,000 US)
Operating Agent	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 annex 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, China and the US, as well as new datasets from upcoming RES measurement campaigns until early 2023.

The general outcome of the annex 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

The project consists of five work packages:

WP 1: Collection and consolidation of existing data

The data to be collected and consolidated will comprise both RES data and relevant data from legislative and RDE tests (chassis dynamometer and PEMS). The collection and consolidation of data will occur in two steps:

- Collection and consolidation of existing data at project start.
- Collection and consolidation of additional data roughly six months before the end of the project.

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

- Comparison between different RES technologies.
- Comparison of RES technologies with PEMS and chassis dynamometer approaches to measure real drive emissions.
- Development and application of simulation tools for the flow and species dispersion of the exhaust plume in vehicle wakes to analyze the effects of different parameters (measurement, vehicle, climatic conditions).

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

This work package pinpoints vehicle owner/driver-imposed impacts on their vehicle's emission performance, such as tampering (use of AdBlue emulators, removal of DPFs, etc.), poor maintenance or very harsh driving. The analysis underpinning the evaluation and proposal will be carried out separately for three groups of vehicle categories:

- Light-duty vehicles (passenger cars and light commercial vehicles)
- Heavy-duty vehicles (trucks and buses)
- Two-wheelers

Links will be made to periodical technical inspections (PTI) and roadside inspections.

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

This work package pinpoints the ability of different vehicle manufacturers to design vehicles (engines and exhaust after-treatment systems) that are compliant and durable in regards to real-world emission performance. As for WP 3, the analysis underpinning the evaluation and proposal will be carried out separately for three groups of vehicle categories:

- Light-duty vehicles (passenger cars and light commercial vehicles)
- Heavy-duty vehicles (trucks and buses)
- Two-wheelers

Links will be made to in-use compliance testing programs. In addition, the use of RES for improving performance and accuracy of road transport emission models and inventory systems, such as HBEFA and COPERT, will be evaluated.

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

This work package includes administrative coordination, communication with the IEA AMF, synthesis of the data, compilation of the final report and dissemination of the results.

Key Findings

- **Application of RES Type 1 for identifying NO_X high- and low-emitting early Euro 6 (6a and 6b) light-duty diesel vehicles**
  Repeat RES Type 1 measurements and, to some extent, even single measurements appear to be useful for identifying NO_X high-emitting early Euro 6 light-duty diesel vehicles in real-world traffic. This is especially true of the worst polluting vehicles, namely those with RDE emissions exceeding 0.5 g/km up to 1.5 g/km (5-10 times the Euro 6 NEDC limit). Ten percent of the most high-emitting early Euro 6 diesel light-duty vehicles was estimated to account for 30% of the overall NO_X emissions from the early Euro 6 diesel LDV fleet in Sweden in 2018. A few engine families were clearly over-represented among the high-emitting early Euro 6 diesel LDVs.

- **Evaluation of RES Type 3 (plume chasing) against PEMS (onboard) emission measurements**
  The comparative tests of heavy-duty vehicles by using concurrent RES Type 3 and PEMS were conducted on a well-controlled track (four vehicles) and real-world highways (12 vehicles). These tested vehicles complied with China III to China VI standards (equivalent to Euro III to Euro VI). The results indicate good agreement of NO_x emission factors between plume chasing and PEMS. For example, the track tests derived an overall R^2 of 0.97 and an average discrepancy of -8% (chasing vs. PEMS; see Fig. 1). The real-world highway tests also had all chased emission factors ranging approximately within ±20% of the corresponding PEMS results. Of note, these comparative tests also validated the reliability of plume chasing for measuring NO_x emissions for older (e.g., China III without SCR) to modern (e.g., China VI) generations of HDVs.

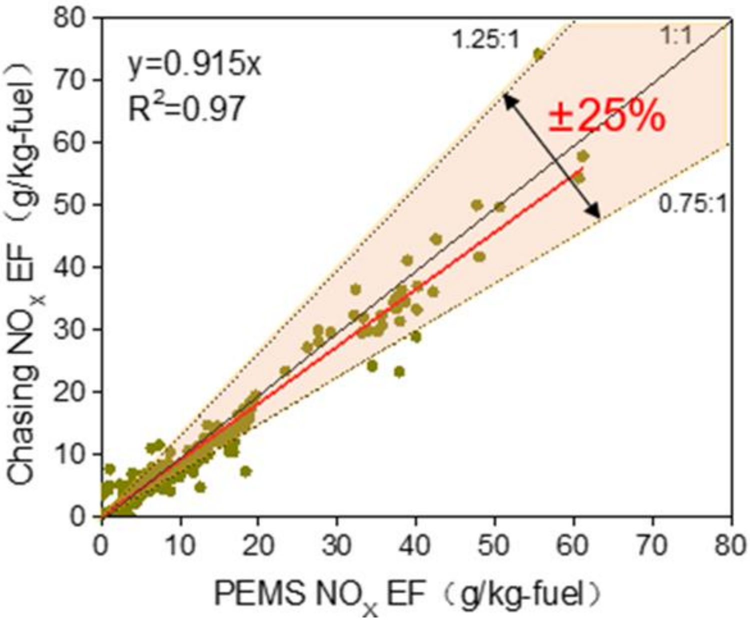


Fig. 1. The comparative tests of NO_x emissions between RES Type 3 and PEMS (four vehicles, 360 chasing events in total).

- **Development and application of simulation tools for the flow and species dispersion of the exhaust plume**
  It is sufficient if air and one pollutant component are simulated, since turbulent diffusion is dominant. A hybrid model of RANS (Reynolds Averaged Navier Stokes equations) for the flow around the vehicle and LES (Large Eddy Simulation) for the wake flow is under development in order to achieve a good trade-off between computational time and accuracy with regard to the simulation of species dispersion.

Main Conclusions

The project is still at a very early stage, since it was launched in fall 2020, but we can conclude:

- EU, Chinese and Swiss institutions have noted the importance of RES technologies in deriving real-world emissions and potentially identifying high-emitters. Governmental funding has been utilized to improve and apply these technologies.
- The preliminary results have shown some promising comparison results between RES technologies and regulatory instruments (e.g., PEMS).

Publications

- H. Wang, Y. Wu, S. Zhang, et al. (2020) Evaluating mobile monitoring of on-road emission factors by comparing concurrent PEMS measurements. *Sc. Tot. Env.*, 736, 139507. https://www.sciencedirect.com/science/article/abs/pii/S0048969720330242
- 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 the GHG in 2019. Passenger and freight kilometers increase continuously, which is the main reason why GHG emissions in transport have seen an increase of 75% since 1990. Due to reduced economic activities and lock-down restrictions applied as a result of the COVID-19 virus, a significant drop in GHG emissions is expected for 2020. First assumptions point to a reduction of more than -17% as the consumption of diesel and gasoline dropped by 17% and 20%, respectively, according to a market assessment by the Association of the Mineral Oil Industry (FVMI). However, a change of the long-term tendency cannot be derived from the pandemic year.

Politics – Recent activities and developments

Austria is committed to carbon neutrality by 2040. This requires substantially increased decarbonization efforts across all energy sectors. Especially in the transport sector, a radical turnaround is needed to contribute to the political goal. Austria, therefore, plans a number of incentives such as a newly designed taxation system, which shall put a price on ecologically destructive activities. The new taxation system is planned to be presented in 2022. In addition, in the same year, an obligatory procurement of zero-emission vehicles by the public sector will take effect. Already put in place for 2021 are an increased NoVA tax and the "Right to Plug," which alleviates previously complicated legal approval hurdles for the installation of charging stations for flat owners at their vehicle parking space in a multi-party building.

National strategies in the area of transport, such as the Mobility Master Plan and the corresponding RDI Mobility strategy plan, and in the area of energy, such as the Hydrogen Strategy Plan, will be published in 2021. However, 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 yet. It is expected to be included in an updated Austrian NECP as the ambitious European Green Deal targets ask for a revision of the document in the near future.

Austrian Integrated National Energy and Climate Plan (NECP)

The integrated National Energy and Climate Plan (NECP) is a new 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, a bonus/penalty system for CO_2 emissions 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 80 € 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, the total fleet of motor vehicles registered in Austria amounted to about 7.1 million, which is, 1.5% more than in 2019. Passenger cars, the most important type of vehicle with a share of 71.7%, showed an increase by 1.0% to 5.1 million vehicles and crossed the 5 million mark for the second time in history. (See Table 1.)

Table 1. Austrian Fleet Distribution of Passenger Vehicles by Drivetrain, 2015–2020

Drivetrain	2015	2016	2017	2018	2019	2020
Gasoline	2,012,885	2,031,816	2,074,442	2,133,473	2,173,772	2,190,388
Diesel	2,702,922	2,749,038	2,770,470	2,776,333	2,772,854	2,762,273
Electric	5,032	9,071	14,618	20,831	29,523	44,507
LPG	1	1	2	2	2	2
CNG	2,475	2,456	2,433	2,365	2,602	2,753
H2	6	13	19	24	41	45
Bivalent gasoline/ ethanol (E85)	6,254	6,165	5,992	5,769	5,770	5,190
Bivalent gasoline/ LPG	311	341	335	333	330	330
Bivalent gasoline/ CNG	2,300	2,574	2,773	3,177	3,143	2,978
Hybrid gasoline/ electric	14,785	18,696	26,039	34,086	45,645	68,983
Hybrid diesel/ electric	1,077	1,337	1,455	2,463	6,172	14,378
Total	4,748,048	4,821,508	4,898,578	4,978,856	5,039,854	5,091,827

Source: Statistik Austria

Registrations of new passenger cars fell to 248,740, which is well below the 20-year average (313,297). This resulted in the highest year-on-year decline ever observed (2019: 329,363). In contrast to the overall decline, alternatively powered passenger cars – electric, natural gas, bivalent drive, combined drive (petrol or diesel hybrid) and hydrogen (fuel cell) – increased both in absolute and in relative terms (2020: 20.1% share with 50,060 vehicles; 2019: 8.0% share with 26,346 vehicles), thus boosting the trend toward advanced alternative propulsion systems (Fig. 1).

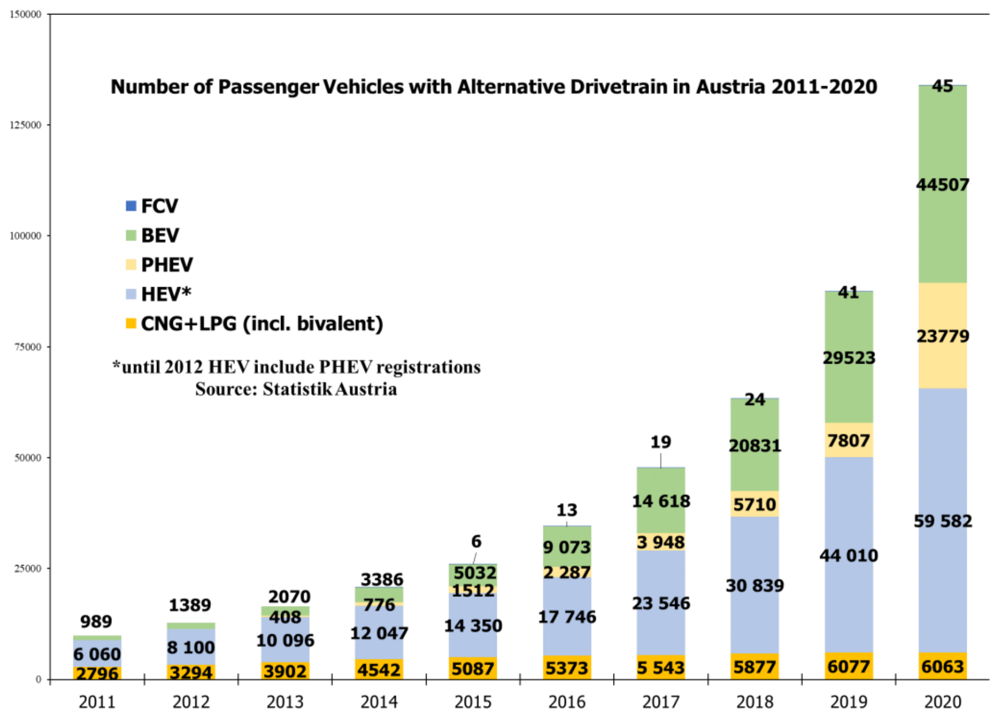


Fig. 1. Trends for vehicles with alternative drivetrains in Austria, 2011-2020
Source: Statistik Austria

Especially for battery electric vehicles (BEVs) and plug-in hybrid electric vehicle (PHEVs), the trend is evident. With registration numbers of 44,507 and 23,779, respectively, the growth follows an exponential trajectory. The number of vehicles driven by CNG and LPG, including bivalent ones, shows a stable linear increase to 6,063. With 45 vehicles, the fuel cell electric vehicle (FCV) fleet is still negligible.

Average CO_2 Emission of Passenger Cars

The Worldwide Harmonised Light Vehicles Test Procedure (WLTP) replaced the New European Driving Cycle (NEDC) framework. Therefore, a detailed analysis of the CO_2 emissions development of the newly registered passenger cars fleet is not carried out, but the NEDC values are stated in brackets. In 2020, CO_2 emissions for newly registered passenger cars, including BEVs, HEVs and FCVs, documented an average of 136 g/km (126 g/km). For gasoline-powered passenger cars, the value is 143 g/km (128 g/km). The reported CO_2 emissions for diesel cars are 156 g/km (133 g/km).

Development of Filling Stations

By the end of 2019, Austria had 2,733 publicly accessible filling stations. As an annual average for 2020, the price of gasoline for private use at a filling station was €1.088 ($1.33 US) and the correlating price of diesel was €1,045 ($1.28 US) per liter. With 149 public CNG stations in 2020, the number of public CNG filling stations has slightly decreased in recent years (2019: 152). For LPG, 37 filling stations are available (2019: 42). In addition, two public LNG filling stations in Ennshafen (Upper Austria) and Feldkirchen (Styria) 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) plans to invest up to €120 million ($146 million US) 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.

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 2014, 4,900 climate friendly mobility projects have been funded. Financial support for about 12,000 alternative vehicles has been provided. The klimaaktiv mobil website offers a map with details of each project. Total financial support amounted to €67 million ($82 million US) until the end of 2020.

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 TCP under the umbrella of the IEA.

Mobility of the Future Program

The research program, Mobilität der Zukunft (Mobility of the Future), is an Austrian national transportation research and development funding program for the period 2012–2021. The program covers four complementary thematic fields: Personal Mobility, Mobility of Goods, Vehicle Technology, and Transport Infrastructure. The annual budget of Mobility of the Future is between €13 million and €19 million ($15 million and $24 million US). A project database is available online.

ERA-NET Bioenergy

In the European Research Area (ERA-NET) Bioenergy, Austria cooperates with Germany, The Netherlands, Poland, Sweden, Switzerland, and the United Kingdom in funding transnational bioenergy research and innovation projects. Austria's contribution to the recent 14th ERA-NET Bioenergy Joint Call amounts to €0.8 million ($1.0 million US).

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. A stronger focus towards biofuels and synthetic fuels in funding programs is in place.

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 fundings, schemes are not directed at improving ICE drivetrains any more. For other use cases, such as heavy duty road transport, aviation or waterborne applications, RDI funding for alternative fuels is being provided.

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 liquid fossil fuels 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: actions that reduce the CI of the fossil fuel throughout its lifecycle, supplying low-carbon fuels, and specified end-use fuel switching in transportation. Parties that complete these actions (e.g., low-carbon fuel producers and importers) can participate in the credit market as voluntary credit creators. It is estimated that the proposed regulations would result in a reduction of up to 20.6 Mt of GHG emissions in 2030.

Renewable Fuels Regulations (RFRs)[1]

The 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.

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[2]

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 (GHG) 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 published. Under these regulations, *Passenger Car and Light Truck GHG Emission Regulations*, the average GHG emissions performance of all new passenger automobiles improved from 255 g/mile in the 2011 model year to 206 g/mile in the 2018 model year, a 19.2% reduction in GHG emissions per vehicle. Canada is currently undertaking a mid-term evaluation of the appropriateness of its standards for model years 2022 to 2025, and intends to publish a final decision document on the findings of this review in early 2021. Any changes or improvements required to the regulations in the near term will be determined by the results of this mid-term evaluation.

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.

[1] https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=103l

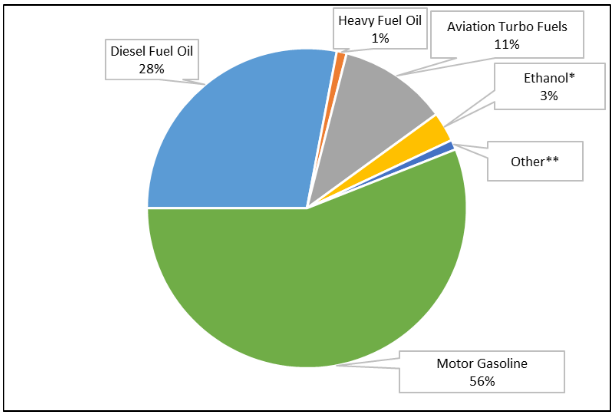
[2] http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html

Future amendments required to both of these regulations will be in line with Canada's strengthened climate plan, "A Healthy Environment and a Healthy Economy," which contains new measures for the transportation sector described in the "Clean Transportation" Annex. This includes further improving the efficiency of light-duty and heavy-duty vehicle standards for post-2025 by aligning with the most stringent standards in North America – whether at the United States federal or state level.

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[3]

Figure 1 shows energy use by fuel type in 2017 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 2017

Table 2. Canadian Supply and Demand of Biofuels in 2018 (in millions of liters)

Parameter	Ethanol	Biodiesel
Canadian production	1,900	400
Imports	1,232	548
Exports	0	301
Domestic use	3,132	647

[3] https://www.nrcan.gc.ca/sites/nrcan/files/energy/energy_fact/energy-factbook-2020-2021-English.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. As of December 2020, approved projects will result in 1,108 electric vehicle fast chargers, 22 natural gas and 15 hydrogen refueling stations, meeting or exceeding all program targets. 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 US 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.

Vehicle Propulsion Technologies (VPT) Program

The National Research Council Canada's VPT program assists Canadian automotive manufacturers to improve the efficiency of internal combustion engines, powertrains, and the use of electric and fuel cell propulsion.

Clean Growth Program (CGP)

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

Breakthrough Energy Solutions Canada (BESC)

The BESC program supports Canadian start-ups to advance clean energy technologies, which could significantly reduce global GHGs, by targeting four areas: manufacturing, electricity, transportation, and buildings. The program was developed in partnership with Breakthrough Energy as well as Business Development Bank of Canada (BDC) to increase the impact of NRCan investment and to give the winners the opportunity to access additional funding and receive valuable insight from private investors.

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.

Incentives for Zero Emissions Vehicles Program

In 2019, Canada set federal ZEV sales targets of 10% of new LDVs by 2025, 30% by 2030, and 100% by 2040. Without any further action, it is projected that Canada could achieve zero-emissions vehicle sales of 4% to 6% of all new light-duty vehicles purchased by 2025, and 5% to 10% by 2030. However, 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 21 Mt between 2005 and 2030, while those for heavy-duty trucks and rail are projected to increase by 11 Mt.

Table 3. Transportation: GHG Emissions (Mt CO_2-eq)[4]

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.

[4] https://unfccc.int/sites/default/files/resource/br4_final_en.pdf

Chile

Drivers and Policies

Chile has acquired and ratified ambitious international commitments to mitigate greenhouse gas (GHG) emissions in the face of climate change. In the long-term horizon, Chile will seek a way that allows it to achieve carbon neutrality by 2050, as established in the draft framework Law on Climate Change that is under discussion in the National Congress. On the other hand, as a goal in the short term, Chile is set to reduce the intensity of emissions by 30% by 2030 compared to the levels observed in 2007.[5]

Chile has great potential for the development of clean energy. It has the highest solar radiation in the world and a coastline of more than 6,000 kilometers, which gives it an enormous advantage to develop non-conventional renewable energies (NCRE), solar, wind, geothermal and marine. In fact, NCRE already generate more than 20% of the electricity consumed in Chile.

To achieve the proposed goals, a multisector effort will be required in the application of policies and measures that allow the effective and permanent reduction of Chile’s GHG emissions over time, with the transport sector being a relevant one in this area. In Chile, 36% of the final energy consumption corresponds to the transport sector and, of this fraction, 99% corresponds to oil derivatives, making it responsible for about 24% of the total emissions of GHG effect of the country. In addition, there is an impact due to pollution caused by combustion engines in urban concentrations.

Given the importance of energy consumption in the transport sector and its environmental implications, Chile has implemented policies for fuels with low sulfur content, local pollutant emission regulations (applying strict European and American standards for light, medium and heavy vehicles), and the establishment of green taxes applied to light and medium gas and diesel vehicles. In 2012, the energy efficiency labeling program was established—initially for light passenger vehicles and some years later for medium vehicles—allowing the buyer to choose the vehicle with the best fuel economy.

Energy Efficiency Law

The Energy Efficiency law was passed in Congress and will be published in early 2021. In terms of the transport sector, the law focuses on improving the energy efficiency of Chile’s vehicle fleet and it mandates that the Ministry of Energy regulates the interoperability of the charging infrastructure for electric vehicles.

In terms of energy efficiency, the Ministries of Energy and Transport will establish standards for light, medium and heavy new motorized vehicles, in 12, 36 and 60 months, respectively. The metric that will be used to define these standards will be the energy efficiency in kilometers per liter of equivalent gasoline in average terms for the total of vehicles sold by each representative or importer of the brand.

Currently, the Ministry of Energy is evaluating three proposed curves to determine one of them as the alternative to apply a curve with energy efficiency standards for light vehicles.

Emissions Regulation

Euro 6 standard for light and medium vehicles

Chile will be the first South American country to require the Euro 6 emissions standard, which must be implemented 24 months after its publication on September 30, 2020. This means that vehicles will also have a particle filter that reduces particulate material with an efficiency of 99% and with a catalytic system that will reduce NO_x emissions by 56%.

It is important to note that the reduction of fine particulate matter is a fundamental measure to protect the Santiago population. According to the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), this type of emissions, generated by combustion engines, is associated with acute and chronic diseases, as well as different types of cancer, such as lung cancer and cardiovascular diseases, which is why it has been reclassified as a carcinogenic substance for humans.

[5] The Committee of Ministers of Sustainability and Climate Change, 2015.

This new stable regulation of gradual implementation establishes two phases of application: Euro 6b Standard at 24 months and Euro 6c at 48 months. The Euro 6c standard establishes more demanding vehicle measurement conditions through more demanding test cycles and, for their compliance, requires superior technology and 10 ppm fuel.

In addition, the Euro 6 engine reduces global emissions of pollutants (CO_2), due to its new technology that allows reducing fuel consumption and by lowering its emissions. It is estimated it will affect a 7% reduction in CO_2 emissions.

Improve Energy Efficiency by Promoting Electromobility

Electric buses
During 2020, there were important advances in the incorporation of electric buses to the public transport bus network of the metropolitan region. We have more than 800 electric buses that operate in the public transport of the Santiago bus fleet.

Although the investment in an electric bus is higher in the beginning, these costs are recovered in a few years. This is because the operational costs, both energy and maintenance, are lower. Operators in practice have found at least the following advantages of the electric bus compared to the diesel bus: lower supply cost, less air pollution, and less noise pollution.

Electric buses have more economical maintenance since they require verification of fewer components and, in the case of the brakes, these wear less because the electrical system helps to brake the vehicle.

Finally, the electric propulsion motor takes up less space and is more versatile than the usual motors of traditional buses. In this way, the space is better used and distributed, gaining in convenience and comfort.

Electric taxis
The Ministry of Energy is coordinating a program for the replacement of basic internal combustion engine taxis, for electric ones. This program was developed during 2020 and was launched in January 2021. This new program seeks to promote electromobility in public transport, specifically in the taxi segment.

Called "My Electric Taxi Program," this initiative is expected to benefit 50 taxi drivers in the Metropolitan Region. It provides co-financing of up to $10,900 to exchange a basic taxi for an electric one, to purchase and install a home electric charger and to monitor the electric vehicle purchased for one year.

The main idea is to remove barriers so that taxi drivers can access electric vehicles, mainly in terms of initial investment, knowledge of technology and load management.

A taxi that travels 80,000 kilometers spends around $5.471 (US) on gasoline. If the same taxi were electric, it would spend around $2.325 (US) on electricity. In addition, an electric vehicle has cheaper maintenance than conventional vehicles. Therefore, it is very convenient economically and environmentally.

Advanced Motor Fuels Statistics

Public Transport of Santiago Bid
The award was made by resolution of the Ministry of Transport and Telecommunications, which must be subsequently processed before the general controller of the Republic.

This new fleet of 2,030 buses is expected to be operational by the end of 2021. These buses will be added to the 2,220 standard Red buses that we currently have in operation, which will mean 62% of the buses fleet in the metropolitan area will be operational by the end of 2021, with a good standard of quality, safety and greater comfort.

A new offer is being made with a new design. In this offer, the bus supply is separate from the operation of the tracks. Among the main attributes and advantages that this tender provides to public transport are greater guarantees for buses and their components. Requirements and guarantees are established to have spare parts and local support. Overhaul or maintenance of the average life of buses and spare parts is required for: batteries, in the case of electric buses; internal and external security cameras; object proximity detection systems to avoid collisions; internal screens to display travel information, energy efficiency systems and driving quality. Safety requirements include training of drivers and maintenance personnel on the following topics: bus operation and components; security and emergency procedures; maintenance and energy efficiency. In addition, the new offer establishes computer and telemetry systems for better online control of the state of the buses.

Research and Demonstration Focus

Improve Energy Efficiency by Promoting Giro Limpio

Giro Limpio is a voluntary national program, administered by the Energy Sustainability Agency (Agencia SE), which seeks to certify and recognize the efforts made by freight transport companies in the field of sustainability and energy efficiency.

In addition, Giro Limpio certifies the cargo generating companies that prefer the certified Giro Limpio transporters, thus helping to reduce energy consumption and emissions of GHGs and other local pollutants that affect people’s health, and reducing the environmental impact of the various value chains in our country. Its main objectives are:

- improve the energy efficiency of the freight transport sector
- reduce fuel consumption
- reduce the costs of the freight transport sector, increasing its competitiveness, and
- reduce GHG emissions and other local pollutants that affect people’s health.

The Giro Limpio program currently has 13,500 trucks equivalent to 5% of the national fleet.

New Trucks Energy Efficiency Measurements

The objective is to obtain the fuel consumption in a sample of trucks in the fleet of vehicles that circulate in the cities and highways of the country, with the purpose of expanding the knowledge in the energy performance of trucks. Accumulating experience is necessary in order to address the standardization of the energy efficiency of these vehicles for the future in Chile.

The test procedure for Annex 57 was used as the basis for testing the trucks on the chassis dynamometer to ensure comparable results with other heavy vehicle labs’ performing measurements. It was only possible to measure fuel consumption (km/l) and particulate matter in three trucks at this stage, but in the future we hope to continue measuring different categories of trucks.

Outlook

Automotive Market

In Chile, there is no national vehicle manufacturing or assembly industry, so all vehicles sold in Chile are imported from different markets. In 2020, 258,835 units of light and medium vehicles of 60 different brands were marketed, with market shares that never exceeded the 15% barrier. The fact that there are no factories with large numbers of workers allows the regulations to the industry to be applied in shorter periods of time.

Additional Information Sources

Ministry of Transportation and Telecommunications: www.mtt.gob.cl
Ministry of Environment: www.mma.gob.cl
Ministry of Energy: www.energia.gob.cl
Vehicles Fuel Economy (Label): www.consumovehicular.cl
Type Approval or Certification: www.mtt.gov.cl/3cv
Sustainable Energy Agency: www.agenciase.org

China

Drivers and Policies

The Goal of Carbon Neutrality

On September 22, 2020, President Xi Jinping delivered an important speech at the general debate of the 75th United Nations General Assembly: The Paris Agreement represents the general direction of the global green and low-carbon transformation, and it is necessary to protect Earth. Countries must take a decisive step. China will increase its contribution, adopt more powerful policies and measures, strive to reach the peak of CO_2 emissions before 2030, and strive to achieve carbon neutrality before 2060.

The Development Plan for the New Energy Vehicle Industry (2021-2035)

In October 2020, the State Council issued the “Notice on Printing and Distributing the Development Plan for the New Energy Vehicle Industry (2021-2035),” which will adhere to the development direction of electrification, interconnection, and intelligence. China will further implement the national strategy for the development of new energy vehicles (new energy vehicles refer to battery electric vehicles, plug-in hybrid electric vehicles and fuel cell electric vehicles). A development vision was put forward: 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.

Technology Roadmap for Energy-Saving and New Energy Vehicles (2.0)

The “Technology Roadmap for Energy-Saving and New Energy Vehicles (2.0)” was issued in October 2020. It put forward goals for the development of China’s automobile industry in 2035. The carbon emissions of the automobile industry will peak ahead of the national carbon emission reduction commitments around 2028, and by 2035 the total carbon emissions will be reduced by more than 20% from the peak. The technology roadmap 2.0 further emphasizes the development strategy of pure electric drive. It is proposed that by 2035, the sales of new energy vehicles will account for more than 50% of the total automobile market, and the population of fuel cell electric vehicles will reach about 1 million.

China’s Energy Development in the New Era

In December 2020, the State Council issued the white book of “China’s Energy Development in the New Era” to promote energy conservation in the transportation field. Its plan is to improve the level of railway electrification, promote natural gas vehicles and ships, develop energy-saving and new energy vehicles, improve the charging and battery swap stations and the hydrogen refueling infrastructure, encourage ships and civil aviation aircraft calling at ports to use shore power during docking, build natural gas refueling stations, and accelerate the elimination of old, high-energy-consuming vehicles and ships.

The Notice on Adjusting Relevant Requirements for the Access of Methanol Automobile Products

In December 2020, the Ministry of Industry and Information Technology (MIIT) issued “The Notice on Adjusting the Relevant Requirements for the Access of Methanol Automobile Products.” The methanol automobile products meeting the requirements of related tests can apply for the products announcement in MIIT. This means that the market introduction of methanol automobiles is incorporated into the administration of MIIT and the full marketization of methanol automobiles is finally on the agenda.

In 2019, China issued guidance on the application of methanol vehicles in some regions, proposing to accelerate the improvement of methanol automobile industry policies and technical standards, promote the rational layout of the industry, accelerate the construction of the methanol automobile manufacturing system, and improve the market application. China will encourage and support enterprises to develop methanol automobile products, accelerate the industrial application of R&D achievements and continue to encourage the promotion and application of methanol automobiles in the four provinces of Shanxi, Shaanxi, Guizhou and Gansu.

Notice on Carrying out the Demonstration and Application of Fuel Cell Electric Vehicles
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 Carrying out the Demonstration and Application of Fuel Cell Electric Vehicles." The incentive fund will be provided to qualified demonstration city groups for the industrialization of key core technologies of fuel cell electric vehicles and demonstration applications in the form of awards instead of purchase subsidies.

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 26127-2010, "Compressed coalbed methane as vehicle fuel" was released on January 14, 2010, and implemented on December 1, 2009.
- 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 37178-2018, "Coal-based synthetic natural gas for vehicle" was released on December 28, 2018, and implemented on July 1, 2019.
- HJ1137-2020, "Measurement methods for non-regulated emissions from methanol fueled vehicles" was released on November 10, 2020, and implemented on the date of issue.

Advanced Motor Fuels Statistics

In 2020, 195 million tons of crude oil were produced in China, an increase of 1.6% year-on-year; 670 million tons of crude oil were processed, an increase of 3.0% year-on-year. Meanwhile, 540 million tons of crude oil were imported, an increase of 7.3% year-on-year.

Natural gas is one of the energy sources for vehicles in China. In 2020, China produced 188.8 billion cubic meters (m^3) of natural gas, an increase of 9.8% year-on-year. China imported 102 million tons of natural gas, an increase of 5.3% year-on-year.

In 2020, China's auto production and sales were 25.225 million vehicles and 25.311 million vehicles respectively, with a year-on-year decrease of 2% for production and 1.9% for sales. The degree of decrease was narrowed down by 5.5% and 6.3%, compared with that of 2019.

In 2020, the production and sales of gasoline vehicles were both 123,000 units, down by 5% and 3.4% year-on-year respectively; the production and sales of diesel vehicles were 368,000 units and 366,000 units respectively, showing an increase of 13.0% year-on-year. The production and sales of new energy vehicles were 1.366 million units and 1.367 million units, showing a year-on-year increase of 7.5% and 10.9% respectively. Among them, the production and sales of battery electric vehicles were 1.105 million units and 1.115 million units; the production and sales of plug-in hybrid electric vehicles were 260,000 units and 251,000 units respectively; and the production and sales of fuel cell electric vehicles were both 1,000 units.

By the end of 2019, the population of natural gas vehicles in China reached 7.32 million units, including 6.72 million units of CNG vehicles and 0.6 million units of LNG vehicles. In 2020, the sales volume of commercial natural gas vehicles was 169,619 units and the top five provinces by sales were Shanxi, Hebei, Shaanxi, Xinjiang and Shandong.

Research and Demonstration Focus

Promotion of Methanol Gasoline Pilot Project

In October 2020, Shanxi Province issued "The implementation plan for accelerating the development of the methanol automobile industry and the vehicle promotion of the province." Shanxi will strengthen the rational layout of the methanol automobile industry, expand the "coal-coke-gas-alcohol-machine" industrial chain, and improve the industrialization and market application of methanol vehicles. Shanxi plans to speed up the construction of a methanol automobile manufacturing system, taking the methanol fuel production and methanol automobile promotion and application as the main direction. The focuses will be on the planning and layout of methanol vehicle production bases across the province in Taiyuan, Jinzhong, Changzhi and Yuncheng, and to build vehicle methanol fuel production bases in Datong, Jincheng, Changzhi, Linfen, and Lvliang.

By the end of 2021, Shanxi is expected to have an annual production capacity of 150,000 methanol vehicles. As many as 5,000 units of M100 methanol vehicles will be promoted in the fields of cruising taxis and online ride-hailing cars, and more than 100 methanol refueling stations will be built in key cities of Taiyuan, Jinzhong, Changzhi and Yuncheng. 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.

Promotion of Ethanol Gasoline Pilot Project

Since 2004, China has promoted ethanol fuel in areas such as Heilongjiang, Jilin, Liaoning, Henan, Anhui and Tianjin.

The raw materials for biofuel ethanol production in China are mainly grain and non-grain. Among them, the production capacity of biofuel ethanol using grain as raw material accounts for 98% of the total production capacity. Corn accounts for 90% of the total production capacity, which takes the largest proportion.

In 2020, the price of biofuel ethanol increased rapidly, reaching RMB 6,400 yuan/ton, or $990/ton (US), which increased by 25% compared with that at the beginning of 2020. One of the main reasons was that the Covid-19 pandemic caused explosive growth in demand for disinfection alcohol. The price of the raw materials for producing biofuel ethanol increased continuously. The positivity of manufactures declined because the biofuel ethanol price was not competitive with the gasoline price. The promotion of ethanol gasoline slowed down.

Outlook

Driven by the goal of carbon neutrality and the "Development Plan for the New Energy Vehicle Industry (2021-2035)", the new energy vehicles in China will develop fast. Fuel cell electric vehicles are expected to realize commercialization by 2035.

Meanwhile, China will insist on the diversity of vehicle fuels development. China will actively promote the construction of natural gas pipelines, natural gas receiving facilities and the use of natural gas and other clean energy vehicles. Natural gas commercial vehicles will develop rapidly. On the premise of ensuring food security, China will continue to promote ethanol gasoline. The application of methanol vehicles in some areas with resources and experiences will be implemented, such as in Shanxi, Shaanxi, Guizhou, and Gansu. The application of M100 methanol vehicles will be accelerated.

Additional Information Sources

- National Development and Reform Commission, https://www.ndrc.gov.cn/fggz/jjyxtj/mdyqy/
- 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 (CATARC), https://www.catarc.ac.cn/
- Asia Pacific Natural Gas Vehicles Association (ANGVA), http://www.angva.org/
- Methanol Institute, A Brief Review of Chinas Methanol Vehicle Pilot and Policy, https://www.methanol.org/methanol-news-en/
- 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 will include 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.

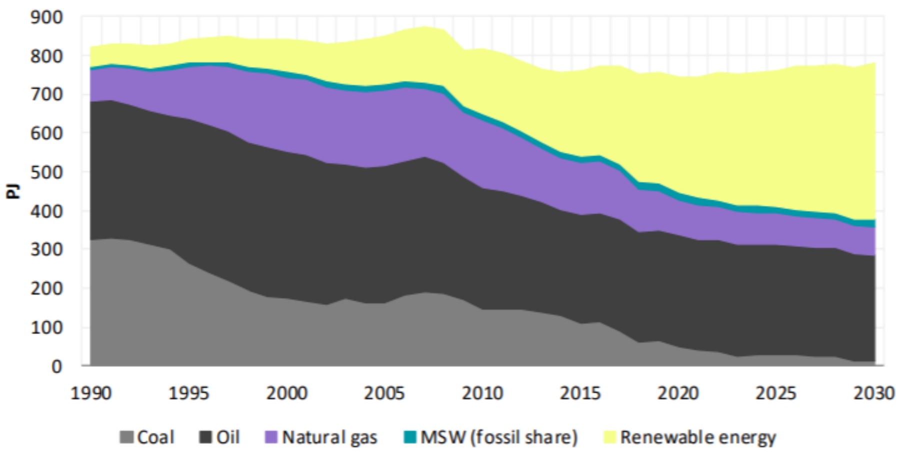


Fig. 1. Gross energy consumption by type of energy 1990-2030 [PetaJoule (PJ)]. The calculation for 1990-2017 has been adjusted for outdoor temperature/degree days relative to normal years (climate-adjusted) and electricity trade with other countries.

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 (RE) Directive (EU, 2009; Eurostat 2018).

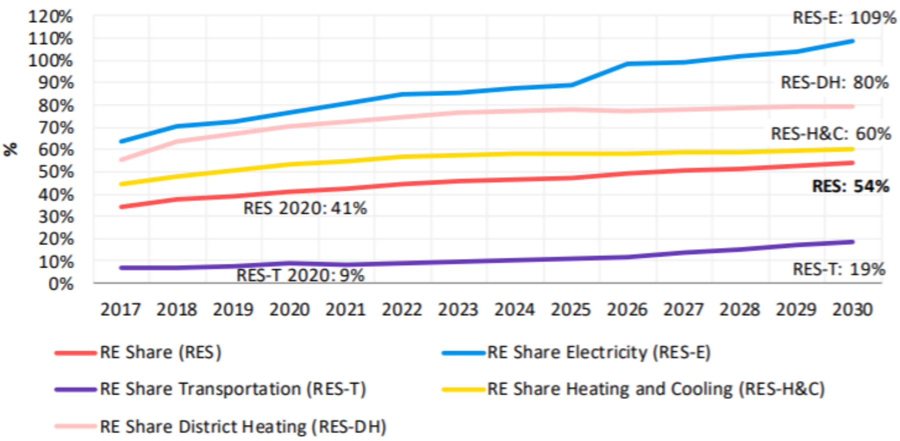


Fig. 2. Renewables shares 2017-2030 [%]. The renewables shares is calculated as defined in the RE Directive (Eurostat, 2018).

The RES and RES-T are subject to binding national EU targets in 2020. The EU RE Directive 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 RE Directive 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 RE Directive 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.

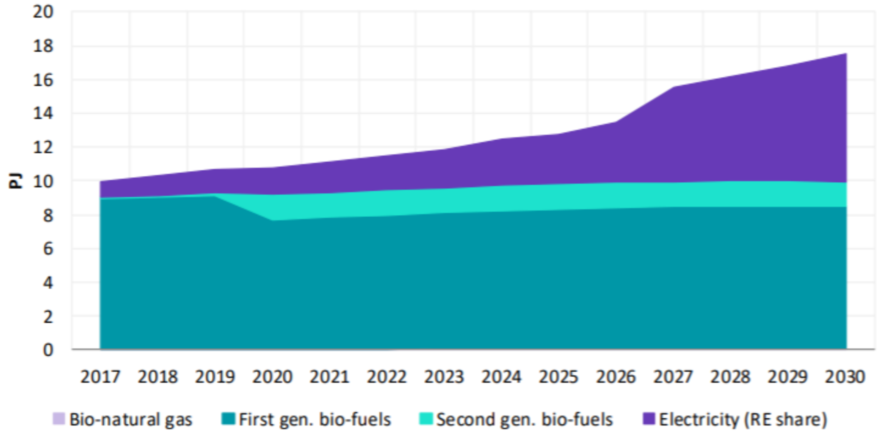


Fig. 3. Renewable energy consumption by the transport sector 2017-2030 [PJ].

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).

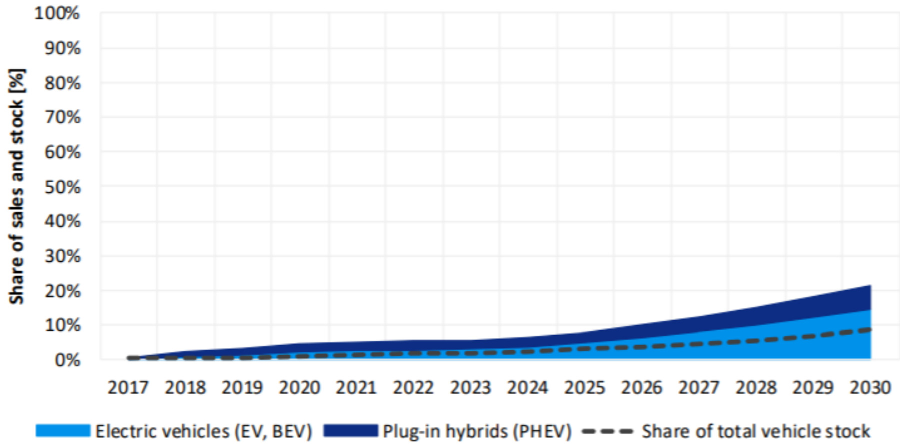


Fig. 4. Electrified vehicles' share of sales of new vehicles and share of total number of passenger cars and vans on the road 2017-2030 [%].

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.

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[6]. 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.

The current biofuels obligation (liquid biofuels) calls for 20% biofuels in 2020, taking into account double counting for advanced biofuels. In spring 2019, the biofuels obligation was revised again, and the pathway toward 2030 was set. The biofuel target for 2030 is 30%, and this time reflects actual energy contribution without double counting. There is also a separate sub target for advanced biofuels: 10%, i.e., one third of the total contribution.[7] In addition, a separate biofuels obligation is set for non-road machinery diesel fuels. 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 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) as of 2008, providing substantial incentives for BEVs and PHEVs.[8]

Advanced Motor Fuels Statistics

In 2019, the energy consumption in domestic transport (all modes together) was 179 PJ, and energy consumption in road transport was 162 PJ or 3.87 Mtoe (Table 1). Relative to the total final consumption of 1,083 PJ in 2019[9], the figures were 16.5% and 15.0%, respectively[10]. In 2019, total CO_2-eq emissions were 53.1 Mt. The emissions from transport were 11.3 Mt (all modes together) and 10.5 Mt (road), 21.3% and 19.8%, respectively.[11,12]

Table 1. Energy in road transport in 2019

2019	PJ	ktoe	Share of fuels (%)	Share of bio (%)
Petrol (fossil)	51.2	1223	31.6	
Biocomp. petrol	3.6	86	2.2	6.6 of petrol
Diesel (fossil)	92.4	2207	57.0	
Biocomp. diesel	14.2	339	8.8	13.3 of diesel
Natural gas	0.24	5.7	0.15	
Biomethane	0.29	6.9	0.18	54.7 of gas
∑ fuels	162.1	3872		11.2 of fuels
	PJ	**ktoe**	**Share of total (%)**	
Electricity	0.26	6.2	0.2	
∑ fuels	161.85	3866	99.8	
Total	**162.1**	**3872**		

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

6 https://tem.fi/en/energy-and-climate-strategy-2016
7 https://www.finlex.fi/fi/laki/alkup/2019/20190419
8 Parkkonen, L. (2013). Taxation of petroleum products and vehicles in Finland. CEN/TC 19 Conference. Helsinki, 27 May 2013.
9 pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehk/statfin_ehk_pxt_12sz.px/
10 http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehk/statfin_ehk_pxt_011_fi.px/
11 http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ymp__khki/ statfin_khki_pxt_111k.px/
12 http://lipasto.vtt.fi/en/liisa/index.htm

The contribution of biofuels relative to the total amount of actual fuels is 11.2% in terms of energy, varying from 6.6% in petrol (mostly ethanol and some ETBE but also bio-naphtha; the statistics do not give details on this) to 55% in methane. The actual amount was 432 ktoe or 11.2% 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. Total production of biofuels in Finland was some 540 ktoe[13]. Compared to the Finnish consumption of biofuels in 2019, 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 2020 (without two- and three-wheelers and light four-wheelers). Table 3 presents the sales figures for new passenger cars in 2015 – 2019 (revised).

Table 2. Vehicle fleet at the end of 2020 (in use, without two- and three-wheelers and light four-wheelers)[14]

Fuel	Cars	Vans	Trucks	Buses	Special vehicles
Petrol	1,914,949	9,604	1,938	21	288
FFV / ethanol	4,423	11	113	2	0
Diesel	761,314	327,279	92,280	9,776	1,623
Methane	5,152	613	134	61	0
Methane bi-fuel	7,202	303	95	1	0
BEV	9,697	444	7	87	0
PHEV petrol	42,658	82	0	0	0
PHEV diesel	2,963	25	0	2	0
Other	90	28	124	5	0
Total	2,748,448	338,389	94,691	9,955	1,911
Fuel	**Cars**	**Vans**	**Trucks**	**Buses**	**Special vehicles**
Petrol	69.7%	2.8%	2.0%	0.2%	15.1%
FFV	0.2%	0.0%	0.1%	0.0%	0.0%
Diesel	27.7%	96.7%	97.5%	98.2%	84.9%
Methane	0.2%	0.2%	0.1%	0.6%	0.0%
Methane bi-fuel	0.3%	0.1%	0.1%	0.0%	0.0%
BEV	0.4%	0.1%	0.0%	0.9%	0.0%
PHEV petrol	1.6%	0.0%	0.0%	0.0%	0.0%
PHEV diesel	0.1%	0.0%	0.0%	0.0%	0.0%
Other	0.0%	0.0%	0.1%	0.1%	0.0%

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

14 https://www.traficom.fi/fi/tilastot/ajoneuvokannan-tilastot

Table 3. Sales of new passenger cars in 2015 - 2019[15]

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	73,251	14	165	39,451	4,668	11	1,115	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

The share of alternative fuel vehicles (PHEVs, HEVs, NGVs, FFVs) ranges from 2.6% (cars) to 0% (special vehicles). Within passenger cars, plug-in hybrids is the largest alternative vehicle group.

From 2018 to 2019, petrol increased and diesel dropped, whereas registrations of BEVs, HEVs and CNG vehicles increased. One abnormality was diesel-fueled HEVs, as registrations increased more than 300%. There are some 300 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, LNG fueled trucks have entered Finnish roads, although still in limited numbers. In the case of buses, the number of battery electric buses has surpassed the number of gas buses.

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.

The MARANDA project (2017-2021), a hydrogen-related project aiming at 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, and ships will be 18 months in commercial operation during the project.

From 2017-2021, Business Finland is running a program called "Smart Energy Finland." The program brings together the services for technical development and exports and will grant 100 million euros to smart energy solution innovations in 2017-2021. The program will also grant 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 is quite wide, and transport-related issues are only a minor part of the program. However, one subtheme of the program is "sustainable bioenergy solutions," covering both biogas and advanced liquid biofuels. Another subtheme is dealing with batteries, thus having couplings to the transport sector.

The project BioMet2020 (2018-2020), focusing on advancing on biomethane usage in agriculture and non-road machinery, was completed. The project was funded by Business Finland. It included three focus areas. The first focus area was development of novel biogas upgrade technology that demonstrated around 50% lower investment and operating costs compared to traditional technologies. The second focus area showed new potential methane storage technologies, either in high pressure or in porous materials. In the third focus area, potentiality of a spark-ignited bi-fuel methane-ethanol non-road engine was studied. Capability for complying with Stage V emission requirements was demonstrated with both fuels, methane and ethanol (RE85).

[15] http://www.aut.fi/tilastot/ensirekisteroinnit/kayttovoimat/henkiloautojen_kayttovoimatilastot
http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__lii__merek/statfin_merek_pxt_11ck.px/table/tableViewLayout1/

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 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[16]) 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 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 both 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. Additionally, the government emphasizes circular economy and the development of biogas.

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

Germany

Drivers and Policies

In 2020, Germany's transport sector was strongly affected by the COVID-19 pandemic. However, with regard to the overall set targets to significantly reduce GHG emissions on EU and national levels (e.g. by the European Green Deal, National Climate Plan 2050 [NCP]), the transition toward decarbonization in the transport sector is ongoing. Germany has committed to reduce its emissions in non-ETS sectors, including the transport sector, by 38% by 2030, compared to 2005 levels, as set in the Effort Sharing Regulation (ESR). Although Germany has already taken comprehensive climate measures, further national efforts are required to achieve the set goal of CO_2 savings.

While national and sector-wide GHG emission reduction targets for 2030 are in line with the German long-term strategy (i.e., NCP), these 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. With the Climate Action Plan, Germany sets binding target saving of at least 40-42% of GHG emission, compared to 1990, in the transport sector. This translates to 98 to 95 Mt CO_2-eq in 2030.[17] In total, the government foresees to invest more than €54 billion in climate protection by 2023.

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 quota. The FQD is defined by EU Member States to implement GHG reduction targets for fuels placed on the market. By 2020, target reduction is set for 6% through alternative and renewable fuels, including the crediting of up to 1.2% upstream emission reductions per UER 2018. Fuel suppliers will be obliged to report GHG emissions for the fuels they have placed on the market.[18] Most recently, the federal government agreed on key points for the national implementation of the RED II. In addition to the gradual increase of the GHG quota to 22% in 2030, it includes the setting of the cap for biofuels from cultivated biomass at 4.4% from 2026.[19] The national implementation of REDII and thus the adjustment of the GHG quota by 2030, must be completed by June 2021. The current trend shows that the GHG quota alone will not meet the actual GHG reduction requirements of -40% by 2030 in comparison to 1990. In fact, fulfillment of this quota requires a high share of renewables in the transport sector, which can only be achieved when almost all fuel options are considered.

The number of electric vehicles and plug-ins has significantly increased since 2017 (See Advanced Motor Fuels Statistics below), although the share in total number of vehicles and final energy consumption remain small. During the last few years, Germany's public debate has been focusing on electric mobility, battery-powered vehicles, PtX and hydrogen. With regard to transport in the agricultural/forestry sector, tax relief for biofuels has been extended by the European Commission (UEBLL, EEAG). 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 compressed natural gas (CNG) infrastructure along the most important middle- and long-distance road networks. The federal government strongly supports the use of liquefied natural gas (LNG) for heavy-duty transport and waterborne application. 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 keys within the National Hydrogen Strategy that was published in June 2020.

Believing e-mobility is essential for climate-friendly mobility, the federal government has been supporting measures since 2016.[20] There are currently 60 electric vehicle models from German manufacturers on the market which are charged with electricity at circa 34,000 publicly accessible

17 https://www.bundesregierung.de/resource/blob/975226/1679914/e01d6bd855f0 9bf05cf7498e06d0a3ff/2019-10-09-klima-massnahmen-data.pdf?download=1

18 https://www.dbfz.de/fileadmin/user_upload/Referenzen/Statements/Hintergrundpapier_Weiterentwicklung_THG-Quote.pdf

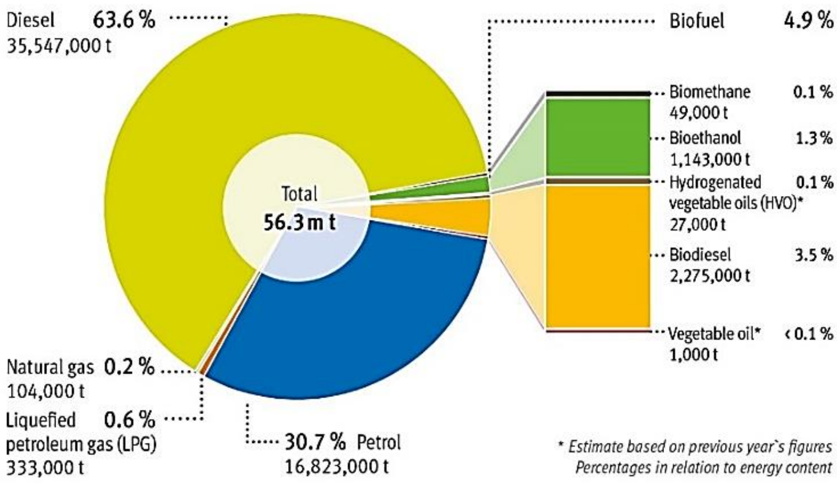
19 https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Glaeserne_Gesetze/19._Lp/thg_quote/Entwurf/thg_quote_refe_bf.pdf

20 https://www.bmwi.de/Redaktion/DE/Dossier/elektromobilitaet.html

charging points as of January 2021.[21] In order to make the use of 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. It is expected that 1 million electric vehicles (battery and plug-in) will be on Germany's roads by 2022 (forecast by NMP).

Advanced Motor Fuels Statistics

Figure 1 shows the 2019 German fuel consumption for use in road transportation. The consumption of biofuels totaled 2.8 Mt, primarily low-level blends of biodiesel, hydrogenated vegetable oil, bioethanol and biomethane. Moreover, to a minor extent, biomethane is used for CNG. Due to lacking incentives, there is no market demand for E85 and pure biodiesel.



Source: FNR based on AGEB, BAFA, BLE, DVFG 2020[22]

Fig. 1. Fuel Consumption in the Transport Sector in Germany in 2019

Tables 1 and 2 show the 2013-20 trends for biofuels and biofuel blends. The switch at the beginning of 2015 in the biofuels quota legislation from quantitative quotas to GHG-reduction quotas, and the settlement of a compromise on the EU level on the RED in 2015 increased the average GHG reduction of biofuels and avoided 10 Mt CO_2-eq in 2019; 13 Mt CO_2-eq are expected for 2020 to meet the GHG quota of 6%.[23] The overall savings in GHG emissions of all biofuels (pure) was 82.6% compared to fossil fuels.[24] The increasing GHG savings of biofuels demonstrate that the physical demand for biofuels to comply with the GHG quota decreased. The 30% jump of biodiesel consumption in 2020 is caused by article 26 of REDII, where 2020 is the reference year for the future ceiling for food crop-based biofuels.[25]

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21 https://www.bundesnetzagentur.de/DE/Sachgebiete/ElektrizitaetundGas/Unternehen_Institutionen/HandelundVertrieb/Ladesaeulenkarte/Ladesaeulenkarte_node.html

22 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]), February 2020.

23 New reference values for fossil fuels according to the 38th BImSchV are in force since 2018. https://www.fuels-of-the-future.com/presse/mehr-klimaschutz-im-verkehr-durch-biokraftstoffe-kurzfristig-erreichbar

24 https://www.ble.de/SharedDocs/Downloads/DE/Klima-Energie/Nachhaltige-Biomasseherstellung/Evaluationsbericht_2019.pdf?__blob=publicationFile&v=4

25 https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32018L2001&from=EN#d1e3461-82-1

Table 1. Trends in German Biodiesel/FAME Sales, 2013–2020, in Mt[26]

Sale	2013	2014	2015	2016	2017	2018	2019	2020
Blend	1.741	1.970	1.978	1.987	2.183	2.296	2.301	3.025
Pure biodiesel	0.030	0.005	0.003	0.001	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

Table 2. Trends in German Bioethanol Sales, 2013–2020, in Mt

Sale	2013	2014	2015	2016	2017	2018	2019	2020
E85	0.014	0.010	0.007	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
ETBE	0.154	0.139	0.119	0.129	0.111	0.110	0.088	0.126
Total	1.209	1.231	1.177	1.176	1.156	1.187	1.177	1.098

Table 3 shows the number of passenger cars in Germany by fuel type for 2016-20. A total of 65.8 million vehicles, including 4.5 million motor bikes, were registered in Germany as of January 1, 2020, along with 47.7 million passenger cars, 3.3 million trucks, 2.3 million towing vehicles and 81,364 buses. At a share of 0.2%, 82,198 CNG-powered cars were registered. The number of hydrogen-powered cars increased from 374 (2019) to 507 (+35.6%). (In the tables, n/a means data not available.)

Table 3. Number of Passenger Cars in Germany by Fuel Type on January 1, 2016–2020

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

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 2020*[27]

Research and Demonstration Focus

Since 2009, the federal government has made circa €3 billion ($3.62 billion US) available for research and development. Public funding for alternative motor fuels on the national scale is supported by the Federal Ministries of Transport and Digital Infrastructure (BMVI) in the areas of National Innovation Programme hydrogen and fuel cell technology, NIPII, infrastructure, e-mobility, LNG, CNG, and jet fuel, and by Education and Research (BMBF) such as P2X and SynErgie, and "Kopernikus Projects". In this context, BMVI has launched a new supporting program for renewable fuels, with €1.5 billion ($1.81 billion US) available for 2021-24, consisting of resources from the Energy and Climate Fund (EKF) and the National Hydrogen Strategy.[28] The Ministry of Economic Affairs and Energy (BMWi), focuses on eFuels in the "Energiewende im Verkehr" program, including a total funding of €130 million ($157 million US). As a central measure, "real laboratories of energy transition" were established; in 2022, a roadmap will be presented.[29] Under the Renewable Resources Funding Scheme of the BMEL, 10 R&D projects related to biofuels and active in 2020 have received funding of €3 million ($3.6 million US). Due to an adverse European framework for biomass-based fuels, increased funding is not anticipated.

26 Bafa March 2021, Official Mineral Oil Data December 2020) 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
27 https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Jahresbilanz/b_jahresbilanz_inhalt.html?nn=2601598
28 https://www.bmvi.de/SharedDocs/DE/Artikel/G/neues-foerderkonzept-erneuerbare-kraftstoffe.html
29 https://www.energieforschung.de/forschung-und-innovation/energiewende-im-verkehr

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. Further R&D activities, such as reducing the GHG emissions of biofuels to make them compatible with the RED II limits, also following the ESR approach, are needed to meet persistent challenges for the near future.

Additional Information Sources

- Bundesverband der deutschen Bioethanolwirtschaft, www.bdbe.de
- Bundesverband Regenerative Mobilität, www.brm-ev.de/en
- Verband der Deutschen Biokraftstoffindustrie, www.biokraftstoffverband.de
- Deutsches Biomasse Forschungszentrum, www.dbfz.de[30]

Major changes

- Increase of GHG Quota to 6%; to be increased to 22% by 2030
- Political agreement on the national implementation of RED II
- National Hydrogen Strategy published in June 2020
- New national supporting programs launched, e.g. renewable fuel program (BMVI).

Benefits of participation in AMF

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

[30] https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-11/

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. Robust growth in prosperity and a population with a high share of young people is driving a huge increase in India's primary energy consumption, which is expected to expand by 1.2 billion toe or 156% by 2040, making India the largest source of energy demand growth, according to BP Outlook India – 2019.

A 2016 initiative to provide universal clean energy access to every household led to a 62% increase in LPG consumption in 2020, 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 and biodiesel) and "advanced biofuels" (e.g., 2G Ethanol, bioCNG, and drop-in fuels) to expand the scope of raw material for ethanol production to include damaged food grains unfit for human consumption. Later, during 2020, India's government has decided to utilize surplus stock of rice lying with Food Corporation of India (FCI) and maize 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, the absolute consumption for oil is expected to double and, for gas, to triple from existing levels. 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.

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 feed stocks for production of ethanol including sugar, sugar cane, sugar syrup, damaged food grain, surplus stock of rice available with FCI, maize etc.; addressing state specific issues, and attractive ethanol prices and availability of molasses in the ecosystem facilitated in improving the supply of ethanol from 154 million liters during Ethanol supply year (ESY) 2012-13 to around

1.88 billion liters during ESY 2018-19, thereby achieving average blending of 5% in petrol during ESY 2018-19. During ESY 2019-20, India has faced one of the toughest lockdown in the world due to the COVID-19 virus and demand for petrol has come down drastically. The COVID-19 related challenges were addressed systematically by timely reallocation of quantities and close supply-logistics coordination, thereby maintaining an average blend percentage of 5.0%, even during ESY 2019-20.

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
Ethanol procured by PSU OMCs* (in million liters)	665	1505	1886	1730
National average blending (in percentage)	2.0%	4.2%	5.0%	5.0%

* 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 (JaivIndhan-VatavaranAnukoolfasalawasheshNivaran) Yojana” which will provide financial assistance of approximate $300 million US for the period from 2018-19 to 2023-24 for supporting commercial projects as well as demonstration projects for second generation (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 feed stocks include agri-residues like rice and wheat straw, cane trash, corn cobs and stover, cotton stalk, bagasse, empty fruit bunches (EFB), etc. 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 stage of construction and are likely to be made operational in two to three years.

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 oil marketing companies under guidance of Ministry of Petroleum and Natural Gas (MoPNG) have released an Expression of Interest (EOI) for biodiesel made from UCO. It provides that the entrepreneurs setting up biodiesel plants get remunerative price and assurance of complete offtake of production by the PSU OMCs. The OMCs have floated EoIs for procurement of biodiesel produced from UCO across 300 locations in the country. OMCs have received offers for setting up 65 biodiesel plants with a production capacity of approximately 1,300 MT/day. 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 Compressed Bio Gas (CBG) plants were classified under priority sector lending by India’s Central Bank on September 4, 2020.

Compressed Biogas (CBG)

The government is promoting the use of CBG, generally known as Bio-CNG, which is purified and compressed biogas, produced through a process of anaerobic decomposition from various waste/biomass sources.

The SATAT initiative was launched in October 2018. Under this initiative, public sector oil and gas marketing companies have invited EOI to procure CBG from potential entrepreneurs for the establishment of 5,000 CBG plants across the country, with an estimated production of 15 MMT CBG per annum by2023-24. About 600 Letters of Intents has been issued to entrepreneurs for production and supply of CBG, and commercial production of CBG has started from 5 plants.

Research and Demonstration Focus

The Centre for High Technology (CHT), PSU OMC's research and development units under MoPNG, Department of Biotechnology (DBT) and Council of Scientific and Industrial Research – Indian Institute of Petroleum (CSIR-IIP), Dehradun are working on the program to support R&D pertaining to energy biosciences in the country through various schemes and with major emphasis on advance biofuels. The DBT-ICT center based in Mumbai has developed lignocelluloses technology, which 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 is a Blue Hydrogen (blue hydrogen is produced by using a fossil fuel like natural gas), or Hydrogen CNG (H-CNG) initiative, where hydrogen is blended with compressed natural gas (CNG) for use as transportation fuel at Rajghat Bus depot, New Delhi. Under this pilot, 50 buses in Delhi are operating on blended Hydrogen in Compressed Natural Gas (CNG). Five other pilots are being planned to explore Green Hydrogen (produced from renewable sources like solar energy, biomass, and others not from fossil fuels) where green hydrogen produced is to be used as transportation fuel as well as an industrial input to refineries.

An ambitious R&D project under the aegis of MoPNG is being done by Indian Oil Corporation Limited (IOCL) at a cost of $18.3 million US. It is the first scientific project in India to address all aspects of the value chain of hydrogen-based mobility. IOCL R&D is procuring 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 40 tons per day will also be set up. Of these, three plants are based on renewable sources (biomass gasification, reforming CBG and solar PV-based electrolysis) producing green hydrogen.

Lanza Tech-USA's patented anaerobic gas fermentation technology is converting CO_2 into acetic acid, and Indian Oil R&D's patented aerobic fermentation technology is converting acetic acid to highly valuable Omega 3-fatty acids (DHAs) and bio-diesel. This value chain makes the overall process economically feasible. Studies are in advanced stage for the world's first pilot plant with capacity of 10 kg/day CO_2 installed at IOC R&D center. More pilot plants at suitable refinery locations/2G ethanol plants where pure CO_2 is available from the Mono Ethyl Glycol/2G ethanol fermentation units and hydrogen from refineries will be planned. 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 CSIR laboratory in the Indian Institute of Petroleum, Dehradun, using Jatropha seeds. After the flight's success, Government of India has moved forward and decided to set up demonstration plants for future growth of Bio-ATF in the country.

Currently, efforts are focused on 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, food waste 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 1,730 million liters of ethanol in ESY 2019-20.O MCs achieved a blending percentage of 5% during ESY 2018-19 and maintained the same during ESY 2019-20 despite COVID-19 related disruptions. 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). Construction of pilot plants for E100 (pure anhydrous ethanol) and M15 (15% methanol blended with petrol) fuel is also in advanced stage, which will also help in increasing the share of biofuel in overall fuel consumption.

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 and has the potential to replace more than 50% of gas imports.

The above-mentioned 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

- Website: www.ppac.org.in for data on fossil fuels production, consumption, Import & Export
- Website: www.mnre.gov.in for data on R&D projects
- Website: https://www.siam.in/ for data on automotive industry
- Website: www.dbtindia.nic.in
- Website: www.iocl.com for data on R&D projects

Israel

Drivers and Policies

Israel is home for more than 9 million people, with a GDP of approximately $40,000 per capita in 2020[31]. Israel's total area is roughly 22,000 square kilometers, and densely populated – close to 422/km^2. It has total road length of about 20,000 km.

The main form of energy consumed by the transportation sector in Israel is hydrocarbon-based liquid fuel (mainly gasoline and diesel).

Israel has two oil refineries with installed distillation capacity greater than the needs of the country. Israel is a net importer of crude oil and exporter of oil distillates.

Taxation on fuel for transportation is high and similar to taxation policy in western European countries such as Italy, France and Germany.

The main energy conversion technology currently dominating the transportation market in Israel is internal combustion engines based on hydrocarbon fuels (internal combustion – piston engines and gas turbines).

A decade ago, large natural gas reservoirs were discovered in the Mediterranean Sea near Israel. These discoveries were developed during the last decade, and a natural gas transmission pipeline network was developed. Local gas networks are still growing. Today these discoveries supply approximately 37% of total energy demand and serve as fuel for electricity generation and industry. Use of natural gas as a direct energy source for transportation is limited mainly to buses.

Israel's energy policy is promoting usage of natural gas instead of coal for electricity generation. Coal was used as the main fuel for electricity generation in Israel for more than 40 years. Israel plans to eliminate coal as an energy source by the end of 2025.

Electricity generation from renewable sources (almost exclusively solar) is promoted by the Ministry of Energy, with a target of 30% of the electricity mix by 2030; it was a little over 6% in 2020.
Heavy railway transportation in Israel is developing fast, and Israel's railway company is pushing toward electrification of all passenger lines, which are currently based on diesel locomotives. Electrification of the first line (Jerusalem – Tel Aviv) was completed during 2019.

Light railway is operating in Jerusalem, and another line in Tel-Aviv will likely be completed in 2022. New lines are planned and would be constructed during this decade.

A new Metro system for the central part of Israel is currently in early design phases. This system would serve about 3 million people.

Israel's energy policy is based on energy security and environmental concerns. Energy conversion technology does not serve as a major consideration since it is dictated usually by the available energy source.

Israel signed the 2015 Paris Agreement and is pursuing decarbonization of energy usage in the country.

[31] https://www.imf.org/en/Publications/WEO/weo-database/2021/April/weo-report?c=512,914,612,614,311,213,911,314,193,122,912,313,419,513,316,913,124,339,638,514,218,963,616,223,516,918,748,618,624,522,622,156,626,628,228,924,233,632,636,634,238,662,960,423,935,128,611,321,243,248,469,253,642,643,939,734,644,819,172,132,646,648,915,134,652,174,328,258,656,654,336,263,268,532,944,176,534,536,429,433,178,436,136,343,158,439,916,664,826,542,967,443,917,544,941,446,666,668,672,946,137,546,674,676,548,556,678,181,867,682,684,273,868,921,948,943,686,688,518,728,836,558,138,196,278,692,694,962,142,449,564,565,283,853,288,293,566,964,182,359,453,968,922,714,862,135,716,456,722,942,718,724,576,936,961,813,726,199,733,184,524,361,362,364,732,366,144,146,463,528,923,738,578,537,742,866,369,744,186,925,869,746,926,466,112,111,298,927,846,299,582,487,474,754,698,&s=NGDPD,PPPGDP,NGDPDPC,PPPPC,&sy=2010&ey=2021&ssm=0&scsm=1&scc=0&ssd=1&ssc=0&sic=1&sort=subject&ds=.&br=1

Because Israel is a densely populated country with positive population growth, the transportation ministry has chosen development of public transportation as a main target. As mentioned above, all rail activity (heavy and light) will be electrified during this decade. This will decrease the demand for hydrocarbon fuel for public transportation.

Currently, most of the buses in Israel are diesel buses, with a few dozen electric buses and a few dozen running on natural gas. Limited subsidies are specifically offered for new alternative energy buses. While public transportation is generally subsidized by the government, the operators are being encouraged by the government in various ways to purchase buses that can use alternative fuels to diesel (NG and electricity). The government is close to a decision that all new urban buses will be electric by 2025.

Heavy duty transportation is solely based on diesel. In this sector, total cost of ownership is a key consideration for operators. The government does not actively intervene in the considerations of the operators regarding choice of energy source and energy conversion method. Subsidy for purchase of natural gas trucks did not attract operators due to lack of fueling infrastructure and limited offer of trucks.

For commercial aviation and maritime activity, Israel is following worldwide regulation.

Light duty transportation (2019) is mostly based on Otto cycle internal combustion technology and gasoline (88%). The proportion of diesel light duty vehicles in Israel is relatively low compared to Europe (5.5%). The proportion of hybrid vehicles is relatively high compared to the world, due to tax incentives (5.6%). The BEV electric vehicles proportion is low (about 1%). Incentives for purchase of BEV, PEV and HEV are given by the government as a tax discount: total taxation on light duty vehicles is ~100%, and total taxation for BEV light duty vehicles is ~30%. There was significant increased purchase of BEV and PEV in 2020. However, BEV adaption by consumers is slow due to limitations in current technology and lack of charging infrastructure. The Ministry of Energy policy for the light duty vehicles sector is to stop import of new gasoline and diesel vehicles in 2030. The Ministry of Energy is also promoting charging infrastructure deployment.

Considerations of energy security (natural gas and renewable electricity), combined with dense population and environmental concerns due to a relatively arid climate, support transportation electrification. As mentioned above, it is expected that all rail transportation would be electrified by the end of this decade. Light duty transportation would be electrified according to the availability of commercial platforms and the development of charging infrastructure. It is expected that regulation regarding limitation of entry into cities of polluting vehicles will increase. Currently, such regulations are active in some zones for commercial vehicles with old euro emission certification.

As a relatively small market, Israel has limited ability to mass produce energy conversion machines at a competitive cost. Therefore, the consumption of such machines is usually following trends in the developed countries. Nevertheless, development of new energy conversion machines and methods is actively done in Israel with the support of the Ministry of Energy's chief scientist and a special administrative division in the prime minister’s office.

Advanced Motor Fuels Statistics

The main transportation indicators which characterize Israel are (2019):

- 3.085 million light duty vehicles
- 0.307 million heavy duty vehicles
- Total kilometers traveled per annum – 63,191 million
- Public buses total kilometers traveled per annum – 703 million
- Total railway passengers per annum – 63 million
- Total railway freight per annum – 8.5 million tons
- Total ship passengers per annum – 0.28 million
- Total ship freight per annum – 58 million tons
- International air transport aircraft movements per annum – 153,000
- International air transport passengers per annum – 24.36 million

The transportation energy consumption indicators which characterize Israel are (2019):
- Gasoline (2019) – 3.3 million ton
- Diesel (2019) – 3.5 million ton
- Kerosene for aviation (2019) – 1.15 million ton
- Liquid fuel for maritime activity (MGO, HFO, IFO, MDO) – 0.36 million ton

Research and Demonstration Focus

From 2016 to 2020, the Ministry of Energy together with the Fuel Choices and Smart Mobility Initiative supported 85 alternative fuels projects with total grants of about 57M NIS – 18 of those were in 2020. Figure1 presents the grants' distribution between sub sectors, including grants for biofuels, natural gas, hydrogen and fuel cells from academic research through startup and demonstration projects.

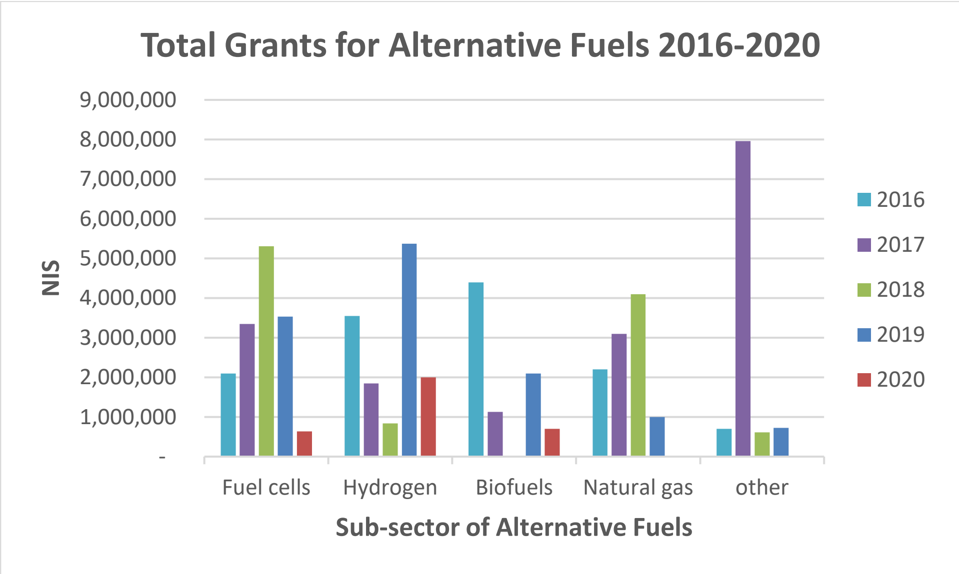

Fig. 1 Total grants for alternative fuel projects in 2016-2020

Some example projects are listed here.

Implementation of 100% Methanol as Fuel for Light and Heavy Duty Engines

This project, among others in the past 10 years, reflects the Israeli effort to develop methanol as an alternative fuel and to promote methanol mixtures not only with gasoline for light vehicles but also as a primary fuel in heavy duty vehicles and generators. In addition, the Standards Institution of Israel created the first standard for low methanol percentage fuel (M15), which was adopted in several countries worldwide. During 2018, Israel adopted two standards, EN 14214 and EN 16709, for biofuel vehicles.

NrgStorEdge – Fuel Cell Fed by Hydrogen from Formate

Founded in 2016 based on the results of research conducted at the Hebrew University of Jerusalem, NrgStorEdge redefines hydrogen energy storage. The technology is based on the hydrogen chemical reaction with potassium bicarbonate, which converts hydrogen into water and formate during the loading of hydrogen on the solution. On demand, hydrogen is then extracted from the water and from the formate, converting the solution back into the original materials – ready for new hydrogen loading. In this project, a small vehicle (See Figure 2) will be continuously charged by NrgStorEdge technology. It will include small plastic tanks for the hydrogen carrier aqueous liquid, a Hydrogen Release Unit (HRU) that extracts the hydrogen from the liquid in a special catalytic process, and a fuel cell that converts hydrogen into electricity. The residual heat of the fuel cell serves to heat the HRU, thus increasing the total energy balance.

Fig. 2 A small vehicle continuously charged by NrgStorEdge

A real-green technology, it uses water as a storage medium, is not inflammable and is nontoxic. Operating in near-to-room conditions with extremely low energy consumption, NrgStorEdge offers an unprecedented cost-effective solution. It solves the most critical challenge of the hydrogen economy, the overall low well-to-wheel energy efficiency of the current mature technologies for the storage and transport of hydrogen.

Anion Exchange Membrane for Fuel Cells

This project aims to commercialize a series of new anion-exchange membranes with unparalleled chemical stability. The membranes developed in this project are orders of magnitude more stable to aggressive alkaline environments compared to other membranes in the market. These membranes are adequate for anion-exchange membrane fuel cells, electrolyzers, flow batteries, and other technologies and devices that require low cost ionic-conducting membranes with superior chemical stability for long operation time.

Additional initiatives include:

- **CNG Refuelling Stations.** Currently Israel has two CNG refuelling stations and 5 mobile stations. In addition, the government subsidized about 20 CNG refueling stations around the country. This project is not progressing as expected, especially with the strong advent of electric mobility.
- **CNG Fueled city buses.** 85 CNG city buses are operating in the Tel Aviv area.
- **CNG Garbage trucks.** 34 CNG garbage trucks are active as of 2018.

Pilot and Industrial Demonstration Example

Our core innovation is the development, production and marketing of a patented, electric, foldable city vehicle, the City Transformer (CT) for Personal Micro Mobility.

CT vehicles fold and expand according to drivers’ needs, allowing drivers to enjoy the benefits of both motorcycles and cars.

CT vehicles enable ease of parking and great maneuverability. They are only 1 meter wide. The CT vehicle also ensures maximal safety and stability in its wider mode, allowing driving of up to 90 Km/h.

The CT vehicle is closing the gap in micro-mobility between cars and E-scooters/E-bikes sharing services. CT foldable vehicles are safe and suit all people, can operate in all weather, and are super flexible and convenient.

We will be offering this expandable, fully-customizable city vehicle initially to sharing fleets, logistics and last-mile delivery companies, first responders, and municipalities. The vehicle will save users time, money, and space while serving as a 100% electric, environmentally-friendly vehicle that is highly reliable, cheaper to own, maintain and repair, and future-ready for autonomy and connected mobility.

Fig. 3 The City Transformer folding vehicle is only 1 meter wide and can go 90 Km/h

Japan

Drivers and Policies

Fossil fuel plays a central role as a source of energy in Japan. The country's domestic sources of fossil fuel are limited, however, making it dependent on imports. The Basic Act of Energy Policy was enacted in June 2002 for the purpose of ensuring the steady implementation of energy policy.
The point of the energy policy is to first and foremost ensure stable supply ("Energy Security") and to realize low-cost energy supply by enhancing its efficiency ("Economic Efficiency ") on the premise of "Safety." It is also important to maximize efforts to pursue environment suitability ("Environment").

The Basic Energy Plan is revised every four years. Its fifth edition[32] was issued on July 3, 2018, and indicated a policy for 2030 and 2050. Currently, Japan is discussing the sixth basic energy plan for the summer of 2021.

In the transportation sector, in order to improve the energy efficiency of automobile transportation, the "New fuel economy standards for passenger cars" was issued. It stipulates the following: (1) Target year: FY2030, (2) Standard value: 25.4km/L (32.4% improvement from FY2016 results), (3) Scope: Gasoline vehicles, diesel vehicles, LPG vehicles, electric vehicles, and plug-in hybrid vehicles. However, on October 26, 2020, Japan's prime minister declared, "Japan aims to realize a carbon-neutral society by 2050." In response, the Ministry of Economy, Trade and Industry (METI) formulated a "Green Growth Strategy towards 2050 Carbon Neutrality" in collaboration with related ministries and agencies. This strategy is an industrial policy to meet the challenging goal of achieving carbon neutrality by 2050, a vision upheld by the Suga administration that aims to generate a positive cycle of economic growth and environmental protection.[33]

Advanced Motor Fuels Statistics

Figure 1 shows the energy sources used in the transportation sector[34] in Japan. 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 (Table 1). Methanol, CNG, hybrid, EVs, and FCVs currently constitute the environmentally friendly vehicles.

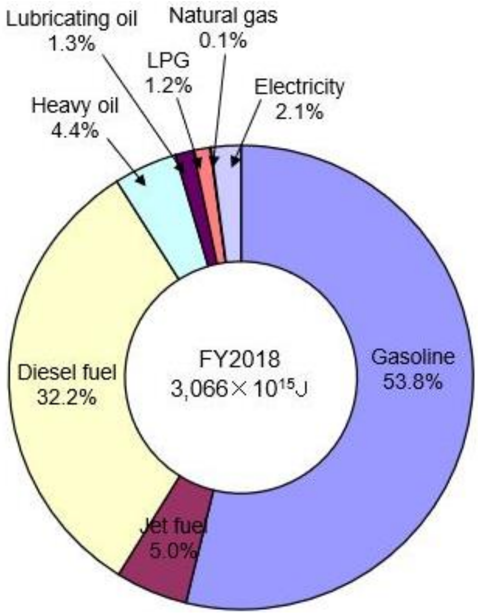

Fig. 1. Energy Sources Used in the Transportation Sector in Japan in 2018

[32] Agency for Natural Resources and Energy, 2018, "Cabinet Decision on the New Strategic Energy Plan" website, https://www.meti.go.jp/english/press/2018/0703_002.html

[33] Ministry of Economy, Trade and Industry, December 25, 2020, https://www.meti.go.jp/english/press/2020/1225_001.html

[34] Energy White Paper 2020, Agency for Natural Resources and Energy, June 2020 (in Japanese)

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 3,695 FCVs.

Table 1. Current Penetration of Environmentally Friendly Vehicles in Japan

<table>
<tr><th>Vehicle Type</th><th>Methanol[35]</th><th>CNG[36]</th><th>Hybrid[37]</th><th>EV[37]</th><th>FCV[37]</th><th>Vehicle Registration[38]</th></tr>
<tr><td>Passenger vehicles</td><td>0</td><td>1,616</td><td>9,145,172
(PHV: 136,208)</td><td>117,315</td><td>3,695</td><td>39,313,588</td></tr>
<tr><td rowspan="2">Light, mid, and heavy-duty trucks</td><td rowspan="2">576</td><td>6,410</td><td rowspan="4">45,190</td><td rowspan="4">1,563</td><td rowspan="2">0</td><td rowspan="2">5,924,307</td></tr>
<tr><td>20,649</td></tr>
<tr><td>Buses</td><td>0</td><td>1,585</td><td>0</td><td>226,271</td></tr>
<tr><td>Special vehicles</td><td>0</td><td>4,129</td><td>0</td><td>1,612,856</td></tr>
<tr><td>Small vehicles</td><td>0</td><td>11,242</td><td>1,494,319</td><td>4,839</td><td>0</td><td>31,313,053</td></tr>
<tr><td>Total</td><td>576</td><td>45,631</td><td>9,587,425</td><td>123,717</td><td>3,695</td><td>78,390,075</td></tr>
</table>

Research and Demonstration Focus

Hydrogen

The Strategic Roadmap for Hydrogen and Fuel Cells (revised version), which includes new goals and specific explanations of the new efforts to be undertaken, was announced on March 12, 2019 based on the Basic Hydrogen Strategy (December 26, 2017).

The strategy sets the following two goals toward the realization of a hydrogen-powered society: 1) To identify three fields and 10 related priority areas for Japan in technological development, and 2) To strive to continuously engage in evaluating technological development projects, creating linkages between areas of demand and technical seeds and enhancing collaboration with overseas countries.

The following targets on mobility are included:[39]

(1) FCV: 800,000 by 2030

Cost of FCV: achieving a cost reduction of FCV to the level of HV around 2025 [Price difference ¥3M ($28,500 US) → ¥0.7M ($6,650 US)], reducing cost of main elemental technologies around 2025 [fuel cell system around ¥20k ($190 US)/kW→¥5k ($48 US)/kW, hydrogen storage system around ¥0.7M ($6,650 US) → ¥0.3M ($2,850 US)]

(2) FC Bus: 1,200 by 2030

- Expansion of regions where FC buses run
- Reducing FC bus's price by half [¥105M ($997,500 US)→¥52.5M ($498,750 US)]
- Self-sustainability by FY2030

(3) Hydrogen refueling station (HRS)

- 320 by FY2025, some 900 by FY2030
- Making HRS independent by the second half of the 2020s
- Reduction of cost for construction and operation by FY2025 [construction cost ¥350M ($3.325 million US)→¥200 M ($1.9 million US), operation cost(¥34M ($323,000 US)/year→¥15M ($142,500 US)/year)]

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[35] LEVO, the Organization for the Promotion of Low Emission Vehicles (cumulative total number: out of production)

[36] Japan Gas Association, as of March 2020 (cumulative total number), https://www.gas.or.jp/ngvj/spread/ (in Japanese)

[37] Next Generation Vehicle Promotion Center, as of March 2019 (estimated numbers of vehicles owned) http://www.cev-pc.or.jp/tokei/hanbai.html (in Japanese)

[38] Automobile Inspection and Registration Information Association, as of October 2020, http://www.airia.or.jp/publish/statistics/number.html

[39] Agency for Natural Resources and Energy, The Strategic Roadmap for Hydrogen and Fuel Cells (revised version), November 18, 2019, https://www.meti.go.jp/english/press/2019/0918_001.html

Setting of cost target for each component [compressor ¥90M ($855,000 US)→¥50M ($475,000 US, high pressure vessels ¥50M ($475,000 US)→¥10M ($95,000 US)]

Hydrogen stations for fuel cell vehicles were operated in 137 locations nationwide in December 2020.[40]

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 [12].[41] The introduction of this heavy-duty CNG truck to the market is expected to increase the use of NGVs for long-distance transportation.

In FY 2018, the 3-year project subsidized by the Japanese Ministry of Environment for development and demonstration of heavy-duty LNG trucks was completed. The trucks' performance with a running range of more than 1,000 km and the availability of LNG filling stations that can also supply CNG were demonstrated. The CO_2 emissions from heavy-duty LNG trucks were reduced by about 10%, compared to the latest diesel trucks. Isuzu Motors Limited and the Organization for the promotion of Low Emission Vehicles (LEVO) are continuing this project after 2019.

Biofuel

With respect to initiatives aiming to encourage the use of biofuels in Japan, in 2019, sales of gasoline blended with Ethyl tert-butyl ether (ETBE) again achieved the target stipulated in the Act on Sophisticated Methods of Energy Supply Structures [500,000 kL (crude oil equivalent) of bioethanol and 1.94 M kL of bio-ETBE each year from 2018 to 2020], which was announced in April 2018.[42] According to trade statistics, approximately 66,000 tons of ethanol were imported in 2019, mainly from Brazil, as raw material for ETBE (equivalent to roughly 153,000 kL of ETBE).[43]

The Guidelines for Biodiesel Usage in the Construction Industry were partially revised in April 2019.

Bio-jet fuel has recently reached the practical adoption phase as a biofuel derived from the same fatty sources as biodiesel. On February 3, 2020, a communique from the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) announced a partial revision to how the standard specifications for alternative jet fuels for aircraft (ASTM D7566) should be handled.[44]

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 mid-2030s at the latest. Furthermore, through efforts to neutralize energy such as e-fuel, Japan aims to achieve net zero CO_2 through the production, use, and disposal of automobiles in 2050.

Additional Information Sources

- Agency for Natural Resources and Energy, Energy White Paper 2020, June 2020, https://www.enecho.meti.go.jp/en/category/whitepaper/pdf/2020_outline.pdf

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.

[40] Next Generation Vehicle Promotion Center, http://www.cev-pc.or.jp/suiso_station/index.html (in Japanese)
[41] Isuzu Motors Limited, website, https://www.isuzu.co.jp/world/index.html
[42] Japan Biofuels Supply LLP, website, http://www.jbsl.jp/effort/index.html (in Japanese)
[43] Japan Alcohol Association, website, http://www.alcohol.jp/statis/import.pdf (in Japanese)
[44] Ministry of Land, Infrastructure, Transport and Tourism, Airworthiness Division, Notification No.1718, https://www.mlit.go.jp/notice/noticedata/pdf/20200204/6-015.pdf (in Japanese)

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

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 the future, the blending ratio is expected to be raised step by step, and an improved system to provide flexibility in fulfillment of obligations (deposit and deferral, etc.) 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 2020.

Table 2. Vehicles Registered in Korea, 2014-2020

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

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

In 2020, new car sales reached 1.9 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 680,000 units.

Specifically, for internal combustion engine vehicles, the number of new gasoline vehicles registered increased by about 10% 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 17% 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. By car type, hybrid cars increased by about 64%, electric cars by about 34%, plug-in hybrid cars by about 152%, and hydrogen cars by about 38%. In particular, 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 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 the Convention on the Prevention of Marine Pollution (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 (scrubber, etc.) 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 introduction of bioethanol in the future.

Hydrogen and Electricity

Korea accumulated about 134,000 electric vehicles in 2020, 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.

In the case of hydrogen, the government is pushing forward to increase fuel efficiency of hydrogen vehicles by more than 30% by investing $24 million US by 2024 through the next-generation hydrogen fuel system development project.

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

Biodiesel is under consideration to increase the mixing ratio sequentially to 5% by 2030 according to Korea's RFS policy.

For marine oil, the amendment to the Convention on the Prevention of Marine Pollution (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 the International Aviation Carbon Offset and Reduction System (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 National Markets and Competition Commission (CNMC), Spain's independent regulator of the energy markets, was entitled as 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 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 2020 was 8.5%. In 2019, double counting of some biofuels entered into force.

In 2020, the CNMC issued a regulation (Circular 5/2020) which develops provisions intended to manage the certification mechanism. It establishes the requirements to be fulfilled by obligated parties and sets 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 (according to the definition established in the Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources).

The CNMC also 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.

A draft Royal Decree to modify Royal Decree 1085/2015 was published in 2020 by the Ministry for Ecological Transition and Demographic Challenge. It aimed at responding 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. It was released after a public consultation which included questions related to the level of the mandatory targets, the possibility to introduce specific targets for aviation or maritime biofuels, the obligated parties, the double counting feedstocks, the maximum limits for some biofuels, the sustainability criteria, the National Sustainability Verification System and complementary options to reduce GHG emissions, among others. The draft Royal Decree proposed mandatory targets for biofuels (in energy content and including double counting for some biofuels) of 9.5% in 2021 and 10% in 2022.

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 150-200 buses with renewable hydrogen fuel cells.
- At least 5,000-7,500 light and heavy hydrogen fuel cell vehicles for the transport of goods.
- A network of at least 100-150 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 2020.

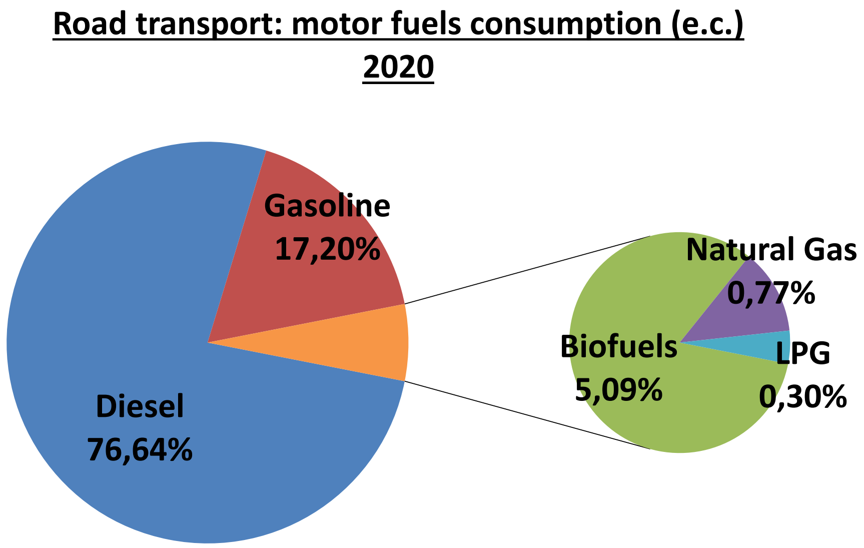

Fig. 1. Fuel Consumption (share in energy content) in Spain in 2020. *Sources: CORES, GASNAM.*

In Figure 2, the alternative fuels consumption in 2020 is shown.

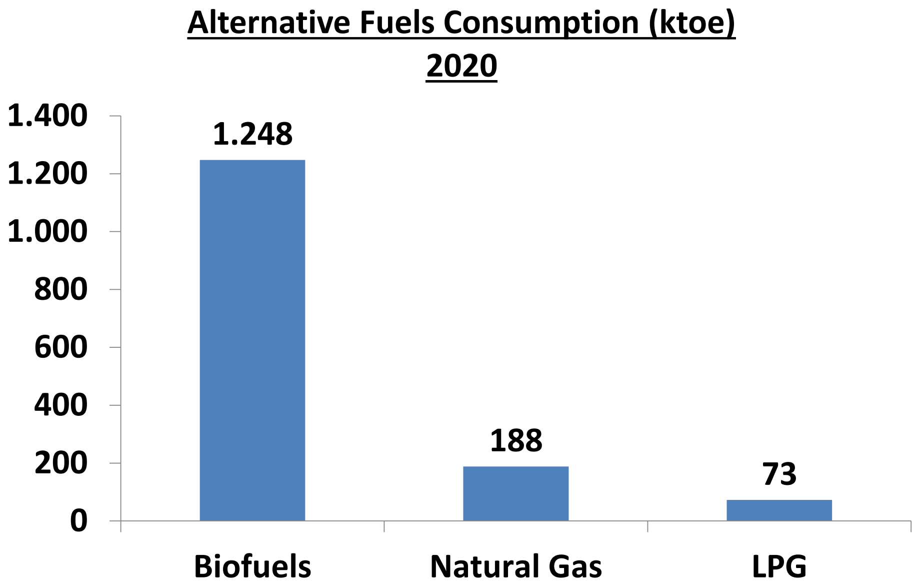

Fig. 2. Alternative Fuel Consumption (ktoe) in Spain in 2020. *Sources: CORES, GASNAM.*

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	34
	B30 or higher	4
Bioethanol blends	E15 or lower	2
	E85	4
LPG		734
Natural gas		98

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 specially 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 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 research, development, and innovation 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 (biofuels for transport, biogas and biomass for electricity generation and thermal uses, bioproducts, etc.). 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 Draft Law on Climate Change and Energy Transition also contains provisions on the establishment of a quota obligation for sustainable aviation fuels.

Additional Information Sources

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

Major changes

The integrated National Energy and Climate Plan is the new framework for renewable energy in the transport sector, including biofuels. It has been developed in accordance with the revised Renewable Energy Directive for the period 2021-2030.

The “Hydrogen Roadmap: a commitment to renewable hydrogen” has been approved. It contains measures and targets for hydrogen development in Spain. As regards transport, specific milestones by 2030 have been set in relation with vehicles fleet and filling stations.

A regulation on the biofuels certification mechanism and a list of feedstock which can be used for biofuel production (including double counting raw materials) has been issued by the Biofuels Certification Entity.

A draft Royal Decree aiming to set new mandatory targets for biofuels in 2021 and 2022 has been published.

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 ($8,400 US).

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 2020, the reduction obligation was 4.2% for petrol and 21% for diesel. A current proposal from the government states increased levels up to 2030. In 2030, the proposed levels are 28% for petrol and 66% for diesel. However, at the time of writing, the levels have not yet been decided. 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.

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 10 million tons in 2019. 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 2019 (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.

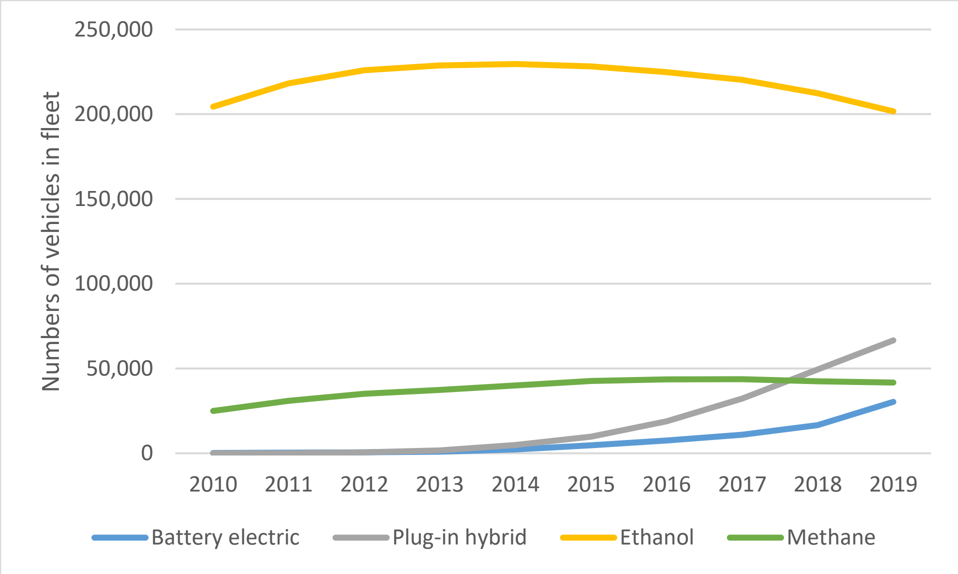

Fig. 1. Number of Advanced Motor Fuel Passenger Cars in the Fleet, 2010 – 2019

The alternative-fueled vehicles correspond to 7% 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 2% and 1%, respectively. However, for buses, the share of vehicles registered as other than petrol- or diesel-fueled is around 20% 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, but from a low absolute number.

The use of renewable biofuels for transport in Sweden amounted to 17 terawatt hours (TWh), or 23% of the transportation fuels sold during 2019 (see Fig. 2). Around 85% of the renewable fuel used in Sweden during 2019 was hydrotreated vegetable oil (HVO) and fatty acid methyl ester (FAME).

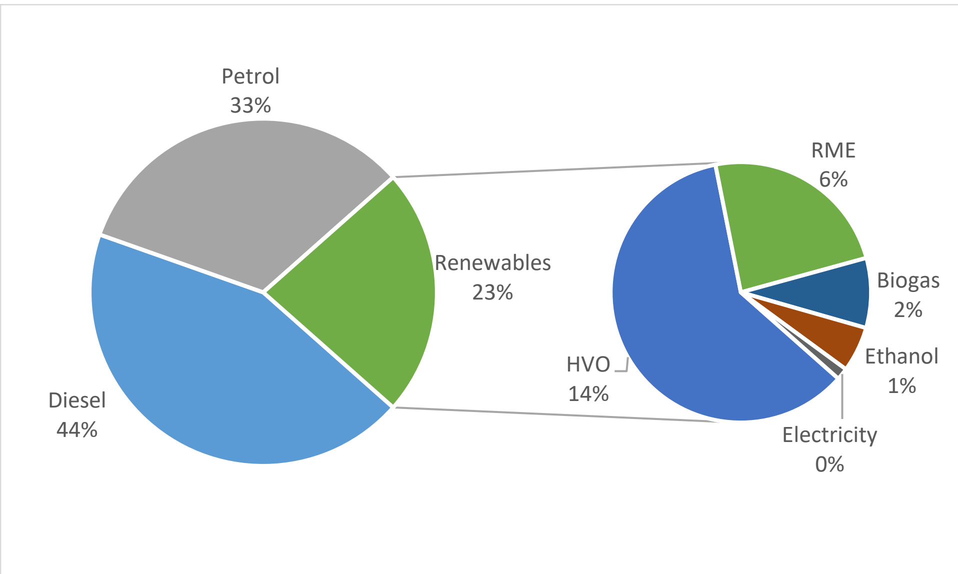

Fig. 2. Fuel Consumption in TWh within the Road Transport Sector during 2019

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. Today, the raw materials are palm fatty acid distillate (PFAD), slaughterhouse wastes, crude tall oil, corn and palm oil 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 2019 corresponded to 8 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.

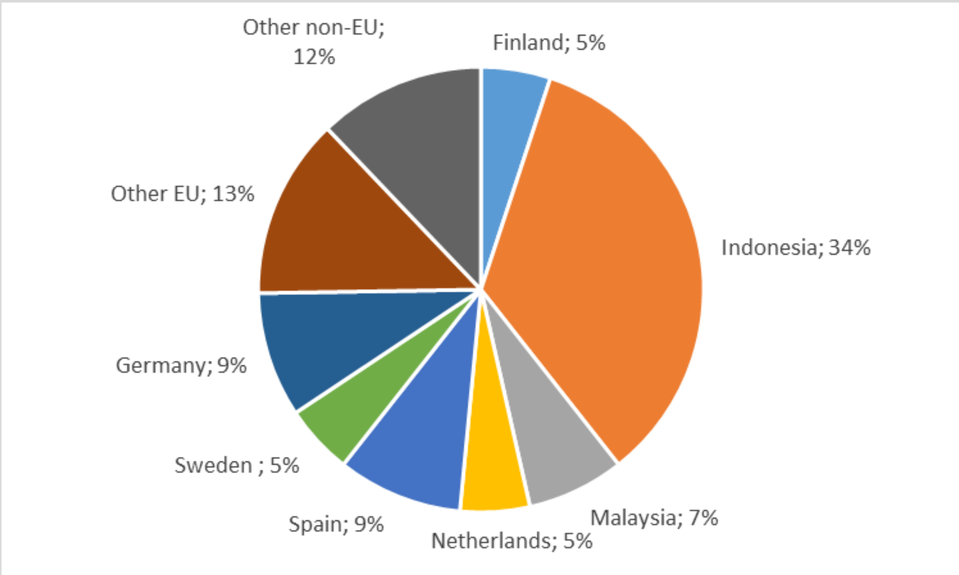

Fig. 3. Country of Feedstock Origin for HVO Consumed in Sweden in 2019

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% 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

After three years of debating revision of the CO_2-Act, the Swiss Parliament passed it in September 2020 [1]. The revised act is 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. Three months later, an optional referendum came to pass. In Switzerland, with a total of 5.5 million voters, only 50,000 signatures are needed to launch a referendum against a new act. Thus, the voters will decide whether to accept or reject the revised CO_2-Act.

Many measures concern the building sector, where fossil-fueled heating systems will be banned in new buildings and a levy of up to €200 per ton CO_2 ($220 US) may be imposed. The mobility sector must also make a substantial contribution to reducing CO_2 emissions. 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. A portion of the climate protection measures financed by the fuel price must be reserved for electric transport or the development of alternative drive concepts. In the parliament's view, this can contribute to the long-term reduction of transport-related CO_2 emissions. In order to finance the corresponding measures, the fuel price can be increased by up to €0.09 ($0.10 US) until 2024 and €0.11 ($0.12 US) after 2025.

It is expected that this will lead to a strong increase in electricity demand for electromobility and heating of buildings (heat pumps). This challenges the energy law in force since 2017 [2], which stipulates a gradual phase-out of nuclear energy, which today covers about 35% of electricity demand in Switzerland. The targets can therefore only be achieved by reducing electricity demand in other areas, and through an expansion of hydropower and new, renewable energy sources.

CO_2 Emission Regulations for Cars

Since 2015, Swiss car importers must pay a penalty if the average new passenger car fleet exceeds 130 g CO_2/km based on the New European Driving Cycle (NEDC). In 2019, the average was 138.1 g CO_2/km, and the penalty amounted to €78.1 million ($86.8 million US) [3]. As of 2021, reduced CO_2 emission regulations apply for new cars. The average level of new passenger cars may not exceed 95 g CO_2/km) and light commercial vehicles (vans up to 3.5 metric tons) 147 g CO_2/km. The limit values will be adjusted and measured with the new World Harmonized Light-Duty Vehicles Test Procedure (WLTP).

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 [4]. The compensation rate was established at 2% in 2014, and was raised to 10% in 2020. In the new CO2-Act, 15% must be compensated from 2021 and 20% from 2025. Importers of fossil motor fuels have to achieve a minimum of 3% by electrification and CO_2-neutral powertrains. For the rest they 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 €0.64 ($0.80 US) 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 [5]. To offset the loss of tax revenue from this tax cut, the fossil fuel tax will be increased until 2028.

Advanced Motor Fuels Statistics

The following numbers and statements are all based on 2019 statistics. This therefore does not represent the impact of the Covid-19 pandemic in 2020.

Final total energy consumption in Switzerland in 2019 amounted to 834,210 terajoules, of which 36.2% was transport fuels (Figure 1) [6]. Compared to 2018, fuel consumption increased only by 0.1%. Only minor changes in specific applications were made in 2019: diesel, 0.0%; gasoline, −0.8%; and aviation fuels, +1.0%. In the same period, the total amount of engine-driven vehicles increased by 0.8% to 6,160,262. Fuel consumption by vehicle has not changed. With a share of 52.4% in 2019, the consumption of diesel was higher than the use of gasoline (43.8%), biofuels (3.5%) and natural gas, including biogas (0.3%). All fossil fuels were imported.

Electricity is used for railroad transportation, and a small amount is used for electric cars. Despite an impressive annual increase of electric vehicles (2016, +42%; 2017, +36%, and 2018, +32%, 2019, + 50 %), the total amount is still very small (28,716 passenger cars are a share of 0.5% of total) [7].

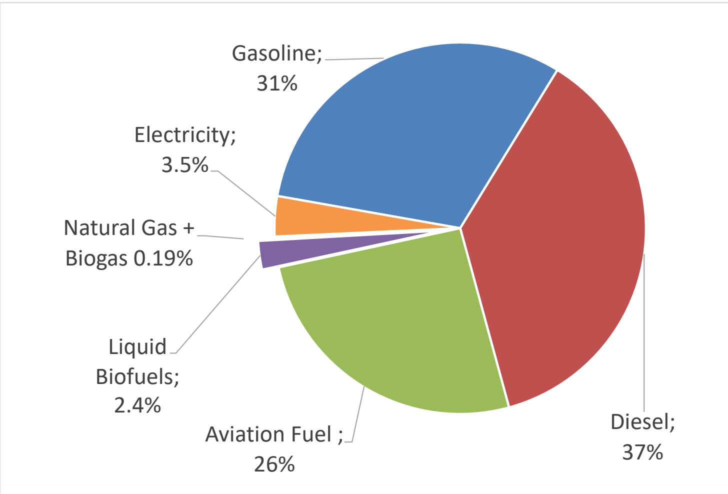

Fig. 1. Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland, 2019 [6]

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 73.3 million L to 260.2 million L. In 2019, 167.5 million L biodiesel and 64.2 million L bioethanol were used (Figure 2). Hydrotreated vegetable oil has only been used in Switzerland since 2016 (2019: 28.5 million L). Pure vegetable oil fuel is almost negligible (0.043 million L). Upgraded biogas as a transport fuel remained at a low level of 3.0 million kg [8].

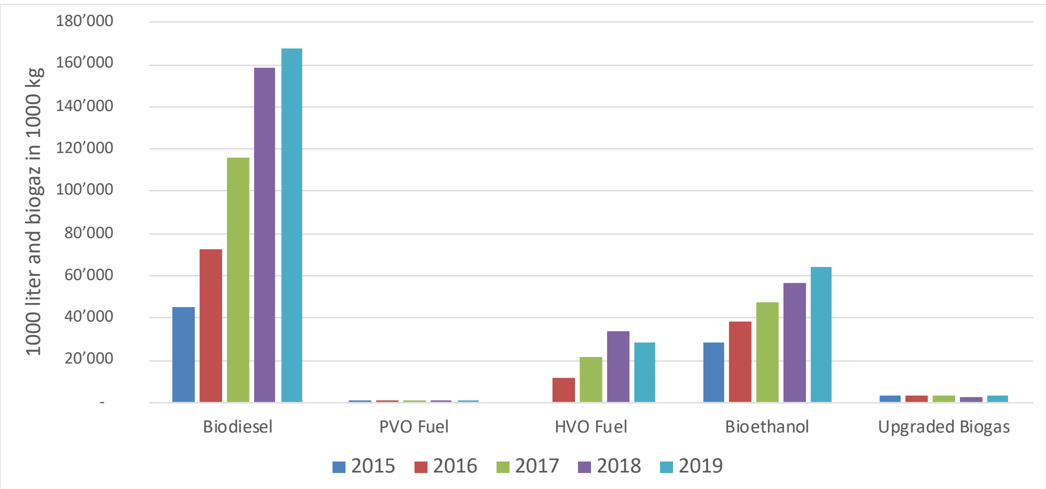

Fig. 2. Development of the Use of Biofuels as Motor Fuels in Switzerland, 2015–2019

Only 13.0 million L of biodiesel was produced in Switzerland. The other 154.5 million L was imported (Germany, 50.9%; Japan, 21.4%; France, 13.0%; China 10.4% and the rest from five other countries). All bioethanol is imported (Poland, 34.8%; Sweden, 18.0%; Norway, 15.6%; Italy, 14.3%; Germany, 10.8%, Holland, 8.6%; and the rest from three other countries) [9]. Hydrotreated vegetable oil is imported from the United States, 99.8%; and China, 0.2%).

The total amount of biogas produced and used in Switzerland in 2019 was 109 million kg. Only 28.4 million kg has been upgraded and fed into the natural gas grid. From this, a small amount (2.9 million kg) has been sold as biogas for cars, and the rest for heating [8]. 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 3 shows the development of the use of biogas and natural gas as motor fuels in cars. Despite an increasing amount of biogas fed into the natural grid, the demand for it as a motor fuel remains at a low level while 89% of biogas is used for residential heating [10].

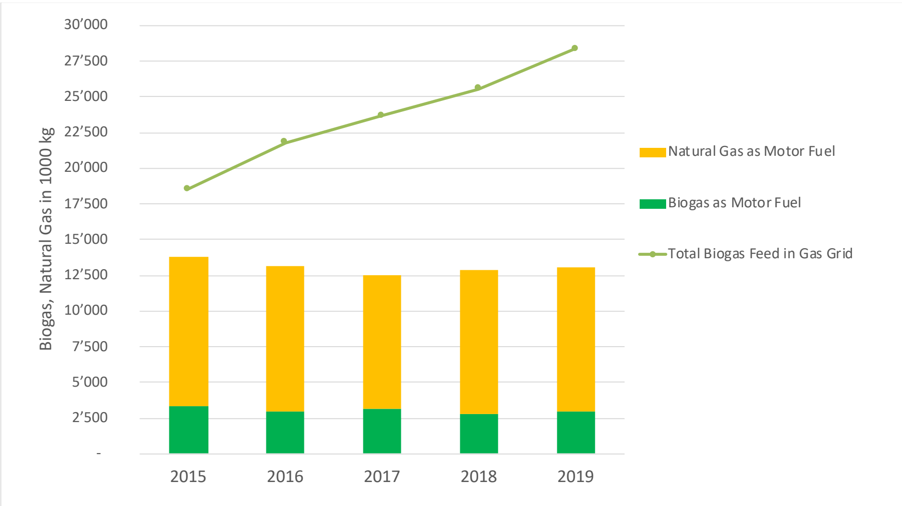

Fig. 3. Development of the Use of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

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 [11]. In addition, Swiss Competence Centers for Energy Research support coordination, improve collaboration, and increase capacity building. One center is dedicated to mobility [12] and another to bioenergy [13], including liquid and gaseous biofuels. Examples of ongoing research projects are detailed below.

Development of alternative biogas transport solutions

In Switzerland, there is currently still a large unused biomass energy potential, especially of farmyard manure from rather small-scale farms. Many of these sites are geographically difficult to develop and are not connected to the gas grid, so road transport of biomethane is an alternative. The organization fahrBiogas has analyzed the economic viability of eight different scenarios for small to medium-sized biogas plants (20 Nm3/h to 80Nm3/h raw gas), as well as explanations on how to deal with technical or regulatory hurdles [14]. It can be seen that in all scenarios, raw biogas production represents the largest cost block, followed by — depending on the scenario — biomethane production or transport. Transportation costs account for 14% to 38% of the total costs. The calculations show that transport by road can be economical for small or medium-sized biogas plants. However, since many factors have an influence, each case must be considered individually. As a general guard rail, the calculations made on the basis of current assumptions show that the raw gas costs must be lower than €0.10/kWh ($0.12 US) and the biomethane processing costs lower than €0.07/kWh ($0.08 US) in order to finance a transport solution at current energy sales prices.

Use of LBG (liquefied biogas) for Swiss heavy-duty transport is investigated in a pilot project. The conditions under which the use of LBG is energetically, technically and economically feasible are evaluated. For this purpose, all energetically relevant influencing variables in the entire value chain of a concrete LBG source of supply are examined, summarized and evaluated in a well-to-wheel analysis. Additionally, to the legal PEMS-RDE (Portable Emission Measuring System for Real Drive Emissions) measurements of the investigated trucks, measurements of several non-legislated components are carried out in the real-world application by means of a portable FTIR (Fourier-Transform-Infrarotspektrometer). [15]

Fig. 4. Truck Fueled with Liquefied Biogas and with FTIR-PEMS Measurement Installation (Source: AFHB)

Investigations of the suitability of DME as an alternative fuel in heavy-duty vehicles. Dimethyl-ether (DME) is a fuel well suited for compression ignition engines, and it can be produced from several renewable sources. To use DME, the fueling system needs to be adapted. Because DME contains oxygen, an interesting NO_x-soot-efficiency trade-off can be expected, especially if exhaust gas recirculation is used. Within this project, a modern heavy-duty engine will be optimized for the use of DME. [16]

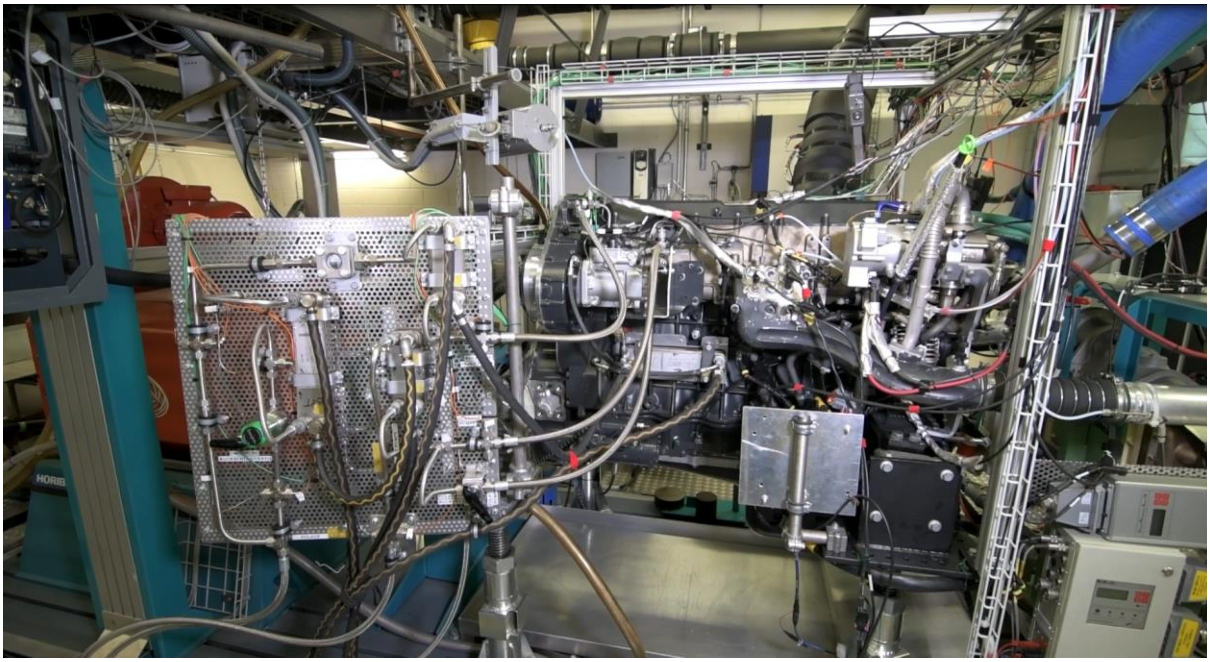

Fig. 5. Test Bench with 6-Cylinder Heavy Duty Engine Fueled with DME. The Low Pressure DME Circuit Feeding the High Pressure Common Rail Pump is on the Left. (Source: EMPA)

New combustion processes for hydrogen engines are investigated in two projects. In a computational study, the potential of a hydrogen engine operated at stoichiometry with exhaust gas dilution is explored. Data on achievable power density, conversion efficiency and minimal NO_x-emissions and a comparative assessment vs. the well-understood lean-burn concept will be provided. In a second project, a combustion engine operating with hydrogen as fuel by using the multi-jet ignition will be built. The goal is to operate the engine with higher air/fuel ratio range and meet the EURO 7 standards without any exhaust after-treatment system. [17,18]

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. In the past, the focus was on natural gas and biogas and it has recently changed to a variety of electro-fuels. This include H_2, methanol, NH_3, DME, and OME. The engines developed for these fuels are intended for long-distance transport, marine transport and different off-road applications.

Additional Information Sources

[1] Federal Office for Environment (FOEN), "Totalrevision CO_2 Gesetz"
[2] The Federal Council, 2017, "730.0 Energiegesetz (EnG)"
[3] SFOE, 2019, "CO_2-Emissionen von Neuwagen …im Jahr 2019"
[4] FOEN, 2012, "CO_2 emission compensation: motor fuels"
[5] Mineralölsteuergesetz (MinöStG), Stand: July 1, 2020
[6] SFOE, 2019, "Gesamtenergiestatistik 2019"
[7] Swiss Federal Statistical Office (BFS), 2020, "Mobility and Traffic"
[8] SFOE, 2020, "Schweizerische Statistik erneuerbarer Energien 2019"
[9] Swiss Custom Administration, 2020, "T2.8 Biogene Treibstoffe 2019"
[10] Association of the Swiss Gas Industry, 2020, "VSG-Jahresstatistik"
[11] www.bfe.admin.ch
[12] www.sccer-mobility.ch
[13] www.sccer-biosweet.ch
[14] https://www.aramis.admin.ch/Grunddaten/?ProjectID=41447
[15] https://www.aramis.admin.ch/Grunddaten/?ProjectID=47462
[16] https://www.aramis.admin.ch/Grunddaten/?ProjectID=41773
[17] https://www.aramis.admin.ch/Grunddaten/?ProjectID=47343
[18] https://www.aramis.admin.ch/Grunddaten/?ProjectID=44967

Major changes

Swiss Parliament passed in September 2020 a revised CO_2-Act. The transport sector is thus also being burdened with further requirements aimed at reducing CO_2 emissions.
A referendum will be held before it enters into force.
Swiss car importers must pay a penalty if the average new passenger car fleet exceeds 130 g CO_2/km. In 2020 they had to pay €78.1 million ($86.8 million US), the highest penalty ever. A total of 314,000 new vehicles were registered and the average was 138.1 g CO_2/km.

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 in this field.

United States

Drivers and Policies

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 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 1.1 billion gasoline gallons equivalent (gge), including 764 million gge from alternative fuels/vehicles and 101 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. However, the U.S. Environmental Protection Agency (EPA) failed to finalize, by the required date of November 30, 2020, the volume requirements and associated percentage standards under the RFS program for calendar year 2021 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The EPA also failed to finalize the volume requirement for biomass-based diesel for 2021.[45] The pandemic reportedly complicated the rulemaking process, but the EPA is expected to finalize volumes in 2021.

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 amount of biofuels — about 2.2 billion gge — were used in California in 2019.

Advanced Motor Fuels Statistics

The U.S. Energy Information Administration (EIA) estimated that total U.S. transportation energy consumption for the first 11 months of 2020 was 20,183 trillion British thermal units (Btu), 23% lower than the same period in 2019.[46] 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 1,151 trillion Btu during these 11 months, natural gas for 919 trillion Btu, electricity for 20 trillion Btu, and propane for 7 trillion Btu.[47]

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.[48] Each RIN is equivalent

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45 Franey, B., 2021, What to Expect from the Renewable Fuel Standards Program in 2021, Lexology, January 11.
46 *EIA Monthly Energy Review*, February 2021.
47 Ibid.
48 EPA, 2021, EPA Moderated Transaction System, January.

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 fell from 18.2 billion gallons in 2019 to 16.5 billion gallons in 2020 due to reduced fuel consumption during the pandemic.

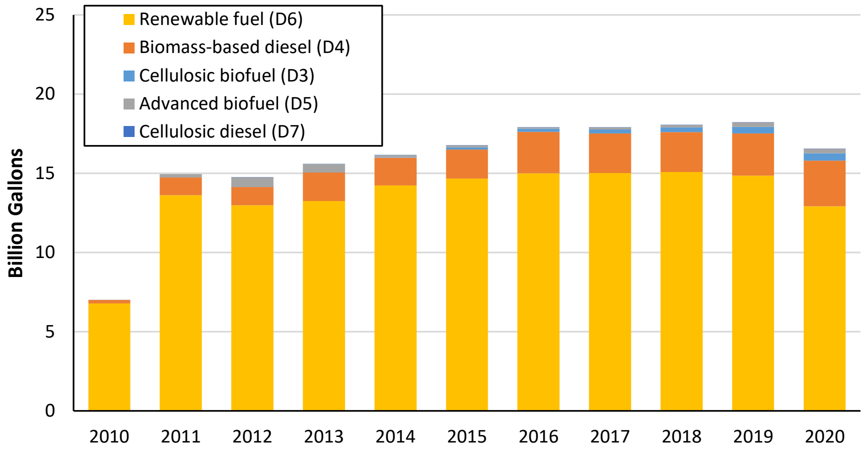

Fig. 1. Renewable Fuel Volumes Resulting from U.S. Renewable Fuel Standard

Electric Vehicles

Sales of plug-in electric hybrids (PHEVs) and battery electric vehicles (BEVs) in 2020, totaling 297,939, were down compared to 325,839 in 2019.[49] However, 442,799 hybrid electric vehicles (non-plug in) were sold in 2020, up from 400,746 in 2019.[50] Available plug-in models totaled 129 as of February 2021, up slightly from 125 in February 2020.[51]

Alternative Fuel Infrastructure

The DOE's Alternative Fuels Data Center provides the number of alternative fuel refueling stations in the U.S.[52] As seen in Table 1, the total number of alternative fueling stations, exclusive of electric recharging stations, in the U.S. increased by 31% between 2012 and 2020. However, the number of natural gas (CNG and LNG) and liquefied petroleum gas (LPG) stations decreased slightly in 2020. The total number of public and private nonresidential electric vehicle recharging outlets jumped by over 700% over this same 8-year period, with a nearly 25% gain in 2020 as well.

Table 1. Number of U.S. Alternative Fuel Refueling Stations by Type, 2012–2019 (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

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

49 Argonne National Laboratory, 2021, "Light Duty Electric Drive Vehicles Monthly Sales Updates"
50 Ibid.
51 DOE, 2021, Alternative Fuels Data Center, "Availability of Hybrid and Plug-In Electric Vehicles"
52 DOE, 2021, "Alternative Fueling Station Counts by State"

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.[53]

Beginning in 2016, the Co-Optimization of Fuels and Engines, or Co-Optima, initiative was led jointly by DOE's VTO and Bioenergy Technology Office (BETO). The goal of Co-Optima is to identify and evaluate technology options for the introduction of high-performance, sustainable, affordable, and scalable co-optimized fuels and engines. For example, molecular-level investigation has led to the identification of several new fuels with desirable properties, such as 4-butoxyheptane, which shows potential for production from corn stover, high performance, low soot and greenhouse gas emissions, and compatibility with existing diesel engines and fueling infrastructure. Co-Optima includes both spark ignition and compression ignition. Identified metrics include:

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

Fiscal 2021 (running from October 2020 through September 2021) will be the final year of the Co-Optima initiative. Follow-on work will examine greater levels of carbon reduction than was originally targeted in Co-Optima.

The DOE's BETO promotes 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 both fuels and high-value chemicals.

Outlook

The EIA's *Annual Energy Outlook 2021* projects decreasing on-road transportation energy use from 2020 through 2043 due to mandated increases in fuel efficiency. However, growth in travel demand will outpace these benefits and energy use will increase from 2044 to 2050.[54] Current laws and regulations are not projected to induce much market growth for alternative fuel vehicles. BEV sales are projected to only increase from 1% to 7% of total light-duty vehicles sold in the U.S. from 2020 to 2050, due to falling battery costs. In 2050, PHEV and hydrogen fuel cell vehicle (FCV) projected sales are small, at 1.0% and 0.03% of sales, respectively. In 2050, projected sales of light-duty BEVs, PHEVs, and FCVs reaches about 8% of projected total sales of light-duty vehicles, while projected sales of those powertrains in medium- and heavy-duty vehicles reaches 1% of sales.

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/

[53] DOE, 2020, *Co-Optimization of Fuels & Engines FY19 Year in Review*, DOE/EE-2055, June.
[54] 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 29 member 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
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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
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[a] Numerical order by annex.

If you have specific questions about an annex, please contact the representatives of Operating Agents as given above.

4.b.iii
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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 2020

Special Report: Ammonia Application in IC Engines

This report compiles the investigations to date of ammonia as an engine fuel and, from the reported issues, draws conclusions about the potential future application of ammonia.

The investigations indicate that passenger vehicles are a large implementation area but need a large re-structuring of the present fuel supply system for the technology to be a success. Additional cons for this area is ammonia's low energy density, which does not promote it as a first choice for a small vehicle. However, engine tests showed good results for an ammonia-fueled SI-engine with a small amount of hydrogen. It seems as if ammonia is most suited for marine engines, where low energy density is of less importance. These engines are mostly based on CI-engines.

Special Report on Ammonia, May 2020
Website

Annex 51: Methane Emission Control

This report identifies the most important mechanisms behind unburned methane emissions from natural gas engines.

Mechanisms include: misfire/bulk quenching, wall quenching, crevice volumes, post oxidation and valve timing/overlap. Particularly low-pressure dual fuel engines are associated with high values of methane emissions. Mixing of hydrogen into natural gas has shown emission and operation advantages. Different oxidation catalyst concepts have shown to be promising for exhaust after treatment. Finally, engine exhaust is found to be the major source of methane slip from NG vehicles.

Final Report, February 2020
Key Messages, February 2020
Website

Annex 54: GDI Engines and Alcohol Fuels

This report assesses the effect of alcohol fuels use in GDI engines.

Ethanol is the most widely used biofuel around the globe. In addition to reducing greenhouse gas emissions, ethanol generally has beneficial effects on both gaseous and particulate matter (PM) tailpipe emissions. Fuel-efficient gasoline direct injection (GDI) engines tend to have high PM emissions and genotoxicity compared to diesel engines. However, both the use of ethanol as a blending component and gasoline particulate filters can alleviate this issue. Annex 54 contributed to the understanding of particulate formation as well as mitigation.

Final Report, February 2020
Key Messages, February 2020
Website

Annex 55: Real Driving Emissions and Fuel Consumption

This report assesses the emissions of passenger cars under real driving conditions and compares them to lab test results.

To obtain reliable fuel consumption and emission data, test procedures have to reflect real driving behavior. Such test procedure further helps ensure compliance of vehicles and identifies defeat devices. The world harmonized light vehicles test procedure (WLTP) could achieve this. Another useful method is on-board measurement through portable measurement equipment (PEMS).

Final Report, February 2020
Appendix to the Final Report, February 2020
Key Messages, February 2020
Website

Annex 56: Methanol as Motor Fuel

This report assesses the use of methanol as fuel in internal combustion engines.

Methanol as motor fuel was demonstrated in large vehicle fleet during the 1980s and 1990s. Despite technical success, methanol was not a commercial success. Recently, there is again an increasing interest in methanol as fuel. Prominent examples are China as the largest user of methanol as automotive fuel and Europe, where methanol is being considered as marine fuel or for use in fuel cell electric vehicles. Internal combustion engines using methanol as fuel could be further developed for high efficiency to gain maximum energy and pollutant savings. However, if methanol will be applied as an automotive fuel with higher blending rates or as pure fuel, technical adjustments of the existing fuel infrastructure are required (e.g., modifications of some fuel-carrying materials, safety measures).

Summary Report, October 2020
Appendices, October 2020
Key Messages, October 2020
Website

Annex 58: The Role of Renewable Fuels in Decarbonizing Road Transport

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.

Final Report – Summary, November 2020
Final Report – Part 1: Key Strategies in Selected Countries, November 2020
Final Report – Part 2: Production Technologies and Costs, November 2020
Final Report – Part 3: Scenarios and Contributions in Selected Countries, November 2020
Final Report – Part 4: Deployment Barriers and Policy Recommendations, November 2020
Website

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

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 €10,250 ($12,065 US)
- Funding for an ExCo delegate to attend two annual meetings
- Cost-sharing contributions to annexes in which you wish to participate; cost shares range from €10,000 to €100,000 ($11,771 to $117,710 US).

Participation in annexes can take place through cost sharing and/or task sharing. The institution participating in an annex 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 62 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 Advanced Motor Fuels Technology Collaboration Programme (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.

Biomass to Liquid (BTL) Fuels

BTL fuel is a type of fuel derived from refining biomass, whether it is a renewable or waste material. Waste animal fats and vegetable oils can be used to create biodiesel. Ethanol can be derived from a vast array of renewable and sustainable sources, including switchgrass, corn, and even sugarcane. Switchgrass is a popular alternative to corn because it does not affect food supplies. Brazil, for example, derives its ethanol from sugarcane. In Europe, BTL fuels are usually used to name synthetic fuels that are produced from lignocellulosic biomass (usually wood chips) via gasification.

Diesel Dual Fuel (DDF)

DDF 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.

Electro-fuel

Electro-fuel 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.

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.

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

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)
BMEL	Federal Ministry of Food and Agriculture (Germany)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Germany)
BMWi	Ministry of Economic Affairs and Energy (Germany)
BTL	Biomass to Liquid
BTX	Biomass
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)
DDF	Diesel Dual Fuel
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
IARC	International Agency for Research on Cancer
ICAO	International Civil Aviation Organization
ICE	Internal Combustion Engine
ICCT	International Council on Clean Transportation
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)
NCRE	Non-Conventional Renewable Energies (Chile)
NEDC	New European Driving Cycle
NECP	National Energy and Climate Plan
NEV	New Energy Vehicle
NGV	Natural Gas Vehicle
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
PtX/P2X	Power to X (Germany)
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)
TEPS	Transportation Electric Power Solutions (Israel)
TOE	Tons of oil equivalent

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)
WHO	World Health Organization
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)
TJ	terajoule(s)
TWh	terawatt hour(s)
W	watt(s)