IEA-Advanced Motor Fuels

ANNUAL REPORT 2019

Technology Collaboration Programme
by iea

IEA Technology Collaboration Programme on

Advanced Motor Fuels Annual Report 2019

The AMF TCP, also known as the Technology Collaboration Programme for Advanced Motor Fuels, functions within a framework created by the International Energy Agency (IEA). The views, findings, and publications of the AMF TCP do not necessarily represent the views or policies of the IEA Secretariat or of all its individual member countries.

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 red spine, which represents action and energy. Throughout 2019, we advanced our mission by updating and modernizing our website, accomplishing diverse work through our annexes, and developing a vision of the future through our strategic plan. These activities, and the many others that drive the AMF mission, embody action and energy.

Cover: We're featuring a ship on this year's cover to highlight the significant addition of a new annex that deals with marine fuels. This notable addition complements our ongoing work on real-driving emissions, alcohol fuels, methane emissions from dual-fuel engines, methanol, heavy- duty vehicles, the role of biofuels in decarbonising the transport sector, and lessons learned from past market introductions of alternative fuels. and marine fuels.

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

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Cover Design: Kate Thomas

Chairperson’s Message

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. We conduct our activities with extensive annex efforts to provide detailed technical results and to synthesize efforts on timely topics on a quick turn-around basis. In 2019, together with Bioenergy TCP and the European Commission, AMF TCP conducted a workshop on decarbonization of transport including the entire chain from feedstock availability to market implementation.

Advanced low-carbon motor fuels are the only measure, aside from curbing mobility, which can reduce GHG emissions from the existing fleet of vehicles. For older engine technologies, advanced motor fuels can contribute to reducing the emission of air pollutants. However, the engine technology itself has the highest impact on the emission formation. Sustainably produced renewable fuels offer a bypass to reducing GHG emissions all over the world. In countries with air quality challenges due to an older vehicle fleet, high-quality alternative fuels offer a reduction in the emission of air pollutants. Advanced motor fuels and engine technologies contribute to both environmental awareness, as specified by the IEA, and to improved energy security by offering new and sustainable fuel pathways.

During 2019, the AMF TCP developed a new strategic plan that was presented to the International Energy Association (IEA) through the Committee on Energy Research and Technology (CERT). As the current chairperson of the AMF TCP, I would like to thank all the member countries and especially Nils-Olof Nylund for a well-formulated strategic plan. We now have a direction to guide our work for the coming five years with broad geographical coverage and a strong focus on energy and emissions. The new strategic plan has already resulted in the start of an annex on the whole range of maritime fuels, from coastal or short sea shipping to ocean-going ships.

In addition to maritime, the AMF TCP will focus on sectors where electrification is challenging. To transform the transport sector to a sustainable system, many solutions and technologies will exist in parallel. Over time, the mix of measures are likely to vary. Advanced motor fuels, applicable to all modes of transport, significantly contribute to a sustainable society around the globe today and in the future.

The current strategic term of AMF TCP will end in February 2020, and our work for the new five-year term has already begun. The contracting parties of AMF TCP identified several areas of significant interest for fuels, vehicles, and system analysis, such as reduction of GHG emissions, assessment of impact and cost, and comparison of energy carriers. **In fuels**, areas of interest are substituting diesel (including substitution of marine fuels); performance evaluation (energy efficiency, GHG, and air quality) of new fuels and technology platforms (with a focus on road vehicles); and conducting (pre) studies of emerging fuels (e.g., electrofuels, ammonia, and alternative aviation fuels). **For vehicles**, areas of interest include real driving emissions, such as deterioration of emission performance over distance; efficiency of heavy-duty vehicles (with possible spill-over toward non-road machinery); and range extender options for electric vehicles. **In system analysis**, we can learn much from comparison of different energy carriers for transport applications (timeline, impact, cost); assessment of drop-in types of fuels versus fuels requiring new vehicles; and new infrastructure.

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

The past five years when I have been the chairperson of the AMF TCP have been very rewarding. During this period, the AMF has implemented several modifications, including key messages for improved communications and a special fund for strategic projects with short start-up time. Now, it is time to pass the torch to a new chairperson. A new strategic term calls for fresh visions and ideas. I would like to thank the AMF TCP for giving me the opportunity to chair the technology collaboration program and I wish the new chairperson all the best.

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, you will not get what you expect — you will get what you inspect!

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 2019, climate changes were exceptionally high on the international agenda. One specific highlight was when 16-year old Greta Thunberg spoke in strong terms at the 2019 World Economic Forum, demanding action against climate change. Widespread forest fires in Australia further increased public awareness and attention to climate changes during 2019.

Within the AMF field of operation, advanced fuels for shipping was an area of focus in 2019. The International Maritime Organization set ambitious climate targets and introduced a global marine fuel standard with 0.5% Sulphur cap. The International Counsil on Clean Transportation (ICCT) doubted the actual benefit of Liquefied Natural Gas (LNG) for shipping, due to the methane slip that occurs with Dual Fuel diesel engines. However, new developments, documented by AMF, showed that methane slip can be reduced dramatically, leading to a much better climate profile of LNG ships in the future.

Winterthur Gas & Diesel introduced a small 2-stroke Dual Fuel marine engine with 2.8 MW suitable for smaller vessels. A 2-stroke engine is less sensitive to cetane and thus more forgiving towards alternative fuels than a 4-stroke. Developments like these increase the confidence in advanced marine fuels.

Advanced fuels for aviation was also high on the agenda in 2019. Some major airlines started using advanced jet fuel (e.g., Hydroprocessed Esters and Fatty Acids (HEFA) jet fuel), for which KLM Royal Dutch Airlines signed a 10-year off-take agreement for 75,000 metric tons per year.

Another major trend in 2019 was the increased focus on electro-fuels. These are not yet economical in comparison with fossil fuels and biofuels, but they may be the primary way forward in the future. Combustion engines can handle any kind of electro-fuel, although ammonia engines still need some work. German research association for combustion engines (FVV) stated in 2019 that cars running on electro-fuels offer lower total cost of ownership than hydrogen or electric cars.

Carbon Engineering stated that it is possible to capture CO_2 from air at a cost of \$94-\$233 USD per ton. That is still above the current cap-and-trade prices for CO_2, but it is not that far above the cost of CO_2 reductions from other technologies (e.g., synthetic liquid biofuel). This supports long-term confidence in Electro-fuels.

The aftermath of the 2015 diesel-scandal was still reverberating in 2019 but is now approaching the end. Its positive outcome has been significantly improved test methods and market surveillance efforts for passenger cars. This was underlined by AMF Annex 55.

Even with the recent tightening of legislation in the European Union (EU) and the United States (US), China 6 is now the most stringent emission regulation for passenger cars in the world. Among passenger cars, the sport utility vehicle (SUV) types are increasingly popular. This is partly why average CO_2 emissions from new cars does not seem to drop. In fact, it was rising in EU through 2019. This accelerates the need for advanced fuels in this segment.

Retrofit solutions for controlling nitrogen oxide emissions on older diesel cars are now becoming available, making them much gentler to the environment, and new diesels both for road and machinery show promising results as well. On the truck side, the diesel-based Scania ED95 has been revived with more power and EURO VI certification. Furthermore, the engine has been modified for methanol combustion by a third party.

Cars running on natural gas or biogas have lagged a bit in terms of efficiency, but that is about to change. A European initiative (Gas On) has shown efficiencies reaching 4045%, which is exceptionally high and should allow for a gasoline-like driving range.

The technological ‘death’ of the combustion engine still seems far away and unnecessary. BMW stated in 2019 that the internal combustion engine will persist for at least 30 more years. Bosch said 75% of new vehicles in 2030 will be internal combustion engines (ICE).

Mazda stated that they will produce electric cars, but only up to 60 kWh. According to Mazda, bigger batteries make no sense in the cradle-to-grave perspective. Anything above 300 km range requires a fuel of some kind.

AMF Annex 56 was able to show in 2019 that a car driven on advanced methanol can deliver a CO_2 footprint of just 40 g/km, which is on par with electric vehicles, even in counties with a very high wind power portion such as Denmark.

In the context of European RED II (Renewable Energy Directive, Phase 2 of 2019), advanced methane can produce a negative carbon footprint of up to 100 gCO_{2eq}/MJ meaning that, essentially, a combustion engine vehicle running on advanced methane could mitigate more CO_2 than an EV running on solar energy.

It is, however, important to highlight that there is no cause for a battle between battery electric, fuel cell and advanced engine drivetrains. At present, non-fossil energy sources cover only 4% of the world's transport energy. This calls for a strong combined effort to cover all modes of transport with the least possible combined environmental impact in the future.

IEA Technology Collaboration Programme for International Energy Agency

Advanced Motor Fuels Annual Report 2019

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	Fachagentur Nachwachsende Rohstoffe (FNR)
India	Ministry of Petroleum and Natural Gas
Israel	Ministry of National Infrastructure, Energy and Water Resources
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 51	Methane Emission Control	Jesper Schramm
Annex 54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
Annex 55	Real Driving Emissions and Fuel Consumption	Thomas Wallner
Annex 56	Methanol as Motor Fuel	Gidi Goldwine,Päivi Aakko-Saksa and Wibke Baumgarten
Annex 57	Heavy Duty Vehicle Evaluation	Petri Söderena
Annex 58	Transport Decarbonization	Dina Bacovsky
Annex 59	Lessons Learned from Alternative Fuel Experiences	Andrea Sonnleitner
Annex 60	The Progress of Advanced Marine Fuels	Kim Winther

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

Magnus Lindgren	Swedish Transport Administration (STA)	Executive Committee Chair
Kim Winther	The Technical Research Centre of Finland (VTT)	Strategy & Technology Subcommittee Head
Dina Bacovsky	BEST – Bioenergy and Sustainable Technologies GmbH	Secretary

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The Advanced Motor Fuels Technology Collaboration Programme

Advanced Motor Fuels Technology Collaboration Programme (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):

- Austrian Agency for Alternative Propulsion Systems (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)
- Fachagentur Nachwachsende Rohstoffe (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 2019, nine projects were ongoing:

- Annex 28: Information Service and AMF Website (AMFI)
- Annex 51: Methane Emission Control
- Annex 54: GDI Engines and Alcohol Fuels
- Annex 55: Real Driving Emissions and Fuel Consumption
- 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

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
- Renewable Energy Technology Deployment

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 Combustion 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 2019

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
51	Methane Emission Control	Jesper Schramm
54	Gasoline Direct Injection Engines and Alcohol Fuels	Debbie Rosenblatt
55	Real Driving Emissions and Fuel Consumption	Thomas Wallner
56	Methanol as Motor Fuel	Gideon Goldwine
57	Heavy-Duty Vehicle Performance Evaluation	Petri Söderena
58	Transport Decarbonization	Dina Bacovsky
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Most of the annexes are continuing in 2020. Annexes 51, 54, and 55, however, were completed in 2019. Final reports and key messages for these annexes are available on the AMF TCP website.

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	€70,000 ($72,963 US) for 2019 €50,000 ($54,920 US) for 2020
Operating Agent	Dina Bacovsky BEST – Bioenergy and Sustainable Technologies GmbH Email: dina.bacovsky@best-research.eu

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.
- 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 2019, additional activities included refreshing the AMF TCP website, and providing a section on the compatibility of biofuels and vehicles to AMF Annex 58.

Refreshing the website was undertaken by a team from Argonne and Bioenergy 2020+ (now BEST). The layout was changed in order to give the website a modern touch and feel. A new landing page was introduced with several modules, each of which contains a visual element (picture/graph) and a paragraph of text. The number of menu items on the first level was reduced to four and some items such as "news" and "events" were dismissed completely. The fuel information subsection was given more visibility as this is the most visited part of the website.

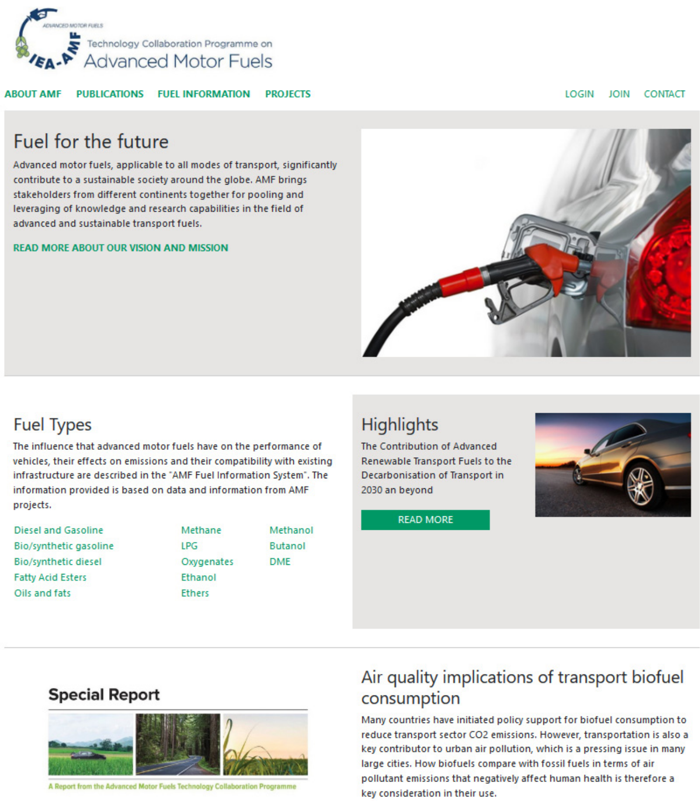

Fig. 1 New landing page of the AMF TCP website

The new layout was implemented in August and now is also adaptive to the width of the viewer´s screen which allows for viewing on mobile devices.

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

Publications

In 2019, three electronic newsletters were published on the AMF TCP website: one each in August, October, and December.

The Alternative Fuels Information System is available on the AMF TCP website. The AMF TCP website is updated frequently with information from Annexes and Executive Committee meetings.

Annex 51: Methane Emission Control

Project Duration	May 2013 - December 2018
Participants **Task Sharing** **Cost Sharing**	Denmark, Finland, Japan (LEVO), Korea, Sweden, Switzerland
Total Budget	To be determined
Operating Agent	Jesper Schramm DTU – Technical University of Denmark Email: js@mek.dtu.dk

Purpose, Objectives, and Key Question

The use of methane (natural gas, biogas) for transport will increase. Although diesel dual fuel (DDF) technology could bring the efficiency of gas engines close to the efficiency of diesel engines, Annex 39 (2010-2014) clearly demonstrated that methane slip remains a serious problem for current DDF engines. Alternatively, advanced spark ignition (SI) technologies (e.g., variable valve trains, cylinder deactivation, and high-level exhaust gas recirculation) could be applied to increase engine efficiency. However, methane catalysts would still be needed because of the unsatisfactory performance and durability of current methane catalysts.

Annex 51 is based on the experience of Annex 39, with the goal of improving engine-out methane emissions, methane catalyst efficiency, and methane emissions from other parts of the vehicle. The annex will also continue to follow up on any information about methane heavy-duty vehicle (HDV) fleets, thus adding to the data already available.

Combustion engines for vehicles can be replaced by or converted to liquefied natural gas (LNG) operation. This conversion has benefits in terms of emissions of CO_2, nitrogen oxides (NO_x), and particulates. Reductions in CO_2 occur partly because the ratio between carbon and hydrogen is less for natural gas than for liquid hydrocarbons (e.g., diesel, gasoline), and partly because the LNG engines can be more efficient than the traditional ones, depending on the combustion principle chosen. With regard to GHG effects, it is a disadvantage that LNG engines emit significantly larger quantities of unburned methane than do traditional engines. Because methane is a GHG 20 times more powerful than CO_2, the overall result could easily be an increase in GHG emissions from vehicles if their engines were converted to run on LNG.

Researchers have considerable experience in studying unburned hydrocarbons in automobile engines. This experience has motivated them to develop engines that emit very low levels of hydrocarbons. Methane, however, is a particularly stable hydrocarbon and is not converted as efficiently as are the other hydrocarbons in combustion engines. At the higher temperatures that occur during the main combustion, the methane is burned as completely as the other hydrocarbons. In colder areas near walls and in crevices, however, some unburned hydrocarbons escape the main combustion. These hydrocarbons are normally post-oxidized in the hot combustion gas, but methane molecules are too stable to be converted at these lower temperatures. This stability also causes problems with regard to converting methane in after-treatment systems like three-way catalytic converters. The onboard storage system for methane (either compressed or liquefied) can also be a source of vehicle methane emissions.

Activities

This annex is comprised of six work packages (WPs).

WP 1: Application of Natural Gas in Combustion Engines

An overview of the application of natural gas in combustion engines for transportation purposes will be given. The project will focus on road and marine transportation, since these are the transport sectors in which the idea of implementing methane in the form of natural gas or biogas dominates.

WP 2: Fundamental Investigations of Methane Combustion

The project will be carried out partly as a theoretical study of the fundamental physical and chemical processes that occur in a natural gas engine. Mathematical models of the processes will be formulated to describe the phenomena that occur during the conversion of the fuel in the engine. The models will describe the influence of the combustion principle (SI or dual-fuel), the combustion chamber geometry, and the application of mixed fuels. For example, mixtures of natural gas and a smaller amount of hydrogen make it possible to reduce unburned methane emissions because the hydrogen promotes the combustion of methane. Methanol/dimethyl ether is another fuel option to promote methane conversion. The models will be verified in experiments in which the relevant engine parameters will be varied.

The unburned methane from engines can be reduced by after-treatment in a catalytic converter in the exhaust pipe. However, it is still difficult to convert the methane at the temperatures that are available. Studies of the most suitable catalyst materials and systems will be carried out, as will studies of the conversion of methane at different concentrations, temperatures, and pressures.

WP 3: Methane Emissions from Parts of the Vehicle Other Than the Engine and Exhaust System

Compared with liquid fuels like diesel, gaseous fuels are more likely to escape from the vehicle. During refueling, the connection and disconnection of the dispensing nozzle could result in small amounts of methane escaping to the ambient air. When both liquefied and compressed methane fuel are being stored, they could be vented to the atmosphere to avoid overpressurization. High-pressure fuel lines and joints could also be a source of leakage that needs to be investigated. The purpose of this project is to study the possibility of methane emissions from parts of the vehicle other than the engine or exhaust system.

WP 4: Natural Gas Application in Light-Duty Vehicles (LDVs)

An overview of the knowledge about unburned methane from today's LDV engines will be given. The study will reveal the available data that can be used for verifying the models developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in these vehicles.

WP 5: Natural Gas Application in Heavy-Duty Vehicles

An overview of the knowledge about unburned methane from today's HDV engines will be given. The study will reveal the available data that can be used for verifying the models developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in these vehicles.

WP 6: Natural Gas Application in Marine Engines

An overview of the knowledge about unburned methane from today's marine engines will be given. The study will reveal the available data that can be used for verifying the models developed in WP 2. Furthermore, the study will focus on both the present technologies that are available and any policies or future plans for using methane-containing fuels in the marine sector.

Main Conclusions

Project results will not only enhance our current understanding of why vehicles emit high levels of unburned methane, but also facilitate determining the best means of reducing these emissions.

Annex 54: Gasoline Direct Injection Engines and Alcohol Fuels

Project Duration	April 2016 - April 2019
Participants	
Task Sharing	Canada, Germany, Israel, Switzerland, United States
Cost Sharing	No cost sharing
Total Budget	~€350,000 (~$400,000 US)
Operating Agent	Debbie Rosenblatt Emissions Research and Measurement Section Environment and Climate Change Canada Email: Debbie.Rosenblatt@Canada.ca

Purpose, Objectives, and Key Questions

Under certain conditions, gasoline direct injection (GDI) may increase particle emissions in comparison to port fuel injection (PFI) engine technologies. Both gasoline particulate filters (GPFs) and alcohol fuel blends, such as E85, have shown the potential to reduce particulate matter (PM) emissions from GDI vehicles.

The objective of Annex 54 was to determine the impacts of alcohol fuels on emissions from GDI engines. In addition to information on combustion processes, the annex focused on gaseous and PM emissions, along with the potential for secondary organic aerosol (SOA) and genotoxic formation. The fuels investigated included ethanol blends (E10 to E85, and E100), methanol blends (M56), and butanol blends. The impact of GPFs and start-stop operation on emissions from GDI vehicles was also investigated.

Activities

Experiments were carried out at the Emissions Research and Measurement Section of Environment and Climate Change Canada.[1] Two light-duty vehicles—one GDI, with and without GPF, and one PFI—were tested on a chassis dynamometer with low-level ethanol blends at 25°C and −7°C.

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[1] Araji, F. and Stokes, J., "Evaluation of Emissions from Light Duty Trucks with and without the Use of a Gasoline Particulate Filter," SAE Technical Paper 2019-01-0971, 2019.

Studies conducted at the Institute of Engineering Thermodynamics (LTT) Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) in Germany provided fundamental investigations of mixture formation and soot formation in an optically accessible GDI engine using laser-based diagnostics. Further characterizations of PM were conducted in the exhaust gas duct of a metal GDI engine. E20, E85 fuel blends and other model fuel mixtures (iso-octane and toluene) and butanol mixtures (Bu20) were studied.

Research conducted under an Israeli-European cooperation between the Technion–Israel Institute of Technology and the Joint Research Centre of the European Commission (JRC) was commissioned by the Ministry of Energy, State of Israel. Emissions tests were conducted with three vehicles, two GDI and one PFI, fueled with gasoline, methanol (M56), and E85.

Switzerland's contribution was provided by the following organizations: Paul Scherrer Institute; University of Applied Sciences Northwestern Switzerland; University of Applied Sciences Bern; and Swiss Federal Laboratories for Materials Science & Technology (Empa).

GDI vehicles, some equipped with GPFs, were tested with ethanol blends (E0, E10, E85) and butanol blends (E10/Bu15 and Bu30). Testing in a smog chamber allowed for a comparison of PM and the genotoxic potential and the SOA formation potential of GDI and diesel vehicles.[2,3]

Through the U.S. Department of Energy's Oak Ridge National Laboratory, a light-duty vehicle equipped with a GDI engine and start-stop operation was tested. Three fuels were evaluated: E0, E21, and iso-butanol (iBu12).[4]

Although Chile was not formally a participant in this annex, relevant findings from studies led by the Centro Mario Molina (CMMCh) were included as supporting information.[5]

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2 EmGasCars, Research of Nanoparticles and of Non-Legislated Emissions from GDI Cars in the Primary Emissions and Secondary Gas and Particle Formation from Vehicles Using Bioethanol Mixtures.

3 Comte, P., et al., "GASOMEP: Current Status and New Concepts of Gasoline Vehicle Emission Control for Organic, Metallic and Particulate Non-Legislative Pollutants," Final Scientific Report of the CCEM-Mobility Project 807.

4 Storey, J., et al., "Characterization of GDI PM during Vehicle Start-Stop Operation," SAE Technical Paper 2019-01-0050, 2019, https://doi.org/10.4271/2019-01-0050.

5 Gramsch, E., et al., 2018, "Variability in the Primary Emissions and Secondary Gas and Particle Formation from Vehicles Using Bioethanol Mixtures," *Journal of the Air & Waste Management Association*, 68:4, 329-346, DOI: 10.1080/10962247.2017.1386600.

Key Findings

- Alcohol fuel blends had generally beneficial effects on both gaseous and PM tailpipe emissions of GDI vehicles.
- The GDI engines equipped with GPFs were effective in reducing PM and particle number (PN) emissions. Some of these results showed PN emissions that could meet the European regulatory limit of 6.0 X 10E11 particles/km.
- A smog chamber study suggested that the rate of secondary pollutant formation in the atmosphere would be slower from GDI vehicles using alcohol blended fuels, thus representing a positive impact on air quality.
- Using the toxicity equivalents approach for eight polycyclic aromatic hydrocarbon (PAH) compounds, the genotoxic potential of the emissions from select GDI vehicles were observed to be higher than a diesel vehicle equipped with a particle filter. It is suggested that catalysed GPFs would reduce the genotoxic potential to that of diesel vehicles.
- The effects of start-stop operation on one GDI vehicle with gasoline alcohol blends were minor and suggested that additional stops and starts after catalyst heat-up would not add significantly to emissions.
- Observations from an optically accessible single cylinder GDI engine showed that soot is formed in fuel rich regions with incomplete evaporation of fuel droplets remaining from the injection event.

Main Conclusions

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 PM tailpipe emissions. Fuel-efficient GDI engines tend to have high PM emissions compared to diesel engines equipped with diesel particulate filters, however, both the use of ethanol as a blending component and GPFs can alleviate this issue. This annex contributed to the understanding of particle formation in GDI engines as well as mitigation.

Publications

Rosenblatt, D., Karman, D. "GDI Engines and Alcohol Fuel." Annex 54 – A Report from the Advanced Motor Fuels Technology Collaboration Programme," Annex 54 Final Report, March 2019.

Annex 55: Real Driving Emissions and Fuel Consumption

Project Duration	November 2015 - November 2019
Participants **Task sharing** **Cost sharing**	 Canada, Denmark, Finland, Sweden, Switzerland, United States No cost sharing
Total Budget	~€400,000 (~$445,000 US)
Operating Agent	Thomas Wallner Argonne National Laboratory Email: twallner@anl.gov

Purpose, Objectives and Key Questions

The levels of air pollutants from internal combustion engine (ICE)-powered vehicles being sold in the marketplace today are much lower than those from vehicles four to 10 years ago. This change is largely the result of technology forcing regulations to control the exhaust emission rates of various air pollutants such as hydrocarbons, carbon monoxide, oxides of nitrogen (NO_x), and particulate matter. Those regulations reflect the extraordinary advances in fuels, engines, and emission control technologies that have been produced by automotive researchers/manufacturers over the past decades. However, there is further evidence to suggest that the performance of vehicles may not be fully captured in compliance or type approval tests, even though they are conducted with varying driving cycles and in an environmentally controlled chamber.

This project aims to develop an emission rate, fuel consumption, and energy efficiency inventory of vehicles driven on-road in varying countries in typical seasonal corresponding climates, using vehicles fueled with advanced, renewable, and conventional fuels. Vehicle performance will be investigated over typical regional driving conditions such as city, highway, arterial, free-speed, and congested routes. In short, the objective of this project is to explore the real driving emissions (RDE) and real-world performance of vehicles operating under a range of worldwide driving conditions.

Activities

The team finalized the Annex 55 formal text in the summer of 2017 and defined the purpose, objectives, audience, and methodologies. The annex members completed the testing and data collection phase in early 2019. On-road testing and dynamometer testing results were shared and compared. Several participants defined their own real-world driving routes.

During a planning conference call of annex participants held in August 2018, a timeline for completing Annex 55 activities was developed, along with a uniform report outline for all Annex 55 member contributions. Based on this timeline, the Annex 55 date was extended from April 2019 to November 2019. Also, it was agreed upon to hold regular conference calls with technical updates. Calls began in September 2018 and continued until the annex was completed in late 2019.

Key Findings

Of the tested vehicles, 94% showed a higher fuel consumption and emission of CO_2 when tested in the New European Driving Cycle (NEDC) compared with the manufacturer declared values. Compared with data from normal use portable emissions measurement system (PEMS), the deviation to the declared values was even higher. If the test procedure better represented real driving behavior, using the Worldwide Harmonised Light Vehicle Test Procedure (WLTP), then the difference was significantly lower, as can be seen in Figure 1.

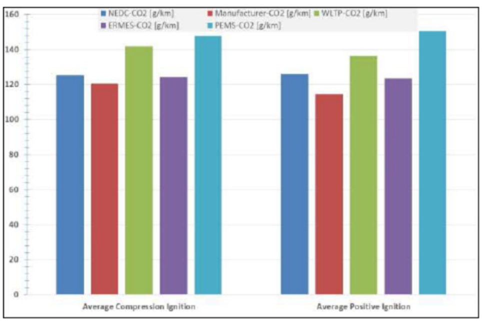

Fig. 1 Average CO_2 emission in g/km for cars with compression ignition and positive ignition engines.

Key findings from the project can be summarized as follows:

- Test cycles have to be developed to represent real driving conditions for certification data (fuel consumption, CO_2 emissions and exhaust gas emissions) to agree well with normal use.
- Real driving testing further helps ensure compliance of vehicles with emissions targets across the entire operating range.

- Engines with compression ignition (diesel) showed better agreement of RDE fuel consumption and CO_2 results compared to certification data than spark-ignited engines (gasoline, compressed natural gas [CNG] and ethanol/E85).
- Low ambient temperature testing assures that after treatment systems are also effective in harsh ambient conditions. Highway driving of diesel vehicles showed little sensitivity to temperature; urban driving resulted in higher NO_x emissions at lower temperatures.
- Real driving methods can help assess the real-world impact of new fuels, e.g. alcohol fuels and paraffins, in different climate regions where cold-starting and other factors could be issues.
- It is not the objective of RDE to achieve maximum repeatability or likeness to WLTP. Rather, it is to ensure the robustness of the emission control in all reasonable operating conditions. Furthermore, RDE seriously counteracts the use of defeat devices.

Main Conclusions

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 identifying defeat devices. The WLTP could achieve this. Another useful method is on-board measurement through PEMS.

Publications

Rosenblatt, D., Winther, K., Petri, S. Lindgren, M., Bütler, T., Czerwinski, J., Duoba, M., Wallner, T. "Real Driving Emissions and Fuel Consumption. A Report from the Advanced Motor Fuels Technology Collaboration Programme," Annex 55 Final Report, November 2019.

Annex 56: Methanol as Motor Fuel

Project Duration	November 2018 – April 2020
Participants **Task sharing** **Cost sharing** **Sponsor**	 Denmark, Finland, Germany, Israel, Sweden Swedish Transport Administration | Trafikverket, Sweden Methanol Institute, USA | Belgium
Total Budget	€ 277,000 ($298,000 US)
Operating Agent	Gideon Goldwine, Technion, Israel Päivi Aakko-Saksa, VTT, Finland (co-sharing), paivi.aakko-saksa@vtt.fi Wibke Baumgarten, FNR, Germany (co-sharing), w.baumgarten@fnr.de

Purpose, Objectives and Key Question

The purpose of this annex is to explore the potential of methanol to act as a motor fuel and to meet global challenges on economy, energy security and climate change. Possibilities to produce methanol economically today creates markets for tomorrow's renewable methanol produced using renewable sources. Different transport sectors will be covered including light-duty and heavy-duty road vehicles, as well as ships. In the marine sector, there are also ambitious current and anticipated regulations on GHGs and other emissions. This annex will identify barriers for commercialization of methanol with suggestions to overcome these barriers.

Activities

Activities in this annex are divided in four work packages (WPs). In addition, reporting is handled as a separate task by three organizations. The following WPs are foreseen:

WP 1: General Issues on Methanol as Motor Fuel, FNR-supported by DBFZ, Germany

The review on the general aspects will include

- 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 what stopped methanol from entering the fuel market earlier
- GHG aspects of methanol/biomethanol
- Cost evaluations

Participants of this annex will send reports and information of the methanol views and activities in their countries to the WP leader.

WP 2: Sector-dependent Evaluations

- Task 2.1, Light-duty sector, DTI, Denmark. The fuels to be considered include M15, M56, M85, M100, MTBE, and GEM fuels.
- Task 2.2, Heavy-duty sector, FNR-supported by DBFZ, Germany. The fuels to be considered include MD95 and M100.
- Task 2.3, Ships, VTT, Finland. The fuels to be considered include diesel/methanol dual fuel and other ship engine developments.

WP2 will handle sector-dependent issues on methanol. Amongst others, the following technical issues will be discussed:

- Infrastructure
- Material compatibility
- Exhaust emission
- Methanol use and research in the participating countries, including ongoing demonstrations
- Potential for future development
- Costs of operation
- Comparisons with selected fuels as appropriate

For example, the review on heavy-duty sector will include aspects according to infrastructure, material compatibility, and exhaust emissions. Cost of operation and methanol R&D projects in the participating countries will be handled limitedly. The assessment is made in comparison to conventional fuels, mainly diesel.

WP 3: Future High-Efficiency Engine for Methanol, Lund University, Sweden

Fundamental combustion research to achieve high-efficiency methanol engines. Next generation engines for alcohols.

WP 4: Barriers to Commercialization, DTI, Denmark

Special contribution in this work is prepared by Nordic Green, Denmark.

Reporting

The final summary report and key message will be compiled by VTT, Finland and DBFZ, Germany. The report will consist of a short summary of all WPs, and the individual task share contributions, which will be added as appendices.

Publications

The final summary report will be made available by the end of the project.

Annex 57: Heavy Duty Vehicle Performance Evaluation

Project Duration	October 2018 - October 2020
Participants **Task sharing** **Cost sharing**	 Canada, Chile, Finland, Japan, Republic of Korea, Sweden Japan and Sweden
Total Budget	~€610,000 (~$671,000 US)
Operating Agent	Petri Söderena VTT Technical Research Centre of Finland petri.soderena@vtt.fi

Purpose, Objectives and Key Questions

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

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 truck measurement program in Chile is delayed because three CV heavy vehicle laboratories have been working on the measurement of electric buses for public transport for the city of Santiago. The test program in Chile covers chassis dynamometer tests of diesel Euro V trucks on 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 tank-to-wheel CO_2 emission and fuel consumption based on longitudinal vehicle dynamics. A fuel consumption map, air drag coefficient, rolling resistance coefficient, and vehicle weight are the main input data of the simulation program. The error between HES results and the chassis dynamometer test results is about 5%. Correlation analysis between HES and VECTO for 21 cases of vehicle data were simulated. The same input data was used for both programs. The coefficients of linear regression and determination are 0.9845, and 0.9932.

Sweden

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

Key Findings

Canada

Tailpipe CO_2 emission rates increased when the vehicles operated with increased payload. NO_x emissions decreased with increased payload likely as a function of exhaust temperature. Emissions of CO_2, CO, NO_x, and hydrocarbons (HC) were highest during the urban driving phase of the RDE tests, which included a cold start. Emission rate differences using the B20 blend compared to diesel were not significant.

Finland

In chassis dynamometer tests, all trucks had gaseous-regulated and PM emissions under the emission limit values independent of testing cycle and load. NO_x emissions were well below the emission limit value. Spark-ignited CNG and dual-fuel trucks had high PN emissions that were higher than the Euro VI limit value. Other trucks, including the spark-ignited LNG truck, had PN emissions below the limit value.

In PEMS testing, according to the Euro VI step C, the conformity factor for NO_x emissions varied between 0.07 and 0.43 depending on the truck. Both SI methane and diesel trucks had low PN emissions in PEMS testing. Dual-fuel trucks had PN emissions well above the emission limit value. However, the reason might be passive regeneration events during the testing.

Sweden

For all tests and fuels, regulated emissions were within legal limits for both chassis dyno measurements and PEMS measurements. For LNG Euro VI step C vehicles, high emissions of N_2O were recorded. A plausible explanation could be a combination of urea injection strategy and SCR technology. Comparative tests with a corresponding diesel engine are ongoing. For the LNG Euro VI step D, no elevated N_2O emissions could be detected.

The CNG vehicles had an energy efficiency that was lower than that for diesel engines, but similar CO_2 emissions. Methane slip was low, except for cold start during which the emissions were slightly increased. PN emissions were significantly higher for the CNG vehicles, especially during cold start. Most of the NO_x emissions from the CNG vehicles were in the form of NO.

Main Conclusions

The main conclusion is that the 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, PN emissions can be substantially higher than in the diesel truck. Energy consumption-wise, the methane-fueled, SI trucks have lower efficiency compared to diesel correspondent trucks, but the CO_2 emissions are similar to each other's, depending on the cycle. No high methane slip was observed for the methane-fueled trucks independent of the combustion method.

Schedule

Annex 57 will be reported in IEA-AMF ExCo meeting 60 in November 2020. Research activities are planned to be due during spring 2020.

Annex 58: Transport Decarbonization

Project Duration	January 01, 2019 – December 31, 2019
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	European Commission Kyriakos Maniatis kyriakos.maniatis@ec.europa.eu
Project Leader	Dina Bacovsky BEST – Bioenergy and Sustainable Technologies GmbH Email: dina.bacovsky@best-research.eu

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.
- **Global context**
  The country assessments are being put into global perspective.
- **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.
- **Workshop**
  A workshop was held in November 2019 in Brussels to discuss the project findings with some 70 participants from the biofuels, the automotive and the oil industry,

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 0 tailpipe emissions). The current policy is depicted in the base case scenario (blue line). If maximizing biofuel utilization, CO_2 emissions can be further reduced (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.

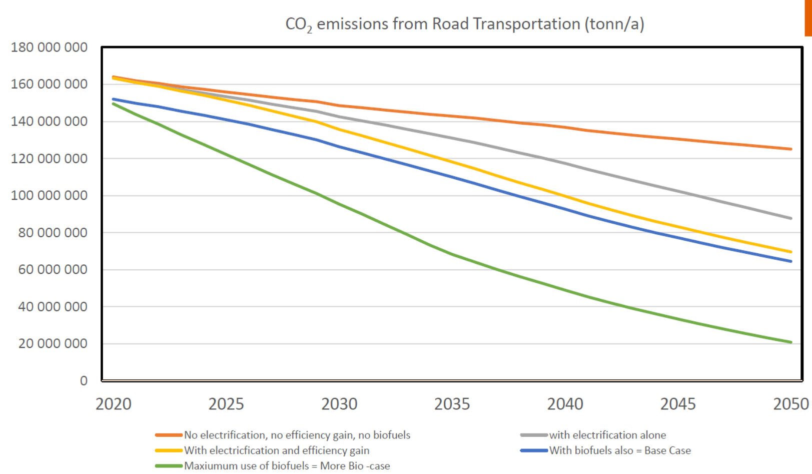

Fig. 2 Scenarios of CO_2 Emissions from Road Transportation for Germany

Main Conclusions

A key message from the project is that decarbonization of the transport sector can only be reached with a set of measures and fuel/energy options, of which biofuels constitute an important part. There is sufficient biomass available to support the large-scale roll-out of biofuels, and current vehicles can accommodate these amounts.

Publications

All workshop presentations are available for download at https://iea-amf.org/content/news/TD-WS. The final report will be published in 2020.

Annex 59: Lessons Learned from Alternative Fuels Experience

Project Duration	April 2019 - September 2020
Participants **Task sharing** **Cost sharing**	 Austria, China, Finland, Japan, Sweden, United States No cost sharing
Total Budget	~€140,000 (~$155,000 US)
Operating Agent	Andrea Sonnleitner BEST Bioenergy and Sustainable Technologies Email: andrea.sonnleitner@best-research.eu

Purpose, Objectives and Key Questions

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.

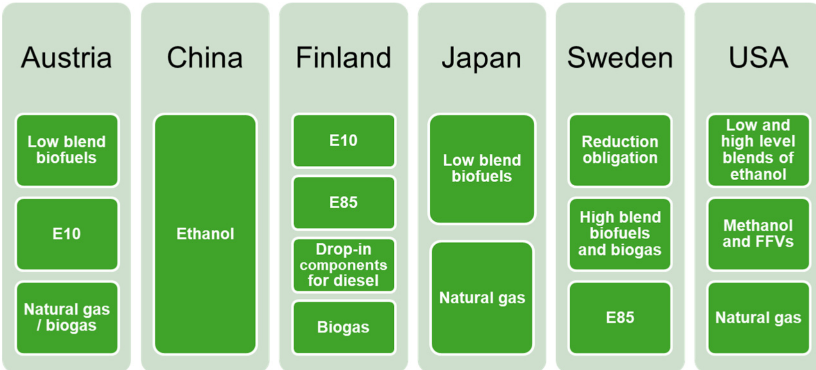

Fig. 1 Overview of the defined specific case studies.

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.

Results will be discussed in an expert workshop with experts from and outside the AMF TCP. 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

Stakeholder interaction

One of the first insights of the project was the complexity of the interaction of the different stakeholder groups. The different groups of stakeholders include automotive industry, motor fuels industry, fuel and vehicle marketers, costumers, government and advocates. For a successful market introduction, the major concerns of all these groups must be addressed and it is beneficial that major issues are not overlooked. Benefits for all stakeholders need to be developed.

Implementation barriers
There are many implementation barriers which can occur within, prior to, or after market introduction of alternative fuels. The findings from the country case studies in the AMF Annex 59 project were clustered into five groups of implementation barriers: Technical issues/Infrastructure, Politics/Authorities, Costs/Economics, Consumers/Public, and Country Specific Barriers.

Importance of policies
Policies are a very important instrument for transitioning the future transport system. A constant political driver is necessary to overcome the peak of implementation barriers. Policy measures need to be strong, comprehensive, and developed with a long-term perspective.

Main Conclusions

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

Publications

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

Annex 60: The Progress of Advanced Marine Fuels

Project Duration	November 2019 – November 2022
Participants **Task sharing** **Cost sharing**	 Canada, Denmark, Finland, Korea, Sweden, Switzerland and USA Methanol Institute
Total Budget	€1.79 million, ($1.9 million US)
Operating Agent	Kim Winther, Danish Technological Institute, kwi@dti.dk

Purpose, Objectives and Key Question

This annex is established to create an assessment of fuel options that have emerged or significantly developed since the 2013 report (AMF Annex 41). The outcome that participants wish to achieve is a better understanding of the potential and limitations of new marine fuel options. The key question that we wish to address is: "How can the new forms of advanced marine fuels contribute to carbon neutral shipping in the future?"

Activities

Activities will include surveys and assessments as well as experiments with methanol engines.

- New IMO 2020 fuel specifications and the problem of standardizing biofuels
- Engines for LNG/Liquefied Petroeum Gas (LPG) mixtures
- Engines for methane/low carbon gas mixtures
- Engines for ammonia and ammonia/hydrogen blends
- Engines and vessels for methanol
- Experiences with biofuels based on organic waste
- After treatment systems for advanced marine fuel engines

Key Findings

Work in this annex has just started and thus no results are available yet. However, we expect to find significant technological development in the use of alternative fuels in ship engines.

The Global Situation for Advanced Motor Fuels

Country Reports of AMF TCP Member Countries

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

GHG Emissions Increase Due to Rising Road Performance

The consumption of diesel and gasoline in Austria was around 8.7 million tons in 2019, according to a market assessment by the Association of the Mineral Oil Industry (FVMI).[6] After a significant increase of 1.6% in the previous year, the number represents a stabilization of total consumption with a modest increase of 0.14% compared to 2018. This was the third year with higher total fuel sales compared to sales recorded in the peak year 2005. The year 2017 is the second year with decreasing amounts of biofuels. The numbers reflect the long-term trend of a rising fuel demand due to (1) an increase of road performance (kilometers driven) in passenger and freight transport and (2) the amount of fuel sold in Austria but used elsewhere as a consequence of higher fuel prices in neighboring countries. Both effects contributed to an overall increase in GHG emissions of +74% between 1990 and 2016 in the transport sector.

Austrian Climate and Energy Strategy: #mission2030

In May 2018, the Austrian government adopted the Austrian Climate and Energy Strategy #mission2030[7], with climate and energy targets for implementing the Paris Agreement. Austria aims to achieve an essentially carbon dioxide (CO_2)-neutral transport sector by 2050. In road transport, the objective is to switch to mainly zero-emission and carbon-neutral vehicles based on renewable energy. Investment in the strategically planned and demand-driven development of infrastructure is included as an essential prerequisite for promoting e-mobility and alternative propulsion systems. Sustainable biofuels, biogas (CNG/LNG), or hydrogen produced from renewable energy will play a crucial role in replacing fossil fuels for applications that are not suitable for electrification, such as long-haul usage of HDVs.

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

6 FVMI: https://www.wko.at/branchen/industrie/mineraloelindustrie/start.html
7 Austrian Climate and Energy Strategy: https://mission2030.info/wp-content/uploads/2018/10/Klima-Energiestrategie_en.pdf

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, NoVA was introduced for taxing the acquisition of new vehicles. As of March 2014, new cars that emit less than 90 g of CO_2/km are exempt from NoVA. 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 million, that is, 1.5% more than in 2018. (See Fig. 1.) Passenger cars, the most important type of vehicle (share: 72%), showed an increase by 1.2% to 5.04 million vehicles and crossed the 5 million mark for the first time in history. (See Table 1.)

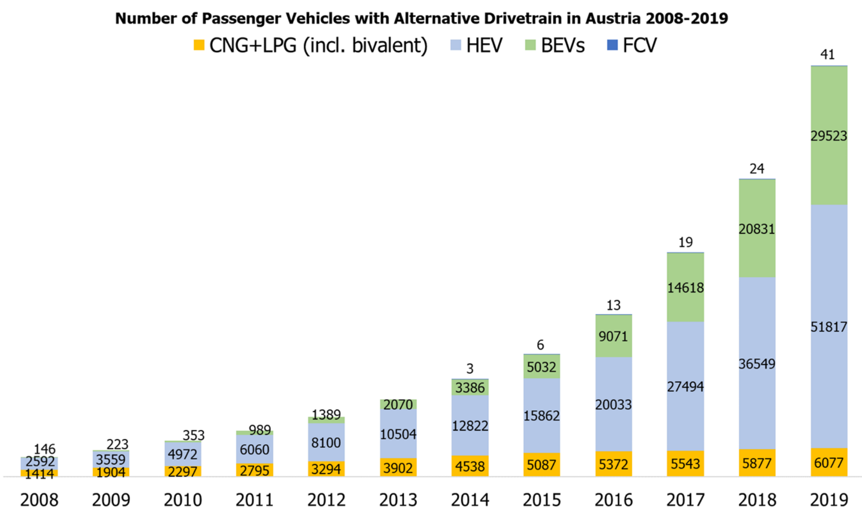

Fig. 1 Trends for vehicles with alternative drivetrains in Austria, 2008-2019
Source: Statistik Austria

An ongoing trend toward advanced alternative propulsion systems can be identified (Fig. 1), especially for battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs). With numbers of 29,523 and 51,817, respectively, the positive trend is evident and follows an exponential trajectory. The number of vehicles driven by CNG and LPG, including bivalent ones, shows a stable linear increase to 6,077. With 41 vehicles, the fuel cell electric vehicle (FCV) fleet is still negligible.

Average CO_2 Emission of Passenger Cars Rises

In 2019, CO_2 emissions for newly registered passenger cars including BEVs, HEVs and FCVs documented an average of 126 g/km. In 2018, it was 123 g/km. For gasoline-powered passenger cars, the value rose from 125 g/km to 128 g/km. Diesel cars recorded an increase in CO_2 emissions from 126 g/km in 2017 to 133 g/km in 2019.

Table 1 Austrian Fleet Distribution of Passenger Vehicles by Drivetrain, 2014–2019
Source: Statistik Austria

Drivetrain	2014	2015	2016	2017	2018	2019
Gasoline	2,004,724	2,012,885	2,031,816	2,074,442	2,133,473	2,173,772
Diesel	2,663,063	2,702,922	2,749,038	2,770,470	2,776,333	2,772,854
Electric	3,386	5,032	9,071	14,618	20,831	29,523
LPG	1	1	1	2	2	2
CNG	2,397	2,475	2,456	2,433	2,365	2,602
H_2	3	6	13	19	24	41
Bivalent gasoline/ ethanol (E85)	6,380	6,254	6,165	5,992	5,769	5,770
Bivalent gasoline/ LPG	279	311	341	335	333	330
Bivalent gasoline/ CNG	1,865	2,300	2,574	2,773	3,177	3,143
Hybrid gasoline/ electric	12,232	14,785	18,696	26,039	34,086	45,645
Hybrid diesel/ electric	591	1,077	1,337	1,455	2,463	6,172
Total	4,694,921	4,748,048	4,821,508	4,898,578	4,978,856	5,039,854

Development of Filling Stations

By the end of 2018, Austria had 2,699 publicly accessible filling stations. As an annual average, the price of gasoline for private use at a filling station was €1.27 ($1.38 US) and the correlating price of diesel was €1.22 ($1.33 US) per liter.

With 152 public CNG stations in 2019, the number of public CNG filling stations has slightly decreased in recent years. For LPG, 42 filling stations are available. 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[8]

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 ($131 million US) in three Energy Model Regions. One such region—WIVA P&G—will demonstrate 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.

klimaaktiv mobil Program

Austria's national action program for mobility management, called klimaaktiv mobil,[9] supports the development and implementation of mobility projects and transport initiatives that aim to reduce CO_2 emissions. Since 2004, 15,000 climate friendly mobility projects have received financial support. Financial support for about 34,300 alternative vehicles, including more than 31,600 electric vehicles, has also been provided. The klimaaktiv mobil website offers a map with details of each project. Total financial support amounted to €122 million ($133 million US) until the end of 2018. In 2018, €13.9 million ($15.2 million US) in funding was available.

Energy Research Program

The Energy Research Program[10] provides research and innovation funding for the introduction and implementation of climate-relevant and sustainable

8 Energy Model Region: https://www.vorzeigeregion-energie.at/wp-content/uploads/Folder-Vorzeigeregion-EN-screen-RZ.pdf

9 klimaaktiv mobil: https://www.bmlrt.gv.at/umwelt/luft-laerm-verkehr/klimaaktivmobil.html

10 Energy Research Program: https://www.klimafonds.gv.at/call/energieforschungsprogramm-2019/

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[11] (Mobility of the Future), is an Austrian national transportation research and development funding program for 2012–2020. 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 ($14.2 million and $20.7 million US).

ERA-NET Bioenergy[12]

In the European Research Area (ERA-NET) Bioenergy, Austria cooperates with Germany, Ireland, The Netherlands, Poland, Sweden, Switzerland, and the United Kingdom in funding transnational bioenergy research and innovation projects. Austria's contribution to the recent 13th ERA-NET Bioenergy Joint Call amounts to €1.0 million ($1.09 million US).

Outlook

Currently, most funding programs and incentives focus on electromobility. As 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 funding shift toward biofuels can be expected.

Austria's current government set the goal to be carbon neutral by 2040, 10 years earlier than the EU's goal. As outlined in the supporting Government Program, alternative energy is identified as critical for reaching that ambitious goal. Based on this political objective, the Austrian Climate and Energy Strategy and NECP are expected to be updated in the course of 2020.

Additional Information Sources

- Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, www.bmk.gv.at/
- Federal Ministry of Agriculture, Regions and Tourism, www.bmlrt.gv.at
- Austrian Association for Advanced Propulsion Systems, www.a3ps.at

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[11] Mobility of the Future: https://open4innovation.at/en/topics/mobility-and-aviation/
[12] ERA-NET Bioenergy: https://www.eranetbioenergy.net/

Canada

Drivers and Policies

Clean Fuel Standard (CFS)[13]

Canada is developing a federal Clean Fuel Standard (CFS) to make fuels used in buildings, vehicles, and industries cleaner. By setting performance standards for various types of fuels, the CFS will encourage the production of clean fuels, drive innovation in the oil and gas sector, and create an incentive to use less polluting fuels. The objective of the CFS is to reduce GHG emissions by 30 million tons (Mt) per year by 2030, making an important contribution to meeting Canada's Paris Agreement target.

Renewable Fuels Regulations (RFRs)[14]

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[15]

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

13 https://www.canada.ca/en/environment-climate-change/news/2017/12/canada_s_clean_fuelstandardhowitwillwork.html
14 https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=1031
15 http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html

Passenger Car and Light Truck GHG Emission Regulations[16]
In 2014, the second phase of action on light-duty vehicles (LDVs) for model years 2017 to 2025, with increasingly stringent GHG standards, were published. Under these regulations, the sales-weighted fuel efficiency of new cars is projected to improve from 8.6 L/100 km in 2010 to 6.4 L/100 km in 2020 and from 12 L/100 km in 2010 to 9.1 L/100 km in 2020 for new passenger light trucks. Canada is currently undertaking a mid-term evaluation of the appropriateness of its standards for model years 2022 to 2025. Improvements beyond 2021 will be determined by the results of this mid-term evaluation.

Heavy-duty Vehicle (HDV) and Engine GHG Emission Regulations[17]
In 2018, the *Regulations Amending the Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations* were published. The amendments established more stringent GHG emission standards, 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.

Advanced Motor Fuels Statistics[18]

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

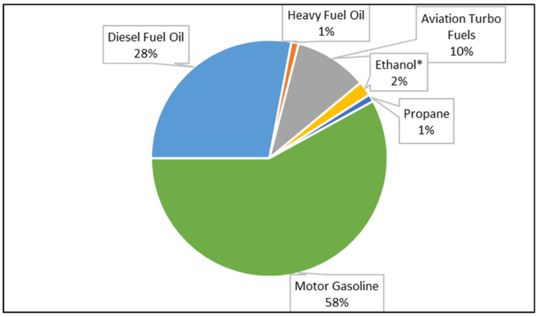

Fig. 1 Fuel Mix of the Canadian Transportation Sector 2018
* Ethanol proportion is estimated on the basis of production data.

[16] https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=104
[17] https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=104
[18] https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/Energy Fact Book_2019_2020_web-resolution.pdf

Table 2 Canadian Supply of and Demand for 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

Research and Demonstration Focus

ecoTECHNOLOGY for Vehicles (eTV) Program[19]
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 electric, CNG, and hydrogen fuel cell vehicles.

Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (EVID)[20]
Natural Resources Canada (NRCan) is investing to expand the network of electric vehicle (EV) charging and alternative refueling stations across Canada. The funding supports the deployment of EV fast chargers; natural gas and hydrogen refueling stations; demonstration of innovative charging technologies and hydrogen refueling infrastructure; and the development of codes and standards for low-carbon vehicles and infrastructure.

Energy Innovation Program (EIP)[21]
NRCan's EIP supports clean energy innovation. 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 transition toward a low-carbon economy.

Program of Energy Research and Development (PERD)[22]
NRCan's PERD supports energy R&D conducted by the federal government and is designed to ensure a sustainable energy future for Canada. Key

19 https://www.tc.gc.ca/en/programs-policies/programs/ecotechnology-vehicles-program.html
20 https://www.nrcan.gc.ca/climate-change/green-infrastructure-programs/electric-vehicle-infrastructure-demonstration-evid-program/20467
21 https://www.nrcan.gc.ca/energy/funding/icg/18876
22 http://www.nrcan.gc.ca/energy/funding/current-funding-programs/perd/4993

research areas focus on knowledge and technology that will help reduce the carbon footprint of fuels and emissions from transportation sources.

Vehicle Propulsion Technologies (VPT) Program[23]
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.

Strategic Innovation Fund[24]
The Strategic Innovation Fund, 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 automotive.

Pan-Canadian Framework on Clean Growth and Climate Change[25]
In 2016, Canada's First Ministers adopted the Pan-Canadian Framework. Along with many other actions to date, the federal *Greenhouse Gas Pollution Pricing Act* was adopted. Also, infrastructure projects including renewable energy projects, electricity interties between provinces, zero emissions vehicle (ZEV) charging and public transit networks are continued.

Clean Transportation System–Research and Development Program (CTS-RD)[26]
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.

Incentives for Zero Emissions Vehicles Program[27]
In 2019, Canada set federal ZEV sales targets of 10% of new LDVs by 2025, 30% by 2030, and 100% by 2040. To help achieve these targets, Canada introduced a suite of new policy measures, including a federal purchase incentive program for eligible ZEVs. Between May 1, 2019, when

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[23] https://nrc.canada.ca/en/research-development/research-collaboration/programs/vehicle-propulsion-technologies-program
[24] https://www.canada.ca/en/innovation-science-economic-development/programs/strategic-innovation-fund.html
[25] https://www.canada.ca/en/environment-climate-change/services/climate-change/pan-canadian-framework-reports/complete-text-for-second-annual-report.html
[26] https://www.tc.gc.ca/en/programs-policies/programs/clean-transportation-system-research-development/apply-funding/applicants-guide.html#Program_description
[27] https://www.tc.gc.ca/en/services/road/innovative-technologies/zero-emission-vehicles.html

the incentive program launched, and December 31, 2019, more than 33,000 Canadians benefitted from the program. Sales of all ZEVs during this period were up 30%, compared with the same timeframe in 2018. ZEV market share in 2019 reached 3% of all new LDV sales, compared with 2% in 2018.

Memorandum of understanding between the California Air Resources Board and Environment and Climate Change Canada[28]
In 2019, California (the most populous U.S. state) and Canada signed a cooperation agreement to advance clean transportation. The agreement 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.

Outlook

As depicted in Table 3, the Canadian transportation sector comprises 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 equivalent)[29]

Transportation Subsector	2005	2020	2030	∆ 2005 to 2030
Passenger Transport	**90**	**88**	**70**	**−20**
Cars, 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.

28 https://www.canada.ca/en/services/environment/weather/climatechange/climate-plan/reduce-emissions/memorandum-understanding-california.html

29 https://unfccc.int/sites/default/files/resource/Canada%E2%80%99s%20Fourth%20Biennial%20Report%20on%20Climate%20Change%202019.pdf

Chile

Drivers and Policies

Chile has acquired and ratified international agreements on GHG emissions and climate change. The country has set itself the objective of promoting the efficient use of energy.

The year 2019 was marked by the search for agreements and the consensus to move toward a more sustainable energy matrix. The initial step was the private public agreement that led to the Decarbonization Plan of the Energy Matrix, with the objective of being carbon neutral by 2050. To achieve this ambitious goal, Chile plans to clean the power generation matrix, in addition to using clean energy in other sectors.

Currently, 40% of the energy produced in Chile is produced with coal, a fuel that generates local pollution and GHG and contributes to global warming. In order to be carbon neutral by 2050, it is essential that Chile reduce the number of power plants that generate energy with coal. The first strategic phase includes the departure by 2024 of eight power plants responsible for a total of almost 1,000 megawatts; these closures had already been announced by the government and by the operating companies. The second strategic phase involves the closure of the remaining 20 coal-fired power plants in the country no later than 2040.

Chile is the country with the highest solar radiation in the world, but it also has enormous wind potential in the south, including a mountain range with approximately 3,000 volcanoes and a coastal edge of more than 6,000 kilometers, which together represent tremendous potential for development of geothermal and marine energies. In fact, non-conventional renewable energies (NCRE), such as solar, wind, geothermal, and others, already generate more than 20% of the electricity consumed in Chile. The country has fulfilled 20% of the goal established for 2025, six years earlier than originally expected.

Regarding transport, 36% of the final energy consumption in Chile corresponds to the transport sector and, of this fraction, 99% corresponds to petroleum products. This sector is responsible for approximately 20% of the country's total GHG emissions.

To meet the challenge of reducing GHGs in the transport sector, the energy efficiency of the country's fleet of vehicles must be improved. Several public projects currently under development have a direct impact on energy efficiency and CO_2 reduction: public/private implementation of a bus system project in Santiago promoting the meeting of emissions standards; measurement of vehicles and their energy efficiency; implementation of energy efficiency standards across sectors, including transport, and promotion of electromobility.

Public Transport of Santiago Bid

A new transportation plan is being offered using an innovative business model in Santiago, the capital and largest city in Chile. In this offer, the bus supply is separate from the operation of the routes.

In November 2019, Chile's government announced a tender for public transport buses in Santiago. In this new model, the buses will be from the State, while the operator will be responsible for the maintenance and the terminals necessary for the operation of the vehicles. The main objective is to separate capital investment from operating expenses. This new system of operation of the buses of public transport for Santiago will allow for the easy replacement of those operators that do not fulfill what was promised; buses will be withdrawn and delivered to a new operator.

The key points of this initiative are:

- Bus supply is separate from the operation of the routes
- More than 2,000 buses of the total current fleet (6,500 buses) will be renovated
- New buses must meet high standards of comfort, safety, accessibility, connectivity and emission control
- In addition to the technical aspects of the tender, buses that have better energy efficiency will have a better assessment weighting.

The most relevant dates pertaining to the new bus transportation offer in Santiago are the call for tender in November 2019, presentation of the offers in February 2020, and adjudication in May 2020.

Implementation of Vehicle Energy Efficiency Regulation[30]

For new light vehicles, Chile became the first Latin American country to implement a compulsory labeling of vehicular energy efficiency in June 2013. In June 2017, this label was expanded to include medium-sized vehicles and electric cars. This allows buyers of new light vehicles, powered by diesel gasoline or electric, to compare their energy performance.

[30] www.consumovehicular.cl

The vehicle label indicating fuel efficiency reports in km/l for petrol or diesel vehicles, or in km/Kwh for electric vehicles. All measurements take into account city, highway, and mixed use driving. The measurements of each vehicle help form a large database. Over the years, these measurements have allowed the development of different studies that will be the basis for the development of energy efficiency regulations and standards for light and medium vehicles.

Project of Law – Energy Efficiency
It is important to improve energy efficiency in different areas of the country, including the housing sector, production sector, transport sector, building sector, and others. In the area of transport, a project of law in Chile proposes defining the energy efficiency standards for fuel consumption in light, medium and heavy vehicles. This project is currently under discussion in the Chilean Congress and was approved by the Senate at the end of 2019, which means it will go on for discussion in the chamber of deputies.

The annex developed different scenarios to define energy efficiency standards initially for light vehicles. Scenarios always consider a baseline obtained from the average performance curve of the vehicle fleet of new vehicles for a given year.

Implementation of energy efficiency standards will be differentiated for the vehicle category. For light vehicles, standards will be measured in the short term; for medium vehicles, standards will be measured in the medium term; and for heavy vehicles, standards will be measured in the long term. The metric that will be used to define these standards will be the energy efficiency in km/l of gasoline equivalent and its equivalence in grams of CO_2/km. Those responsible for ensuring vehicles comply with energy efficiency standards will be importers or representatives for each brand of vehicle sold in Chile. The control of compliance with these energy efficiency standards will be annual. Non-compliance by importers or representatives for each vehicle brand will be sanctioned.

Research and Demonstration Focus

Energy efficiency in buses, and measurement of fuel consumption in Transantiago
Energy consumption measurements in electric buses were made in 2019, in accordance with Ministry of Transport and Telecommunications Resolution 2243, which details technical regulations to obtain energy consumption in urban public transport buses in the city of Santiago . The results can be

found on the website of the vehicle control and certification center belonging to the Ministry of Transport and Telecommunications "3CV": https://mtt.gob.cl/3cv.html (left column: Certificación características funcionales y dimensionales Buses estándar Transantiago).

Evaluation of the performance of heavy vehicles (Annex 57)
The project to evaluate the performance of trucks worldwide is coordinated by "AMF of AIE". The local objective of Annex 57 is to obtain fuel consumption, using a sample of trucks that represents the fleet of vehicles circulating in the cities and roads of Chile. The procedure for carrying out the tests considers:

- The measurement of fuel consumption is km/l
- The type of test is "World Harmonized Vehicle Cycle" (WHVC), with vehicles measured on the chassis dynamometer in all categories
- The measurement site is Emissions Laboratory of the 3CV Vehicle Control and Certification Center, Ministry of Transportation and Telecommunications of Chile.

To begin this program, the measurement of fuel consumption was coordinated with three companies in the field that offer customized trucks. Measurements began in January 2020 and at least six trucks are expected to be measured during the year.

Outlook

Public Private Agreement
Together with the Ministries of Transportation and Environment, the Ministry of Energy leads the implementation of the National Electromobility Strategy through the execution of the proposed actions on the 2018-2022 Energy Route. During 2019, important advances were made. More than 400 electric buses currently operate in the public transport of the Santiago bus fleet. We also anticipate an increase in the already extensive network of electric chargers in Chile and an increasing rate of electric car sales.

To the extent that Chile meets its goal of cleaning its energy matrix (private/public agreement for decarbonization of the energy matrix, with the objective of being carbon neutral by 2050), it can use that clean energy in private vehicles, cargo vehicles and public transport. Therefore, Chile must continue to prepare for this on multiple levels. To date, 54 companies or public/private organizations have committed to improving the energy matrix, namely through the creation of specific financial instruments for investment in electromobility, the development of human capital, the expansion of the supply of electric vehicles, the increase in the number of chargers, and other significant actions.

Additional Information Sources

- Transport: www.mtt.gob.cl
- Pollutant, Environment: www.mma.gob.cl
- Energy: www.energia.gob.cl
- Vehicles Fuel Economy (Label): www.consumovehicular.cl
- Type Approval or Certification: www.mtt.gov.cl/3cv

Benefits of Participation in the AMF TCP

Chile's participation in the AMF TCP facilitates work on energy efficiency projects in the country's transport sector by providing international support. Knowledge of the different programs of the various partner countries enables the implementation of best practices. The exchange of information with international experts from the various emissions laboratories and research centers is an invaluable experience.

China

Drivers and Policies

Technology Roadmap for Energy-Saving and New Energy Vehicles

The Chinese Society of Automotive Engineers released a "Technology Roadmap for Energy-Saving and New Energy Vehicles" for China in October 2016. This newest, comprehensive guideline indicates the direction of energy saving and new energy vehicles (NEVs) in the Chinese automotive industry until 2030. It also takes into account China's "Made in China 2025" initiative, China's policy for becoming a manufacturing powerhouse.

The energy-saving path of alternative fuel sharing will be executed in the field of commercial vehicles. The stable development of commercial vehicles using alternative fuels—mainly natural gas, supplemented by dimethyl ether, biofuel, and methanol/diesel—will be appropriately promoted. Demonstration operations and pilot applications will be conducted.

Expansion of Biofuel Ethanol Production and Promotion of Ethanol Gasoline for Vehicles

In addition to the focus on promoting the industrialization of pure electric and plug-in hybrid electric vehicles, China is expanding ethanol production and use. On September 13, 2017, China's National Development and Reform Commission released a new policy paper on the expansion of biofuel ethanol production and the promotion of ethanol gasoline for vehicles in conjunction with 14 other government organizations, including the National Energy Administration and the Ministry of Finance.

The country aims to roll out the use of ethanol in gasoline nationwide by 2020, and by 2025, China will look to realize the large-scale production of cellulosic ethanol, which is made from plant fibers, making the nation a world leader in biological liquid fuel technology, equipment, and industry. The National Energy Administration gave no indication what level of ethanol would be required in ethanol gasoline, but it is expected to be 10%.

On August 22, 2018, Premier Li Keqiang proposed the overall layout of the biofuel ethanol industry at the State Council executive meeting: "insisting on volume cap control, limited producers, fair access, moderately deploying of grain-based fuel ethanol production; accelerating the construction of cassava fuel ethanol project, and carrying out the industrialization of fuel ethanol utilizing of cellulosic stalk and exhaust gas from steel industry."

Guidance on the Application of Methanol Vehicles in Some Areas
On March 19, 2019, eight departments including the Ministry of Industry and Information Technology of the People's Republic of China issued guidance on the application of methanol vehicles in some regions. The relevant regions should actively create conditions for the application of methanol vehicles, and give preferential policies for the purchase and operation of methanol vehicles that meet the requirements of China's sixth-stage motor vehicle pollutant emission standards and methanol vehicle emission limits.

Policy support will also be offered to efforts to improve efficiency in producing methanol fuel and making equipment that absorbs carbon dioxide emissions. To promote the use of methanol-fueled cars, China will increase the number of methanol cars in places such as North China's Shanxi Province and Southwest China's Guizhou Province. The use of methanol cars for official trips, rental services and other areas will be encouraged.

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.

Advanced Motor Fuels Statistics

In 2019, 191.12 million tons of crude oil were produced in China, an increase of 1% year-on-year. Meanwhile, 381.39 million tons of petroleum products were produced in China, an increase of 3.6% year-on-year. From January to December 2019, China consumed 329.61 million tons of petroleum products (including diesel and gasoline fuels), an increase of 1.4% year-on-year. Of this total, the consumption of gasoline fuels increased by 2.3%, and diesel fuels decreased by 0.5%. Fuel consumption by road transportation vehicles is the main source of total Chinese gasoline and diesel consumption.

Natural gas is another main energy source for vehicles in China. In 2019, China produced 177.7 billion cubic meters (m^3) of natural gas, an increase of 11.5% year-on-year. Meanwhile, China imported 132.2 billion m^3 of natural gas, an increase of 6.5% year-on-year. From January to December 2019, natural gas consumption reached 306.7 billion m^3, an increase of 9.4% from 2018.

In 2019, China's auto production and sales were 25.7 million vehicles and 25.8 million vehicles, respectively, with a year-on-year decrease of 7.5% for production and 8.2% for sales.

In 2018, China had 0.53 million new CNG vehicles, while total ownership reached 6.26 million cars, an increase of 9.2% over 2018. In 2018, there were about 300 new CNG stations, and the total number of stations was 5,600, an increase of 5.7% over 2018. In 2018, more than 90,000 new LNG vehicles were produced, while total ownership reached 0.44 million cars, an increase of 25.7% over the previous year. The total number of LNG stations increased to about 3,400 in 2018.

Research and Demonstration Focus

Promotion of Methanol Gasoline Vehicles Pilot Project

At the end of February 2012, the Ministry of Industry and Information Technology announced the launch of three pilot projects involving methanol vehicles — one each in the Shanxi, Shanghai, and Shaanxi provinces. This indicated that methanol gasoline had entered a new era of development. By the end of 2013, 26 provinces had entered the field, to different degrees, where five provincial governments had organized and implemented the pilot projects.

Under the pilot program, 1,024 methanol fueled vehicles were placed into operation in Jinzhong, Changzhi, Xi'an, Baoji, Yulin, Hanzhong, Lanzhou, Pingliang, and Guiyang, including 904 Geely M100 methanol taxis, 100 M100 methanol buses of Zhengzhou Yutong Bus, five methanol/diesel duel fuel tracks from Shaanxi Heavy Auto Enterprise, and 15 M100 multi-function automobiles from Shaanxi Tongjia Automobile Co., Ltd.

Average vehicle running time is over two years, with the longest running time of three years. The total pilot mileage is over 184 million kilometers, with methanol fuel consumption over 24,000 metric tons. Thirty-two models of methanol vehicle were certified in the pilot. Some cities expanded their methanol vehicle operation fleets, and the total number of methanol vehicles being operated in China reached over 7,000 units in 2019.

In the pilot, health checks were conducted on 1,199 people from a variety of occupations with potential methanol exposure, including vehicle drivers, maintenance workers, fueling station staff, and operators in methanol fuel blending. No human health issues were observed.

Chinese original equipment manufacturers (OEMs) have produced a number of new light- and heavy-duty methanol vehicle models, with 32 models certified by MIIT for commercial sales. Leading the mass production of methanol vehicles, Geely Auto has established production facilities capable of producing 300,000 to 500,000 units of methanol engines and cars at manufacturing bases in China.

Promotion of Ethanol Gasoline Vehicles Pilot Project

China first developed an ethanol fuel industry 15 years ago, when ethanol was employed for the increased utilization of corn in the country. In 2004, 11 provinces used ethanol gasoline, making up one-fifth of the country's total gasoline consumption.

Until the end of 2019, ethanol gasoline was promoted in the Heilongjiang, Jilin, Liaoning, Henan, Anhui, Guangxi, Shangxi, Hebei and Tianjin provinces with a fully closed type. Hubei (nine cities), Shandong (eight cities), Jiangsu (five cities), Guangdong (one city) and Inner Mongolia (three cities) provinces promoted ethanol gasoline with a semi-closed type. Ethanol gasoline has not been rolled out as quickly as expected.

The promotion of ethanol gasoline for motor vehicles in Tianjin started before August 31, 2018. The closed operation in Tianjin was realized on September 30. Ordinary gasoline was basically replaced by ethanol gasoline in the entire city. Tianjin has 874 fuel stations in the city, with an annual sales volume of about 2.5 million tons. According to the standard of adding ethanol, about 260,000 tons of fuel ethanol is needed every year. By the end of July 2019, a total of 1.6 billion liters of ethanol gasoline for vehicles were sold in Tianjin, with 52.5 million vehicles filled with ethanol gasoline.

Outlook

According to the study of the China Industrial Gases Industry Association, China will usher in the golden age of natural gas vehicle development over the next 10 years. According to the national plan, by 2020, China's natural gas (LNG and CNG) vehicle output could reach 1.2 million vehicles per year, including buses and trucks at 200,000 (LNG cars accounting for 50%) and passenger cars at 1 million (LNG cars accounting for about 20%). By 2020, the population of natural gas vehicles will reach 10.5 million, which means the position of natural gas as the number one alternative vehicle fuel will be unshakable.

Plans call for China to develop a demonstration facility by 2020 that can make 50,000 tons of ethanol a year from cellulose, according to the Cabinet's National Energy Administration. The administration said that would expand to commercial scale by 2025. Ethanol gasoline for motor vehicles (E10) will be used in almost 34 provinces of China by 2020.

Within five years, the fleet of M100 vehicles in China could reach 50,000 cars, trucks and buses, consuming more than 500,000 metric tons of methanol.

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), http://www.catarc.ac.cn/ac_en/index.htm
- 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.

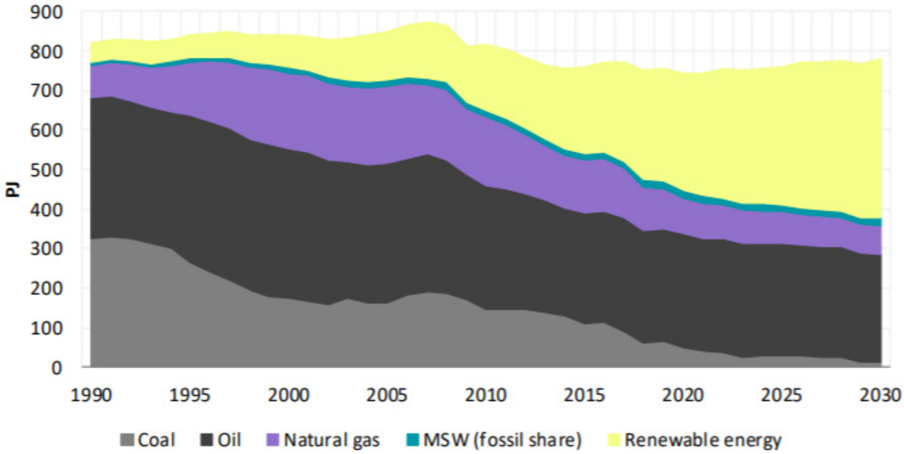

Fig. 1 Gross energy consumption by type of energy 1990-2030 [PetaJoule (PJ)]. The calculation for 1990-2017 has been adjusted for outdoor temperature/degree days relative to normal years (climate-adjusted) and electricity trade with other countries

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).

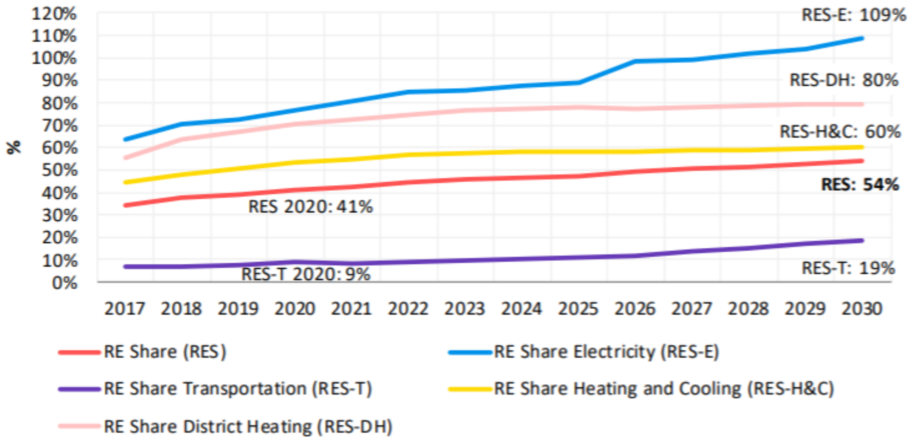

Fig. 2 Renewables shares 2017-2030 [%]. The renewables shares is calculated as defined in the RE Directive (Eurostat, 2018).

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.

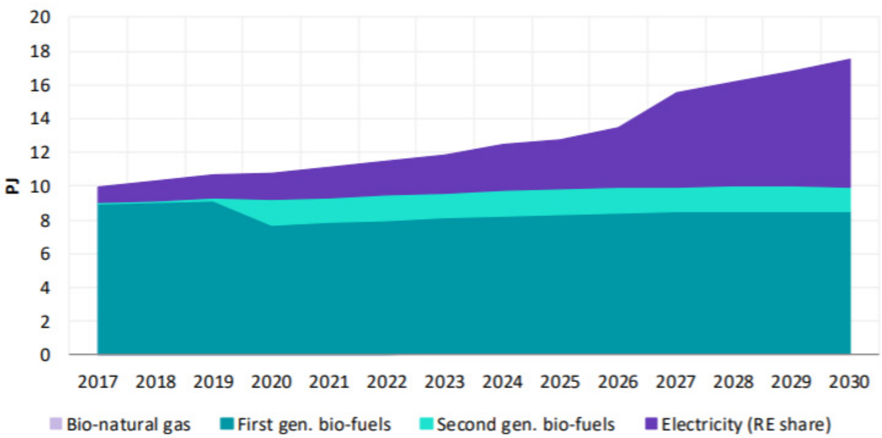

Fig. 3 Renewable energy consumption by the transport sector 2017-2030 [PJ].

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).

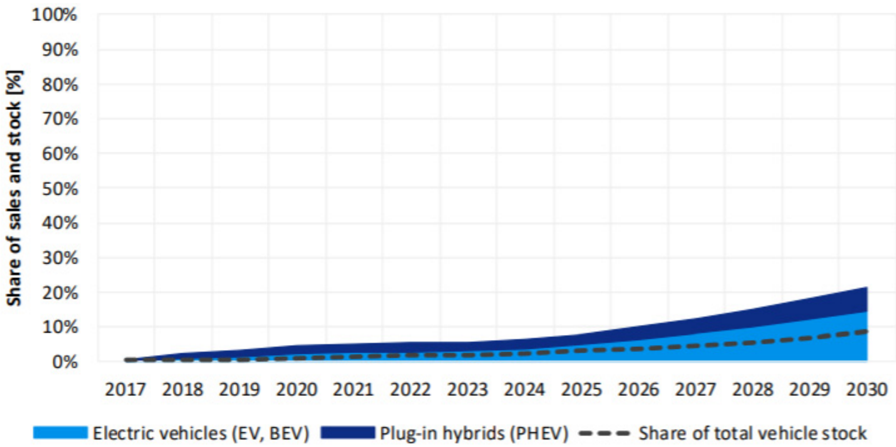

Fig. 4 Electrified vehicles' share of sales of new vehicles and share of total number of passenger cars and vans on the road 2017-2030 [%].

Research and Demonstration Focus

R&D 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 for 2030 calls for a 50% reduction of CO_2 emissions from transport by 2030, the reference year being 2005.[31] Three key measures to reduce emissions are listed, improving the energy efficiency of the transport system, improving the energy-efficiency of vehicles and replacing oil-based fossil fuels with renewable and/or low emission alternatives. The 2019 Government Programme basically follows the 2016 energy and climate strategy, with a couple of additions related to low-emission transport.[32] A new upper level target was set: 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 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.[33]

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 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.[34]

Advanced Motor Fuels Statistics

In 2018, the energy consumption in domestic transport (all modes together) was 181 PJ, and energy consumption in road transport 165 PJ or 3.94 Mtoe (see Table 1). Relative to the total final consumption of 1128 PJ the figures were 16.0% and 14.6%, respectively.[35] In 2018, total CO_{2eqv} emissions were

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[31] https://tem.fi/en/energy-and-climate-strategy-2016
[32] https://valtioneuvosto.fi/en/rinne/government-programme
[33] https://www.finlex.fi/fi/laki/alkup/2019/20190419
[34] Parkkonen, L. (2013). Taxation of petroleum products and vehicles in Finland. CEN/TC 19 Conference. Helsinki, 27 May 2013.
[35] http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/StatFin__ene__ehk/statfin_ehk_pxt_011_fi.px/

56.4 Mt. The emissions from transport were 11.7 Mt (all modes together) and 10.9 Mt (road), 20.7% and 19.3%, respectively.[36,37]

Table 1 Energy in road transport in 20185

2018	PJ	ktoe	Share of fuels (%)	Share of bio (%)
Petrol (fossil)	52.3	1250	31.8	
Biocomp. petrol	3.4	82	2.1	6.2
Diesel (fossil)	96.7	2310	58.7	
Biocomp. diesel	11.8	281	7.2	10.9
Natural gas	0.14	3.2	0.1	
Biomethane	0.20	4.7	0.1	59.1
∑ fuels	164.6	3932		9.4
	PJ	**ktoe**	**Share of total (%)**	
Electricity	0.17	4.0	0.1	
∑ fuels	164.6	3932	99.9	
Total	**164.8**	**3936**		

The contribution of biofuels relative to the total amount of actual fuels is 9.4% in terms of energy, varying from 6.2% in petrol (mostly ethanol, some ETBE and also bio-naphtha, but the statistics do not give details on this) to 59% in methane. In 2018, the biofuels mandate (for liquid fuels) called for a 15% share of biofuels. The actual amount was 364 ktoe or 9.3% 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.[38] As the Finnish consumption of biofuels in 2018 was some 370 ktoe, 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.

[36] http://www.stat.fi/til/khki/2018/khki_2018_2019-12-12_kat_001_fi.html
[37] http://lipasto.vtt.fi/en/liisa/index.htm
[38] https://valtioneuvosto.fi/artikkeli/-/asset_publisher/10616/selvitys-biopolttoaineiden-kustannustehokkaat-toteutuspolut-vuoteen-2030

Table 2 presents the vehicle fleet in use at the end of 2019 (without two- and three-wheelers and light four-wheelers). Table 3 presents the sales figures for new passenger cars in 2015 to 2019.

Table 2 Vehicle fleet at the end of 2019 (in use, without two- and three-wheelers and light four-wheelers)[39]

Fuel	Cars	Vans	Trucks	Buses	Special vehicles
Petrol	1 916 849	9 780	1 764	26	321
FFV[a]	4 298	9	101	0	0
Diesel	760 330	319 769	93 000	12 425	1 738
Methane	3 121	460	84	52	0
Methane bi-fuel	6 255	274	91	0	0
BEV	4 661	312	2	62	0
PHEV petrol	22 653	25	0	0	0
PHEV diesel	2 050	14	0	3	0
Other	90	28	99	9	0
Total	2 720 307	330 671	95 141	12 577	2 059
Fuel	**Cars**	**Vans**	**Trucks**	**Buses**	**Special vehicles**
Petrol	70,5 %	3,0 %	1,9 %	0,2 %	15,6 %
FFV	0,2 %	0,0 %	0,1 %	0,0 %	0,0 %
Diesel	28,0 %	96,7 %	97,7 %	98,8 %	84,4 %
Methane	0,1 %	0,1 %	0,1 %	0,4 %	0,0 %
Methane bi-fuel	0,2 %	0,1 %	0,1 %	0,0 %	0,0 %
BEV	0,2 %	0,1 %	0,0 %	0,5 %	0,0 %
PHEV petrol	0,8 %	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 %

[a] Flexible fuel vehicle.

Table 3 Sales of new passenger cars in 2015 – 2019[40]

Year	Petrol	FFV	CNG	Diesel	HEV P	HEV D	PHEV P	PHEV D	BEV
2015	66248	105	158	38797	2817	29	400	15	243
2016	73251	14	165	39451	4668	11	1115	93	223
2017	70520	1	433	36060	8512	2	2401	152	502
2018	73065	0	1161	28710	11631	224	4797	135	776
2019	67751	0	2142	20871	14582	990	5807	159	1897

[39] https://www.traficom.fi/fi/tilastot/ajoneuvokannan-tilastot
[40] http://www.aut.fi/tilastot/ensirekisteroinnit/kayttovoimat/henkiloautojen_kayttovoimatilastot

The share of alternative fuel vehicles (including electric vehicles) ranges from 1.6% (cars) to 0% (special vehicles). Within passenger cars, plug-in hybrids is the largest alternative vehicle group.

From 2018 to 2019, registrations of petrol cars fell 7% and registrations of diesel cars fell 27%, whereas registrations of BEVs increased 144% and CNG vehicles 84%. Registrations of PHEVs and petrol-fueled HEVs all increased some 20%. 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

There are currently no major end-use related research and demonstration programs going on. The BioOneHundred pilot project, led by Helsinki Region Transport (HSL) and covering years 2016 to 2019, has ended. The project focused on high-concentration biofuels for carbon-neutral urban traffic. Partners in the project were, in addition to HSL, the Construction Services of the City of Helsinki (Stara), the cities of Espoo and Vantaa, the Finnish Post, Neste, St1, UPM, the Smart & Clean Foundation and VTT. The project was supported financially by the Ministry of Economic Affairs and Employment. No technical problems were accounted for, and preparedness to implement high concentration biofuels is now there.

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.

From 2017 to 2021, Business Finland is running a program called "Smart Energy Finland."[41] The program brings together the services for technical development and exports and will grant 100 million euros to smart energy solution innovations in 2017 to 2021. The program will also grant support for the international expansion of growth-oriented companies that possess

41 https://www.businessfinland.fi/en/for-finnish-customers/services/programs/smart-energy-finland/

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.

Outlook

Finland has to reduce its CO_2 in the non-ETS (emissions trading system) 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 the 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 Programme, 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[42]) 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.

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
The Government changed in the spring of 2019. Still with the old Government in place, a new liquid biofuels obligation law calling for 30% (actual energy share) in 2030 was approved. This means that Finland is implementing one of the most progressive biofuels policies. The new Government sustains the target of a 50% CO_2 for transport by 2030. Additionally, the new Government emphasizes circular economy and the development of biogas. A new upper level target for Finland to be CO_2 neutral by 2035 has been set.

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

Germany

Drivers and Policies

Germany has committed to reduce its emissions in non-ETS sectors, including the transport sector, by 38% by 2030 compared to 2005 levels. Although Germany has already taken comprehensive climate measures, further national efforts are required to achieve the set goal of CO_2 savings. These have already been set out in the Federal Government's Climate Action Plan 2050[43] and are now specified in the Climate Action Programme 2030,[44] adopted by the Federal Government in October 2019.

The Climate Action Programme 2030 comprises four components for concrete CO_2 emissions mitigation: (1) support programs and incentives for cutting CO_2; (2) carbon pricing: revenues from carbon pricing will be reinvested in measures promoting climate action or (3) will be returned to citizens, and (4) regulatory measures that will enter into force successively until 2030.[45] With the Climate Action Plan, Germany sets the binding target of saving at least 40 to 42% of greenhouse gas (GHG) emission compared to what was saved in 1990 in the transport sector. In total, the government plans to invest more than €54 billion ($61 billion, US) in climate protection by 2023.

The main public driver regarding policy in the transport sector remains the revised EU Renewable Energy Directive II (RED II).[46] The discussion about diesel engines has been ongoing since 2015. The current trend shows that the GHG quota alone (in force since 2015) will not meet the actual GHG reduction requirements of -40% by 2030 in comparison to 1990. In fact, fulfilling 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 new infrastructure of production facilities for advanced fuels including biomass to liquid (BTL)/power to liquid (PTL) will be required from 2021 at the latest.[47] Further, the number of electric vehicles and plug-ins has significantly increased since 2017 (see Advanced Motor Fuels Statistics below), although the share in the total number of vehicles

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[43] https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/

[44] https://www.bundesregierung.de/breg-en/issues/climate-action/klimaschutzprogramm-2030-1674080

[45] https://www.bundesregierung.de/breg-en/issues/climate-action/klimaschutzziele-finanzieren-1694724

[46] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

[47] Meisel et al. (2019). Untersuchungen zur Ausgestaltung der Biokraftstoffgesetzgebung in Deutschland. DBFZ

remains small. Exploiting synergies in combining biomass (BTx)- and electricity/power (PTx)-based technologies in context of SynBioPTx (e.g., by using bio-CO_2, using PT-hydrogen for product synthesis and fuel refining) also offers new perspectives in the transport sector.[48]

Germany's public debate focuses mainly on electric mobility and battery-powered vehicles concerning transport in metropolitan areas, and on a speed limit for highways (German Autobahn).[49] Only a committed policy to support advanced motor fuels would strengthen the market perspective, which is partly reflected in the Government's Mobility and Fuels Strategy,[50] the Climate Action Programme[51] and national and European legislation.

Since January 2018, the Upstream Emissions Reductions (UER)[52] ordinance implementing EU legislation, has entered into force. Depending on the development of the total amount of fuel used, the average specific GHG prevention and compliance with up to 1.2% GHG avoidance through UER resulted in a constant absolute amount of biofuels in 2019.[44] From 2020 on, the mineral oil industry can apply UER measures to comply with legal requirements, including a reduction in GHG emissions by 6%, with a base year of 2010. Furthermore, the German Emission Control Act[53] bans all double-counting and excludes animal fats from the quota eligibility. However, recent regulations expand the list to include bio-based, co-refined hydrated oils that have been produced sustainably, Power to X (P2X),[54] and the use of electricity in electric vehicles.[55]

To decarbonize the transport sector, high priority has recently been given not only to electromobility for short-distance traffic and passenger cars, but also to the enforcement of CNG infrastructure along the most important middle- and long-distance road networks. In addition, the government strongly supports the use of LNG for heavy-duty transport and waterborne application. Use of CNG/LNG is discussed but controversial in expert groups like the Federal Government-convened National Platform Future of

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48 Naumann, K. et al. (2019): Monitoring Biokraftstoffsektor. 4th Ed. DBFZ Rep. No. 11

49 https://www.bundestag.de/parlament/plenum/abstimmung/abstimmung?id=622; http://dip21.bundestag.de/dip21/btd/19/140/1914000.pdf

50 https://www.bmvi.de/SharedDocs/EN/Dossier/MKS/mobility-and-fuels-strategy.html

51 https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klima schutzprogramm_2030_umsetzung_klimaschutzplan.pdf (Sections 3.4.3.4 ff.)

52 https://www.gesetze-im-internet.de/uerv/UERV.pdf

53 https://www.gesetze-im-internet.de/bimschv_38_2017/BJNR389200017.html; https://www.buzer.de/gesetz/12898/v219254-2019-05-25.htm

54 https://www.gesetze-im-internet.de/biokraft-nachv/BJNR318200009.html

55 https://www.gesetze-im-internet.de/emog/BJNR089800015.html

Mobility (NPM).[56,57] Application of hydrogen as transport fuel is one of the keys within the National Hydrogen Strategy now drafted to begin during 2020. Since 2009, Germany has funded eMobility with around €5 billion ($5.4 billion US) and is working to make electromobility more attractive.[58]

By the end of 2020, the Federal Ministry of Transport and Digital Infrastructure (BMVI) will support the establishment of at least 15,000 publicly accessible charging stations with a total of €300 million ($331 million US) by the charging infrastructure funding program. Since August 2019, around 10,000 additional normal and quick charging points have been funded by BMVI. The overall coordination of the needs-based charging infrastructure is carried out using the location tool (German "StandortTool"[59]) developed in 2018. As of December 2019, around 23,840 public and partially public charging points for energy companies, car park and parking lot operators, supermarkets and hotels have been recorded.[60] That is an increase of over 50% within one year. The share of fast charging stations is around 12%.

Advanced Motor Fuels Statistics

Figure 1 shows 2018 German fuel consumption for use in road transportation. The consumption of biofuels totaled 3.5 Mt — primarily low-level blends of biodiesel, hydrogenated vegetable oil, bioethanol and biomethane. Moreover, to a minor extent, biomethane is used for CNG. Lacking incentives, there is no market demand for E85 and pure biodiesel.

[56] https://www.plattform-zukunft-mobilitaet.de
[57] https://www.plattform-zukunft-mobilitaet.de/wp content/uploads/2019/10/NPM_Bericht_AG-5_Roadmap-LNG-CNG_rz01-1.pdf
[58] https://www.bmvi.de/SharedDocs/EN/Dossier/Electric-Mobility-Sector/electric-mobility-sector.html
[59] https://www.standorttool.de/
[60] https://www.bdew.de/energie/elektromobilitaet-dossier/energiewirtschaft-baut-ladeinfrastruktur-auf/

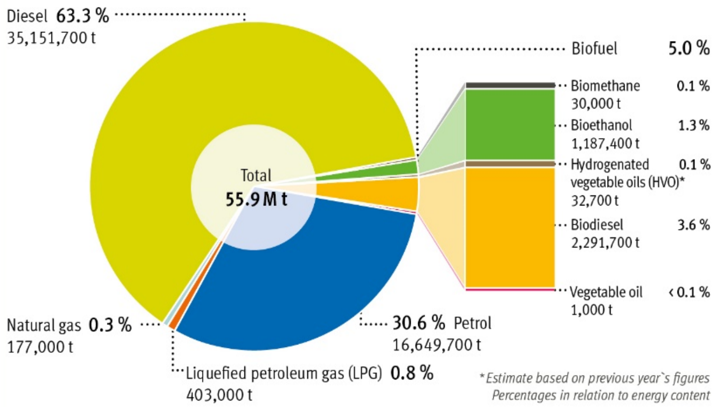

Fig. 1 Fuel Consumption in the Transport Sector in Germany in 2018
Source: FNR on the basis of BAFA, Destatis, DVFG, BDEW, BLE 2019[61]

Tables 1 and 2 show the 2012-2019 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, have increased the average GHG reduction of biofuels on the German market to 84% and avoided an estimated 9.5 million tons CO_2-eq. in 2018.[62] Table 3 shows the number of passenger cars in Germany by fuel type for 2015- 2019. (In the tables, n/a means data not available.)

A total of 64.8 million vehicles, including 4.4 million motor bikes, were registered in Germany as of January 1, 2019,[63] along with 47.1 million passenger cars, 3.1 million trucks, 2.2 million towing vehicles, 80,500 buses, and 303,607 other vehicles.

61 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 2019.

62 New reference values for fossil fuels according to the 38th BImSchV are in force since 2018. https://www.ble.de/SharedDocs/Downloads/EN/Climate-Energy/EvaluationAndProgressReports2018.pdf?__blob=publicationFile&v=2

63 https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/b_jahresbilanz.html

Table 1 Trends in German Biodiesel/FAME Sales, 2012 – 2019, in mt

Sale	2012	2013	2014	2015	2016	2017	2018	2019
Blend	1.928	1.741	1.970	1.978	1.987	2.183	2.296	2.314
Pure biodiesel	0.131	0.030	0.005	0.003	0.001	n/a	n/a	n/a
Total	2.059	1.772	1.975	1.981	1.988	2.183	2.296	2.314

Table 2 Trends in German Bioethanol Sales, 2012 – 2019, in mt

Sale	2012	2013	2014	2015	2016	2017	2018	2019
E85	0.021	0.014	0.010	0.007	n/a	n/a	n/a	n/a
Ethanol	1.090	1.041	1.082	1.049	1.047	1.045	1.077	1.076
ETBE	0.142	0.154	0.139	0.119	0.129	0.111	0.110	0.088
Total	1.253	1.209	1.231	1.177	1.176	1.156	1.187	1.177

Table 3 Number of Passenger Cars in Germany by Fuel Type on 2015 – 2019

Year	Gasoline	Diesel	LPG	CNG	EV	Hybrid	Plug-in
2015	29,837,614	13,861,404	494,148	81,423	18,948	107,754	X
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

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 2019*[64]

Research and Demonstration Focus

Public funding for alternative motor fuels on the national scale is supported by the BMVI[65] (infrastructure, e-mobility, LNG, CNG, jet fuel, "National Strategy to Extend the Infrastructure for Alternative Fuels"; €300 million [$325 million US] will be made available by 2020), and the Federal Ministry of Education and Research (BMBF)[66] (P2X and SynErgie; "Kopernikus Projects"[67]). In addition, the Ministry of Economic Affairs and Energy (BMWi),[68] focusing on E-Fuels in the "Energiewende im Verkehr"

64 KBA (Kraftfahrt-Bundesamt; Federal Motor Transport Authority), 2020, https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Jahresbilanz/2019_b_barometer.html?nn=2084378 and https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/b_jahresbilanz.html?nn=644526

65 https://www.bmvi.de/EN

66 https://www.bmbf.de/en; www.bmbf.de/foerderungen/bekanntmachung-2292.html

67 https://www.kopernikus-projekte.de/en/home

68 https://www.bmwi.de/Navigation/EN/Home/home.html

program, includes a total funding of €87 million ($96.2 million US). As a central measure, "real laboratories of energy transition" were established; in 2022, a roadmap will be presented.[69] Under the Renewable Resources Funding Scheme of the BMEL,[70] 23 R&D projects related to biofuels received funding of €11 million ($12 million US) in 2019. Due to an adverse European framework for biomass-based fuels, increased funding is not envisaged.

Outlook

Germany is currently approving different measures for supporting the future market uptake of synthetic fuels on the basis of renewable energy (i.e., P2X). Such instruments comprise quota for the implementation of P2X products, but also direct promotion of production and corresponding regulations on EU level.[71] Further R&D activities (e.g., reducing GHG emissions of biofuels to make them compatible with the RED II, following the ESR[72] approach) are needed to meet persistent challenges for the near future.

Additional Information Sources

- Bundesverband der deutschen Bioethanolwirtschaft, www.bdbe.de
- Bundesverband Regenerative Kraft, www.brm-ev.de/en
- Verband der Deutschen Biokraftstoffindustrie, biokraftstoffverband.de

[69] https://www.energieforschung.de/forschung-und-innovation/energiewende-im-verkehr
[70] https://www.bmel.de/EN
[71] https://dipbt.bundestag.de/doc/btd/19/168/1916829.pdf
[72] https://ec.europa.eu/clima/policies/effort/regulation_en

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.[73]

A 2016 initiative to provide universal clean energy access to every household led to an increase in LPG consumption by 56% in 2019, 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 83% 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 renewable energy efficiency norms, and 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. By 2030, the policy envisages achieving 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel. 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 like wheat, broken rice, and rotten potatoes unfit for human consumption.

[73] BP Outlook 2019, India

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 accounts for around 35% of India's energy consumption; it 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.[74] 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 with 10% ethanol (E10) depending upon its availability. Supplies were not forthcoming until 2013-14. In order to augment the supply of ethanol for EBP, the Government decided to administer ethanol prices. This combined with a slew of other measures, such as easing restrictions on the movement of ethanol between states; allowing more sources of feedstocks for production of ethanol including sugar, sugar cane, damaged food grain, 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 1.86 billion liters during ESY 2018-19, thereby achieving 5% blending in petrol.

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

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

[74] BP Outlook 2019, India

2G Ethanol Program

The Indian Government has approved the "Pradhan Mantri JI-VAN (Jaiv Indhan-Vatavaran Anukool fasal awashesh Nivaran) Yojana" which will provide financial support of approximate $300 million US for the period from 2018-19 to 2023-24 for supporting 12 commercial projects and 10 demonstration projects for second generation bioethanol projects. These 12 bio-refineries shall produce around 300 to 350 million liters of ethanol annually, thus contributing significantly toward the EBP program.

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. 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 public sector units (PSU) OMCs. The EOI has been launched in 200 cities in the country.

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.

Oil and gas PSUs launched the Sustainable Alternative Towards Affordable Transportation (SATAT) initiative 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 by 2023.

Research and Demonstration Focus

The Centre for High Technology (CHT), PSU OMC's R&D 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.

Indian Oil Corporation Ltd. R&D center (IOC R&D) is doing research work in the area of multi-feed gasification and has installed a multi-feed fluidized bed gasification pilot plant (1-2 kg/hr) with various analytical and feed characterization facilities. It has developed a novel concept on integrated gasification for optimal use of available gasifier designs by segregation of feedstock according to reactivity and ash content. A 2-Tonnes per day (TPD) integrated gasification demonstration pilot plant for synthetic gas production is being set up in a second R&D campus by 2022 for validating the concept and generation of data for further scale up.

The IOC R&D has also developed a single-step compact steam methane reforming process for production of an 18% hydrogen CNG (HCNG) blend directly from CNG, which is more economical and technically attractive as compared to high pressure physical blending of hydrogen and natural gas to produce HCNG. It has developed an in-house, two-step bio-methanation process for conversion of food waste into biogas which uses high-performing bacterial inoculum responsible for the conversion of waste into biogas with high methane (>80%) content. For CO^2 capturing and conversion in value-added products, third generation biofuel technology has been developed by integrating two technologies – Lanza Tech-USA's patented anaerobic gas fermentation technology to convert carbon dioxide into acetic acid, and Indian Oil R&D's patented aerobic fermentation technology to convert 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 progress on the world's first pilot plant of capacity of 10 kg/day CO^2 installed at IOC R&D center. Once proven at pilot scale, commercial 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 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. Further work is being done to look into the availability of feedstock across India for production of biojet fuel; current demand for biojet fuel; estimation of future requirements and cost of production; formulation of standards, and specifications in line with international standards.

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, foodwaste and Municipal Solid Waste, and cost effective biofuels from industrial waste gases.

Outlook

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

Ethanol procurement by PSU OMCs reached 1,886 million liters of ethanol in ESY 2018-19 and achieved 5% blending level, which is an all-time high in a single ESY. 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). Recently, the Indian Government mandated PSU OMCs to run pilot for E 100 (pure anhydrous ethanol) and M 15 (15% methanol blended with petrol) fuel to increase the share of biofuel in overall fuel consumption.

The SATAT initiative launched by Oil and Gas PSUs 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% gas imports of the country.

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: www.siamindia.com for data on automotive industry.
- Website: www.dbtindia.nic.in

Israel

Drivers and Policies

The distribution of energy sources in the Israeli final energy consumption can be seen in Figure 1. The dominant parts are electricity (32%), fuels for local transportation (21% gasoline, 18% diesel) and fuels for industrial use (most of the rest). Renewables are mainly residential solar water heating systems (see Fig. 1). The transportation sector is the primary consumer of oil—more than 95%. In 2011, the government declared a national effort to decrease the reliance on imported oil in transportation (decision number 5327). Under this decision, the Fuel Choices and Smart Mobility Initiate[75] was established.

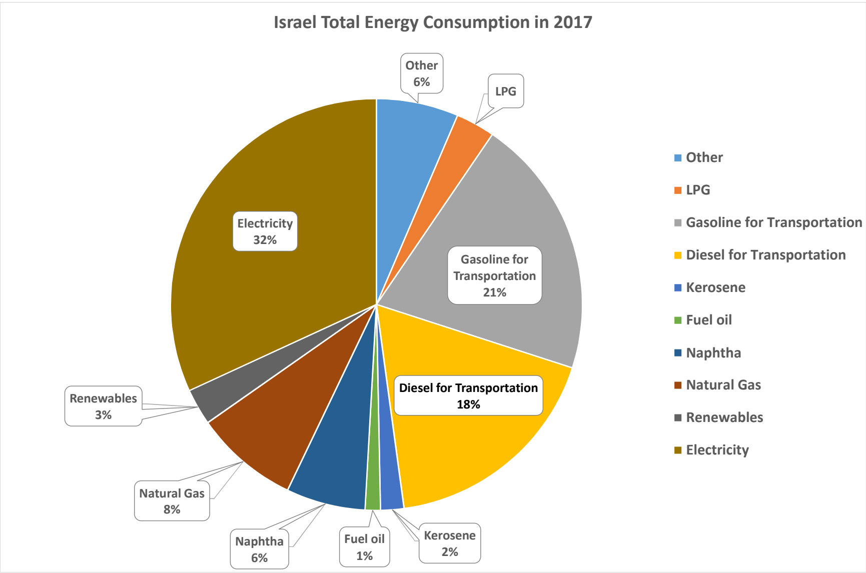

Fig. 1 Israel Total Energy Consumption in 2017

The Ministry of Energy,[76] together with the Fuel Choices and Smart Mobility Initiative, encourages entrepreneurship and innovation in the field of alternative fuels by supporting research and development along their development stages. This formal support is present from the academic research stage, continues through preliminary implementation, and is maintained through pilot and demonstration projects. Biodiesel, fuel

75 http://www.fuelchoicesinitiative.com/
76 https://www.gov.il/en/departments/guides/projects_science

emissions, biochemical conversion, algae, natural gas based fuels and others, are part of the support program in Israel.

Motor Fuels Statistics

There is a total of about 3.5 million vehicles in Israel. Figure 2 shows data on segmentation of fuel consumption in 2018. The data indicate that most vehicles use gasoline (more than 80%), but there is also strong growth in hybrid vehicles.

In order to accelerate the penetration of electric vehicles (EV) in Israel, several measures were taken. The Ministry of Energy published an ambitious plan for 2030, where 100% percent of new vehicles will be all electric. In pursuit of that objective, the Ministry published four different tenders with a total budget of about 30 million NIS ($8.4 million US) to support the installation of EV charging stations around the country, including more than 100 fast DC charging stations. In addition, reduced tax rates for hybrid and electric vehicles are offered. The excise tax on BEVs is only 10% compared with up to 84% on Internal Combustion vehicles.

The Ministry of Environmental Protection established a "Low Emission Zone" in two central cities in Israel—Haifa and Jerusalem. In these zones, the entry of heavy diesel trucks (without catalytic convertor) is not allowed. This measure is part of the national plan for air pollution reduction in Israel.

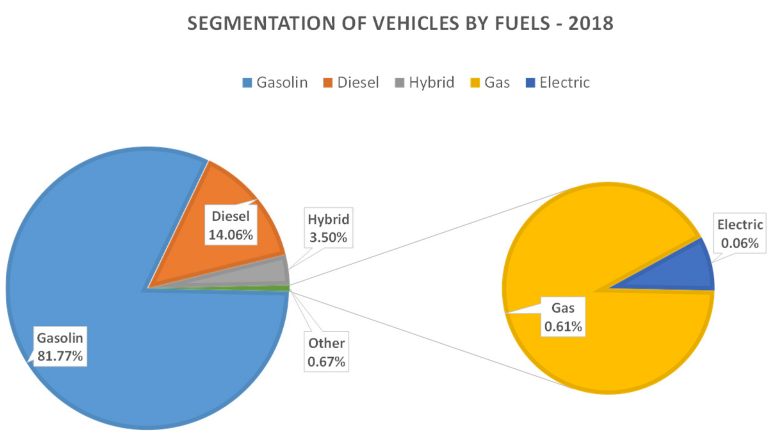

Fig. 2 Israel segmentation of vehicles by fuels in the year 2018[77]

[77] *Israel, Central Bureau of Statistics, https://old.cbs.gov.il/publications19/1762/pdf/t12.pdf*

Research and Development

Between 2016 to 2019, the Ministry of Energy together with the Fuel Choices and Smart Mobility Initiative, supported 67 alternative fuels projects with total grants of about 78 million NIS ($21.8 million US). Figure 3 presents the grants' distribution between the subsectors, including grants for biofuels, natural gas, hydrogen, fuel cells and electric vehicles, from academic research through start-up and demonstration projects. Some examples from the biofuels projects are as follows:

- *Implementation of 100% methanol as fuel for light and heavy duty engines.* This project, among others in the past 10 years, is representative of Israeli effort for the development of methanol as an alternative fuel. Promoting methanol mixtures, not only with gasoline for light vehicles, but also as a primary fuel in heavy duty vehicles and generators is a key initiative for Israel. 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.
- *Exhaust emissions of compression ignition engines fueled with dimethylether (DME).*
- *Design and construction of microbial electrolysis cell for hydrogen generation from wastewater.*
- *Mini-electrosomes biofuel cells.*
- *Development of continuous biodiesel production from grease trap wastes.*
- *A novel emulsion-based biocatalytic microreactor for conversion of cellulosic biomass to biodiesel*.
- *Develop a continuous Hydrothermal Liquefaction (HTL) reactor for rapid and effective conversion of biomass into bio-crude.*

Additional initiatives include:

- *CNG Refueling Stations*. Currently, Israel has two CNG refueling stations and 5 mobile stations. In addition, the government subsidized about 20 CNG refueling stations around the country. They are expected to be completed by the end of 2021. In order to promote the use of CNG, a new tender will be published in 2020 to build additional CNG refueling stations.
- *CNG Fueled city buses.* There are 85 CNG city buses operating in the Tel Aviv area.
- *CNG Garbage trucks.* There are 34 CNG garbage trucks active since 2018.

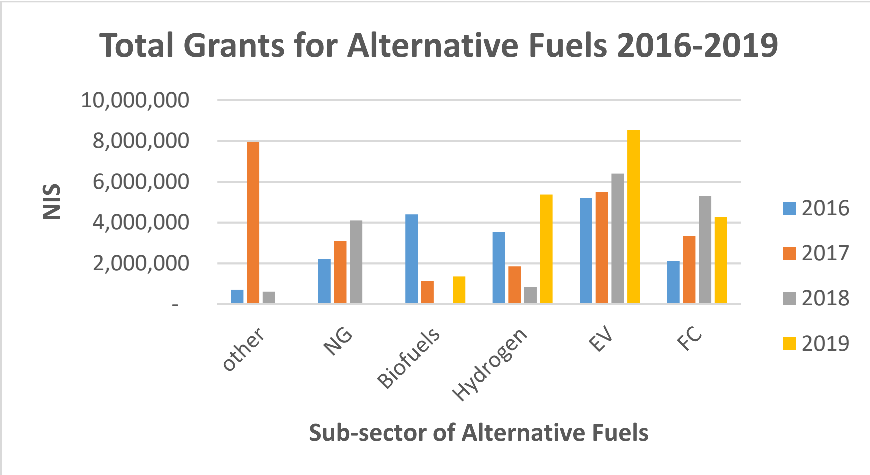

Fig. 3 Total grants for alternative fuel projects in 2016-2019

- *LNG Activities.* Currently, the Ministry of Energy is examining LNG standards adaptation and construction of four LNG refueling stations.
- *Ministry of Environmental Protection*[78] *Activities:* Starting in 2016, the Ministry of Environmental Protection has launched programs aimed at reducing vehicular air pollution. The aims of the programs include: encouraging shift to hybrid vehicle (HV) taxis and electric buses, installing particle filters on garbage trucks, promoting electric car ride shares, reducing commutes in private cars, and establishing low-emission zones. As part of these goals, the main measures were as follows:
  - *HV Taxis.* Supported the purchase of hybrid taxis. Currently, there are about 725 new hybrid taxis.
  - *EV Buses*. Supported the purchase of 79 electric buses. A new tender with a total budget of 17 million NIS ($4.75 million US) is planned for the end of 2020 to support about 60 additional electric buses into the public transportation system.

Pilot and Industrial Demonstration Example

Development, production and marketing of an intercity CNG bus
A grant of 2.6 million NIS ($727,000 US) was approved in 2019 for the pilot of a CNG intercity bus. This project will contribute to the development of a CNG-based transportation market. The development of a CNG intercity bus will enable public transport operators to experiment and operate

[78] https://www.gov.il/he/departments/topics/transportation

intercity long range lines while relying on local natural gas, saving fuel costs and significantly reducing air pollution.

Benefits of Participation in the AMF TCP
Participation in the AMF TCP has given Israel access to information on alternative fuels and helped to build collaboration with other countries. It is important to have a worldwide knowledge sharing platform, especially when all countries are seeking to achieve similar solutions.

Japan

Drivers and Policies

Fossil fuel plays a central role as a source of energy in Japan. However, the country's domestic sources of fossil fuel are limited, making it dependent on imports. Japan enacted the Basic Act of Energy Policy in June 2002 to ensure the steady implementation of energy policy.

Primarily, the point of Japan's energy policy is to ensure stable supply ("Energy Security") and to realize low-cost energy supply by enhancing 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[79] was issued July 3, 2018, and indicated a policy for 2030 and 2050. For 2030, to achieve the goal of "steadily realizing an energy mix to reduce greenhouse gases by 26%", the main measures are (1) renewable energy, (2) nuclear power, (3) fossil fuel, (4) energy saving, and (5) hydrogen/electricity storage/distributed energy. For 2050, Japan is aiming for "80% reduction of greenhouse gases and taking on the challenge of energy conversion and decarbonization". The main measures in addition to the above items are heat, transportation, and distributed energy, and there is focus on decarbonization by hydrogen and electricity storage and decentralized energy systems.

In the transportation sector, to improve the energy efficiency of automobile transportation, "New fuel economy standards for passenger cars" was issued[80]. This effort focuses on (1) target year: FY2030, (2) a standard value of 25.4km/L (32.4% improvement from FY2016 results), (3) scope, which includes gasoline vehicles, diesel vehicles, liquefied petroleum gas (LPG) vehicles, electric vehicles (EVs), and plug-in hybrid vehicles (PHEVs).

Furthermore, Japan will take measures such as increasing the ratio of next-generation vehicles (e.g., hybrid vehicles, EVs, PHEVs, fuel cell vehicles [FCVs], clean diesel vehicles, and compressed natural gas [CNG] vehicles) to all new vehicles to 50% to 70% by 2030.

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[79] 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

[80] The Ministry of Economy, Trade and Industry 2019.6.3 https://www.meti.go.jp/english/press/2019/0603_002.html

Now that biofuels, electricity, natural gas, LPG, and hydrogen are available as energy sources, an environment is being created in which consumers' vehicle choice promotes competition not only for fossil fuels, but also for a wider variety of energy sources.

In spreading and expanding the introduction of next-generation vehicles, research and development and infrastructure building are indispensable. Thus, the Government of Japan and the private sector will collaborate to disseminate infrastructure for next-generation vehicles.

Advanced Motor Fuels Statistics

Figure 1 shows the energy sources used in the transportation sector[81] in Japan. Oil-related energy accounts for 97.9% 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. 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 3,009 FCVs.

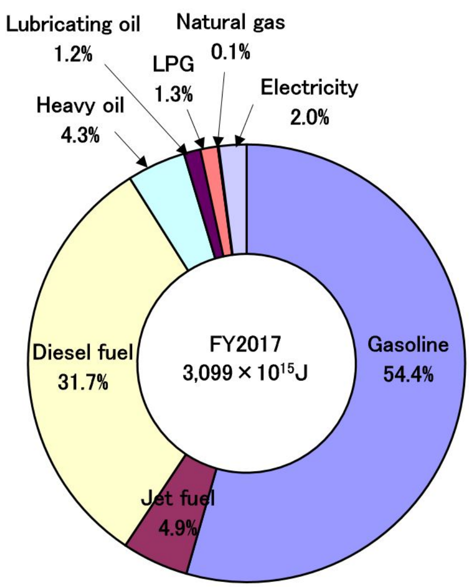

Fig. 1 Energy Sources Used in the Transportation Sector in Japan in 2017

[81] Government's white paper on energy, 2017 (in Japanese).

Table 1 Current Penetration of Low-Emission Vehicles in Japan

<table>
<tr><th>Vehicle Type</th><th>Methanol[82]</th><th>CNG[83]</th><th>Hybrid[84]</th><th>EV[6]</th><th>FCV[6]</th><th>Vehicle Registration[85]</th></tr>
<tr><td>Passenger vehicles</td><td>0</td><td>1,607</td><td>8,331,443
(PHV:122,008)</td><td>105,919</td><td>3,009</td><td>39,498,871</td></tr>
<tr><td rowspan="2">Light,mid,and heavy-duty trucks</td><td rowspan="2">576</td><td>6,318</td><td rowspan="5">31,493</td><td rowspan="5">1,512</td><td rowspan="2">0</td><td rowspan="2">5,916,211</td></tr>
<tr><td>20,457</td></tr>
<tr><td>Buses</td><td>0</td><td>1,584</td><td>0</td><td>232,933</td></tr>
<tr><td rowspan="2">Special vehicles</td><td rowspan="2">0</td><td rowspan="2">4,095</td><td rowspan="2">0</td><td rowspan="2">1,598,298</td></tr>
<tr></tr>
<tr><td>Small vehicles</td><td>0</td><td>11,092</td><td>1,102,481</td><td>6,323</td><td>0</td><td>31,137,246</td></tr>
<tr><td>Total</td><td>576</td><td>45,153</td><td>9,587,425</td><td>113,754</td><td>3,009</td><td>78,383,559</td></tr>
</table>

Research and Demonstration Focus

Hydrogen

The Strategic Roadmap for Hydrogen and Fuel Cells[86] (revised version), which includes new goals and specific explanations of the new efforts to be undertaken, was released on March 22, 2016. In concrete terms, the revised version of the roadmap stipulated the following:

- Future price targets for household fuel cells.
- Targets for the dissemination of FCVs: in total, about 40,000 vehicles by 2020, about 200,000 vehicles by 2025, and about 800,000 vehicles by 2030.
- Targets for the construction of hydrogen stations: about 160 stations by 2020 and about 320 stations by 2025.
- Clarification of descriptions concerning hydrogen power generation.
- The technical and economic challenges concerning the utilization of hydrogen generated using renewable energy.

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

[83] Japan Gas Association, as of March 2018 (cumulative total number). https://www.gas.or.jp/ngvj/spread/ (in Japanese)

[84] Next Generation Vehicle Promotion Center, as of March 2018 (estimated numbers of vehicles owned). http://www.cev-pc.or.jp/tokei/hanbai.html (in Japanese)

[85] Automobile Inspection and Registration Information Association, as of August 2019. http://www.airia.or.jp/publish/statistics/number.html

[86] Agency for Natural Resources and Energy, 2016, *The Strategic Roadmap for Hydrogen and Fuel Cells*, (revised version), March 22.

On December 26, 2017, the Ministerial Council on Renewable Energy, Hydrogen and Related Issues held its second meeting and decided on a basic hydrogen strategy to accomplish a world-leading hydrogen-based society.[84]

The goals pertaining to hydrogen for 2030 are: (1) Supply: Build an international hydrogen supply chain and establish hydrogen production technology; (2) Supply volume: Meet capacity for 300,000 tons; (3) Cost: Provide hydrogen supply for 30 yen (about 33 cents)/Nm3; (4) Use (power generation): Generate supply for 17 yen (about 18.7 cents)/kWh; (5) Mobility: Build and maintain 900 stations or more, 800,000 FCVs, 1,200 FC buses, 10,000 FC forklifts, and (6) FC utilization: Aim to reach 5.3 million Ene-Farm (domestic fuel cell type cogeneration system). By 2050, the goals are (1) Supply: Provide CO_2 free hydrogen (brown coal x CCS, using renewable energy); (2) Supply volume: Increase to 10 million tons; (3) Cost: Reduce cost to 20 yen (about 22 cents)/Nm3; (4) Use (power generation): Generate supply for 12 yen (about 13.2 cents)/kWh, and (5) Mobility: Aim to replace gasoline and gas stations.

As of December 2019, hydrogen stations for fuel cell vehicles are operated in 112 locations nationwide.[87]

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

In fiscal year 2018, the three-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 both demonstrated. CO_2 emissions from heavy-duty LNG trucks were reduced by about 10% in the latest diesel trucks. Isuzu Motors Limited and the Organization for the promotion of Low Emission Vehicles (LEVO) are continuing this project beyond 2019.

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[87] Next Generation Vehicle Promotion Center. http://www.cev-pc.or.jp/suiso_station/index.html (in Japanese)

[88] Isuzu Motors Limited, website, http://www.isuzu.co.jp/product/giga/cng/

Bioethanol

The Ministry of Environment's 2011 project in Okinawa Prefecture to promote the use of biofuels such as E3 gasoline terminated in fiscal year 2016 because of no clear path to commercialization.[89] In Miyakojima City, the supply of E3 gasoline was terminated in April 2016.[90] Sale of bio-gasoline blended with ethyl-tertiary-butyl ether (ETBE) is continuing to the 2017 target of 500,000 kL (crude oil equivalent) of bioethanol established in the Act on Sophisticated Methods of Energy Supply Structures,[91] in 2016, sales of this blended gasoline reached a total of 441,000 kL.[92]

Outlook

In July 2018, the Japanese government approved the Strategic Energy Plan (the fifth plan),[93] which forms the basis for Japan's energy policies. The plan further strengthens efforts toward the realization of the energy mix in 2030 and sets forth the challenge for energy conversion and decarbonization in 2050 with new energy options.

Additional Information Sources

- FY2018 Annual Report on Energy, https://www.meti.go.jp/english/press/2019/pdf/190607_001.pdf
- Agency for Natural Resources and Energy, July 2015, Long-term Energy Supply and Demand Outlook, http://www.meti.go.jp/english/press/2015/pdf/0716_01a.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.

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89 Ministry of Environment website, http://www.env.go.jp/earth/ondanka/biofuel/okinawabio/bio_hokokusyo.pdf. (in Japanese)

90 The Miyakomainichi newspaper, http://www.miyakomainichi.com/2016/09/92895/ (in Japanese)

91 Petroleum Association of Japan website, http://www.paj.gr.jp/eco/biogasoline/ (in Japanese)

92 Ministry of Economy, Trade, and Industry, Agency for Natural Resources and Energy (1/2018), http://www.meti.go.jp/committee/kenkyukai/energy_environment/bio_nenryo/pdf/002_03_00.pdf (in Japanese)

93 Ministry of Economy, Trade, and Industry, Agency for Natural Resources and Energy (7/2018), http://www.enecho.meti.go.jp/en/category/others/basic_plan/5th/pdf/strategic_energy_plan.pdf

Republic of Korea

Drivers and Policies

South Korea enacted the new Renewable Fuel Standard (RFS) program in 2019. Accordingly, it is mandatory to supply biodiesel to diesel fuel, and refineries must mix and sell both at a predetermined ratio, as shown in Table 1.

Table 1 Ratio of New and Renewable Energy Fuel Blending 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.

As of July 31, 2015, the annual compulsory ratio will be reviewed every three years, taking into consideration the level of technology development of new and renewable energy and the fuel supply and demand situation.

As of January 1, 2018, the blending ratio was revised to 3%; after the standardized three-year period, the blending ratio again will be reviewed in 2020. However, the blending ratio can be changed before 2020 depending on market conditions and mixed performance results.

In the case of bioethanol, an empirical study was undertaken for South Korea's supply beginning in May 2016. The feasibility of this fuel for manufacturing, supply, infrastructure, and vehicle use was verified by the end of April 2019. Researchers selected one gas station and checked equipment and storage problems by season for 365 days. Researchers also tested durability for 45,000 km using four demonstration vehicles, systemically checking emission gas and vehicle condition. Additionally, new technology development for parts affected by fuel (combustion system, fuel pump) is being pursued.

In the case of marine fuels, the amendment to the International Maritime Pollution Prevention Convention (MARPOL) came into force in January 2020 through the International Maritime Organization (IMO), limiting the sulfur content to 0.5% m/m for marine fuels internationally. In order to prepare for this change, domestic desulfurization facilities were developed through government and private companies and the expansion of low-sulfur crude oil supply; use of liquefied natural gas (LNG) was considered. In South Korea, technological development and private investment in the production of low-sulfur oil and emission reduction technologies (e.g., scrubber) are increasing.

SK energy plans to start operating the Residual Oil Desulfurization Facility (VRDS) in April 2020. This is an eco-friendly, low-sulfur oil production facility that began construction in November 2017. S-OIL is also seeking to supply low sulfur oil through capacity expansion.

In order to prepare for the introduction of bio aviation oil, research on bio aviation oil synthesis and empirical evaluation using non-petroleum-based raw materials has been conducted in several industries, in academia and research fields such as the Advanced Biomass R&D Center and the Institute for Advanced Engineering.

In particular, since December 2016, the Agency for Defense Development (ADD) has studied the application of biofuel derived from vegetable oils produced by applying domestic technology to jet engines. Korean Air made its first 14-hour flight to Chicago in November 2017, with a 5% blended fuel oil extracted from plants.

Advanced Motor Fuels Statistics

Table 2 shows classification of newly registered vehicles in South Korea, from 2014 to 2018, by fuel type. Figure 1 shows the change rate of the vehicle registration number by year in comparison with the previous year. New registrations for gasoline vehicles did not change much by year, and for diesel vehicles, new registrations decreased from 2016.

The South Korean government is providing tax benefits and subsidies for the dissemination of eco-friendly hybrid cars, electric cars and hydrogen fuel cell cars. As a result, new registrations for hybrid and electric vehicles are steadily increasing. The number of newly registered CNG and hydrogen fuel cell vehicles is not large but has continued to increase since 2015.

Table 2 Vehicle registration number by fuel type

Year	2014	2015	2016	2017	2018
Gasoline	661,919	681,601	747,718	758,635	777,499
Diesel	805,609	962,127	872,640	820,457	792,404
LPG	149,014	137,121	123,077	137,932	118,436
HEV, PHEV	34,516	39,014	62,210	84,614	93,094
Electric	1,315	2,932	5,177	14,332	31,154
CNG, Fuel Cell, etc.	9,495	10,991	12,219	14,018	14,554
Total	1,661,868	1,833,786	1,823,041	1,829,988	1,827,141

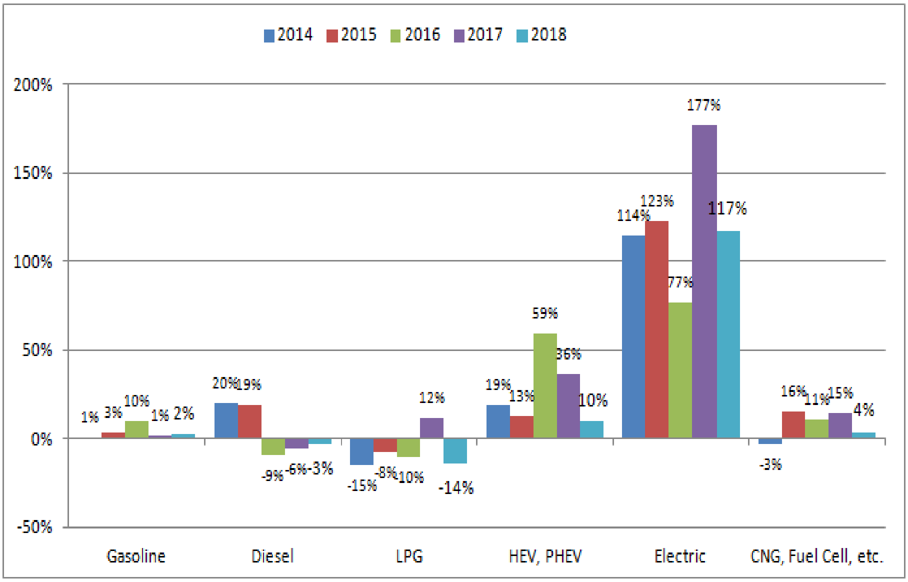

Fig. 1 Annual change rate of vehicle registration

Research and Demonstration Focus

The South Korean government supplied 80,000 electric cars and 3,500 hydrogen cars as of September 2019, and it has plans to increase the proportion of eco-friendly vehicles by 33% by 2030.

In the case of electric vehicles, South Korea aims to electricize all models of sedans, SUVs, and trucks (more than 5 tons) to have 600 km in driving range and three times the charging speed in comparison to those in existence now.

In the case of hydrogen vehicles, South Korea is promoting the localization and R&D of parts to ensure durability up to 500,000 km and to lower vehicle price to $34,000 US.

Figure 2 shows Kia Motors' Niro EV, which is produced in Korea and exported abroad. Figure 3 shows Neptune, a hydrogen heavy duty truck of Hyundai Motors, which began exporting to Switzerland in 2020.

Fig. 2 Kia Motors' Niro EV, a Gen3 Hydrogen vehicle

Fig. 3 Hyundai Motors' Neptune, a Fuel Cell Manufacturing Plant Fuel Cell Bus

To expand the infrastructure for eco-friendly cars, the South Korean government developed a plan to build 15,000 rapid chargers for electric vehicles by 2025, and 660 hydrogen charging stations by 2030.

In the case of electric car chargers, the plan provides for the building of more than 1,500 units every year, intended for supermarkets, gas stations, and rest areas. New hydrogen refueling stations are planned for construction within 20 minutes of major cities and within 75 kilometers on highways.

The government plan also allows for the expansion of the supply of eco-friendly vehicles by providing tax reduction and purchase subsidies

In the case of subsidies provided to manufacturers, the subsidies will be reorganized around performances such as energy consumption efficiency and mileage of electric vehicles to induce higher efficiency and improve performance. Subsidies provided to consumers will be expanded, but the scale of those subsidies will be reviewed after 2022, and the level of subsidies will be changed.

Outlook

According to the RFS policy of South Korea, the blending ratio of biodiesel to diesel fuel will be maintained at 3% until July 2020. In 2020, however, the blending ratio will be reviewed through a separate review process.

Although bioethanol has been studied with biobutanol, it remains unclear whether the exact pilot operation plan or supply plan has been finalized.

Based on the results of research on the application of bio-aviation oil through government departments, aviation oil is expected to establish a legal, institutional, and infrastructure maintenance base for domestic bio-aviation oil utilization.

Additional Information Sources

- Advanced Biomass R&D Center, https://www.biomass.re.kr
- Institute for Advanced Engineering, www.iae.re.kr
- K-Petro, www.kpetro.or.kr
- Korea Register, www.krs.co.kr
- Ministry of Trade, Industry and Energy, www.motie.go.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. Mandatory targets for sale or consumption were established in Royal Decree 1085/2015, on the promotion of biofuels. For the years 2019 and 2020, the targets (in energy content) are 7% and 8.5%, respectively. In 2019, double counting of some biofuels entered into force. Certificates can be carried over to the following year (up to 30% of the annual obligation) and can also be traded.

From October 2018 onwards, the new EU-wide harmonized labelling in filling stations is required. Gasoline-type fuels are marked by an "E" inside a circle: E5 (5% vol. ethanol in petrol), E10, etc.; diesel-type fuels, by a "B" inside a square: B7 (7% vol. biodiesel in diesel), B10, etc. or XTL (synthetic diesel); and gaseous-type fuels, by their specific subtype within a rhombus.

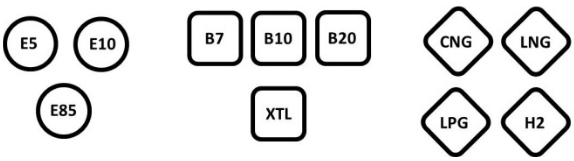

Fig. 1 Examples of symbols used for fuel labelling

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

Figure 2 shows data on fuel consumption in 2019. Biofuels account for the largest part of alternative transportation fuel in Spain.

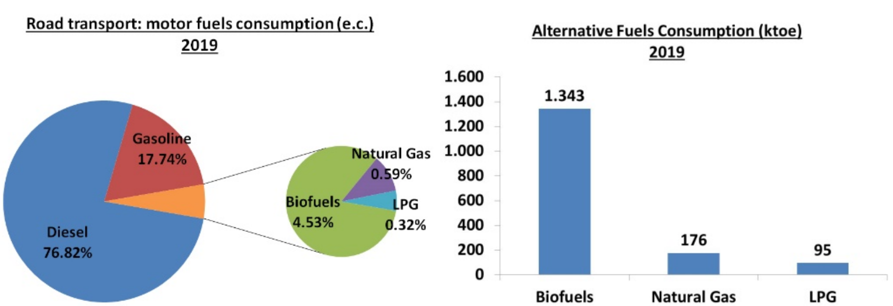

Fig. 2 Fuel Consumption (share in energy content) and Alternative Fuel Consumption (ktoe) in Spain in 2019. *Sources: CORES, GASNAM.*

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	39
	B30 or higher	8
Bioethanol blends	E15 or lower	2
	E85	4
LPG		673
Natural gas		89

Sources: MITECO (Geoportal),GASNAM.

Figures 3, 4 and 5 provide information on the feedstock, feedstock origin country, and production country of biofuels consumed in Spain in 2019.

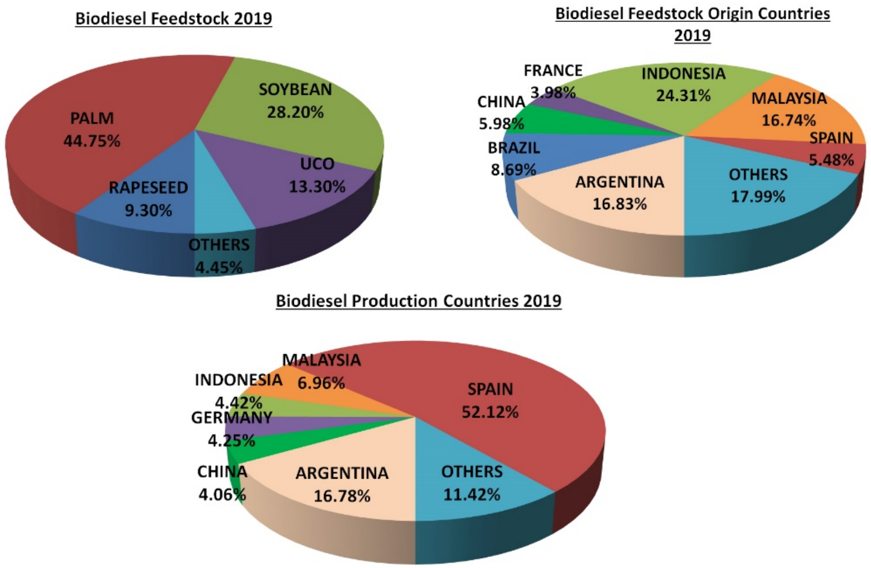

Fig. 3. Feedstock, Feedstock Origin Country, and Production Country of Biodiesel Consumed in Spain in 2019

Source: CNMC.

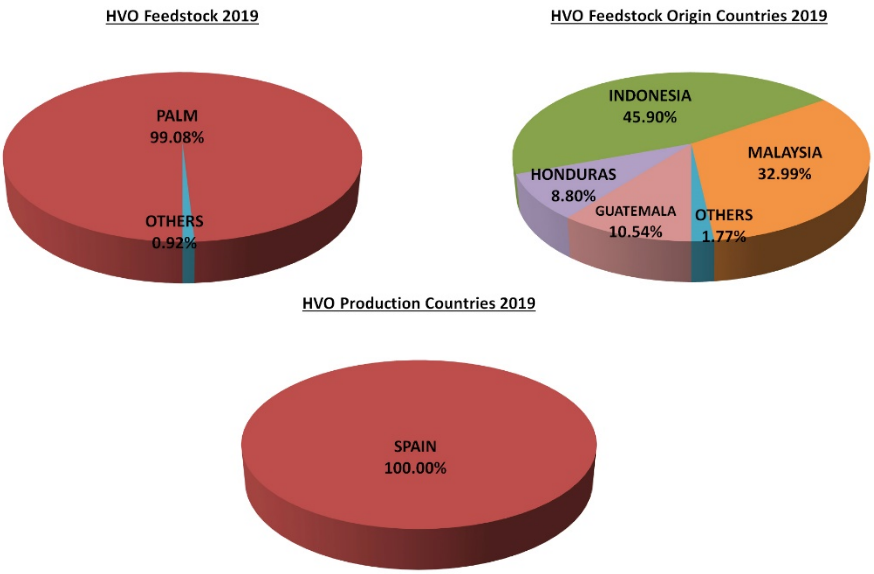

Fig. 4 Feedstock, Feedstock Origin Country, and Production Country of Hydrotreated Vegetable Oil (HVO) Consumed in Spain in 2019
Source: CNMC.

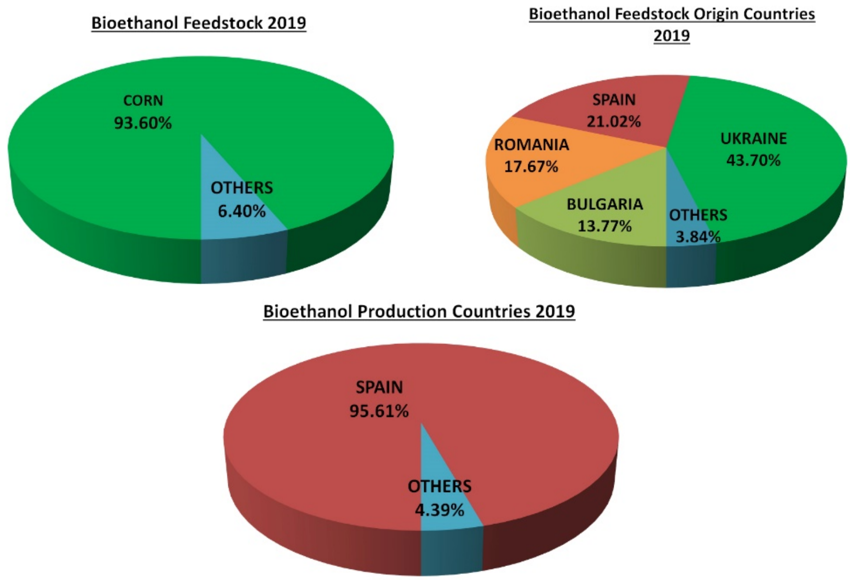

Fig. 5. Feedstock, Feedstock Origin Country and Production Country of Bioethanol Consumed in Spain in 2019
Source: CNMC.

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. It 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 Draft 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.

Outlook

The National Renewable Energy Action Plan foresees a consumption of biofuels of 2,713 ktoe in 2020 in order to fulfill the targets set in the current Renewable Energy Directive.

The revised Renewable Energy Directive, published in December 2018, 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 draft 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 programmes 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, 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 (MITECO): 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).
- MITECO: Ministry for Ecological Transition and Demographic Challenge www.miteco.gob.es (in Spanish).

Major changes
The Draft 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.

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 95 g/km) 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 60,000 ($6,448 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 2019, the reduction obligation is 2.6% for petrol and 20% for diesel. The reduction obligation will be increased over time with an indicative target of 40% reduction in 2030. 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 have been 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 2018. 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 320,000 at the end of 2018 (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.

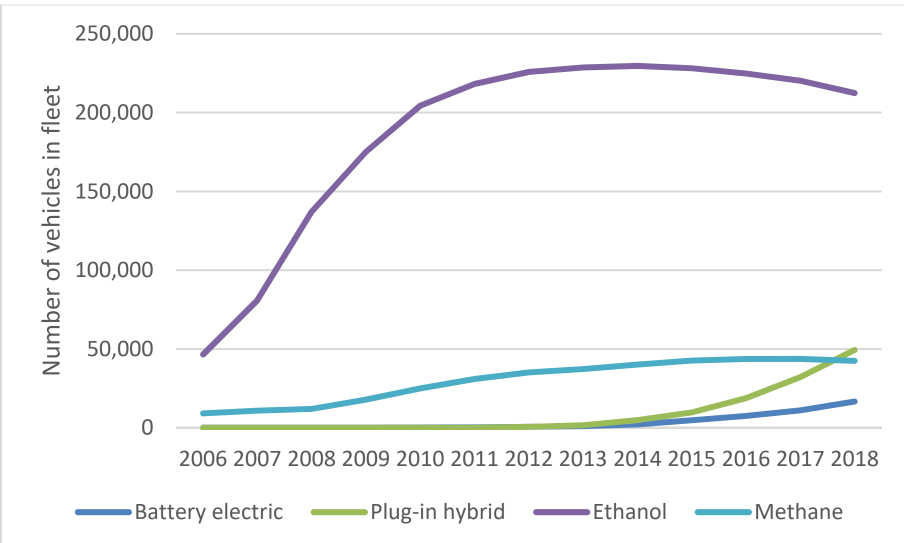

Fig. 1 Number of Advanced Motor Fuel Passenger Cars in the Fleet, 2006 – 2018

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 just under 30% 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 2018 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 17.5 terawatt hours (TWh), or 22% of the transportation fuels sold during 2018 (see Fig. 2). Almost 60% of the renewable fuel used in Sweden during 2018 was low blending of hydrotreated vegetable oil (HVO) and fatty acid methyl ester (FAME) in diesel. On average, the renewable share in diesel corresponded to 22%. Some individual diesel products sold on the Swedish market have a renewable share of 50%.

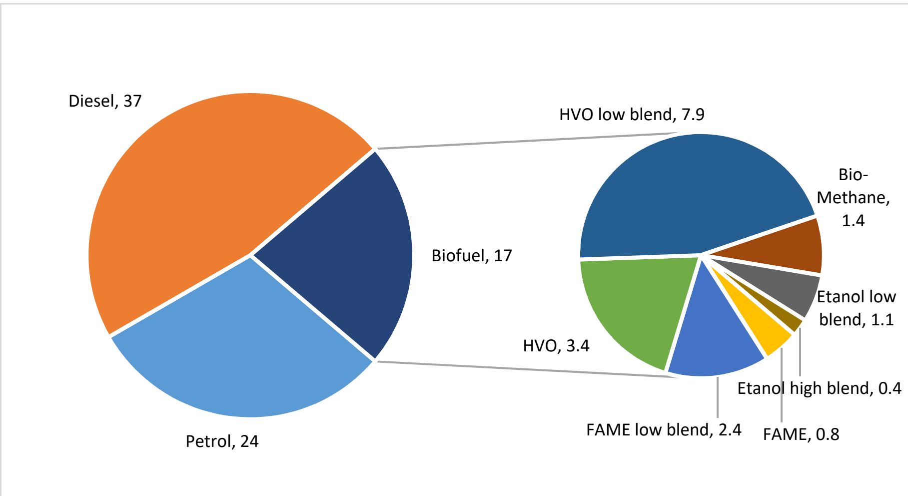

Fig. 2 Fuel Consumption in TWh within the Road Transport Sector during 2018

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 2018 corresponded to 8.8 g carbon dioxide equivalent (CO_2 eq) per megajoule (MJ). For FAME, the corresponding figure was 32.1 g CO_2 eq/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.

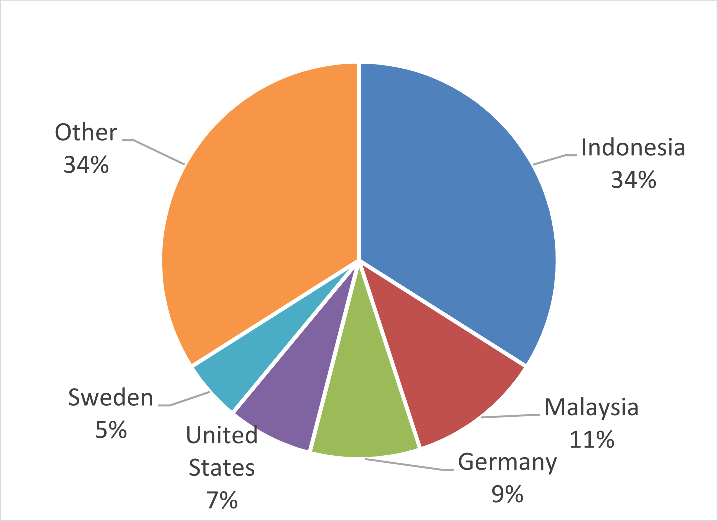

Fig. 3 Country of Feedstock Origin for HVO Consumed in Sweden in 2018

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 for 2018 to 2023 on a system level. The call does not accept projects that focus on technology development of vehicle or engine technologies.
- Energy-efficient vehicles in 2015 to 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

Swiss energy policy is characterized by two fundamental drivers: Phase out the use of nuclear energy, and reduce greenhouse gas emissions. The challenge is to achieve these objectives while maintaining security of supply at affordable prices and reducing carbon dioxide (CO_2) emissions.

The core measures of the revised Energy Act in force since 2017 [1] are therefore to withdraw step by step from the use of nuclear, to reduce electricity consumption, and an expansion of hydropower and new, renewable energy sources. The Swiss Parliament has been debating revision of the CO_2-Act [2] since 2018 and has not reached a conclusion by the end of 2019.

Climate change discussions worldwide and the strikes of young people locally affected parliamentary elections in autumn 2019. Green party candidates won numerous seats and several cities and cantons declared states of climate emergency. Furthermore, the Federal Council has decided in August 2019 to reduce Switzerland's net carbon emissions to zero by 2050. Therefore the new parliament is expected to pass the revised CO_2-Act soon, in which importers of motor fuels will have to compensate for at least 20% of CO_2 emissions by 2025. 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. To finance the respective measures, the revised Act is expected to specify that fuel price can be increased up to €0.09 ($0.10 US).

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. In 2018, the average was 137.8 g CO_2/km, and the penalty amounted to €27.9 million ($31.7 million US) [3]. In alignment with the European Union Commission, the Federal Council aims, from 2021 to 2024, to reduce average CO_2 emissions from passenger cars to 95 g CO_2/km and from light commercial vehicles (vans up to 3.5 metric tons) to 147 g CO_2/km [2]. Further reductions are foreseen for 2025 to 2029 and the use of synthetic CO_2-neutral fuels should be allowed to achieve the limit values.

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, will be raised to 10% in 2020, and will probably be 20% by 2025. Importers of fossil motor fuels may carry out their own projects or acquire certificates. The Swiss Petroleum Association established the Foundation for Climate Protection and Carbon Offset (KliK). It launches and subsidizes projects to reduce CO_2 emissions in fields such as transportation, industry, buildings, and agriculture. Another measure to reduce CO_2 emissions is to blend fossil fuels with biofuels.

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 standards are completely or partially exempt from the mineral oil tax. As a result, the tax reduction for biofuels is up to €0.64 ($0.72 US) per liter (L) in comparison with fossil fuels. The mineral oil tax reduction is only valid until 2020 [5].

Advanced Motor Fuels Statistics

Final total energy consumption in Switzerland in 2018[94] amounted to 830,880 terajoules, of which 36.3% was transport fuels (Figure 1) [6]. Compared to 2017, fuel consumption increased by 2.1%. Some changes in specific applications were made in 2018: diesel, +1.3%; gasoline, −1.6%; and aviation fuels, +5.7%. In the same period, the total amount of engine-driven vehicles increased by 1.0% to 6,113,791. Fuel consumption by vehicles dropped by 1.0%. With a share of 52.2% in 2018, the consumption of diesel was higher than the use of gasoline (44.1%), biofuels (3.4%) and natural gas, including biogas (0.3%). All fossil fuels were imported.

Electricity is used for railroad transportation, and a negligible amount is used for electric cars. Despite an impressive annual increase of electric vehicles (2015, +70%; 2016, +42%; 2017, +36%, and 2018, +32%), the total amount is still very small (19,181 passenger cars) [7].

[94] At the time this report was prepared, only data from 2018 were available.

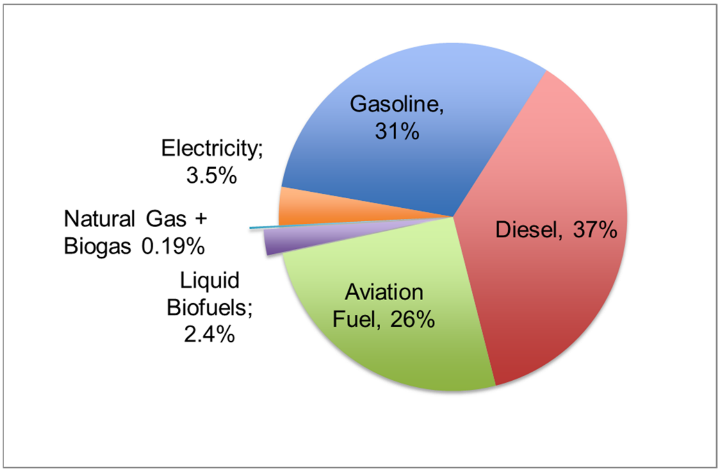

Fig. 1 Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland in 2018 [6]

As mentioned, importers of fossil motor fuels started blending fossil fuels with biofuels in 2014, due to the obligation to reduce CO_2 emissions. Within five years, the use of liquid biofuels rose from 29.4 million L to 248.5 million L. In 2018, 158.1 million L biodiesel and 56.3 million L bioethanol were used (Figure 2). Hydrotreated vegetable oil has only been used in Switzerland since 2016 (2018: 34.1 million L). Pure vegetable oil fuel is almost negligible (0.038 million L). Upgraded biogas as a transport fuel remained at a low level of 2.8 million kg [8].

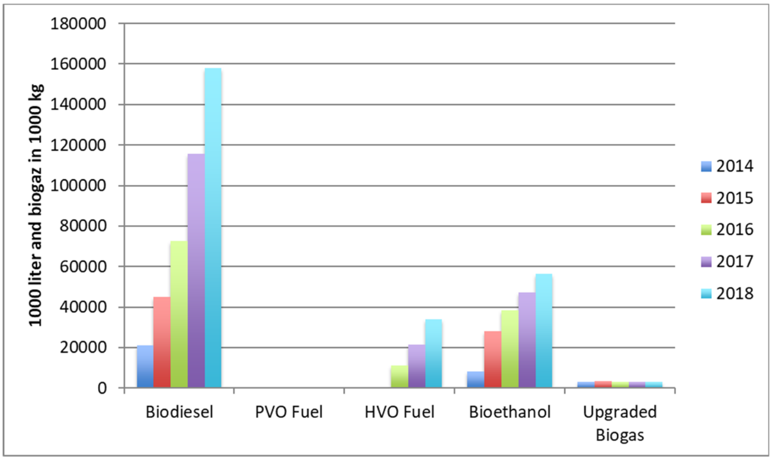

Fig. 2 Development of the Use of Biofuels as Motor Fuels in Switzerland, 2011–2015

Only 12.5 million L of biodiesel was produced in Switzerland. The other 145.5 million L was imported (73% from Germany, and the rest from nine other countries). All bioethanol is imported (Poland, 45.2%; Norway, 15.8%; Sweden, 11.8%; Germany, 11.0%, Holland, 8.6%; and Italy, 7.6%) [9]. Hydrotreated vegetable oil is imported from the United States, 94.6%; and Finland, 5.4%).

The total amount of biogas produced and used in Switzerland in 2018 was 113 million kg. Only 25.6 million kg has been upgraded and fed into the natural gas grid. From this, a small amount (2.8 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].

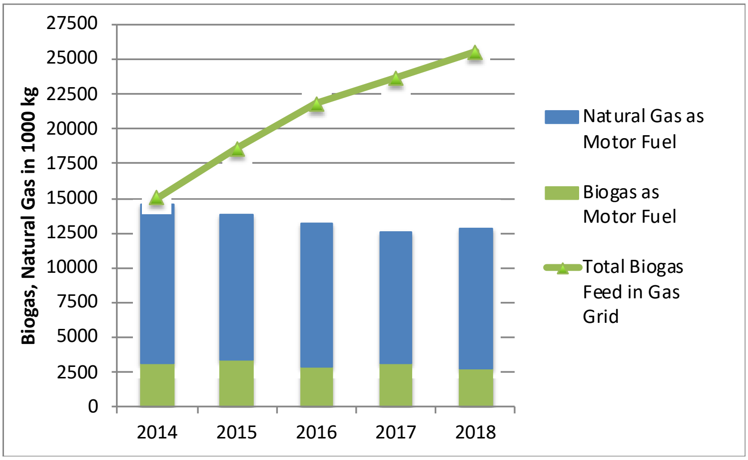

Fig. 3 Development of the Use of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

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.

Investigations of the suitability of DME as an alternative fuel in heavy-duty vehicles. Methanol/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.

Diesel engine with neat $OME_{3\text{-}6}$. Polyoxymethylene-dimethylether (OME) fuel has a high potential for reducing CO_2. The combustion characteristics of OME increase efficiency and simplify the exhaust after-treatment system, which increases the market chances of the more expensive fuel. This project's goal is to lay out an optimum OME engine and after-treatment configuration. This procedure includes detailed optical investigations, modelling of the combustion process, and testing of bench experiments.

Investigations with Diesel-butanol blend fuels. Diesel-butanol blends are durable with a reduced heat value, increased oxygen content, lower cetane number and no aggressive or corrosive properties. With the lower butanol blending ratios (< 10%), no operating differences are noticeable in the vehicle. Higher butanol contents (> 30%) result in worse cold start behavior, higher irregularity of engine running, and less dynamic performance at part-load operation. Emissions are unchanged with modern exhaust after-treatment systems.

Outlook

The new CO_2-Act will accelerate both use of biofuels and sales of electric and hybrid vehicles. By 2025, the petrol industry has to compensate for 20% of CO_2 emissions. In addition, the average of CO_2 emissions from passenger cars has to be reduced by 15% compared to 2021; after 2030, the average must be reduced by 37.5 %. The Swiss gas industry has set a goal to achieve a 30% share of renewable gas in the gas grid by 2030. To meet this goal different sources of renewable gas are needed. This includes power-to-gas technologies to produce hydrogen that can be methanated and fed in the natural gas grid. The Swiss engine industry and research institutes are intensively engaged in developing engines that can use natural gas/biogas and renewable liquid and gaseous fuels for passenger, long-haul, marine transportation and other off-road applications.

Additional Information Sources

[1] The Federal Council, 2017, "730.0 Energiegesetz (EnG)."
[2] Federal Office for Environment (FOEN), "Totalrevision CO_2 Gesetz."
[3] SFOE, 2019, "CO2-Emissionen von Neuwagen …im Jahr 2018."
[4] FOEN, 2012, "CO_2 emission compensation: motor fuels."
[5] Mineralölsteuergesetz (MinöStG), Stand: Jan. 1, 2012.
[6 SFOE, 2019, "Gesamtenergiestatistik 2018."
[7] Swiss Federal Statistical Office (BFS), 2019, "Mobility and Traffic."
[8] SFOE, 2019, "Schweizerische Statistik erneuerbarer Energien 2018."
[9] Swiss Custom Administration, 2019, "T2.8 Biogene Treibstoffe 2018"
[10] Association of the Swiss Gas Industry, 2019, "VSG-Jahresstatistik"
[11] www.bfe.admin.ch
[12] www.sccer-mobility.ch
[13] www.sccer-biosweet.ch

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) 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 2018 and show that the program saved 1.06 billion gasoline gallons equivalent (gge), including 744 million gge from alternative fuels/vehicles and 97 million gge from electric and hybrid vehicles.

The transportation sector continues to use a large amount of renewable fuels. The primary driver of renewable fuel use in the U.S. is the Renewable Fuel Standard (RFS), which was adopted in 2005 and expanded in 2007 (RFS2). It requires increasing the volume of renewable fuel to be used in motor fuels. On December 19, 2019, the U.S. Environmental Protection Agency (EPA) finalized the volume requirements and associated percentage standards under the RFS program for calendar year 2020 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The EPA also finalized the volume requirement for biomass-based diesel for 2021.[95] These volumes were slightly higher than those for 2019 compliance. However, the values were significantly lower than those originally targeted in the RFS legislation, which envisioned much more growth in cellulosic fuel production than has materialized. In 2019, the EPA finalized a rule allowing E15 in place of E10 in gasoline year-round and nationwide, which will increase demand by overcoming the so-called blending wall for ethanol in gasoline.[96]

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

[95] EPA, Final Renewable Fuel Standards for 2020, and the Biomass-Based Diesel Volume for 2021, December.

[96] EPA, 2019, Modifications to Fuel Regulations to Provide Flexibility for E15 June.

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 1.9 billion gge—were used in California in 2018.

Advanced Motor Fuels Statistics

The U.S. Energy Information Administration (EIA) estimated that total U.S. transportation energy consumption for the first 10 months of 2019 was 23,719 trillion British thermal units (Btu), less than 1% lower than the same period in 2018.[97] 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 1,176 trillion Btu during these 10 months, natural gas for 791 trillion Btu, electricity for 22 trillion Btu, and propane for 7 trillion Btu.[98]

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.[99] Each RIN is equivalent to 1 gallon of ethanol by Btu content; RINs are generated when a motor fuel refiner/blender blends or sells the renewable fuel or fuel blend.

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[97] *EIA Monthly Energy Review*, January 2020.
[98] Ibid.
[99] EPA, 2020, EPA Moderated Transaction System, February.

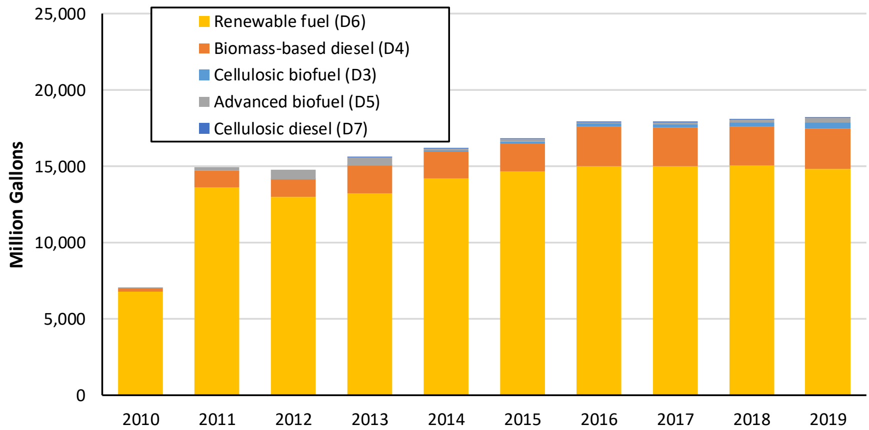

Fig. 1 Renewable Fuel Volumes Resulting from U.S. Renewable Fuel Standard

Electric Vehicles

Sales of plug-in electric hybrids (PHEVs) and battery electric vehicles (BEVs) in 2019, totaling 325,839, were down compared to 361,315 in 2018.[100] In addition, 400,746 hybrid electric vehicles (non-plug in) were sold in 2019, up from 343,285 in 2018.[101] Available plug-in models totaled 125 as of February 2020, up from 85 in February 2019.[102]

Alternative Fuel Infrastructure

The DOE's Alternative Fuels Data Center provides the number of alternative fuel refueling stations in the U.S.[103] As seen in Table 1, the total number of alternative fueling stations in the U.S., exclusive of electric recharging stations, increased by 31% between 2012 and 2019. However, the number of biodiesel (B20) and liquefied petroleum gas (LPG) stations decreased slightly in 2019. The total number of public and private nonresidential electric vehicle recharging outlets jumped by over 550% over this same 7-year period, with a large gain in 2019 as well.

[100] Argonne National Laboratory, 2020, "Light Duty Electric Drive Vehicles Monthly Sales Updates," anl.gov/es/light-duty-electric-drive-vehicles-monthly-sales-updates

[101] Ibid.

[102] DOE, 2020, Alternative Fuels Data Center, "Availability of Hybrid and Plug-In Electric Vehicles," afdc.energy.gov/vehicles/electric_availability.html

[103] DOE, 2020, "Alternative Fueling Station Counts by State," afdc.energy.gov/fuels/stations_counts.html

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

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

Research and Demonstration Focus

The DOE's Vehicle Technologies Office (VTO) sponsors research in fuels and advanced combustion engines for the purpose of displacing petroleum-derived fuels, matching engines and fuel characteristics better, and increasing engine and vehicle efficiencies. This research covers a very broad range of fuel, engine, and vehicle technologies. The summary provided here focuses on fuels and fuel effects and is based on annual program reports.[104,105]

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. The current Co-Optima program was designed to run for 10 years, including research on the relationship between fuels and engines to achieve optimum efficiency and emissions with consideration of fuel production pathways that can enable commercial introduction. For example, in 2019, researchers identified the top 10 biofuel-derived blendstock candidates to improve turbocharged spark-ignited engine efficiency at a competitive cost, after a comprehensive assessment of more than 400 bio-derived molecules and

[104] DOE, VTO, 2019, *Advanced Combustion Engines and Fuels 2018 Annual Progress Report*, DOE/EE-1833, April.

[105] DOE, VTO, 2019, *Co-Optimization of Fuels & Engines FY18 Year in Review*, DOE/GO-102019-5150, June.

mixtures across many chemical families. Co-Optima includes both spark ignition technologies targeted for commercialization by 2025, and compression ignition technologies targeted for commercialization by 2030. 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.

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 2020* projects decreasing transportation energy use from 2020 through 2038 due to mandated increases in fuel efficiency. However, growth in travel demand will outpace these benefits and energy use will increase from 2039 to 2050.[106] BEV sales will increase from 2% to 11% of total light-duty vehicles sold in the U.S. over 2019 to 2050, due to falling battery costs. In 2050, PHEV and hydrogen fuel cell vehicle (FCV) projected sales are small, at 1.4% and 0.02% of sales, respectively. In 2025, projected sales of light-duty BEVs, PHEVs, and FCVs will reach nearly 700,000, or about 4% of projected total sales of light-duty vehicles. The use of natural gas in medium- and heavy-duty vehicles is also projected to increase its share of total sales.

Additional Information Sources

- Oak Ridge National Laboratory, 2020, "Transportation Energy Data Book," tedb.ornl.gov/
- DOE, 2020, Federal and State Laws and Incentives, afdc.energy.gov/laws/
- EIA, 2019, *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/

[106] Energy Information Administration, Annual Energy Outlook 2020, 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, see 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; and
- Working Party on Renewable Energy Technology (REWP): technologies, socioeconomic issues, and deployment policies.

Each Working Party coordinates the research activities of relevant IEA Technology Collaboration Programmes (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 (www.iea.org/tcp).

4.b
AMF TCP Contact Information

4.b.i
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Michael	Wang	Alternate	USA	mqwang@anl.gov

[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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Kim	Winther	60	kwi@dti.dk

[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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Dina	Bacovsky	Secretary	dina.bacovsky@best-research.eu

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

4.c
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, at dina.bacovsky@best-research.eu.

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

Financial obligations of membership include:

- An annual membership fee, currently €10,250 ($11,600 US);
- Funding for an ExCo delegate to attend two annual meetings; and
- Cost-sharing contributions to annexes in which you wish to participate; cost shares range from €10,000 to €100,000 ($11,318 to $113,177 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 ExCo delegate.

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

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 fuelling 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 also 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
3CV	Center for Vehicle Control and Certification (Chile)
ADD	Agency for Defense Development (Republic of Korea)
AFV	Alternative Fuel Vehicle
AMFI	Advanced Motor Fuels Website
B20	Biodiesel
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)
BMK	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology (Austria)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Germany)
BMWi	Ministry of Economic Affairs and Energy (Germany)
BTL	Biomass to Liquid
BTX	Biomass
CAAM	China Association of Automobile Manufacturers
CATARC	China Automotive Technology and Research Center
CERT	Committee on Energy Research and Technology (IEA)
CFS	Clean Fuel Standard (Canada)
CGSB	Canadian General Standards Board
CHP	Combined Heat and Power
CHT	Centre for High Technology (India)
CMMCh	Centro Mario Molina (Chile)
CBG	Compressed Biogas
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2 eq	Carbon Dioxide Equivalent

DBT	Department of Biotechnology (India)
DDF	Diesel Dual Fuel
DF	Dual Fuel
DME	Methanol/Dimethyl Ether
DOC	Diesel Oxidation Catalyst
DOE	U.S. Department of Energy
DPF	Diesel Particulate Filter
E85	85% Ethanol in Gasoline Fuel
EBP	Ethanol Blended Petrol
EGR	Exhaust Gas Recirculation
EIA	U.S. Energy Information Administration
EIP	Energy Innovation Program (Canada)
EMPA	Swiss Federal Laboratories for Materials Science and Technology (Switzerland)
EPA	U.S. Environmental Protection Agency
ERA-NET	European Research Area Bioenergy
ESY	Ethanol Supply Year
ETBE	Ethyl Tertiary-Butyl Ether
ETN	Energy Technology Network (IEA)
ETS	Emissions Trading System (EU)
eTV	ecoTechnology for Vehicles (Canada)
EU	European Union
EV	Electric Vehicle
EVID	Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative (Canada)
ExCo	Executive Committee
FAME	Fatty Acid Methyl Ester
FAU	Friedrich-Alexander-Universität Erlangen-Nürnberg (Germany)
FCV	Fuel Cell Vehicle
FFV	Flex-Fuel Vehicle
FNR	Fachagentur Nachwachsende Rohstoffe
FVMI	Association of the Mineral Oil Industry (Austria)
FVV	Forschungsvereinigung Verbrennungskraftmaschinen
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
HPCL	Hindustan Petroleum Corporation, Ltd. (India)
HSL	Helsinki Region Transport
HTL	Hydrothermal Liquefaction
HVO	Hydrotreated Vegetable Oil
IAE	Institute for Advanced Engineering (Republic of Korea)
ICE	Internal Combustion Engine
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IMO	International Maritime Organization
JRC	Joint Research Centre of the European Commission
KLIEN	Austrian Climate and Energy Fund
KliK	Foundation for Climate Protection and Carbon Offset (Switzerland)
LCFS	Low-Carbon Fuel Standard (US)
LDV	Light-Duty Vehicle
LEVO	Organization for the Promotion of Low Emission Vehicles (Japan)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LTT	Institute of Engineering Thermodynamics (Germany)
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 (Chile)
MTT	Ministry for Transport and Telecommunication (Chile)
NCRE	Non-Conventional Renewable Energies
NEDC	New European Driving Cycle
NECP	National Energy and Climate Plan (Austria)
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
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
PtX/P2X	Power to X (Germany)
R&D	Research and Development
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)
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
SOA	Secondary Organic Aerosol
SUV	Sport Utility Vehicle
SynBioPTx	Synergies Combining Biomass and Power Technologies
TAEE	Tertiary-Amyl Ethyl Ether
TCP	Technical Collaboration Program (IEA)
TEPS	Transportation Electric Power Solutions (Israel)
UER	Upstream Emissions Reductions (Germany)
UN	United Nations
VPT	Vehicle Propulsion Technologies Program (Canada)
VTO	Vehicle Technologies Office (US)

WHVC	World Harmonized Vehicle Cycle
WLTP	Worldwide Harmonized Light Vehicle Test Procedure
WP	Work Project

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	megatonnes of oil equivalent
PJ	petajoule(s)
TJ	terajoule(s)
TWh	terawatt hour(s)
W	watt(s)