IEA-Advanced Motor Fuels

ANNUAL REPORT 2018

iea Energy Technology Network

ADVANCED MOTOR FUELS IEA-AMF

IEA Technology Collaboration Programme on

Advanced Motor Fuels Annual Report 2018

Rainbow Spine: The colors used for the spines of Advanced Motor Fuels Annual Reports follow the colors of the rainbow: violet, blue, green, yellow, and red. Using colors allows readers to easily distinguish among the different editions of the annual report. The spines of previous editions in the current AMF working period violet, blue, and green.

This year´s edition has a yellow spine, because it is the fourth annual report in this working period. Yellow indicates foresight, hope, and the future. AMF is looking into the future. We wish to contribute to a sustainable society around the globe by advancing the development and use of advanced motor fuels. Advanced renewable transport fuels have a particularly important role to play in the decarbonisation of the transport sector, and may furthermore contribute to reduced local emissions.

Cover:
This is a heavy-duty truck fuelled by liquefied natural gas (LNG). The technology is based on compression ignition and thus also needs a small amount of diesel to create a pilot ignition. The result is energy efficiency comparable with that of a conventional diesel engine. The combination of high energy efficiency and the lower carbon content of methane, compared to diesel, enables lower specific carbon dioxide (CO_2) emissions, even if fuelled with natural gas. If the truck were fuelled with biomethane and renewable diesel (for example, HVO [hydrotreated vegetable oil]), this would still be a fossil-free, heavy-duty road freight hauler.

Methane, and thereby also LNG, is a global commodity, which enables a widespread adoption of this technology around the globe. A methane-fuelled engine, such as LNG or compressed natural gas (CNG), is fully compatible with renewable methane without any adaptations to the engine or fuel system.

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

Photo credit: Volvo Trucks
Cover Design: Katie Ekins (Argonne National Laboratory)

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 with synthesis efforts on timely topics on a quick turn-around basis. In 2018 AMF TCP also contributed to the Renewable Energy Market Report of the International Energy Agency (IEA) with information on the impact of different renewable fuels on the emissions of air pollutants as well as on the Global Fuel Efficiency Initiative 2018 report.

Advanced low-carbon motor fuels are the only measure, besides curbing mobility, which can reduce the GHG emissions from the existing fleet of vehicles. For older engine technologies, advanced motor fuels can also contribute to reduce 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 the environmental awareness, as specified by the IEA, and an improved energy security by offering new and sustainable fuel pathways.

Advanced motor fuels are important and will continue to be important for the transport sector. During 2018, India joined AMF, through Ministry of Petroleum & Natural Gas. As the current chairperson of AMF, I am very glad to welcome one of the largest countries in the world to our Technology Collaboration Programme. India has a rapidly growing transport sector, and an aim to improve the energy security and reduce the emissions of exhaust gases. I am looking forward to a long and rewarding cooperation.

Today, AMF TCP is represented by contracting parties in North America, South America, Europe, and Asia. Large and expansive economies such as the ones in India and China are covered. **In total, the contracting parties of AMF TCP represent almost 50% of the world's population.** AMF TCP has a truly worldwide engagement, although 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 current strategic term of AMF TCP will end in February 2020, and we have started our work for the new 5-year term. The contracting parties of AMF TCP have identified several areas of significant interest, such as reduction of GHG emissions, assessment of impact and cost, and comparison of energy carriers. The likely focus areas of the next term are as follows:

Fuels:
- Focus on fuels 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)
- (Pre) studies on emerging fuels (such as electrofuels, ammonia, and alternative aviation fuels)

Vehicles:
- Real driving emissions, including deterioration of emission performance over distance
- Efficiency of heavy-duty vehicles (with possible spill-over toward non-road machinery)
- Range extender options for electric vehicles

System analysis:
- Comparison of different energy carriers for transport applications (timeline, impact, cost)
- Assessment of drop-in types of fuels vs. fuels requiring new vehicles and new infrastructure

Speaking of the future, there are arguments that the future transport sector will be electric and that the internal combustion engine is dead. I do not believe in this at all. We will need a wide pallet of measures to be able to replace the vast amount of fossil fuels used in today's society. We will most likely need a combination of renewable fuels, electrification, energy efficiency, modal shift, and a transport-efficient society. **Advanced motor fuels, in parallel with electrification, enable transport to serve a sustainable society around the globe.**

In 2018 the AMF TCP started several interesting annexes, such as methanol as motor fuel, heavy-duty vehicle evaluation, and lessons learned. All these projects have importance and strategic relevance both for the participating countries and for a broader audience. The **2018 Climate and Clean Air Award for Enabling Policy** for reducing diesel air pollution given to Chile is a good example of the impact of an AMF annex, Annex 53, on a sustainable bus system.

Last year also included some losses for AMF. PTT Public Company Limited from Thailand had to leave AMF since the company changed its strategic direction. We wish PTT and Thailand all the best with their future activities. AMF also lost a valuable asset and a good friend in Ralph McGill who passed away in 2018. We thank Ralph for everything he did for AMF. Our thoughts go to his family and friends.

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

The vision of the members of the Advanced Motor Fuels Technology Collaboration Programme (AMF TCP) is a sustainable transportation system that uses advanced, alternative, and renewable fuels; has reduced emissions of greenhouse gases and air contaminants; and meets the needs for personal mobility and the movement of goods on both a local and global scale. The AMF TCP contributes to the achievement of this vision by providing a solid basis for decision making (information and recommendations) and by providing a forum for sharing best practices and pooling resources internationally.

Mission

The mission of the AMF TCP is to provide sound scientific information and technology assessments to citizens and policy makers to allow them to make informed and science-based decisions about options involving the use of advanced fuels for transportation systems. To provide such data to decision makers, the AMF TCP acts as a clearinghouse by:

- Pooling resources and information on an international level;
- Identifying and addressing technology gaps and barriers to deployment;
- Performing cooperative research on advanced motor fuels;
- Demonstrating advanced motor fuels and related vehicle and after-treatment technologies; and
- Aggregating data and deriving key recommendations for decision makers within governments, municipalities, and industry.

The AMF TCP fulfills its mission through the international cooperation of academia, industries, governmental institutions, and nongovernment organizations. The Annexes in the AMF TCP are a starting point to enable members to cooperate in groups that share common interests and to learn and grow as they interact and share different perspectives.

Highlights on Advanced Motor Fuels

Nils-Olof Nylund, with input from Magnus Lindgren, Michael Wang, Kim Winter, Yutaka Takada, and C.B. Lee

Looking back at 2018, a lot of transport-related news focused on planned bans of internal combustion engine (ICE) cars, electrification, and autonomous vehicles. One can note that the theme — advanced motor fuels — was not that appealing. Notwithstanding, almost all of the current vehicle fleet is propelled by ICEs, and although electrification of passenger cars is progressing rapidly, the bulk of the world vehicle fleet will still be depending on ICEs in 2030. This means that we need fuels now and in the future, however, hopefully cleaner fuels and fuels with lower carbon intensity than we have today. AMF will be contributing to a cleaner and more sustainable future by carrying out collaborative research and demonstrations of clean fuels and clean ICE technology.

Still, there is some good news for ICEs as well as advanced motor fuels, both regarding policies and technology. The regulatory framework for exhaust emissions is constantly improving, contributing to lower real-driving emissions (RDEs). Data released by the European Automobile Manufacturers' Association (ACEA) at the end of 2018 provide evidence that latest-generation diesel cars emit low pollutant emissions on the road.[1] The new data for some 270 Euro 6d-TEMP-certified cars show that all of these diesel cars performed well below the nitrogen oxide (NO_x) threshold of the RDE test, which applies to all new car types since September 2017. What is more, most of these vehicles already show results that are below the stricter NO_x threshold that will be mandatory from January 2020.

Data generated within AMF also show that new Euro VI heavy-duty vehicles perform well. When combined with a sustainable and renewable fuel, we have a viable option combining low local emissions and low climate impacts.

On petrol engines, we are beginning to see gasoline particulate filters, in practise eliminating nanoparticle emissions from fuel-efficient, direct-injection petrol engines. The evidence is there — the ICE can be very clean.

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1 https://www.acea.be/press-releases/article/diesel-new-data-proves-that-modern-diesel-cars-emit-low-pollutant-emissions

Progress has also been made in actual engine technology. The Japanese car manufacturer Mazda has been working on advanced combustion systems for a while. The newest SKYACTIV-X engine, featuring spark-controlled compression ignition, combines the benefits of a spark-ignition petrol engine (e.g., low exhaust emissions) with those of a compression-ignition diesel engine (superior initial response and fuel economy) to produce a crossover engine that delivers the best of both worlds.[2]

In Europe, the update of the Renewable Energy Directive (RED II) was finally approved in December 2018.[3] The European Union's 2030 climate strategy does not encompass a target for renewable energy in transport. However, such a target is now included in RED II. The Directive states: "*Each Member State shall set an obligation on fuel suppliers to ensure that the share of renewable energy in the transport sector is at least 14 % by 2030*."

The listing of renewable energy includes biofuels, biogas, renewable liquid and gaseous fuels of non-biological origin (electrofuels), recycled carbon fuels, and electricity. Traditional biofuels from food and feed crops are capped at 7%. The contribution from advanced biofuels (Annex IX A) will be at least 3.5% in 2030. Various multipliers exist for electricity as well as advanced biofuels. Basically, the updated Directive is good news for electricity, but also for advanced biofuels and electrofuels as well.

In the U.S., the Environmental Protection Agency is directed by the White House to develop a rule for E15 nationwide.[4] There is interest in higher ethanol concentration in petrol in Europe as well, and E20/25 is being investigated.

The individual states in the U.S. have the possibility to set their own rules and regulations. California has always been progressive in reducing emissions of all kinds. The California Air Resources Board has adopted the next phase of its Low-Carbon Fuel Standard (LCFS), extending it from 2020 to 2030 with additional carbon intensity reductions between 2020 and 2030.[5]

Canada is developing its Clean Fuel Standard for the entire country to promote the use of a broad range of low carbon fuels and energy sources

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2 http://www.mazda.com/en/innovation/technology/skyactiv/

3 https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

4 https://www.whitehouse.gov/briefings-statements/president-donald-j-trump-expanding-waivers-e15-increasing-transparency-rin-market/

5 https://www.arb.ca.gov/fuels/lcfs/lcfs.htm

such as renewable and alternative fuels. The objective of the Clean Fuel Standard is to achieve 30 megatonnes of annual reductions in greenhouse gas (GHG) emissions by 2030.[6]

India is strongly promoting biofuels. A National Biofuels Policy was established in 2018. The indicative targets for 2030 are 20% ethanol in petrol and 5% biodiesel in diesel fuel. There is substantial interest in advanced biofuels. Ten demonstration plans for second-generation ethanol will receive funding support. There are also activities in biogas as well as in biodiesel from used cooking oil.

Hydrogen is high on the agenda in Japan. The Japanese government has consistently been aiming to realize a hydrogen society, and the budget for hydrogen-related projects has been expanded for fiscal year 2019. Activities include alternative sources for hydrogen, development of refueling stations, review of the regulatory framework, development of technology, and reduction of costs for hydrogen-related systems. Fuel cell technology is promoted for vehicle as well as stationary applications. The Tokyo 2020 Olympic and Paralympic Games will be one of the showcases for promoting the hydrogen society and fuel cell vehicles.

In Korea, natural gas is making progress in vehicles and in the marine sector. Drivers are energy diversification and carbon dioxide reduction. In the road sector, demonstrations of heavy-duty liquefied natural gas (LNG) trucks are under way. According to the renewable fuel policy of Korea, 3% biodiesel is blended into diesel fuel. The Korean government has set targets for alternative vehicles in 2022: 430,000 electric cars and 65,000 hydrogen fuel cell cars (numbers in 2017 were 25,593 electric cars and 177 hydrogen cars).

The interest in methane, especially biogas or biomethane, seems to be growing worldwide. In Europe, the proposal for the update in the Directive on Clean and Energy Efficient Vehicles[7] lists the following types of alternative fuel heavy-duty vehicles as clean vehicles: electricity, hydrogen, and natural gas including biomethane, in gaseous form (compressed natural gas) and liquefied form (LNG). In addition, the RED II Directive gives some very favourable default values for well-to-wheel GHG savings for wet manure-based biogas, actually showing manure-based biogas as a carbon sink.

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6 https://www.canada.ca/en/environment-climate-change/services/managing-pollution/energy-production/fuel-regulations/clean-fuel-standard.html

7 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52017PC0653

In the 2017 AMF Annual Report, it was mentioned that three heavy-duty vehicle manufacturers had launched new powerful (400 plus horsepower) methane trucks. Annex 57 of AMF, "Heavy-Duty Vehicle Performance Evaluation," was kicked off at the fall 2018 AMF Executive Committee meeting in New Delhi. The new Annex will test, among other heavy-duty vehicles, all these three new heavy-duty methane vehicles, thus delivering first-line AMF data on the true performance of new generation heavy-duty methane vehicles.

Even if electrification is gaining market shares in the light-duty sector, we also have to consider heavy-duty vehicles, construction equipment, agricultural machinery, ships, and airplanes. These are even more dependent on a gaseous or liquid fuel than the passenger car sector. In the heavy-duty road sector, we see a range of vehicles adapted for methane (both in the form of compressed and liquefied methane), ethanol (compression ignition), and even dimethyl ester. Renewable diesel (hydrotreated vegetable oil [HVO]) and traditional biodiesel (fatty acid methyl ester) only require minor adaptation of the vehicles; in some cases, renewable diesel requires no modifications at all.

Some similarities can be seen in the marine sector and in aviation. Renewable HVO-type kerosene has already been certified to be used up to 50% blending in aviation. In the marine sector, methane as well as methanol are fuels of high interest. A new energy carrier that could have a significant potential is ammonia. In 2018, the AMF Executive Committee decided to launch a strategic project on ammonia as an energy carrier in transportation. AMF stays alert and is constantly monitoring policy as well as technology. And, very important, we have the ability to generate solid performance data for various vehicle technology and fuel combinations.

IEA Technology Collaboration Programme on

Advanced Motor Fuels Annual Report 2018

This Annual Report was produced by Kevin A. Brown (project coordination/ management), Margaret A. Clemmons (editor), Vicki Skonicki (document production), and Gary Weidner (printing) of Argonne National Laboratory. The cover was designed by Katie Ekins, 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 Transport, Innovation and Technology (BMVIT)
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	Instituto para la Diversificación y Ahorro de la Energía (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 53	Sustainable Bus Systems	Alfonso Cádiz
Annex 54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
Annex 55	Real Driving Emissions and Fuel Consumption	Thomas Wallner
Annex 57	Heavy-Duty Vehicle Performance Evaluation	Petri Söderena

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)	ExCo Chair
Nils-Olof Nylund	The Technical Research Centre of Finland (VTT)	Strategy & Technology Subcommittee Head
Dina Bacovsky	BIOENERGY 2020+	Secretary

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1 The Advanced Motor Fuels Technology Collaboration Programme

Technology Collaboration Programme for Advanced Motor Fuels (AMF TCP)

The Need for Advanced Motor Fuels

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

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

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

Our Approach

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

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

By verifying existing 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 programmes and projects on a wide range of energy technologies and related issues (see also Section 4a). TCP activities and programmes 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 programme 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 programme, for continuous development of AMF's scope, and for reacting to any technology gaps or market barriers that have been identified.

Current Work Program

As of June 2019, nine projects are ongoing:

- Annex 28: Information Service and AMF Website
- Annex 51: Methane Emission Control
- Annex 53: Sustainable Bus Systems
- 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: Advanced Renewable Transport Fuels to Transport Decarbonisation in 2030 and Beyond
- Annex 59: Lessons Learned from Alternative Fuel Experiences

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 for 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 a new project together with IEA Bioenergy is under development.

2 Ongoing AMF TCP Annexes

2.a
Overview of Annexes

Ongoing Annexes in 2018

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
51	Methane Emission Control	Jesper Schramm
53-2	Sustainable Bus Systems	Alfonso Cadiz
54	GDI 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

Recently Completed Annexes

Annex Number	Title	Operating Agent
50	Fuel and Technology Alternatives in Non Road Engines	Magnus Lindgren
52	Fuels for Efficiency	Somnuek Jaroonjitsathian
53-1	Sustainable Bus Systems	Alfonso Cadiz

The final reports for the recently completed 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, Thailand, United States
Total Budget	€50,000 ($56,125 US) for 2018 €65,000 ($72,963 US) for 2019
Operating Agent	Dina Bacovsky BIOENERGY 2020+ Email: dina.bacovsky@bioenergy2020.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 2018, an additional activity included the preparation of a section for the IEA publication, "Renewables 2018," on air quality implications of transport biofuel consumption. The content is based on the findings of several AMF Annexes. Tables 1 and 2 show the effect that the combination of fuel and vehicle technology has on local emissions of vehicles.

Table 1 Air pollutant emissions by fuel from modern and older cars

	Modern cars			**Older cars**		
Fuel	NO_x	PM	VOCs	NO_x	PM	VOCs
Gasoline	green	yellow	yellow	green	green	orange
Ethanol (E85)	green	green	yellow	green	green	orange
Biomethane	green	green	green	green	green	yellow
Diesel	orange	green	green	red	red	orange
FAME Biodiesel	orange	green	green	red	orange	yellow
HVO	orange	green	green	orange	orange	yellow

Emissions from lowest to highest (left to right): green, yellow, orange, red

Notes: Older = Euro 3 or equivalent (e.g., model year 2000 in Europe); modern = vehicles that meet Euro 6 emissions standards or equivalent. Assessing the relative performance of biofuels compared with fossil fuels in terms of air pollutant emissions, and therefore health impact, is complex. Consequently, ranking different fuels according to health impact can be subject to debate because biofuels can decrease some air pollutant emissions compared with fossil fuels while increasing others. Consideration must also be given to the fossil fuel substituted, how the biofuel is consumed, e.g., blended (at a low or high share) or unblended, and the level of sophistication of the vehicle's engine and after-treatment technology. In addition, the relative health risks of different air pollutants must also be taken into account. Particulate matter (PM) categorisation for modern cars is made on the basis that direct injection gasoline engines have higher PM emissions than particulate filter-equipped diesel cars.

Table 2 Air pollutant emissions by fuel from modern and older heavy-duty vehicles

	Modern heavy-duty			**Older heavy-duty**		
Fuel	NO_x	PM	VOCs	NO_x	PM	VOCs
Diesel	yellow	green	green	red	red	orange
FAME Biodiesel	yellow	green	green	red	orange	yellow
HVO	yellow	green	green	orange	orange	yellow
Biomethane	yellow	green	green	yellow	green	yellow

Emissions from lowest to highest (left to right): green, yellow, orange, red

Note: Please see notes below Table 1.

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 2018, three electronic newsletters were published on the AMF TCP website: one each in June, 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.

The Special Report, "Air Quality Implications of Transport Biofuel Consumption," is available on the website.

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 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 carbon dioxide (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 greenhouse gas (GHG) effects, it is a disadvantage that LNG engines emit significantly larger quantities of unburned methane than do traditional engines. Because methane is a twenty times more powerful GHG 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

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 refuelling, 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 53: Sustainable Bus Systems

Project Duration	November 15–December 2017
Participants **Task Sharing** **Cost Sharing**	Canada, Chile, Finland, Israel, Sweden, United States
Total Budget	$600,000 US (Estimated Budget)
Operating Agent	Alfonso Cádiz Technical Secretary of 3CV Ministry of Transport and Telecommunications of Chile Email: acadiz@mtt.gob.cl

Purpose, Objectives, and Key Question

Some cities in Latin America are facing the renewal of their bus fleets. At this time, it is essential that bus transport systems be energy efficient, low polluting, and soot-free buses. In this context, advanced technologies require an appropriate characterization of the advantages of clean and energy-efficient buses in terms of emissions, operational costs, and fuel economy. These characteristics vary, however, depending on local operating conditions, emission regulations, fuel quality, and type of service the buses provide. Verified performance data are needed, as well as test and assessment methodologies that reflect local needs and conditions.

The main objective of Annex 53 is to develop a methodology for establishing requirements for clean and energy-efficient buses that can be used in the tendering process for public transportation operators in developing regions. Such a methodology includes guidance and recommendations on control and follow-up of the buses in operation. A methodology to assess emission stability over time will also be considered. Only original equipment manufacturer products will be considered; retrofit solutions will not be addressed.

Activities

Activities include analysis of the performance of existing buses, evaluation of the operating conditions in pilot regions, comparison of these with existing test cycles, development of a common test methodology, execution of tests with selected fuels and vehicles, data analysis, and the development of guidelines for buses in sustainable bus transport systems. To facilitate the analysis, the project included a work exchange between European and South American researchers.

Key Findings

The buses found in different international markets may differ greatly, particularly in developing regions, hence, the importance of evaluating the operational condition of the urban bus systems in local settings (Figure 1). Regarding emissions under local conditions, a Euro VI bus measured in the TS-STGO cycle is twice as high as the results seen under the Braunschweig cycle. Furthermore, its energy consumption is higher in the TS-STGO cycle versus the Braunschweig cycle, seeing consumptions that are 60% higher for the same Euro VI diesel bus.

Battery electric buses consume less than a quarter of the energy than a diesel bus requires per kilometer under the TS-STGO cycle; however, this consumption is still higher than in other cities (Figure 2).

The report of the energy consumptions under the TS-STGO cycle will allow the fleet renewal process with Euro VI buses and the progressive introduction of battery electric buses, to produce the highest possible reductions in energy consumption and local emissions with market-ready technologies.

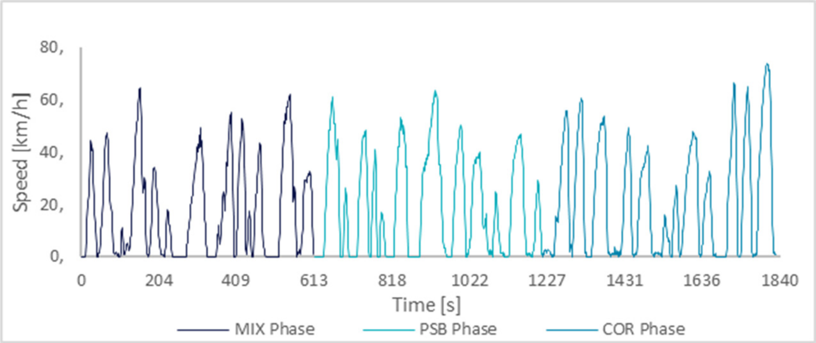

Fig. 1 Santiago Driving Cycle

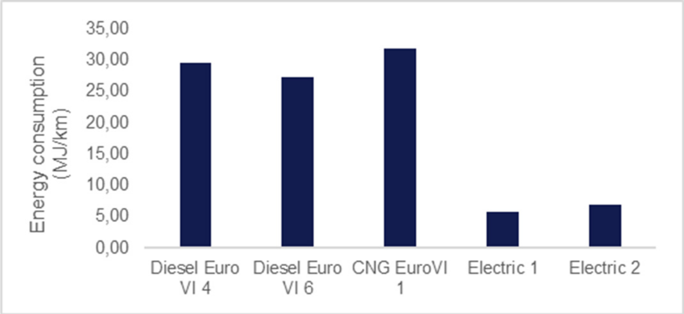

Fig 2. Energy Consumption for Urban Buses (Santiago driving cycle, 1.4% slope)

Finally, a document was developed that describes the parameters to be considered in a methodology for establishing requirements for clean and energy-efficient buses for use in the tendering process for public transport operators in developing regions. The methodology includes guidance and recommendations to control and follow up the buses. Follow-up is important, especially in the case of Euro VI, in terms of (1) the importance of driving cycles, (2) the measurement of emissions and fuel/energy consumption, (3) vehicle technologies, (4) fuels, (5) approval of engines to be used in heavy-duty vehicles, and (6) inspection and maintenance (periodic technical inspection).

Publications

- Annex 53-1, "Sustainable Bus Systems" (final report).
- Resolution 2.243, Ministry of Transport and Telecommunications of Chile, "Technical Protocol to Obtain Energy Consumption in Urban Public Transport Buses in the City of Santiago," 2018, available at http://bcn.cl/26gbi
- "Potential for Electric Buses in Santiago," VTT, 2018.
- Technological Consortium for the Promotion of Electromobility, Centro Mario Molina, 2018.
- "Analysis of Potential Public Transport Routes to Electrify in Santiago de Chile," Centro Mario Molina, 2018 MOVE Webinar, available at https://bit.ly/2IHwFFP
- "Development of a Labeling System for Energy Efficiency and Emissions for Transantiago Buses," Centro Mario Molina, 2017.

Annex 54: GDI Engines and Alcohol Fuels

Project Duration	April 2016–April 2019
Participants **Task Sharing** **Cost Sharing**	 Canada, Germany, Israel, Switzerland, United States 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 Question

Under certain conditions, gasoline direct injection (GDI) may increase particle emissions in comparison with port fuel injection (PFI) engine technologies, up to levels that are over the emissions from diesel vehicles equipped with diesel particulate filters (DPFs). Both gasoline particulate filters (GPFs) and alcohol fuel blends, such as E85 (85% ethanol in gasoline fuel), have shown the potential to reduce particulate matter (PM) emissions from GDI vehicles.

The objective of this Annex is to determine the impacts of alcohol fuels on emissions from GDI engines. In addition to information on combustion processes, the focus will be on tailpipe gaseous emissions and PM, along with the potential for secondary organic aerosol (SOA) and genotoxicity formation. The fuels investigated include ethanol blends (E10 to E85, and E100), methanol blends (M56), and butanol blends. The impacts of GPFs and start-stop operation on emissions from GDI vehicles will also be investigated.

Activities

The main activities of this Annex are chassis dynamometer tests of vehicles with GDI engines and comparable counterpart engines. These vehicles will be chassis dynamometer tested over varying drive cycles and ambient temperatures. The vehicles will also be tested with fuels of varying alcohol content (e.g., ethanol, methanol, and butanol) to assess the impact of alcohol fuels on emissions from GDI engines. Some vehicles will be equipped with GPFs in order to determine their efficiency in reducing emissions from GDI engines.

The focus of this project is to obtain detailed information about particulate and particle emissions from GDI technologies. Along with gaseous emissions, fuel economy and efficiency will be quantified. The impact of alcohol fuels and GPFs on PM, particle number (PN), and BC emission rates will be measured. Also, the potential for SOA formation using different vehicle fuel and technology combinations will be assessed.

Experiments were carried out at the Emissions Research and Measurement Section of Environment and Climate Change Canada. Two light-duty vehicles, one GDI and one PFI, were tested on a chassis dynamometer with low-level ethanol blends. The drive cycles used were the Federal Test Procedure (FTP-75) and the Supplemental Federal Test Procedure (US06) at 25°C and −7°C. Tests were also conducted with the GDI vehicle equipped with and without a GPF. Emissions characterization includes carbon monoxide (CO), nitrogen oxide (NO_x), hydrocarbon (HC), gravimetric PM, and PN and BC.

Chile's contribution was led by the Centro Mario Molina (CMMCh). Experiments will be carried out at the Center for Vehicle Control and Certification (3CV) laboratory and photochemical chamber at the Ministry for Transport and Telecommunication (MTT).[8] Chassis dynamometer tests were conducted with light-duty vehicles using the New European Driving Cycle (NEDC) and FTP test cycle, with varying blends of ethanol fuel (e.g., E0, E10, and E85, E22, and E100). In addition to primary gaseous measurements of HC, non-methane hydrocarbon (NMHC), NO_x, and CO, secondary gas formation and particle formation were quantified for ultraviolet irradiation-aged emissions.

Studies conducted at the Institute of Engineering Thermodynamics (LTT) Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) in Germany contain fundamental investigations of mixture formation and soot formation in an optically accessible GDI engine using laser-based diagnostics. Further characterizations of PM are conducted in the exhaust gas duct of a metal GDI engine. Different ethanol-gasoline mixtures (e.g., E20, E85) and other model fuel mixtures (including iso-octane and toluene) as well as butanol mixtures (e.g., Bu20) were studied in a wide range of operating points.

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[8] Gramsch, E., Papapostolou, V., Reyes, F., Vásquez, Y., Castillo, M., Oyola, P., López, G., Cádiz, A., Ferguson, S., Wolfson, M., Lawrence, J., and Koutrakis, P., 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.

The research conducted under 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, and ethanol gasoline fuel mixtures (RON95, E85, M56) over the New European Driving Cycle (NEDC). Emissions characterization includes NO_x, HC, CO, PM, PN, and formaldehyde.

Switzerland's contribution was provided by the following organizations:

- Paul Scherrer Institute
- University of Applied Sciences Northwestern Switzerland
- University of Applied Sciences Bern
- Swiss Federal Laboratories for Materials Science and Technology (Empa)

GDI vehicles were tested with ethanol gasoline blends (E0, E10, E85) and butanol blends (E10/Bu15 and Bu30). The drive cycles included the Worldwide Harmonized Light Vehicles Test Cycle, NEDC, and steady-state cycle. Some of the vehicles were equipped with GPFs and compared to a diesel vehicle. Regulated gaseous emissions, along with formaldehyde, polycyclic aromatic hydrocarbon, ammonia, and metals, were quantified along with nanoparticles. Testing in a smog chamber allowed for a comparison of the particle burden and the genotoxic potential and the SOA formation potential of GDI and diesel vehicles.[9,10]

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 chassis dynamometer tested with the FTP-75 drive cycle. Many manufacturers are implementing start-stop operation to enhance vehicle fuel economy. During start-stop operation, the engine shuts off when the vehicle is stationary for more than a few seconds. When the driver releases the brake, the engine restarts. Three fuels were evaluated: an 87 AKI gasoline (E0), a 21% splash blend of ethanol and the 87 AKI gasoline (E21), and a 12% splash blend of iso-butanol and the 87 AKI gasoline (iBu12). PM mass,

9 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.

10 Comte, P., Czerwinski, J., Keller, A., Kumar, N., Muñoz, M., Pieber, S., Prévôt, A., Wichser, A., and Heeb, N., "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.

transient PN concentration and size distribution, and soot mass concentration were evaluated for both start-stop operation and *no start-stop* operation on each fuel.[11]

Main Conclusions

The overall outcome will focus on the impacts of alcohol fuels and varying technologies on emissions from GDI and comparable technology vehicles.

This Annex will result in the following:

- Information of fundamental processes of combustion and pollutant formation in a GDI engine;
- Data on the impacts of alcohol fuel blends on both gaseous PM and PN emission rates from GDI vehicles operated under varying conditions;
- The effect of start-stop operation on emissions;
- The effects of GPF on emissions from GDI vehicles;
- Provision of information on the SOA forming potential; and
- Information on the genotoxicity of emissions from GDI vehicles.

Initial results clearly show that using alcohol fuels can decrease PM and PN emissions from GDI vehicles. The use of GPFs also resulted in a significant decrease in PM and PN emissions. The type of catalyst coating and filter technology impacted both PM and gaseous emissions.

Publications

The work performed under Annex 54 will result in a final report, "GDI Engines and Alcohol Fuel."

[11] Storey, J., Moses-DeBusk, M., Huff, S., and Thomas, 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.

Annex 55: Real Driving Emissions and Fuel Consumption

Project Duration	November 2015–November 2019
Participants **Task Sharing** **Cost Sharing**	 Canada, Denmark, Finland, Sweden, Switzerland, USA No cost sharing
Total Budget	~€400,000 ($454,046 US)
Operating Agent	Thomas Wallner Argonne National Laboratory (USA) Email: twallner@anl.gov

Purpose, Objectives, and Key Question

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 4 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 (CO_2), oxides of nitrogen (NO_x), and particulate matter. Over time, changes to those regulations have reflected the extraordinary advances in fuels, engines, and emission control technologies produced by automotive researchers and manufacturers over the past decades. Evidence suggests 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 fuel. The project will investigate vehicle performance 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 and real-world performance of vehicles operating under a range of driving conditions worldwide.

Activities

The team finalized the Annex 55 formal text in the summer of 2017. The purpose, objectives, audience, and methodologies are defined. The team defined the following work packages (WPs):

- WP 1: Annex management

- WP 2: Literature review and world regulation review
- WP 3: Fuel and technology effects on real-world driving emissions and efficiency
- WP 4: Comparison of on-road testing to laboratory testing
- WP 5: Assessment of weather conditions on real-world driving emissions and efficiency
- WP 6: Evaluation of different emissions measurement techniques

Currently, the annex members are in the testing and data collection phase. On-road testing and dynamometer testing results have been shared and compared. Several participants defined their own real-world driving routes.

A planning conference call of annex participants in August 2018 led to the development of a timeline for completing Annex 55 activities, along with a uniform report outline for all Annex 55 member contributions. On the basis of this timeline, the Annex 55 date was extended from April 2019 to November 2019. Also, participants agreed to hold regular conference calls with technical updates; these were held in September and November 2018.

Key Findings

Canada completed on-road testing of 40 vehicles in Ottawa, Ontario, with five distinct driving segments. The vehicles were also tested in the laboratory on a chassis dynamometer with the Federal Test Procedure (FTP) and Highway Fuel Economy Test Cycle (HWFCT) drive cycles. Great variability in test results occurred during the on-road emissions testing compared to the chassis dynamometer testing. Canada found that fuel consumption from real-world testing is, on average, 22% higher than the observed fuel consumption from tests on a chassis dynamometer. Furthermore, 84% of vehicles tested on-road presented a statistically significant increase in NO_x when comparing real-world and laboratory results on a chassis dynamometer.

Denmark completed the testing of five Euro 6b class vehicles in cold weather conditions on track as well as on an 80-kilometer real driving emission route. The results showed a wide range of NO_x emissions between the different test cars in real-world driving.

Finland executed one testing campaign on chassis dynamometer for four Euro 6 diesel vehicles and one on-road Portable Emissions Measurement System (PEMS) measurement campaign for two of the vehicles. A wide variation in emissions was observed between the New European Driving Cycle (NEDC) and Worldwide Harmonized Light Vehicles Test Procedure

(WLTP) driving cycles on chassis dynamometer and on-road among the three different routes. More detailed data analysis is in process.

Sweden tested almost 200 vehicles evenly divided between diesel and gasoline (only 5 ethanol flex fuel) over several different test cycles, such as PEMS, WLTP, European Research Group on Mobile Emission Sources (ERMES), and NEDC. All 200 vehicles have not been tested in all of the cycles; for example, PEMS have been tested on almost 60 vehicles. Of the vehicles tested in the NEDC (type I) cycle, 94% had a higher recorded CO_2 value compared with the declared values, despite using the same settings on the vehicle dynamometer. The average difference was almost 7%. Emissions of CO_2 during real driving was even higher. A new test procedure, the WLTP, has been developed to better represent real-world driving. The difference between WLTP and PEMS in real driving conditions was only 3% for diesel vehicles and 11% for gasoline vehicles. However, the emissions on NO_x from the diesel vehicles was on average 6.6 times higher than the certified value. These data include results from Euro 5 vehicles. Also, some gasoline vehicles with direct injections showed high NO_x emissions during real-world driving. Emissions of particles was low from all diesel vehicles, as those vehicles are equipped with diesel particulate filters. However, gasoline vehicles, especially those with direct injection, showed rather high emissions of particles. None of the tested gasoline vehicles was equipped with a filter. A shift from diesel to gasoline might result in lower emissions of NO_x but higher emissions of particles and CO_2. On average, the difference in CO_2 emissions between similar-sized diesel and gasoline vehicles was 20%.

In Switzerland, the Swiss laboratory for exhaust emission control and ICEs of the Bern University of Applied Sciences (AFHB) performed several on-road (RDE) and chassis dynamometer measurements with two flex-fuel gasoline/ethanol vehicles (FFV E0/E85) and one hybrid electric vehicle (HEV). The FFV measurements show that the use of E85 instead of E0 fuel leads to a reduction of NO_x and PN-emissions for both investigated vehicles and in all driving conditions. The HEV-tested vehicle shows very low emissions and fuel consumption. In real world driving conditions, the HEV's ICE works between 39% and 59% of the total cycle time.

Empa, the Swiss Federal Laboratory for Materials Science and Technology, completed the chassis dyno, the RDE testing, and the data evaluation on passenger cars (diesel and gasoline, both Euro 6b) and light-duty commercial vehicles (diesel Euro 6b) for the emission inventory project on behalf of the Swiss Federal Office for the Environment (FOEN). The reporting for this project is ongoing and will be finalized in the beginning of

2019. The field test activities for the comparison of real-world energy demand of different vehicle types (hybrid, plug-in hybrid, compressed natural gas, and electric vehicle) and auxiliary consumers during real-world operation could be finished. The data evaluation for this project on behalf of the Swiss Federal Office of Energy (SFOE) is still ongoing and is expected to be finalized in the beginning of 2019.

The U.S. tested a gasoline vehicle as well as a plug-in hybrid vehicle on three specific routes (urban, arterial, and highway) on roads in the Chicago metropolitan area. The vehicles were extensively instrumented beyond the portable emissions measurement equipment. On the basis of specific drive metrics (e.g., potential kinetic energy and accelerations), the dynamometer testing was very repeatable in energy intensity compared to the on-road testing. For the gasoline vehicle, the emissions, as well as the driving aggressiveness, in the real world were generally higher (30%–100%) than laboratory certification testing. For the plug-in hybrid vehicle, small amounts of emissions came from the engine through short operations during the charge-depleting phase. Overall, emissions are still very low in both charge-depleting mode and charge-sustaining mode.

Annex 57: Heavy-Duty Vehicle Performance Evaluation

Project Duration	October 2018–October 2020
Participants **Task sharing** **Cost sharing**	Canada, Chile, Finland, Republic of Korea, Sweden No cost sharing
Total Budget	~€510,000 (~$580,000 US)
Operating Agent	Petri Söderena VTT Technical Research Centre of Finland petri.soderena@vtt.fi

Purpose, Objectives and Key Question

The purpose and objective of this project are to demonstrate and predict the progress in energy efficiency of heavy-duty vehicles, thus generating information to be used by transport companies, those procuring transport services, and those forming transport policy. The project will encompass the newest diesel technologies on different markets, but also alternative-fueled vehicles and advanced powertrain configurations.

The methodology to be used comprises laboratory and on-the-road testing as well as simulation of energy consumption of various types of heavy-duty vehicles. The participating laboratories will use common test protocols for actual vehicle testing to ensure comparability of the results. The actual testing will measure both energy consumption and tailpipe emissions. Energy efficiency and carbon dioxide (CO_2) emissions will be evaluated on a well-to-wheel basis.

This project will form a basis for (1) understanding the performance of best available diesel and alternative-fueled vehicles and (2) estimating development toward 2030. The proposed overall activity will thus cover three time dimensions:

- Legacy vehicles and a reference backward through completed AMF annexes,
- A current snapshot of the performance of the current best-available technology heavy-duty vehicles using conventional and alternative fuels (focal point of this activity), and
- A projection into the future of how energy efficiency and emissions can develop (this projection will rely on input from combustion TCP as well as modelling by the AMF TCP for estimating the effects of alternative vehicle and powertrain configurations).

Activities

The project consists of nine work packages:

- WP 0: Collection and consolidation of the existing data
- WP 1: Agreement on common test procedures and protocols
- WP 2: Vehicle chassis dynamometer testing
  - Contemporary diesel vehicles as well as alternative fuel and vehicle technologies in different vehicle categories
  - Parameters to be varied in chassis dynamometer: fuel composition, driving cycle, payload (50% and 100%)
- WP 3: Vehicle on-road testing with Portable Emissions Measurement System (PEMS)
  - Contemporary diesel vehicles as well as alternative fuel and vehicle technologies in different vehicle categories
  - Parameters to be varied on road: fuel composition, driving cycle, payload (50% and 100%), ambient conditions (summer and winter)
- WP 4: Vehicle on-road emissions and fuel consumption monitoring
  - Contemporary diesel vehicles as well as alternative fuel and vehicle technologies in different vehicle categories
  - Operation in real driving and ambient conditions
  - Nitrogen oxide concentration and fuel consumption variation during a long monitoring period
- WP 5: Heavy-duty vehicle simulation
  - Assessment of current and proposed simulation methods for CO_2 assessment
  - Model that accounts different fuel options for fuel consumption evaluation
  - Parameters to be varied in case studies: fuel, chassis structure, vehicle overall mass
- WP 6: Regional information on transportation sector energy options (originally a WP in COMVEC but still valid)
  - Information from project participants on regional challenges and opportunities that drive the development of energy options in transportation sectors and effects on the available fuel selection; this regional information will also shed light on various alternative technology options potential in different regions.
- WP 7: Analysis and comparison of chassis dynamometer, on-road testing, and simulation

  - Recommendation for improving test methods and modelling
- WP 8: Cooperation with combustion TCP
  - Data and information exchange considering on-road emissions and energy consumption
  - Information and data exchange considering future internal combustion engine concepts (fuels and technology) and their emissions and energy consumption
  - AMF delivery of time-resolved vehicle data to combustion TCP
  - Combustion TCP to assist in projecting future improvements in internal combustion engine technology
- WP 9: Coordination of the project, synthesis, and reporting
  - Administrative coordination, communication with the International Energy Agency AMF Executive Committee, synthesis of the data, compilation of the final report, and dissemination of the results

Currently, the annex members are in the testing, data collection, and data-handling phase. Results have not been shared at this time.

Key Findings

Analyzed data are not yet available.

Main Conclusions

Analyzed data are not yet available

Publications

Publications are not yet available.

Schedule

The results of this project will be reported at the IEA AMF Executive Committee meeting in 2020. Figure 1 shows the Annex timeline, including the timeline for its participants.

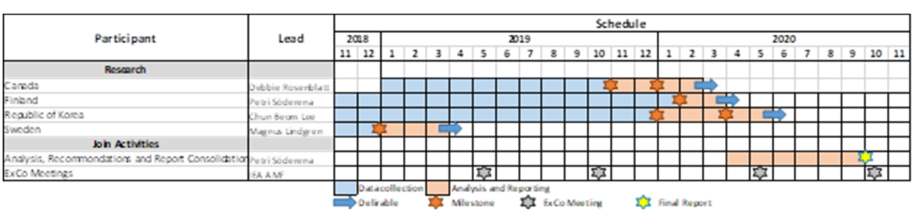

Fig. 1 Schedule for Annex 57 and Its Participants

The Global Situation for Advanced Motor Fuels

3.a
Overview of Advanced Motor Fuels – Statistical Information on Fuels

Globally, the transport sector is responsible for around 28% of energy consumption, and demand is still growing (Figure 1). While delivered transportation energy consumption is projected to stabilize for Organisation for Economic Co-operation and Development (OECD) countries, it is projected to increase for non-OECD countries.

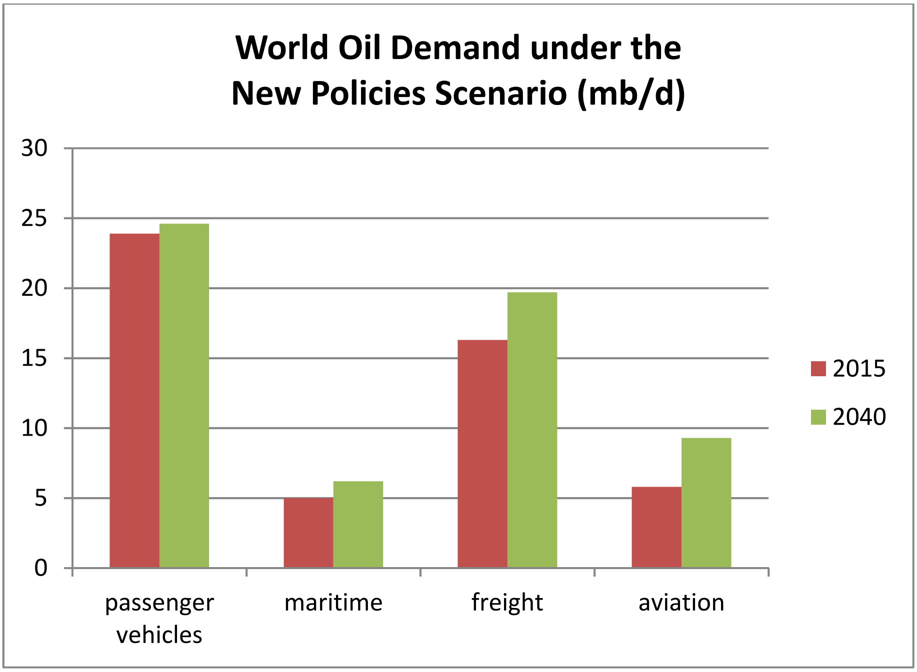

Fig. 1 World Oil Demand of the Transport Sector under the New Policies Scenario
Source: IEA World Energy Outlook 2016

According to the International Energy Agency's (IEA's) *World Energy Outlook 2016*, under the New Policies Scenario, almost all of the projected growth in oil demand to 2040 comes from freight, aviation, and petrochemicals for the industrial sector because of the lack of alternative fuels.

The transport sector constitutes about 56% of global oil consumption, and it is heavily dependent on oil products (92%) (Figure 2). Alternatives to oil products are natural gas, biofuels, and electricity (*Key World Energy Statistics 2016*).

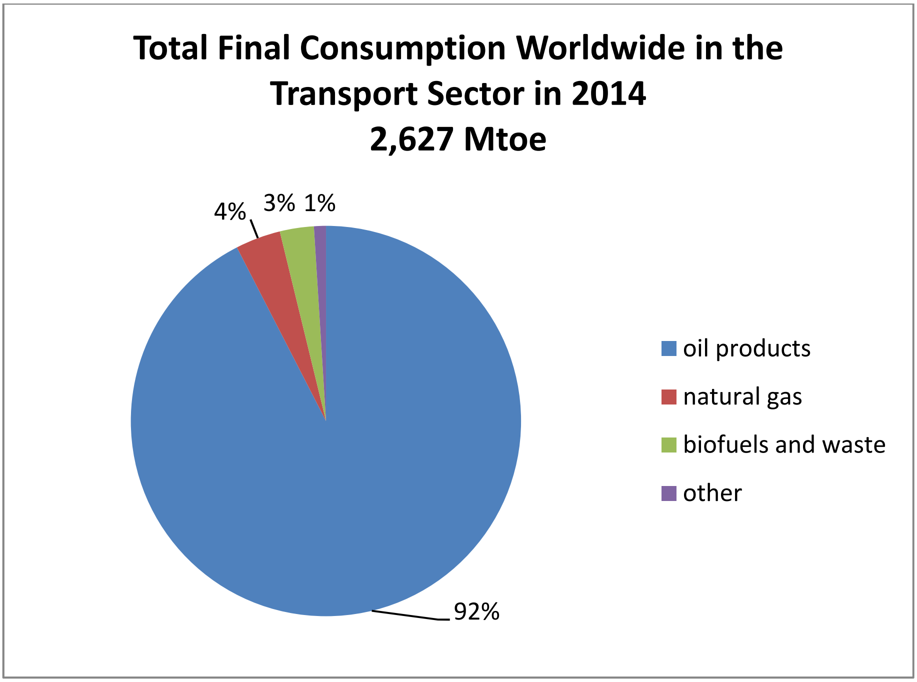

Fig. 2 Total Final Consumption of the Transport Sector in 2014
Source: IEA Key World Energy Statistics 2016

Natural gas use in transport constitutes only 6.9% of total natural gas consumption. According to the IEA's *World Energy Outlook 2016*, natural gas use in transport is slowly growing. Two-thirds of the projected growth is occurring in road transport; most of the remainder is liquefied natural gas (LNG) for the shipping sector.

Biofuels currently contribute around 3% of energy used in transport globally. Biofuels production has more than tripled since 2005 and has reached 74 megatonnes of oil equivalent (Mtoe) in 2014 (Figure 3). An estimated three-fourths of this production is fuel ethanol, and most of the remainder is biodiesel produced by the esterification of fatty acids; hydrotreated fats and oils also contribute a minor but increasing share. Advanced biofuels production from lignocellulosic biomass is still under development, and volumes produced are estimated to constitute less than 1% of total biofuel volumes.

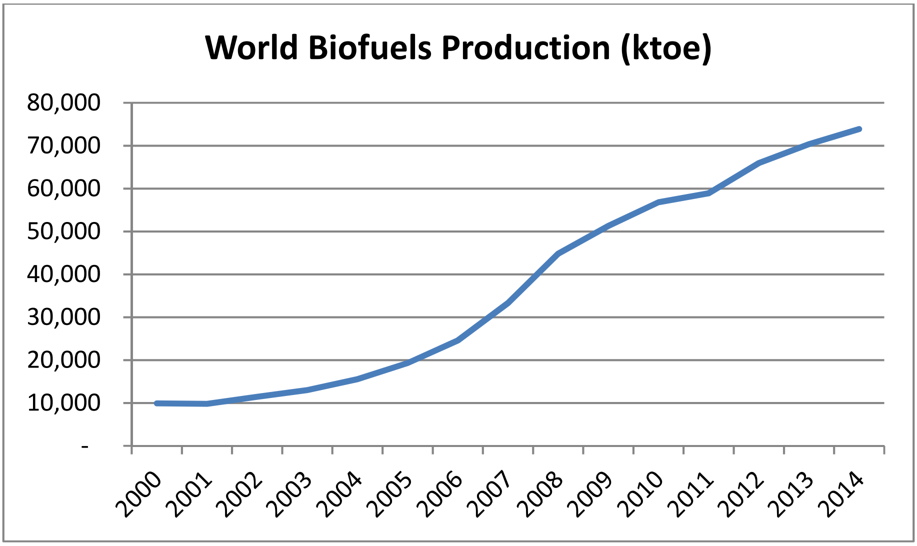

Fig. 3 World Biofuels Production in 2014 (ktoe)
Source: IEA Headline Energy Data 2016

Most of the biofuels produced are consumed in low-level blends in conventional vehicles; alternative fuel vehicles, which need to use high-level blends of biofuels or other sources of energy, have been adopted quite slowly. As an example, Figure 4 shows the number of alternative fuel vehicles in California in 2015.

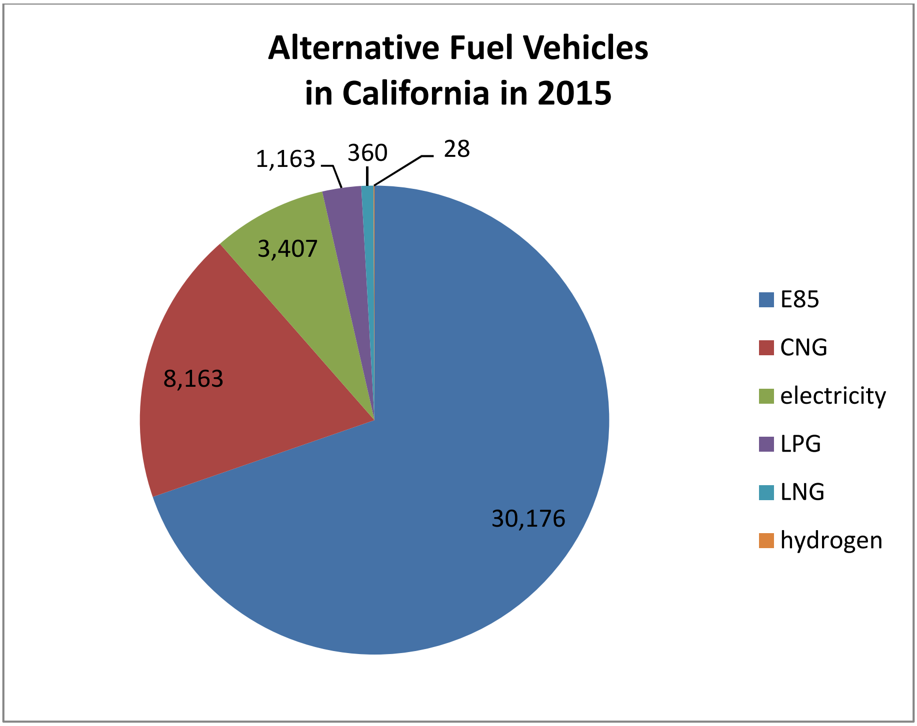

Fig. 4 Number of Alternative Fuel Vehicles in California in 2015
Source: U.S. Energy Information Administration, Alternative Fuel Vehicle Data

Electric vehicles (EVs; full battery electric and plug-in hybrid EVs) have seen a sharp rise in sales in 2015. According to the IEA's *Global EV Outlook 2016: Beyond One Million Electric Cars*, the global stock of EVs climbed to 1.3 million, a near doubling of the stock in 2014. Yet, the share of electric cars in the global vehicle stock is only 0.1%. China is now the largest market for EV sales, followed by the United States.

Oil demand in transport (and thus also greenhouse gas [GHG] emissions from transport) can also be cut by improvements in energy efficiency. The U.S. Energy Information Administration's (EIA's) *International Energy Outlook* states that nine countries and regions, which together account for 75% of global fuel consumption by light-duty vehicles, have adopted mandatory or voluntary standards for increasing fuel economy and reducing GHG emissions. These are the European Union (EU), India, Canada, Brazil, Japan, China, the United States, Mexico, and the Republic of Korea.

3.b
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 tonnes in 2018, according to a market assessment by the Association of the Mineral Oil Industry (FVMI).[12] The number represents an increase of 1.6% compared to 2017 and reflects 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 neighbouring countries. Both effects contributed to an overall increase in greenhouse gas (GHG) emissions of +62% between 1990 and 2015 in the transport sector.

Austrian Climate and Energy Strategy #mission2030

In May 2018, the Austrian government adopted the Austrian Climate and Energy Strategy #mission2030[13] 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 (bio-compressed natural gas [CNG]/bio-liquefied natural gas [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 heavy-duty vehicles.

Revised Renewable Energy Directive (RED II)[14]

In November 2018, the European Parliament approved new targets for renewables, energy efficiency, and second-generation biofuels, with obligation on Member States to require fuel suppliers to deliver a 14% overall share of fuels from renewable energy sources to encourage the continuous development of alternative renewable transport fuels. Austria has to transpose RED II into national law within 18 months.

[12] FVMI: https://www.wko.at/branchen/industrie/mineraloelindustrie/start.html

[13] Austrian Climate and Energy Strategy: https://mission2030.info/wp-content/uploads/2018/10/Klima-Energiestrategie_en.pdf

[14] RED II Directive: https://ec.europa.eu/energy/sites/ener/files/documents/directive_renewable_factsheet.pdf

Taxes and Incentives

Starting in July 2008, the Normverbrauchsabgabe (NoVA) — a bonus/penalty system for CO_2 emissions — 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 6.90 million, that is, 1.8% more than in 2017. Passenger cars, the most important type of vehicle (share: 72.2%), showed an increase by 1.6%, or 4.98 million vehicles.

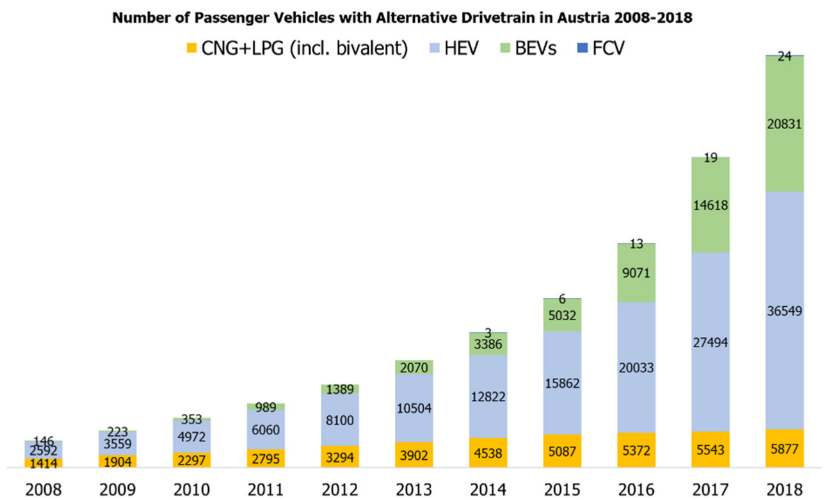

Fig. 1 Trends for vehicles with alternative drivetrains in Austria, 2008–2018
Source: Statistik Austria

An ongoing trend toward advanced alternative propulsion systems can be identified (Figure 1), especially for battery electric vehicles and hybrid electric vehicles. With numbers of 20,831 and 36,549, respectively, the trend is evident. The number of vehicles driven by CNG and liquefied petroleum gas (LPG), including bivalent ones, shows a stable increase to 5,877. With 24 vehicles, the fuel cell electric vehicle fleet is still negligible.

Average CO_2 Emission of Passenger Cars Rises to 126 g/km

In 2018, CO_2 emissions for newly registered passenger cars documented an average of 126 g/km (2000: 169 g/km). For gasoline-powered passenger cars, the value rose from 122 g/km to 125 g/km (2000: 176 g/km). Diesel cars recorded an increase in CO_2 emissions from 125 g/km in 2017 to 129 g/km in 2018 (2000: 162 g/km).

Table 1 Austrian Fleet Distribution of Passenger Vehicles by Drivetrain, 2014–2018
Source: Statistics Austria

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

Development of Filling Stations

By the end of 2017, Austria had 2,685 publicly accessible filling stations. As an annual average for 2017, the price of gasoline at the filling station was €1.18 ($1.35 US) and for diesel €1.10 ($1.23 US) per liter.

With 157 public CNG stations in 2018, the number of public CNG filling stations has slightly decreased in recent years. For LPG, 52 filling stations are available. In addition, 1 public LNG filling station in Ennshafen (Upper Austria) is 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; and one is dedicated to hydrogen research. Except for the latte,r all HFSs support a pressure of 70 MPa.

Research and Demonstration Focus

Flagship Region Energy[15]

In the coming 8 years, the Austrian Climate and Energy Fund (KLIEN) will invest up to €120 million ($137 million US) in three flagship regions. The flagship 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

The national action program for mobility management, called klimaaktiv mobil,[16] supports the development and implementation of mobility projects and transport initiatives that aim to reduce CO_2 emissions, for example, by vehicles with alternative drivetrains or electric mobility. Since 2006, 11,600 climate friendly mobility projects received financial support. The klimaaktiv mobil website offers a map with the details of each project. The financial support amounted to €106 million ($121 million US) until the end of 2017. In 2017, €13.9 million ($15.9 million US) funding was available.

Energy Research Program

The Energy Research Program[17] provides research and innovation funding for the introduction and implementation of climate-relevant and sustainable measures and energy technologies. The strategic research focus is on sectors contributing significantly to greenhouse gas emissions such as the transport sector. In addition, funding is dedicated to the participation of Austrian stakeholders in international organisations like the Technical Collaboration Program (TCP) under the umbrella of the IEA.

Mobility of the Future Program

The research program, Mobilität der Zukunft[18] (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

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15 Flagship region Energy: https://www.vorzeigeregion-energie.at/wp-content/uploads/Folder-Vorzeigeregion-EN-screen-RZ.pdf

16 klimaaktiv mobil: https://www.bmnt.gv.at/english/environment/Air-Noise-Traffic/klimaaktivmobil.html

17 Energy Research Program: https://www.klimafonds.gv.at/call/energieforschungsprogramm-2018/

18 Mobility of the Future: https://www.bmvit.gv.at/en/innovation/mobility/future_mobility.html

between €13 million and €19 million (between $15 million and $22 million US).

ERA-NET Bioenergy[19]

In the ERA-NET Bioenergy, Austria cooperates with Germany, Ireland, The Netherlands, Poland, Sweden, Switzerland, and 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 ($1.14 million US).

Outlook

Currently, most funding programs and incentives focus on electro-mobility. As advanced motor fuels play a crucial role in the Austrian Climate and Energy Strategy and are considered as an important element for a successful Austrian transition toward sustainable mobility, a funding shift toward biofuels can be expected.

Due to the low price of fossil fuels in 2017, biofuels sales decreased (see Figure 1). With the recovery of the crude oil price and the implementation of the European RED II directive, biofuel demand for biodiesel will increase.

A significant increase of vehicles with alternative powertrains can be expected for electric vehicles. For other vehicles, such as CNG, the market development is sluggish despite well-established CNG infrastructure and existing technological and regulatory framework conditions. A future awareness campaign could highlight the advantages for the customer and the environment.

Additional Information Sources

- Federal Ministry for Transport, Innovation and Technology, www.bmvit.gv.at/
- Federal Ministry of Sustainability and Tourism, www.bmnt.gv.at
- Austrian Association for Advanced Propulsion Systems, www.a3ps.at

[19] ERA-NET Bioenergy: https://www.eranetbioenergy.net/

Canada

Drivers and Policies

Renewable Fuels Regulations (RFRs)[20]

The RFRs require fuel producers and importers to have an average renewable content of (1) at least 5% based on the volume of gasoline that they produce or import into Canada 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 among participants, and also require recordkeeping and reporting to ensure compliance.

Clean Fuel Standard (CFS)[21]

The CFS, currently under development, will set separate requirements for liquid, gaseous, and solid fossil fuels, based on lifecycle analysis. Primary suppliers of fossil fuels will be the parties responsible for meeting carbon intensity requirements. Liquid fuels regulations will be developed for publication in spring 2019. By 2030, primary suppliers of fossil fuels will be required to reduce the carbon intensity of liquid fuels to 10 g of CO_2e per MJ below their reference carbon intensity, which corresponds to a reduction of approximately 11% and up to 23 Mt of incremental emissions reductions in 2030. Publication of gaseous and solid fuels regulations will follow.

Renewable-fuels-related Standards (Table 1)

The Canadian General Standards Board (CGSB) is the responsible authority for developing fuel quality standards, including standards for renewable fuel quality through a consensus process with the public and private sectors.

Table 1 CGSB Renewable Fuel-quality-related Standards[22]

Fuel Standard	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

20 http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=0AA71ED2-1

21 https://www.canada.ca/en/environment-climate-change/news/2017/12/canada_s_clean_fuelstandardhowitwillwork.html

22 http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html

Passenger Automobile and Light Truck GHG Emission Regulations[23]

In 2010, the Government of Canada released the final *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations*. In 2014, the second phase of action on light-duty vehicles (LDVs), which contain increasingly stringent greenhouse gas (GHG) emissions standards for LDVs of model years 2017–2025, were published. Under both phases of LDV regulations, spanning model years 2011–2025, the sales-weighted fuel efficiency of new cars is projected to improve from 8.6 liters per 100 kilometers (L/100 km) in 2010 to 6.4 L/100 km in 2020 and to 5.1 L/100 km by 2025. The sales-weighted fuel efficiency of new passenger light trucks is projected to improve from 12.0 L/100 km in 2010 to 9.1 L/100 km in 2020 and to 7.6 L/100 km by 2025.

Heavy-duty Vehicle (HDV) and Engine GHG Emission Regulations[24]

In 2013, the Government of Canada published the *Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations,* which introduce GHG emission standards for on-road heavy-duty vehicles and engines of the 2014 and later model years. In 2018, the *Regulations Amending the Heavy-duty Vehicle and Engine Greenhouse Gas Emission Regulations and Other Regulations Made under the Canadian Environmental Protection Act, 1999* (the Amendments) were published in the *Canada Gazette*, Part II. The Amendments establish more stringent GHG emission standards, starting with the 2021 model year for on-road heavy-duty vehicles and engines. Further, the Amendments introduce new GHG emission standards that apply to trailers hauled by on-road transport tractors for which the manufacture is completed on or after January 1, 2020. The Amendments are estimated to result in cumulative fuel savings of about 27.7 billion liters with respect to the portion of the lifetime operation of model years 2020–2029 vehicles that occurs over the 2020–2050 period.

Advanced Motor Fuels Statistics

Figure 1 shows the energy use by fuel type in 2015 for transportation in Canada. Table 2 shows the Canadian supply of and demand for ethanol and biodiesel in 2015. The ethanol proportion is estimated on the basis of production data.

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23 https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=104

24 https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=119

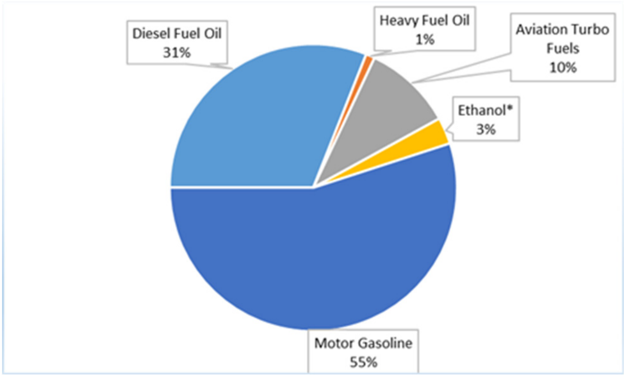

Fig. 1 Fuel Mix of the Transportation Sector 2015[25]

Table 2 Canadian Supply of and Demand for Biofuels in 2015 (in millions of liters)[26]

Parameter	Ethanol (2015)	Biodiesel (2015)
Canadian production	1,720	307
Imports	1,100	383
Exports	0	238
Domestic use	2,820	452

Research and Demonstration Focus

ecoTECHNOLOGY for Vehicles (eTV) Program[27]

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-fuelled vehicles, including electric, compressed natural gas, and hydrogen fuel cell vehicles. Testing results from the eTV Program are being used to develop safety and environmental regulations and industry codes and standards to ensure that new innovations can be introduced in Canada in a safe and timely manner.

25 https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/energy-factbook-oct2-2018%20(1).pdf

26 https://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/pdf/EnergyFactBook_2016_17_En.pdf

27 https://www.tc.gc.ca/en/programs-policies/programs/ecotechnology-vehicles-program.html

Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative[28]

Natural Resources Canada (NRCan) is investing to expand the network of electric vehicle charging and alternative refuelling stations across Canada. The funding supports the deployment of electric vehicle fast chargers; natural gas and hydrogen refuelling stations; the demonstration of next generation charging technologies; and the development of codes and standards for low-carbon vehicles and infrastructure.

Energy Innovation Program (EIP)[29]

NRCan's EIP supports clean energy innovation. Accelerating clean technology research and development (R&D) is a key component of the Government of Canada's approach to promoting sustainable economic growth and to supporting Canada's transition toward a low-carbon economy.

Program of Energy Research and Development (PERD)[30]

PERD is a federal, interdepartmental program operated by NRCan. PERD supports energy R&D conducted in Canada by the federal government and is designed to ensure a sustainable energy future for Canada. Part of PERD consists of coordinated research activities designed to extend key areas of knowledge and technology that will help reduce both the carbon footprint of fuels and vehicle emissions from transportation sources in Canada.

Vehicle Propulsion Technologies (VPT) Program[31]

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[32]

The Strategic Innovation Fund, managed by Innovation, Science and Economic Development Canada, is a government grant provided to support Canadian businesses investing in innovative products, processes, and services. Through cost-sharing assistance, the program helps offset a portion of costs related to researching and implementing new technologies, including automotive technology.

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[28] https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/18352
[29] https://www.nrcan.gc.ca/energy/funding/icg/18876
[30] http://www.nrcan.gc.ca/energy/funding/current-funding-programs/perd/4993
[31] https://www.nrc-cnrc.gc.ca/eng/solutions/collaborative/vpt.html
[32] https://www.canada.ca/en/innovation-science-economic-development/programs/strategic-innovation-fund.html

Pan-Canadian Framework on Clean Growth and Climate Change (PCF)[33]

In 2016, Canada's First Ministers adopted the PCF. The initial years of the PCF focused on the design, planning, and delivery of four pillars: pricing carbon pollution; complementary actions to reduce emissions across the economy; adaptation and climate resilience; and clean technology, innovation, and jobs. Looking ahead, this will include work to implement the federal carbon pollution pricing system; publish the Clean Fuel Standard; announce funding decisions for the Low Carbon Economy Fund Challenge; continue construction of renewable energy projects; host the Clean Energy Ministerial/Mission Innovation Ministerial; and undertake scientific activities to address knowledge gaps.

Outlook

As depicted in Table 3, the Canadian transportation sector consists of distinct subsectors — passenger, freight, air, and others (e.g., recreational). Each subsector exhibits different trends during the projected period. GHG emissions from cars, trucks, and motorcycles are projected to decrease by 25 Mt between 2005 and 2030, while those for heavy-duty trucks and rail are projected to increase by 11 Mt. Although absolute emissions are expected to grow in the freight subsector, emissions are expected to decrease relative to business-as-usual levels as a result of various federal, provincial, and territorial programs.[34]

Table 3 Transportation: GHG Emissions (Mt CO_2 equivalent)[35]

Transportation Subsector	2005	2020	2030	∆ 2005 to 2030
Passenger Transport	**97**	**89**	**73**	**−24**
Cars, trucks, and motorcycles	88	80	64	**−25**
Bus, rail, and domestic aviation	9	9	9	**1**
Freight Transport	**3**	**70**	**73**	**11**
Heavy-duty trucks, rail	55	63	66	**11**
Domestic aviation and marine	8	7	7	**0**
Other: recreational, commercial, and residential	**11**	**9**	**11**	**−1**
Total	**171**	**168**	**157**	**−14**

33 http://publications.gc.ca/collections/collection_2018/eccc/En1-77-2018-eng.pdf

34 https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/emission-trends-2014.html

35 https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/2016-greenhouse-gas-emissions-case/chapter-2.html

Chile

Drivers and Policies

Chile's transport sector accounts for 36% of final energy consumption. Of this total, 99% corresponds to oil derivatives, making the sector responsible for about 20% of the total emissions of greenhouse gases (GHG) in the country. In addition, pollution caused by consumption of oil derivatives occurs more frequently in urban areas. To mitigate this problem, Chile would like to promote the efficient use of energy by establishing an ambitious goal of a 20% reduction in energy demand with respect to that projected for the year 2025 (Ministry of Energy 2014).

At the same time, Chile has acquired and ratified international agreements on GHG emissions and climate change, committing itself on the level of mitigation to reduce by 2030 the intensity of emissions by 30% compared to the levels observed in 2007 (The Committee of Ministers for Sustainability and Climate Change 2015).

If the transport sector is responsible for one-third of the country's energy consumption, two public policies are important and directly impact energy efficiency and carbon dioxide (CO_2) reduction:

- Improvement of energy efficiency by promoting electromobility. Assuming challenges in the implementation of public policies and working with academia and the private sector, electromobility is a reality. The incorporation of 200 electric buses for public transport, which have operated since the beginning of this year in the Transantiago bus fleet, is part of the stimulus and support for electromobility at the national level.
- Promotion of a Law of Energy Efficiency Project. To improve energy efficiency in the transport sector, Chile will define the energy efficiency standards for fuel consumption in light, medium, and heavy vehicles. This project is currently under discussion in the Congress of Chile.

Since 2015, a collaboration framework agreement between the Ministry of Energy and the Ministry of Transport and Telecommunications has been in force. The objective is to advance regulations, policies, and programs aimed at improving energy efficiency in the country's vehicle fleet.

Public Transport of Santiago Bid

The Transantiago bid for buses for the beginning of 2018 was declared void. Another bid with a new design will be commissioned in 2019. The revised bid will primarily focus on achieving the following:

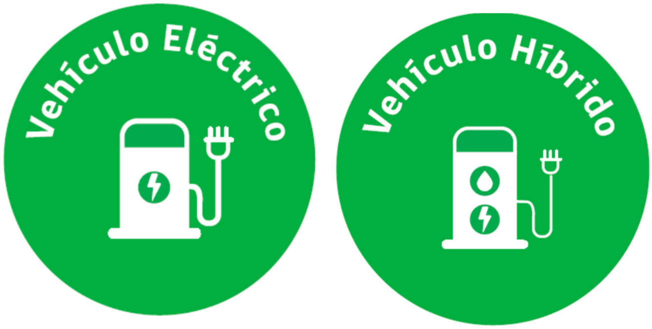
- Separate capital investment from operation expenses.
- Improve fleet standards.
- Promote competition in bidding processes and contracts.
- Reduce the cost of the system.
- Promote clean technologies.
- Facilitate operational continuity.
- Reduce unit size.
- Provide greater flexibility.

Environmental advantages of the fleet include an optional complementary criterion for bid evaluation in road tenders. In saturated zones, bidding bases must take into consideration additional scores for the presentation of fleets with non-polluting technologies, which provides an opportunity for the introduction of electric buses to the transport system. Of the total fleet to renew 6,500 buses during the next 4 years (which would operate until 2030), at least 500 electric buses will be incorporated.

Implementation of Vehicle Energy Efficiency Regulation

Chile was the first Latin American country to implement compulsory labeling of vehicular energy efficiency for new vehicles. As of February 2013, this labeling allows buyers of new light vehicles, fueled by either diesel or gasoline, to compare their energy performance (www.consumovehicular.cl). After June 2017, the vehicle energy efficiency label was expanded to include medium-sized vehicles (light trucks and vans) and hybrid and pure electric vehicles. In addition, as part of the labeling implementation, dealers must include city fuel consumption in written advertising (i.e., publications in magazines, newspapers, and other written publications).

According to Supreme Decree No. 145 of December 2017, Article 3 from the Ministry of Transport and Telecommunications defines a label to identify electric and hybrid vehicles and its implementation initiation from December 29, 2018. The label must be affixed to the rear window of the vehicle on its right inner surface (with respect to the observer) so that it is easily visible. The label must indicate “Electric Vehicle” or “Hybrid Vehicle,” as appropriate, and include a visual icon. The phrase must be in the upper area of the circle, while the icon must be centered below it. The label is green with white letters and must follow a specified size (Figure 1).



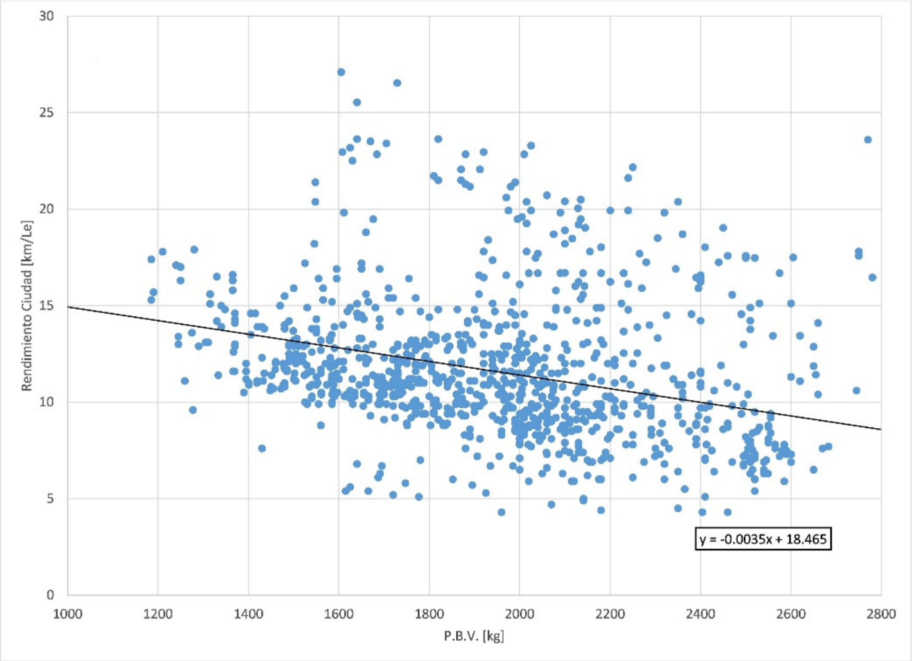
Measurement	Size (mm)
Diameter of circle	83
Height of letters	7,2
Width of letters	1,6
Width and height of icons	31 x 29 (electric vehicle) 30 x 20 (hybrid vehicle)

Fig. 1 Labels for Electric and Hybrid Vehicles in Chile, along with Their Specified Size Restrictions

Law of Energy Efficiency Project

The main objective of the Law of Energy Efficiency Project in the transport sector is to improve energy efficiency in Chile's vehicle fleet. The project is currently in Congress under analysis by the Committees of the Senate of Mining and Energy.

The Ministry of Energy, together with the University of Chile through an agreement with the university's Energy Center, developed a proposal of energy efficiency standards for light vehicles, simulating different scenarios, based on all the units sold (brands and models) in 2017 (Figure 2). This proposal is available for incorporation in the short term as regulation once the Energy Efficiency Law is approved. In addition, Chile is collecting data from medium-size vehicles (vans, light trucks) to make a medium-term request proposal. Further, a long-term standard or regulation for heavy vehicles will also be planned.



Chile sales 2017 light vehicles - Kilometers per liter of gasoline equivalent using weight as a descriptor *Source: Chile University*

Fig. 2 Sales of Light Vehicles in Chile in 2017

Research and Demonstration Focus—*Energy Efficiency in Buses*

Measurement of Fuel Consumption in Transantiago

In accordance with Resolution 2243 of July 23, 2018, the Ministry of Transport and Telecommunications approved an official technical regulation to obtain energy consumption statistics in urban public transport buses in the city of Santiago. This regulation incorporates the TS DRIVING CYCLE - STGO. The development of this regulation was possible due to previous work by the Ministry of Transport and Telecommunications with the support of the Mario Molina Center of Chile, the Ministry of Energy of Chile, and the VTT Laboratory of Finland.

Measurement of Fuel Consumption in Buses from Other Cities, Urban and Interurban

Also, as in the Transantiago bus project, through an agreement with the Ministry of Transport and Telecommunications and the Ministry of Energy, and the Emissions Laboratory of Heavy Vehicles of the Vehicle Control and

Certification Center (3CV), the consumption of fuel was measured in the most representative buses driving in the cities most important in the country (outside Santiago). With these data, the ISCI Institute of the University of Chile developed a methodology that allows a comparison of the most efficient vehicles, considering distances, costs, and the number of passengers that move. The pending challenge is to implement a platform on a website that allows operators and decision makers to use this tool.

Outlook

Energy Route 2018–2022

Confirming its commitment to electromobility, the Ministry of Energy incorporated an electromobility strategy into a work plan called “Energy Route 2018–2022.” The Ministry of Energy is leading the implementation of the National Electromobility Strategy, together with the Ministries of Transport and the Environment, through the execution of the actions proposed in Energy Route 2018–2022, in the axis efficient transportation. The objective for the year 2022 is to have at least 10 times more electric vehicles on the streets compared with 2018 data.

Considering the 2050 target for light vehicles, it is estimated that the entry of electric vehicles would avoid the emission of 11 million tons of CO_2 per year and reduce the country’s energy expenditure by more than US $3,300 million per year.

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

Development Plan for an Energy-Saving and Alternative-Energy Automotive Industry (2012–2020)

The automotive industry is a main industry in the Chinese economy and plays an important role in the country's economic and social development. Along with China's sustained, rapid economic development and accelerating urbanization, automotive demands continue to increase, and the resulting energy shortage and environmental pollution problems will become more prominent. Speeding up the cultivation and development of energy-saving and alternative-energy vehicles is urgently needed to effectively alleviate energy and environmental pressures and promote the sustainable development of the automobile industry. It is also needed as a strategic initiative to accelerate the transformation and upgrading of the automobile industry and to cultivate new economic growth and give China a competitive advantage internationally. China's plan is especially formulated to implement the decisions of the State Council to develop a strategic emerging industry and to strengthen energy savings and emission reductions, as well as to accelerate the cultivation and development of an energy-saving and alternative-energy automotive industry. The plan spans 2012–2020.

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 roadmap indicates the direction of energy saving and new energy vehicles (NEVs) in the Chinese automotive industry until 2030. This technology roadmap is the newest comprehensive guideline for energy-saving vehicles and NEVs and takes into account China's "Made in China 2025" initiative, its 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 the pure electric and plug-in hybrid electric vehicles, China is also 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 would be 10%.

The latest plan (2017) is intended in part to use up aging stockpiles of corn, which total 270 million tons. The scale of consumption of biofuel ethanol is growing rapidly worldwide, increasing from 36.28 million tons in 2005 to 79.15 million tons last year. China ranks third globally, with only 2.6 million tons consumed per year.

On August 22, 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.”

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 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 2018, 189.28 million tons of crude oil were produced in China — a decrease of 1.1% year-on-year. Meanwhile 367.99 million tons of petroleum products were produced in China — an increase of 6.3% year-on-year. From January to December 2018, China consumed 325.14 million tons of petroleum products (including diesel and gasoline fuels) — an increase of 6.0% year-on-year. Of this total, the consumption of gasoline fuels increased by 7.8%, and diesel fuels increased by 4.1%. 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 2018, China produced 161.0 billion cubic meters (m^3) of natural gas — an increase of 7.5% year-on-year. Meanwhile, China imported 125.6 billion m^3 natural gas — an increase of 31.9% year-on-year. From January to December 2018, natural gas consumption reached 280.3 billion m^3— an increase of 18.1% from 2017.

In 2018, China's auto production and sales were 27.8 million vehicles and 28.1 million vehicles, respectively, with a year-on-year decrease of 4.2% for production and 2.8% for sales.

In 2017, China had 0.414 million new CNG vehicles, while total ownership reached 5.73 million cars — an increase of 7.8% over 2017. In 2017, there were about 200 new CNG stations, and the total number of stations was 5,300 — an increase of 3.9% over 2017. In 2017, more than 90,000 new LNG vehicles were produced, while total ownership reached 0.350 million cars — an increase of 34.6% over the previous year. The total number of LNG stations increased to about 3,100 in 2017.

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 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 5 provincial governments had organized and implemented the pilot projects.

By the end of 2018, 1,024 methanol pilot vehicles were cumulatively utilized in Shanxi, Shanghai, Shaanxi, Guizhou, and Gansu provinces. The pilot cities included Jinzhong, Changzhi, Xi’an, Baoji, Yulin, Hanzhong, Lanzhou, Pinliang, Guiyang, and Shanghai. On March 13, 2013, Jinzhong took the lead in launching the methanol auto pilot in the country. The pilot vehicles included methanol passenger cars, buses, multi-purpose minibuses, and heavy-duty trucks. During the pilot, operating vehicles ran 184 million kilometers (km). The largest single vehicle operating range was 350,000 km. The total consumption of methanol fuel was 24,000 tons.

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 now, ethanol gasoline was promoted in Heilongjiang, Jilin, Liaoning, Henan, Anhui, and Guangxi provinces with a fully closed type. Hubei (9 cities), Shandong (8 cities), Hebei (6 cities), Jiangsu (5 cities), and Inner Mongolia (3 cities) provinces promoted the ethanol gasoline with a semi-closed type. The promotion was expanded in an orderly manner in 15 provinces, including Beijing and Tianjin.

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 2.54 million tons. According to the standard of adding ethanol, about 260,000 tons of fuel ethanol is needed every year.

Outlook

On June 28, 2012, the State Council officially issued the “Development Plan for Energy-Saving and Alternative Energy Vehicle Industry (2010–2020),” which defines the technical pathways and main goals of energy-saving and alternative-energy vehicle development. By 2050, the accumulative output of pure electric vehicles and plug-in hybrid vehicles will reach 500,000; by 2020, the capacity will reach 2 million, and the accumulative production and sales amount will reach more than 5 million. The plan clarified five tasks:

(1) technical innovation project for energy-saving and alternative-energy vehicles, (2) scientific plan for industry structure, (3) accelerated promotion of demonstrations, (4) active promotion of charging equipment manufacturing, and (5) enhancement of step utilization and recycling of power batteries.

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 vehicle (LNG and CNG vehicles) 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.

Plans are that by 2020 the use of methanol gasoline will be up to 2.4 million tons, the number of refitted vehicles will reach 120,000, and new methanol load vehicles will reach 40,000.

Additional Information Sources

- China Association of Automobile Manufacturers (CAAM), http://www.caam.org.cn/
- China Automotive Technology and Research Center (CATARC), http://www.catarc.ac.cn/ac_en/index.htm
- China EV Corporation, http://www.chinaev.org/
- National Development and Reform Commission, http://www.ndrc.gov.cn/fzgggz/jjyx/gjyx/
- *2013 Yearbook of Energy-Saving and New Energy Vehicles*, China Economic Publishing House, 2014, http://www.chinabookshop.net/energysaving-energy-vehicles-yearbook-2013-english-p-19196.html?osCsid=sb14t34uh7lm5b88jdmcvd1v62

Denmark

Drivers and Policies

Energy Strategy 2050 represents a giant step toward realizing the Danish Government's vision of becoming independent of coal, oil, and gas.[36] In 2010, the Danish Commission on Climate Change Policy concluded that transition to a fossil-fuel-independent society is a real possibility. Energy Strategy 2050 builds on this work. The strategy outlines the energy policy instruments needed to transform Denmark into a green sustainable society with a stable energy supply. The strategy is fully financed and takes into account Danish competitiveness. In March 2012, Denmark reached a historic new Energy Agreement. The Energy Agreement from 2012 provides the overall framework for the Danish energy policy. According to the agreement, Denmark must reduce total energy consumption by 7% in 2020, compared to energy consumption in 2010. The long-term goal of the agreement is that the country's energy supply becomes independent of fossil fuels by 2050.

Advanced Motor Fuels Statistics

General Energy Data

The total share of renewables (RES) is expected to be 39.8% in 2030 in the absence of any new initiatives, which results in a shortfall of 10.2 percentage points relative to the goal in the Government's Political Platform of at least 50% RES in 2030. The RES share will increase up to 2021 to 43.6%, followed by a decline due to an increase in electricity consumption and a decrease in the deployment of renewable energy. The RES share is expected to be 42.0% in 2020, whereby Denmark will have met, and exceeded, its EU obligation for a 30% RES share by 2020.

In 2020, Denmark's total greenhouse gas emissions are expected to be 38%–39% below emissions in the United Nations (UN) baseline year of 1990. Up to 2021, emissions will fall to 39% below the UN baseline year. After 2021, emissions are expected to increase in the absence of any new initiatives. This trend is contingent on the level of energy-related emissions in particular. The EU obligation for the non-EU Emissions Trading System (ETS) sector for the period 2013–2020 will be fulfilled and exceeded. Non-ETS emissions for the period 2021–2030 are expected to fall short of the EU obligation by between 32 million and 37 million tonnes carbon dioxide equivalent (CO_2 eq), subject to an uncertainty of ±10 million tonnes CO_2 eq.

[36] Information is primarily from Danish Energy Agency, 2018, "Danish Energy and Climate Outlook 2018," https://ens.dk/sites/ens.dk/files/Basisfremskrivning/deco18.pdf; see also Energistyrelsen, www.ens.dk

Electricity consumption (exclusive of grid losses) will increase from 31.3 terrawatt hours (TWh) in 2017 to 42.2 TWh in 2030. This increase depends in particular on increased electricity consumption by data centres, which will account for 65% of the increase. Further, these centres are expected to account for 16.7% of total electricity consumption (exclusive of grid losses) in 2030. Future demand for electricity by data centres is subject to significant uncertainty. Increasing electricity demand in combination with new electricity interconnectors to high-price areas means that domestic electricity production will increase up to 2023 and that Denmark is expected to be a net exporter of electricity from 2020 to 2024. After this time, electricity imports will increase due to declining deployment of new domestic capacity. Assuming no new initiatives are introduced, net imports are expected to amount to 8.6 TWh in 2030, corresponding to 19% of electricity consumption (including grid losses).

The share of electrified vehicles (electric cars and plug-in hybrid cars) is expected to increase steadily and will account for 7% of the total number of cars and vans on the road in 2030 as well as for 1.2% of electricity consumption (excluding grid losses). Electrified vehicles' share of sales of new cars up to 2030 is subject to significant uncertainty. The 10% renewables obligation in transport by 2020 will not be achieved in the absence of new initiatives.

Consumption of bioenergy will be constant from 2021, but, with a share of 67% in 2030, it is expected to still make up the majority of renewable energy consumption. Consumption of renewable energy in the form of ambient heat by large and small heat pumps will increase by 7.3% annually and will account for 8% of renewable energy consumption in 2030. Heat pumps will increasingly displace household use of wood pellets, natural gas, and oil. In 2030, oil for heating will account for less than 2% of household energy consumption.

In the absence of any new initiatives, energy consumption in industry and services will fall by 0.4% annually up to 2020. After 2020, it is expected to increase by 2.2% annually up to 2030 due to an increase in electricity consumed by data centres and the discontinuation in 2021 of the scheme concerning the energy-saving efforts of energy companies.

Uncertainties and assumptions subject to sensitivity affect the key results. For example, uncertainty is associated with the projection of electricity consumption by data centres, as well as with assumptions about the CO_2 allowance price, fossil fuel prices, transport volume, number of dairy cattle, decommissioning of coal-fired electricity production capacity, and the distribution of vehicle types in sales of new cars.

Details on Advanced Motor Fuels

In 2017, energy consumption in transportation accounted for 34% of Danish energy consumption. The share of fossil fuels in energy consumption will fall from 95% in 2017 to 93% in 2030. Up to the financial crisis in 2008, energy consumption in transportation had been increasing steadily. The financial crisis and greater focus on the energy efficiency of cars resulted in a fall in energy consumption up to 2013. After 2013, energy consumption by road transport has followed an upward curve again, due in particular to an increase in the number of vehicles, which reflects an increase in sales of small petrol cars and medium-sized diesel cars. This has also meant an increase in the number of kilometers driven by cars.

Figure 1 shows energy consumption by use for the period 2017–2030. Road transport will account for 75% of energy consumption, of which cars will account for 47%. Aviation will account for 19%, whereas rail transport, maritime transport, and military transport will account for the rest.

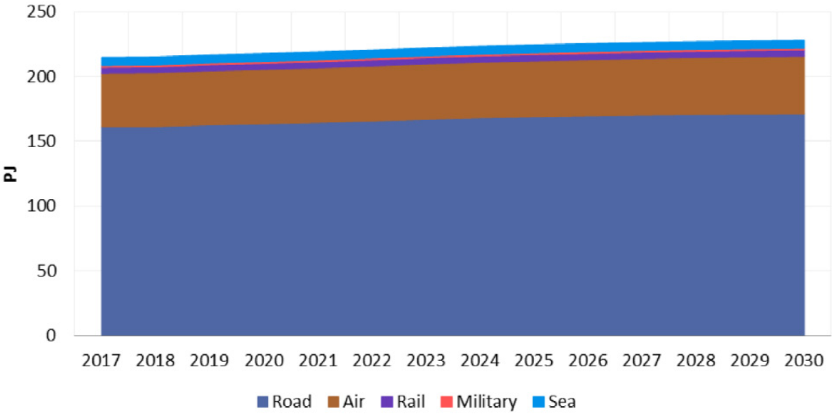


Fig. 1 Final Energy Consumption by the Transport Sector in Denmark by Use, 2017–2030 (PJ)

The increase in energy consumption will mainly come from road transport. Road transport is expected to increase by 6% in total from 2017 to 2030. Of this, the increase in energy consumption by cars will account for 80%. The reason for this increase in energy consumption is that improvements in energy efficiency will not offset the increase in the number of kilometers driven. It should be stressed that a significant improvement in efficiency is assumed up to 2030. The analysis shows that energy consumption in transportation will increase, particularly because of energy consumption by cars. Energy consumption in transportation up to 2030 will continue to be predominantly covered by fossil fuels.

Energy consumption by the aviation sector is expected to increase by 8% from 2017 to 2030 due to an increase in air traffic of 35%; however, energy efficiency will increase by 26%. The aviation sector has announced ambitious plans for biofuel blending, but these announcements are not assessed to be binding, nor are they assessed to reflect a profitable development pathway for companies in the absence of any new initiatives. Consequently, it is assumed that there will be no biofuel blending in aviation.

Sales of electrified vehicles (electric cars, plug-in hybrid cars, and hydrogen cars) will increase up to 2030 as a result of technological developments and falling technology costs and are expected to account for 22% of total sales of new cars in 2030 in the absence of any new initiatives. This central estimate means that electrified vehicles will account for 7% of the total number of cars and vans on the road in 2030. The associated electricity consumption is expected to account for 1.2% of total electricity consumption in 2030.

Figure 2 shows the development in electrified vehicles' share of total car sales. The figure shows that electric cars are expected to account for the largest share of sales of electrified vehicles. Sales of hydrogen cars are expected to be insignificant.

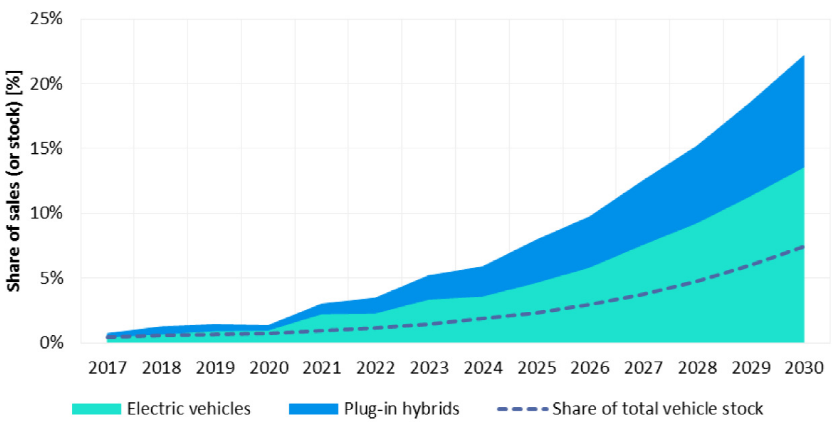


Fig. 2 Electrified Vehicles' Share of Sale of New Cars and the Share of Cars and Vans on the Road in Denmark, 2017–2030 (%)

This central estimate for sales of electrified vehicles is subject to significant uncertainty, which has been addressed in a sensitivity analysis. The analysis shows that electric cars and plug-in hybrid cars as a central estimate are expected to account for 22% of sales and 7% of the total number of cars and vans on the road in 2030. The associated electricity consumption is expected to account for 1.2% of total electricity consumption in 2030. Sensitivity analyses examine, among other things, the effect of the significant uncertainty about the trend in sales of electrified vehicles.

The share of fossil fuels in transportation will fall from 95% to 93% from 2017 to 2030, primarily due to electrification of railways and, to a lesser extent, electrification of road transport. An increase in the use of biofuels by buses is expected, which primarily depends on municipal targets.

Consumption of biofuels (excluding biogas) is expected to increase to 10.7 petajoules (PJ) in 2030, corresponding to 5% of energy consumption in transportation. If all gas used in transportation is assumed to be biogas, biogas will contribute 0.4%. Consumption of electricity is expected to increase to 5.8 PJ in 2030, corresponding to 3% of energy consumption in transportation. Biofuel blending for road transport will not increase after 2020 in the absence of any new initiatives. The analysis shows that the share of fossil fuels in energy consumption in transportation will fall from 95% in 2017 to 93% in 2030.

Research and Demonstration Focus

Research and demonstration in Denmark focus on electric vehicles and fuel cell vehicles for passenger cars. Several demonstration projects have been initiated. For heavy-duty vehicles, 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. The government's goal is that by 2050 all of the Danish energy supply will be met by renewable energy, including that required by the transportation sector. In February 2012, the Danish Energy Agency finalized a report on alternative fuels for the transportation sector, including socioeconomic aspects, energy efficiency, and environmental impact. The analysis 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.

Finland

Drivers and Policies

In 2017, total energy consumption in Finland was 1,348 petajoules (PJ), and the share of renewable energy was 36%. Furthermore, road transportation consumed about 163 PJ of energy (i.e., 15% of final energy end use of 1,100 PJ). Transport produces about one-fifth of Finnish greenhouse gas (GHG) emissions, and 92% of transport emissions are from road transport.[37]

In November 2016, the National Energy and Climate Strategy outlined the actions that will enable Finland to (1) attain the targets specified in the government programme and (2) set the course for achieving an 80% to 95% reduction in GHG emissions by 2050.[37] The government's medium-term climate policy plan targets carbon neutrality for Finland by 2045. The proposed action plan to achieve targets includes using zero- and low-emission cars, renewable fuels, mileage reduction of passenger cars, and sustainable forms of transportation.[38] Taxes and fees would be increased for those vehicles and modes that produce the most emissions ("polluter pays principle"). Simultaneously, transition into emission-free technologies and sustainable forms of mobility would be supported. Community planning is at the heart of sustainable mobility, namely, minimizing the need for transport, guiding people to move on foot or by bicycle, or using carpooling or public transportation. The action plan includes the following targets:

- In 2030–2045, Finland would have about 670,000–2 million electric cars, 130,000–250,000 gas-fueled cars, about 7,000–42,000 heavy-duty (HD) electric vehicles (EVs), and 6,000–22,000 HD natural gas vehicles (NGVs).
- The share of liquid biofuels would change to 30% of all liquid fuels in 2030 and to 100% in 2045. The use of domestically produced biogas will increase strongly. The sale of fossil transport fuels would be prohibited in 2045.

Advanced Motor Fuels Statistics

The total consumption of gasoline and diesel in Finland in 2017 was 3.8 megatonnes of oil equivalent (Mtoe) (Table 1). In 2017, the actual share of biofuels was about 10.5%,[39] while the target for 2017 was 12% (with

[37] http://www.stat.fi/ and http://lipasto.vtt.fi

[38] Action programme for carbon-free transport 2045. Final report by the Transport Climate Policy working group (in Finnish); www.lvm.fi

[39] Not necessarily equal to the formal reporting of biofuel obligation due to different principles and restrictions in data availability due to the EU's rules on competition.

double-counting). The Finnish biofuel obligation allows "banking," as long as the overall cumulative volumes are met. Finland uses ethanol both as such and as fuel ethers, that is, as ethyl tertiary-butyl ether (ETBE) and tertiary-amyl ethyl ether (TAEE). Finland also uses biogasoline as a blending component. The bioportion of diesel fuel mainly consists of paraffinic renewable diesel fuel.

Table 1 Use of Road Transportation Fuels in Finland, 2017

Gasoline/Diesel[a] (Mtoe)	Ethanol, Ethers and Biogasoline[c] (Mtoe)	Renewable Diesel and Biodiesel[b] Total/Bio[c] (Mtoe)	Methane Total/Bio (Mtoe)
1.3/2.5	0.086	0.310	0.0048/0.0026

[a] Includes alternative/bio.
[b] Mainly renewable diesel, only minor amount of FAME.
[c] Bio = meets EU's sustainability criteria (2009/28/EC; without double-counting).

Source: Tilastokeskus, see also, http://pxnet2.stat.fi/PXWeb/pxweb/fi/StatFin/

Finland's total road vehicle fleet in September 2018 was about 3 million (excluding non-road) vehicles (Table 2). This included around 4,100 flex-fuel vehicles (FFVs) capable of using E85, around 6,300 gas vehicles using natural gas or biomethane (or bi-fuel gasoline/methane), and 13,100 plug-in hybrids and 2,700 battery electric vehicles (BEVs). The average age of cars was 12 years in 2017, and the age of cars scrapped was 21 years.

Table 2 Types and Numbers of Vehicles in Use in Finland by December 31, 2018[a]

Passenger Cars	Vans	Trucks	Buses	Two-Wheelers	Non-road
2,696,300	325,660	96,170	12,480	279,030	538,420

[a] 28% of cars were diesel cars.

Source: Traficom, trafi2.stat.fi/PXWeb/pxweb/fi/TraFi/TraFi__Liikennekaytossa_olevat_ajoneuvot

Renewable Diesel Fuels

Renewable diesel is currently the main renewable component in Finnish automotive fuels.

Neste produces a renewable paraffinic diesel fuel, Neste MY Renewable Diesel, with a worldwide capacity of 2.6 Mtoe/year. Around 80% of Neste's renewable diesel production is based on waste and residue raw materials. Neste MY Renewable Diesel is made 100% from waste and residues, and Pro Diesel contains at least 15% of renewable diesel.[40]

[40] Neste, www.neste.com/.../neste-my-renewable-diesel, accessed in January 2019

UPM, a pulp and paper company, produces hydrotreated renewable diesel, UPM BioVerno, from crude tall oil in Lappeenranta. St1 Biofuels Oy (Diesel Plus) and ABC (Smart Diesel) refueling stations in Finland sell 10 vol% of UPM BioVerno blended into diesel fuel. Finland uses a small amount of conventional esterified biodiesel (i.e., fatty acid methyl esters [FAME]).

Bioalcohols and Ethers

Fuel ethanol and fuel ethers (fossil and bio-origin) are blended in gasoline in Finland (E10) and sold as E85 for FFVs. RED95 ethanol-diesel has been tested in a limited number of vehicles.

The energy company, St1 Renewable Energy Oy, has four decentralized Etanolix® plants using waste from the food industry and one in Gothenburg, Sweden, and one Bionolix® plant using biowaste from shops and households as their feedstock (0.5–3.5 ktoe/year/unit ethanol). The Bionolix® unit in Hämeenlinna is combined with a biogas production plant.

In 2017, St1 Renewable Energy Oy started its Cellunolix® bioethanol production in Kajaani, using sawdust and chips as feedstock. The production capacity of the plant is 10 million liters of advanced ethanol per year. The Kajaani Cellunolix® Plant is the first in the world utilizing sawmill residues of softwood in ethanol production in commercial scale. In addition, lignin, wood vinasse, wood turpentine, furfural, carbon dioxide, and biogas are produced in the Cellunolix® biorefinery.

Biogasoline

Biogasoline contains only biohydrocarbons (oxygen-free). Small amounts of biogasoline components are produced at Neste's and UPM's renewable diesel processing units and blended in gasoline. Neste produces traffic fuels also using tall oil pitch as a co-feeding feedstock at the Naantali refinery.[41]

Natural Gas and Biomethane

Finland has some 40 methane filling stations, 4 of which offer liquefied natural gas (LNG). In addition to natural gas, renewable methane (biogas) is used for transport.[42] Renewable methane is mostly distributed though co-feeding into the natural gas grid. LNG terminals have been built for industry and ships in Pori (15,000 metric tons) and Tornio (Manga 50,000 m^3).

41 https://www.neste.com/en/neste-oil-uses-tall-oil-pitch-produce-traffic-fuel
42 http://www.kaasuyhdistys.fi/sisalto/kaasutilastot

Renewable Jet Fuel

Neste's renewable aviation fuel is refined in Porvoo, and it meets the strict quality requirements for aviation fuels. Partnership in renewable aviation fuel has expanded to Lapland Airports, Air BP, Norway, SFO, Alaska Airlines, Dallas DFW, American Airlines, and Stuttgart Airport.

Electric and Hybrid Electric Vehicles

Helsinki Region Transport (HSL), the public transportation authority in metropolitan Helsinki, has ordered 12 electric buses from the Finnish start-up company Linkker. Operations with Linkker buses started in Espoo in 2015 and in Helsinki in 2017.[43] The goal is to have 400 electric buses operating in the Helsinki region by 2025 (roughly one-third of the fleet). In the fall 2018 tendering round for bus services, HSL for the first time required a number of electric buses, if only 5, for a certain route. This was the real opening of commercial e-bus services.

Hydrogen

Finland's first commercial hydrogen fueling station opened in 2014 in Helsinki. It is now closed, however, and the only hydrogen fueling station is at Voikoski, and, so far, also the only hydrogen car in Finland.

Research and Demonstration Focus

The TransDigi program, started in 2017, created a collaboration and innovation platform for sustainable, seamless, and safe mobility. The BioOneHundred pilot project, led by HSL and covering 2016–2019, focuses on high-concentration biofuels for carbon-neutral urban traffic. In Helsinki, bus services procured by HSL and the vehicles of Helsinki City Construction Services, Stara, aim at using sustainable biofuels in minimum 50% in 2018 and 70%–90% in 2019. In 2018, the cities of Espoo and Vantaa and also the Finnish Post joined the project.

There are also projects on developing a catalytic pyrolysis technology for upgrading bio-oil. Biomass-to-liquid (BTL)-related projects aim to produce transport fuels from biomass by gasification-based concepts. Neo-Carbon Energy, 2014–2019, creates a new energy system, including the world's first pilot plant capable of producing hydrocarbons from the air by using solar power as the energy source.

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[43] HLS, 2017, "Helsinki's First Fully Electric Bus to Hit the Road in January," www.hsl.fi/en/news/2017/helsinkis-first-fully-electric-bus-hit-road-january-9590

MARANDA (2017–2021) is a hydrogen-related project aiming at hydrogen-fuelled fuel cell-based hybrid powertrain system for marine applications. The LOHCNESS (2017–2019) project studies liquid organic hydrogen carriers aiming at hydrogen storage media compatible with the present infrastructure for liquid fuels.

Outlook

Bioethanol and renewable diesels will be used increasingly as biofuels in Finland. In the long term, cellulosic BTL is expected to cover a significant share of the diesel pool in Finland.

Neste strengthens its global leading position in renewable products with a major investment increasing Neste's renewable product overall capacity in Singapore by up to 1.3 million tons per year, bringing the total renewable product capacity close to 4.5 million tons per year in 2022.

St1 is planning 50-million-liter (~25 ktoe) Cellunolix® biorefineries in Nordic countries in the near future and further on in all softwood producing countries in the world. Feasibility studies and environmental impact assessments for three sites — two in Finland and one in Norway — are already processed. North European Bio Tech Oy is also looking into expanding the Kajaani Cellunolix® plant. Suomen Bioetanoli Oy plans to build a straw bioethanol plant at Myllykoski, Kouvola (~45 ktoe/year). St1 is planning to invest 50 million liters Cellunolix® biorefineries in Nordic countries in the near future.

The LNG infrastructure being built offers opportunities to consider LNG for heavy-duty transportation. A new LNG terminal in Hamina will have a 30,000-m^3 LNG storage tank by 2020, and a second 20,000-m^3 storage tank may be added at a later date. Finland and Estonia will construct a gas pipeline, Balticconnector, which will enable the opening of Finnish gas markets starting in 2020 (currently, demand in Finland is met only by Russian natural gas). The energy company Gasum increased its shareholding in Skangas to 100%. Gasum is now the leading Nordic LNG provider.

Major Changes

The government's climate change policy plan targeting carbon neutrality in Finland by 2045 was supported by the action plan proposed by an expert group. The proposed actions include, for example, goals of having about 670,000 EVs (also hydrogen and rechargeable hybrids) and 130,000 gas-powered vehicles by 2030. The increase in the share of renewable fuels would be 30% of all liquid fuels in 2030, and a strong increase in domestically produced biogas.

Germany

Drivers and Policies

The development of advanced motor fuels in Germany is driven by two goals: (1) complying with European and international climate protection strategies and (2) reducing particulate matter and nitrogen oxide emissions in highly polluted metropolitan areas. The main public driver regarding policy in the transport sector is the revised European Union (EU) Renewable Energy Directive II (RED II). By the end of 2020, a fleet consumption limit of 95 grams of carbon dioxide (CO_2) per kilometer will apply to all newly registered passenger cars and a fleet consumption reduction of 37.5% in 2030 compared to the reference year (2021).[44,45] The discussion about diesel engines has been ongoing since 2015. In February 2018, the Supreme Administrative Court allowed diesel-driving bans for cars up to Euro 5. The current trend shows that the greenhouse gas (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, the need for expanding advanced biofuels has been questioned by the increasing electrification of the fleet; further, the number of electric vehicles and plug-ins has increased since 2017 (see "Advanced Motor Fuels Statistics" [AMFS]), although the share in the total number of vehicles 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) offers new perspectives also in the transport sector.[46] The German Energy Agency (dena) launched the Global Alliance Power Fuels in September 2018 with key partners from industry.[47] In general, Germany's public debate focuses on electric mobility and battery-powered vehicles. Only a committed policy to support advanced motor fuels would strengthen the market perspective, which is only partly reflected in the Government's Mobility and Fuels Strategy[48] and the national and European legislation. In January 2018, the Upstream Emissions Reductions (UER)[49] ordinance, implementing EU legislation, was published.

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44 https://eur-lex.europa.eu/eli/reg/2009/443/

45 https://ec.europa.eu/germany/news/20181218-co2-grenzwerte-autos_de

46 Naumann, K., Schröder, J., Oehmichen, K., Etzold, H., Müller-Langer, F., Remmele, E., Thuneke, K., Raksha, T., and Schmidt, P., 2019, Monitoring Biokraftstoffsektor. 4. überarbeitete und erweiterte Auflage, Leipzig: DBFZ (DBFZ-Report Nr. 11), ISBN 978-3-946629-04-7

47 https://www.dena.de/en/newsroom/meldungen/dena-launches-global-alliance-power-fuels/

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

49 https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl# _bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl118005.pdf%27%5D__1520407817723

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, the absolute amount of biofuels will probably remain at a constant level until 2019.[2] From 2020 on, the mineral oil industry can apply UER measures to comply with legal requirements. The Government requires the mineral oil industry to reduce its GHG emissions by 6% from 2020 on, with a base year of 2010. Furthermore, the latest amendment to the German Emission Control Act[50] has banned all double-counting and excludes animal fats from the quota eligibility. However, recent regulations expand the list, including bio-based, co-refined hydrated oils that have been produced sustainably, Power to X (PtX),[51] and the use of electricity in electric vehicles (EVs).[52] To decarbonise the transport sector, high priority has recently been given not only to electro-mobility for short-distance traffic and passenger cars, but also to the enforcement of compressed natural gas (CNG) infrastructure along the most important middle- and long-distance road networks. CNG mobility is expanding, as reflected in the Volkswagen Group's "TOGETHER – Strategy 2025."[53,54] In addition, the Government strongly supports the use of liquefied natural gas (LNG) for heavy-duty transport and waterborne application. In 2016, the Federal Ministry of Transport and Digital Infrastructure (BMVI) provided €1 billion ($1.2 billion US) in incentives for improving alternative fuelling infrastructure, implementing grants to buy EVs, and fostering R&D and demonstration in these fields, including the implementation of a competitive infrastructure for hydrogen and fuel cell technology.[55] A total of €300 million ($339 million US) is available for the 2017–2020 programme, foreseeing the installation of 15,000 (normal and fast) charging stations. In addition, the BMVI established grants for public procurement to equip car fleets with EVs.[56] Recently, the Government postponed its goal to have at least 1 million registered EVs by 2020 to 2022. Despite the new incentives, EV sales remain low (see AMFS) but have increased since 2017. Thus, Germany remains at risk for missing the 1 million-EV goal and its climate targets for road transportation. The EC's Alternative Fuel Infrastructure Directive foresees that until 2025, 208,000 charging stations will be required.[57] In contrast, the National Platform E-mobility (NPE) considers

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50 https://www.gesetze-im-internet.de/bimschg/BJNR007210974.html
51 https://www.gesetze-im-internet.de/biokraft-nachv/BJNR318200009.html
52 https://www.gesetze-im-internet.de/emog/BJNR089800015.html
53 https://www.volkswagenag.com/en/group/strategy.html
54 https://www.ngvglobal.com/blog/status-cng-mobility-germany-rising-0222
55 "National Strategy for the Expansion of Alternative Fuels' Infrastructure"
56 https://www.bmvi.de/DE/Themen/Mobilitaet/Elektromobilitaet/Ladeinfrastruktur/Ladeinfrastruktur.html
57 https://t3n.de/news/ladeinfrastruktur-e-autos-2025-966132/

70,000 public ac charging points, 7,100 public dc charging points and an additional 2.4 to 3.5 million private charging points in 2022.[58] Currently, large cities have only one public charging station per 50,000 inhabitants. An investment of an estimated €1.6 billion to €2.5 billion ($1.8 billion to $2.8 billion US) would be required to create sufficient coverage. German natural gas (CNG) interest groups have supported the CNG infrastructure. Tax reliefs for CNG have been extended until 2024 and will decrease afterward. In 2019 and 2020, lorries powered by natural gas are exempt from road tolls. Tax exemptions on biofuels in the agricultural and forestry sector underpin a niche market and will be effective beyond 2018; those for liquefied petroleum gas (LPG) will be phased out by 2023.

Advanced Motor Fuels Statistics

Figure 1 shows the 2017 German fuel consumption for use in road transportation. The consumption of biofuels totaled 3.4 Mt, primarily low-level blends of biodiesel, hydrogenated vegetable oil, bioethanol, and biomethane.

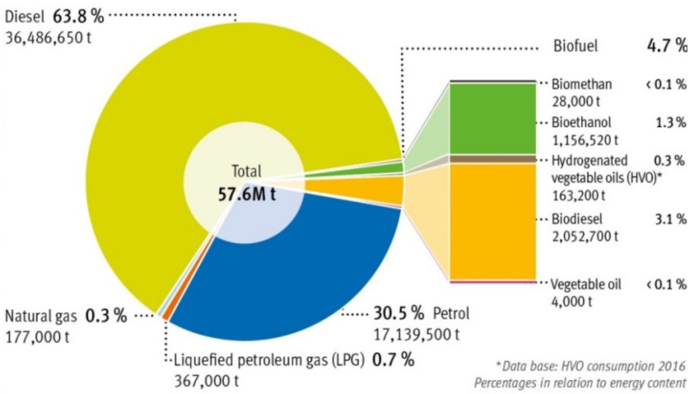

Fig. 1 Fuel Consumption in the Transport Sector in Germany, 2017
Source: FNR on the basis of BAFA, Destatis, DVFG, BDEW, BLE 2018[59]

[58] Fortschrittsbericht 2018. Markthochlaufphase. Hg. v. Gemeinsame Geschäftsstelle Elektromobilität der Bundesregierung (GGEMO). Berlin. http://nationale-plattform-elektromobilitaet.de/fileadmin/user_upload/Redaktion/NPE_Fortschrittsbericht_2018_barrierefrei.pdf

[59] Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle), BAFA et al. (Federal Statistics Office [Destatis], DVFG [German LPG Association], the Federal Ministry of Finance [Bundesministerium der Finanzen, or BMF], Agency for Renewable Resources [Fachagentur Nachwachsende Rohstoffe e.V., or FNR]), February 2018.

Moreover, to a minor extent, biomethane is used for CNG. Lacking incentives, there is no market demand for E85 and pure biodiesel. Tables 1 and 2 show the 2010–2018 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, has increased the average GHG reduction of biofuels on the German market to 81% in 2017.[60] Table 3 shows the number of passenger cars in Germany by fuel type for 2015–2018. (In the tables, n/a means data not available.)

Table 1 Trends in German Biodiesel/FAME Sales, 2010–2018, in mt

Sale	2010	2011	2012	2013	2014	2015	2016	2017	2018
Blend	2,236	2,116	1,928	1,741	1,970	1,978	2,000	2,063	2,177
Pure biodiesel	0,293	0,097	0,131	0,030	0,005	0,003	0,001	n/a	n/a
Total	2,529	2,213	2,059	1,772	1,975	1,981	2,001	2,063	2,177

Table 2 Trends in German Bioethanol Sales, 2010–2018, in mt

Sale	2010	2011	2012	2013	2014	2015	2016	2017	2018
E85	0,018	0,019	0,021	0,014	0,010	0,007	n/a	n/a	n/a
Ethanol	1,028	1,054	1,090	1,041	1,082	1,049	1,047	1,043	1,079
ETBE	0,122	0,162	0,142	0,154	0,119	0,116	0,124	0,111	0,110
Total	1,165	1,233	1,249	1,206	1,209	1,171	1,167	1,154	1,189

Table 3 Number of Passenger Cars in Germany by Fuel Type on January 1, 2015–2018

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

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*[61]

[60] https://www.ble.de/SharedDocs/Downloads/EN/Climate-Energy/EvaluationAndProgressReports2017.pdf;jsessionid=E12E6C1FC9997802159DF7A542FF49BD.1_cid335?__blob=publicationFile&v=3

[61] KBA (Kraftfahrt-Bundesamt; Federal Motor Transport Authority), 2019, https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/j%C3%A4hrlich/2019_b_barometer.html?nn=2084378

A total of 56.5 million vehicles, including 4.4 million motor bikes, were registered in Germany as of January 1, 2018,[62] along with 46.5 million (82%) passenger cars, 3 million trucks, 2.2 million towing vehicles, 79,400 buses, and 296,000 other vehicles.

Research and Demonstration Focus

Public funding for alternative motor fuels on the national scale is supported by the BMVI[63] (infrastructure, e-mobility, LNG, CNG, jet fuel, "National Strategy to Extend the Infrastructure for Alternative Fuels"), the Federal Ministry of Education and Research (BMBF)[64] (PtX; "Kopernikus Projects"), and the Ministry of Economic Affairs and Energy (BMWi),[65] focusing on eFuels in the "Energiewende im Verkehr" programme, including a total funding of €87 million ($97.7 million US).[66] Under the Renewable Resources Funding Scheme of the BMEL,[67] 23 R&D projects have received funding of €6 million ($6.74 million US) in 2018. Novel routes for the production of fuels or fuel additives and the adaptation of internal combustion engines to multiple fuels are examples of the main topics. Because of an adverse European framework for biomass-based fuels, increased funding is not envisaged.

Outlook

Energy policy and research and innovation frameworks at the EU and international level have the potential to strengthen the advanced motor fuel market, if consensus is reached that all measures are required to meet CO_2 reduction targets. But new EU legislation, mainly the RED II, also presents risks to alienate fuel producers and the related market. Measures discussed above to promote e-mobility, CNG, and LNG will have a positive impact on the market in general but not necessarily for advanced biofuels. Further R&D activities (e.g., reducing the GHG emissions of biofuels to make them compatible with the RED II) 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

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62 https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/FahrzeugklassenAufbauarten/b_fzkl_zeitreihe.html
63 https://www.bmvi.de/EN
64 https://www.bmbf.de/en
65 https://www.bmwi.de/Navigation/EN/Home/home.html
66 https://www.energieforschung.de/forschung-und-innovation/energiewende-im-verkehr
67 https://www.bmel.de/EN

India

Drivers and Policies

At $2.5 trillion (US), India's economy is currently the seventh largest in the world. The International Monetary Fund forecasts that India will grow at 7.4% in fiscal year (FY) 2018–2019. The demand for energy is growing rapidly, especially in the transport sector. Domestic crude oil production, however, can meet only about 17.9% of the demand; the remainder must come from imported crude.

The government intends to reduce the import bill by 10% by 2022 and has prepared a roadmap to reduce import dependency in the oil and gas sector. India's five-phase strategy includes (1) increasing domestic production, (2) adopting biofuels and renewables, (3) adopting energy-efficiency norms, (4) improving refinery processes, and (5) substituting demand. This plan envisages a strategic role for biofuels. India enacted a national policy for biofuels in 2009. Since 2014, the government has undertaken multiple interventions to promote biofuels through structured programmes, such as the Ethanol Blended Petrol (EBP) Programme and the Bio-diesel Blending Programme. A target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel is proposed by 2030.

Hydrocarbon fuels, along with greenhouse gas (GHG) emissions, have adversely affected the environment. To reduce GHG emissions and improve air quality, India introduced the Bharat Stage (BS) norms — emission control standards based on European regulations — in 2000. BS IV (equivalent to Euro 4) norms have been applicable in India since April 1, 2017, and the government is committed to implementing BS VI (equivalent to Euro 6) norms at the national level on April 1, 2020, directly leapfrogging from BS IV norms to BS VI norms, with India's refineries investing approximately $44 billion (US). Diesel sulphur content was reduced from 10,000 parts per million (ppm) in 1996 to a maximum of 50 ppm in 2017. The proposed BS VI regulation will reduce diesel sulphur to a maximum of 10 ppm, enabling the introduction of advanced emission control technologies, including diesel particulate filters and selective catalyst reduction systems, which will be needed to meet BS VI emission standards.

Advanced Motor Fuels Statistics

India expects to double its consumption of petroleum and become the third largest consumer in the world by 2030. Energy demand is highest across the transport sector. As vehicle ownership expands so will the demand for petroleum products. It is estimated that the demand for diesel and petrol will increase from 80.4 million metric tons (Mt) and 26.1 million Mt, respectively, in the years 2017–2018 to 110 million Mt and 31.1 million Mt by the years 2021–2022, respectively, if the present situation prevails. Consumption of all petro products combined together has increased from 148.1 million Mt in FY 2011–2012 to 203 million Mt in FY 2017–2018 at a CAGR of 5.4% (depicted in Figure 1), while net import has increased from 126.1 million Mt in FY 2011–2012 to 188.1 million Mt at a CAGR of 7%.

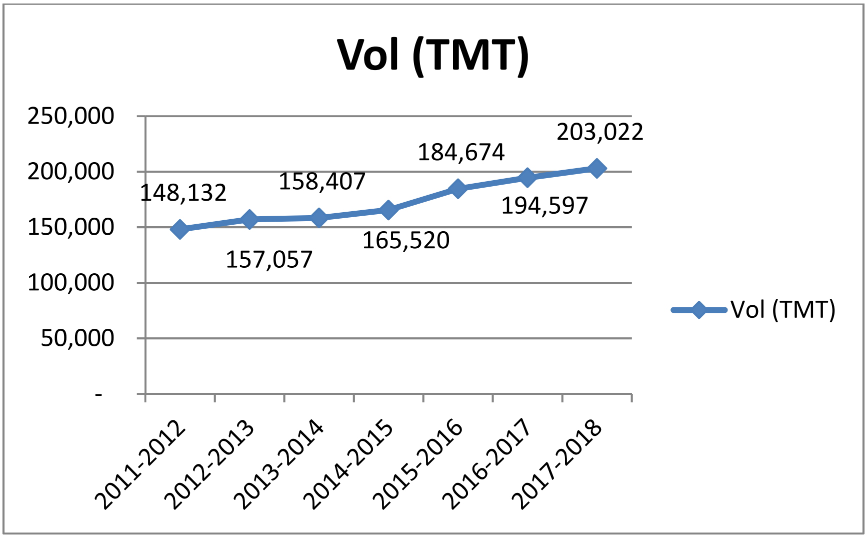

Fig. 1 Consumption of Petroleum Product
Note: Data for 2017–2018 is actually for April–December 2017 and extrapolated for FY 2017–2018 to facilitate the comparison.
Source: PPAC website ppac.org.in

Details on Advanced Motor Fuels

The government has been promoting and encouraging production and use of (1) ethanol derived from sugar molasses and/or second generation (2G) biofuels (e.g., biomass, agricultural waste) for blending with petrol and (2) biodiesel derived from inedible oils, tree-borne oil seeds, and oil waste for blending with diesel.

Ethanol-blended Petrol Programme

Under the Ethanol Blended Petrol (EBP) Programme, oil marketing companies (OMCs) sell petrol blended with ethanol up to 10% depending on availability. Supplies were not forthcoming until 2013–2014. To augment the supply of ethanol for EBP, on December 10, 2014, the government decided to administer ethanol prices. This decision, along with other measures, such as an excise duty waiver addressing state-specific issues and availability of molasses in the ecosystem, facilitated improving the supply of ethanol from 154 million L during 2012–2013 to 1,110 million L during 2015–2016, thereby achieving 3.5% blending in petrol. For the ethanol supply year 2016–2017, about 665.1 million L of ethanol could be procured due to lower sugarcane production in the country.

Second Generation Ethanol Programme

Oil PSUs are also working to set up 12 2G ethanol bio-refineries in 11 states to boost production of ethanol. The estimated investment for the bio-refineries is $1,550 million (US). These bio-refineries will produce around 300–350 million L of ethanol annually, thus contributing significantly towards the EBP. Hindustan Petroleum Corporation Ltd. (HPCL) is constructing the first 2G ethanol bio-refinery in India at Bathinda (Punjab) for which the foundation stone-laying ceremony was held on December 25, 2016, with an estimated annual production capacity of 34 million L of ethanol. Oil PSUs have completed a detailed feasibility report (DFR) for the first few 2G bio-ethanol plants, and oil PSUs are now seeking environmental clearance for their projects.

Biodiesel

In June 2017, the government allowed the 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. From April 2017 to November 2017, the biodiesel quantity procured by OMCs was 43.55 million L vis-à-vis 34.91 million L procured during the same period in 2016 (i.e., an increase of 24%).

Research and Demonstration Focus

The Centre for High Technology (CHT) under MoPNG and Department of Biotechnology (DBT) are working on the programmes to support research and development (R&D) pertaining to energy biosciences in the country with major emphasis on advanced biofuels. Efforts are being made to support the R&D towards development of cost-effective, next-generation biofuels like algae biodiesel, cellulosic ethanol, bio-butanol, and bio-hydrogen. DBT has established four bioenergy centres to strengthen the research base in biofuels and to promote translation of process and technologies from research to scale-up and commercialization. Various technologies, including cellulosic ethanol, have been developed. Lignocelluloses technology is being demonstrated at a pilot scale.

Recently, Bharat Petroleum Corporate R&D Centre completed a project with CSIRO, Australia and Indian Institute of Petroleum, Dehradoon for the production of di-methyl ether (DME) from stranded natural gas. Natural gas is first converted into synthesis gas (syngas), which is then converted into DME. The project focuses on developing modular reactor configuration and catalyst for direct conversion of syngas to DME. As part of the program, BPCL Corporate R&D Centre has developed a novel catalyst for direct conversion of syngas to DME. The project also led to the development of an efficient tubular reactor configuration for carrying out exothermic gas solid reactions such as syngas conversion to DME. The concept has been demonstrated in laboratory scale. Further development towards commercialization, in terms of scale up of catalyst to commercial scale and fabrication of a pilot-scale reactor system, is underway.

The IOC-DBT Advanced Bio-Energy Centre has recently commissioned the first integrated pilot plant in India for conversion of Ligno-cellulosic biomass to ethanol with technological support from the National Renewable Energy Laboratory. The pilot plant can process 5 kg/hour biomass and a variety of feedstock.

With regard to drop-in fuels, few technologies have been developed on the laboratory/demonstration scale to yield advanced biofuels, such as 2G ethanol, drop-in fuels, and bio-CNG, by companies/organizations such as IOCL, HPCL, M/s Praj Industries, M/s Shell, DBT-ICT, and more. Indian investors are assessing the commercial viability of such plants for ramping up the existing technologies to commercial scale.

Outlook

The outlook for biofuels in India will remain promising, considering the government’s decision to promote biofuels and advance biofuels as environmentally friendly fuels. From the view of EBP, the ongoing sugar year will see improved cane production/crushing (more than 22% over last year), resulting in higher molasses availability, which can be converted to alcohol/ethanol. With the continuation of the government’s policy to administer prices of ethanol for EBP, India has approved an enhanced ex-mill ethanol price of $0.63 (US) per liter for 2017–2018. Additionally, Goods and Service Tax and transportation will be paid to the suppliers. Against the tendered ethanol demand of 3.13 billion L during 2017–2018, PSU OMCs have allocated 1.39 billion L, which is an all-time high in a single ethanol supply year. As the demand for petrol rises, the demand for ethanol will increase annually. Considering, estimated petrol consumption of

31.1 MMTPA during 2021–2022, the ethanol requirement for 10% blending will be 3.11 MMTPA (4 billion L per year).

A National Policy on Biofuels – 2018 is being formulated. This policy looks at the future for biofuels. It reinforces ongoing biofuels supplies by increasing domestic production, setting up 2G bio-refineries, developing new feedstock and conversion technologies for biofuels, and creating a suitable environment for biofuels and its integration with the main fuels. To invigorate the present EBP, address environmental issues caused due to burning of biomass, and provide remuneration to farmers for agriculture residues, in 2014 the government allowed procurement of ethanol produced from other non-food feedstock besides molasses, like cellulosic and lignocelluloses materials, including petrochemicals, subject to meeting the relevant BIS standards. Pursuant to the aforesaid decision, oil PSUs have decided to set up 12 2G ethanol bio-refineries in 11 states across the country. These bio-refineries will yield around 300–350 million L of ethanol per year and are expected to be set up with an investment of about $1.56 billion (US).

Bio-CNG is also being looked as next major development in the alternate fuel segment. Indian Oil Corporation, one of the government oil companies, has entered into a Memorandum of Understanding with State Government of Punjab for setting up 400 biomass to bio-CNG plants in the next 5 years. These initiatives may be a precursor to biofuel schemes that the government may announce in coming years to provide an impetus to the Indian Biofuel Programme.

Additional Information Sources

- www.ppac.org.in for data on fossil fuels production, consumption, import and export
- www.mnre.gov.in for data on R&D projects
- www.siamindia.com for data on automotive industry
- India Economic Survey 2018
- www.fame-india.gov.in
- India Biofuel policy 2009
- www.dbtindia.nic.in
- www.indianoil.com

Israel

Drivers and Policies

In 2011, the Fuel Choices and Smart Mobility Initiative,[68] Israel's national program for alternative fuels and means of transportation, was launched as a joint governmental effort headed by the Prime Minister's Office. The Initiative aims to establish Israel as a showcase to the world for knowledge and industry in alternative fuels and smart mobility. Together with 11 partner government ministries, the Initiative aims to create a business-supportive environment for the market through simplification of bureaucratic processes and a means to quickly respond to market changes and needs. It supports Israel's interdisciplinary nature and Israeli entrepreneurs' operational agility, as well as cutting-edge academic research and exceptional cooperation between academic institutions and industry. The scope of work performed by Initiative partners within the various government ministries and related agencies is immense and affects about 550 companies, 300 research groups, and hundreds of entrepreneurs (see Table 1).

Table 1 Growth of Israel's Alternative Fuels Research Groups, Industry, and Investment, 2011–2018

Year	Research Groups	Companies	Cumulative Investments (€ million)
2011	45	60	250
2018	300	550	4,500

Standardization

A committee composed of Initiative members, including the Ministry of Environmental Protection, the Ministry of Energy, and the Ministry of Transport, works together with government agencies such as the Standards Institution of Israel to:

- Create standards and regulations for new vehicle types,
- Adopt new fuel and mobility standards,
- Support training for industry professionals,
- Enable applied experiments of innovative solutions and technologies, and
- Promote propulsion and vehicular technologies.

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68 http://www.fuelchoicesinitiative.com/our-goals

Recent Standards

During 2016, the Standards Institution of Israel issued a new standard for M15 (85% gasoline with 15% methanol) — the first standard for low methanol percentage fuel issued outside of China. This standard is currently being adopted by different countries. Additional steps were taken in order to promote the usage of M15 in the local market such as suitable taxation and M15-compatible vehicles approval.

During 2017, several new standards regarding electric vehicle (EV) charging stations were issued or revised. In addition, National Outline Plan No. 18 was adjusted to include criteria for compressed natural gas (CNG) fueling stations. Furthermore, standardization of hydrogen transport, storage, and fueling was initiated. All standards and methods regarding implementation for CNG vehicles, fuel stations, and vehicle repair shops were also issued in the last few years.

Taxation

In March 2016, the 3rd Green Taxation Interministerial Committee released comprehensive policy recommendations to promote the use of oil substitutes through economic incentives, a focus on environmental benefits, and an emphasis on the country's energy security. The recommendations include a differentiated taxation policy ("Green" Progressive Taxation) for the three fields related to energy for transportation — infrastructure, fuel types, and motor vehicles. In March 2018, the finance committee of the Israeli parliament approved new taxation recommendations.

Research and Demonstration Focus

Fuel Choices and Smart Mobility Initiative activities, some in cooperation with local authorities, include the following:

- *CNG refuelling stations*. In March 2018 the Ministry of Energy published a public tender offering financial support for building CNG refuelling stations. The total budget was 100 million NIS (€248 million, $280 million US), and 37 proposals were selected, offering a nationwide distribution of stations.
- *Alternative fuel shuttle buses.* In a governmental resolution passed in early 2017, the government mandated that all shuttle buses in future fast lane projects surrounding Tel Aviv must be powered by CNG or electric power.
- *Promotion of public transportation tenders.* Resolution 1837 of the Israeli government called for a provision of 50% mandatory electric or CNG buses in all future public transportation operator tenders. Considering the high mileage covered by buses, the use of alternative

fuel buses will make a significant contribution toward reducing pollutant emissions and dependence on oil. During 2018, few new tenders for operating public transportation have been released with this requirement. Prior to the resolution, the Ministry of Environmental Protection encouraged the purchase of electric buses, resulting in about 65 fully electric buses operating in Israel.

- *CNG garbage trucks.* Resolution 529 of the Israeli government called for reducing air pollution and environmental risks in Haifa Bay. In accordance with this goal, the Ministry of Environmental Protection, together with the Municipality of Haifa, acquired 25 CNG garbage trucks. These trucks have operated in Haifa since March 2018.
- *EV car sharing.* The Fuel Choices and Smart Mobility Initiative, together with the Ministry of Environmental Protection, started an EV car-sharing initiative in urban environments. So far, the initiative has proven successful in Haifa and Netanya, where 150 electric car-sharing vehicles are currently operating.
- *Deploying EV charging infrastructure in Israel*. The Ministry of Energy, along with the Fuel Choices and Smart Mobility Initiative, is supporting the deployment of about 2,000 EV charging stations. The charging infrastructure will be composed of both direct current and alternating current stations and is forecasted to be in place by the end of 2019.

Major Research Centers

- The Israel National Research Center for Electrochemical Propulsion (INREP) is a multidisciplinary center dedicated to the research and development (R&D) of electric mobility. R&D areas of focus include advanced materials and technologies for EVs, batteries, and fuel cell-based propulsion for transportation.
- The Israeli Fuel Cells Consortium (IFCC) was formed in October 2016 to advance fuel cell research in Israel, with an emphasis on solutions for electro-mobility. The IFCC is composed of 12 leading labs from 4 universities in Israel. It is funded by the Fuel Choices and Smart Mobility Initiative and works under the umbrella of INREP. In addition to research, it is tasked to train new scientists and engineers in the field and support Israeli industry.
- The National Research Centre for Smart Transportation has a goal to promote and develop ideas and ground-breaking research in the field of smart transportation, both from an academic and an entrepreneurial aspect. The research center will be established in one of Israel's universities and will start its operation in mid-2019.

Ministerial Research Grants and Programs

- The Ministry of Energy holds different programs that encourage entrepreneurship and innovation in the field of alternative fuels. The programs support R&D in several stages of the development process, from academic research through support of pre-seed ideas, all the way to pilot and demonstration projects. In addition, the Ministry has a student scholarship program for academic institutions in Israel and abroad that aims to develop the human resources pool for different areas of expertise in the alternative fuel professions and research areas.
- The Israel Science Foundation (ISF) has developed several programs aiming to promote, encourage, and support excellent research in the field of oil alternatives for transportation, including individual research grants and grants for holding international workshops.
- Through the ISF, the Center of Knowledge program encourages interdisciplinary research in the fields of hydrogen and synthetic fuels, as well as photo-electrochemistry.
- The Ministry of Science, Technology, and Space established a national foundation for engineering and applied sciences in order to bridge the gap between basic research and industrial research in different fields related to energy, big data, and smart mobility. The Ministry is also in charge of international scientific cooperation at the governmental level. It creates bi-national agreements and represents Israel in international scientific organizations (e.g., Horizon 2020).
- The Ministry of Transport and Road Safety promotes research projects for the advancement of scientific and technological innovation in the transportation sector, such as sustainable transport. In addition, it promotes tools to enrich data required for efficient and sustainable transport planning and encourages the application of innovative systems.
- The Ministry of Environmental Protection promotes research projects and coordinates knowledge in relation to the environmental impact and aspects of fuel alternatives for transportation.

Pilots and Industrial Demonstrations Program

The Fuel Choices and Smart Mobility Initiative and the Ministry of Energy through its Chief Scientist Office encourage entrepreneurship and innovation in the field of alternative fuels by supporting R&D in various stages. The Pilots and Demonstration tool of the Ministry of Energy enables companies to scale their innovative products or solutions to full production deployment. As of 2017, this grant supported more than 30 active projects.

To encourage demonstrations in the field of smart mobility in Israel, together with the Ministry of Transport and Road Safety, the following steps are taken:

- Advancing the establishment of a testing centre for autonomous vehicles for supporting smart transportation, and
- In collaboration with the Innovation Authority and the Fuel Choices and Smart Mobility Initiative, advancing field experiments and pilot projects for new technologies and operational concepts in the transportation sector with the potential for reducing congestion, traffic accidents, use of petroleum, or encouraging the use of public transportation, with the aim of streamlining and improving transportation, both in Israel and abroad.

Industrial R&D TEPS (MAGNET Program)

Transportation Electric Power Solutions (TEPS) is an Israeli consortium of industries and academia initiated and sponsored by the Fuel Choices and Smart Mobility Initiative and the Magnet Directorate Chief at the Israel Innovation Authority. Its objective is to incubate and promote generic innovative industry-oriented technologies for power sources for electric vehicles. TEPS industrial members, including Elbit, Tadiran, ETV, and Electric Fuel, closely collaborate with Israeli academia to pursue innovative solutions in the field of energy storage and electrical propulsion.

Benefits of Participation in the AMF TCP

Participation in the AMF TCP has given Israel greater access to the most relevant and up-to-date information and research on alternatives to traditional transport fuels. Leveraging this international expertise has helped Israel build its national research capabilities in support of its current and projected strategies.

Japan

Drivers and Policies

Fossil fuel plays a central role as a source of energy in Japan. The country's domestic sources of fossil fuel are limited, however, making it dependent on imports.

In 2002, Japan enacted the Basic Act of Energy Policy to ensure the steady implementation of energy policy. The primary goal of the energy policy is to ensure a stable supply ("Energy Security") and to realize a low-cost energy supply by enhancing its efficiency ("Economic Efficiency") on the premise of "Safety." It is also important to maximize efforts to pursue environment suitability ("Environment").

In terms of primary energy, Japan's new Strategic Energy Plan, approved in 2014, discusses the use of nuclear power and the need to ensure safety, improve the efficiency of electricity generation, expand the use of liquefied natural gas (LNG) and liquefied petroleum gas (LPG), and emphasize reducing the cost of renewable energy.

In 2015, the Ministry of the Environment and the Ministry of Economy, Trade and Industry (METI) presented a government proposal that sets a target for reducing the level of greenhouse gases in 2030 "by 26% compared to the level in 2013."

In the transportation sector, in order to improve the energy efficiency of automobile transportation, Japan will, for example, increase the ratio of next-generation vehicles (e.g., hybrid vehicles, electric vehicles [EVs], plug-in hybrid vehicles [PHEVs], fuel cell vehicles [FCVs], clean diesel vehicles, and compressed natural gas [CNG] vehicles) to all new vehicles to 50% to 70% by 2030.

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 in Japan in 2016 [1]. Oil-related energy accounts for 97.9% of total usage. The market for alternative fuels is minimal in Japan as is the number of alternative fuel vehicles (Table 1). Methanol, CNG, hybrid, EVs, and FCVs currently constitute 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 2,449 FCVs.

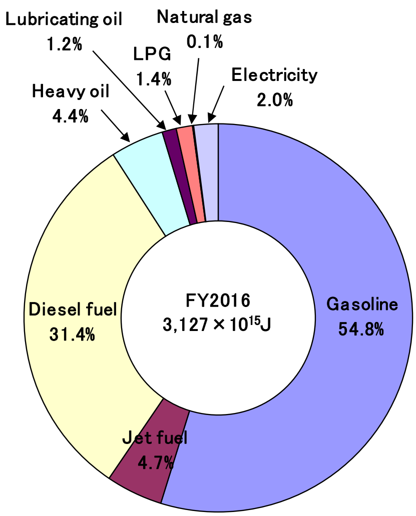

Fig. 1　Energy Sources Used in the Transportation Sector in Japan in 2016

Table 1　Current Penetration of Low-Emission Vehicles in Japan

<table>
<tr><th>Vehicle Type</th><th>Methanol [2]</th><th>CNG [3]</th><th>Hybrid [4]</th><th>EV [4]</th><th>FCV [5]</th><th>Vehicle Registration [6]</th></tr>
<tr><td>Passenger vehicles</td><td>0</td><td>1,603</td><td>7,409,635 (PHV:103,211)</td><td>91,357</td><td>2,440</td><td>39,585,729</td></tr>
<tr><td rowspan="2">Light, mid, and heavy-duty trucks</td><td rowspan="2">576</td><td>6,200</td><td rowspan="4">26,244</td><td rowspan="4">1,514</td><td rowspan="2">0</td><td rowspan="2">5,882,863</td></tr>
<tr><td>20,291</td></tr>
<tr><td>Buses</td><td>0</td><td>1,582</td><td>8</td><td>233,288</td></tr>
<tr><td>Special vehicles</td><td>0</td><td>4,056</td><td>1</td><td>1,585,018</td></tr>
<tr><td>Small vehicles</td><td>0</td><td>10,927</td><td>771,579</td><td>10,698</td><td>0</td><td>30,963,808</td></tr>
<tr><td>Total</td><td>576</td><td>44,659</td><td>7,041,358</td><td>103,569</td><td>2,449</td><td>78,250,706</td></tr>
</table>

Research and Demonstration Focus

Hydrogen

In 2016, *The Strategic Roadmap for Hydrogen and Fuel Cells* (revised) [7] was released. It includes new goals and specific explanations of the new efforts to be undertaken. The revised version of the roadmap stipulates the following:

1. Future price targets for household fuel cells;
2. 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;
3. Targets for the construction of hydrogen stations: about 160 stations by 2020 and about 320 stations by 2025;
4. Clarification of descriptions concerning hydrogen power generation; and
5. The technical and economic challenges concerning the utilization of hydrogen generated using renewable energy.

In 2017, the Ministerial Council on Renewable Energy, Hydrogen and Related Issues held its second meeting and agreed on a basic hydrogen strategy to accomplish a world-leading, hydrogen-based society [8]. The strategy includes the use of hydrogen for transportation such as fuel cell (FC) buses, FC trucks, and FC ships. In April 2018, hydrogen stations for FCVs operated in 100 locations nationwide [9].

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 [10]. 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 (FY) 2016, the Japanese Ministry of Environment subsidized a 3-year project for developing and demonstrating heavy-duty LNG trucks, with a running range of more than 1,000 km and an optimum LNG filling station that can also supply CNG. Carbon dioxide emissions from heavy-duty LNG trucks will be reduced by about 10% for the latest diesel trucks. Isuzu Motors Limited, Shell Japan Limited, and the Organization for the Promotion of Low Emission Vehicles (LEVO) have been driving this project since its inception. On June 1, 2018, Japan launched its first LNG refueling station in Osaka and started road demonstrations of its first two heavy-duty LNG trucks. In addition, in September 2018, an L-CNG filling station that supplied CNG from LNG at the Keihin Truck Terminal in Japan was converted to an L+CNG filling station, which could also supply LNG to heavy-duty trucks. Thus, LNG stations for heavy-duty vehicles were set in Osaka and Tokyo.

Bioethanol

Since 2011, the Ministry of Environment in Okinawa Prefecture has promoted the use of biofuels (e.g., E3 gasoline); however, in FY 2016, the project terminated because of no clear idea for a commercialization [11]. In Miyakojima City, the supply of E3 gasoline was terminated in April 2016 [12]. The sale of bio-gasoline blended with ethyl-tertiary-butyl ether (ETBE) continues to the target of 500,000 kiloliters (kL) (crude oil equivalent) of bioethanol in 2017, based on the Act on Sophisticated Methods of Energy Supply Structures [13]. In 2016, sales of this blended gasoline reached a total 441,000 kL [14].

Methanol/Dimethyl Ether (DME)

The standardization of fuel supply systems (excluding the on-board fuel tank) and refueling port for DME vehicles is making progress. The International Organization for Standardization (ISO) established a working group (ISO/TC22/SC41/WG8) and has been holding meetings regularly since its first international meeting in 2016. The Society of Automotive Engineers of Japan established a subcommittee for DME under the Environment Technical Committee in 2017 to address these issues. International meetings were held in Vancouver, Canada, in February 2017, and in Ostuni, Italy, in November 2017. Japan proposed the addition of the pressure equalizing refueling port to the standard.

Outlook

In July 2018, the Japanese government approved the Strategic Energy Plan (the fifth plan) [15], which forms the basis for Japan’s energy policies. This plan strengthens further 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.

References

[1] Government’s white paper on energy, 2017 (in Japanese)
[2] LEVO, cumulative total number, out of production

[3] Japan Gas Association, as of March 2018 (cumulative total number), https://www.gas.or.jp/ngvj/spread/ (in Japanese)
[4] 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)
[5] Automobile Inspection and Registration Information Association, as of October 2018, https://www.airia.or.jp/publish/file/r5c6pv000000m21m-att/r5c6pv000000m221.pdf
[6] Automobile Inspection and Registration Information Association, as of October 2018, http://www.airia.or.jp/publish/statistics/number.html
[7] Agency for Natural Resources and Energy, 2016, *The Strategic Roadmap for Hydrogen and Fuel Cells*, (revised), March 22.
[8] Ministry of Economy, Trade, and Industry, 2017, "Basic Hydrogen Strategy Determined," website, http://www.meti.go.jp/english/press/2017/1226_003.html
[9] Next Generation Vehicle Promotion Center, http://www.cev-pc.or.jp/suiso_station/index.html (in Japanese)
[10] Isuzu Motors Limited, website, http://www.isuzu.co.jp/product/giga/cng/
[11] Ministry of Environment, website, http://www.env.go.jp/earth/ondanka/biofuel/okinawabio/bio_hokokusyo.pdf (in Japanese).
[12] The *Miyakomainichi* newspaper, http://www.miyakomainichi.com/2016/09/92895/ (in Japanese)
[13] Petroleum Association of Japan, website, http://www.paj.gr.jp/eco/biogasoline/ (in Japanese)
[14] 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)
[15] 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

Additional Information Sources

- Japan's Energy White Paper 2017 (brochure), http://www.enecho.meti.go.jp/en/category/whitepaper/pdf/whitepaper_2017.pdf (in Japanese)
- Agency for Natural Resources and Energy, 2015, *Long-term Energy Supply and Demand Outlook*, July, http://www.meti.go.jp/english/press/2015/pdf/0716_01a.pdf

Republic of Korea

Drivers and Policies

The new Renewable Fuel Standard (RFS) program was enacted in South Korea's National Assembly in July 2015. Accordingly, it is mandatory to supply biodiesel to diesel fuel, and refineries must mix and sell them at a predetermined ratio (see Table 1).

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

Year	Blending Ratio
2015	0.025
2016	0.025
2017	0.025
2018	0.03
2019	0.03
2020	0.03

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

The annual compulsory ratio will be reviewed every three years as of July 31, 2015, taking into consideration the level of technology development of new and renewable energy and the fuel supply and demand situation. On July 31, 2018, the blending ratio was revised to 3%. The blending ratio will be reviewed in 2020 and can be changed before 2020, depending on market conditions and mixed performance results.

In the case of bioethanol, an empirical study is underway for the supply from May 2016, and the feasibility of this fuel for manufacturing, supply, infrastructure, and vehicle is under verification. We selected one gas station and are checking the equipment and storage problems by season for 365 days. We are also carrying out the durability test for 42,000 kilometers (km) through four demonstration vehicles and checking the emission gas and vehicle condition. Apart from this, technology development for parts affected by fuel (combustion system, fuel pump) is also being carried out.

In the case of marine fuels, the amendment to the International Maritime Pollution Prevention Convention (MARPOL) will come into force in January 2020 through the International Maritime Organization (IMO), limiting sulfur content to 0.5% m/m for marine fuels internationally. To prepare for this change, government and private companies are developing domestic desulfurization facilities, the low-sulfur crude oil supply is being expanded, and the use of liquefied natural gas (LNG) is under consideration. In Korea, technological development and private investment in the production of low-sulfur oil and emission reduction technologies (scrubber, etc.) are increasing. For example, domestic SK energy will invest KRW 1 trillion by 2020 to build a desulfurization plant with a production capacity of 40,000 barrels per day, while S-OIL is also planning to construct an upgrading facility for residual oil.

For the introduction of bio-aviation oil, aviation oil is part of ongoing research on the synthesis and demonstration evaluation of bio-aviation oil using non-petroleum-based raw materials in various industry-university-institute efforts, such as the Advanced Biomass R&D Center (ABC, https://www.biomass.re.kr) and the Institute for Advanced Engineering (IAE, www.iae.re.kr). In particular, since December 2016, the Agency for Defense Development (ADD) has been studying the application of biofuel derived from vegetable oils produced by applying domestic technology to jet engines. Korean Air made its first 14-hour flight in November 2017 to Chicago, using a 5% blend of fuel oil extracted from plants. Currently, the Ministry of Land, Infrastructure and Transport (MOLIT) is conducting a feasibility study on biofuel for greenhouse gas (GHG) reduction in order to introduce domestic biofuel in 2017.

Advanced Motor Fuels Statistics

Table 2 shows the classification of the newly registered vehicles in Korea from 2013 to 2017 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 government is providing tax benefits and subsidies for disseminating 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 new registrations of compressed natural gas (CNG) and hydrogen fuel cell vehicles has steadily increased since 2015.

Table 2 Vehicle Registration Number by Fuel Type

Year/Fuel	2013	2014	2015	2016	2017
Gasoline	656,128	661,919	681,601	747,718	758,635
Diesel	672,025	805,609	962,127	872,640	820,457
LPG	175,958	149,014	137,121	123,077	137,932
HEV, PHEV	29,060	34,516	39,014	62,210	84,614
Electric	614	1,315	2,932	5,177	14,332
CNG, Fuel Cell, etc.	9,779	9,495	10,991	12,219	14,018
Total	1,543,564	1,661,868	1,833,786	1,823,041	1,829,988

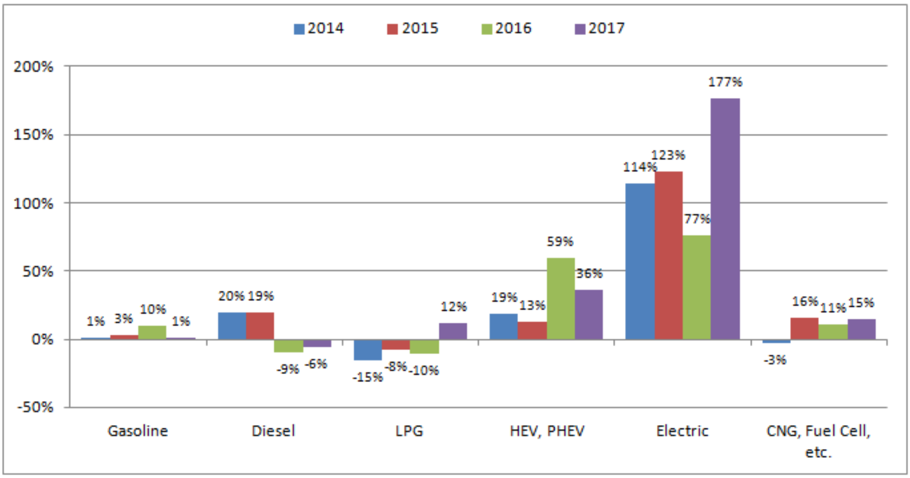

Fig. 1 Annual Change Rate of Vehicle Registration

Research and Demonstration Focus

The Government of Korea supplied 25,593 electric cars and 177 hydrogen cars by 2017. In addition, 1,790 high-speed electric chargers and 12 hydrogen filling stations are under operation. In 2022, however, 430,000 electric cars and 65,000 hydrogen fuel cell cars will be supplied. To meet this volume, 10,000 high-speed electric chargers and 310 hydrogen filling stations will be constructed. The government is working to expand the supply of eco-friendly vehicles through tax relief and subsidies, but the electric charging and hydrogen filling stations are still insufficient compared to domestic gas stations (about 12,000 stations). We are continuing to provide support for additional supplies.

Subsidies for electric cars will be maintained until 2022 but then will be reduced step by step. In the case of hydrogen fuel cell cars, mass production will be maintained until the prices of parts and vehicles are stabilized. However, after the stabilization, the subsidy will be reduced step by step.

In addition, the city of Ulsan initiated the operation of the first hydrogen fuel cell bus in October 2018 (Figure 2). Thirty hydrogen fuel cell buses in six cities will be operated on a pilot basis from March 2019 until the end of 2020. By improving operational problems and resolving technical problems during the pilot stage, the Korean government plans to supply 2,000 hydrogen fuel cell buses by the end of 2022. Moreover, 310 hydrogen filling stations will be constructed to meet the supply of hydrogen buses.

In August 2017, Hyundai Mobis Company, a Korean auto parts company, built a facility capable of producing powertrain fuel cell complete modules, which integrate various core parts of hydrogen vehicles. This facility can produce 3,000 units per year and is expected to produce all the core parts required for hydrogen automobiles in one factory, which will help to expand the supply of hydrogen automobiles (Figure 3).

Fig. 2 Hyundai Gen3 Hydrogen Fuel Cell Bus

Fig. 3 Fuel Cell Manufacturing Plant

Outlook

According to the RFS policy of 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 still is not clear whether the exact pilot operation plan or supply plan has been finalized.

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

Additional Information Sources

- K-Petro, www.kpetro.or.kr
- Korea Register, www.krs.co.kr

Spain

Drivers and Policies

Biofuel consumption in Spain is primarily supported by the mandatory targets for sale or consumption established in Royal Decree 1085/2015, on the promotion of biofuels. These targets (in energy content) are 6% (2018), 7% (2019), and 8.5% (2020).

The Spanish Alternative Energy Vehicle Incentive Strategy 2014–2020 is the framework for specific programs and plans intended to promote the purchase of electric, liquefied petroleum gas (LPG), natural gas, and bio-fuel vehicles.

Advanced Motor Fuels Statistics

Figure 1 shows data on fuel consumption in Spain in 2018. Biofuels represent the largest share of alternative transportation fuel.

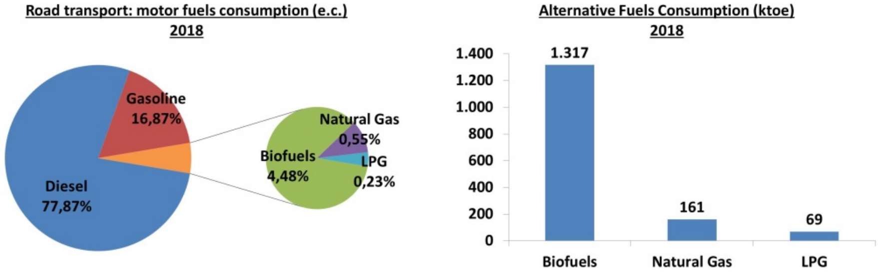

Fig. 1 Fuel Consumption (share in energy content) and Alternative Fuel Consumption (ktoe) in Spain in 2018
Sources: CNMC, CORES, GASNAM

Regarding the vehicle fleet, of a total of 35.6 million vehicles, around 75,000 are fuelled by LPG and 14,216 use natural gas (compressed or liquefied), while only a few hydrogen vehicles have been developed in pilot projects.

Table 1 includes the number of public filling stations with alternative fuels in Spain.

Table 1 Filling Stations for Alternative Fuels in Spain

Alternative Fuel		Number of Filling Stations
Biodiesel blends	B20 or lower	47
	B30 or higher	8
Bioethanol blends	E15 or lower	2
	E85	6
LPG		607
Natural gas		71
Hydrogen		6

Sources: MITECO (Geoportal), Gas Licuado, GASNAM, AEH2

Biofuels are the major alternative transportation fuels in Spain. Figures 2, 3, and 4 provide information on the feedstock, feedstock origin country, and production country of biofuels consumed in Spain in 2018.

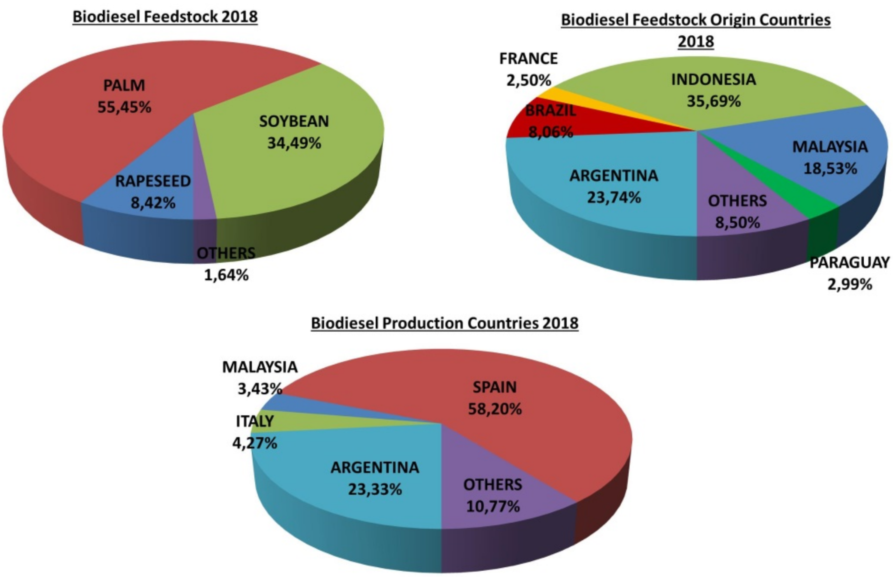

Fig. 2 Feedstock, Feedstock Origin Country, and Production Country of Biodiesel Consumed in Spain in 2018
Source: CNMC

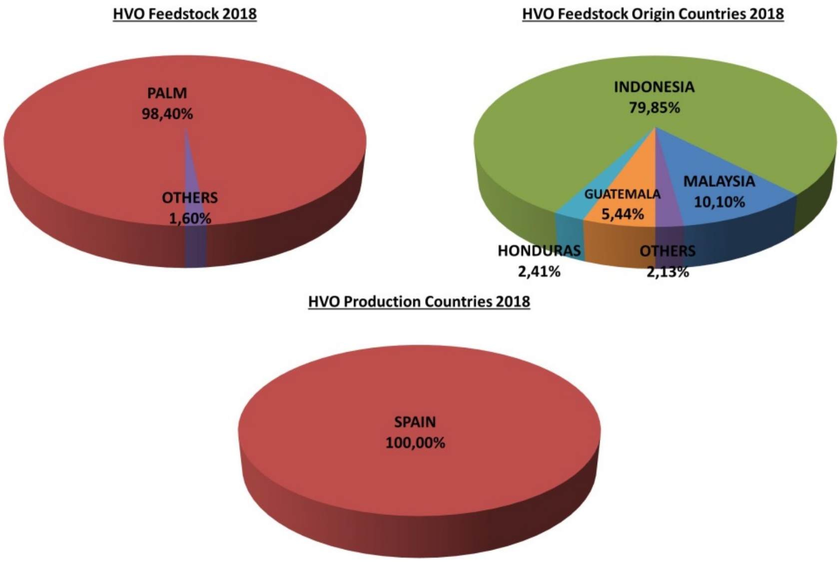

Fig. 3 Feedstock, Feedstock Origin Country, and Production Country of Hydrotreated Vegetable Oil (HVO) Consumed in Spain in 2018
Source: CNMC

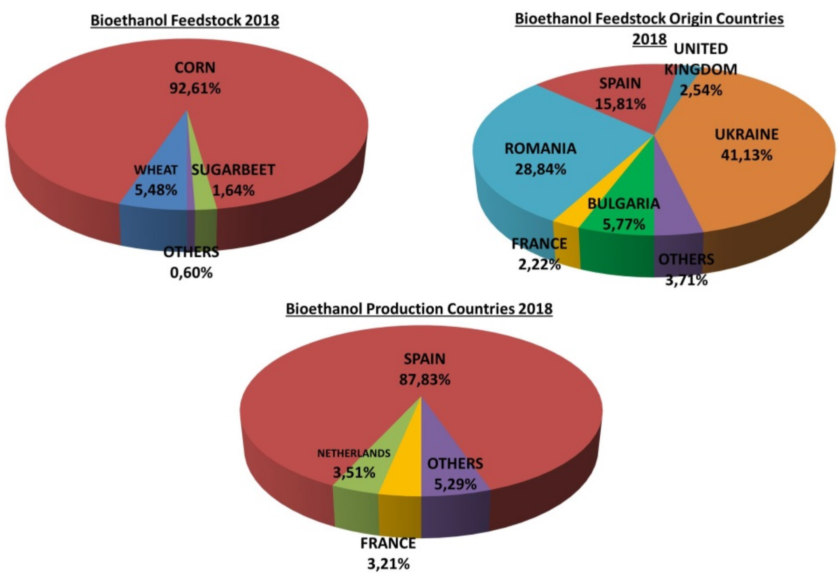

Fig. 4 Feedstock, Feedstock Origin Country, and Production Country of Bioethanol Consumed in Spain in 2018
Source: CNMC

Research and Demonstration Focus

As regards biofuels, in January 2018, the Spanish State Scientific and Technical Research and Innovation Plan 2017–2020 was published. The State Plan 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 research, development, and innovation activities. Such activities are in turn aligned with the European agenda on this issue, in particular with the Strategic Energy Technology Plan (SET Plan). In this sense, research and innovation projects receiving funding from this State Plan shall address, *inter alia*, 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 includes several programs intended to support research, development, and innovation: creation of clusters for innovation, incentives, cooperation through technology platforms, and support to research centers.

Research activity in relation to hydrogen technologies continues to be carried out in Spain within the frameworks of national and European initiatives.

Outlook

According to the National Renewable Energy Action Plan, to fulfill the committed targets included in the current Renewable Energy Directive, consumption of biofuels is expected to reach 2,713 kilotonnes of oil equivalent in 2020.

The revised Renewable Energy Directive was adopted and published in December 2018. This new regulatory framework for the period 2021–2030 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. Each Member State will define the detailed trajectory to reach this target in an Integrated National Energy and Climate Plan. Within that 14%, there is a dedicated subtarget 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.

The National Action Framework for Alternative Energies in Transport states that, by 2020, the natural gas fleet will reach 18,000 vehicles, the LPG fleet will consist of 200,000 to 250,000 vehicles, and it seems feasible that more than 500 hydrogen vehicles will be commercialized.

Additional Information Sources

- AEH2: Spanish Hydrogen Association, www.aeh2.org (in Spanish)
- Gas Licuado: Spanish Association of Liquefied Gas, www.gaslicuado.org (in Spanish)
- 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 the Ecological Transition www.miteco.gob.es (in Spanish)

Major Changes
A new framework for renewable energy in the transport sector, including biofuels, was established by means of the revised Renewable Energy Directive for the period 2021–2030.

Benefits of Participation in the AMF TCP
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 greenhouse gases (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 Government introduced what is known as a bonus-malus system, whereby environmentally adapted vehicles with relatively low carbon dioxide (CO_2) emissions (up to 60 g/km) 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 (€5,732; $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 more than 4.8 million vehicles. At the same time, GHG emissions from passenger cars have been rather stable at around 13 million tonnes from 1990 to 2007. However, since 2007, emissions have been reduced significantly and were about 10 million tonnes in 2017. 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 just under 310,000 at the end of 2017 (Figure 1).

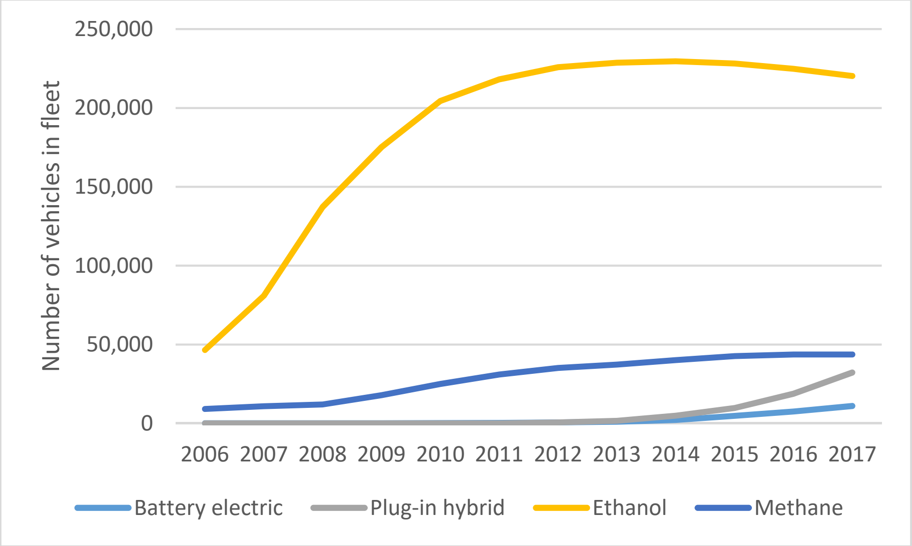

Fig. 1 Number of Advanced Motor Fuel Passenger Cars in the Fleet, 2006–2017

The alternative-fueled vehicles correspond to 6% of the total fleet of passenger cars. 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.

Although flex fuel ethanol vehicles are the most common type of alternative fuel vehicle in Sweden, the ethanol fuel (E85) sold during 2017 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. On the other hand, the number of methane-fueled vehicles has increased steadily over the last 10 years and has now passed 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 almost 18 terawatt hours (TWh), or 22% of the transportation fuels sold during 2017 (Figure 2). Almost 60% of the renewable fuel used in Sweden during 2017 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 21%. Some individual diesel products sold on the Swedish market have a renewable share of 50%.

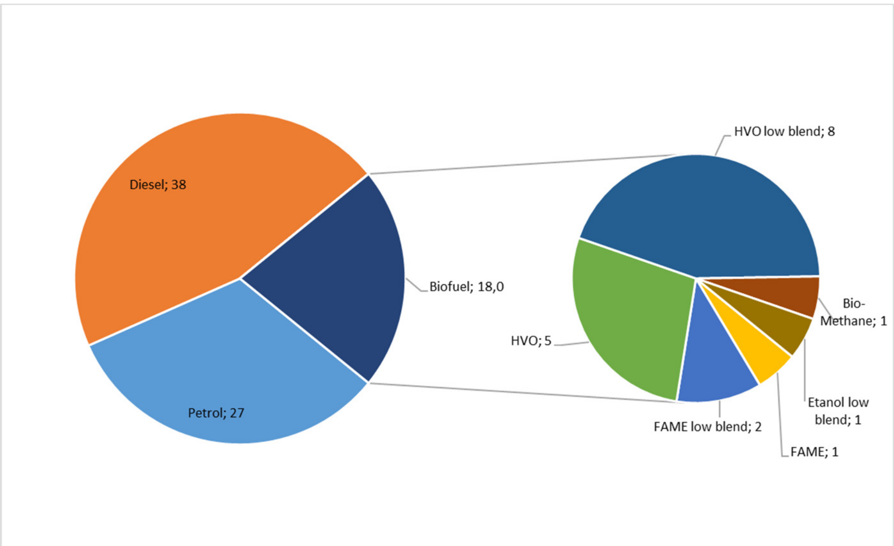

Fig. 2 Fuel Consumption in TWh within the Road Transport Sector during 2017

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 slaughterhouse wastes, palm fatty acid distillate (PFAD), crude tall oil, palm oil, corn and rapeseed, 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 2017 correspond to 11.1 g carbon dioxide equivalent (CO_2 eq) per megajoule (MJ). For FAME, the corresponding figure was 31.1 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.

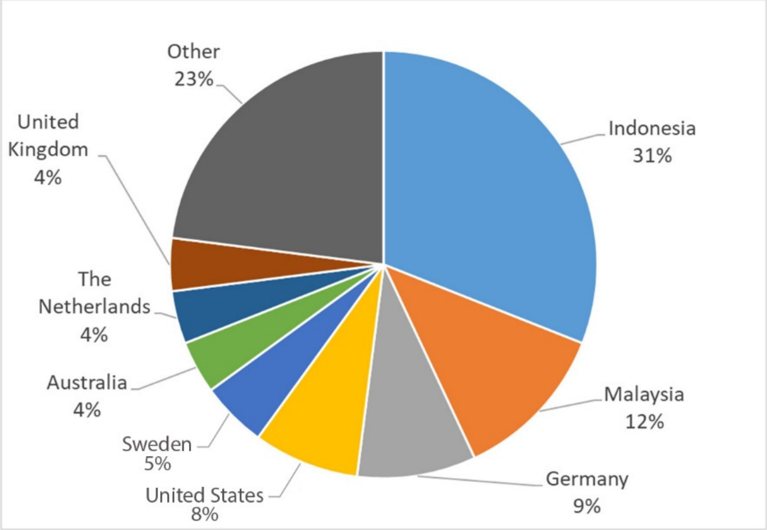

Fig. 3 Country of Feedstock Origin for HVO Consumed in Sweden in 2017

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 the English automotive industry's competitiveness in a global perspective.
- Research program for transport-efficient society for 2018–2023 on a system level. The call does not accept projects that focus on technology development of vehicle or engine technologies.
- Energy-efficient vehicles in 2015–2019. 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, f3.
- Three Competence Centers in internal combustion engine research and one Competence Centre for catalysis research. The Competence Centre is a collaboration among the automotive industry, the university, and the Swedish Energy Agency. Each party finances one-third of the cost.
- The Swedish Gasification Center. This center is focused on large-scale biomass gasification for biofuels production, but it also covers other applications of biomass gasification.

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

Since 2017, a fundamentally revised new Energy Act has been in force [1]. The core measure is to withdraw step by step from the use of nuclear energy without increasing carbon dioxide (CO_2) emissions. This goal can be achieved by increased energy savings (energy efficiency); expansion of hydropower and new renewable energy sources; and, if necessary, imports of electricity and fossil-fuel-based electricity production. By the end of 2017, the Federal Council launched a revised CO_2 Act, and the parliament started the debate in spring 2018 [2]. By the end of 2018, no agreement was achieved, and the debate will continue in 2019. The target is to reduce CO_2 emissions at least 50% from their 1990 levels by 2030. Measures to reduce CO_2 emissions from traffic should be tightened, as these emissions cause one-third of Swiss greenhouse gas emissions. Two groups must contribute: the automobile industry and the fossil fuel industry.

CO_2 Emission Regulations for Cars

Since 2015, Swiss car importers must pay a penalty if the average new passenger car fleet exceeds 130 grams (g) of CO_2 per kilometer (km). In 2017, the average was 134 g CO_2/km, and the penalty amounted to €2.4 million or $2.9 million US [3]. In alignment with the European Union Commission, the Federal Council aims to reduce average CO_2 emissions from passenger cars from 2021 to 2024 to 95 g CO_2/km and from light commercial vehicles (vans up to 3.5 metric tons [t]) to 147 g CO_2/km [2]. Further reductions are foreseen for the period 2025–2029. The use of synthetic CO_2-neutral fuels should be taken into account.

CO_2 Emissions Compensation: Motor Fuels

Since 2014, importers of fossil motor fuels must use domestic measures to compensate CO_2 emissions generated by the entire transportation sector [4]. The compensation rate started in 2014 at 2% and will be raised to 10% in 2020. 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. Blending causes a substantial increase of biofuels. Compared to 2013, the use of biofuels in 2017 was 10 times higher. The draft new CO_2 Act foresees that at least 5% of CO_2 emissions caused by traffic must be compensated with renewable fuels instead of an obligation for blending fossil fuels with biofuels at a fixed rate.

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 2017[69] amounted to 849,790 terajoules (TJ), of which 35% was transport fuels (Figure 1) [6]. Compared to 2016, fuel consumption remains the same. In the same period, the total amount of engine-driven vehicles increased by 1.2%, in the sum of 6,053,258. Fuel consumption by vehicle dropped by 2.8%. Some changes in specific applications were made in 2017: diesel, −0.3%; gasoline, −3.1%; and aviation fuels, +2.4%. All fossil fuels were imported.

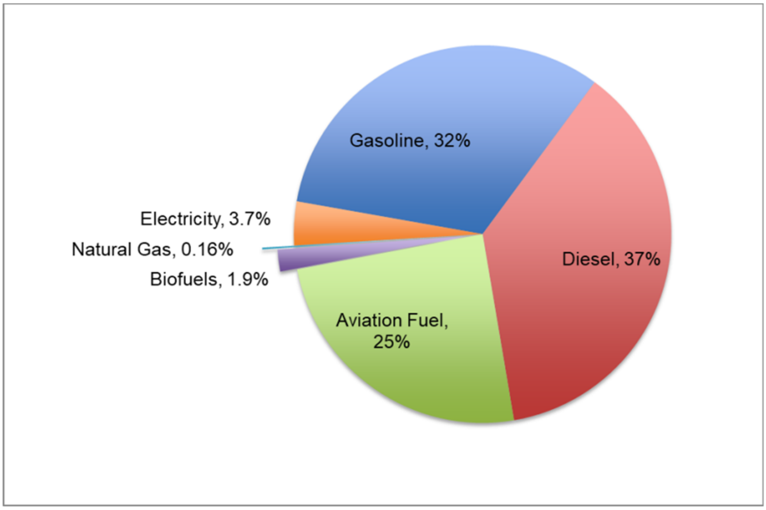

Fig. 1 Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland in 2017 [6]

Electricity is used for railroad transportation, and a negligible amount is used for electric cars. Despite an impressive annual increase of electric vehicles (2014, +65%; 2015, +70%; 2016, +42%; and 2017, +36%), the total amount is still very small (14,539 passenger cars) [7]. In 2000, the

[69] At the time this report was prepared, only data from 2017 were available.

share of diesel of the total amount of fuels (without aviation) amounted to 26%. With a share of 52% in 2017, the consumption of diesel was higher than the use of gasoline (45%) and biofuels (2.6%).

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 5 years, the use of liquid biofuels rose from 16.035 million to 189.650 million L. In 2017, 116.370 million L biodiesel and 51.668 million L bioethanol were used (Figure 2). Hydrotreated vegetable oil has only been used in Switzerland since 2016 (2017: 21.523 million L). Pure vegetable oil fuel is almost negligible (0.089 million L). Upgraded biogas as a transport fuel remained at a low level of 3.116 million kg [8].

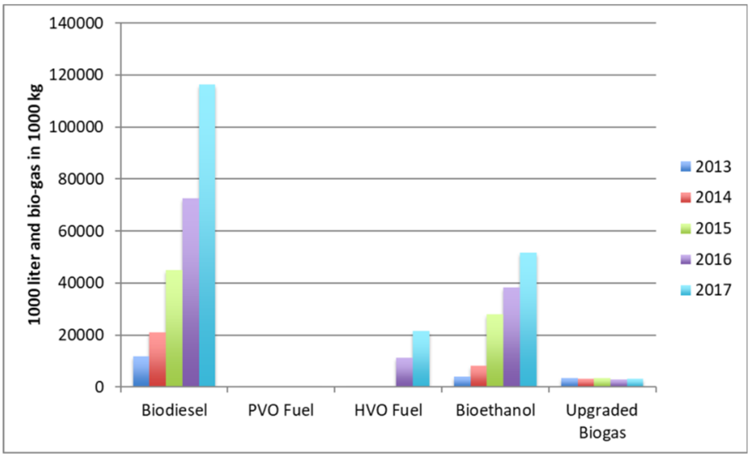

Fig. 2 Development of the Use of Biofuels as Motor Fuels in Switzerland, 2011–2015

Only 8.688 million L of biodiesel was produced in Switzerland. The other 107.682 million L was imported (Germany 75% and the rest from six other countries). All bioethanol is imported (Holland, 40.6%; Sweden, 21.3%; Poland, 13.6%; Norway, 12.5%; Italy, 11.5%; and Germany, 0.5%) [9].

The total amount of biogas produced and used in Switzerland in 2017 was 109,425 t. Only 23,667 t has been upgraded and fed into the natural gas grid. From this, a small amount (3,116 t) has been sold as biogas for cars, and the rest for heating [8]. Most 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. The demand for biogas is stable, but the demand for natural gas is decreasing year by year. Figure 3 shows that the amount of upgraded biogas fed into the natural gas grid has more than doubled in the last 5 years due to an increased demand for biogas for residential heating but not for automotive applications [10].

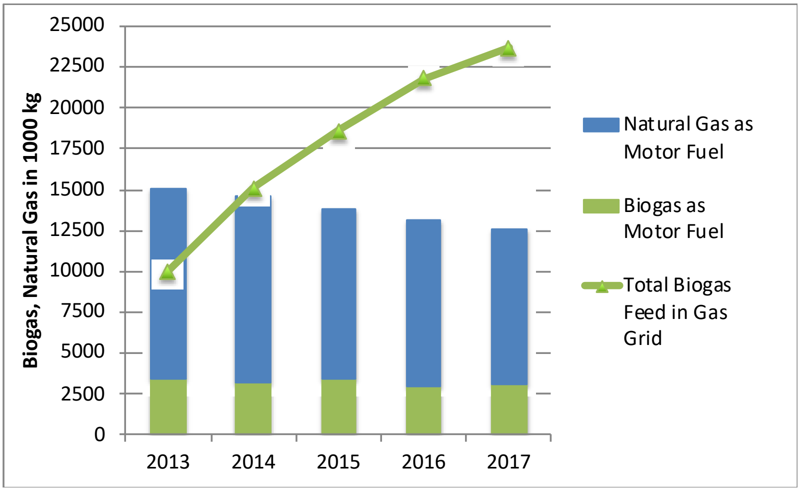

Fig. 3 Development of the Use of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

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 is dedicated to mobility [12] and another to bioenergy [13], including liquid and gaseous biofuels. Examples of ongoing research projects are detailed below.

Adapted fuels for dual-fuel and diesel combustion. A novel optically accessible test facility is used to examine combustion processes at engine-relevant flow, temperature, and pressure conditions. Of particular interest are investigations of lean gas/air-premixed dual-fuel combustion with adapted pilot fuels as well as optimization of diesel-combustion with respect to emissions and particulate matter by tailored alternative liquid fuels.

Investigations of the suitability of DME as an alternative fuel in heavy-duty vehicles. Methanol/dimethyl-ether (DME) is a well-suited fuel for compression ignition engines, which 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.

Outlook

The main driver to increase the use of biofuels is the government's requirement that the petrol industry compensate 10% of CO_2 emissions via domestic measures. The target to reduce average CO_2 emissions from passenger cars by 2020 from 130 to 95 g CO_2/km will increase sales of hybrid, electric, and gas-driven vehicles. With the drafted new CO_2 Act, these drivers will be amplified. The Swiss gas industry aims to achieve a share of 30% of renewable gas in the heating market by 2030. To achieve this target, different sources of renewable gas are needed, including power-to-gas technologies. Gas is mainly used for heating purposes. Only a negligible amount is used as motor fuel. Despite this, several new research projects focus on the improvement of the gas engine technology. Perhaps the request to reduce CO_2 emissions will boost gas as a relevant motor fuel.

Additional Information Sources

[1] The Federal Council, 2017, "730.0 Energiegesetz (EnG)."
[2] Federal Office for Environment (FOEN), "Totalrevision CO_2 Gesetz."
[3] SFOE, 2018, "CO2-Emissionen von Neuwagen …im Jahr 2017."
[4] FOEN, 2012, "CO_2 emission compensation: motor fuels."
[5] Mineralölsteuergesetz (MinöStG), Stand: Jan. 1, 2012.
[6 SFOE, 2018, "Gesamtenergiestatistik 2017."
[7] Swiss Federal Statistical Office (BFS), 2018, "Mobility and Traffic."
[8] SFOE, 2016, "Schweizerische Statistik erneuerbarer Energien 2016."
[9] Swiss Custom Administration, 2017, "Mineralölstatistik."
[10] Association of the Swiss Gas Industry, 2018, "Mineralölsteuer …"
[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 that certain centrally fuelled fleets (federal, state, and alternative fuel provider fleets, such as utility companies) acquire light-duty alternative fuel vehicles (AFVs) as most of their new vehicle acquisitions. Further, AFVs are being promoted for their benefits on emission reductions, energy diversification, and low costs of operations.

The U.S. Department of Energy (DOE) Technology Integration Program (formerly the Clean Cities Program) is a government-industry partnership program 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 functioning of the program has been described in previous AMF annual reports. More information on the program can be found at www.cleancities.energy.gov. The most recent data from the Technology Integration Program are for 2017 and show that the program saved 972,600,000 gasoline gallons equivalent (gge), which included 730,400,000 gge from alternative fuels/vehicles and 83,400,000 gge from electric and hybrid vehicles.

The U.S. 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 November 30, 2018, the U.S. Environmental Protection Agency (EPA) finalized the volume requirements and associated percentage standards under the RFS program for calendar year 2019 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The EPA also finalized the volume requirement for biomass-based diesel for 2020.[70] These volumes were slightly higher than those for 2018 compliance. However, the values were significantly lower than those originally targeted in the RFS legislation, which envisioned much more robust growth in cellulosic fuel production than has materialized.

The cellulosic biofuel category was created largely with cellulosic ethanol in mind. However, renewable natural gas from landfills and anaerobic

[70] U.S. EPA, Final Renewable Fuel Standards for 2019, and the Biomass-Based Diesel Volume for 2020, https://www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2019-and-biomass-based-diesel-volume

digesters, treated as cellulosic biofuel by the EPA through rulemakings in 2013 and 2014, has dwarfed liquid fuels in that category. Biomass-based diesel is mainly traditional biodiesel, derived from soy, corn oil, canola, and other vegetable and animal fats and oils. These categories are nested into the category of advanced biofuels, which also includes renewable diesel, biogas, renewable heating oil, and renewable fuels co-processed in petroleum refining. Finally, the broad category "Renewable Fuel" includes all of these categories combined with starch- and sugar-based ethanol. Various federal and state programs provide incentives for other alternative and advanced motor fuels. Lists of these are available at afdc.energy.gov/laws/.

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, the LCFS was revised to extend to 2030 with reduced carbon intensities for California's transportation fuels.[71] 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 are used in California, more than 1.8 billion gge in 2017.

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 2018 was 23,561 trillion British thermal units (Btu), up about 1% from the same period in 2017.[72] 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 1,177 trillion Btu during these 10 months, natural gas for 708 trillion Btu, electricity for 22 trillion Btu, and propane for 9 trillion Btu.[73]

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.[74] Each RIN is equivalent to

71 California Air Resources Board, Unofficial electronic version of the Low Carbon Fuel Standard Regulation, https://www.arb.ca.gov/fuels/lcfs/fro_oal_approved_clean_unofficial_010919.pdf
72 *EIA Monthly Energy Review*, January 2019.
73 Ibid.
74 EPA, 2018, "Fuels Registration, Reporting, and Compliance Help," https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rins-generated-transactions

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.

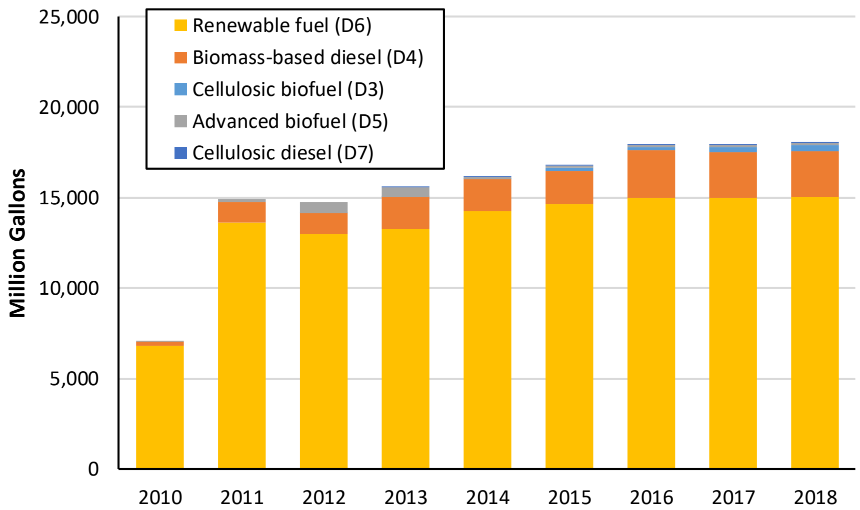

Fig. 1 Renewable Fuel Volumes Resulting from U.S. Renewable Fuel Standard

Electric Vehicles

Sales of plug-in electric hybrids (PHEVs) and battery electric vehicles (BEVs) in 2018, totaling 361,315, were up strongly compared to 195,571 in 2017.[75] In addition, 343,219 hybrid electric vehicles (non-plug-in) were sold in 2018, down from 362,868 in 2016.[76] Available plug-in models totaled 85 as of February 2018, down from 90 in January 2018.[77]

Alternative Fuel Infrastructure

The DOE's Alternative Fuels Data Center provides the number of alternative fuel refueling stations in the U.S.[78] As seen in Table 1, the total number of alternative fueling stations, exclusive of electric recharging stations, in the U.S. increased by 32% between 2012 and 2018. However, the number of biodiesel (B20), compressed natural gas (CNG), liquefied

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75 Argonne National Laboratory, 2019, "Light Duty Electric Drive Vehicles Monthly Sales Updates," anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates

76 Ibid.

77 DOE, 2016, Alternative Fuels Data Center, "Availability of Hybrid and Plug-In Electric Vehicles," afdc.energy.gov/vehicles/electric_availability.html

78 DOE, 2018, "Alternative Fueling Station Counts by State," afdc.energy.gov/fuels/stations_counts.html

natural gas (LNG), and liquefied petroleum gas (LPG) stations decreased slightly in 2018. The total number of public and private nonresidential electric vehicle recharging outlets jumped by over 500% over this same 6-year period, with a significant gain in 2018 as well.

Table 1 Number of U.S. Alternative Fuel Refueling Stations by Type, 2012–2018 (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

[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.[79,80]

In 2015, DOE introduced a new initiative known as the Co-Optimization of Fuels and Engines, or Co-Optima. The initiative is 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. DOE envisions that the effort will run for approximately 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. It includes both spark

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79 DOE, VTO, 2013, *Fuels and Lubricant Technologies 2012 Annual Progress Report*, DOE/EE-0911, June.

80 DOE, VTO, 2012, *Advanced Combustion Engine Research and Development 2012 Annual Progress Report*, DOE/EE-0872, December.

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, and
- Enable an additional 9% to 14% fleet greenhouse gas 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. For additional information, visit energy.gov/eere/bioenergy.

Outlook

The EIA's *Annual Energy Outlook 2019* projects decreasing transportation energy use from 2019 through 2038 due to mandated increases in fuel efficiency.[81] It projects that BEV sales will increase from 2% to 14% of total light-duty vehicles sold in the U.S. over 2018 to 2050, due to falling battery costs. In addition, PHEV projected sales will increase from less than 1% to 3% over the same period. Hydrogen fuel cell vehicle (FCV) projected sales are 0.3% of sales in 2050. In 2025, projected sales of light-duty BEVs, PHEVs, and FCVs will reach 1.3 million, about 9% 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, 2019, "Transportation Energy Data Book," January, cta.ornl.gov/data/tedbfiles/Edition37_Full_Doc.pdf
- EIA, 2019, *Annual Energy Outlook 2019*, eia.gov/outlooks/aeo/pdf/0383(2017).pdf
- EIA, 2019, *Monthly Energy Review*, Energy Information Administration, eia.gov/totalenergy/data/monthly/

[81] Energy Information Administration, *Annual Energy Outlook 2019*, https://www.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 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: technologies and processes to improve efficiency in the buildings, electricity, industry, and transport sectors;
- Working Party on Fossil Fuels: cleaner use of coal, improvements in gas/oil exploration, and carbon capture and storage;
- Fusion Power Coordinating Committee: fusion devices, technologies, materials, and physics phenomena; and
- Working Party on Renewable Energy Technology: 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 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
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4.b.i
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[a] Alphabetical order by country name.

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4.b.ii
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[a] Numerical order by annex.

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

4.c AMF TCP Publications in 2018

Special Report: Air Quality Implications of Transport Biofuel Consumption

Prepared as a contribution of AMF to the IEA publication, “Renewables 2018,” this special report provides a better understanding of how vehicle emissions relate to fuel and vehicle technology in use.

Annex 53-1: Sustainable Bus Systems

This report describes development of a special test cycle/methodology representing the conditions for urban buses in Santiago de Chile. The observed energy consumption of the buses was greater in the cycles adopted for the actual conditions in Santiago de Chile compared to other cycles not representative to the real local driving conditions. These differences may vary depending on the technology used (e.g., diesel, gas, electric).
Final Report, Phase 1, March 2018
Key Messages, December 2018

Annex 52: Fuels for Efficiency

This analysis of five different concepts for improving fuel efficiency revealed that the use of ethanol-blended fuels and paraffinic fuels, as well as the use of a methanol steam reformer, all allow for better fuel efficiency if operated with modern engines and eventually adapting the engines regarding ignition timing or fuel injection duration. Modern engines should be flexible for a wide range of fuels.
Key Messages, April 2018

Annex 50: Fuel and Technology Alternatives in Non-Road Engines

Compared with on-road vehicles, old non-road mobile machinery are high emitters of local pollutants. Annex 50, however, shows that the latest emission class, Stage V, results in extremely low emissions during real-world operation of non-road mobile machinery. The recommendation is, when possible, to leapfrog directly from less sophisticated technology to Stage V. Alternatively, if sulfur-free diesel cannot be guaranteed, leapfrogging to Tier 3/Stage IIIA would be the best option. Renewable and advanced drop-in fuels are a viable option to reduce greenhouse gas (GHG) and regulated emissions from both new and existing machinery.
Final Report, April 2018
Key Messages, May 2018

Annex 48: Value Proposition Study on Natural Gas Pathways for Road Vehicles

The goal of this study was to identify the cost-effective and technically feasible ways to use natural gas (NG) in transportation, so that it may have the potential to emerge into the mainstream market. Although country-specific results varied across NG fuel pathways due to differing upstream operations, fuel production and transport conditions, and vehicle operation, the analysis showed multiple NG pathways to be potentially “clear winners” for both light- and heavy-duty vehicles in individual countries.

Key Messages, December 2018

Annex 47: Reconsideration of DME Fuel Specifications for Vehicles

The idea for methanol/dimethyl ether (DME) fuel specifications for vehicles is that ISO16861: 2015 will be based with revision of “Residue after Evaporation” for lubricity improver. The Annex will explain test methods of lubricity because it is hard to standardize the test method of lubricity by special high-frequency reciprocating rig (HFRR) at this moment. It is necessary have continuous discussions with Volvo regarding the lubricity test method.

Final Report, December 2018

Key Messages, December 2018

Annex 44: Research on Unregulated Pollutant Emissions of Vehicles Fuelled with Alcohol Alternative Fuels

The use of alcohol fuels blended with gasoline in vehicles can reduce engine-out emissions of hydrocarbons (HC) and carbon monoxide (CO). With the increase of alcohol content in fuels, BTEX, olefins, particulate matter (PM) and particulate number (PN) decrease proportionally and depending on the type of alcohol used formaldehyde or acetaldehyde emissions can increase. Emissions were highest during engine start-up but the three-way catalyst has a great ability to reduce the carbonyls, aromatic hydrocarbons and olefins, when it lights-off. The effect of test temperature was evident for most emissions. The regulated and unregulated emissions at low ambient temperature are significantly higher than those at standard ambient temperature. The use of oxygenated fuel may also decrease the emissions of CO_2 and CO_2e GHG.

Key Messages, December 2018

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

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

If you are interested in joining the AMF TCP, please contact the AMF Secretary, Dina Bacovsky, at dina.bacovsky@bioenergy2020.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.

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.

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

2G	Second Generation
3CV	Center for Vehicle Control and Certification (Chile)
ABC	Advanced Biomass Research and Development Center (Republic of Korea)
ACEA	European Automobile Manufacturers' Association
ADD	Agency for Defense Development (Republic of Korea)
AFV	Alternative Fuel Vehicle
AMFS	Advanced Motor Fuels Statistics
B20	Biodiesel
BC	Black Carbon
BETO	Bioenergy Technology Office (US)
BEV	Battery Electric Vehicle
BMBF	Federal Ministry of Education and Research (Germany)
BMEL	Federal Ministry of Food and Agriculture (Germany)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Germany)
BMVIT	Federal Ministry of Transport, Innovation and Technology (Austria)
BMWi	Ministry of Economic Affairs and Energy (Germany)
BS	Bharat Stage (India)
BTL	Biomass to Liquid
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)
CHT	Centre for High Technology (India)
CMMCh	Centro Mario Molina (Chile)
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

dena	German Energy Agency
DFR	Detailed Feasibility Report (India)
DME	Methanol/Dimethyl Ether
DOE	U.S. Department of Energy
DPF	Diesel Particulate Filter
E85	85% Ethanol in Gasoline Fuel
EBP	Ethanol Blended Petrol
EC	European Commission
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
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
ExCo	Executive Committee
FAME	Fatty Acid Methyl Ester
FAU	Friedrich-Alexander-Universität Erlangen-Nürnberg (Germany)
FC	Fuel Cell
FCV	Fuel Cell Vehicle
FFV	Flex-Fuel Vehicle
FTP	Federal Test Procedure (US)
FVMI	Association of the Mineral Oil Industry (Austria)
FY	Fiscal Year
GDI	Gas Direct Injection
GHG	Greenhouse Gas
GPF	Gasoline Particulate Filter
HDV	Heavy-Duty Vehicle
HEV	Hybrid Electric Vehicle
HFS	Hydrogen Fueling Station
HPCL	Hindustan Petroleum Corporation, Ltd. (India)
HSL	Helsinki Region Transport
HVO	Hydrotreated Vegetable Oil

IAE	Institute for Advanced Engineering (Republic of Korea)
ICE	Internal Combustion Engine
IEA	International Energy Agency
IFCC	Israeli Fuel Cells Consortium
IMO	International Maritime Organization
INREP	Israel National Research Center for Electrochemical Propulsion
ISF	Israel Science Foundation
ISO	International Organization for Standardization
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)
MOLIT	Ministry of Land, Infrastructure and Transport (Republic of Korea)
MTT	Ministry for Transport and Telecommunication (Chile)
NEDC	New European Driving Cycle
NEV	New Energy Vehicle
NGV	Natural Gas Vehicle
NMHC	Non-Methane Hydrocarbon
NO_x	Nitrogen Oxide(s)
NoVA	Normverbrauchsabgabe (Austria)
NPE	National Platform E-mobility (Germany)
NRCan	Natural Resources Canada
OMC	Oil Marketing Company
OME	Polyoxymethylene-dimethylether

PCF	Pan-Canadian Framework (Canada)
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	Power to X (Germany)
R&D	Research and Development
RD&D	Research, Development, and Demonstration
RDE	Real Driving Emission
RED	Renewable Energy Directive
RES	renewables, total share of (Denmark)
RFR	Renewable Fuels Regulations (Canada)
RFS	Renewable Fuel Standard (US)
RIN	Renewable Identification Number (US)
SET Plan	Strategic Energy Technology Plan (Spain)
SI	Spark Ignition
SOA	Secondary Organic Aerosol
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)

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)
TWh	terawatt hour(s)