IEA-Advanced Motor Fuels

ANNUAL REPORT 2016

iea Energy Technology Network

ADVANCED MOTOR FUELS IEA-AMF

IEA Technology Collaboration Programme on

Advanced Motor Fuels Annual Report 2016

Rainbow Spine: The colors used for the spines of Advanced Motor Fuels Annual Reports follow the colors of the rainbow. Using colors allows readers to easily distinguish among the different editions of the annual report. The spines of previous editions (2010, 2011, 2012, 2013, 2014, and 2015) were blue, dark green, light green, yellow, red, and violet, respectively.

This year's edition has a blue spine, because this is the second color in the rainbow, representing the second year of the new AMF working period which started in 2015. A preference for blue indicates success and blue sky. AMF's commitment to the development of clean-burning engines to reduce smog out of cities will contribute to ensuring that the sky remains blue.

Cover: Both individual and public transport are important elements of urban environments. Advanced fuels and engine technologies reduce local emissions and contribute to local air quality.
Cover Design: Alyssa Montealegre, Argonne National Laboratory, USA

Chairperson’s Message

The Advanced Motor Fuels Technology Collaboration Programme (AMF TCP) has, since its inception in 1984 (then as alcohols as motor fuels), considered air pollution as an important aspect in relation to energy. Today, air quality is high on the political agenda, from international institutions, such as the International Energy Agency (IEA), which published the first world energy outlook special report on energy and air pollution, to individual cities that restrict or even forbid vehicles with high levels of exhaust gases, especially nitrogen oxides (NO_x).

Another topic high on both global and local agendas is the reduction of greenhouse gas (GHG) emissions. In mid-April 2017, more than 140 Parties to the Convention had ratified the Paris Agreement. Many AMF TCP participant countries have introduced ambitious targets to reduce GHG emissions, thereby increasing energy efficiency and strengthening energy security.

The transport sector is a key area in this transition to a low-carbon society. The fulfillment of the long-term goals of the Paris Agreement can be combined with opportunities for economic growth, the creation of centers of knowledge, and improvement of air quality. Sustainable advanced motor fuels can make a significant contribution.

This shows that the AMF TCP has been on the right track for a long time, by providing sound scientific information and technology assessments that allow citizens and policy makers to make informed and science-based decisions about options involving the use of advanced fuels for transportation systems. This is partly thanks to our strategic plan, but in the end, the results depend on the actual Annexes implemented and the Delegates, Alternates, and Operating Agents who have formed AMF TCP over time.

Considering global concern regarding both energy and air pollution, we have conducted the correct analysis. But why did it take such a long time, and what could we have done better? The AMF TCP has modified its communication products to meet the needs of its audience. The individual annex reports continue to address the target group of engineers and scientists, while this annual report has been streamlined and condensed. Within the annual report, country and annex reports have been shortened, which makes them more accessible to analysts and informed readers. The biggest change in our means of communication, however, has been the key messages for policy makers and lay persons. I hope that these three levels of reports will make AMF even more successful and a source of information for all levels of society.

Sustainable produced advanced motor fuels offer a bypass lane to the mitigation of GHG emissions from the current vehicle fleet, a fleet that in part will still exist in 2030. Most AMF TCP Annexes investigate different pathways to utilize advanced motor fuels in an efficient manner within the transport sector. The reduction of GHG emissions is often one of the main drivers for our activities.

In 2014, biofuels provided 4% of the world's transportation fuel. According to the IEA technology roadmap for biofuels for transport, biofuels could make up 27% of world transport fuel in 2050.

In an IEA special report on energy and air pollution, the transport sector, and especially diesel engines, has been identified as the most important source of NO_x emissions. The AMF TCP has several annexes related to this challenge, thus addressing one or more of the following:

- Clean fuels resulting in lower emissions, especially for engines with less sophisticated exhaust after-treatment;
- State-of-the-art engine technology, with low air pollution;
- Real-world emission and energy efficiency; and
- Development of new standards and regulations.

History has shown that, despite good intentions, some regulations for increasing energy efficiency and reducing air pollution and GHG emissions have not delivered the desired results. The AMF TCP, however, contributes with an unbiased, scientifically based foundation of knowledge easily available for decision makers and other stakeholders. In combination with sustainable advanced motor fuels, clean combustion engines are a good option for local environments as well as the global climate.

I would like to extend my appreciation to all participants of the AMF TCP, and especially to the Operating Agents who have delivered annex reports and key messages. A special and personal appreciation is directed to our Outreach Chair, Larry Johnson, for keeping the Chair on track, identifying potential members of the AMF TCP, and above all for being a good friend.

Magnus Lindgren
AMF Chairperson

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 started to enable members to cooperate in groups that share common interests and to learn and grow as they interact and share different perspectives.

Advanced Motor Fuels Highlights

Liquid crude-oil-based fuels have dominated the transportation sector for many years and probably will do so for many years to come. Local air pollution and greenhouse gas (GHG) emissions caused by the use of fossil oil-based fuels are major concerns for the ever-growing transport sector. However, clear signs indicate an understanding of the benefits and the willingness to convert to more sustainable fuels in the future. Because of existing liquid-based infrastructure, liquid biofuels or electrofuels could become significantly important since they combine liquid fuels with sustainability.

In 2016, AMF observed the following major developments.

Road Transportation: Many countries at the beginning of the 21st century, particularly in Europe, switched to the application of more diesel fuel. However, the awareness of higher nitrogen oxides (NO_x) emissions from real driving compared to test values will probably have a negative effect on this tendency, even though this has yet to be demonstrated.

Air quality in many cities has exceeded expected values with respect to NO_x emissions for quite some time. Recent discoveries concerning real driving emissions (RDEs) from diesel cars appear to provide an explanation. The vehicles of many car companies (not only Volkswagen) exceeded NO_x emissions standards multiple times, and studies indicate a couple of reasons for this. In Europe, the main factor lies in the test procedure. European legislation allows some equipment (e.g., emission controlling equipment) to be switched off, if certain testing circumstances would damage the vehicle. Car manufacturers interpret this rule differently. Some companies switch essential NO_x regulating equipment off at 17°C and below. This degree of freedom encourages national test institutions to protect their own industry and promotes the growth of neutral test institutions, thus compromising environmental safety (Transport and Environment: "Dieselgate: Who? What? How?" 2016).

The result is, quite naturally, a search for different propulsion systems and fuels. Electric vehicles (EVs), in particular, have been seen as replacements for traditional combustion-engine-equipped vehicles. Emissions problems in Europe can be attributed to the diesel car. However, it is not a good policy to simply ban all diesel vehicles, because this would stop the competition for better GHG emission performance. It would be better to call for zero-emission vehicles; that is, to define performance requirements rather than discriminate amongst technologies. EVs will undoubtedly become significant competitors for internal combustion engines. However, combustion-engine-based vehicles and EVs should not be competitors; plug-in hybrid electric vehicles (PHEVs) combine both technologies and allow for many benefits.

The trend worldwide, regarding traditional combustion-engine-equipped vehicles, is toward "advanced fuels for advanced engines." Many researchers in industry and universities study low-temperature combustion (LTC) intensively. LTC covers a wide range of new combustion principles and has many benefits with regard to emissions and fuel consumption. The development of new advanced engines requires advanced fuels with combinations of typically gasoline and diesel fuel characteristics. The result will most likely be that many cars will be running on both gasoline and diesel in the near future.

Marine Transportation: Fuels and engine technologies for marine transportation have also transformed recently due to dramatic changes in regulations established by the International Maritime Organization (IMO). Important initiatives in this context are the implementation of new specifications for fuel sulphur content, new NO_x regulations, establishment of so-called Emission Control Areas (ECAs), and the introduction of the Energy Efficiency Design Index (EEDI) for new ships. Particularly, the introduction of ECAs has started a wave of research, development, and demonstration (R&DD) activities on the implementation of alternative fuels like natural gas and methanol in the countries around these areas. Even battery-driven ships are being introduced, but on a small scale. These new fuels will to some extent, also reduce carbon dioxide (CO_2) emissions, depending on the origin of the fuels (e.g., C/H ratio, biofuels, and electrofuels [power-to-gas and power-to liquids]).

The major driving force for introducing alternative fuels in marine transportation is more competitive fuel prices, due to the low sulphur requirements in traditional marine fuels. The major problem for batteries is the limited range capacity, whereas methane emissions from liquefied natural gas (LNG) ships, lack of infrastructure, and safety aspects are limiting factors for the introduction of LNG. Fuel capacity seems to be a minor problem.

Aviation: The aviation sector is very dependent on liquid fuels, and the only viable sustainable solution seems to be liquefied biofuels. Biofuels for aviation are being demonstrated by airline companies such as SAA and KLM.

IEA Technology Collaboration Programme on Advanced Motor Fuels Annual Report 2016

This Annual Report was produced by Kevin A. Brown (project coordination/management), Pat Hollopeter (lead editor), Carolyn Steele (proofreading), Vicki Skonicki (document production), and Gary Weidner (printing) of Argonne National Laboratory. The cover was designed by Alyssa Montealegre, 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	Ministry of Transport, Innovation, and Technology (BMVIT)
Canada	CanmetENERGY
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 Rohsoffe (FNR)
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)
Thailand	PTT Research and Technology Institute
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 43	Performance Evaluation of Passenger Car, Fuel, and Powerplant Options	Juhani Laurikko
Annex 44	Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels	Fan Zhang
Annex 47	Reconsideration of DME Fuel Specifications for Vehicles	Mitsuharu Oguma
Annex 49	COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Nils-Olof Nylund
Annex 50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
Annex 51	Methane Emission Control	Jesper Schramm
Annex 52	Fuels for Efficiency	Somnuek Jaroonijtsathian
Annex 53	Sustainable Bus Systems	Alfonso Cadiz
Annex 54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
Annex 55	Real Driving Emissions and Fuel Consumption	Henning Lohse-Busch

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

Magnus Lindgren	Swedish Transport Administration (STA)	ExCo Chair
Jesper Schramm	Technical University of Denmark (DTU)	Technology Subcommittee Head
Dina Bacovsky	BIOENERGY 2020+	Secretary

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The Advanced Motor Fuels Technology Collaboration Programme

Technology Collaboration Programme on Advanced Motor Fuels (AMF TCP)

The Need for Advanced Motor Fuels

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

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

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

Our Approach

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

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

By verifying existing 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.

AMF Contracting Parties
Ministry of Transport, Innovation, and Technology (BMVIT)
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 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)
PTT Research and Technology Institute (Thailand)
United States Department of Energy (USA)

Recent changes in membership include:

- Japan joined the AMF TCP in January 2017 with a third contracting party, the National Traffic Safety and Environment Laboratory (NTSEL).
- France and Italy withdrew from the AMF TCP in February 2017 and October 2016, respectively.
- India is interested in joining the AMF TCP, and both the Ministry of Road Transport and Highways and the Ministry of Petroleum and Natural Gas have sent high-level officials to the latest Executive Committee (ExCo) Meeting.

AMF Management

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

The AMF TCP work program is carried out through **Annexes**, which are projects with defined objectives, a defined work scope, and defined starting and ending dates. Annexes can be task shared, cost shared, or a combination of task shared and cost shared. Work in specific annexes is led by Operating Agents. The representatives of Operating Agents participate in ExCo meetings so as to present updates on the progress of work in the annex. They are also responsible for pulling together individual contributions and produce the final report.

To support the work of the ExCo and to enable discussions in smaller groups, three **subcommittees** were installed, with a focus on (1) strategy, (2) technology, and (3) 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 ExCo, 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 ExCo meetings and represents the AMF TCP at conferences, workshops, and IEA-related meetings. Several vice-chairs assist the ExCo 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 ExCo 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 ExCo, the Strategy Subcommittee, and the Technology Subcommittee serve to discuss new developments and to identify knowledge gaps and implementation barriers. All delegates are encouraged to propose topics for new annexes. Whenever three or more contracting parties support a proposal and sufficient funding is raised, a new annex can be established. This system allows for flexible adaptation of the annual work program, for continuous development of AMF's scope, and for reacting to any technology gaps or market barriers that have been identified.

Current Work Program

As of May 2017, seven projects are ongoing, and one is just being established.

AMF Work Program
Annex 28: Information Service and AMF Website (AMFI)
Annex 50: Fuel and Technology Alternatives in Non-Road Engines
Annex 51: Methane Emission Control
Annex 52: Fuels for Efficiency
Annex 53: Sustainable Bus Systems
Annex 54: GDI Engines and Alcohol Fuels
Annex 55: Real Driving Emissions and Fuel Consumption
Methanol as Motor Fuel

Several projects have just been completed and are thus also included in the reporting in this Annual Report. See Section 2 for details.

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 ExCo meetings, identifying fields of common interest, and participating in projects of other TCPs. Currently, Bioenergy Task 39 (Liquid Biofuels) and AMT (Advanced Materials in Transportation) participate in AMF Annex 52 on Fuels for Efficiency.

2 Ongoing AMF TCP Annexes

2.a
Overview of Annexes

Ongoing Annexes in 2016

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
43*	Performance Evaluation of Passenger Car Fuel and Powerplant Options	Juhani Laurikko
44*	Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels	Fan Zhang
47	Reconsideration of DME Fuel Specifications for Vehicles	Mitsuharu Oguma
49*	COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Nils-Olof Nylund
50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
51	Methane Emission Control	Jesper Schramm
52	Fuels for Efficiency	Somnuek Jaroonjitsathian
53	Sustainable Bus Systems	Alfonso Cadiz
54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
55	Real Driving Emissions and Fuel Consumption	Henning Lohse-Busch

* Final report available at www.iea-amf.org.

Recently Completed Annexes

Annex Number	Title	Operating Agent
48*	Value Proposition Study on Natural Gas Pathways for Road Vehicles	Ralph McGill

* Final report available at www.iea-amf.org.

2.b
Annex Reports

Annex 28: Information Service and AMF Website

Project Duration	January 28, 2004–Continuous
Participants	
Task Sharing	None
Cost Sharing	All contracting parties: Austria, Canada, Chile, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, South Korea, Spain, Sweden, Switzerland, Thailand, United States
Total Budget	€59,800 ($68,897 US) for 2016 €50,000 ($52,934 US) for 2017
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 North America, 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 (Figure 1).
- 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 (Figure 2).
- 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,

Fig. 1 AMF TCP Newsletters Published in 2016

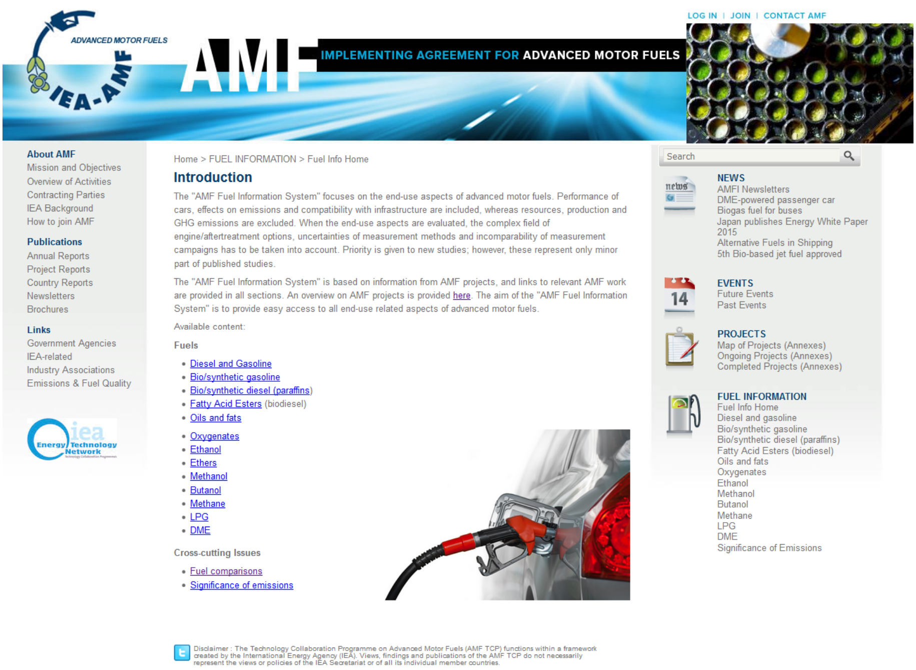

Fig. 2 Screenshot of the Fuel Information System

and Operating Agents on various topics (e.g., strategies, proposals, decisions, and Executive Committee meetings of the AMF TCP).

Key Findings

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

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 laymen 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 2016, 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 was updated frequently with information from Annexes and Executive Committee meetings.

Annex 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options (CARPO)

Project Duration	January 2011–June 2016
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Finland, Japan, Sweden, United States None
Total Budget	~€450,000 ($622,755 US)
Operating Agent	Juhani Laurikko VTT Technical Research Centre of Finland Ltd, FI Email: juhani.laurikko@vtt.fi

Purpose, Objectives, and Key Question

Major de-carbonizing actions need to take place in the road transport sector. There is no single solution for solving the de-carbonization challenge. Multiple technologies must be considered in order to find the alternatives that are best suited for each given set of boundary conditions.
The core of the study consisted of benchmarking a set of passenger car makes and models that offer multiple options for fuels and powerplants. Another project goal was to demonstrate the differences in efficiency that arise from engine types and sizes by testing engines with different power outputs offered on the same vehicle platform.

The test matrix allowed for modulation of the duty cycle and ambient temperature in order to obtain more application-specific and environment-specific data. To make the assessment as realistic as possible, the evaluation was based on a set of different operating conditions and duty cycles. This varying of conditions is important, since previous experience has shown that cars tend to be optimized to type-approval conditions and common driving cycles.

The primary objective of the project was to produce comparable information about different powerplant options with regard to fuel efficiency, energy efficiency, and tailpipe emissions. By using selected vehicle platforms and by basically performing “internal” comparisons between powerplant options, the vehicles themselves can be “nullified.” This approach emphasized the differences between alternative engine technologies, rather than the differences between car makes and models. Full fuel cycle performance was calculated by combining well-to-tank (WTT) data for various fuels generated in Annex 37.

Activities

The data used in this assessment were either the result of tests specific to this study (China, Sweden, Canada, or Finland), or came from other suitable pre-existing available data (United States, Japan). Therefore, the test protocols and duty cycles used were not 100% homogeneous, as most of the tests were conducted using the European type approval procedure (New European Driving Cycle [NEDC]); some data were acquired using other types of approval cycles (United States, Japan).

The fuel options included gasoline, without ethanol (or methanol) as low blends (E5, E10, and M15), high-concentration ethanol (E85), and compressed methane (compressed natural gas/compressed biogas [CNG/CBG]). For compression ignition (CI) engines, regular mineral-oil-only diesel fuel was used, without any bio-component, or as a low blend of the conventional biodiesel fatty acid methyl acid (FAME) (B7), or other similar vegetable oil. A paraffinic, fully synthetic and renewable diesel fuel (hydrotreated vegetable oil [HVO]) completed the fuel matrix. Most of the tests were run at +23°C; some additional ones were run at +5 and −7°C. Altogether, 27 different cars representing 8 platforms were involved. First, an evaluation of the end-use performance (tank-to-wheel [TTW]) was conducted, and then the data were combined with the WTT data from the Joint Research Centre (JRC) test fuel study (2014) to provide information on the complete fuel cycle (well-to-wheel [WTW]). Figure 1 depicts the results.

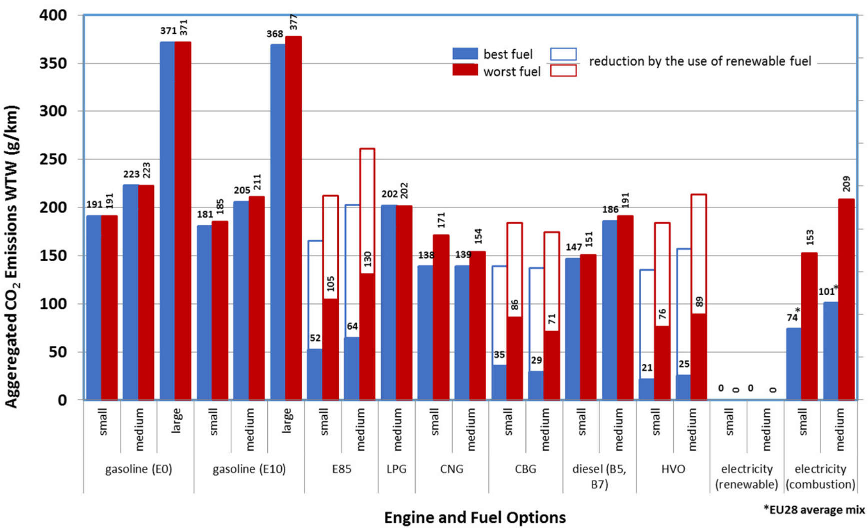

Fig.1 Aggregated WTW CO_2 for the “Best” and “Worst” Fuel Pathways

Key Findings

A high WTW carbon dioxide (CO_2) emissions rate is the major flaw of present-day motor fuels based only on mineral oil. However, with the right kind of fuel, the internal combustion engine (ICE) remains a viable option. For example, a spark ignition (SI) engine with a simple and robust three-way catalyst meets even the most stringent emission regulations and allows the use of renewable energy via biomethane, with low harmful emissions and good low-temperature response. While CI engines have better efficiency, the control of nitrogen oxides (NO_x) emissions is much more complicated. Furthermore, paraffinic, fully synthetic renewable diesel fuels, known as HVO, allow for very high amounts of renewable contents in the fuel, accompanied by positive effects on exhaust emissions. The high efficiency of the electric powertrain ascertains that the WTW CO_2 emissions rate remains low, even if the electricity used is not 100% renewable; however, with current state-of-the-art batteries, the range is short and costs are high.

Main Conclusions

In the overall synthesis, the electric drive proved to be the best option. It was still better than any fossil fuel ICE option, even when the electricity was assumed to contain the European Union (EU)28 average carbon footprint. The best ICE engine option was a CI engine using a fully renewable HVO-type of fuel, followed by an SI engine on bio-methane, as a close contender. The lowest combined score was attributed to SI/gasoline and SI/liquefied petroleum gas (LPG). Fuels with high amounts of renewable contents help to reduce WTW CO_2 emissions significantly. Furthermore, the use of more sophisticated fuels is still well justified, as they help to reduce tailpipe emissions. However, this study was limited to Euro 5, whereas use of the more stringent Euro 6 level technology may change this claim, at least to some extent. Thus, future assessment is highly advisable.

Publications

Nuottimäki, J., J. Laurikko, and N.-O. Nylund, 2014, "Performance Evaluation of Passenger Car, Fuel and Powerplant Options," Paper F2014-CET-040, published in *Proceedings of 2014 FISITA World Automotive Congress*, Maastricht, Belgium, June.

Laurikko, J. (ed.), 2016, *Performance Evaluation of Passenger Car, Fuel and Powerplant Options*, Research Report VTT-R-00892-16.

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

Project Duration	July 2012–June 2016 (4 years)
Participants	
Task Sharing	Canada, China, Finland, Israel, Sweden
Cost Sharing	China, Finland, Sweden
Total Budget	€80,000 ($103,000 US)
Operating Agent	Fan Zhang China Automotive Technology & Research Center (CATARC) Email: zhangfan@catarc.ac.cn

Purpose, Objectives, and Key Question

Alcohol fuels have the advantage of a wide range of sources. These fuels can be manufactured from biomass raw materials, agricultural raw materials (e.g., sugar cane, cereals, and rice), timber and urban waste, and fossil fuels (e.g., natural gas, petrochemical, and coal). A number of countries support the use of alcohol alternative fuels. The United States, Brazil, and Sweden encourage the use of ethanol fuel made from biomass materials. Several regions in China, including Shanxi Province and the City of Shanghai, have initiated a pilot program to promote the use of methanol fuel.

However, the use of alcohol fuels blended with gasoline in vehicles may result in the emission of more unregulated pollutants, such as polycyclic aromatic hydrocarbons, aldehydes, and ketones. These substances have very strong stimulation and sensitization. They also have potential genetic toxicity and carcinogenic activity, which could significantly impact human health. This issue is an important factor that could hinder further development of alcohol alternative fuels. Thus unregulated pollutant emissions from vehicles fuelled with alcohol alternative fuels require investigation. This type of research promotes the application of alcohol alternative fuels in a more expedient manner. Measuring the unregulated pollutant emissions of vehicles fuelled with alcohol fuels facilitated achieving the primary objectives of this project — to obtain the unregulated pollutant emission levels of alcohol-fuelled vehicles and to gradually establish the measurement methods and limits of unregulated pollutant emissions. Our research also examined the influences that measurement methods, automotive technology, fuel alcohol content, ambient temperature, test cycles, and other relevant factors have on vehicle unregulated pollutant emissions.

Activities

China carried out the obligations of the Operating Agent during this Annex. As a task-sharing participant, China conducted emissions tests on the chassis dynamometer by using port fuel injection (PFI) and gasoline direct injection (GDI) light-duty vehicles fuelled with gasoline, E10, E20, M15, and M30. The driving cycles were New European Driving Cycle (NEDC) and Federal Test Procedure (FTP)75.

Finland measured two vehicles with three different fuels (E10, E85, and E100). Measurements were made in ambient temperatures of +23°C and −7°C.

Canada provided chassis dynamometer emissions measurements from PFI and GDI vehicles operating on E0, E10, and E20 at 25°C, −7°C, and −18°C using the FTP 75 cycle.

Israel conducted a test program where M15, E10, and normal 95 octane gasoline fuels were used in four different car models. Two driving cycles were used: NEDC and the U.S. Environmental Protection Agency's US06.

Sweden conducted a literature review regarding low blending of alcohol fuels in passenger cars. The review included both regulated and unregulated emissions as well as other experiences related to the use of alcohol fuels. Fourier transform infrared radiation (FTIR), high-performance liquid chromatography (HPLC), and gas chromatography-mass spectrometry (GC-MS) were utilized to synchronously measure regulated and unregulated pollutant emissions from the vehicles in different participant countries.

Key Findings

Key findings from the project can be summarized as follows:

- The transient unregulated emissions, such as formaldehyde, acetaldehyde, toluene, propylene, and 1,3-butadiene, had the highest peak during the first acceleration condition. Then with the catalyst lights off, the emissions values gradually decreased to nearly zero and remained there until the end of the driving cycle.
- Using low-content alcohol fuels (M15 and E10) did not have statistically significant effects on carbonyl emissions. For unregulated emissions of middle-content (M30 and E20) alcohol fuels, unburned methanol or ethanol, formaldehyde, and acetaldehyde increased proportionally (not more than 2 times). BTEX (benzene, toluene, ethylbenzene, and xylene), propylene, 1,3-butadiene, and isobutene

decreased slightly compared to those emissions from gasoline vehicles. For high-content (E85) alcohol fuels, formaldehyde and acetaldehyde were 3 and 9 times higher, respectively, with the use of E85 compared to E0, and BTEX emission rates were approximately 70% to 84% lower with the use of the E85 fuel compared to E0 at 22°C.

- The effect of test temperature was evident for most emissions. The regulated and unregulated emissions in the low ambient temperature were significantly higher than those in the normal ambient temperature. Acetaldehyde was roughly 2 orders of magnitude higher on E85 than on E0 at −18°C. Reductions in BTEX by approximately 50% were also observed at −7°C, and, to a lesser extent, at −18°C, due to the use of the E85 fuel.
- The difference in hydrocarbon (HC) emissions in the entire process of the evaporative emission tests of E10, gasoline, and M15 fuels was slight. Although there was a difference in unregulated emissions in the diurnal test of the three fuels, the difference was very small.
- The average unregulated emissions levels of GDI and PFI test vehicles were in the same order of magnitude. Although there were differences in the average emission levels from the same light-duty vehicle during different driving cycles, the largest variation was not more than 2 times. In contrast to nitrogen oxides (NO_x) emissions, the average levels of aromatic hydrocarbons, aldehydes, ketones, and olefins emissions had the same tendency.

Main Conclusions

When the alcohol content in fuels is increased, formaldehyde and acetaldehyde emissions increase, while BTEX, olefins, particulate matter (PM) and particle number (PN) decrease proportionally. The three-way catalyst had 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 in the low ambient temperature were significantly higher than those in the normal ambient temperature. In contrast to NO_x emissions, the average levels of aromatic hydrocarbons, aldehydes, ketones, and olefins emissions during different driving cycles had the same tendency.

Publications

The Final Report Draft was submitted in April 2016.

Annex 47: Reconsideration of DME Fuel Specifications for Vehicles

Project Duration	July 2013–December 2015
Participants **Task Sharing** **Cost Sharing**	 Japan, Korea, Sweden, Thailand Not provided
Total Budget	5,000,000 JPY or €38,546 ($41,924 US)
Operating Agent	Mitsuharu Oguma National Institute of Advanced Industrial Science and Technology (AIST) Email: mitsu.oguma@aist.go.jp

Purpose, Objectives, and Key Question

AMF has investigated the potential of dimethyl ether (DME) as an alternative fuel for diesel engines through several earlier Annexes from 1997 to 2004. Since there was no DME market for vehicles at that time, the investigations were based on the supposition that the DME market for vehicles would be established in the near future.

Now, China, Sweden, and Japan are demonstrating DME utilization in trucks and buses. The International Organization for Standardization (ISO) has been discussing standardization of DME fuel through TC28/SC4/WG13 since 2007. The scope of the DME standardization effort can be classified into three use categories: (1) as a feedstock for home and industrial use; (2) as a blendstock with liquefied petroleum gas (LPG); and (3) as an alternative to diesel fuel for power systems, including vehicles.

AMF Annex 47 supports the efforts of the ISO working group to establish specifications for the use of DME in vehicles. The main issues to be investigated in this Annex are (1) the effects of fuel impurities and (2) the effects of additives (e.g., lubricity improvers, odorants, if any) on DME diesel engine systems.

Activities

The effects of fuel impurities and additives on DME diesel engine systems were discussed with experts from Japan, Korea, Sweden, and Thailand.

Work undertaken in Japan, the European Union, and the United States shall be connected to achieve a combined fuel standardization effort.

Key Findings

The following ISO DME fuel specifications for basic fuel (not for vehicles only, but included for diesel engines) and the test methods were published in 2015.

- ISO 16861:2015, Petroleum products — Fuels (class F) – Specifications of dimethyl ether (DME), 2015-05-15
- ISO 17196:2014, Dimethyl ether (DME) for fuels – Determination of impurities – Gas chromatographic method, 2014-11-15
- ISO 17197:2014, Dimethyl ether (DME) for fuels – Determination of water content – Karl Fischer titration method, 2014-11-15
- ISO 17198:2014, Dimethyl ether (DME) for fuels – Determination of total sulfur, ultraviolet fluorescence method, 2014-11-15
- ISO 17786:2015, Dimethyl ether (DME) for fuels – Determination of high temperature (105°C) evaporation residues, mass analysis method, 2015-05-01

Table 1 shows the final fuel specifications for DME basic fuel.

The intention for DME fuel specifications for vehicles is that ISO16861:2015 will be based on revising the "Residue after Evaporation" standard for a lubricity improver. Test methods for lubricity will be explained in the Annex, because it is currently difficult to standardize the test method for lubricity by special high frequency reciprocating rig (HFRR). The Japanese Industrial Standard (JIS) will be revised similarly. Discussions with Volvo regarding the lubricity test method should continue.

Two laboratories in Japan have conducted a new set of round robin tests of DME fuel specification; other laboratories, including a few foreign countries, will begin such testing in 2016. These data will be used for future regular revisions of the ISO test methods.

Table 1 DME Fuel Specifications for Base Fuel[a]

<table>
<tr><th>Characteristic</th><th>Unit</th><th>Limit</th><th>ISO/DIS16861</th><th>Mutual Agreement Value of AMF Annex (1998)</th></tr>
<tr><td>Purity</td><td>Mass %</td><td>Minimum</td><td>98.5</td><td>99.6</td></tr>
<tr><td>Methanol</td><td>Mass %</td><td>Maximum</td><td>0.050</td><td>0.05</td></tr>
<tr><td>Water</td><td>Mass %</td><td>Maximum</td><td>0.030</td><td>0.01</td></tr>
<tr><td>Hydrocarbons (up to C_4)</td><td>Mass %</td><td>Maximum</td><td>1.00</td><td rowspan="7">Others
Methyl ethyl ether <0.2
Higher alcohol <0.05
Higher ether <0.05
Ketones <0.05
Lubricity improver <0.2
Odorant <0.002</td></tr>
<tr><td>CO_2</td><td>Mass %</td><td>Maximum</td><td>0.10</td></tr>
<tr><td>CO</td><td>Mass %</td><td>Maximum</td><td>0.010</td></tr>
<tr><td>Methyl formate</td><td>Mass %</td><td>Maximum</td><td>0.050</td></tr>
<tr><td>Ethyl methyl ether</td><td>Mass %</td><td>Maximum</td><td>0.20</td></tr>
<tr><td>Residue after evaporation</td><td>Mass %</td><td>Maximum</td><td>0.0070</td></tr>
<tr><td>Sulfur</td><td>mg/kg</td><td>Maximum</td><td>3.0</td></tr>
</table>

[a] Draft values were derived from ISO/TC28/SC4/WG13.

Publications

The Annex 47 final report is available on the AMF website.

Annex 49: COMVEC — Fuel and Technology Alternatives for Commercial Vehicles

Project Duration	July 2013–October 2016
Participants **Task Sharing** **Cost Sharing**	 Canada, Chile, China, Denmark, Finland, Japan, Korea, Sweden, Thailand None
Total Budget	~€900,000 ($1,000,000 US)
Operating Agent	Nils-Olof Nylund VTT Technical Research Centre of Finland Ltd Email: nils-olof.nylund@vtt.fi

Purpose, Objectives, and Key Question

Commercial goods vehicles — light-, medium- and heavy-duty vehicles — represent about 25% of the total energy used in transport and are the second largest segment after passenger cars. Therefore, this vehicle category is important, not only for its contribution to economic activities, but also for its share of energy use and emissions.

The goals of the "COMVEC" project (Fuel and Technology Alternatives for Commercial Vehicles) were twofold:

1. To agree upon common test procedures for testing and comparing different types of commercial vehicles; and
2. To generate performance data specific to commercial vehicles (goods vehicles), thus adding to the information on alternative fuels and vehicle technologies generated in previous AMF activities (Annex 37 on buses, Annexes 38 and 39 on trucks, and Annex 43 on passenger cars).

With data covering all road vehicle classes, it will eventually be possible to evaluate the best fit for alternative fuels and new vehicle technologies for road transport, thereby resulting in a more effective way of allocating alternative technologies.

Activities

The project focused on three main activities:

- Development of common test procedures and protocols,
- Vehicle testing (carried out in chassis dynamometers), and
- Full fuel-cycle evaluation.

In the "COMVEC" project, eight partners from three continents teamed up to generate performance data (energy efficiency, exhaust emissions) for commercial vehicles. As for the test program and testing parameters, most of the tests were carried out using one specific test cycle (World Harmonized Vehicle Cycle [WHVC]), 50% load, and normal ambient temperature (25 ±5°C). Altogether, 35 different vehicles, ranging from light commercial vehicles (vans) to heavy-duty vehicles for trailer combinations, were tested on chassis dynamometers. In addition, one engine, installed on an engine dynamometer, was tested. The test program covered several fuel options — diesel, diesel substitute fuels, natural gas, ethanol, and even electricity, in the category of light commercial vehicles. The emission certification classes covered were Euro 4, Euro 5, and Tier 2 for light-duty commercial vehicles, and Euro III, Euro IV, Euro V, Euro VI, and US 2010 for the heavier vehicles (see Figure 1).

Key Findings

Key findings from the project can be summarized as follows:

- Euro VI vehicles perform extremely well.
- Going from Euro III to Euro IV or Euro V vehicles does not necessarily deliver real emission benefits; one should leapfrog directly to Euro VI or to US 2010 regulations to obtain real-life low emissions.
  - This has implications for those regions that are contemplating more stringent emission regulations, as well as for the tendering of transport services.
- The regulated emissions of a vehicle are, first and foremost, determined by the emission control technology and not the fuel.
- The response to substitute fuels (fuels that can replace conventional diesel in existing vehicles) varies from vehicle to vehicle, as well as by vehicle category (light-duty vehicles vs. heavy-duty vehicles).
  - Heavy-duty Euro VI engines are so clean that any effect of the fuel will be negligible.
- The carbon intensity of the fuel or the energy carrier is decisive for well-to-wheel (WTW) carbon dioxide (CO_2) emissions, not vehicle technology.
- CO_2 assessment should be carried out on a WTW basis and not only assess tailpipe CO_2 emissions.
- Electrification, with low-carbon electricity, is a good option for local emissions as well as WTW CO_2 emissions.
  - One should keep in mind that not all applications are suitable for electrification.
- Euro VI (alternatively US 2010), in combination with a renewable fuel, is a good option for the local environment as well as the climate.

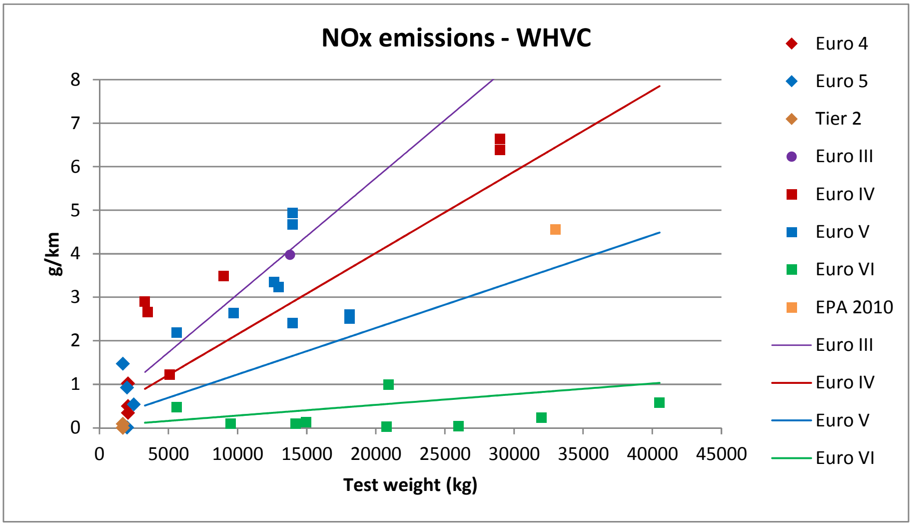

Fig. 1 NO_x Emissions by Emission Class (identified by color) (The solid lines depict the expected performance of various emission classes. For each color, dots below the solid lines represent compliance; dots above the lines represent non-compliance.)

Main Conclusions

There is a clear need to reduce regulated emissions, as well as greenhouse gas (GHG) emissions, from commercial vehicles that will be dependent on internal combustion engines for many years to come. Measurements within COMVEC show that the latest generation of vehicles (Euro VI) have significantly reduced regulated emissions, including during testing under conditions that correspond to real-life operation. These findings should be used as a guide in countries with less stringent emission regulations and also for procuring transport services. The recommendation is to leapfrog directly from less sophisticated technologies to Euro VI. Advanced renewable fuels will help to reduce GHG emissions in applications for which electrification is feasible.

Publications

Nylund, N-O. (ed.), 2016, *Annex 49, Fuel and Technology Alternatives for Commercial Vehicles, A Report from the IEA Advanced Motor Fuels Technology Collaboration Programme*, October, http://www.iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Annex_49.pdf.

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

Project Duration	May 2014–June 2017
Participants **Task Sharing** **Cost Sharing**	 Canada, Finland, Germany, Sweden, Switzerland None
Total Budget	More than €200,000 ($312,145 US)
Operating Agent	Magnus Lindgren Swedish Transport Administration Email: Magnus.Lindgren@trafikverket.se

Purpose, Objectives, and Key Question

Non-road mobile machinery is used to produce food, feed, and industrial material. Based on several different studies (mostly U.S. and European), this sector is often responsible for between 10% and 25% of diesel consumption and contributes significantly to overall emissions. However, discussions on alternative fuels and greenhouse gas emissions, both general and within the AMF TCP, have focused on road vehicles.

The purpose and first objective of Annex 50 is to put some focus on the non-road sector. This includes the collection of existing fuel consumption and emission data, measurements of real driving performance, studies of hybridization, and possible measures to reduce fuel consumption and emissions from non-road mobile machinery. This approach is undertaken for different engine technologies, fuel specifications, and machinery applications, including the consideration of engine load cycles.

Activities

Annex 50 activities are divided into nine different work packages covering areas from global emission regulations to the local level. For the local level, the work packages cover the national emission situation in some of the participating countries, in-lab emission measurements, as well measurements during real operation of machinery. Two of the work packages deal with the possibility of reducing the fuel consumption of non-road mobile machinery by either political or technical measures.

In addition to the Annex 50 Final Report, a 2-page summary written for a non-scientific audience will be published.

Key Findings

The results and deliverables of Annex 50 will be a written Final Report presenting data on fuel consumption and emissions from various types of non-road mobile machinery. It will cover emissions stages, technology and alternative fuels, and machinery operation.

For most road vehicles, such as passenger cars, buses, and heavy-duty trucks, the normal usage/driving pattern can be represented by a fairly limited number of cycles. Non-road mobile machinery consists of a much broader group of applications with a highly variable usage pattern. Thus the usage of non-road mobile machinery cannot easily be described by a few general test cycles. Studies of wheel loaders conducted within Annex 50 show a significant reduction in emissions of air pollution with increasing emission standards. Tests on a wheel loader with a pre-Stage V engine have shown that emissions are kept at an acceptable low level at all tested usage patterns — from low loads to highly transient operation. One of the new requirements for Stage V emission regulations is in-use testing, which can be compared with real driving emissions currently under discussion for passenger cars or implemented for heavy-duty vehicles in Europe.

Tests with hydrotreated vegetable oil (HVO) have shown good drivability and reduced air pollutant emissions compared with conventional diesel (fulfilling EN 590). Emissions of particulate matter were reduced by up to 10% on a Stage IV engine without a diesel particulate filter (DPF). On the same engine, emission of nitrogen oxides (NO_x) was reduced by up to 15% with HVO during normal operation with a warm engine.

Main Conclusions

Emission Class of Engines

- Stage V technology (DPF, selective catalytic reduction [SCR], and heat management) are needed to obtain low real-world emissions.
- Going from Stage II or Tier 2 to Stage IIIB/IV or Tier 4i/4f does not necessarily deliver real emission benefits; one should leapfrog directly to Stage V regulations to get real-life low emissions.
  - This has implications for regions that are contemplating more stringent emission regulations, as well as for procurement of non-road mobile machinery.

Fuel Quality

- The older the engine (lower emission classification), the bigger reduction potential with high-quality fuel, both in test cell and in real-world operation.
- Sustainable produced advanced renewable diesel fuel, such as HVO, can reduce carbon dioxide (CO_2) emissions for all engine emission classes.

Real-World Operation

- Non-road mobile machinery consists of a significant variation in types of machinery that can be used in many different operations.
- Fuel consumption and exhaust emissions are dependent on the type of machinery, operation, emission classification, and fuel specification.

Publications

The following national project reports have been presented:

- TEST REPORT OMT 4005, 2015, On-board Emission Measurement on Wheel Loaders with Different Emission Standards, Sweden, AVL MTC.
- TEST REPORT OMT 5005, 2016, On-board Emission Measurement on Wheel Loaders in Different Test Cycles, Sweden, AVL MTC.
- Simulation of Wheel Loader – Energy Consumption, 2017, VTT-R-05718-16, VTT Technical Research Centre of Finland Ltd.
  Fuel and Technology Alternatives for Non-road Mobile Machinery – Finland's Contribution to IEA AMF Annex 50, 2017, VTT-R-00044-17, VTT Technical Research Centre of Finland Ltd.

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, there would still be a need for methane catalysts, due to 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 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 20-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 WP 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, we know that 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. Dimethyl ether (DME) 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 out to the atmosphere to avoid overpressurization. High-pressure fuel lines and joints could also be a source of leakage that need to be investigated. The purpose of this WP 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

An overview of the knowledge about unburned methane from today's light-duty vehicle (LDV) engines will be given. The study will reveal the available data that can be used for verifying the models that are 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 that are 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 that are 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 52: Fuels for Efficiency

Project Duration	April 2015–March 2017
Participants **Task Sharing** **Cost Sharing**	 Denmark, Israel, Finland, Thailand IEA Bioenergy Task 39 No cost sharing
Total Budget	€450,000
Operating Agent	Dr. Somnuek Jaroonjitsathian, PTT Public Company Limited email: somnuek.j@pttplc.com

Purpose, Objectives, and Key Question

Annex 52, Fuels for Efficiency, was initiated in compliance with the global requirement of improving fuel efficiency for road transport fuel application. In general, automotive original equipment manufacturers (OEMs) try to improve their engines' efficiency while controlling the exhaust emission with regard to the country's requirement. The implication for advanced motor fuels, or the method for optimizing the fuels in order to maximize engine efficiency, has rarely been discussed worldwide.

Annex 52 intends to demonstrate how to optimize fuel with specific engines in terms of thermal efficiency gain, without any constraints on the format of fuel utilization, engine technology, or chemical additives. All members expect that the results will enable a new approach to automotive fuel optimization.

Activities

Annex 52 comprises a range of different experimental setups on various subtopics of improving fuel efficiency. Each has been designed according to the specific interests of the respective task-sharing participant:

- Information Exchange with IEA Bioenergy Task 39 (Survey on Advanced Fuels for Advanced Engines) and Others (IEA-AMT)
- Performance Evaluation of Chemical Friction Modifiers for Diesel and Gasoline Fuels (Denmark)
- Waste Heat Recovery – Thermodynamic Potential of Fuels Reforming (Technion – Israel)
- Performance Assessment of Various Paraffinic Diesel Fuels (Finland)

- Opportunity for Enhancing Fuels Efficiency by Ethanol Blended Gasoline Fuels (Thailand)

The technical work packages are complemented by work packages on project management, literature survey, data assessment and final report, and dissemination.

Key Findings

WP 3: The experimental results show the possibility that the friction modifier additive is applicable only for gasoline engines. The 2.7% fuel efficiency improvement can be detected only at a specific condition. Overall test conditions resulted in only a slight percentage improvement. While cetane improver additives seem to have an insignificant effect on fuel saving under all conditions. ***Thus, the friction modifier additive is one of the key solutions for gasoline fuel saving without engine modification.***

WP 4: The methane steam reformer improved fuel efficiency by 18 to 39% when running under the low-to-medium load condition. The major improvement comes from the wide flammability limit of hydrogen-rich fuel, which allows the engine to operate unthrottled, especially at low-load conditions or pumping losses reduction. In addition, the waste heat recovery from exhaust gas helps to maintain the endothermic reactions of methanol steam reforming (MSR). Thus, MSR is one of the major technologies for fuel efficiency improvement for a modified stationary gasoline engine.

WP 5: Paraffinic diesel seems to increase fuel efficiency when run with optimized modern diesel engine technology. The key deliverable from this experiment shows that all paraffinic diesels with low soot content highly improve fuel efficiency, which allows modification of the fuel injection duration. Incidentally, the nitrogen oxides (NO_x) content is limited by emission regulations. ***Paraffinic diesel is one of the most promising fuels for modern diesel technology.***

WP 6: Ethanol blended fuel has significantly improved fuel sensitivity (research octane number [RON] – motor octane number [MON]), which results in the possibility of higher engine output, if operated with the advance ignition timing feature. Because advance ignition timing is a strategy used in modern direct injection spark ignition (DISI) engines, the use of ethanol-blended fuel is expected to improve the fuel efficiency of those engines. ***Thus, fuel efficiency***

improvement in modern gasoline DISI engines can be achieved by using ethanol blended fuel.

Publications

The final report is expected to be published by March 2017; several technical publications will result from Annex 52.

Annex 53: Sustainable Bus Systems

Project Duration	November 15–December 2017
Participants **Task Sharing** **Cost Sharing**	Canada, Chile, Finland, 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 of the biggest cities in Latin America are facing the renewal of their bus fleets. It is essential that, at this juncture, energy-efficient, low-polluting, and soot-free buses be introduced into their bus transport systems.

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 (OEM) products will be considered; no retrofit solutions will be addressed.

Activities

Activities include analysis of the performance of existing buses, evaluation of the operational 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, finally, 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

Annex 53 started with an analysis of the performance of existing buses and the evaluation of operational conditions in the public transportation system of Santiago, Chile. The Ministry of Transport, in cooperation with the Ministry of Energy and Centro Mario Molina, conducted a comprehensive analysis of bus fleets and routes to obtain a preliminary sample of 19 routes that total more than 800 km. The routes were selected based on average speed, length, rate of occupancy, and number of bus stops.

In cooperation with the Technical Research Center of Finland (VTT), 5 of the 19 routes were selected for vehicle instrumentation. During April 2016, data on time, speed, position, altitude, rate of occupancy, and bus condition were collected for each selected route.

These data were used to analyze how well existing international bus driving cycles represent conditions in the City of Santiago. From this, a representative Santiago driving cycle was developed, in which a micro-trip approach was used. The driving cycle was separated into phases representing kinds of routes. On the basis of the transport system, there are three main types: Only Bus, Corridor, and Mixed. “Only Bus” is a road not physically segregated like Corridor type. However, it has restrictions on private vehicles, and about 4.4% of the public transport road network is Only Bus. “Corridor” is a road type physically segregated. It is similar to Bus Rapid Transit (BRT) road, and about 2.5% of the public transport road network is Corridor. Finally, “Mixed” is a road type where there are no restrictions on private vehicles, taxis, motorcycles, or bicycles. Mixed routes represent about 92% of the public transport road network. Figure 1 shows the cycle profile for the City of Santiago, which is being validated, mainly to determine whether there are significant differences among the three phases.

At the end of 2016, dynamometer tests were conducted at the VTT and Center for Vehicle Control and Certification (3CV) laboratories. At the VTT laboratory, buses with Euro VI and Euro V technology were tested; during 2017 more buses will be tested, including electric technology. The 3CV laboratory tested Euro V buses.

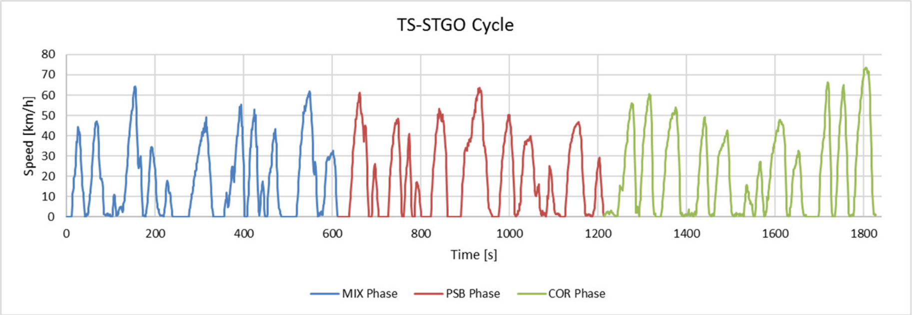

Fig. 1 Preliminary Santiago Driving Cycle

In addition, in September 2016, 3CV and Centro Mario Molina Chile researchers convened at the VTT laboratory to learn about the methodology for developing the driving cycle and to gain knowledge about advanced technologies for electric buses.

Furthermore, Sweden delivered a draft document in which it 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, especially in the case of Euro VI, in operation in terms of:

- Importance of driving cycles,
- Measurement of emissions and fuel/energy consumption,
- Vehicle technologies,
- Fuels,
- Approval of engines to be used in heavy-duty vehicles, and
- Inspection and Maintenance (I&M) (periodic technical inspection [PTI]).

A second set of data will be collected for characterizing the different kinds of bus route infrastructure available in the South American region (BRT corridors, exclusive lines for buses without physical segregation, and streets with mixed traffic with private cars). This second set of data will include other cities, like Lima, Peru.

Annex 54: GDI Engines and Alcohol Fuels

Project Duration	April 2016–April 2019
Participants **Task Sharing** **Cost Sharing**	 Canada, Chile, Germany, Israel, United States No Cost Sharing
Total Budget	~€300,000
Operating Agent	Debbie Rosenblatt Emissions Research and Measurement Section Environment and Climate Change Canada Email: Debbie.Rosenblatt@Canada.ca

Purpose, Objectives, and Key Question

It has been shown that 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, mainly 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 gaseous emissions, the focus will be on the tailpipe emissions of PM and black carbon (BC), along with the secondary organic aerosol (SOA) formation potential. The fuels investigated include ethanol blends (E10 and E85) and methanol blends (M56, M15, and M30). The impacts of GPFs on particles from GDI engines with varying fuels 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 and methanol) 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 SOA formation potential of different vehicle fuel and technology combinations will be assessed.

Canada's Task-Sharing Contribution
Experiments will be carried out at the Emissions Research and Measurement Section of Environment and Climate Change Canada. A light-duty GDI vehicle will be tested on a chassis dynamometer with both low-level ethanol and high-level ethanol blends. The drive cycle used will be the Federal Test Procedure (FTP) with cold start at 25°C, −7°C, and −18°C. The US06 cycle will also be conducted at 25°C. Additional tests will be conducted with the GDI vehicle equipped with a GPF.

Along with fuel economy and criteria air contaminants, detailed characterization of PM and particle emissions will be undertaken. This characterization will include gravimetric PM, organic and elemental carbon, PN per mile, and particle size distribution.

Chile's Task-Sharing Contribution
Chile's contribution will be 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). Chassis dynamometer tests will be conducted with light-duty vehicles using the New European Driving Cycle (NEDC) and FTP test cycle, with varying blends of ethanol fuel (E0, E10, and E85). In addition to measurements of nitrogen oxides (NO_x) and nonmethane hydrocarbons (NMHCs), particle chemical composition and PN size distribution will be quantified for ultraviolet (UV) irradiation-aged emissions. Determinations of SOA formation potential for each vehicle fuel combination will be made. A light-duty diesel vehicle will also be tested for comparative purposes.

Israel's Task-Sharing Contribution
Emissions tests will be conducted with GDI vehicles fueled with methanol gasoline and ethanol gasoline fuel mixtures (M56, E85, M15, E10, and M30). Emission testing will be performed according to NEDC and US06 cycles. Emissions characterization will include NO_x, HC, carbon monoxide (CO), PM, PN, and formaldehyde. The test vehicles will include both GDI and PFI engines.

United States' Task-Sharing Contribution

This contribution will be provided by Argonne National Laboratory's Center for Transportation Research, Advanced Powertrain Research Facility. Tasks will include chassis dynamometer tests of two vehicles of the same model types — one vehicle with a GDI engine powertrain with a GPF and one vehicle with a GDI engine powertrain without a GPF. The test protocol will include an FTP with cold start and the NEDC with hot start at 22°C (72°F) ambient temperature. Detailed characterization of PM will include transient soot mass, particle size distributions, primary total solid PN, and emissions of heavy hydrocarbons known to have high SOA potential.

Main Conclusions

Experimental work has just started. This Annex will result in the following:

- Comparative emissions rates of PM and particles from GDI test vehicles operated under varying conditions with different blends of alcohol fuels;
- Criteria air contaminant emissions, along with fuel consumption will be reported; and
- For a select set of vehicle tests, comparative information will be provided on the SOA forming potential.

The overall outcome will focus on the impacts of alcohol fuels and exhaust emission controls on PM, particles, BC, and the SOA forming potential from GDI and comparable technology vehicles.

Publications

Annex 54 work will result in a Final Report, "GDI Engines and Alcohol Fuel."

Annex 55: Real Driving Emissions and Fuel Consumption

Project Duration	November 2015–April 2019
Participants	
Task Sharing	Canada, Denmark, Finland, Sweden, Switzerland, United States
Cost Sharing	No cost sharing
Total Budget	~€400,000
Operating Agent	Henning Lohse-Busch Argonne National Laboratory (USA) Email: hlb@anl.gov

Purpose, Objectives, and Key Question

The levels of air pollutants from internal combustion engine (ICE)-powered vehicles that are being sold in the marketplace today are much lower than those from vehicles 4 to 10 years ago. This is largely the result of technology forcing regulations to control the exhaust emission rates of various air pollutants such as hydrocarbons, carbon monoxide, oxides of nitrogen, and particulate matter. Over time, changes to those regulations have reflected the extraordinary advances in fuels, engines, and emission control technologies that have been produced by automotive researchers/manufacturers over the past decades. There is evidence to suggest that the performance of vehicles may not be fully captured in compliance or type approval tests, even though they are conducted with varying driving cycles and in an environmentally controlled chamber.

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

Activities

The first phase of this annex is a review of existing work, including an evaluation of different Portable Emissions Measurement Systems (PEMSs), along with an evaluation of different driving conditions and types of vehicles. Existing or upcoming legislation concerning the thresholds for boundary conditions (e.g., maximum/minimum temperatures, altitude, and fuel specification), as well as corresponding evaluation methods, are analyzed and available data sets are identified.

The second phase of the work is to conduct emissions and energy efficiency measurements that will include:

- Different fuel specifications, such as advanced and renewable fuels;
- Regionally adopted driving cycles;
- Ambient temperature variations;
- Inclusion of cold start emissions, and
- In some cases, a comparison to regulatory cycle emissions and efficiency.

Key Findings

In the summer of 2016, Canada conducted some on-road testing using a GMC Sierra 2500 flex-fuel vehicle with commercial unleaded gasoline (E0) and commercial E85. The vehicle was driven in Ottawa, Ontario, Canada, on a test route that included five different sections. The vehicle was also tested on a chassis dynamometer. Great variability in test results occurred during the on-road emissions testing compared to the chassis dynamometer testing. The differences between E0 and E85 carbon dioxide emissions rates were comparable with the on-road and chassis dynamometer data.

The other participants are collecting data ranging from on-road testing to chassis dynamometer testing and a mix of both.

3 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.

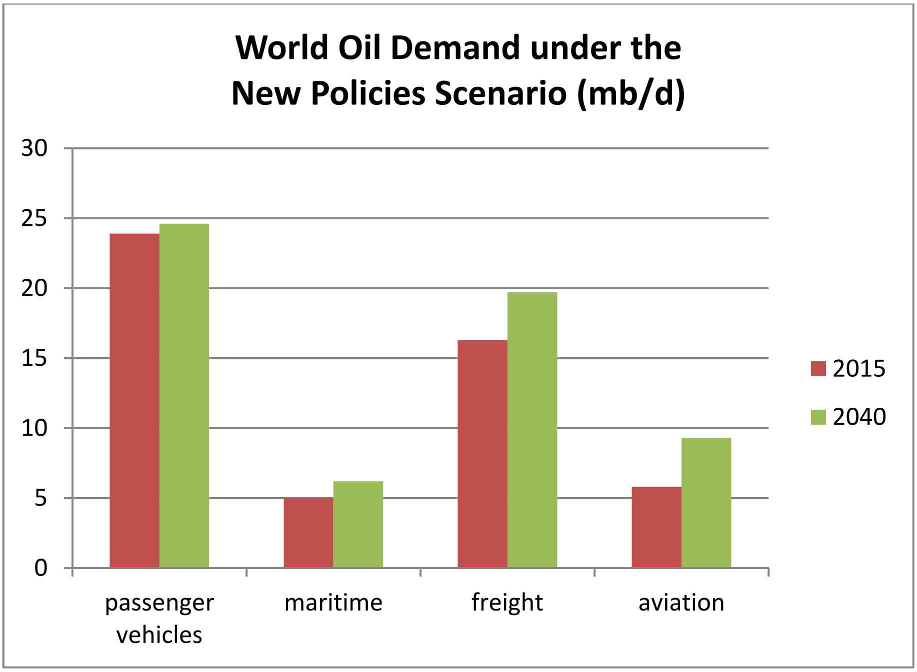

Fig. 1 World Oil Demand of the Transport Sector under the New Policies Scenario *(Source: IEA World Energy Outlook 2016)*

According to the International Energy Agency (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).

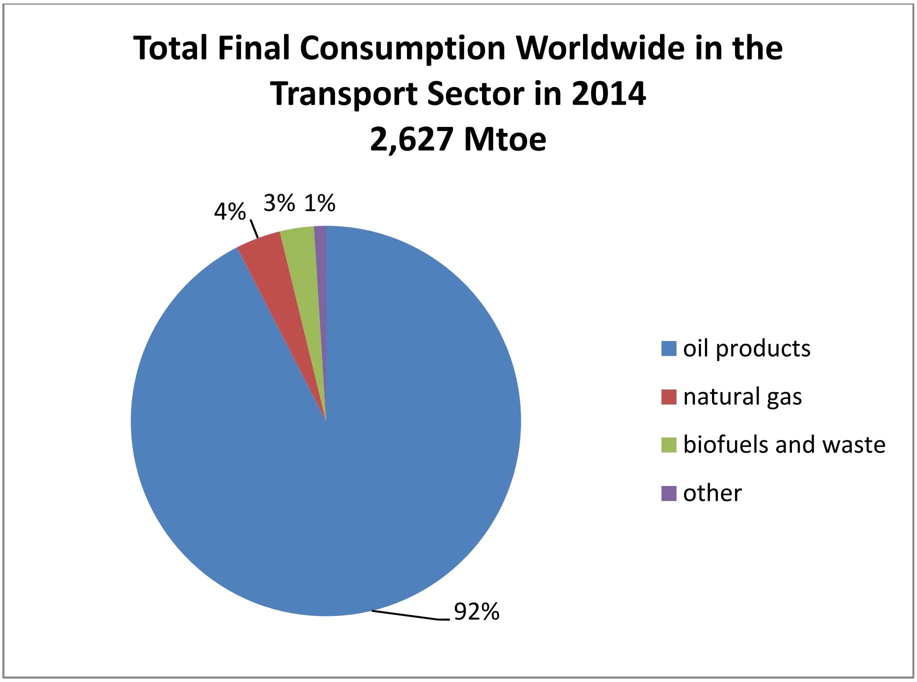

Fig. 2 Total Final Consumption of the Transport Sector in 2014
(Source: IEA Key World Energy Statistics 2016)

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.

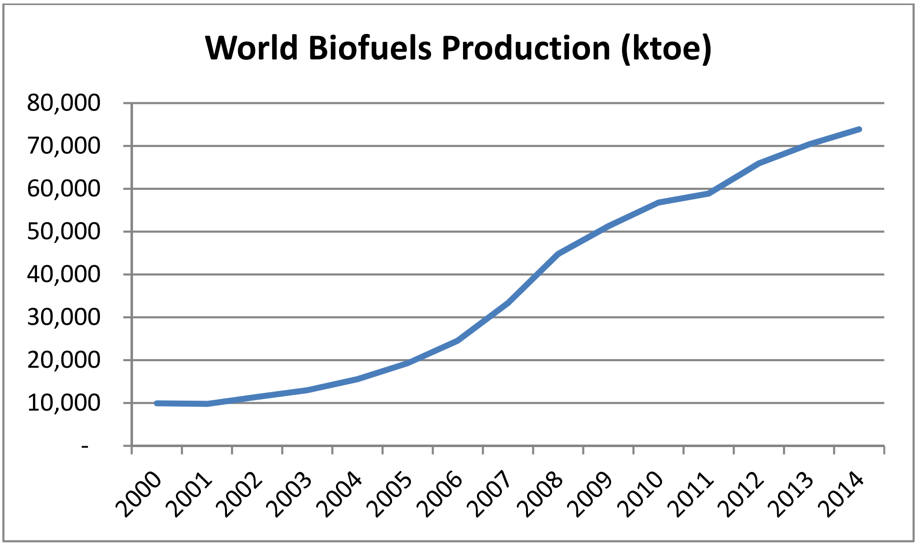

Fig. 3 World Biofuels Production in 2014 (ktoe)
(Source: IEA Headline Energy Data 2016)

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.

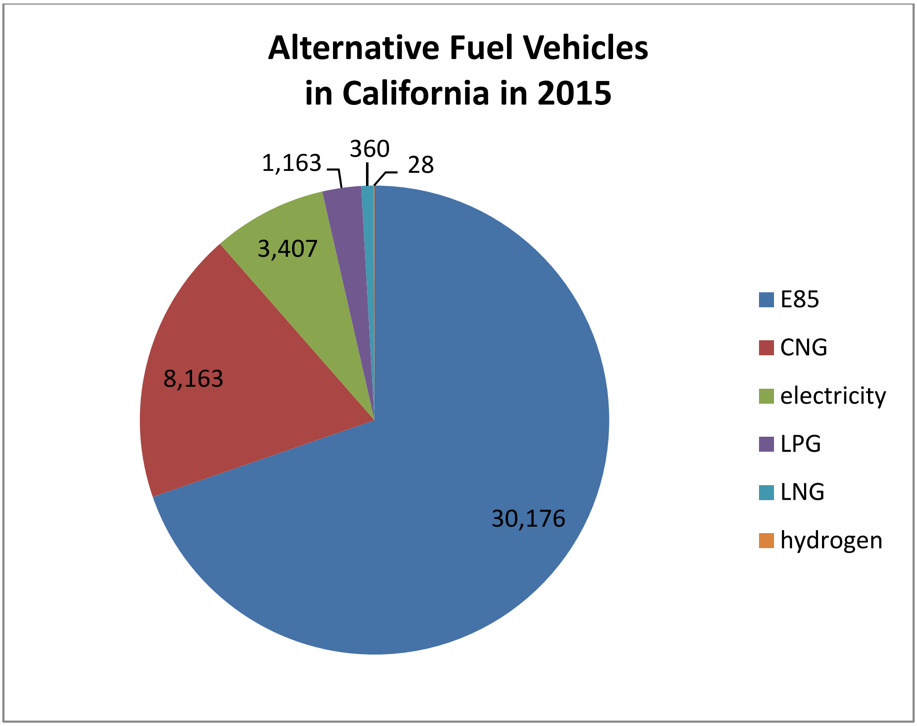

Fig. 4 Number of Alternative Fuel Vehicles in California in 2015
(Source: U.S. Energy Information Administration, Alternative Fuel Vehicle Data)

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 South Korea.

3.b
Country Reports of AMF TCP Member Countries

All 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

In December 2016, the national strategy framework "*Saubere Energie im Verkehr*" (Clean Energy in Transportation)[1] was introduced to the Ministerial Council by the Federal Ministry for Transport, Innovation and Technology, the Ministry of Science, Research and Economy, and the Ministry of Agriculture, Forestry, Environment and Water Management, and was approved. With this national strategic framework, Austria fulfilled an obligation of Directive 2014/94/EU of the European Parliament and Council on the installation of an infrastructure for alternative fuels such as electricity, compressed natural gas (CNG), liquefied natural gas (LNG), and hydrogen (H_2).

Gasoline, especially diesel, is less expensive in Austria than in most neighboring countries because of the relatively low mineral oil tax.

- For gasoline containing a minimum of 46 L biofuel and a maximum of 10 mg/kg sulphur, the tax is €482 ($523 US); the tax is €515 ($559 US) for gasoline with a lower share of biogeneous fuel.
- For diesel containing a minimum of 66 L biofuel and a maximum of 10 mg/kg sulphur, the tax is €397 ($431 US); the tax is €425 ($462 US) for diesel with a lower share of biogeneous substances.

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.

Starting in July 2008, the *Normverbrauchsabgabe* (NoVA) — a uniquely bonus/malus system for carbon dioxide (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 do not have to pay the NoVA. The excess amount (i.e., amount over 90 g) is divided by 5 and gives the NoVA tax rate. For vehicles with CO_2 emissions above 250 g/km, the NoVA increased by €20 ($21.72 US) per g of CO_2.

Austria is pushing strongly for eco-mobility. In November 2016, the Austrian Minister of Transport, Innovation and Technology (bmvit) and the Minister of Agriculture, Forestry, Environment and Water Management (BMLFUW), together with the spokesman of the Austrian automobile importers, presented a package of measures to support electro mobility with €72 million ($78.2 million US), including incentives for buying electric

[1] https://www.bmvit.gv.at/verkehr/elektromobilitaet/downloads/strategierahmen.pdf.

vehicles, installation of charging stations, and a particular number plate for electric vehicles. In addition, states and communities offer many promotions such as purchase premiums.

Advanced Motor Fuels Statistics

Fleet Distribution and Number of Vehicles in Austria

As of December 31, 2016, 8.6 million people were living in Austria. According to Statistics Austria, a total of 6,64,168 vehicles (including 4,821,508 passenger cars) were registered in Austria as of December 31, 2016. Newly registered motor vehicles totaled 430,648 in 2016 (an increase of 7.4% in comparison to 2015). Newly registered passenger cars accounted for 329,604 vehicles — an increase of 6.8% compared to 2015.

An ongoing trend toward advanced propulsion systems can be seen in the number of vehicles with alternative drivetrains on Austrian roads in 2016 (Figure 1).

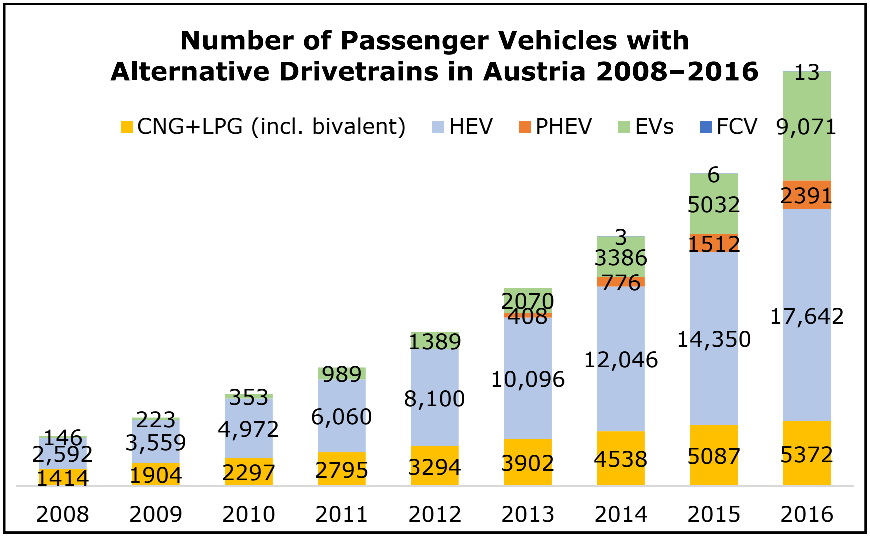

Fig. 1 Trends in Vehicles with Alternative Drivetrains in Austria 2008–2016
(Data Source: Statistik Austria)

Electric vehicles have become more popular within the last few years in Austria. The number of battery electric vehicles (BEVs) increased to 9,071 in 2016 (5,032 in 2015). The number of vehicles driven by CNG and liquefied petroleum gas (LPG), including bivalent ones, rose to 5,372. The number of fuel cell vehicles (FCVs) driven by H_2 increased to 13.[2]

Taking into account the total number of new registrations based on alternative drivetrains (9,028 vehicles), vehicles with alternative drivetrains account for 2.7% of all new registered vehicles. Table 1 shows the development of the fleet distribution of passenger cars by drivetrains between 2013 and 2016.

Table 1 Fleet Distribution of Passenger Cars by Drivetrain in Austria, 2013–2016

Drivetrain	2013	2014	2015	2016
Gasoline	1,997,302[a]	2,004,724	2,012,885	2,031,816
Diesel	2,621,133	2,663,063	2,702,922	2,749,038
Electric	2,070	3,386	5,032	9,071
LPG	1	1	1	1
CNG	2,219	2,397	2,475	2,456
H_2	0	3	6	13
Bivalent gasoline/ ethanol (E85)	6,397	6,380	6,254	6,165
Bivalent gasoline/ LPG	250	279	311	341
Bivalent gasoline/ CNG	1,432	1,865	2,300	2,574
Hybrid gasoline/ electric	10,049	12,232	14,785	18,696
Hybrid diesel/ electric	455	591	1,077	1,337
Total	4,641,308	4,694,921	4,748,048	4,821,508

[a] Includes gasoline/ethanol (E85).

Source: Statistics Austria, KFZ Bestand as per the end of 2013 through December 31, 2016.[3]

Development of Filling Stations

Generally, established trends in the saturated domestic petrol market of petrol stations continued in 2016. By the end of 2016, Austria had a total of 2,622 publicly accessible petrol stations. As an annual average, the price of Eurosuper at the petrol station was €1.11 ($1.21 US) per L; for diesel, the

[2] http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/strasse/kraftfahrzeuge_-_bestand/index.html.

[3] http://www.statistik.at/web_de/statistiken/energie_umwelt_innovation_mobilitaet/verkehr/index.html.

price was €1.03 ($1.12 US) per L. The EU average continued to be clearly above the Austrian average, by €0.19 ($0.21 US) per L for Eurosuper and by €0.11 ($0.12 US) per L for diesel.

The number of natural gas filling stations has slightly decreased in recent years. However, with 171 CNG stations in 2016, 5 of which are biomethane stations, the number of public CNG filling stations compared to the size of the country is still far above the European average. By the end of 2016, three H_2 refueling stations, but no public LNG filling stations, were in operation in Austria.

Research and Demonstration Focus

Federal Funds and Supporting Programs

Since 2007, the Austrian Government has more than tripled public funding in the energy research, development and demonstration (RD&D) sectors, adopted a new energy research strategy, and launched several priority programs. In 2015, Austria's public expenditures for energy-related R&D amounted to €128.4 million ($139 million US), a decrease of €14.7 million ($16.0 million US) compared to 2014. The research areas of energy efficiency (44.4%), smart grids and storage (27.9%), and renewables (17.2%) define the priorities of publicly financed energy research within Austria.

With €10.1 million ($11.1 million US) in 2015, the funding volume for bioenergy slightly increased in comparison to 2014. About 50% of the bioenergy funding was used for applications for heat and electricity. For research in the fields of liquid biofuels and biogas, about €410.000 ($445.000 US) and €510.000 ($554.000 US), respectively, were allocated.

Austria has several programs that fund and support the implementation of advanced fuels and drivetrains. One launched in 2004, called "klima:aktiv Mobil," is Austria's action program for mobility management to reduce CO_2 emissions and to promote environmentally friendly and energy-efficient mobility. The program provides free advice and financial support to help businesses, fleet operators, and property developers, as well as cities, municipalities, regions, and tourism operators to develop and implement sustainable mobility projects and transport initiatives.

In order to develop a sustainable energy system, the "e!MISSION.at" program was funded in 2012 by the Climate and Energy Fund. It supports innovations that make a significant contribution toward protecting the climate and increasing efficiency. The focus of funding is on energy efficiency, renewable sources of energy, smart energy systems, and eco-mobility.

In 2006, bmvit established the Austrian Association for Advanced Propulsion Systems (A3PS) as a strategic public-private partnership for close cooperation among industry, research institutions, and the ministry, with the goal of developing and launching alternative propulsion systems and fuels.

"Mobility of the Future," Austria's national transportation research funding program (2012–2020), was developed and adopted by bmvit. It is a mission-oriented R&D program to help Austria create a transport system designed to meet future mobility and social challenges by identifying and refining middle- to long-term technological improvements. It includes four complementary areas in which different research themes are addressed: personal mobility, transport infrastructure, vehicle technologies, and mobility of goods.

Outlook

Currently, most funding programs and incentives focus on electromobility. Nevertheless, advanced motor fuels are still seen as an important part of the transition toward sustainable mobility in Austria. Some logistic companies run their fleets on biodiesel. However, because of the low price of diesel in Austria and a lack of incentives that cover investment costs, it is unlikely that the trend toward more biofuel vehicles will advance rapidly. Despite well-established CNG infrastructure and existing technological and regulatory framework conditions, market development of CNG vehicles is sluggish. Austria is planning further development of the H_2 infrastructure linked to market development of vehicles running on H_2.

Additional Information Sources

Relevant institutions and programs:

- Austrian Ministry for Transport, Innovation and Technology, https://www.bmvit.gv.at/
- Austrian Federal Ministry of Agriculture, Forestry, Environment and Water Management, https://www.bmlfuw.gv.at/en.html
- Mobility of the future, https://mobilitaetderzukunft.at/en/about/
- klimaaktiv mobil, http://www.klimaaktiv.at/english/
- Climate and Energy funds, https://www.klimafonds.gv.at/home-en-US/
- Austrian Association for Advanced Propulsion Systems, http://a3ps.at

Canada

Drivers and Policies

Renewable Fuels Regulations (RFRs)[4]

The RFRs require fuel producers and importers to have an average renewable content of at least 5% based on the volume of gasoline that they produce or import commencing December 15, 2010. These 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. The RFRs also require fuel producers and importers of diesel fuel and heating distillate oil to have an average annual renewable fuel content equal to at least 2% of the volume of diesel fuel and heating distillate oil that they produce and import commencing July 1, 2011. The *2013 Regulations Amending the RFRs* introduced a national exclusion of heating distillate oil volumes for space heating purposes as of January 1, 2013.

Renewable-Fuels-Related Standards

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 shows the biofuel-related standards for transportation.

Table 1 CGSB Renewable Fuel Quality Related Standards[5]

Fuel Standard	Number
Oxygenated automotive gasoline containing ethanol (E1–E10)	CAN/CGSB 3.511
Automotive ethanol fuel (E50–E85)	CAN/CGSB 3.512
Denatured fuel ethanol for use in automotive spark ignition fuels	CAN/CGSB 3.516
Automotive 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

Passenger Automobile and Light Truck Greenhouse Gas (GHG) Emission Regulations[6]

In 2010, the Government of Canada released the final *Passenger Automobile and Light Truck GHG Emission Regulations*, which prescribe progressively

4 http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=0AA71ED2-1.
5 http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html.
6 https://ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1.

more stringent annual emission standards for new vehicles of model years 2011 to 2016. The Government also published regulations in 2014 for the second phase of action on light-duty vehicles (LDVs), which contain increasingly stringent GHG emissions standards for LDVs of model years 2017 to 2025. Under both phases of LDV regulations, spanning model years 2011 to 2025, the fuel efficiency of new cars will increase by 41% as compared with model year 2010, and the fuel efficiency of new passenger light trucks will increase by 37%. 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 and Engine GHG Emission Regulations[7]

The *Heavy-duty Vehicle and Engine GHG Emission Regulations* establish mandatory GHG emission standards for new on-road heavy-duty vehicles and engines. The regulations apply to companies manufacturing and importing new on-road heavy-duty vehicles and engines of the 2014 and later model years for the purpose of sale in Canada. These include the whole range of on-road heavy-duty full-size pickup trucks, vans, tractors, and buses, as well as a wide variety of vocational vehicles such as freight, delivery, service, cement, and dump trucks. The regulations also include provisions that establish compliance flexibilities, which include a system for generating, banking, and trading emission credits. The regulations include additional credits for hybrid and electric vehicles, as well as for innovative technologies to reduce GHG emissions. The average fuel efficiency of trucks will improve from 2.3 L/100 tonne-km in 2012 to 2.2 L/100 tonne-km by 2020.

Advanced Motor Fuels Statistics

Figure 1 shows the energy use by fuel type in 2013 for transportation in Canada.

[7] https://ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1.

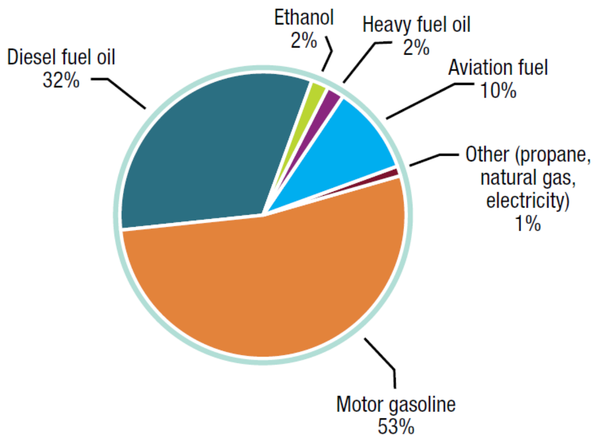

Fig. 1 Energy Use by Fuel Type for Transportation in 2013[8]

Table 2 shows the Canadian supply of and demand for ethanol and biodiesel in 2015.

Table 2 Canadian Supply of and Demand for Biofuels (in millions of liters) in 2015[8]

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[9]

Transport Canada’s eTV Program conducts in-depth safety, environmental, and performance testing on a range of new and emerging advanced vehicle technologies for passenger cars and heavy-duty trucks. The eTV Program will help ensure that Canada is ready for new and emerging advanced vehicle technologies, and that Canadians can benefit from these new innovations.

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

9 https://www.tc.gc.ca/eng/programs/ecotechnology-vehicles-program.html.

Program of Energy Research and Development (PERD)[10]

PERD is a federal, interdepartmental program operated by Natural Resources Canada. PERD supports energy research and development conducted in Canada by the federal government and is concerned with all aspects of energy supply and use. 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.

Energy Innovation Program (EIP)[11]

The EIP supports innovation in the clean energy sector by providing funding for research, development, and demonstration (RD&D) projects. EIP is integral to supporting the Government of Canada’s commitment that Canada's total GHG emissions be reduced, and to contributing to Canadian prosperity and competitiveness by advancing clean energy RD&D.

Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative[12]

The objective of this initiative is to increase the awareness, availability, and use of lower carbon vehicles and fuels in Canada by supporting the installation of up to 70 vehicle fast-charging units, and 6 natural gas and 2 hydrogen refuelling locations along key transportation corridors.

Outlook

As depicted in Table 3, the transportation sector consists of several distinct subsectors — passenger, freight, air, and others (e.g., rail and marine). Each subsector exhibits different trends during the projected period. For example, GHG emissions from passenger transportation are projected to decrease by 8 megatonnes (Mt) between 2005 and 2020, while those for ground freight, off-road, and other vehicles are projected to increase by 10 Mt over the same time period due to economic growth. As a result, net emissions remain essentially stable over the period. Although absolute emissions are expected to grow in the freight subsector due to economic growth, emissions are expected to decrease relative to business-as-usual levels as a result of various federal, provincial, and territorial programs.[13]

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10 http://www.nrcan.gc.ca/energy/funding/current-funding-programs/perd/4993.
11 http://www.nrcan.gc.ca/energy/funding/current-funding-programs/18709.
12 http://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/18397.
13 https://ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1.

Table 3 Transportation: GHG Emissions (Mt CO_2 equivalent)

Transportation Subsector	2005	2012	2020
Passenger Transport	96	94	88
Cars, trucks, and motorcycles	87	85	78
Bus, rail, and domestic aviation	9	8	9
Freight Transport	57	61	67
Heavy-duty trucks, rail	49	54	59
Domestic aviation and marine	8	7	8
Other: recreational, commercial and residential	14	11	12
Total	168	165	167

Passenger energy demand declines over the projection period, largely due to increasing fuel economy associated with Canada's *Passenger Automobile and Light Truck GHG Emission Regulations*. Since passenger travel consumes the majority of gasoline in the transportation sector, this leads to a decrease in the fuel share of gasoline demand. Freight demand is driven by growth in the goods-producing industries and increases at a slower rate than it did from 1990 to 2013. This is from fuel economy gains, associated with Canada's *Heavy Duty Vehicle and Engine GHG Emission Regulations* and somewhat slower economic growth over the projection period. The increase in freight share leads to an increase in the fuel share of diesel.[14]

Additional Information Sources

- National Research Council Canada
  - Automotive and Surface Transportation[15]
  - Industrial Research Assistance Program[16]
- Natural Sciences and Engineering Research Council of Canada[17]
- Sustainable Development Canada[18]

14 https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html.
15 http://www.nrc-cnrc.gc.ca/eng/rd/ast/.
16 http://www.nrc-cnrc.gc.ca/eng/irap/index.html.
17 http://www.nserc-crsng.gc.ca/index_eng.asp.
18 https://www.sdtc.ca/en/apply/funds.

Chile

Drivers and Policies

Chile has considerable potential for implementing energy efficiency measures that would improve the safety of the country's energy supply and achieve significant economic, social, and environmental impacts.

The transport sector represents almost one-third of Chile's final energy consumption, of which 82.6% is due to land transport. Of this energy, 99% is derived from oil, resulting in a high dependence on this energy source, which is mostly imported. Chile only produces about 2% of the oil it consumes.

In 2017, the City of Santiago will initiate one stage of improving public transport through a bidding process for bus operators. The goals of this effort are to reduce travel times, ensure economic sustainability, and improve air quality and energy efficiency. These improvements will be incorporated into the current bus fleet, making the buses cleaner and more efficient.

New Vehicle Energy Efficiency Regulation

The most important targets in relation to the energy efficiency of vehicles in 2016 were the agreements with industry, and the development (administrative, technical, and legal procedures) and final enactment of Decree 107, a new vehicle energy efficiency regulation.

Decree 107 allows for the extension of current Supreme Decree No. 61, enacted in June 2012. This incorporates other vehicle categories under the label of energy efficient, and requires that vehicle energy efficiency be included in written vehicle advertisements, a very important step in advancing regulation. Decree 107 includes all light-duty and medium-duty vehicles that carry cargo and passengers, use diesel fuel, gasoline, are hybrid or electric, and weigh less than 3,860 kg. This regulation was published in December 2016 and should be applicable beginning June 26, 2017. Supreme Decree No. 61 only included s light-duty, diesel, and gasoline vehicles up to 2,700 kg used for passenger transport.

Project of Law – Energy Efficiency

This regulation is still being developed, and it is expected to be submitted to Congress in 2017 to initiate official procedures for its approval. The main objective in the transport sector is to gradually improve the energy efficiency of Chile's vehicle fleet. The first step will be to incorporate standards for light vehicles and later establish standards for other vehicle categories. Development and support are being provided by the Ministry of Energy and the Energy Center of the University of Chile, with the participation of the Ministry of Transport and Telecommunications.

Research and Demonstration Focus

Clean and Energy-Efficient Buses

During 2016 and 2017, Chile has been developing a drive cycle test for Transantiago buses. Transantiago is Santiago's public transport system. Research on heavy vehicles is being conducted at the Center for Vehicle Control and Certification (3 CV) emissions laboratory (Figure 1). The objective is to develop a methodology for establishing requirements for clean and energy-efficient buses. In stage one, the Ministry of Energy, the Ministry of Transport and Telecommunications, and the Mario Molina Center of Chile are obtaining parameters from real bus operations in different routes, lines, and the main avenues of Santiago. These parameters will serve as the basis for developing a drive cycle dynamometer chassis to measure the energy efficiency of the buses. The second stage consists of developing the theoretic cycle, which is being supported by the VTT Technical Research Centre of Finland and AMF programs through Annex 53, Sustainable Bus Systems.

Fig. 1 Chilean Emission Laboratory for Heavy Vehicles with Chassis Dynamometer in the 3CV

Outlook

Metropolitan Region – Santiago, Euro VI Standards for New Buses from 2019

In October 2016, the Chilean Government announced the new phase of its implementation plan for the City of Santiago, which includes Euro VI standards for new buses starting in 2019.

Also, at the end of December 2016, the Ministry of Transport initiated a bidding process for public transport operators in the City of Santiago. New buses were to include Euro VI requirements.

Bus manufacturers responded quickly at the start of 2017 and presented buses for certification (emission, dimension, and safety compliance). Mercedes Benz brought two types of buses built under the Santiago requirements. One uses a European chassis with a body built in Brazil (two buses are running in a regular route). A second Mercedes Benz bus arrived for certification, with a body built by another Brazilian manufacturer. Volvo brought its first bus with a Swedish chassis and Brazilian body for the same process.

Table 1 presents prices for buses in Chile based on information collected in 2016, through consultation with bus manufacturers and dealers.

Table 1 Bus Prices in Chile, 2016

	Urban Bus Diesel Euro V MB from Brazil	Urban Bus Diesel Euro VI MB from Europe	China Bus Yutong Euro V	China Bus Yutong Euro VI[a]	Urban Bus Diesel Euro VI Volvo from Europe	Urban Bus HEV Euro VI Volvo from Europe[b]	Urban Bus PHEV Volvo from Europe
Price aprox. ($1,000 US)	197	224	185	222	231	254	461
Increase in cost over Euro V Brazil		14%	−5%	13%	17%	29%	134%
Comments						10% over diesel version	100% over diesel version

[a] Euro VI buses from China are not in the market yet, but dealers are actively promoting them.
[b] HEVs from Volvo are still Euro V from Brazil; no information is available about when Volvo will bring a Euro VI version from Sweden.

Figure 2 shows Euro VI buses arriving for certification in December 2016.

Mercedes Benz Euro VI – CAIO Body

Volvo Euro VI – CAIO Body

Fig. 2 Euro VI Buses Arriving for Certification in December 2016

The City of Santiago is currently the test laboratory for the development of Latin American low-emission buses. This has been demonstrated by the participation of bus manufacturers in the City's bidding process for bus operators.

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 energy shortage and environmental pollution problems that are resulting 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 was 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.

The goal is to make the pure electric drivetrain a main technology used in developing alternative vehicles and transforming the automotive industry. Currently, the focus is on promoting the industrialization of the pure electric and plug-in hybrid electric vehicle. As part of this focus, China will promote and popularize non-plug-in hybrid and energy-saving vehicles with internal combustion (IC) engines to improve the overall technological level of the country's automotive industry.

Alternative fuel vehicles will be developed according to local conditions. This is a necessary complement to reduce vehicle fuel consumption. The research and application of automotive alternative fuels manufacturing technology will be actively carried out. The development of alternative fuel vehicles will be encouraged in resource-rich regions of natural gas (including liquefied natural gas [LNG]), biofuels, and other fuels. China will explore the application of other alternative fuel technologies and promote the development of vehicle energy diversification.

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 18047-2000, “Compressed natural gas as vehicle fuel” was released on April 3, 2000, and implemented on July 1, 2000. This standard specified the technical requirements for compressed natural gas (CNG) and the test method.
- GB 18350-2001, “Denatured fuel ethanol,” and GB 18351-2001, “Ethanol gasoline for motor vehicles,” were released on April 2, 2001, and implemented on April 15, 2001.
- GB 18351-2013, “Ethanol gasoline for motor vehicles (E10),” and GB/T 22030-2013, “Blendstocks of ethanol gasoline for motor vehicles,” were released on October 10, 2013, and implemented on January 1, 2014.
- GB/T 20828-2007, “Biodiesel blend stock (BD100) for diesel engine fuels,” was released in March 26, 2007, and implemented on May 1, 2014.
- GB/T 25199-2010, “Biodiesel fuel blend (B5),” was released on September 26, 2010, and implemented on February 1, 2011.
- GB/T 25199-2014, “Biodiesel fuel blend (B5),” and GB 20828-2014, “Biodiesel blend stock (BD100) for diesel engine fuels,” were released on February 19, 2014, and implemented on June 1, 2014.
- GB/T 25199-2015, “Biodiesel fuel blend (B5),” and GB 20828-2014, “Biodiesel blend stock (BD100) for diesel engine fuels,” were released on May 8, 2015, and implemented on May 8, 2015.

Advanced Motor Fuels Statistics

In 2016, 197 million tons of crude oil were produced in China — a decrease of 7.3% year-on-year. Meanwhile 324 million tons of petroleum products were produced in China — an increase of 7.8% year-on-year. From January to December 2016, 289 million tons of petroleum products (including diesel and gasoline fuels) were consumed in China — an increase of 5.0% year-on-year. Of this, the consumption of gasoline fuels increased by 12.3% and diesel fuels decreased by 1.2%. 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 2016, 137.1 billion cubic meters (m^3) natural gas, were produced in China — an increase of 1.5 % year-on-year. Meanwhile, 72.1 billion m^3 natural gas were imported — an increase of 17.4 % year-on-year. From January to December 2016, natural gas consumption reached 205.8 billion m^3— an increase of 6.6% from 2015.

In 2016, China's auto production and sales were 28.1 million vehicles and 28.0 million vehicles, respectively, with a year-on-year growth of 14.5% for production and 13.7% for sales.

CNG stations have spread over more than 300 cities across the country's 31 provinces. In 2015, there were 0.55 million new CNG vehicles, while total ownership reached 4.96 million cars — an increase of 12.5% over 2015. In 2015, there were about 245 new CNG stations, and the total number of stations was 4,700— an increase of 5.5% over 2015. In 2015, more than 46,000 new LNG vehicles were produced, while total ownership reached 0.230 million cars — an increase of 25.0% over the previous year. The total number of LNG stations increased to about 2,650 in 2015.

By the end of 2015, there were more than 1,100 filling stations with gasoline with a low proportion of methanol in Shanxi Province. There were approximately 63 stations with gasoline with a high proportion of methanol (M85 and M100). The annual production ability of methanol fuels was about 5.0 million tons. The annual sales of methanol gasoline fuels was more than 0.6 million tons.

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 that three pilot projects involving methanol vehicles had been launched 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 five provincial governments had organized and implemented the pilot projects.

Shanghai is one of the cities that are carrying out the methanol vehicle pilot project required by the Ministry. As part of that project, a taxi test was conducted for 36 months. The cumulative quantity of methanol gasoline used for refuelling has risen to 1,551,200 L. The traveling distance covered by vehicles running on this fuel was 9,695,300 km during the 36-month test, without any related security incidents.

Shanxi Province was the first province to promote the use of methanol gasoline. The province now has 14 production bases. There are more than 900 filling stations operated by Sinopec, Petro China, and the Government that sell methanol gasoline. In 2012, sales reached 800,000 tons. In 2013, a total of 281 methanol vehicles (four models) ran in the pilot operation carried out in Shanxi Province. The pilot cities included Jinzhong, Changzhi, Xi'an, Baoji, Xianyang, Yulin, Hanzhong, and Shanghai.

In June 2015, 100 methanol taxis appeared on the streets of Guiyang, which officially marked the national pilot run of methanol vehicles in the city. By the end of 2015, more than 300 methanol taxis ran on the streets of Guiyang.

By the end of 2015, 628 methanol pilot cars were cumulatively utilized in Shanxi, Shanghai, Shaanxi, Guizhou, and Gansu Provinces. On March 13, 2013, Jinzhong City took the lead in launching the methanol auto pilot in the country. One hundred and fifty methanol cars completed a 2-year pilot run in December 2015. During the pilot, operating vehicles ran 21.29 million km. The largest single vehicle operating range was 244,000 km. The total consumption of methanol fuel was 3.27 million L, and the alcohol consumption rate was 15.35 L per 100 km.

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.

- In terms of industrial structure, China should focus on building the power battery industry to form two to three leading enterprises with an output of more than 10 billion watt hours; establishing the research and production capability for key materials; and developing two to three key industries for components and materials, such as anodes and cathodes, diaphragms, and electrolytes.

- In terms of application and commercialization, China should enlarge the demonstration scope of alternative-energy vehicles in public areas of medium- and large-sized cities; carry out a pilot program for subsidizing the private purchase of alternative-energy vehicles; explore different business models for alternative-energy vehicles, battery leasing, and charging services; and greatly promote and popularize energy-saving vehicles.
- In terms of the construction of charging facilities, China should focus on (a) developing and implementing pilot programs for charging facilities within cities, (b) bringing charging facilities into the relevant industrial areas of city-wide transportation systems and construction, and (c) actively carrying out the spreading slow-charging mode at private and public parking stands.

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 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[19]

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. 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 to transform Denmark into a green sustainable society with a stable energy supply. The strategy is also fully financed and takes full account of Danish competitiveness. In March 2012, a historic new Energy Agreement was reached in Denmark. 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 become independent of fossil fuels by 2050.

Advanced Motor Fuels Statistics

Energy consumption by the transport sector today amounts to about 30% of total Danish final energy consumption and is almost entirely composed of fossil fuels. The sector includes road transport, rail transport, aviation, and domestic shipping, as well as energy consumption by the military for transport purposes. Road transport today accounts for 75% of energy consumption, followed by aviation (20%), of which most is for international air travel. With regard to road transport, cars account for more than 60% of energy consumption, vans and lorries each account for about 15%, while buses and motorcycles account for the remaining 10%.

Historically, the number of kilometers driven and energy consumption increased steadily until the 2008 economic crisis, which came at the same time as greater focus on energy-efficient cars. Increases in energy efficiency are due to a European Union (EU) Regulation under which car manufacturers must reduce carbon emissions. This led to a greater range of small, energy-efficient cars. In Denmark, the use of energy-efficient cars has been further promoted by changes in the vehicle registration tax introduced in 2007 favoring such vehicles.

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19 The information given in this report was mainly derived from Danish Energy Agency, 2015, *Danish Energy and Climate Outlook 2015,* December, https://ens.dk/sites/ens.dk/files/Analyser/danish_energy_and_climate_outlook_2015.pdf.

Thus far, the green transition of the transport sector has been very limited. A small percentage of rail transport is powered by electricity, and, since 2006, biofuels have been mixed in petrol and diesel for road transport. Otherwise, almost all other energy consumption is from fossil oil products (about 95%).

Total energy consumption by the transport sector is expected to increase by slightly more than 2% up to 2020 compared with the current level (Figure 1). After this, energy consumption will rise slightly in the period 2020 to 2025. The rise will primarily be due to an increase in international air travel of 12% up to 2025, and a small drop in energy consumption for road transport.

Consumption of diesel will continue to increase, with a corresponding drop in petrol consumption, and, from 2020, it is expected that a greater percentage of biofuels will be used. It is currently unclear whether, and to what extent, there will be requirements to increase the level of biofuel blending.

It is unlikely, however, that a mix of up to 10% will be realistic, as has previously been assumed. On the other hand, an increased biofuel blending in petrol has been assumed from 2020, bringing the total biofuel blending in petrol and diesel to about 6.6% (in relation to the energy content).

It is expected that the number of kilometers driven on the roads will increase in the future (Figure 2). More efficient vehicles ensure that total energy consumption is kept more or less constant, despite an increasing number of kilometers driven. Developments are shown for total road transport; however, there will be differences between the different types of transport. Thus, in 2020, 11% more kilometers will be driven than in 2014, and in 2025, 20% more kilometers will be driven than in 2014. Both passenger and freight transport will increase. The increase is due to economic growth combined with expansion of the infrastructure, which will lead to greater mobility for society. At the same time, new cars are expected to be more energy efficient, although not to the same degree as the efficiency improvements seen between 2007 and 2012. If the trend of recent years continues, new sales will meet the standard EU requirement of 95 grams of carbon dioxide per kilometer (95 gCO_2/km), which will apply from and including 2021. Overall, vehicles on the roads will be more efficient as older vehicles are scrapped and replaced with new, more efficient vehicles. This increased efficiency balances out the increases in the number of kilometers driven, so that total energy consumption will remain more or less stable. This assessment takes into account the changes in vehicle registration tax adopted in the 2016 Finance Act9.

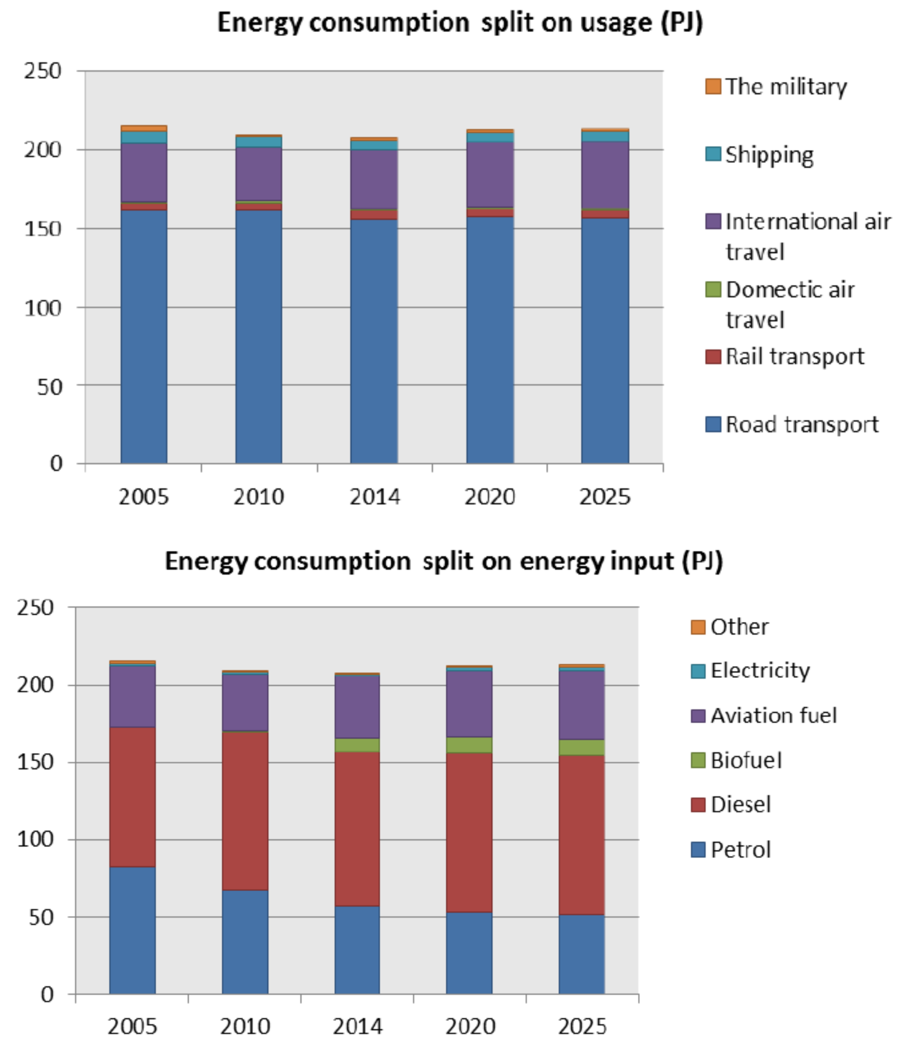

Fig. 1 Expected Development of Energy Consumption in Denmark, 2005–2025

However, there is great uncertainty regarding changes in efficiency and number of kilometers driven. This uncertainty can be attributed to factors such as consumer behavior, including the type of car consumers buy, how often they replace their car, and how much they use it.

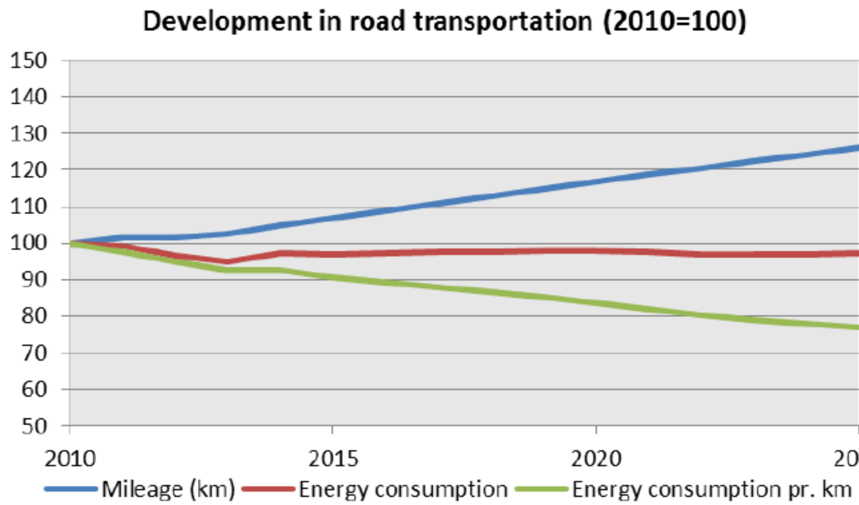

Fig. 2 Expected Development of Transport Work in Denmark, 2010–2025, Relative to Work in 2010

There is no indication that cars, buses, and lorries will move away significantly from petrol and diesel power to electricity, natural gas, and hydrogen before 2025. These alternatives are still expensive compared with conventional fuels, and there is a lack of infrastructure (primarily for gas and hydrogen). No significant technological breakthroughs are expected up to 2025 under current conditions to enable these alternative vehicles to become more widespread; therefore, there will be only limited increases (see Table 1). The alternative vehicles account for less than 0.4% of energy consumption by road transport in 2025.

Table 1 Cars, Buses, and Lorries in Denmark Using Alternative Fuels, 2016–2025[a]

Vehicle Type	Fuel	2016	2020	2025
Cars (number)	Electricity	4,000	6,000	10,000
	Natural gas/biogas	~0	~0	~0
	Hydrogen	~0	200	400
Busses and lorries	Electricity	5	100	300
	Natural gas/biogas	10	300	750

[a] Limited increases in the number of alternative vehicles running on electricity, natural gas, and hydrogen are expected; together, these are also likely to have a very small effect on energy consumption. There are possibly a few cars in Denmark running on gas and hydrogen, but how much these cars are used in practice is unclear, and, therefore, numbers have been rounded to 0 in the projection.

Research and Demonstration Focus

Research and demonstration in Denmark are focused on electric vehicles and fuel cell vehicles for passenger cars. Several demonstration projects have been initiated. For 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 has a goal 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.

Additional Information Sources

Further information can be found in Energistyrelsen, www.ens.dk.

Finland

Drivers and Policies

In 2015, total energy consumption in Finland was 1,305 petajoules (PJ), and the share of renewable energy was 35%. In 2015, road transportation consumed about 17% (177 PJ) of the total final energy consumption.[20] Transport produces 20% of Finnish greenhouse gas (GHG) emissions, and 90% of transport emissions are from road transport.[21]

In November 2016, the National Energy and Climate Strategy outlined the actions that will enable Finland to attain the targets specified in the Government Programme and to set the course for achieving an 80 to 95% reduction in GHG emissions by 2050.[21] The targets for transport include:

- Reducing traffic emissions by 50% compared to 2005, by 2030.
- Increasing the physical share of biofuel energy content in fuels sold for road transport to 30% by 2030.
- Increasing the number of electric vehicles (EVs) (or hydrogen-powered and rechargeable hybrids) to a minimum of 250,000 and the number of gas vehicles to 50,000 by 2030.

Other measures include improving the energy efficiency of vehicles and the transport system as a whole, and speeding up the replacement rate of Finland's vehicle fleet. The refueling station network for new fuels and the network of recharging points for EVs will mainly be built on market-based terms.[21] The role of increased use of alternative propulsion systems in vehicles and drop-in biofuels has been emphasized.[22]

Advanced Motor Fuels Statistics

The total consumption of gasoline and diesel in Finland in 2015 was 4.1 megatonnes of oil equivalent (Mtoe) (Table 1). Of that, 492 ktoe were biofuels, with an actual share of 12% (with double-counting about 23%). This already surpasses the target of the national biofuel obligation law, calling for 20% biofuels (calculatory) in 2020. Ethanol is used in Finland both as such and as fuel ethers; that is, as ethyl tertiary-butyl ether (ETBE) and tertiary-amyl ethyl ether (TAEE). The bioportion of diesel fuel mainly consists of paraffinic renewable diesel fuel.

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[20] http://www.stat.fi/.

[21] Huttunen, R. (ed.), 2017, "Ministry of Economic Affairs and Employment," December.

[22] Ministry of Transport and Communications of Finland (MINTC), 2015, *Alternative Fuels Infrastructure – A Proposal for a National Framework until 2020/2030*.

Table 1 Use of Road Transportation Fuels in Finland in 2015

Gasoline[a] (Mtoe)	Diesel[a,b] (Mtoe)	Ethanol & Ethers[c] Total/Bio[d] (Mtoe)	Renewable Diesel[b] Total/Bio[d] (Mtoe)	Bio-gasoline (Mtoe)	Methane Total/Bio (Mtoe)
1.5	2.6	0.149/0.069	0.421/0.421	0.009	0.004/0.002

[a] Includes alternative/bio.
[b] Mainly renewable diesel as biocomponent.
[c] Ethanol partly as fuel ethers.
[d] Bio = meets EU's sustainability criteria (2009/28/EC; without double-counting).

Source: Finnish Petroleum and Biofuels Association and Finnish Customs

The total road vehicle fleet in use in Finland in 2015 was approximately 3 million (excluding non-road) vehicles (Table 2). This included around 3,500 flex-fuel vehicles (FFVs) capable of using E85, around 2,000 gas vehicles using natural gas or biomethane (or bi-fuel gasoline/methane), and 1,000 EVs. The average age of cars was 11.7 years in 2015, and the age of cars scrapped was greater than 20 years.

Table 2 Types and Numbers of Vehicles in Use in Finland by December 31, 2016[a]

Passenger Cars	Vans	Trucks	Buses	Two-Wheelers	Other Vehicles	Non-road
2,629,432	311,376	94,780	12,471	314,639	2,749	533,263

[a] 479 cars per 1,000 inhabitants; 37% of cars were diesel cars.

Source: Finnish Transport Safety Agency, Trafi

Renewable Diesel Fuels

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

Neste Corporation produces a renewable paraffinic diesel fuel, NEXBTL, at worldwide capacity of 2.6 Mtoe/year. In 2016, almost 80% of Neste's renewable diesel production was based on waste and residue raw materials. Neste Pro Diesel contains at least 15% Neste renewable diesel. In the beginning of 2017, a renewable diesel fuel made entirely from waste and residues, Neste MY Renewable Diesel, was launched at select service stations. Neste's renewable diesel is increasingly used in global markets.[23]

[23] www.neste.com/en/neste-renewable-diesel-power-fleet-yet-another-major-californian-city-city-san-diego-switched; www.neste.com/en/nestes-renewable-diesel-decarbonize-hamburg-airports-ground-fleet.

The Finnish pulp and paper company UPM produces approximately 0.12 Mtoe annually of hydrotreated renewable diesel, UPM BioVerno, from crude tall oil in Lappeenranta. Currently, 10 vol-% of UPM BioVerno is blended to diesel fuel and sold at St1 Biofuels Oy (Diesel Plus) and ABC (Smart Diesel) refueling stations in Finland.

A minor amount (~0.019 Mtoe) of conventional esterified biodiesel, that is, fatty acid methyl esters (FAME), was used in Finland in 2015.

Bioalcohols and Ethers

In 2015, 56 ktoe of fuel bioethanol was sold in Finland (8.2 ktoe E85). Since 2011, RED95 ethanol-diesel has been tested in Helsinki using Scania's ethanol-diesel engines in three trucks and two buses. The energy company St1 Biofuels has four decentralized Etanolix® plants using waste from the food industry, 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. The majority of transportation fuel bioethanol consumed in Finland is still imported.

In 2015, approximately 83 ktoe of bioethers, mainly ETBE and TAEE, were blended in gasoline in Finland.

Biogasoline

Small amounts of biogasoline components are produced at Neste's and UPM's renewable diesel processing units, and blended in gasoline. Neste Oil produces traffic fuels also using tall oil pitch as a feedstock at the Naantali refinery.[24] Biogasoline contains only biohydrocarbons (oxygen-free).

Natural Gas and Biomethane

At Gasum's public filling stations, approximately 40% of customers select biomethane.[25] The bus company Helsingin Bussiliikenne switched to biomethane in 2016. Several enterprises have opted for gas vehicles. Skangas has Finland's first liquefied natural gas (LNG) terminal for industry and ships in Pori (30,000 cubic meters [m^3], 15,000 metric tons [t]).[26] Gasum has opened Finland's first LNG fuelling station for heavy-duty

[24] www.neste.com/en/neste-oil-uses-tall-oil-pitch-produce-traffic-fuel.

[25] Gasum Financial Statements, 2015, https://www.gasum.com/globalassets/avainluvut/avainluvut-2015/gasum_financial_statements_2015.pdf.

[26] www.skangas.com/en/our-portfolio/terminals/pori-terminal/.

vehicles at Vuosaari in Helsinki.[27] Skangas also has LNG production plants and a terminal in Porvoo, Finland.

Electric and Hybrid Electric Vehicles (HEVs)

Demonstration of fully electric buses started in Espoo in 2012. The public transportation authority in metropolitan Helsinki, Helsinki Region Transport (HSL), 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.[28] The goal is to have 400 electric buses operating in the Helsinki region by 2025.

Hydrogen

Demonstration of fuel-cell–powered working machinery commenced in the harbor of Helsinki in 2013. The first commercial hydrogen fueling station in Finland opened in 2014 in Helsinki, and at Voikoski, one station opened for Finland's first, and, so far, only hydrogen car.

Research and Demonstration Focus

Special funds have been made available to stimulate research and demonstration of next-generation biofuels in Finland. The TransSmart program started by the Technical Research Centre of Finland Ltd (VTT) in 2013 focuses on four core areas: low-carbon energy, advanced vehicles, smart transportation services, and transportation systems.[29] HSL has offered bus operators the opportunity to test new electric buses without impacting operators' finances. LignoCat, 2013–2017, is focusing on developing a catalytic pyrolysis technology for upgrading bio-oil and will commercialize the solution. BTL2030, 2016–2017, aims to produce transport fuels from biomass by gasification-based concepts integrated with industries and district heat power plants. The High Value Bio-oils for Transportation and Diesel Power Plants project, 2014–2017, supports Finnish industries in developing and introducing second-generation biofuels.

Outlook

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

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27 www.gasum.com/gasum-yrityksena/medialle/uutiset/2016/suomen-ensimmainen-raskaan-liikenteen-kaasutankkausasema-vuosaaren-satamaan/.

28 www.hsl.fi/en/news/2017/helsinkis-first-fully-electric-bus-hit-road-january-9590.

29 http://www.transsmart.fi/transsmart/in_english.

Ethanol

In 2017, St1 Biofuels starts Cellunolix® bioethanol production in Kajaani, using sawdust and chips as feedstock (5 ktoe/year). St1 and SOK´s joint venture North European Bio Tech Oy (NEB) is planning a 50-million liter (L) (~25 ktoe) Cellunolix® bioethanol plant in Pietarsaari. It is estimated that the investment decision will be made in 2018, and the Cellunolix® plant could start up in 2020. NEB is also looking into expanding the Kajaani Cellunolix® plant by 25 ktoe/year. Suomen Bioetanoli Oy received 30 million € (34 million $US) energy support from The Ministry of Employment and the Economy in 2014 to build a new straw bioethanol plant at Myllykoski, Kouvola (~45 ktoe/year).

Renewable Jet Fuel

Oslo's Airport at Gardermoen is the world's first airport to offer renewable aviation fuel refined by Neste.[30] Lufthansa, SAS, and KLM announced that they will refuel their planes with this renewable fuel in Oslo. Neste's renewable aviation fuel is refined in Porvoo, and it meets the strict quality requirements for aviation fuels. The fuel is transported to Oslo as a 50% blend with fossil aviation fuel.

Methane

The LNG infrastructure being built up offers opportunities to consider LNG for heavy-duty transportation. The Tornio Manga LNG project plans to construct a terminal with 50,000 m^3 of storage capacity by 2018.[31] Gasam will construct four LNG/liquefied compressed natural gas (LCNG) refuelling stations for heavy-duty vehicles in 2016–2017. Haminan Energia Oy has plans to construct a LNG terminal in Hamina. 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).

Major Changes

In 2016, the National Energy and Climate Strategy outlined the actions that will enable Finland to reduce GHG emissions. The targets aim at, amongst others, to cut traffic emissions by some 50% by 2030 compared to 2005, and to increase the physical share of biofuel energy content for road transport to 30%. The goal is to have a minimum of 250,000 EVs (also hydrogen and rechargeable hybrids) and 50,000 gas-powered vehicles by 2030.

30 https://www.neste.com/en/oslo-airport-first-world-offer-nestes-renewable-aviation-fuel.

31 http://www.torniomangalng.fi/en/hankkeen-esittely/.

Germany

Drivers and Policies

The development of advanced motor fuels in Germany is driven by the goals of fulfilling European and international climate protection strategies and reducing particulate matter (PM) and nitrogen oxide (NO_x) emissions in highly polluted metropolitan areas. The Volkswagen NO_x emission incident remains a leading public driver for improving test cycles and better controlling of vehicle manufacturers, as well as for the ban of high-pollutant engine technologies in urban centers. Major changes in the consumption of advanced fuels have been seen in the electrification of the fleet, although overall numbers remain at a comparable low level (see Advanced Motor Fuels Statistics [AMFS]). In the field of research, development, and exploitation, refineries implemented by, for example, Clariant (BtL – Biomass to Liquid) and Audi AG in Werlte (PtG – Power to Gas) have again proven market readiness for the advanced fuels' market.[32] German market players are predicting a challenging situation for advanced fuels in the near future due to the establishment of European Union (EU) and German policies, as well as the remaining low price of conventional fossil fuels. Only a committed policy to support advanced motor fuels can strengthen an advanced fuel market.

Since January 2015, the benchmark for biofuel quotas has been based on a net greenhouse gas (GHG) reduction. This net quota increased from 3.5% in 2015 to 4% in 2017, and will rise to 6% in 2020. Biomethane can also be used to fill the quota. Furthermore, the amendment to the German Emission Control Act (Bundes-Immissionsschutzgesetz-BImSchG, December 2014) has banned all double-counting and excludes animal fats and bio-based oils that are co-refined with fossil-based oils from the quota eligibility. Biofuels are currently the only way to fulfill the target. However, a recent bill will expand the list to include animal fats, co-refinering, Power to X (PtX), the use of electricity in electric vehicles (EVs), and the upstream emissions reduction.

To decarbonize the transport sector, high priority has recently been given 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. In addition, liquefied natural gas (LNG) for heavy duty transport (HDT) and waterborne

[32] Clariant sunliquid® (www.clariant.com/en/Innovation/Innovation-Spotlight-Videos/sunliquid); Mercedes fleet (www.haltermann-carless.com/fleet_test_with_mercedes_benz_vehicles_proves_fuel_quality_of_2nd_generation_biofuel_sunliquid_20); Audi (www.hz-inova.com/cms/en/home?page_id=4896).

application is strongly supported by the German Government. The Federal Ministry of Transport and Digital Infrastructure (BMVI) has provided €1 billon ($1.2 billion US) in incentives for improving alternative fuelling infrastructure, implementing buyers' grants to buy EVs, and fostering research, development, and demonstration (RD&D) in these fields. This also includes the implementation of a competitive infrastructure for hydrogen and fuel cell technology ("National Strategy for the Expansion of Alternative Fuels' Infrastructure"). In addition, in 2015, the BMVI established grants for public procurement incentives to equip fleets with EVs.

The German Government's goal is to have at least 1 million registered EVs by 2020. Electrification of transport is the main governmental strategy for reducing GHG emissions in this sector. But despite the new incentives given since 2016, EV sales remain low (see AMFS), and thus Germany is still at risk of missing the 1 million EV goal and its climate targets for road transportation.

The support of the CNG infrastructure is well received by the German NG interest groups. However, the experts also underline that the current tax reliefs for NG must be prolonged beyond 2018 to guarantee the viability of this fuel type in Germany. The absence of a political decision about tax reliefs has already negatively affected the deployment of NG vehicles and infrastructure in the market (see AMFS). A recent bill foresees prolongation of tax exemptions for CNG beyond 2018 — until 2026. Tax exemption for liquefied petroleum gas (LPG) will be phased out.

Recently, direct incentives have been implemented for using advanced motor fuels by a partial tax exemption for natural gas (CNG and LNG) and LPG as transport fuel until the end of 2018. Tax exemptions on biofuels in the agricultural and forestry sector underpin a niche market and will be effective beyond 2017.

Advanced Motor Fuels Statistics

The discussion, figures, and tables that follow show fuel consumption in Germany and the number of registered vehicles separated by fuel type.

Figure 1 shows the 2016 German fuel consumption for use in road transportation. The consumption of biofuels amounted to 3.4 Mt, with the majority being low-level blends of biodiesel and hydrotreated vegetable oil (HVO) and bioethanol. Due to the inexistence of incentives (e.g., tax

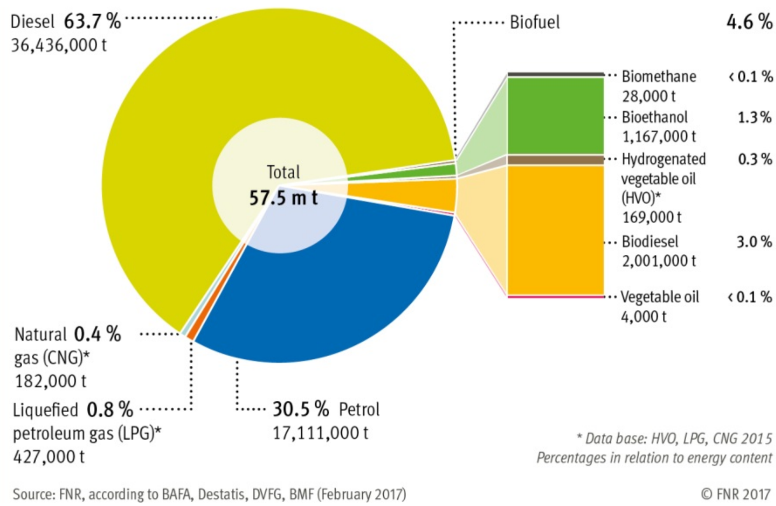


Fig. 1 Fuel Consumption in the Transport Sector in Germany in 2016
(Source: FNR on the basis of BAFA et al. 2017.[33])

exemption) there is no market demand for E85 and pure biodiesel (see Tables 1 and 2).

Tables 1 and 2 show the 2016 trends for biofuels and biofuel supplements. The switch at the beginning of 2015 in the biofuels quota legislation from quantitative quotas (energy content) to GHG-reduction quotas, and the settlement of a compromise on the EU level on the Renewable Energy Directive (RED) in 2015, has provided a small impetus for using advanced biofuels.

Table 1 Trends in German Biodiesel Sales, 2009–2016

Sale (kt)	2009	2010	2011	2012	2013	2014	2015	2016[a]
Blend	2,191	2,236	2,116	1,928	1,741	1,970	1,979	2,001
Pure biodiesel	241	293	97	131	30	5	3	NA
Total	2,431	2,529	2,213	2,059	1,772	1,975	1,983	2,005

[a] Data available for Jan–Nov 2016; extrapolated for Dec 2016.

Source: FNR on the basis of BAFA et al. 2017.[33]

[33] Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle; BAFA) et al., 2017, (Federal Statistics Office [Destatis], DVFG [German LPG Association], the Federal Ministry of Finance [Bundesministerium der Finanzen; BMF], Agency for Renewable Resources [Fachagentur Nachwachsende Rohstoffe e.V.; FNR]), February.

Table 2 Trends in German Bioethanol Sales, 2009–2016

Sale (kt)	2009	2010	2011	2012	2013	2014	2015	2016[b]
E85[a]	9(7)	18(15)	19(16)	21(17)	14(11)	10(8)	7(6)	n/a
Ethanol	687	1,028	1,054	1,090	1,041	1,082	1,049	1,043
ETBE[c]	198	122	162	142	154	119	116	124
Total	892	1,165	1,233	1,249	1,206	1,209	1,171	1,167

[a] Including only share of ethanol.
[b] Data available for Jan–Nov 2016; extrapolated for Dec 2016.
[c] Ethyl tertiary-butyl ether; percentage by volume share of bioethanol in ETBE = 47%.

Source: FNR on the basis of BAFA et al. 2017.[33]

In 2016, 97% of the crude oil used in Germany had to be imported. Sources of imported crude oil are relatively well diversified, whereas 40% account for imports from the Russian Federation.[34]

Table 3 shows the number of passenger cars on the road in Germany by fuel type for 2012 through 2016.

Table 3 Number of Passenger Cars in Germany by Fuel Type on January 1 of Given Year[a]

Year	Gasoline	Diesel	LPG	NG	EV	Hybrid
2012	30,452,019	11,891,375	456,252	74,853	4,541	47,642
2013	30,206,472	12,578,950	494,777	76,284	7,114	64,995
2014	29,956,296	13,215,190	500,867	79,065	12,156	85,575
2015	29,837,614	13,861,404	494,148	81,423	18,948	107,754
2016	29,825,223	14,532,426	475,711	80,300	25,502	130,365

[a] LPG = liquefied petroleum gas according to European fuel quality standard EN 589. NG = natural gas according to German fuel quality standard DIN 51624. EV = electric vehicle.

Source: KBA 2016.[35]

A total of 54.6 million vehicles, including 4.2 million motor bikes were registered in Germany as of January 1, 2016; 45.1 million (86%) were passenger cars. Of the registered vehicles, 2.8 million (5.1%) were trucks and 1.4 million were agricultural and forestry machinery. The rest were buses and other vehicles.

[34] BAFA, 2016, *EnergieINFO, Rohölimporte*, December.
[35] KBA (Kraftfahrt-Bundesamt; Federal Motor Transport Authority), 2016, *Fahrzeugbestand im Überblick am 1. Januar 2016*.

Research and Demonstration Focus

Public funding in the field of advanced motor fuels on the national scale is supported by the BMVI (infrastructure, e-mobility, LNG, CNG; “national Strategy to Extend the Infrastructure for Alternative Fuels”), the Federal Ministry of Education and Research (BMBF) (PtX; “Kopernikus Projects”), and the Federal Ministry of Food and Agriculture (BMEL) (biofuels, biomass-to-liquid [BTL]).

Under the Renewable Resources Funding Scheme of the BMEL, 19 R&D projects are receiving funding of €5 million ($5.3 million US; ongoing projects in 2016). This support includes funding for projects related to bioethanol, biodiesel, vegetable oils, biomethane, and advanced biofuels.

The focus of the advanced fuels projects has been on the production of:

- Hydrocarbon from biochemical pathways,
- Fuels by other renewable resources (e.g., kerosene from algae), and
- Renewable oxygenates as gasoline and diesel blending components.

Nevertheless, under this funding scheme, a reasonable decrease in funded projects related to biofuels can still be seen.

Outlook

Policy and research development frameworks at the EU and international level will strengthen the advanced motor fuel market. But new debates by the European Commission (EC) to revise the RED and Food Quality Directive (FQD) and the advanced fuels quota, will again alienate fuel producers and the related market. Measurements discussed above to promote e-mobility, CNG, and LNG will have a positive impact on the market. Further R&D activities (e.g., reducing the GHG emissions of biofuels to make them compatible with the amended RED and FQD, and upscaling advanced biofuel production processes to an industrial scale) are persistent challenges for the near future.

Additional Information Sources

- Bundesverband der deutschen Bioethanolwirtschaft, www.bdbe.de
- Bundesverband Regenerative Kraft, www.brm-ev.de/en
- Federal Ministry of Transport (BMVI), www.bmvi.de/EN
- Federal Ministry of Education and Research (BMBF), www.bmbf.de/en
- Federal Ministry of Food, Agriculture (BMEL), www.bmel.de/EN
- Federal Motor Transport Authority (KBA), www.kba.de/EN
- Verband der Deutschen Biokraftstoffindustrie, biokraftstoffverband.de

Israel

Drivers and Policies

In 2011, the Fuel Choices Initiative (http://www.fuelchoicesinitiative.com /our-goals), 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 10 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 500 companies, 220 research groups, and hundreds of entrepreneurs (see Table 1).

Table 1 Growth of Israel's Alternative Fuels Research Groups, Industry, and Investment, 2011–2016

Year	Research Groups	Companies	Cumulative Investments (€million)
2011	45	60	250
2016	220	500	2,000

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.

Recent Standards

The Standards Institution of Israel issued in 2016, a new standard for M15 (85% gasoline with 15% methanol). This is the first standard for a low percentage methanol fuel issued outside of China. Standards and methods of implementation for compressed natural gas (CNG) vehicles, fuel stations, and vehicle repair shops have also been issued in the last few years.

Taxation

On 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.

Advanced Motor Fuels Statistics

Table 2 presents fuel and vehicle use in Israel in 2016.

Table 2 Fuel and Vehicle Use in Israel in 2016

Parameter	Gasoline	Diesel				Jet Fuel
Type of Vehicle	Mainly Private Vehicles	Trucks	Buses	Private Vehicles, Minibuses, Taxis, and Other	Trains	Jet Planes
No. of vehicles	2,665,274	324,137	20,146	100,000	Not specified	Not specified
Total fuel consumption (thousand tons)	3,169	3,216				934
Current usage of fuel (%)	43	44				13

Research and Demonstration Focus

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

- *Subsidies for 500 Electric Vehicle (EV) taxis.* The Israeli Government issued 500 reduced rate taxi licenses (Medallion Licenses) for electric taxis.
- *Eilat EV taxi pilot.* Initiation of a pilot project in Eilat to examine the practical and economic aspects of operating EV taxis.
- *Support for the purchase of electric buses*. The Israeli Government provides budgetary support in order to encourage the purchase of electric buses. Egged, one of the largest public transport operators in Israel, was the first to win a grant for 25 electric buses in the Haifa area. The Initiative also supports the testing of other electricity-based technologies in buses, such as super-capacitors.
- *CNG buses and garbage trucks.* The Ministry of Transport allocates budgets for purchasing CNG buses for public transport operators. With the high number of annual kilometers traveled by buses, the use of CNG buses will make a significant contribution to reducing pollutant emissions and dependence on oil. Resolution 529 of the Israeli Government called for reducing air pollution and environmental risks in Haifa Bay. Egged and the Haifa Municipality are preparing for implementation by acquiring CNG buses and garbage trucks.
- *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.
- *Railway network electrification.* A program that aims to upgrade Israel's rail infrastructure and train fleet to electrically powered propulsion. The upgrade will reduce oil consumption by 85%, increase energy efficiency, reduce pollutant emissions, improve operations and transportation system reliability, and save on energy maintenance costs.

Major Research Centers and Grants

The following activities are being carried out by major research centers and grants:

- 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.
- The Ministry of Environmental Protection promotes research projects and coordinates knowledge in relation to the environmental impacts and aspects of alternative fuels for transportation.
- The Ministry of Transport 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 National Infrastructure, Energy and Water Resources supports different programs that encourage entrepreneurship and innovation in the field of alternative fuels. The programs support research and development (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, in order to develop the human resources pool for different areas of expertise in the alternative fuel professions and research areas.
- The Ministry of Economy and Industry
  One-Stop Center for Companies
  The Fuel Choices Initiative operates a special “onestop” center for businesses, together with the Ministry of Economy, under the auspices of the Israel NewTech Division and the Investment Promotion Center. The center assists businesses in overcoming obstacles in the regulation process.
  Scale Up: Co-Invest Fund
  A 400 million NIS ($100 million US) co-investment fund promotes large investments in venture-backed companies working in the field of alternative fuels and smart mobility. Companies benefit from the program by receiving additional funding from the Government, in the form of a conditional loan, on top of investment raised privately. The investor has the option of paying off the government loan and receiving additional shares in the company for the same terms of the original round of investment. If the investor does not exercise this option, the company must repay the loan only in the case of financial success, through royalties from sales.

Ministerial Research Grants and Programs

The Fuel Choices Initiative, together with the Council for Higher Education, supports several major research programs at Israeli universities.

- The Israel National Research Center for Electrochemical Propulsion (INREP) is a multi-disciplinary center dedicated to the R&D of electric mobility. This includes development of advanced materials and technologies for EVs, batteries, and fuel cell-based propulsion for transportation.
- The Israel Science Foundation (ISF) has developed several programs aiming to promote, encourage, and support excellent research in the field of petroleum alternatives for transportation, including individual research grants and grants for holding international workshops.

Outlook

Figure 1 shows the expected penetration rate for alternative fuels in Israel for 2015 through 2030.

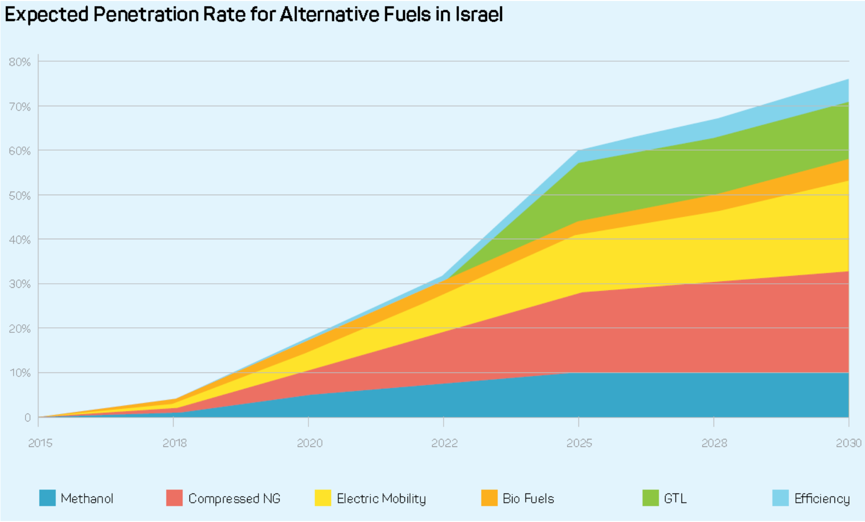


Fig. 1 Expected Penetration Rate for Alternative Fuels in Israel, 2015–2030
(Source: Prime Minister's Office, 2016, Fuel Choices Initiative Report, http://www.fuelchoicesinitiative.com/wp-content/uploads/2016/07/Fuel_choices_initiative-WEB-2016.pdf)

Additional Information Sources

- Israel's automotive and smart mobility industry – Roland Berger's Study,http://www.fuelchoicesinitiative.com/wp-content/uploads/2016/07/Israels-automotive-and-smart-mobility-industry.pdf
- Fuel Choices Initiative Brochure, http://www.fuelchoicesinitiative.com/wp-content/uploads/2016/07/Fuel_choices_initiative-WEB-2016.pdf

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. The "Basic Act of Energy Policy" was enacted in June 2002 for the purpose of ensuring the steady implementation of energy policy.

The point of the energy policy is to first and foremost ensure stable supply ("Energy Security") and to realize low-cost energy supply by enhancing its efficiency ("Economic Efficiency") on the premise of "Safety." It is also important to make maximum efforts to pursue environment suitability ("Environment").

In terms of primary energy, Japan's new Strategic Energy Plan, approved in April 2014, discusses the use of nuclear power and ensuring safety, improving the efficiency of electricity generation, expanding the use of liquefied natural gas (LNG) and liquefied petroleum gas (LPG), and places an emphasis on reducing the cost of renewable energy.

On April 30, 2015, the Ministry of the Environment (MOE) and the Ministry of Economy, Trade and Industry (METI) presented a Government proposal that sets a target for the level of greenhouse gases in 2030 "to be reduced by 26% compared to the level in 2013."

In the transportation sector, in order to improve the energy efficiency of automobile transportation, Japan will take measures such as increasing 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 for a wider variety of energy sources.

In spreading and expanding the introduction of next-generation vehicles, research and development (R&D) 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 [1] in Japan. Oil-related energy accounts for 97.8% of total usage. The market for alternative fuels is very small in Japan, as is the number of alternative fuel vehicles (Table 1). Methanol, CNG, hybrid, EVs, and FCVs currently constitute the low-emission 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 already launched; Japan has 630 FCVs.

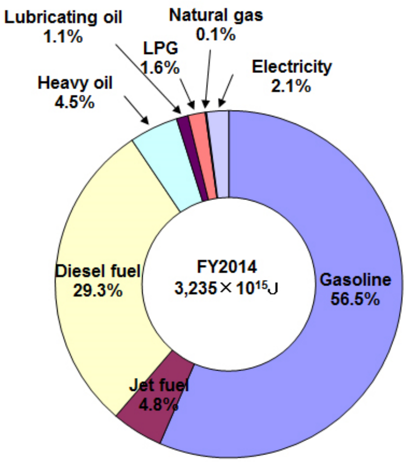


Fig. 1 Energy Sources Used in the Transportation Sector in Japan in 2014

Table 1 Current Penetration of Low-Emission Vehicles in Japan

Vehicle Type	Methanol [2]	CNG [3]	Hybrid [4]	EV [4]	FCV [4]	Vehicle Registration [5]
Passenger vehicles	0	1,591	5,558,725	62,134	630	39,506,932
Light, mid-, and heavy-duty trucks	576	5,928 19,723	14,026	1,270	0	5,868,283
Buses	0	1,577	1089	39	0	232,169
Special vehicles	0	3,988	7,729	37	0	1,712,158
Small vehicles	0	10,416	239,962	17,031	0	Not available
Total	576	43,223	5,821,531	80,511	630	Not available

Research and Demonstration Focus

Hydrogen

The Revised Version of the Strategic Roadmap for Hydrogen and Fuel Cells [6], which includes new goals and specific explanations of the new efforts to be undertaken, was released on March 22, 2016. In concrete terms, the revised version of the roadmap stipulated the following.

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.
5. The technical and economic challenges concerning the utilization of hydrogen generated using renewable energy.

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 [7]. The introduction of this heavy-duty CNG truck to the market is expected to increase the use of NGVs for long-distance transportation. In addition, events such as the opening of the first combined gasoline and L-CNG filling station in Japan at the Keihin Truck Terminal in March 2016, hints at future, more widespread use of NGVs in the commercial vehicles sector.

Many papers concerning natural gas engines presented at the 26th Internal Combustion Engine Symposium held in Japan from December 8 to 10, 2015, included research on the impact of hydrogen and carbon dioxide on knock resistance, research investigating the effects on combustion and fuel efficiency with a compression ignition (CI) engine, and research investigating the effects on exhaust emission and fuel efficiency with a dual fuel engine using diesel fuel and CNG.

A Ministry of Land, Infrastructure Transport and Tourism project is pursuing research on boil-off gas countermeasures as part of an effort to commercialize heavy-duty LNG vehicles with a long-distance cruising range.

Bioethanol

A project underway in Okinawa Prefecture to promote the use of biofuels supplied roughly 72,000 kiloliters (kL) of E3 and E10 fuel in FY 2015, and had established 34 service stations supplying E3 fuel and 32 service stations supplying E10 fuel as of March 2016. [8]. In Miyakojima City, the Japanese Government is continuing to support a verification project for the high-efficiency production of bioethanol from molasses and the promotion and dissemination of E3 biofuel based on previous successes [9]. In contrast, the number of service stations in Japan selling bio-gasoline blended with ethyl tertiary-butyl ether (ETBE) decreased by approximately 2% from April 2015 to 3,230 stations as of April 10, 2016 [10].

Methanol/Dimethyl ether (DME)

DME is attracting attention as an alternative fuel to diesel because it can be easily produced from methanol. Two Japanese companies — Mitsubishi Gas Chemical Company Inc. and Mitsubishi Corporation — have plans to produce DME for vehicles in Trinidad and Tobago, and Isuzu Motors, Ltd. is supplying low-pollution vehicles with DME engines [11].

Field tests on public roads in Japan have been conducted after obtaining ministerial authorization, and a technical standard proposal for DME vehicles has been drafted based on the resulting data. The Ministry of Land, Infrastructure Transport and Tourism officially announced the applicable standards in January 2015, thus opening the door for the approval and registration of the remodeling of DME vehicles in Japan. In June 2016, a DME truck compliant with the safety regulations became the first such registered vehicle [12].

Outlook

In April 2014, the Japanese Government approved the new Strategic Energy Plan (the fourth plan) [13], which forms the basis for Japan's energy policies for the immediate future. The basic concepts behind this plan are ensuring stable energy supplies, economic efficiency, and environmental suitability. With the addition of safety to these concepts, the plan is now summed up as "3E+S."

References

[1] Government's white paper on energy, 2016 (in Japanese).
[2] LEVO, the Organization for the Promotion of Low Emission Vehicles (cumulative total number: out of production).
[3] Japan Gas Association (JGA), as of March 2016.

[4] Next Generation Vehicle Promotion Center (NeV), as of March 2016 (estimated number).
[5] Automobile Inspection and Registration Information Association, as of October 2016.
[6] Agency for Natural Resources and Energy, 2016, the Revised Version of the Strategic Roadmap for Hydrogen and Fuel Cells, March 22.
[7] Isuzu Motors Limited, website; http://www.isuzu.co.jp/product/giga/cng/ (in Japanese).
[8] Miyakojima City website; http://www.city.miyakojima.lg.jp/gyosei/ecoisland/index.html (in Japanese).
[9] Ministry of Environment website; http://www.eco-biofuel.go.jp/ (in Japanese).
[10] Petroleum Association of Japan website; http://www.paj.gr.jp/eco/biogasoline/ (in Japanese).
[11] 6th International DME Conference, 2014, San Diego, California, October 7–9.
[12] IEA-AMF Newsletter, “First DME Truck Registered in Japan,” October 2015, issue no. 3/2015, http://www.iea-amf.org/app/webroot/files/file/Newsletters/AMFInewsletter_3-2015.pdf.
[13] Ministry of Economy, Trade and Industry (METI), Agency for Natural Resources and Energy, as of April 11, 2014, Cabinet Decision on the New Strategic Energy Plan, http://www.meti.go.jp/english/press/2014/0411_02.html.

Additional Information Sources

- Japan’s Energy White Paper, 2016, http://www.enecho.meti.go.jp/en/category/whitepaper/pdf/whitepaper_2016.pdf
- Agency for Natural Resources and Energy, Long-term Energy Supply and Demand Outlook, http://www.meti.go.jp/english/press/2015/pdf/0716_01a.pdf

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

Republic of Korea

Drivers and Policies

During the 21st Session of the Conference of the Parties to the United Nations Framework on Climate Change Conference (COP21) in 2015, Korea suggested a 37% carbon dioxide (CO_2) reduction by 2030. Discussions are now underway as to how to achieve this goal.

Under this plan, the transport sector has to reduce greenhouse gas (GHG) emissions by 24.6% (25.9 million tons) to meet the 2030 GHG target (business as usual [BAU] 105.2 million tons). This target will be met by reducing GHG emissions by 15.7 million tons with the expansion and dissemination of green passenger cars: 640,000 electric vehicles (EVs), 1 million hydrogen vehicles, and 4 million hybrid vehicles. In turn, average fuel economy will increase: 19.9 kilometer per liter (km/L) in 2017, 21.3 km/L in 2018, 22.8 km/L in 2019, and 24.3 km/L in 2020. The introduction of an average fuel economy scheme for medium- and heavy-duty vehicles will reduce GHG emissions by 6.3 million tons with the dissemination of EV buses.

Finally, by improving green transportation systems, such as an advanced public transportation system and modal shift system, GHG emissions will be reduced by 3.9 million tons.

The new Renewable Fuel Standard (RFS) program was enacted in South Korea’s National Assembly in July 2015. This new RFS requires that new diesel fuel be blended with biodiesel (BD) 2.5. It also indicates that joint indemnity and fraternal insurance should be provided to business operators who work with manufacturers and supply these renewable fuels.

According to the revised RFS, oil refining agents and petroleum import and export agents are obligated to blend transportation fuel with a certain percentage or more of a renewable energy fuel. A system was established to impose a penalty on any violator. Also, an RFS task force of professionals was formed to manage the work related to implementing this RFS. According to legislation, it is expected that the mixing or blending of BD and bioethanol (BE) will reach 3% in 2018, as a result of incremental increases in the mixing ratios associated with the new renewable energy sources each year.

Advanced Motor Fuels Statistics

South Korea's RFS policy sets mandates for transportation fuel businesses. In terms of vehicles, however, the policy only affects approximately 42.1% (8.8 million) of diesel vehicles out of the approximately 21 million vehicles in the country (Table 1). Biodiesel oil consumption per year is about 400,000 kiloliters (kL); of that, 172,000 kL comes from domestic waste edible oil and 238,000 kL is imported. The expectation is that in the near future, BE will be used for gasoline vehicles, which account for approximately 47.1% (9.9 million) of all vehicles in South Korea, that liquefied petroleum (LPG) vehicles will account for 10.6% (2.23 million), and natural gas vehicles (NGVs) will account for 0.2% (39,800 city buses).

Table 1 Number of Vehicles, by Fuel, in South Korea in 2016

Gasoline	Diesel (BD2.5)	LPG	NGV	Total
9,902,836	8,838,993	2,229,256	39,800	21,010,885

Research and Demonstration Focus

The Korea Institute of Machinery and Materials (KIMM) and Doosan Infracore developed the first hydrogen (H_2) enriched compressed natural gas (HCNG) engine. This engine emits fewer gas emissions (one-third of the EURO-6 standard), emits less CO_2 (18% reduction), and gives an 8% energy gain compared with the base CNG engine. Two HCNG buses are under demonstration in the South Korean cities of Ulsan and Incheon. The company KOGAS constructed an H_2/HCNG station that is using CNG; H_2 is produced by reforming CNG. This H_2/HCNG station can service three HCNG buses and five FCVs a day (Figures 1 and 2).

Fig. 1 HCNG Bus

Fig. 2 KOGAS H_2/HCNG Station

Korea has eight biomethane production plants for transport fuel in operation (Figure 3) by such companies as KOGAS and Potlatch. GS Caltex developed a lignocellulosic base biobutanol process and is constructing a biobutanol pilot plant (10 kilograms [kg]/day) (Figure 4); this pilot plant will be in operation in early 2017.

Fig. 3 Biomethane Charging Station

Fig. 4 Biobutanol Pilot Plant

For the next generation of fuels that will give high biomass productivity, non-food resources, a high CO_2 reduction, and the use of various water, two projects are being conducted to develop microalgae BD — one at KAIST's Advanced Biomass R&D Center and one at Inhae University's Marine Bioenergy Research Center.

Outlook

According to the new Korean RFS, which takes into account the supply and demand for raw materials, in the three-step, long-term plan for 2015 to 2023, BE3 and BD3 would be introduced in 2018. During the first step from 2015 to 2018, the introduction of BE and an increase in the BD percentage up to 2.5% would be reviewed. In the second step from 2018 to 2020, BE3 and BD3 would be introduced. The final step from 2020 to 2023 would be the introduction of BD5~7 and BE5~7. The introduction of biogas (BG) beginning in 2017 is also being considered.

Currently, there is no stimulus for using biofuels in LPG vehicles, which account for approximately 14% of all vehicles in the country. However, biofuels, such as biopropane and biodimethyl ether (bioDME), which are currently in research and development, will need to be commercialized and adopted into the market. Other alternative fuels, such as BE, DME, and synthetic liquid transportation fuels (collectively known as XTL), have been developed or demonstrated by Government institutes and some

South Korean companies. However, it is not clear when these fuels will be introduced.

Additional Information Sources

- KPetro, www.kpetro.or.kr/ (in Korean)
- "Commercialization of HCNG Bus Opened," http://www.todayenergy./news/articleView.html?idxno=112499 (in Korean)

Spain

Drivers and Policies

The only legal incentive for biofuel consumption in Spain is the blending mandate. Royal Decree 1085/2015, on the promotion of biofuels, establishes mandatory goals for biofuels. These blending targets (in energy content) are 4.3% (2016), 5% (2017), 6% (2018), 7% (2019), and 8.5% (2020).

The Alternative Energy Vehicle Mobility Incentive Plan (MOVEA) is a measure that forms part of Spain's 2014–2020 Alternative Energy Vehicle Incentive Strategy. Royal Decree 1078/2015 regulates the guidelines for the direct granting of aid for the purchase of electric, liquefied petroleum gas (LPG), and natural gas vehicles.

Directive 2014/94/EU on the deployment of alternative fuels infrastructure requires Member States to establish national policy frameworks for market development of alternative fuels and their infrastructure. The Spanish National Action Framework was approved in December 2016.

Advanced Motor Fuels Statistics

Spain has very little domestic oil and gas production and relies heavily on imports. Figure 1 shows the oil products the country has imported and exported in 2016.

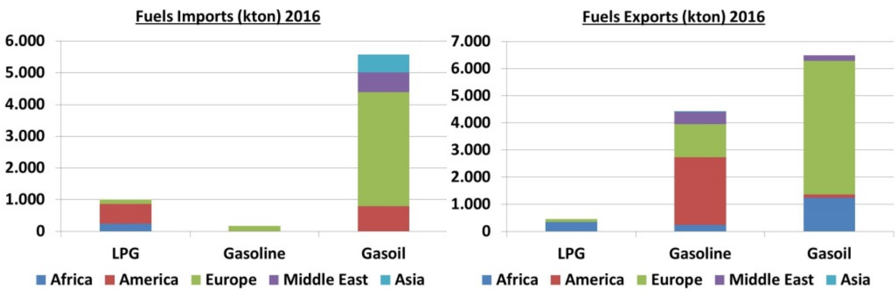
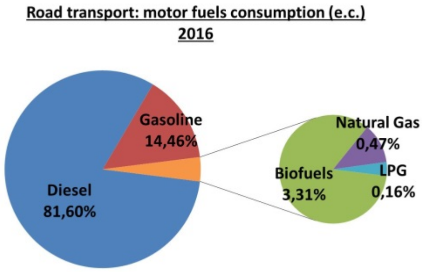


Fig. 1 Imports and Exports of Oil Products in Spain in 2016
(Source: CORES)

As for the utilization of fossil and alternative fuels, Figures 2 and 3 and Table 1 show data on fuel consumption, vehicle fleet, and the number of public filling stations with alternative fuels. Regarding hydrogen vehicles, only a few have been developed as part of pilot projects.



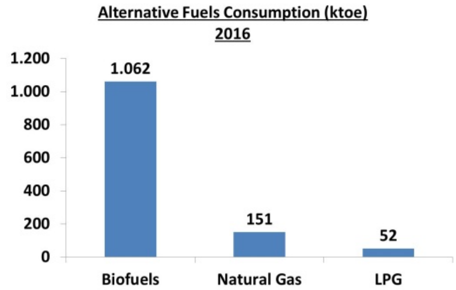
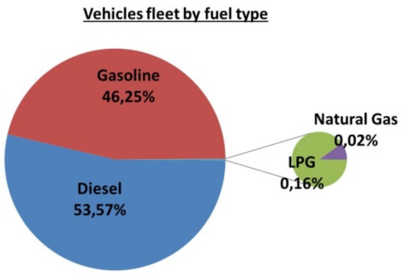


Fig. 2 Fuel Consumption (share in energy content) and Alternative Fuel Consumption (ktoe) in Spain in 2016
(Source: CORES, GASNAM)



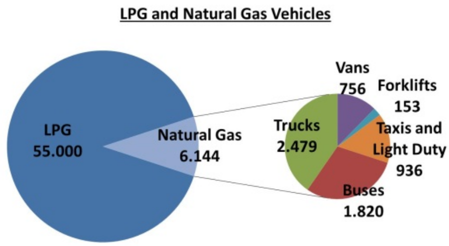


Fig. 3 Vehicle Fleet Broken Down by Fuel Type and Number of Vehicles in Spain That Could Use LPG and Natural Gas
(Source: IDAE elaboration on data from DGT, AOGLP and GASNAM)

Table 1 Filling Stations for Alternative Fuels in Spain

Alternative Fuel		Number of Filling Stations
Biodiesel blends	B20 or lower	60
	B30 or higher	17
Bioethanol blends	E15 or lower	4
	E85	9
LPG		540
Natural gas		46
Hydrogen		6

Sources: MINETAD (Geoportal), AOGLP, GASNAM, AEH2

Biofuels represent the largest share of alternative transportation fuels in Spain. Figures 4, 5, and 6 provide information on the feedstock, feedstock origin country, and production country of biofuels consumed in Spain.

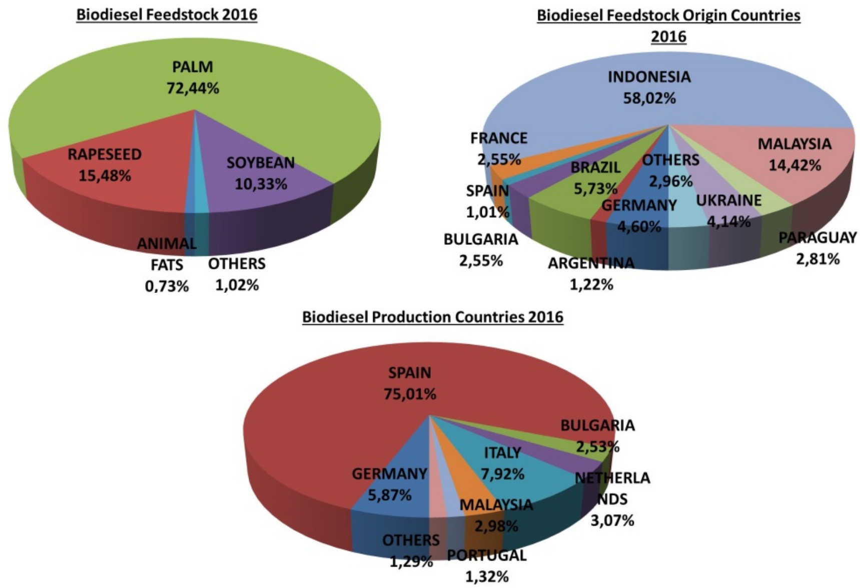


Fig. 4 Feedstock, Feedstock Origin Country, and Production Country of Biodiesel Consumed in Spain in 2016
(Source: CNMC)

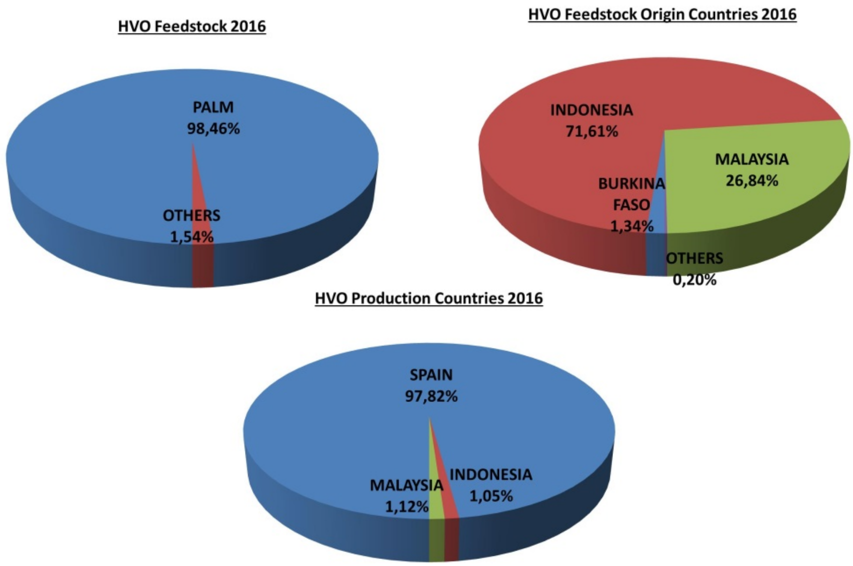


Fig. 5 Feedstock, Feedstock Origin Country, and Production Country of Hydrotreated Vegetable Oil (HVO) Consumed in Spain in 2016
(Source: CNMC)

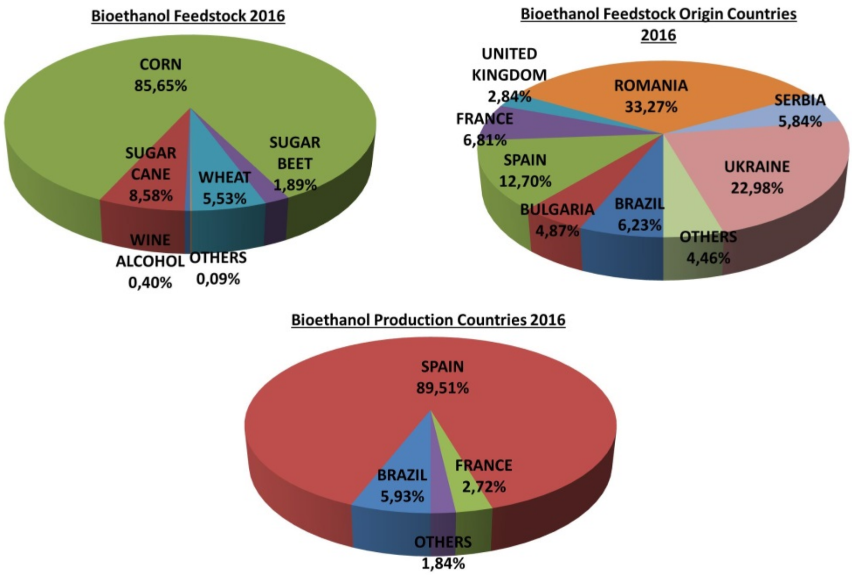


Fig. 6 Feedstock, Feedstock Origin Country and Production Country of Bioethanol Consumed in Spain in 2016
(Source: CNMC)

Research and Demonstration Focus

With regard to biofuels, the Spanish Bioeconomy Strategy, developed by the State Secretariat for Research, Development and Innovation (Ministry of Economy, Industry and Competitiveness), aims at fostering, among others, the bioenergy sector with a special focus on biorefineries. The First Annual Action Plan includes specific measures to promote public and private research and company investment in innovation.

In the National Action Framework for Alternative Energies in Transport, several programs are considered in order to support research, development and innovation (R&D&i): creation of clusters for innovation, incentives, cooperation through Technology Platforms, and support to research centers.

Wide research activity is carried out in Spain in relation to hydrogen technologies within the frameworks of national and European initiatives. Moreover, the World Hydrogen Energy Conference 2016 took place in Zaragoza, Spain, June 13–2016.

Outlook

According to the National Renewable Energy Action Plan, in order to fulfill the committed targets, consumption of biofuels is expected to reach 2,713 kilotonnes of oil equivalent (ktoe) in 2020.

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)
- AOGLP: Spanish Association of LPG Operators, www.aoglp.com (in Spanish)
- Bioeconomy: http://bioeconomia.agripa.org/ (in Spanish)
- 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 (MINETAD): 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)
- MINETAD: Ministry of Energy, Tourism and Digital Agenda www.minetad.gob.es (in Spanish)
- MOVEA Plan: http://www.moveaplan.gob.es/ (in Spanish)

Major Changes
The Spanish Bioeconomy Strategy developed its First Annual Action Plan, and a National Action Framework for Alternative Energies in Transport was approved.

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 2016, several new proposals to break Sweden's fossil-fuel dependency were presented. The proposals must be effective and provide long-term rules. The long-term climate goal means that by 2045, at the latest, Sweden will have no net emissions of greenhouse gases (GHGs), according to a proposal by the Parliamentary Cross party committee. 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 can be included. For the transport sector, a reduction in emissions (not including domestic air travel) of at least 70% by 2030, compared with 2010, has been proposed.

The Government intends to introduce what is known as a bonus-malus system, whereby environmentally adapted vehicles with relatively low carbon dioxide (CO_2) emissions are awarded a bonus at the time of purchase, and vehicles with relatively high CO_2 emissions are subject to a higher tax (malus).

Other measures are a CO_2-based fuel tax, a CO_2 differentiated vehicle tax, and environmental car subsidies. The environmental car subsidy depends on the certified CO_2 emissions. Vehicles with a CO_2 emission below a specific 95 grams per kilometer (g/km)-line (counted as a slope according to European Union [EU] regulation No. 443/2009) are exempted from vehicle tax for a period of 5 years. Vehicles with a certified CO_2 level less than 50 g/km also receive a subsidy of 20,000 SEK ($2,200 US), and zero emission vehicles receive a subsidy of 40,000 SEK ($4,400 US). Emissions of CO_2 are always considered as tail-pipe emissions.

Advanced Motor Fuels Statistics

Since 1990, the number of passenger cars has increased from approximately 3.5 million vehicles to more than 4.5 million vehicles. At the same time, GHG emissions have been rather stable at around 13 million tonnes from 1990 to 2007. However, since 2007, emissions have reduced significantly and were about 10 million tonnes in 2015. The main reason for the reduction is the increased energy efficiency of new vehicles.

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 320,000 at the end of 2015, as shown in Figure 1.

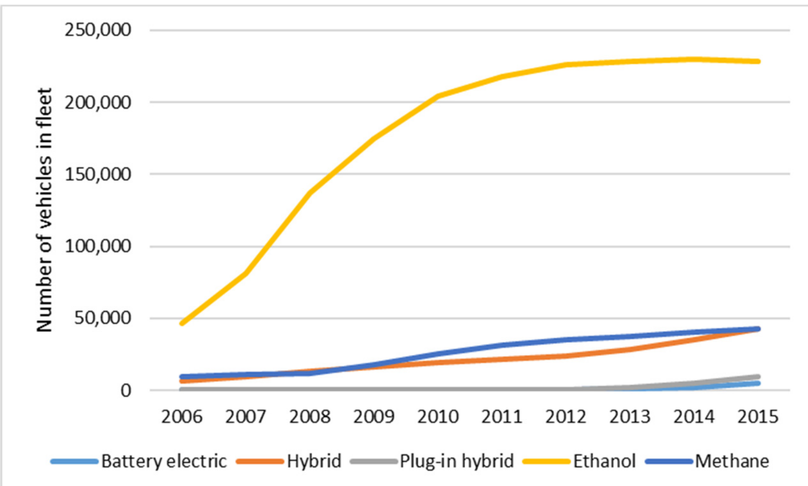


Fig. 1 Number of Advanced Motor Fuel Passenger Cars in the Fleet, 2006–2015

The alternative-fueled vehicles correspond to just under 7% 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 exceeds 25% 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 2015 only corresponded to approximately 1% of the energy content of transportation fuels sold. The GHG reduction per liter of ethanol has decreased compared with last year as a consequence of measures in other regions close to

Sweden. In Germany, fuels with a high reduction percentage have stronger incentives than in Sweden. In 2015, the number of ethanol-fuelled vehicles in Sweden's fleet decreased for the first time. On the other hand, the number of methane-fuelled 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 use of renewable biofuels for transport in Sweden amounted to almost 13 terawatt hours (TWh), or 14% of the transportation fuels sold during 2015 (Figure 2). Only 2.5 TWh were used in pure form as fatty acid methyl ester (FAME) (1.7 TWh), hydrotreated vegetable oil (HVO) (0.2 TWh), or E85 (0.6 TWh). Methane for transport consists of 70% biogas (1.1 TWh) and 30% natural gas. The remaining portion of the renewable fuels were sold as low blending in either diesel or petrol. Almost 50% of the renewable fuel used in Sweden during 2015 was low blending of HVO in diesel. On average, the renewable share in diesel corresponded to 17%. Some individual diesel products sold on the Swedish market have a renewable share of 50%.

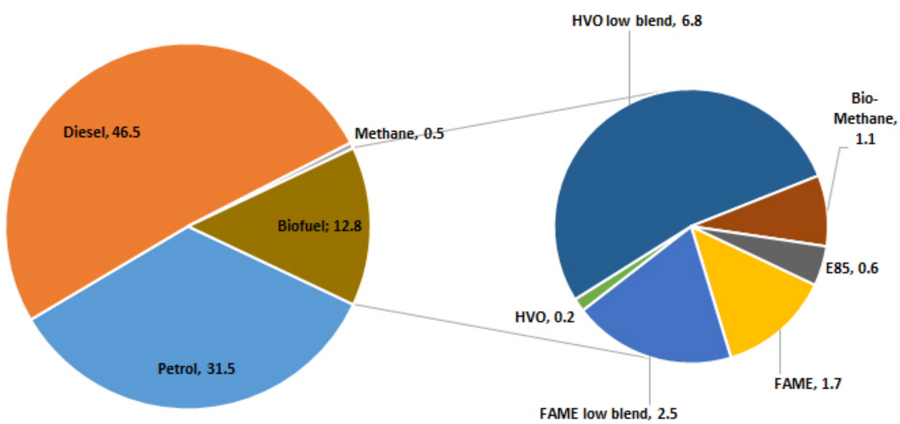


Fig. 2 Fuel Consumption in TWh within the Transport Sector during 2015

Approximately 50% of the feedstock used for producing the renewable fuels consumed in Sweden has also been produced in Sweden. 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, vegetable or animal waste oils, crude tall oil, palm oil, and animal fat in descending order. Most of the feedstocks come from Sweden and other European countries; palm oil comes from Indonesia and Malaysia. The average GHG emissions from HVO use in Sweden during 2015 correspond to 12.0 g carbon dioxide equivalent (CO_2 eq) per megajoule (MJ). For FAME, the corresponding figure was 38.8 g CO_2 eq/MJ.

FAME or biodiesel are primarily produced from either rapeseed oil or used cooking 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. About 94% of rapeseed oil has been imported, as shown in Figure 3.

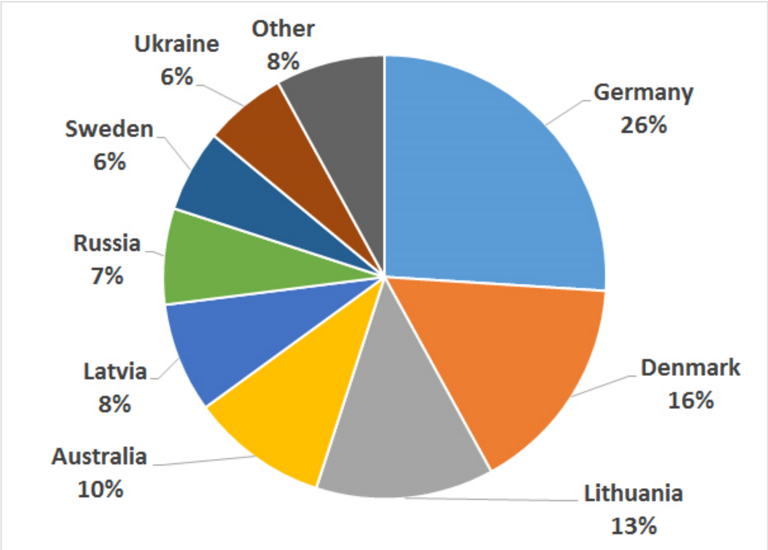


Fig. 3 Country of Origin for Rapeseed Oil Used for FAME Consumed in Sweden in 2015

Research and Demonstration Focus

The Swedish Energy Agency has several energy-related research, development, and demonstration (RD&D) programs:

- Energy & Environment 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 programs for energy efficiency in the transport sector for 2014–2019 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, 2014–2017. The renewable fuels research program is a collaborative program between the Swedish Energy Agency and the Swedish Knowledge Centre for Renewable Transportation Fuels, f3.

Outlook

The goal is set high in Sweden, with a fossil-independent vehicle fleet by 2030 (likely to correspond to 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, the use of advanced motor fuels would be necessary to reach these targets. Currently, 13 TWh of renewable fuels are used, but this level would probably need to be doubled by 2045 or earlier.

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 early 2017, the Swedish Government proposed a new climate law with the following targets:

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

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

Switzerland

Drivers and Policies

In 2016, the Swiss Parliament passed a fundamentally revised new Energy Act. It is the first part of a long-term energy policy called “Energy Strategy 2050 [1].” The core measure is to withdraw step by step from the use of nuclear energy without increasing carbon dioxide (CO_2) emissions. This should be achieved by increased energy savings (energy efficiency); the expansion of hydropower and new renewable energy sources; and, if necessary, fossil-fuel-based electricity production (cogeneration facilities, gas-fired combined-cycle power plants) and imports. Important measures related to motor fuels include (1) reducing CO_2 emissions; (2) increasing energy efficiency; (3) increasing the use of renewable energy sources, including biomass; and (4) strengthening energy research.

CO_2 Emission Regulations for Cars

Swiss importers are required to reduce the level of CO_2 emissions from new passenger cars to an average of 130 grams (g) of CO_2 per kilometer (km). Importers who do not meet that target have to pay a penalty. The average CO_2 emissions of new passenger cars in 2015 was 135 g CO_2/km. The penalty amounted to 12.6 million U.S. dollars [2]. In alignment with the European Union (EU) Commission, the Federal Council aims to reduce average CO_2 emissions from passenger cars by 2020 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 [1].

CO_2 Emissions Compensation: Motor Fuels

All importers of fossil motor fuels are required to use domestic measures to compensate for 10% of CO_2 emissions generated by the entire transportation sector by 2020 [3]. The compensation rate started in 2014 at 2% and will be raised to the level of 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.

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. The tax for natural gas used as a motor fuel was reduced to 0.22 U.S. dollars/kg [4]. 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 0.72 USD per liter (L), in comparison with fossil fuels.

Advanced Motor Fuels Statistics

Final total energy consumption in Switzerland in 2015[36] amounted to 838,360 terajoules (TJ), of which 35% was transport fuels (Figure 1) [5]. Compared to 2014, fuel consumption for vehicles decreased by 4.4%. In the same period, the total amount of vehicles increased by 1.8%, in the sum of 6,299,234. Fuel consumption by vehicle dropped by 6.0%. Some changes in specific applications were made in 2015: diesel −1.4%, gasoline −7.3%, and aviation fuels +3.3%. All fossil fuels were imported.

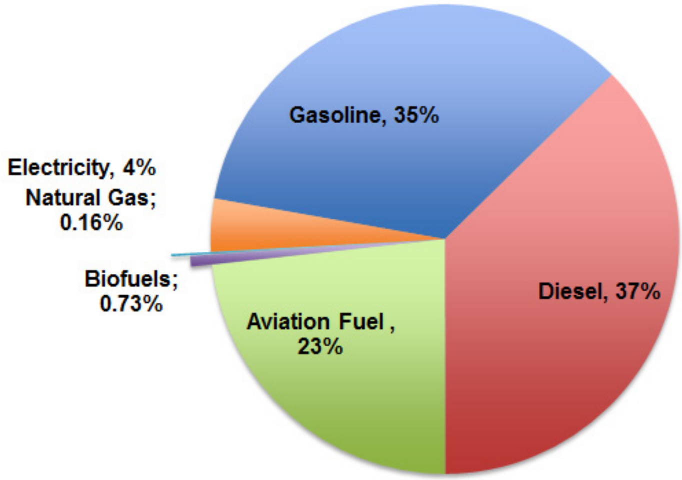


Fig. 1 Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland in 2015 [1]

Electricity is used for railroad transportation, and a negligible amount is used for electric cars. Despite an impressive annual increase of electric vehicles (2013 + 52.6%; 2014 + 65.4%, and 2015 + 69.7%), the total amount is still very small (7,531 passenger cars) [6]. In 2000, the share of diesel of the total amount of fuels (without aviation) amounted to 26%. With a share of 53% in 2015, the consumption of diesel was higher than the use of gasoline.

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[36] At the time this report was prepared, only data from 2015 were available.

In Switzerland, firms marketing motor fuels are not under any obligation for blending. This could explain the rather low share of biofuels in the total amount of motor fuels in the past. Since 2014, fuel importers are required to compensate CO_2 emissions by domestic measures. The measure to blend fuel with biofuels is one solution, and a substantial increase of biodiesel (45.055 million L) and bioethanol (28.064 million L) can be observed in 2015 (Figure 2). Pure vegetable oil (PVO) fuel dropped almost to zero (0.111 million L), and upgraded biogas remained at a low level of 3.380 million kg in 2015. Even if the total amount of biofuel consumption doubled compared to the year before, it is still a very small share (0.94%) of the total amount of motor fuels used in Switzerland [7].

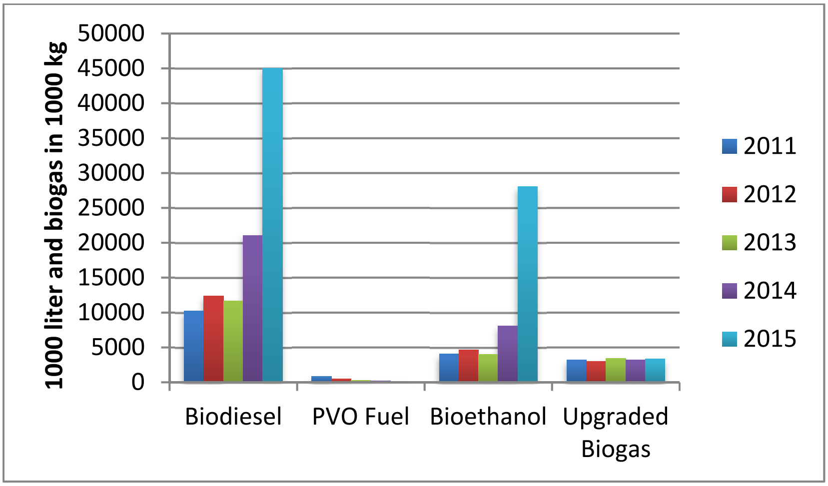

Fig. 2 Development of the Use of Biofuels as Motor Fuels in Switzerland, 2011–2015

Only 7.054 million L of biodiesel was produced in Switzerland. The other 38.000 million L was imported (Germany 52%, France 38%, the rest from six other countries). All bioethanol is imported (Holland 84%, Norway 14%, the rest from two other countries).

The total amount of biogas produced and used in Switzerland in 2015 amounted to 99,031 t. Only 18,570 t have been upgraded and fed into the natural gas grid. From this, only a small amount — 3,380 t — has been sold as biogas for cars [8]. The rest has been used for cogeneration and heating. This means that Switzerland has a potentially large amount of upgraded biogas (15,190 t) for automotive applications. All biogas used as motor fuel in cars is upgraded biogas fed into the natural gas grid. Therefore, cars need no special requirements for biogas as a fuel. Figure 3 shows the development of the use of biogas and natural gas as motor fuels in cars. The demand for biogas is stable, but the demand for natural gas is slightly decreasing. As shown in Figure 3, the total amount of upgraded biogas fed into the natural gas grid has increased threefold in the last 5 years. This is caused by increased demand for biogas for residential heating.

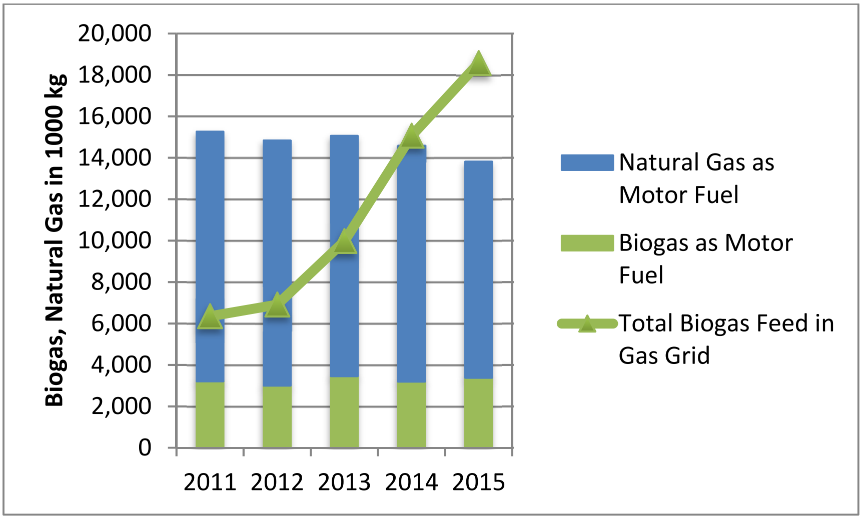

Fig. 3 Development of the Use of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

Research and Demonstration Focus

In the research, development, and demonstration (RD&D) funding framework of the Swiss Federal Office of Energy, three programs — bioenergy, combustion, and mobility — are supporting AMF research activities. To coordinate research, to improve collaboration, and increase capacity building, in 2013, eight Swiss Competence Centers for Energy Research (SCCERs) were established. One of them is dedicated to mobility [9] and another to bioenergy [10], including liquid and gaseous biofuels.

Hydrogen-enriched natural gas in passenger cars: Natural gas enriched with higher amounts (15% and 25%) of hydrogen was investigated on a chassis dynamometer with passenger cars. Demonstration showed that by adapting the engine control system, an efficiency increase of 2% can be achieved, as well as a reduction of hydrocarbons (between 30 and 60%) and nitrogen oxide emissions (NO_x) after the catalyst (IEA AMF Annex 51).

Effects of gasoline-butanol blend fuels on emissions and combustion in spark ignition (SI) engines: With different butanol blends (BuXX), basic combustion research was performed on a SI-engine dynamometer with accesses for engine parameterization and pressure indication. In the second part of the project, two vehicles were investigated on a chassis dynamometer, with special consideration of non-legislated emission components.

Higher methane yield from biogas: Biogas produced from waste and sewage sludge in fermentation plants contains methane and up to 40% CO_2. To feed only the methane into the natural gas grid, the CO_2 has to be removed. With a newly developed technology, it is possible to convert the residual CO_2 by adding renewable hydrogen to methane and water. A demonstration plant has been set up at a fermentation and wastewater treatment plant in Zurich.

Outlook

The main drivers in Switzerland to increase the use of biofuels are and will remain tax exemptions and the Government's requirement that the petrol industry compensate 10% of CO_2 emissions via domestic measures. Switzerland has an extensive natural gas grid and a huge potential of biogas. For many years, natural gas sales been stable, even slightly decreasing. Combined with political demands to stop using fossil fuels, public utilities are discussing how to dismantle their gas grids. Promising developments are showcase projects with power to gas technologies and methanization of hydrogen with CO_2-rich biogas from wastewater treatment plants or anaerobic digestions plants. These supports arguments to keep natural gas grids and to use them for renewable gases.

Additional Information Sources

[1] Swiss Federal Office of Energy (SFOE), "Energy Strategy 2050."
[2] Federal Office of Environment (FOEN), 2016.
[3] FOEN, 2012, "CO_2 emission compensation: motor fuels."
[4] Mineralölsteuergesetz (MinöStG), Stand: Jan. 1, 2012.
[5] SFOE, 2015, "Gesamtenergiestatistik."
[6] Swiss Federal Statistical Office (BFS), 2016, "Mobility and Traffic,"
[7] Swiss Custom Administration, 2016, "Mineralölstatistik."
[8] SFOE, 2016, "Schweizerische Statistik erneuerbarer Energien 2015."
[9] www.sccer-mobility.ch.
[10] www.sccer-biosweet.ch.

Thailand

Drivers and Policies

On the basis of worldwide climate change, international policies have established a framework for stabilizing atmospheric concentrations of greenhouse gas (GHGs) to avoid dangerous anthropogenic interference with the climate system. In 2015, the 2015 Paris Climate Change Conference (COP21) aimed to achieve universal agreement on the climate by keeping global warming below 2°C. Thailand, as a member of COP, volunteered to reduce GHGs by 20 to 25% in 2030, as well as reduce the country's high dependency on foreign energy, which puts its energy security at risk.

In 2016 (January through October), final energy consumption was 65,822 ktoe, an increase of 0.6% from 2015 [1]. The total value of final energy consumption was 680,676 million baht (19,228 million $US). Moreover, Thailand's energy demand has been forecast on the assumption that the gross domestic product (GDP) will increase approximately 3.94% per year, on the basis of population growth rate, and on a model developed using statistical data dating back to 1994 to 2013. In order to respond to a growing economy, increased population, urbanization, and increased public awareness of fuel usage, as well as the need to reduce pollution, the Ministry of Energy established the Thailand Integrated Energy Blue Print 2015–2036. The plan consists of five integration master plans and focuses on security, economy, and ecology:

1. Thailand Power Development Plan (PDP 2015),
2. Energy Efficiency Plan (EEP 2015),
2. Alternative Energy Development Plan (AEDP 2015),
3. Natural Gas Supply Plan (Gas Plan 2015), and
4. Oil Supply Management Plan (Oil Plan 2015).

The goal of EEP 2015 is to reduce energy intensity by 30% in 2036, which aligns with the goals of the other four major energy plans issued by the Ministry of Energy. The main measures promoted in EEP 2015 will be applied to the transportation sector, with the target of decreasing the sector's energy consumption by approximately 30,213 ktoe of the predicted total energy consumption (56,142 ktoe) using 12 measures. These measures are laid out in EEP 2015 and include regulation of fuel prices to reflect actual cost, the introduction of electric vehicles, and the development of mass transportation infrastructure [1]. To strengthen the energy security of Thailand, the energy demand outlook in all national energy plans contributes to the AEDP 2015 goal of ramping up the ratio of renewable energy usage to 30% of final energy consumption in 2036 [2].

Advanced Motor Fuels Statistics

The final energy consumption by economic sector covers energy demand in the agriculture, commercial, residential, industrial, and transportation sectors. In 2016, transportation had the greatest portion of total energy consumption at 37.6%, followed by industrial at 36.4%, residential at 14.2%, commercial at 7.9%, and agricultural at 3.9% [3] (Figure 1).

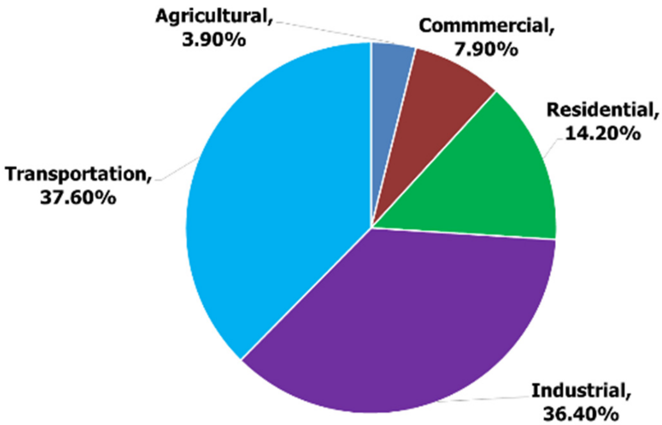

Fig. 1 Final Energy Consumption in Thailand by Economic Sector, January through October 2016

The Thai Government has officially promoted and implemented policies for the use of alternative energy. Therefore, the use of alternative energy, mainly biofuels in the transportation sector, has been significantly increasing. At the time this report was prepared (January–October 2016), biodiesel consumption was up to 3.49 ML/day, and ethanol consumption was up to 3.36 ML/day [3]. Moreover, alternative fuel consumption shared 13.97% of final energy consumption, an increase of 11.7% from 2015.

By the end of December 2016, there were 37,338,139 vehicles in Thailand. Of this number, 607,116 were newly registered. Gasoline vehicles accounted for 25,520,553 units, corresponding to 68.35% of the total. Diesel vehicles accounted for 9,887,129 units or 26.48% of the total, and bi-fuel vehicles (gasoline or diesel with liquid petroleum gas [LPG]) accounted for 1,174,646 units or 3.15% of the total. Table 1 shows the total number of vehicles in Thailand, by fuel, as of December 2016 [4]. Since the Thai Government has implemented policies to promote the use of alternative fuels, the consumption of ethanol blended fuel (E10, E20, and E85) accounts for 32% of total energy consumption for land transportation. Figure 2 presents the energy consumption for the land transportation sector in Thailand by the end of November 2016 [5].

Table 1 Number of Vehicles, by Fuel, in Thailand, as of December 31, 2016 [4]

Fuel Type	Units	Percentage of Total
Gasoline	25,520,553	68.35
Diesel	9,887,129	26.48
Bi-fuel (gasoline or diesel with LPG)	1,174,646	3.15
Bi-fuel (gasoline or diesel with compressed natural gas [CNG])	341,270	0.91
Hybrid	79,711	0.21
Mono-fuel CNG	63,225	0.17
Mono-fuel LPG	22,882	0.06
Electric	1,488	0.00
Non-fuel and others	247,235	0.66
Total	37,338,139	100.00

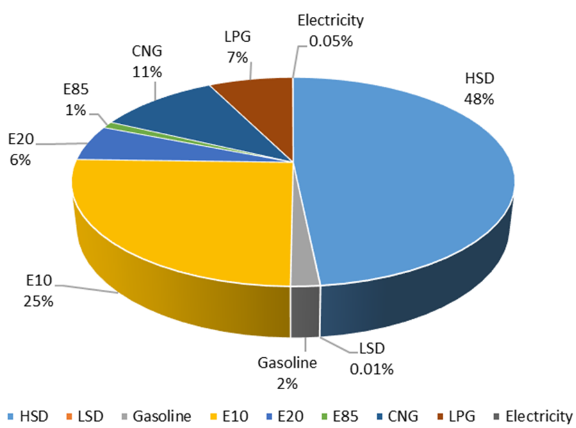

Fig. 2 Energy Consumption in Thailand for Land Transportation, January–November 2016 [5]

Research and Demonstration Focus

Thailand has policies in place to support the development of domestic renewable energy technology and to carry out research and development to promote the country’s competitiveness in the international market. The Thai Government is encouraging research in the development of renewable energy in the following areas in 2015–2016:

1. Biodiesel
   a. Research is focusing on boosting the biodiesel content in the transportation sector to comply with EEDP 2015 and AEDP 2015 [6].
2. Ethanol
   a. Research is focusing on reducing the cost of ethanol production in the commercial scale [6].
   b. Research is focusing on the use of gasohol E85 in small agricultural engines and motorcycles [7].

Outlook

Biofuel development in Thailand has followed the Government's initiative since a decade ago, when a policy for the country's energy security and renewable energy was established with a special focus on replacing diesel and gasoline with domestic production of biofuel. The development of renewable energy is a part of the overall policy framework, which drives the AEDP 2015. Within the AEDP 2015, the Ministry of Energy presents strategies to advocate for renewable energy development in electricity production, heat production, and biofuels in the transportation sector. Under Thailand's energy outlook, in Oil Plan 2015, fuel demand in the transportation sector is projected to be approximately 34,798 ktoe, thus meeting the AEDP 2015 goal of increasing the ratio of renewable energy. The target in the promotion of biofuel production takes into account the energy demand in the transportation sector and biofuel production capacity, as shown in Table 2.

Table 2 Status and Target of Fuel Production from Renewable Energy in the Transportation Sector in Thailand

Energy Type	2016[b]	2036	
Biofuel	**ML/day**	**ML/day**	**ktoe**
Biodiesel	3.49	14.00	4,404.82
Ethanol	3.63	11.30	2,103.50
Pyrolysis oil	–	0.53	170.87
Compress bio-methane (ton/day)	–	4,800.00	2,023.24
Other alternative energy[a]	–		10.00
Total	6.10		8,712.43

[a] For example, bio oil, hydrogen.
[b] Average data from Jan–Oct 2016.

Additional Information Sources

[1] Ministry of Energy, 2016a, Energy Efficiency Plan 2015, Energy Policy and Planning Office, http://www.eppo.go.th/index.php/th/plan-policy/tieb/eep (in Thai)

[2] Ministry of Energy, 2016b, Alternative Energy Development Plan 2015, Energy Policy and Planning Office, http://www.eppo.go.th/index.php/th/plan-policy/tieb/aedp (in Thai)

[3] Ministry of Energy, 2016c, Energy Situation (January–October 2016), Department of Alternative Energy Development and Efficiency, http://www.dede.go.th/ewt_news.php?nid=44451 (in Thai)

[4] Ministry of Energy, 2016d, Number of vehicles registered by fuel as of December 31, 2016, Transport Statistics Subdivision, Planning Division, Department of Land Transport

[5] Department of Alternative Energy Development and Efficiency, 2016, Thailand Energy Commodity Account January–November 2016, http://www.dede.go.th/ewt_news.php?nid=42079 (in Thai)

[6] Ministry of Energy, 2016e, Biodiesel, Department of Alternative Energy Development and Efficiency, http://www.dede.go.th/more_news.php?cid=402&filename=index (in Thai)

[7] Ministry of Energy, 2016f, Gasohol, Department of Alternative Energy Development and Efficiency, http://www.dede.go.th/more_news.php?cid=84&filename=index (in Thai)

Benefits of Participation in the AMF TCP

Thailand is pleased to be a participant in the AMF TCP and to be part of the global effort to solve the grave issue of climate change. The AMF TCP provides a database of knowledge that enables participating countries to learn from one another.

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 as most of their new vehicle acquisitions.

The U.S. Department of Energy (DOE) 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 Clean Cities has been described in previous AMF annual reports. More information on the Clean Cities Program can be found at www.cleancities.energy.gov.

The most recent data from the Clean Cities Program are for 2015 and show that the program saved 1,079,200,000 gasoline gallons equivalent (gge), of which 640,500,000 gge came from alternative fuels/vehicles (27% increase from last year), 91,900,000 gge from electric and hybrid vehicles (8% increase), and 37,700,000 gge from idle reduction technologies. Of the total, 840,600,000 gge savings were from fleets belonging to Clean Cities coalitions, with the remainder coming from other fleets and vehicle owners utilizing Clean Cities services, resources, and infrastructure funded by Clean Cities. For additional data, see http://www.afdc.energy.gov/uploads/publication/2015_metrics_report.pdf.

U.S. Environmental Protection Agency (EPA) Requirements under the Renewable Fuels Standard (RFS)

The primary driver of renewable fuel use in the United States is the RFS, which was adopted in 2005 and expanded in 2007 (RFS2). It requires increasing the volumes of renewable fuel to be used in motor fuels. On December 12, 2016, the EPA finalized the volume requirements and associated percentage standards under the RFS program for calendar year 2017 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The EPA also finalized the volume requirement for biomass-based diesel for 2018 (see Tables 1 and 2). These volumes were greater than those for 2016 compliance but significantly lower than those originally targeted in the RFS legislation, which envisioned much more robust growth in cellulosic fuel production than has as yet materialized.

The cellulosic biofuel category was created largely with cellulosic ethanol in mind. However, renewable natural gas from landfills and anaerobic digesters, treated as cellulosic biofuel by the EPA through a combination of rulemakings in 2013 and 2014, has dwarfed liquid fuels in that category. Biomass-based diesel is mainly traditional fatty acid methyl ester (FAME) biodiesel, derived from soy, corn, canola, camellia oils, 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 (and dominated by) starch- and sugar-based ethanol.

Other alternative and advanced motor fuels are incentivized by various federal and state programs. Lists of these are available at http://www.afdc.energy.gov/laws/.

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 2016 would be 23,286 trillion British thermal units (Btu), up from 22,859 trillion Btu for the same period in 2015.[37] More than 90% of this consumption would be petroleum-based fuels (gasoline and diesel), with almost the entire remainder being ethanol blended into gasoline at 10%.[38] This biomass would account for 1,182 trillion Btu during these 10 months, natural gas for 605 trillion Btu, and electricity for 21 trillion Btu.[39]

Biofuels

The best data on the use of biofuels in transportation come from the EPA’s recording of Renewable Identification Numbers (RINs) filed by refiner/marketers of liquid transportation fuels, as shown in Table 1. Each RIN is equivalent to 1 gallon of ethanol by Btu content; RINs are generated when a motor fuel refiner/blender blends or sells the renewable fuel or fuel blend.

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[37] *EIA Monthly Energy Review*, p. 29, Table 2.1, Energy Consumption by Sector; p. 37, Table 2.5, Transportation Sector Energy Consumption.

[38] Ibid., p. 155, Table 10.3, Fuel Ethanol Overview.

[39] Liquefied petroleum gas, which the EIA treats as petroleum, accounted for 34 thousand barrels per day (bpd) equivalent average for that period. *EIA Monthly Energy Review*, p. 67, Table 3.7c, Petroleum Consumption: Transportation and Electric Power Sectors.

Table 1 2016 RINs Generated

Fuel (D Code)	Net RINs Generated
Cellulosic biofuel (D3)	176,317,538
Biomass-based diesel (D4)	3,992,475,109
Advanced biofuel (D5)	96,920,307
Renewable fuel (D6)	15,145,664,554
Cellulosic diesel (D7)	480,988

Electric Vehicles

Sales of plug-in electric vehicles (EVs) (plug-in hybrids and battery electric models) in 2016 were up strongly overall from 2015, totaling 157,112 compared to 118,773 in 2015. In addition, 346,948 hybrid electric vehicles (non-plug-in) were sold in 2016, down from 384,404 in 2015.[40] Available plug-in models totaled 56 as of February 2017, down from 73 in March 2016.[41]

Alternative Fuel Infrastructure

Table 2 provides the number of alternative fuel refueling stations, including private stations, in the United States according to DOE's Alternative Fuels Data Center.[42]

Table 2 Number of U.S. Alternative Fuel Refueling Stations by Type in 2012–2013, and 2014 (including public and private stations)

Year	B20	CNG	E85	Electric Outlets[a]	H_2	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

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

[40] http://www.electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952.

[41] http://www.afdc.energy.gov/vehicles/electric_availability.html. Updated information with a breakdown by state and individual station locations can also be accessed on the Alternative Fuels Data Center site (http://www.afdc.energy.gov/).

[42] See http://www.afdc.energy.gov/fuels/stations_counts.html.

As can be seen in Table 2, the total number of alternative fueling stations, exclusive of electric recharging stations, in the United States increased by 33% between 2012 and 2016. The total number of public and private nonresidential electric vehicle recharging outlets jumped by more than 350% over this same 4-year period.

Research and Demonstration Focus

The DOE Vehicle Technologies Office sponsors research in fuels and advanced combustion engines for the purposes 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 brief summary provided here focuses on fuels and fuel effects and is based on recent DOE annual program reports.[43,44]

In fall 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 Vehicle Technologies Office and Bioenergy Technology Office. The goal of Co-Optima is to identify and rigorously evaluate co-optimized technology options for the introduction of high-performance, sustainable, affordable, and scalable fuels and engines. DOE envisions that the effort will span more than 15 years, including not only research on the relationship between fuels and engines to achieve optimum efficiency and emissions reductions, but also fuel production research and pathways for successful commercialization of the products. It includes both spark ignition (SI) technologies (focusing on high-knock resistance for efficiency), targeted for commercialization by 2025, and compression ignition (CI) technologies (including the use of kinetically controlled and higher reactivity fuels), targeted for commercialization by 2030. Identified metrics include:

- Enable additional 15% fuel efficiency,
- Accelerate deployment of 15 billion gallons/year of advanced biofuels, and
- Enable an additional 9% to 1% fleet GHG reduction by 2040.

The DOE Bioenergy Technology Office promotes the development of new fuels from initial concepts, laboratory research and development (R&D), and pilot and demonstration plant phases. Research areas include feedstocks, algae, biochemical conversion, and thermochemical conversion for both

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43 DOE Vehicle Technologies Office, 2013, *Fuels and Lubricant Technologies 2012 Annual Progress Report*, DOE/EE-0911, June.

44 DOE Vehicle Technologies Office, 2012, *Advanced Combustion Engine Research and Development 2012 Annual Progress Report*, DOE/EE-0872, December.

fuels and high-value chemicals. For additional information, see the AMF 2015 Annual Report.

Outlook

The EIA's *Annual Energy Outlook 2017* ("reference case") projects decreasing overall transportation energy use from 2018 through 2034 due to mandated increases in fuel efficiency. It projects that battery electric vehicle (BEV) sales will increase from less than 1% to 6% of total light-duty vehicles sold in the United States over 2016 to 2040, and plug-in hybrid electric vehicle (PHEV) sales will increase from less than 1% to 4% over the same period due to falling battery costs. Hydrogen fuel cell vehicle (FCV) sales will grow to approximately 0.6% of sales by 2040. In 2025, projected sales of light-duty battery electric, plug-in hybrid electric, and hydrogen fuel cell vehicles will reach 1.5 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, 2016, Transportation Energy Data Book, October, http://info.ornl.gov/sites/publications/files/Pub44660.pdf
- EIA (Energy Information Administration), 2017, Annual Energy Outlook 2017, https://www.eia.gov/outlooks/aeo/pdf/0383(2017).pdf
- EIA, 2017, Monthly Energy Review, Energy Information Administration, http://www.eia.gov/totalenergy/data/monthly/

Benefits of Participation in the AMF TCP

DOE's Vehicle Technologies Office is an active participant in the AMF TCP through the Advanced Combustion Systems and Fuels Program. The U.S. Government benefits from participation in several ways. One major way is through its ability to leverage finances and technical expertise on research programs of mutual interest. U.S. Government researchers also benefit from their ability to maintain contacts with international experts and to interact with them in research and policy discussions. Many of the countries participating in the AMF TCP are facing the same fuel-related issues as the United States and are active in international import and export markets for fuels, renewable fuels, and fuel components. Mutual cooperation has proven beneficial in the past and should continue to do so in the future.

4 Further Information

4.a
About the International Energy Agency (IEA)

Established in 1974, the International Energy Agency (IEA) carries out a comprehensive program of energy co-operation for its 29 member countries and beyond by examining the full spectrum of energy issues and advocating policies that will enhance energy security, economic development, and environmental awareness and engagement worldwide. The IEA is governed by the IEA Governing Board, which is supported through a number of specialized standing groups and committees. For more information on the IEA, see www.iea.org.

The IEA Energy Technology Network

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

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

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

The IEA Technology Collaboration Programmes (TCPs)

The IEA Technology Collaboration Programmes (TCPs) are international groups of experts who enable governments and industries from around the world to lead programs and projects on a wide range of energy technologies and related issues, from building pilot plants to providing policy guidance in support of energy security, economic growth, and environmental protection. The first TCP was created in 1975. To date, TCP participants have examined close to 2,000 topics. Today, TCP participants represent more than 300 public and private-sector organizations from over 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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4.b.ii
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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 2016

Annex 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options

Performance Evaluation of Passenger Car, Fuel and Powerplant Options. Final Report. May 2016.

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

Research on Unregulated Pollutants from Alcohol-Fuelled Vehicles. Final Report. October 2016.

Annex 46: Alcohol Application in CI Engines

Alcohol Applications in Compression Ignition Engines. Final Report. January 2016.

Annex 49: COMVEC – Fuel and Technology Alternatives for Commercial Vehicles

COMVEC – Fuel and Technology Alternatives for Commercial Vehicles. Final Report. October 2016.

Annex 49 Key Messages. October 2016.

All annex reports are available at www.iea-amf.org.

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 give you details on the AMF TCP and invite you to attend an Executive Committee (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 €9,500 ($10,327 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 €2,000 to €100,000 ($2,118 to $105,909 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 AMF TCP.

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.

Biodiesel Fuel (BDF)

A form of diesel fuel (methyl ether) derived from biomass; BDF has benefits over petroleum-derived diesel because it can be created from renewable and sustainable sources. Such blends of biodiesel include fatty acid methyl esters, soy methyl esters, and rapeseed methyl esters. In Brazil, ethyl ester or fatty acid alkyl ester are referred to as biodiesels.

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.

Direct Injection Spark Ignition (DISI)

DISI is a fuelling strategy currently being implemented in light-duty vehicles on the road today. A fuel resistant to auto-ignition, such as gasoline, is injected directly into the combustion chamber of a spark-ignited internal combustion engine. This fuel delivery process is more efficient than its port fuel injection predecessor because it creates a charge cooling effect in the combustion chamber, allowing for higher compression ratios to be run.

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.

ED95/RED95

ED95 is a blend of diesel fuel consisting of 95% bio-ethanol and 5% of an ignition improver for the fuel. Sweden’s transportation sector has adapted some of its heavy-duty diesel buses to run on this biofuel blend.

The RED95 Ethanol-Diesel project is a 3-year joint project of NEOT, ST1, VTT, Scania, HSL, and Helsingin Bussiliikenne Oy that concentrates on the environmental impacts and energy consumption of waste-ethanol-powered buses. The aim is to demonstrate that ethanol can be utilized as bus traffic fuel, thereby significantly reducing peri-urban emissions and greenhouse gases. Since November 2013, two ethanol-powered buses have been used on HSL Route 41(source of information for RED95: http://www.neot.fi/en/neot-en/current-projects).

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.

Fischer-Tropsch

The Fischer-Tropsch process involves taking low-value refinery products, such as coal, and converting them into high-value fuels that can be produced from biomass gasification. The resulting Fischer-Tropsch fuels, when compared to standard diesel fuels, can reduce nitrogen oxides, carbon dioxide, and particulate matter. Fischer-Tropsch fuels can also be produced from biomass gasification. Again, the properties of the resulting fuels are better than those of conventional diesel fuels. The cetane number, a measure of diesel fuels' propensity to auto ignite, is higher with Fischer-Tropsch fuels than it is with conventional petroleum-based diesels.

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.

Methyl Tertiary-Butyl Ether (MTBE)

MTBE is an additive derived from methanol, which can be used to oxygenate and increase the octane rating of gasoline. MTBE is not commonly used anymore due to the risk of it contaminating groundwater supplies.

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.

NEXBTL

NEXBTL is a renewable diesel production process commercialized by the Finnish oil and refining company Neste Oil.

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 leanburn 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.

Rapeseed Methyl Ester (RME)

RME is a form of biodiesel derived from rapeseed (canola) oil. This form of biodiesel is also renewable, allowing it to be produced domestically. RME can then be blended with petroleum-based diesel to produce varying blends of biodiesel.

Well-to-Wheel (WTW)

The WTW 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.

xTL

Synthetic liquid transportation fuels, collectively known as xTL fuels, are produced through specialized conversion processes.

Notation and Units of Measure

A3PS	Austrian Association for Advanced Propulsion Systems
AEDP	Alternative Energy Development Plan (Thailand)
AIST	National Institute of Advanced Industrial Science and Technology (Japan)
AMF TCP	Advanced Motor Fuels Technology Collaboration Programme
AMFI	Advanced Motor Fuels Information System
AMT	Advanced Materials Transport
BAFA	Federal Office for Economic Affairs and Export Control (Germany)
BC	black carbon
BD	biodiesel
BD100	100% pure biodiesel (blendstock)
BD2	2% biodiesel, 98% petrodiese blend
BD5	5% biodiesel, 95% petrodiesel blend
BDF	biodiesel fuel
BE	bioethanol
BE5	5% bioethanol, 95% gasoline
BEV	battery electric vehicle
BG	biogas
BMEL	Federal Ministry of Food and Agriculture (Germany)
BMLFUW	Ministry for Agriculture, Forestry, Environment and Water Management (Austria)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Germany)
BMVIT	Federal Ministry for Transport Innovation and Technology (Austria)
BRT	Bus Rapid Transit
BTEX	benzene, toluene, ethylbenzene, and xylene
BTL	biomass-to-liquid (fuel) (method, plant, process)
3CV	Center for Vehicle Control and Certification (Chile)
CATARC	China Automotive Technology and Research Center
CERT	Committee on Energy Research and Technology (IEA)
CGSB	Canadian General Standards Board
CH_4	methane
CI	compression ignition

CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COP21	21st Session of the Conference of Parties to the 1992 United Nations Framework on Climate Change
CORES	Corporación de Reservas Estratégicas
DDF	diesel dual fuel
DI	direct injection
DISI	direct injection spark ignition
DME	dimethyl ether
DOE	U.S. Department of Energy (United States)
DPF	diesel particulate filter
DTU	Technical University of Denmark
E5	5% ethanol, 95% gasoline blend
E10	10% ethanol, 90% gasoline blend
E85	85% ethanol, 15% gasoline blend
EC	European Commission
ECA	Emission Control Area
ED95	ethanol diesel fuel mix of 95% ethanol and 5% ignition improver
EEP	Energy Efficiency Plan (Thailand)
EIA	Energy Information Administration
EIP	Energy Information Program
EPA	U.S. Environmental Protection Agency (United States)
ETBE	ethyl tertiary-butyl ether
eTV	ecoTECHNOLOGY for Vehicles Program
EU	European Union
EUWP	Working Party on Energy End Use Technologies
EV	electric vehicle
ExCo	Executive Committee
FAME	fatty acid methyl ester; conventional esterified biodiesel
FCV	fuel cell vehicle
FFV	flex-fuel vehicle
FNR	Fachagentur Nachwachsende Rohsoffe
FQD	Fuel Quality Directive
FTIR	Fourier transform infrared radiation
FTP	Federal Test Procedure (U.S. Environmental Protection Agency)

GC	gas chromatography
GDI	gasoline direct injection
GDP	gross domestic product
GHG	greenhouse gas
GPF	gasoline particulate filter
H_2	hydrogen
HC	hydrocarbon
HCNG	hydrogen-compressed natural gas
HDV	heavy-duty vehicle
HEV	hybrid electric vehicle
HPLC	high-performance liquid chromatography
HSL	Helsinki Regional Transport Authority
HVO	hydrotreated vegetable oil
IC	internal combustion
ICE	internal combustion engine
IDAE	Instituto para la Diversificación y Ahorro de la Energía
IEA	International Energy Agency
ISO	International Organization for Standardization
JGA	Japan Gas Association
KBA	Kraftfhart-Bundesamt - Federal Motor Transport Authority (Germany)
LDV	light-duty vehicle
LEVO	Organization for the Promotion of Low-Emission Vehicles (Japan)
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LTC	low-temperature combustion
M85	85% methanol, 15% gasoline blend
METI	Ministry of Economy, Trade, and Industry (Japan)
MON	motor octane number
MS	mass spectrometry
MSR	methane stream reforming
MTBE	methyl tertiary-butyl ether
NEB	North European Bio Tech Oy
NEDC	New European Driving Cycle
NGV	natural gas vehicle

NIS	New Israel Shekel
NO_x	nitrogen oxides, composed of nitric oxide (NO) and nitrogen dioxide (NO_2)
NoVA	Normverbrauchsabgabe (Austria)
NTSEL	National Traffic Safety and Environment Laboratory (Japan)
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
PDP	Power Development Plan (Thailand)
PERD	Program of Energy Research and Development (Canada)
PFI	port fuel injection
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
PVO	pure vegetable oil
R&D	research and development
RD&D	research, development, and demonstration
RDE	real driving emission
RED	Renewable Energy Directive
RFR	Renewable Fuels Regulation
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
RME	rapeseed methyl ester
RON	research octane number
SEK	Swedish Krona
SFOE	Swiss Federal Office of Energy
SI	spark ignition
SOA	secondary organic aerosol
STA	Swedish Transport Administration
TAEE	teriary-amyl ethyl ether
TransSmart	Smart Mobility Integrated with Low-Carbon Energy
VTT	VTT Technical Research Centre of Finland
WP	work package
WTT	well-to-tank
WTW	well-to-wheel
xTL	synthetic liquid transportation fuels

Units of Measure

baht	Thai currency
Btu	British thermal unit(s)
°C	degree(s) Celsius
d	day(s)
°F	degree(s) Fahrenheit
g	gram(s)
gge	gasoline gallon equivalent
h	hour(s)
kg	kilogram(s)
kL	kiloliter(s)
km	kilometer(s)
kt	kilotonne(s)
ktoe	kilotonne(s) of oil equivalent
L	liter(s)
mb	million barrels
m^3	cubic meter(s)
mg	milligram(s)
MJ	megajoule(s)
Mt	megatonne(s) or million metric ton(s)
Mtoe	megatonne(s) of oil equivalent
PJ	petajoule(s) (1×10^{15} joules)
t	metric ton(s) or tonne(s) (1,000 kg)
t/a	metric ton(s) per year (annum)
TJ	terajoule(s)
ton	U.S. ton (907 kg or 2,000 lb, not abbreviated)
tonne	metric ton or t (1,000 kg)
TWh	terawatt-hour(s)
vol%	volume percent
€	euro(s) (European Union currency)
$	dollar(s) (US currency)