IEA-Advanced Motor Fuels

ANNUAL REPORT 2017

iea Energy Technology Network

ADVANCED MOTOR FUELS IEA-AMF

IEA Technology Collaboration Programme on

Advanced Motor Fuels Annual Report 2017

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, 2015, and 2016) were blue, dark green, light green, yellow, red, violet, and blue, respectively.

This year's edition has a green spine, because this is the third color in the rainbow, representing the third year of the new AMF working period, which started in 2015. Green also indicates health, nature, and the environment. AMF is committed to reduce the impacts of vehicle exhaust emissions on human health and on nature, by evaluating exhaust emissions of vehicles running on alternative motor fuels.

Cover: This car is carrying a portable emission measurement system (PEMS) to measure real-world driving emissions. Recently, large deviations between certification testing and real-world driving emissions have been reported for modern engines. To ensure that modern engines deliver on the promised low NO_x and PM emissions, measurements of real-world driving emissions have now been included in the latest Euro 6 regulations.

The car is depicted driving along a sugarcane plantation. Sugarcane is the least-expensive feedstock for ethanol production and grows in tropical countries, such as Brazil, India, Thailand, and Australia. Ethanol can be blended into gasoline for use in the existing vehicle fleet or as pure ethanol in dedicated engines. Ethanol from sugarcane is a striking option for emerging economies to meet their growing fuel demand with a low-carbon fuel.

URL: http://www.iea-amf.org/content/publications/annual_reports

Photo credit: Thomas Wallner, Argonne National Laboratory, USA
Cover Design: Bryan Murray, 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 last year published the first *World Energy Outlook* (WEO) 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. By March 2018, more than 170 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.

There is a strong belief in electrification. Advantages of electric motors include high energy efficiency and the lack of polluting exhaust emissions from the vehicle. Drawbacks are the limited traveling range, the need for dedicated vehicles, and the need to utilize renewable energy that is low in life-cycle GHG emissions and local pollutants from electricity generation. Thus, both electric vehicles and advanced motor fuels in internal combustion engines play important roles in the future of low-carbon transport. It is important to stress that competition among the various sustainable solutions should be avoided, as all will be needed to reach our ambitious goals.

In 2016, biofuels provided 3.3% of the world's transportation fuel according to the WEO 2017. For the sustainable development scenario, this needs to increase to almost 23% by 2040. The European Union Clean Power for Transport Package shows that biofuels are the only solution to reduced GHG emissions that can be utilized over all modes of transport. Liquid fuels, in particular, have a high energy density, which is requested in many modes of transport such as long-haul road, maritime, and aviation. Up to 2030, sustainable produced fuels will be the most important solution to reach highly ambitious GHG reduction targets.

With its work program, 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.

AMF TCP communication products are well tailored to meet the needs of different audiences. Final reports from AMF annexes continue to address the target group of engineers and scientists. The AMF Annual Report has recently been streamlined to provide condensed and to-the-point information on the status of annex work and of advanced motor fuels in AMF member countries. A third communication product consists of key messages for policy makers and laypersons that provide a brief description of the main messages from annex work. I hope that these three levels of reports will make AMF even more successful and a source of information for all levels of society.

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 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. Today, many countries and metropolitan areas are evaluating a ban on diesel engines due to their historically high emissions. Diesel vehicles fulfilling the most stringent emission requirements are clean. A ban of a certain technology is not a sustainable solution — we should ban high emissions and poor emission regulations. Emerging economies could learn from the mistakes made and leapfrog directly to the most stringent emission requirements.

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.

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

The total transport system could be described as a big ship with huge inertia. It takes some time to put this ship on a totally new course. The year 2017 brought some minor changes to the course, but major changes are still needed to reach the climate goals of 2030 and, especially, 2050. Regarding greenhouse gas (GHG) emission reductions in transport, the ambitions vary significantly country by country. The Nordic countries have high ambitions. Sweden has set a goal to reduce GHG emissions from transport by 70% by 2030 (reference year 2010),[1] and Finland has set a reduction goal of 50% by 2030 (reference year 2005).[2] Canada has committed to reducing overall GHG emissions by 30% below 2005 levels by 2030.[3]

Taking into account the relatively short lead time to 2030, it is clear that one single solution cannot deliver all emission reductions needed. To reach such stringent climate goals, we need to implement a wide range of measures, including traffic management, improved energy efficiency on the system as well as on the vehicle level, and finally the introduction of low-carbon energy carriers (e.g., renewable fuels and renewable electricity). Betting on just one horse, be it electrification or some other single technology, will not take us to the goal.

Renewable fuels, either used as blending components in conventional fuels (typically low-level blending of ethanol and conventional biodiesel) or used as such (drop-in-type fuels such as hydrotreated vegetable oil [HVO]), can be implemented with short notice, as modifications to the refuelling infrastructure or to the vehicles are not needed. Mandates for biofuels have been used with success all over the globe. Renewable fuels, gaseous as well as liquid, could also be produced by using renewable electricity and captured carbon dioxide (CO_2). Currrently, interest in electrofuels has been growing, and some IEA-coordinated activities can be expected in 2018.

The two countries with the highest share of biofuels in road transport are most probably Brazil and Sweden. In 2017, the energy share of biofuels was

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1 http://www.government.se/articles/2017/06/the-climate-policy-framework/.

2 http://tem.fi/documents/1410877/2769658/Government+report+on+the+National +Energy+and+Climate+Strategy+for+2030/0bb2a7be-d3c2-4149-a4c2-78449ceb1976.

3 https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/progress-towards-canada-greenhouse-gas-emissions-reduction-target.html.

21.9% in Brazil, with ethanol contributing 82% and biodiesel 18%.[4] In Sweden, the share of biofuels in road transport was 20.8%.[5] In the case of Sweden, the distribution within biofuels differs totally from that in Brazil. In Sweden, 86% was diesel substitutes (within diesel substitutes the share of HVO was 81% and the share of conventional biodiesel fatty acid methyl ester [FAME] was 19%), 8% biogas, and only 6% ethanol.

In 2016, the total amount of biofuels for road transport within the European Union (EU) was 14.4 Mtoe, or some 5% of the total fuel consumption.[6] As in the case of Sweden, diesel substitutes dominate with a share of some 81%. Since 2011, the total biofuels volume has been more or less constant, mainly because of an uncertain policy framework. The so-called indirect land-use change (ILUC) directive, capping crop based at 7%, was implemented in 2015. A proposal for the update of the directive on the promotion of renewable energy was presented in late 2016 (Renewable Energy Directive [RED II]). A final directive, defining sustainable feedstocks and setting targets and limits for various types of biofuels and renewable fuels, is expected in 2018.

In the U.S., the situation is also somewhat challenging for the fuel suppliers, as the volume requirements under the Renewable Fuel Standard (RFS) program are decided upon on an annual basis. The 2018 biofuel targets were set on November 30, 2017.[7] Nonetheless, the U.S. RFS and the California Low-carbon Fuel Standard continue to play an important role to introduce bioethanol, biodiesel, renewable diesel, and renewable natural gas into the U.S. transportation fuels market. In addition, research and development efforts are under way to introduce high-octane fuels (especially with an ethanol blending level of 20% or above) for new vehicle engines to gain efficiency and to introduce natural gas into medium- and heavy-duty truck sectors to deliver affordable energy and to achieve emission reductions.

Notwithstanding, fuels and energy carriers requiring dedicated vehicles and dedicated infrastructure (e.g., gaseous fuel vehicles and electric vehicles) face more obstacles in entering the market. Alternative vehicles are promoted through, for example, incentives and public sector procurements.

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4 https://gain.fas.usda.gov/Recent%20GAIN%20Publications/Biofuels%20Annual_Sao%20Paulo%20ATO_Brazil_9-15-2017.pdf.

5 http://www.mynewsdesk.com/se/svebio/pressreleases/2017-aennu-ett-rekordaar-foer-biodrivmedel-2423505.

6 https://www.eurobserv-er.org/biofuels-barometer-2017/.

7 https://www.epa.gov/renewable-fuel-standard-program/final-renewable-fuel-standards-2018-and-biomass-based-diesel-volume.

Alternatively powered cars accounted for a total of 5.7% of the EU new car market in 2017.[8] The share of plug-in vehicles (battery electric and plug-in hybrids) was 1.4%, hybrids (autonomous) 2.9%, and other alternative-fuelled vehicles (mainly gas-fuelled vehicles) 1.4%. For alternative vehicles, either plug-in vehicles or gas-fuelled vehicles to make a substantial impact in the vehicle fleet and overall GHG emissions, sales numbers must grow significantly. Currently, the impact of both electric- and gas-fuelled vehicles is much smaller compared to the use of liquid biofuels.

The fact remains that in practice one size does not fit all. Electrification is best suited for urban services and short driving distances, whereas high-energy density liquid fuels will be needed for a long time in applications such as long-haul trucking, agriculture, marine use, and aviation. Through a series of Annexes (projects), the AMF TCP has been defining optimum uses for alternative energy carriers (e.g., cars, trucks, buses, mobile machinery). In 2017, IEA published a report called *The Future of Trucks. Implications for Energy and the Environment*.[9] The report states the following:

> …[t]he use of alternative fuels and alternative fuel trucks could help achieve key energy and environmental policy goals, such as diversifying the fuel supply of road freight and reducing CO_2 and air pollutant emissions. Natural gas, biofuels, electricity and hydrogen are the main alternatives to oil, but they differ in the extent to which they can contribute to policy objectives.

It could be added that the alternatives also differ in, for example, practicality and applicability, timeframe of implementation, and cost-effectiveness.

The offering of plug-in electric passenger cars from many major automotive manufacturers is growing rapidly. The offering of gas-fuelled vehicles from European manufacturers is ample, as well. As for heavy-duty, gas-fuelled vehicles, three manufacturers (i.e., Iveco, Scania, Volvo) launched new powerful methane engines (13 litre, 400 plus horsepower) in 2017, significantly improving the outlook for methane fuels in heavy road transport. The liquefied natural gas (LNG) market is growing rapidly in Asian countries. In Japan, which has the largest demand for LNG in the

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8 http://www.acea.be/statistics/tag/category/electric-and-alternative-vehicle-registrations.

9 https://www.iea.org/publications/freepublications/publication/TheFutureofTrucksImplicationsforEnergyandtheEnvironment.pdf.

world, a first fleet test for heavy-duty LNG trucks will get under way in 2018.

The diesel scandal has definitely hurt the reputation of internal combustion engines (ICEs). In 2017, many cities and even governments presented plans to ban ICE vehicles in the future. Most probably, the process will start with banning old diesel passenger cars from certain areas. However, one should keep in mind that the main reason for the diesel scandal was not lack of technology, but rather shortcomings in the emission legislation. The European Euro VI regulation, effective as of 2013, includes requirements for real driving emissions (RDEs). Testing within AMF Annex 49 "COMVEC"[10] demonstrated that Euro VI vehicles really deliver low regulated emissions (e.g., nitrogen oxides, particulates). Combine this emission performance with a high-quality renewable fuel, and you have a combination compatible with the future. In Europe, RDE requirements were introduced for passenger cars as well in late 2017.

AMF will continue to contribute to a cleaner and more sustainable future by carrying out collaborative research and demonstrations of clean fuels and clean ICE technology. The ICE is by no way obsolete yet. There is a lot of potential for improvements, and we should harness this potential.

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[10] http://www.iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Annex_49.pdf.

IEA Technology Collaboration Programme for International Energy Agency

Advanced Motor Fuels Annual Report 2017

This Annual Report was produced by Kevin A. Brown (project coordination/management), Margaret A. Clemmons (editor), Vicki Skonicki (document production), and Gary Weidner (printing) of Argonne National Laboratory. The cover was designed by Bryan Murray, 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	Natural Resources Canada
Chile	Ministry of Energy
China	China Automotive Technology and Research Center (CATARC)
Denmark	Technical University of Denmark (DTU)
Finland	The Technical Research Centre of Finland (VTT)
Germany	Fachagentur Nachwachsende Rohsoffe (FNR)
India	Ministry of Petroleum and Natural Gas
Israel	Ministry of National Infrastructure, Energy and Water Resources
Japan	• National Institute of Advanced Industrial Science and Technology (AIST) • Organization for the Promotion of Low Emission Vehicles (LEVO) • National Traffic Safety and Environment Laboratory (NTSEL)
Republic of Korea	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Spain	Instituto para la Diversificación y Ahorro de la Energía (IDAE)
Sweden	Swedish Transport Administration (STA)
Switzerland	Swiss Federal Office of Energy (SFOE)
Thailand	PTT Research and Technology Institute
USA	United States 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 50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
Annex 51	Methane Emission Control	Jesper Schramm
Annex 52	Fuels for Efficiency	Padol Sukajit
Annex 53	Sustainable Bus Systems	Alfonso Cádiz
Annex 54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
Annex 55	Real Driving Emissions and Fuel Consumption	Thomas Wallner

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

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

Contents

1 The Advanced Motor Fuels Technology Collaboration Programme

Technology Collaboration Programme for Advanced Motor Fuels (AMF TCP)

The Need for Advanced Motor Fuels

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

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

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

Our Approach

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

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

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

Benefits

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

About the AMF TCP

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

Currently, 18 contracting parties from 16 countries participate in AMF (Japan has designated three contracting parties):

- Austrian Agency for Alternative Propulsion Systems (Austria)
- Natural Resources Canada (Canada)
- Ministry of Energy (Chile)
- China Automotive Technology and Research Center (China)
- Technical University of Denmark (Denmark)
- The Technical Research Centre of Finland (Finland)
- Fachagentur Nachwachsende Rohstoffe (Germany)
- Ministry of Petroleum and Natural Gas (India)
- Ministry of Energy and Water Resources (Israel)
- National Institute of Advanced Industrial Science and Technology (Japan)
- Organization for the Promotion of Low Emission Vehicles (Japan)
- National Traffic Safety and Environment Laboratory (Japan)
- Korea Institute of Energy Technology Evaluation and Planning (Republic of Korea)
- Institute for Diversification and Saving of Energy (Spain)
- Swedish Transport Administration (Sweden)
- Swiss Federal Office of Energy (Switzerland)
- PTT Research and Technology Institute (Thailand)
- United States Department of Energy (USA)

AMF Management

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

The AMF TCP work program is carried out through **Annexes**, which are projects with defined objectives, a defined work scope, and defined starting and ending dates. Annexes can be task shared, cost shared, or a combination of task shared and cost shared. Work in specific annexes is led by Operating Agents. The representatives of Operating Agents participate in 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 producing the final report.

To support the work of the ExCo and to enable discussions in smaller groups, two **subcommittees** were instituted with a focus on (1) strategy and technology and (2) outreach. The subcommittees regularly review and, as needed, develop and revise AMF's strategy, provide new stimuli to encourage technology development, and encourage the participation of new members. Each subcommittee is headed by one of the experts within the AMF 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 programme, for continuous development of AMF's scope, and for reacting to any technology gaps or market barriers that have been identified.

Current Work Program
As of April 2018, seven projects are ongoing, and two are just being established:

- 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
- Heavy-duty Vehicle Evaluation

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

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 2017

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
51	Methane Emission Control	Jesper Schramm
52	Fuels for Efficiency	Padol Sukajit
53	Sustainable Bus Systems	Alfonso Cádiz
54	GDI Engines and Alcohol Fuels	Debbie Rosenblatt
55	Real Driving Emissions and Fuel Consumption	Thomas Wallner

Recently Completed Annexes*

Annex Number	Title	Operating Agent
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

* The Final Reports for the recently completed Annexes can be found on the AMF TCP website.

2.b
Annex Reports

Annex 28: Information Service and AMF Website

Project Duration	January 28, 2004–Continuous
Participants **Task Sharing** **Cost Sharing**	 None All contracting parties: Austria, Canada, Chile, China, Denmark, Finland, Germany, Israel, Japan, Republic of Korea, Spain, Sweden, Switzerland, Thailand, United States
Total Budget	€50,000 ($60,913 US) for 2017 €50,000 ($60,913 US) for 2018
Operating Agent	Dina Bacovsky BIOENERGY 2020+ Email: dina.bacovsky@bioenergy2020.eu

Purpose, Objectives, and Key Question

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

Activities

- Review relevant sources of news on advanced motor fuels, vehicles, and energy and environmental issues in general. News articles are provided by experts in the Americas, Asia, and Europe.
- Publish three electronic newsletters per year (on average) on the AMF TCP website, and use an email alert system to disseminate information about the latest issues (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

Fig. 1 AMF TCP Newsletters Published in 2017

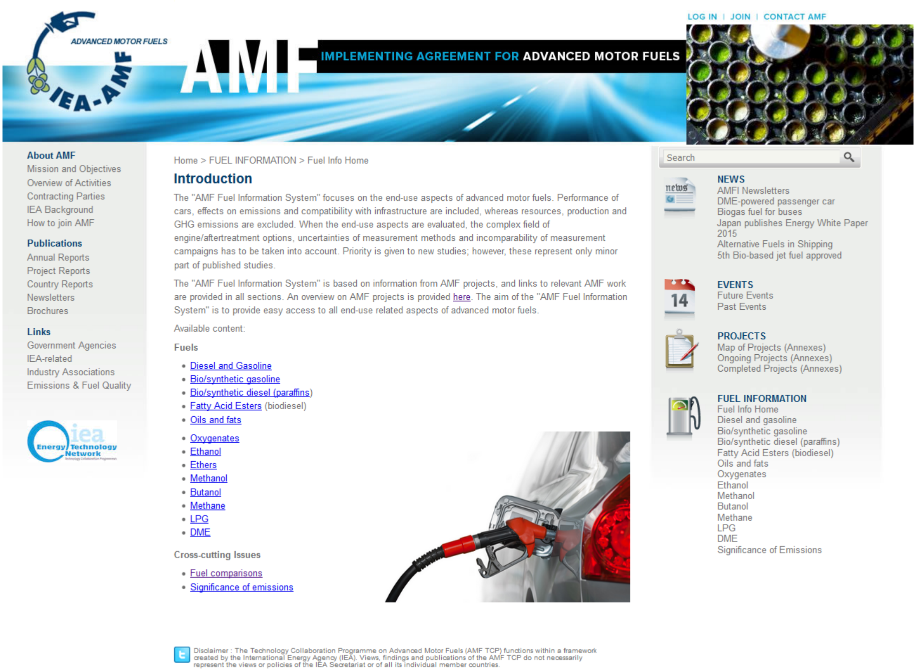

Fig. 2 Screenshot of the Fuel Information System

storing and distributing internal information for Delegates, Alternates, and Operating Agents on various topics (e.g., strategies, proposals, decisions, and Executive Committee meetings of the AMF TCP).

Key Findings

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

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

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

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

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

Publications

In 2017, three electronic newsletters were published on the AMF TCP website: one each in May, September, and December.

The Alternative Fuels Information System is available on the AMF TCP website.

The AMF TCP website is updated frequently with information from Annexes and Executive Committee meetings.

Annex 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 are 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 as 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 two-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, 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 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 conversion has benefits in terms of emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulates. Reductions in CO_2 occur partly because the ratio between carbon and hydrogen is less for natural gas than for liquid hydrocarbons (e.g., diesel, gasoline), and partly because the LNG engines can be more efficient than the traditional ones, depending on the combustion principle chosen. With regard to greenhouse gas (GHG) effects, it is a disadvantage that LNG engines emit significantly larger quantities of unburned methane than do traditional engines. Because methane is a twenty times more powerful GHG than CO_2, the overall result could easily be an increase in

GHG emissions from vehicles if their engines were converted to run on LNG.

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

Activities

WP 1: Application of Natural Gas in Combustion Engines
An overview of the application of natural gas in combustion engines for transportation purposes will be given. The Work Package (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, mixtures of natural gas and a smaller amount of hydrogen make it possible to reduce unburned methane emissions because the hydrogen promotes the combustion of methane. Methanol/dimethyl ether is another fuel option to promote methane conversion. The models will be verified in experiments in which the relevant engine parameters will be varied.

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

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

Compared with liquid fuels like diesel, gaseous fuels are more likely to escape from the vehicle. During refuelling, the connection and disconnection of the dispensing nozzle could result in small amounts of methane escaping to the ambient air. When both liquefied and compressed methane fuel are being stored, they could be vented to the atmosphere to avoid overpressurization. High-pressure fuel lines and joints could also be a source of leakage that needs to be investigated. The purpose of this 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 (LDVs)

An overview of the knowledge about unburned methane from today's LDV engines will be given. The study will reveal the available data that can be used for verifying the models 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, Finland, Israel, Thailand IEA Bioenergy Task 39 No cost sharing
Total Budget	€450,000 ($543,229 US)
Operating Agent	Padol Sukajit PTT Public Company Limited email: padol.s@pttplc.com

Purpose, Objectives, and Key Question

Annex 52, Fuels for Efficiency, was initiated in compliance with the global requirement to improve 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:

- WP I: Information Exchange with IEA Bioenergy Task 39 (Survey on Advanced Fuels for Advanced Engines) and others (IEA-AMT)
- WP II: Performance Evaluation of Chemical Friction Modifiers for Diesel and Gasoline Fuels (Denmark)
- WP III: Fuel Reforming by Thermo-chemical Recuperation (Technion – Israel)

- WP IV: Performance Assessment of Various Paraffinic Diesel Fuels (Finland)
- WP V: Opportunity for Enhancing Fuels Efficiency by Ethanol-blended Gasoline Fuels (Thailand)

Key Findings

WP I: A survey on advanced fuels for advanced engines based on a review of the literature from the last 5 to 10 years mentions that the diversity of fuels will increase further on. New advanced fuels will be introduced in the market (e.g., BTL) or will be more in the focus of research activities (e.g., OME). The concept of drop-in fuel would be more user friendly for the new entrance into the market according to the available infrastructure. Furthermore, to achieve the mutual benefit between engine–fuel interaction, the new engine technique must be more flexible for a wide range of fuel. The megatrend on electric power will make broader use of biomass to electricity, while emissions are the major concern when using new fuel.

WP II: The experiment on performance evaluation of the chemical friction modifier additive for gasoline and diesel fuels proved that fuel economy improved. The result from gasoline engines shows that a 2.7% fuel efficiency improvement can be detected only at a specific condition, but overall test conditions resulted in only a slight percentage improvement. Cetane-improver additives seem to have an insignificant effect on fuel saving under all conditions. Thus, the effect of a chemical friction modifier in gasoline and the cetane improver in diesel fuel were not the promising solution for fuel efficiency improvement, at least for conventional engine technology.

WP III: 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 IV: The aim of this project was to optimize non-road diesel engines for one paraffinic diesel fuel and compare the results with typical European-grade diesel fuel measured with OEM engine parameters. Optimization strategy was to increase the engine efficiency as high as possible without increasing emissions over the level defined with reference fuel and OEM engine parameters. Test fuel consisted of gas to liquid (GTL) and hydrotreated vegetable oil (HVO) from two sources and EN590 reference fuel (B7). The experiment was ongoing with the fully controllable diesel engine. The overall result showed the improvement in the engine efficiency for paraffinic fuels was in the range of 1.7%–2.0% (rel.) for NRSC and 1.1%–1.5% (rel.) for NRTC compared to reference fuel with OEM parameters. The key deliverable is all paraffinic diesels with low soot content have highly improved 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 V: 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. Since advanced ignition timing is a strategy used in modern Gasoline Direct Injection (GDI) engines, the use of ethanol-blended fuel is expected to improve the fuel efficiency of those engines. In this study, the experiment on research GDI engines was conducted to prove and determine the optimum ratio of ethanol blends (E0–E85) that engines could perform with high efficiency for GDI application by comparing the antiknock quality. The result is that E20–E85 blends have high potential for improving thermal efficiency in the range of 7%–17% compared to gasoline. Therefore, this benefit must use advanced ignition timing from ECU control, and an improvement in fuel efficiency can be achieved in modern gasoline GDI engines by using ethanol-blended fuel.

Publications

The final report is expected to be published soon; 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, Israel, Sweden, United States
Total Budget	$600,000 US (Estimated Budget)
Operating Agent	Alfonso Cádiz Technical Secretary of 3CV Ministry of Transport and Telecommunications of Chile Email: acadiz@mtt.gob.cl

Purpose, Objectives, and Key Question

Some 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 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 Chile, 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 de Chile. 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 different 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 for transport operations, such as the Corridor type, but with restrictions on private vehicle usage. These roads represent about 4.4% of the public transport road network. “Corridor” is a road type physically segregated for urban buses. It is similar to Bus Rapid Transit 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.

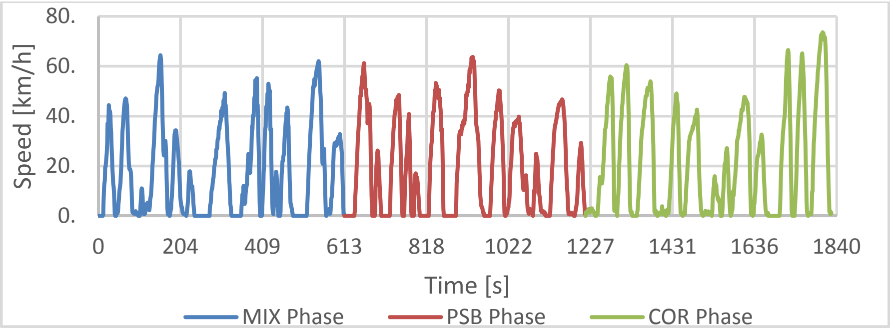

Fig. 1 Santiago Driving Cycle

Different driving conditions were evaluated to determine the parameters for the Santiago driving cycle. As a result of this analysis, the test is conducted under a warm start, with a 50% load and 0/1.4% slope. During 2016 and 2017, dynamometer tests were conducted at the VTT and Center for Vehicle Control and Certification (3CV) laboratories. At the VTT laboratory, buses with Diesel Euro V, Diesel Euro VI, CNG Euro VI, and electric technology/standard were tested. At the 3CV labs, battery electric and Diesel Euro VI buses were tested (see Figures 2 and 3). In addition, with Argonne National Laboratory's support, Centro Mario Molina (CMMCh) carried out energy consumption models using the Autonomie modeling framework, where the performance of different bus technologies and operation conditions were simulated under diverse driving cycles. The main results of these tests show that for local pollutants, the bus testing program operating in the conditions of a developing city, such as Santiago, may have higher emissions. For electric buses, the results show that these are significantly more efficient than conventional technology buses, even in demanding operating conditions during the Santiago bus cycle. Independent of this advantage, the energy consumptions are greater than those observed in other cycles with less demanding operating conditions; however, these differences may vary depending on the technology used by the electric bus.

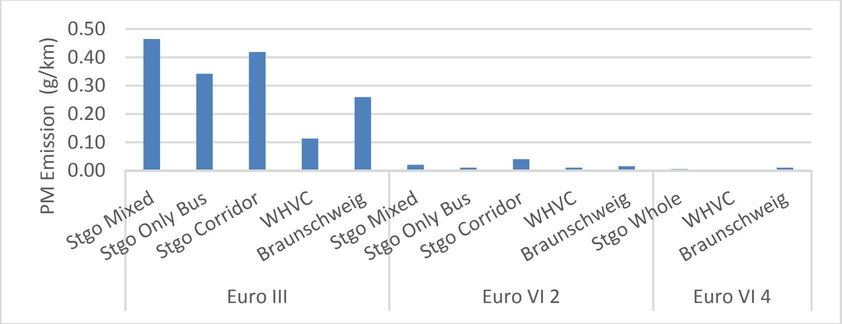

Fig. 2 Particulate Matter Emissions for Different Driving Cycles

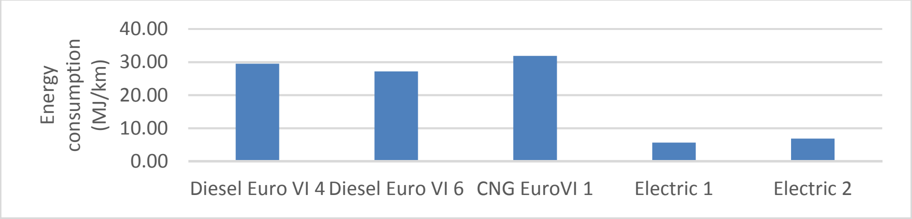

Fig. 3 Energy Consumption for Urban Buses, Santiago Driving Cycle (1.4% gradient)

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	~ €330,000 ($394,808 US)
Operating Agent	Debbie Rosenblatt Emissions Research and Measurement Section Environment and Climate Change Canada Email: Debbie.Rosenblatt@Canada.ca

Purpose, Objectives, and Key Question

Under certain conditions, gasoline direct injection (GDI) may increase particle emissions in comparison with port fuel injection (PFI) engine technologies, up to levels that are over the emissions from diesel vehicles equipped with diesel particulate filters (DPFs). Both gasoline particulate filters (GPFs) and alcohol fuel blends, 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 low-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 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.

Germany's Task-Sharing Contribution
The addition of the German studies conducted at institutes of engineering thermodynamics (LTT, FAU Erlangen-Nürnberg) will allow for fundamental investigations of soot formation in an optically accessible GDI engine using laser-based diagnostics. Further characterizations of PM are conducted in the exhaust gas duct of a metal GDI engine potentially equipped with a GPF. Different ethanol-gasoline mixtures (e.g., E10, E20)

and other model fuel-mixtures (including ISO-octane and toluene) as well as butanol mixtures (B10, B20) are studied in a wide range of operating points.

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, 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 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;
- Reports of criteria air contaminant emissions, along with fuel consumption; and
- For a select set of vehicle tests, provision of comparative information 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** **Cost Sharing**	 Canada, Denmark, Finland, Sweden, Switzerland, USA No cost sharing
Total Budget	~€400,000 ($483,764 US)
Operating Agent	Thomas Wallner Argonne National Laboratory (USA) Email: twallner@anl.gov

Purpose, Objectives, and Key Question

The levels of air pollutants from internal combustion engine (ICE)-powered vehicles that are being sold in the marketplace today are much lower than those from vehicles 4 to 10 years ago. This change is largely the result of technology forcing regulations to control the exhaust emission rates of various air pollutants such as hydrocarbons, carbon monoxide, oxides of nitrogen (NO_x), and particulate matter. Over time, changes to those regulations have reflected the extraordinary advances in fuels, engines, and emission control technologies 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 fueled 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 and real-world performance of vehicles operating under a range of worldwide driving conditions.

Activities

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

- Work package 1: Annex management

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

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

Key Findings

Canada completed on-road testing in Ottawa, Ontario, with five distinct driving segments. The vehicles were also tested in the laboratory on a chassis dynamometer. Great variability in test results occurred during the on-road emissions testing compared to the chassis dynamometer testing. Canada tested several vehicles: a cylinder deactivation vehicle, a compressed natural gas/gasoline bi-fuel vehicle and its gasoline counterpart for baseline, and three pairs of vehicle with both gasoline and diesel models. Canada found that fuel consumption from real-world testing is, on average, 22% higher than the observed fuel consumption from tests on a chassis dynamometer. Furthermore, 84% of vehicles that were tested on-road presented a statistically significant increase in NO_x when comparing real-world and laboratory results on a chassis dynamometer.

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

Sweden completed the testing of 30 vehicles on different cycles and ambient conditions. The data analysis is currently in progress.

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

The Global Situation for Advanced Motor Fuels

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

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

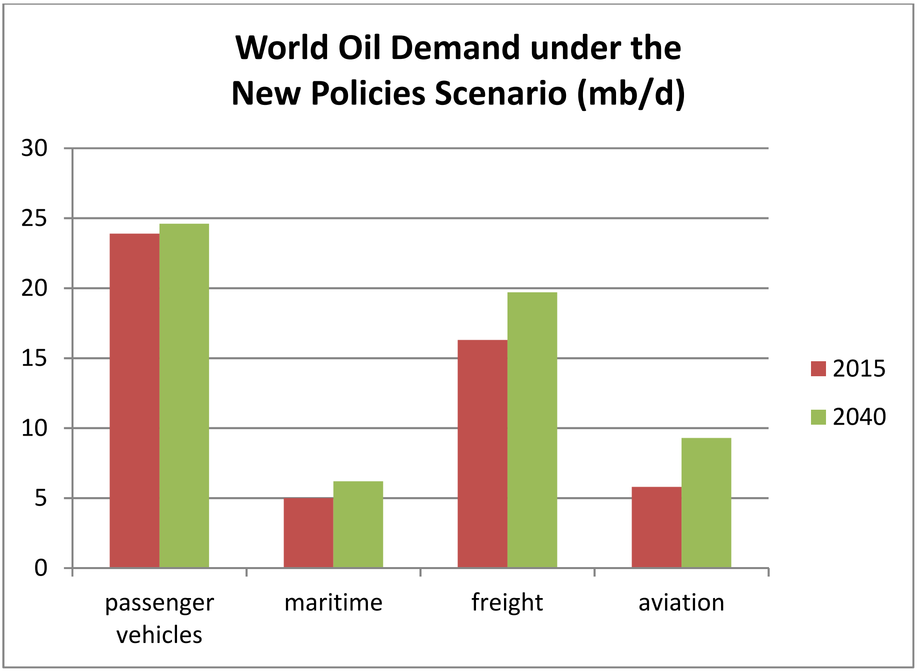

Fig. 1 World Oil Demand of the Transport Sector under the New Policies Scenario
Source: IEA World Energy Outlook 2016

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

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

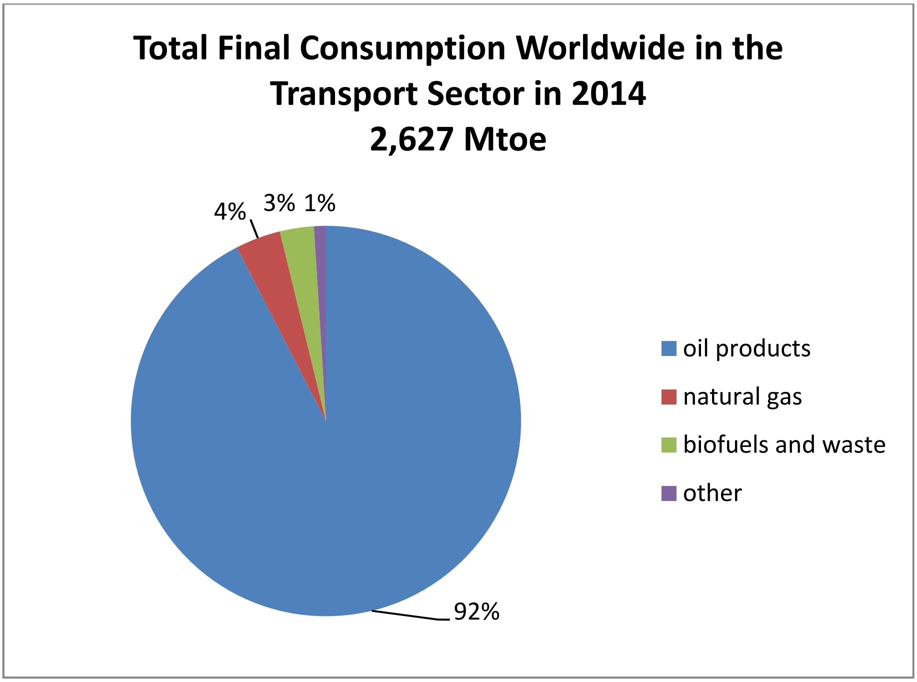

Fig. 2 Total Final Consumption of the Transport Sector in 2014
Source: IEA Key World Energy Statistics 2016

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

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

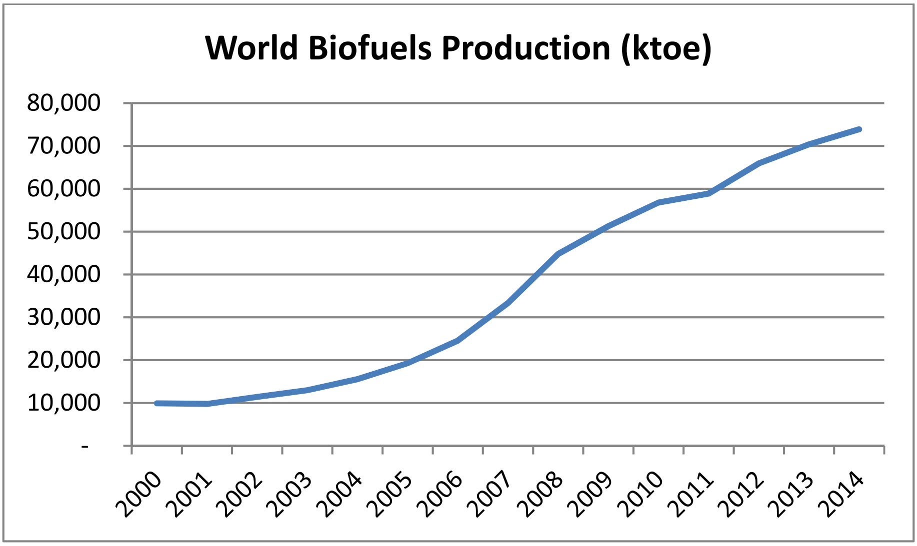

Fig. 3 World Biofuels Production in 2014 (ktoe)
Source: IEA Headline Energy Data 2016

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

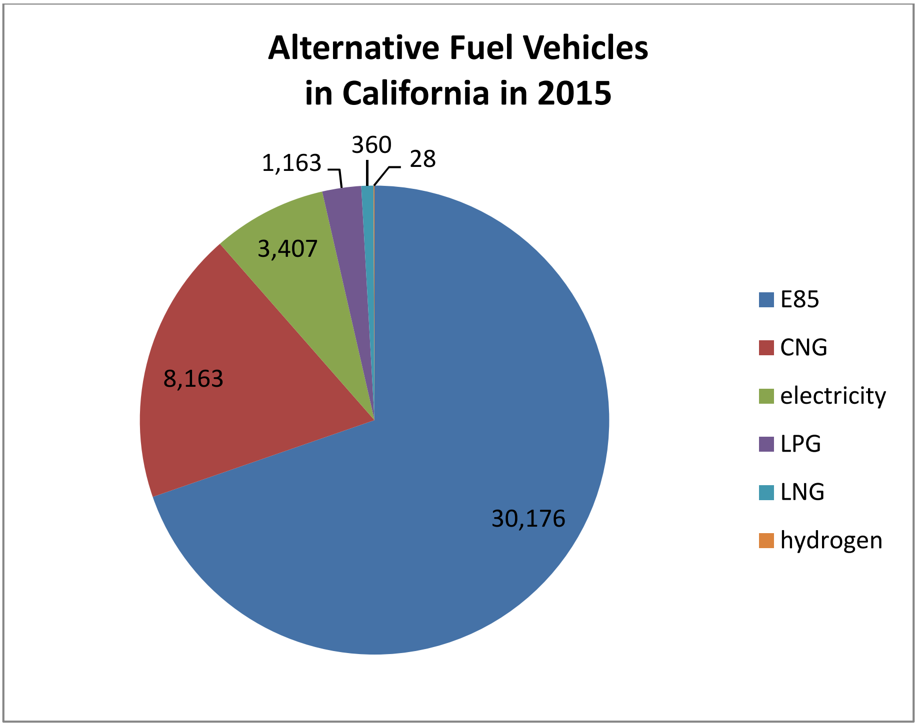

Fig. 4 Number of Alternative Fuel Vehicles in California in 2015
Source: U.S. Energy Information Administration, Alternative Fuel Vehicle Data

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

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

3.b
Country Reports of AMF TCP Member Countries

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 Austrian Council of Ministers approved the national strategy framework, *Saubere Energie im Verkehr* (Clean Energy in Transportation)[11]. 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).

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

- For 1000 L gasoline containing a minimum of 4.6% biofuel and a maximum of 10 mg/kg sulphur, the tax is €482 ($587 US); the tax is €515 ($627 US) for gasoline with a lower share of biogeneous fuel.
- For 1000 L diesel containing a minimum of 6.6% biofuel and a maximum of 10 mg/kg sulphur, the tax is €397 ($483 US); the tax is €425 ($517 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 ($24.34 US) per g of CO_2.

Austria is pushing strongly for eco-mobility. In November 2016 Austria presented a package of measures to support electro-mobility with €72 million ($88 million US), including incentives for buying electric 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.

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

Advanced Motor Fuels Statistics

Fleet Distribution and Number of Vehicles in Austria

As of December 31, 2017, 8.8 million people were living in Austria. According to Statistics Austria, a total of 7,559,192 vehicles (including 4,898,578 passenger cars) were registered in Austria as of December 31, 2017. Newly registered motor vehicles totaled 457,174 in 2017 (an increase of 6.2% in comparison to 2016). Newly registered passenger cars accounted for 353,320 vehicles — an increase of 7.2% compared to 2016.

An ongoing trend toward advanced propulsion systems can be seen in the number of vehicles with alternative drivetrains on Austrian roads in 2017 (Figure 1).

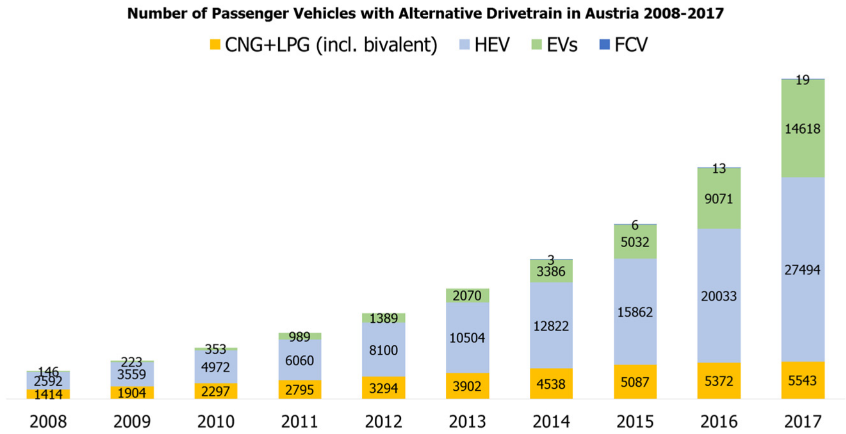

Fig. 1 Trends in Vehicles with Alternative Drivetrains in Austria, 2008–2017
Source: Statistik Austria.

Electric vehicles have become more popular within the last few years in Austria. The number of battery electric vehicles increased to 14,618 in 2017 (9,071 in 2016). The number of vehicles driven by CNG and liquefied petroleum gas (LPG), including bivalent ones, rose to 5,543. The number of fuel cell vehicles driven by H_2 rose to 19.[12]

Taking into account the total number of new registrations based on alternative drivetrains (14,161 vehicles), vehicles with alternative drivetrains

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

account for 4.0% of all new registered vehicles. Table 1 shows the development of the fleet distribution of passenger cars by drivetrains between 2013 and 2017.

Table 1 Fleet Distribution of Passenger Cars by Drivetrain in Austria, 2013–2017

Drivetrain	2013	2014	2015	2016	2017
Gasoline	1,997,302[a]	2,004,724	2,012,885	2,031,816	2,074,442
Diesel	2,621,133	2,663,063	2,702,922	2,749,038	2,770,470
Electric	2,070	3,386	5,032	9,071	14,618
LPG	1	1	1	1	2
CNG	2,219	2,397	2,475	2,456	2,433
H_2	0	3	6	13	19
Bivalent gasoline/ ethanol (E85)	6,397	6,380	6,254	6,165	5,992
Bivalent gasoline/ LPG	250	279	311	341	335
Bivalent gasoline/ CNG	1,432	1,865	2,300	2,574	2,773
Hybrid gasoline/ electric	10,049	12,232	14,785	18,696	26,039
Hybrid diesel/ electric	455	591	1,077	1,337	1,455
Total	4,641,308	4,694,921	4,748,048	4,821,508	4,898,578

[a] Includes gasoline/ethanol (E85).

Source: Statistics Austria, KFZ Bestand, as per the end of 2013 through December 31, 2017.[13]

Development of Filling Stations

By the end of 2017, Austria had a total of 2,670 publicly accessible filling stations. As an annual average, the price of Eurosuper at the filling station was €1.18 ($1.44 US) per L; for diesel, the price was €1.10 ($1.34 US) per L.

The number of natural gas filling stations has slightly decreased in recent years. However, with 161 public CNG stations in 2017, 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 2017, five H_2 refuelling stations and one public LNG filling stations (Ennshafen, Upper Austria) were in operation in Austria.

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

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 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 ($156 million US), a decrease of €14.7 million ($17.9 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 ($12.3 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 ($499.000 US) and €510.000 ($620.000 US), respectively, were allocated.

Austria has several programs that fund and support the implementation of advanced fuels and drivetrains. One launched in 2004, called "klimaaktiv 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.

The Climate and Energy Fund launched in 2014 the "Energieforschungs-programm" (Energy Research Program) replacing its predecessor, the "e!MISSION.at" program. The program supports energy and mobility technology innovations contributing to climate protection and security of supply. In 2017 the program offered a funding of €16.0 millon ($19.5 million US) for topics such as the mutual optimisation of combustion engines and alternative fuels and supports Austrian participation in R&D Collaboration Programmes in the context of the International Energy Agency (IEA).

In the ERA-NET Bioenergy Austria cooperates with Germany, Ireland, The Netherlands, Poland, Sweden, Switzerland and United Kingdom in funding transnational bioenergy research and innovation projects. The Austrian's contribution to the 2017 12th ERA-NET Bioenergy Joint Call amounts to €1.0 million ($1.22 million US).

"Mobilität der Zukunft" (Mobility of the Future), Austria's national transportation research funding program (2012–2020), is a mission-oriented R&D program aiming to create a transport system which is able to meet future mobility and social challenges by identifying and refining mid- 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.

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.

Outlook

Currently, most funding programs and incentives focus on electro-mobility. 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:

- Federal Ministry for Transport, Innovation and Technology, www.bmvit.gv.at/.
- Federal Ministry of Sustainability and Tourism, www.bmnt.gv.at.
- Mobility of the future, www.mobilitaetderzukunft.at/en.
- klimaaktiv mobil, www.klimaaktiv.at/mobilitaet.html.
- Climate and Energy Fund, www.klimafonds.gv.at/home-en-US/.
- Austrian Association for Advanced Propulsion Systems, www.a3ps.at.

Canada

Drivers and Policies

Renewable Fuels Regulations (RFRs)[14]
The RFRs require fuel producers and importers to have an average renewable content of (1) at least 5% based on the volume of gasoline that they produce or import into Canada and (2) at least 2% based on the volume of diesel fuel and heating distillate oil that they produce or import into Canada. The regulations include provisions that govern the creation of compliance units, allow trading of these units among participants, and also require recordkeeping and reporting to ensure compliance.

Clean Fuel Standard (CFS)[15]
The CFS will require producers, importers, or distributors to reduce the carbon intensity of fuels, which includes the greenhouse gas (GHG) emissions associated with production, processing, distribution and use of a fuel. The CFS will be technology-neutral and set different reduction targets for gas, liquid and solid fuels. The aim is to publish draft regulations by late 2018. Once implemented, the CFS will help drive clean growth in Canada, while reducing GHG emissions by 30 megatonnes (Mt) annually by 2030.

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[16]

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
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

14 http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=0AA71ED2-1.
15 https://www.canada.ca/en/environment-climate-change/news/2017/12/canada_s_clean_fuelstandardhowitwillwork.html.
16 http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html.

Passenger Automobile and Light Truck GHG Emission Regulations[17]

In 2010, the Government of Canada released the final *Passenger Automobile and Light Truck GHG Emission Regulations*, which prescribe progressively more stringent annual emission standards for new vehicles (i.e., model years 2011–2016). In 2014 the second phase of action on light-duty vehicles (LDVs), which contain increasingly stringent GHG emissions standards for LDVs of model years 2017–2025 were published. Under both phases of LDV regulations, spanning model years 2011–2025, the sales-weighted fuel efficiency of new cars is projected to improve from 8.6 liters per 100 kilometers (L/100 km) in 2010 to 6.4 L/100 km in 2020 and to 5.1 L/100 km by 2025. The sales-weighted fuel efficiency of new passenger light trucks is projected to improve from 12.0 L/100 km in 2010 to 9.1 L/100 km in 2020 and to 7.6 L/100 km by 2025.

Heavy-duty Vehicle (HDV) and Engine GHG Emission Regulations[18]

The *Heavy-duty Vehicle and Engine GHG Emission Regulations* establish mandatory GHG emission standards for new on-road HDVs and engines. The regulations apply to companies manufacturing and importing new on-road HDVs and engines of model years 2014 and later 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. Table 2 shows the Canadian supply of and demand for ethanol and biodiesel in 2015.

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

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

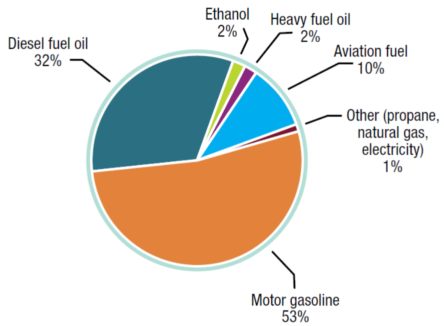

Fig. 1 Energy Use by Fuel Type for Transportation in 2013[19]

Table 2 Canadian Supply of and Demand for Biofuels in 2015 (in millions of liters)[20]

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[21]

Transport Canada's eTV Program tests the safety, environmental impact, and driving performance of new technologies for passenger cars and heavy-duty trucks. Testing results from the eTV Program help provide the information needed to create regulations and standards for these new products.

Electric Vehicle and Alternative Fuel Infrastructure Deployment Initiative[22]

Natural Resources Canada (NRCan) is investing to expand the network of electric vehicle charging and alternative refuelling stations across the nation as part of the government's efforts to encourage Canadians to reduce their

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

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

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

22 https://www.nrcan.gc.ca/energy/alternative-fuels/fuel-facts/ecoenergy/18397.cleangrowth/19780.

carbon footprint. The funding will support the deployment of electric chargers; natural gas and hydrogen refuelling stations; the demonstration of new, innovative electric vehicle charging technologies; and the development of codes and standards.

Energy Innovation Program (EIP)[23]
NRCan's EIP supports clean energy innovation. Accelerating clean technology research and development (R&D) is a key component of the Government of Canada's approach to promoting sustainable economic growth and to supporting Canada's transition towards a low-carbon economy.

Program of Energy Research and Development (PERD)[24]
PERD is a federal, interdepartmental program operated by NRCan. PERD supports energy R&D 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.

Vehicle Propulsion Technologies (VPT) Program[25]
The National Research Council Canada's VPT program assists Canadian automotive manufacturers to improve the efficiency of internal combustion engines, powertrains, and the use of electric and fuel cell propulsion.

Strategic Innovation Fund[26]
The Strategic Innovation Fund, managed by Innovation, Science and Economic Development Canada, allocates repayable and non-repayable contributions to firms of all sizes across all of Canada's industrial and technology sectors. The program consolidates and simplifies the Strategic Aerospace and Defence Initiative, Technology Demonstration Program, Automotive Innovation Fund, and Automotive Supplier Innovation Program.

[23] https://www.nrcan.gc.ca/energy/funding/current-funding-programs/18709.icg/18876.
[24] http://www.nrcan.gc.ca/energy/funding/current-funding-programs/perd/4993.
[25] https://www.nrc-cnrc.gc.ca/eng/solutions/collaborative/vpt.html.
[26] https://www.canada.ca/en/innovation-science-economic-development/programs/strategic-innovation-fund.html.

Outlook

As depicted in Table 3, the transportation sector consists of several distinct subsectors — passenger, freight, air, and others (e.g. recreational). Each subsector exhibits different trends during the projected period. For example, GHG emissions from cars, trucks, and motorcycles are projected to decrease by 25 Mt between 2005 and 2030, while those for heavy-duty trucks and rail are projected to increase by 11 Mt over the same time 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.[27]

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.[28]

Table 3 Transportation: GHG Emissions (Mt CO_2 equivalent)[29]

Transportation Subsector	2005	2020	2030	Δ 2005 to 2030
Passenger Transport	**97**	**89**	**73**	**-24**
Cars, trucks, and motorcycles	88	80	64	**-25**
Bus, rail, and domestic aviation	9	9	9	**1**
Freight Transport	**62**	**70**	**73**	**11**
Heavy-duty trucks, rail	55	63	66	**11**
Domestic aviation and marine	8	7	7	**0**
Other: recreational, commercial and residential	**11**	**9**	**11**	**-1**
Total	**171**	**168**	**157**	**-14**

27 https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/emission-trends-2014.html.
28 https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2016/index-eng.html.
29 https://www.canada.ca/en/environment-climate-change/services/climate-change/publications/2016-greenhouse-gas-emissions-case/chapter-2.html.

Chile

Drivers and Policies

In Chile, the transportation sector is responsible for 35% of the country's energy consumption. Of this percentage, oil derivatives account for 98% of usage (National Balance of Energy 2016), making them responsible for about 20% of the total emissions of greenhouse gases in Chile. In addition, the consumption of oil derivatives in urban areas causes pollution. As a result, public policies are needed that focus on the efficient use of energy in the transportation sector. These policies should aim to reduce carbon dioxide (CO_2) gases and pollutants emitted in the environment, while also decreasing Chile's dependence on imported fuels and the nation's associated vulnerability.

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

An example of MTT and energy efficiency is the public transport system in Santiago. The main objectives are to have an efficient, safe, and high-quality transport system. At present, the system is in the bid stage of evaluation. The MTT has prepared a bidding process for the concession of the use of roads for four of the seven current business units. The business units to be bid represent 47% of the total of the system and cover 2,855 of currently operating buses.

The most relevant topics are the technology requirements and bus emissions. Interested operators of transport services must have a number of buses that comply with local regulations. Regarding pollutant emissions, companies are required to meet standard Euro VI or EPA2010. Furthermore, each winning company must have at least 15 electric buses and 15 buses with special attributes for each business unit, meaning that vehicles incorporate additional conditions over the minimum required. Examples include having a low floor and air-conditioning and having emission technology that exceeds the standards required by current regulations.

New Vehicle Energy Efficiency Regulation

Chile was the first Latin American country – as of February 2013 – to implement compulsory labeling of vehicular energy efficiency. Such labeling allows buyers of new light vehicles, either diesel or gasoline, to compare their energy performance (www.consumovehicular.cl). In June 2017, vehicle energy-efficiency labeling was expanded to include mid-sized vehicles (light trucks and vans) and hybrid and electric vehicles. Figure 1 shows examples of labels for various types of vehicles. In addition, since labeling was implemented, dealers are obligated to include city fuel consumption in written advertising, which applies to magazines, newspapers, and other printed materials.

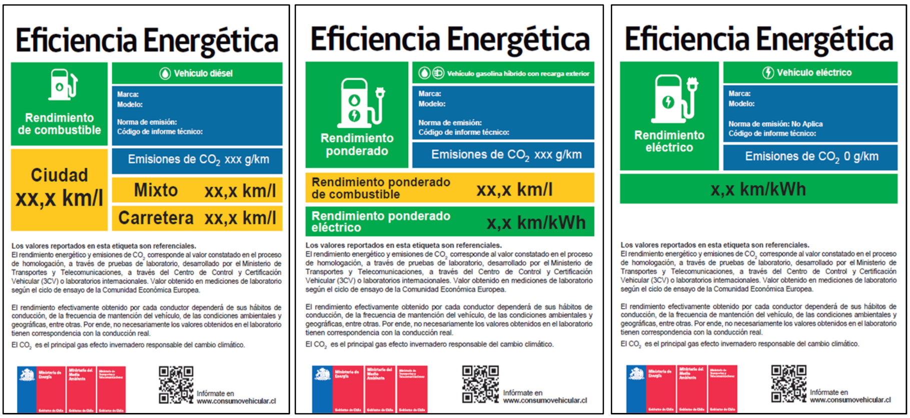

Fig. 1 Examples of Labels for Diesel Vehicles, Hybrid Vehicles, and Electric Vehicles

Project of Law – Energy Efficiency

This project was already admitted in the congress and is currently under analysis in the Chamber of Deputies. The main objective in the transportation sector is to improve the energy efficiency of Chile's vehicle fleet. The Ministry of Energy, together with the University of Chile, through an agreement with the university's Energy Center, developed a proposal of energy-efficiency standards for light vehicles, simulating different scenarios, based on all the units sold (brands and models) in 2015. This proposal is available for incorporation in the short term as a regulation, once the Energy Efficiency Law is approved. In addition, Chile is collecting data from mid-sized vehicles (i.e., vans, light trucks) to make a mid-term request proposal. Eventually, a long-term standard or regulation for heavy vehicles will also be planned. Figure 2 shows sales of light vehicles in 2015.

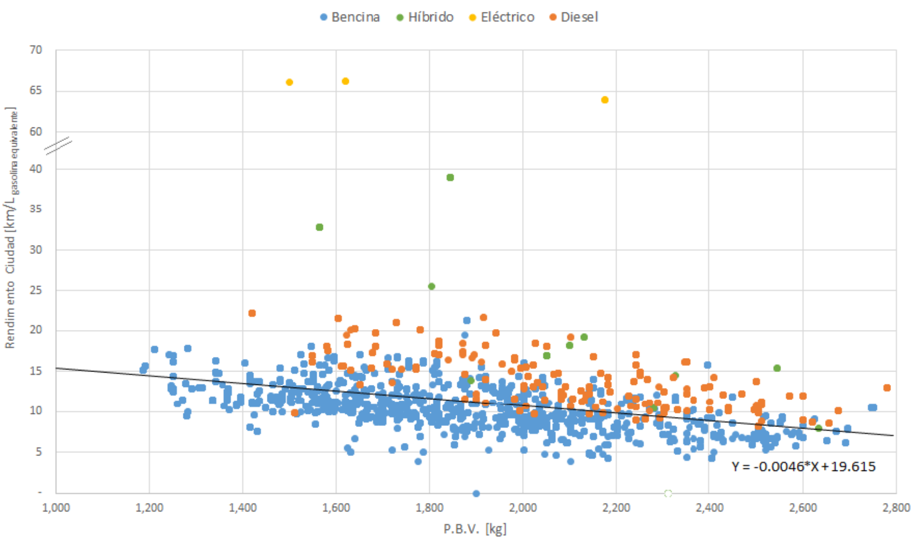

Fig. 2 Sales of Light Vehicles in Chile in 2015 (km/L of gasoline equivalent using weight as a descriptor)
Source: University of Chile.

Research and Demonstration Focus

Energy-Efficient Buses in Santiago

As a result of the collaboration agreement with MTT, Chile has made progress in creating a methodology to measure the energy efficiency of public transport buses. The Vehicle Control and Certification Center (3 CV) developed the "TS-STGO" driving cycle of Transantiago (i.e., public transport system of Santiago), with the support of the Chile Mario Molina Center, Ministry of Energy, and the VTT Finland Laboratory. The DRIVING CYCLE TS-STGO has a total distance of 9.98 km, a duration of 1,827 s, an average speed of 19.66 km/h and takes into consideration gradient and maximum speed.

Because Chile can already measure the energy efficiency of urban public transport buses in Santiago, the future challenge is to ensure that all new models added to the Transantiago fleet are measured in terms of energy efficiency. In the medium term, regulations are being developed to define minimum energy-efficiency standards for all buses entering the Santiago bus fleet.

Buses from Other Cities – Urban and Interurban

Through an agreement between MTT and the Ministry of Energy, and through the 3 CV Heavy Vehicle Emissions Laboratory, the energy efficiency of the most representative buses used in the most important cities of the country (like Santiago) will be measured. The challenges are to have an energy-efficiency comparison platform for buses in the regions. For this, an agreement of transfer of resources with the Institute of Complex Systems of Engineering belonging to the University of Chile is in force. They are creating a database and developing the necessary tools to reach this target.

Efficient Driving Program for the Public Sector

Efficient driving involves the type of driving and attitude that allows attaining higher fuel efficiency, emitting less CO_2 during travel, and prolonging the life of the vehicles. The Efficient Driver Training Program for drivers in the public sector was initiated in 2014. This program is a cost-effective program with economies of scale. The valued savings achieved per year by the implementation of this program exceed their annual costs. Since the program's inception 4 years ago, more than 1,300 professionals have been trained (from 20 ministries).

Outlook

Metropolitan Region – Santiago, December 2017: the Government of Chile Launches the National Strategy of Electro-mobility

Electric vehicles are expected to be the international standard by 2030. Electric vehicles can be up to four times more efficient than conventional ones. In addition, they produce less noise, require less maintenance, and emit fewer pollutants. On the basis of electricity generation and distribution network, an electric vehicle in Chile would emit around one-third of the CO_2 emissions of a conventional vehicle. In addition, they use three times more copper than conventional vehicles, and it is expected that by 2025, around 40% of the world's lithium production will go to electric vehicles. Chile is the largest copper producer in the world, with 34% of world production, and the second country in the world in lithium production.

The Ministry of Energy, together with MTT and the Ministry of the Environment, developed the National Electromobility Strategy. According to this strategy, by the year 2050, 100% of the national urban public transport fleet will be electric, as well as 40% of the private vehicle fleet. In addition, the strategy incorporates strategic axes and lines of work and is established with specific deadlines to develop the necessary environment to promote this technology. Five strategic axes and 20 lines of action are identified. The five strategic axes are listed below:

- Adopt regulation and standards,
- Promote the penetration of electric vehicles in public transport,
- Support research and development and strengthen human capital,
- Continue to develop electro-mobility, and
- Transfer knowledge and disseminate information.

Only considering the target for the year 2050 of light vehicles, it is estimated that the entry of electric vehicles would avoid the emission of 11 million tons of CO_2 per year and reduce the country's energy expenditure by more than $3,300 million US per year, which is equivalent to 1.5% of the PIB 2016 (https://www.datosmacro.com/pib/espana).

Additional Information Sources

- Transport: Ministry of Transport and Telecommunications, www.mtt.gob.cl.
- Pollutants and the environment: Ministros del Medio Ambiente, www.mma.gob.cl.
- Energy: Ministry of Energy, www.energia.gob.cl.
- Vehicle fuel economy (label): www.consumovehicular.cl.
- Type approval or certification: Ministry of Transport and Telecommunications, "3 CV," 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.

In addition to the focus on promoting the industrialization of the pure electric and plug-in hybrid electric vehicle as described in last year's AMF Annual Report, China is now also expanding ethanol production and use.

On September 13, 2017, China's National Development and Reform Commission released a new policy paper on the expansion of biofuel ethanol production and the promotion of ethanol gasoline for vehicles in conjunction with 14 other government organizations, including the National Energy Administration and the Ministry of Finance.

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

China first developed an ethanol fuel industry 15 years ago, when it was employed for the increased utilization of corn in the country. Ethanol gasoline was used in 11 provinces in 2004, making up one-fifth of the country's total gasoline consumption. However, China banned the use of food crops in 2007, prompting suppliers to switch to straw stalks and other materials. In recent years, regulators eased the ban on the use of food crops in some areas.

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

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 20828-2015, "Biodiesel blend stock (BD100) for diesel engine fuels" was released and implemented on May 8, 2015.
- GB 18351-2017, "Ethanol gasoline for motor vehicles (E10)" was released and implemented on September 7, 2017.
- GB/T 22030-2017, "Blendstocks of ethanol gasoline for motor vehicles" was released and implemented on September 7, 2017.
- GB 18047-2017, "Compressed natural gas as vehicle fuel" was released on September 7, 2017, and implemented on April 1, 2018.
- GB/T 25199-2017, "B5 diesel fuels" was released and implemented on September 7, 2017.

Advanced Motor Fuels Statistics

In 2017, 191.42 million tons of crude oil were produced in China — a decrease of 3.2% year-on-year. Meanwhile 346.17 million tons of petroleum products were produced in China — an increase of 6.9% year-on-year. From January to December 2017, 306.61 million tons of petroleum products (including diesel and gasoline fuels) were consumed in China — an increase of 5.9% year-on-year. Of this, the consumption of gasoline fuels increased by 10.2% and diesel fuels increased by 2.0%. 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 2017, China produced 148.7 billion cubic meters (m^3) of natural gas — an increase of 8.5% year-on-year. Meanwhile, 92.0 billion m^3 natural gas was imported — an increase of 27.6% year-on-year. From January to December 2017, natural gas consumption reached 237.3 billion m^3— an increase of 15.3% from 2016.

In 2017, China's auto production and sales were 29.0 million vehicles and 28.9 million vehicles, respectively, with a year-on-year growth of 3.19% for production and 3.04% for sales.

CNG stations have spread over more than 300 cities across the country's 31 provinces. In 2016, there were 0.356 million new CNG vehicles, while total ownership reached 5.316 million cars — an increase of 7.2% over 2016. In 2016, there were about 400 new CNG stations, and the total number of stations was 5,100 — an increase of 8.5% over 2016. In 2016, more than 30,000 new LNG vehicles were produced, while total ownership reached 0.260 million cars — an increase of 13.0% over the previous year. The total number of LNG stations increased to about 2,700 in 2016.

By the end of 2015, China had 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 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.

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 call for China to develop a demonstration facility by 2020 that can make 50,000 tons of ethanol a year from cellulose, according to the Cabinet's National Energy Administration. It said that would expand to commercial scale by 2025.

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

Additional Information Sources

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

Denmark[30]

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.

30 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 Act.

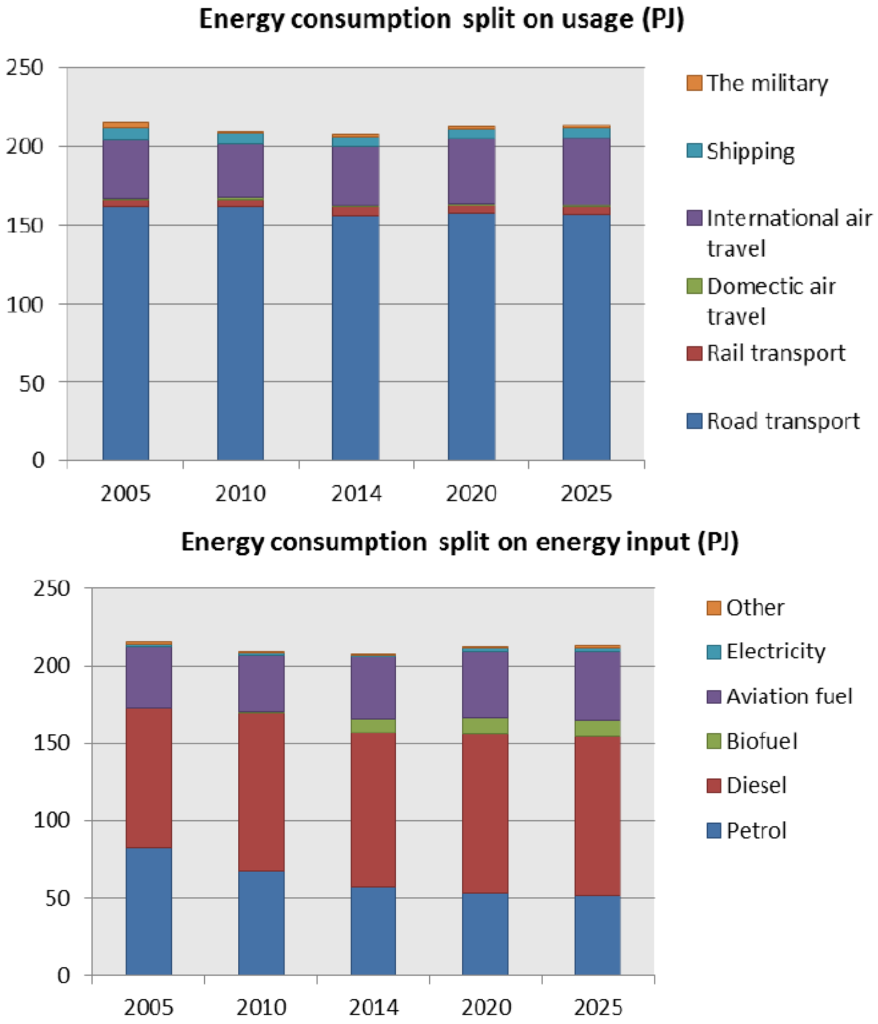

Fig. 1 Expected Development of Energy Consumption in Denmark, 2005–2025

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.

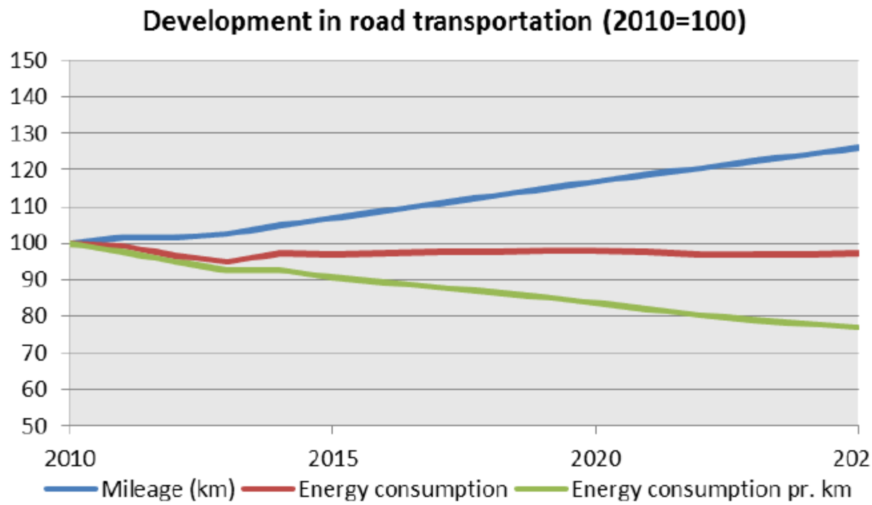

Fig. 2 Expected Development of Transport Work in Denmark, 2010–2025, Relative to Work in 2010

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
Buses 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 2016, total energy consumption in Finland was 1,362 petajoules (PJ), and the share of renewable energy was 35%. In 2016, road transportation consumed about 17% (185 PJ) of the total final energy consumption. Transport produces 21% of Finnish greenhouse gas (GHG) emissions, and 94% of transport emissions are from road transport.[31]

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.[31] The intermediate (2030) 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; and
- 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.[32] The role of increased use of alternative propulsion systems in vehicles and drop-in biofuels has been emphasized.[33]

Advanced Motor Fuels Statistics

The total consumption of gasoline and diesel in Finland in 2016 was 3.8 megatonnes of oil equivalent (Mtoe) (Table 1). In 2015, the actual share of biofuels was approximately 12% (approximately 23% with double-counting). In 2016, actual biofuel volumes dropped to below 5% (below 8% with double-counting). Since 2008, Finland has a biofuels obligation aiming at 20% in 2020. The target for 2016 was 10% (all targets with double-counting). This obligation allows "banking," as long as the overall cumulative volumes are met, thus allowing the biofuel suppliers to

31 http://www.stat.fi/ and http://lipasto.vtt.fi.

32 Huttunen, R. (ed.), 2017, "Ministry of Economic Affairs and Employment."

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

maximize profits. 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). Biogasoline is also used as a blending component. The bioportion of diesel fuel mainly consists of paraffinic renewable diesel fuel.

Table 1 Use of Road Transportation Fuels in Finland, 2016

Gasoline/Diesel[a] (Mtoe)	Ethanol, Ethers and Biogasoline[c] Total/Bio[c] (Mtoe)	Renewable Diesel and Biodiesel[b] Total/Bio[c] (Mtoe)	Methane Total/Bio (Mtoe)
1.5/2.3	0.162/0.073	0.108/0.108	0.0034/0.0018

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

Source: Finnish Petroleum and Biofuels Association, Finnish Tax Administration, http://www.kaasuyhdistys.fi/sisalto/kaasutilastot.

The total road vehicle fleet in use in Finland in 2017 was approximately 3 million (excluding non-road) vehicles (Table 2). This included around 3,800 flex-fuel vehicles (FFVs) capable of using E85, around 2,900 gas vehicles using natural gas or biomethane (or bi-fuel gasoline/methane), and 5,700 plug-in hybrids and 1,450 battery electric vehicles (BEVs). The average age of cars was 12 years in 2017, and the age of cars scrapped was 21 years.

Table 2 Types and Numbers of Vehicles in Use in Finland by December 31, 2017[a]

Passenger Cars	Vans	Trucks	Buses	Two-Wheelers	Other Vehicles	Non-road
2,668,930	319,460	95,948	12,623	292,283	2,605	536,071

[a] 485 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 produces a renewable paraffinic diesel fuel, Neste MY Renewable Diesel, with a worldwide capacity of 2.6 Mtoe/year. In 2017, around 80% of Neste’s renewable diesel production was based on waste and residue raw materials. In the beginning of 2017 Neste MY Renewable Diesel, made

100% from waste and residues, was launched in Finland at selected Neste stations. Pro Diesel (sold in Neste stations in Finland, Estonia, Latvia, and Lithuania) contains at least 15% of renewable diesel. Neste MY Renewable Diesel is increasingly used in global markets, especially in US (California).[34] The Finnish pulp and paper company UPM produces hydrotreated renewable diesel, UPM BioVerno, from crude tall oil in Lappeenranta. Currently, 10 vol% of UPM BioVerno is blended into diesel fuel and sold at St1 Biofuels Oy (Diesel Plus) and ABC (Smart Diesel) refueling stations in Finland.

A minor amount of conventional esterified biodiesel, that is, fatty acid methyl esters (FAME), was used in Finland in 2016.

Bioalcohols and Ethers

In 2016, fuel ethanol and fuel ethers (fossil and bio-origin) were blended in gasoline in Finland. A total of 5.3 ktoe of ethanol is sold as E85. Since 2011, RED95 ethanol-diesel has been tested in a limited number of vehicles. The energy company St1 Renewable Energy Oy has four decentralized Etanolix® plants using waste from the food industry and one in Gothenburg, Sweden, and one Bionolix® plant using biowaste from shops and households as their feedstock (0.5–3.5 ktoe/year/unit ethanol). The Bionolix® unit in Hämeenlinna is combined with a biogas production plant. In 2017, St1 Renewable Energy Oy started its Cellunolix® bioethanol production in Kajaani, using sawdust and chips as feedstock.

Biogasoline

Small amounts of biogasoline components are produced at Neste's and UPM's renewable diesel processing units and blended in gasoline. Neste produces traffic fuels also using tall oil pitch as a feedstock at the Naantali refinery.[35] Biogasoline contains only biohydrocarbons (oxygen-free).

Natural Gas and Biomethane

In 2017, Finland had 33 methane filling stations, 4 of which offer liquefied natural gas (LNG). The share of renewable methane (biogas) in methane for transport was 53% in 2016.[36] Skangas has Finland's first LNG terminal for industry and ships in Pori (30,000 cubic meters [m^3], 15,000 metric tons [t]).[37]

34 Neste, https://www.neste.com/fi/en/neste-my-renewable-diesel.
35 https://www.neste.com/en/neste-oil-uses-tall-oil-pitch-produce-traffic-fuel.
36 http://www.kaasuyhdistys.fi/sisalto/kaasutilastot.
37 www.skangas.com/en/our-portfolio/terminals/pori-terminal/.

Renewable Jet Fuel

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.

Electric and Hybrid Electric Vehicles

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.[38] The goal is to have 400 electric buses operating in the Helsinki region by 2025 (roughly one-third of the fleet).

Hydrogen

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 focused on four core areas: low-carbon energy, advanced vehicles, smart transportation services, and transportation systems.[39] The following TransDigi program started in 2017, creating a collaboration and innovation platform for sustainable, seamless, and safe mobility. The BioOneHundred pilot project, led by HSL and covering 2016–2019, focuses on high-concentration biofuels for carbon neutral urban traffic. In Helsinki, bus services procured by HSL and the vehicles of Helsinki City Construction Services, Stara, aim at using sustainable biofuels in minimum 50% in 2018 and 70%–90% in 2019.

LignoCat, 2013–2017, is focusing on developing a catalytic pyrolysis technology for upgrading bio-oil. BTL2030, 2016–2017, aims to produce transport fuels from biomass by gasification-based concepts. The High Value Bio-oils for Transportation and Diesel Power Plants project, 2014–2017, supports Finnish industries in developing and introducing second-generation biofuels. Neo-Carbon Energy, 2014–2019, creates a new energy

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

[39] Transsmart, "TransSmart: Towards Smart Sustainable Mobility," http://www.transsmart.fi/transsmart/in_english.

system, including the world's first pilot plant capable of producing hydrocarbons from the air by using solar power as the energy source.

Outlook

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

St1 is planning a 50-million-liter (~25 ktoe) Cellunolix® bioethanol plant in Pietarsaari, Kajaani or Follum, Norway. 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).

The LNG infrastructure being built offers opportunities to consider LNG for heavy-duty transportation. New LNG terminals planned are the Tornio Manga LNG project (50,000 m^3 of storage capacity by 2018)[40] and Hamina LNG terminal. 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, cutting traffic emissions by some 50% by 2030 compared to 2005, and increasing 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.

[40] Manga LNG Oy, 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 and nitrogen oxide (NO_x) emissions in highly polluted metropolitan areas. The main public driver in the German policy landscape regarding the transport sector is the Renewable Energy Directive II (RED II).[41] Besides this, "dieselgate," caused mainly by the Volkswagen NO_x emission incident, resulted in improving test cycles and better controlling of vehicle manufacturers, as well as for the ban of high-pollutant engine technologies in urban centers. However, this incident has to be considered rather as a driver of public interest, but not as the main actual driver with respect to the further development of advanced fuels. In fact, the need for expanding advanced biofuels has been questioned by the increasing electrification of the fleet, although overall numbers remain at a comparable low level (see Advanced Motor Fuels Statistics [AMFS]). In research and development (R&D) and exploitation, projects implemented by, for example, Clariant (ethanol from lignocellulosic biomass) have again proven market readiness for new technologies.[42] Moreover, Audi AG is continuing its e-fuels strategy. Recently, a general trend regarding the development of so-called e-fuel could be observed. [43] However, 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.

In January 2018, the Upstream Emissions Reductions (UER)[44] ordinance, implementing EU legislation, was published. From the year 2020 on, the mineral oil industry is allowed to apply UER measures to comply with legal requirements. The Federal Government promotes climate protection and renewable energies in the transport sector by requiring the mineral oil industry to reduce its greenhouse gas (GHG) emissions by 6% from 2020 on, taking 2010 as the basis into account. Furthermore, the latest amendment to the

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41 https://ec.europa.eu/energy/en/topics/renewable-energy/renewable-energy-directive.

42 Clariant sunliquid®, "Clariant to Build Flagship Sunliquid® Cellulosic Ethanol Plant in Romania," https://www.clariant.com/de/Corporate/News/2017/10/Clariant-to-build-flagship-sunliquid-cellulosic-ethanol-plant-in-Romania.

43 https://www.audi-mediacenter.com/de/pressemitteilungen/audi-treibt-e-fuels-technologie-voran-neuer-treibstoff-e-benzin-im-testeinsatz-9912.

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

German Emission Control Act (Bundes-Immissionsschutzgesetz-BImSchG, December 2014, from July 2017)[45] has banned all double-counting and excludes animal fats from the quota eligibility. However, recent regulations expand the list, including bio-based co-refined hydrated oils that have been produced sustainably, Power to X (PtX),[46] and the use of electricity in electric vehicles (EVs).[47]

To decarbonize the transport sector, high priority has recently been given not only to electro-mobility for short-distance traffic and passenger cars, but also to the enforcement of compressed natural gas (CNG) infrastructure along the most important middle- and long-distance road networks. In addition, liquefied natural gas (LNG) for heavy-duty transport and waterborne application is strongly supported by the German Government. In 2016, the Federal Ministry of Transport and Digital Infrastructure (BMVI) provided €1 billion ($1.2 billion US) in incentives for improving alternative fuelling infrastructure, implementing buyers' grants to buy EVs, and fostering R&D, and demonstration in these fields, including the implementation of a competitive infrastructure for hydrogen and fuel cell technology.[48] A total of €300 million ($373 million US) is made available for the 2017–2020 programme, foreseeing the installation of 15,000 charging stations. In addition, the BMVI established grants for public procurement incentives to equip car fleets with EVs.[49] The German Government's goal is to have at least 1 million registered EVs by 2020. Despite the new incentives given since 2016, EV sales remain low (see AMFS). 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 natural gas (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.[50] 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

45 https://www.gesetze-im-internet.de/bimschg/BJNR007210974.html.

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

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

48 "National Strategy for the Expansion of Alternative Fuels' Infrastructure"

49 https://www.bmvi.de/DE/Themen/Mobilitaet/Elektromobilitaet/Ladeinfrastruktur/Ladeinfrastruktur.html.

50 https://www.gesetze-im-internet.de/energiestg/BJNR153410006.html.

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 following figures and tables show fuel consumption in Germany and the number of registered vehicles separated by fuel type. Figure 1 shows the 2017 German fuel consumption for use in road transportation. The consumption of biofuels totaled 3.4 Mt, with the majority being low-level blends of biodiesel and hydrotreated vegetable oil (HVO) and bioethanol. Due to the nonexistence of incentives (e.g., tax exemption), there is no market demand for E85 and pure biodiesel (see Tables 1 and 2).

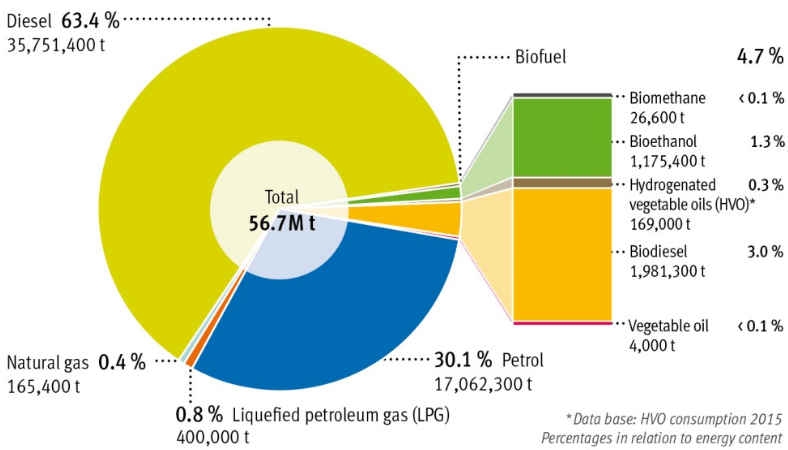

Fig. 1 Fuel Consumption in the Transport Sector in Germany in 2017
Source: FNR on the basis of BAFA et al. 2017.[51]

Tables 1 and 2 show the 2009–2017 trends for biofuels and biofuel blends. 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 RED in 2015, has increased the average GHG reduction of biofuels on the German market to 73% in 2016.

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

Table 1 Trends in German Biodiesel Sales, 2009–2017, in mt

Sale	2009	2010	2011	2012	2013	2014	2015	2016	2017
Blend	2.191	2.236	2.116	1.928	1.741	1.970	1.972	2.150	2.207
Pure biodiesel	0.241	0.293	0.097	0.131	0.030	0.005	0.003	<0.001	n/a
Total	2.431	2.529	2.213	2.059	1.772	1.975	1.975	2.150	2.207

n/a = not applicable.
Source: FNR on the basis of BAFA et al. 2017.

Table 2 Trends in German Bioethanol Sales, 2009–2017, in mt

Sale	2009	2010	2011	2012	2013	2014	2015	2016	2017
E85[a]	0.009	0.018	0.019	0.021	0.014	0.010	0.007	n/a	n/a
Ethanol	0.687	1.028	1.054	1.090	1.041	1.082	1.049	1.047	1.043
ETBE[b]	0.198	0.122	0.162	0.142	0.154	0.119	0.116	0.124	0.111
Total	0.892	1.165	1.233	1.249	1.206	1.209	1.171	1.167	1.154

n/a = not applicable.
[a] Including only share of ethanol.
[b] Ethyl tertiary-butyl ether; percentage by volume share of bioethanol in ETBE = 47%.
Source: FNR on the basis of BAFA et al. 2017.

Table 3 shows the number of passenger cars on the road in Germany by fuel type for 2014 through 2017. A total of 55.5 million vehicles, including 4.3 million motor bikes were registered in Germany as of January 1, 2017[52]; 45.8 million (83%) were passenger cars. Of the registered vehicles, 2.9 million (5.2%) were trucks, 2.2 million were towing vehicles, 79,000 were buses, and 289,000 were other vehicles.

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

Year	Gasoline	Diesel	LPG	NG	EV	Hybrid
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
2017	29,978,635	15,089,392	448,025	77,187	34,022	165,405

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 2018.[53]

52 https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/FahrzeugklassenAufbauarten/2017_b_fzkl_eckdaten_pkw_dusl.html?nn=652402.

53 KBA (Kraftfahrt-Bundesamt; Federal Motor Transport Authority), 2017, *Fahrzeugbestand im Überblick am 1. Januar 2017.*

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"); the Ministry of Economic Affairs and Energy (BMWi); and the Federal Ministry of Food and Agriculture (BMEL) (advanced biofuels). Under the Renewable Resources Funding Scheme of the BMEL, 31 R&D projects are receiving funding of €11 million ($13.7 million US). The focus of the advanced fuels projects funded by the BMEL has been on (1) the production of hydrocarbons from biochemical and thermochemical pathways, (2) the assessment and testing of advanced motor fuel components, and (3) the production and testing of advanced fuels for small engines. BMEL's project management organization FNR strives to expand support of R&D projects on advanced biofuels.

Outlook

Energy policy and research and innovation frameworks at the EU and international level will strengthen the advanced motor fuel market. But new legislation by the European Commission to revise the RED, which is debated controversially, 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 the Fuel Quality Directive, 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 Ministry of Ministry of Economic Affairs and Energy (BMWi), http://www.bmwi.de/Navigation/EN/Home/home.html.
- Federal Motor Transport Authority (KBA), www.kba.de/EN.
- Verband der Deutschen Biokraftstoffindustrie, biokraftstoffverband.de.

India

Drivers and Policies

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

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

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

Advanced Motor Fuels Statistics

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

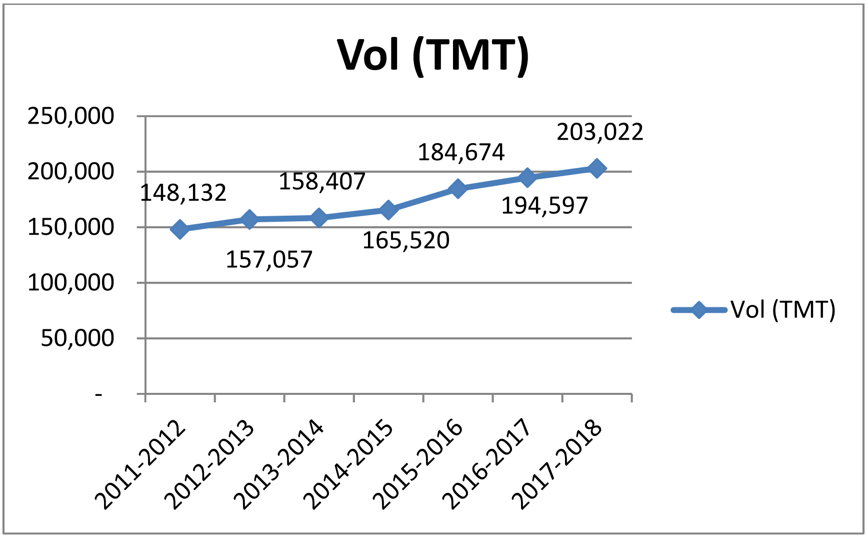

Fig. 1 Consumption of Petroleum Product

Source: PPAC website ppac.org.in.

Note: Data for 2017–2018 is actually for April–December 2017 and extrapolated for FY 2017–2018 to facilitate the comparison.

Details on Advanced Motor Fuels

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

Ethanol-blended Petrol Programme

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

Second Generation Ethanol Programme

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

Biodiesel

In June 2017, the government allowed the direct sale of biodiesel (B-100) for blending with high-speed diesel to all consumers, in accordance with the specified blending limits and the standards specified by the Bureau of Indian Standards. From April 2017 to November 2017, the biodiesel quantity procured by OMCs was 43.55 million L vis-à-vis 34.91 million L procured during the same period in 2016 (i.e., an increase of 24%).

Research and Demonstration Focus

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

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

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

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

Outlook

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

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

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

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

Additional Information Sources

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

Israel

Drivers and Policies

In 2011, the Fuel Choices and Smart Mobility Initiative,[54] 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 550 companies, 300 research groups, and hundreds of entrepreneurs (see Table 1).

Table 1 Growth of Israel's Alternative Fuels Research Groups, Industry, and Investment, 2011–2017

Year	Research Groups	Companies	Cumulative Investments (€million)
2011	45	60	250
2017	300	550	4,200

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.

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

Recent Standards

During 2016 the Standards Institution of Israel issued a new standard for M15 (85% gasoline with 15% methanol). This is the first standard for low methanol percentage fuel that was issued outside of China. This standard is currently being adopted by different countries.

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

Taxation

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

Research and Demonstration Focus

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

- *EV Fast Charging Network.* The Ministry of Energy, along with the Fuel Choices and Smart Mobility Initiative, is supporting research conducted by the Samuel Neaman Institute regarding the deployment of public charging infrastructure in Israel. The research will include clear recommendations regarding the technical, financial, and spatial aspects of the future network.
- *Alternative Fuel Shuttle Buses.* In a governmental resolution passed in early 2017, the government mandated that all shuttle buses in future fast lane projects surrounding Tel Aviv must be powered by CNG or electric power.
- *Promotion of public transportation tenders.* Resolution 1837 of the Israeli government called for a provision of 50% mandatory electric or CNG buses in all future Public Transportation Operator tenders.
- *Support for purchase of electric buses.* The Israeli government provides budgetary support 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. These buses are currently operating in the Haifa Bay area and are part of the 65 electric bus fleets operating in Israel. The Initiative also supports testing of other electricity-based technologies in buses, such as super-capacitors.

- *CNG buses.* The Ministry of Transport allocates budgets for purchasing CNG buses for public transport operators. Considering the high mileage covered by buses, the use of CNG buses will make a significant contribution toward reducing pollutant emissions and dependence on oil. In 2017, bus company Metropolin won a tender for operating 84 CNG buses in the Sharon-Holon area.
- *CNG garbage trucks.* Resolution 529 of the Israeli government called for reducing air pollution and environmental risks in Haifa Bay. In accordance with this goal, the Ministry of Environmental Protection, together with the Municipality of Haifa, acquired 25 CNG garbage trucks. These trucks are expected to operate in Haifa in March 2018.
- *EV car sharing.* The Fuel Choices and Smart Mobility Initiative, together with the Ministry of Environmental Protection, started an EV car-sharing initiative in urban environments. So far, the initiative has proven successful in Haifa, where 100 electric car-sharing vehicles are currently operating. The vehicles charge in any of 50 public charging stations in the city.
- *Railway network electrification.* A program that aims to upgrade Israel's rail infrastructure and train fleet to electrically powered propulsion 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

- The Israel National Research Center for Electrochemical Propulsion (INREP) is a multidisciplinary center dedicated to the research and development (R&D) of electric mobility. R&D areas of focus include advanced materials and technologies for EVs, batteries, and fuel cell-based propulsion for transportation.
- The Israeli Fuel Cells Consortium (IFCC) was formed in October 2016 to advance fuel cell research in Israel, with an emphasis on solutions for electro-mobility. The IFCC is composed of 12 leading labs from 4 universities in Israel. It is funded by the Fuel Choices and Smart Mobility Initiative and works under the umbrella of INREP. In addition to research, it is tasked to train new scientists and engineers in the field and support Israeli industry.

- The Capsula@TAU Center for Innovation in Transportation has a goal to promote and develop ideas and ground-breaking research in the field of transportation, both from an academic and an entrepreneurial aspect. The center annually awards grants to researchers from all universities in Israel. In addition, the center operates the Capsula Studio Accelerator to encourage entrepreneurs who are in the initial developmental stages of promising and innovative ideas in the field of transportation.

Ministerial Research Grants and Programs

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

Pilots and Industrial Demonstrations Program

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

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

- Advancing the establishment of a testing center for autonomous vehicles for supporting smart transportation, and
- Advancing field experiments and pilot projects for new technologies and operational concepts in the transportation sector with the potential for reducing congestion, traffic accidents, use of petroleum, along with encouraging the use of public transportation.

Industrial R&DTEPS (MAGNET Program)

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

Benefits of Participation in the AMF TCP

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

Japan

Drivers and Policies

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

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

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 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 from 50% to 70% by 2030.

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

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

Advanced Motor Fuels Statistics

Figure 1 shows the energy sources used in the transportation sector [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.

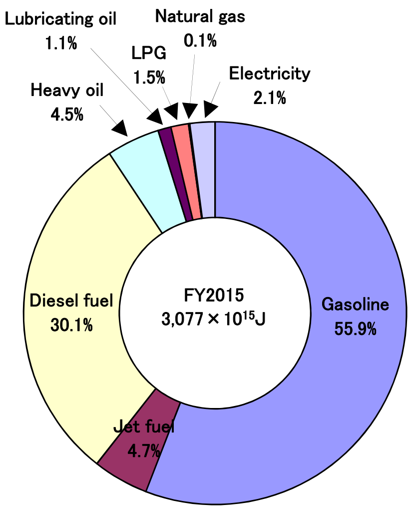

Fig. 1 Energy Sources Used in the Transportation Sector in Japan in 2015

Table 1 Current Penetration of Low-Emission Vehicles in Japan

<table>
<tr><th>Vehicle Type</th><th>Methanol [2]</th><th>CNG [3]</th><th>Hybrid [4]</th><th>EV [4]</th><th>FCV [4]</th><th>Vehicle Registration [5]</th></tr>
<tr><td>Passenger vehicles</td><td>0</td><td>1,599</td><td>6,544,266 (PHV:70,323)</td><td>73,378</td><td>1,807</td><td>39,620,175</td></tr>
<tr><td rowspan="2">Light-, mid-, and heavy-duty trucks</td><td rowspan="2">576</td><td>6,079</td><td rowspan="4">24,687</td><td rowspan="4">1,640</td><td rowspan="2">0</td><td rowspan="2">5,872,240</td></tr>
<tr><td>19,936</td></tr>
<tr><td>Buses</td><td>0</td><td>1,579</td><td>0</td><td>233,796</td></tr>
<tr><td>Special vehicles</td><td>0</td><td>4,010</td><td>0</td><td>1,732,163</td></tr>
<tr><td>Small vehicles</td><td>0</td><td>10,701</td><td>472,405</td><td>14,826</td><td>0</td><td>Not available</td></tr>
<tr><td>Total</td><td>576</td><td>43,904</td><td>7,041,358</td><td>89,844</td><td>1,807</td><td>Not available</td></tr>
</table>

Research and Demonstration Focus

Hydrogen

The Strategic Roadmap for Hydrogen and Fuel Cells (revised version) [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.

On December 26, 2017, the Ministerial Council on Renewable Energy, Hydrogen and Related Issues held its second meeting and decided on a basic hydrogen strategy to accomplish a world-leading hydrogen-based society [7]. The strategy includes the use of hydrogen for transportation such as fuel cell (FC) buses, FC trucks, and FC ships.

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 [8]. 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.

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. To reduce carbon dioxide (CO_2) emissions from road vehicles, in fiscal year 2016, the Japanese Ministry of Environment subsidized the 3-year project for a development and demonstration of heavy-duty LNG trucks, with a running range of more than 1,000 km and an optimum LNG filling station that can also supply CNG. Isuzu Motors Limited, Shell Japan Limited and Organization for the Promotion of Low Emission Vehicles participate in this project. CO_2 emissions from heavy-duty LNG trucks will be reduced by about 10% to the latest diesel trucks.

Bioethanol

A project of Ministry of Environment from 2011 in Okinawa Prefecture to promote the use of biofuels such as E3 gasoline terminated in fiscal year 2016 because of no clear idea for a commercialization [9]. In Miyakojima City, the supply of E3 gasoline was terminated in April 2016 [10]. Selling of bio-gasoline blended with ethyl-tertiary-butyl ether (ETBE) is continuing to the target of 500,000 kL (crude oil equivalent) in Sophisticated Methods of Energy Supply Structures [11].

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 [12].

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 [13].

Outlook

In April 2014, the Japanese government approved the new Strategic Energy Plan (the fourth plan) [14], 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, 2017 (in Japanese).
[2] LEVO, the Organization for the Promotion of Low Emission Vehicles (cumulative total number: out of production).
[3] Japan Gas Association, as of March 2017 http://www.gas.or.jp/ngvj/spread/index.html (in Japanese).

[4] Next Generation Vehicle Promotion Center, as of March 2017 (estimated numbers of vehicles owned) http://www.cev-pc.or.jp/tokei/hanbai.html (in Japanese).
[5] Automobile Inspection and Registration Information Association, as of October 2017.
[6] Agency for Natural Resources and Energy, 2016, *The Strategic Roadmap for Hydrogen and Fuel Cells* (revised version), March 22.
[7] Ministry of Economy, Trade, and Industry, 2017, "Basic Hydrogen Strategy Determined," website, http://www.meti.go.jp/english/press/2017/1226_003.html.
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[13] 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.
[14] Ministry of Economy, Trade, and Industry, Agency for Natural Resources and Energy, as of April 11, 2014, Cabinet Decision on the New Strategic Energy Plan, web site, Archives 2014, http://www.enecho.meti.go.jp/en/whatsnew/.

Additional Information Sources

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

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 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 must reduce greenhouse gas (GHG) emissions by 24.6% (25.9 million tons) to meet the 2030 GHG target (business as usual 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 kilometers 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 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, the mixing or blending of BD increased from 2.5% to 3% in January 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 42.5%

(9.58 million) of diesel vehicles out of the approximately 22.5 million vehicles in the country (Table 1). Biodiesel oil consumption per year is about 520,000 kiloliters (kL); of that, 172,000 kL comes from domestic waste edible oil and 348,000 kL is imported. The expectation is that in the near future, bioethanol (BE) will be used for gasoline vehicles, which account for approximately 46.0% (10.37 million) of all vehicles in South Korea; liquefied petroleum (LPG) vehicles will account for 9.3% (2.10 million); and natural gas vehicles will account for 0.2% (38,918 city buses).

Table 1　Number of Vehicles, by Fuel, in South Korea in 2017

<table>
<tr><th>Gasoline</th><th>Diesel (BD2.5)</th><th>LPG</th><th>HEV</th><th>Total</th></tr>
<tr><td>10,369,752</td><td>9,576,395</td><td>2,104,675</td><td>378,052</td><td rowspan="3">22,528,295</td></tr>
<tr><th>CNG</th><th>EV</th><th>FCV</th><th>ETC</th></tr>
<tr><td>38,918</td><td>25,108</td><td>170</td><td>99,421</td></tr>
</table>

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 fuel cell vehicles (FCVs) per 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 per day) (Figure 4); this pilot plant has been in operation since 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 Research and Development 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, BD3 was introduced in January 2015. During the first step, from 2015 to 2017, BD2.5 was supplied. In the second step, from 2018 to 2020, BD3 will be supplied. The final step, from 2020 to 2023, would be the introduction of BD5~7 and BE5~7.

Currently, there is no stimulus for using biofuels in LPG vehicles, which account for approximately 9.3% 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).
- http://www.ebn.co.kr/news/view/818151 (in Korean).

Spain

Drivers and Policies

Biofuel consumption in Spain is primarily supported by the mandatory targets for sale or consumption established in Royal Decree 1085/2015, on the promotion of biofuels. These targets (in energy content) are 5% (2017), 6% (2018), 7% (2019), and 8.5% (2020).

The Alternative Energy Vehicle Mobility Incentive Plan (MOVEA) forms part of Spain's 2014–2020 Alternative Energy Vehicle Incentive Strategy. In 2017, Royal Decree 617/2017 was issued to regulate the guidelines for the MOVEA 2017 Plan. Furthermore, the Institute for Energy Diversification and Saving (IDAE) launched another plan called MOVALT. Both programs established direct granting of aid for the purchase of electric, liquefied petroleum gas (LPG), natural gas, and bi-fuel vehicles.

Advanced Motor Fuels Statistics

Figure 1 shows data on fuel consumption in 2017. Biofuels remain the major alternative transportation fuel in Spain.

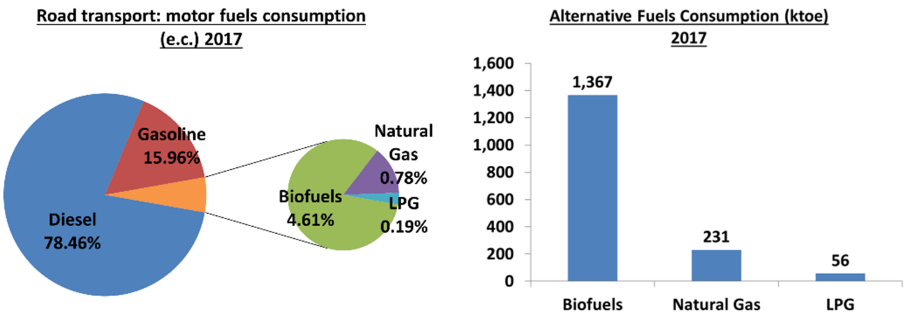

Fig. 1 Fuel Consumption (share in energy content) and Alternative Fuel Consumption (ktoe) in Spain in 2017
Sources: CNMC, CORES, GASNAM.

As for the vehicle fleet, of a total of 34.8 million vehicles, around 55,000 are fuelled by LPG and 8,471 use natural gas (compressed or liquefied), while only a few hydrogen vehicles have been developed in pilot projects.

Regarding the number of public filling stations with alternative fuels, Table 1 shows updated data on stations that sell high-biofuel blends, LPG, compressed natural gas, liquefied natural gas, or hydrogen.

Table 1 Filling Stations for Alternative Fuels in Spain

Alternative Fuel		Number of Filling Stations
Biodiesel blends	B20 or lower	51
	B30 or higher	11
Bioethanol blends	E15 or lower	5
	E85	6
LPG		569
Natural gas		57
Hydrogen		6

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

As mentioned before, biofuels represent the largest share of alternative transportation fuels in Spain. Figures 2, 3, and 4 provide information on the feedstock, feedstock origin country, and production country of biofuels consumed in Spain in 2017.

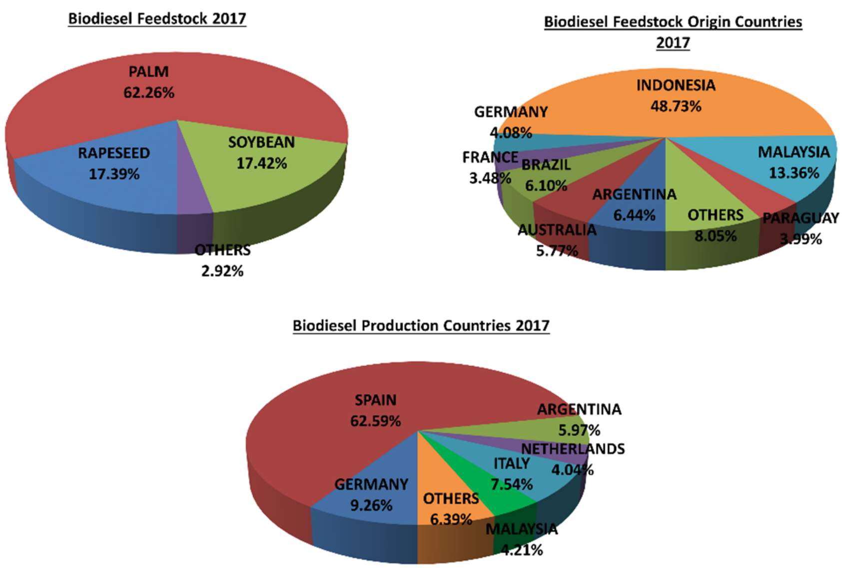

Fig. 2 Feedstock, Feedstock Origin Country, and Production Country of Biodiesel Consumed in Spain in 2017
Source: CNMC.

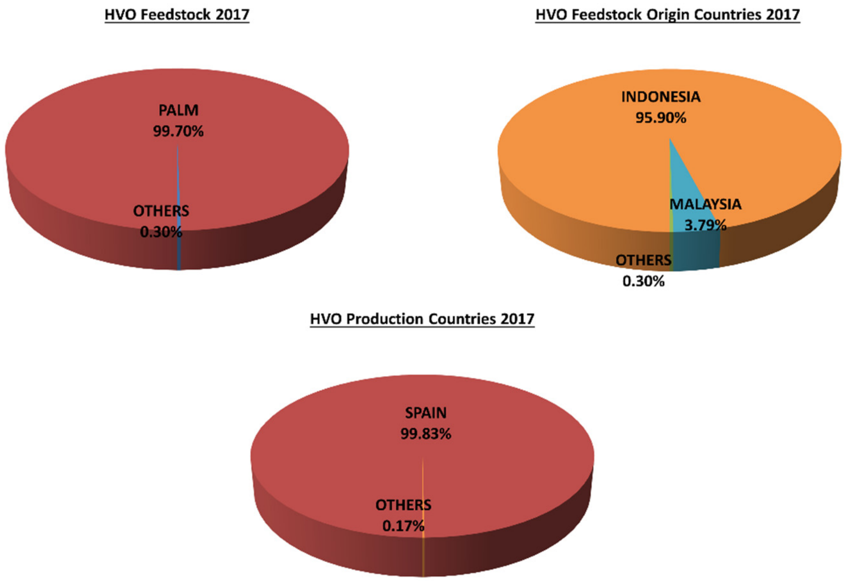

Fig. 3 Feedstock, Feedstock Origin Country, and Production Country of Hydrotreated Vegetable Oil (HVO) Consumed in Spain in 2017
Source: CNMC.

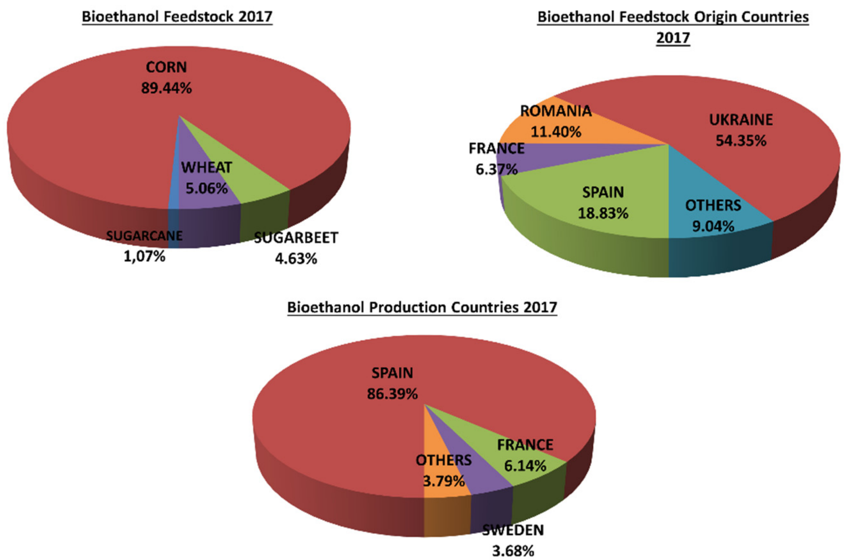

Fig. 4 Feedstock, Feedstock Origin Country and Production Country of Bioethanol Consumed in Spain in 2017
Source: CNMC.

Research and Demonstration Focus

As regards biofuels, in 2017, the Spanish Biorefineries Manual was published. It is intended to define the types of biorefineries that are suitable for development in Spain and to address the environmental, socio-economic, and political framework within which biorefineries may be deployed.

The National Action Framework for Alternative Energies in Transport includes several programs intended to support research, development, and innovation: creation of clusters for innovation, incentives, cooperation through technology platforms, and support to research centers.

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

Outlook

According to the National Renewable Energy Action Plan, to fulfill the committed targets, consumption of biofuels is expected to reach 2,713 kilotonnes of oil equivalent 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).
- Bioplat: Spanish Biomass Technology Platform, www.bioplat.org.
- CNMC: National Markets and Competition Commission, www.cnmc.es (in Spanish).
- CORES: Corporación de Reservas Estratégicas (Oil Stockholding Agency), www.cores.es (in Spanish).
- GASNAM: Spanish Association of Natural Gas for Mobility, www.gasnam.es (in Spanish).
- Geoportal (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 2017: www.minetad.gob.es/industria/es-ES/Servicios/plan-movea/2017/Paginas/ayudas-movea.aspx (in Spanish).

Major Changes
The Spanish Biorefineries Manual was developed, and two new plans for the granting of aid for the purchase of alternative fuels vehicles were 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 2017, a new climate policy framework was approved. The long-term climate goal means that by 2045, at the latest, Sweden will have no net emissions of greenhouse gases (GHGs). In more precise terms, the long-term climate goal means that emissions from activities on Swedish territory will be cut by at least 85% compared with emissions in 1990. To achieve net zero emissions, flexibility measures are included. For the transport sector, a reduction in emissions (not including domestic air travel) of at least 70% by 2030, compared with 2010, has also been adopted.

The Government has introduced 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). Mid-2018 this system will enter into force.

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. With the new bonus-malus, the incentives will change.

Advanced Motor Fuels Statistics

Since 1990, the number of passenger cars has increased from approximately 3.5 million vehicles to more than 4.7 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 and advanced motorfuels.

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 350,000 at the end of 2016, as shown in Figure 1.

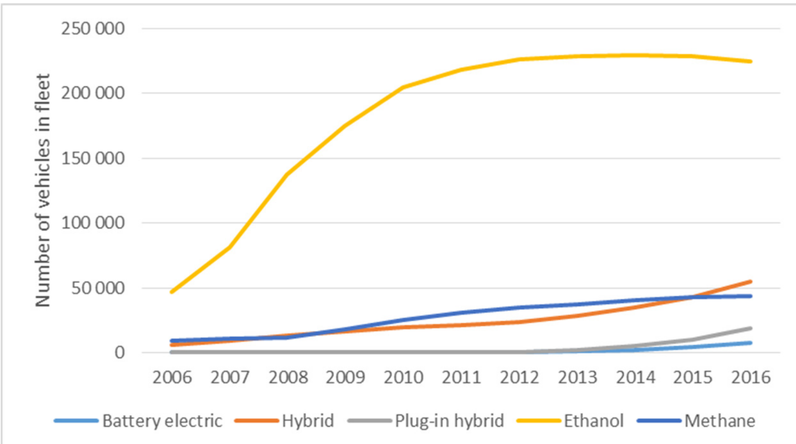

Fig. 1 Number of Advanced Motor Fuel Passenger Cars in the Fleet, 2006–2016

The alternative-fueled vehicles correspond to just above 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 is just under 30% of the fleet.

Although flex fuel ethanol vehicles are the most common type of alternative fuel vehicle in Sweden, the ethanol fuel (E85) sold during 2015 only corresponded to less than 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. Since 2015, the number of ethanol-fuelled vehicles in Sweden's fleet has decreased. 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 number of chargeable vehicles has more than doubled, but from a low absolute number.

The use of renewable biofuels for transport in Sweden amounted to almost 17.5 terawatt hours (TWh), or 19% of the transportation fuels sold during 2016 (Figure 2). Only 3.5 TWh were used in pure form as fatty acid methyl ester (FAME) (0.7 TWh), hydrotreated vegetable oil (HVO) (2.5 TWh), or E85 (0.2 TWh). Methane for transport consists of 83% biogas (1.7 TWh) and 17% natural gas. The remaining portion of the renewable fuels was sold as low blending in either diesel or petrol. Almost 70% of the renewable fuel used in Sweden during 2016 was low blending of HVO in diesel. On average, the renewable share in diesel corresponded to 20%. Some individual diesel products sold on the Swedish market have a renewable share of 50%.

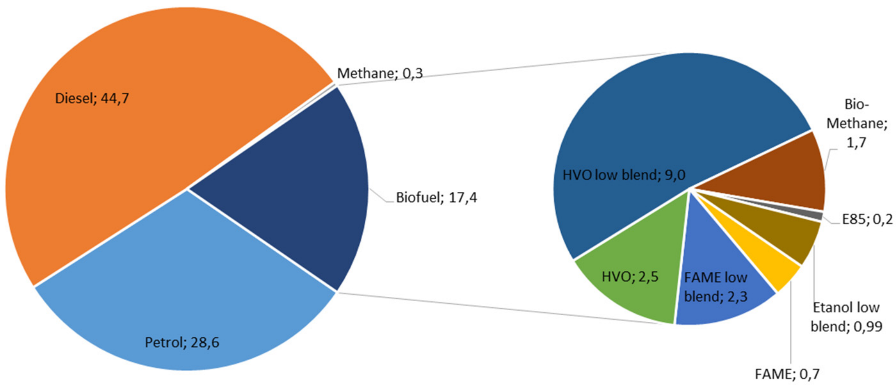

Fig. 2 Fuel Consumption in TWh within the Transport Sector during 2015

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 vegetable or animal waste oils, slaughterhouse wastes, Palm Fatty Acid Distillate (PFAD), corn, rapeseed, and crude tall oil in descending order. The majority of feedstock for HVO has been imported, as shown in Figure 3. The average GHG emissions from HVO use in Sweden during 2016 correspond to 15.7 g carbon dioxide equivalent (CO_2 eq) per megajoule (MJ). For FAME, the corresponding figure was 39.1 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.

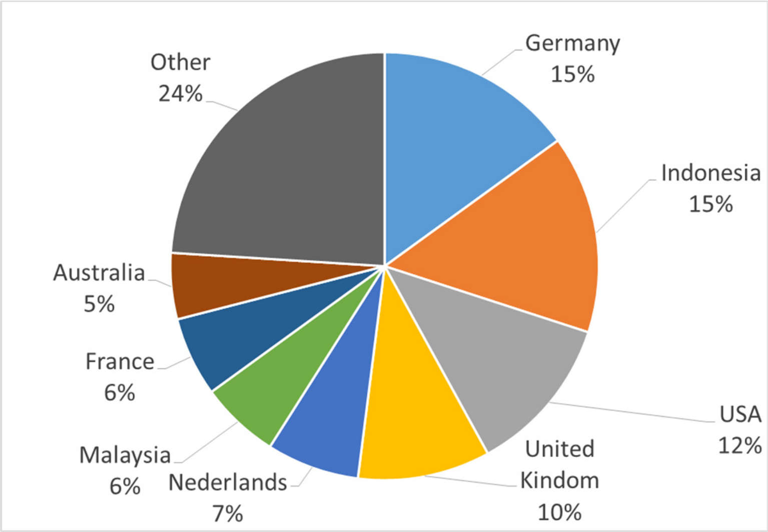

Fig. 3 Country of Feedstock Origin for HVO Consumed in Sweden in 2016

Research and Demonstration Focus

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

- Energy and environment program is focused on automotive-related research, innovation, and development activities in the areas of increased energy efficiency, transition to renewable fuels, reduction of local/regional environmental impacts, and areas with potential to strengthen the Swedish and the English automotive industry's competitiveness in a global perspective.
- Research 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, 17 TWh of renewable fuels are used, but this level needs to be increased to 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 2017, the Swedish Parliament adopted a new climate law with the following targets:

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

Benefits of Participation in the AMF TCP

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

Switzerland

Drivers and Policies

In May 2017, the Swiss voters approved 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

Since 2012, 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 must pay a penalty. The average CO_2 emissions of new passenger cars in 2016 totaled 134 g CO_2/km. The penalty amounted to \$2.4 million US [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 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. Since 2014, a substantial increase of biofuels can be observed.

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 US/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 US per liter (L), in comparison with fossil fuels. The mineral oil tax reduction is only valid until 2020.

Advanced Motor Fuels Statistics

Final total energy consumption in Switzerland in 2016[55] amounted to 854,300 terajoules (TJ), of which 35% was transport fuels (Figure 1) [5]. Compared to 2015, fuel consumption for vehicles decreased by 1%. In the same period, the total amount of engine-driven vehicles increased by 1.6%, in the sum of 5,980,512. Fuel consumption by vehicle dropped by 0.7%. Some changes in specific applications were made in 2016: diesel, +1.1%; gasoline, −3.1%; and aviation fuels, +4.7%. All fossil fuels were imported.

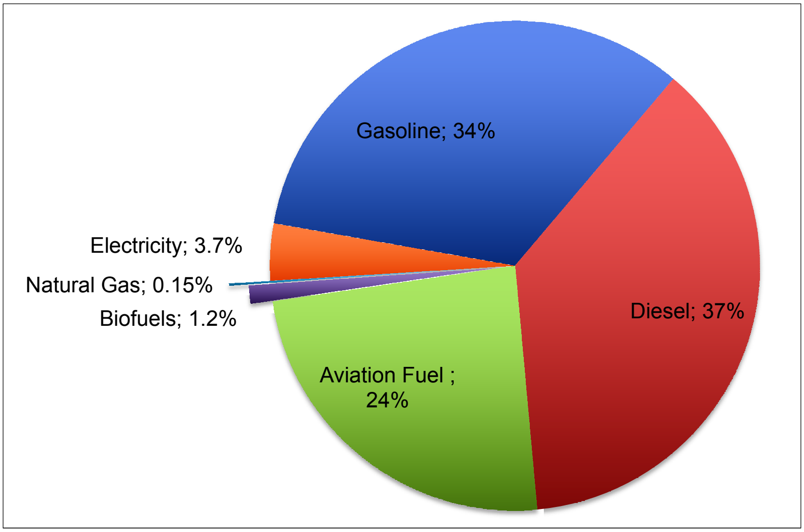

Fig. 1 Shares of Energy Sources in Energy Consumption for the Transportation Sector in Switzerland in 2016 [1]

Electricity is used for railroad transportation, and a negligible amount is used for electric cars. Despite an impressive annual increase of electric vehicles (2014, + 65 %; 2015, + 70%; and 2016, +42%), the total amount is still very small (10,724 passenger cars) [6]. In 2000, the share of diesel of the total amount of fuels (without aviation) amounted to 26%. With a share of 52% in 2016, the consumption of diesel was higher than the use of gasoline (46%) and biofuels (1.2%).

55 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 (72.509 million L) and bioethanol (38.193 million L) can be observed in 2016 (Figure 2). Pure vegetable oil (PVO) fuel dropped almost to zero (0.043 million L), and upgraded biogas remained at a low level of 3.380 million kg. In 2016, for the first time hydrotreated vegetable oil (HVO) was used (11.303 million L). Even if the total amount of biofuel consumption increased by 60% compared to the year before, it is still a very small share (1.2%) of the total amount of motor fuels used in Switzerland [7].

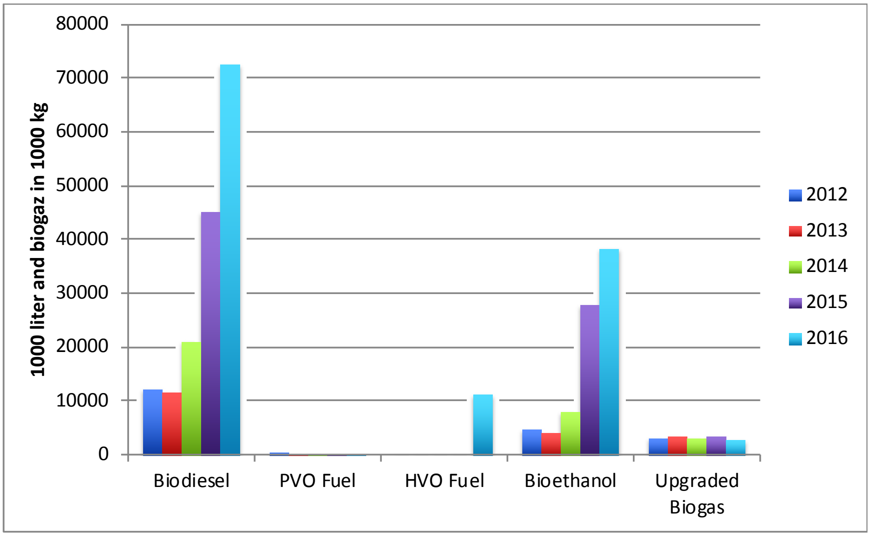

Fig. 2 Development of the Use of Biofuels as Motor Fuels in Switzerland, 2011–2015

Only 8.143 million L of biodiesel was produced in Switzerland. The other 64.366 million L was imported (Germany 82%, France 13%, the rest from four other countries). All bioethanol is imported (Holland 63%, Norway 17%, Italy 15%, the rest from two other countries).

The total amount of biogas produced and used in Switzerland in 2016 amounted to 105,650 t. Only 21,798 t have been upgraded and fed into the natural gas grid. From this, only a small amount (2,948 t) has been sold as biogas for cars, and the rest for heating [8]. All biogas used as motor fuel in cars is upgraded biogas fed into the natural gas grid. Therefore, cars need no special requirements for biogas as a fuel. Figure 3 shows the development of the use of biogas and natural gas as motor fuels in cars. 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 but not for automotive applications.

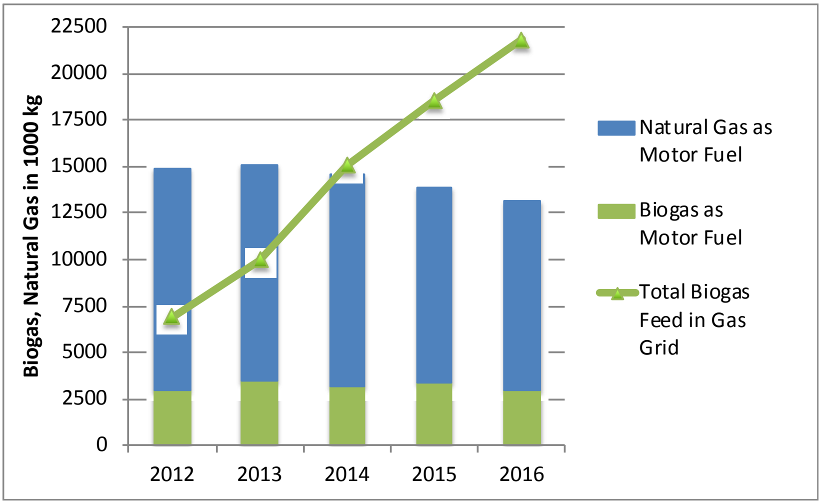

Fig. 3 Development of the Use of Natural Gas and Biogas as Motor Fuel for Cars and Total Upgraded Biogas Fed into the Natural Gas Grid (green line)

Research and Demonstration Focus

In the research, development, and demonstration funding framework of the Swiss Federal Office of Energy, three programs — bioenergy, combustion, and mobility — 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.

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

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

Investigation of ignition/early flame propagation and flame-wall interactions in gas engines: In-depth understanding of combustion in gas engines through Direct Numerical Simulation and its experimental validation based on evaluation of appropriate models for industrial applications. There are three major issues of interest: early flame propagation within the prechamber, flame stability at the entrance in the main combustion chamber, and influence of a wall on the turbulent flame.

Outlook

The main drivers in Switzerland to increase the use of biofuels will remain tax exemptions and the Government's requirement that the petrol industry compensate 10% of CO_2 emissions via domestic measures. The target to reduce average CO_2 emissions from passenger cars by 2020 from 130 to 95 g CO_2/km will increase sales of hybrid and electric vehicles. Swiss gas industry aims to achieve a share of 30% of renewable gas for heating purposes in the natural gas grid by 2030. To achieve this target, different sources of renewable gas are needed. A promising development is a showcase project with power to gas technology and methanization of hydrogen with CO_2-rich biogas from a wastewater treatment plant. It was successfully tested and increases the bio-methane yield by 60% [11]. For market entry, further developments are needed.

Additional Information Sources

[1] Swiss Federal Office of Energy (SFOE), "Energy Strategy 2050."
[2] SFOE, "CO2-Emissionen von Neuwagen …im Jahr 2016," 2017.
[3] FOEN, 2012, "CO_2 emission compensation: motor fuels."
[4] Mineralölsteuergesetz (MinöStG), Stand: Jan. 1, 2012.
[5] SFOE, 2017, "Gesamtenergiestatistik 2016."
[6] Swiss Federal Statistical Office (BFS), 2017, "Mobility and Traffic."
[7] Swiss Custom Administration, 2017, "Mineralölstatistik."
[8] SFOE, 2016, "Schweizerische Statistik erneuerbarer Energien 2016."
[9] www.sccer-mobility.ch.
[10] www.sccer-biosweet.ch.
[11] Erneuerbare Energien, 2017. Alles nutzen was im Klärgas steckt.

Thailand

Drivers and Policies

The worldwide increase in the demand for energy is caused primarily by population and economic growth (especially income per person). Another important issue related to energy demand is the 2015 Paris Climate Conference (COP21). This conference led to the establishment of international policies for stabilizing atmospheric concentrations of greenhouse gas (GHG) emissions to avoid dangerous anthropogenic interference by keeping the global warming below 2°C.

The policy and direction of Thailand's future economy reflect the need to save energy. In 2017 (January–October), Thailand's energy consumption totaled 66,074 ktoe, an increase of 0.4% from 2016,[56] at a cost of 856,911 million baht ($25,967 million US). Thailand's energy consumption covers all energy supplied to consumers for all energy uses. Petroluem products represent the major portion at 50.6% of final energy consumption, followed by electricity, renewables, natural gas, conventional renewable energy, and coal/lignite, respectively (see Figure 1).[57]

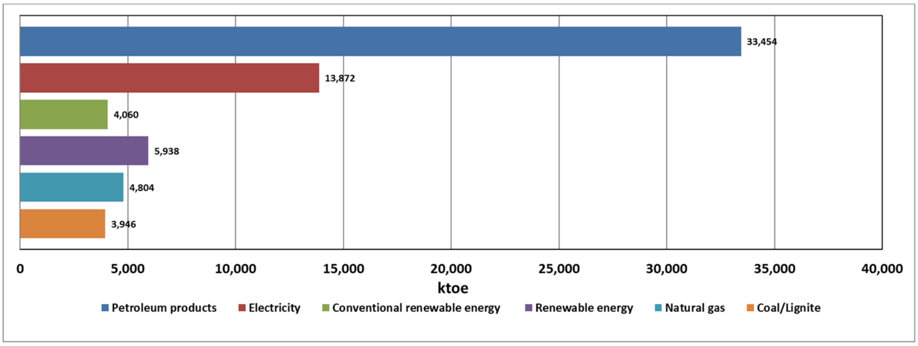

Fig. 1 Energy Consumption in Thailand, January–October 2017 (Renewable enegy includes firewood, husk, bagasse, agricultural waste, and biogas. Conventional renewable energy comprises firewood, husk, bagasse, and agricultural waste used in households and industry.)

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56 Ministry of Energy, 2017, Energy Situation (January–October 2017), Department of Alternative Energy Development and Efficiency, http://www.dede.go.th/ewt_news.php?nid=42079.

57 Ministry of Energy, 2017, Energy Situation (January–October 2017), Department of Alternative Energy Development and Efficiency, http://www.dede.go.th/ewt_news.php?nid=42079.

Advanced Motor Fuels Statistics

The final energy consumption by economic sector covers energy demand in the agriculture, commercial, residential, industrial, and transportation sectors. In 2017, transportation had the greatest portion of total energy consumption at 40.5%, followed by industrial at 34.8%, residential at 13.1%, commercial at 8.4%, and agricultural at 3.2% (see Figure 2).

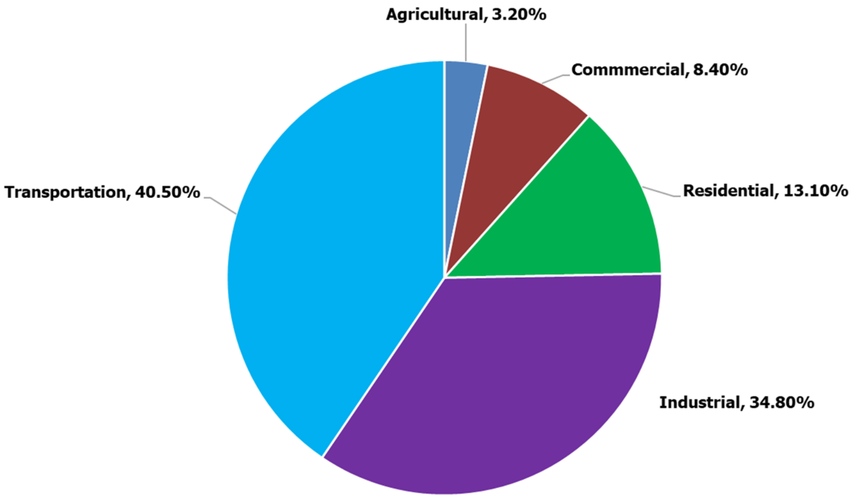

Fig. 2 Energy Consumption in Thailand by Economic Sector, January–October 2017

The Thai Government has officially promoted and implemented policies for the use of alternative energy, mainly biofuels in the transportation sector, which have increased significantly. From January to October 2017, biodiesel consumption and ethanol consumption increased to 3.72 ML/day and 3.92 ML/day, respectively. Moreover, alternative fuel consumption shared 14.46% of final energy consumption, with +3.9% from 2016.

By the end of December 2017, Thailand had 38,308,763 vehicles; 3,067,278 of these were newly registered. Gasoline vehicles accounted for 26,127,855 units, corresponding to 68.20% of the total. Diesel vehicles accounted for 10,327,819 units or 26.96% of the total, and bi-fuel vehicles (gasoline or diesel with liquid petroleum gas [LPG]) accounted for 1,086,531 units or 2.84% of the total. Table 1 shows the total number of vehicles in Thailand, by fuel, as of December 2017.[58] Since the government implemented policies

[58] Number of vehicles registered by fuel as of December 31, 2016, Transport Statistics Subdivision, Planning Division, Department of Land Transport (2016).

to promote using alternative fuel, the consumption of ethanol blended fuel (E10, E20, E85) has been 31% of total energy consumption for land transportation. Figure 3 presents the energy consumption for the land transportation sector in Thailand by the end of November 2017.[59]

Table 1 Number of Vehicles, by Fuel, in Thailand as of December 31, 2017
Source: *Thailand Energy Commodity Account 2016.*

Fuel Type	2017 (Units)	Percentage of Total (2017)
Gasoline	26,127,855	68.20
Diesel	10,327,819	26.96
Bi-fuel (gasoline or diesel with LPG)	1,086,531	2.84
Bi-fuel (gasoline or diesel with compressed natural gas [CNG])	325,555	0.85
Hybrid	102,308	0.27
Mono-fuel CNG	59,838	0.16
Mono-fuel LPG	21,423	0.06
Electric	1,394	0.00
Non-fuel and others	256,040	0.67
Total	38,308,763	100.00

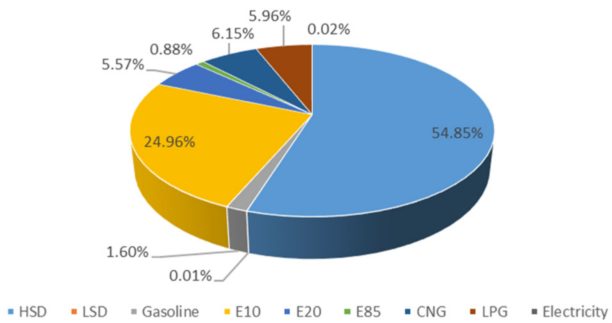

Fig. 3 Energy Consumption for Land Transportation in Thailand (January–November 2017)[60]

[59] Thailand Energy Commodity Account Jan-Nov 2016, Department of Alternative Energy Development and Efficiency (2016), http://www.dede.go.th/ewt_news.php?nid=42079.

[60] Ministry of Energy, 2017, Alternative Energy Development Plan 2015, Energy Policy and Planning Office, http://www.eppo.go.th/index.php/th/plan-policy/tieb/aedp.

Research and Demonstration Focus

Policies support the development of domestic renewable energy technology and research and development (R&D) to promote Thailand's competitiveness in the international market. The R&D policies focus on the development of sustainable and environmentally friendly energy in the following areas from 2015 to 2019[61]:

- Development of alternative raw materials and investigation of potential areas and technology for the production and use of renewable energy.
- Promotion of the investment, the reduction of production costs, and an increase in the business performance for both domestic and international manufacturers.
- Encouragement of the conservation and production of renewable energy in the community through the Community Renewable Energy Investment Program, including prototypes of biogas, CBG, and other types of renewable energy by using the development fund around the power plant to develop community-based renewable energy.
- Development of a prototype city for energy management (i.e., smart city).

Outlook

The Government of Thailand has focused on renewable energy for a decade. The development of biofuels is under the policy framework, which continues to drive the Alternative Energy Development Plan (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.[62]

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[61] Ministry of Energy, 2017, Alternative Energy Development Plan 2015, Energy Policy and Planning Office, http://www.eppo.go.th/index.php/th/plan-policy/tieb/aedp.

[62] Ministry of Energy, 2017, Alternative Energy Development Plan 2015, Energy Policy and Planning Office, http://www.eppo.go.th/index.php/th/plan-policy/tieb/aedp.

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

Energy Type	2017[b]	2036	
Biofuel	**ML/day**	**ML/day**	**ktoe**
Biodiesel	3.72	14.00	4,404.82
Ethanol	3.92	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 January to October 2017.

Benefits of Participation in the AMF TCP

As a participant in the AMF TCP, Thailand continues to focus on energy consumption by:

- Encouraging international collaboration among countries to work towards sustainable energy;
- Securing a strategic alternative source of energy, apart from petroleum-based energy; and
- Creating value to Thailand's agricultural wastes by converting them into an energy source.

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) Technology Integration Program (formerly the Clean Cities Program) is a government-industry partnership program that supports local decisions to reduce petroleum use in the transportation sector through the use of alternative fuels, hybrid and electric-drive vehicles, idle reduction technologies, smarter driving practices, and improved fuel economy measures. The functioning of the program has been described in previous AMF annual reports. More information on the Program can be found at www.cleancities.energy.gov.

The most recent data from the Technology Integration Program are for 2016 and show that the program saved 1,084,500,000 gasoline gallons equivalent (gge), of which 736,500,000 gge came from alternative fuels/vehicles (15% increase from last year), 100,300,000 gge from electric and hybrid vehicles (9% increase), and 38,900,000 gge from idle reduction technologies. Of the total, 963,800,000 gge savings were from fleets belonging to the coalitions between DOE and individual cities, with the remainder coming from other fleets and vehicle owners utilizing services, resources, and infrastructure funded by the program.

The primary driver of renewable fuel use in the U.S. is the Renewable Fuel Standard (RFS), which was adopted in 2005 and expanded in 2007 (RFS2). It requires increasing the volume of renewable fuel to be used in motor fuels. On December 12, 2017, the U.S. Environmental Protection Agency (EPA) finalized the volume requirements and associated percentage standards under the RFS program for calendar year 2018 for cellulosic biofuel, biomass-based diesel, advanced biofuel, and total renewable fuel. The EPA also finalized the volume requirement for biomass-based diesel for 2019. These volumes were slightly higher than those for 2017 compliance, except for cellulosic biofuel, which was 7% lower. However, the values were significantly lower than those originally targeted in the RFS legislation, which envisioned much more robust growth in cellulosic fuel production than has 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 rulemakings in 2013 and 2014, has dwarfed liquid fuels in that category. Biomass-based diesel is mainly traditional biodiesel, derived from soy, corn, canola, and other vegetable and animal fats and oils. These categories are nested into the category of advanced biofuels, which also includes renewable diesel, biogas, renewable heating oil, and renewable fuels co-processed in petroleum refining. Finally, the broad category "Renewable fuel" includes all of these categories combined with starch- and sugar-based ethanol. Other alternative and advanced motor fuels are incentivized by various federal and state programs. Lists of these are available at afdc.energy.gov/laws/.

The State of California developed the Low-Carbon Fuel Standard (LCFS) to reduce the average carbon intensity of its transportation fuels by 10% from 2010 to 2020. Using life-cycle analysis, different carbon intensities were developed for different fuels, including alternative fuels and biofuels. With both the RFS and LCFS, a significant amount of biofuels is used in California, more than 1.5 billion gallons in 2016.

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 2017 was 23,462 trillion British thermal units (Btu), up from 23,283 trillion Btu for the same period in 2016.[63] More than 90% of this consumption would be petroleum-based fuels (gasoline and diesel), with most of the remainder being ethanol blended into gasoline at 10%. Biomass accounted for 1,189 trillion Btu during these 10 months, natural gas for 611 trillion Btu, propane for 33 trillion Btu, and electricity for 21 trillion Btu.[64]

Biofuels

The best biofuel use data come from the EPA's recording of Renewable Identification Numbers (RINs) filed by refiner/marketers of liquid transportation fuels, as shown in Figure 1.[65] 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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[63] *EIA Monthly Energy Review*, January 2018.

[64] Ibid.

[65] EPA, 2017, "Fuels Registration, Reporting, and Compliance Help," epa.gov/fuels-registration-reporting-and-compliance-help/2017-renewable-fuel-standard-data.

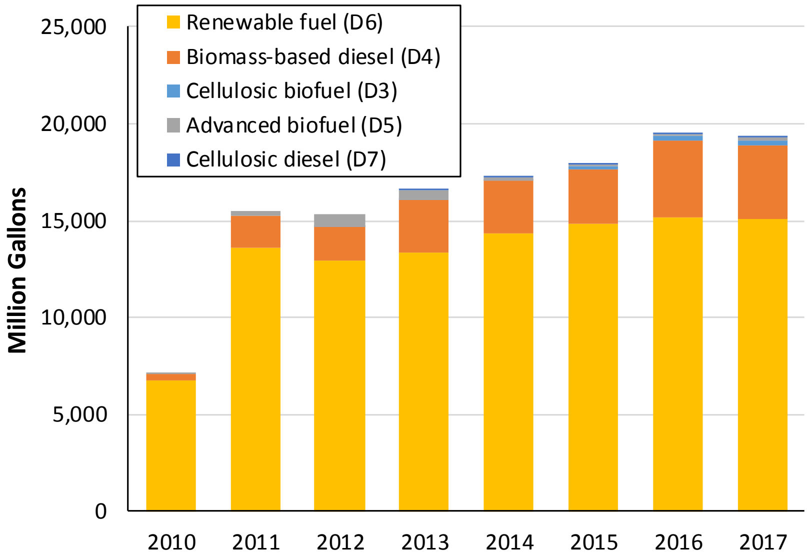

Fig. 1 Renewable Fuel Volumes Resulting from U.S. Renewable Fuel Standard

Electric Vehicles

Sales of plug-in electric hybrids (PHEVs) and battery electric vehicles (BEVs) in 2017, totaling 195,579, were up strongly compared to 159,616 in 2016. In addition, 370,680 hybrid electric vehicles (non-plug-in) were sold in 2017, up from 346,949 in 2016.[66] Available plug-in models totaled 90 as of January 2018, up from 56 in February 2017.[67]

Alternative Fuel Infrastructure

The DOE's Alternative Fuels Data Center provides the number of alternative fuel refueling stations, in the U.S.[68] As seen in Table 1, the total number of alternative fueling stations, exclusive of electric recharging stations, in the U.S. increased by 33% between 2012 and 2017. However, the number of biodiesel (B20), compressed natural gas (CNG), liquefied natural gas (LNG), and liquefied petroleum gas (LPG) stations decreased slightly in 2017. The total number of public and private nonresidential

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66 Argonne National Laboratory, 2018, "Light Duty Electric Drive Vehicles Monthly Sales Updates," anl.gov/energy-systems/project/light-duty-electric-drive-vehicles-monthly-sales-updates.

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

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

electric vehicle recharging outlets jumped by almost 400% over this same 5-year period, with a steady gain in 2017 as well.

Table 1 Number of U.S. Alternative Fuel Refueling Stations by Type, 2012–2017 (including public and private stations)

Year	B20	CNG	E85	Electric Outlets[a]	H2	LNG	LPG	Total	Total Non-electric
2012	675	1,107	2,553	13,392	58	59	2,654	20,498	7,106
2013	757	1,263	2,639	19,410	53	81	2,956	27,159	7,749
2014	784	1,489	2,780	25,511	51	102	2,916	33,633	8,122
2015	721	1,563	2,990	30,945	39	111	3,594	39,963	9,018
2016	718	1,703	3,147	46,886	59	139	3,658	56,310	9,424
2017	704	1,671	3,399	53,141	63	136	3,478	62,592	9,451

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

Research and Demonstration Focus

The DOE's Vehicle Technologies Office (VTO) sponsors research in fuels and advanced combustion engines for the purpose of displacing petroleum-derived fuels, matching engines and fuel characteristics better, and increasing engine and vehicle efficiencies. This research covers a very broad range of fuel, engine, and vehicle technologies. The summary provided here focuses on fuels and fuel effects and is based on annual program reports.[69,70]

In 2015, DOE introduced a new initiative known as the Co-Optimization of Fuels and Engines, or Co-Optima. The initiative is led jointly by DOE's VTO and Bioenergy Technology Office (BETO). The goal of Co-Optima is to identify and evaluate 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 technologies, targeted for commercialization by 2025, and compression ignition technologies, targeted for commercialization by 2030. Identified metrics include:

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

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

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

The DOE's BETO promotes the development of new fuels from initial concepts, laboratory research and development, and pilot and demonstration plant phases. Research areas include feedstocks, algae, biochemical conversion, and thermochemical conversion for both fuels and high-value chemicals. For additional information, visit energy.gov/eere/bioenergy.

Outlook

The EIA's *Annual Energy Outlook 2017* projects decreasing transportation energy use from 2018 through 2034 due to mandated increases in fuel efficiency. It projects that BEV sales will increase from less than 1% to 6% of total light-duty vehicles sold in the U.S. over 2016 to 2040, and 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 BEVs, PHEVs, and FCVs 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, 2017, "Transportation Energy Data Book," December, cta.ornl.gov/data/tedb36/Edition_36_Full_Doc.pdf.
- EIA, 2017, *Annual Energy Outlook 2017*, eia.gov/outlooks/aeo/pdf/0383(2017).pdf.
- EIA, 2018, *Monthly Energy Review*, Energy Information Administration, 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 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. 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 30 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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[a] Alphabetical order by country name.

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

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

4.b.iii
Chairs and Secretariat

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

4.c
AMF TCP Publications in 2017

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

Influence of fuel ethanol content on primary emissions and secondary aerosol formation potential for a modern flex-fuel gasoline vehicle. Research article published in *Atmospheric Chemistry and Physics*, April 2017.

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 ($11,567 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 ($2,435 to $121,763 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.

Biomass to Liquid (BTL) (Fuels)

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

Diesel Dual Fuel (DDF)

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

Dimethyl Ether (DME)

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

E85

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

Ethanol (C_2H_5OH)

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

Ethyl Tertiary-Butyl Ether (ETBE)

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

Fatty Acid Methyl Ester (FAME)

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

Flex-Fuel Vehicle (FFV)

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

Fuel Cell Vehicle (FCV)

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

Greenhouse Gas (GHG)

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

Hydro-treated Vegetable Oil (HVO)

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

Internal Combustion Engine (ICE)

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

Liquefied Natural Gas (LNG)

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

Liquefied Petroleum Gas (LPG)

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

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.

Nitrogen Oxides (NO_x)

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

Particulate Matter (PM)

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

Plug-in Hybrid Electric Vehicle (PHEV)

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

Port Fuel Injection (PFI)

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

Well-to-Wheel

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

Notation and Units of Measure

A3PS	Austrian Association for Advanced Propulsion Systems
AEDP	Alternative Energy Development Plan (Thailand)
AMF TCP	Advanced Motor Fuels Technology Collaboration Programme
AMFS	Advanced Motor Fuels Statistics
BC	Black Carbon
BD	Biodiesel
BD2	2% biodiesel, 98% petrodiesel blend
BD5	5% biodiesel, 95% petrodiesel blend
BD100	100% pure biodiesel (blendstock)
BDF	biodiesel fuel
BE	Bioethanol
BE5	5% bioethanol, 95% gasoline
BMEL	Federal Ministry of Food and Agriculture (Germany)
BMVI	Federal Ministry of Transport and Digital Infrastructure (Germany)
BMVIT	Federal Ministry for Transport Innovation and Technology (Austria)
3CV	Center for Vehicle Control and Certification (Chile)
CAGR	Compound Annual Growth Rate
CATARC	China Automotive Technology and Research Center
CERT	Committee on Energy Research and Technology
CFS	Clean Fuel Standard
CGSB	Canadian General Standards Board
CH_4	Methane
CMMCh	Centro Mario Molina (Chile)
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
COP21	2015 Paris Climate Conference
DDF	Diesel Dual Fuel
DME	Di-methyl Ether
DOE	U.S. Department of Energy
DPF	Diesel Particulate Filter
E5	5% ethanol, 95% gasoline blend

E10	10% ethanol, 90% gasoline blend
E85	85% ethanol, 15% gasoline blend
EC	European Commission
EIA	U.S. Energy Information Administration
EIP	Energy Innovation Program
EPA	U.S. Environmental Protection Agency
EPAct	Energy Policy Act of 1992
ETBE	Ethyl Tertiary-butyl Ether
ETN	Energy Technology Network
eTV	EcoTechnology for Vehicles
EU	European Union
EUWP	Working Party on Energy End-use Technologies
EV	Electric Vehicle
ExCo	Executive Committee
FAME	Fatty Acid Methyl Ester
FCV	Fuel Cell Vehicle
FFV	Flex-fuel Vehicle
FPCC	Fusion Power Coordinating Committee
FQD	Food Quality Directive
FTP	Federal Test Procedure (Canada)
GDI	Gasoline Direct Injection
GHG	Greenhouse Gas
GPF	Gasoline Particulate Filter
GTL	Gas to Liquid
H_2	Hydrogen
HCNG	Hydrogen-enriched Compressed Natural Gas
HDT	Heavy-duty Transport
HDV	Heavy-duty Vehicle
HEV	Hybrid Electric Vehicle
HSL	Helsinki Regional Transport Authority
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
IEA	International Energy Agency
IFCC	Israeli Fuel Cells Consortium
ILUC	Indirect Land-use Change
INREP	Israel National Research Center for Electrochemical Propulsion
ISF	Israel Science Foundation
ISO	International Organization for Standardization

KIMM	Korea Institute of Machinery and Materials
KliK	Foundation for Climate Protection and Carbon Offset
LCFS	Low-carbon Fuel Standard
LDV	Light-duty Vehicle
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
M15	85% gasoline, 15% methanol
MON	Motor Octane Number
MOVEA	Alternative Energy Vehicle Mobility Incentive Plan (Spain)
MSR	Methanol Steam Reforming
MTBE	Methyl Tertiary-butyl Ether
MTT	Ministry of Transport and Telecommunications (Chile)
NEDC	New European Driving Cycle
NG	Natural Gas
NGV	Natural Gas Vehicle
NMHC	Nonmethane Hydrocarbon
NO_x	Nitrogen Oxide(s)
NRCan	Natural Resources Canada
OMC	Oil Marketing Company
PERD	Program of Energy Research and Development
PFAD	Palm Fatty Acid Distillate
PFD	Port Fuel Injection
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PN	Particle Number
RD&D	Research, Development and Demonstration
RDE	Real Driving Emissions
RED	Renewable Energy Directive
REWP	Working Party of Renewable Energy Technology
RFR	Renewable Fuel Regulations
RFS	Renewable Fuel Standard
RIN	Renewable Identification Number
RON	Research Octane Number

SI	Spark Ignition
SOA	Secondary Organic Aerosol
TAEE	Tertiary-amyl Ethyl Ether
TCP	Technology Collaboration Programme
TEPS	Transportation Electric Power Solutions (Israel)
UER	Upstream Emission Reductions
VPT	Vehicle Propulsion Technologies
VTT	Technical Research Center of Finland
WP	Work Package
WPFF	Working Party of Fossil Fuels

Units of Measure

Baht	Thai Currency
Btu	British thermal unit(s)
g	gram(s)
gge	gasoline gallon(s) equivalent
kL	kiloliter(s)
km	kilometer(s)
L	liter(s)
L/km	liter(s) per kilometer(s)
MJ	megajoule(s)
Mt	megaton(s)
Mtoe	megatonnes of oil equivalent
PJ	petajoule(s)
t	metric ton(s) or tonne(s) (i.e., 1,000 kg)
TJ	terajoule(s)
TWh	terawatt-hour(s)
€	Euro(s)
$	Dollar(s)