IEA-Advanced Motor Fuels

ANNUAL REPORT 2014

iea Energy Technology Network

ADVANCED MOTOR FUELS IEA-AMF

IEA Implementing Agreement for a Programme on Research and Demonstration on

Advanced Motor Fuels Annual Report 2014

Rainbow Spine: The colors used for the spines of Advanced Motor Fuels Annual Reports follow the colors of the rainbow. This allows readers to easily distinguish different yearly editions from each other. The spines of previous editions (2010, 2011, 2012, and 2013) were blue, dark green, light green, and yellow, respectively. This year´s edition has a red spine. The next AMF IA working period, which will start in 2015, will then begin again with the first color of the rainbow: violet.

This year´s color, red, stands for action and energy. The AMF IA is a very active agreement; it currently has 10 active annexes. Its efforts in 2014 were dedicated to contributing to a low-carbon energy future.

Cover: Fuel combustion in a partially open engine. Photo courtesy of Bosch.

Cover Design: Sana Sandler, Argonne National Laboratory, USA

International Energy Agency

Advanced Motor Fuels
Annual Report 2014

This Annual Report was produced by Kevin A. Brown (project coordination/management), Marita Moniger (lead editor), Pat Hollopeter (proofreading/editing), Vicki Skonicki (document production), and Gary Weidner (printing) of Argonne National Laboratory. The cover was designed by Sana Sandler, also of Argonne National Laboratory.

Contributions were made by a team of authors from the Advanced Motor Fuels Implementing Agreement, as listed below.

Country reports were delivered by the Contracting Parties and one Observer (Chile):

Austria	Ministry of Transport, Innovation, and Technology (BMVIT)
Canada	CanmetENERGY
Chile	Centro Mario Molina Chile
China	China Automotive Technology and Research Center (CATARC)
Denmark	Technical University of Denmark (DTU)
Finland	The Technical Research Centre of Finland (VTT)
France	Institut Francais du Pétrole (IFP)
Germany	Fachagentur Nachwachsende Rohsoffe (FNR)
Israel	Ministry of National Infrastructure, Energy and Water Resources
Italy	ENI S.p.A.
Japan	• National Institute of Advanced Industrial Science and Technology (AIST) • Organization for the Promotion of Low Emission Vehicles (LEVO)
Republic of Korea	Korea Institute of Energy Technology Evaluation and Planning (KETEP)
Spain	Instituto para la Diversificación y Ahorro de la Energía (IDAE)
Sweden	Swedish Transport Administration (STA)
Switzerland	Swiss Federal Office of Energy (SFOE)
Thailand	PTT Research and Technology Institute
USA	U.S. Department of Energy (DOE)

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

Annex 28	Information Service and AMF Website	Dina Bacovsky
Annex 35-2	Particulate Measurements: Ethanol and Butanol in DISI Engine	Debbie Rosenblatt
Annex 38-2	Environmental Impact of Biodiesel Vehicles	Norifumi Mizushima
Annex 39-2	Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines	Magnus Lindgren
Annex 42	Toxicity of Exhaust Gases and Particles from IC-Engines	Jan Czerwinski
Annex 43	Performance Evaluation of Passenger Car, Fuel, and Powerplant Options	Juhani Laurikko
Annex 44	Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels	Fan Zhang
Annex 45	Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation	Benjamin Stengel
Annex 46	Alcohol Application in CI Engines	Jesper Schramm
Annex 47	Reconsideration of DME Fuel Specifications for Vehicles	Mitsuharu Oguma
Annex 48	Value Proposition Study on Natural Gas Pathways for Road Vehicles	Ralph McGill
Annex 49	COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Nils-Olof Nylund
Annex 50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
Annex 51	Methane Emission Control	Jesper Schramm

Other sections of this report were delivered by the Chair and the Secretary:

Magnus Lindgren	Swedish Transport Administration (STA)	ExCo Chair
Dina Bacovsky	BIOENERGY 2020+	Secretary

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The Advanced Motor Fuels Implementing Agreement

1.a Chairperson's Message

The energy technology initiative on advanced motor fuels is now taking a step into the future, with the AMF End of Term Report representing the completion of the last period ending in 2014. The future will bring lots of new challenges and possibilities. For example, we will probably have to deal with changes in global policies, the threat of climate change, a scarcity of sustainable energy, the availability of shale gas, and the deployment of advanced fuels, including first- and second-generation biofuels — to mention only a few items.

It is possible that an increased availability of shale gas, a reduction in the price of crude oil, political discussions regarding the effects of land use, and other issues and activities might take the focus away from alternative and sustainable fuels. Yet it is more important than ever that the AMF Implementing Agreement (IA) delegates (i.e., "the AMF") look into future needs and challenges in order to propose the right actions today. I believe that the AMF is well prepared to face this challenge through the new strategic plan, its set of Annexes, and the participation of all the individual delegates of this IA.

In 2011, energy use in the entire transport sector exceeded 100 exajoules (EJ; road transport accounted for 76 EJ); this usage represented an increase of more than 20% over that in reference year 2000 and contributed to more than 22% of the global emissions of carbon dioxide (CO_2). Of the global petroleum demand, the transport sector accounts for approximately 50%, and the demand for the middle distillates, such as diesel and kerosene, is especially high. This development is in direct contrast with the International Energy Agency's (IEA's) 2°C Scenario (2DS), in which it was concluded that all sectors of society, including transport, need to reduce their greenhouse gas (GHG) and CO_2 emissions.

Within the transport sector, both the need for petroleum products and the extent of CO_2 emissions could be reduced significantly if there was a combination of a transport-efficient society, energy-efficient vehicles/vessels, an efficient use of energy, and the use of advanced motor fuels, including electricity. Behind these goals are principles that are described as “avoid/shift/improve.” “Avoid” involves city planning and dealing with demand requirements. “Shift” deals with making changes in the transport modes for both passengers (e.g., promoting more efficient transport modes like cycling, walking, and public transport) and goods (e.g., moving from air and road to rail and maritime transport). According to the IEA publication *Energy Technology Perspective* (ETP 2014), energy efficiency has the highest potential for reducing CO_2 emissions in the transport sector, but the use of renewable fuels is not far behind, with those fuels anticipated to meet 20% of energy demand in the 2DS Scenario.

The North American shale gas boom, the reduction in the price of crude oil, and changes in various regional policies have made investments in biofuel production less interesting. Still, any societal expenditures that would result from the use of petroleum products in the transport sector would outweigh the costs associated with using advanced technologies and fuels (ETP 2014). The use of shale gas could even be a bridge to the use of renewable methane. From an engine perspective, there is no difference between a methane molecule from shale or natural gas and a methane molecule from a renewable feedstock, such as upgraded biogas. Advanced and sustainable liquid fuels are also the only known energy carrier (besides grid-connected electricity) that have both a sufficient energy density and the potential for low CO_2 emission levels, from a well-to-wheel perspective.

As participants in the IEA’s AMF IA, we have an important role to play in this transition by evaluating the effects from using current and future alternative and renewable motor fuels. We can bring stakeholders from different continents together to pool and leverage their knowledge and research capabilities in the field of advanced and sustainable transportation fuels. With our broad geographical representation, we are able to take regional and local conditions into consideration as we facilitate the deployment of new fuel and vehicle technologies.

The AMF vision is to achieve “a sustainable transportation system with a significant contribution from advanced, alternative, and renewable fuels, resulting in reduced emission of greenhouse gases and air contaminants, meeting needs for personal mobility and the movement of goods on a local and a global scale.” Thus, a reduction in GHG emissions should not be achieved at the expense of air quality; the future transport system must be both clean and green.

There are several examples of individual AMF Annexes that have contributed valuable information with regard to the transition of the transport sector, such as these:

- Annex 36 results provided the basis for further investigations of ethanol blends and related standards by the European Commission.
- Annex 38 results were used to prepare appropriate policies for introducing biodiesel fuel and vehicles into the Japanese market.
- Annex 39 results were used to support the Swedish Commission on Fossil-Free Road Transport with regard to the use of methane-fueled heavy-duty vehicles.
- Annex 39 results were used to enable the homologation of dual-fuel engines within the Euro VI regulation through the UNECE (United Nations Economic Commission for Europe)
- Annex 43 results were used to set objectives and recommendations for passenger car transport in Finland.

With the increased use of shale gas, the idea of using methane fuel in the transport sector has become a more interesting. Several AMF Annexes in this area recently ended; they include Alternative Fuels for Marine Applications (Annex 41), Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines (Annex 39), and Fuel and Technology Alternatives for Buses (Annex 37). There are also a few ongoing Annexes in this area, like COMVEC – Fuel and Technology Alternatives for Commercial Vehicles (Annex 49), and Value Proposition Study on Natural Gas Pathways for Road Vehicles (Annex 48). All these studies identified a need for further information, investigations, and searches for solutions; this conclusion, in turn, resulted in the initiation of Methane Emission Control (Annex 51). This is just one example of the good work being done within the AMF, in which individual Annexes, working together, create a bigger picture, much like individual pieces, put together, make up and complete an entire puzzle.

The AMF also engages in wide-ranging areas of research, as demonstrated by the Annexes, which cover passenger cars, buses, heavy-duty trucks, marine applications, and, recently, a new Annex that addresses the non-road sector. However, the advanced motor fuels themselves are not enough. Even if a fuel has excellent properties as an engine fuel (having high energy efficiency and resulting in only low levels of CO_2 and other exhaust pollutants being emitted from the tailpipe), in order for it to be a fuel for the future, the whole chain — from extraction/production to end use — must work well. The AMF, in combination with other energy technology initiatives (e.g., Bioenergy, Hydrogen, Gas and Oil Technologies, and other transport-related energy technology initiatives), could result in a system perspective. However, there is still one area in which there is no initiative: transport-efficient city planning (to be compared with the “avoid” principle of ETP 2014). This is something that we all need to consider when we are implementing the results from the AMF and other energy technology initiatives.

I’m privileged to be the new chairperson when the AMF will be taking its first steps into the future with the new Strategic Plan — but I’m not alone on this journey. My travel companions include a trustworthy secretary keeping me on the path, experienced vice-chairs to give me guidance, and — the most important part — all the delegates and operating agents who make up the AMF. Thank you all!

Magnus Lindgren
AMF Chairperson

1.b
Introduction to the International Energy Agency

The International Energy Agency (IEA) is an autonomous agency that was established in 1974. The IEA carries out a comprehensive program of energy cooperation among 28 advanced economies, each of which is obliged to hold oil stocks equivalent to 90 days of its net imports. The aims of the IEA are to:

- Secure the access of member countries to reliable and ample supplies of all forms of energy and, in particular, maintain effective emergency response capabilities in case of oil supply disruptions.
- Promote sustainable energy policies that spur economic growth and environmental protection in a global context, particularly in terms of reducing greenhouse gas emissions that contribute to climate change.
- Improve the transparency of international markets through collection and analysis of energy data.
- Support global collaboration on energy technology to secure future energy supplies and mitigate their environmental impact, through improved energy efficiency and the development and deployment of low-carbon technologies.
- Find solutions to global energy challenges through engagement and dialogue with nonmember countries, industries, international organizations, and other stakeholders.

To attain these goals, increased cooperation among industries, businesses, and governments engaged in energy technology research is indispensable. The public and private sectors must work together and share burdens and resources while, at the same time, multiplying results and outcomes.

The multilateral technology initiatives (Implementing Agreements or IAs) supported by the IEA are a flexible and effective framework for IEA member and nonmember countries, businesses, industries, international organizations, and nongovernment organizations to conduct research on breakthrough technologies, fill existing research gaps, build pilot plants, and carry out deployment or demonstration programs — in short, to encourage technology-related activities that support energy security, economic growth, and environmental protection.

More than 6,000 specialists carry out a vast body of research through these various initiatives. To date, more than 1,000 projects have been completed. There are now 41 IAs that work in the following categories:

- Cross-cutting activities (information exchange, modeling, technology transfer),

- End-use (buildings, electricity, industry, transport),
- Fossil fuels (greenhouse gas mitigation, supply, transformation),
- Fusion power (international experiments), and
- Renewable energies and hydrogen (technologies and deployment).

The Implementing Agreement for Advanced Motor Fuels (AMF IA) belongs to the category of “end-use.”

The IAs are at the core of a network of senior experts consisting of the Committee on Energy Research and Technology (CERT), four working parties, and three expert groups. One of CERT’s key roles is to provide leadership by guiding the IAs in shaping work programs that address current energy issues in a productive way, by regularly reviewing their accomplishments, and by suggesting reinforced efforts where needed. For further information on the IEA, CERT, and IAs, please consult http://www.iea.org/techinitiatives/.

1.c Implementing Agreement for Advanced Motor Fuels

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 we use solid data for decision making.

Our Approach

We have 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) IAs, and
- Do a better job of involving industry in our work.

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

Benefits
We bring 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.

Competition
Internationally, there are several fuels-related organizations. However, without exception, these organizations are working for a specific fuel or group of fuels — for example, alcohols, natural gas, liquid petroleum gas, and synthetic fuels. In addition, there are organizations promoting electromobility. In the field of transportation fuels, we are the only internationally recognized, technology-neutral clearinghouse for fuel-related information.

Sustainable Transport Systems
- Reduce GHG emissions globally,
- Secure a stable supply of fuel for transport services, and
- Reduce emissions of toxic pollutants.

Vision

The vision of the members of the Advanced Motor Fuels Implementing Agreement (AMF IA) 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 IA 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 IA 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 IA 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 IA fulfills its mission through the international cooperation of academia, industries, governmental institutions, and nongovernment organizations. The Annexes in the AMF IA 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.

1.d
How to Join the Advanced Motor Fuels Implementing Agreement

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

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

The Secretary will give you details on the AMF IA 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 IA.

Contracting Parties to AMF IA are usually governments. Therefore, you need to seek support from your government to join the IA. The government will later appoint a Delegate and an Alternate to represent the Contracting Party in the ExCo.

Financial obligations of membership include:

- An annual membership fee, currently €9,500 ($10,294 US);
- Funding for an ExCo Delegate to participate at two annual meetings; and
- Cost-sharing contributions to Annexes in which you wish to participate; cost shares range from €10,000 to €100,000 ($10,834 to $108,339 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 IA Secretary and IEA Secretariat will guide you through the formalities of joining the AMF IA.

2 The Global Situation for Advanced Motor Fuels

2.a
Overview of Advanced Motor Fuels[1]

The transport sector (including road, rail, marine, and aviation) is the largest consumer of oil products, with a share of 63% of respective global consumption in 2011 (Figure 1).

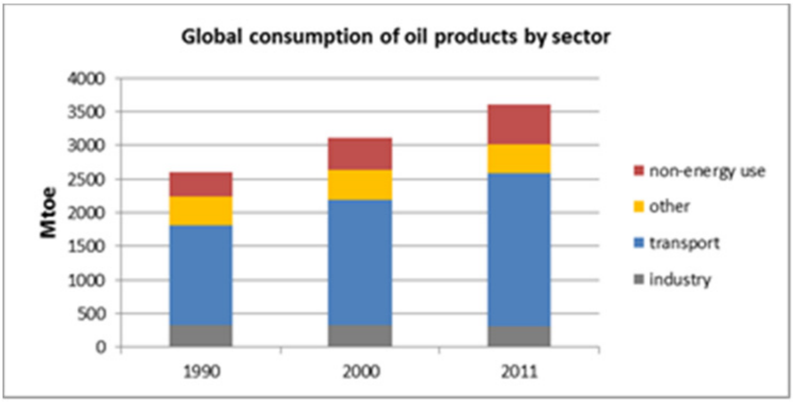

Fig. 1 Global Consumption of Oil Products[2]
(Source: IEA Statistics)

While the industry sector´s total final energy consumption is about as large as that of the transport sector (2,556 Mtoe in industry versus 2,445 Mtoe in transport in 2011), only 12% of industry´s energy consumption is provided through oil products, whereas the transport sector is almost entirely dependent on fossil oil products.

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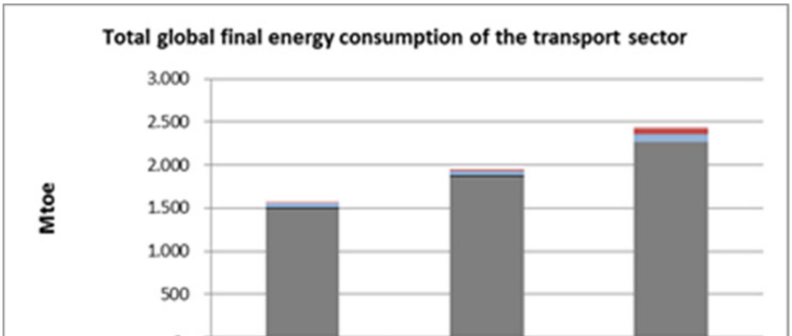
[1] The information in this section on Overview of Advanced Motor Fuels was not updated. It was taken directly from the 2013 *IEA-Advanced Motor Fuels Annual Report.*

[2] Industry: manufacturing and construction industries
Transport: road, rail, marine, and aviation
Other: agriculture, commercial and public services, residential, and non-specified other
Non-energy use: chemical feedstocks and non-energy products

The use of alternative fuels (such as natural gas and biofuels) has increased tremendously over the past two decades, yet oil products still provided 93% of all transport fuels in 2011, while natural gas accounted for 3.8%, biofuels for 2.4%, and electricity for 1% (Figure 2).



	1990	2000	2011
electricity	21	19	25
biofuels and waste	6	10	59
natural gas	56	58	93
coal	13	4	3
oil products	1.485	1.868	2.265

Fig. 2 Total Global Final Energy Consumption of the Transport Sector
(Source: IEA Statistics)

Of course, the use of alternative motor fuels depends on available vehicle technology. Only a few countries have more than a 30% share of alternative fuel vehicles in their vehicle stock (IEA Energy Technologies Perspectives 2012). Examples include Argentina, Armenia, Bangladesh, Bolivia, Iran, and Pakistan, which have significant shares (20–30%) of natural gas vehicles (NGVs), and Brazil, where 28% of vehicles in 2010 were flex fuel vehicles (FFVs).

Absolute numbers of alternative fuel vehicles cited include10 million FFVs on the road in the United States in 2011 (US Energy Information Administration), 17 million FFVs produced between 2003 and 2012 in Brazil (Brazilian Automobile Industry), and 16.7 million NGVs operating globally in 2012 (NGV Global, Figure 3). In comparison with more than 1 billion vehicles on the road today globally, these figures altogether represent less than 1% of vehicle stock.

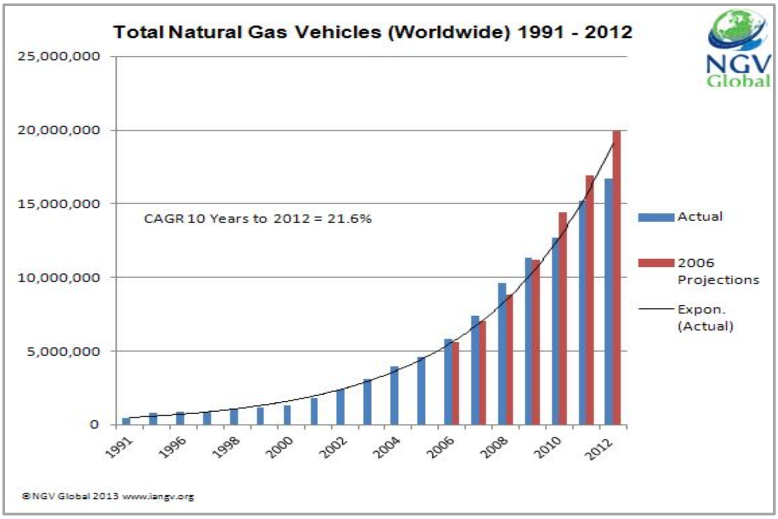


Fig. 3 Total Number of Natural Gas Vehicles Worldwide
(Source: NGV Global)

Energy demand for road transport is projected to decline in OECD (Organisation for Economic Co-operation and Development) countries in the coming years, but it will be offset by the projected increase in non-OECD countries (Figure 4).

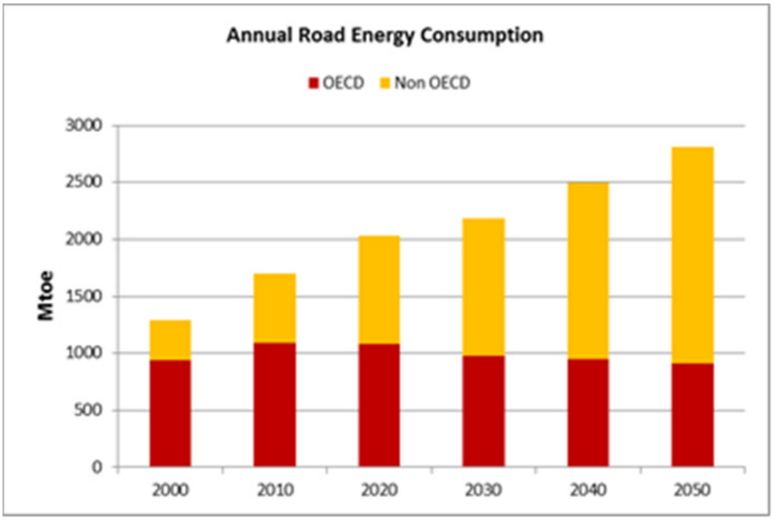


Fig. 4 Global Annual Road Energy Consumption Projections
(Source: IEA Energy Technology Perspectives 2012)

Non-OECD countries with strong economic growth are also projected to have strongly increasing road transport demand, as can be seen for China and India (Figure 5).

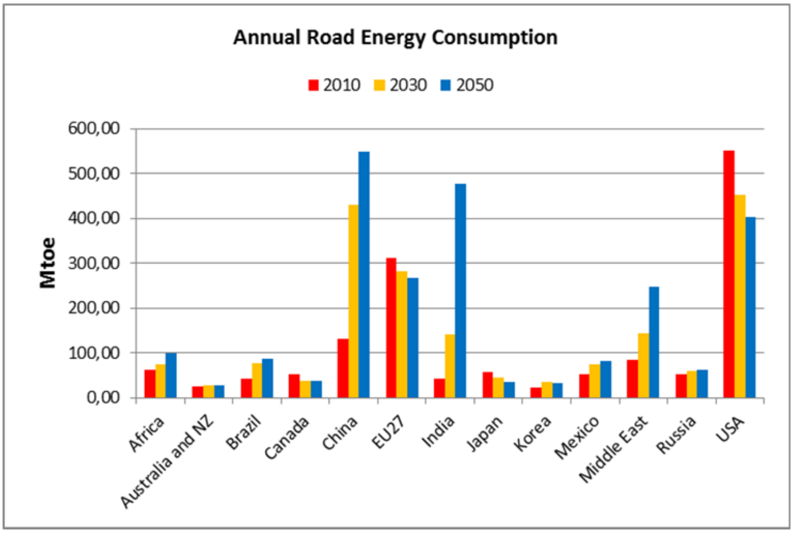


Fig. 5 Global Road Energy Consumption by Selected Countries
(Source: IEA Energy Technology Perspectives 2012)

The transport sector is the largest consumer of oil products, with projections of continued growth in non-OECD countries. Despite the tremendous increase in the use of such alternative motor fuels as biofuels and natural gas, the transport sector still is 93% dependent on oil products. Research on and use of advanced motor fuels and vehicle technologies – in OECD countries but even more in non-OECD countries – will thus have a major impact on local air pollution, greenhouse gas emissions, and total demand for oil products.

2.b
Country Reports of AMF IA Member Countries

Most of the countries participating in the AMF IA 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

Introduction

In 2013, the growth rate of the global economy, which was 3.2% in 2012, fell to 3%, according to the Austrian Institute of Economic Research (WIFO). The strong growth that had been achieved by the threshold countries and been propelling the global economy in recent years lost its dynamics in 2013.

The growth rate in the Austrian economy was just 0.4% in 2013, the lowest figure since the 2008/2009 recession. The weak economy and the decline in the prices for raw materials — especially oil products — kept inflation in Austria at a low level (2% in 2013), although this level was still relatively high compared with the average level found in the "euro zone." A large part of the reversal was due to the increasingly negative contribution that oil-based products made to inflation.

The Austrian import price for crude, the chief component of its energy imports, dropped to $112.4 US/billion barrels (bbl) in 2013, a decline of 2% over 2012. Using the euro as the basis, imports became cheaper by 5.2%, as the euro gained over the dollar. The value of crude oil and natural gas imports fell by 11% in 2013. Altogether, imports of fuels and energy dropped by 14.4% in 2013. Fuel consumption rose by a total of 3.9% in 2013, the result of a growth in diesel consumption. On the other hand, petrol consumption (almost entirely by passenger cars) declined by 2.9%, while diesel consumption was up by 5.8% over the previous year.

In 2013, the final quantity of energy consumed in Austria was about 1,120 PJ (petajoules), which was an increase from that in 2012 (1,100 PJ).[3] The transport sector, whose consumption was 370 PJ, still had the highest share of final energy consumption at 33.08%; the production sector followed at 29.99% (336 PJ). This distribution (share/proportion between the transport and production sectors) did not change much within the last years, but the energy consumed by the transport sector increased by 4.43%, which was the first increase since 2010.

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3 http://www.statistik.at/web_de/statistiken/energie_und_umwelt/energie/energiebilanzen/.

In 2013, oil production remained steady, while natural gas production declined significantly over that in 2012. In Austria, the companies OMV and RAG are prospecting for and extracting crude oil and natural gas in economically relevant quantities at the Vienna Basin, and in the molasses zone of Upper Austria and Salzburg. Specifically, overall annual crude and natural gas liquids (NGL) production amounted to 917,149 tons. Crude production without NGL amounted to 847,952 tons, which was nearly the same level as that in 2012.

In the world market for oil consumption, Austria represented a level of 0.3%. With this low percentage and an oil import dependency of about 85.6%, Austria had hardly any opportunity of detaching itself from international development. Austria’s main crude suppliers were Kazakhstan, Nigeria, and Russia. Altogether, crude for Austria was sourced from 17 countries.

Oil was still the most important fuel in Austria, accounting for 34% of the total prime energy supply in 2013. The country’s oil security is on a sound basis, since it holds oil stocks equaling more than 110 days of net imports. Also, although Austria imports most oil products, the sources of and transport routes used for these imports are well diversified. The security of the country’s natural gas supply has been a more recent area of focus for the Austrian government. Imports cover 80% of the country’s gas demand, and almost all imports are physically sourced from Russia. At the same time, the volume of gas that moves through Austria is many times larger than the volume consumed domestically. In 2013, natural gas extraction (which included petroleum gas) ran to 1.36 billion cubic meters (m^3), of which 1.13 billion m^3 was natural gas (83%) and 0.23 million m^3 was petroleum gas; this represented a decrease of about 371 million m^3 from 2012 levels. Based on all mineral oil products, the total oil consumption was about 10.9 million tons in Austria in 2013. (This total included fuels, extra light fuel oil, light and heavy fuel oils, lubricants, and bitumen, and it excluded petrochemical basics; see Figure 1.) Thus, petroleum consumption increased by almost 2% over that in the previous year (2012), when it was 10.7 million tons, and it decreased by 15% from its peak value in 2005 of 12.9 million tons. The Schwechat refinery, which is the only refinery in Austria and one of 646 refineries operating worldwide, has spread out on a 1.42-km^2 site and become one of the largest and most modern non-seashore refineries in Europe.

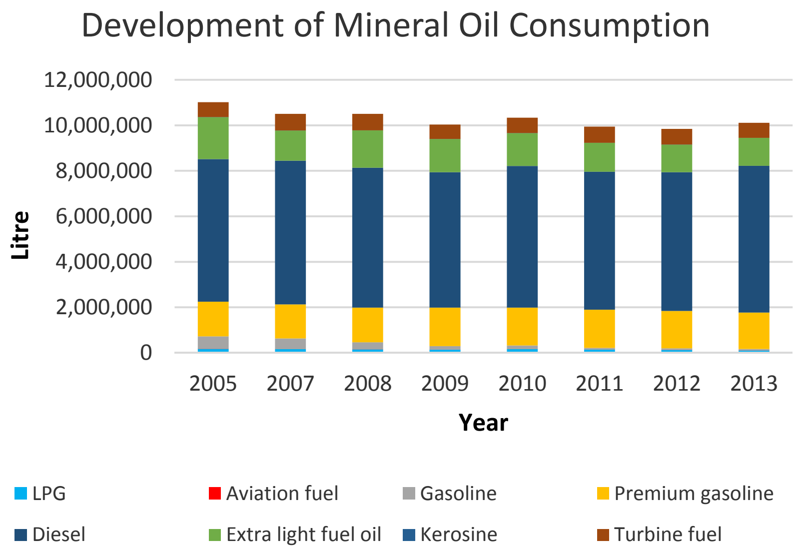


Fig. 1 Consumption of Mineral Oil by Type of Fuel between 2005 and 2013 in Austria
(Source: Mineralölbericht 2014)

In 2013, fuel consumption in Austria (excluding kerosene) was about 8.1 million tons (9.8 billion L, including biogenic components), of which 2.2 billion L was petroleum fuel (22.5%) and about 7.6 billion L was diesel fuel (77.5%) (see Figure 2). The total demand for fuel increased slightly from 2012 demand. The trend in gasoline consumption (–2.9%) was different than the trend in diesel consumption (+5.8%). One reason for the decrease in gasoline consumption was that there were more energy-efficient engine technologies. The increase in diesel consumption occurred mainly in the commercial sector ; it was an indicator of a relatively stable economy. Diesel consumption in 2013, at 7.6 billion L, was just above the top level of 2007. At 656,000 tons, the consumption of jet fuel in 2013 was almost 4.5% less than it was in 2012.

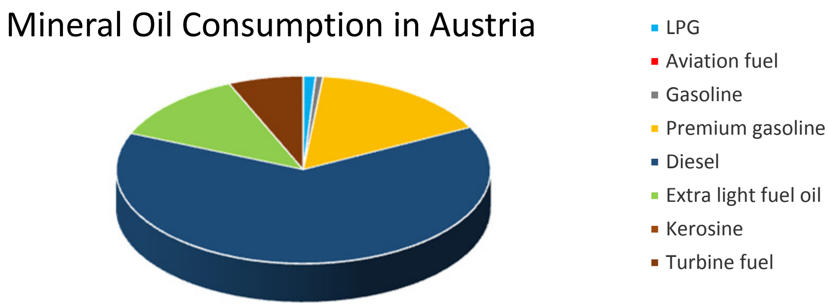


Fig. 2 Austria’s Mineral Oil Consumption
(Source: Mineralölbericht ’14)

Greenhouse Gas Emissions in Austria from 1990 till 2020

The Kyoto Protocol aimed to reduce greenhouse gas (GHG) emissions in industrialized countries in the first commitment period (2008–2012) by an average of 5.2 % compared to 1990 levels. In 2012, GHG emissions in Austria amounted to 80.1 million tons of carbon dioxide (CO_2) equivalent. The GHG emissions were thus 2.5% above the level in 1990 and 11.3 million tons above the annual mean value of the Kyoto target stipulated for 2008–2012. Overall, except for the year 2010, the trend in Austrian GHG emissions decreased from 2005 through 2013. By adopting the European Union (EU) climate and energy package in the second period (i.e., until 2020), the member states committed themselves to a 20% reduction in their GHG emissions below the level of the base year 1990. To achieve these targets, a 16% reduction in emissions is planned for Austria within this second period up to 2020 compared with the level in the reference year 2005. Another target is to raise the share of renewable energy sources in the gross final energy consumption volume across the EU to 20%; Austria’s share in total renewables is 34%. In the transport sector, a minimum of 10% of the energy used has to come from renewable energy sources.

Sector Emissions and Targets of the Austrian Climate Strategy

The main sources of GHG emissions in 2012 were the following sectors: industry (30.8%), transport (27.1%), energy production (15.5%), and space heating and small consumers (11.9%). GHG emissions in the transport sector in 2013 amounted to about 21.7 million tons of CO_2 equivalent. The reduction in emissions was due to the decrease in fuel sales as a result of higher fuel prices, a slow economic recovery, and increased efficiencies in fleet-specific fuel consumption. From 1990 until 2013, there was a

54% increase in emissions from the transport sector owing to an expanded car fleet, growth in transit freight transport, and relatively low fuel prices that attracted buyers from neighbouring countries; fuel sales to foreigners accounted for up to 30% of total fuel sales. The use of biofuels resulted in savings of about 1.7 million tons of CO_2 equivalent in 2013.

Quantities of Biofuels in Austria

From October 2005 through September 2007, biofuels in the Austrian market were primarily mixes of biodiesel and diesel fuels; from October 2007, they were mostly mixes of bioethanol and fossil petroleum fuel grades. By October 1, 2009, the "substitution obligation" to substitute biofuels for other fuels in accordance with fuel regulations had been increased to 5.75%.

Since the introduction of the 2012 Austrian Fuel Regulations, the country has been obligated to substitute at least 3.4% of fossil gasoline fuels and at least 6.3% of fossil diesel fuels with biofuels. In addition to blending fuels, municipal and business vehicle fleets were obliged to migrate to pure biofuels or to increase their use of biofuels by more than 40%.

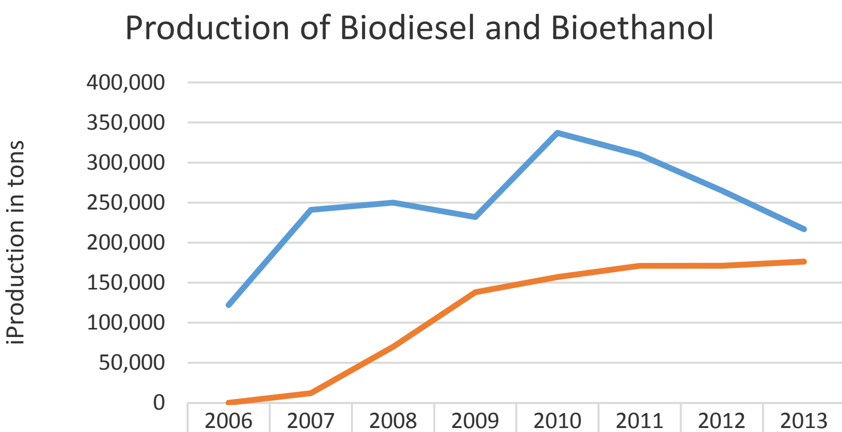
In 2013, a high percentage of fossil fuels had been substituted with biofuels. Compared to 2012 levels, the amount of biofuels used largely remained constant, while the consumption of conventional fuels increased slightly.

In total, about 507,529 tons of biodiesel, 88,843 tons of bioethanol, and 17,842 tons of vegetable oil were used in Austria. Over the course of calendar year 2013, the required substitution target of 5.75% (measured by energy content) was significantly exceeded; the final was 6.2%. Thus, the substitution rate in 2013 decreased slightly from that in 2012, from 6.77% to 6.2%. Austria, together with Germany, France, and Sweden, is at the top of EU 28.

Biodiesel and Bioethanol in Austria

In 2013, 6,191,575 tons of diesel were sold, of which 5,936,007 tons (95.9%) were blended with 7.0 vol% of biodiesel (Figure 3). Thus, about 444,835 tons were added to fossil fuels, and 62,694 tons were used in the transport sector either as pure biofuel or as diesel fuel with a higher, nonstandard biofuel component. Austria's capacity to produce biodiesel is about 600,000 tons in total. In 2013, 216,866 tons were produced in Austria by the following producers: Eco Fuels Danube, BIOIL, Agrana Bioethanol, ABID Biotreibstoffe, BioDiesel Kärnten, Münzer Bioindustrie, Münzer Paltental, Novaol Austria, PPM, and SEEG Mureck.

In 2013, a total of 1,665,482 tons of gasoline was sold. All gasoline fuels contained at least 4.60 vol% bioethanol. Therefore, with the addition of the quantities marketed as "superethanol," some 88,843 tons of bioethanol were sold in 2013. The total demand for bioethanol as a biofuel substitute could be covered by the production plant Pischelsdorf, which can process up to 191,000 tons of grain into fuel in a year. In 2013, 176,200 tons of ethanol were processed from using 55% maize and 45% grain.



	2006	2007	2008	2009	2010	2011	2012	2013
biodiesel	122,000	241,000	250,000	232,000	337,000	310,000	265,000	216,866
bioethanol	0	12,000	70,000	138,000	157,000	171,000	171,000	176,200

Fig. 3 Trends in the Production of Biodiesel and Bioethanol in Austria

Vegetable Oil and Biogas in Austria

In 2013, the total quantity of vegetable oil (which is also used in agricultural machinery) used in Austria was 17,842 tons. The amount of vegetable oil produced in Austria was 17,050 tons. In Austria, biogas produced from biomass is used almost entirely to generate electricity and heat. At the end of 2014, there were a total of 373 biogas plants with a maximum capacity of 109 MW Austria. Currently, 7 biogas plants supply purified biogas directly into the natural gas grid. This enables the produced biogas to be transported over long distances. According to experts, the sum of biogas produced in Austria annually amounted to about 380,000 tons.

Fleet Distribution and Number of Vehicles in Austria

As of December 31, 2014, a total of 7,194,362 vehicles (including 4,694,732 passenger cars) were registered in Austria (Table 1). According to Statistics Austria, 395,637 new motor vehicles were registered in Austria in

January–December 2014. Passenger cars accounted for 303,318 of them; this number represents a decrease of 4.7% from 2013. The number of bivalent (gasoline/compressed natural gas [CNG]) passenger vehicles especially increased; in 2014, the number increased 194% over that in 2013.

Table 1 Fleet Distribution of Passenger Cars by Drivetrain in Austria

Drivetrain	2011	2012	2013	2014
Gasoline	1,997,066[a]	1,994,839	1,997,302	2,011,050
Diesel	2,506,511	2,570,124	2,621,133	2,662,933
Electric	989	1,389	2,070	3,386
LPG (liquefied petroleum gas)	No data	1	1	1
CNG	1,572	1,826	2,219	2,397
H_2 (hydrogen)	0	0	0	3
Bivalent gasoline/ ethanol (E85)	No data	6,456	6,397	6,380
Bivalent gasoline/LPG	125	184	250	276
Bivalent gasoline/CNG	1,098	1,283	1,432	1,864
Hybrid gasoline/electric	6,056	7,762	10,049	12,231
Hybrid diesel/electric	4	338	455	591
Total	4,513,421	4,584,202	4,641,308	4,694,732

[a] Includes gasoline/ethanol (E85).

Source: Statistik Austria, KFZ Bestand from end of 2011 through December 31, 2014.

Development of Filling Stations

By the end of 2013, Austria had a total of 2,640 petroleum fuel stations. In Europe, Austria ranks in the middle in terms of number of users per station (at about 3,200 users); Greece is at the high end, and Romania is at the low end. Austria is one of the cheapest countries in Europe with regard to the price of diesel and gas fuels. December 2014 was the cheapest month for refilling a conventional car since December 2010. As an annual average, in Austria, the price of Eurosuper at the petrol station is €1.294/L; in other EU countries, it is €1.42. For diesel, the price is €1.252/L in Austria and €1.35/L elsewhere in the EU. At the end of December 2014, the cheapest price for Eurosuper was €0.99/L.

Table 2 shows the number of filling stations in Austria. The number of natural gas filling stations has increased in recent years. Today, there are about 178 public filling stations in Austria that have CNG dispensers; they are exclusively private ones. In Europe, Austria is currently the champion in terms of the number of CNG filling stations per size of the country; it offers the best CNG coverage in Europe. In the current expansion phase, an increase to 220 CNG filling station is foreseen.

Table 2 Filling Stations for Alternative Fuels and Conventional Gas Stations in Austria

Filling Station	2012	2013	2014
CNG (public)	146	175	179
LPG	32	36	38
Biogas	1	3	3
E85	28	33	33
Electric vehicle (public charging station, Level 2 AC)	1,060	1,160	1,449 (total 3,400)
Hydrogen (public station)	1	1	1
Vegetable oil	19	20	20
Conventional (public)	2,575	2,515	2,640

Source: Fachverband der Mineralölindustrie, Mineralölbericht 2014

Policies and Legislation

An increase in the mineral oil tax has applied since the beginning of 2011. It is €0.04/L for gasoline and €0.05/L for diesel. As compensation for drivers, the commuting allowance was increased by 10%. In Austria, pure biofuel is exempted from tax.

Since December 2010, the tax rates have been as follows for 1,000 L of fuel:

- For gasoline containing a minimum of 46 L of biofuel and a maximum of 10 mg/kg of sulphur, the tax is €482 ($656.2 US); the tax is €515 ($701.11 US) for gasoline without this.
- For diesel containing a minimum of 66 L of biofuel and a maximum of 10 mg/kg of sulfur, the cost is €397 ($540.4 US), the tax is €425 ($578.5 US) for diesel without this.

Starting in July 2008, the Normverbrauchsabgabe (NoVA) — a uniquely bonus/malus system for emissions of CO_2 and nitrogen oxides (NO_x) as well as particle filter — was introduced for taxing the acquisition of new vehicles. As of March 2014, the calculation of the NoVA has been in accordance with the CO_2 emissions of the car. 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 five and gives the NoVA tax rate. Thus, a car that emits 120 g of CO_2 would be taxed at a rate of 6% (120 – 90 = 30; 30/5 = 6). For vehicles with CO_2 emissions above 250 g/km, the NoVA increased by €20/g of CO_2.

Until the end of 2015, vehicles that run on an environmentally friendly motor (hybrids, those using fuels E85, CNG, LNG, LPG, or H_2) receive a tax reduction of €600 ($780.7 US). Further, many insurance companies provide a discount of 10–20% for EVs.

Federal Funds and Supporting Programs

Since 2007, the Austrian government has more than tripled public funding in the energy RD&D sectors, adopted a new energy research strategy, and launched several priority programs. In 2013, Austria's public expenditures for energy-related R&D amounted to €124,545,848. About 75% of this amount was provided by governmental authorities; the remaining 25% came from (publicly funded) research institutions, and universities provided in equity capital.

The subcategories with the highest expenditures in 2013 (shown in millions of euros) were as follows: (a) efficient residential and commercial buildings (about €16), (b) electricity transmission and distribution (€14.8), (c) photovoltaics (€1.1), (d) energy efficiency in industry (€0.6), (e) communities and smart cities (€10), (f) bioenergy (€8.4), (g) hybrid and electric vehicles (€7.6), (h) energy storage (€4.8), (i) hydropower (€4.3) and (j) the production and storage of hydrogen (€3.5). About 65% of the amount was used for applied research, and 18% was used for experimental development.

With €8.4 million in 2013, bioenergy expenditures experienced a particularly significant decline, especially funding by the federal ministries (see Figure 4). The still relatively high proportion not (detailed) attributable to activities came from the competence center Bioenergy 2020+.

Austria has some programs that fund and support the implementation of advanced fuels. One launched in 2004 called "Klima:akiv Mobil" is Austria's action program for mobility management. It was designed to reduce CO_2 emissions; promote environmentally friendly and energy-efficient mobility; and stimulate new, innovative business opportunities and green jobs. In general, the program has been providing funding, motivation, education, certification, and lessons learned. Between 2007 and 2012, more than 2,900 project partners were able to reduce about 530,000 tons of CO_2 equivalent emissions per year through their projects.

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

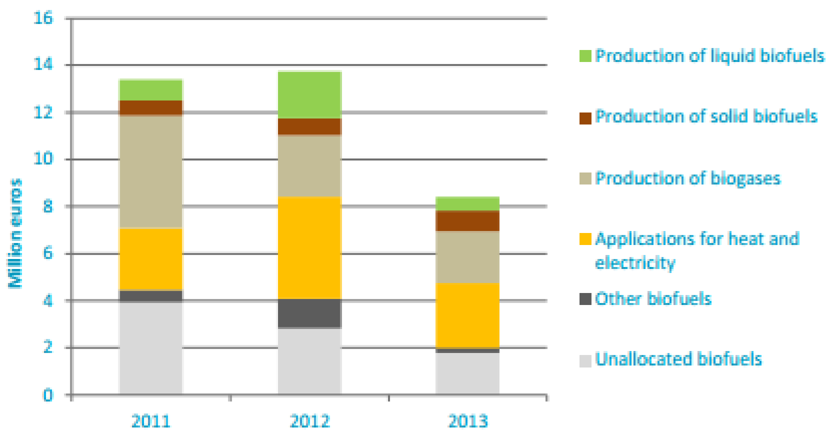


Fig. 4 Trends in Public Expenditures on Energy Research in Bioenergy in Austria in 2011–2013

(Source: bmvit 2014; see http://www.nachhaltigwirtschaften.at/iea/results.html/id7664)

"Mobility of the Future," Austria's national transportation research funding program (2012–2020), was developed and adopted by the Federal Ministry of Transport, Innovation, and Technology (abbreviated bmvit). It includes four complementary areas in which different research themes are addressed: passenger transport; transport infrastructure; vehicle technologies and freight transport. The annual budget amounts for around €15 million.

In 2014, a lot of R&D took place in Austria. Here are some excerpts about ongoing R&D:

- *Fischer-Tropsch (FT) project to produce biofuels from biomass.* In Austria, a realistic concept for producing FT biofuels from biomass at about 200,000 tons per year was developed. The effort included a comprehensive evaluation of the concept with regard to available biomass resources and to economic and ecological benefits. Thus, the work provided a profound basis for both industries and funding agencies to make decisions regarding the future potential of this technology. (Source: http://www.energiesystemederzukunft.at/results.html/id4954)

- *Project to produce biofuel from algae.* This project was initiated in 2008; the goal was to determine which algae species is the most efficient. A type of algae was identified, and its suitability for industrial production was demonstrated in a feasibility study. The project also aims to evaluate the optimal conditions for production.
- *BISUNFUE project to investigate the use of sweet sorghum to produce ethanol and biogas.* Sweet sorghum, a rather new crop used in Austrian agriculture, can be used for the combined production of ethanol and biomethane. This research project investigates the sustainable use of sweet sorghum as a feedstock for biofuels. (Source: http://www.joanneum.at/uploads/media/Poster_GHG_reduction.pdf)
- *bioCRACK project to use a pilot plant to convert wood chips directly into diesel fuel.* The pilot plant produces diesel to meet the growing demand for this fuel, while simultaneously increasing the biogenic share. The test phase was completed in September 2014. Ongoing steps are (1) doing the engineering for the upscale of the pilot plant to a demonstration plant and (2) elaborating on the plant's GHG-saving potential by continuing the research project "bioBOOST:HDO" for producing bioCRACK pyrolysis oil in cooperation with the Technical University of Graz. (Source: http://www.bdi-bioenergy.com)

European providers of technology for biofuels have been receiving an increasing number of orders related to the construction of biofuel facilities. Austrian companies working in that field include these five.

(1) Bio Energy International AG (BDI) has received several orders for biodiesel plants.
(2) Vogelbusch delivers distillation technology for ethanol plants (Inbicon).
(3) Repotec provides plants for gasification (GoBiGas).
(4) Andritz supplies treatment plants for the digestion of cellulose (POET, Biochemtex, etc.).
(5) Ecoduna offers a technology for algae cultivation.

It is clear that Austria is quite involved in developing and implementing the use of advanced biofuels. The implementation of biofuels has made a particularly huge step forward.

Implementation: The Use of Advanced Motor Fuels

Two of the main aims of Austrian energy policy have been to reduce its dependence on energy imports and to strengthen the security of its supply. Import dependence had been reduced slightly, from 65% in 2000 to 62% in 2012, largely due to increases in the supply of bioenergy.

Bioenergy and waste now provide around 20% of the total prime energy supply, an exceptionally high share compared to others internationally. Austria, with the large extent of its hydropower resources and its large reservoir of pumped storage plants, could play an energy storage role for the wider region. In 2013, alternative fuels used in the transportation sector represented a share of about 8.35% (7.2% in 2012) of the fuel used, as shown in Figure 5. The predominant fuel consumed was diesel blended with 7.0 vol% biodiesel, followed by gasoline with at least 4.60 vol% bioethanol. The number of registered vehicles with alternative drive trains increased in 2013. As shown in Table 4, the number of alternative fuel stations is still increasing, with CNG and electrical charging stations being notable.

Outlook

Austria has more than tripled public funding for energy R&D and demonstration since 2007, and the government is still trying to increase that funding as well. As Austria aims to enhance its domestic energy security, the IEA says that it should also increase its energy efficiency and produce more natural gas domestically. In the report *Energy Policies of IEA Countries: Austria 2014 Review,* the IEA encourages Austria to start shale gas exploration activities to increase its energy security and reduce its dependence on Russian imports. The introduction of a law in Austria now obliges companies to have a detailed environmental inspection before each planned project, but this raises costs. The Austrian energy group OMV has abandoned plans to produce shale gas in Austria because addressing all the environmental concerns related to fracking makes it not viable economically.

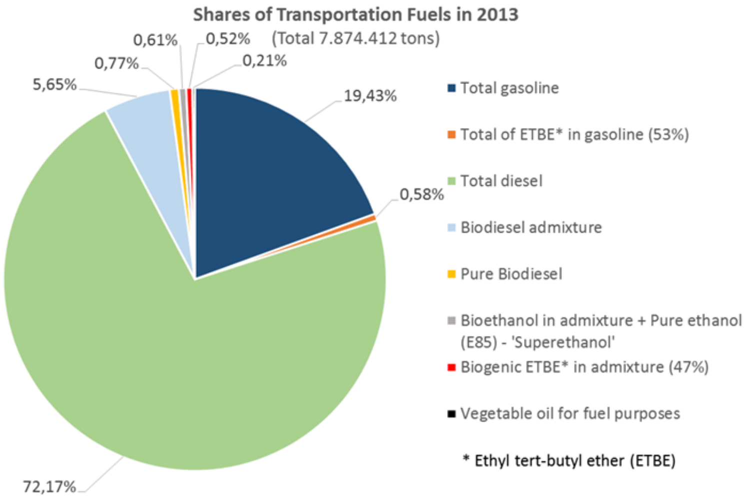


Fig. 5 Shares of Transportation Fuels in Austria in 2013
(Source: Lebensministerium 2014)

It can be seen, however, that there is a trend toward advanced propulsion systems in Austria (Figure 6). The number of new registered passenger vehicles with an alternative drive train increased in the last few years.
In 2014, the total amount of such passenger vehicles was about 20,749. The majority of these vehicles were flex-fuel vehicles (powered by gasoline or ethanol [E85]) and hybrid vehicles (with gasoline engines and electric motors). Because of the strong progress in the electrification of drivetrains, it is foreseeable that the amount of hybrid vehicles will greatly increase in the next few years. The number of registered electric cars began to rise in the last few years, but it is still at a low level. It could be that the desired number of 200,000 e-cars in the year 2020 is not realistic anymore. It is still possible, however, that the proportion of e-vehicles and hybrid vehicles will strongly increase as a result of the progressive electrification of drivetrains in both the short term and medium term. In addition to blending bioethanol and biodiesel into fossil fuels, Austria tries to force the use of pure biodiesel B100, bioethanol (E85 or "superethanol"), or vegetable oil, and it promotes a significant increase in the use of biogas; the goal is to reach a total of 200,000 cars powered by a bio-CNG by 2020.According to Austria's National Energy Strategy, the most effective measure will be the introduction of E10 and B10 after the corresponding European Standards for these fuels are approved. In 2013, using biofuels achieved a savings of about 1.7 million tons of CO_2 equivalent.

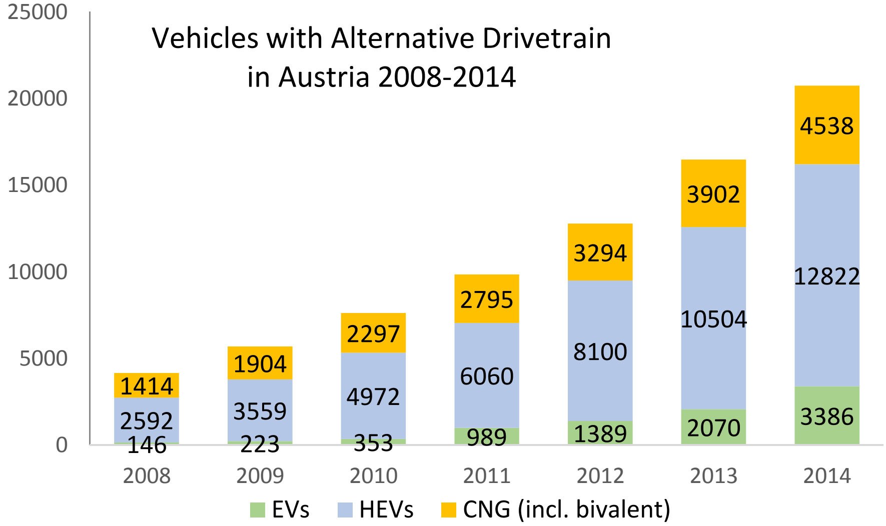


Fig. 6 Trends in Vehicles with Alternative Drivetrains in Austria in 2008–2014

Additional References

Relevant institutions and programs:

- Klima:Aktiv Initiative, www.klimaaktiv.at
- Statistic Austria, www.statistik.at

Benefits of Participation in the AMF IA
Austria benefits in a number of ways from its participation. Membership offers great opportunities with regard to making international contacts and exchanging knowledge, information, and results that can support domestic authorities. Participating in this IA gives Austria wider and easier access to information and analyses. Thus, it helps to raise awareness on advanced motor fuel issues and areas that need for further development.

Canada

Introduction

Canada has a vast and diversified portfolio of energy resources. Taking advantage of this endowment, Canada produces large quantities of energy for both domestic consumption and export. It is also an energy-intensive country, given its northern climate, vast territory, industrial base, and high standard of living.

Production of crude oil in Canada totalled 167.4 million cubic meters (m^3) in 2010. Oil sands accounted for 51.9% of production, exceeding conventional sources for the first time. About two thirds of crude oil production is exported, while the balance is processed by Canadian refineries into refined petroleum products, such as gasoline, diesel, and heating oil. Canadian refineries — especially those far from major domestic production areas — also process imported crude oil purchased on the international market.

Natural gas proven reserves at the end of 2010 totalled 1,727.5 billion m^3. Of this amount, about 95% was from conventional sources, and the remainder was from unconventional sources (such as coal-bed methane and shale gas). The total potential from conventional resources is estimated to be 10.1 trillion m^3, while recent estimates suggest that the potential from unconventional resources is in the range of 10.7 to 26.8 trillion m^3. Marketable production of natural gas in Canada amounted to 144.4 billion m^3 in 2010. Close to two-thirds of this production was exported to the United States, and the balance was sold to Canadian consumers.[4]

In 2010, Canada accounted for 2% of world ethanol production (fifth-highest in the world) and 1% of world biodiesel production (Table 1). The principal agricultural feedstocks for producing ethanol (a gasoline substitute) include corn, wheat, and barley. Canada is a major world producer and exporter of these grains.[5]

4 http://www.nrcan.gc.ca/publications/statistics-facts/1239.
5 http://www.nrcan.gc.ca/energy/renewable-electricity/7295.

Table 1 Supply of and Demand for Biofuels in Canada (in millions of liters)[6]

Parameter	Ethanol (2013)	Biodiesel (2013)
Canadian production	1,706	124
Imports	1,080	546
Exports	Not available	123
Domestic use	2,786	547

A breakdown of Canada's emissions by economic sector shows the sources of Canada's greenhouse gas (GHG) emissions in 2012 (Figure 1). The emissions can be attributed to seven key areas of the economy: oil and gas (25% of total emissions), transportation (24%), electricity (12%), buildings (11%), emissions-intensive and trade-exposed industries (11%), agriculture (10%), and waste and others (7%).

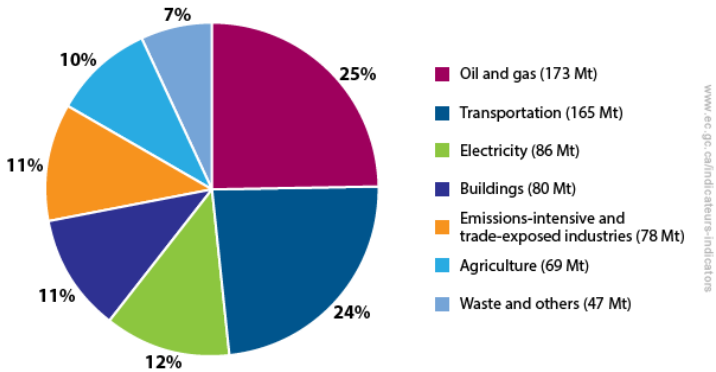


Fig. 1 Distribution of GHG Emissions by Economic Sector in Canada in 2012[7]

Canada has more than a million kilometers of (two-lane-equivalent) roads, of which roughly 38,000 km make up the National Highway System. Road transportation is the most important mode for passenger and freight transportation, local (intra-city) and intercity transportation, intra-provincial transportation activities, and trade between Canada and the United States (in terms of value transported).

6 http://www.nrcan.gc.ca/energymarketsfacts.
7 https://www.ec.gc.ca/indicateurs-indicators/default.asp?lang=en&n=F60DB708-1.

Canada's road network is shared by a wealth of different users, including 21 million light vehicles, 983,000 medium- and heavy-duty trucks, 89,000 buses, and 672,000 motorcycles and mopeds.[8,9]

Policies and Legislation

The *Renewable Fuels Regulations* (SOR/2010-189),[10] published on September 1, 2010, in the *Canada Gazette,* Part II, require fuel producers and importers to have an average renewable content of at least 5% based on the volume of gasoline that they produce or import commencing on December 15, 2010. These regulations include provisions that govern the creation of compliance units, allow trading of these units among participants, and require recordkeeping and reporting to ensure compliance.

The regulations also require fuel producers and importers of diesel fuel and heating distillate oil to have an average annual renewable fuel content equal to at least 2% of the volume of diesel fuel and heating distillate oil that they produce and import commencing on July 1, 2011. The 2013 *Regulations Amending the Renewable Fuels Regulations* (SOR/2013-187)[11] introduced a national exclusion of heating distillate oil volumes for space heating purposes as of January 1, 2013.

These regulations are one pillar of the Canadian Government's broader renewable fuels strategy. The strategy's two regulatory requirements, combined with provincial regulations (Table 2), will ensure a total volume of renewable fuel that will reduce annual GHG emissions by an estimated 4 megatonnes (i.e., 4 million metric tons or 4 Mt) by 2012; this is the equivalent of taking about 1 million vehicles off the road.[12]

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8 http://www.tc.gc.ca/eng/policy/anre-menu-3021.htm.
9 http://www.statcan.gc.ca/tables-tableaux/sum-som/l01/cst01/trade14a-eng.htm.
10 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/DetailReg.cfm?intReg=186.
11 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/DetailReg.cfm?intReg=217.
12 http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=0AA71ED2-1.

Table 2 Canadian Federal and Provincial Regulations on Biofuels[13]

Location	Percent of Renewable Fuels Content	
	Gasoline	Diesel
Canada	5	2
British Columbia	5	4
Alberta	5	2
Saskatchewan	7.5	2
Manitoba	8.5	2
Ontario	5	2 (April 1, 2014)
Quebec	5 (target only)	0

The Canadian General Standards Board (CGSB) is the responsible authority for developing fuel quality standards (including standards for renewable fuel quality; see Table 3) through a consensus process with the public and private sectors.[14]

Table 3 CGSB Renewable Fuel Quality-Related Standards[15]

Oxygenated Automotive Gasoline Containing Ethanol (E1–E10)	CAN/CGSB 3.511
Automotive Ethanol Fuel (E50–E85)	CAN/CGSB 3.512
Denatured Fuel Ethanol for Use in Automotive Spark Ignition Fuels	CAN/CGSB 3.516
Automotive Diesel Fuel Containing Low Levels of Biodiesel (B1–B5)	CAN/CGSB 3.520
Diesel Fuel Containing Biodiesel (B6–B20)	CAN/CGSB 3.522
Biodiesel (B100) for Blending in Middle Distillate Fuels	CAN/CGSB 3.524

In October 2010, the Government of Canada released the final *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* (SOR/2010-201).[16] These prescribe progressively more stringent annual emission standards for new light-duty vehicles (LDVs) of model years 2011 to 2016 (LDV1). The Government of Canada also published proposed

[13] http://www.nrcan.gc.ca/energymarketsfacts.
[14] http://www.gazette.gc.ca/rp-pr/p2/2010/2010-09-01/html/sor-dors189-eng.html.
[15] http://www.tpsgc-pwgsc.gc.ca/ongc-cgsb/index-eng.html.
[16] http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=192.

regulations in the *Canada Gazette* in 2014 for the second phase of action on light-duty vehicles (LDVs). These contain increasingly stringent GHG emission standards for LDVs of model years 2017 to 2025 (LDV2) (SOR/2014-207)[17].

Under both phases of LDV regulations, spanning model years 2011 to 2025, the fuel efficiency of new cars will increase by 41% as compared with model year 2010 (and by 50% as compared with model year 2008), and the fuel efficiency of new passenger light trucks will increase by 37%. The sales-weighted fuel efficiency of new cars is projected to improve from 8.6 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.

These improvements in efficiency are expected to help reduce emissions over the longer term. Total transportation emissions are projected to decrease by 1 Mt, from 168 Mt in 2005 to 167 Mt by 2020. This departure from historical trends is expected to continue as a result of greater fuel efficiency in vehicles being accelerated by federal vehicle emissions regulations, despite projected increases in the population and number of vehicles. Emissions are expected to further decline as the stock of existing vehicles is gradually replaced with the newer, more efficient models.

As depicted in Table 4, the transportation sector comprises several distinct subsectors: passenger, freight, air, and others (e.g., rail and marine). Each subsector exhibits different trends during the projected period. For example, emissions from passenger transportation are projected to decrease by 8 Mt between 2005 and 2020, while those from ground freight, off-road, and other vehicles are projected to grow by 10 Mt over the same period due to anticipated economic growth. As a result, net emissions will remain essentially stable over the period.

Although absolute emissions are expected to grow in the freight subsector due to expected economic growth, emissions are expected to decrease relative to business-as-usual levels as a result of various federal, provincial, and territorial programs. The regulations for heavy-duty vehicles (HDVs) will improve the average fuel efficiency of trucks from 2.3 L/100 tonne-km in 2012 to 2.2 L/100 tonne-km by 2020.[18]

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17 http://www.ec.gc.ca/lcpe-cepa/eng/regulations/DetailReg.cfm?intReg=215.

18 http://www.ec.gc.ca/ges-ghg/default.asp?lang=En&n=E0533893-1&offset=5&toc=show.

Table 1 Transportation Emissions in Canada (Mt of CO2-equivalent emissions)[18]

Transportation Subsector	2005	2012	2020	Change (2005 to 2020)
Passenger transport	96	94	88	–8
Cars, trucks, and motorcycles	87	85	78	–9
Bus, rail, and domestic aviation	9	8	9	0
Freight transport	57	61	67	10
Heavy-duty trucks, rail	49	54	59	10
Domestic aviation and marine	8	7	8	0
Other: Recreational, commercial, and residential	14	11	12	–2
Total	168	165	167	–1

Implementation: Use of Advanced Motor Fuels

The market demand for natural gas in transportation was 0.3 billion cubic feet per day (ft^3/d) in 2012.[19]

Transport Canada's ecoTECHNOLOGY for Vehicles Program (eTV) conducts in-depth safety, environmental, and performance testing on a range of new and emerging advanced vehicle technologies for passenger cars and heavy-duty trucks.

The Government of Canada has committed to developing increasingly stringent GHG emission regulations for passenger cars and trucks, in alignment with the United States. In order to meet these standards, manufacturers will introduce a wide range of technology innovations to improve vehicle efficiency over the next several years.

Transport Canada's eTV Program will help ensure that Canada is ready for new and emerging advanced vehicle technologies and that Canadians can benefit from these new innovations. To achieve this, eTV is proactively testing and evaluating a range of new advanced vehicle technologies. Results are helping to inform the development of environmental and safety regulations to ensure that these technologies are introduced in Canada in a safe and timely manner.

The program also supports the Canada-U.S. Regulatory Cooperation Council. Test results will help align vehicle regulations throughout

[19] http://www.nrcan.gc.ca/energymarketsfacts.

North America, in order to reduce and prevent barriers to cross-border trade, lower costs for businesses and consumers, and support jobs and growth.[20]

Outlook

In 2011, passenger travel accounted for 54% of transportation sector energy demand, freight transport accounted for 42%, and nonindustrial off-road vehicles accounted for the remainder. It is expected that in 2020, these shares will reverse, and that by 2035, freight travel will account for 56% and passenger travel will account for 40% (Figure 2). Because gasoline is used primarily by passenger vehicles, and diesel is used primarily by freight vehicles, this shift has implications for the use of those fuels. Figure 3 shows that over the projection period, motor gasoline consumption in the transportation sector declines by 0.2% per year, while diesel consumption increases by 1.6% per year.

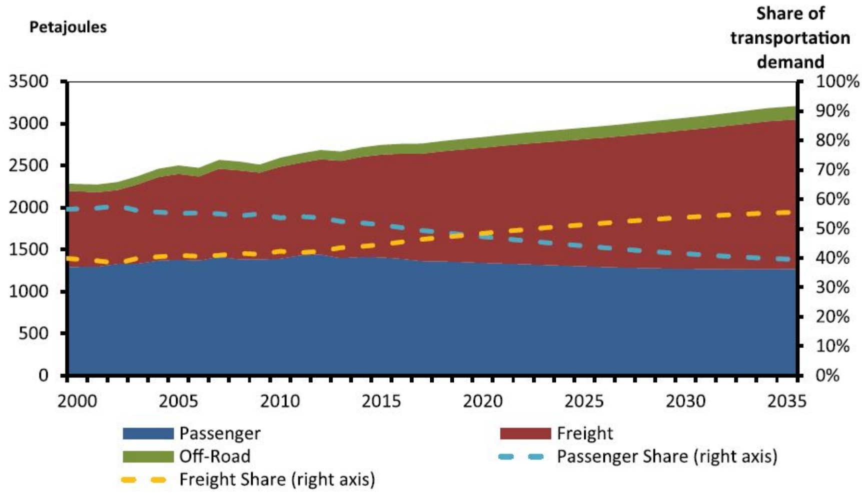

Fig. 2 Transportation Energy Demand by Travel Type: Reference Case[21]

20 http://www.tc.gc.ca/eng/programs/environment-etv-menu-eng-118.htm.
21 http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.pdf.

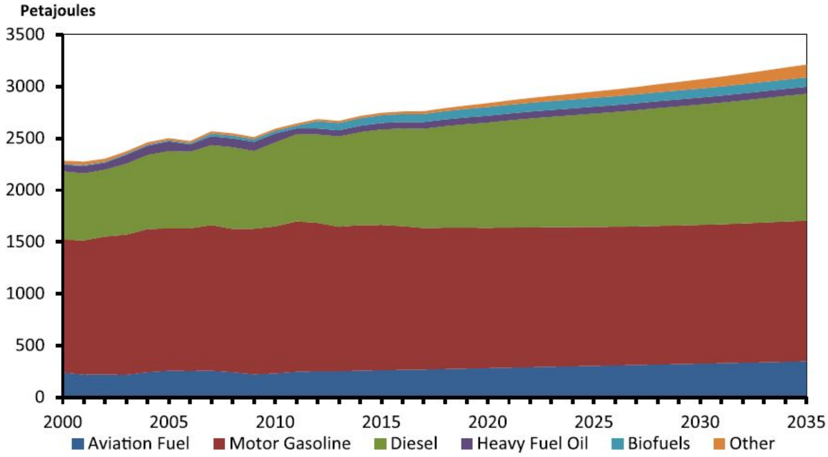

Fig. 3 Transportation Energy Demand by Fuel Type: Reference Case[21]

There is also interest in using natural gas (often liquefied natural gas or LNG) for medium- and heavy-duty trucks, particularly for operations during which the vehicles return to central locations often and use key regional transport corridors. In the reference case, freight natural gas vehicles (NGVs) will use 100 PJ or 7.4 million m^3/d (261 million ft^3/d) of natural gas in 2035, representing 6% of total freight transport fuel demand. This is equivalent to about 60,000 medium- and heavy-duty freight NGVs.[22]

Additional References

- Natural Resources Canada, Program of Energy Research and Development, Government of Canada, http://www.nrcan.gc.ca/energy/science/programs-funding/1603
- Natural Resources Canada, the ecoENERGY Innovation Initiative, http://www.nrcan.gc.ca/energy/funding/current-funding-programs/eii/4985

[22] http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.pdf.

Benefits of Participation in the AMF IA

Canada has a long history of collaborative work, both domestically and internationally. Through its 30 years of participation in the IEA AMF IA, Canada has been able to access and provide input for an unbiased source of data and recommendations recognized throughout the world, and it has been able to leverage resources by either initiating or participating in a multitude of Annexes. Participation in the AMF IA, in addition to providing opportunities for the usual cooperative interactions between member parties, also offers chances to form liaisons with top experts and institutions from host countries, such as national R&D laboratories, universities, and fuel and transportation technology industries, and to create links with representatives from nonmember countries who are invited to attend as observers to the IEA AMF IA, with a potential for future participation.

Chile

Introduction

In 2010, the Ministry of Environment was created, and Chile started implementing a national strategy to control air pollution that focused on the reduction of $PM_{2.5}$ (particulate matter with a diameter of 2.5 micrometers or less). According to a report on Chile's environmental status from 2011, more than 10 million Chileans were exposed to very high levels (more than permitted) of $PM_{2.5}$ (see http://www.oecd.org/cfe/leed/Green_growth_Chile_Final2014.pdf).

At an urban level, the transport sector is one of the main sources of pollution, which directly affects the health of citizens in urban zones. Chile is now in a state of economic growth, and the transport sector has a wide potential for growth, too. During 2010, vehicle sales reached a historic record of 300,000 units. The potential for growth in the transport sector relates to Chile's motorization rate, which, at one vehicle per 6.3 inhabitants, is low compared to the rates of other countries having a similar level of development. If Chile reached a motorization rate similar to that of countries like Portugal (which has a rate of one vehicle per 2.0 inhabitants), the size of its vehicle fleet would increase and could reach up to 8 million vehicles.

In this context, the Chilean control strategy assumes that the growth of the fleet would not have a greater impact on the environment, affecting local pollutant emissions and greenhouse gases, as well as efficiency related to fuel consumption.

Policies and Regulation: Progress in Transport Regulation

Chile's already-implemented strategy is summarized here as four strategies. Although Chile's regulations were processed between 2010 and 2014, they took effect mainly between September 2013 and September 2014.

The first strategy is a program for updating the regulations on incoming vehicles at a national level.

- Emission standards for heavy-duty vehicles (DS N°4/2012, Ministry of Environment)
- Emission standards for medium-duty vehicles (DS N°28/2012, Ministry of Environment)
- Emission standards for light-duty vehicles (DS N°29/2012, Ministry of Environment)

These standards were allowed to advance from Euro 3 to Euro 5 standards at the national level, in every vehicle category, for the year 2014, except for motorcycles, which was reviewed to establish Euro 3 standards.

The second strategy is a program for reducing the sulfur content in fuels. Regulations to adjust the maximum level of sulfur in diesel and gasoline fuels were coordinated with the emission standards for new vehicles at the national level.

- Maximum sulfur level of 15 parts per million (ppm) in gasoline fuel (DS N°60/2011, Ministry of Energy)
- Maximum sulfur level of 15 ppm in diesel fuel (DS N°60/2013, Ministry of Energy)

The third strategy consists of incentives for cleaner and more efficient vehicles. In February 2013, a compulsory system for labelling the emissions and efficiency of new vehicles took effect; it is directed toward the promotion of cleaner and more efficient vehicles. This represented a pioneering effort in Latin America. It was developed by the Ministries of Environment, Transport and Telecommunications, and Energy working together.

The labelling system was established in the Regulation of Emissions and Efficiency Labelling for New Vehicles (DS N°61/2012, Ministry of Energy). More information can be found at www.consumovehicular.cl.

In May 2014, a new law regarding the “green tax” was approved; it affects new vehicles sold after December 31, 2014. The tax is calculated based on a vehicle’s efficiency and emissions of nitrogen oxides (NOx), and it complements the labelling system. This tax reform, which stipulates the green tax on emissions and vehicle efficiencies, is part of Law 20.720 (October 1, 2014).

The Ministry of Energy is developing efficiency regulations for new light-duty, medium-duty, and heavy-duty vehicles, which could be published in 2015.

The fourth strategy is to incorporate diesel particulate filters (DPFs) in public transport systems. In 2007, a modernization program for the public transport system in the metropolitan region started. This program considered (1) integrating the underground transport system with the public transport system, (2) new routes, and (3) a process for technology change in order to reduce emissions. The technology change process consisted of progressively removing vehicles without emissions certificate approval from the market and incorporating the use of buses with DPFs. In 2014, up to 50% of the fleet, or more than 3,000 buses, had DPFs.

Use of Advanced Motor Fuels

Electric Mobility in Santiago

Chile is making a great effort to introduce electric mobility in Santiago. The country is expecting to use new and advanced technologies to reduce air pollution. These changes could be observed, for example, in the taxi fleet in the next years.

Electric Taxis in Santiago

In 2014, the Ministry of Transport and Telecommunications started a new process of tender (process by which the government invites bids for large projects that must be submitted within a finite deadline) for taxis (basic taxis and executive taxis). This process involved 250 new basic taxis and 250 executive taxis, in which 50 of each were exclusively electric vehicles. In total, 68 electric taxis were assigned in this tender. As Figure 1 shows, the new taxis will be painted green and white (these colors are different from the colors used for regular taxis) (Figure 1).

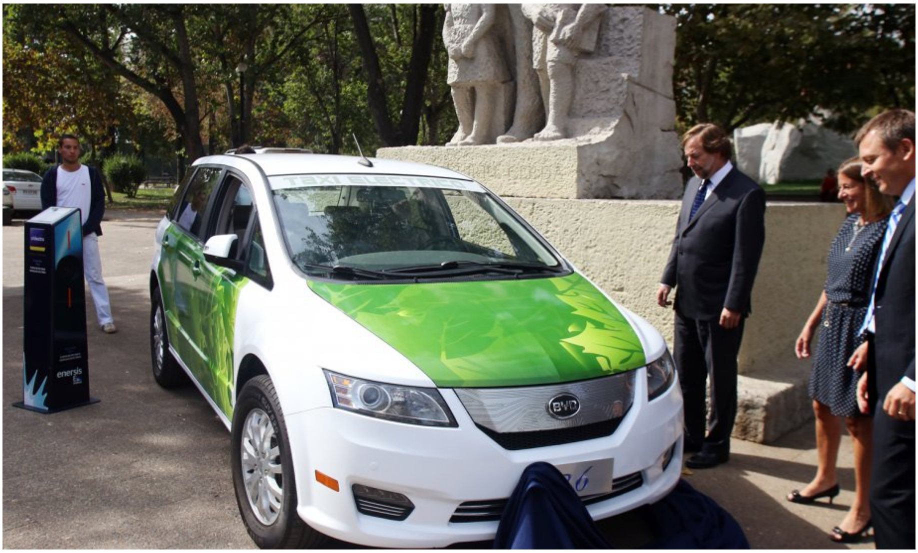

Fig. 1 New Design for Electric Taxis in Santiago, Chile

To ease the introduction of electric mobility in Santiago, there are currently about 20 public charger points in the city. In addition, some other projects directed toward this change to electric mobility are now running in Santiago.

Pilot Project with BYD Company Ltd. Electric Buses
In 2013/2014, Endesa Chile (Chilectra), working together with Mayor University, presented the first electric bus to be used in Santiago: the BYD model K9 electric bus (Figure 2). The pilot project was executed to introduce electric mobility in public transport and prove that it would bring social and environmental benefits to the city, such as reducing pollution there.

In addition, as a part of the pilot project, the energy consumption, efficiency, and costs of this bus were measured, as were driving conditions, the number of passengers, and the speed of travel.

This bus, 100% electric, was part of the Smartcity Santiago project (www.smartcitysantiago.cl). Santiago was the first "intelligent city" of Chile, and implementing this project saved 4 tons of carbon dioxide emissions in about one month, contributing to the decontamination of the city and saving almost 75% of the amount of fuel used compared with the amount used by traditional buses.

Fig. 2 Pilot Project in Santiago, Chile: BYD Electric Bus

Outlook

Defining a Roadmap to Introduce Electric Mobility in Santiago's Public Transport System
Last year, Mario Molina Center, together with Chilectra, worked on a project called "Vision of More Sustainable Public Transport for Santiago." This project is expected to introduce electric mobility in public transport. About 30% of the bus fleet could be replaced with trolley buses and battery electric buses by 2020. Under this new scenario, particulate matter (PM) emissions in Santiago's city center would be 35% lower relative to those under the diesel Euro V scenario, and NO_x emissions would be reduced by 33% by 2020. This initiative will facilitate the implementation of environmental zones in some areas of Santiago.

Introducing Advanced Shared Taxis in Santiago
Mario Molina Center worked together with the Ministry of Transport and Telecommunications on a project, supported by the British Government, to define the procedures and conditions for new subsidies to improve the public transport fleet. The Chilean Government will provide incentives to taxi owners to purchase more efficient vehicles based on the information from the new fuel economy labelling that has been mandatory in Chile since February 2013, including incentives for electric vehicles.

China

Introduction

From January to November in 2014, 247 million tons of petroleum products (including diesel and gasoline fuels) were consumed in China — an increase of 2.6% year-on-year. In 2013, total diesel and gasoline fuel consumption in China amounted to 264 million tons. Of this, 186 million tons of fuel were consumed by vehicles, as shown in Figure 1. Fuel consumption by road transportation vehicles is the main source of total Chinese gasoline and diesel consumption.

Natural gas (NG) is another main energy source for vehicles in China. From January to November in 2014, NG consumption reached 159.2 billion cubic meters (m^3) — an increase of 7.4% from 2013.

Before November 2014, China's auto production and sales were 21.4 million vehicles and 21.1 million vehicles, respectively, with a year-on-year growth of 7.2% for production and 6.1% for sales.

Compressed natural gas (CNG) stations have spread over more than 200 cities across the country's 31 provinces. In 2013, there were 446 new liquefied petroleum gas (LPG) stations, and the total number of stations was 2,784 — an increase of 19% over the previous year. Liquefied natural gas (LNG) stations accounted for 22.8% of the total stations. In 2013, there were 0.473 million new NG cars, while total ownership reached 1.577 million cars — an increase of 40% over the previous year. More than 71,000 new NG cars were LNG vehicles. About 12.6 billion m^3 of NG was consumed as NG vehicle fuel, while the production value was about 47 billion RMB (renminbi).

By the end of 2013, cumulative sales of M15 methanol gasoline in Shanxi Province amounted to 2.8 million tons. Also, about 300,000 tons of gasoline with a high proportion of methanol (M85–M100) was consumed. The number of fill-ups was more than 100 million. The number of vehicles refited for the use of high-methanol blends in Shanxi Province was more than 130,000; of these, the one with the "highest mileage" (i.e., the longest driving distance) had gone more than 400,000 km. The number of filling stations with gasoline with a low proportion of methanol in Shanxi Province was more than 1,200. The number of stations with gasoline with a high proportion of methanol (M85 and M100) was approximately 39.

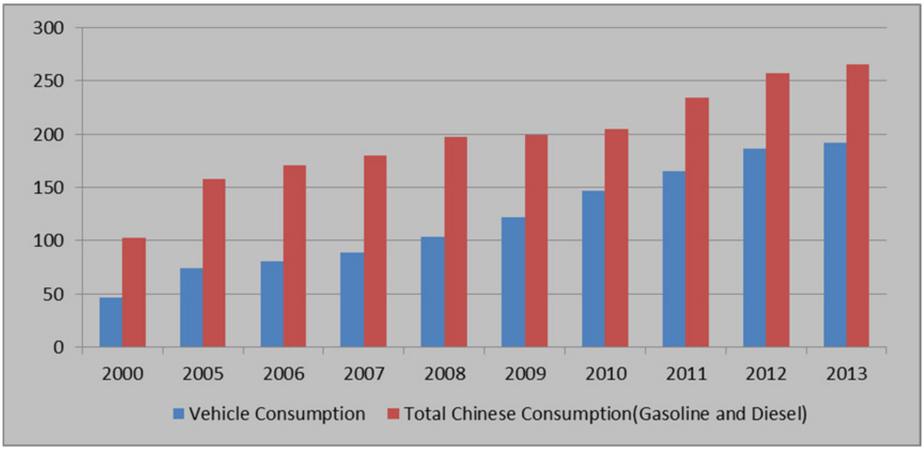

Fig. 1 Fuel Consumption in China (million tons)

Policies and Legislation

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 its 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 an 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.

Technical Route

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

Main Objectives

- *Significantly advance industrialization.* By 2015, the cumulative production and sales of pure electric vehicle and plug-in hybrid vehicles must be up to 500,000 vehicles. By 2020, the production capacity for pure electric and plug-in hybrid vehicles must be up to 2 million, and cumulative production and sales must be more than 5 million cars. The development of fuel cell vehicles and the hydrogen vehicle industry in China must be done in cooperation with the international community.
- *Significantly improve fuel economy.* By 2015, the average fuel consumption of current passenger vehicles must be reduced to 6.9 L/100 km, and that of energy-saving passenger vehicles must be reduced to 5.9 L/100 km or less. By 2020, the average fuel consumption of current passenger vehicles must be reduced to 5.0 L/100 km, and that of energy-saving passenger vehicles must be reduced to 4.5 L/100 km or less. The fuel consumption capacity of commercial vehicles must be comparable to the advanced level around the world.
- *Substantially increase the level of technology.* Alternative energy vehicles, power batteries, and key components must achieve the technologically advanced level recognized around the world. Together, the energy savings associated with using gas hybrids, advanced internal combustion engines, efficient transmissions, automotive electronics, lightweight materials, and other key core technologies are expected to be leveraged to form a group of energy-saving and alternative-energy vehicle enterprises that are more competitive.
- *Significantly enhance the ability to support technology.* Both the technology levels and production scales of key components must meet China's basic market demands. The construction of charging facilities must meet the requirements of alternative-energy vehicles and their operation in key regions and within cities.
- *Significantly optimize the management system.* China plans to (a) establish an effective management system associated with energy-saving and alternative-vehicle companies and products; (b) build a marketing, after-sales service and battery recycling system; and (c) improve support policies to form a relatively complete system of technical standards and management practices.

Main Tasks

- *Implement a technical innovation project to create energy-saving and alternative-energy vehicles.* Enhancing the capability for technical innovation is central to cultivating and developing the energy-saving and alternative-energy vehicle industry. To accomplish that objective, China will:
  - Strengthen the industry position as it relates to technological innovation.
  - Concentrate innovative elements toward preponderant enterprises.
  - Improve the technological innovation system to define market orientation, in combination with production and research.
  - Through the national science and technology plan, special projects, and other channels, increase support for key, breakthrough core technologies and enhance industrial competitiveness.
- *Increase technical research and development (R&D) on energy-saving vehicles.* China plans to significantly improve vehicle fuel economy and actively promote the integration and innovation of vehicle energy-saving technology, as well as its introduction, absorption, and secondary innovation. In addition, China will:
  - Focus on the development of hybrid technology research, develop special hybrid engine and electromechanical coupling devices, and support R&D on efficient internal combustion technology and advanced electronic control technology, including diesel high-pressure common-rail, direct injection, homogeneous combustion, and turbo-charging engines.
  - Support the development of six-gear and more mechanical transmissions, dual-clutch automatic transmissions, and automatic control mechanical transmissions for commercial vehicles.
  - Create breakthrough low-resistance components, lightweight materials, and laser welding molding technology.
  - Substantially increase the technology level of small-displacement engines.
  - Effectively carry out technical research on polluting emissions, such as nitrogen oxides.
- *Accelerate the establishment of an R&D system for energy-saving and alternative-energy vehicles.* China will guide industry to increase its R&D investment in energy-saving and alternative-energy vehicles, encourage the establishment of cross-industry technology development of energy-saving and alternative-energy vehicles, and accelerate the construction of common technology platforms. In addition, China will:
  - Focus on the R&D of key core technology for pure electric passenger vehicles, plug-in hybrid passenger vehicles, hybrid commercial vehicles, and fuel cell vehicles.

- Establish a (a) shared test platform of related industries, (b) product development database, and (c) patent database to enable resource sharing, and integrate existing science and technology resources.
- Construct several national research and test bases for vehicles and components.
- Build a sound foundation platform for technological innovation.
- Construct several international advanced engineering platforms.
- Develop a number of industrial technology innovation alliances led by industry, with active participation by research institutions and universities.
- Encourage industry to implement trademark and brand strategies.
- Strengthen intellectual property right creation, utilization, protection, and management.
- Build the patent system for the whole industry chain and improve industrial competitiveness.

Existing National Standards on Alternative Motor Fuels

- GB/T 23510-2009, “Fuel methanol for motor vehicles” was released on April 8, 2009, and implemented on November 1, 2009.
- GB/T 23799-2009, “Methanol gasoline (M85) for motor vehicles” was released on May 18, 2009, and implemented on December 1, 2009.
- GB 18047-2000, “Compressed natural gas as vehicle fuel” was released on April 3, 2000, and implemented on July 1, 2000. This standard specified the technical requirements for compressed natural gas and the test method.
- GB 18350-2001, “Denatured fuel ethanol,” and GB 18351-2001, “Ethanol gasoline for motor vehicles,” were released on April 2, 2001, and implemented on April 15, 2001.
- GB 18351-2013, “Ethanol gasoline for motor vehicles (E10),” and GB/T 22030-2013, “Blendstocks of ethanol gasoline for motor vehicles,” were released on October 10, 2013, and implemented on January 1, 2014.
- GB/T 20828-2007, “Biodiesel blend stock (BD100) for diesel engine fuels,” was released in January 2007 and implemented on May 1, 2014.
- GB/T 25199-2010, “Biodiesel fuel blend (B5),” was released on September 26, 2010, and implemented on February 1, 2011.
- GB/T 25199-2014, “Biodiesel fuel blend (B5),” and GB 20828-2014, “Biodiesel blend stock (BD100) for diesel engine fuels,” were released on February 19, 2014, and implemented on June 1, 2014.

Implementation: Use of Advanced Motor Fuels

Promotion of Methanol Gasoline Vehicles Pilot Project
By the end of February 2012, the Ministry of Industry and Information Technology announced that three pilot projects involving methanol vehicles were launched in Shanxi, Shanghai, and Shaanxi Provinces. This indicated that methanol gasoline had entered a new era of development. By the end of 2013, 26 provinces had entered the field, to different degrees, where five provincial governments had organized and implemented the pilot projects.

Shanghai is one of the cities that is carrying out the methanol vehicle pilot project required by the Ministry. As part of that project, a taxi test has been underway for 36 months. The cumulative quantity of methanol gasoline used for refuelling has risen to 1,551,200 L. The cumulative distance traveled by these vehicles to date is 9,695,300 km, 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, PetroChina, 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 “two provinces and one city”: (Jinzhong, Changzhi, Xi’an, Baoji, Xianyang, Yulin, Hanzhong, and Shanghai).

Air Purification Project — Clean Vehicle Action
In early 1999, the Ministry of Science and Technology and the Ministry of Environmental Protection jointly established the National Clean Vehicle Action Commission and carried out the “Air Purification Project — Clean Vehicle Action.” The project’s aim was to promote NG vehicles and accelerate the construction of an NG vehicle filling station infrastructure. The project encouraged the development of NG, increased its use in the primary energy structure, and clearly defined NG vehicles as a “first class” gas project. A total of 450 NG vehicle models (including chassis) were listed in the national motor vehicle announcement. The annual number of sales reached 60,000, including buses, passenger cars, trucks, special municipal cars, and others. The number of alternative fuel vehicles in the top 10 demonstration cities are shown in Table 1.

Table 1 Number of Alternative Fuel Vehicles in Top 10 Demonstration Cities in China

City	Vehicle Fuel Type				Subtotal
	LPG	LNG	CNG	Alcohol	
Sichuan	180	1,048	349,500	0	350,728
Shanghai	281,800	50	3,340	0	285,190
Urumqi	0	0	156,941	0	156,941
Chongqing	0	100	97,177	0	97,277
Shandong	0	4,582	55,223	0	59,805
Shanxi	0	0	0	50,936	50,936
Yinchuan	0	0	41,350	0	41,350
Guangzhou	26,018	421	0	0	26,439
Xi'an	0	0	22,623	0	22,623
Shijiazhuang	0	0	20,410	0	20,410
Subtotal in top 10 demonstration cities	307,998	6,201	746,564	50,936	1,111,699
Total in China	316,549	15,516	876,612	51,036	1,259,713

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 cumulative production of pure electric vehicles and plug-in hybrid vehicles will reach 500,000; by 2020, the capacity will reach 2 million, and the cumulative production and sales of vehicles 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 distribution of the slow-charging mode at private and public parking stands.

According to the biomass energy section of *12th Five-Year Development Plan (2011–2015) for Renewable Energy,* the power-generation capacity of biomass will reach 13 million and 30 million kW by the end of 2015 and 2020 respectively, thereby increasing the capacity 1.36 fold and 4.45 fold from 5.5 million kW at the end of 2010. By the end of the *12th Five Year* period, agriculture and forestry biomass power generation will reach 800 million kW, methane power generation will reach 200 million kW, and waste-incineration power generation will reach 300 million kW. During the *12th Five-Year* period, the use of biomass molding fuel, biomass ethanol, biodiesel, and aviation biofuel will reach 10 million tons, 3.5–4 million tons, 1 million tons, and 100,000 tons, respectively.

According to the study of the China Industrial Gases Industry Association, China will usher in the golden age of NG vehicle development over the next 10 years. According to the national plan, by 2020, China's NG 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 NG vehicles will reach 10.5 million, which means the position of the NG as the number one alternative vehicle fuel will be unshakable.

Plans are that by 2015, the use of methanol gasoline will be up to 3 million tons, and the number of refitted vehicles will reach 200,000 and new methanol load vehicles will reach 50,000.

Additional References

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- China EV Corporation, http://www.chinaev.org/
- *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[23]

Introduction

Energy Strategy 2050 represents a huge step toward realizing the Danish government's vision of becoming independent of coal, oil, and gas. Figures 1–4 present data on energy consumption for various transportation applications in Denmark between 1990 and 2012. 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. This strategy is the first of its kind in Denmark and in the rest of the world. The strategy outlines the energy policy instruments to transform Denmark into a green sustainable society with a stable energy supply. The strategy is fully financed and takes full account of Danish competitiveness. In March 2012, a historic new Energy Agreement was reached in Denmark. The Agreement contains a wide range of ambitious initiatives, bringing Denmark a step closer to the target of 100% renewable energy in the energy and transportation sectors by 2050.

In many ways, Denmark has started the green transition well. The Agreement calls for achieving goals more rapidly, with large investments expected in energy efficiency, renewable energy, and the energy system by 2020. In 2020, we expect approximately 50% of electricity consumption to be supplied by wind power and more than 35% of final energy consumption to be supplied from renewable energy sources.

No energy agreement has ever been reached by a larger and broader majority in the Danish Parliament than this one, and no Danish energy agreement has previously covered such a long time horizon. In other words, a solid framework has been established to enable a huge private and public investment to be made in the years to come.

[23] The information in this section on Denmark was not updated. It was taken directly from the 2013 *IEA-Advanced Motor Fuels Annual Report*.

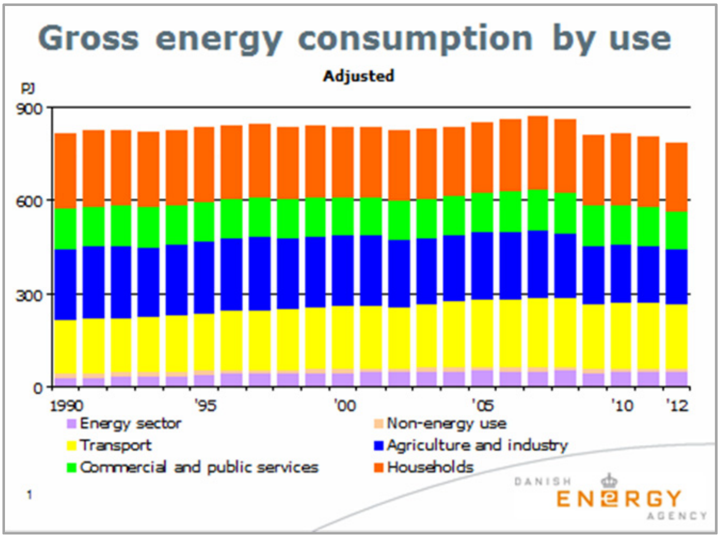

Fig. 1 Gross Energy Consumption by Use in the Period 1990–2012

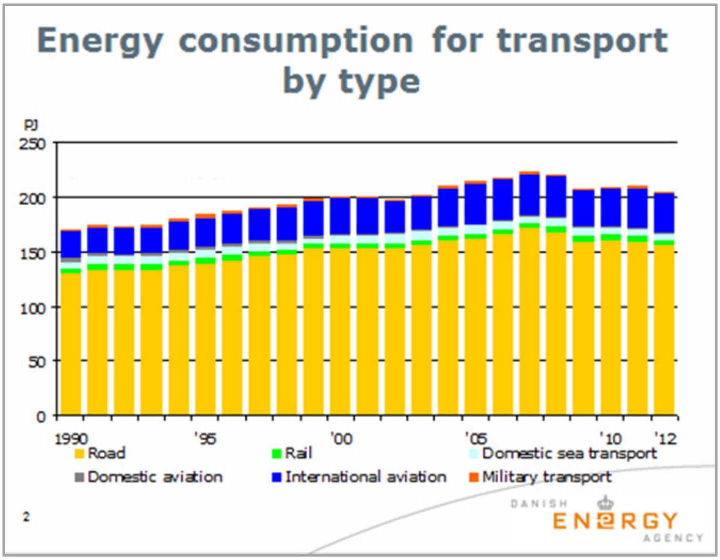

Fig. 2 Energy Consumption for Transportation by Transportation Type in the Period 1990–2012

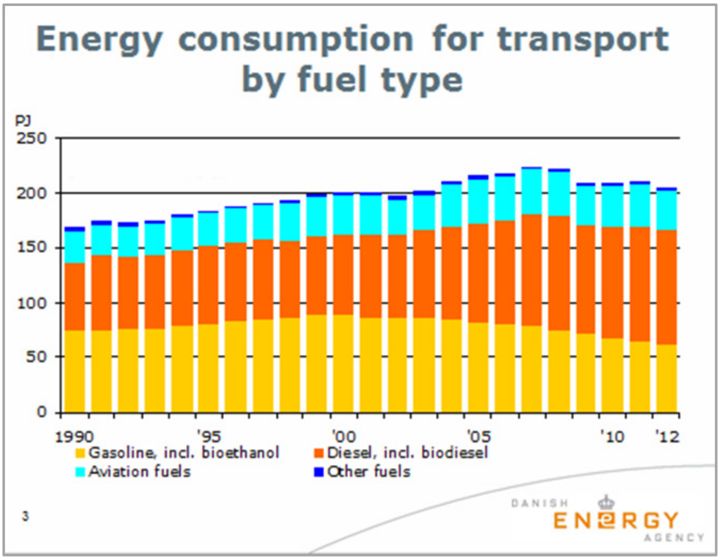

Fig. 3 Energy Consumption for Transportation by Fuel Type in the Period 1990–2012

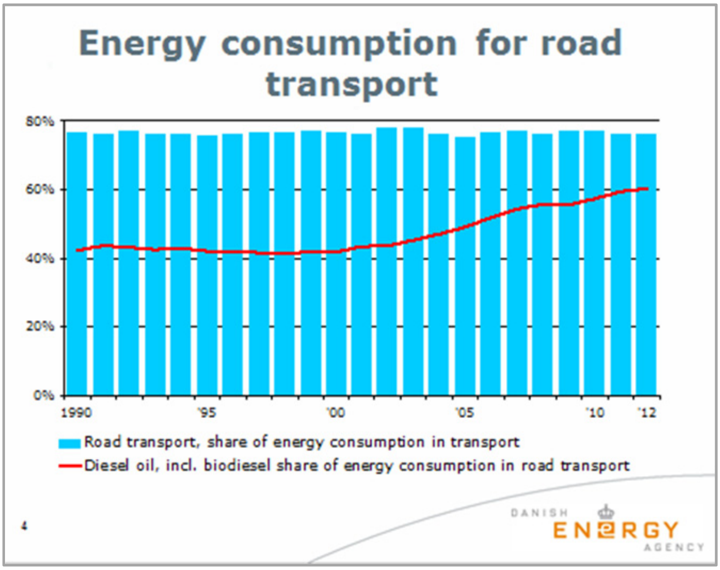

Fig. 4 Energy Consumption for Road Transportation in the Period 1990–2012

Policies and Legislation

Climate Policy

Denmark has committed to meeting an ambitious and binding target for reducing greenhouse gases by 2020. This target is the most ambitious in the European Union (EU): by 020, Denmark must have reduced greenhouse gas emissions from Danish non-ETS (Emissions Trading System) sectors by 20% relative to 2005.

Denmark's international commitment to a significant reduction in greenhouse gas emissions not covered by the ETS in 2013–2020 poses a special challenge. The government's climate target is to cut greenhouse gas emissions by 40% by 2020 relative to those in 1990. To reach both the total target for 2013–2020 and the target of 40%, the government presented a climate plan in 2012. The Danish government's ambitious goals underscore the need for a Danish policy that will give Denmark the highest return on climate and energy investments. A good example of such a climate and energy policy is investing in wind turbines.

Another good example is investing in the electric car. Expanding the current infrastructure to accommodate electric cars is a relatively inexpensive way to reduce CO_2 emissions from the transportation sector. The electric car would contribute to the solution of three problems in one, since it also would provide energy savings and opportunities for increasing the share of renewable energy in our energy system.

Energy Savings – The Road Forward

Energy savings and improved energy efficiency are important components of Danish energy policy and contribute to limiting energy consumption. We need significant and cost-effective energy savings within all areas. We need to use less energy in our homes, enterprises need to be made more energy efficient, and we need to focus special efforts on conserving energy in public institutions.

The initiatives agreed on in the Energy Agreement will result in a reduction of energy costs by almost 7.6% in 2020 relative to 2010.

Renewable Energy in Denmark

Along with security of supply, energy savings, and green energy growth, expanding the use of renewable energy in Denmark is at the core of Danish energy policy.

As a result of the Energy Agreement, renewable energy in Denmark is expected to represent more than 35% of final energy consumption in 2020. This is a major step toward achieving the long-term goal of establishing a green-energy growth economy with 100% renewable energy in the energy and transportation sectors.

The binding target in the EU is that, by 2020, at least 30% of final energy consumption be renewable energy in Denmark. This target is stated in the EU Climate and Energy Package for 2008. In addition, there is a binding target that 10% of total energy consumption in the transport sector be represented by renewable energy by 2020.

Security of Supply

The best strategy to ensure the long-term security of the Danish energy supply is to reduce energy consumption through energy savings, increased use of renewables, and closer collaboration among countries in Europe.

Implementation: Use of Advanced Motor Fuels

Transport

In Denmark, the transportation sector is still almost entirely dependent on oil. The government has a goal that by 2050 all Danish energy needs will be supplied 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 socio-economic aspects, energy efficiency, and environmental impact. The analysis indicates that by 2020 and beyond, electricity, biogas, and natural gas could become especially attractive 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.

Funding Priorities

The Energy Agreement includes a decision to establish a pool of DKK (Danish krone) 70 million ($13 million US) in the years 2013–2015, which will provide funding for the establishment of more recharging stations for electric cars, infrastructure for hydrogen, and facilities for gas in heavy duty vehicles. Furthermore, an overall strategy will be prepared for the promotion of energy-efficient vehicles, such as electric cars. In addition, DKK 15 million ($2.8 million US) has been earmarked for the continuation of the electric-car pilot scheme in 2013–2015. The government is also giving priority to joint efforts in the EU to promote electric cars, with focus on development and rollout of a car-recharging infrastructure.

Additional References

- Energistyrelsen, www.ens.dk.

Finland

Introduction

In 2013, the total consumption of energy in Finland amounted to 1,373 PJ (about 32.8 million metric tons or megatonnes of oil equivalent [Mtoe]; about 381 terawatt-hours [TWh]), which was approximately the same amount as in 2012. Electricity used totaled 84 TWh (–1% when compared to 2012). The energy mix in Finland is well balanced, including contributions from oil, coal, nuclear energy, and hydropower (Figure 1). The amount of renewable energy slightly decreased and was 31% in 2013 (32% in 2012). Wood fuels represented the majority of the renewable energy used in Finland, at about 87%. Bioenergy is used for heat and power production for industry and municipalities in general. In addition, peat is used for energy purposes, and wood is used for heating small houses.

Directive 2009/28/EC sets a target of 20% renewable energy use in the European Union (EU) by 2020. A national target of 38% is set for Finland by 2020. In 2013, the level of renewable energy use in Finland as calculated according to the EU instructions was 35%. Carbon dioxide (CO_2) emissions from the production and use of energy totaled 46 megatonnes (Mt) in 2013 (preliminary data; see OSF 2013).[24]

On October 24, 2014, the European Council approved the 2030 Framework for Climate and Energy, which has binding target objectives to be met by 2030: (a) reduction of at least 40% in greenhouse gas (GHG) emissions compared to 1990 levels and (b) use of renewable energy at a level of at least 27% in the EU. A target to increase energy efficiency by at least 27%, to be reviewed by 2020, was set, while an EU level of 30% for 2030 was also kept in mind. By 2050, the target is to decrease GHG emissions by 80% compared to levels in the 1990s.

Finland is a sparsely populated country with long distances between cities. Energy use for transportation work per capita, for both people and goods, is among the highest in the world. Transportation consumed about 218 PJ of Finland’s primary energy in 2013, which was about 16% of the total energy consumption in Finland for that year (Figure 2; lipasto.vtt.fi, Statistics Finland). In 2013, transportation in Finland produced GHG emissions amounting to about 12.6 Mt of CO_2-equivalents, of which about 90% was

[24] OSF (Official Statistics of Finland), 2013, *Energy Supply and Consumption,* e-publication, ISSN=1799-7976, 4th Quarter, 2013, Statistics Finland, Helsinki, http://www.stat.fi/til/ehk/2013/04/ehk_2013_04_2014-03-24_tie_001_en.html, accessed December 1, 2015.

produced by road traffic (consisting of about 60% passenger cars and about 35% vans and trucks).[25]

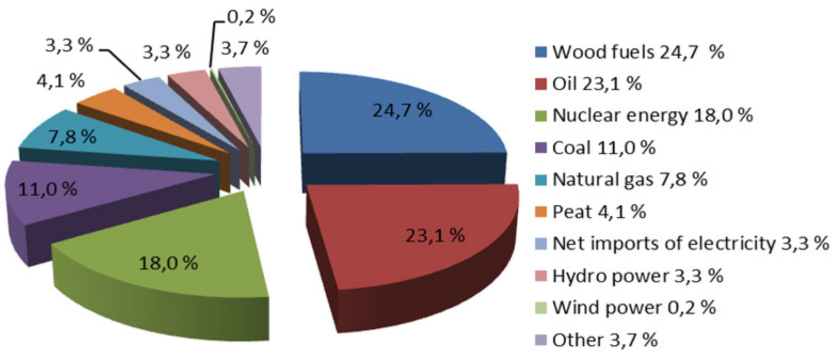

Fig.1 Total Energy Consumption in Finland in 2013
(Source: OSF 2013)

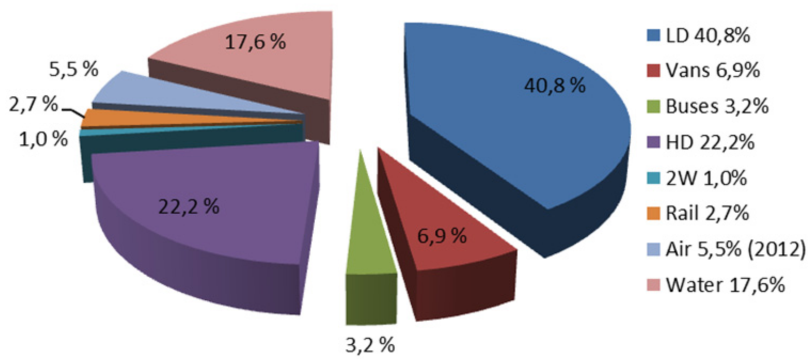

Fig. 2 Energy Consumption in Finnish Transportation Sectors in 2013
(Sources: Figure by Roslund; data from Lipasto, http://lipasto.vtt.fi/indexe.htm, Mäkelä)

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[25] Ministry of Transport and Communications, *Liikenne- ja Viestintäministeriön Hallintoalan Ilmastopoliittinen Ohjelma 2009–2020 – Seuranta 2014,* 30/2014, http://urn.fi/URN:ISBN:978-952-243-434-0.

Policies and Legislation

In Finland, a national law requires fuel distributors to provide biofuels to the market. The target is 6% for 2011–2014, then it increases incrementally to 20% (share of energy) in 2020 (Figure 3). The fuel distributors can decide how best to meet targets, and they can transfer all or part of their obligation to another company. According to Directive 2009/28/EC, the obligation is expected to be partly met by fuels eligible for multiple counting, thus reducing the actual share of biofuels.

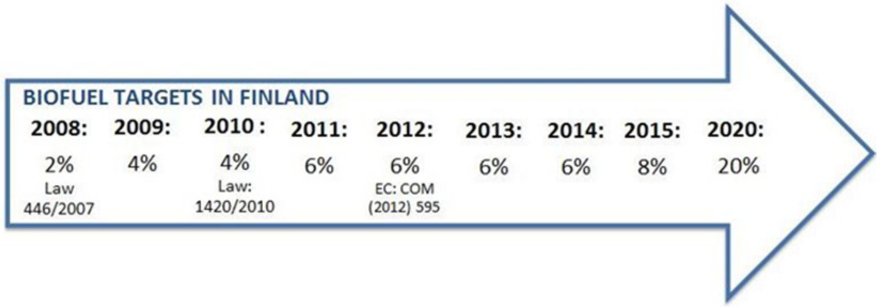

Fig. 3 Biofuel Laws and Target Energy Shares in Finland

In 2009, the Climate Policy Program target was for the use of biofuels to yield a 10% reduction in GHG emissions by 2020. The Ministry of Transport and Communications stated that the most efficient measure for cutting GHG emissions is renewing the passenger car fleet with fuel-efficient vehicles representing CO_2 emissions of 95 g/km by 2020 and 20 to 30 g/km by 2050. In December 2013, the Ministry of Transport and Communications published an environmental strategy for transport.[26] In addition to emphasizing low-emission vehicle technologies and alternative fuels, the new strategy also emphasized the influence of the citizens' behavior when they use the various transportation modes. This environmental strategy also updated the Ministry's Climate Policy Program. For example, 50% of new passenger cars in 2020 and all of the cars sold in 2030 are targeted to be compatible with alternative energy sources. Another target is for 70% of heavy-duty vehicles to be compatible with liquid or gaseous alternative fuels in 2050.

[26] http://www.lvm.fi/pressreleases/4373528/a-new-environmental-strategy-for-transport.

A working group of the Ministry of Transport and Communications published a report, *Future Transport Power Sources,* in 2013.[27] The group's vision was that passenger car traffic, rail transportation, and boating will be almost entirely independent of oil in 2050.

In November 2014, the Ministry of Transport and Communications published a report, *Deployment of Aviation Biofuels in Finland*. According to the study, a potential alternative to bio-kerosene is a bio-based diesel, but this fuel has not yet been internationally approved as aviation fuel. (It could be approved by 2016.) In Finland, Neste Oil has developed a globally unique technology for aviation biofuel production.[28]

In December 2014, the Finnish Government passed a law concerning a trial incentive program for car scrappage. The six-month trial period starts in July 2015. The aim is to promote new car sales, lower emissions, and improve traffic safety. During the trial period, anyone who buys a new, low-emission car and scraps a car that is more than 10 years old will get a rebate of €1,500 (€1,000 funded by the Government and €500 by the importer).

Taxes

The latest tax reforms in Finland are summarized in Table 1. The CO_2-based purchase tax has been an effective instrument in reducing CO_2 emissions from new passenger cars; the average value dropped from 180 g/km in 2007 to 133 g/km in 2013.

In December 2013, a working group of the Ministry of Transport and Communications published the report, *Fair and Intelligent Transport.*[29] The report indicates that steps could be taken toward introducing kilometer-based taxation of car use in Finland.

Research Programs

Special funds have been made available to stimulate research in and the demonstration of next-generation biofuels.

To encourage "smart mobility" integrated with low carbon energy, the research program TransSmart was started by VTT in 2013.[30] TransSmart is a multidimensional framework for transportation-related research that enables

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[27] http://www.lvm.fi/publication/4156469/future-transport-power-sources-executive-summary.
[28] Liikenne-ja viestintäministeriö, 34/2014, http://urn.fi/URN:ISBN:978-952-243-435-7.
[29] http://www.lvm.fi/publication/4387221/fair-and-intelligent-transport-working-group-final-report.
[30] http://www.vtt.fi/research/spearhead_transsmart.jsp.

the cooperation of the private and public sectors for common goals. TransSmart focuses on four core areas: low-carbon energy, advanced vehicles, smart transportation services, and transportation systems.

Table 1 Taxes in Finland

Tax	Based on	Comments
Fuel taxes	• Volumetric heat value, • CO_2 emissions, • Local emissions such as nitrogen oxides [NO_x] and particulate matter (PM)	• Implemented in 2012, 2013. • Low volumetric heating value of biofuels is compensated for. • Biofuels are exempted from carbon component tax, depending on well-to-wheel GHG emissions. • Bonus is given for paraffinic diesel and methane.
Vehicle purchase tax	• Tailpipe CO_2 emissions	• 2008, revised in 2012. • Minimum: 0 g/km CO_2 = 5% tax. • Maximum: 360 g/km CO_2 = 50% tax.
Annual vehicle tax	• Tailpipe CO_2 emissions or • A base tax and a “fuel-fee” tax, depending on the energy source	• Minimum: 0 g/km CO_2 = €43/year. • Maximum: 400 g/km CO_2 = €606/year. • In 2013, it was modified (the annual fuel-fee tax for a 1500-kg car is, for example, €301 for diesel, €82 for electricity, €170 for methane)

Tekes (the Finnish Funding Agency for Technology and Innovation) has a research program dedicated to electric vehicles. The program, called EVE, runs from 2011 to 2015. The total volume involved in the EVE program is €80 M (million), with a contribution of €37 M from Tekes.

A five-year project called LignoCat (lignocellulosic fuels by catalytic pyrolysis) funded by Tekes started in October 2013. In this project Fortum, UPM, and Valmet have joined forces to develop a new technology to produce advanced, high-value, lignocellulosic fuels, such as transportation fuels or higher-value bio liquids. The idea is to develop catalytic pyrolysis technology for upgrading bio-oil and to commercialize the solution.

St1 and VTT signed a two-year, €1.2 million contract in autumn 2014 to start a development project to optimize the production process for wood-based bioethanol. The research project is a part of Tekes' BioEthanol2020 (Green Growth)[31] project, which aims to secure the competitiveness of the Finnish bio-economy.

Implementation: Use of Advanced Motor Fuels

Table 2 presents the main types and numbers of vehicles in Finland on September 30, 2014, according to Trafi, the Finnish Transport Safety Agency. The size of the vehicle fleet that was registered totaled about 4.9 million vehicles (including nonroad vehicles and excluding all registered trailers), and the number in use amounted to about 4.1 million (including nonroad vehicles and excluding all registered trailers).

There were about 3,000 flex-fuel vehicles (FFVs) capable of using high-concentration ethanol fuel (E85) at the end of 2013. Approximately 110 refuelling stations carried E85. There were about 1,600 natural gas vehicles (NGVs) that used only methane (natural gas or biomethane) or that were bi-fuel gasoline/methane vehicles. There were 24 public refuelling stations that carried methane.

Table 2 Types and Numbers of Vehicles Registered (in Use) in Finland on September 30, 2014, According to Trafi[a]

Passenger Cars	Vans	Trucks	Buses	Two-Wheelers	Other Vehicles	Nonroad
3,160,000 (2,640,000)	397,000 (303,000)	136,000 (100,000)	16,000 (13,000)	564,000 (444,000)	45,000 (29,000)	597,000 (533,000)

[a] *There were about 483 passenger cars per 1,000 inhabitants in use (about 578 were registered).* A share of about 24% of the passenger cars in use were diesel passenger cars by the end of 2013.

The dominant fuels were petrol and diesel. In 2013, total consumption was about 3.97 Mt, of which 39% was gasoline and 61% was diesel. In 2013, the national biofuels obligation called for 6% biofuels (energy share) (Figure 3). In total, the contribution from alternative liquid fuels, including fossil fuel options, was about 297 kilotonnes of oil equivalent (ktoe) in 2013. In 2012, biofuel consumption in the transportation sector was 7.9%.[32] It is estimated

31 http://www.tekes.fi/en/programmes-and-services/tekes-programmes/green-growth/.

32 http://www.tem.fi/files/38668/Uusiutuvan_edistymisraportti_2013.pdf.

that using different biofuels in road traffic reduced GHG emissions by 828 kt in 2013 (and 804 kt in 2012).

Ethanol is used on its own and as fuel ethers ETBE (ethyl tertiary butyl ether) and TAEE (tertiary amyl ethyl ether). With regard to diesel, the "bio" portion mainly consists of hydrotreated vegetable oil (HVO)-type, paraffinic, renewable diesel fuel. In 2013, the contribution to liquid fuels from biofuels fulfilling the European Union's sustainability criteria amounted to about 222 ktoe. Table 3 shows the use of road transportation fuels in Finland.

Table 3 Road Transportation Fuels Used in Finland in 2013

Petrol[a] (Mt)	Diesel[b] (Mt)	Ethanol and Ethers[c] (Total/"Bio" Portion) (Mtoe)	"Bio" Origin Diesel[b] (Total/"Bio" Portion) (Mtoe)	Natural Gas (Mtoe)	Biomethane (Mtoe)
1.5	2.4	0.141/0.067[d]	0.155/0.155[d]	0.003	0.0009

[a] E10 = 0.89 Mt, E5 = 0.65 Mt, and E85 = 0.0067 Mt.
[b] Diesel contains mainly HVO as a bio-component.
[c] Ethanol is used partly as fuel ethers in Finland.
[d] Fulfills the EU's sustainability criteria.

Source: Finnish Petroleum Federation and Finnish Customs

Hydrotreated Oils and Fats

HVO is currently a main bio-component in Finnish diesel fuel. Neste Oil's NEXBTL is a renewable paraffinic diesel fuel that has a high cetane number; excellent ignition properties; and no sulfur, nitrogen, aromatics, or oxygen. The EN590 specification for diesel fuel can be met with blends containing up to about 30% NEXBTL. Paraffinic diesel fuel is covered by European standard CEN/TS 15940:2012. Neste Oil's total NEXBTL production capacity is about 2 Mt/year. Production of NEXBTL is mainly based on palm oil and animal fats. In 2013, the percentage of waste and residues in NEXBTL production was 52.6% (35.1% in 2012).

FAME

A minor amount of conventional esterified biodiesel (fatty acid methyl ester or FAME) is used in Finland. RME (rapeseed methyl ester) has been produced on a small scale, mainly on farms.

Bio-ethers

Neste Oil has processed ETBE since 2004. Also, methyl tertiary butyl ester (MTBE) and tertiary amyl butyl ester (TAME) are currently produced at Porvoo refinery. In 2013, about 81 ktoe of bioethers, mainly ETBE and TAEE, were blended in petrol in Finland. The ethanol contained in ETBE is imported, and the end product is mixed with petrol.

Bio-alcohols

In 2011, petrol containing 10 vol% ethanol (E10) was launched in Finland. E10 sales in 2013 were around 58% of ethanol-vehicle sales, and 42% of the total ethanol-vehicle sales was still E5, even though the majority of petrol cars are E10-compatible. High-concentration ethanol, E85, is sold at about 110 refuelling stations in Finland. At present, around 3,000 FFVs are operating in Finland.[33]

Starting in 2011, RED95 ethanol-diesel has been tested in the Helsinki region in Finland, using Scania's ethanol-diesel engines in delivery vans and garbage trucks. Two ethanol-diesel buses are also running in Helsinki.

The energy company St1 is focusing on the decentralized production of fuel ethanol from using side streams from the food industry, via a process called Etanolix®. Waste is converted into an ethanol-water (8–15%) mixture at food industry sites and then concentrated to a purity of 99.8%. St1 also has a centralized dehydration facility in Hamina that has a capacity of 88,000 m^3/year (about 45 ktoe). Five decentralized ethanol units are currently running; they have a production capacity of about 800–7,000 metric tons (t)/year per unit. The Bionolix™ unit in Hämeenlinna is also combined with a biogas production plant to convert side products of ethanol into green energy; it uses biowaste from households. The total production of fuel bioethanol in Finland was 12 ktoe in 2013.

The majority of bioethanol consumed in Finland is imported.

Natural Gas and Biomethane

A total of about 1,600 vehicles (consisting of about 40 natural gas buses operating in the Helsinki region, about 100 heavy-duty vehicles, and the majority of passenger cars and vans) are running on pure methane or are bi-fuel gasoline/methane vehicles. There are currently 24 public natural gas/biomethane refuelling stations, and the construction of new stations is continuing. Natural gas is imported to Finland from Russia.

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[33] The FFV classification was not systematically registered for the Euro 4 car models, which may lead to underestimation of the FFV car population.

The majority of commercially available biogas in Finland is currently produced by Gasum in Suomenoja Espoo, Mäkikylä Kouvola, and Kujala Lahti. The upgraded biomethane is then injected into the natural gas transmission network. Biomethane is sold at Gasum's filling stations in southern and southeastern Finland. Gasum and the Helsinki Region Environmental Services Authority (HSY) cooperate to produce biomethane for use as a public transportation fuel. In 2013, up to 40 local buses had access to biomethane produced locally from wastewater by the Suomenoja wastewater treatment plant. The upgrading facility produces up to 20 GWh (1.7 ktoe) of biomethane.

All in all, biogas production for the transport sector (upgraded biomethane) was 32.8 GWh, and consumption was10.8 GWh in 2013 in Finland. Part of the surplus biogas was stored for later use, and part of it was exported.

Liquefied Petroleum Gas (LPG)

In the 1990s, there was some interest in using LPG to power heavy-duty vehicles. That interest faded, and no vehicles are running on LPG in Finland today.

Electric and Hybrid Vehicles

Hybrid electric vehicles (HEVs) have not made a major breakthrough in Finland. About 600 electric vehicles (EVs) were in use in 2014; the number has almost doubled every year. The new CO_2-based purchase tax has increased the competitiveness of hybrids.

Within Tekes' research program EVE,[34] a testbed consisting of an estimated 400 EVs and 850 charging points will be created in Helsinki, Espoo, Kauniainen, Lahti, and Vantaa[35]. The first Finnish demonstration of fully electric busses started in Espoo in 2012.

A spin-off company, EkaBus, was established in Finland in 2014 to commercialize the development of electric bus research projects and to use new technologies in the existing construction of energy-efficient buses.

Hydrogen

The demonstration of fuel-cell-powered working machinery began in the harbor of Helsinki in 2013. The first commercial and hydrogen fuelling station in Finland opened in March 2014 for private cars and buses at the Port of Helsinki. At Voikoski, one hydrogen fuelling station opened in

34 http://www.tekes.fi/programmes/EVE.
35 http://sahkoinenliikenne.fi.

January 2014 for Finland's first hydrogen car being used by national gas manufacturer Woikoski Oy.

Outlook

Bioethanol and HVO renewable diesel will be used as biofuels more and more over time in Finland.

The use of ethanol produced by St1 in Finland has been increasing as St1 has been broadening its feedstock sources to include straw and waste fibers. St1 is constructing an ethanol plant in Kajaani that will use sawdust to produce about 5 ktoe/year of Cellunolix™ ethanol by 2016.

Suomen Bioetanoli Oy received €30 million in support from the Ministry of Employment and the Economy in December 2014 to invest in a new bioethanol plant at Myllykoski Kouvola. The Myllykoski plant will produce about 90 million L (about 45 ktoe) of bioethanol from straw.

The RED95 ethanol-diesel project is a three-year joint project involving NEOT, St1, VTT, Scania, HSL, and Helsingin Bussiliikenne Oy. It focuses on the environmental impacts and energy consumption of waste-ethanol-powered buses. The aim of the project, which started in 2013, is to demonstrate that ethanol can be used as bus fuel, thereby significantly reducing emissions and GHGs in peri-urban areas. Ethanol-diesel was also added to the Finnish fuel taxation table as its own category on January 1, 2014. ("Ethanol-diesel" means a fuel containing 83–92 vol% ethanol and 5–10 vol% additives that improve ignition.)

In 2014, Neste Oil ended its two-year research program on producing microbial oil at a pilot plant in Porvoo. It concluded, "Lignocellulose material is not a financially competitive industrial feedstock for producing renewable diesel using the microbial oil process at the moment. We will continue researching agricultural and forestry waste and residues, and believe that lignocellulose inputs will play an important role in future renewable applications."[36] With regard to a potentially new alternative feedstock source for NEXBTL production, Neste Oil and Renewable Algal Energy (RAE, a U.S.-based algae biomass producer) signed a contingent commercial algae oil off-take agreement.[37] In December 2014, Neste Oil was also granted €3.3 million in support from the Finnish Ministry of Employment and the Economy to develop the continuous refining of

[36] Neste Oil Corp., press release, October 6, 2014, at 8 p.m. (EET).
[37] Neste Oil Corp., press release, June 24, 2014, at 9 a.m. (EET).

biofuels (biodiesel, biogasoline, and other renewable fractions), involving a total of about 40, 000 t/year from tall oil pitch, at its Naantali refinery.

The Finnish pulp and paper company UPM built a biorefinery in Lappeenranta that uses hydrotreatment to produce biofuels from crude tall oil. Each year, the biorefinery will produce about 120 million L (about 97 ktoe) of advanced, hydrotreated, biodiesel UPM BioVerno for transportation. The commercial production of UPM BioVerno started in January 2015.

In the long-term, cellulosic BTL fuel is expected to cover a significant share of the diesel pool in Finland. Finland's State-owned (50.1%) energy company, Vapo Oy, was awarded €88.5 million to build a wood-based biodiesel plant in northern Finland (in Kemi). In addition, UPM was awarded €170 million for a solid wood-based biorefinery project in Strasbourg, France. In February 2014, Vapo Oy decided to freeze its plans for the biodiesel plant in Kemi. Vapo (Forest BTL) was also planning to build another 500-MW biodiesel plant in Kaskinen, but in February 2014, it decided to freeze this project as well. UPM has not published its final investment decision yet.

Interest in using biomethane for transportation has been increasing. Gasum has biomethane-related plans, including plans for a large-scale, wood-based, bio-SNG (synthetic natural gas) plant in Joutseno. Total production of biogas could amount to about 1,600 GWh (about 138 ktoe), and the biogas would be transferred via Gasum's natural gas transmission network to end users (power plants, transportation sector). The aim was to complete gathering the information required for a possible investment decision in 2014. The construction of the refinery will take 2 to 3 years from the time the decision to go ahead is made.

In Finland, the LNG infrastructure is currently being built up for marine transportation as a result of sulfur regulations. The Finnish Ministry of Employment and the Economy, in autumn 2014, granted investment support to Tornio, Pori, Rauma, and Hamina for four LNG projects. Finland also decided, with Estonia, to construct a gas pipeline between the two countries in 2019 and also to build LNG terminals for both countries, if the EU grants sufficient support for the projects. This support would offer an opportunity to consider LNG options for transportation other than marine transportation (e.g., for long-haul and heavy-duty transportation).

The first integration of wood-based pyrolysis oil production in a power boiler was done by Metso for Fortum in Finland in 2013.[38] The bio-oil plant produced bio-oil amounting to approximately 50,000 t in 2013. Currently, bio-oil substitutes for heavy and light fuel oils in heating applications. However, in the future, bio-oil could also be feedstock for producing transport fuels and various chemicals.

AMF IA Success Stories

Finland has been a forerunner in developing and implementing advanced biofuels. This effort has been accentuated by the country's very ambitious national mandate of making transport fuels consist of 20% biofuels by 2020.

Not only has the AMF IA initiative enabled Finnish experts to link to international researchers in the field and take advantage of their expertise, has enabled international researchers to benefit from Finnish experiences. This win-win, bidirectional cooperation has resulted in shared resources and better project outcomes for more than 25 years.

The AMF IA has given the Finnish companies that are actively involved with alternative fuels as well as the VTT Technical Research Centre of Finland international visibility.

[38] Fortum's bio-oil plant commissioned in Joensuu - first of its kind in the world, press release 29.11.2013 (www.fortum.com).

France

Introduction

EU countries have agreed on a new 2030 framework for climate and energy that includes EU-wide targets and policy objectives for the period between 2020 and 2030. The targets are designed to help the EU have a more competitive, secure, and sustainable energy system and to meet its long-term 2050 greenhouse gas (GHG) reduction target.

Accordingly, on June 18, 2014, the French Energy Minister presented a draft version of the Law on Energy Transition (LTE) to the Council of the Minister. The aim of this law is to help France fight more efficiently against climate change and strengthen the country's energy independence. It was debated in the French Parliament and examined in a plenary session in October 2014. It should be definitively adopted in 2015. The LTE sets targets such as these:

- Reduce GHG emissions by 40% (compared to 1990 levels) in 2030, in line with the EU target.
- Reduce fossil fuel consumption by 30% by 2030.
- Reduce the share of nuclear power in the country's energy mix. Indeed, the proportion of nuclear in electricity consumption is set to decrease from the current 75% to 50% by 2025.
- Meet a target of 32% of renewables in final total energy consumption by 2030. In that year, this goal will come within the target of 15% of renewables in final fuel consumption for transport.
- Divide final energy consumption by two at the time horizon of 2050.

The Government Road Map for Energy Transition focuses mainly on residential and tertiary (i.e., service) sectors; however, transport and sustainable mobility are treated in Parts 3 and 5 of the LTE, in which links are made between health and the environment. The principal items and measures on which a final decision should be reached are these:

- "Clean vehicle" is to be defined.
- Clean vehicles are to be a 50% share of the new public fleet.
- Electric vehicle charging systems are to be deployed at 7 million stations by 2030.
- Various fiscal incentives are to be employed.
- The target of 10% of energy to come from renewable sources is to be achieved in all modes of transport in 2020.

Policies and Legislation

Incentives to Promote Use of Renewable Energy in Transport

Under the National Action Plan for Renewable Energy,[39] following the Grenelle de l'Environnement, a number of incentives were introduced to promote the use of energy from renewable resources in the transport sector.

Incentives to Use Biofuel Blends

- On April 1, 2009, the launch of new SP95-E10 in the gasoline sector corresponded to an incorporation rate of 10% ethanol in gasoline (composition of between 7% and 8% ethanol, effectively). This product has been approved for sale in petrol stations since 2009. It aims to replace the SP95 (5% bioethanol) in accordance with European directives. In 2014, the SP95-E10 accounted for a 32% share of the gasoline volume sold — a 3% increase compared to 2013 (29%). Since 2012, sales of SP95-E10 have exceeded those of SP98.

  France is the European country that has the largest number of petrol stations distributing SP95-E10 (available in around 52% of the total distributing network). In 2014, 93% of the French fleet was compatible with SP95-E10, as well as almost all petrol vehicles registered since 2000.

- Fuels with high levels of biofuel were authorized for use, including E85 in the gasoline sector and B30 in diesel fuel production. In 2014, superethanol E85, which contains 65–85% bioethanol, registered a 6% growth in sales over those in 2013. As of October 2014, E85 has been sold in 500 petrol stations. To encourage the E85's development, it is subsidized and accordingly benefits from reduced pump prices (€0.86/L in April 2014). The E85 price savings, compared to SP95, reached 20 to 40 cents/L (over-consumption effect is included).

  Since 2013, many manufacturers have suspended marketing flex-fuel vehicles. As a consequence of the tightening of European standards, only two models are now available for sale: the Ford Focus 1.6 Ecoboost flex-fuel vehicle and the Jeep Grand Cherokee. In 2012, however, the number of sales of flex-fuel vehicles had reached 7,341.

[39] Directive 2009/28/EC of April 23, 2009, requires Member States to have a "National Action Plan for Renewable Energy" that sets out objectives in terms of a "renewable energy mix" in 2020 and annual trajectories by energy type (i.e., biomass, hydro, wind, solar).

They accounted for no more than 203 vehicle registrations in 2014. About 30,000 flex-fuel vehicles are in circulation on French roads.

With regard to B30 (gasoil that is not authorized for sale to the public), the Senate adopted two amendments in November 2014 that aim to apply a taxation scheme to B30 that is adapted to its low environmental impact, as is done for superethanol E85.

Fiscal Incentive Schemes

- A tax exemption is being granted to biofuels. It complies with European Directive 2003/96/EC on the taxation of energy, which allows Member States to have a special tax for biofuels to ensure their development and promotion.

- A general tax on polluting activities (Taxe Générale sur les Activités Polluantes, or TGAP) was levied to enable France to reach national objectives with regard to using biofuels. TGAP is an additional levy that must be paid by the operators and distributors (refiners, supermarkets, and independent dealers) that sell fuel containing a lower proportion of biofuels than the proportions represented by national goals. This rate increased from 1.75% in 2006 to 3.5% in 2007, 5.75% in 2008, and 6.25% in 2009. The objective since 2010 of incorporating biofuels fixed at 7% was almost reached in 2013 (6.8%). The 2014 Finance Act established an incorporation target of 7.7% biodiesel in diesel. A decree in December 2014 authorized the incorporation of 8% fatty acid methyl ester (FAME) in diesel. For gasoline, the rate is maintained at 7%. To promote the second-generation biofuels industry, TGAP is double-counted. This incentive was designed to encourage the development of the production of biofuels that would not compete with farming for the production of food. In 2014, the amount of biofuels that benefitted from this advantage was limited to 0.3% for incorporation in diesel and 0.25% for incorporation in gasoline. These limits were introduced to limit biofuel production from imported waste, which was observed in 2011.

- The domestic tax on consumption (Taxe Intérieure sur la Consommation, or TIC) aims to reduce the extra cost of manufacturing biofuels over the cost of manufacturing fossil fuels. This is a partial tax exemption for biodiesel and bioethanol and a total exemption for pure vegetable oil used as fuel for agriculture and fishing. After a gradual decrease, the tax exemption rates were stabilized from 2011 to 2013. The 2014 Finance Act (“Loi de Finances”) proposes a further reduction of the tax exemption for 2014 and 2015 until its abolition in 2016. The biodiesel sector benefitted from a reduction of €4.5/hectoliter (hL) in 2014 and will benefit from a reduction of €3/hL in 2015, compared to €8/hL in 2013. The bioethanol sector tax exemption was €8.25/hL in 2014 and will be €7/hL in 2015, compared to €14/hL in 2013. Taxation applied to superethanol E85 was maintained at a rate of €17.29/hL from 2011 to 2014. The energy product consumption tax (Taxe Intérieure de Consommation sur les Produits Énergétiques, or TICPE) will decrease to €12.62/hL in 2015.

The Climate Energy Contribution (CEC) came into force on April 1, 2014. It introduced a carbon component within the TICPE that was progressive and proportionate to CO_2 emissions from energy products under the TICPE, according to the value for a ton of CO_2 being fixed at €7 in 2014, €14.5 in 2015, and €22 in 2016.

Measures to Encourage Fleet Renewal (content updated March 2015)

- The bonus-malus system that applied to the purchase of a new vehicle and had been amended in November 2013 evolved again on January 1, 2015, for the bonus calculation scale, whereas the malus calculation scale established on January 1, 2014, remained unchanged for 2015. The bonus amount was revised downward, with the maximum CO2 release being set at 60 g/km (it had been 90 g/km previously). The maximum bonus of €6,300 introduced in 2013 has remained the same. The €150 bonus for the purchase of thermal vehicles (from 61 to 90 g CO_2/km) was removed.

  For a vehicle emitting more than 130 g CO_2/km, the ecological malus generates an increase in the purchase price of €150 up to €8,000. The objective of the bonus-malus system is to start the ecological transition by using measures that encourage individuals to acquire low-emission vehicles and consequently renew the old automotive fleet. The bonus-malus system from 2008 to 2015, with hybrid electric vehicles (HEVs) and electric vehicles (EVs) excluded, is shown in Figure 1; Figure 2 shows the bonus-malus for HEVs and EVs.

Emissions de CO2 en g/km	2008 -2009	2010	2011	Du 1/1/2012 au 31/07/2012	Du 1/8/2012 au 31/12/12	Au 1/01/2013	Du 01/01/2014 Au 31/12/2014	Du 01/01/2015 Au 31/12/2015	Emissions de CO2 en g/km
0-20	-5000	-5000	-50003	-5000	-7000	-7000	-6300	-6300	0-20
20-50					-5000	-5000	-4000	-4000	20-50
51-60				-3500	-4500	-4500			51-60
61-90	-1000	-1000	-800	-400	-550	-550	-150	0	61-90
91-95			-400	-100	-200	-200	0		91-95
96-100		-500							96-100
101-105	-700								101-105
106-110				0		0			106-110
111-115									111-115
116-120		-100	0						116-120
121-125	-200								121-125
126-130		0							126-130
131-135	0						150	150	131-135
136-140						100	250	250	136-140
141-145				200	200	300	500	500	141-145
146-150						400	900	900	146-150
151-155			200	500	500	1000	1600	1600	151-155
156-160		200	750	750	750	1500	2200	2200	156-160
161-165	200	750							161-165
166-175	750								166-175
176-180						2000	3000	3000	176-180
181-185				1300	1300	2600	3600	3600	181-185
186-190						3000	4000	4000	186-190
191-195			1600	2300	2300	5000	6500	6500	191-195
196-200		1600							196-200
201-230	1600			3600	3600	6000	8000	8000	201-230
231-240			2600						231-240
241-245									241-245
246-250		2600							246-250
250-…	2600								250-…

Fig. 1 Bonus-Malus System from 2008 to 2015 with HEVs and EVs Excluded

Emissions de CO2 en g/km	2008 -2009	2010	2011	Du 1/1/2012 au 31/07/2012	Du 1/8/2012 au 31/12/12	Au 01/01/2013	Au 01/01/2014	Au 01/01/2015	Emissions de CO2 en g/km
0-20					-7000	-7000	-6300	-6300	0-20
20-50	-5000	-5000	-5000	-5000	-5000	-5000	-4000	-4000	20-50
51-60				-3500					51-60
61-90									61-90
91-95	-1000	-1000				-4000	-3300	-2000	91-95
96-100			-2000	-2000	-4000				96-100
101-105									101-105
106-110		-500							106-110
111-115	-700								111-115
116-120									116-120
121-125		-100				0	0	0	121-125
126-130	-200			0	0				126-130°
131-135			0				150	150	126-135
136-140						100	250	250	136-140
141-145		0				300	500	500	141-145
146-150	0			200	200	400	900	900	146-150
151-155			200	500	500	1000	1600	1600	151-155
156-160		200							156-160
161-165	200				750	1500	2200	2200	161-165
166-175			750	750					166-175
176-180		750				2000	3000	3000	176-180
181-185						2600	3600	3600	181-185
186-190	750			1300	1300	3000	4000	4000	186-190
191-195									191-195
196-200				2300	2300	5000	6500	6500	196-200
201-230		1600	1600						201-230
231-240	1600						8000	8000	231-240
241-245						6000			241-245
246-250			2600	3600	3600				246-250
250-...	2600	2600							250-...

Fig. 2 Bonus-Malus System from 2008 to 2015 for HEVs and EVs

Environmental Bonus for Hybrid Vehicles

The aid applies only to hybrid vehicles with CO_2 emissions below 110 g/km. Hybrid vehicles are very much affected now (in 2015) by the new device. The amount of aid being allocated is only 5% (it was 8.25% in 2014) of the vehicle price, with the minimum amount being €1,000 (€ 1,650 in 2014) and the maximum being €2,000 (€3,300 in 2014) (see Table 1).

Table 1 Environmental Bonuses for HEVs

CO_2 Emissions (g/km)	Bonus in 2013	Bonus in 2014	Bonus in 2015	Comments	Examples of Vehicles
Less than 110	€2,000–4,000	€1,650–3,300	€1,000–2,000	Maximum financial aid of 5% of the acquisition cost plus the cost of the battery if it is rented.	Toyota Yaris HSD, Peugeot 3008 Hybrid4

With regard to plug-in HEVs (PHEVs), the bonus is capped at 20% of the purchase cost, plus the cost of the battery if it is rented. The aid applied is €4,000 as a maximum for a vehicle emitting less than 60 g CO_2/km. Conditions remain unchanged for the year 2015.

Support for Electric Vehicles

Electric cars and vans. These encompass electric light-duty vehicle Categories M1, M2, N1, and N2 of European Commission Regulation 715/2007 of June 20, 2007. They are eligible for the highest environmental bonus levels. The bonus granted for purchasing an electric car or van that emits less than 20 g CO_2/km fell from €7,000 to €6,300. The aid applied may not exceed 27% of the purchase price, including all taxes plus the cost of the battery if the vehicle is rented. The conditions for the bonus have remained unchanged as of January 1, 2015 (Table 2).

Table 2 Environmental Bonuses for EVs

CO_2 Emissions (g/km)	Bonus in 2013	Bonus in 2014	Bonus in 2015	Comments	Examples of vehicles
Less than 20	€7,000	€6,300	€6,300	Bonus is capped at 27% of the purchase price, plus the cost of the battery if it is rented.	Renault ZOE, Nissan LEAF

Electric two-wheelers. There is no financial aid for electric two-wheelers. Nevertheless, some cities like Paris, Nice, Villeneuve-lés-Avignon, Lyon, and Aix-les-Bains have implemented a support system at the local level.

The Super Bonus

In 2013 and 2014, a "super bonus" of €200 was granted for acquiring a vehicle eligible for the bonus system and for scrapping a vehicle more than 15 years old.

As part of the Law on Energy Transition, the Minister of Economy announced in October 2014 that a cumulative premium, together with the automotive bonus device, could add up to:

1. €500 for the purchase of a vehicle that meets the Euro 6,
2. €2,500 for a PHEV, and
3. €3,700 for EVs.

This super bonus will be set for the purchase of one of those three types of vehicles and the scrapping of a diesel vehicle more than 13 years old. For the purchase of an EV, the device will, under certain conditions, allow the amount to reach €10,000.

Bonus-Malus Budget

Since the introduction of the bonus-malus system, revenues issued from the malus system were to balance expenses associated with the bonus system. However, this device was in deficit from 2008 to 2011, with a gap between revenues and expenses that reached nearly €1.5 billion. It is now subject to adjustment annually in order to account for technological developments and ensure that the budget is balanced.

After a balance was reached for the first time in 2012, the system had a deficit of €53 million in 2013, having collected €276.6 million for malus and paid €329.1 million for bonus, according to the final data of the Court of Auditors. With regard to 2014, provisional data indicated that malus receipts would amount to about €300 million, while bonus spending would reach €230 million, resulting in a €70 million profit.

The government estimated that the percentage of vehicles being granted a bonus should reach 8.10% in 2014, and that the percentage of vehicles getting a malus would be 17.6%. The recent amendments to the bonus-malus system have led to a situation in which the majority of vehicles are being sold in the "neutral zone" (i.e., no bonus and no malus). This percentage reached 74.3% in 2014; it had been 67% in 2013.

In 2014, of 1.8 million new vehicle registrations, EVs accounted for only 0.59% of vehicle sales, representing 15,045 EV registrations (up 7.8% from 2013).

The bonus-malus system has been a key element causing France to have one of Europe's lowest CO_2 emission levels in the new vehicles market; in 2014, emissions amounted to about 114 g CO_2/km.

With regard to 2015, the government expects expenditures of €214 million for bonus, based on the following assumptions about "clean vehicle" sales: 18,900 EVs, 1,904 PHEVs, and 49,000 hybrid vehicles.

Research and Development (R&D) in the Transportation Sector

Public support for innovation and R&D deployed within competing clusters (i.e., associations or partnerships) results in the following:

- Financial support via the single interdepartmental fund, Fond Unique Interministériel (FUI). It involves the participation of various partners, such as (1) the National Research Agency (NRA, or, in French, Agence Nationale de la Recherche or ANR) through a Carnot device,40 (2) OSEO, which is now incorporated in La Banque Publique d'Investissement ou Bpifrance, or (3) Caisse des Dépôts in project financing; and
- Tax exemptions for companies with a cluster involved in an R&D project financed by the government.

NRA R&D Projects

The NRA, established in 2005, is responsible for implementing financing projects designed to boost the research sector, France's competitiveness, and the visibility of France's research abroad. The NRA is mobilized to focus its research efforts on economic and societal priorities at the highest level of the State and to consult with other stakeholders in the research results and develop European and international collaborations. Now the action of the NRA revolves around nine major societal challenges identified in the Strategic Research Agenda that are consistent with the European Strategic Agenda. Two of the challenges are related to transport issues: (1) clean, safe, and efficient energy and (2) sustainable mobility and urban systems.

[40] The Association Institut Carnot is a network of 34 Carnot institutes. It is a research network dedicated to fostering enterprise innovation. A major national multidisciplinary research task is to build economic development through technologies and innovation: Founded in 2006, the Carnot label was designed to develop partnership-based research, meaning that research efforts are conducted by public laboratories in partnership with socioeconomic players, primarily enterprises (from subject matter experts to large corporations), to serve the partners' needs.

In 2014, projects funded by the NRA were in the fields of biofuels, transport, and energy. They included the following:

- **CATAPILS.** This project deals with the catalytic conversion of lignin into biofuels and simple aromatic compounds by an innovative hybrid system composed of metallic nanoparticles stabilized by polymerized ionic liquids (PILs). The "semi-heterogeneous" PIL-nanoparticle catalyst will combine the advantages of traditional homogenous or heterogeneous catalysts: catalytic activity, modularity, selectivity, and recyclability. In order to transform lignin into biofuels or simple aromatic compounds, oxygen-containing functions will have to be removed, while aromatic residues will have to be reduced. Developing an efficient catalyst for such reactions as hydrogenation, hydrogenolysis, dihydroxylation, or hydrodeoxygenation is one of the key aspects of this project. The last step of the project will be to study the catalytic transformation of bio-oils resulting from the cracking of lignin, or of lignin itself, into biofuels or simple aromatic compounds.
- **Cellutanol.** This project aims to build, within four years, an Escheria coli strain that will directly convert crystalline cellulose into butanol at a high yield and will be able to be used to produce third-generation biofuel with a better octane rating than that of ethanol. The proposal relies on the complementary expertise of two academic groups: one in the field of cellulolysis (Partner 1, CNRS, Marseille) and the other in the fields of synthetic biology coupled with metabolic engineering (Partner 2, INSA, Toulouse). The last stage of the project will involve the combination of both phenotypes by integrating all necessary heterologous genes for cellulolysis in the chromosome of the butanol-overproducing strain. The final deliverable will be a prototype strain of *E. coli* that will secrete an efficient cellulolytic system; exhibit a high butanol titer, tolerance, and productivity; and generate almost no by-products.
- **DIGAS.** This project aims to develop a heterogeneous catalytic process for the direct synthesis of dimethyl ether (DME) from sustainable sources to use in several energy applications. The DIGAS project focuses on the direct, one-step synthesis of DME from biomass-derived syngas in two reactions. The process will require the presence of catalysts with both metallic and acidic functions. Plans within the framework of this project are to investigate the reactivity, robustness, selectivity, and stability of the catalytic materials in the model reaction and to gain deeper insight into the mechanism of the direct conversion of biosyngas into DME.

- **GreenAlgOhol.** The goals of this project are to develop efficient biomass production schemes and optimized enzymatic hydrolysis of seaweed glucans to produce algal glucose. In a second step, glucose can lead to many platform molecules. As proof of concept, the project will focus on fermentation into ethanol. As part of a biorefinery concept, other specific green seaweed carbohydrates and noncarbohydrate components will be investigated to identify and quantify potentially interesting compounds.
- **Four Projects on Modeling, Forecasting, and Risk Evaluations.**
  - FOREWER: Develop reliable theoretical and numerical models of and scenario generators for wind resource distribution and power output at various spatial and temporal scales, with a focus on the medium to long term;
  - HYSTOR: Develop an unconventional approach for synthesizing a new class of porous, carbon-based, hybrid materials that could be optimal adsorbents of hydrogen for mobile applications;
  - APPIBio: Investigate the effects of biodiesel on the durability of on-board exhaust gas systems (targeting diesel oxidation catalyst [DOC] and selective catalytic reduction [SCR] catalyst poisoning, specific soot reactivity, etc.), taking into account the interactions involving the deterioration of each element of the post-treatment system; and
  - ECN (European Combustion Network) France: Develop innovative diagnostics for diesel injection and combustion.

Under the NRA umbrella, a decision was also made to select and launch a new approach through ITE (les Instituts pour la Transition Energétique, previously les Instituts d'Excellence en Matière d'Énergies Décarbonées, or, in English, the Institutes of Excellence in Low-Carbon Energies, or IEED). The approach involves interdisciplinary platforms in the field of low-carbon energy that bring together industrial and public research experts. Among these, the following are highlighted here:

- **PIVERT.** The IEED's PIVERT project is a platform that involves a collaborative effort and that focuses on vegetable chemistry based on oleaginous biomass (e.g., rapeseed, sunflower, and other seeds). The future refinery will use local agricultural and forest resources of the Picardie region. The budget will be €246 million over 10 years.
- **VeDeCoM.** This project is supported by the competitiveness cluster Mov'eo and the local government (i.e., Council of Yvelines) and is active in the field of land transportation and eco-mobility. The centers will receive an allocation of €54.1 million.

The central role of competitiveness clusters (Pôles de Compétitivité), such as Mov'eo (automotive cars) and LUTB (heavy trucks), in the field of transportation should also be emphasized, since the clusters represent an important tool in supporting that sector.

ADEME R&D Projects

ADEME, the French energy public agency, also hosts R&D programs, such as these:

- **Bioresources, Industries, and Performance (BIP) Program.** Projects must be enrolled under at least one of the two topics detailed in the text of the "call for projects":
    1. Biorefineries: (1) plant chemistry, (2) bio-based products for chemicals and materials, and (3) biofuels
    2. Renewable and clean energy from biomass
- **Road Vehicle of the Future Program.** Projects cover (1) technology and (2) systems and mobility (Investissements d'Avenir). Possible levers include alternative energy and auxiliary functions (including safety, comfort, and energy management).

Some examples in the areas of advanced biofuels and the development of EVs and PHEVs are discussed here.

ADEME Advanced Biofuels Programs

A majority of the biofuels currently consumed are produced by "first-generation" processes. The first-generation biofuels refer to the fuels derived from sources like starch, sugar, animal fats, and vegetable oil. The oil was obtained by using conventional production techniques. Some of the most popular types of first-generation biofuels are biodiesel, vegetable oil, and bio-alcohols.

"Second-generation" processes are designed to produce "sustainable" biofuels by transforming the whole plant tissues of a wide range of agricultural, forestry, and waste industry residues and wastes, dedicated crops, and waste organics. Other processes could benefit from microalgae or microorganisms capable of converting high volumes of biomass or oil into biodiesel with an improved energy and environmental balance. In France, the challenges to developing these industrial sectors are considerable and include (1) reducing GHG emissions in the transport sector, (2) limiting the country's energy dependence, and (3) creating new economic activities.

Projects in France that aim to remove a number of scientific and technical bottlenecks are summarized here.

- **Futurol.** Launched in 2008, the Futurol project aims to develop and commercialize a complete solution for producing cellulosic ethanol, from the field to the finished product. The project has developed a process that is particularly well optimized in terms of industrial integration and performance. Thanks to its pilot plant (180 m^3/yr) and the involvement of its partners, the project has made breakthroughs in terms of the three key elements: pretreatment, enzymes, and yeasts. The project will use a cocktail of enzymes that can be produced in situ in the process from co-products, resulting in performance that is equivalent to that of the industrial cocktails available. The yeasts are used to ferment all the sugars likely to produce ethanol. A demonstration unit capable of producing 3,500 m^3 per year should start up in 2015. Industrialization of the project technology is expected starting in 2016, and the process will be marketed by Axens. Led by the company PROCETHOL 2G, the Futurol project involves 11 partners. The project is supported by Bpifrance and approved by the Industries and AgroResources (IAR) competitive cluster.
- **BioTfueL.** The BioTfueL project aims to develop and bring to the market a chain of processes for producing second-generation biodiesel and bio-kerosene by using a thermochemical process. It is led by a group of six partners: Avril, Axens, CEA, IFP Énergies Nouvelles, Thyssenkrupp Industrial Solutions, and Total. It is making progress toward constructing two demonstrators. In November 2014, Bionext, which is composed of all the partners in this program, announced that the project's detailed design phase had ended and the demonstration phase could begin. To do the demonstration phase work, two preindustrial units will be built for a total project investment of €180 million. The Avril site in Venette (Picardy) will house a €12 million biomass preparation installation using the torrefaction process. Total's refinery site in Dunkirk (Flanders establishment) will house the gasification unit at the heart of the process, together with the Fischer-Tropsch synthesis process developed by IFPEN. It entails an investment of almost €110 million. In September 2014, the construction contracts for the main works packages at the Total site in Dunkirk were signed by Bionext, with Prosernat (for synthesis gas treatment), SME RBL-REI (for load preparation), and ThyssenKrupp Industrial Solutions (for the gasification unit and overall integration of the facility). The start of on-site work is planned in the first quarter of 2015.
- **Gaya.** This project involves bioSNG (synthetic natural gas made of renewable resources) production by a thermochemical process (bio-methane fuel produced by gasification followed by a methanation step). The research demonstrator, selected under the demonstrator fund for second-generation biofuels, explores the full chain of bioSNG

production. The project, which is supported by the EC, aims to demonstrate a commercial pathway for the gasification and methanation of residues (e.g., wood, straw) to produce synthetic bio-methane at the industrial scale. The project has lasted seven years; it began in June 2010 and brings together 11 partners. Public support amounts to €18.9 million (total budget is €46.5 million). The GDF SUEZ Group will coordinate the project, which will involve subject matter experts and public research organizations. The construction of the R&D GAYA platform was launched in October 2013.

- **Syndiese.** The aim of this project is to build a preindustrial demonstrator for producing second-generation biofuels that has a capacity of 10 metric tons per hour (t/h). As a result of their R&D programs, Air Liquide and CEA are working together to develop a concept for transforming biomass into synthesis gas. (It is called BtS, for biomass to syngas.) CEA is responsible for developing a chain of pretreatment processes for crushing into fine powder, pressurize, dosing and conveying of solid biomass at the Bure Saudron site and CEA Grenoble Center. Pretreated biomass is converted into synthesis gas by using an oxy-burner technology under development at the Air Liquide research centers in France and Germany. In October 2014, CEA inaugurated the platform for biomass pretreatment by crushing it at Bure Saudron. The BtS technology will be validated in a 1-t/h pilot unit before being used in the demonstrator.

ADEME and Other EV and PHEV Programs

The electrification of vehicles has great potential for reducing fuel consumption, limiting the impact of vehicles on the environment, and diversifying energy sources. Many projects aim to eliminate existing technical barriers to this goal. Examples are given here.

- **CITYBRID.** This project aims to develop hybrid transport solutions optimized for urban use and, more specifically, their market presence and distribution. The demonstration vehicles developed under this program will be used to evaluate the in situ use of rechargeable hybrid-electric trucks. CITYBRID will also offer benefits that might be valued by a customer (e.g., electric propulsion; compliance with regulations, local incentives, or labels). The project will consider the kinematic chain as a whole, or even the entire vehicle, in anticipation of future regulations beyond the Euro 6 norm. It will also consider forthcoming regulations on CO_2 emissions. The project involves six partners having complementary skills: four industrial companies (Renault Trucks, FRAPPA, Carrosserie [i.e., car body work] Vincent, and SAFT) and two public research organizations (IFP Énergies Nouvelles and Joseph Fourier University). The total budget for this project amounts to

€14.2 million, of which €4.6 million is financed by the FUI (Fond Unique Interministériel) and territorial partner entities (Collectivités Territoriales). The project was extended until May 2015.

- **HYDIVU.** This project will focus on an innovative solution for diesel hybrid powertrain, light utility vehicles (i.e., family vans and Trafic and Master ranges [ranges are a van category]). Renault has partnered with Valeo and Continental, leading suppliers to the automotive industry, and with IFP Énergies Nouvelles and LMS to support this project. Launched in 2013, the three-year project has a budget of €90 million. At the end of the project, Renault will equip the Trafic and Master van ranges with a new hybrid engine. The diesel consumption and CO_2 emissions associated with these two models will be reduced considerably.
- **ESSENCYELE.** The aim of this project is to combine a high-efficiency gasoline engine with a mild hybrid low-voltage powertrain. The goal is to reduce the consumption of fuel by 25%, while using affordable technologies, based on:
  - A mild hybrid gasoline powertrain that takes advantage of all the synergies offered by the combined motorization;
  - A high-efficiency, downsized engine that implements affordable technologies;
  - Hybridization at low cost with an operating voltage of 48 V and with zero-emissions vehicle (ZEV) capability; and
  - A technological breakthrough in the electrical energy storage system due to the use of ultra capacitors.
- **Drive'n Spark.** The goal of the first phase of this project is to produce an automobile engine with a variable compression ratio of 1.0 to 1.3 L, three or four 120- to 160-kW cylinders, and 300 to 420 Nm of torque that can reduce fuel consumption by 15–25%. The purpose of the second phase is the realization of vehicles operating with either gasoline or natural gas, equipped with the engine that was developed in the first phase and then adapted to both fuels.

Air Transportation

In the field of air transportation, R&D (particularly research focusing on alternative powertrains, combustion, and low-carbon fuels) is conducted in cooperation with European partners. Examples of projects in the aviation sector include these:

- **CAER.** The goal of the French R&D project CAER (Alternative Fuels for Aeronautics) is to identify new industrial aviation fuel sectors that will complement those already certified; namely, fuel from Fischer-Tropsch synthesis and hydro-treated vegetable oils. With a budget of € 8.5 million and supported by the Ministry of Transportation (DGCA), CAER is coordinated by IFP Énergies Nouvelles, in partnership with key stakeholders in research done in this domain (CNRS, INRA, and INRIA) and in industry (Airbus, Air France, Dassault Aviation, EADS_IW, Snecma, Total).

- **CORAC.** The CORAC (Conseil pour la Recherche Aéronautique Civile, or Council for Civil Aeronautics Research), which brings together the French players in civil aeronautics, formalized the launch of three new major R&D programs in October 2014. They will focus on:
  - New methods for the production and assembly of aircraft in plants;
  - New aircraft configurations that are even more quiet and fuel efficient; and
  - New control systems that will ultimately enable airline companies to increase the operational capabilities of their aircraft.
- **CORE Jet Fuel.** On the European level, this project supports the EC in its dynamic and informed implementation of research and of innovative projects in the field of sustainable alternative fuels for aviation. It links initiatives and projects at the EU and Member State level, serving as a focal point in this area to all public and private stakeholders. The aim of the project is to set up a European network of excellence for alternative fuels in aviation that brings together technical expertise from all across this complex thematic field and to help coordinate both the members' R&D and implementation efforts. The Agency for Renewable Resources (FNR) is coordinating the project development and the team, with partners from Bauhaus Luftfahrt e.V. (Munich), SENASA (Madrid), WIP (Munich), EADS-IW (Paris), and IFP Énergies Nouvelles (Paris). This FP7 Coordination and Support Action is funded by the EU and its duration is three years, from September 2013 until August 2016.

Germany

Introduction

The discussion, figures, and tables that follow show fuel consumption in Germany and the number of registered vehicles separated by fuel type. The assumptions about fuel consumption for 2014 are based on real data from 2013 and on trends-based assessments for January until October 2014.

Figure 1 shows Germany's 2013 consumption, with the following ranking from most to least consumed fuel: diesel (61%), gasoline (33%), and renewable fuels (5%).

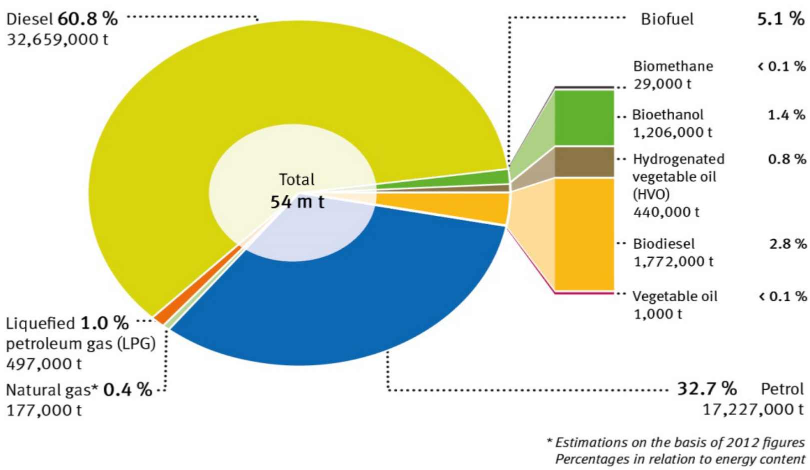

Fig. 1 Fuel Consumption in Germany in 2013

(Source: BAFA [Bundesamt für Wirtschaft und Ausfuhrkontrolle] et al. 2014)
© FNR 2014

In 2013, German fuel consumption for use in road transportation amounted to 54.0 million metric tonnes (mt), including biofuels. Of this amount, of 17.2 mt of gasoline and 32.7 mt of diesel were consumed (excluding those blended with biofuels). The consumption of biofuels amounted to 3.4 mt, with the majority being low-level blends of biodiesel and hydrotreated vegetable oil (2.2 mt) and bioethanol (1.2 mt). Quantities of other biofuels consumed in 2013 were (a) pure biodiesel at 33.1 kilotonnes (kt); (b) ethyl tertiary butyl ether or ETBE, the additive for motor gasoline, at 159.1 kt;

(c) pure vegetable oil at 1.2 kt; and (d) E85 at 14.0 kt. The consumption of biofuels in 2013 was a little bit less than it was in 2012, at 3.8 mt.

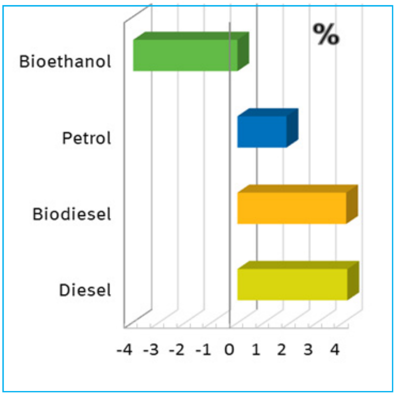

Fig. 2 Trends in Fuel Consumption in Germany, January–September 2014
(Source: Federal Office for Economic Affairs and Export Control [BAFA])

The graph in Figure 2 shows the 2014 trends for the most relevant fuel types. There is a small increase of about 4% for biodiesel and pure diesel. About 2% more petrol was consumed than in the prior year, whereas bioethanol had a "fallback" of about 4%.

Due to the small total amounts, no relevant changes were seen for pure biofuels (pure biodiesel, ethyl tertiary butyl ester [ETBE], pure vegetable oil, E85) in 2014. Because Germany withdrew any tax exemption for pure biofuels, since January 2013, pure biofuels had the same tax rate as fossil-based diesel fuel. There was only an insignificant share of biofuels on the market in 2014 (48 kt) (BAFA 2014a). Roughly 97% of the crude oil used in Germany (for fuel, among other uses) had to be imported. German sources of imported crude oil are relatively well diversified, with the Russian Federation accounting for 34% of imports, another 17% coming from Norway, 11% coming from Great Britain, 8% each coming from Kazakhstan and Azerbaijan, and 23% coming from 25 other countries worldwide (BAFA 2014b).

Table 1 shows the number of passenger cars on the road in Germany by fuel type for the years 2006 through 2014.

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

Year	Gasoline	Diesel	LPG	NG	EV	Hybrid
2006	35,918,697	10,091,290	40,585	30,554	1,931	5,971
2007	35,594,333	10,819,760	98,370	42,759	1,790	11,275
2008	30,905,204	10,045,903	162,041	50,614	1,436	17,307
2009	30,639,015	10,290,288	306,402	60,744	1,452	22,330
2010	30,449,617	10,817,769	369,430	68,515	1,588	28,862
2011	30,487,578	11,266,644	418,659	71,519	2,307	37,256
2012	30,452,019	11,891,375	456,252	74,853	4,541	47,642
2013	30,206,472	12,578,950	494,777	76,284	7,114	64,995
2014	29,956,296	13,215,190	500,867	79,065	12,156	85,575

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

Source: Kraftfahrt-Bundesamt, the Federal Motor Transport Authority (KBA 2014a)

A total of 53 million vehicles were registered in Germany as of January 1, 2014, with 43.9 million of them (82.8%) being passenger cars. Of the registered vehicles, 4.1 million (7.7 %) were motorcycles and 2.6 million (5.0 %) were trucks. The rest were buses, tractors, and other vehicles. Of the passenger cars, 13.2 million (30.0%) were diesel-fuelled and 30.0 million (68.3%) were petrol-fuelled (see Table 1). Vehicles with alternative powertrains numbered 677,663 (1.5%). This total included 12,156 electric vehicles (EVs), 85,575 hybrid vehicles, 500,867 vehicles using liquefied petroleum gas (LPG), and 79,065 vehicles using natural gas (NG) (KBA 2014b).

Policies and Legislation

Since January 2015, the benchmark for biofuel quotas has been converted from energy content to a net greenhouse gas (GHG) reduction. This net quota will increase in three steps: from 3.5% in 2015, to 4.5% in 2017, and to 6% in 2020. Biomethane of natural-gas-quality mixed with natural gas can also be used to fill the quota. This aspired-to quota will be 1% lower by 2020 than the quota previously proposed in 2013. Furthermore, the amendment to the German Emission Control Act (December 2014’s Bundes-Immissionsschutzgesetz-BImSchG) bans all double-counting and excludes animal fats and bio-based oils that are co-refined with fossil-based oils from the quota eligibility. It is expected that there will be provisions for electricity use in road transport in the law in the future.

The sustainable criteria for biofuels agreed to at the European level under the Renewable Energy Directive (RED, 2009/28/EC [European Commission]) and under the Fuel Quality Directive (FQD, 98/70/EC) became German law in 2009. The December 2014 amendment also reflects concerns about the sustainability and GHG-reduction benefits of some biofuels. The new law strives to consider the upcoming EU legislation and aligns to the EU Energy Council's political agreement on a draft amendment to RED and the FQD from June 2014.

In December 2014, the German Agency for Renewable Energy (DENA), which is strongly aligned to the Federal Ministry of Economic Affairs and Energy, presented a policy paper for sustainable mobility in the EU to the EC. DENA considers the "use of renewable liquid and gaseous fuels of non-biological origin [as] essential for achieving the EU's climate protection objectives in the transport sector." It recommended:

- The minimum quota for advanced biofuels is 2.5% in 2020.
- Renewable liquid and gaseous fuels of nonbiological origin shall be considered to be four times their energy content.
- Fuels produced from carbon-rich (CO or CO_2) gas streams from agricultural residues, waste, and residues of nonrenewable energy sources shall be considered to be four times their energy content.
- The use of renewable hydrogen in refineries is to be considered as a possible method of reducing the GHG emissions of fossil fuels (DENA 2014).

Since 2007, firms marketing petrol and diesel had been obliged to market a legally prescribed minimum percentage of such fuels in the form of biofuels. The level of this quota in relation to the energy content of the fossil-based fuel of concern, plus the energy content of the biofuel replacing it, had been 4.4% for diesel and 2.8% (from 2010 to 2014) for petrol. Since 2009, there had also been an overall quota for diesel and petrol combined. This overall quota had been set at 5.25% for 2009 and at 6.25% for 2010 to 2014.

The tax rate for pure vegetable oil outside the quota had started at 18.5 euro cents ($0.22 US) per liter, and for biodiesel (B100), the rate had started at 18.6 euro cents ($0.22 US) per liter. These amounts had been gradually increased, and from January 2013 on, pure biofuels had the same tax rate as fossil-based diesel fuel (45.03 euro cents [$0.54 US] per liter). Until December 2015, tax credit is being given for pure biofuels in agriculture, and complete tax relief exists for some bioethanol blends (e.g., bioethanol in high blends between 70% and 90%; lignocellulosic ethanol), synthetic hydrocarbons made of biomass, and biomethane. Tax relief for NG and LPG used as fuel remains in effect until 2018.

In addition to the promotion of an appropriate, consistent tax and regulatory business environment, the promotion of research and development (R&D) is also occurring across the various biofuel sectors to create conditions conducive to boosting biofuel use. In this context, the German Federal Government supports projects that will further develop existing biofuel technologies and develop new ones from scratch. This support encompasses the full value chain, including the provision of raw materials (e.g., growing of crops), biomass conversion, quality assurance, and the use of biofuels in vehicles (e.g., emissions, material compatibility).

Under the Renewable Resources Funding Scheme of the Federal Ministry of Food and Agriculture (BMEL), about 70 R&D projects related to biofuels now receive funding of more than €23 million ($27 million US). This support includes funding for projects related to bioethanol, biodiesel, vegetable oil, biomethane, and advanced biofuels, as well as to areas like biofuel sustainability. The aid is granted through the BMEL's project sponsor, the Agency of Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V., or FNR).

With regard to advanced biofuels, project support was focused on biomass-to-liquid (BTL) fuels, which have not been introduced to the market yet but are considered a promising option because of their broad raw material base and chemical composition. In addition, the production of hydrocarbons from biochemical pathways is playing an increasingly important role with regard to funding activities. Another funding focus is on developing ways to deploy energy from renewable resources, such as algae.

For vegetable oil, which is likely to remain a niche fuel because of its properties, priorities include creating engines that run on vegetable oils. Since 2013, FNR has funded the project PraxTrak, which by the end of 2014 had developed a tractor engine that can be fuelled with different types of pure vegetable oil and that applies to the European emission standard Euro 4. Since January 2015, farmers can purchase the tractors with the stated engine from John Deere. At the same time, farmers also stopped retrofitting conventional fossil-fuelled tractors.

Since 2013, the project AUFWIND (with 12 partners) has been receiving financial support. The aim of the project is to produce kerosene made of algae. To identify the sustainable biomass potential of biofuel and to prevent some kind of impact related to indirect land use change (ILUC), BMUB (the Federal Ministry for Environment, Nature Conservation, Building, and Nuclear Safety) and BMEL (the Federal Ministry of Food and Agriculture) funded four projects having a common priority: conducting "studies on aspects of the sustainability of biofuels." Results will be published in 2015.

The Federal Ministry of Transport and Digital Infrastructure (BMVI) launched the "Mobility and Fuel Strategy" in 2011 aimed at creating environment- and climate-friendly, socially responsible, and economically efficient modes of future transportation. It is based on a strategy launched in 2004 that was completed in 2013. The recent strategy does not favor a specific technology but includes all important transportation modes (road, aviation, railway, and waterborne) and all relevant drivetrains and energy sources (fossil-based fuels, biofuels, electric mobility, and fuel cells). It is organized as a consistent and adaptive process, and stakeholders from government, industry, academia, society, and nongovernmental organizations (NGOs) participate. The main goals of its dialogue process are to find medium- and long-term prospects for the substitution of fossil fuels, to develop fuels based on renewable sources of energy, and to identify promising drivetrain technologies and the supply infrastructure required to support them. The process proceeded in 2014; currently, there are no new results.

With respect to electrified transportation, the goal of the German Government is to have at least 1 million electric vehicles (EVs) on German roads by 2020. Electrification of transport is the main Governmental strategy for reducing GHG emissions in this sector. In May 2010, the National Platform for Electro Mobility (Nationale Plattform Elektromobilität [NPE]) was founded. In the NPE, all relevant car manufacturers, suppliers, and research facilities are represented; they are organized into seven working groups who discuss specific issues and identify measures for dealing with them. Nevertheless, in 2014, only 24,000 electric cars were sold instead of the planned 100,000 EVs. Thus, Germany is at risk of missing its climate targets for road transportation. Leading politicians from the German Government and the NPE are demanding stronger support of the sector, that would amount to €3 billion for the coming years (*Focus Online* 2014). Only light tax incentives have been implemented for electro mobility.

Synthetic biofuels, however, do have a high importance in the German R&D funding scheme for renewable resources. FNR and the Federal Ministry for Agriculture supported the bioliq® project from 2005 to 2013. This project achieved large-scale BTL fuel production from sustainable biomass. It tackled the challenge of the widely distributed rising of biomass by implementing a decentralized pretreatment of the biomass to obtain an intermediate energy carrier of high energy density (bioliq Syncrude). In the later process of chemical synthesis, the biomass is converted into drop-in fuels or standalone products that are completely compatible to existing diesel- or gasoline-type fuels. Nearly any type of dry biomass can be used for this process. Since the end of 2014, the pilot plant has been running successfully along the complete process chain. Depending on the operating conditions and on the biomass selected, the products obtained are made up of 40–70% liquid pyrolysis oil, 15–40% pyrolysis char, and a fraction of noncondensable pyrolysis gas whose combustion heat can be used for heating or drying. In the pilot plant, 500 kg/h (2 MW) of biomass are converted by fast pyrolysis into biosyncrude. The bioliq pilot gasifier is designed for 5 MW (1 t/h) for further processing. The investment totals €64 million, of which €24 millionwere granted by FNR and the Ministry.

The program called the "Initiative for Natural Gas-Based Mobility – CNG and Biomethane as Fuels" supports the German Government's goal of encouraging greater use of natural gas vehicles (NGVs). Currently, natural gas is only 0.3% of the fuel mix. CNG and biomethane have the potential to reach 4% by 2020 in Germany, which would represent a greater-than-tenfold increase. The members of the initiative are consumer organizations and well-known energy and transportation sector companies along the entire value chain. The initiative is coordinated by the Deutsche Energie-Agentur GmbH (DENA), the German Energy Agency. According to the initiative, 38% more NGVs were sold in 2014 than in 2013 in Germany; however, the share of CNG vehicles is still rather low. In the same period, the methane mixture achieved a higher share of biomethane (20%) than the year before, thus reducing GHG emissions and dependency on fossil-based natural gas (DENA 2015).

After the federal election in September 2013, the coalition agreement between the three parties forming the German Government — CDU (Christian Democratic Union), CSU (Christian Social Union), and SPD (Social Democratic Party) — was published in November 2013. The agreement supports the development of new powertrains and fuels. The Government wants to develop a biofuels strategy oriented toward the potential of sustainable biomass. It was proposed to extend the tax relief for natural gas.

At the end of January 2015, the international convention called "Fuels of the Future 2015" took place in Berlin. More than 500 visitors were expected.

Implementation: Use of Advanced Motor Fuels

Incentives for using advanced motor fuels include a full tax exemption for specific biofuels (i.e., BTL, bioethanol from lignocellulose, biomethane, and E85 [E70–E90]) until the end of 2015 and a partial tax exemption for natural gas (CNG and LNG) and LPG as transport fuel until the end of 2018. The switch in the beginning of this year in the biofuels quota legislation from quantitative quotas (energy content) to GHG-reduction quotas (6% from 2020 on) will provide a further impetus for using advanced biofuels. Biofuels performing better than the minimum GHG-reduction requirements of the RED and FQD (which are reductions of 35% until 2017, 50% from 2017 on, and 60% from 2018 on for new production facilities) should be rewarded by higher market prices.

The German car manufacturers Audi and Mercedes-Benz are already testing advanced motor fuels. Under the leadership of Audi in Werlte, Lower Saxony, the world's first power-to-gas plant was built on an industrial scale to produce synthetic natural gas (Figure 3).

Fig. 3 Power-to-Gas Plant to Produce E-Gas
(Source: Audi AG)

The plant opened in June 2013. The Audi e-gas plant in Werlte produces hydrogen and synthetic methane from renewable energy surpluses, which will permit mobility that is almost CO_2-neutral. The Audi e-gas plant uses renewable electricity in the first stage for electrolysis — splitting water into oxygen and hydrogen (Audi e-hydrogen), which could power fuel cell vehicles some day. Because there is not a widespread hydrogen infrastructure, however, the hydrogen is then reacted with CO_2 in a methanation plant to produce renewable synthetic methane, or Audi e-gas.

Chemically speaking, this e-gas is identical to fossil-based natural gas. As such, it can be distributed to CNG stations via a natural gas network. The e-gas from Werlte (roughly 1,000 tons per year) can power 1,500 new Audi A3 Sportback g-tron vehicles for a distance of 15,000 km (9,320 mi) every year.

Since July 2012, Clariant AG in Straubing near Munich has produced cellulosic ethanol on a large scale by using its Sunliquid® process. This process converts wheat straw into cellulosic ethanol. Mercedes-Benz decided to run fleet tests for 1 year with Sunliquid 20 (Figure 4). German car manufacturers in general see significant benefits from using an E20 fuel, if engines are optimized for this fuel grade.Cellulosic ethanol is mixed with conventional fuel components to create the new fuel. As a benefit, cellulosic ethanol is virtually CO_2-neutral, and there is no competition with food production or for agricultural acreage. According to the tests, Sunliquid 20 improves engine efficiency so that its 4%-less energy content (compared with that of E10) is more than compensated for. Another notable finding was the 50% improvement in particle count emissions of Sunliquid 20 over those from using the EU reference fuel, EU5. In addition, the fuel blend of cellulosic ethanol 20 demonstrates GHG emission savings of up to 95% across the entire value chain (well-to-wheel) (Clariant AG 2014).

Fig. 4 Mercedes-Benz Cars in Front of the Sunliquid® Demonstration Plant
(Source: Daimler AG)

Outlook

At present, it is very difficult to provide a reliable outlook for the use of advanced motor fuels over both the short and long term. The EU target for 2020 is still to use 10% renewable energy sources in transportation. The biggest uncertainty is how the 2014 RED/FQD amendment/political agreement of the European Council will be implemented (i.e., as a cap on food-crop-based biofuels, multiple counting, ILUC factor). Discussions in the European Parliament are ongoing. Also, an EU white paper on the post-2020 energy future, published on January 22, 2014, does not provide specific incentives for the transportation sector. So it is still uncertain when decisions can be expected. On a national level in Germany, the replacement of the biofuels quota with a CO_2-reduction quota will need to be implemented on a large-scale, actionable basis from 2015 onward. Further R&D activities (e.g., reducing the GHG emissions of biofuels to make them compatible with the amended RED/FQD, upscaling advanced biofuel production processes to an industrial scale) are other important challenges.

Additional Sources

- Biofuels Portal, www.bio-kraftstoffe.info
- Kraftfahrt-Bundesamt, www.kba.de
- Union zur Förderung von Oel–und Proteinpflanzen e.V., www.ufop.de
- Bundesverband der deutschen Bioethanolwirtschaft, www.bdbe.de
- Bundesverband Regenerative Kraft, www.brm-ev.de/de
- Verbad der Ölsaaten-verarbeitenden industrie in Deutschland, www.ovid-verband.de
- Verband der Deutschen Biokraftstoffindustrie e.V., www.biokraftstoffverband.de
- Agentur für Erneuerbare Energien, www.unendlich-viel-energie.de
- Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, www.tfz.bayern.de
- Initiative for natural gas-based mobility, www.erdgasmobilitaet.info/en/home.html

Benefits of Participation in the AMF IA

The German biofuels market is one of the largest in the world. And a result of Germany's changing political framework, advanced motor fuels will become more important there over both the short and the long terms. FNR, as a national funding organization, addresses many different issues related to advanced motor fuels made of biomass. The AMF IA addresses most of the issues that are important in Germany (such as facilitating the widespread use of sustainable fuels of high quality). Most of the sponsored research projects under the AMF IA umbrella are relevant to Germany's funding activities, and the AMF IA's common projects that involve many sponsors offer Germany the opportunity for cost-efficient participation. Being part of the AMF IA also gives German researchers and stakeholders the chance to be part of a network of researchers from around the world who are doing excellent science. For example, Germany recently presented results on work being done for the research project Annex 45, "Synthesis, Characterization, and Use of Hydro Treated Oils and Fats for Engine Operation," with partners from Denmark and the United States. The operating agent for the Annex is the Chair of Piston Machines and Internal Combustion Engines at Rostock University.

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fileadmin/user_upload/downloads/Positionen_Thesen/141204_dena_Policy_paper_RED_FQD_final.pdf, accessed January 20, 2015.

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Israel

Introduction

Israel was, until recently, an energy-poor country that relied almost entirely on imports of primary energy commodities. Despite discoveries of natural gas (NG) from offshore fields, the main challenge associated with decreasing dependency on oil imports remains how to implement the use of alternative fuels in the transportation sector.

In the year 2014, the consumption of fuels for transportation in Israel had grown at 2%, with consumption reaching approximately 2.7 million tons of gasoline and a similar amount of diesel. Details on the vehicle fleet in Israel are presented in Table 1.

Table 1 Fuel and Vehicle Use in Israel in 2014

Parameter	Gasoline	Diesel					Jet Fuel
Type of vehicle	Mainly private vehicles	Light-duty trucks	Medium- and heavy-duty trucks	Buses	Private vehicles and taxis	Trains	Jet planes
No. of vehicles	2.2 million	217,000	75,000	16,000	100,000	Not specified	Not specified
Current usage of fuel (%)	43	14.5	18	5.5	5.5	0.5	13

Policies and Legislation

On January 2013, the Cabinet of the Government of Israel approved a program to encourage lowering dependence on crude oil for transportation for energy security, economic, and environmental reasons. This “Fuel Choices Initiative” sets ambitious targets for Israel: cut the use of oil for transportation by 30% by 2020 and by 60% by 2025, as compared with currently projected, “business as usual” oil consumption. The targets are based on a bottom-up analysis of the various Israeli transportation market sectors, under the assumption that any solution must be economically viable for the end user as well as for the economy.

Among the alternative fuels are compressed natural gas (CNG, mainly for heavy-duty trucks and buses), methanol blends (for cars, starting with a 15% blend and advancing later to higher blends), and electric mobility (mainly for buses, mass transit solutions, and inner solutions). The Fuel Choices Initiative also aims to implement, in the longer term, projects that use biofuels from second- and third-generation nonedible crops (developed in Israel) and a process of waste-to-energy conversion.

More information about this program can be found at http://www.fuelchoicesinitiative.com/.

Activities pursued by the Israeli Government for the local market include these:

- Set regulations for new types of fuels,
- Establish pilot projects for methanol production,
- Sponsor local infrastructure
- Implement Green Tax 3: adopt the tax regime to new types of fuels,
- Set up pilot projects for E- Bus,
- Switch major users to alternative fuels, and
- Support other types of transportation.

Implementation: Use of Advanced Motor Fuels

Main achievements thus far:

- Four research centers:
  - Solar Fuels I-Core. To address the challenge to generate clean, efficient energy from renewable sources.
  - Israel National Research Center for Electrochemical Propulsion (INREP). To address the challenge to improve energy storage and integration into mobility platforms.
  - Agro-Energy Research (Vulcani) Center. To address the challenge to generate clean, efficient energy from renewable sources.
  - Institute for Innovation in Transportation.
- Research grants (involving a total of 130 groups of researchers).
- Start-up investments (there are a couple of dozen start-ups)
- $100-million Co- Invest Fund
- 15 pilot projects
- Ecomotion community (consists of 800 entrepreneurs)

Natural Gas and Synthetic Fuels for the Domestic Market

Recent findings on off-shore NG fields are turning Israel into a leading regional energy supplier. To fulfill the economic and energy potential of its NG resources, the Israeli Government is building a long-term strategy and policies for increasing the use of NG in Israel.

One of the main targets of the Government is to increase the use of NG and NG-based synthetic fuels in the Israeli transportation sector. This target, backed by Government policies and regulations, is expected to generate significant investments and vibrant business activity in the growing local market. Companies and investors that will enter this new and innovative alternative energy sector will also lead in the growing global NG sector.

The Ministry of Energy and Water Resources acts to implement fuels that are based on NG — namely, CNG, GTL (gas-to-liquid; drop-in) fuels, and methanol. The Ministry conducts well-to- wheel (WTW) projects and is involved in all technical, regulatory, and economic aspects. This task is supported by a number of pilot and demonstration projects in this field and by a techno-economical study of these fuels and their relevance to the Israeli market. The extensive analysis has considered all relevant segments of the supply chain, including the production, transportation, and consumption of the fuels by end-users, and the required infrastructure. An executive summary of the analysis can be found at http://energy.gov.il/Subjects/EGOil Replacement/Documents/ORcng.pdf.

CNG

The regulatory status of CNG is relatively established. The Israeli mandatory requirements (IMRs) for motor vehicles are compatible with the European requirements, regulations, and documentation as specified in the Whole Vehicle Type Approval (WVTA, certificate from EU).

Other mandatory requirements, laws, and standards for NG and CNG can be uploaded from the website of the Ministry of National Infrastructure, Energy and Water Resources at http://energy.gov.il/English/Subjects/ Natural%20Gas/Pages/GxmsMniNGLobby.aspx:

- Gas (Safety and Licensing) Law, 5749-1989,
- Natural Gas Sector Law, 5762-2002,
- Industrial Gas Installation Directive – NGA, and
- Compressed Natural Gas Directive – NGA.

The following standards can be purchased from the website of the Israel Standards Institute at www.sii.org.il:

- Automotive NG: I.S 6119 and
- CNG fuelling stations for vehicles: I.S. 6236.

Methanol

Israel is promoting the use of methanol as fuel for transportation. This promotion is being implemented by a program that is testing the use of M15 (15% methanol and 85% gasoline) as fuel for unmodified vehicles that are intended for use with RON95 (Research Octane Number 95).

As part of this program, Israel is cooperating with the JRC VELA laboratory in Italy to develop standardized emissions tests for the M15 fuel. These tests compared carbonyl emissions from RON95, M15, and E10. The results suggest that the use of M15 or E10 does not have a significant effect on carbonyl emissions.

Field experiments are being conducted to examine the feasibility of using M15 both in the gasoline vehicles used in Israel and in the logistic systems used to transport the gasoline all the way to the vehicles (including fuel tankers, underground fuel tanks, piping, and fuel dispensers at the filling stations). All experiments involve comparisons with standard 95-octane gasoline. The experiments include testing the influence of the blend on the durability of the various types of rubber and plastic found in the fuel chain, testing metals for corrosion, testing the influence of the blend on the oils in vehicles, reviewing the effect of the different fuels on the driver, testing the vehicle's performance, checking differences in the exhaust fumes from this fuel and in those from gasoline, testing the wear in the engine parts, and other additional tests.

From the various tests conducted thus far it appears that at this stage, there are very few and only small modification needed, if any.

Several car manufacturers showed interest in the results. Accordingly, the Government started to work on creating a national standard for M15 fuel.

GTL Fuels

In the past year, the Ministry has studied the potential benefits of developing GTL plants in Israel for producing liquid synthetic fuels (gasoline and diesel) from NG. The main strengths of GTL fuels are as follows:

- Energy security and diversity. GTL fuels make up the highest percentage of oil substitutes. The ability to rely on self-produced fuels greatly diminishes the risks and dependencies associated with relying on imported oil.
- Use of existing infrastructure. The fuel can be used without requiring any modifications to existing infrastructure, vehicles, or driving habits.
- Other uses: The GTL process allows for the production of various distillates, such as kerosene and petrochemical products, that hedge demand risks.
- Export potential. An increasing demand in Europe and elsewhere may result in export markets for hedging local demand.
- Economics. The techno-economic analysis has shown that the economic viability of developing a GTL plant is highly attractive, especially if the plant is in a configuration that is integrated with existing refineries.

Capital costs are estimated to range from $60,000 to $100,000 US per barrel of daily production, depending on the plant configuration, with the higher estimated cost reflecting the expense of a standalone facility.

In June 2014, the Ministry of National Infrastructure, Energy and Water Resources of Israel published an invitation to submit standpoints, information, and expressions of interest regarding the possibility of building and operating a GTL facility in Israel.

Electric Vehicle (EV) and Energy Storage Cluster

The EV and Energy Storage Cluster emerged from decades of academic and applied research in the fields of electrochemistry and electric engineering; from the development and production of special energy applications for use in the defense and biomedical sectors; from world-class, innovative information and communication technology industries; and from a local business culture that supports entrepreneurship and innovation.

Israel has pioneering startup and technological companies that have entered the world of EVs and energy storage, offering innovative solutions and products for transforming electric transportation into an economically and technologically viable alternative. Companies in the cluster develop and produce improved batteries; new types of fuel cells, super-capacitors, and metal-air batteries; grid and battery management systems; EV infrastructure solutions; and managed EV charging systems.

The Israeli Government has taken steps to incentivize a local market for implementing EV technologies and infrastructures and is offering large tax benefits and regulatory support. The Israeli business environment for EV technologies and infrastructures and the Government incentives are creating a local ecosystem that supports the expansion of companies into global markets.

Engines, Composite Materials, and Other Technologies

Thanks to advanced academic and applied research and defense-related developments in diverse technological fields and also to the local entrepreneurial spirit, many Israeli companies and startups are providing various solutions to help vehicles reduce oil consumption. Creative companies are developing new engines; efficient powertrain technologies; and new, composite, light materials.

Biofuels and Energy Agriculture Cluster

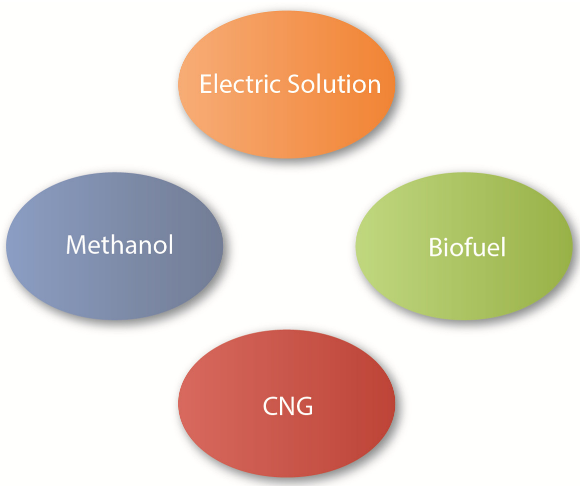
The Biofuels and Energy Agriculture Cluster emerged from decades of academic and applied research in the fields of biotech, agriculture, and chemistry; from world-leading agro-tech and agro-industry; and from advanced biotech industries.

Israeli startups and technology companies are at the forefront of biofuel and agricultural R&D and considered world leaders on multiple fronts. New types of fuel and biomass crops, as well as algae technologies, are being developed; better methods for breeding, cultivating, and irrigating energy crops are positioning energy production at the forefront of the next generation of agriculture; and innovative processes and catalysts for converting feedstock and waste into fuels are about to change the economics of biofuels.

Leading Israeli agricultural companies are starting to work on global agricultural projects, introducing their knowledge and experience and improving crop yields. The local Israeli market, due to its small size, is focusing on promoting second- and third-generation, locally produced biofuels, and through that effort, giving its companies and investors a global competitive edge.

Outlook

Figures 1 and 2 show where the market is expected to go.



Light-duty private vehicles, trucks, and taxis; heavy-duty buses and trucks; EVs and PHEVs; jets

Fig. 1 Market for Advanced Motor Fuels in Israel

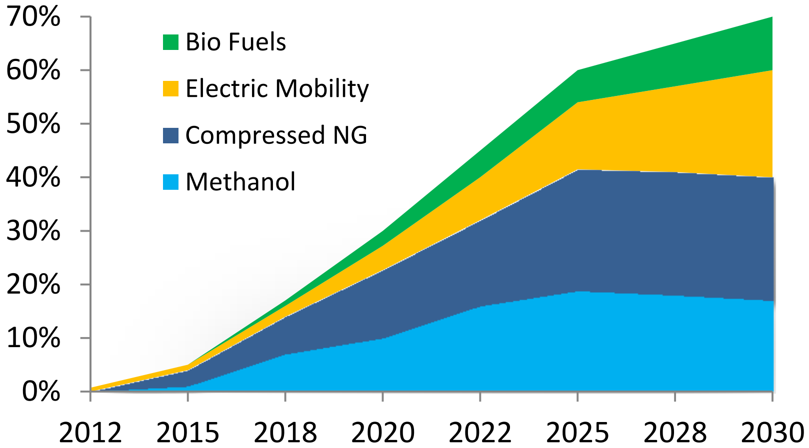


Fig. 2 Expected Penetration Rate for Alternative Fuels in Israel

Additional References

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AMF IA Success Stories
Participation in the AMF IA 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 its projected strategies.

Italy

Introduction

In 2013, the consumption of primary energy in Italy was around 172,994 million metric tons or megatons of petroleum equivalent (Mtpe). As in previous years, oil remained the main energy source, representing 33% of consumption. Natural gas (NG) followed closely at 34%, and the percentage for renewable sources was 20% of consumption (Figure 1).

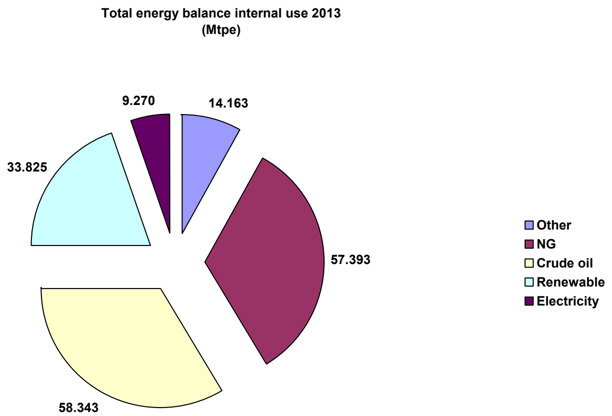

Fig. 1 Total Energy Balance by Type of Source in Italy in 2013
(Source: Ministry for Economic Development, 2013, National Energy Balance)

In 2013, Italy depended largely on imported oil; it imported 77,815 Mtpe (Figure 2).

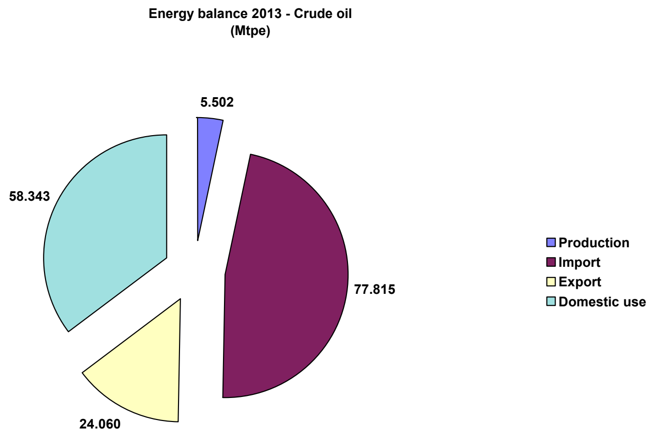

Fig. 2 Crude Oil Energy Balance in Italy in 2013
(Source: Ministry for Economic Development, 2013, National Energy Balance)

The major user (about 67%) of derived oil products in 2013 was the transportation sector (Figure 3).

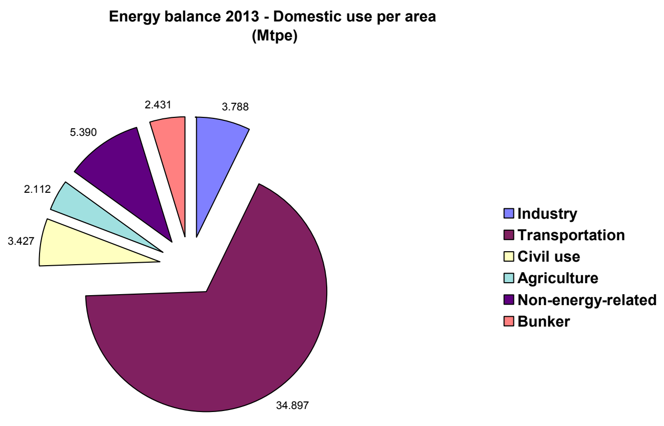

Fig. 3 Domestic Use of Oil per Sector in Italy in 2013
(Source: Ministry of Economic Development, 2013, National Energy Balance)

The main fuels used in road transportation were diesel fuel (66%), followed by gasoline (26%). Significant amounts of natural gas (NG, 3%) and liquefied petroleum gas (LPG, 5%) were also used in this sector (Figure 4).

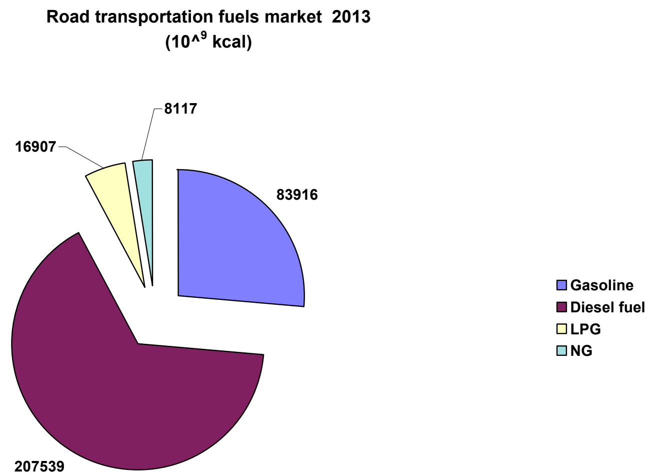

Fig. 4 Market for Different Types of Fuels in the Road Transportation Sector in Italy in 2013
(Source: Ministry for Economic Development, 2012, National Energy Balance)

With regard to the types of vehicles using the fuels, the top categories (in terms of number of vehicles) were passenger cars (75.95%), followed by motorcycles (13.48%) and lorries (8.09%) (Figure 5).

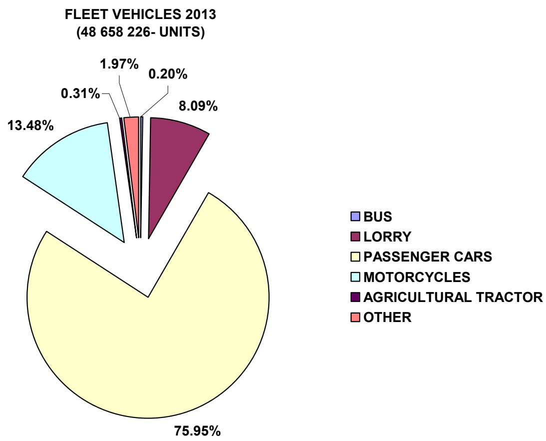

Fig. 5 Types of Fleet Vehicles Used in the Road Transportation Sector in Italy in 2013
(Source: ACI, 2013, Autoritratto)

With regard to passenger cars, the top categories were those that ran on gasoline (52.06%), followed by diesel fuel (40.35%). A significant percentage of vehicles also ran on NG (2.09%) and LPG (5.37%) (Figure 6).

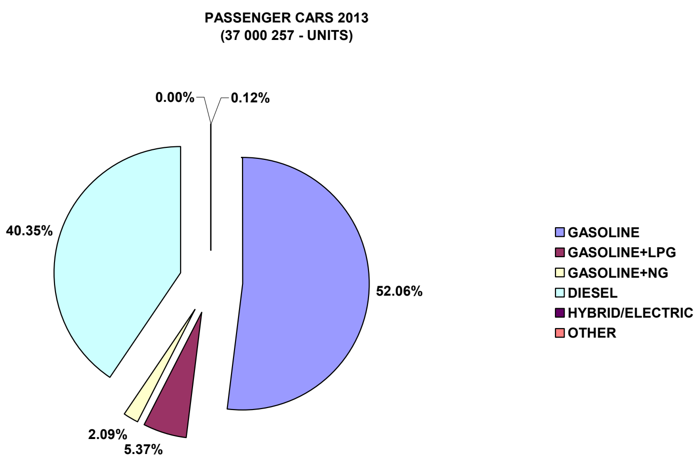

Fig. 6 Types of Fuel Used by Passenger Cars in Ital in 2013
(Source: ACI – Autoritratto 2013)

In addition, diesel-fuelled vehicles could employ up to 7% of biodiesel, and gasoline-fuelled vehicles could employ gasoline containing oxygenated bio-fuels in which the oxygen content could amount to 3.7%.

Policies and Legislation

In both the long term and the very long term (until 2030–2050), Italy will subscribe to the spirit of the European Roadmap 2050 for a low-carbon economy. It aims to reduce emissions by up to 80%. In recent decades, however, it has been difficult to predict developments in technology and to predict vehicle and fuel markets, especially over the long term. Italy therefore intends to adopt a flexible and efficient long-term strategy for pursuing its key low-carbon policy. It will focus on and exploit (especially through research and technological developments) any pursuits that could result in significant positive changes. Examples would be more rapid cost reductions in renewable and storage technologies, use of biofuels, and the capture and storage of carbon dioxide (CO_2).

Italian Law has adopted two European directives: the Renewable Energy Directive (RED, 2009/28/EC) and Fuel Quality Directive (FQD, 2009/30/EC). Under Italian Law 2009/99 (July 23, 2009) and in accordance with European Specification EN590:2009, the Italian Government has given permission for diesel fuel to contain biodiesel fuel (fatty acid methyl ester or FAME) in a percentage of up to 7%, as in other European countries. Italian Decree 2011-28 acknowledges all European directives that promote the use of fuels or any other renewable sources. Italy grants energy incentives, like double-counting for using second-generation renewable sources (like those derived from wood cellulose or plant and animal residues). Italian Decree 2012-83 of June 22, 2012, established a limit of 20% for double-counting assigned to second-generation renewable sources.

Moreover, Italian municipalities have implemented important local measures that affect transportation. In order to improve air quality, reduce emissions of particulate matter with a mean diameter of 10 µm or less (PM_{10}), “smooth out” traffic on the road system, and lower noise in the cities, they have introduced measures to limit traffic in urban areas.

Implementation: Use of Advanced Motor Fuels

Biodiesel is the primary source for renewable advanced motor fuel in Italy. From 2009 until the present, biodiesel has been blended with up to 7 vol% diesel fuel. The renewable fuel currently used in gasoline is bio-ethyl tertiary butyl ether (ETBE), derived from bioethanol. In 2013, the amount of bio-ETBE used in gasoline was 85,000 metric tons (85 kt), and the amount used in bio-ethanol was 2.3 kt.

At the end of 2013, there were 996 NG stations in the country, as well as a fleet of more than 700,000 passenger cars that use NG. The network was located mostly in northern Italy; central and southern Italy were not homogenously represented. In the region of Sardinia Island, there were no NG service stations at all. At the end of 2013, the LPG filling station network consisted of 3,250 stations, and there was a fleet of more than 1.9 million LPG-fuelled passenger cars. Figure 7 shows percentages of motor fuels used in 2013.

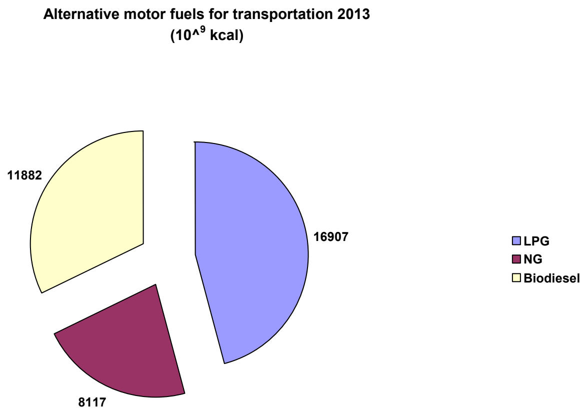

Fig. 7 Alternative Motor Fuels Used for Transportation in Italy in 2013
(Source: Ministry for Economic Development, 2013, National Energy Balance)

In 2012 the Italian oil and gas company Eni launched the Green Refinery Project, which will lead to the conversion of the Venice Refinery into a bio-refinery, producing innovative, high-quality bio-fuels. The project is the first in the world designed to convert a conventional refinery into a bio-refinery by using the UOP/Eni Ecofining™ technology developed and patented by Eni in collaboration with UOP, a Honeywell company.

The Green Refinery Project started with an initial conversion of the existing facilities of the Venice refinery; that was started in the second quarter of 2013 and completed by the end of 2013. Biofuel production started in the second quarter of 2014 and has grown progressively as new facilities have begun operating. The new facilities still to be built under the project will be completed in 2015.

At the new green plant site in Venice, industrial operations will be maintained in an economically sustainable manner over the long term, with a low environmental impact. Another activity associated with the Green Refinery Project will be the construction of a new logistics center at the Venice plant site.

The Green Refinery Project is based on distinctive environmental technologies that are highly compatible with Eni's continued commitment to research and innovation.

In 2006, Chemtex-M&G began research and development)R&D) activities designed to demonstrate the technological and environmental sustainability of second-generation bioethanol production from lignocellulosic feedstock (PROESA™ technology). Specifically, Chemtex-M&G conducted research on cellulosic crop optimization and agronomics; designed, engineered, developed, and tested (at both laboratory and pilot scales) proprietary technology and components for key aspects of the biomass-to-fuel conversion process; and partnered with leading technology providers to obtain the key biological process components. The construction of a bioethanol facility to demonstrate this technology in Europe is the next step in developing the Chemtex-M&G technology. The world's largest cellulosic ethanol plant — in Crescentino, Vercelli Province, Italy — began production in 2012. The M&G PROESA™ process technology is extremely economical in converting nonfood biomass to sugars for the production of bioethanol. On October 9, 2013, the new technology was inaugurated at the plant in the presence of the Minister of Economic Development and other local authorities

With regard to the optimization of the fossil-fuel-refining process, in 2013, Eni completed construction of the first plant for the total conversion of fossil fuel crudes at the Sannazzaro Refinery. The conversion process is based on its proprietary Eni Slurry Technology (EST). Startup was completed on October 14, 2013. This new hydroconversion process, which can completely convert unconventional oil, heavy crude, and tar sands into high-quality, high-performance fuels, is based on slurry technology that uses a special catalyst and self-starting hydrogen from natural gas. EST is the first invention in the history of scientific discoveries related to the oil sector that came out of Italy, and it came 40 years after the last oil manufacturing process was invented. Unlike traditional oil processes, EST can produce gasoline and gas-oil without generating coke or fuel oil, for which the market is constantly declining.

Outlook

Italy has confirmed the 2020 target of 10% for biofuels. At the same time, the country intends to play an active part in reviewing the European Directive, with a view toward promoting second- and third-generation biofuels. The review should leave open the possibility for a European assessment on whether to postpone the target, in case more time is needed to adequately develop these technologies.

In the short run, the Italian Government has already adopted a number of "tactical" measures to steer the sector toward second-generation biofuel production (where Italy has reached levels of excellence). These measures are also designed to foster the development of the domestic and EU system throughout the production sector.

In the transport sector, biofuel development is the subject of a wide-ranging international debate, in view of doubts regarding the real sustainability of "traditional" biofuels. The key decision will be whether to transition to second- and third-generation biofuels. For now, however, these biofuels are not able to completely replace traditional sources.

It will also be important to carefully evaluate the prospects for developing the domestic production of bio-methane for transport use.

Italian Decree 10 October 2014 GU n°250 27-10-2014 defined the yearly minimum increases in the percentage of energy to be derived from biocomponents from 2015 to 2022 as follows:

- From January 1 to December 31, 2015: 5% biocomponents
- From January 1 to December 31, 2016: 5.5% biocomponents
- From January 1 to December 31, 2017: 6.5% biocomponents
- From January 1 to December 31, 2018: 7.5% biofuels, of which at least 1.2% is advanced biofuels
- From January 1 to December 31, 2019: 9% biofuels, of which at least 1.2% is advanced biofuels
- From January 1 to December 31, 2020: 10% biofuels, of which at least 1.6% is advanced biofuels
- From January 1 to December 31, 2021: 10% biofuels, of which at least 1.6% is advanced biofuels
- From January 1 to December 31, 2022: 10% biofuels, of which at least 2% is advanced biofuels

In 2014 the minimum percentage of energy to be derived from bio-components was 5%. Algae, straw, crude glycerin, bagasse, shells, and other cellulosic material were considered advanced biofuels.

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AMF IA Success Stories
In Italy, information on AMF IA activities is disseminated during regular meetings at the Ministry of Economic Development attended by the ExCo delegates of the IEA “end use” Implementing Agreements.

Japan

Introduction

The transportation sector accounts for 23.1% of total energy consumption in Japan. Of this transportation sector energy consumption, passenger transport is responsible for 62.6%, and freight transport is responsible for the other 37.4%. Energy for transport in Japan depends mostly on imported oil (Figure 1).

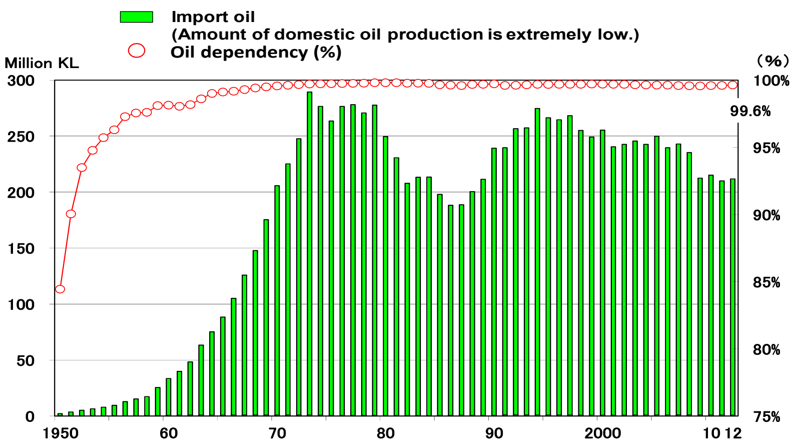

Fig. 1 Transition of Crude Oil Imports and Oil Dependency in Japan [1]

Figure 2 shows the energy sources used in the transportation sector [2]. Oil-related energy accounts for 97.8% of the total usage. The market for alternative fuels is very small in Japan, and the number of alternative fuel vehicles is small (Table 1). Methanol, compressed natural gas (CNG), hybrid, and electric vehicles currently constitute the low-emission vehicles. The number of hybrid vehicles is rather large, and the number of passenger hybrid vehicles contributes to this. CNG vehicles currently account for the largest number of vehicles in the low-emission truck category. The latest news is that Toyota launched a fuel cell passenger vehicle in December 2014.

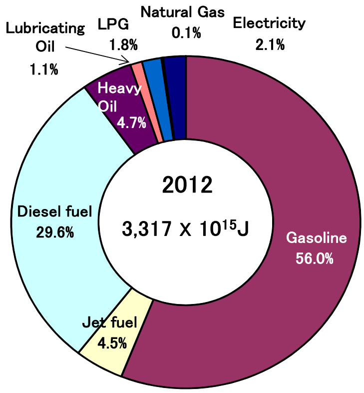

Fig. 2 Energy Sources Used in the Transportation Sector in Japan in 2012

Table 1 Current Penetration of Low-Emission Vehicles in Japan in 2014

Vehicle Type	Methanol [3]	CNG [4]	Hybrid [5])	EV [6]	Vehicle Registration [7]
Passenger vehicles	–	1,564	3,823,057	38,794	40,009,350
Light, mid, and heavy-duty trucks	576	5,667 18,984	13,200	31	5,912,253
Buses	–	1,570	969	28	226,047
Special vehicles	–	3,901	6,144	34	1,654,739
Small vehicles	–	11,915	188	15,870	Not available
Total	576	43,601	3,843,558	54,757	No available

Policies and Legislation

In April 2014, the Japanese Government approved the new Strategic Energy Plan, which forms the basis for Japan's energy policies for the immediate future [8]. The basic concepts behind this plan are to ensure stable energy supplies, environmental suitability, and the use of market principles in a long-term, comprehensive, and systematic set of policies. The plan places a powerful emphasis on a comprehensive, strategic approach to energy, including the development and introduction of various types of energy sources, the technological development of fuel cells and other types of new energy sources, the use of nuclear power based on the assumption that safety can be ensured, the establishment of an energy infrastructure, and the revision of regulations. It also incorporates measures to ensure stable oil supplies, such as the adoption of a comprehensive raw materials strategy, including strengthening relations with oil-producing nations, and building a robust business foundation for the oil industry.

Implementation: Use of Advanced Motor Fuels

Liquefied Petroleum Gas (LPG) Engines

The number of registered vehicles in Japan that run on LPG has been decreasing steadily since reaching a peak of 319,000 in 1991. In 2013, this figure was 236,000, a decrease of around 8,000 vehicles from 2012. The reasons behind this decline were the long-term rise in LPG prices and the erosion of the relative cost merit of LPG vehicles as gasoline vehicles become more fuel efficient.

Most of the LPG imported into Japan is produced in the Middle East, and the import price is strongly influenced by the contract price (CP) published by the Saudi Arabian Oil Company (also known as Saudi Aramco), a national petroleum company in Saudi Arabia. However, the production of natural gas (NG) is dramatically increasing in North America, resulting in higher production of LPG derived from this source. The LPG market price in this region (called the Mont Belvieu price) is lower than the CP. It has been pointed out that if Japan imported LPG from North America, the CP might cease to be the dominating force in the market, causing the price of LPG to fall. It currently takes 35 to 45 days to transport gas from North America to Japan, from ports of loading on the U.S. Eastern or Southern Coasts, across the Atlantic Ocean, and through the Suez Canal or around the Cape of Good Hope. However, once expansion work of the Panama Canal is completed (scheduled date of completion: 2016), the transportation time will be cut in half to 20 days, which should make it easier to import cheaper LPG from North America.

Focusing on technological developments, two reports that were published in 2013 describe research on how to accurately measure the octane number, one of the fundamental properties of fuel. The octane number of a conventional liquid fuel can be measured by using Cooperative Fuel Research (CFR) engines. However, these engines are not designed to handle gaseous fuels. Morganti, Dryer, and others added a supply system capable of independently adjusting the flow rates of the four main components of LPG (propane, propylene, n-butane, and i-butane) into a conventional CFR engine to measure the octane number of LPG. This method was used to measure the research octane number (RON) and motor octane number (MON) of each element separately and as a mixed gas. The octane numbers obtained using this method matched those measured in accordance with the (currently expired) test method defined by the American Society for Testing and Materials (ASTM) from the 1940s to 1960s.

Genchi et al. measured the MON of a mixed fuel containing LPG (MON: 92.6) and commercially available gasoline (MON: 84.1) by changing the fuel supply method from a carburetor to an injector based on a CFR engine. Results yielded an empirical formula for obtaining the MON of a fuel blend as a function of its LPG content. According to this method, a fuel with an LPG content of 30% will have a MON of 88.1, and a fuel with an LPG content of 40% will have a MON of 90, which is equivalent to premium gasoline. Therefore, blending LPG with gasoline may be regarded as a way of increasing the octane number of the fuel.

The Hyundai research group reported on the particulate emission number from gasoline direct injection (DI) and LPG direct injection (LPDI) engines. In the case of LPDI, most particulate matter emissions are nucleation mode particles that are 23 mm or less in size. In the Federal Test Procedure (FTP) of the U.S. Environmental Protection Agency (EPA), commonly known as FTP-75), the PN of LPDI emissions is set 60% lower than that of gasoline DI engines.

Other notable reports described the emissions performance of large LPG engines for buses, improvements to the injection performance of a lean-burn LPDI engine, and safety evaluations of LPG tanks for passenger vehicles.

Natural Gas Engines

On May 17, 2012, the U.S. Department of Energy announced that it would permit the export of liquid natural gas (LNG) to countries, such as Japan, that had yet to sign a free trade agreement (FTA) with the United States. As a result, exports of LNG to Japan are due to start in or around 2017. The resulting diversification of LNG procurement should help to lower the price of natural gas in Japan.

In December 2012, the Japanese Government announced the Basic Act for National Resilience Contributing to Preventing and Mitigating Disasters. This Act calls for activities to promote the popularization of CNG vehicles to help improve energy security in the fields of transportation and logistics. Because of this, the use of natural gas vehicles (NGVs) is gaining momentum in Japan.

At the end of 2013, there were roughly 19.9 million NGVs on the road worldwide, an increase of about 2.7 million from 2012. Of this total, there were 43,601 NGVs on the roads in Japan at the end of March 2014.

In June 2012, Isuzu Motors Ltd. announced that it would launch a large gross vehicle weight (GVW) CNG vehicle (25-t Class), start a monitored LNG vehicle test drive program, and develop an ultra-high efficiency NG engine using a technique called dual-fuel compression ignition. In addition, Mazda Motor Corporation unveiled the Mazda3 SKYACTIV-CNG concept (Figure 3) at the Tokyo Motor Show in January 2012. This vehicle uses a dual-fuel system that enables it to switch between running on gasoline or on CNG.

Outside Japan, in June 2012, the Swedish automaker Scania AB delivered the world's first NG truck that complies with the Euro VI emission regulations to a delivery company in Sweden. Scania designed two Euro VI-compliant engines with the same performance as a diesel engine. The power ratings of these engines are 280 hp (torque: 1,350 Nm) and 340 hp (1,600 Nm).

Basic research for NG engines is being carried out mainly by universities. Waseda University is running a trial of an auxiliary ignition method using diesel injection to control combustion, including homogeneous charge compression ignition (HCCI) in an NG engine. This research has confirmed that stable ignition and combustion can be achieved by adjusting the supply proportion of diesel, even with high rates of exhaust gas recirculation (EGR), which conventionally make it difficult to ignite the fuel. Honda R&D Co., Ltd., is working on identifying the effects of the combustion chamber shape in a high-compression-ratio NG engine. By comparing two prototype engines with the same displacement but with different stroke/bore ratios (1.0 and 2.1), this research has confirmed that brake thermal efficiency can be increased by 9.1% with a stroke/bore ratio of 2.1 (39.0%) compared to a stroke/bore ratio of 1.0 (29.9%).

The goal is that this research will help automakers soon launch NG vehicles powered by highly efficient engines to the Japanese market soon.

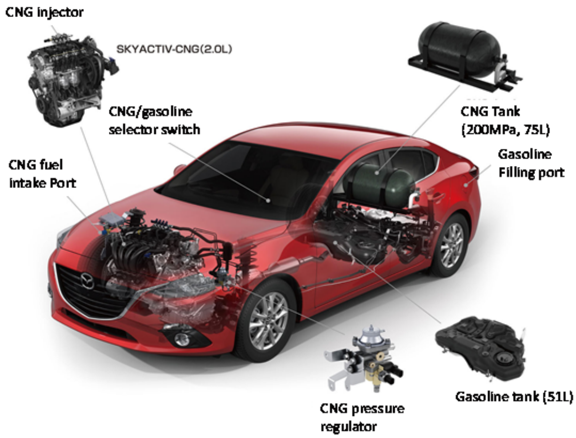

Fig. 3 Mazda SKYACTIV-CNG Concept

Hydrogen Engines

Hydrogen is regarded as having a critical role to play in the future to help improve energy security and address global warming. Hydrogen engines use the same power source as fuel cell electric vehicles (FCEVs) but can be produced at a lower cost by using existing production equipment and auxiliary equipment based on well-established technology. Universities, research institutions, and automakers inside and outside Japan are currently researching these engines. Issues associated with hydrogen engines include restricting abnormal combustion caused by the high ignitability of hydrogen, employing measures to counter the large quantities of nitrogen oxides (NO_x) generated during high-power operating regimes, and improving thermal efficiency. In recent years, research has started to focus on DI as a way to help resolve these issues.

In 2013, several research papers were published both inside and outside Japan. Published research in Japan included papers by Tokyo City University and the National Traffic Safety and Environmental Laboratory (NTSEL) group, Mazda, and Toyota. Tokyo City University and the NTSEL group proposed a combustion concept that ignites a rich-mixture plume during the injection period or directly after the completion of injection (called the plume ignition combustion concept, or PCC). Shadowgraph analysis was carried out to identify why thermal efficiency in partial-load operation improved in comparison with pre-mixed combustion. This analysis found that this method increased combustion speed, reduced unburned hydrogen, and lowered cooling loss. However, the issue of increased NO_x remains.

Mazda is developing a low-pressure DI hydrogen rotary engine, taking advantage of the suitability of rotary engines for low-pressure DI. Computer aided engineering (CAE) analysis of the mixture's distribution suggested potential improvements in thermal efficiency by optimizing the direction and timing of injection. Furthermore, a vehicle equipped with a hydrogen rotary engine as a range extender had NO_x emissions substantially below super ultra-low emission vehicle (SULEV) standards in the JC08 test cycle, when used in combination with lean-burn and a NO_x storage catalyst.

Toyota is researching a high-thermal-efficiency, NO_x-free, argon-circulated hydrogen engine. This engine uses an argon circulation method in which oxygen is supplied to an argon-filled intake manifold, hydrogen is directly injected and combusted, and the water vapor combustion byproduct is separated from the exhaust gas by condensation. This research has confirmed the auto-ignition performance of the method, the combustion chamber shape, injector nozzle position, oxygen concentration, and number of injector nozzle holes. Measurements indicated that this engine achieved an indicated thermal efficiency of 60.9% by improving the degree of constant volume combustion and reducing cooling losses.

Outside Japan, the University of Michigan and Ford Motor Company group developed a dual-zone combustion system, in which hydrogen is injected to the left and right of the cylinder head center and one spark plug is provided on each side. This engine achieved an indicated thermal efficiency of 47.7% and NO_x emissions of 51 parts per million (ppm).

Dimethyl Ether (DME) Engines

After the so-called shale gas revolution, researchers in North America have begun to study DME as a way of making use of the abundant NG resources in the region. In a press release on June 6, 2013, Oberon Fuels announced that it would start North America's first production of fuel-grade DME at a pilot plant starting in 2015. The company also started DME fuel-quality standardization efforts in conjunction with ASTM. In addition, Volvo issued a press release on June 7, 2013, stating that it would start mass production of a DME truck in North America in 2015.

The standardization of DME fuel is being promoted through discussions in International Organization for Standardization (ISO)/TC 28/SC 4/WG (Working Group) 13. Draft international standard (DIS) balloting has been completed with respect to DME quality as a base fuel, including as a base fuel for vehicles (ISO DIS 16861), and four analytic methods under discussion by WG 14 in the same organization: (1) determination of total sulfur by the ultraviolet fluorescence method (DIS 17198), (2) determination of evaporation residues (DIS 17786), (3) determination of water content (DIS 17197), and (4) determination of impurities by the gas chromatographic method (DIS 17196). Various technical comments were received, so these DISs are still pending registration as final draft international standards (FDISs). If a majority are found to be in favor as obtained by FDIS balloting within 2 months, plans are to issue these as ISO standards in 2014. Additional studies on DME fuel quality for vehicles are also due to start.

Stirling Engines

Stirling engines have been adopted mainly for combined heat and power (CHP) systems for household use, solar power generation, and as a closed-cycle engine for propulsion and power generation on submarines.

Commercial projects using these applications, in addition to engines and engine systems in or close to mass production, are as follows: Infinia Corporation in the United States has developed a 3.5-kW-class, solar power generation system using a free-piston Stirling engine. A solar farm consisting of 429 dishes (1.5 MW) using this system has been installed at the Tooele U.S. Army Depot in Utah. At the end of 2013, Qnergy acquired the assets of Infinia Corporation and started preparing to mass-produce 3.5-kW and 7.5-kW-class, free-piston engines developed by Infinia. The main applications for these engines are CHP systems for household use and solar power generation.

In addition, a CHP unit for household use fuelled by utility gas (power generation capacity of 1 kW, heating capacity range of 3 to 24 kW) has already been commercialized. MEC Microgen in the United Kingdom and the Netherlands is mass-producing a 1-kW-class, free-piston engine generator in China. Production in 2013 reached 5,000 units.

Other Stirling-engine-based CHP units include a 1-kW-class, four-cylinder, double-acting, engine generator developed by Whisper Tech Ltd. in New Zealand (power generation capacity of 1 kW, heating capacity range of 7.5 to 14.5 kW) and a 10-kW-class, single-acting, alpha-type, V-cylinder-arrangement engine developed by Cleanergy in Sweden (power generation capacity of 2 to 9 kW, heating capacity range of 8 to 26 kW).

Units under development in Japan include 0.2-kW to 10-kW-class engines for relatively low-temperature waste heat and biomass combustion power generation using waste heat from vehicle engines, marine diesel engines, and factories. However, these are either still in the development phase or available only on a made-to-order basis.

Bioethanol

According to statistics compiled by F.O. Licht, global ethanol production in 2013 increased by roughly 4% to a record high of 106.60 million kL. Of this, about 83% was used for fuel. Of the two main producing countries (accounting for 75% of total global production), the proportion of ethanol production in Brazil increased by about 18% compared to 2012, as the price of sugar produced alongside sugar cane fell. In contrast, U.S. production hit the so-called “blend wall.” Due to safety concerns, the EPA decided to approve E10 blend fuel instead of E15, restricting the actual usage amount of ethanol and causing production to slow. In reaction to the market situation, the EPA proposed a renewable fuels standard (RFS) in November 2013 that included the first-ever reduction in the amount of mandated biofuel (including ethanol). The proposed standard for 2014 was 15.21 billion gal, 8% less than that for 2013.

As part of its Renewable and Alternative Energy Development Plan for 2012 to 2021, Thailand ended sales of regular gasoline on January 1, 2013. As a result, sales of E10 increased, reaching 9,180 kL per day in June 2013, 1.6 times the level in 2012. Ethanol production increased by 29% compared to 2012.

In Japan, the main activities that promote the use of biofuels are the three biofuel production site establishment projects between 2012 and 2016 managed by the Ministry of Agriculture, Forestry and Fisheries (MAFF), which are due to continue in the future. The project to popularize the use of biofuels in Okinawa supplied roughly 40,000 kL of E3 in 2013 and had established 58 E3 service stations as of April 2014. Sales of E10 started in August 2013, and 13 E10 service stations had been established as of July 1, 2014. In contrast, the number of service stations in Japan selling bio-gasoline blended with ETBE decreased by about 2% from April 2013 to reach 3,360 as of June 10, 2014.

MAFF examined bioethanol production technology through the Project for Developing Soft Cellulosic Resources Utilization Technology that ended in 2012. Based on the results of this project, Taisei Corporation provisionally calculated that the overall cost of ethanol from raw material harvesting and transportation to ethanol production equaled 85.2 yen/L, and Kawasaki Heavy Industries, Ltd., announced the establishment of a commercial-scale subcritical water-based technology capable of producing bioethanol at a cost of 40 yen/L.

Test methods for ethanol fuels are currently being standardized by the International Organization for Standardization (ISO). The methods of determining the electrical conductivity and total acidity by potentiometric titration are currently under discussion and have reached the Final Draft International Standard (FDIS) stage.

Biodiesel

In 2013, only a small number of research papers were presented at automotive conferences in Japan that related to FAME and other biodiesels. The pace of research on these fuels in Japan has slowed considerably. In contrast, at the 2013 Powertrains, Fuels and Lubricants Meeting, co-hosted by the Society of Automotive Engineers (SAE) and the Korean Society of Automotive Engineers (KSAE) at the COEX venue in Seoul between October 21 and 23, 21 of the 192 papers presented related to FAME as a first-generation biodiesel, and there were growing numbers of reports from India and Southeast Asia. Most of this research covered the engine performance and emissions characteristics of FAME in vehicles. Other reports described the results of (a) investigations and analyses of FAME with various fuel-property-derived cold-flow properties, (b) research related to the reduction in fuel lubricating ability due to oxidation degradation, and (c) research describing high fuel dilution by oil in B7 blend diesel. These papers indicated that research and production technologies for biodiesel obtained from transesterification reactions are at a fairly advanced stage in Japan, Europe, and the United States.

Recent technological advances have taken place in the fields of algae-derived biodiesel production and biodiesel production using biomass-to-liquid (BTL) methods. Examples include plans by Solazyme Inc. to establish several algae-based production plants mainly in the United States and plans in Europe to set up a number of BTL production plants as B7 becomes more widespread.

In November, E4tech Ltd. in the United Kingdom published the results of research that predicted that biodiesel will become more popular in Europe in the future. According to the published roadmap, B7 will consist of 7% FAME by 2030, whereas the commercialization of Fischer-Tropsch (FT) diesel and hydrogenated biodiesel will start to fall off by 2020. After that point, the report predicts that technological innovations will lead to the start of commercial fuel production of new algae-derived diesels.

Natural Gas

In 2012, confirmed accessible reserves of NG across the globe stood at 187.3 trillion m^3. These reserves are located mostly located in Iran (33.6 trillion m^3 or 17.9%), Russia (32.9 trillion m^3 or 17.6%), Qatar (25.1 trillion m^3 or 13.4%), Turkmenistan (17.5 trillion m^3 or 9.3%), the United States (8.5 trillion m^3 or 4.5%), and Saudi Arabia (8.2 trillion m^3 or 4.4%). According to statistics published by the Japanese Ministry of Finance (MOF), Japan imports NG mainly from Qatar, Australia, Malaysia, and Russia. In 2013, the import price to Japan varied between $15 and $16 US/MMBtu. This was higher than the import price to the UK ($10 US/MMBtu) and the United States ($3 US/MMBtu). (MMBtu is an abbreviation for 1 million British thermal units and is roughly equivalent to 25 m^3 of NG.)

The United States is home to abundant reserves of shale gas. Production has increased rapidly due to the development of horizontal drilling and hydraulic fracturing techniques (the so-called shale gas revolution). In 2012, U.S. shale gas production rose by 23% to reach 9.7 trillion cubic feet (TCF). This accounted for 40% of all U.S. NG production, a figure that is predicted to grow to 56% in 2040. The shale gas revolution has greatly decreased U.S. dependence on imported oil, and the country is likely to become an exporter in the future. However, possible risks related to shale gas and oil production include environmental concerns, such as groundwater contamination. There have been calls for greater regulation and the enforcement of stricter environmental standards.

Natural Energy and Hydrogen

Natural energy sources, such as wind, solar, and geothermal power, have rapidly gained prominence in recent years. In Europe, roughly 70% of additional power generation in 2012 came from natural energy sources. Growth was particularly rapid in Germany, with natural energy sources accounting for 22.9% of power consumption. The capacity of new wind power generators in 2013 was 33.5 GW, with China (at 16.1 GW) accounting for 45% of the global growth in wind power. China was followed by Germany (3.2 GW), the United Kingdom (1.8 GW), India (1.7 GW), Canada (1.6 GW), and the United States (1.1 GW). Total global wind power capacity has reached 318.1 GW. The capacity of new solar power generators in 2013 was 38.4 GW. Growth was strongest in China (11.8 GW), followed by Europe (11 GW), Japan (6.9 GW), and the United States (4.8 GW). Asian countries have emerged as leaders in this field. In Japan, policies to use these renewables are restricted to the importation of liquid hydrogen and other energy sources by energy carriers.

The Strategic Energy Plan includes policies to use hydrogen as a secondary energy source, with the aim of achieving a hydrogen-based society. On June 24, 2014, the Council for a Strategy for Hydrogen and Fuel Cells, under the auspices of the Japanese Ministry of Economy, Trade and Industry (METI), released a Strategic Road Map for Hydrogen and Fuel Cells up to 2030.

In 2013, METI also started the development of technology for the storage and transportation of renewable energy sources. From 2014, these efforts were absorbed into the advanced R&D projects for the use of hydrogen being carried out by the New Energy and Industrial Technology Development Organization (NEDO). These projects are focusing on hydrogen production; the conversion, storage, and transportation of liquid hydrogen; and the potential for various types of energy carriers to use cheap, renewable energy sources, such as wind power, outside Japan. A dramatic increase in hydrogen use after 2030 is anticipated. Furthermore, the Cross-Ministerial Strategic Innovation Promotion Program (SIP) includes an energy carrier program that started R&D on hydrogen gas turbines and other practical, related technologies in 2014.

Methanol and Dimethyl Ether (DME)

The use of methanol as a fuel is already well accepted, since it can be produced easily from NG. The sharp rise in oil prices caused by the sub-prime loan crisis in July 2008 and the increased use of methanol for blending into gasoline in China increased global demand by 50%, from 40 million tons in 2009 to 60 million tons in 2012. Statistics published by HIS Chemical forecast that methanol demand will reach 100 million tons in 2016.

DME is attracting attention as an alternative to diesel that can be produced easily from methanol. Mitsubishi Gas Chemical Company Inc. and Mitsubishi Corporation are reportedly working toward the production of DME in Trinidad and Tobago.

Outlook

In December 2013, METI established the Council for a Strategy for Hydrogen and Fuel Cells. Since that time, the Council has been studying ideal approaches to the future use of hydrogen energy, through collaborations among industry, academia, and the Japanese Government. On June 23, 2014, the Council compiled measures to be taken by people involved in work toward realizing a hydrogen society into a Strategic Road

Map for Hydrogen and Fuel Cells. METI hereby publicized the road map [9].

On April 11, 2014, the Cabinet decided to approve the new Strategic Energy Plan as the basis for the orientation of Japan's new energy policy, considering the dramatic changes in energy environments inside and outside Japan, including those caused by the Great East Japan Earthquake and the subsequent accidents at TEPCO's Fukushima Daiichi Nuclear Power Station. The 2014 plan is the fourth plan, and I is the first to be released after the Great East Japan Earthquake.

References

[1, 2] Government's white paper on energy 2014 (in Japanese)
[3] LEVO, the Organization for the Promotion of Low Emission Vehicles (cumulative total number: out of production)
[4] Japan Gas Association (JGA)
[5, 6] Japan Automobile Research Institute (JARI), as of March 2014 (estimated number)
[7] Automobile Inspection and Registration Information Association
[8] Agency for Natural Resources and Energy, http://www.meti.go.jp/english/press/2014/0411_02.html
[9] Agency for Natural Resources and Energy, http://www.meti.go.jp/english/press/2014/0624_04.html

AMF IA Success Stories
It is possible to get much of the latest worldwide information on advanced motor fuels through the activities of the AMF IA. A knowledge of what's going on in the field of motor fuels in various countries is important for stakeholders like policy makers, industries, etc.

Republic of Korea

Introduction

In Korea, all city buses (more than 38,000) use natural gas (NG) (Figure 1), and all taxis use liquefied petroleum gas (LPG). However, it is now mandatory that all diesel fuel contain 2.5% biodiesel fuel (i.e., BD2) by July 2015, and this percentage is to be increased to 3.0% by 2020. There is no policy on bioethanol (BE) use.

The Korean Government discussed future scenarios on how introduce BD and create a long-term roadmap. This discussion was finalized, and the conclusions were incorporated in new Korean Renewable Fuel Standard (RFS) in June 2013.

Fig. 1 Liquefied Natural Gas (LNG) Bus (Hyundai Motor Company)

Policies and Legislation

The new RFS was enacted in South Korea's National Assembly in July 2013. This law requires that a renewable energy fuel must be blended with any transportation fuel. 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 carrying out this RFS.

However, the Korean Government, by allowing a 2-year grace period to implement the RFS system, enabled oil refinery companies and bioenergy-related enterprises to prepare the fuels. The Government felt that the RFS policy would be more acceptable if there was enough time to implement it.

According to legislation, it is expected that the mixing or blending of BD and bioethanol (BE) will reach 5% in 2020, as a result of incremental increases in the mixing ratios associated with the new renewable energy sources each year. Also, the Ministry of Trade, Industry and Energy announced that the quality standards exist to ensure that of renewable energy sources are of the proper quality, and it is mandating that related companies register to obtain indemnity or fraternal insurance to cover a third party for any damage caused by defects in the renewable energy processes.

Implementation: Use of Advanced Motor Fuels

More than 38,000 natural gas vehicles (NGVs) and 164 compressed natural gas (CNG) or LNG stations are currently being operated in Korea. Since 2000, the Ministry of Environment has promoted NGVs — mainly city buses — by offering subsidies and low-priced NG to reduce air pollution in urban areas and cut greenhouse gas emissions. About 80% of NGVs are original equipment manufacturer (OEM) transit buses, and the other 20% are OEM trucks and dual-fuel retrofit passenger cars. Dedicated CNG buses and trucks are supplied by Korean automakers, such as Hyundai, Daewoo Bus, and Tata Daewoo. NGVs run mainly on CNG. However, dedicated buses that were recently developed by Hyundai (which also developed a CNG hybrid bus in 2010) and some LNG-diesel dual-fuel trucks with retrofit technology are in use. Hydrogen-CNG (HCNG) engine technology is currently being developed as part of a Government project.

BD has been used as an automotive fuel in Korea since 2002. After a few years of demonstration, the Ministry of Trade, Industry and Energy decided to introduce BD0.5 nationwide. After that, the blending ratio of BD in diesel oil has been increased gradually, and the blending ratio of BD2 has been fixed since 2010. Major feedstocks for BD are waste cooking oil and imported soybean oil and palm oil. At present, there are 16 BD production companies, and production capacity is more than 1 million tons.

Other alternative fuels, such as BE, dimethyl ether (DME), and synthetic liquid transportation fuels (collectively known as XTL), have been developed or demonstrated by Government institutes and some companies. However, it is not clear when these fuels will be introduced.

Outlook

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

Additional References

- www.kpetro.or.kr

Spain

Introduction

Spain has very little domestic oil and gas production and relies heavily on imports (Figure 1). In 2014, oil imports increased over those in the previous year. Nigeria became the biggest supplier of crude oil (16.76%), followed by Mexico (14.49%), Saudi Arabia (12.26%), and Russia (11.98%). These four countries represented 55% of total Spanish imports in this period.

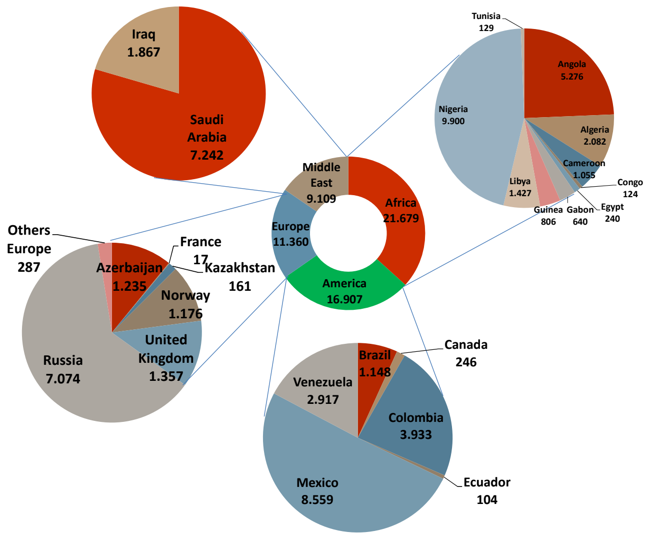

Fig. 1 Oil Imports to Spain in 2014 (kt)
(Source: CORES)

With regard to the external trade of oil products, by November 2014 (latest consolidated data available) total imports amounted to 15,479 kilotons (kt), while exports reached 17,554 kt. Figure 2 shows imports and exports of oil products over the 12 months of December 2013 through November 2014).

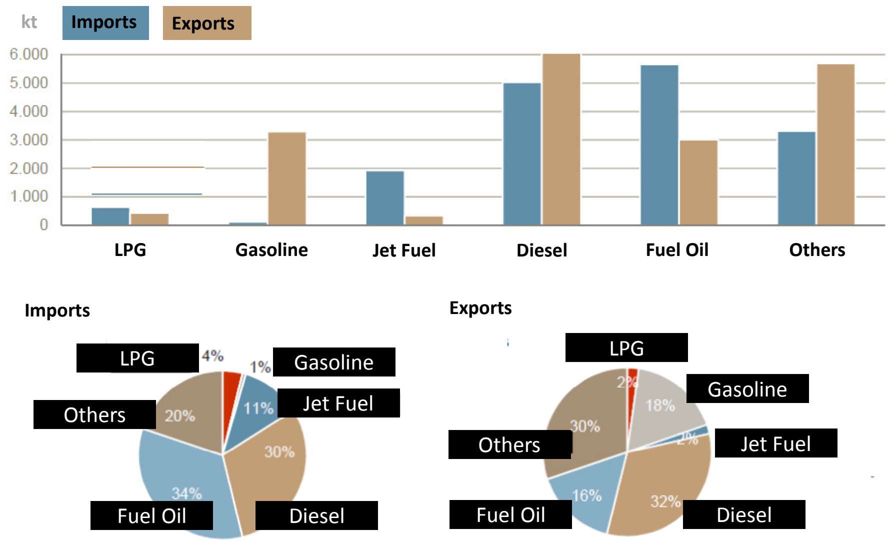

Fig. 2 Imports and Exports of Oil Products in Spain from December 2013 through November 2014
(Source: CORES)

Policies and Legislation

The only legal incentive for biofuel consumption in Spain is the blending mandate. Wholesale and retail operators of fuels, as well as consumers of fuels not supplied by wholesale or retail operators, are obliged to sell / consume a minimal quota of biofuels. The minimal amount is set at a general level (all biofuels) and at a specific level (minimal amount of biofuels in diesel and in gasoline). Each obligated subject has to present a number of certificates to the national certification entity (the National Markets and Competition Commission) to prove compliance. Certificates have a value of 1 metric ton of oil equivalent (toe). In case of noncompliance with the targets, a penalty fee applies. In case of overcompliance (some parties selling or consuming more than they are obliged to), the amounts collected from the penalty fees are redistributed by the certification entity proportionally to the subjects that sold/consumed biofuels exceeding their set quota obligation. Table 1 provides the 2014 mandatory blending targets.

Table 1 Mandatory Biofuel Blending Targets in Spain[a]

Overall	Biofuels in Diesel	Biofuels in Gasoline
4.1%	4.1%	3.9%

[a] The source of the blending percentages is Law 11/2013, which was designed to support entrepreneurs and boost economic growth and job creation. Article 41 establishes mandatory goals for biofuels for 2013 and the years after that.

A resolution dated April 2, 2014, by the Secretary of State of Energy, approved the list of biofuels that are eligible for double counting (i.e., used cooking oil and animal fats), but further regulation is needed to implement the double counting. That is still being developed by the National Markets and Competition Commission.

With regard to the specific biodiesel obligations, a Ministerial Order to establish a biodiesel production quota system was issued in 2012. During 2013, biodiesel facilities requested quotas up to the limits of their authorized capacities. Only biodiesel that is produced in a plant that has obtained a quota will be eligible to meet the consumption mandates. Neither the total volume of biodiesel produced in a processing plant with no quota allocation, nor the volume fraction of produced biodiesel exceeding the allocated quota of a specific plant, will be eligible to count toward the biofuel mandatory targets on fuel sector operators. The total amount of biodiesel distributed among producers eligible to count toward target achievement reached 5.5 million metric tons per year. The biodiesel production quota assigned to each plant is defined according to the level of fulfilment of the following criteria: environmental protection, security of energy, security of supply, the plant's biodiesel annual production capacity (properly audited) and its economic and financial viability. The definitive list of fatty acid methyl ester (FAME) plants was approved by means of a Resolution dated January 24, 2014, by the Secretary of State of Energy.

Implementation: Use of Advanced Motor Fuels

Biofuels represent the largest share of alternative transportation fuels in Spain. At the time of preparing this report, the Spanish Biofuel Certification Entity (the National Markets and Competition Commission) had published data for the period January through March 2014. Figures 3, 4, and 5 show the balances for biofuels production, consumption, imports, and exports.

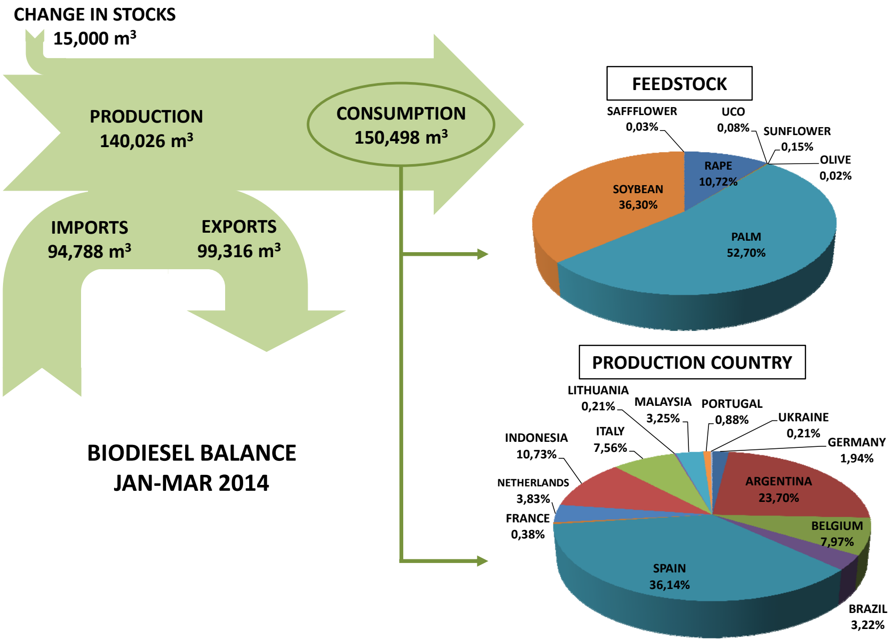

Fig. 3 Biodiesel Balance in Spain in January through March 2014
(Source: CNMC)

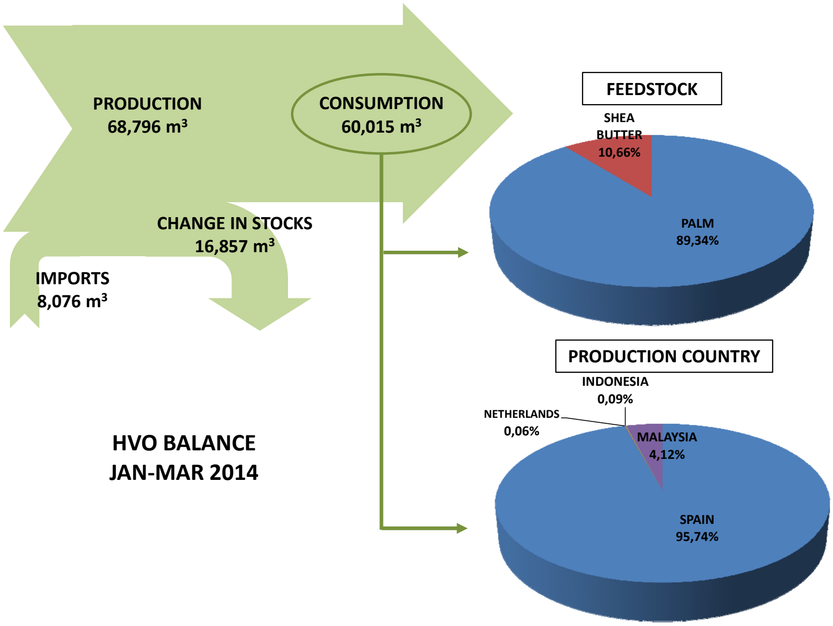

Fig. 4 Hydrotreated Vegetable Oil (HVO) Balance in Spain in January through March 2014
(Source: CNMC)

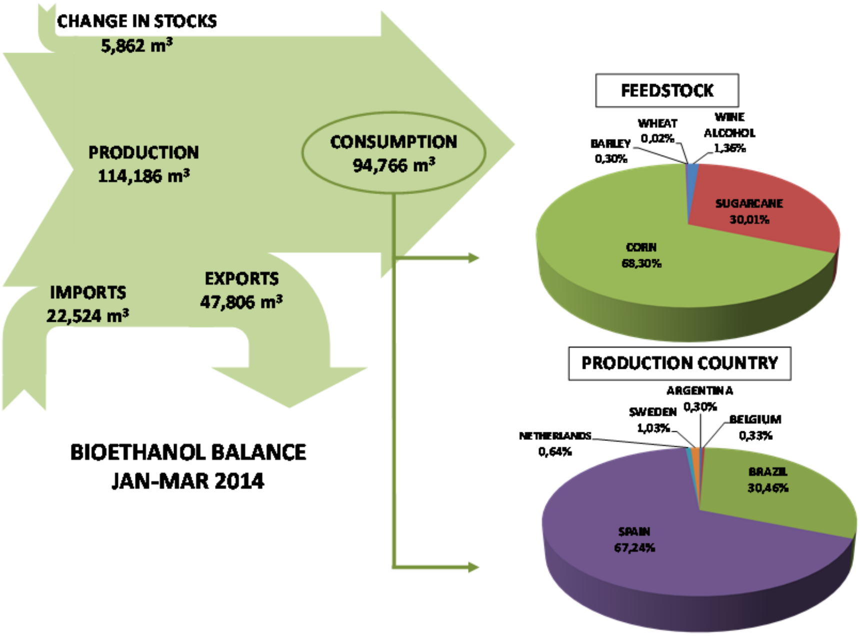

Fig. 5 Bioethanol Balance in Spain in January through March 2014
(Source: CNMC)

With regard to other alternative fuels, liquefied petroleum gas (LPG) and natural gas constitute a small part of the total market. The current number of vehicles capable of using these fuels is shown in Figure 6.

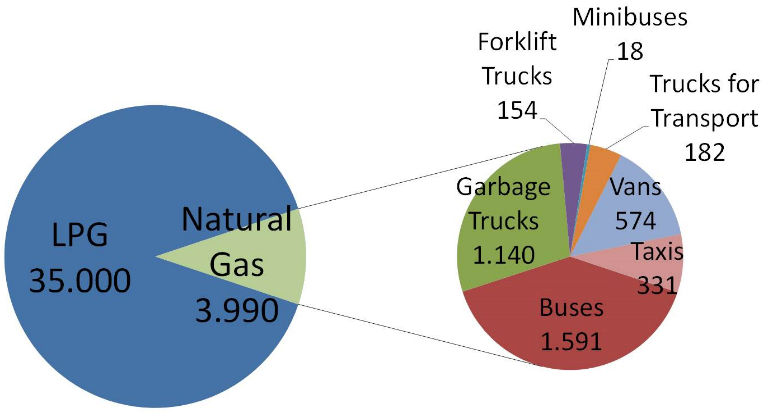

Fig. 6 Number of Vehicles in Spain That Could Use LPG and Natural Gas
(Source: IDAE)

There is also a wide range of research activity in Spain on hydrogen technologies. With regard to vehicles, a few pilot projects (not commercialized today) have been developed (cars, micro-cars, scooters).

Table 2 shows the number of public filling stations with alternative fuels.

Table 2 Filling Stations for Alternative Fuels in Spain

Alternative Fuels		No. of Filling Stations
Biodiesel blends	B10 or lower	42
	B12	38
	B15	8
	B20	38
	B30	34
	B40	1
	B97	1
Bioethanol blends	E10	1
	E85	15
LPG		410
Natural gas		39
Hydrogen		4

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

Outlook

According to the National Renewable Energy Action Plan, in order to fulfill the committed targets, the consumption of biofuels is expected to reach 2,713 ktoe in 2020. Of this, 400 ktoe corresponds to biofuels in gasoline (bioethanol and bio-ETBE [ethyl tertiary-butyl ether]), and 2,313 ktoe corresponds to biofuels in diesel (mainly FAME and HVO; HVO achieved a significant market penetration in 2013 and 2014).

Additional References

- AEH2: Spanish Hydrogen Association, www.aeh2.org
- AOGLP: Spanish Association of LPG Operators, www.aoglp.com
- CNMC: National Markets and Competition Commission, www.cnmc.es
- CORES: Corporación de Reservas Estratégicas, www.cores.es
- GASNAM: Spanish Association of Natural Gas for Mobility, www.gasnam.es
- IDAE: Instituto para la Diversificación y Ahorro de la Energía, www.idae.es

- MINETUR: Ministry of Industry, Energy and Tourism, www.minetur.gob.es
- Geoportal (MINETUR): Filling Stations, www.geoportalgasolineras.es

AMF IA Success Stories
Membership in the AMF IA provides wider and easier access to information and helpful analyses that can be used to guide national policies and programs. It also helps to raise awareness about issues and ongoing research related to advanced motor fuels and the need for future development of advanced motor fuels.

Sweden[41]

Introduction

Total energy use in the transport sector, including foreign transport, amounted to 121 terawatt-hours (TWh) in 2012. The shares of energy use for the different transport modes are shown in Figure 1. Bunkering for foreign maritime traffic amounted to 20 TWh, and fuel for nondomestic aviation accounted for slightly less than 9 TWh. Swedish domestic transport used 92 TWh, representing almost one quarter of the country's total energy use, in 2012. Petrol and diesel oil met 85% of the country's energy requirements for domestic transport.

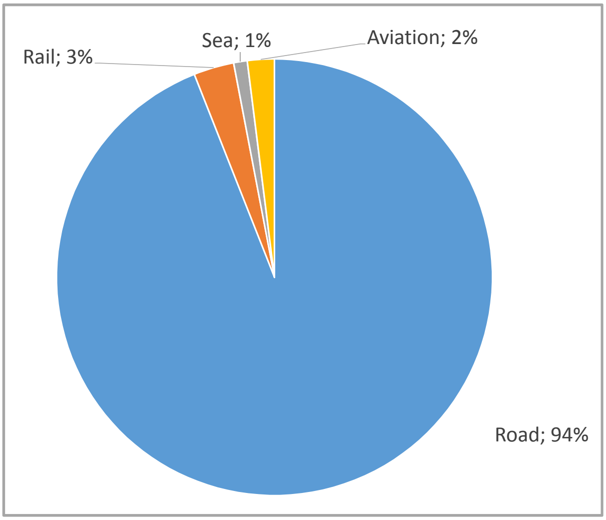

Fig. 1 Share of Energy Use among Different Transport Modes in 2012

Sweden imported 20.4 million tonnes of crude oil in 2012 and net-exported 3.9 million tonnes of refinery products. Around 50% of Sweden's total crude oil imports came from the North Sea, mainly from Denmark and Norway. Imports from Russia increased significantly in recent years and now amount to 42% of total imports.

[41] The information in this section on Sweden was not updated. It was taken from the 2013 *IEA-Advanced Motor Fuels Annual Report.*

Between 2004 and 2012, the use of diesel fuel increased by 42%, while the use of petrol fell by 30% over the same period. One reason for this was the change in the mix of different types of vehicles on the road.

The proportion of renewable motor fuels used by road vehicles increased in recent years. In 2012, the proportion amounted to 8.1%. The main biofuels presently used by vehicles are ethanol, biogas, fatty acid methyl ester (FAME), and a small portion of hydrotreated vegetable oil (HVO) as a 15% admixture. Figure 2 shows the percentages for various alternative fuels.

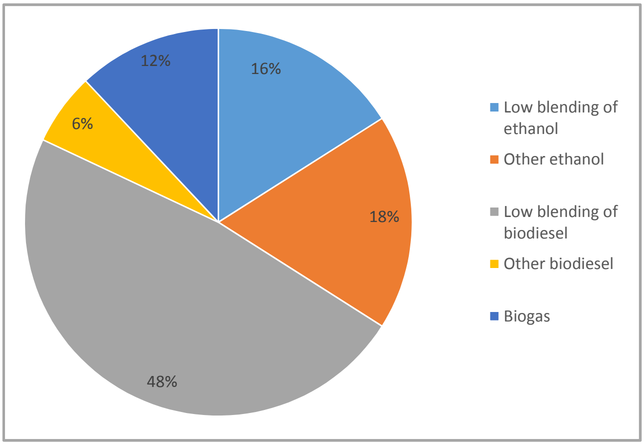

Fig. 2 Share of Alternative Fuel Use in 2012

Ethanol is blended with gasoline, and it is also the main constituent in fuels such as E85 and the ethanol-diesel mix, ED95. FAME is blended with regular diesel fuel and is also used (to a limited extent) as 100% FAME. The use of biogas has increased rapidly during the last couple of years. Currently the content of almost all petrol is 5% ethanol, while about 90% of diesel fuel contains a 5% blend of biodiesel.

Policies and Legislation

Sweden is using a relatively high proportion of biofuels in relation to most other countries in the European Union (EU). The main driver behind biofuel policy is to decrease the amount of carbon dioxide (CO_2) emissions from the transport sector. Another policy aim, not directly related to biofuels, is to increase overall energy efficiency in the transport system.

The motor vehicle tax was changed in October 2006 to be based on a vehicle's CO_2 emissions instead of its weight, as was previously the case. The purpose of this change was to encourage the sales of more low−carbon vehicles. Some other tax relief is provided for vehicles that are capable of running on bio-based motor fuels. Starting in 2011, the vehicle tax for newly registered light goods vehicles, buses, and motor caravans was also subject to the CO_2 tax charge. The vehicle tax for heavy goods vehicles does not include a CO_2 element but depends on the vehicle's weight and level of regulated emissions.

The fuel tax consists of two parts: an energy tax and a CO_2 tax. In 2014, the taxes will change as an effect of the introduction of a quota system for low blending of biofuels in motor fuels. All petrol sold must contain, on average, at least 4.8 volume percent (vol%) ethanol. (The percentage will increase to 7 vol% in 2015 onward). The corresponding quota for diesel is 9.5 vol%, of which 3.5% must be from biofuels with additional environmental benefits (i.e., not FAME). All the biofuel must fulfill the sustainability criteria set out by the EU.

Bio-based motor fuels that are part of the quota are subject to an energy tax on the basis of their energy content but are not subject to a CO_2 tax. There is no energy tax or CO_2 tax on high-blending fuels (i.e., fuels with a high percentage of biofuel) and pure (not blended) biofuels.

Starting on July 1, 2009, new "clean vehicles" have been exempted from the vehicle tax for five years. The definition of a clean vehicle was revised in 2013 as follows:

- A vehicle with a mass in running order[42] of 1,372 kilograms (kg) is allowed to emit 95 grams (g) of CO_2 per kilometer (km) if it runs on petrol or diesel fuel. Vehicles capable of running on alternative fuels (i.e., all other fuels than diesel and gasoline/petrol) are allowed to emit 150 g CO_2/km.
- Heavier vehicles can emit more, while lighter vehicles must emit less (the slope corresponds to 4.57 g CO_2/100 kg).
- The electricity consumption of electric vehicles, including plug-in hybrid vehicles, must be less than 37 kilowatt-hours (kWh)/100 km.

The market share of diesel cars is increasing rapidly. In 2012, the proportion of new vehicles that were diesel−powered amounted to 60%. In the last 10 years, the number of diesel-powered vehicles increased to almost four

[42] Mass in running order is the term to be used according to CO_2 legislation on passenger cars in the EU.

times what it was at the beginning of that period. Also, over the last several years, on average, the CO_2 emissions of newly registered passenger cars in Sweden decreased to 8 g CO_2/km per year. However, in 2013, this trend was broken, partly due to a significant increase in the share of four-wheel-drive cars.

Implementation: Use of Advanced Motor Fuels

The sustainability criteria for biofuels and bioliquids aim to reduce greenhouse gas (GHG) emissions and ensure that no areas with "high biological values" according to the definition in Directive 2009/28/EC have been damaged as a consequence of the production of renewable fuels. Starting in the spring of 2012, those operators in the Swedish economy that must report on their biofuel and bioliquid use have had to submit annual reports. The reports describe the quantities of sustainable biofuels and bioliquids used in Sweden in the previous year.

Emission Reduction of More Than 1 Million Tonnes of CO_2

Biofuels used in 2012 included ethanol, FAME, biogas, HVO, ethyl tertiary butyl ether (ETBE), and dimethyl ether (DME) (Table 1). The total amount of sustainable biofuels was equivalent to more than 7 TWh. Of the biofuels used, HVO showed the highest increase, from 0.3 to 1.3 TWh. None of the feedstock that was used for the production of biofuels to supply the Swedish biofuel market was cultivated in Africa, almost none was from Asia, and very little was from any Latin America country other than Brazil. Most of the feedstock was cultivated in Europe. The current emission reduction requirement is set at 35% for biofuels (compared to fossil fuels); however, half of the biofuels in Sweden that have been reported on already fulfill the 50% reduction requirement that will not come into force until 2017.

Feedstocks and Emission Reductions

The most common biofuels are ethanol, FAME, and HVO. The emissions from the cultivation of biomass often constitute a large proportion of the total emissions from biofuels from a life-cycle perspective. Depending on the feedstock, the average emission reduction that results from using ethanol varies between 50% and 85%. HVO is associated with the largest reduction in GHG emissions at 85%, while use of FAME, based mostly on rapeseed, has achieved a 40% reduction.

Table 1 Biofuel Use and Emission Reductions in 2012

Fuel Category	Amount of Energy(GWh)	Sustainable Quantity Produced from Sustainable Crops(m^3)	Emission Reduction (tonnes of CO_2)
Ethanol	2 253	385 093	416 337
FAME	2 481	296 923	345 962
Gaseous biogas	901	92 815 195	206 822
Liquid biogas	14	1 019 900	2 383
HVO	1 367	146 449	305 729
ETBE	43	6 632	6 993
DME	3	329	591
Verified sustainable	7 062	94 670 521	1 329 817

The ethanol delivered in 2012 was derived from 12 different types of feedstock, mostly wheat and corn (Figure 3). About one-third of the ethanol was produced from domestic feedstock. Europe was the main area of origin for the remaining percentage (Figure 4). HVO is based mainly on tall oil, which is a residue from the forest industry, and waste oil (of both vegetable and animal origins). HVO use results in, on average, an emission reduction of 88%. Almost 20% of the biofuels, besides biogas, were produced from residues; this percentage represents a significant increase from 2011, when only 8% came from residues. Examples of these residues include brown liquor, black liquor, and crude tall oil, which are used to produce ethanol, DME, and HVO, respectively. Other examples include vegetable and animal waste oil and molasses from sugar beet, which have been used to produce FAME and ethanol, respectively. (Figure 5 shows the countries of origin for FAME feedstock.)

Biogas intended for transport is subject to the sustainability criteria. Swedish feedstock contributed to 93% of the biogas used for transport in 2012. The biogas was produced from various feedstocks, which, in most cases, were waste or residues. The biogas produced from manure yields the best reduction in emissions: more than 80%. Cultivated biomass, such as barley, rye, corn, and ley crops, result in the lowest emission reduction: 40–60%. Approximately 25% of the biofuel quantities also meet certain requirements for social and economic sustainability by having been certified under one of the EU Commission’s eight approved voluntary certification schemes.

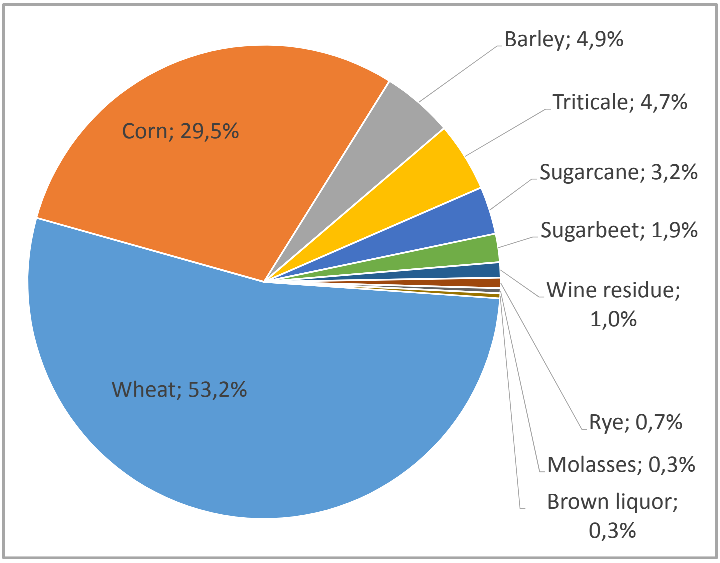

Fig. 3 Ethanol Feedstocks

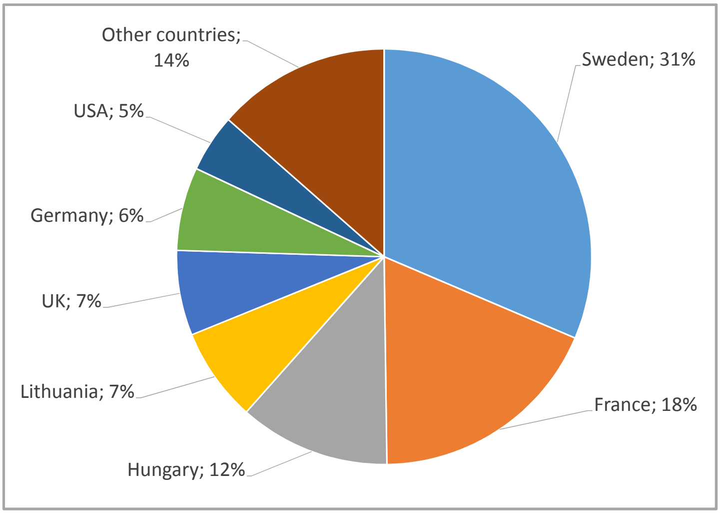

Fig. 4 Countries of Origin for Ethanol Feedstocks

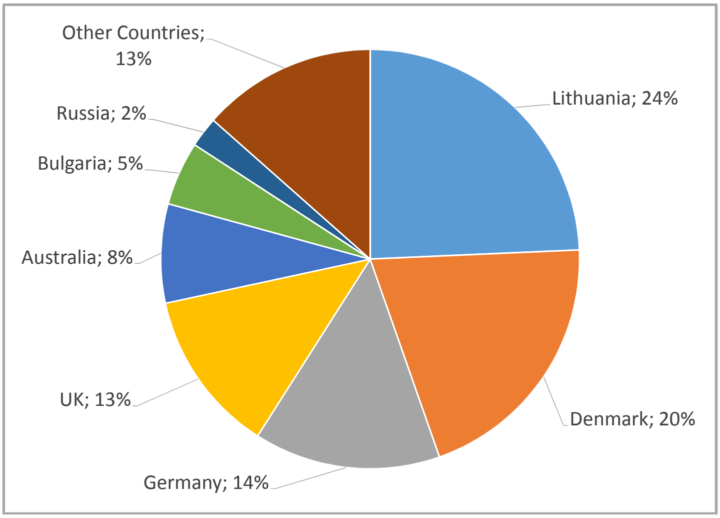

Fig. 5 Countries of Origin for FAME Feedstocks

Outlook

In December 2013, the Swedish Commission on Fossil-Free Road Transport presented possible courses of action and identified measures to reduce the emissions from and dependence on fossil fuels within the transport sector. The suggestions are in line with Sweden's 2050 vision and priority of having a fossil-independent vehicle fleet in 2030. Four different groups of actions were identified:

- Planning and developing attractive, accessible towns and cities with a reduced demand for transport and greater transport efficiency;
- Instituting infrastructure-related measures and changes in modes of transport;
- Using more efficient vehicles and more energy-efficient driving strategies; and
- Using biofuels, including electric-powered road vehicles.

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Switzerland

Introduction

Final total energy consumption in Switzerland in 2013[43] amounted to 896,000 TJ, of which 34% was transport fuels [1]. Compared to 2012, transport fuel consumption remained at the same level. In specific applications, there were some changes: aviation fuels +1.1%, diesel +4.4%, and gasoline –4.6%. All fossil fuels were imported. Figure 1 shows shares of energy sources in energy consumption for all kinds of transportation. With regard to aviation fuel, 10% is used for domestic flights [2]. Electricity is used for railroad transportation.

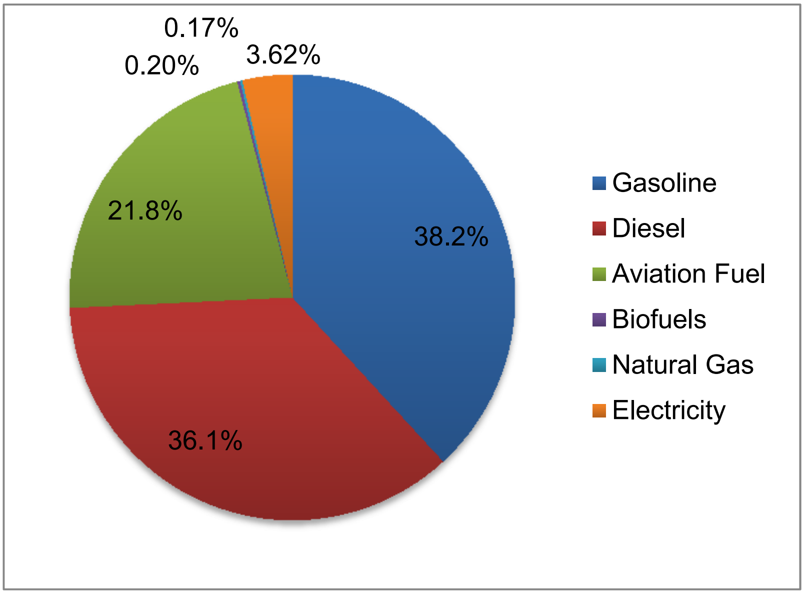

Fig. 1 Transportation Sector: Shares of Energy Sources in Energy Consumption in Switzerland in 2012 [1]

The share of biofuels was very small (0.2% of total transport fuels), at 640 TJ, in 2013. This represented a 3% decrease from 2012 [1]. The decrease was mainly due to lower sales of biodiesel and bioethanol.

43 At the time this report was prepared, only data from 2013 were available for Switzerland.

In 2013, a total of 402,114 motor vehicles were newly registered [3]. This represented a rise of 1.6% in the total amount of 5,693,642. Of passenger cars, 310,154 are newly registered, and with 4,320,885 units in total, these cars represent the most important share (76%). Of all passenger cars, 75% had gasoline engines, and 24% had diesel engines. The percentage represented by other propulsion systems was 1.2% (34,834 hybrid, 2,683 electric, 12,965 other). The average age of the passenger car fleet was 8.2 years [4].

Within the last 10 years (through 2013), the consumption of transport fuels (minus aviation fuel) increased by only 3.4%. In the same period, the number of cars (all types) rose by 15%. Use of gasoline decreased by 25%, and use of diesel increased by 68%. The average fuel consumption per car dropped significantly, and an important change in the kind of motor fuel used took place. The consumption of biofuels rose by 630% in this 10-year timeframe, but it represented a very low percentage of the overall motor fuel demand, increasing from 0.12% to 0.20%. Figure 2 shows the development in gasoline and diesel consumption by motor vehicles in 2004–2013.

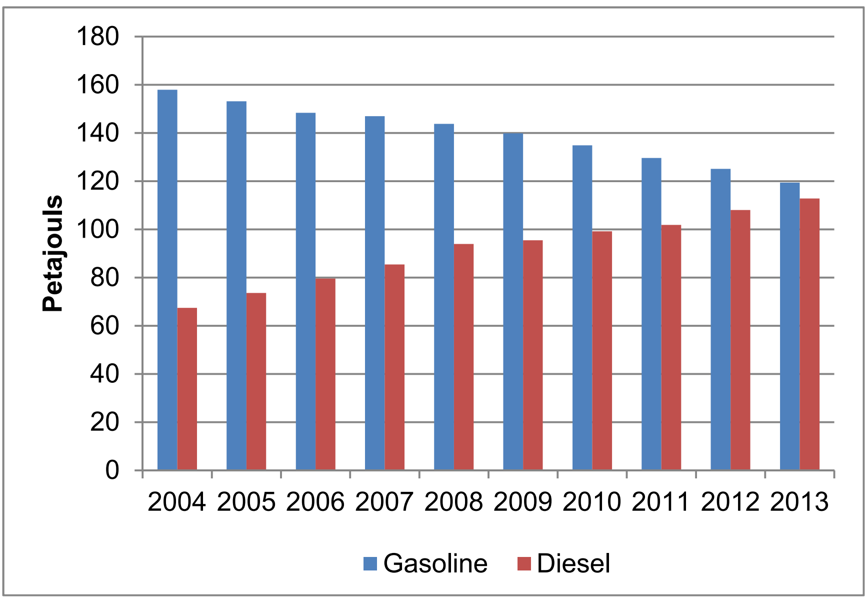

Fig. 2 Development in Gasoline and Diesel Consumption by Motor Vehicles in Switzerland in 2004–2013 [1]

In Switzerland, there is no obligation for blending for firms marketing motor fuels like there is in other countries. This could be a reason for the rather low share of biofuels in the total amount of motor fuels.
Different cantons (Swiss member states) give vehicle tax reductions or even exemptions for purchasing environmentally friendly and energy-efficient vehicles, but there is still scepticism about alternative propulsion systems because of their higher capital costs and reduced ranges.

Policies and Legislation

Energy Strategy 2050

In 2011, the Federal Council decided that Switzerland would withdraw from the use of nuclear energy on a step-by-step basis without increasing carbon dioxide (CO_2) emissions [5]. The existing five nuclear power plants, which provide 40% of the electricity in Switzerland, will be decommissioned when they reach the end of their safe service life and will not be replaced by new ones.

To ensure a secure supply of energy, the Federal Council is emphasizing 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. To achieve these targets, the Swiss energy system will need to be successively restructured during the time period up to 2050. In view of this, the Federal Council developed a long-term energy policy: Energy Strategy 2050. In September 2013, the Council launched an initial package of measures aimed at securing the country's energy supply over the long term [6]. This package will be supported by a fundamental revision of the Energy Act. In 2014, the Parliament started the debate over Energy Strategy 2050 and the new Energy Act. The final decision is expected in 2015. Important measures related to motor fuels are to (1) reduce CO_2 emissions, (2) increase energy efficiency, (3) increase the use of renewable energy sources including biomass, and (4) strengthen energy research.

CO_2 Emission Regulations for Cars

Like the European Union (EU), Switzerland has introduced CO_2 emission regulations for new cars. These regulations entered into force on July 1, 2012. Swiss importers are required to reduce the level of CO_2 emissions from passenger cars registered for the first time in Switzerland to an average of 130 grams (g) of CO_2 per kilometer (km) by 2015 [7].

All importers are required to meet a specific CO_2 target for their new vehicle fleet (or, in the case of small or private importers, they must meet a vehicle-specific target). This target is influenced by the vehicle's mass. Effective as of July 1, 2012, a penalty applies if the CO_2 emissions per kilometer exceed the specified target. In the year 2012, 65% of the passenger cars had to reach the target value of 130 g CO_2/km. This percentage requirement increased to 75% in 2013, to 80% in 2014, and it will be 100% in 2015.

Along with introducing a new Energy Act, the Federal Council aims to align with the EU Commission's legislative proposal to tighten CO_2 regulations on cars. By the end of 2020, the average CO_2 emissions from passenger cars have to be reduced to 95 g CO_2/km. A law for light commercial vehicles (vans up to 3.5 metric tons [t]) similar to the one for new passenger cars is awaiting formal adoption. For new vans sold in Switzerland, the targets are a fleet average of 175 g CO_2/km by 2017 and 147 g CO_2/km by 2020 [5]. In 2012, the average was 180.2 g CO_2/km.

CO_2 Emissions Compensation: Motor Fuels

Since 2012, importers of fossil motor fuels have been required to use domestic measures to compensate for 10% of the CO_2 emissions caused by the entire transportation sector by 2020 [8]. They may carry out their own projects or acquire attestations. The obligation to compensate for emissions caused by motor fuels replaces the temporary "climate cent" (i.e., special fee) that was used until 2012. Importers of petrol, diesel, natural gas, and kerosene that exceed the threshold of 1,000 t of CO_2 must compensate for their emissions. They may group together to form compensation pools. In response to this, the Swiss Petroleum Association established the Foundation for Climate Protection and Carbon Offset (KliK), a nonprofit organization. It operates as a carbon offset group for mineral oil companies that are responsible for releasing fossil motor fuels for consumption. On behalf of its affiliates, it fulfills the legal carbon offset obligation for CO_2 emissions resulting from the use of fossil motor fuels that came into force on January 1, 2013.

The Federal Council may set the percentage of motor fuel emissions for which importers must compensate within an average range of 5–40%. However, compensation costs may not exceed 5 centimes per liter (L). To comply with the statutory reduction target of 20%, it will be necessary to compensate for up to 1.5 million t of CO_2 by 2020. This equals 10% of the CO_2 emissions caused by the transportation sector. The compensation rate will start at 2% and be raised in four subsequent steps as follows:

- 2% for 2014 and 2015,
- 5% for 2016 and 2017,

- 8% for 2018 and 2019, and
- 10% for 2020.

Energy Label for Motor Vehicles and Tiers

The energy label for motor vehicles is intended to support efforts aimed at reducing the average fuel consumption of motor cars. It provides information about the kind of motor fuel, fuel consumption (liters per 100 km) and CO_2 emissions (grams per kilometer) in relation to the curb weight of the vehicle. It increases the transparency of (i.e., ease of access to) this information, helping buyers of new cars decide which model to buy. A car's operating costs, and particularly its fuel costs [9], depend directly on the model chosen.

In 2014, Switzerland introduced a label for tiers. It classifies, among other qualities, the rolling resistance of the tier and, with this, its energy efficiency.

Mineral Oil Tax (Petroleum Tax)

The mineral oil tax is an excise tax that encompasses the following [10]:

- A mineral oil tax on crude oil, other mineral oils, natural gas, their processed products, and engine fuels and
- A mineral oil surtax on engine fuels.

The mineral oil tax varies heavily depending on the product and its use (engine fuel, heating fuel, technical purposes). For instance, the tax per liter is:

- 0.73 CHF for unleaded petrol,
- 0.76 CHF for diesel oil, and
- 0.003 CHF for extra light heating oil.

Tax reductions are provided for engine fuels used in agriculture, forestry, professional fishing, licensed transport companies, and other industries.

Mineral Oil Tax Reduction for Natural Gas

To support Switzerland's target for CO_2 emissions, a reduction or even an exemption for environmentally friendly motor fuels came into force on July 1, 2008, with the amendment to the Mineral Oil Tax Act. The tax for natural gas used as a motor fuel was reduced to 0.22 CHF/kg [9].

Mineral Oil Tax Exemption for Biofuels

Switzerland is the first country in the world to introduce sustainability criteria, such as minimum ecological and social requirements for the production of biofuels, into its legal framework. To promote the use of biofuels (e.g., biogas, bioethanol, biodiesel, vegetable and animal oils) that satisfy minimum environmental and social standards, those biofuels are completely or partially relieved from the mineral oil tax. As a result, the tax reduction for biofuels is up to 0.72 CHF per liter, in comparison with fossil fuels. The fiscal measures came into force with the amendment to the Mineral Oil Tax Act in 2008.The tax reduction on biofuels has an effect on the federal budget, which is why there is a higher tax on petrol to compensate for the reduction in revenue [9].

To get a tax exemption, the following criteria, which apply to both the cultivation and utilization of fuels, have to be fulfilled:

- Emissions of greenhouse gases from the biofuels must be at least 40% lower than emissions from fossil fuels.
- The environmental impact may not be greater than that from fossil fuels.
- The protection of rain forests and biodiversity must not be endangered.
- The biofuels must be obtained from raw materials that were produced in accordance with the local social standards.

Implementation: The Use of Advanced Motor Fuels

Use of Biofuels as Motor Fuels

The share of biofuels within total transport fuels was very small (0.2%). The most important biofuel is biodiesel, and an increasing amount of upgraded biogas is being used in vehicles. Figure 3 shows the development since 2004. The next subsections provide detailed information.

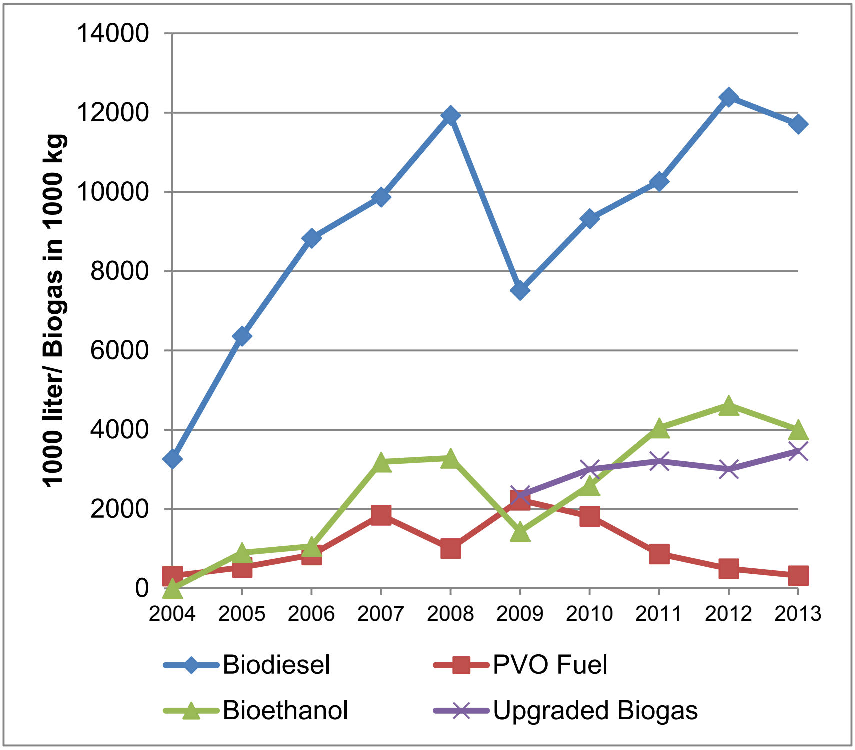

Fig. 3 Trends in Biofuel Consumption by Motor Vehicles in Switzerland in 2004–2013 [1, 2]

Biodiesel and Pure Vegetable Oil (PVO) Fuel

The consumption of biodiesel fuel in Switzerland amounted to about 11.7 million L in 2013 (Table 1). Compared to 2012, this is a reduction of 5.5%. In the 10 years up through 2013, consumption increased by 360 %. Compared to consumption of fossil-fuel-based motor fuels, however, the amount was still very low, representing a share of 0.16%. Then in 2013, the consumption of PVO fuel significantly decreased again (i.e., –35% with respect to 2012). After reaching a maximum of 2.2 million L in 2009, consumption of PVO decreased to 0.3 million L in 2013. That amount was 15% of the maximum value and the same level as in 2004.

Biodiesel and PVO fuel are used only in some local diesel fleets (mostly in agriculture) [12]. In 2010, there were 216 fuel stations that provided B5 (5% biodiesel/95% diesel) and 12 stations that provided B100 (100% biodiesel).

Table 1 Consumption of Biodiesel and PVO Fuel in Switzerland in 2004–2013 (in 1,000 L/yr) [11, 13]

Year	Biodiesel (1,000 L)			PVO Fuel (1,000 L)		
	National Production	Imports	Total	National Production	Imports	Total
2004	3,158	104	3,262	313	0	313
2005	6,180	181	6,361	529	0	529
2006	8,717	116	8,833	845	0	845
2007	9,756	113	9,869	1,846	0	1,846
2008	11,915	12	11,927	849	158	1,007
2009	6,837	679	7,516	808	1,418	2,226
2010	6,945	2,380	9,325	869	950	1,819
2011	7,161	3,101	10,262	641	229	870
2012	7,797	4,594	12,391	496	0	496
2013	5,633	6,076	11,709	293	29	322

Bioethanol

In 2013 the consumption of bioethanol as a motor fuel amounted to about 4 million L (Table 2). Compared to the amount in 2012 (4.6 million L), this was a decrease of 14%. In 2013, the entire volume of bioethanol that was used as a motor fuel was imported from Norway: 38 fuel stations provided E85, and 90 fuel stations provided E5.

The use of bioethanol as a motor fuel started in Switzerland in 2005. Until 2008, the whole volume was produced in Switzerland by Borregaard Schweiz. The closing of bioethanol production in Switzerland in 2008 affected consumption in 2009; there was a large drop in that year. Since then, demand has been recovering. A stimulating effect on consumption was the opening of the market to the private economy. Until 2010, only Alcosuisse (a Profit Center of the Swiss Alcohol Board) was allowed to import and sell ethanol. The Government resigned its activities related to the trade of bioethanol and opened the market to the private economy in the autumn of 2010.

Table 2 Consumption of Bioethanol Fuel in Switzerland in 2005–2013[a] (in 1,000 L/yr) [1, 11]

Year	National Production	Imports	Total
2005	901	0	901
2006	1,060	0	1,060
2007	3,188	0	3,188
2008	3,284	0	3,284
2009	0	1,438	1,438
2010	0	2,593	2,593
2011	0	4,047	4,047
2012	0	4,619	4,619
2013	0	4,004	4,004

[a] No bioethanol was used as a motor fuel before 2005.

Biogas and Natural Gas

In 2013, the total use of gaseous motor fuels remained at roughly the same level as it was in the here previous years (Table 3). Data have been available since 2009. The share of biogas used as a motor fuel in the total amount of gaseous motor fuels increased slightly. from 20% to 23%. The total amount of upgraded biogas fed in the gas grid increased from 6,915 to 9,981 t (+44%), but its use as a motor fuel remained much lower (3,461 t). The reason is that not all the upgraded biogas could be sold for use in vehicles. There were 140 fuel stations providing gaseous motor fuels.

However the total amount of biogas produced in Switzerland was (as it was in the years before) much higher than the amount used as a motor fuel (Table 4). Only 3.9% of the total biofuel produced in Switzerland and only 35% of the upgraded biofuel were used as a motor fuel. With regard to upgraded biogas, not all of it could be sold because of its higher price. As it was fed into the natural gas grid, it was used as a general fuel for heating. Table 4 shows the production and the use of biogas in 2013.

Table 3 Use of Biogas and Natural Gas as Motor Fuels (via gas grid and directly at fuel pump) in Switzerland in 2009–2013 (in 1,000 kg/yr) [14]

Year	Upgraded Biogas Used as Feed in Gas Grid	Upgraded Biogas Used as Motor Fuelin Cars	Upgraded Biogas: Other Uses	Natural Gas Used as Motor Fuel in Cars	Total Gaseous Motor Fuels Used in Cars	Share of Biogas Used as Motor Fuel in Total Amount of Gaseous Motor Fuels
2009	3,152	2,349	803	10,373	12,722	19%
2010	4,505	3,002	1,503	12,080	15,082	20%
2011	6,350	3,210	3,140	12,051	15,711	20%
2012	6,915	3,005	3,910	11,830	14,835	20%
2013	9,981	3,461	6,520	11,599	15,060	23%

Table 4 Production and Use of biogas in Switzerland in 2013 [11, 14]

Parameter	Production or Use Values	
	1000 kg	TJ (terajoule)
Total national biogas production	88,181	4,088
Direct use for power and heat generation	78,200	3,626
Upgraded feed in natural gas grid	9,981	462
Use as motor fuel in cars	3,461	160
Other uses (heating, cogeneration)	3,348	155
Upgraded biogas not sold	3,172	147

Energy Research

The Swiss Government supports energy research in the amount of 200 million CHF each year. From this amount, only a small part is dedicated for research in the field of advanced motor fuels. In support of Energy Strategy 2050, the Swiss Parliament in 2011 decided to increase subsidies for pilot and demonstration projects from a yearly amount of 5 million CHF to 35 million CHF in 2014. A second important decision that increased energy-related research activities and competencies in Switzerland was for a grant of an additional total of 200 million CHF for the period 2013 to 2016. The target was to launch and build the capacity of seven Swiss Competence Centers for Energy Research (SCCERs). Two SCCERs are important with regard to advanced motor fuels: SCCER BIOSWEET (Biomass for Swiss Energy Future) [15] and SCCER Mobility (Efficient Technologies and Systems for Mobility) [16].

The targets of energy research are described in *Energy Concept 2013–2016* [17]. It is published by the Federal Energy Research Commission (CORE), which acts as a consultative body for the Federal Council. On the basis of this publication, the Swiss Federal Office of Energy (SFOE) published a detailed research plan [18] covering 20 topical areas. Here are some examples of ongoing research projects related to advanced motor fuels.

Micro-thermal gas-quality sensor for detecting the composition of methane-rich gases for feed-forward control of engines [19]. Depending on the exact composition of methane-rich gases, engines have to be adapted with regard to their combustion process and their control system calibration. The limiting parameters are inflammability and the knock resistance. A novel micro-thermal gas quality sensor (Figure 4) was developed up to a pre-production status, and the use of the sensor information for feed-forward-control with different combustion concepts was elaborated.

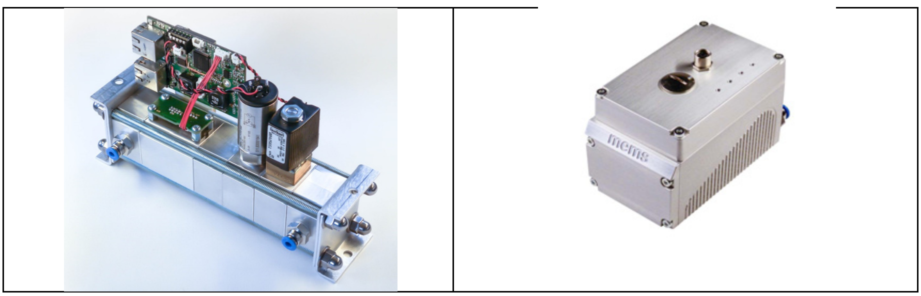

Fig. 4 Micro-thermal Gas-Quality Sensor as Preliminary Product for Tests (left) and as an Updated and Improved Pre-product (10 × 6 × 6 cm in size) (right)

Renewable energy sources in the future energy supply (RENERG2) [19]. This project includes research activities in the fields of chemical electricity storage, the efficient use of stored electricity, and interactions with the electric grid. The target of the project is to demonstrate the potential for increasing efficiency and reducing pollution in the whole chain, from electrolytic hydrogen production to use in energy converters, as well as capabilities for grid stabilization.

Metal-nanoparticles and other nonlegislated emissions from cars with blended gasoline and alcohol fuels [19]. Metal-nanoparticles (including those in sizes below 20 nm) from gasoline cars are being investigated for different engine technologies (12 cars) (Figure 5). The investigations focus on the composition and potential of secondary aerosols. Supplementary research is being done on nanoparticles at cold start, gaseous nonlimited components (especially NO_2, NH_3, and aldehydes), and operation with alcohols. The project, under the lead of the Laboratory for IC (Internal Combustion) Engines and Exhaust Control (AFHB) at the University of Applied Science Biel/Biennne, is a collaboration with Paul Scherrer Institute (PSI) and the Swiss Federal Laboratories for Materials Science and Technology (Empa) (Figure 6).

Fig. 5 Preparation of a Vehicle for a Field Test with CNG and Successive Switches to HCNG (2 vol% H_2)

Fig. 6 Test Facility at the Laboratory for IC-Engines and Exhaust Control (AFHB)

Investigations of fuel flexibility at conditions typical of those experienced by future large marine diesel engines during combustion of nonconventional fuels [19]. This project targets an investigation of the effects of nonconventional fuels and of off-specification fuel properties on spray and combustion processes at conditions typical of those experienced by future large diesel and dual-fuel engines. The well-established and unique spray combustion chamber test facility of Wärtsilä Switzerland Ltd. serves as the basis for these studies, which are complementary to activities already in progress in the context of the EU-funded HERCULES-C project (Figure 7).

Fig. 7 Spray Combustion Chamber Test Facility Setup at Diesel Technology Center of Wärtsilä Switzerland Ltd.

Outlook

The use of advanced motor fuels, such as biodiesel, biogas, and synthetic fuels, still constitutes a very low share of 0.30% of the overall use of fuel for transportation in Switzerland. Not even all of the upgraded biogas that was fed in the natural gas grid was used for transport applications. Other than the support for tax exemptions and tax reductions, there is no strong political support for using biofuels in the transportation sector in Switzerland at present. In 2014, the start of construction of a new biodiesel plant with a capacity of 100,000 tons per year had to — once more — be postponed to the next year. The reason was a lack of sufficient demand.

Constraints on increasing the use of renewable motor fuels were restrictions on various kinds of biofuels and a lack of regulations on blending fossil fuel with biodiesel or ethanol. Food production has priority over fuel production in Switzerland because the areas for agricultural production there are limited. Waste is thus preferred for the production of biofuels for ecological reasons.

Drivers for increasing the amount of advanced motor fuels were regulations as foreseen in the new energy law, such as the pathway toward a goal of reducing CO_2 emissions. One solution is to blend fossil fuel with renewable fuels. Other solutions are to use hybrid and electric vehicles, which are technologies that are very competitive with advanced motor fuels.

The target of Swiss Energy Strategy 2050, however, is to increase the amount of renewable energy. The additional grants for energy research will encourage a lot of research activities related to producing and using advanced motor fuels. Important fields of research are wood methanation, power to gas,[44] and flexible fuel combustion.

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[18] SFOE, 2012b: Energieforschungskonzept 2013–2016

[44] “Power to gas” is a pathway envisioned to balance electricity production and demand by converting electric power to gaseous fuel, through electrolysis production of hydrogen and oxygen. The hydrogen could then be fed into the natural gas system or used in a fuel cell (in a fuel cell vehicle for mobility); it could also be combined with CO_2 from various origins (e.g., biogas) to produce methane, which is added to the natural gas system. All related technologies are available, but cost is still an issue.

[19] SFOE, 2014d: Überblicksbericht Forschungsprogramm Verbrennung und WKK

Benefits of Participation in the AMF IA
Membership offers great opportunities with regard to making international contacts and exchanging knowledge. The information provided is always current and of good value. Furthermore, membership in AMF IA facilitates international project collaborations that are mutually beneficial. It helps promote national projects and provides support for national authorities.

Thailand

Introduction

Thailand's high dependency on foreign energy puts its energy security at risk. In 2014 (January through October), Thailand imported its total energy consumption of 63,978 kilotonnes of oil equivalent (ktoe), accounting for 1.558 trillion baht ($44,212 million US), which is a 2.3% increase from the corresponding period of the previous year [1]. In this amount of consumption value, the cost of imported energy accounted for 1.14 trillion baht (34,545 million US). Thailand's final energy consumption covers all energy supplied to the final consumer for all energy uses, and petroleum products represent the major part of the energy consumption, as shown in Figure 1. Petroleum products represented the highest consumption of 47.3%, followed by renewable energy, electricity, natural gas, and coal/lignite. Energy consumption from all economic sectors increased: agricultural, industrial, residential, commercial, and transport sectors increasing by 2.9%, 4.1%, 2.0%, 1.7%. and 0.8% respectively [1]. Figure 2 shows that of all fuel types, diesel fuel used for commercial energy consumption represented the most consumption, accounting for 46.1% [2]. Consumption of diesel was followed by consumption of liquefied petroleum gas (LPG), gasoline/ethanol blend, jet fuel, and fuel oil (Figure 2).

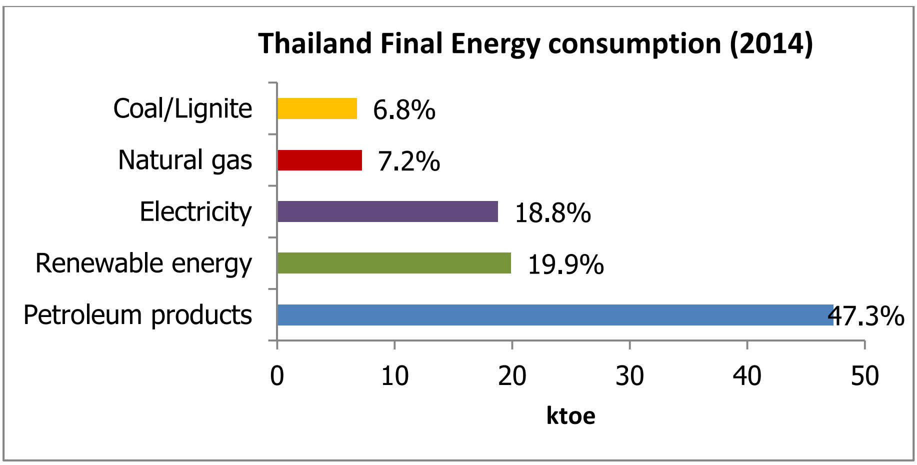

Fig. 1 Energy Consumption in Thailand in January–October 2014 [1]

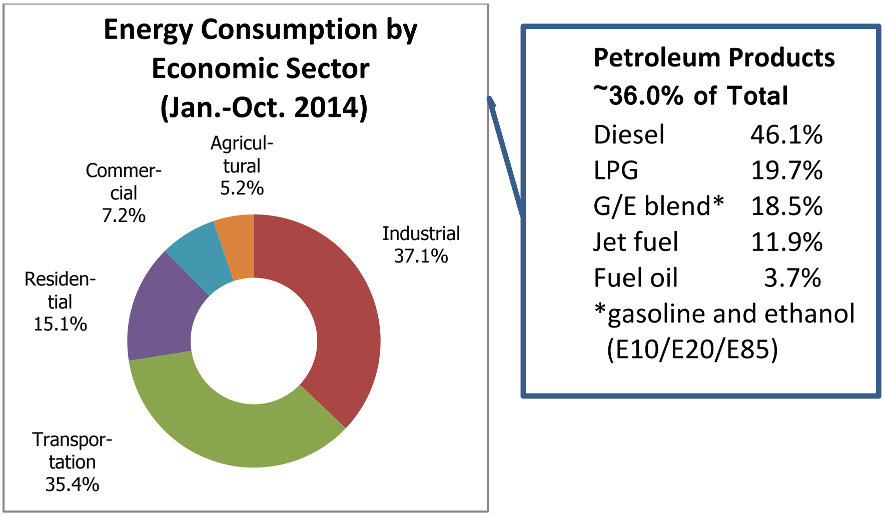

Fig. 2 Final Energy Consumption by Economic Sector in Thailand in January–October 2014 [1, 2, 3]

According to the Government's policy, both Governmental and private sectors have been encouraged to increase the use of renewable energy and improve energy conservation and efficiency. Hence, from January to October of 2014, renewable energy consumption increased to 7,542 ktoe, an 11.9% increase over consumption in the same period of the previous year. In this regard, biofuel use also rose around 2.07%.

A total of 2,344,621 new vehicles were registered in January through September 2014. By the end of September 2014, there were 35,650,355 vehicles in Thailand. Among these, gasoline vehicles accounted for 24,714,589 units, amounting to about 69.34% of the total, as shown in Table 1 [4].

Table 1 Transport Statistics for Thailand in September 2014 [4]

Fuel Type	Quantity	Percent of Total
Gasoline	24,714,589	69.34
Diesel	9,022,143	25.31
Mono-fuel LPG	25,434	0.07
Bi-fuel or dual-fuel LPG and gasoline or diesel	1,190,267	3.33
Mono-fuel compressed natural gas (CNG)	65,313	0.18
Bi-fuel or dual-fuel CNG and gasoline or diesel	344,256	0.96
Electric	2,684	0.01
Hybrid	61,280	0.17
Non-fuel and others	224,389	0.63
Total	35,650,355	100.00

Policies and Legislation

Climate change and high energy demand have led most countries, including Thailand, to launch national policies and plans to promote bioenergy as one of the key renewable energy resources. Therefore, agricultural commodities such as tapioca, sugar cane, and oil palm will experience increased demand, and their prices will rise. This situation is changing land use from food to energy crops. It has created vulnerabilities with regard to the nation's food security and export competitiveness.

Therefore, the Thai Government issued the *Eleventh National Economic and Social Development Plan 2012–2016* to promote and strengthen both its food and its energy security. The plan describes the following strategies [5]:

1. Enhance the efficiency of production and services based on local wisdom, knowledge, innovation, and creativity by developing food and energy security, while reforming the structure of the economy so that consumption becomes more environmentally friendly and while strengthening relations with neighboring countries in the region for economic and social benefits.
2. Develop an efficient and sustainable economy by upgrading production and services based on technology, innovation, and creativity via the use of effective regional links; by improving food and energy security; and by upgrading eco-friendly production and consumption to move toward a low-carbon society.

3. Strengthen the agricultural sector to foster food and energy security, with an emphasis on the management of natural resources that are the basis for agriculture.
4. Encourage farmers to plant trees, including energy crops, on their own land as well as in community forests. This will create benefits when the crops are appropriately exploited and will conserve ecosystem services essential for agriculture and carbon sinks.
5. Promote research and apply technology to increase the productivity of energy crops. Undertake research on other nonfood crops, such as algae, as alternative sources of renewable energy in order to reduce food shortages.
6. Establish an agricultural product management system for food and energy. Focus on food security with regard to crops such as oil palm, cassava, and sugar cane.
7. Enhance efficiency in bioenergy production. Use the manufacturing and service sectors in order to reduce dependence on imported fossil fuels and to stabilize commodity prices.
8. Provide mechanisms to monitor bioenergy prices. The aim is to achieve price stabilization and fairness to both consumers and producers without affecting national food production.

In response to the *Eleventh National Economic and Social Development Plan 2012–2016,* the Energy Policy and Planning Office, Ministry of Energy, has established a four-year action plan. The formulation of a four-year (2012–2015) strategic direction and targets for Thailand is mentioned in the action plan as follows:

- Strategy 1: Create a Thai national energy policy and administration,
- Strategy 2: Promote and develop renewable and clean energy,
- Strategy 3: Promote energy conservation and efficiency in the Governmental sector and private sectors,
- Strategy 4: Develop information and communication technology related to Thai national energy issues, and
- Strategy 5: Strengthen the Energy Policy and Planning Office to make it a high-performance organization focused on energy management.

In addition, key performance indicators and targets related to renewable and clean energy development during 2012–2015 were established (Table 2).

Table 2 Targets for Renewable and Clean Energy Development in Thailand

Description	% Increase in Alternative Energy Use			
	2012	2013	2014	2015
CNG for natural gas vehicles (NGVs)	0.5	0.5	0.4	0.4
Biofuel	10.1	10.7	11.1	12.4

In the first quarter of 2014, renewable energy consumption was 2,133 ktoe, contributing about 11.6% of final energy consumption and representing an 11.8% increase over that in the previous year. Biofuel use was 428 ktoe (ethanol amounting to 196 ktoe, and biodiesel amounting to 232 ktoe), accounting for 20% of renewable energy consumption. The use of CNG for NGVs was around 9,097 tons/day, representing a 5.8% increase from that in the previous year. The increase in CNG consumption was due to the Government policy supporting the use of CNG in NGVs, which involved 491 CNG service stations [6].

Implementation: The Use of Advanced Motor Fuel

Ethanol

The Thai Government indicated that the 10-year *Alternative Energy Development Plan (2012–2021) for Ethanol* remains in place. The plan is still set to increase ethanol consumption to 9 million liters (L) per day (d) by 2021. Ethanol consumption increased to 3.18 million L/d in April 2014, up from an average of 2.6 million L/d in 2013, when the Government terminated the sales of octane-91 regular gasoline. The Government is still promoting the use of E20 and E85 gasohol consumption through price incentives. The subsidies make ethanol blends 12% to 40% cheaper than E10 octane–95 gasoline. The price subsidies are paid by the State Oil Fund. The Government still provides gasoline station marketing subsidies totaling 1 to 2 baht/L ($0.12 to $0.23 US/gallon [gal]) and 5 to 6 baht/L ($0.58 to $0.70 US/gal) to entice the stations to expand sales of E20 and E85 gasohol. In addition, the Government continues to support the manufacturing of E20 vehicles that are compatible with E20 gasohol and flex-fuel vehicles (FFVs). The excise tax rate for the manufacturing of the Eco-cars (<1,300-cc [cubic centimeter] engines with a fuel consumption rate of 5 L/100 kilometers [km]) is 17%, compared with 30% for E10 vehicles. With regard to feedstock, the plan focuses on improving existing feedstock supplies of molasses and cassava. The target is to increase average sugarcane yields to more than 94 tons/hectare (ha) compared to the current average yield of

75 tons/ha. The plan also aims to increase the average cassava yield to more than 31 tons/ha, with total production of 35 million t per year [7].

Biodiesel

The Thai Government's *Biodiesel Development Plan* remains unchanged from last year. The Government has maintained its B100 consumption target at 5.97 million L/d by 2021. The plan focuses on both supply and demand. On the supply side, the Government will promote the expansion of oil palm acreage to a targeted 880,000 ha, with a total oil palm harvest area of 848,000 ha by 2021. Average yields are expected to reach 30 t/ha in 2021, while crude palm oil crushing rates should be above 18%. On the demand side, the Government anticipates balancing its compulsory production of biodiesel with domestic palm oil supplies. The Plan also introduces pilot projects for using B10 or B20 blends in fleet trucks and fishery boats. Nonetheless, B100 producers — especially those that are not part of those integrated with CPO processors and petroleum oil refineries — are struggling to survive, primarily because of higher production costs [7].

The list that follows shows the historical implementation of mandatory use for specific biodiesels since 2007 [7]:

- June 2007: Implement mandatory use of B2 and voluntary use of B5,
- June 2010: Implement mandatory use of B3 and voluntary use of B5,
- March 2011: Implement mandatory use of B2 and voluntary use of B5,
- May 2011: Implement mandatory use of B3–B5,
- July 2011: Implement mandatory use of B4,
- January 2012: Implement mandatory use of B5,
- July 19, 2012: Implement mandatory use of B3.5,
- November 1, 2012: Implement mandatory use of B5,
- April 2013: Cabinet agrees to implement mandatory use of B7 commencing on January 1, 2014,
- January 1, 2014: Implement mandatory use of B7,
- February 17, 2014: Adjust mandatory use from B7 to B3.5, and
- May 14, 2014: Return to implementing mandatory use of B7.

The Government also intends to support the research and development plan called the *Future New Fuel for Diesel Substitution,* which encourages the cultivation of new energy crops (jatropha and micro algae), diesohol (blending ethanol with diesel), and oil conversion technology (hydrotreated vegetable oil or HVO and biomass to liquid or BTL) between 2014 and 2017. Table 3 shows projected biodiesel and bioethanol sales.

Table 3 Sales of Bioethanol and Biodiesel in Thailand [7]

Fuel	Sale Quantity (million L/d), Average or per Month								
	2554 (avg.)	2555 (avg.)	2556 (avg.)	2557 (avg.)	2557 Jan	Feb	Mar	Apr	May
Gasohol 95 (E10)	5.82	5.27	8.28	7.44	7.36	7.48	7.51	7.50	7.38
Gasohol 95 (E20)	0.61	1.00	2.63	3.45	3.15	3.27	3.45	3.75	3.65
Gasohol 95 (E85)	0.02	0.10	0.38	0.74	0.63	0.67	0.73	0.83	0.84
Gasohol 91	5.09	5.74	9.12	9.54	9.25	9.50	9.61	9.75	9.60
Ethanol	1.23	1.38	2.59	3.02	2.82	2.92	3.02	3.18	3.14
High-speed diesel (HSD)	52.58	55.99	53.34	58.82	57.90	59.02	59.21	58.97	58.99
Biodiesel B100	1.87	2.24	2.13	2.76	4.05	2.07	2.07	2.06	3.54

Advanced Biofuels

A molasses-based ethanol plant recently opened a second production line using cane bagasse. This second-generation biofuel pilot project was established by the Thai Roong Ruang Group, one of the largest sugar mills in Thailand, the Japanese Government, and the Thai Government. The project is still in the experimental stage, with a production capacity of 10,000 L/d, mainly because the production costs have remained higher than those for the first-generation ethanol derived from sugar molasses or cassava roots [8].

Outlook

In addition to biofuel production, logistics and transport management (LTM) is another approach for mitigating fossil fuel consumption [9]. The Institute of Industrial Energy conducted the LTM Project with support from the Energy Policy and Planning Office. The aim of the project is to encourage (and consult with) the transportation sector to increase fuel efficiency and fuel economy and decrease the cost of energy for transport. The expert team conveys advice on how to improve transportation management in terms of four dimensions: engineering and technology, management, driving, and task force. More than 130 organizations have joined this project now, with their target being to diminish energy use by about 5 ktoe per year.

Not only bioethanol and biodiesel but also biomethane gas or biogas are promising biofuels for vehicles, especially with the increasing use of LPG and CNG as alternative fuels for vehicles in Thailand. LPG imports constituted more than 22% of domestic LPG consumption. In addition, the Thai Government planned to import liquefied natural gas (LNG) amounting to about 0.5 to 1 million tons per year [10]. In response to the problem of needing to import, the Energy Research and Development Institute – Nakornping, at Chiang Mai University, established a "Sustainable Compressed Bio-methane Gas (CBG) Development for Vehicles" Project [11]. In this project, a new mobile CBG production system unit was successfully invented. The unit is ready to serve users by filling NG and CNG vehicles. The CBG gas production system uses biogas, a byproduct from dairy farms, as a raw material, and the gas quality is enhanced via a water scrubbing process, which is an accomplished technology. The resulting gas qualifies as CNG or NG for NGVs, according to the announcement of the Department of Energy Business in the 2009 document, *The Term of Characteristics and Quality of Natural Compressed Gas for Vehicles*. This project has drawn interest from both the public and private sectors in Thailand and abroad, and the resulting gas may be further used as an alternative energy.

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[1] *Energy Situation (January– October 2014),* Department of Alternative Energy Development and Efficiency, Ministry of Energy (2014).

[2] *Final Modern Energy Consumption (Original Unit),* Energy Forecast and Information Technology Center, Energy Policy and Planning Office, Ministry of Energy (2014), http://www.eppo.go.th/info/stat/T01_02_01.xls.

[3] *Commercial Primary Energy Consumption (KTOE),* Energy Forecast and Information Technology Center, Energy Policy and Planning Office, Ministry of Energy (2014), http://www.eppo.go.th/info/stat/T01_01_10.xls.

[4] *Transport Statistics as of September 2014,* Transport Statistics Subdivision, Planning Division, Department of Land Transport (2014).

[5] *Announcement of the Royal Command,* Subject: "The Eleventh National Economic and Social Development Plan 2012–2016," National Economic and Social Development Board, Office of the Prime Minister (2012).

[6] *Four-Year Action Plan and 2014 Action Plan,* Energy Strategy Development Group, Energy Policy and Planning Division, Energy Policy and Planning Office, Ministry of Energy (2014).
[7] "Fuel Situation," Energy Policy and Planning Office, *Energy Policy Journal*, Volume 104 (April–June 2014).
[8] *Thailand, Biofuels Annual, August 2014,* AgroChart (2014), http://www.agrochart.com/en/news/news/290814/thailand-biofuels-annual-aug-2014.
[9] "Logistics and Transport Management," Energy Policy and Planning Office, *Energy Policy Journal,* Volume 99 (January–March 2013).
[10] "Compressed Biomethane Gas: LPG and CNG Substitution?," Energy Policy and Planning Office, *Energy Policy Journal,* Volume 102 (October–December 2013).
[11] *CMU Ensures the Quality of Bio-Gas Is 100% Ready and Free to Use,* Chiangmai University (2013), http://www.prcmu.cmu.ac.th/hotnews_detail_eng.php?perin_id=457.

Benefits of Participation in the AMF IA

Thailand benefits in a number of ways by participating in the AMF IA. Through its participation, Thailand has opportunities to promote a domestic research and development (&D) project through the IEA AMF IA scheme and participate in a collaborative research project (Annex) that involves international specialists and experts. In addition, Thailand is able to gather updated information from global participants on advanced motor fuels R&D, establish international links and contacts, exchange knowledge, and better develop ideas for creating or modifying the country's national energy development plan.

United States

Introduction

The U.S. Energy Information Agency (EIA) estimated that total U.S. transportation energy consumption in 2013 was about 27,272 trillion Btu, a level that had changed little since 2008.[45] It projected that the 2014 total would also be very near 27 trillion Btu.[46] More than 90% of this consumption was petroleum-based fuels (gasoline and diesel), with almost the entire remainder being ethanol blended into gasoline at 10% (some 95% of U.S. gasoline now in early 2015 consists of such blends).[47]

The U.S. net dependence on foreign oil had dropped from approximately 60% of U.S. petroleum use in 2005 to about 40% at the end of 2012, with 2016 imports preliminarily estimated.[48] These large reductions were due mainly to increased domestic production of "tight oil," including shale deposits; enhanced recovery at mature conventional fields; rising energy prices; and increases in vehicle efficiency.[48]

Undoubtedly the most significant development in 2014 with regard to prospects for advanced motor fuel production and use was the collapse in world oil prices — a global phenomenon that had been particularly pronounced in the United States. Much of the impetus for converting to the use of natural gas (NG), as well as other fuels such as ethanol and propane, in transportation and for purchasing electric vehicles is likely to diminish in 2015 and the years immediately following it.

As of the time of this writing in early 2015, the EIA is in the process of substantially revising its projections for the use of petroleum and alternatives due to the collapse of oil prices. Therefore, its *Annual Energy Outlook* has not been released as of this time, and thus this country report has omitted such projections.

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45 http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_11.pdf.

46 http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2013ER&subject=15-AEO2013ER&table=46-AEO2013ER&region=0-0&cases=early2013-d102312a,full2012-d020112c.

47 Ibid. The EIA shows only 1,252 trillion Btu of this as being renewable fuel, including ethanol (http://www.eia.gov/totalenergy/data/monthly/). Because 14.9 trillion Btu of the total was projected to be motor gasoline — 95% of which contained 10% ethanol — and 5.0 trillion Btu was diesel fuel (http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2013ER&subject=15-AEO2013ER&table=46-AEO2013ER&region=0-0&cases=early2013-d102312a,full2012-d020112c) — some of which contained renewable components — this estimate appears low.

48 See http://www.eia.gov/forecasts/aeo/er/early_production.cfm?src=Petroleum-b1.

Policies and Legislation

The U.S. Federal Government and state governments provide many incentives for the development, deployment, and use of alternative fuels and alternative fuel vehicles. While they are too numerous to catalog here, some of the more important ones are described here.

The Energy Policy Act of 1992 (EPAct 92) requires that certain centrally fuelled fleets (federal, state, and alternative fuel provider fleets, such as utility companies) get light-duty alternative fuel vehicles as most of their new vehicle acquisitions. Fleets of alternative fuel providers must also use alternative fuels in the vehicles, where available for use.

The U.S. Department of Energy (DOE) Clean Cities Program is a government-industry partnership program that supports local decisions to reduce petroleum use in the transportation sector. To accomplish this goal, the program encourages the public and private sectors to reduce petroleum consumption by using alternative fuels and by increasing vehicle efficiency through technologies such as alternative-fuelled vehicles, hybrid and electric-drive vehicles, fuel blends, idle reduction technologies, and fuel economy measures. Clean Cities carries out its mission by working in cooperation with nearly 100 geographically diverse, community-based coalitions nationwide. Coalitions form partnerships within their communities to design projects to suit their area's needs, resources, and strengths. At the national level, Clean Cities gives manufacturers, trade associations, national fleets, government agencies, and other stakeholders coordinated strategies and resources that they can leverage to implement effective petroleum reduction practices. Clean Cities also gives coalitions access to information and incentives from DOE, other federal and state agencies, and industry partners that can help fund significant, high-impact projects.

As shown in Figure 1, the Clean Cities coalition users of alternative motor fuels displaced 390 million gallons of gasoline equivalent (MGGE) in 2013 (most recent data), an increase of about 15% from 2012 levels. Over half of the savings came from NG-powered vehicles, typically heavy-duty trucks and city buses. The savings come from approximately 475,000 vehicles tracked by the Clean Cities coalitions. Note that the consumption quoted by Clean Cities was mainly done by fleet vehicles that were in an area tracked by a Clean Cities coalition partner. The U.S. Federal Government does not have an active role in operating the majority of these fleets. More information on the Clean Cities program can be found at www.cleancities.energy.gov.

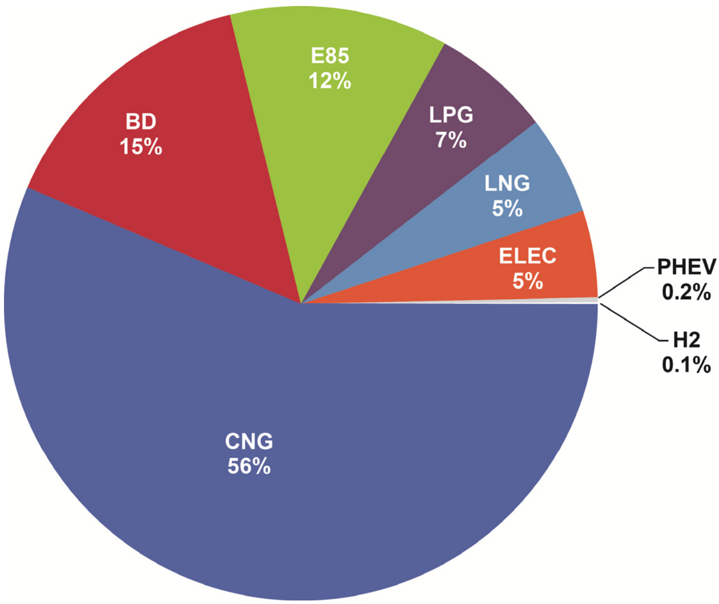

Fig. 1 Clean Cities 2013 Data for Advanced Fuel Vehicles (AFVs) and Petroleum Displacement[49]

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

The primary driver of renewable fuel use in the United States is the RFS, adopted in 2005 and expanded in 2007 (RFS2). It requires increasing volumes of renewable fuel to be used in motor fuels.

In 2013, the EPA issued a proposed rulemaking for the 2014 volume requirements for renewable fuels,[50] proposing a reduction in both total volume requirements and the requirements for specific categories, compared to volumes originally proposed in 2010. Total renewable fuel requirements were reduced from a mandated 18.15 billion gallons per year (gal/yr) (of ethanol equivalent) in 2013 to 16.55 billion gal/yr actual volume, and the proposed volume for 2014 was 15.21 billion gal/yr. To date (early 2015),

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[49] See http://www.afdc.energy.gov/uploads/publication/2012_metrics_report.pdf. BD = biodiesel, E85 = ethanol 85, LPG = liquefied petroleum gas, LNG = liquefied natural gas, Elec = electricity, PHEV = plug-in hybrid electric vehicle, H2 = hydrogen, and CNG = compressed natural gas.

[50] EPA (U.S. Environmental Protection Agency), 2014. "Standards for Renewable Fuels Standards Program – Proposed Rule," *Federal Register*, Vol. 78, No. 230, Nov. 29, 2013 (comment period to end Jan. 28, 2014).

however, the EPA has not finalized the volume requirements for 2014, creating considerable uncertainty for both obligated parties under the regulation (refiners) and producers/blenders of ethanol. The proposed reduction in volumes was due to a number of factors. The EPA cited (a) reduced market fuel volumes (e.g., gasoline consumption declined from 18.67 quadrillion Btu/yr to 15.84 quadrillion Btu/year in the period 2007–2013), (b) the ethanol blend wall (combining the factors of the market acceptance and availability of E15 gasoline blends and the limited availability and acceptance of E85), and (c) limited production of biodiesel and other advanced biofuels. Cellulosic ethanol requirements were reduced from a previously mandated 1.75 billion gal/yr in 2014 to a proposed 17 million gal/yr, citing lack of production capacity. Biomass-based diesel was proposed at 1.28 billion gal/yr, citing under-utilization of capacity due to feedstock cost and uncertainty regarding tax credits for 2014. (See section on alternative fuel use for estimates of 2014 production based on EPA recorded volumes.)

The EPA divides renewable fuels into several categories for regulatory purposes, some of which are nested. Liquid cellulosic biofuel is fuel derived from biomass by enzymatic conversion and fermentation, by pyrolysis, or by gasification. The category was created largely with cellulosic ethanol in mind, but cellulosic ethanol production continues to be plagued with problems. As shown here, renewable NG from landfills and anaerobic digesters, treated as cellulosic biofuel by the EPA through a combination of rulemakings in 2013 and 2014, has dwarfed liquid fuels in that category. Biomass-based diesel is mainly traditional fatty acid methyl ester (FAME) biodiesel, derived from soy, corn, canola, camellia oils, and other vegetable and animal fats and oils. These categories are nested into the category of advanced biofuels, which also includes renewable diesel, biogas, renewable heating oil, and renewable fuels co-processed in petroleum refining. Finally, the category renewable fuel includes all the above categories combined with (and dominated by) starch- and sugar-based ethanol.

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

Use of Advanced Motor Fuels

Biofuels

In 2012, the first commercial production of cellulosic ethanol in the United States came on line. Although the total volume remains very small (less than 1 million gal), several facilities came on line in 2013, and more were added in 2014. As of mid-December 2014, 35 facilities were registered with the EPA for generation of D3 (cellulosic fuels other than diesel) Renewable Identification Numbers (RINs), the great majority of which were for cellulosic ethanol production, although not all of these facilities were actually producing (see Figure 2).[51]

The EPA shows RINs for 2014 (representing the Btu equivalent of a gallon of ethanol) at 32,959,561, for total advanced biofuel (mostly sugarcane ethanol imports) at 142,890,997, and for total renewable fuel (mostly corn ethanol) at 14,330,376,691.[52] Of the nearly 33 million cellulosic biofuel RINs, more than 32 million were from renewable NG, 683,643 were from cellulosic ethanol, and 44,168 were from cellulosic gasoline.[53] Renewable NG includes both landfill gas and gas from anaerobic digesters using partial cellulosic feeds.

Biomass-based diesel RINs generated in 2014 totaled 2,686,879,869, of which 2.14 billion were for biodiesel and 555.54 million were for renewable diesel hydrocarbons. Only 54,308 RINs were generated for cellulosic diesel fuel.[54]

At this time (early 2015), blends of greater than 15% ethanol are marketed in the United States at special dispensers for use only in flex-fuel vehicles (FFVs) designed for use with up to E85. There were an estimated 2,472 stations selling FFV fuel in the United States by December 2014, including "blender pumps," which sell blends for conventional vehicles and a range of blends for FFVs (e.g., E20, E30, and E85). The FFVs using high-ethanol blends have experienced problems with starting and drivability in winter months in some regions. In 2011, ASTM International revised its Specification D5798-11 (Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines) to allow for blends of

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[51] D3 RINs also include hydrocarbon fuels/blendstocks made from cellulosic sources and CNG for vehicles made from landfill gas and some anaerobic digester gas.

[52] http://www.epa.gov/otaq/fuels/rfsdata/2014emts.htm.

[53] Ibid.

[54] Ibid.

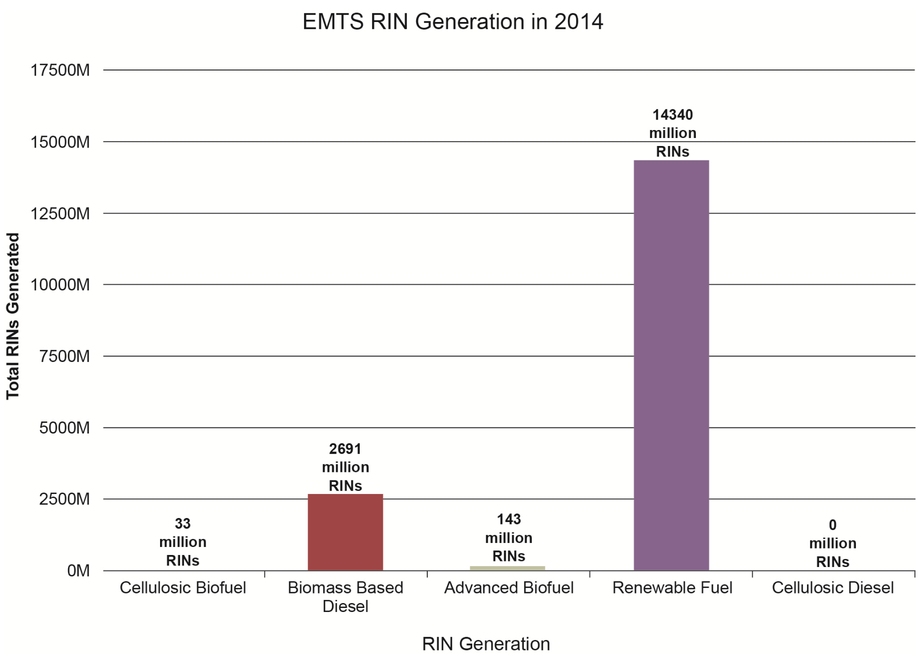

Fig. 2 Generation of Renewable Identification Numbers under the EPA Renewable Fuel Standard in 2014 (Each RIN represents the equivalent of a gallon of ethanol.)
(Source: Chart from Voegele, E., 2015, "EPA: 2014 RIN Generation Tops 33 Million," *Biomass Magazine,* Jan. 15, http://www.biomassmagazine.com/articles/11438/epa-2014-cellulosic-rin-generation-tops-33-million. Data from EPA.)

down to 51% ethanol to be used as FFV fuel.[55] There is, however, no legal barrier to marketing blends of even lower than 51% for use in FFVs. As noted previously, some marketers are offering lower blends year-round through blender pumps.

Natural Gas

The growth of hydraulic fracking in the United States has revolutionized the energy industry, created some problems relative to infrastructure, and been the focus of political and economic debate. NG production in the United States has increased steadily in recent years and is projected to continue to increase in future years though at reduced rates of growth (Figure 3).

55 See http://www.afdc.energy.gov/fuels/ethanol_locations.html.

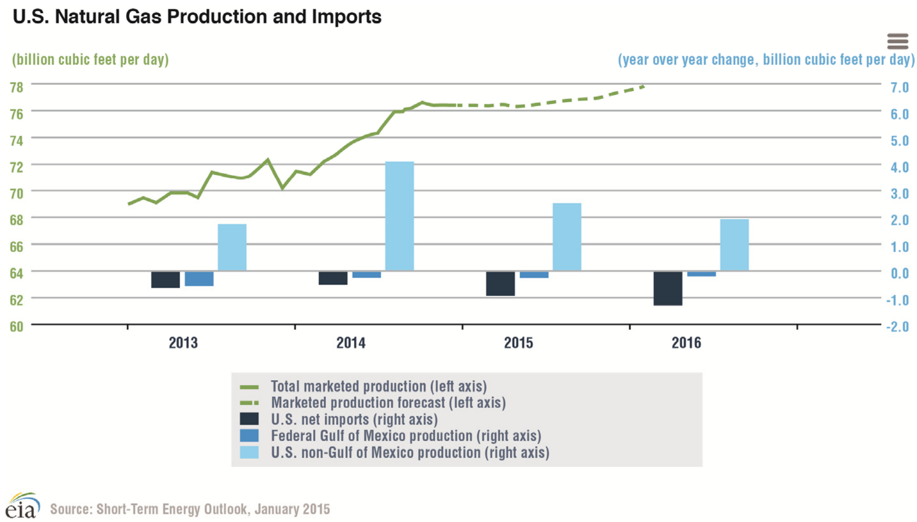

Fig. 3 Natural Gas and Crude Oil Production in United States from 2013 through 2016[56]

Use of NG for transportation had been expected to grow in the coming decades, mainly in the heavy-duty vehicle sector, but the collapse of oil prices has called those projections into question, at least regarding the rate of such growth. Other problems surrounding the use of NG as a motor fuel are mainly infrastructure-related rather than vehicle-related.

In 2011, the EPA revised its regulations governing the conversion of conventional vehicles to alternative fuels, making it easier for conversion systems for NG and propane to get approval for vehicles older than two years. This revision has resulted in many more AFV conversion systems being registered with the EPA.

Electric Vehicles

Sales of plug-in electric vehicles in 2014 continued to fluctuate on a month-to-month basis but were up substantially from 2013, totaling 118,773 compared to 96,702 in 2013; this represented a 23% increase. Cumulative sales since 2010 now in early 2015 total 286,390. Plug in models and fuel cell models combined totaled 24 as of the end of 2014, with another 20 models expected in 2015. In addition, 418,400 hybrid electric (non-plug-in) were sold in 2014.[57]

[56] EIA (Energy Information Administration), 2015, *Short Term Energy Outlook,* Jan.
[57] See http://www.electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952.

Alternative Fuel Infrastructure

Table 1 provides the counts of alternative fuel refuelling stations, including private stations, in the United States according to DOE's Alternative Fuels Data Center.[58] Updated information, with a breakdown by state and individual station locations, can also be accessed on the Alternative Fuels Data Center site.

Table 1 Counts for U.S. Alternative Fuel Refuelling Stations by Type in 2012, 2013, and 2014 (including public and private stations)

Year	B20	CNG	E85	Electric Outlets[a]	H_2	LNG	LPG	Total	Total Non-electric
2012	675	1,107	2,553	13,392	58	59	2,654	20,498	7,106
2013	757	1,263	2,639	19,410	53	81	2,956	27,159	7,749
2014	784	1,489	2,780	25,511	51	102	2,916	33,633	8,122

[a] Numbers for 2012 and 2013 and first number for 2014 are total number of recharging outlets, not sites.

As can be seen from the table, the total number of alternative fuelling stations, exclusive of electric recharging stations, in the United States increased by just more than 14% between 2012 and 2014. The total number of public and private nonresidential EV recharging outlets jumped by more than 90% over this same two-year period, indicating not only the emphasis being placed on vehicle electrification by public and private entities but the rapid growth in the number of motorists choosing EVs.

Advanced Fuels and Engines

The DOE Vehicle Technologies Office sponsors research in fuels and advanced combustion engines for the purposes of displacing petroleum-derived fuels, matching engines and fuel characteristics better, and increasing engine and vehicle efficiencies. This research covers a very broad range of fuel, engine, and vehicle technologies. The brief summary provided here focuses on fuels and fuel effects and is based on recent DOE annual program reports.[59, 60] Fuels can affect combustion and efficiency by altering in-cylinder mixing of fuel and air, by enabling a higher compression ratio

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

[59] DOE (U.S. Department of Energy) Vehicle Technologies Office, 2013, *Fuels and Lubricant Technologies 2012 Annual Progress Report*, DOE/EE-0911, June.

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

through high octane, and by having chemical effects on important properties, such as burning velocity and ignitability.

Much of the research on the benefits of higher octane in the United States for spark-ignited engines has centered on ethanol, a readily available, high-octane gasoline component. In one study by Anderson et al.,[61] ethanol blends were found to outperform high-octane gasoline relative to knock-limited spark timing at high loads, thus allowing for both higher loads and improved fuel economy. In several studies,[62] it was also proposed to use ethanol selectively in a vehicle for high-load operation, either through the use of two fuel tanks or onboard separation. They reported a significant margin for further engine optimization by spark advance, an increase in the compression ratio, and engine downsizing for blends of ethanol in gasoline from 51% to 85%, such as those used in FFVs.

While high-octane fuel is desirable for traditional spark-ignited engines, it might not be ideal for kinetically controlled engines using homogeneous charge compression ignition (HCCI) or premixed charge compression ignition (PCCI) combustion. Such engines depend on a combination of fuel volatility and ignitability to allow optimum fuel-air mixing before combustion. Although the research regarding this conclusion is still preliminary, HCCI or PCCI engines will likely not benefit from higher-octane fuels. They may, however, actually benefit from lower-octane fuels that are somewhere between current diesel and gasoline for cetane and octane ratings. The more likely scenario would be HCCI or PCCI engines benefiting from a range of octanes and cetanes for different operating conditions.

For diesel engines, efficient, dilute combustion can be brought about by delaying ignition in the diesel spray, resulting in a combustion mode described as "lifted flame." Several projects (DOE-Sandia National Laboratories and Ford Motor Company through DOE award under solicitation DE-FOA-0000239) are investigating this strategy, including the

61 Anderson, J.E., et al., 2012, "High Octane Number Ethanol–Gasoline Blends: Quantifying the Potential Benefits in the United States," *Fuel* 97:585–594, July, http://www.sciencedirect.com/science/journal/00162361/97

62 Blumberg, P.N., et al., 2008, "Simulation of High Efficiency Heavy Duty SI Engines Using Direct Injection of Alcohol for Knock Avoidance," SAE paper 2008-01-2447, October 6; Partridge, R.D., et al., 2014, "Onboard Gasoline Separation for Improved Vehicle Efficiency," SAE paper 2014-01-1200, April 1; Moore, W., et al., 2011, "Engine Efficiency Improvements Enabled by Ethanol Fuel Blends in a GDi VVA Flex Fuel Engine," SAE paper 2011-01-0900, April 12.

use of oxygenated fuel components that could be derived from bio-feedstocks.

Several DOE and industry projects are developing surrogate fuels for new or emerging fuels. Surrogate fuels allow more accurate kinetic modeling of fuel effects, since they are normally built of components for which detailed kinetic mechanisms exist. The development of surrogates also leads to a deeper understanding of the relative importance of fuel properties, chemistry, and molecular structure in engine combustion. This knowledge can then be used to predict performance and optimize fuels and fuel components for emerging fuels.

The DOE Bioenergy Technology Office 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.[63]

The Bioenergy Technologies Office has estimated there is the potential for converting 1 billion tons/yr of biomass. Various pricing and yield assumptions predict there is the potential for producing from 20 to 70 billion gal/yr of advanced biofuels by 2022.[64] Other highlights[65] include demonstrating that cellulosic ethanol is cost-competitive with petroleum, assisting in the support of 25 integrated bio-refineries, and helping support the development of co-processing of pyrolysis oil with petroleum.

Standards for Alternative Fuels

The American Society for Testing Materials (ASTM) published standard specifications for a number of alternative fuels. These include the ones shown in Table 2.

63 DOE Bioenergy Technologies Office, 2013, *Peer Review 2013*, May 20–23.
64 Perlack, R.D., and B.J. Stokes (leads), 2011, *2011 US Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry*, ORNL/TM-2011/224, Oak Ridge National Laboratory, Oak Ridge, TN, Aug.
65 DOE Bioenergy Technologies Office, *Bioenergy Successes*, www.eere.energy.gov.

Table 2 ASTM Fuel Specifications

Fuel	Specification No.
Ethanol Fuel Blends for Flexible Fuel Spark Ignition Engines (51–83%)	ASTM D-5798-13a
Mid-Level Ethanol Fuel Blends for Spark Ignition Engines (16–50%)	ASTM D-7794-12
Biodiesel Blends (6–20%)	ASTM D-7467-13
Biodiesel 100% Stock for Blending	ASTM D-6751-12
Dimethyl Ether (for Compression Ignition Engines)	ASTM D-7901-14
Methanol (for Spark Ignition Engines)	ASTM-D5797-13

Outlook

As noted, the outlook for all alternatives to petroleum motor fuel has been made uncertain by the 2014 collapse of oil prices. In order to account for the impact of the price collapse, the release of EIA's *Annual Energy Outlook* has been delayed until after the preparation of this country report. Last year, the EIA projected that the dependence ratio for U.S. petroleum imports would continue to decline to about 25% in 2016 and then rise to 32% in 2040 for the same reasons identified in the introduction for the decline since 2005.[66]

Apart from being affected by lower oil prices, it is expected that ethanol, the principal U.S. alternative fuel, will continue being constrained in 2015 by the challenges associated with blending at levels over 10% in gasoline as well as concerns over misfuelling, compatible systems, and other issues.

An interesting development in recent years has been the interest expressed by automakers in offering FFVs optimized for use with a blend higher than E15 (frequently theorized as somewhere between E20 and E40). These vehicles could take advantage of both the higher octane and the higher heat of vaporization of ethanol and thus essentially offset ethanol's lower energy content. In 2014, however, there was little indication of any substantial progress in the development of such vehicles.

[66] See http://www.eia.gov/forecasts/aeo/er/executive_summary.cfm.

Additional References

- Alternative Fuels & Advanced Vehicle Data Center, www.afdc.energy.gov
- EIA Annual Energy Outlook, www.eia.doe.gov/oiaf/ieo/index.html
- DOE Office of Vehicle Technologies, http://www1.eere.energy.gov/vehiclesandfuels/
- DOE Office of Biomass Program, http://www1.eere.energy.gov/biomass/
- DOE EERE (Office of Energy Efficiency and Renewable Energy) Information Center, http://www1.eere.energy.gov/informationcenter
- Bioenergy Feedstock Information Network, http://bioenergy.ornl.gov/
- Biomass R&D Initiative, www.biomass.govtools.us

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

3

Ongoing AMF IA Annexes

3.a
Overview of Annexes

Ongoing Annexes in 2014

Annex Number	Title	Operating Agent
28	Information Service and AMF Website	Dina Bacovsky
42	Toxicity of Exhaust Gases and Particles from IC- Engines – International Activities Survey (EngToxIn)	Jan Czerwinski
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
46	Alcohol Application in CI Engines	Jesper Schramm
47	Reconsideration of DME Fuel Specifications for Vehicles	Mitsuharu Oguma
48	Value Proposition Study on Natural Gas Pathways for Road Vehicles	Ralph McGill
49	COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Nils-Olof Nylund
50	Fuel and Technology Alternatives in Non-Road Engines	Magnus Lindgren
51	Methane Emission Control	Jesper Schramm

Recently Completed Annexes

Annex Number	Title	Operating Agent
35-2	Particle Measurements: Ethanol and Butanol in DISI Engines	Debbie Rosenblatt
38-2	Environmental Impact of Biodiesel Vehicles in Real Traffic Conditions	Norifumi Mizushima
39-2	Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines Phase 2	Magnus Lindgren
45	Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation	Benjamin Stengel

The final reports on the recently completed Annexes 35-2, 38-2, 39-2, and 45 are published on the AMF IA website.

3.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, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, South Korea, Spain, Sweden, Switzerland, Thailand, United States
Total Budget	€47,000 for 2014 ($53,500 US) €61,000 for 2015 ($69,500 US)
Operating Agent	Dina Bacovsky BIOENERGY 2020+ Email: dina.bacovsky@bioenergy2020.eu

Background

Today, a wealth of information on thousands of topics is easily available on the worldwide web. So much information is available that filtering out all the irrelevant items can be very time-consuming. In theory, everyone can access the information, even the information being published on the other side of the globe. However, someone may not know where to look for it or may need it to be translated.

Purpose and Objectives

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

Activities

- Review relevant sources of news on advanced motor fuels, vehicles, and energy and environmental issues in general. News articles are provided by experts in North America, Asia, and Europe.
- Publish four electronic newsletters per year (on average) on the AMF website, and use an email alert system to disseminate information about the latest issues (Figures 1 and 2).
- Prepare an Alternative Fuels Information System. The goal of this effort is to collate relevant 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 . The system does not cover information on fuel resources, fuel production, or greenhouse gas emissions. Different organizations are working together in close cooperation to build an AMF IA guidebook that is accessible electronically on the AMF IA website.
- Update the AMF IA website to provide information on issues related to transportation fuels, especially those associated with the work being done under the AMF IA. The website, in addition to providing public information, has a special password-protected area that is used for storing and distributing internal information for Delegates, Alternates, and Operating Agents on various topics (strategies, proposals, decisions, Executive Committee meetings of the AMF IA, etc.).

Results and Reports/Deliverables

- In 2014, four electronic newsletters were published: one each in March, June, October, and December.
- The Alternative Fuels Information System is available on the AMF IA website.
- The AMF IA website was updated frequently with information from Annexes and Executive Committee meetings.

ADVANCED MOTOR FUELS IEA-AMF

March 2014, issue no. 1/2014

AMFI Newsletter

Lidköping Biogas: one of the world's first plants for liquefied biogas, as to fuel cars and trucks more

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
- Werner TOBER and Robert ROSENITSCH, TU Vienna
- Manfred WÖRGETTER, BIOENERGY 2020+

Editing by Dina Bacovsky and Andrea Sonnleitner, BIOENERGY 2020+.
Checking by *Ralph McGill, FEEC and Päivi Aakko-Saksa, VTT.*
The AMFI Newsletter is available online at: www.iea-amf.org

CONTENTS

AMFI Newsletter, March 2014 – Page 1(14)

ADVANCED MOTOR FUELS IEA-AMF

July 2014, issue no. 2/2014

AMFI Newsletter

Biogas filling stations in Finland more

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
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Editing by Dina Bacovsky and Andrea Sonnleitner, BIOENERGY 2020+.
Checking by *Ralph McGill, FEEC and Päivi Aakko-Saksa, VTT.*
The AMFI Newsletter is available online at: www.iea-amf.org

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AMFI Newsletter, July 2014 – Page 1(20)

ADVANCED MOTOR FUELS IEA-AMF

October 2014, issue no. 3/2014

AMFI Newsletter

Off-Engine Fuel System Engine Fuel System Westport

AMF Annex 39 on the use of biomethane in HD engines completed more

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
- Werner TOBER and Robert ROSENITSCH, TU Vienna
- Shinichi GOTO, AIST
- Manfred WÖRGETTER, BIOENERGY 2020+

Editing by Dina Bacovsky and Christa Kristöfel, BIOENERGY 2020+.
Checking by *Ralph McGill, FEEC and Päivi Aakko-Saksa, VTT.*
The AMFI Newsletter is available online at: www.iea-amf.org

CONTENTS

AMFI Newsletter, October 2014 – Page 1(14)

ADVANCED MOTOR FUELS IEA-AMF

December 2014, issue no. 4/2014

AMFI Newsletter

Commercial-scale cellulosic ethanol plants opening more

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
The AMFI releases four electronic newsletters each year.
A group of authors prepares contributions to this newsletter:
- Ralph MCGILL, FEEC
- Werner TOBER and Robert ROSENITSCH, TU Vienna
- Shinichi GOTO, AIST
- Manfred WÖRGETTER, BIOENERGY 2020+

Editing by Dina Bacovsky and Nikolaus Luwiczek, BIOENERGY 2020+.
Checking by *Ralph McGill, FEEC and Päivi Aakko-Saksa, VTT.*
The AMFI Newsletter is available online at: www.iea-amf.org

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AMFI Newsletter, December 2014 – Page 1(15)

Fig. 1 AMF IA Newsletters Published in 2014

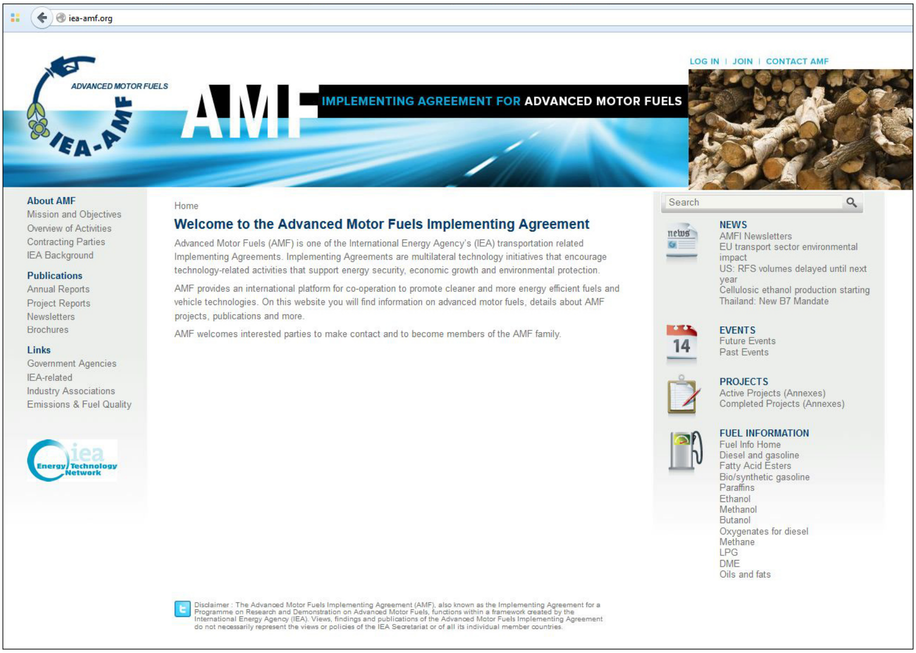


Fig. 2 Screenshot of the AMF Website

Future Plans

Future plans include updating the Alternative Fuels Information System on the AMF IA website, continuing to publish four electronic newsletters each year, and updating the website frequently.

Annex 35: Ethanol as Motor Fuel Sub-task 2: Particle Measurements: Ethanol and Butanol in DISI Engines

Project Duration	November 2010 – May 2014
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Finland, United States None
Total Budget	~€225,000 ($310,000 US)
Operating Agent	Debbie Rosenblatt Environment Canada Email: Debbie.Rosenblatt@ec.gc.ca

Background

As renewable fuel mandates get enacted and revised worldwide and as fuel economy standards get more demanding, there is a need to better understand the synergies between the proposed fuels that meet cleaner domestic renewable energy production goals and the technologies that allow better fuel economy.

Globally, vehicle manufacturers are pursuing a number of ways to improve engine efficiency. Two notable strategies are to downsize engines and to use direct injection (DI) with turbocharged spark ignition (SI) engines. Emissions of particulate matter (PM) are not currently a problem associated with gasoline engines; however, the particle number concentrations from DISI engines have been shown to be greater than those from port fuel-injected gasoline engines and those from compression-ignition engines with diesel particulate filters. With PM emission regulations becoming more stringent, there is a need to ensure that interactions between renewable energy and energy efficiency solutions do not produce undesirable effects.

Purpose and Objectives

As a result of the increasing use of ethanol, the growing number of DISI engines available from vehicle manufacturers, and the impact on the design and effectiveness of after-treatment systems, there is a need to understand particulate formation due to the interaction of alcohol-gasoline blends in DISI engines. Initial research has shown that low-level ethanol blends have the potential to decrease PM formation, but further confirmation is needed. Data on particulates associated with the use of butanol blends in DISI engines are also limited. This Sub-task 2 to Annex 35 is designed to investigate these issues.

Activities

The activities carried out under this Annex relate to conducting experiments and generating new data on particulates from DISI engines.

The project involves comparing the direct injection of alcohol-blended fuels — ethanol or isobutanol — to the direct injection of gasoline injected fuels. Both steady-state engine dynamometer tests and transient chassis dynamometer vehicle tests were conducted, as described here. The strategy was to evaluate the impact of ethanol and isobutanol on emissions from DISI engines operating under varying conditions; efforts were undertaken by the different participating countries.

U.S. Project Activities

The U.S. portion of the project was performed at Argonne National Laboratory by using a 2.2-liter (L), in-line, four-cylinder, 16-valve DISI engine at idle conditions and at 25%, 50%, and 75% load at 2,000 revolutions per minute (rpm). The fuels tested were gasoline, E10, E85, and isobutanol-16 (iB16). Particulate measurements, including number and size distribution, were obtained by using a scanning mobility particulate sizer, and soot morphology was measured by using a transmission electron microscope (EM).

Canada Project Activities

Environment Canada's Emissions Research and Measurement Section (EC/ERMS) conducted chassis dynamometer tests on a model year 2012 flex-fuelled vehicle with a 2.0-L DISI engine certified to Tier 2, Bin 4, North American emission standards (Figure 1). Particles were measured over the Federal Test Procedure (FTP)-75 driving cycle and New European Driving Cycle (NEDC) at 22°C and –7°C by using an engine exhaust particle sizer (EEPS). Test fuels included gasoline, E10, and E85.

In addition, chassis dynamometer tests and particle measurements were conducted on a model year 2011 light-duty vehicle with a 2.4-L DISI engine that met U.S. Environmental Protection Agency (EPA) Tier 2, Bin 5 emission standards and that was fuelled with gasoline and splash blends of E10, E15, E20 and an iB16 blend. Two transient drive cycles were used — FTP-75 and US06 (aggressive driving) — at ambient test temperatures of 22°C and –18°C.

Fig. 1 Vehicle Emissions Testing on Environment Canada's Chassis Dynamometer

Three Canadian Universities (University of Alberta, University of British Columbia and University of Toronto) studied particle number and size distribution by using a scanning mobility particulate sizer, particle density by using a centrifugal particle mass analyzer, and soot particle morphology by using a TEM) from a 2.0-L, four-cylinder, DISI engine fuelled with gasoline and ethanol-blended fuel (E10 and E30). Test conditions for both cold and hot starts included simulated highway cruise and high-speed, low-torque conditions.

Finland Project Activities

Chassis dynamometer tests were conducted at facilities of the VTT Technical Research Centre of Finland on a model year 2011 passenger vehicle with a 1.4-L, turbocharged, DISI engine that met Euro 5a European Union emission standards. The fuels tested were E10 and E85, and the tests were performed at two ambient temperatures, 23°C and –7°C. Measurements were taken during the transient NEDC. Particulate size distributions were measured with an electrical low-pressure impactor (ELPI).

Participants

- Canada: Environment Canada, Emissions Research and Measurement Section (ERMS)
- Canada: University of Alberta, University of British Columbia, and University of Toronto

- Finland: VTT Technical Research Centre of Finland
- United States: Argonne National Laboratory

Time Schedule

This Annex is completed.

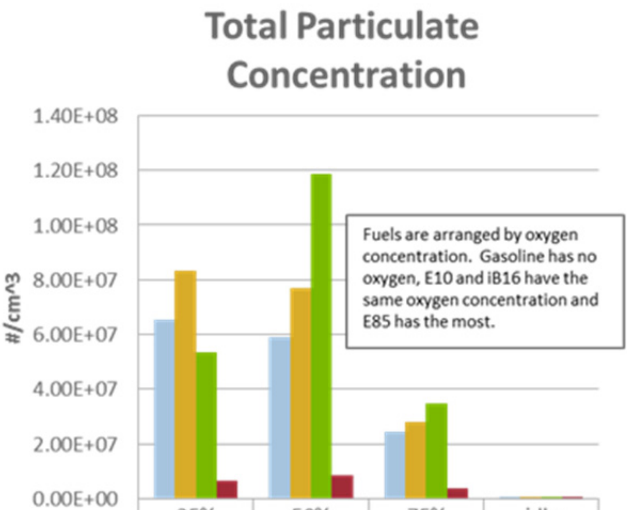
Results/Key Messages

This Annex demonstrated the potential for E85 to mitigate particulate emissions from DISI engines. Engine testing in the United States and chassis vehicle testing in Canada and Finland showed that a significant reduction in particulate emissions from a gasoline direct injection (GDI) engine could be realized with E85 regardless of the ambient temperature. The use of lower alcohol blend levels had varied impacts on particulate emissions.

As illustrated in Figure 2, results from the U.S. study showed significant differences in the levels of particulates produced as a result of using different fuels and different load/speed combinations. Using E85 resulted in significantly lower particulate levels than did using any of the other fuels tested. The iB16 resulted in levels slightly above those from using the other fuels at 75% load conditions and in levels slightly below them at 25% load conditions. At 50% load, iB16 resulted in significantly higher particulate levels than did the other fuels.

Canada's results from a DISI flex-fuelled vehicle also showed decreases in particles with the use of E85, as illustrated in Figure 3. The differences in particles with gasoline (E0) compared with the use of splash-blended E10 were less significant than those when compared with the use of E85.

Finland's test results also showed that at temperatures of both 23°C and –7°C, light-duty vehicle particle concentrations with E85 were significantly lower than those with E10. With both fuels, the particle counts were higher at lower ambient test temperatures, as illustrated in Figure 4.



	25%	50%	75%	idle
Gasoline	6.52E+07	5.90E+07	2.43E+07	2.40E+05
E10	8.32E+07	7.68E+07	2.78E+07	2.54E+04
ib16	5.36E+07	1.19E+08	3.49E+07	6.97E+04
E85	6.36E+06	8.61E+06	3.85E+06	2.92E+04

Fig. 2 Total Particulate Concentration (number/cm^3): 2.2-Liter DISI Engine

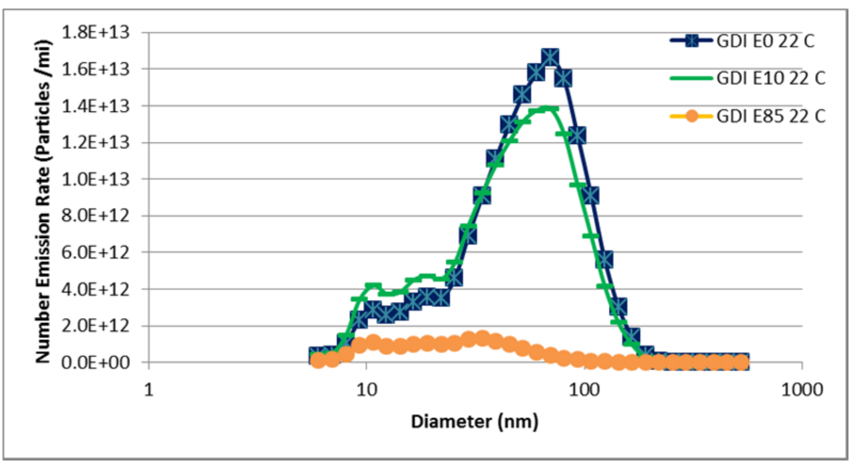


Fig. 3 Particle Size Distributions (number/mile) for DISI Vehicle Running on E0 and E85 over the FTP-75 Drive Cycle

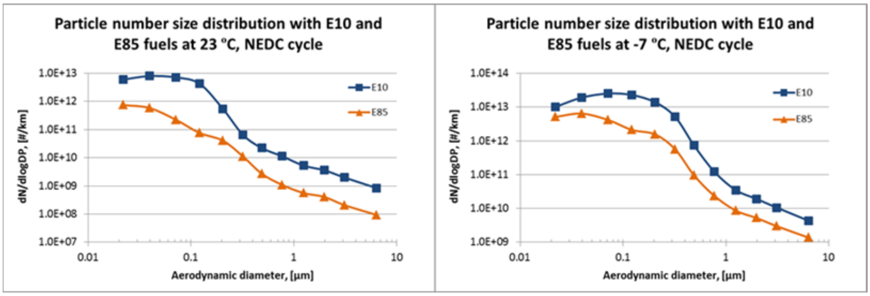


Fig. 4 Particle Size Distributions (number/km) for DISI Vehicle Running on E10 and E85 over the NEDC at Various Ambient Temperatures

Publications

- Chan, T., E. Meloche, J. Kubsh, D. Rosenblatt, et al., 2012, "Evaluation of a Gasoline Particulate Filter to Reduce Particle Emissions from a Gasoline Direct Injection Vehicle," *SAE Int. J. Fuels Lubr.* 5(3):1277–1290, doi:10.4271/2012-01-1727.
- Lee, K., H. Seong, W. Church, and S. McConnell, 2012, "Examination of Particulate Emissions from Alcohol Blended Fuel Combustion in a GDI Engine," published in *Proceedings of the 8th International Conference on Modeling and Diagnostics for Advanced Engine Systems COMODIA 2012*, JSME No. 12-201, Fukuoka, Japan, July 23–26.
- Nuottimäki, J., and T. Murtonen, 2013, *Fuel Properties Effect to the Particulate Emissions on a Direct Injection Gasoline Vehicle*, Research Report VTT-R-07737-13, VTT Technical Research Centre of Finland, July 11.
- Chan, T., E. Meloche, J. Kubsh, R. Brezny, et al., "Impact of Ambient Temperature on Gaseous and Particle Emissions from a Direct Injection Gasoline Vehicle and its Implications on Particle Filtration," *SAE Int. J. Fuels Lubr.* 6(2):350–371, doi:10.4271/2013-01-0527.
- Graves, B., R. Dastanpour, S. Rogak, P. Mireault, M. Ramos, J. Wallace, and J. Olfert, 2013, "Morphology of Particles Emitted from a GDI Engine Fuelled on Gasoline and Ethanol Blends," presented at American Association for Aerosol Research 32nd Annual Conference, Sept.

Success Stories

Renewable fuels have the potential to reduce emissions and improve air quality, in addition to contributing to energy independence. Sub-task 1 of Annex 35 investigated Ethanol as a Fuel in Road Vehicles. Research for

Sub-task 1 was led by the Technical University of Denmark, and the results were reported in a final AMF IA publication. From this research, it was concluded that the most benefits in terms of engine efficiencies and emission reductions were realized from using fuels blended with a high level of ethanol. Annex 35, Sub-task 2 builds on the Sub-task 1 results by exploring the relationship between alcohol-blended fuels and energy efficient technologies operated under various driving conditions and by exploring their impacts on particle emissions.

At the 20th International Symposium on Alcohol Fuels in March 2013, a representative from Annex 35, Sub-task 2, provided a presentation on the AMF IA studies related to alcohol fuels. The presentation highlighted not only the impacts of alcohol fuels on particles from DISI engines (Annex 35, Sub-task 2), but also the preliminary results from the other current Annexes with a focus on alcohol fuels:

- Annex 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options
- Annex 44: Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels
- Annex 46: Alcohol Application in CI Engines

A review of historic annexes related to alcohol fuels was also provided.

Future Plans

Canada, China, and Finland, as participants of Annex 44, will provide data in support of its research. The China Automotive Technology and Research Center (CATARC) is the operating agent for Annex 44. The objective of the research is to examine how unregulated pollutants from vehicles are influenced by measurement methods, automotive technologies, alcohol contents, ambient temperatures, test cycles, and other test parameters. The objective is to establish measurement methods and limits of unregulated pollutants. Both DISI and port-fuel-injected vehicles are included in this study, and particulate mass and particle number size distributions are measured.

Data from Finland's study from Annex 35, Sub-task 2, will also be used to support Annex 43. The objective of the Annex, as operated by Finland's VTT Technical Research Centre, is to develop benchmark data on a variety of vehicle makes and models with regard to their fuel efficiency, engine efficiency, and tailpipe emissions. The emphasis is on the differences between alternative engine technologies. The goal is to enable develop and compare different fuel options. In this way, particulate emissions from DISI engines fueled with E85 and E10 may be compared with emissions from vehicles with different technology and fuel options.

Through supplemental test programs, Canada and other countries are investigating the impacts of emission control technologies (e.g., gasoline particulate filters) used in conjunction with alcohol fuels. The goal is to investigate any synergistic effects of the technologies and alcohol fuels on particulate emissions from DISI engines.

Annex 38: Environmental Impact of Biodiesel Vehicles in Real Traffic Conditions (Phase 2)

Project Duration	January 2012 – June 2014 (2.5 years)
Participants	
Task Sharing	Canada, Japan (LEVO, Organization for the Promotion of Low Emission Vehicles)
Cost Sharing	Finland, Germany, Sweden, United States
Total Budget	€95,000 ($124,450 US)
Operating Agent	Norifumi Mizushima, Dr. Eng. Environment Research Department National Traffic Safety and Environment Laboratory (NTSEL) Email: mizusima@ntsel.go.jp

Background

From the standpoint of seeking to lower greenhouse gas (GHG) emissions and pursue “carbon-neutral” strategies, biodiesel fuel (BDF) is receiving attention because of its potential to contribute significantly to environmental protection on a global basis. It is also anticipated that BDF made from waste cooking oil could be recycled. As a result of this potential, efforts to promote the production and use of BDF have been taking place all over the world.

On the other hand, the diesel vehicles that are adapted to the latest emission regulations have leading-edge technologies with precise electronic control systems for reducing exhaust emissions. However, these technologies provide benefits for vehicles fuelled with ultra-low-sulfur diesel (ULSD). So, even if BDF was simply used for the diesel vehicles with these advanced technologies, the exhaust emissions would not be reduced as much as they are when ULSD vehicles are used, since the emission properties are much different from each other. The exhaust emissions from BDF vehicles might get worse.

Nevertheless, BDF is promoted as being highly effective for reducing GHG emissions. Thus, the possibility of increasing harmful exhaust emissions is a concern when BDF vehicles are being developed. In this context, the emission characteristics of the latest vehicles fuelled with BDF must be researched.

Purpose and Objectives

The use of BDF vehicles has progressed in many countries. For example, in Kyoto City, Japan, route buses and refuse trucks fuelled with “neat” waste cooking oil BDF (fatty acid methyl ester [FAME]) are running on roads. It is thus important to determine not only the emission levels in the certification tests but also the real-world emissions.

In this research, the on-road driving tests that use a portable emission measurement system (PEMS) are conducted on new diesel vehicles adapted to the latest emission regulations equivalent to Euro 5 level regulations (Phase 1 of this annex) and Euro 6 level regulations (Phase 2 of this annex). The test diesel vehicles are not customized for BDF operation, and this study aims to clarify the real-world emissions that could result from the use of ULSD and BDF (including both first-generation and next-generation fuels).

In addition, the Japanese heavy-duty diesel vehicles meeting the latest emissions regulations are also adapted to the fuel economy standards for heavy-duty vehicles, which Japan, as a pioneer, introduced. Given that the effects of BDF on fuel economy and emissions levels cannot be ignored, the real-world fuel economy can also be investigated by using the test vehicle used in this research.

Activities

Main activities include the following:

- Tasks are carried out by NTSEL and LEVO. NTSEL and LEVO will have meetings to ensure that progress is made in the tasks.
- Tests use the latest heavy-duty diesel vehicle that complies with the Japanese 2009 regulation (Figure 1).
- Chassis dynamometer tests use the latest heavy-duty diesel vehicle fuelled with ULSD, first-generation BDF (FAME), or next-generation BDF (hydrotreated vegetable oil [HVO] and biomass-to-liquid [BTL]), which was the first fuel used for Phase 2 of this annex).
- On-road driving tests use the latest heavy-duty diesel vehicle fuelled with ULSD, first-generation BDF (FAME), or next-generation BDF (HVO and BTL).
- Engine bench tests are conducted to evaluate the combustion and emission characteristics of BTL.

Fig. 1　Test Vehicle That Complies with Japanese 2009 Regulations

Participants

Finland, Germany, Sweden, United States, and Japan (LEVO)

Time Schedule

The schedule is shown in Table 1.

Table 1　Time Schedule, January 2012–June 2014

	2012				2013				2014	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Chassis dynamometer test (ULSD)	→									
Chassis dynamometer test (FAME)	→									
Chassis dynamometer test (HVO)	→									
Chassis dynamometer test (BTL)					→					
Setup of on-road driving test		→								
On-road driving test (ULSD)			→	→						
On-road eco-driving test (ULSD)			→	→						
On-road driving test (FAME)			→	→						
On-road eco-driving test (FAME)			→	→						
On-road driving test (HVO)			→	→						
On-road eco-driving test (HVO)			→	→						
On-road driving test (BTL)									→	
On-road eco-driving test (BTL)									→	
Setup of engine bench						→	→			
Engine bench test (BTL)								→		
Preparation of the final report										→

Planned　→ Done

Results/Key Messages

- Chassis dynamometer tests with ULSD, first-generation BDF (FAME), and next-generation BDF (HVO and BTL) were finished.
- PEMS was installed on the test vehicle.
- On-road driving tests (normal and eco-driving) with ULSD, first-generation BDF (FAME), and next-generation BDF (HVO and BTL) were finished.
- An engine bench, with an engine that is the same as the one mounted on the test vehicle, was prepared to evaluate the combustion and emission characteristics of BTL (Figure 2).
- Engine bench tests for the analysis of combustion characteristics of BTL were conducted.
- Test data from the on-road driving were analyzed (Figure 3).
- Final report was published.

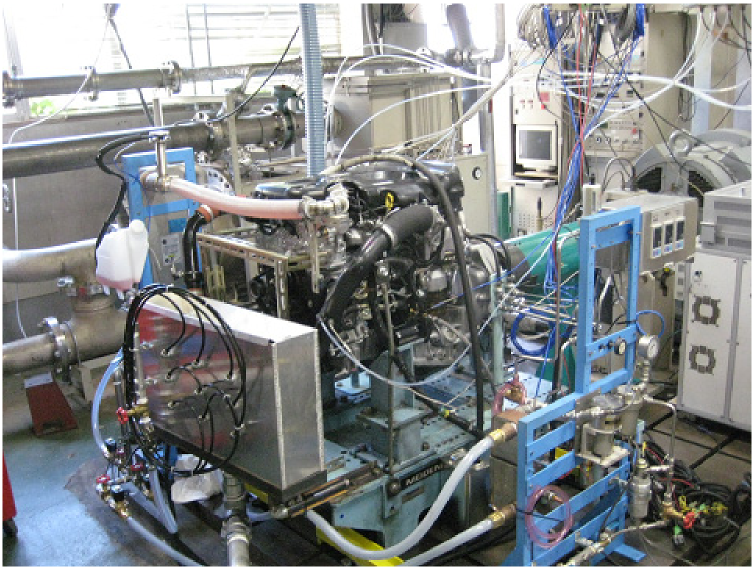


Fig. 2 Test Engine

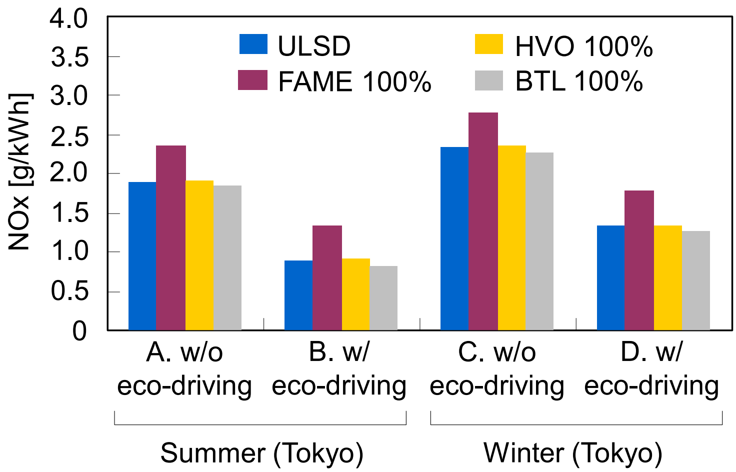


Fig. 3 Results from Evaluation of Real-World NO_x (Nitrogen Oxides) Emissions

Publications

- Evaluation of Environmental Impact of Biodiesel Vehicles in Real Traffic Conditions, IEA-AMF Annex 38, Phase 2, final report
- Evaluation of Real-World Emissions from Heavy-Duty Diesel Vehicle Fuelled with FAME, HVO and BTL Using PEMS, SAE Paper 2014-01-2823

Success Stories

This annex can provide real-world emissions data on the latest heavy-duty vehicles (Euro 6 level) fuelled with various types of BDF. The results of this Annex will be used to develop measures that will counter exhaust emissions from BDF vehicles and help in developing appropriate policies for introducing biofuels into the market.

Annex 39: Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines Phase 2

Project Duration	November 2010 – July 2014
Participants	
Task Sharing	Sweden, Finland, Canada, Asia Pacific Natural Gas Vehicles Association (ANGVA)
Cost Sharing	Sweden, Finland, Canada, Japan, Germany, Directorate General for Energy
Total Budget	€325,000 ($430,000 US)
Operating Agent	Magnus Lindgren Swedish Transport Administration (STA) Email: Magnus.Lindgren@trafikverket.se

Background

The availability of energy resources is the key to the economic growth and welfare of a country. To help quell the rapidly increasing levels of greenhouse gases (GHGs) in the atmosphere and to secure the energy supply, it is important to continue moving forward in the quest for sustainable alternatives to fossil fuels. Moreover, from the standpoint of cost-effective manufacturing, the ideal candidate fuel should be compatible with present engine technologies and not impair their emissions performance.

Two viable solutions are possible. One is to substitute crude-oil-based diesel oil with a synthetic fuel such as Fischer-Tropsch diesel or hydrotreated vegetable oil (HVO). The other is to modify the heavy, compression-ignited engine so it can use other fuels. Methane could be such a fuel, one reason being that it is used on a global basis. Because of methane's wide use, manufacturers are pursuing the development of highly efficient methane engines.

Using methane is of particular interest in developing countries, where the vehicle fleet is rather old and the prospect of implementing new advanced vehicle technologies in the near future seems farfetched. Although methane is a good candidate fuel, any emissions of it into the atmosphere must be strictly avoided, since it is a strong GHG with a global warming potential (GWP) of 72 in a timeframe of 20 years (IPCC 2007). In fact, it is likely that in the upcoming 2014 IPCC assessment report, the GWP of methane will be increased to 84.

Unfortunately, in some of the existing technologies that use methane as their fuel, the methane slips through the combustion process and the exhaust after-treatment system. Furthermore, up to now, to a lesser or greater degree, vehicles fueled with liquid methane, under various conditions, have had problems with methane leaking from the fuel storage system into the atmosphere (boil-off). So even though methane has great potential as an alternative fuel, the gas engine technology still needs some improvements.

Methane is commercially available in the form of biogas or natural gas. Biogas is produced by the anaerobic processing of organic waste products; natural gas (unlike biogas), however, is extracted from the ground. This means that natural gas is considered a fossil fuel and cannot be classified as a sustainable source of energy. Nevertheless, natural gas still has an advantage over petrol and diesel fuel, since it is usually found in connection with the extraction of crude oil in the ground, as a byproduct. Overall, then, it is better to use methane as a fuel than to release it directly to the atmosphere or burn it (flaring). Other arguments for changing to natural gas and staying away from petrol and diesel are that natural gas could result in cleaner exhaust gas and be more economically beneficial.

Efforts have been made to assess the emissions performance and fuel efficiency of heavy-duty methane engines in Annex 39.

Purpose and Objectives

The purpose of Annex 39 is to evaluate the performance of methane-fueled heavy-duty vehicles (HDVs) by looking at three aspects: energy efficiency, emissions, and fields of application. A further objective is to enable the homologation (accreditation) of dual-fuel engines within the framework of the United Nations Economic Commission for Europe (UNECE) Working Party on Pollution and Energy, and thus in the European Union (EU) and other regions.

Activities

The first phase of Annex 39 included a literature review. The second phase involves the benchmarking of commercially available methane fuel concepts. Sweden, as the operating agent, will compile test results and data from experiences in emission laboratories in the member countries that participate on task-sharing basis (Finland and Canada). Sweden will also carry out emission tests of state-of-the-art methane concepts for HDVs. A sophisticated test program has been provided to participating member countries. Details of the test program can be found in the IEA AMF IA Annual Report for 2010. Four vehicles were tested in Sweden in 2012, both in a laboratory environment and on the road during "real life" operation. The vehicles ranged from commercially available vehicles with dedicated gas engines to newly developed methane diesel or dual-fuel vehicles. The tests of the dual-fuel vehicles were conducted in close cooperation with vehicle manufacturers in order to verify the emission potential from methane-fueled HDVs.

The activities in the project are summarized as follows:

- Conduct a literature review.
- Plan the overall test campaign.
- Carry out emission testing in laboratories and on the road.
- Compile emission test results from other laboratories.
- Analyze test results.
- Present an interim report for the Annex members at Executive Committee (ExCo) Meeting 45.
- Elaborate and present a technical report for IEA AMF IA.
- Present the results at seminars and workshops.

Participants

- Japan: Organization for the Promotion of Low-Emission Vehicles (LEVO) and Japan Gas Association (JGA)
  - Cost share
- Germany
  - Cost share
- DG-Energy via IEA Bioenergy
  - Cost share
- ANGVA (Asia Pacific Natural Gas Vehicles Association)
  - Provide information on natural gas vehicles in Asia and on compressed natural gas (CNG) consumption in Asia
- Sweden, Canada, and Finland
  - Provide test results on methane-fueled HDVs participating in national programs and cost share

Time Schedule

Table 1 shows the schedule.

Table 1 Project Schedule for Annex 39[a]

	2010	2011			2012					2013				2014	
	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Vehicle 1 testing (DDF #2)	●														
Vehicle 2 testing (SI #1)							●								
Vehicle 3 testing (SI #2)								●							
Vehicle 4 testing (DDF #1)									●						
Interim report											●				
Input from Canada													●		
Input from Finland													●		
Final report															●

[a] *DDF = diesel dual fuel; SI = spark ignition; Q1, 2, 3, 4 = first, second, third, fourth quarter.*

Results/Key Messages

The project is split in two phases — a literature study and testing in Canada, Finland, and Sweden of state-of-the-art engine technology for methane as a fuel. Testing was carried out on the road with vehicles in normal operation and during various driving conditions and in sophisticated emission laboratories. Methane is a global fuel with a high potential for use in HDVs, but additional development is still needed for it to perform adequately with regard to fuel efficiency and exhaust emissions.

Key findings from the project can be summarized as follows:

- SI engines meeting the latest EU/US emission requirements are commercially available on the market. Emissions of GHG will, in the best cases, not increase (compared to emissions from similar diesel engines). When biogas is used, GHGs will be reduced, but the reduction will depend on the origin of the gas.
- The fumigation (DDF) technology available on the market will not meet mandatory emission requirements. The level of diesel replacement is not what was expected. Modifications to vehicles in use (retrofitting) will neither decrease GHG emissions nor improve energy efficiency.
- So far, pilot injection (DDF) technology is available only in the North American market. This technology is more advanced than fumigation. It might be the only alternative for original equipment manufacturers

(OEMs). It offers only limited driving performance when a vehicle runs out of gas.

This Annex 39 project clearly indicates that dual-fuel technology needs additional development if it is to meet market requirements related to the level of diesel replacement and emissions performance, especially with regard to emissions of methane. In addition, the technology's energy efficiency has to be improved, and its air/fuel management must be more tolerant of different specifications for the gas/liquid used as fuel. Remaining concerns to be addressed in the project were identified as follows:

- Since the development of engines is ongoing, a continuous follow-up covering new technology in this field is recommended.
- The durability of the emissions performance of methane-fuelled HDV engines is not in line with that of corresponding diesel engines, mainly due to the performance of catalysts; the durability of these engines' performance needs to be further validated.
- For countries that are not implementing the latest emission requirements, retrofitting the diesel vehicles in use by adding dual-fuel technology and thereby reducing emissions of particles might be the solution for improving ambient air quality. Dealing with retrofit applications has not been a part of this project, but it should be considered.
- In cases in which liquefied methane is used as fuel to extend the driving range of a vehicle), special concern must be given to "bleed off" (evaporation of the liquid gas).

Publications

- IPPC, 2007, *Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt], M. Tignor, and H.L. Miller (editors), Cambridge University Press, Cambridge, United Kingdom and New York, N.Y., USA.
- Broman, R., P. Stalhammar, and L. Erlandsson, 2010, *Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines*, Final Report, AVL MTC Motortestcenter AB, Haninge, Sweden, May 24, http://www.iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Annex_39-1.pdf.
- Olofsson, M., L. Erlandsson, K. Willner, 2014, *Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines*, Final Report. AVL MTC Motortestcenter AB, Haninge, Sweden, May 10, http://iea-amf.org/app/webroot/files/file/Annex%20Reports/AMF_Annex_39-2.pdf.

Success Stories

When the project started, it was not possible to approve engines that worked with dual-fuel technology in accordance with UNECE/EU emission regulations. The exchange of experiences between participants in this Annex and informal working groups in the UNECE and EU has now opened up this possibility. Regulation 49 of UNECE has been amended. That amendment includes approval of dual-fuel engines.

The evaluation of various technologies for dual-fuel operation has shown that some of them result in more methane emissions than initially anticipated. If the results from this Annex are taken into account in future work, it is possible that an increase in GHG emissions from HDV transport could be avoided.

Future Plans

The environmental performance of dedicated gas engines has proven to be good, and their use can be encouraged in situations where low emissions are important. From a climate perspective, a dedicated gas engine is not better than a conventional diesel engine. Dual-fuel technology needs further development in order to reach its full potential as a clean and energy-efficient solution; thus, its use needs to be monitored in the coming years.

Annex 42: Toxicity of Exhaust Gases and Particles from IC-Engines — International Activities Survey (EngToxIn)

Project Duration	November 2010 – December 2012 Continuation: May 2013 – May 2015
Participants **Task Sharing** **Cost Sharing**	 Austria, Canada, China, Denmark, Finland, France, Germany, Japan, Sweden, Switzerland, United States • All AMF IA members through the common fund • AMF IA nonmembers: Czech Republic, Greece, Netherlands, Norway
Total Budget	€40,000 ($55,356 US) • Task-sharing AMF IA budget: €10,000 ($13,839 US) • Swiss contribution: €10,000 ($13,839 US) • Continuation AMF IA budget: €20,000 ($27,678 US)
Operating Agent	Jan Czerwinski AFHB (Laboratory for Exhaust Gas Control) University of Applied Sciences, Switzerland Email: jan.czerwinski@bfh.ch

Background

The toxic effects of exhaust gases as combined aerosols (i.e. , all gaseous components together with particulate matter and nanoparticles) can be investigated in a global way, by exposing the living cells or cell cultures to the aerosol; this results in a simultaneous superposition of all toxic effects from all active components.

Several researchers showed that this method provides more objective results for validating toxicity than do other methods that have been used to date. This method can also give researchers insights about the toxic effects relatively quickly by enabling them to consider all superimposed influences of the aerosol.

The scientific questions of the new methodology focus on the degree of correlation among (1) the reduction in toxicity, as expressed by the biological parameters; (2) the toxicity equivalence (TEQ), as expressed by the chemical parameters; and (3) the reduction in the number, surface, and mass of particles and other physical parameters of particles, as evaluated by the aerosol analytics.

Purpose and Objectives

The present Annex offers information services and aids in knowledge transfer. The Annex also helps in finding supporters in the European Commission (EC) and other potential sponsors for Engine Toxicity Network (EngToxNet) activities and helps to spread the knowledge of these activities worldwide.

The Annex informs and encourages oversea partners/members to contribute to activities in the domain of toxicology and health risks.

The Annex helps several nonmember states to become AMF IA members.

Activities

International Activities

Several toxicologists, biologists, and medical doctors are doing research on the toxic influences of vehicle exhaust emissions (Figure 1). In the Netherlands, the Ministry of Environment (VROM) charged the National Institute of Public Health and Environment (RIVM) to deliver basic propositions for new legal prescriptions. This activity of RIVM, which tries to coordinate the knowledge of toxicologists by organizing and evaluating different international meetings, is called SETPOINT.

To obtain a common, validated, biotoxicological testing procedure, more worldwide testing activities need to take place. Several European countries declared their interest in participating in the European Union (EU) project EngToxNet, a round-robin program for validating toxicological procedures.

Present Annex

Activities conducted by the annex are as follows:

- Contact different research groups,
- Collect information,
- Prepare annual information report,
- Coordinate with cooperating agents, and
- Send report to AMF IA.

Figure 2 shows an example of human lung cell cultures, which are used for the experiments with whole aerosol exposures.

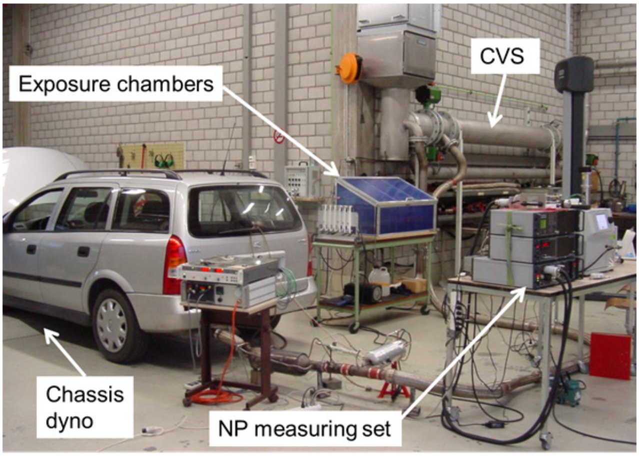


Fig. 1 Exposure Tests on a Diesel Passenger Car
(CVS = constant volume sampling; NP = nanoparticle)

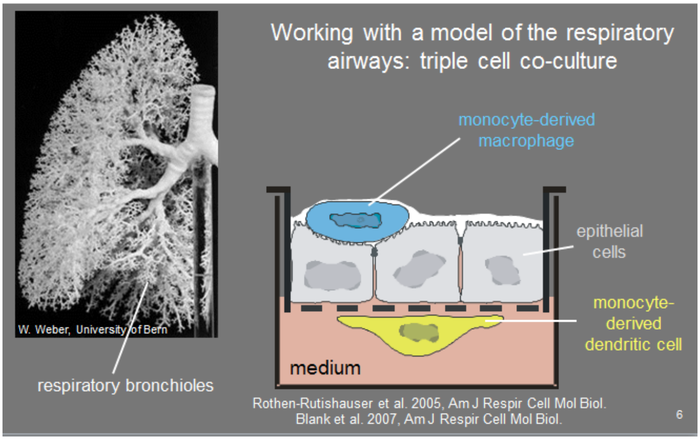


Fig. 2 Structure of the Lung and the Triple-Cell Model

Participants

All IEA AMF IA members

Time Schedule

November 2010–May 2015

Results/Key Messages

- Provide information and enable knowledge exchange through four annual reports: (1) Information Report for 2010/2011, AFHB B315, Sept. 2011; (2) Information Report for 2012, AFHB B344, Oct./Nov. 2012; (3) Information Report for 2013, AFHB B370, Oct./Nov. 2013; and (4) Information Report for 2014, AFHB B400, Nov./Dec. 2014)
- Help coordinate future activities
- AMF IA homepage: http://www.iea-amf.org/ — look for "Project Reports, then for "Annex 42"

Publications

EngToxIn reports, see previous section on "Results"

Success Stories

The Annex helps disseminate information on health effects and raises the public's and the scientific community's consciousness of them. It fosters progress in protecting the environment, especially in highly populated areas, and in protecting workplaces. It could lead to further improvements in research and policies in the future.

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

Project Duration	January 2011 – May 2014
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Finland, Japan, Sweden, United States None
Total Budget	~€450,000 ($622,755 US)
Operating Agent	Juhani Laurikko VTT Technical Research Centre of Finland Email: juhani.laurikko@vtt.fi

Background

Major de-carbonizing actions need to take place in the road transport sector. There is no single solution that could solve the de-carbonization challenge, however. Multiple technologies must be considered to find the alternatives that are best suited for each given set of boundary conditions. Moreover, the importance of energy efficiency is increasing. Engine downsizing, switching to diesel fuel, and opting for hybridization contribute to fuel efficiency. Renewable energy can be introduced, either through biofuels or through electricity from renewable sources.

Passenger cars are a major class of on-road vehicles. Since the number of individual vehicle types, makes, and models is very large, the evaluation of future options is quite challenging. The goal of this research project is to deliver first-hand, primary data for this type of evaluation, which could improve the possibilities for making appropriate choices from among the many available options. The available technology options are increasing for both fuel and powertrain alternatives. Therefore, unbiased data sanctioned by the IEA on the performance (energy use and emissions) of new technologies are needed by decision makers at all levels.

Purpose and Objectives

The core of the study consists of benchmarking a set of makes and models of passenger cars that offer multiple options for fuels and "powerplants." A project goal is also to demonstrate the differences in efficiency that arise from different engine types and sizes by testing engines with different power outputs offered on the same vehicle platform.

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

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

Activities

The activities carried out under this Annex 43 in year 2014 concentrated mainly on experimental work and data collection.

Literature Review

Well-to-tank analyses done in this project are based on the information generated in Annex 37. However, since the main scientific basis for this part of the exercise is the Joint European well-to-wheel (WTW) analysis,[67] an update[68] of which was released in May 2014, that needs to be taken into account.

Method Development

Agreement on common test protocols was essential for this project, and work on this had already been done in 2011. The purpose of common test protocols is to ensure that the baselines for test results will be comparable, although participant-specific test conditions were also allowed and encouraged.

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67 http://setis.ec.europa.eu/newsroom-items-folder/jec-well-to-wheels-wtw-analysis-of-future-automotive-fuels-and-powertrains-in-the-european-context.

68 http://iet.jrc.ec.europa.eu/about-jec/.

Data Collection

Japan and the United States are participating in this Annex by sharing existing data. Due to different test protocols (mainly the use of different driving cycles), these data are not directly comparable with other experimental test results. However, the data from Japanese and American participants were accepted because they supplement the test matrix with valuable information on hybrid powertrains and liquefied petroleum gas (LPG) as a fuel.

Experimental Work

Canada, China, Finland, and Sweden have conducted new experimental work for this Annex. The experimental work has been carried out in a laboratory environment by using a chassis dynamometer and emission measurement equipment. The test vehicles have represented the types of passenger cars typical of each participating country. The test matrix has also included various test fuels and drive cycles.

Finland and Sweden concluded their tests in 2012 and submitted their results. China concluded measurements in 2013 and submitted a preliminary sub-report that is still going to be supplemented. Also, Canada finished its tests and submitted a pre-release of its data in May 2014.

Table 1 summarizes the dimensions of the activities of the participants in terms of the number of different cars (or powerplant options on a single vehicle platform), duty cycles, fuels, and ambient temperatures used in the measurements.

Table 1 Summary of the Elements Used for Measurement Activities by the Participants

Participant	No. of Different Cars	No. of Duty Cycles	No. of Fuels	No. of Ambient Temperatures Used
Japan	1	4	2	1
Canada	3	5	8	2
China	6	1	5	1
Sweden	3	4	2+EV	2
Finland	7	4	6+EV	2
USA	4	4	2	1

Data Assessment

Data are evaluated in two steps. First an evaluation of the end-use performance is done by each individual participating country within the tested vehicle model's family. The second evaluation is done in the final report based on all the information generated. The second evaluation phase combines the well-to-tank data of the test fuels with end-use performance data to provide information on the complete fuel cycle.

Information Dissemination

Information will be disseminated at AMF IA Executive Committee meetings, in the Final Report, and possibly also at suitable conferences. Already, a short summary of the idea behind the project and of the Finnish test results was presented at the Fisita 2014 Congress in June of that year.

Participants

Policy-Related Participants

- Finnish Transport Agency (Finland)
- New Energy and Industrial Technology Development Organization (NEDO) (Japan)
- Organization for the Promotion of Low Emission Vehicles (LEVO) (Japan)
- Swedish Energy Agency, Swedish Road Administration Agency (Sweden)
- Tekes – The Finnish Funding Agency for Innovation (Finland)

Industry Participants

- European Batteries (Finland)
- Gasum (Finland)
- Neste Oil (Finland)
- Nikki Co. Ltd. (Japan)
- St1 (Finland)

Academia and Test Laboratory Participants

- Argonne National Laboratory (United States)
- AVL MTC Motortestcenter AB (Sweden)
- Beijing Institute of Technology (China)
- China Automotive Technology and Research Centre (China)
- Environment Canada (Canada)
- National Traffic Safety and Environment Laboratory (NTSEL) (Japan)
- VTT Technical Research Centre of Finland (Finland)

Time Schedule

The duration of the project was prolonged in order to reserve time for participants to deliver their sub-reports. The remaining sub-reports were expected to be delivered early in 2014, and originally, the Final Report was scheduled to be ready by summer 2014. However, the Operating Agent at VTT resigned, and due to the internal situation at VTT, a new one could not be appointed; only a deputy was appointed. For this reason, an extension was requested, and ExCo accepted prolonging the project to the end of February 2015 in its meeting in November 2014. The present, revised schedule is presented in Table 2.

Table 2 Revised Project Schedule for Annex 43

	2011				2012				2013				2014				2015
TASK	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
Preparations, test protocols																	
Vehicle measurements																	
Reporting, sub-reports																	
Synthesis and Final report																	

Results/Key Messages

The preliminary results indicate that there is no single solution that could solve all the challenges of road transport. Instead, there seem to be pros and cons with regard to the tested fuel and powertrain alternatives depending on their operating environment. Electric vehicles are an energy-efficient option for various driving conditions, but they suffer from having a limited driving range. In addition, the WTW carbon dioxide (CO_2) emissions of electric vehicles seem to be the most sensitive to upstream energy production of all the available powertrain options. The most suitable option thus seems to vary with the driving conditions and user needs. However, the preliminary results indicate that sophisticated fuels might help to reduce the tailpipe emissions and WTW CO_2 emissions of traditional vehicles.

Publications

Plans are now to publish the Final Report in February 2015 A short summary of VTT's test results was already presented at the Fisita 2014 Congress under the title "Performance Evaluation of Passenger Car, Fuel and Powerplant Options."[69]

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

Success Stories

The outputs of this study were used as inputs in the Finnish Transport Agency's final report, *Alternative Propulsion for the Transport of the Future.* The report is used in national policy making, and it sets objectives and recommendations for the transport of the future.

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

Project Duration	July 2012 – December 2014 (2.5 years)
Participants **Task Sharing** **Cost Sharing**	 China, Canada, Finland, Sweden, Israel China, Sweden, Finland
Total Budget	€80,000 ($103,000 US)
Operating Agent	Fan Zhang China Automotive Technology & Research Center (CATARC) Email: zhangfan@catarc.ac.cn

Background

The gradual depletion of petroleum resources throughout the world has generated an increased urgency to develop alternative energy sources. Alcohol fuels have the advantage of having a wide range of sources. These fuels can be manufactured from biomass raw materials, agricultural raw materials (e.g., sugar cane, cereals, rice), timber and urban waste, and fossil fuels (e.g., natural gas, petrochemical, coal). A number of countries support the use of alcohol alternative fuels. For example, the United States, Brazil, and Sweden encourage the use of ethanol fuel made from biomass materials. In addition, several regions in China, including Shanxi Province and Shanghai, have initiated a pilot program to promote the use of methanol fuel.

Due to reductions in the limits for regulated pollutant emissions, unregulated pollutant emissions in vehicle exhaust have attracted an increasing amount of attention. Studies indicate that the use of alcohol fuels blended with gasoline in vehicles can reduce engine-out hydrocarbon (HC) and carbon monoxide (CO) emissions to some extent. The reduction occurs because the oxygen content in the fuel can promote the fuel's complete combustion. However, more unregulated pollutants may be emitted, such as polycyclic aromatic hydrocarbons, aldehydes, and ketones. These substances stimulate strong negative reactions in sensitive recipients. They could also have genetic toxicity and carcinogenic activity that could significantly affect human health. This factor is an important one that could hinder further development of alcohol alternative fuels.

As a result of these concerns, it is necessary to investigate the unregulated pollutant emissions from vehicles fuelled with alcohol alternative fuels. This type of research would serve to promote the application of alcohol alternative fuels in a more expedient manner.

Purpose and Objectives

The two main purposes of this project are to take measurements in order to (1) obtain the unregulated pollutant emission levels of alcohol-fuelled vehicles and (2) gradually establish the measurement methods and limits of unregulated pollutant emissions. Furthermore, the research in this Annex 44 will be done to examine the influences that the measurement methods, automotive technologies, alcohol contents in the fuels, ambient temperatures, test cycles, and other relevant factors have on the unregulated pollutant emissions of vehicles.

Activities

Researchers in China conducted emissions tests on a chassis dynamometer by using a gasoline direct-injection (GDI) vehicle fuelled with gasoline, E10, E20, M15, and M30. The driving cycle was the New European Driving Cycle (NEDC). Fourier transform infrared radiation (FTIR), high-performance liquid chromatography (HPLC), and gas chromatography-mass spectrometry (GC-MS) were used to synchronously measure regulated and unregulated emissions from the vehicle. The results for methanol, formaldehyde, acetaldehyde, acetone, benzene, toluene, xylene, and other unregulated emissions at a temperature of 25°C were quantitatively determined. The results for unregulated emissions are still in analysis. In addition, evaporative emissions tests were done by using a port fuel injection (PFI) vehicle fuelled with gasoline, E10, and M15. HPLC and GC-MS were used to measure the unregulated emissions.

Researchers in Sweden conducted a literature review on the low blending of alcohol fuels in passenger cars. The report was finalized in October 2013, and it was delivered for the task-sharing contribution of Annex 44. The report covers both regulated and unregulated emissions as well as experiences related to the use of alcohol fuels. The focus was on methanol.

Researchers in Finland conducted emissions tests on a chassis dynamometer by using two vehicles and three fuels (E10, E85, and E100). Measurements were made at ambient temperatures of +23°C and –7°C. In addition to regulated emissions, selected individual hydrocarbons (GC), aldehydes

(2,4-dinitrophenylhydrazine [DNPH] by HPLC), and particulate mass were measured. The driving cycles were cold-start NEDC and hot- start Federal Test Procedure (FTP)-5 (of the U.S. Environmental Protection Agency).

Researchers in Canada conducted emissions tests on a model year 2012 Ford Focus flex-fuelled vehicle (FFV) with a 2.0-L, wall-guided, GDI engine. Test cycles included FTP-75, US06, and a limited set of NEDCs. All tests were conducted at 25°C. In addition, FTP-75 tests were performed at ambient temperatures of –7°C and –18°C. Analysis is ongoing. In addition to regulated emissions, unregulated pollutant emissions of CO, nitrogen oxides (NO_x), HCs, and carbon dioxide (CO_2) were collected by using HPLC and GC-flame ionization detection (FID) for compounds such as acetaldehyde, formaldehyde, acetone, benzene, toluene, etc. Test fuels were E0, E10, and E85.

Researchers in Israel conducted a test program in which M15 fuel was used in four different car models. During this program, they measured regulated and unregulated (focusing on formaldehyde and acetaldehyde) emissions. All tests were performed in a closed climatic chamber on a chassis dynamometer. Two driving cycles were used: NEDC and US06. The main objective was to compare the emissions of normal 95-octane gasoline and M15.

Results/Key Messages

China

The test results from China indicate that from a light-duty GDI vehicle using methanol fuels, formaldehyde emissions of M30 and M15 were 156.0% and 122.7%, respectively, of those from gasoline. The benzene emission of M30 was 71.2% of that from gasoline, while M15 was 77.7% of that from gasoline. The toluene emissions of M30 and M15 were 59.1% and 80.1% of those from gasoline. Ethylene, propylene, 1,3-butadiene, and isobutene emissions decreased with the increasing methanol proportion in the fuel. Figure 1 shows the unregulated emissions during the NEDC cycle at 25°C when methanol fuels were used in the GDI engine. The task-sharing report was finalized on November 16, 2014.

VTT

Figure 2 shows an overview of unregulated emissions during different driving cycles using ethanol fuels. The test results show that ethanol emissions dominated when the E85 and E100 fuels were used in the NEDC test. Surprisingly high ethanol emissions were observed even at +23°C for

E100 and E85. Ethanol emissions were low in the hot-start FTP-75 test cycle. Formaldehyde and acetaldehyde emissions were higher when E85 and E100 were used than when E10 was used, particularly at –7°C. Ammonia, nitric oxide (NO), and nitrogen dioxide (NO_2) were higher at –7°C in the NEDC test than at +23°C in the NEDC and hot-start FTP-75 tests. Ammonia emissions were substantial in many cases, particularly with the DISI car and the use of E10 at –7 C in the NEDC test. The task-sharing report was finalized on September 15, 2014.

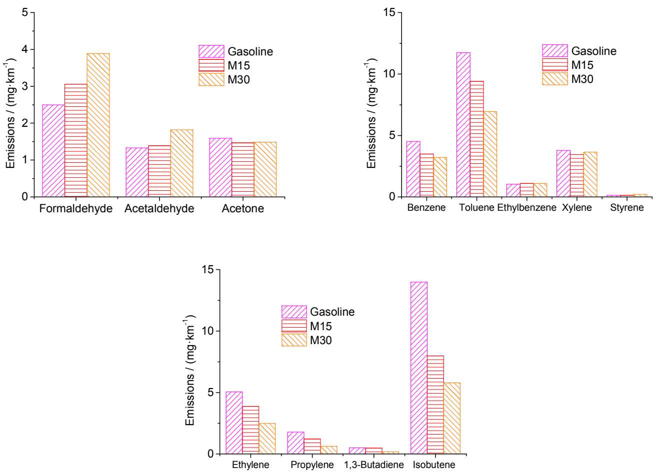

Fig. 1 Unregulated Emissions, Methanol Fuels, NEDC, 25°C, GDI Engine

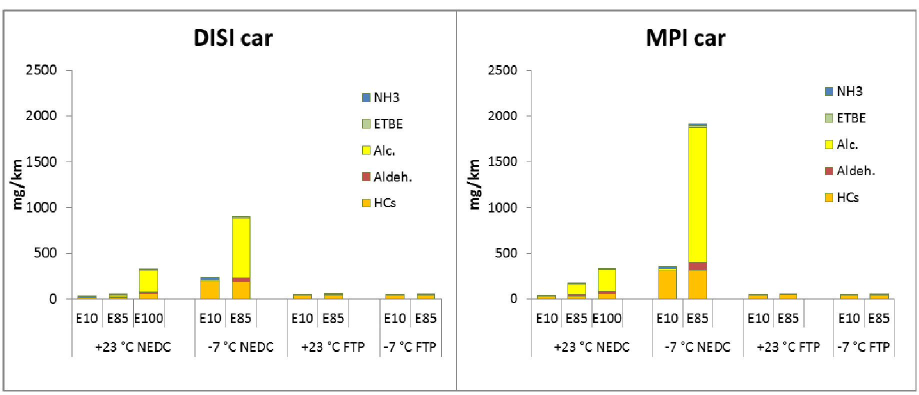

Fig. 2 Overview of Unregulated Emissions, Ethanol Fuels

Israel
Researchers in Israel conducted a test program in which research octane number 95 (RON95), M15, and E10 fuels were used in three car models: Skoda Octavia 1.8-L direct injection engine (Euro 5), Toyota Corolla 1.6-L engine (Euro 5), and Ford Focus 1.6-L engine (Euro 3). Preliminary results on formaldehyde and acetaldehyde emissions were shown. The task-sharing report will be finalized in the beginning of 2015.

Canada
Figure 3 shows unregulated emissions of PFI and GDI vehicles at –18°C when ethanol fuels were used. The use of E10 fuel led to statistically significant increases in formaldehyde and acetaldehyde of about 1.5 times and 6–7 times, respectively, for both the GDI and PFI vehicles at –18°C. The acetone emission rate was 1.7 times higher when the PFI vehicle was fuelled with E10 than when it ran on E0. Acetaldehyde emissions increased by more than two orders of magnitude when the GDI vehicle was operated on E85 fuel at –18°C. An increase in formaldehyde (of more than 6 times) was also measured. The task-sharing report was finalized before the end of 2014.

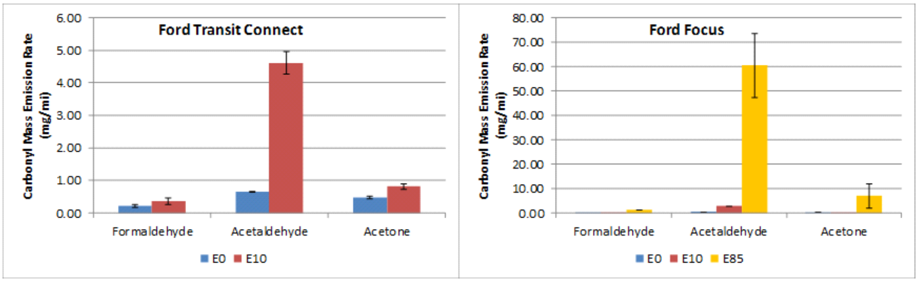

Fig. 3 Unregulated Emissions of PFI and GDI Vehicles at –18°C, Ethanol Fuels

Participants

- China Automotive Technology and Research Center (CATARC)
- CanmetENERGY (Canada)
- The Technical Research Centre of Finland (VTT)
- Swedish Transport Administration (STA)
- Israeli Ministry of Energy and Water Resources

Time Schedule

The estimated project duration is 2.5 years, beginning in July 2012. The main breakdown of the schedule is as follows:

- Preparation of project: July 2012 ~Sept. 2012
- Literature survey: Oct. 2012 ~Dec. 2012
- Measurement with methanol fuels: Jan. 2013 ~Dec. 2013
- Measurement with ethanol fuels: March 2013 ~Sept. 2014
- Final report: Oct. 2014 ~April 2015

Publications

The final report is expected to be published before the middle of 2015.

Annex 45: Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation

Project Duration	March 2013 – February 2014 (prolonged to September 2014)
Participants **Task Sharing** **Cost Sharing**	 Canada, Denmark, Finland, Germany, United States None
Total Budget	€197,000 ($271,453 US)
Operating Agent	Dipl.-Ing. Benjamin Stengel University of Rostock, Germany Email: benjamin.stengel@uni-rostock.de

Background

The conventional use of fossil fuels for passenger car and ship engines will persist in the upcoming decades, despite increases in the cost of oil. However, because there are emissions from internal combustion engines and only limited stocks of oil, research on alternative fuels is needed. One promising approach is to substitute renewable fuels for fossil fuels. The European Union has established a goal of reaching a 10% share of renewable energy in the transport sector by 2020. Currently, vegetable oils, in connection with transesterification (fatty acid methyl esters [FAME]), are used for blending mainly with fossil diesel. However, increased use of FAME blends can lead to the dilution of lubrication oil, resulting in shorter intervals between oil changes. Furthermore, fouling can occur, which leads to the damage of high-pressure injection pumps.

One promising alternative is to use hydrotreated vegetable oil (HVO) as a substitute for diesel. HVO has characteristics very similar to those of conventional diesel, and its use results in reduced exhaust emissions. Further research is needed to reduce the high production costs of HVO. Simultaneously, the production method for FAME must also be improved to decrease costs.

Purpose and Objectives

The goal of this project is to analyze the use of algae-HVO, next-generation biomass to liquid (NEXBTL, diesel developed by Neste Oil), FAME, and enzymatic FAME (eFAME) as diesel substitutes in Euro VI diesel passenger car engines. Fuel analyses will provide information about characteristic values (e.g., heating value, cetane number). Engine tests will be carried out and focus on the fuel's impacts on combustion, emissions, and the efficiency of exhaust after-treatment systems. In addition, the fuels will be analyzed, and their production costs and sustainability will be compared.

Activities

A literature review was conducted that focused on engine tests with algae-HVO/HVO and eFAME/FAME fuels. Denmark organized the eFAME supply, while Germany and Finland organized the supply of NEXBTL. Engine tests were conducted at the Institute of Piston Machines and Internal Combustion Engines in Germany by using a Euro VI passenger car diesel engine with state-of-the-art exhaust after-treatment. The test bench was completed with equipment for measuring emissions and in-cylinder pressure as well as for recording engine data and engine control unit (ECU) data. The efficiency of each component of the exhaust after-treatment system was measured through several sampling points in the exhaust path. Engine tests were conducted for the reference diesel (EN 590), NEXBTL, and FAME. In addition, Denmark performed a cost/quality analysis that showed the relationship of cost and quality for several alternative fuels compared with standard EN 590 diesel.

Participants

- University of Rostock, Institute of Piston Machines and Internal Combustion Engines (academia, Germany)
- Danish Technological Institute (industry, Denmark)
- Neste Oil (industry, Finland)
- CanmetENERGY (industry, Canada)
- Solazyme (industry, United States)

Time Schedule

The time schedule for this project is presented in Figure 1.

Time schedule																					
No.	Tasks	Partner	Months																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
1	Literature survey	all	■	■																	
2	Obtainment of fuels	DK/USA		■	■	■	■	■	■	■	■	■	■	■	■	■	■	■			
3	Fuel analysis	CAN											■	■	■			■	■	■	
4	Engine tests (standard ECU calibration)	GER			■	■	■	■	■												
5	Evaluation of measurement data	GER								■	■	■	■			■	■	■	■	■	
6	E-FAME and HVO process cost analysis	DK																			
7	Engine tests (fuel adapted ECU calibration)	GER											■	■	■	■	■	■	■	■	
8	Systematisation of parameter sets	GER														■	■	■	■	■	
9	Sustainability analysis	DK																			
10	Final report	all																	■	■	■
11	Project coordination	GER	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■

Fig 1 Schedule for Annex 45

Results/Key Messages

Engine tests were performed for EN 590 diesel, HVO, FAME, and eFAME. The analysis of pressure traces and heat release rates showed that HVO and FAME positively affect combustion by a decreased ignition delay. eFAME showed an increase in ignition delay caused by its lower cetane number.

Raw exhaust emissions of soot could clearly be reduced with HVO. Carbon monoxide (CO) and total hydrocarbon (THC) emissions were slightly reduced, while emissions of nitrogen oxides (NO_x) were similar to those of standard diesel (Figure 2). Operation with FAME and eFAME resulted in enormous reductions in CO, THC, and soot (in Figure 2, FSN stands for filter smoke number), while NO_x emissions increased slightly.

The low heating values of FAME and eFAME led to shifts in the ECU maps and thereby influenced combustion and emissions. However, fuel-adapted ECU settings showed that the fuel consumption of HVO and eFAME could be enhanced while emission limits would still be met.

A quality/cost analysis was done and showed that HVO is a product of higher quality and higher cost than standard EN 590 diesel (Figure 3). The quality of eFAME and FAME is lower than that of diesel, while their costs are higher than the cost of standard diesel.

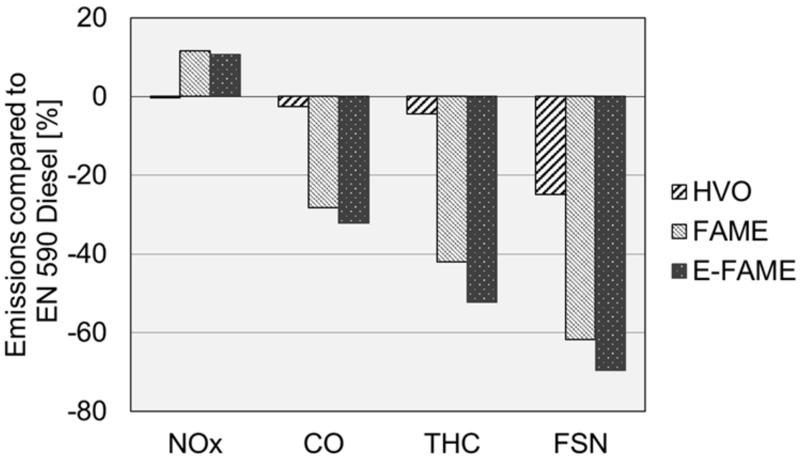

Fig. 2 Average (Nonweighted) Reduction in Emissions from Using HVO, FAME, and eFAME at Selected Operation Points Compared with Those from Using Standard EN 590 Diesel

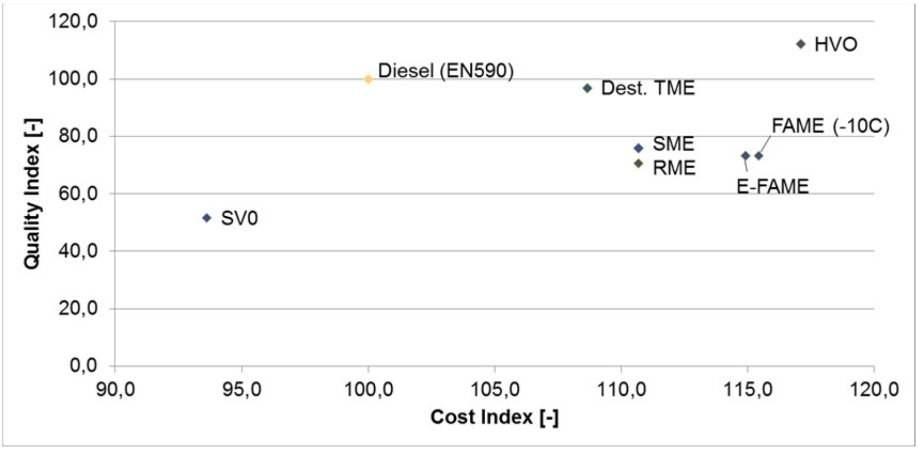

Fig. 3 Quality/Cost Analysis of Several Alternative Diesel Fuels

Publications

- Stengel, B., T. Sadlowski, and V. Wichmann, 2013, "HVO-Kraftstoffe in Euro-VI-Motoren," presented at 7. Rostocker Bioenergieforum, Rostock, Germany, June 20–21.
- Stengel, B., T. Sadlowski, and V. Wichmann, 2014, "Influences of HVO and FAME on Combustion and Emissions in Euro-VI Diesel Engines," presentation at 2nd International Conference of the Cluster of Excellence Tailor-Made Fuels from Biomass, Aachen, Germany, June 16–18, 2014.
- Stengel, B., T. Sadlowski, and V. Wichmann, 2014, "Einflüsse von HVO und FAME auf die Verbrennung und Emissionen moderner PKW-Dieselmotoren," presented at 8. Rostocker Bioenergieforum, Rostock, Germany, June 19–20.

Annex 46: Alcohol Application in CI Engines[70]

Project Duration	March 2013 – February 2015
Participants **Task Sharing** **Cost Sharing**	 Denmark, Finland, Sweden None
Total Budget	~€300,000 ($398,460 US)
Operating Agent	Jesper Schramm DTU Technical University of Denmark Email: js@mek.dtu.dk

Background

In Europe, Directive 2009/28/EC on renewable energy sets the transport bioenergy obligation in 2020 at a minimum of 10% of the transport energy use. Modern spark-ignition (SI) vehicles are compatible with 10% ethanol in gasoline (E10), which represents 6% of the bioenergy content. Since a higher ethanol content can be used only with a limited car population, ethanol use is limited — even if higher amounts are commercially available (the so-called “blending wall”).

Alcohols represent superior fuels for the SI engine with respect to key properties, such as octane number and latent heat of vaporization. Basically, alcohols can withstand high pressures and temperatures without igniting uncontrollably. In many parts of the world, ethanol is widely used in low-concentration blends with gasoline, and it has a more limited use in high-concentration blends. In the case of low-ethanol blends (E5−10), it is possible to produce fuels with a slightly higher or similar octane number compared to that for regular gasoline. Most modern cars are able to regulate the ignition timing and advance the timing to a degree that increases engine efficiency by a few percentage points. A high share of ethanol, up to 85%, can be used in special SI flexible-fuel vehicles.

Fuel economy is an increasingly important current issue. An obvious goal is to achieve efficiencies similar to diesel engines with the alcohol applications. However, the application of alcohols in a diesel engine requires a fuel additive to ignite the unburned mixture. An option is to use additised ethanol in heavy-duty ethanol diesel engines, which are now manufactured

[70] The information in this section on Annex 46 was not updated. It was taken directly from the 2013 *IEA-Advanced Motor Fuels Annual Report*.

by Scania. These engines run with so-called Etamax D fuel that consists of 95% hydrous ethanol together with an ignition improver, a corrosion inhibitor, and denaturants (i.e., methyl tertiary-butyl ether and isobutanol). This fuel is manufactured by SEKAB in Sweden. With this concept, relatively small modifications are required in the engine. The compression ratio is increased, and the fuel system is modified. The exhaust catalyst is developed to prevent excessive aldehyde emissions. This concept, for example, is used in buses in Stockholm. In total, around 1,000 heavy-duty vehicles are running with Scania's ethanol engines.

The most interesting option would be a "flex fuel" diesel engine that can run with both ethanol and diesel fuel without pilot injection technology. Engines that can use only ethanol would be suitable only in restricted areas, where availability of fuel can be controlled. Diesel engines and their control technologies have advanced considerably in recent years. For example, the common-rail system enables fine adjustments of injection. Ethanol diesel engines could be used in road transport, machinery, and the marine sector — especially in countries where ethanol is produced on a large scale.

Alcohols, particularly those produced from biomass, are the obvious fuels for more intense combustion engine applications in the near future. Therefore, it is relevant to initiate a general study on the best way to produce alcohols from biomass. The goal is to combine good fuel economy with low emissions. This type of project is suited for an AMF IA study, since many member countries are interested in fuel/additive development. For example, Brazil, Finland, and Thailand would like to consider alternative, locally produced additive packages. In addition, there are ideas for new combustion schemes (e.g., reactant controlled combustion), which could eliminate the need for the dedicated ignition improver additive. (Scania's current technology is based on an additive package that includes an ignition improver and a lubricity additive, as well as a high compression ratio of the engine.)

Purpose and Objectives

The goal is to report the best possibilities for the implementation of alcohols in diesel engines. One of the main objectives of the project is to secure the supply of fuels for diesel engines, in this way by focusing on sustainable biofuels in the form of alcohols. The project involves one of the main diesel engine producers in Europe, as well as some of the most powerful research institutions and universities in Europe. The project will therefore result in worldwide frontline experiences, and it will have a large influence on strategies for the implementation of alternative fuels in many countries.

Thus, the project will contribute to the achievement of many relevant political goals, such as support of a sustainable energy policy, independency of fossil energy, and reduced emissions — including carbon dioxide.

Activities

The work is divided into the following work packages (WPs):

WP 1: Review of Alcohol Application in Diesel Engines

Fuels, additives, and engine concepts will be reviewed on the basis of existing literature, experimental data, and information from engine manufacturers. In this context, the focus will center on fuels with an alcohol content over 50%. The review of additives will be divided into ignition improvers, emulsifiers, and other additives. Special attention will be given to bio-origin additives.

WP 2: Ethanol Application in a Diesel Engine

New ethanol fuel formulations and additive options will be studied with the VTT Scania ethanol engine, which is instrumented to study injection and combustion parameters. In the fuel development, priority will be given to bio-origin additives. Both additives and denaturants could be bio-components. In addition, vegetable oil esters and bio-oxygenates could be considered as fuel components. Physical properties can be changed, for example, with high-viscosity components. Commercial Etamax D fuel will be used as a reference.

The fuel matrix will cover approximately 15 fuel combinations by varying ethanol content, additives, and other components. The ethanol content will be a minimum of 50%. The basic fuel properties will be analyzed from samples.

In the engine tests, combustion parameters will be monitored, as well will regulated gaseous emissions. High emissions of unburned fuel and rough engine running indicate an inefficient combustion process. The best fuel candidates will be selected for more detailed analysis, including particulate matter emissions. This activity will be carried out in cooperation with Scania and the Finnish energy company, St1, which produces ethanol from waste.

WP 3: Analysis of the Applicability of Ethanol in a Diesel Engine

The project will include analyses of the obtained experimental data in order to optimize the fuel conversion with respect to fuel economy and emissions. To characterize the best possible operation area, it is essential to characterize and understand the spray formation and heat release pattern during engine operation for different fuels/additives.

This WP will result in an evaluation of the possibilities and limitations of operating a diesel engine on ethanol-based fuels. The evaluation will be based on emission and fuel consumption perspectives, as well as the potential to operate the engine as a normal diesel-fueled engine.

WP 4: Project Organization and Compilation of Results

The project will be carried out under the umbrella of the Advanced Motor Fuels Implementing Agreement and in collaboration with the Combustion Implementing Agreement. The work will result in a final report that gathers information from the mentioned WPs. The report also will include information about related work from the Combustion Implementing Agreement. In addition, the overall management of the project is part of this WP.

Results and Reports/Deliverables

The project is carried out through the Advanced Motor Fuels Implementing Agreement. Therefore, the specifics of the project will be detailed in an official IEA report. Furthermore, the results will be presented at international conferences that focus on transportation issues, such as the International Council on Combustion Engines, the Society of Automotive Engineers International, and the International Symposium of Alcohol Fuels.

Annex 47: Reconsideration of DME Fuel Specifications for Vehicles

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

Background

Although the price of crude oil has come down to a stable level, continuous energy security is still imperative worldwide. With a view toward reducing the environmental impact from vehicles and relieving world dependence on oil, expectations for using dimethyl ether (DME) are still high. Currently, DME is produced from coal and natural gas. If the use of techniques for producing DME by using synthetic gases from waste paper fluid (black liquor) or wood-based biomass from unused wood (including thinned wood) could be realized, a dramatic well-to-tank reduction in greenhouse gases would be achieved, and DME could become the most attractive next-generation biofuel.

Under the AMF IA, the potential of using DME as an alternative fuel for diesel engines had been investigated through some Annexes (e.g., Annexes XIV, XX, and XVII) from 1997 to 2004. Since there was no DME market for vehicles at that time, the investigations had been done based on the supposition that the DME market for vehicles would be established in the near future.

In China, a DME market for vehicles has developed, and production capacity reached 13 million tons. A field test of 10 city buses running on DME is being conducted on a commercial bus line in Shanghai city. Sweden is now operating the BioDME project, in which 14 trucks running on DME are being field tested. In Japan, two trucks with business license plates are running on DME, with the goal being to build technical regulations for DME vehicles. The DME fuel situation has been changing, and its commercialization is being accelerated.

The International Organization for Standardization (ISO) has been discussing the standardization of DME fuel through its Working Group TC28/SC4/WG13 from 2007. The person who proposed this Annex was a convener of WG13. The scope of the DME standardization effort can be classified into three use categories: (1) as a feedstock for home and industrial use, (2) as a blendstock with liquefied petroleum gas (LPG), and (3) as an alternative to diesel fuel for power systems, including vehicles. WG13 has a draft values for DME fuel specifications; however, the values are not for the final DME product for vehicles but for the base fuel to be used in various applications. Therefore, it is necessary to standardize the DME specifications for vehicles, and now is the time to do it, in an Annex that considers the current situation of DME fuel commercialization.

Purpose and Objectives

The objective of this Annex is to conduct an "investigation of DME fuel specifications for vehicles." The basic specifications are taken from the draft values of ISO/TC28/SC4/WG13 (shown in Table 1). The main issues to be investigated in the Annex are (a) the effects of fuel impurities and (b) the effects of additives (e.g., lubricity improvers, odorants, if any) on DME diesel engine systems.

Table 1 DME Fuel Specifications for Base Fuel
(Draft Values from ISO/TC28/SC4/WG13)

Characteristic	Unit	Limit	ISO/ DIS16861	Mutual agreement value of AMF Annex (1998)
Purity	mass %	min.	**98.5**	**99.6**
Methanol	mass %	max.	**0.050**	**0.05**
Water	mass %	max.	**0.030**	**0.01**
Hydrocarbons (up to C_4)	mass %	max.	**1.00**	**Others** **Methyl ethyl ether <0.2** **Higher alcohol <0.05** **Higher ether <0.05** **Ketones <0.05** **Lubricity Improver <0.2** **Odorant <0.002**
CO_2	mass %	max.	**0.10**	
CO	mass %	max.	**0.010**	
Methyl formate	mass %	max.	**0.050**	
Ethyl methyl ether	mass %	max.	**0.20**	
Residue after evaporation	mass %	max.	**0.0070**	
Sulfur	mg/kg	max.	**3.0**	

Activities

The effects of fuel impurities and additives on DME diesel engine systems were discussed in 2014 as follows:

- On March 20, at a face-to-face meeting involving Sweden, Japan, and Korea and
- On December 9, in a phone call involving Sweden and Japan.

The minutes from these discussions are summarized here.

- A potential way to move forward in this effort could be to connect the lubricity test evaluation proposal to the work being done toward achieving a "final fuel for engine standard."
- The Japanese are working toward such a standard, including (a) specifying a lubricity improver and its concentration range and (b) describing the MPT-HFRR (multi-pressure/temperature high-frequency reciprocating rig) lubricity test in an Annex.
- Participants should connect the work being done in Japan, the European Union, and the United States to achieve regional final fuel standards into a combined fuel standard effort.
- Lubricity test participants can start working on describing the three methods, which could be included in the Annex for a final fuel standard, and then doing a round of testing for the three methods with the same lubricity improver concentrations. These results could also be included in the final fuel standard Annex.

The next steps are listed here.

- Japan will comment on the lubricity test proposal.
- Sweden will check on the next steps for a European standard for a final fuel.
- The United States will work toward achieving a U.S. final fuel standard (or check if the current American Society for Testing and Materials (ASTM) standard is enough.
- Some meetings will be continued.

Participants

Japan

- National Institute of Advanced Industrial Science and Technology (AIST)
- Isuzu Advanced Engineering Center, Ltd.
- Denso Corporation

Sweden

- Swedish Transport Administration (STA)

- Swedish Energy Agency
- Volvo

Korea
- Korea Automotive Technology Institute (KATECH)
- University of Ulsan

Thailand
- PTT Research and Technology Institute

China
- Shanghai Jiao Tong University

Time Schedule

- Discuss the DME fuel specification for vehicles: June 2015
- Make a draft of the DME fuel specification for the ISO new work item proposal: June–October 2015
- Deliver final report: October–November 2015
- Follow up on the ISO discussion: End of 2015

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

Project Duration	October 2013–July 2015
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Denmark, Finland, Israel, United States Canada, Denmark, United States
Total Budget	• Canada – \$24,000 US (€22,448) • Denmark – \$10,000 US (€9.353) • United States – \$160,000 US (€149,652)
Operating Agent	Ralph McGill Fuels Engines and Emissions Consulting Email: rnmcgill@yahoo.com

Background

Compressed natural gas (CNG) vehicles have achieved moderate popularity throughout the world; however, they continue to suffer from limited range and, possibly, excessive weight. Liquefied natural gas (LNG) has demonstrated some practicality for use in heavy-duty vehicles, but it is currently too heavy to store onboard in light-duty vehicles. A third candidate, synthetic fuels derived from natural gas (synfuels), possibly represents a more feasible utilization of available energy; to date, however, such fuels have typically been more expensive to produce than CNG or LNG. Electricity derived from natural gas (NG) offers a fourth candidate for fuelling vehicles, especially with the current emergence of electric vehicles (EVs) and their accompanying infrastructure worldwide.

A key advantage that CNG and LNG combustion offers is the avoidance of an intermediate conversion/processing step into a secondary fuel prior to fuelling the vehicle — a step that introduces extra cost and fuel efficiency losses.

The production of synfuels, on the other hand, is likely to result in energy loss in the synthesis conversion process. Some of this expense will likely be offset, in part, by the elimination of other costs due to the fact that they provide simpler transport of fuels, higher vehicle efficiencies, and so forth. Synthetic fuels derived from NG offer additional benefits, including the use of a fuel that resembles petroleum fuels (also referred to as “drop-in” fuels for use in legacy vehicles) in some cases, and the use of a fuel that can often be delivered through the existing pipeline infrastructure.

Using NG to generate electricity for use in EVs also presents unique benefits, including power generation and transmission through power lines rather than pipelines, the ongoing development of the charging infrastructure, and favorable vehicle efficiencies. New EVs with improved range and fuel economies have been regularly introduced in recent years, and much momentum has been building in this market segment throughout the world.

For the benefits of NG-derived fuels to be realized, the resultant fuels would have to be produced, delivered, and used in vehicles at prices that are competitive with those of petroleum-based fuels. Balancing the trade-offs on an economic basis will help drive the selection of fuels for road transportation. Also, in addition to cost, emphasis should be placed on the environmental benefits, energy consumption, and energy security that each fuel pathway can offer to a particular nation.

Purpose and Objectives

Canada, Denmark, and the U.S. Department of Energy (DOE) together with partners will conduct a value proposition study that investigates different NG pathways for on-road vehicles in order to assess the advantages and disadvantages of the various options. Aspects studied will include, but not be limited to, the options' cost, life-cycle emissions, energy consumption, and societal implications. The goal is to identify the most cost-effective and technically feasible way to use NG in transportation, so that in many countries, NG would have the potential to emerge into the mainstream market rather than just continue being a niche market.

Activities

Main Activities

The team will first establish what fuel pathways will be investigated and provide general descriptions of each pathway, covering foreseeable opportunities and barriers. Although there are many possible fuel pathways that could originate from NG, only about six pathways can realistically be investigated because of the brevity of the study. Figure 1 shows a preliminary breakdown of fuel pathways considered for investigation.

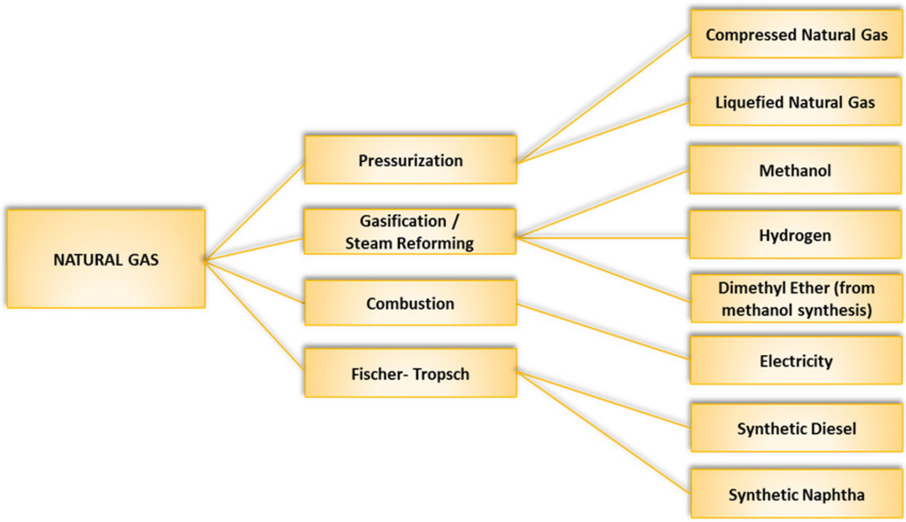

Fig. 1 Breakdown of Fuel Pathways

Since the viabilities of different NG-derived fuel pathways are likely to vary across different geographic settings, the project team will conduct a number of country-specific case studies that will cover ranges of NG reserves, production levels, consumption levels, import levels, and infrastructure levels. NG reserves will likely be a dominating factor in determining how viable the production and distribution of fuel could become. Furthermore, countries with large reserves may have already established traditional and synthetic NG operations. However, countries that heavily import and consume NG may also have a strong distribution network that could facilitate greater use of NG in road transport.

Life-cycle emissions will also be compared across each NG pathway investigated in this study. These emissions are expected to vary across fuel pathways due to differing upstream operations, fuel production and transport conditions, and vehicle operation (depending on engine design). Also, the composition of NG may vary across different reserves, although the primary component is assumed to be methane; therefore, emission factors will need to be established for each case study.

After the selection of the fuel pathways and case studies is complete, the project team will design a framework for assessing the costs and benefits of each fuel pathway that will cover:

- Vehicle/fuel combinations for both light-duty and heavy-duty vehicles;
- A selection of modeling tools that simulate different vehicles, costs, and emissions;
- Key modeling assumptions (defined with inputs from participating countries) regarding
  - Vehicle powertrain,
  - Fuel characteristics,
  - Market (e.g., fuel prices, infrastructure presence),
  - Regulatory factors (e.g., incentives, tax credits),
  - Emission factors, and
  - Life-cycle analysis (LCA) model boundaries;
- Cost/benefit components including
  - Cost of production and upstream activities,
  - Cost of vehicle ownership,
  - Purchase price,
  - Operating cost, and
  - Maintenance cost; and
- Environmental impacts covering
  - Greenhouse gas (GHG) emissions and
  - Particulate matter.

Once the framework has been established, the team will run simulations with identified modeling tools to calculate the costs and benefits for each fuel pathway of interest. Results will be analyzed to determine which NG pathways appear to be the most technically and economically feasible for each case study. Then the team will compare the results with traditional transportation options (e.g., petroleum-derived gasoline, diesel) to see whether any pathways are competitive within existing markets. Finally, it will draw conclusions about which pathways should be considered more heavily for the production of transportation fuels due to their economic or environmental benefits.

Sub-Activities

Sub-activities, to be completed by task-sharing countries, include these:

- Providing data for modeling and analysis inputs specific to the case study countries and
- Reviewing respective country profiles and final analysis results.

Workshops and Seminars

No workshops or seminars are planned.

Participants and/or Experts' Meetings

Representatives from participating countries will convene for status meetings on a biannual basis in coordination with planned IEA AMF IA Executive Committee (ExCo) Meetings.

Publications/Newsletters

Other than the IEA-published final report, the project team may pursue the preparation and submission of publications to non-IEA journals and/or venues, provided approval is received from all participating countries.

Results and Reports/Deliverables

The following milestones have been met for this annex:

- Categories/boundaries for investigation were defined by selecting:
  - Costs of fuel processing activities and vehicle operations (not feedstock acquisition),
  - Environmental impacts and energy use for fuel processing activities and vehicle operation (not feedstock acquisition), and
  - Policy status and market drivers that affect NG-derived fuels.
- Necessary modeling tools (to address fuel processing costs, vehicle operations, and environmental impacts) were identified and acquired. The IEA's Mobility Model (MoMo) and the GREET model were both initially identified as being strong candidates but were ruled out for various reasons. Canadian-based GHGenius is now being used for emission, cost, and vehicle operation modeling. Key reasons for selecting GHGenius included these: It is free of charge, is easily accessible, has strong ongoing support from developers, and addresses logistics, powertrain, and fuel pathway issues experienced by other models.
- Country-specific case studies were identified for investigation. Case studies are being performed for each participating annex country that provides inputs: Canada, China, Denmark, Finland, Israel, and the United States.
- NG-derived fuel pathways were selected. These were down-selected from the full list of GHGenius feedstock/fuel combinations for light-duty and heavy-duty vehicles.
- Other key modeling assumptions were set. Internationally consistent modeling assumptions were set for GHGenius for energy use and emissions, including life-cycle boundaries (starting after NG has reached the fuel processing plant and extending through vehicle operations) and the timeframe (2015 to assess present day capabilities).
- Relevant data were requested and retrieved from participating countries. Requests were sent to participating countries to fill out templates for

GHGenius inputs that are not consistent worldwide (since GHGenius houses only Canadian and US data), including these:
  - Feedstock composition (e.g., sulfur and oxygen content, methane and ethanol levels),
  - Level of renewable NG used in transportation,
  - Electricity generation mix (stationary),
  - Fuel processing efficiencies, and
  - Plant designs/techniques and equipment types.

  Inputs were received from all participating countries.
- Preliminary modeling simulations were run. They were run as part of the process of troubleshooting issues with model developers.

Next, results will be analyzed to determine the most economically feasible pathways for each country. These results will be compared with those on traditional transportation fuels to determine their level of competitiveness. Results will be documented in a final report detailing the costs and benefits associated with each NG pathway investigated in this study. The report will also include conclusions and recommendations on which pathways appear to be the most economically and technically feasible with regard to energy consumption, different modes of road transportation, and variations among nations. In addition to cost information, results on environmental impacts and potential implications on energy security will be provided.

Progress on milestones will be presented at IEA AMF IA ExCo Meetings.

Time Schedule

The period of performance of this annex, which extends from October 1, 2013, to July 31, 2015, is broken down by component in Figure 2.

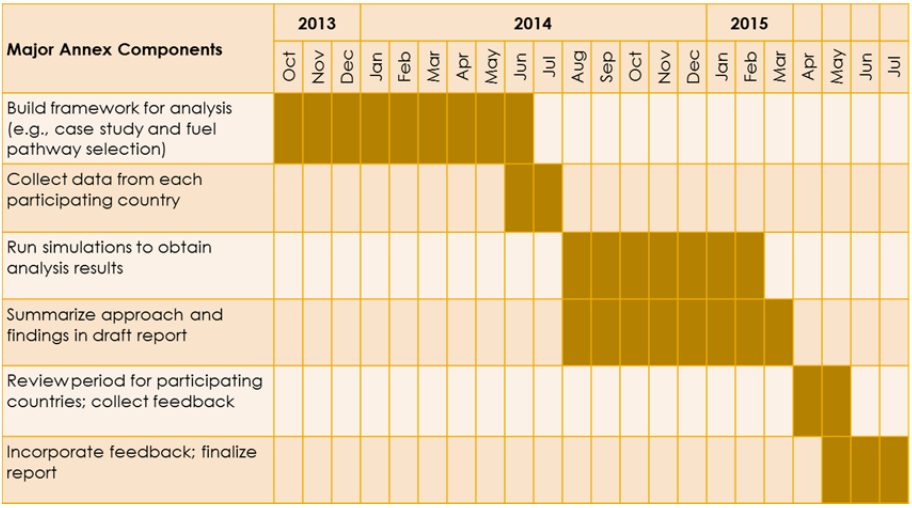

Fig. 2 Period of Performance for Annex 48, Broken Down by Component

Participants and Annex Activities

Rights and Obligations of Participants

This annex is both cost-shared and task-shared.

Cost-Sharing Participants

The cost-sharing participants are Canmet for Canada. DTU for Denmark, and the U.S, Department of Energy for the United States.

Task-Sharing Participants

The United States will lead the execution of this Annex, which includes the preparation and development of case studies, the modeling framework and simulations, and a technical analysis, and the preparation of the deliverable. Canada, China, Denmark, Finland, and Israel will be responsible for the following:

- Providing data for modeling and analysis inputs that are specific to the case study countries and
- Reviewing respective country profiles and final analysis results.

Management

The following information was requested and is provided here.

a. *The identity of the entity or individual responsible for the management and for the leadership of the activities carried out under this Annex.* Ralph McGill (Fuels, Engines and Emissions) is the Operating Agent for this Annex and is thus responsible for managing and leading the activities carried out under this task.

b. *The Operating Agent's rights, obligations, and responsibilities, in addition to those indicated in the main body of the Implementing Agreement and the organization of the work under this Annex (regarding, for instance, his remuneration and reimbursement of expenses, the preparation of a detailed program of work and budget in consultation with the Participants under this Annex, the preparation and distribution of assessments, reports, newsletters or other information, the organization of meetings, workshops, seminars, training sessions, the preparation of guidelines for the work to be carried out under this Annex, the management of a common fund, if any, etc.).* The Operating Agent's rights, obligations, and responsibilities align with those already indicated in the main body of the Implementing Agreement (IA).

c. *Operating Agent's meetings.* The Operating Agent will organize and lead internal project team meetings to report on project progress. In addition, he will lead biannual check-in meetings with participating countries in coordination with ExCo Meetings.

d. *The rights, obligations, and responsibilities of Task Leaders and Sub-task Leaders, if any (see examples under letter b).* This is not applicable.

e. *The content and schedule of assessments, reports to be submitted by the Operating Agent and by the Task and Sub-task Leaders to the ExCo, the Working Party, the Committee on Energy Research and Technology (CERT), and/or the IEA, to newsletters.* The Operating Agent will submit a final report to the participants of the ExCo as the single deliverable from this Annex.

Admission, Participation, and Withdrawal of Participants

There are no special provisions outside those already indicated in the main body of the IA.

Information and Intellectual Property

There are no special provisions outside those already indicated in the main body of the IA.

Entry into Force, Term, and Extension

This Annex shall enter into force on October 1, 2013, and shall remain in force for a period of 1.75 years, until July 31, 2015. At the conclusion of that period, this Annex can be extended by at least two Participants, acting in the ExCo, for a period to be determined at that time, provided that in no event shall the Annex continue beyond the current term, or actual termination, of the IA.

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

Project Duration	July 2013 – June 2015
Participants **Task Sharing** **Cost Sharing**	 Canada, Chile, China, Denmark, Finland, Israel, Japan, Korea, Sweden, Thailand None
Total Budget	~€900,000 ($1,245,510 US)
Operating Agent	Jukka Nuottimäki VTT Technical Research Centre of Finland Email: jukka.nuottimaki@vtt.fi

Background

Major de-carbonizing actions need to take place in the transport sector. There is no single solution that could solve the de-carbonization challenge, however. To get the best possible results, all transport subsectors should be taken into consideration. Due to scarce resources of advanced and carbon-neutral fuels, information on the usability of alternative fuels and technologies and on their impacts on energy consumption and emissions in a given transport task must be obtained. In addition, an overall assessment of these alternatives and their full fuel-cycle performance is needed. This would provide insight on where certain technologies could be best utilized, thus leading to the "optimal allocation" of various alternatives.

Previous Annexes have assessed the performance of buses (Annex 37) and passenger cars (Annex 43). This Annex 49 focuses on commercial vehicles, vans, and trucks.

With regard to tailpipe emissions, one could say that the game is changing. Euro VI/U.S. 2010 emission regulations have decreased emission levels to close to zero. This means that differences arising from the fuel itself are diminishing, and that overall energy consumption and greenhouse gas emissions are becoming increasingly important issues.

Purpose and Objectives

This project aims to deliver comparable data on the tailpipe emissions and energy consumption of commercial light-duty and heavy-duty vehicles. This study also provides data on well-to-wheel energy consumption and emissions, and even costs, to supplement the information that has already been generated in Annexes 37, 38, 39 and 43.

In combination with the information generated in previous Annexes, the goal of this study is to gain further knowledge about the optimal allocation of alternative fuels and technologies for road transport. (In other words, this Annex exists because the optimal solutions for passenger cars differ significantly from those for heavy-duty long haul tractor and trailer combinations.)

Several governments are developing roadmaps for the introduction of alternative and carbon-neutral fuels. For example, Sweden is aiming at a vehicle fleet independent of fossil fuels, and Finland has set a very ambitious biofuels target of 20% by 2020. This project will support the development of strategies for deploying alternative fuels and alternative energy.

Activities

The modus operandi of the project is equivalent to the one used in Annex 43: Several laboratories add to a common pool of test data by running tests according to jointly defined test programs and test protocols. The development of common test procedures for use by the research partners is thus a key element in the project. At least one common test cycle should be used for all vehicle categories. The project consists of eight work packages (WPs), as follows:

WP 0: Collection and consolidation of the existing data

WP 1: Development of common test procedures and protocols

WP 2: Vehicle testing

- Three different vehicle categories (light-duty commercial vehicles (vans), medium heavy-duty trucks, and long-haul semi-trailer tractors) that include several alternative fuel and vehicle technologies
- Parameters to be varied: fuel composition, driving cycle, payload (0, 50, and 100%), environmental conditions (ambient temperature)

WP 3: Aggregation of well-to-tank information

- Based on test fuel matrix and information gathered in Annexes 37 and 43

WP 4: Regional information on the energy options in the transport sector

- Information from project participants on regional challenges and opportunities that drive the development of energy options in the transport sector and affect the available fuel selection. This regional information will also clarify what the potentials of alternative technologies in different locations are.

WP 5: Full fuel-cycle evaluation (integration of WP 2 and WP 3)

- Well-to-wheel fuel consumption, energy efficiency, and emissions

WP 6: Life-cycle cost analysis

- Determine how alternative fuels and vehicle technologies, together with the operation of the vehicles, influence life-cycle costs. The objective is to find a cost-effective way to reduce emissions and energy consumption for a given commercial vehicle application.

WP 7: Coordination of the project, synthesis, and reporting

- Administrative co-ordination, communication with the IEA AMF IA Executive Committee, synthesis of the data, compilation of the Final Report, and dissemination of the results

WP 1 was finalized in 2013. By the end of 2014, a significant part of the actual vehicle testing had been carried out. The focus in 2015 will be on processing and collating the data. The Final Report for the project will be available at the end of 2015.

Figure 1 shows one of the vehicles being tested for the project.

Fig. 1 One of the Vehicles — a Diesel Dual-Fuel Truck — Being Tested for Annex 49

Participants

Policy Related Participants

- Finnish Transport Agency
- Danish Energy Agency
- Israel Ministry of National Infrastructure, Energy and Water Resources
- Natural Resources Canada
- Organization for the Promotion of Low Emission Vehicles (LEVO) (Japan)
- Swedish Road Administration Agency
- Tekes – The Finnish Funding Agency for Innovation

Industry Participants

- Gasum (Finland)
- Neste Oil (Finland)
- UPM (Finland)
- PTT Public Company Limited St1 (Thailand)

Academia and Test Laboratory Participants

- AVL MTC Motortestcenter AB (Sweden)
- Centro Mario Molina Chile
- China Automotive Technology and Research Centre (CATARC)
- Environment Canada
- Danish Technological Institute

- Korean Automotive Technology Institute (KATECH)
- National Traffic Safety and Environment Laboratory (NTSEL) (Japan)
- Vehicle Control and Certification Center (3CV) (Chile)
- VTT Technical Research Centre of Finland

Time Schedule

The schedule is presented in Figure 2.

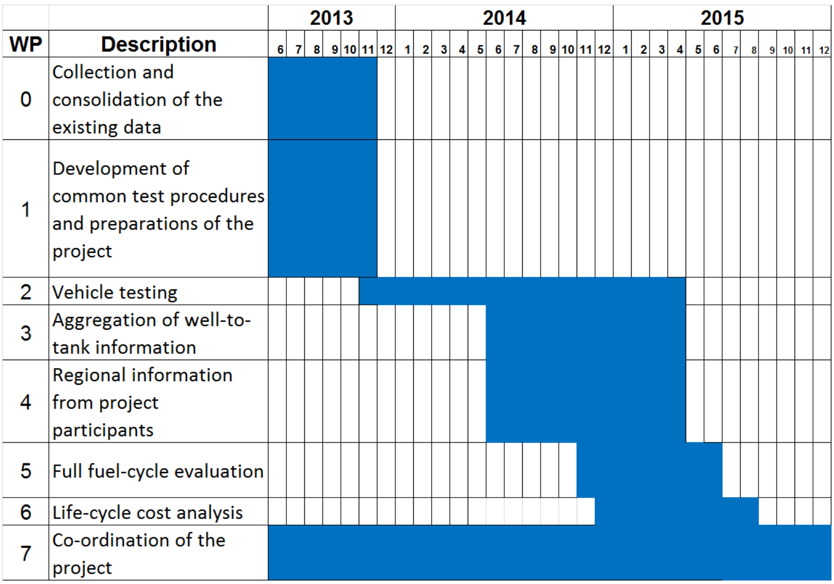

Fig. 2 Project Schedule for Annex 49

Results/Key Messages

WP 1, the development of common test procedures, was completed during year one (2013), as planned. WP 1 defined the test methods and minimum requirements for emissions to be measured. The work of WP 1 also covered the minimum requirements for one baseline test fuel and mandatory requirements for reporting the test results. Figure 3 shows the World Harmonized Vehicle Cycle (WHVC), which was chosen to be used as the common test cycle in the vehicle testing phase (WP 2).

Most of the actual vehicle testing was carried out during year two (2014).

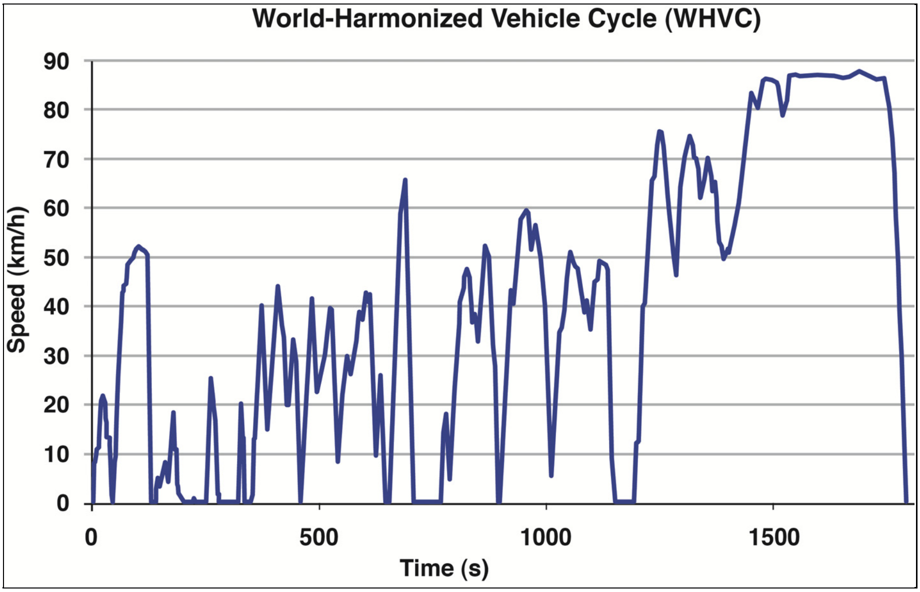

Fig. 3 World Harmonized Vehicle Cycle

Publications

The results of this project are expected to be reported at the end of 2015.

Success Stories

This project has attracted several IEA AMF IA member countries. In addition, Chile, which is in the process of joining the AMF IA, has contributed to this Annex. What is unique about this project is that vehicle laboratories on four continents (Asia, Europe, North America, and South America) are jointly creating a database on commercial vehicle performance.

Year one was spent on defining the project and the common test methodology. Year two's focus was on actual vehicle measurements.

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

Project Duration	May 2014 – June 2017
Participants	
Task Sharing	Sweden, Finland, Germany, Canada
Cost Sharing	To be determined
Total Budget	More than €200,000 ($312,145 US)
Operating Agent	Magnus Lindgren Swedish Transport Administration Email: Magnus.Lindgren@trafikverket.se

Background

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 IEA AMF IA, have focused on on-road vehicles.

Purpose and Objectives

The purpose and first objective of Annex 50 is to evaluate the fuel efficiencies and emissions performance associated with different engine technologies, fuel specifications, and machinery applications, including a consideration of engine load cycles. A second objective is to develop emission factors for inventories of non-road mobile machinery in the participating countries and to investigate the potential that technology developed in the on-road sector would be useful for non-road applications (hybridization, exhause gas after-treater, friction re duction). A third objective is to assess the possible effects of retrofitting the legacy fleet on fuel efficiency and emissions.

Activities

Literature Review

- Compare non-road and on-road emissions legislation (Work Package or WP 1)
- Determine the availability and applicability of alternative technologies (e.g., alternative fuels, hybridization, electrification, fuel cell technology) (WP 2)
- Obtain national and regional information on non-road mobile machinery policy options (WP 4)

Method Development

- Develop common test procedures and protocols (WP 6)
- Simulate components and/or machinery in order to address fuel consumption (WP 8)

Collation of Existing Data

- Collect existing data (on the number of machines, working hours, engine power, etc.) for fuel consumption and emission inventories (WP 3)

Experimental Work to Generate New Data

- Test machinery (e.g., conduct portable emissions measurement system [PEMS] testing of complete machinery, chassis dynamometer testing of road-vehicle-like machinery, and engine dynamometer testing of standalone engines) (WP 7)

Data Assessment/Evaluation

- Included in the earlier activities

Information Dissemination

- Write and distribute reports, including both a Final Report and a two-page summary (WP 9)

Participants

Policy-Related Participants

- Swedish Transport Administration
- Natural Recourses Canada
- VTT Technical Research Centre of Finland
- Agency for Renewable Resources (FNR) (Germany)

Industry Participants

- John Deere GmbH & Co. KG (Germany)
- Proventia Emission Control OY (Finland)
- Neste Oil (Finland)
- Skanska (Sweden)
- Volvo Construction Equipment (Sweden)
- Agco (Finland)

Time Schedule

Figure 1 shows the project schedule for Annex 50.

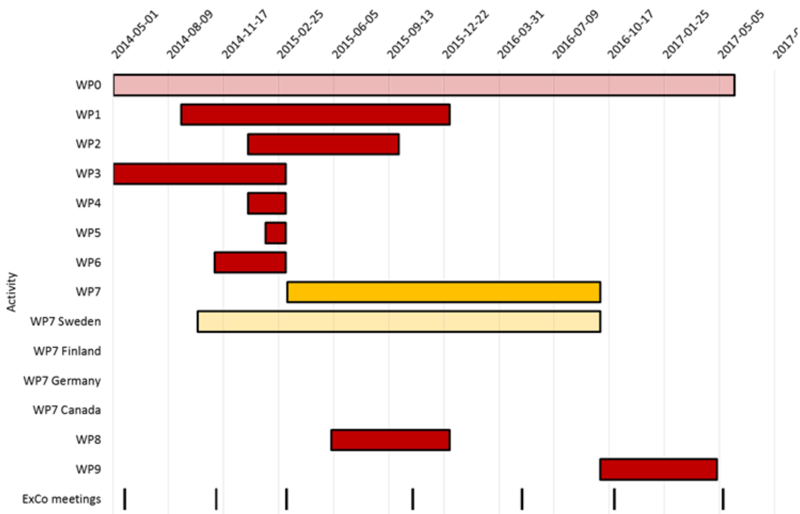

Fig. 1 Project Schedule for Annex 50

Results/Key Messages

The results and deliverables of this Annex will be a written report presenting data on fuel consumption and emissions from various types of non-road mobile machinery. It will cover:

- Emission stages,
- Technologies and alternative fuels, and
- Machinery operations.

Publications

The Annex started recently; there are no publications yet.

Success Stories

The Annex started recently; success stories will be described later.

Future Plans

The Annex started recently; future plans will be described later.

Annex 51: Methane Emission Control

Project Duration	May 2013–December 2018
Participants	
Task Sharing	Denmark, Finland, Germany, Japan, Korea, Sweden
Cost Sharing	No cost sharing
Total Budget	To be determined
Operating Agent	Jesper Schramm DTU – Technical University of Denmark (DTU Email: js@mek.dtu.dk

Background

The use of methane (natural gas [NG], biogas) for transport will increase. Although dual diesel fuel (DDF) technology could bring the efficiency of gas engines close to the efficiency of diesel engines, Annex 39 clearly demonstrated that methane slip is still a serious problem for current DDF engines. Alternatively, advanced spark ignition (SI) technologies (e.g., variable valve trains, cylinder deactivation, high-level exhaust gas recirculation) could be applied to increase engine efficiency. However, there would still be a need for methane catalysts, but the performance and durability of current methane catalysts are not satisfactory.

This new Annex 51 will be based on the experience from Annex 39, with a 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.

Purpose and Objectives

Combustion engines for vehicles can be replaced by or converted to liquefied natural gas (LNG) operation. This has benefits in terms of emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and particulates. Reductions in CO_2 occur partly because the ratio between carbon and hydrogen is less for natural gas (NG) than for liquid hydrocarbons (diesel, gasoline, etc.), 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 the LNG engines emit significantly larger quantities of unburned methane than do the traditional engines. Because methane is a 20-times more powerful

GHG than CO_2, the overall result could easily be an increase in GHG emissions from vehicles if their engines were converted to run on LNG.

Researchers have a lot of 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 the 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 methane emissions from a vehicle.

The purpose of this project is to identify and understand what causes high emissions of unburned methane or what causes emissions of methane from vehicle parts other than the engine and to then determine the best ways to reduce these emissions.

Activities

Work Package (WP) 0: Project Management

The project management will be done by DTU – the Technical University of Denmark.

WP 1: Application of Natural Gas in Combustion Engines

An overview of the application of NG in combustion engines for transportation purposes will be given. The WP will focus on road and marine transportation, since these are the transport sectors in which the idea of implementing methane in the form of NG 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 an NG engine. Mathematical models of the processes will be formulated to describe the phenomena that occur during the conversion of the fuel in the engine. The models will describe the influence of the combustion principle (SI or dual-fuel), the combustion chamber geometry, and the application of mixed fuels.

For example, we know that mixtures of NG and a smaller amount of hydrogen make it possible to reduce unburned methane emissions because the hydrogen promotes the combustion of methane. Dimethyl ether (DME) is another fuel option to promote methane conversion. The models will be verified in experiments in which the relevant engine parameters will be varied**.**

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

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

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

WP4: 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.

Results and Reports/Deliverables

The results will be published in a common report that will be delivered at the end of the project period. In addition, the results will be published at international conferences and in international journals.

Time Schedule

The project will start in 2014 and be finished in 2018.

4 Further Information

4.a AMF IA Executive Committee (ExCo) Meetings

ExCo 47, May 20–23, 2014, Copenhagen, Denmark

The 47th Meeting of the AMF IA ExCo was held on May 20–23, 2014, in Copenhagen, Denmark. There were 27 participants, including Chile as an Observer. The main topics of the meeting were a request to extend the AMF IA and a discussion on ideas for new Annexes. There was also an intense exchange of information between the participants in this IA and those in two other IAs: Bioenergy IA and Hybrid and Electric Vehicles (HEV) IA.

At the meeting, some last changes were made to the End of Term Report and the Strategic Plan, and a self-assessment (measured against IEA Committee on Energy Research and Technology [CERT] criteria) was carried out. All documents were unanimously approved.

Extension of the Implementing Agreement

Shortly after the meeting, following an earlier unanimous decision to request the extension of the AMF IA, the request was submitted to the Working Party on Energy End-Use Technologies (EUWP) by the AMF IA Chairperson, Sandra Hermle.

Strategy Subcommittee

Olle Hadell, Swedish Delegate and head of the Strategy Subcommittee, retired from his position in the Swedish Transport Administration and also from the AMF IA. Magnus Lindgren has taken over as head of the Strategy Subcommittee.

Ideas for New Annexes

Seven of the twelve active Annexes are scheduled to close in 2014. To stimulate thoughts on what new Annexes might be needed to replace them, a significant amount of time during the meeting was devoted to a discussion of new ideas for Annexes. The following topics were identified:

- Non-road mobile machinery
- Advanced fuels for plug-in hybrids
- Unburnt methane in natural gas engines

- Technology options for public transport, and adapted driving cycles to use for evaluating the best technology choice for buses
- Emissions and fuel consumption during real driving conditions
- Preparation of a report on the outlook for fuels and powertrains, including maritime fuels and powertrains (it is not to be a technical report but a report on how different countries see them)
- Advanced fuels in advanced engines
- Investigation of fuel-saving additives
- How to transport and store renewable energy carriers

There was significant support for some of these topics, and two new Annexes were started!

- Annex 50: Fuel and Technology Alternatives in Non-Road Engines
- Annex 51: Methane Emission Control

Collaboration within the Energy Technology Network

Three IA ExCo meetings (AMF, Bioenergy, HEV) happened to take place in the same week in Copenhagen. This coincidence offered an opportunity for joint activities and part-time participation in each other's meetings.

AMF and Bioenergy experts participated in a workshop on infrastructure-compatible transport fuels. Presentations provided an overview on transport policies, case studies of Sweden and Brazil, highlights on new developments in biofuel production technologies, and descriptions of end-use aspects related to the use of biofuels in various engines.

AMF experts also met with HEV experts to discuss the new Strategic Plans and areas of possible collaboration. Discussions were continued over a joint dinner.

The new desk officer for the AMF IA, Tali Trigg, who is also desk officer for the HEV IA, participated in part of the ExCo meeting. David Baxter, Task Leader of Bioenergy Task 37 joined the AMF IA meeting when Magnus Lindgren reported on the contribution of the AMF IA to a Task 37 brochure on methane for transportation.

Membership

Chile and Uruguay are preparing to join the AMF IA as Contracting Parties.

Next Meetings

- ExCo 48 in Israel: October 27–31, 2014, in Jerusalem.[71]
- ExCo 49 in South Korea: March 10–14, 2015, in Gwangju, in conjunction with the 21st International Symposium on Alcohol Fuels (ISAF)

Work Program Updates

- **Annex 28:** Information Service and AMF Website
  The website had 6,500 visitors in the past year. The Fuel Information System brings significant traffic to the website, primarily through its pages on liquefied petroleum gas (LPG), butanol, methane, and methanol.
- **Annex 35:** Particle Measurements: Ethanol and Butanol in DISI Engines.
  Testing was completed, and a draft final report was prepared. The Annex was prolonged until October 31, 2014. China withdrew from Annex 35-2 and moved its contribution to Annex 44.
- **Annex 38:** Environmental Impact of Biodiesel Vehicles – Phase 2.
  The final report is complete, and results will be presented at a Society of Automotive Engineers (SAE) conference. Canada moved its contribution to Annex 49. Annex 38 is to be closed by written procedure by the end of June.
- **Annex 39:** Enhanced Emission Performance and Fuel Efficiency of HD Methane Engines – Phase 2.
  Annex work is complete, and the final report is ready. It is urgent that the results be made available to decision makers, since some issues that need further research issues arose from the project, particularly with regard to unburnt methane emissions. The Annex is closed.
- **Annex 42:** Toxicity of Exhaust Gases and Particles from IC-Engines.
  The health impacts from diesel exhaust and particulates were confirmed, leaving no doubts about their toxic nature. The Operating Agent will continue to collate related information with the help of AMF IA Contracting Parties.
- **Annex 43:** Performance Evaluation of Passenger Car Fuel and Powerplant Options.
  Annex 43 was prolonged until October 31, 2014, to enable the incorporation of all test results into the final report.
- **Annex 44:** Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels.
  All tests were carried out, but the analysis of results is still ongoing. The

[71] In August 2014, it was decided to postpone the invitation to Israel to ExCo 50. ExCo 48 took place in France instead.

Annex was prolonged until end of 2014. Switzerland cancelled its task-sharing participation in Annex 44 due to timing reasons.

- **Annex 45:** Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation.
  First results were presented. No changes were proposed, and no decisions were required.
- **Annex 46:** Alcohol Application in CI Engines.
  This annex facilitated a staff exchange from the Technical University of Denmark (DTU) to VTT Technical Research Centre of Finland (VTT). A seminar for discussing Annex 46 results together with the Combustion IA participants was planned for December 2014. The AMF IA provided support for this activity with €2,000 from the Common Fund.
- **Annex 47:** Reconsideration of DME Fuel Specifications for Vehicles.
  Work on the International Organization for Standardization (ISO) standard is progressing. Japanese and Korean participants met with Volvo and ETC for a discussion in March 2014. More face-to-face meetings are needed (e.g., with China Automotive Technology and Research Center [CATARC]).
- **Annex 48:** Value Proposition Study on Natural Gas Pathways for Road Vehicles.
  Data from the Annex participants are being collated to run the simulations (with the GREET modeling tool). The work is running a bit late, but no changes have been required yet.
- **Annex 49:** COMVEC – Fuel and Technology Alternatives for Commercial Vehicles.
  Currently most of the task-sharing participants are performing vehicle testing (Work Package 2). The measurement phase might be delayed, but no changes have been required yet.

ExCo 48, November 03–05, 2014, Paris, France

The 48th Meeting of the AMF IA ExCo was held on November 3–5, 2014, in Paris, France. There were 26 participants; they included Chile and the Methanol Institute as Observers and 7 members of the Energy Technology Network. The informal meeting was held at IEA headquarters, which offered the possibility of strengthening ties with the IEA Secretariat.

Information Exchange with IEA Experts

Drawing on the opportunity just mentioned, part of the informal meeting was dedicated to an information exchange with IEA experts. Presentations included an outlook on biofuels (Anselm Eisentraut), modeling of transportation for the oil market group (Matthew Parry), and the focus of

Energy Technology Perspectives publications in 2015 and 2016 (J.F. Gagne).

The production of biofuels is falling far behind the targets of the IEA Biofuel Roadmap. Although emerging markets continue expanding biofuel production, the shifting policy policies in the established markets of Europe and North America undermine medium-term growth in biofuel production. One reason for the loss of political support in the EU is concern over indirect land use change (ILUC) caused by biofuels. In the United States, late publishing of mandated market volumes and repeated diminution of the target volumes for cellulosic ethanol add to the uncertainty about future advanced biofuels markets. Stable, long-term policy frameworks, including clear sustainability guidelines, are vital for further growth.

Technology Subcommittee

The Technology Subcommittee identified the following research needs:

- Methane slip from heavy-duty engines: The literature is contradictory, and further research is needed.
- Current diesel vehicles seem to emit higher NO_x emissions during real driving than in test procedures: There is a need to evaluate test procedures to address the NO_x problem.
- Particulate emissions from gasoline engines: These emissions indicate the need to investigate gasoline particulate filters.

Strategy Subcommittee

The Strategy Subcommittee defined its role as being to identify and react to societal needs that the AMF IA could respond to. Whereas the Technology Subcommittee is, in a way, working from the bottom up, the Strategy Subcommittee is basically working in a top-down fashion. All delegates are asked to provide any national white papers related to transport or alternative fuels.

Collaboration within the Energy Technology Network

Representatives from Bioenergy Task 39 (Liquid Biofuels), the Hybrid and Electric Vehicles (HEV) IA, and the Advanced Fuel Cell (AFC) IA attended the AMF IA ExCo 48 meeting. Each group briefly presented their work and identified opportunities for collaboration:

- “Advanced fuels in advanced engines” (Bioenergy Task 39)
- “Heavy-duty vehicles” and “alternative infrastructure requirements” (HEV IA)

- "Hydrogen and fuel cells in the transport sector" (AFC IA)

Management
Carrie Pottinger, Energy Technology Network (ETN) Programme Manager at IEA, attended part of the formal meeting. Magnus Lindgren, delegate for Sweden, was elected ExCo Chair. Nils-Olof Nylund, delegate from Finland, and one of the two delegates from Japan were elected Vice-Chairs. The Financial Officer, Larry Johnson, was asked to further contract the American Society of Engineering Education (ASEE) to handle AMF IA Funds. Dina Bacovsky shall be further contracted as Secretary.

Annex Proposals
Several topics were discussed as being relevant for new Annexes, as follows:
- Sustainable bus systems: Canada, Finland, and Sweden agreed to join such an Annex if Chile would join the AMF IA and be the Operating Agent.
- Fuel technologies for high-efficiency engine operation: Kim Winther should prepare a proposal for ExCo 49.
- Real driving emissions and fuel consumption. Magnus Lindgren should prepare a proposal for ExCo 49.
- Advanced fuels in advanced engines: This topic should be further discussed with Bioenergy Task 39.
- Marine fuels, aviation fuels, and transportation and storage of renewable energy carriers: These topics shall be followed through news articles in the newsletter.

Membership
Chile is close to joining AMF IA as a Contracting Party. The Methanol Institute is interested in several Annexes and might consider joining the AMF IA as a Sponsor.

Next Meetings
- ExCo 49 in South Korea: March 10–14, 2015, in Gwangju, in conjunction with the ISAF conference
- ExCo 50 in Israel: October 26–30, 2015, in Jerusalem

Work Program Updates at ExCo 48
- **Annex 28:** Information Service and AMF Website.
  The website had 10,500 visitors in the past year. The Fuel Information System brings significant traffic to the website, primarily through its pages on LPG, butanol, methane, and methanol.

- **Annex 35:** Particle Measurements: Ethanol and Butanol in DISI Engines.
  All of the E85 studies in this annex yielded consistent results, indicating the potential to mitigate particulate matter (PM) emissions from gas direct-injection (GDI) engines. The final report will be published soon. The annex was closed.
- **Annex 38:** Environmental Impact of Biodiesel Vehicles – Phase 2.
  The final report was published, and the annex was closed by written procedure by July 11, 2014.
- **Annex 42:** Toxicity of Exhaust Gases and Particles from IC-Engines.
  Health impacts were confirmed with no doubts regarding their toxicity. A last overview report is to be provided by the end of the year. All delegates are encouraged to provide relevant contacts and information.
- **Annex 43:** Performance Evaluation of Passenger Car Fuel and Powerplant Options.
  Testing resulted in a list of advantages and disadvantages of the different fuel and powerplant options. To prepare the final report, the annex was prolonged until February 28, 2015. Juhani Laurikko will take over project leadership from Jukka Nuottimäki (both are associated with VTT).
- **Annex 44:** Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels.
  Testing was completed, but some participants are still working on their final reports. The annex final report is to be prepared and circulated by the end of December 2014.
- **Annex 45:** Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation.
  Hydrotreated vegetable oil (HVO), fatty acid methyl ester (FAME), and enzymatic FAME (eFAME) were compared in engine tests. FAME and eFAME showed a significant potential for reducing emissions of carbon monoxide (CO), total hydrocarbon (THC), and soot. Adaption of the engine control unit (ECU) to these fuels resulted in decreasing fuel consumption. The final report is to be distributed by the end of November.
- **Annex 46:** Alcohol Application in CI Engines.
  Testing at VTT has been completed. At DTU, an engine broke down, and testing has thus been delayed. A seminar for discussing annex results together with the Combustion IA participants is planned for February 2015. The annex was prolonged until December 31, 2015.
- **Annex 47:** Reconsideration of DME Fuel Specifications for Vehicles.
  Work on the ISO standard for dimethyl ether (DME) as a fuel is progressing. Four test methods have been approved and are to be published by the end of 2014. A new set of round-robin tests will be

started soon, and anyone interested in participating should contact Mitsuharu Oguma.

- **Annex 48:** Value Proposition Study on Natural Gas Pathways for Road Vehicles.
  Simulations are run with the GREET modeling tool. First assessments indicate that most natural gas vehicles seem to be less costly than current gasoline options.
- **Annex 49:** COMVEC – Fuel and Technology Alternatives for Commercial Vehicles.
  Nils-Olof Nylund will take over project leadership from Jukka Nuottimäki (both are associated with VTT). The annex was prolonged until December 31, 2015.
- **Annex 50:** Fuel and Technology Alternatives in Non-Road Engines.
  Individual contributions of annex participants are still being discussed, and new participants are still welcome to join. At the meeting, Canada was accepted as a new participant. Switzerland, Chile, and Thailand might also join. The HEV IA might also be interested in cooperation.
- **Annex 51:** Methane Emission Control.
  Individual contributions of annex participants, except for Denmark, are still to be defined. A request was made to include in the scope of the annex the topic of methane slip from the fuels system and the vehicle. New participants are still welcome to join.

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

4.b.iii
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4.c
AMF IA Publications in 2014

Annex 45: Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation

Synthesis, Characterization and Use of Hydrotreated Oils and Fats for Engine Operation. Final Report. February 2015.

Annex 42: Toxicity of Exhaust Gases and Particles from IC-Engines – International Activities Survey

Toxicity of Exhaust Gases and Particles from IC-Engines – International Activities Survey (EngToxIn). Fourth Information Report for IEA Implementing Agreement AMF, Annex 42, International Activities. December 2014.

Annex 39: Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines

Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines. Research Report. Final Report. Report AVL OMT 1032. May 2014.
Key Messages 2014.

Annex 38: Environmental Impact of Biodiesel Vehicles

Evaluation of Environmental Impact of Biodiesel Vehicles in Real Traffic Conditions, prepared by Norifumi Mizushima, National Traffic Safety and Environment Laboratory (NTSEL) and Yutaka Takada, Organization for the Promotion of Low Emissions Vehicles (LEVO). June 2014.

Annex 35-2: Ethanol as a Fuel for Road Transportation – Particle Measurements: Ethanol and Butanol in DISI Engines

Ethanol as a Fuel for Road Transportation – Particulate Measurements: Ethanol and Iso-Butanol in Direct Injection Spark Ignited Engines. Final Report. September 2014.

Glossary

Advanced Motor Fuels (AMF)

A part of the International Energy Agency (IEA), this transportation-related sector is also an Implementing Agreement of the IEA. The AMF IA promotes more advanced vehicle technologies, along with cleaner and more-efficient fuels. Transportation is responsible for approximately 20–30% of all the energy consumed and is considered to be the main producer of harmful emissions. Although the transportation sector is still highly dependent upon crude oil, advances are being made to allow for domestically made biofuels and other forms of energy.

Biodiesel Fuel (BDF)

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

Biomass to Liquid (BTL) (Fuels)

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

Diesel Dual Fuel (DDF)

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

Dimethyl Ether (DME)

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

Direct Injection Spark Ignition (DISI)

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

E85

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

ED95/RED95

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

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

Ethanol (C_2H_5OH)

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

Ethyl Tertiary Butyl Ether (ETBE)

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

Fatty Acid Methyl Ester (FAME)

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

Fischer-Tropsch

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

Flex-Fuel Vehicle (FFV)

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

Fuel Cell Vehicle (FCV)

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

Greenhouse Gas (GHG)

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

Hydro Treated Vegetable Oil (HVO)

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

Internal Combustion Engine (ICE)

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

Liquefied Natural Gas (LNG)

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

Liquefied Petroleum Gas (LPG)

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

Methyl Tertiary-Butyl Ether (MTBE)

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

Natural Gas (NG)

NG 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. NG 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 NG.

Natural Gas Vehicle (NGV)

NGVs are alternative fuel vehicles that use compressed or liquid natural gas, which are much cleaner-burning than traditional fuels. Current vehicles can be converted to run on natural gas, and such conversion is a popular trend among fleet vehicles. The only new original equipment manufacturer (OEM) NGV available in the U.S. market is the Honda Civic GX compressed natural gas car; in years past, by comparison, multiple vehicles were available. Countries in Europe and Asia offer a much wider selection of OEM NGVs.

NEXBTL

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

Nitrogen Oxides (NO_x)

Nitrogen oxides are composed of nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x is formed from the nitrogen and oxygen molecules in the air and is a product of high combustion temperatures. NO_x is responsible for the formation of acid rain and smog. The three-way catalyst, which operates most efficiently at stoichiometric air-fuel ratios, has tremendously reduced NO_x emissions in spark-ignited engines. A 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.

Rapeseed Methyl Ester (RME)

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

Well-to-Wheel (WTW)

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

xTL

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

Notation and Units of Measure

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie (France)
AFHB	Lab for Exhaust Gas Control, University of Applied Sciences, Biel-Bienne, Switzerland
AIST	Advanced Industrial Science and Technology (Japan)
AMF IA	Advanced Motor Fuels Implementing Agreement
AMFI	Advanced Motor Fuels Information
ANGVA	Asia Pacific Natural Gas Vehicles Association
ANR	Agence Nationale de la Recherche (French National Research Agency, same as NRA)
ASTM	American Society for Testing and Materials
BD	biodiesel
BD100	100% pure biodiesel (blend stock)
BD2	2% biodiesel, 98% petrodiese blend
BD5	5% biodiesel, 95% petrodiesel blend
BDF	biodiesel fuel
BE	bioethanol
BE5	5% bioethanol, 95% gasoline
BG	biogas
bioSNG	synthetic natural gas made of renewable resources
BIO	10% biofuel, 90% diesel
BTL	biomass-to-liquid (fuel) (method, plant, process)
CATARC	China Automotive Technology and Research Center
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives (French Alternative Energies and Atomic Energy Commission)
CEC	Climate Energy Contribution
CEN	European Committee for Standardization
CERT	Committee on Energy Research and Technology (IEA)
CHP	combined heat and power
CI	compression ignition
CNG	compressed natural gas
CO	carbon monoxide
CO_2	carbon dioxide
CORES	Corporación de Reservas Estratégicas

DDF	diesel dual fuel
DG	Directorate General (European Union)
DI	direct injection
DISI	direct injection spark ignition
DME	dimethyl ether
DOE	U.S. Department of Energy (United States)
E5	5% ethanol, 95% gasoline blend
E10	10% ethanol, 90% gasoline blend
E85	85% ethanol, 15% gasoline blend
EC	Environment Canada, European Commission
ECN	European Combustion Network
ECU	engine control unit
ED95	ethanol diesel fuel mix of 95% ethanol and 5% ignition improver
EED	Energy Efficiency Directive
eFAME	enzymatic fatty acid methyl ester
EngToxNet	Engine Toxicity Network
EPA	U.S. Environmental Protection Agency (United States)
ETBE	ethyl tertiary-butyl ether
ETS	emission trading scheme
eTV	ecoTECHNOLOGY for Vehicles Program
EU	European Union
EUWP	Working Party on Energy End Use Technologies
EV	electric vehicle
EVE	Electric Vehicles Systems Programme
ExCo	Executive Committee
FAME	fatty acid methyl ester; conventional esterified biodiesel
FCEV	fuel cell electric vehicle
FCV	fuel cell vehicle
FFV	flex-fuel vehicle
FID	flame ionization detection
FTIR	Fourier transform infrared radiation
FTP	Federal Test Procedure (U.S. Environmental Protection Agency)
FUI	Fond Unique Interministériel (France), France-UK-Ireland
GC	gas chromatography
GDI	gasoline direct injection
GHG	greenhouse gas
GTL	(natural) gas-to-liquid (fuel) (method, plant, process)
GWP	global warming potential

H_2	hydrogen
HC	hydrocarbon
HCCI	homogeneous charge compression ignition
HCNG	hydrogen-compressed natural gas
HD	heavy duty
HDV	heavy-duty vehicle
HEV	hybrid electric vehicle
HPLC	high-performance liquid chromatography
HVO	hydrotreated vegetable oil
IA	Implementing Agreement
IC	internal combustion
ICE	internal combustion engine
IEA	International Energy Agency
IFP	French Institute of Petroleum (Institut Français du Pétrole)
IFPEN	Energies Nouvelles
ISO	International Organization for Standardization
JGA	Japan Gas Association
LDV	light-duty vehicle
LEVO	Organization for the Promotion of Low-Emission Vehicles (Japan)
LHV	lower heating value
LMFA	Laboratoire de Mécanique des Fluides et d'Acoustique
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LTE	Law on Energy Transport (France)
M85	85% methanol, 15% gasoline blend
METI	Ministry of Economy, Trade, and Industry (Japan)
MON	motor octane number
MS	mass spectrometry
MTBE	methyl tertiary-butyl ether
NEDC	New European Driving Cycle
NG	natural gas
NGL	natural gas liquid
NGO	nongovernmental organization
NGV	natural gas vehicle
NO_x	nitrogen oxides, composed of nitric oxide (NO) and nitrogen dioxide (NO_2)
NoVA	Normverbrauchsabgabe (Austria)

NPE	Nationale Plattform Elektromobilität (Germany)
NRA	National Research Agency (France, same as ANR)
NTSEL	National Traffic Safety and Environment Laboratory (Japan)
OECD	Organisation for Economic Co-operation and Development
OEM	original equipment manufacturer
PCCI	premixed charge compression ignition
PEMS	Portable Emission Measurement System (Japan)
PFI	port fuel injection
PHEV	plug-in hybrid electric vehicle
PM	particulate matter
PROGELEC	Renewable Generation and Management of Electricity (France)
PVO	pure vegetable oil
R&D	research and development
RFS	Renewable Fuel Standard
RIVM	National Institute of Public Health and Environment (The Netherlands)
RE85	high-concentration ethanol fuel (similar to E85), manufactured from bio-waste (helps to reduce CO_2 emissions); sold by St1
RME	rapeseed methyl ester
RON	research octane number
SAE	Society of Automotive Engineers
SFOE	Swiss Federal Office of Energy
SI	spark ignition
TAME	tertiary amyl butyl ester
Tekes	Finnish Funding Agency for Technology and Innovation
TGAP	Taxe Générale sur les Activités Polluantes (French tax on polluting activities)
THC	total hydrocarbon
TIC	Taxe Intérieure sur la Consommation (French tax on consumption)
TICPE	Taxe Intérieure de Consommation sur les Produits Énergétiques (French tax on energy product consumption)
TransSmart	Smart Mobility Integrated with Low-Carbon Energy
UNECE	United Nations Economic Commission for Europe

VELROUE	Véhicule Utilitaire Léger Hybride Bimode (France)
VTT	VTT Technical Research Centre of Finland
WP	work package
WTW	well-to-wheel
WVTA	Whole Vehicle Type Approval (EU certificate)
xTL	synthetic liquid transportation fuels

Units of Measure

baht	Thai currency
bbl	barrel(s)
cc	cubic centimeter(s)
CHF	Swiss franc(s) (currency)
cm	centimeter(s)
DKK	Danish krone(s) (currency)
euro(s)	European Union currency
ft	foot (feet)
ft^3	cubic foot (feet)
g	gram(s)
GW	gigawatt(s)
GWh	gigawatt-hour(s)
h	hour(s)
ha	hectare(s)
hL	hectoliter(s)
hp	horsepower
kg	kilogram(s)
kg/h	kilogram(s) per hour
kL	kiloliter(s)
km	kilometer(s)
kt	kilotonne(s)
kt/a	kilotonne(s) per year (annum)
ktoe	kilotonne(s) of oil equivalent

kW	kilowatt(s)
kWh	kilowatt-hour(s)
L	liter(s)
m^3/a	cubic meters per year (annum)
Mboe	million barrels of oil equivalent
mi	mile(s)
Mt	megatonne(s) or million metric ton(s)
Mt/a	megatonne(s) per year (annum)
Mtoe	megatonne(s) of oil equivalent
MW	megawatt(s)
Nm	Newton-meter(s) (torque)
PJ	petajoule(s) (1×10^{15} joules)
ppm	part(s) per million
t	metric ton(s) or tonne(s) (1,000 kg)
t/a	metric ton(s) per year (annum)
TJ	terajoule(s)
ton	U.S. ton (907 kg or 2,000 lb, not abbreviated)
tonne	metric ton or t (1,000 kg)
TWh	terawatt-hour(s)
vol%	volume percent
€	euro(s) (currency)
€/a	euro(s) per year (annum)
$	dollar(s) (currency)