IEA-Advanced Motor Fuels

ANNUAL REPORT 2013

IEA Implementing Agreement for a
Programme on Research and Demonstration on

Advanced Motor Fuels
Annual Report 2013

Rainbow Spine: The color of the spine of AMF Annual Reports follows the colors of the rainbow. This allows to easily distinguish yearly editions from one another. The 2010 edition of the AMF Annual Report had a blue cover, the 2011 edition a green cover, and the 2012 edition a very light green one. This year’s edition is yellow, and the 2014 cover will be red. The next working period of AMF, which will start in 2015, will then start again with the first color of the rainbow: violet.

This year´s yellow color stands for foresight, hope, and future. This color is very appropriate because AMF leadership has recently been discussing and defining the strategic plan for the next five-year working period. We are confident that the AMF Implementing Agreement will enable significant contributions toward a future sustainable transport system by providing a solid basis for decision making, by sharing best practices, and by pooling resources, internationally.

Cover Photo: Autonomie plug-and-play architecture supports the rapid evaluation of advanced vehicle technologies

Credit: Argonne National Laboratory

International Energy Agency

Advanced Motor Fuels
Annual Report 2013

This Annual Report was produced by Kevin A. Brown (editing and project coordination/management), Joe Harmon (editing), Pat Hollopeter (editing), Andrea Manning (editing), Marita Moniger (editing), Else Tennessen (editing), Linda Conlin (document production), and Gary Weidner (printing) of Argonne National Laboratory. The cover was designed by Renee Carlson and 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:

Austria	Ministry of Transport, Innovation, and Technology (BMVIT)
Canada	CanmetENERGY
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	United States Department of Energy (DOE)

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

Annex 28	Information Service & AMF Website (AMFI) and Fuel Info	Dina Bacovsky Päivi Aakko-Saksa
Annex 35-2	Particulate Measurements: Ethanol and Butanol in DISI Engine	Debbie Rosenblatt
Annex 38-2	Environmental Impact of Biodiesel Vehicles	Norifumi Mizushima
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Annex 42	Toxicity of Exhaust Gases and Particles from IC-Engines	Jan Czerwinski
Annex 43	Performance Evaluation of Passenger Car, Fuel, and Powerplant Options	Jukka Nuottimäki
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	Jukka Nuottimäki

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

Sandra Hermle	Swiss Federal Office of Energy (SFOE)	ExCo Chair
Dina Bacovsky	BIOENERGY 2020+	Secretary

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1.a Chairperson's Message

Projections of worldwide energy consumption by the transportation sector have been made by several different agencies. In the reference case used in *International Energy Outlook 2013* (U.S. Department of Energy/Energy Information Administration), worldwide energy consumption by this sector increases by an average of 1.1% per year from 2010 to 2040. Moreover, the transportation sector accounts for the largest share (63%) of the total growth in world consumption of petroleum and other liquid fuels from 2010 to 2040.

Recently, most of the growth in transportation energy use has happened in the countries that are not members of the Organisation for Economic Co-operation and Development (OECD), and it is expected to occur there in the future as well. In these non-OECD countries, the combination of the projected high growth in their economies and populations, as well as in their relatively immature transportation sectors, is expected to create a large increase in demand for transport-related energy. This demand will lead to an average increase of 2.2% per year in the consumption of transportation energy from 2010 to 2040 in non-OECD countries.

The fastest growth in transportation sector energy consumption per capita in this timeframe will occur in China and India, with average annual increases of 4.1% and 4.6%, respectively. It should be noted, however, that in both China and India, the total transportation energy use per capita will remain much lower than it is in the OECD regions. In contrast, in OECD regions, transportation sector energy use will continue to decline, due to slow economic growth, improvements in energy efficiency, and stable or declining population levels *(International Energy Outlook 2013)*.

Coal, natural gas, and oil accounted for 87% of global primary energy consumption in 2012. While natural gas and coal increased their shares of global primary energy consumption, from 23.8% to 23.9% and from 29.7% to 29.9%, respectively, during 2012, oil's share fell from 33.4% to 33.1%. One factor influencing these statistics is the shale revolution that is occurring in the United States, which is reshaping global oil and gas markets (Worldwatch Institute, *Fossil Fuels Dominate Global Primary Energy Consumption,* 2013). With regard to oil products, growth in demand has been triggered mainly by the demand for middle distillates, with the demand for diesel showing the largest increase by far (in terms of volume) between 2012 and 2035, going from 5 million to 31 million barrels per day. The net increase in diesel demand is coming mainly from the road-transport sector in non-OECD countries (International Energy Agency, *World Energy Outlook 2013* [IEA-WEO 2013]). However, new emission regulations for the marine sector will result in an increased demand for middle distillates in this sector as well.

With regard to gas, IEA-WEO 2013 states that the fastest projected rate of growth in gas use will be in the transport sector, with most of the increase coming from its use for road vehicles. The technologies are well-proven; in fact, the number of natural gas vehicles increased from about 1.3 million in 2000 to an estimated 13.7 million in 2012. However, this figure has to be considered in context with the number of vehicles running on liquid fuels today, which is more than 1 billion (IEA-WEO 2013). It is projected that in 2035, natural gas will account for around 5.6% of total transport energy demand (up from 3.8% today) and for 4.8% of road transport demand (up from 1.8%) (IEA-WEO 2013). There is also the potential for gas to be used in the form of liquefied natural gas (LNG) as marine bunker fuel in ships, where it will replace heavy fuel oil.

With regard to biofuels, IEA-WEO 2013 projects an increase in consumption from 1.3 million barrels of oil equivalent per day (Mboe) in 2011 to 4.1 Mboe in 2035, to meet 8% of road-transport fuel demand in that year. Demand from the United States, Brazil, the European Union, and China makes up more than 80% of the demand for all biofuels (IEA-WEO 2013). Advanced biofuels offer the prospect of increasing the supply of biofuels while reducing or even eliminating concerns about their sustainability. The large-scale production of advanced biofuels, however, is still lagging behind expectations.

In Europe, the European Commission (EC) is pushing the realization of pilot units and demonstration units for different conversion technologies (also for biofuels) through the Strategic Energy Technology Plan (SET-Plan). The big challenge is to find investors willing to spend money on high-risk technologies. In the IEA's "new policy scenario," advanced biofuels become available at commercial scale around 2020, with their share in the total supply of biofuels rising from below 1% today to almost 20% in 2035 (IEA-WEO 2013). From a European perspective, however, one has to take into account the latest EC-related policy developments and climate and energy goals when making plans going toward 2030. The EC wants to see a more holistic and integrated approach, with policy development focusing on electric vehicles, second- and third-generation biofuels, and other alternative, sustainable fuels. The scientific assessment of how to minimize indirect land-use change emissions made clear that first-generation biofuels have a limited role in decarbonizing the transport sector. Therefore, it is recommended that food-based biofuels should not receive public support after 2020 (EC COM [2014] 15). These statements of the EC show that the use of biofuels faces an uncertain future in Europe.

As the demand for transport fuels is increasing, the international community should strive for more sustainable transportation fuels — sustainable from the point of supply and environmental impacts. This is exactly what the Advanced Motor Fuels (AMF) Implementing Agreement (IA) is striving to achieve.

The year 2013 was a very active one for the AMF IA. Currently, there are 12 running annexes covering a wide variety of topical issues. They include research projects on different fuels like ethers, alcohols, renewable diesel, and natural gas. Although the mix of transportation fuels needs to be enlarged, we also first need to fully understand the effects of the alternatives with regard to the toxicity of their exhaust gases, particle emissions, fuel efficiency, vehicle operability, etc. In 2013, three new annexes were started; the lead countries are Japan, the United States, and Finland. It could be said that the new annexes were started partly in response to the increased interest in and supply of fuels derived from natural gas.

Annex 47 covers the topic of dimethyl ether (DME) fuel specifications for vehicles, with a focus on investigating the effect of fuel impurities on DME diesel engine systems. Annex 48 deals with a value proposition study of natural gas pathways (direct use of natural gas as well as use of methane-derived gaseous and liquid fuels) for on-road vehicles. The aim of this Annex is to assess the advantages and disadvantages of various options, including their costs, life-cycle emissions, associated energy consumption, and societal benefits. The latest Annex, Annex 49, focuses on commercial heavy- and light-duty vehicles; it follows up on the previous activities that focused on buses (Annex 37) and passenger cars (Annex 43). Common test procedures will be developed in order to compare tailpipe emissions and energy consumption.

The current work of AMF certainly demonstrates how it is striving to contribute to sustainable solutions for the transportation sector that are so urgently needed.

Besides the initiation of new annexes, activities in 2013 revolved around the extension of the IA that is due in the spring of 2015. In September 2013, the strategy group initiated an online survey to define common areas of interest for the contracting parties. In October, a core group (Executive Committee [ExCo] Chair and Vice-Chairs, heads of subcommittees, Secretary) spent two days in face-to-face discussions in Switzerland. The input from the survey and discussions was used to draft the new strategic plan at the ExCo 46 meeting in November in Santiago de Chile.

Many transportation challenges (e.g., the needs to reduce greenhouse gas [GHG] emissions globally, reduce local pollutant emissions, secure a stable supply of transport services, and install clean and efficient transportation systems in developing countries) have been addressed. Proposals for new activities have come out of the work done to meet these challenges. A few examples are efforts designed to contribute to a smart balance between the fuel supply and market needs, to an infrastructure for alternative energy carriers, to implementing the power-to-gas or power-to-liquid concept and determining its implications on the transport sector. The draft strategic plan is still a work in progress, and I would like to thank all who have contributed and are still contributing to the development of the document, which will result in a meaningful strategic plan for 2015–2020.

The year 2013 was also a success with regard to our outreach activities. We welcomed three new contracting parties: (1) the National Institute of Advanced Industrial Science and Technology (AIST), which took over from the New Energy and Industrial Technology Development Organization (NEDO), for Japan; (2) PTT Research and Technology Institute, for Thailand; and (3) the country of Israel, which is a new country in the group. In our spring meeting in Gothenburg, we welcomed Poland and the Methanol Institute as observers. Furthermore, our outreach efforts yielded fruit related to our decision to hold the autumn meeting in Chile, which is not a member country yet. Santiago de Chile was chosen as the meeting venue as a part of our outreach activity focused on South America. In addition to observers from Chile, observers from Brazil, Norway, and Uruguay attended that meeting, and all showed potential interest in our work and information exchange efforts. These positive results were due not only to the excellent work of the Annexes but also to AMF's successful integration in different international groups of experts on fuel-related issues (Transport Contact Group of the IEA End Use Working Party, Transportation Technologies and Fuels Forum, Combustion, Bioenergy, Hydrogen, HEV, etc.). These relationships are important for discovering and working in areas of mutual interest and for bringing forward new findings and ideas in a political context. This last goal is also strongly supported by our contracting parties, as was indicated in our online survey of September 2013. In the survey, it was clearly stated that AMF's work should address finding a nontechnical language that policy makers can understand.

Researchers are already a target group, because information exchange is already an important part of AMF collaborations and will continue to be so. What we have to work on in the upcoming years, however, is to pass on our messages to policy makers. So in the near future, providing advice related to both technologies and policies will be a major task in which the Annexes as well as the ExCo will be involved. A second important message that the survey results indicated is to encourage stronger involvement from industry. There is no doubt that on a project level or Annex level in each participating country, industry participation is good; however, when it comes to the ExCo level, we need to focus more on the involvement of industry. One possibility might be to integrate industries as sponsors. We have to find good ways to attract more industry participation in the future.

Last, but not least, I would like to stress the fact that the success of an IA is driven by its motivated and active members. I would like to express my special thanks to Dina Bacovsky for running the Secretariat in a very professional and encouraging manner. Furthermore, I would like to thank "my" Vice-Chairmen: Dr. Shinichi Goto, Dr. Nils-Olof Nylund, and Mr. Kevin Stork, for their valuable input and "open ears" in discussions. I also very much appreciate the work that has been done by the different subcommittees. The Outreach Committee has been of indispensable help in supporting new contracting parties interested in joining AMF. Also indispensable has been the Strategy Committee, especially Olle Hadell as the Strategy Chair, who always pushed the discussions for our new strategic plan. The strategic plan also benefits from the input from the technology subcommittee, which has discussed new trends and brought forward new ideas, resulting in the identification of relevant research topics. And I would like to say a big "thank you" to all ExCo members for their commitment to AMF. It is a great pleasure for me to work with all of you, and I truly appreciate the vast amount of expertise that can be found within our ExCo.

Dr. Sandra Hermle
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; 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 program — 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. At present, there are 41 IAs working in the categories of:

- 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 end-use category just mentioned.

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. A key role of the CERT is to provide leadership by guiding the IAs to shape work programs that address current energy issues productively, regularly reviewing their accomplishments, and suggesting reinforced efforts where needed. For further information on the IEA, the CERT and the IAs, please consult http://www.iea.org/techinitiatives/.

1.c Implementing Agreement for Advanced Motor Fuels

The transportation sector is facing many challenges. Today, this sector is practically totally dependent on fuels derived from crude oil. The number of vehicles around the world is increasing rapidly — and so are the environmental impacts and the use of energy in transport. Whereas many other sectors of society have been able to stabilize or cut carbon dioxide (CO_2) emissions, transport-related CO_2 emissions tend to be increasing in both relative and absolute terms.

At the same time, new possibilities are opening up. The array of options is broadening, not narrowing. This is true for both fuel and vehicle technology options. We are closer than ever to a wide-scale use of alternative fuels. However, the increasing number of options makes decision making harder. This is true for private consumers, fleet operators, communities, and governments. One of most important tasks at Advanced Motor Fuels (AMF) is to provide decision makers at all levels with unbiased and solid data on the performance and potential of various options.

We should note that AMF must always take note of the fact that the properties of commercial fuel and the sophistication of vehicles vary significantly among different regions of the world. All candidate future fuels face obstacles and barriers (bottlenecks) that might be either unique to a given fuel or shared with other fuels (Figure 1).

The body of knowledge in the AMF contributed by the national delegates and experts helps to point out the obstacles and identify the types of research and development needed to eliminate and/or overcome those obstacles. Making policies for implementing the use of alternative fuels requires that the desirable attributes of the various fuels be prioritized and that the priorities be balanced against practical realities with regard to costs and benefits. Figure 1 illustrates the process of defining the priorities, along with the barriers (or bottlenecks).

CRITICAL BOTTLENECKS	Fuel A	Fuel B	Fuel C
Feedstock availability			
Feedstock location/transport		●	
Fuel processing			
Fuel transport			
Dispensing	●		
Vehicle end-use	●		
Sustainability		●	
Overall environmental impact		●	
Overall energy use			
Overall costs	●		

Fig. 1 Bottlenecks to Alternative Fuel Implementation

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

AMF Mission
The mission of AMF is to provide sound scientific information and technology assessments that allow citizens and policy makers to make informed and science-based decisions about options involving the use of advanced fuels for transportation systems. In order to provide such data to decision makers, AMF 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 industries.

AMF fulfills its mission through the international cooperation of members of academia, industries, governmental institutions, and nongovernment organizations. The annexes in AMF 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.

Fuels included under the definition of "advanced motor fuels" fulfill one or more of the following criteria:

- Low toxic emissions,
- Improved life-cycle efficiency,
- Reduced greenhouse gas emissions,
- Renewable energy sources,
- Fuels for new propulsion systems,
- Sustainability in transportation,
- Security of supply, and/or
- High energy efficiency.

Advanced motor fuels studied in the framework of the AMF Program are as follows:

- Alcohols (ethanol, methanol), ethers (e.g., DME, ETBE, MTBE [dimethyl ether, ethyl tertiary butyl ether, methyl tertiary butyl ether), esters (e.g., RME [rapeseed methyl ester]), and gaseous fuels (e.g., natural gas, biogas, hydrogen, LPG [liquefied petroleum gas]);
- Reformulated gasoline and diesel fuels, including oxygenated versions;
- Synthetic fuels, such as Fischer-Tropsch fuels; and
- Fuels for new types of engines and fuel cells.

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 to join the AMF IA, please contact the AMF Secretary Dina Bacovsky (dina.bacovsky@bioenergy2020.eu).

The Secretary will provide you with details on the 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 will include:

- An annual membership fee, currently 9,500 € ($13,017 US);
- Funding for participation of an ExCo Delegate 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 € ($13,702 to $137,007 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 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

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).

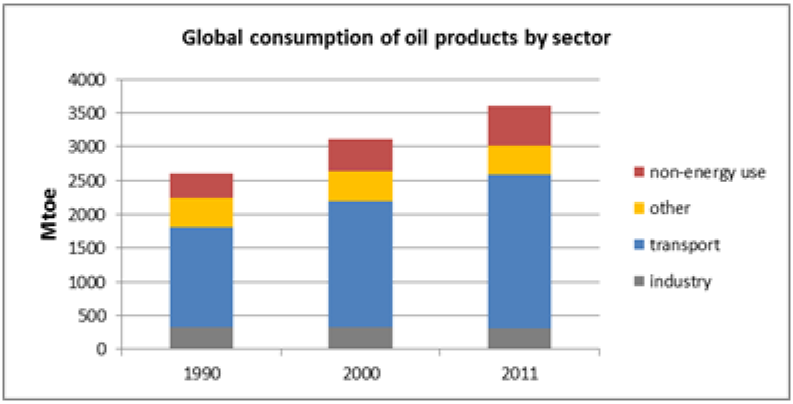


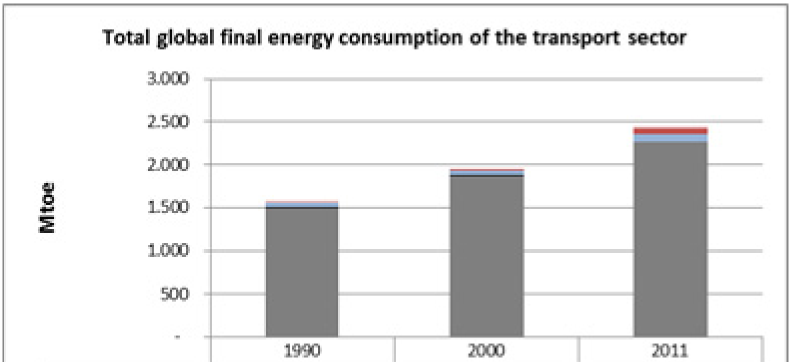
Fig. 1 Global Consumption of Oil Products[1] (IEA Statistics)

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 2445 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.

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%

[1] 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

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 (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.

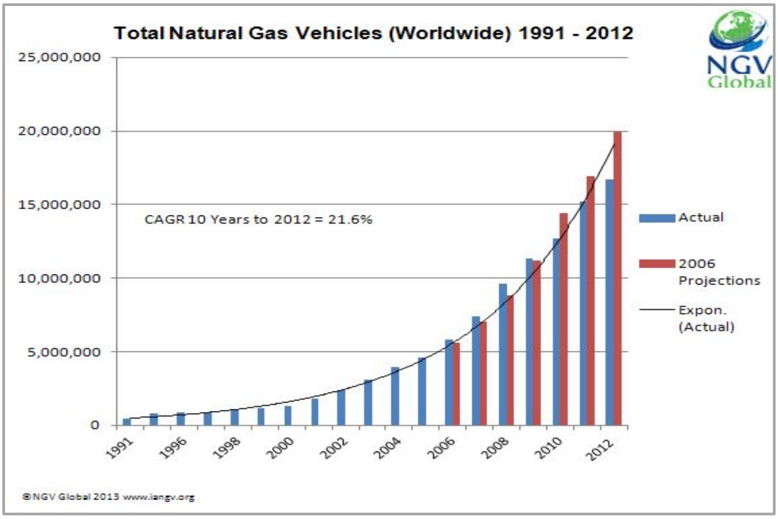


Fig. 3 Total Number of Natural Gas Vehicles Worldwide (NGV Global)

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).

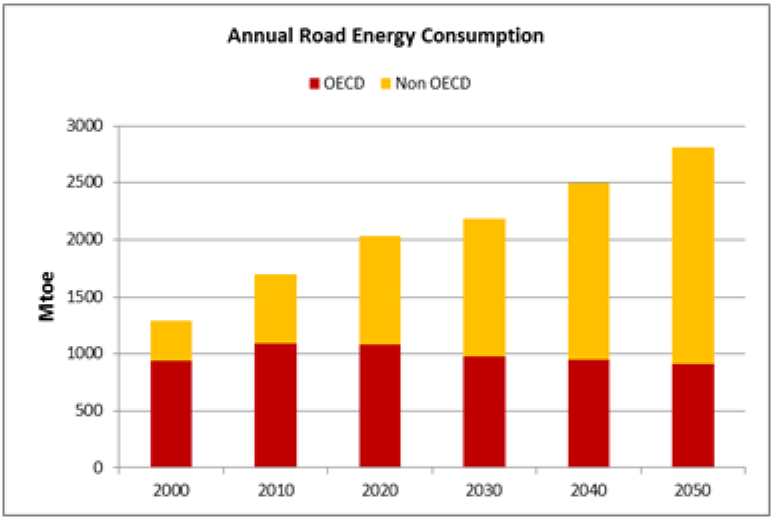


Fig. 4 Global Annual Road Energy Consumption Projections
(IEA Energy Technology Perspectives 2012)

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).

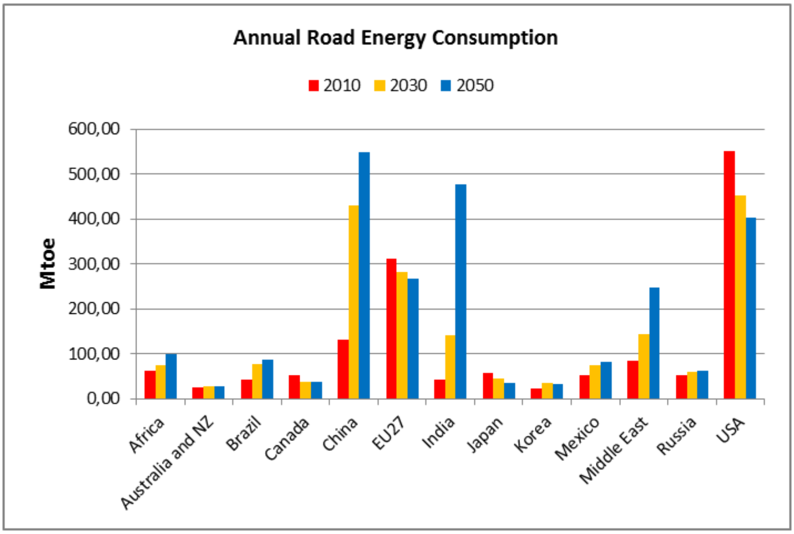


Fig. 5 Global Road Energy Consumption by Selected Countries (IEA Energy Technology Perspectives 2012)

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 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

World Foundry Organization figures show that energy consumption continued to fall in Austria throughout 2013. A key factor was the weak economy, which grew just 0.8% in its real gross domestic product.

In 2013, the final **energy consumption** in Austria was about 1.096 Petajoule (PJ) per year. The production sector, with 32.10% (352 PJ), still has the highest share of final energy consumption, followed by the transportation sector, with 30.27% (332 PJ). This distribution did not change much in the last few years. Compared to 2011, transportation energy consumption decreased by 1.93% in 2013.

Austria consumes only 0.3% of the world market's oil. With this low percentage and an **oil import dependency** of about 90%, Austria cannot be unaffected by international market developments.

In 2013, **oil production** in Austria was 917,352 tons, of which 79,791 tons was natural gas liquids (NGL). On the basis of all mineral oil products, the total **oil consumption** in Austria in 2013 was about 10.7 million tons, as shown in Figure 1.

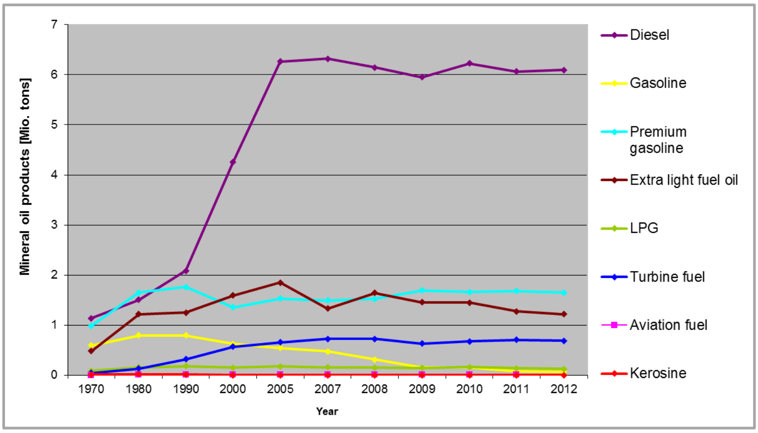


Fig. 1 Consumption of Mineral Oil by Type of Fuel, 1970 to 2012

(Source: Mineralölbericht 2012, Fachverband der Mineralölindustrie Österreichs [FVMI][2])

2 Fachverband der Mineralölindustrie Österreichs, "Mineralölbericht 2012," https://www.wko.at/Content.Node/branchen/w/Mineraloelindustrie/Jahresbericht_2012.pdf

Under the European Union burden sharing agreement, Austria is committed to reduce its **greenhouse gases** (GHG) by 13% of 1990 levels between 2008 and 2012.

In 2013, Austria's total GHG emissions were equivalent (eq.) to 80.2 million tons of CO_2, missing the 68.8-million-ton target set by the Kyoto Protocol for Austria by 11.4 million tons. Emissions increased by 3% compared to the base year (1990). The increase is dominated by an increase in the most important sector - production - with a total of 24.8 million tons CO_2 eq. in 2013.

Transportation sector total emissions in 2013 were 21.7 million tons CO_2 eq. Compared to 2011, there was a decrease of 0.5% (0.1 million tons CO_2 eq.). The large rise in emissions since 1990 in transportation (54%) is due to an increase in road performance (kilometers driven) and the amount of fuel bought in Austria but driven elsewhere, which increased considerably. Recent studies show that the proportion of new vehicles producing low CO_2 emissions is rising (Table 1).

Table 1 Percentage of New Registered Passenger Cars by CO_2 Values (2010–2012)

Percentage of New Registered Passenger Cars by CO2 Values	2010	2011	2012
> 160 g CO_2/km	19.6%	14.0%	12.1%
141–160 g CO_2/km	26.3%	24.0%	21.6%
120–140 g CO_2/km	33.5%	36.5%	35.0%
< 120 g CO_2/km	20.6%	25.4%	30.9%

Source: Statistik Austria 2014, VCÖ[3]

At the beginning of 2014, the Umweltbundesamt presented the final results of the Kyoto period. Austria successfully met the Kyoto targets.

Quantities of Biofuels in Austria

Since October 2005, biofuels have been placed on the market in Austria primarily by mixing biodiesel with diesel and, since October 2007, by mixing bioethanol with fossil petrol grades. By the beginning of 2009, the overall percentage by volume (% vol.) of biodiesel blends and bioethanol

[3] Statistik Austria, "KFZ- Neuzulassungen," http://www.statistik.gv.at/web_de/statistiken/verkehr/strasse/kraftfahrzeuge_-_neuzulassungen/index.html

blends was approximately 4.7%. From January 2009, the maximum proportion for the blending of biodiesel was raised to 7% vol. In addition to blending, municipal and business vehicle fleets were obliged to migrate to pure biofuels or to increase their use of biofuels by more than 40% under the Ministry of Agriculture, Forestry, Environment and Water Management. From October 1, 2020, and forward, the substitution goal will be 8.45%.

During 2012, the annual substitution was at 6.77% (Table 2), surpassing the target of 5.75% (calculated on the basis of energy content) by a large margin. Thus, Austria is at the top of the EU (European Union) 27 list.

Table 2 Share of Biofuels in Austria

Share of Biofuels	2010	2011	2012
Bioethanol in Gasoline	5,53 Vol-%	4,6 Vol-%	4,6 Vol-%
Biodiesel in Diesel	6,68 Vol-%	6,72 Vol-%	7,0 Vol-%
Share of biofuels	6,58%	6,75%	6,77%

Source: Umweltbundesamt (Biokraftstoffe im Verkehrssektor 2013)[4]

Biodiesel

In 2012, 6,093,841 tons of diesel were sold, of which 5,920,523 tons (97%) were blended with 7.0 Vol-% biodiesel. In 2012, a total of 498,761 tons of biodiesel was used in Austria. Of this total, 440,938 tons were added to fossil fuels, and 57,823 tons were used either as pure biofuel or as diesel fuel with a higher, non-standard biofuel component in the transportation sector. According to “ARGE Biokraft,” Austria’s capacity to produce biodiesel was 645,000 tons. In 2012, 265,445 (309,598) tons of biodiesel were produced.

Bioethanol

In 2012, a total of 1,714,586 tons of gasoline were sold. To all gasoline fuels, at least 4.60 Vol-% of bioethanol was added. Therefore, with the addition of the quantities marketed as “superethanol,” 105,715 tons of bioethanol were sold during 2012. The total demand of bioethanol for biofuel substitution can be met by the output of the production plant in Lower Austria (Pischelsdorf), which can annually process up to 620,000 tons of grain into fuel. In 2012, 171,000 tons of ethanol were manufactured from 500,000 tons of grain. Of the 84,000 tons of ethanol sold

4 Umweltbundesamt, “Biokraftstoffe im Verkehrssektor 2013,” http://www.umweltbundesamt.at/umweltsituation/verkehr/elna/

in Austria, almost the entire amount (83,000 tons) was delivered to the petroleum industry; the remaining 87,000 tons were exported.

Vegetable Oil and Biogas

In 2012, the total quantity of vegetable oil (also used in agricultural machinery) was 16,191 tons. According to experts, the total of biogas produced in Austria was 269,742-423,401 tons. In 2012, 540 tons of biomethane was used for refueling.

Fleet Distribution and Number of Vehicles in Austria

According to Statistics Austria, 415,313 new motor vehicles were registered in 2013. New registered passenger cars accounted for 319,035 of the total, a decrease of 5.05% (16,959 passenger cars) from 2012. At the end of December 2013, a total of 4,641,308 cars were registered in Austria (Table 3).

Table 3 Fleet Distribution of Passenger Cars by Fuel Type

Fuel Type	2011	2012	2013
Gasoline	1.997.066[5]	1.994.839	1.997.302
Diesel	2.506.511	2.570.124	2.621.133
Electric	989	1.389	2.070
LPG	-	1	1
CNG (Compressed Natural Gas)	1.572	1.826	2.219
H_2 (Hydrogen)	0	0	0.
Bivalent Gasoline/Ethanol (E85)	-	6.456	6.397
Bivalent Gasoline/LPG	125	184	250
Bivalent Gasoline/CNG	1.098	1.283	1.432
Hybrid Gasoline/Electric	6.056	7.762	10.049
Hybrid Diesel/Electric	4	338	455
Total	**4.513.421**	**4.584.202**	**4.641.308**

Source: Statistik Austria, Vehicle Fleet per end of 2011–2013[6]

While the number of conventional gas stations has decreased, the number of alternative fuel stations is still increasing, as shown in Table 4.

5 Includes gasoline/ethanol (E85)
6 Statistik Austria, “KFZ- Bestand,” http://www.statistik.gv.at/web_de/statistiken/verkehr/strasse/kraftfahrzeuge_-_bestand/index.html

Table 4 Filling Stations for Alternative Fuels and Conventional Gas Stations in Austria

Type of Filling Station	2012	2013
CNG	146	175
LPG	32	36
Biogas	1	3
E85	28	33
Electric vehicle (Public charging station-Level 2 AC)	1060	1160
Vegetable oil	19	20
Conventional	2.575	2.515

Source: Fachverband der Mineralölindustrie, Mineralölbericht 2013[7]

Policies and Legislation

At the beginning of 2011, the mineral oil tax was increased by EUR 0,04/L for gasoline and EUR 0,05/L for diesel. To compensate drivers, the commuting allowance was increased by 10%. Pure biofuel is exempt from the tax.

Since December 2010, the tax rates per 1000 liters of fuel are:

- For gasoline with a minimum biofuel content of 46l and a sulphur maximum of 10 mg/kg: EUR 482 (USD $656.2), or else EUR 515 (USD $701.11)
- For diesel with a minimum biofuel content of 66l and a sulphur maximum of 10 mg/kg: EUR 397 (USD $540.4), or else EUR 425 (USD $578.5)

Starting in July 2008, the NoVA (Normverbrauchsabgabe: a bonus/malus system for CO_2 and NO_x emissions, as well as particle filters) was introduced to tax new vehicle purchases. For vehicles with CO_2 emissions below 120 g/km, there is a bonus of EUR 300 (USD $408.4). If the CO_2 emission is over 150 g/km, there is a penalty due (Table 5).

As of January 1, 2013, the NoVA is calculated for each additional gram of CO_2, as seen in Table 3. Regarding NO_x emissions, gasoline vehicles with emissions no higher than 60 mg/km (in the case of diesel vehicles, no higher

7 Fachverband der Mineralölindustrie, “Mineralölbericht 2012,” https://www.wko.at/Content.Node/branchen/oe/Mineraloelindustrie/Final_JB_fvmi2011_WEB_2.pdf

than 80 mg/km) and particle emissions no higher than 0,005 g/km receive a tax reduction of maximum EUR 200 (USD $272.3). Until August 31, 2014, vehicles running on alternative fuels, such as E85, CNG, LPG, biogas, or hydrogen, receive a tax reduction of maximum EUR 500 (USD 680.7). Electric vehicles are exempt from NoVA taxation.

Table 5 Emission Taxation System

Emission	Tax Increase
Emissions over 150 g CO_2/km	EUR 25 (USD 34)/g CO_2
Emissions over 170 g CO_2/km	EUR 50 (USD 68.1)/g CO_2
Emissions over 210 g CO_2/km	EUR 75 (USD 102.1)/g CO_2

Source: Federal Ministry of Finance (http://www.bmf.gv.at)

Austria's government plans to make changes in the NoVA system and the vehicle insurance tax in 2014. The calculation of the new NoVA system depends on the CO_2 emissions of new cars, which would be a step toward increased sustainability and an incentive to purchase of fuel-efficient cars. New cars that emit less than 90 grams of CO_2 per kilometer do not have to pay the NoVA. The excess amount is divided by five and gives the NoVA tax rate. For example, 120 grams of CO_2 would mean a rate of 6 percent ([120–90]/5). Thus, the new model is much easier to use than before.

Federal Funding and Supporting Programs

Several federal programs fund and support the implementation of alternative fuels and propulsion systems in Austria.

"Klima:aktiv mobil" is Austria's mobility management action program to reduce CO_2 emissions, promote environmentally friendly and energy-efficient mobility, and stimulate new innovative business opportunities and green jobs. The program was launched in 2004 and is undertaken by the Austrian Federal Ministry of Agriculture and Forestry, Environment and Water Management, as part of the implementation of the Austrian Climate Strategy and the EU Climate and Energy Package.

"Klima: aktiv mobil" generally offers funding (transportation projects to reduce CO_2); motivation (for cycling, eco-driving, clean vehicles), education, and certification; and lessons learned and successful results.

During the first period of this program (2007–2012), more than 2,900 project partners eliminated 53,000 tons CO_2 eq. per year with their projects. In 2013, Austria's Federal Ministry of Agriculture and Forestry, Environment and Water Management provided funding of EUR 10 million (USD $13.6 million) to support the "klima:aktiv mobil" program.

Since 2012, "e!MISSION.at," funded by the Climate and Energy Fund, supports innovations that make a significant contribution to climate protection and increased energy efficiency. The key goal is to develop a sustainable energy system. Funding is focused on energy efficiency, renewable sources of energy, smart energy systems, and electromobility projects. In 2011, relevant areas in transportation called for a total budget of EUR 26 million (USD $35.2 million), including energy efficiency and renewable energy carriers.

The "Future Mobility" program of the Federal Ministry of Transport, Innovation, and Technology (BMVIT) is another mobility program focused on personal mobility, freight mobility, transportation infrastructure, and vehicle technologies. The first two calls focused on alternative vehicle technologies, alternative fuels, and changing mobility options. The current call is focused on the new organization of freight mobility and the development of alternative automotive technologies. Up to EUR 10.3 million (USD $14.01 million) was reserved for these topics.

The Environment Ministry and Austria's industry wants to assist all motorists in the selection of fuel-efficient and environmentally friendly vehicles. The website (http://www.autoverbrauch.at) provides an overview of all passenger vehicles and their fuel consumption and CO_2 emissions (separately for gas and diesel), as well as alternative drives.

Implementation: The Use of Advanced Motor Fuels

In 2012, alternative fuels used in the transportation sector represented approximately 7.2% of the fuel used, as shown in Figure 4. The predominant fuel consumed was diesel blended with 7.0 Vol-% biodiesel, followed by gasoline with at least 4.60 Vol-% of bioethanol added, as shown in Figures 3 and 4.

The number of registered vehicles with an alternative drivetrain increased in 2012. As shown in Table 4, the number of conventional gas stations has decreased, while the number of alternative fuel stations is still increasing.

The Climate and Energy Fund has supported the development of climate and energy model regions since 2009. As of 2011, there are 106 regions with a population of 2.5 million people (29.7% of the Austrian population) very engaged in creating a more sustainable future. Nevertheless, the Climate and Energy Fund mostly funds projects that are related to electromobility.

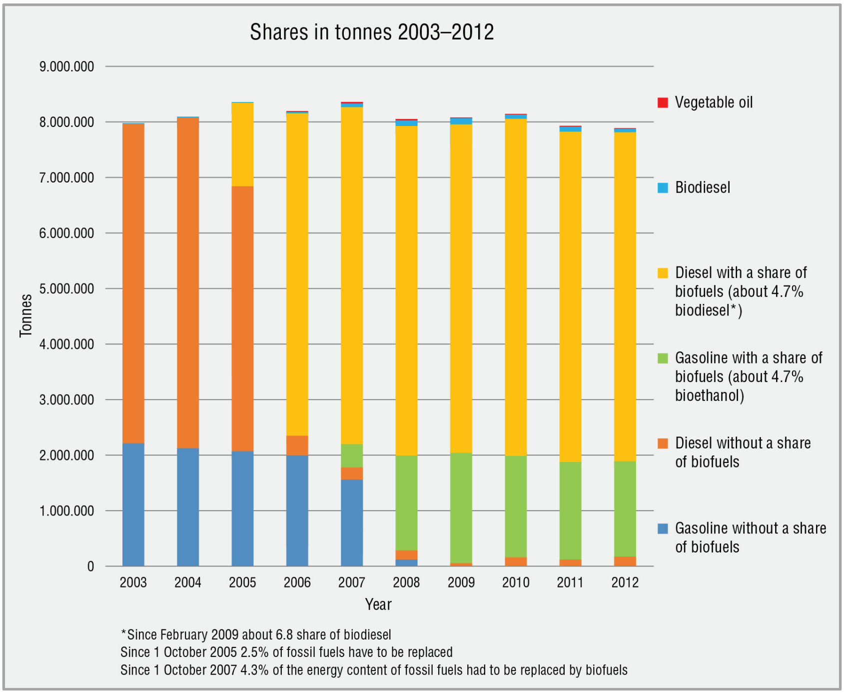


Fig. 3 Overview of Shares of Biofuels in Tons in Austria
(Source: Austrian Federal Environment Agency (2013)[8])

Outlook

Taking into account emission trading, as well as Joint Implementation and Clean Development Mechanism (JI/CDM) projects and the forestation/deforestation balance, the calculated deviation in 2012 from the climate strategy target of 2007 was about 2.1 million tons CO_2 eq. When all years (2008–2012) are taken together, the resulting gap corresponds to an extra need for flexible instruments (in addition to the JI/CDM measures planned under the Austrian climate strategy) amounting to 21.4 million tons CO_2 eq.[9]

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8 Lebensministerium, "Österreichischer Biokraftstoffbericht 2013," http://www.bmlfuw.gv.at/umwelt/luft-laerm-verkehr/biokraftstoffbericht.html

9 106. Bundesgesetz: Klimaschutzgesetz – KSG, 21. November 2011, https://www.help.gv.at/Portal.Node/hlpd/public/module?gentics.am=Content&p.contentid=10007.64188#Ver

To balance the Austrian Kyoto account, the relevant legal arrangements were made for extending the emissions trading program. Austria will thus comply with its European and international law commitments related to the Kyoto targets. Overall, except for 2010, a decreasing trend in Austrian GHG emissions has been observed since 2005. Transportation is the sector with the most substantial deviation from the sector's climate strategy target.

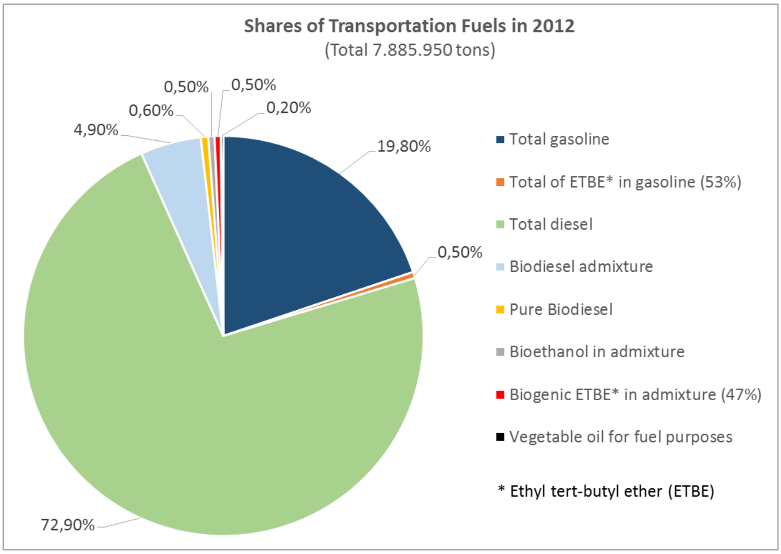

Fig. 4 Shares of Transportation Fuels in 2012
(Source: Lebensministerium (2013)[10])

In 2011, an Austrian Climate Change Act (Klimaschutzgesetz) was begun. It targeted those sectors that are not covered by the emission trading system (e.g., road transport) and places an emission ceiling on them corresponding to the 2007 climate strategy targets for the 2008–2012 period. In an amendment to this law, ceilings for the 2013–2020 period are also specified for each sector. In 2012, sector negotiating groups developed measures designed to enable compliance with these sector ceilings. Additional costs due to possible exceedance of target emissions will be allocated to the local authorities by a separate agreement. The law was approved in June 2013 and specified the annual sector limits of GHG emissions (the sectors being waste management, energy and industry, fluorinated gases, buildings, agriculture and transport) for 2013–2020.

[10] Lebensministerium, "Facts and Figures 2013," http://www.bmlfuw.gv.at/publikationen/allgemein/factsandfigures2013.html

Austria tries to reach the required targets by using multiple activities, such as tax incentives for energy efficient mobility, improvement and enlargement of the public transport system, promotion and reward of rush hour public transportation usage, promotion of green vehicles, and the widespread introduction of electric mobility, as well as the implementation of the EU Renewable Energy Directive to increase the share of renewable fuels in the transportation sector to 10%.

To ensure this amount of renewable fuel, there is an increasing demand for agricultural land. Therefore, the European Commission discussed limiting the proportion of biofuel materials from food crops to a total of 5%. The ongoing discussion of this proposal without any definite decision has led to great uncertainty among potential investors.

In addition to blending bioethanol and biodiesel with fossil fuels, Austria tries to force the pure use of biodiesel (B100), bioethanol (E85 or "superethanol") and vegetable oil, and a significant increase of biogas to reach a total of 200,000 cars powered by a CNG by 2020.

According to the National Energy Strategy, the most effective measure is the introduction of E10 (10% ethanol and 90% gasoline) and B10 (10% biofuel and 90% diesel) after approval of the corresponding European Standard for these fuels. There is still no consensus regarding the introduction of biofuels to the European Union. Since 2012, the introduction of E10 in Austria is still not allowed.

The number of new registered passenger vehicles with alternative drivetrains increased in the last few years. In 2012, the total amount was 20,000 passenger vehicles. The majority of these vehicles are flex-fuel vehicles (powered by gasoline or ethanol [E85]) and hybrid vehicles (with gasoline engine and electric motor). As a result of progress in drivetrain electrification, it is foreseeable that the number of hybrid vehicles will increase.

The number of new registered electric cars began to rise in the last few years but is still three orders of magnitude lower than the number of conventional registered vehicles. In the short and medium term, we foresee that the proportion of hybrid vehicles will increase as a result of progress in drivetrain electrification.

Additional References

Relevant institutions and programs:

- Statistic Austria (www.statistik.at)
- Federal Environment Agency (www.umweltbundesamt.at)
- Ministry of Life (www.lebensministerium.at)
- Austrian Economic Chambers (http://portal.wko.at/)
- Klima:Aktiv Initiative (www.klimaaktiv.at)
- Austrian Research Promotion Agency (FFG) (http://www.ffg.at)

Benefits of Participation in the AMF IA

Working on this Implementation Agreement offers great opportunities for international contact and the exchange of knowledge, information and results which support domestic authorities. It helps to raise awareness of advanced motor fuel issues and the 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 (http://www.nrcan.gc.ca/publications/statistics-facts/1239).

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 agriculture feedstock for producing ethanol, a gasoline substitute, includes corn, wheat, and barley. Canada is a major world producer and exporter of these grains. Vegetable oils and animal fats can be used to produce biodiesel, a diesel substitute. In 2010, the domestic production capacity of biofuels in Canada was about 1,400 million liters (L) of ethanol and about 139 million L of biodiesel (http://www.nrcan.gc.ca/energy/renewable-electricity/7295).

In 2010, Canadians (including individuals and businesses) spent $70.7 billion on fuel for transportation — this expenditure for fuel was the largest one made by any sector in the country. It was 91% higher than that of the industrial sector. This expenditure can be explained by the particularly high cost of transportation fuels compared with the costs of other energy sources used in the other sectors.

Table 1 Canadian Supply of and Demand for Biofuels (in millions of liters)[11]

Parameter	Ethanol (2012)	Biodiesel (2011)
Canadian production	1,725	157
Imports	1,022	252
Exports	11	Not available
Domestic use	2,736	Not available

The transportation sector is second (at 31%; see Figure 1) in energy consumption in Canada, and it is first (at 37%; see Figure 2) in emissions of associated greenhouse gases (GHGs). This sector produces the greatest portion of GHG emissions because the main fuels consumed for transportation are more GHG-intensive than those consumed in other sectors of the economy. In 2011, passenger transportation accounted for 54% of the total sector energy consumption, while freight transportation accounted for 42%. The remaining 4% of energy was consumed by off-road vehicles.

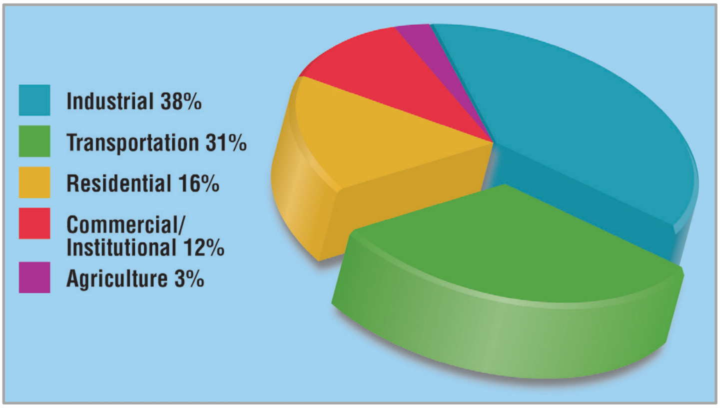

Fig. 1 Energy Consumption by Sector in 2010
(Source: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/trends.cfm?attr=0)

[11] http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/2013/EnergyMarket_e.pdf

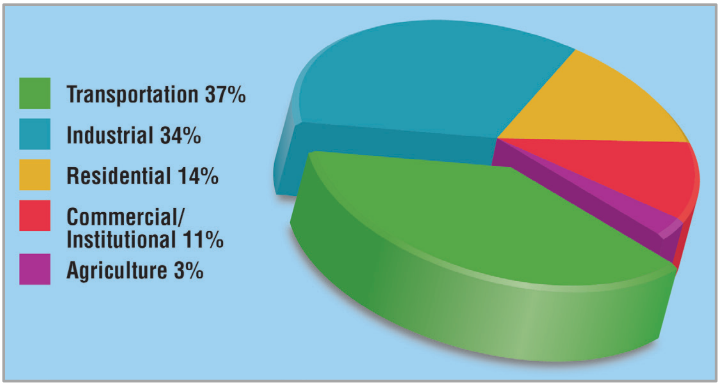

Fig. 2 GHG Emissions by Sector in 2010
(Source: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/trends.cfm?attr=0)

Between 1990 and 2010, total energy consumption for the transportation sector increased by 38%, from 1,877.9 to 2,595.0 petajoules (PJ), and associated GHG emissions increased by 36%, from 131.4 to 179.2 megatons (Mt). Among the subsectors, freight transportation experienced more rapid growth, representing 63% of the increase in energy consumption in the transportation sector. Furthermore, the growing preference to use heavy-duty trucks, which typically consume more energy than do other modes of transportation, in itself accounted for 74% of the increase in energy consumption that occurred in the freight transportation subsector and 47% of the increase that occurred in the entire transportation sector.

The choices made by Canadians to meet their transportation needs are contributing to an increase in energy consumption. A growing number of Canadians bought light trucks (including minivans and sport utility vehicles [SUVs]) rather than other vehicles that have a better ranking in fuel consumption. In 2010, light-truck sales made up 46% of new vehicles sold for passenger transportation, compared to 26% in 1990. This shift from cars to light trucks has resulted in a significant increase in energy consumption for passenger transportation. Between 1990 and 2010, energy consumption associated with the use of light trucks increased at a faster pace than that associated with any other mode of passenger transportation, representing an increase of 121% (Figure 3).

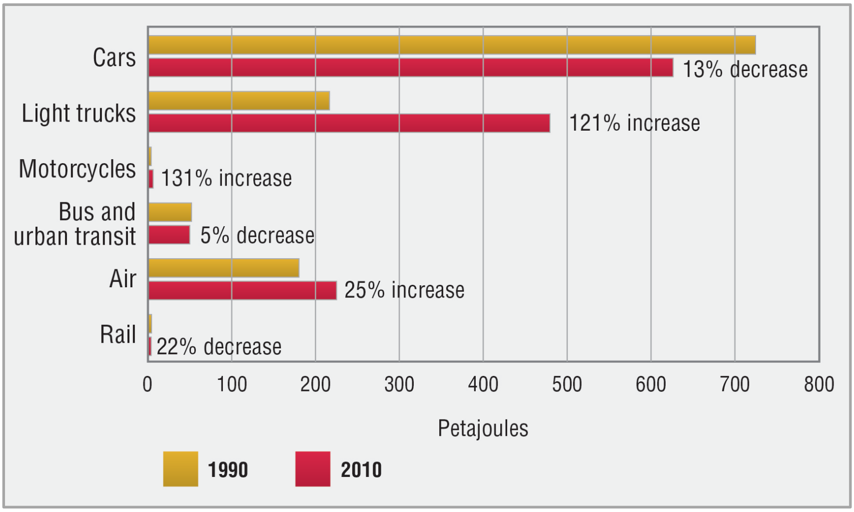

Fig. 3 Energy Consumption for Passenger Transportation by Mode of Transportation in 1990 and 2010
(Source: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/trends.cfm?attr=0)

During the period from 1990 to 2010, diesel consumption increased by 73%, particularly because of the increasing use of heavy-duty vehicles on Canadian roads — this alone contributed to 98% of this increase. Moreover, motor gasoline consumption increased by 30%, with passenger vehicles accounting for over half (184.5 PJ) of that figure, and freight transportation vehicles accounting for about a third (102.4 PJ) of it. Consumption of aviation gasoline, propane, and electricity declined over the same period (http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/trends.cfm?attr=0) (Figure 4).

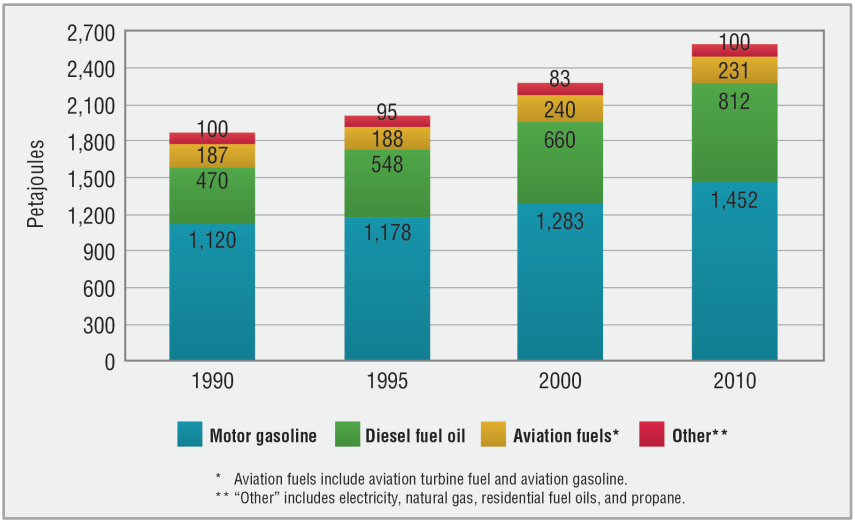

Fig. 4 Transportation Sector Energy Use by Energy Source in Selected Years
(Source: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/data_e/trends.cfm?attr=0)

Policies and Legislation

The *Renewable Fuels Regulations* (SOR/2010-189) (http://laws-lois.justice.gc.ca/eng/regulations/SOR-2010-189/index.html), 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 December 15, 2010 (Table 2). 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 (http://www.ec.gc.ca/energie-energy/default.asp?lang=En&n=0AA71ED2-1).

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 July 1, 2011. The 2013 Regulations Amending the Renewable Fuels Regulations *(SOR/2011-143)* introduced a national exclusion of heating distillate oil volumes for space heating purposes as of January 1, 2013 (see http://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailReg.cfm?intReg=202).

Table 2 Federal and Provincial Regulations on Biofuels[12]

Location	Percent of Renewable Fuels Content	
	Gasoline	Diesel
Canada	5.0	2
British Columbia	5.0	4
Alberta	5.0	2
Saskatchewan	7.5	2
Manitoba	8.5	2
Ontario	5.0	Under consideration
Quebec	5.0 (target only)	0

In October 2010, the Government of Canada released the final *Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations* (SOR/2010-201) (i.e., Phase 1 light-duty vehicle or LDV1 regulations; see https://www.ec.gc.ca/lcpe-cepa/eng/regulations/detailreg.cfm?intReg=192), which prescribe progressively more stringent annual emission standards for new vehicles of model years 2011 to 2016. The Government has also published proposed regulations in the *Canada Gazette* for the second phase of action on light-duty vehicles, which contains increasingly stringent GHG emission standards for light-duty vehicles of model years 2017 to 2025 (i.e., LDV2 regulations).

These regulations will achieve significant and sustained GHG reductions and fuel-savings benefits. Preliminary estimates suggest that by 2020, Canadian regulations for model years 2011 to 2016 will lead to annual reductions of between 9 and 10 Mt in Canada. Preliminary estimates indicate that the proposed regulations for model years 2017 to 2025 will reduce GHG emissions by an additional 3 Mt in 2020, with growing reductions in subsequent years.

Under both phases of light-duty vehicle regulations, spanning model years 2011 to 2025, the fuel efficiency of new cars will increase by 41% as compared to model year 2010 efficiency, 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 per 100 kilometers

[12] http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/2013/EnergyMarket_e.pdf

(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.

Total transportation emissions are projected to increase from 168 Mt in 2005 to 176 Mt by 2020, a marked deceleration of growth from the historical long-term trend. This deceleration from historical trends is expected to occur as a result of higher gasoline and refined petroleum prices and because federal vehicle emission regulations are accelerating an increase in fuel efficiency in vehicles.

Although absolute emissions are expected to grow in the freight transportation subsector, emissions are expected to decrease relative to business-as-usual levels as a result of various federal, provincial, and territorial programs. The recently announced heavy-duty vehicle regulations will improve the average fuel efficiency of trucks from 2.5 L/100 tonne-km to 2.1 L/100 tonne-km by 2020 (http://www.ec.gc.ca/ges-ghg/985F05FB-4744-4269-8C1A-D443F8A86814/1001-Canada's%20Emissions%20Trends%202013_epdf).

Implementation: Use of Advanced Motor Fuels

The market demand in transportation for natural gas was 0.3 billion cubic feet per day in 2011 (http://www.nrcan.gc.ca/sites/www.nrcan.gc.ca/files/energy/files/pdf/2013/EnergyMarket_e.pdf).

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. 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 these new innovations and that Canadians can benefit from them. To achieve this outcome, 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 North America, in order to reduce and prevent barriers to cross-border trade, lower costs for businesses and consumers, and support jobs and growth (http://www.tc.gc.ca/eng/programs/environment-etv-menu-eng-118.htm).

Outlook

In 2011, passenger travel accounted for 54% of transportation sector energy demand, freight transport accounted for 42%, and non-industrial 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 5). 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 6 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.

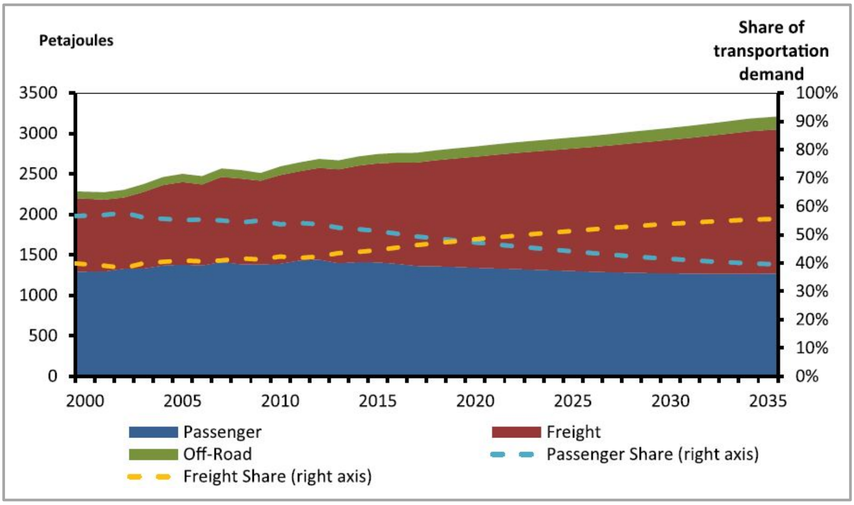

Fig. 5 Transportation Energy Demand by Travel Type: Reference Case
(Source: http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.pdf)

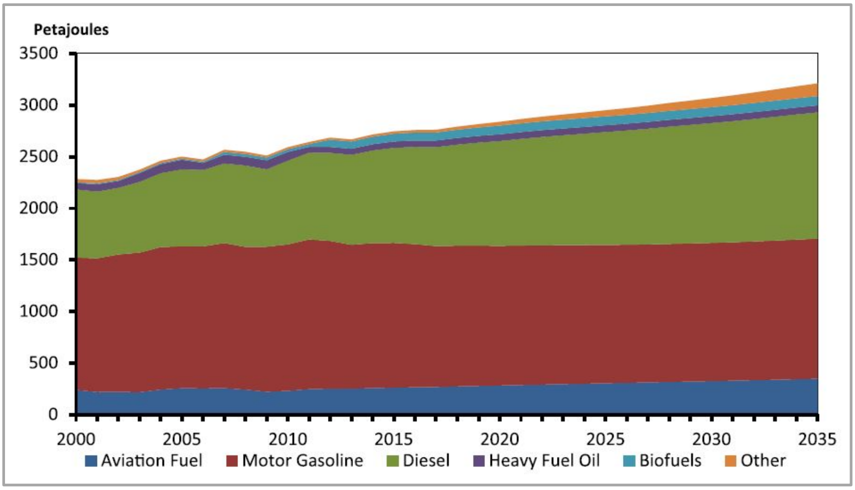

Fig. 6 Transportation Energy Demand by Fuel Type: Reference Case
(Source: http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.pdf)

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. Several fueling stations are currently being constructed in key strategic highway locations, and several trucking companies have placed orders for natural-gas-fueled trucks. In the reference case, freight natural gas vehicles (NGVs) will use 100 PJ or 7.4 million m^3 per day (260 million cubic feet per day) of natural gas in 2035, representing 6% of total freight transport fuel demand. This is approximately equivalent to 60,000 medium- and heavy-duty freight NGVs (see National Energy Board, 2013, *Canada's Energy Future 2013, Supply and Demand Projections to 2035,* Nov., http://www.neb-one.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/nrgyftr/2013/nrgftr2013-eng.pdf).

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.

AMF Success Stories

In a recent study in support of Canada's ecoENERGY Innovation Initiative and the International Energy Agency's Advanced Motor Fuels Implementing Agreement, researchers from Environment Canada's Emissions Research and Measurement Section characterized the exhaust emissions from a Class 8 transport truck equipped with a high-pressure direct-injection system that uses liquefied natural gas (LNG) as the primary fuel, along with a small amount of diesel as a pilot ignition source. Emission rates from the LNG truck were compared to emissions from a conventional diesel-fueled truck while operating over different driving cycles.

Along with reduced carbon dioxide tailpipe emissions, the LNG truck had lower emissions of oxides of nitrogen (NO_X) and particulate matter (PM) compared to the diesel truck. Methane was emitted from the LNG truck but not from the diesel truck. The LNG carbon dioxide equivalency rate (CO_2e) was lower than that for diesel for some of the driving cycles but only higher by 3% for select driving cycles. Both methane and nitrous oxide were accounted for in the (CO_2e). Compared to the diesel truck, diesel-equivalent fuel consumption from the LNG truck was increased; however, this increase depended on the drive cycle. Generally, for both trucks, driving at a steady-state speed representing highway driving resulted in better fuel economy and efficiency and lower emissions when compared to transient driving.

This study will support policy- and decision-makers as mandatory greenhouse gas emission standards are implemented for new on-road heavy-duty vehicles and engines under the *Heavy-Duty Vehicle and Engine Greenhouse Gas Emission Regulations* (SOR/2013-24) (http://ec.gc.ca/lcpecepa/eng/regulations/detailReg.cfm?intReg=214) of the Canadian Environmental Protection Act, 1999 (http://www.ec.gc.ca/scitech/default.asp?lang=En&n=6A2D63E5-1&xsl=privateArticles2,viewfull&po=7B18B4FA).

China

Introduction

Total diesel and gasoline fuel consumption in China amounted to 264 million tons in 2013. Of this, 186 million tons were due to vehicle consumption, 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. Natural gas consumption has reached 147 billion cubic meters, an increase of 13% from 2011. At the end of 2012, the use of NG vehicles was encouraged in 80 Chinese cities. There are more than 1.2 million natural gas vehicles in China, with 1,600 refueling stations for them.

In 2012, 470,000 tons of M15 methanol gasoline and 64,000 tons of M85-M100 methanol fuel were consumed in Shanxi Province, China. Refitted vehicles totaled 33,271 (including taxi and cars), of which 11,513 vehicles were inside the province and 21,758 vehicles were outside the province. Sales from methanol fuel and methanol-fueled vehicles totaled 6 billion RMB (Chinese Renminbi), and initial industrialization of the methanol fuel application has been achieved. By 2015, the use of methanol gasoline will be up to 3 million tons, and the number of refitted vehicles and new methanol load vehicles will reach 20,0000 and 50,000 vehicles, respectively.

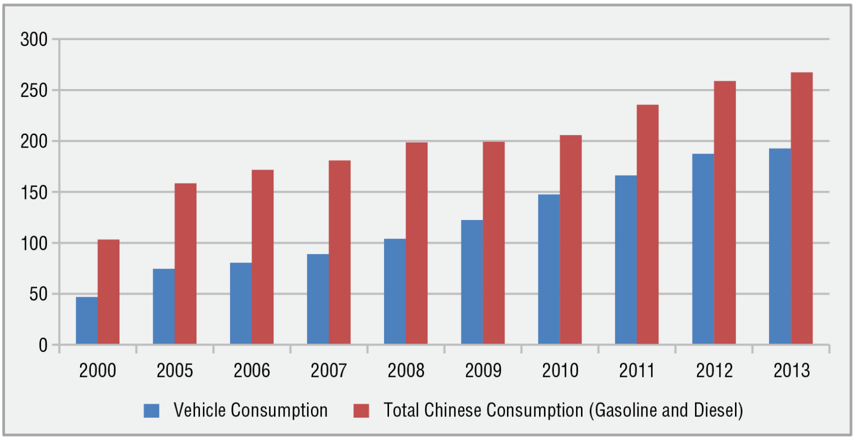

Fig. 1 Fuel Consumption in China (million tons)

Policies and Legislation

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

The automotive industry is an important main industry of the Chinese national economy and plays an important role in economic and social development. With the sustained, rapid economic development and accelerating urbanization of China, increasing automotive demands continue to grow, and the resulting energy shortage and environmental pollution problems will become more prominent. Speeding up the cultivation and development of energy-saving and alternative-energy vehicles is not only urgently needed to effectively alleviate energy and environmental pressures and promote the sustainable development of the automobile industry, but it is also a strategic initiative for accelerating the transformation and upgrading of the automobile industry and cultivating new economic growth and an international competitive advantage. China's plan is especially formulated to implement the decisions of the State Council to develop a strategic emerging industry and to strengthen energy savings and emissions reduction, as well as accelerate the cultivation and development of an energy-saving and alternative-energy automotive industry. The plan spans 2012–2020.

1. Technical Route

The goal is to make the pure electric drive a main technology in the development of alternative vehicles and in the transformation of 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.

2. Main Objectives

1. *Significantly advance industrialization.* By 2015, the cumulative production and sales of pure electric vehicle and plug-in hybrid vehicle must be up to 500,000 vehicles. By 2020, the production capacity for pure electric and plug-in hybrid vehicles must 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 in cooperation with the international community.
2. *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. Improvement in fuel consumption by commercial vehicles in China must be comparable to that of advanced commercial vehicles around the world.

3. *Substantially increase the level of technology.* Alternative-energy vehicles, power batteries, and key components in China must be as technologically advanced as around the world. Together, energy savings associated with gas hybrids, advanced internal combustion engines, efficient transmissions, automotive electronics, lightweight materials, and other key core technologies are expected to form a group of energy-saving and alternative-energy vehicle enterprises that are more competitive.
4. *Significantly enhance the ability to support technology.* Both the technology level and production scale of key components 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.
5. *Significantly optimize the management system.* China plans to (i) establish an effective management system associated with energy-saving and alternative vehicle companies and products; (ii) build a marketing, after-sales service, and battery recycling system; and (iii) improve support policies to form a relatively complete system of technical standards and management practices.

3. Main Tasks

1. *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 to key, breakthrough core technologies and enhance industrial competitiveness.
2. *Increase technical research and development of 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 the development and research of 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.

3. *Accelerate the establishment of a research and development system for energy-saving and alternative-energy vehicles.* China will guide industry to increase the development and research 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 shared test platform of related industries, a product development database, and a patent database to enable resource sharing. 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 actively participation by research institutions and universities.
   - Encourage industry to implement trademark and brand strategies.
   - Strengthen intellectual property right (IPR) creation, utilization, protection, and management.
   - Build the patent system for the whole industry chain and improve industrial competitiveness.

Implementation: the Use of Advanced Motor Fuels

China "10 cities, 1000 units" Energy-Saving and Alternative-Energy Vehicle Demonstration

In 2009, the four ministries under the State Council jointly started the "10 cities, 1000 units" energy-saving and alternative-energy vehicle demonstration operation pilot project. Battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs) were placed in the field as public buses, taxis, postal cars, and service cars through government financial subsidies.

The first stage of the project to demonstrate the use of energy-saving and alternative-energy vehicles in China was finished in December 2012. The Ministry of Finance, the Ministry of Science and Technology, the Ministry of Industry and Information Technology, and the National Development and Reform Commission jointly evaluated the use of energy-saving and alternative-energy vehicles in public areas of 25 pilot cities (including six cities that encouraged the private purchase of alternative-energy vehicles). Site inspection was conducted according to national demonstration requirements, and implementation plans were approved by the four authorities for each city.

By the end of December 2012, the total amount of demonstration vehicles in the 25 cities reached 27,432, including 23,032 various vehicles in public service areas and 4,400 privately owned vehicles. There were 12,156 hybrid buses, 3,703 hybrid passenger cars, 2,526 pure electric buses (including plug-in electric buses), 6,853 pure electric passenger cars (including plug-ins), and 2,194 other types. The distribution of demonstration vehicles based on different types is shown in Figure 2; the demonstration public and private purchases of the alternative-energy vehicles are shown in Figures 3 and 4, respectively.

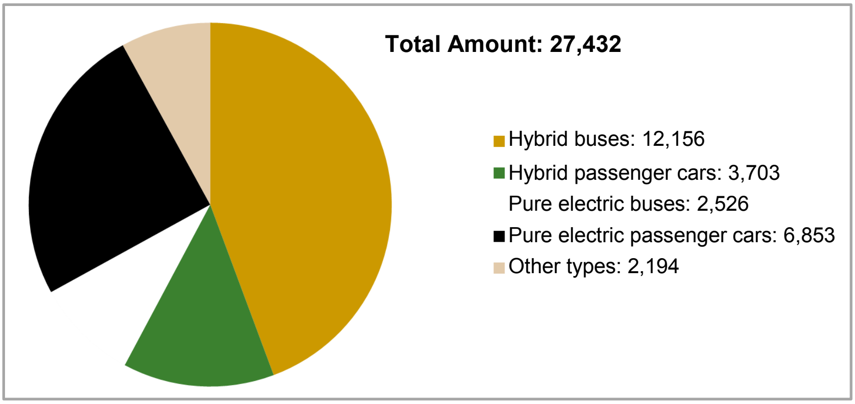

Fig. 2 Distribution of Demonstration Vehicles Based on Different Types (unit: vehicles)

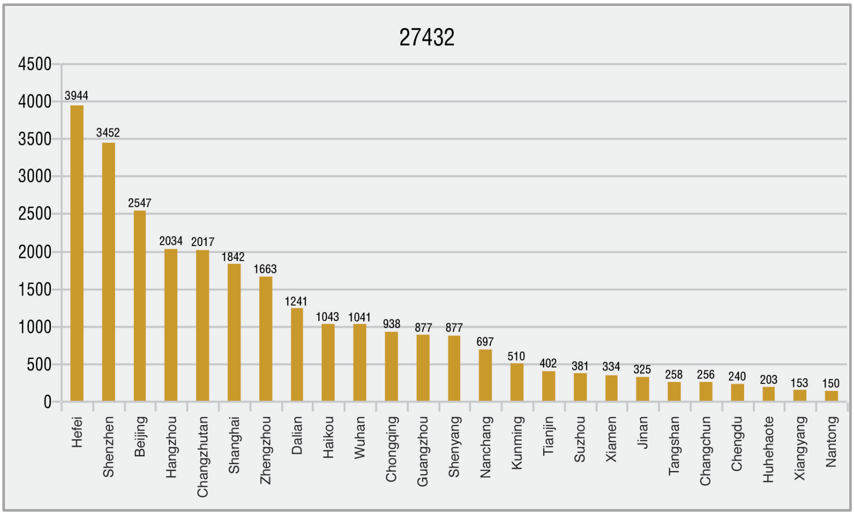

Fig. 3 Number of Public Purchases of Alternative-Energy Vehicles in Demonstration Cities (unit: vehicles)

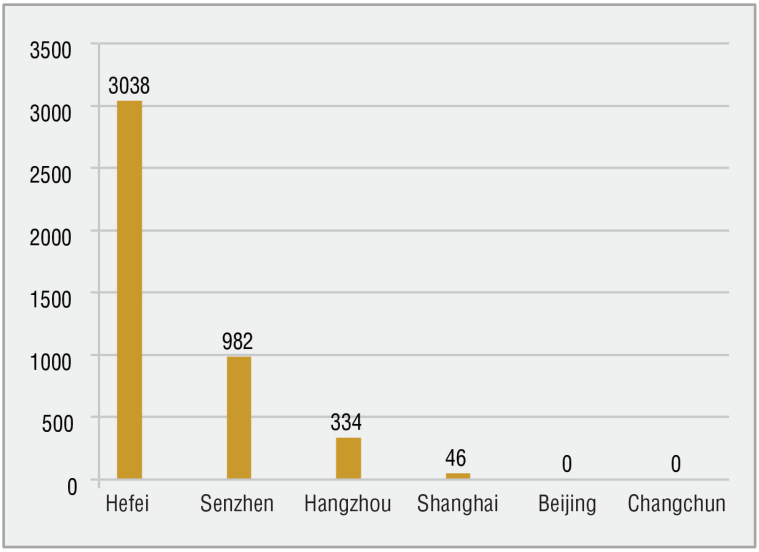

Fig.4 Number of Private Purchases of Alternative-Energy Vehicles in Demonstration Cities (unit: vehicles)

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 aim of this project was to promote natural gas vehicles and accelerate the construction of a natural gas vehicle filling station infrastructure. The project encouraged the development of natural gas, increased its use in the primary energy structure, and clearly defined NG vehicles as a "first class" gas project. A total of 450 NGV models (including chassis) were listed in the national motor vehicle announcement; the annual sale number reach 60,000, including buses, passenger cars, trucks, special municipal cars, and others. The number of alternative fuel vehicles in the top 10 demonstration cities is shown in Table 1.

Table1 Number of Alternative Fuel Vehicles in Top 10 Demonstration Cities

City	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 Ten Demonstration City	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 accumulative output of pure electric vehicles and plug-in hybrid vehicles will reach 500,000; by 2020, the capacity will reach two million, and the accumulative production and sales amount will reach more than five million. The plan clarified five tasks, namely, a technical innovation project for energy-saving and alternative-energy vehicles, a scientific plan for industry structure, accelerated promotion of demonstration, active promotion of charging equipment manufacture, and 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 such components and materials as anodes and cathodes, diaphragm, 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 developing and implementing pilot programs for charging facilities within cities, bringing charging facilities into the relevant industrial areas of city-wide transportation systems and construction, and actively carrying out the scattering 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 kW and 30 million kW by, respectively, the end of 2015 and 2020, 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.

Additional References

The following may be consulted for additional information:

- China Automotive Technology and Research Center (CATARC). http://www.catarc.ac.cn/ac_en/index.htm
- 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

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.

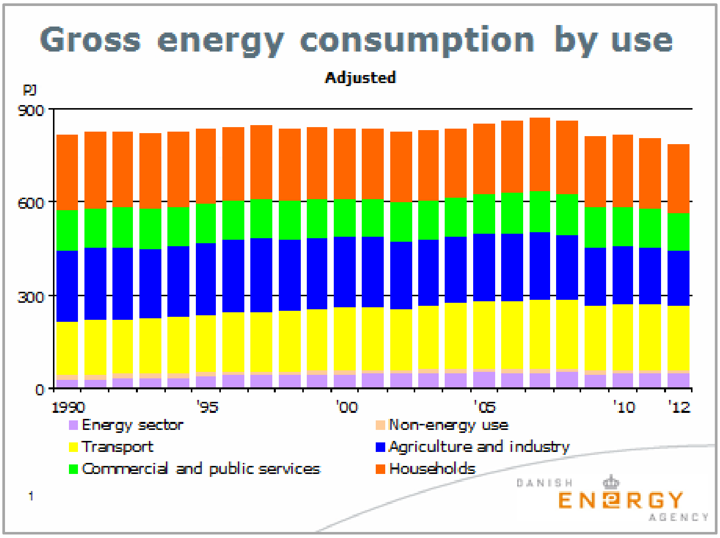

Fig. 1 Gross Energy Consumption by Use in the Period 1990–2012

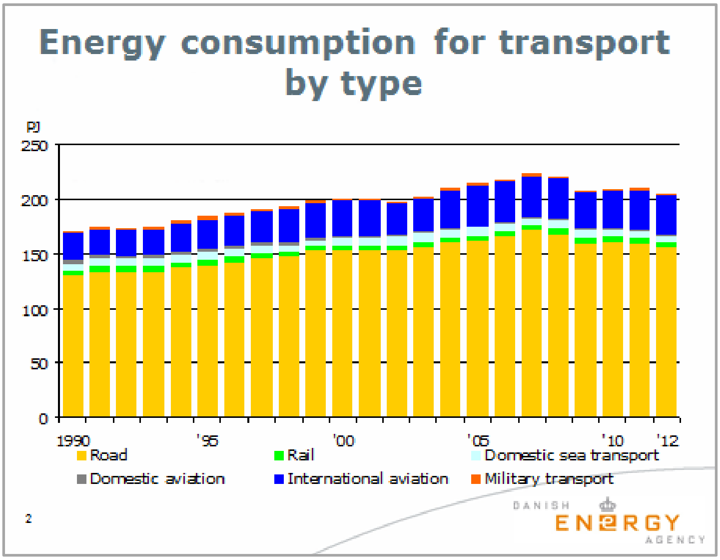

Fig. 2 Energy Consumption for Transportation by Transportation Type in the Period 1990–2012

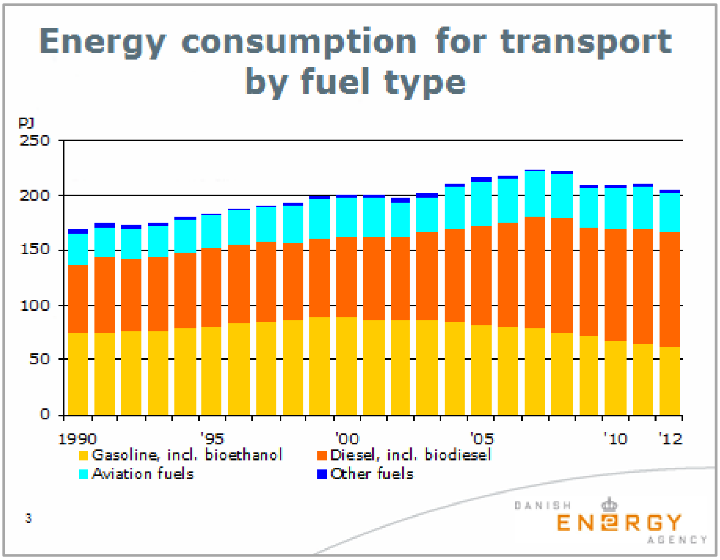

Fig. 3 Energy Consumption for Transportation by Fuel Type in the Period 1990–2012

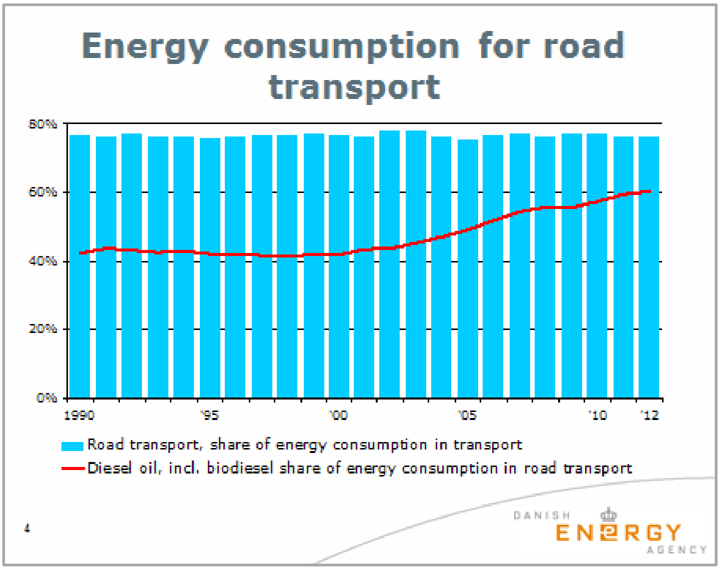

Fig. 4 Energy Consumption for Road Transportation in the Period 1990–2012

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 2012[13], the consumption of energy in Finland totaled 1 372 PJ (~32.8 Mtoe; ~381 terawatt hours [TWh]), which was 1% less than in 2011. Electricity used totaled 85.1 TWh. The energy mix was well-balanced and included contributions from oil, coal, nuclear energy, and hydropower (Figure 1). The amount of renewable energy was exceptionally high, with a total of 32% in 2012, an increase of 4%-units from 2011. Wood fuels comprised 84% of the renewable energy used. Bioenergy was used for heat and power production for industry and municipalities in general. In addition, peat was used for energy purposes, and wood was used for heating small houses.

Directive 2009/28/EC set a target of 20% renewable energy use in the European Union (EU) by 2020. A national target of 38% was set for Finland by 2020. Carbon dioxide (CO_2) emissions from the production and use of energy totaled 46.4 megatons in 2012 (preliminary data, Statistics Finland, www.stat.fi[14]). In January 2014, the European Commission published new climate and energy targets for 2030: a 40% reduction in greenhouse gas (GHG) emissions compared to 1990 levels and a share of 27% energy from renewable sources by the same date. EU member states will also have an “indicative” target (not legally binding) of improving energy efficiency by 25% by 2030.

Finland is a sparsely populated country. Transportation work per capita, for both people and goods, is among the highest in the world. Transportation consumed about 219 PJ of Finland’s primary energy in 2012, around 16% of the total energy consumption in Finland for that year (Figure 2). In 2012, transportation in Finland produced GHG emissions of ~13 Mt of CO_2-eqs, of which about 90% was produced by road traffic.

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13 *Information presented in this 2013 report was current at the time of preparation. Information for calendar year 2013 will be presented in the 2014 Annual Report.*

14 Official Statistics of Finland (OSF): Energy supply and consumption [e-publication]. ISSN=1799-7976. 2012. Helsinki: Statistics Finland [referred: 14.1.2014]. Access method: http://www.stat.fi/til/ehk/2012/ehk_2012_2013-12-12_tie_001_en.html.

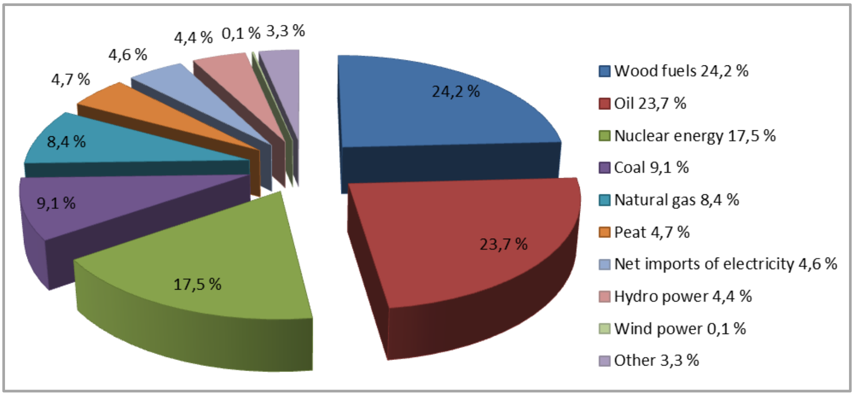

Fig. 1 Total Energy Consumption in Finland in 2012 (www.stat.fi[15])

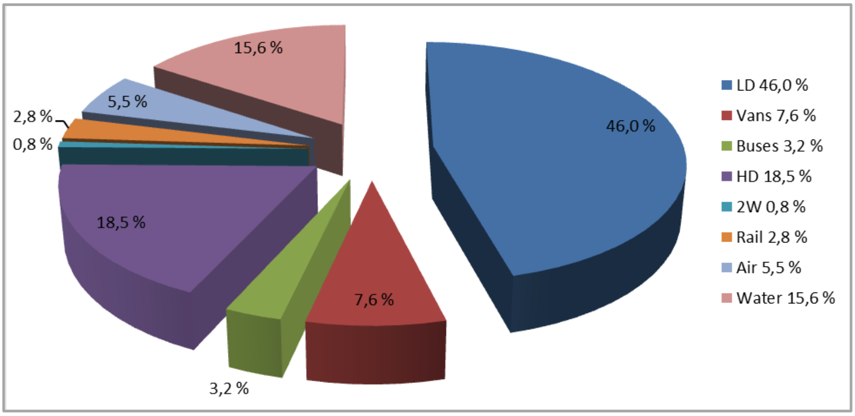

Fig. 2 2012 Energy Consumption in Finnish Transportation Sectors (Figure by Roslund; data by lipasto.vtt.fi)

[15] Official Statistics of Finland (OSF): Energy supply and consumption [e-publication].
ISSN=1799-7976. 2011, Appendix figure 1. Total energy consumption 2011. Helsinki: Statistics Finland [referred: 4.6.2013].
Access method: http://www.stat.fi/til/ehk/2011/ehk_2011_2012-12-13_kuv_001_en.html. http://www.stat.fi/til/ehk/2011/ehk_2011_2012-12-13_tie_001_en.html.

Policies and Legislation

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

Fig. 3 Biofuel Laws and Target Energy Shares in Finland

The Climate Policy Program in 2009 targeted a 10% reduction in GHG emissions by 2020 and stated that the most efficient way to cut GHG emissions was to replace the passenger car fleet with fuel-efficient vehicles with CO_2 emissions of 95 g/km by 2020 and 20–30 g/km by 2050 (Ministry of Transport and Communications, 2009). In December 2013, the Ministry of Transport and Communications published a new environmental strategy for transport[16]. In addition to low-emission vehicle technologies and alternative fuels, the new strategy also emphasized the influence of citizens' behavior when using the various transportation modes. This Environmental Strategy also updated the Ministry's Climate Policy Programme. For example, 50% of new passenger cars in 2020, and all cars sold in 2030 must be compatible with alternative energy sources. The target is also to have 70% of heavy-duty vehicles compatible with liquid or gaseous alternative fuels by 2050.

[16] 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 called "Future transport power sources" in 2013[17]. The group's vision is to have passenger car traffic, rail transportation, and boating almost entirely oil-independent by 2050. Liquid and gaseous biofuels should cover at least 70% of the fuels used in heavy-goods transportation by 2050, and electricity should have an equally large share in bus and delivery transportation in urban areas. In aviation, biokerosene could replace 40% of air transportation needs. And in maritime shipping, 40–50% of the emission cuts should be implemented by using alternative fuels and by improving energy efficiency. Transportation in airports and port terminals should be at near-zero emissions by 2030. The ability of different options to replace oil vary; for example, liquid biofuels, natural gas, and biomethane are already commercially available, whereas electric vehicles are still in the market introduction phase, and hydrogen is still in its infancy.

Taxes

Finnish tax reforms are summarized in Table 1. The CO_2-based purchase tax has been an effective instrument in reducing CO_2 emissions of new passenger cars; the average value dropped from 180 g/km in 2007 to 135.5 g/km in January 2012.

In December 2013, a working group in the Ministry of Transport and Communications published the report, "Fair and intelligent transport."[18] The report states that steps could be taken toward introducing kilometer-based taxation of car use in Finland. Transportation policy goals would be part of the taxation policy, and a kilometer-based tax would be an efficient financial steering tool that would decrease car traffic by volumes (and, thus, emissions and accidents) and increase the use of public transportation services. Intelligent transportation innovations will also enable new forms of transportation pricing.

[17] http://www.lvm.fi/publication/4156469/future-transport-power-sources-executive-summary

[18] http://www.lvm.fi/publication/4387221/fair-and-intelligent-transport-working-group-final-report

Table 1 Finnish Taxes

Tax	Based on	Comments
Fuel	• Volumetric heat value • CO_2 emissions • Local emissions (e.g., NO_X and PM)	• Implemented in 2012, 2013 • Low volumetric heating value of biofuels compensated. Biofuels exempted from carbon component tax depending on WTW (well-to-wheels) GHG emissions. • Bonus for paraffinic diesel and methane
Vehicle purchase	• Tailpipe CO_2 emissions	• 2008, revised in 2012 • Min. 0 g/km CO_2 = 5% tax • Max. 360 g/km CO_2 = 50% tax
Annual vehicle	• Tailpipe CO_2 emissions • A base tax and a “fuel-fee” tax depending on the energy source	• Min. 0 g/km CO_2 = 43 €/a • Max. 400 g/km CO_2 = 606 €/a

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

Smart mobility integrated with low carbon energy *TransSmart* — is a new research program started by VTT Technical Research Centre of Finland in 2013[19]. TransSmart is a multi-dimensional framework for transportation-related research enabling co-operation between private and public sectors to achieve common goals. TransSmart will focus on four core areas: low-carbon energy, advanced vehicles, smart transportation services, and transportation systems. Demonstrations of new low-carbon fuels and advanced vehicles will continue within this new framework. The “UPM BioVerno,” a wood-based biofuel manufactured by the Finnish pulp and paper company UPM, was demonstrated in 2013. A dual-fuel concept, in which methane (natural gas or biomethane) is used in a diesel engine with pilot injection of diesel fuel, was optimized for a combination of biomethane and renewable diesel as the pilot fuel. Biomethane from the national gas company Gasum and NExBTL renewable diesel from national oil company Neste Oil will be demonstrated next. Ethanol from the national energy company, St1, will be demonstrated as fuel for heavy-duty transportation in

19 http://www.vtt.fi/research/spearhead_transsmart.jsp

special vehicles. The previous *TransEco* programme (2009–2012) laid the foundation for this kind of cooperation.

Tekes has a research program dedicated to electric vehicles. The program, called *EVE*, will run from 2011 to 2015. The total costs of the EVE program will be some 80 M€, with a contribution of 37 M€ from Tekes.

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

Earlier, biofuels were also part of the national research program *BioRefine* (2007–2012), which was financed by Tekes[20]. Tekes also had a research program for fuel cells (2007–2013), but this program was mainly devoted to sectors other than transportation.

Implementation: Use of Advanced Motor Fuels

Table 2 shows the main types and numbers of vehicles in Finland in 2013. The total number of all vehicles registered was approximately 5.82 million (approximately 4.95 million in use). There were around 3,000 flex-fuel vehicles (FFV) capable of using high-concentration ethanol fuel (E85) at the end of 2013. Around 90 refueling stations carry E85. There were around 1,300 natural gas vehicles (NGVs) that used only methane (natural gas or biomethane) or were bi-fuel gasoline/methane vehicles. Twenty refueling stations carried methane. In 2012, biofuel consumption in the transportation sector was 7.9%.[21]

[20] http://www.tekes.fi/en/programmes-and-services/recently-ended-programmes/biorefine/

[21] http://www.tem.fi/files/38668/Uusiutuvan_edistymisraportti_2013.pdf.

Table 2 Types and Numbers of Vehicles Registered (*in use*) in Finland in 2013 According to Trafi (Finnish Transport Safety Agency)

Passenger Cars	Vans	Trucks	Buses	2-Wheelers	Other Vehicles	Non-road
3,110,000 (2,580,000)	388,000 (301,000)	133,000 (97,000)	15,000 (12,000)	551,000 (443,000)	44,000 (27,000)	587,000 (534,000)
~ 473 passenger cars per 1000 inhabitants in use (~ 570 registered) ~ 24% share of passenger cars in use are diesel passenger cars						

The dominant fuels used were petrol and diesel. In 2012, the total consumption was approximately 4.0 Mt, of which 40% was gasoline and 60% diesel. In 2012, the national biofuels obligation called for 6% biofuels (see Figure 3). In total, the contribution from alternative fuels, including fossil fuel options, was around 255 ktoe in 2012. Bioethanol was blended in gasoline as bioethanol, and it was used also as feedstock for the production of ETBE (ethyl *tert*-butyl ether) and TAEE (tertiary-amyl ethyl ether), which were also blended in the gasoline. As for diesel, the bio portion consisted mainly of hydrotreated vegetable oil (HVO) -type paraffinic renewable diesel fuel. In 2012, the contribution to fuels from biofuels fulfilling sustainability criteria was around 200 kilotons of oil equivalent (ktoe), without electricity. Table 3 shows the use of road transportation fuels in Finland.

Table 3 2012 Road Transportation Fuels in Finland
(Source: Finnish Petroleum Federation and Finnish Customs)

Petrol (Mt)	Diesel (Mt)	Ethanol and Ethers[c] (total/bio-portion) (Mtoe)	Bio-origin Diesel[b] (total/bio-portion) (Mtoe)	Natural Gas (Mtoe)	Bio-Methane (Mtoe)
1.6[a]	2.4[b]	0.142/0.090[d]	0.109/0.105[d]	0.004	0.0004

[a] *E10 = 0.86 Mt, E5 = 0.71 Mt, and E85 = 0.0049 Mt.*

[b] *Diesel contains mainly HVO as bio-component.*

[c] *Ethanol is used partly as fuel ethers in Finland.*

[d] *Fulfills EU's sustainability criteria.*

Hydrotreated Oils and Fats

Hydrotreated oils and fats, or HVO, is a main bio-component in Finnish diesel fuel. Neste Oil's NEXBTL is a renewable paraffinic diesel fuel that has a high cetane number and excellent ignition properties, but it does not have sulfur, nitrogen, aromatics, or oxygen. The EN590 specification for diesel fuel can be met by using blends with up to 30% NEXBTL. Paraffinic diesel fuel is covered by the European standard CEN/TS 15940:2012. Neste Oil's total NEXBTL production capacity is about 2 Mt/a (in Finland ~380 kt/a; in Singapore and in Rotterdam, ~800 kt/a each). Production of NEXBTL is based mainly on palm oil and animal fats. In 2013, the percentage of waste and residues in NEXBTL production was 52.6% (35.1% in 2012 and 40.3% in 2011). Neste Oil's pilot plant for producing microbial oil (see the "Outlook" section) exemplifies one approach to reaching this goal.

FAME

Only a small amount of conventional esterified biodiesel (FAME) is used in Finland. RME (rapeseed methyl ester) has been produced on a small scale, mainly on farms. In 2012, 0.012 Mtoe of FAME was used in Finland and 0.009 Mtoe of it fulfilled EU's sustainability criteria.

Bio-ethers

Neste Oil has processed ETBE (ethyl tert-butyl ether) since 2004. In 2012, 75 ktoe of bioethers, mainly ETBE and TAEE (tertiary-amyl ethyl ether), were blended with petrol. The ethanol contained in ETBE is imported and the end product is mixed with petrol; the bioenergy portion of these ethers was 23 ktoe in 2012.

Bio-alcohols

In 2011, petrol containing 10 vol-% of ethanol (E10) was first sold in Finland. E10 sales were around 55% and 44% are still E5, even though 70% of petrol cars are E10 compatible. St1 also sells a high-concentration ethanol, RE85, at ~90 refueling stations in Finland. The hydrocarbon part of the RE85 is a special mix made to operate well at low ambient temperatures. FFV cars and St1's RE85 were introduced to the Finnish market in the spring of 2009. At present, around 2500 FFVs are operating in Finland.[22]

Starting in 2011, RED95 ethanol-diesel was 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 by using side streams from the food industry, via a process called

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

Etanolix. Waste is converted into an ethanol (85%) -water 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/a (~45 ktoe). Five decentralized ethanol units are currently running with a production capacity of ~800–5,500 t/a per unit. In 2012, a Bionolix™ unit in Hämeenlinna was combined with a biogas production plant to convert side products of ethanol into green energy, by using biowaste from households. The total production of fuel bioethanol in Finland was some 12 ktoe in 2013.

The majority of bioethanol consumed in Finland is imported.

Natural Gas and Biomethane

A total of about 1,300 vehicles, consisting of 65 natural gas buses, 20 heavy-duty vehicles, and 1,160 cars and vans are running on pure methane or are bi-fuel gasoline/methane vehicles in Finland. There are currently 20 public natural gas/biomethane refueling stations, and construction of new stations is continuing. Natural gas is imported into Finland from Russia.

Biomethane is injected into the natural gas transmission network in Finland by Gasum. Biogas is manufactured, for example, at the Kymen Bioenergia Oy biogas facility in Kouvola and upgraded by KSS Energia Oy. 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 2012, up to 50 local buses had access to biomethane produced locally from wastewater by the Suomenoja wastewater treatment plant. The new, upgraded facility produces up to 20 GWh (1.7 ktoe) of biomethane. So far, the sludge produced as a wastewater treatment plant by-product has been used to generate electricity and heat used by the plant. In 2012, 570 GWh of energy was produced from biogas and used mainly as electricity (160 GWh) and heat (410 GWh).

Liquefied Petroleum Gas – LPG

In the 1990s, there was also some interest in using LPG to power heavy-duty vehicles, but interest has 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. Only 340 electric vehicles (EVs) were in use in 2013. The new CO_2-based purchase tax has increased the competitiveness of hybrids.

Within the Tekes' research program, EVE[23], a test bed consisting of an estimated 400 EVs and 850 charging points will be created in Helsinki, Espoo, Kauniainen, Lahti, and Vantaa[24]. The first Finnish demonstration of fully electric buses started in Espoo in 2012. The electric bus fleet of Veolia Transport Finland is comprised of buses rented from Portugal and China. Manufacturers of these electric buses find that testing their buses in Finnish cold winters yields valuable data.

A spin-off company, EkaBus, was established in Finland in 2014 to commercialize the developments from electric bus research projects and to combine the new technologies with existing energy-efficient bus technologies.

The Finnish car manufacturer Valmet Automotive, which formerly assembled Porsche sports cars and began manufacturing the new Mercedes-Benz A Class in August 2013, has announced a strategy for EVs. In Uusikaupunki, Valmet Automotive has manufactured EVs, such as the small Think City car, a luxury golf cart, Garia, and the luxury Fisker Karma plug-in hybrid.

The Finnish company European Batteries was the first company to manufacture large automotive lithium-ion batteries in Europe, but the factory closed in 2013.

Hydrogen

Demonstration of fuel-cell-powered working machinery began in the harbor of Helsinki in 2013. The first commercial hydrogen fueling station opened in March 2014 for private cars and buses at the Port of Helsinki. At Voikoski, one hydrogen fueling station, operated by national gas manufacturer Woikoski Oy, opened in January 2014 for Finland's first hydrogen car. During the winter season of 2011–2012, one hydrogen fueling station was available in Rovaniemi to enable different hydrogen vehicle manufacturers to test their products in cold winter conditions.

Outlook

Bioethanol and HVO renewable diesel will be increasingly used as biofuels in Finland.

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23 http://www.tekes.fi/programmes/EVE
24 http://sahkoinenliikenne.fi

Ethanol produced by St1 in Finland is increasing as St1 broadens its feedstock sources to include straw and waste fibers. St1 is planning to build an ethanol plant in Kajaani that will use sawdust to produce around 5 ktoe/a ethanol by 2015. The target for 2020 is to produce some 150 ktoe bioethanol (300 000 m^3) per year. St1 also plans to expand its RE85 distribution chain in Finland.

The total production capacity of Neste Oil's NEXBTL (HVO) is already close to 2 Mt/a (Finland, Singapore, and Rotterdam plants). In 2012, Neste Oil built a pilot plant for producing microbial oil for use as a feedstock for NEXBTL renewable diesel. A wide range of different waste and residue materials can be used, such as straw and side streams from the pulp and paper industry, which makes feedstock optimization possible. In 2014, Neste Oil and DONG Energy announced a partnership. DONG Energy's Inbicon technology is to be used in the first part of the process to pre-treat biomass and produce cellulosic sugars that can be further converted to microbial oil using Neste Oil's technology. Commercial-scale production is expected by 2015 at the earliest.

The Finnish pulp and paper company, UPM, is building a biorefinery in Lappeenranta that will use hydrotreatment to produce biofuels from crude tall oil. The biorefinery will produce approximately 100 kt/a of advanced hydrotreated biodiesel for transportation annually. Construction of the biorefinery is expected to be finished in 2014.

In the long term, cellulosic BTL is expected to cover a significant share of the diesel vehicle pool in Finland. Finland's state-owned energy company, Vapo, was awarded 88.5 million euros for a wood-based biodiesel plant in northern Finland (Kemi) that could produce renewable fuels around 100,000 t/a, but the plan is frozen. In addition, UPM was awarded 170 million euros for a solid-wood-based biorefinery project in Strasbourg, France.

There is increasing interest in the use of biomethane for transportation. Gasum has biomethane-related plans, including a large-scale, wood-based bio-SNG (Synthetic Natural Gas) plant. In total, production of biogas could be around 150 ktoe in 2016. An LNG (Liquefied Natural Gas) infrastructure for marine transportation is currently being built in Finland as a result of upcoming sulphur regulations. This offers an opportunity to consider LNG options for long-haul and heavy-duty transportation.

The first wood-based pyrolysis oil production integrated into a power boiler was built by Metso for Fortum in Finland in 2013[25]. However, pyrolysis oil will replace heavy and light fuel oils in heating applications. In the future, pyrolysis oil could be used for producing transport fuels and various chemicals.

Benefits of Participation in the AMF IA

Finland has been involved in a number of projects and studies within the AMF. The AMF organization is a flexible platform with effective tools to start and implement immediate actions to generate new data in order to fill knowledge gaps without heavy bureaucracy. Executive Committee working principles combined with different possibilities to contribute by cost-sharing or task-sharing routes offer suitable options for different purposes. *AMF generates and synthesizes information, which is of primary importance for research and development, as well as for decision-making bodies*. Finland, with its ambitious targets for biofuels in transportation, really needs solid data for decision-making.

The AMF Implementing Agreement is a unique collaborative forum simultaneously covering the whole spectrum of advanced motor fuels, from fuel production to end-use. A network of world-class experts representing different types of organizations and expertise allows for multidisciplinary synthesis and analysis of a complex field of different technologies and policies in the transportation sector.

[25] 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

The new Energy Efficiency Directive (EED; 2012/27/EU), formally approved in 2012, repeals the Cogeneration Directive (2004/8/EC) and the Energy End-Use Efficiency and Energy Services Directive (2006/32/EC). The EED is ambitious and puts a major focus on targets, including the reduction of energy consumption by 20% by 2020. The EED also translates elements of the European Efficiency Plan into binding measures on Member States. In this context, France has committed to achieving 23% renewable energy by 2020. In April 2014, the French Ministry of Ecology, Sustainable Development and Energy submitted its action plan for energy efficiency in compliance with this Directive to the European Commission. This roadmap, which is a result of the national debate on energy transition conducted in 2013, set two targets:

1. Reducing final energy consumption to 131 Mtoe by 2020 (compared to 155 Mtoe at present), excluding international air transportation;
2. Reducing primary energy consumption to 236 Mtoe (compared to 260 Mtoe at present), excluding international air transportation.

To achieve these goals and realize energy savings, France has already implemented a number of measures in various economic sectors, including the building sector.

Policies and Legislation

1. Incentives to Promote Use of Renewable Energy in Transport

Under the "National Action Plan for Renewable Energy"[26] following the "Grenelle de l'environnement," a number of incentives have been introduced to promote the use of renewable energy in the transportation sector.

Use of Biofuel Blends

- The launch in April, 2009 of new SP95-E10 fuel in the gasoline sector corresponds to an incorporation rate of 10% ethanol in gasoline (between 7 and 8% effectively). This product has been approved for sale in petrol stations since 2009. It aims to replace SP95 (5% bioethanol) in accordance with European directives. In 2013, the SP95-E10 comprised

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

a 29% share of gasoline volumes sold — a 5% increase compared to 2012 (24%). The marketed volumes of SP95-E10 grew by 18% in 2013, while the market for gasoline fell 3%. In 2012, sales of SP95-E10 exceeded those of SP98 for the first time.

In Europe, France has the largest number of petrol stations distributing SP95-E10. Today, more than one out of three stations sells SP95-E10. In 2013, 88% of the French fleet was compatible with SP95-E10, as well as almost all petrol vehicles registered since 2000.

- High-level biofuels (including E85 in the gasoline sector and B30 in diesel fuel production) have been authorized. In 2013, super ethanol E85, which contains 65–85% bioethanol, registered an 8% growth in sales compared to 2012. As of January 2014, E85 was selling in 363 petrol stations. To encourage sales growth, E85 is subsidized and accordingly benefits from reduced pump prices (€ 0.91 [$1.21 US] on January 1, 2014). The E85 price savings, compared to SP95, reached 20–40 cents/liter (over-consumption is included).

  In 2012, 7,341 flex-fuel vehicles were sold; 30,000 vehicles are now available on the market. Since 2013, however, only two models have been for sale: the Ford Focus 1.6 Eco boost Flex fuel and the Jeep Grand Cherokee.

- The current maximum incorporation rates for biodiesel and ethanol (as provided by texts on fuel quality in volume) are 7% and 10% respectively.

Fiscal Incentive Schemes

- A tax exemption is granted to biofuel users. 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) is levied to enable reaching biofuel goals. This is an additional TGAP levy that must be paid by operators and distributors (refiners, supermarkets, and independent retailers) who sell fuel containing a lower proportion of biofuels than the national goals of incorporation. This rate increased from 1.75% in 2006 to 3.5% in 2007, 5.75% in 2008, and 6.25% in 2009. It was set at 7% as of 2010 and remains unchanged. This rate is increasing every year, as defined above. It is reduced from biofuels placed on the market in percentage of energy (LHV, or Lower Heating Value).

The domestic tax on consumption (taxe intérieure sur la consummation, or TIC) aims to reduce the extra cost of manufacturing biofuels as compared to fossil fuels. This is a partial exemption of TCI 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 during 2011–2013. 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 will benefit from a reduction of €4.5/hL ($6.14 US/hL) in 2014 and €3/hL ($4.09 US/hL) in 2015 versus €8/hL ($10.92 US/hL) in 2013. The bioethanol sector tax exemption will be €8.25/hL ($11.26 US/hL) in 2014 and €7/hL ($9.55 US/hL) in 2015 versus €14/hL ($19.10 US/hL) in 2013. Taxes applied to super ethanol E85 are being maintained at a rate of €17.29/hL ($23.59 US/hL) from 2011 to 2014.

Measures to Encourage Fleet Renewal

- The Bonus-Malus system applied to the purchase of a new vehicle was amended in November 2013 for the bonus, whereas the malus calculation scale changed as of January 1, 2014. The Bonus amount was revised downward: the maximum CO2 release is now being set at 90 g/km. The maximum bonus of €7,000 ($9,551.50 US) introduced in 2012 was reduced to €6,300 ($8,596.35 US). For a vehicle emitting more than 130 g of CO2/km, the ecological malus generates an increase in the purchase price of 150 to €8,000 ($10,916 US). The objective of the Bonus-Malus system is to start the ecological transition via measures that encourage individuals to buy low-emission vehicles and to stimulate technological innovation, as stipulated in the 2013 Finance Act.

Changing Scales

CO_2 Emissions/km	Bonus from Aug. 1 2012 to Oct. 31 2013	Bonus since Nov. 1, 2013
Less than or equal to 20 gCO_2/km	7 000 € ($9,551.50 US)	6 300 € ($8,596.35 US)
Between 21 and 50 gCO_2/km	5 000 € ($6,822.50 US)	4 000 € ($5,458 US)

CO_2 Emissions/km	Malus in 2013	Malus in 2014
Less than or equal to 130 g	0 €	0 €
Between 131 and 135 g	0 €	150 € ($204.68 US)
Between 136 and 140 g	100 € ($136.45 US)	250 € ($341.13 US)
Between 141 and 145 g	300 € ($409.35 US)	500 € ($682.25 US)

CO_2 Emissions/ km	Bonus from Aug. 1 2012 to Oct. 31 2013	Bonus since Nov. 1, 2013
Between 51 and 60 gCO_2/km	4 500 € ($6,140.25 US)	4 000 € ($5,458 US)
Between 61 and 90 gCO_2/km	550 € ($750.48 US)	150 € ($204.68 US)
Between 91 and 105 gCO_2/km	200 € ($272.90 US)	0 €
More than 105 gCO_2/km	0 €	0 €

CO_2 Emissions/ km	Malus in 2013	Malus in 2014
Between 146 and 150 g	400 € ($548.80 US)	900 € ($1,228.05 US)
Between 151 and 155 g	1 000 € ($1,364.50 US)	1 600 € ($2,183.20 US)
Between 156 and 175 g	1 500 € ($2047.75 US)	2 200 € ($3,001.90 US)
Between 176 and 180 g	2 000 € ($2,729 US)	3 000 € ($4,093.50)
Between 181 and 185 g	2 600 € ($3,547.70)	3 600 € ($4, 912.20 US)
Between 186 and 190 g	3 000 € ($4,093.50)	4 000 € ($5,458 US)
Between 191 and 200 g	5 000 € ($6,822.50)	6 500 € ($8,869.25 US)
More than 200 g	6 000 € ($8,187)	8 000 € ($10,916 US)

Environmental Bonus for Hybrid Vehicles

The bonus applies only to hybrid vehicles with CO_2 emissions below 110 g/km. The bonus granted was reduced from €4,000 ($5,458 US) to €3,300 ($4,502.85 US), within a limit of 8.25% of the purchase price, with a minimum of €1,650 ($2,251.43 US).

CO_2 Emissions/ km	Bonus in 2013	Bonus in 2014	Comments	Examples of Vehicles
Less than 110 g	€2,000–4,000 ($2,729–5,458 US)	€1,650–3,300 ($2,251.43–4,502.85 US)	Maximum financial aid of 8.25% of the acquisition cost plus the cost of the battery if it is rented.	Toyota Yaris HSD Peugeot 3008 HYbrid4

For plug-in hybrid electric vehicles (PHEVs), the Bonus is capped at 20% of the purchase cost, plus the cost of the battery if it is rented. The maximum aid that can be applied is €4,000 ($5,458 US) for a vehicle emitting less than 60 g CO_2/km.

Environmental Bonus for LPG Vehicles

Aid for the acquisition or transformation of an LPG vehicle was abolished in 2011. The aid was subject to the same conditions as the aid for the purchase of clean vehicles running on gasoline or diesel.

- **Support for Electric Vehicles:**
  – *Electric Cars and Vans:*
  Electric cars are eligible for the highest environmental bonus. The bonus granted for the purchase of an electric vehicle (car or truck) emitting less than 20 g CO_2/km fell from €7,000 ($9,551.50 US) to €6,300 ($8,596.35 US). The aid applied may not exceed 27% of the purchase price, including all taxes and the cost of the battery if it is rented.

CO_2 Emissions/ km	Bonus in 2013	Bonus in 2014	Comments	Examples of Vehicles
Less than 20 g	€7,000 ($9,551.50 US)	€6,300 ($8,596.35 US)	Bonus is capped to 27% of the purchase price plus the cost of the battery if it is rented.	Renault ZOE Nissan LEAF

  – *Electric Two-wheelers:*
  Electric two-wheelers do not receive financial aid. However, 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 ($272.90 US) is granted for the acquisition of a vehicle eligible for the bonus system and for scrapping a vehicle more than 15 years old. This program was stopped in 2010 and 2011 in favor of a "scrapping-premium."

- **The Bonus-Malus Budget**
  Since the introduction of the Bonus-Malus system, revenues from the Malus system were for expenses associated with the Bonus system. However, this device created a deficit from 2008 to 2011, with the gap between revenues and expenses reaching nearly €1.5 ($2.05 US) billion.

  For 2013, the initial Finance Act planned that budget expenses relating to the Bonus grants would reach about €452 ($616.75 US) million, compared to the €226 ($308.38 US) million forecast for 2012 (i.e., it doubled). Indeed, under a plan to support the automotive industry and announced on July 25, 2012, the government decided to increase the Bonus grant beginning August 1, 2012. Conversely, Article 17 of the Finance Act 2013 strengthened the Malus calculation scale.

  After reaching a balance for the first time in 2012, forecasts showed a €100 ($136.45 US) million deficit in 2013. Changes in the system must be able to rebalance the plan. For 2014, the government expects that revenues from the Malus system will rise to €269.9 ($368.28 US) million, an amount equivalent to the estimated expenditure of the bonus system, thus balancing the entire plan.

The government anticipates that 1.75 million vehicles will be sold in 2014, compared to 1.93 million in 2012 and 1.85 million in 2013.

The government estimates that the percentage of vehicles granted a Bonus should reach 10.5% in 2014, and that the percentage of vehicles earning a Malus will be 16.9%. The recent amendments to the Bonus-Malus system lead to a majority of vehicles being sold in a "neutral zone" (i.e., no Bonus or Malus). This percentage could reach 73%; it was 47% in 2013.

The Bonus-Malus system has been a key element leading France to have, in 2013, one of Europe's lowest CO_2 emissions in the new vehicles market, in the range of 117 g CO_2/km.

2. R&D in the Transportation Sector

Public support for innovation and R&D deployed within competing clusters (i.e., association or partnership) resulted in:

- Financial support via a single interdepartmental fund (Fond Unique Interministériel [FUI]), which involves various partners, such as the ANR (see Carnot device[27]), OSEO or Caisse des Dépôts that participated in project financing, and
- Tax exemptions for companies with a cluster involved in an R&D project financed by the government.

The National Research Agency, established in 2005, is responsible for the implementation of financed projects, the purpose of which is to boost the research sector, France's competitiveness, and the visibility of its research abroad.

The NRA is mobilized to focus research efforts on economic and societal priorities at the highest level of the State, in consultation with other

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[27] Association Instituts Carnot is a network of 34 Carnot institutes dedicated to fostering enterprise innovation. A major national multi-disciplinary 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 socio-economic players, primarily enterprises (from SMEs to large corporations), to serve their needs.

stakeholders in research, and to develop international and European collaborations. The great societal challenges that are now facing the ANR revolve around nine major societal challenges identified in the Strategic Research Agenda and are consistent with the European Strategic Agenda. Two of them are related to transportation issues:

- Clean, safe, and efficient energy
- Sustainable mobility and urban systems

In 2013, a call for proposals devoted to advanced fuels was made that included:

- **Biomaterials and Energy (Bio-ME):** The program focused on bio-refineries. It aimed at recovering energy from all components of biomass and to develop material for the synthesis of molecular "platforms," the basic constituents of "green" chemistry — in particular, a program goal is to ensure the economic and environmental viability of the proposed plans. Efforts focused on:
  - Improving the availability and cost reduction provision of biomass;
  - Improving forms of biomass for energy and chemical recovery;
  - Developing effective and sustainable industrial technologies for converting ligno-cellulosic biomass;
  - Improving the technical and economic performance of sector, for integrated material/energy co-valuation; and
  - Exploring new avenues for technological breakthrough; in particular, for the production of bio-lipids and other substances by microorganisms.

  The Bio-ME program is organized into four themes:
  - Axis 1: Contact — mobilization, pre-packs, chains, and sustainability
  - Axis 2 : Development of integrated sectors for thermochemical conversion
  - Axis 3 : Development of integrated biological transformation pathways
  - Axis 4 : Technological Bricks

- **Renewable Generation and Management of Electricity (PROGELEC):** PROGELEC is largely based on the foundations of three old programs, (1) Smart Homes and Solar Photovoltaics (HABISOL), (2) Innovative Energy Storage (Stock-E), and (3) Hydrogen and Fuel Cells (H-CAP). The objectives of the program are to:

- Develop innovative systems for electricity production from renewable energy, including solar photovoltaics;
- Manage intermittent production through the development of buffer storage devices;
- Develop embedded and stationary efficient storage and/or production systems;
- Pilot domestic and mobile electricity use; and
- Design reliable devices and "smart" energy management.

Public support is also employed through the Research Demonstrator Fund on New Energy Technologies (NET), which aims to fund research demonstrations.

ADEME, the French public agency, also has R&D programs, such as:

- Bioresources, Industries & Performance (BIP): Projects must enroll in at least one of the two topics detailed in the Call for Projects:
    1. Biorefineries: Plant chemistry, bio-based products for chemicals and materials, and biofuels
    2. Renewable and clean energy from biomass
- Road Vehicle of the Future: technology, systems and mobility ("investissements d'avenir"); alternative energy, auxiliary functions (including safety, comfort, energy management)

Some examples can be cited in the areas of advanced biofuels and development of electric vehicles, as well as plug-in hybrids.

- **Advanced Biofuels:**
  A majority of the biofuels currently consumed are produced by processes known as "first generation." First-generation biofuels are fuels that have been derived from sources like starch, sugar, animal fats, and vegetable oil. The oil is 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 using whole plant tissues from a wide range of agricultures, forestry, and waste/residues from these industries; dedicated crops; and organic waste. Other processes could benefit from microalgae or microorganisms capable of producing high biomass or oil converted into biodiesel, with improved energy and environmental balance. In France, challenges to the development of these industrial sectors are considerable: reducing GHG emissions in transport, limiting the country's energy dependence, and creating new economic activities.

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

- *Futurol:* This project involves ligno-cellulosic ethanol production by using a biochemical process. The project, initiated in September 2008 by a consortium known as Procethol 2G, seeks to develop and market processes, technologies, and products for producing second-generation bioethanol from not only dedicated energy crops but also agricultural and forestry by-products, green waste, and other lignocellulose-containing biomass. Approved by the competitiveness cluster with a global reach, Industries and Agro-Resources (IAR), the Futurol Project requires a total investment of €74 ($101 US) million and has received support from OSEO (the French state innovation agency) for €29.9 ($41) million. The 8-year project timeline is centered on the implementation of a lab-scale pilot project and then an industrial pilot project, in parallel with ongoing R&D work.

- *BioTfuel:* This project aims to develop and bring to the market by 2020 a chain of processes for producing second-generation biodiesel and bio-kerosene by using a thermochemical process. These fuels will be used, alone or in combination, in all types of diesel engine and turbojet aircraft. The process involves a sequence of individual steps: gasification of biomass, purification of the syngas produced, Fischer-Tropsch synthesis, and hydro-isomerisation to produce hydrocarbons. Selected under the Demonstrators Fund, "Biofuels Second-generation," which is supported by ADEME and the Regional Council of Picardy, BioTfuel brings together R&D organizations (IFP Énergies nouvelles and CEA) and industrial firms (Axens, Sofiprotéol, Total, and ThyssenKrupp Uhde) for a complete chain of production of kerosene and synthetic-diesel BtL. The project integrates all of these steps. Once developed or adapted to fossil fuel/biomass co-processing, these technologies will have to be assembled and validated via several demonstration projects to ensure efficiency on an industrial scale. This should result in the development of an integrated process by 2020.

  The budget for this project is €112.7 ($153.78 US) million, of which €33.2 ($45.3 US) million comes from public funding (ADEME Demonstrators Fund).

- *Gaya:* This project focuses on BioSNG (synthetic natural gas made of renewable resources) production by using a thermochemical process (bio-methane fuel by gasification followed by a methanation step). This research demonstration project, selected under the Demonstrator Fund "Second-generation Biofuels," explores the full chain of BioSNG production. This project, supported by the EC, aims to demonstrate a commercial pathway for gasification and methanation of residues (e.g., wood, straw) to produce synthetic bio-methane at an industrial scale. The project, lasting seven years, began in June 2010 and brings together 11 partners. Public support amounts to $18.9 ($25.79 US) million (total budget: €46.5 [$64.45 US] million). The GDF SUEZ Group will coordinate this project and will involve SMEs and public research organizations. In October 2013, the construction of the R&D GAYA platform was launched.

- *Salinalgue:* This project deals with the cultivation and processing of seaweed. The objective is to create a sustainable business culture and recovery of microalgae. The project aims to control the culture and harvesting of highly recoverable microalgae on a massive scale in an open environment on untapped salts. In addition, the project integrates bio-refinery activity in order to manufacture and commercialize bio-products (biodiesel, biogas, and molecules with high added value such as beta-carotene and omega 3) and protein for aquaculture. A demonstration project will validate the pre-industrial technical and economic feasibility of the production chain. Project management is provided by Compagnie du Vent, GDF-Suez Group; the research partners are IFREMER, INSA Toulouse, Green University, CEA Marcoule, SUPAGRO, INRIA and Tour du Valat; and the industrial partners are IDEE Aquaculture, Air Liquide, and Naskeo. The budget is €7.5 ($10.23 US) million, of which €3.9 ($5.32 US) million is financed by the FUI (Fond Unique Interministériel) and territorial entities (Collectivités Territoriales).

- *IEED (Institutes of Excellence in Low-carbon Energies) PIVERT:* The IEED PIVERT project is a collaborative platform dedicated to vegetable chemistry based on oleaginous biomass (rapeseed, sunflower, etc.). This future refinery will use local agriculture and forest resources from the Picardie region. The budget will be €246 ($335.67 US) million over 10 years.

- **Electric Vehicles and Plug-in Hybrid:**
  Vehicle electrification has great potential to reduce fuel consumption, limiting the impact on the environment and diversifying energy sources. Many projects aim to eliminate existing technical barriers. Some examples include:
  - The ANR e-MECA Project, launched in 2011 and coordinated by Valeo, aims to develop innovative solutions for ultra-compact electric powertrains with high specific power. This type of machine offers significant potential for mass production at an affordable price. The industrial partners involved in the project are Valeo and SKF; research laboratories are Satie, Dynfluid and Tempo, together with IFP Énergies nouvelles. ANR funding for this project is €1.5 ($2.05 US) million.
  - The SYNERGY project aims to simultaneously reduce CO_2 emissions and pollutants from diesel engine cars. Currently, experimental studies are being conducted to optimize the system and its settings to achieve the ambitious target of reducing CO_2 emissions by 20%. IFP Energies nouvelles (coordinator), Renault, Faurecia, Valeo, Delphi, Ecole Centrale Nantes, Mechadyne, and Honeywell are associated with this ANR project. The project is approved by the competitiveness clusters Mov'eo and Vehicles of the Future. The overall budget is €3.8 ($5.19 US) million, of which €1.6 ($2.18 US) million comes from public funding (ANR).
  - The CITYBRID project aims to develop hybrid transport solutions optimized for urban use and, more specifically, distribution. Developed under this program, demonstration vehicles will evaluate the *in situ* use of rechargeable hybrid-electric trucks. CITYBRID will also offer benefits that may be valued by the customer (electric propulsion, compliance with regulations/local incentive, or quality label). In particular, the project will show the interest in considering the kinematic chain as a whole, or even the entire vehicle, in anticipation of future regulations beyond the EURO6 norm. It will also help prepare the market for forthcoming regulations on CO_2 emissions. The project involves six partners having complementary skills: four industrial companies (Renault Trucks, FRAPPA, Vincent car-body work, and SAFT) and two public research organizations (IFP Énergies nouvelles and Joseph Fourier University). The total budget for this project is €14.2 ($19.38 US) million, of which €4.6 ($6.28) million is financed by the FUI (Fond Unique Interministériel) and territorial partner entities (Collectivités Territoriales).

  - The central role of competitiveness clusters ("Pôles de Compétitivité") in the field of transportation should also be emphasized. They are an important tool to support that sector — for example, Mov'eo (automotive car) and LUTB (Heavy trucks).
  - The IEED (Institutes of Excellence in Low-Carbon Energies) VeDeCoM project is supported by the competitiveness cluster Mov'eo and the local government (Council of Yvelines) and is active in the field of land transportation and eco-mobility. The center will receive an allocation of €54.1 ($73.82 US) million. The ANR is the public operator in charge of IEED centers.

- **Concerning the Demonstrators Fund, projects include:**
  - The Hydole (HYbride à Dominante électrique) project developed by PSA, EDF, Freescale, Leroy Somer, CEA, and IFP Énergies nouvelles. This project seeks to evaluate the potential of a new concept of dual-mode plug-in hybrid electric vehicle (pure electric and hybrid).
  - The MELODYS project (MEdium Duty & LOw Emission for DYStribution) aims to achieve three 12T and more demonstrators for different uses: delivery of dry product, refrigerated transport, and transportation with tipper (dustcart). The hybrid powertrain (diesel/electric) will be provided by an electric motor supplied with a battery-powered and/or rechargeable super-capacitors, or by a range extender (thermal "downsized" engine), or by the electric grid. The project is led by Renault Trucks, with IFP Énergies nouvelles and PVI as partners. The ADEME Research Demonstrator Fund finances the project up to an amount of €3.16 ($4.31 US) million. The second phase of the "MELODYS II" project involved experimenting, together with the Norbert Dentressangle Company, on a 16-ton truck with range extender. This vehicle was tested in the Paris area during June 2013 to early 2014.
  - The VELROUE (Véhicule Utilitaire Léger hybride bi mode) project, developed by Michelin, Renault, and IFP Énergies nouvelles, and the TIGRE (Technologies Innovantes pour Grands Routiers Économes) project, developed by Renault Trucks together with Plastic Omnium, Michelin, Tenesol, Renault, IFP Énergies nouvelles, CEP, CETHIL, and LMFA , were closed in 2012.

- **Air Transportation:**
  In the field of air transportation, R&D is being conducted in cooperation with European partners, particularly on research focusing on alternative powertrains, combustion, and low-carbon fuels.

Examples of projects in the aviation sector include:

- The CAER project: The ambition of the French R&D project CAER (Alternative Fuels for Aeronautics) is to identify new industrial sectors of aviation fuel that will complement those already certified, namely fuel from a Fischer-Tropsch synthesis and hydro-treated vegetable oils. With a budget of €8.5 ($11.6 US) million and supported by the Ministry of Transportation (DGCA), CAER is coordinated by IFP Énergies nouvelles in partnership with key stakeholders in research (CNRS, INRA, and INRIA) and industry (Airbus, Air France, Dassault Aviation, EADS_IW, Snecma, TOTAL).
- On the European level, the CORE-Jet Fuel project supports the European Commission in its dynamic and informed implementation of research and innovation 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 for all public and private stakeholders. This project is aimed 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 helps to coordinate R&D, as well as implementation efforts. The Agency for Renewable Resources (FNR) is coordinating the project development and the team, with the 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 European Union and will last three years, from September 2013 to August 2016.

Germany

Introduction

Figure 1 shows Germany's 2013 consumption levels (in percentages by weight; estimated in December), with the following ranking from most to least consumed: diesel, gasoline, and renewable fuels.

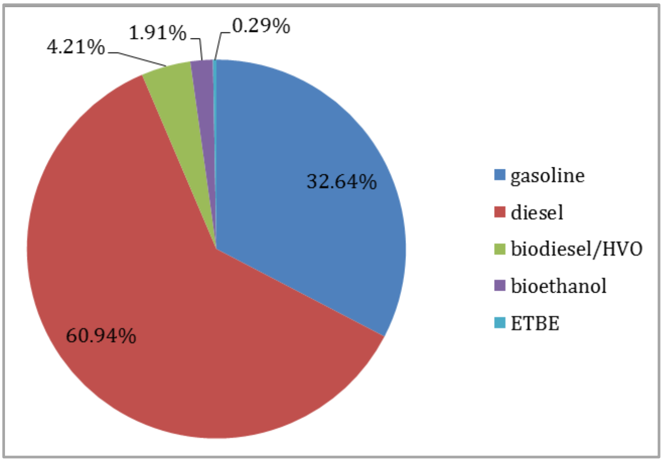

Fig. 1 2013 Consumption Levels of On-Road Transportation Fuels (%-weight) in Germany
(Source: BAFA [Bundesamt für Wirtschaft und Ausfuhrkontrolle (Federal Office of Economics and Export Control)])

In 2013, German fuel consumption for use in road transportation amounted to 53.0 million tons (mt), including biofuels. Of this amount, of 17.3 mt gasoline and 32.3 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 hydro-treated vegetable oil (2.2 mt) and bioethanol (1.0 mt). Quantities of other biofuels consumed in 2013 were pure biodiesel (32.6 kilotons [kt]); ethyl tertiary butyl ether (ETBE, [156.3 kt]), the additive for motor gasoline; pure vegetable oil (1.2 kt); and E85 (14.1 kt). The consumption of biofuels in 2013 was a little bit less than the consumption in 2012, with 3.8 mt. The consumption of pure biofuels decreased dramatically. As a consequence, the number of filling stations selling pure vegetable oil decreased from 377 in 2010 to 177 in 2013. Roughly 98% of the crude oil used in Germany (among others for fuel) has to be imported. Germany has relatively well diversified sources of imported crude oil, with countries from the former USSR accounting for

50% of imports, another 25% coming from OECD countries (mostly European), and a further 20% of crude oil imports from a range of OPEC (Organization of the Petroleum Exporting Countries) countries (notably Nigeria, Algeria, Angola, and Libya).

Table 1 shows the number of passenger cars on the road in Germany by fuel type for the years 2006 through 2013.

Table 1 Passenger Cars in Germany by Fuel on January 1 of Given Year
(Source: KBA [Kraftfahrt-Bundesamt (Federal Motor Transport Authority)])

Year	Gasoline	Diesel	LPG1	NG2	EV3	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

[1] *Liquefied Petroleum Gas, according to European fuel quality standard EN 589*

[2] *Natural Gas, according to German fuel quality standard DIN 51624*

[3] *Electric Vehicles*

A total of 52.4 million vehicles were registered in Germany as of January 1, 2013, with 43.4 million of them (82.9%) being passenger cars. Of registered vehicles, 4 million (7.6%) were motorcycles and 2.6 million (4.9%) were trucks. The rest were buses, tractors, and other vehicles. Of passenger cars, 12.6 million (29.0%) were diesel fueled and 30.2 (69.6%) were petrol fueled. Vehicles with alternative powertrains numbered 645,702 (1.5%). This total included 7,114 electric vehicles (EVs), 64,995 hybrid vehicles, 494,777 vehicles using liquefied petroleum gas (LPG), and 76,284 vehicles using natural gas (NG).

Policies and Legislation

Since 2007, firms marketing petrol and diesel are 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 fuel concerned, plus that of the biofuel replacing it, is 4.4% for diesel and 2.8% (from 2010 to 2014) for petrol. Since 2009, there has also been an overall quota for diesel and petrol combined. This overall quota was set at 5.25% for 2009 and at 6.25% for 2009 to 2014. From 2015, the benchmark for biofuel quotas will be converted from the present energy evaluation to a net greenhouse gas (GHG) reduction. This net quota will increase from 3% in 2015 to 4.5% in 2017 and to 7% in 2020. Biomethane mixed with natural gas can also be used to fill the quota.

The tax rate for pure vegetable oil outside the quota started at 18.5 Euro cents ($0.26 USD) per liter and at 18.6 Euro cents ($0.26 USD) per liter for biodiesel (B100). These amounts have gradually increased, and from January 2013 on, pure biofuels have the same tax rate as fossil diesel fuel (45.03 Euro cents [$0.63 USD)] per liter). Until 2015, tax credit is 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 natural gas and LPG used as fuel remains in effect until 2018.

The sustainable criteria for biofuels agreed to at the European level under the Renewable Energy Directive (RED; 2009/28/EC [European Commission]) and the Fuel Quality Directive (FQD; 98/70/EC) became German law in 2009. On October 17, 2012, the European Commission published a proposal for an amendment of the RED and FQD (COM [2012] 595 final)[28]. The amendment:

- Places a limit of 5% on food-based biofuels to meet a target of using 10% renewable energies in the transportation sector and to phase out state aid for these fuels after 2020,
- Includes indirect land use change (ILUC) in the reporting when assessing GHG performance of biofuels, and
- Increases the minimum GHG-saving threshold to 60%.

[28] COM type documents are legislative proposals and other European Commission communications to the Council and/or the other institutions (e.g., legislative proposals, communications, reports).

The amendment is still under discussion, because the EU Energy Council refused Lithuania's compromise proposal in December 2013. It is uncertain when the Council and Parliament will achieve a compromise.

In 2011, the German government launched the 36th Federal Emission Control Ordinance (36. BImSchV [Bundes-Immissionsschutzverordnung number 36]). It allows "double counting" of particular biofuels (e.g., biofuels based on waste and residues like straw) in accordance with article 21(2) of RED.

In addition to ensuring an appropriate, consistent tax and regulatory business environment, research and development (R&D) must be promoted across the various biofuel sectors to create conditions conducive to boosting the use of biofuels. In view of this goal, Germany's federal government supports, among other things, projects for the further development of existing and the development of new biofuel technologies. 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), around 130 R&D projects related to biofuels received funding of more than € 57 million ($78 million USD) over the last seven years. This support includes funding for projects related to bioethanol, biodiesel, vegetable oil, biomethane, and biomass-to-liquid (BTL) fuels, as well as to such areas as biofuel sustainability. The aid is granted through the Ministry's project sponsor, the Agency of Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V. or FNR). For vegetable oil, which is likely to remain a niche fuel because of its properties, priorities include creating engines (Tier 4/Stufe IV since January 2013) that run on vegetable oils.

With respect to biodiesel, the emphasis is on engine performance and critical emissions (e.g., nitrogen oxides [NO_x]) of pure biodiesel, as well as on diesel and biodiesel mixtures. With regard to advanced biofuels, project support was focused on 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. Another funding focus is on the development of ways to deploy energy from renewable resources, such as algae. At present, the project "AUFWIND" (with 12 partners) is 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 ILUC, the Federal Ministry for Environment, Nature Conservation, Building, and Nuclear Safety (BMUB) and the BMEL currently fund four projects under a common priority called "Studies on aspects of the sustainability of biofuels."

The Federal Ministry of Transport and Digital Infrastructure (BMVI [formerly BMVBS]) launched the "Mobility and Fuel Strategy" in 2011 with a major public event in Berlin 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 and was completed in 2013. The 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 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. This breadth of participation helps to ensure that the dialogue is broad-based and transparent. The main goal is 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 for their support.

With respect to electrified transportation, for example, the goal of the German government is to have at least one million electric vehicles on German roads by 2020. In May 2010, the national platform for electro mobility (Nationale Plattform Elektromobilität [NPE]) was founded during a summit talk with German Chancellor Angela Merkel. In the NPE, all relevant car manufacturers, suppliers, and research facilities are represented and within seven working groups, they discuss in specific issues and identify concrete measures.

The "Initiative for Natural Gas-based Mobility – CNG and Biomethane as Fuels" program supports the German government's goal of encouraging greater use of natural gas vehicles. Currently, natural gas comprises 0.3% of the fuel mix. CNG and biomethane have the potential to reach 4% by 2020 in Germany – representing 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.

After the federal election in September 2013, the coalition agreement between the three parties forming the 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 and. Sustainability will be included in the portfolio of subjects managed by FNR (Fachagentur Nachwachsende Rohstoffe e.V., or the Agency for Renewable Resources).

In January 2014, the international convention “Fuels of the Future 2014” took place in Berlin and was attended by more than 500 visitors from more than 30 countries. One central topic was the possible change in European biofuels policy. However, presentations and a panel discussion with members of the European Parliament did not provide clear conclusions.

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) 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 biofuels quota legislation in 2015 from quantitative quotas (energy content) to GHG reduction quotas (7% from 2020 on) will provide further impetus for advanced biofuels. Biofuels performing better than the minimum GHG reduction requirement of the RED and FQD (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.

Fig. 2 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 almost CO_2-neutral mobility. 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 one day power fuel cell vehicles. Since 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) will power 1,500 new Audi A3 Sportback g-tron vehicles for a distance of 15,000 kilometers (9,320.57 miles) every year.

Since July 2012, Clariant AG in Straubing near Munich produces cellulosic ethanol on a large scale by using the sunliquid® process. The Clariant sunliquid® process converts wheat straw into cellulosic ethanol. Mercedes-Benz decided to run fleet tests for one year with sunliquid®20. German car manufacturers in general see significant benefits from an E20 fuel, if engines are optimized for this fuel grade.

Fig. 3 Mercedes-Benz Cars in Front of the Sunliquid® Demonstration Plant
(Source: Daimler AG)

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. The fleet test will demonstrate the technical capability of sunliquid®20 with series vehicles.

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 2020 target is still to use 10% renewable energy sources in transportation. The biggest uncertainty is how the RED/FQD amendment proposal of the European Commission from October 2012 will be implemented (i.e., as a cap on food crop-based biofuels, multiple counting, ILUC factor). 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, the replacement of the biofuels quota in terms of its energy equivalent for 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, up-scaling advanced biofuel production processes to an industrial scale) will be other important challenges.

From a process technology perspective, ethanol from lignocellulose material, biomethane, and BTL fuels may become promising mid-term options for replacing fossil fuels in Germany.

Additional References

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- Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten, www.tfz.bayern.de

Benefits of Participation in the AMF IA
The German biofuels market is one of the largest in the world. Because of changing political framework, advanced motor fuels will become more important over the short and long term in Germany. FNR, as a national funding organization, addresses many different issues regarding advanced motor fuels made of biomass. AMF addresses most of the issues that are important in our country (e.g., to facilitate the widespread use of sustainable fuels of high quality). Most of the sponsored research projects under the AMF umbrella are relevant to our funding activities, and common project sponsoring offers cost-efficient participation. Furthermore, participation in the AMF provides German researchers and stakeholders with the opportunity to become part of a scientific network of excellent researchers from around the world. For example, Germany participates in 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. Its operating Agent is Rostock University, Chair of Piston Machines and Internal Combustion Engines.

Israel

Introduction

Israel is a fuel-poor country and is forced to refine most of the fuel products it requires by using imported raw petroleum or to import ready-made fuel products. The Israeli government desires to decrease petroleum dependency on the basis of energy security, security of supply, geopolitical issues, economic benefits, and environmental benefits.

As of 2012, the consumption of fuels for transportation in Israel grew 2% since 2011 and used approximately 2.7 million tons of gasoline and a similar amount of diesel for transportation. The vehicle fleet in Israel consists of 85% gasoline fueled vehicles and 15% diesel cars, which are mainly heavy-duty vehicles, buses, and trucks.

On January 13, 2013, the Government of Israel's cabinet approved a program to encourage lowering dependence on crude oil for transportation. The program sets ambitious targets for Israel: cut the use of oil for transportation by 30% by 2020 and by 60% by 2025, as compared to the currently projected "business as usual:" oil consumption.

The government resolution is an extension of the Alternative Fuels Initiative program from 2011. The original initiative aimed to serve as a catalyst for reducing global dependence on crude oil for the purposes of geopolitical stability, economic security, and environmental protection, while establishing Israel as a center of knowledge and industry in the field of oil alternatives for transportation.

The targets (30% reduction by 2020 and 60% by 2025) are based on a bottom-up analysis of the various Israeli transportation market sectors, under the assumption that any solution must be economically viable to the end user, as well as to the economy.

Among the alternative fuels being considered are compressed natural gas (mainly for heavy-duty trucks and buses), methanol (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 Alternative Fuels Initiative also aims for and projects, in the longer term, use of biofuels from second- and third-generation non-edible crops (developed in Israel), and a process of waste to energy conversion.

The latest resolution focuses on activities that will help build an alternative fuels ecosystem and includes pilots for new technologies, regulation and standardization of fuels and vehicles, infrastructure, and an alternative fuel-friendly tax policy (in addition to the current progressive tax policy for fuel efficiency). Together, these efforts and others aim to accelerate the adoption of alternative fuels in Israel and throughout the world.

A forecast of the economic viability of fuels and market needs is presented in Figure 1.

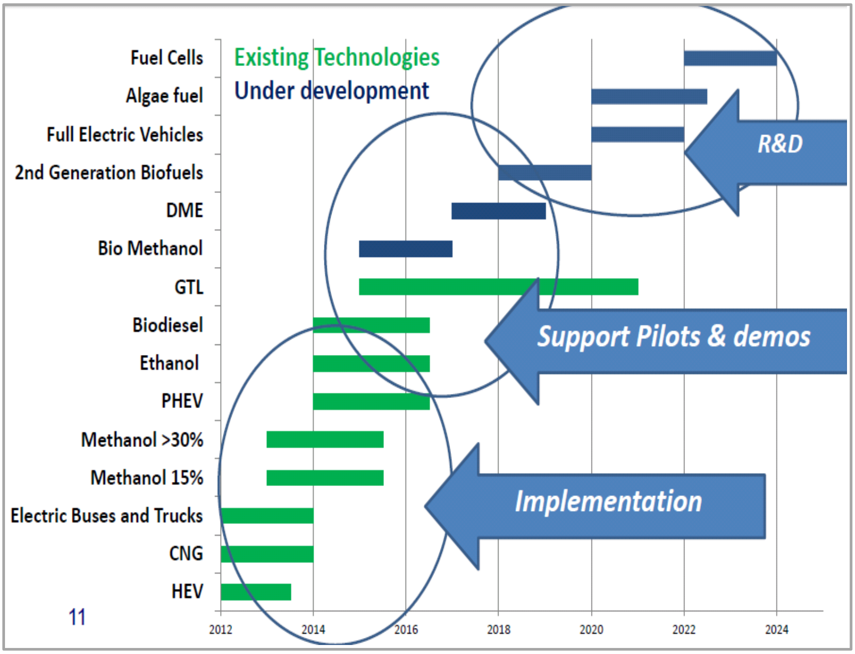

Fig. 1 Economic Viability of Fuels and Market Needs
(Source: The Israel Alternative Fuel Initiative website)

Government Activity

- One-stop center
- Academic centers and grants
- Clusters of academia/industry
- Pilots and test bed
- Unified regulation process
- Chief scientist and co-investment fund
- New global pricing

- Seminars
- Bilateral agreements

Implementation

At present, there are 87 oil-alternative start-ups and commercial spin-offs that need funding.[29]

The companies' activities are in the fields of:

- Feedstocks — raw material that is eventually converted into fuel (21% of companies)
- Fuel production — converting biomass or non-biomass feedstocks to fuel (34% of companies)
- Vehicles — platform or components that make transportation less expensive per kilometer than standard oil-dependent vehicles (34% of companies)
- Infrastructure — critical technologies that enable oil independence (11% of companies)

The Ministry of National Infrastructure, Energy and Water Resources acts to implement fuels based on natural gas; namely, CNG, GTL (gas-to liquid) fuels (drop-in fuels), and methanol. The Ministry conducts "well-to-wheel" projects, including their technical, regulatory, and economic aspects. The task is supported by a number of pilot and demonstration projects in this field and a techno-economical study of these fuels and their relevance to the Israeli market. The extensive analysis considered all relevant segments of the supply chain, including production, transportation, and consumption of fuels by end users, as well as the infrastructure required.

[29] IEP Database of OACs initiated in December 2009 by the Israeli Institute for Economic Planning, last updated fully in 2011 Q3.

Italy

Introduction

In 2012, consumption of primary energy in Italy was around 176.350 megatons of petroleum equivalent (Mtpe). As in previous years, oil remained the main energy source, representing 36% of consumption; natural gas (NG) followed closely at 35%; and the percentage for renewable sources increased a bit to 15% of consumption (Figure 1).

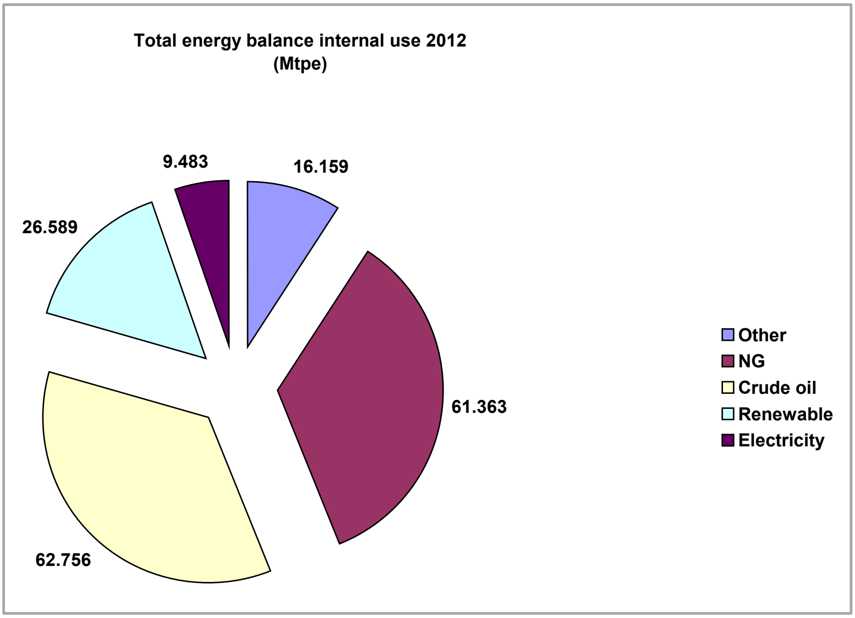

Fig. 1 Total Energy Balance by Type of Source in 2012
(Source: Ministry for Economic Development, 2012, National Energy Balance)

In 2012, Italy depended largely on imported oil; it imported 85.464 Mtpe (Figure 2).

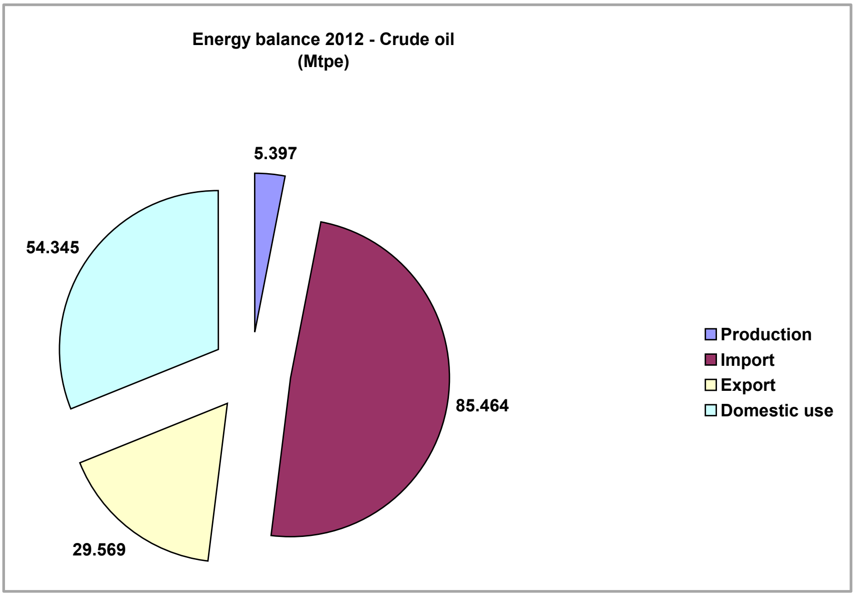

Fig. 2 Crude Oil Energy Balance in 2012
(Source: Ministry for Economic Development, 2012, National Energy Balance)

The major user (about 66%) of derived oil products in 2012 was the transportation sector (Figure 3).

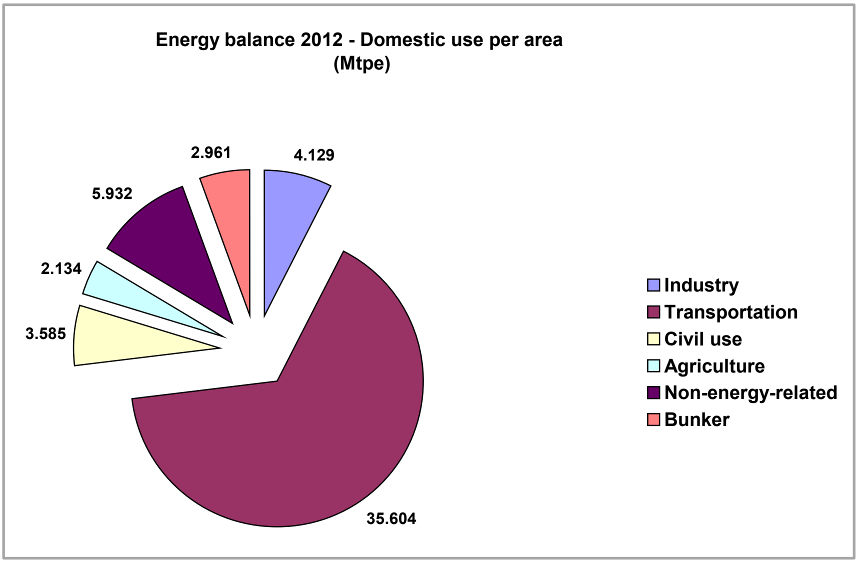

Fig. 3 Domestic Use of Oil per Sector in 2012
(Source: Ministry of Economic Development, 2012, National Energy Balance)]

The main fuels used in the road transportation were diesel fuel (66%), followed by gasoline (28%). Significant amounts of natural gas (2%) and liquefied petroleum gas (LPG = 3.9%) were also used in this sector (Figure 4).

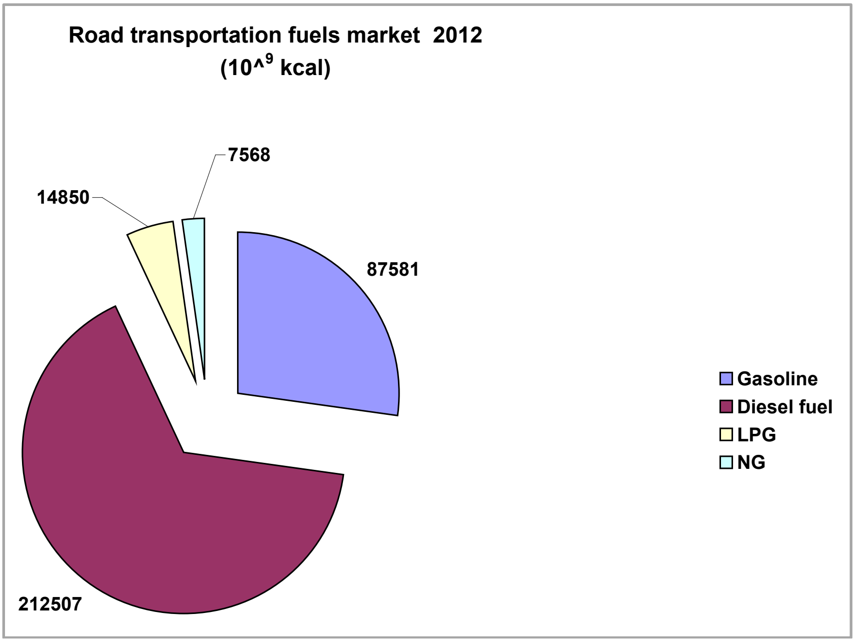

Fig. 4 Market for Different Types of Fuels in Road Transportation Sector in 2012
Source: Ministry for Economic Development, 2012, National Energy Balance)

With regard to the types of vehicles using the fuels, the top categories (in terms of number of vehicles) were passenger cars (75.4%), followed by motorcycles (13.2%) and lorries (8.2%) (Figure 5).

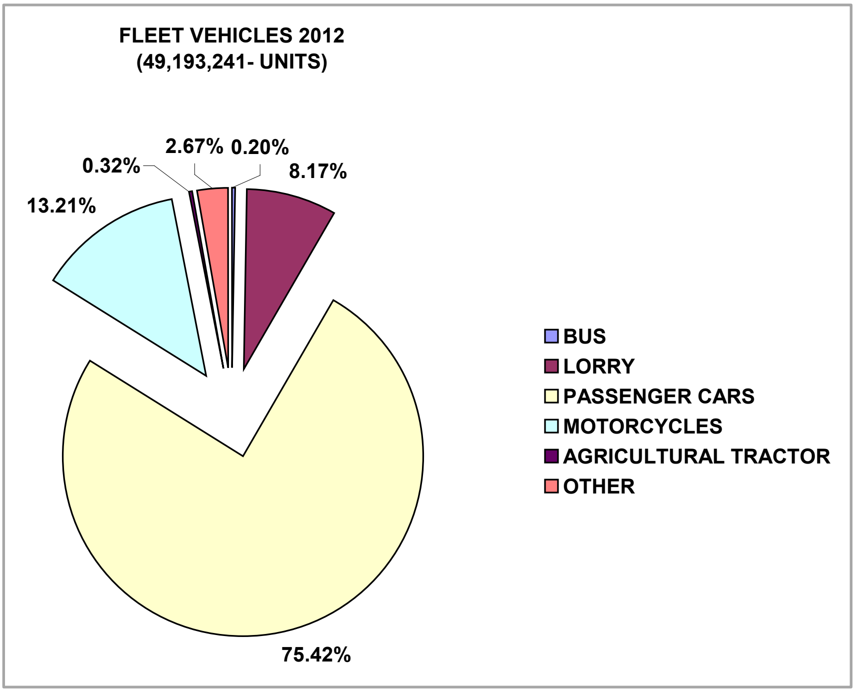

Fig. 5 Types of Fleet Vehicles Used in Road Transportation Sector in 2012
(Source: ACI, 2011, Autoritratto)

With regard to passenger cars, the top categories were those that ran on gasoline (53.25%), followed by diesel fuel (39.77%). A significant percentage of vehicles also ran on natural gas (1.94%) and LPG (5.02%) (Figure 6).

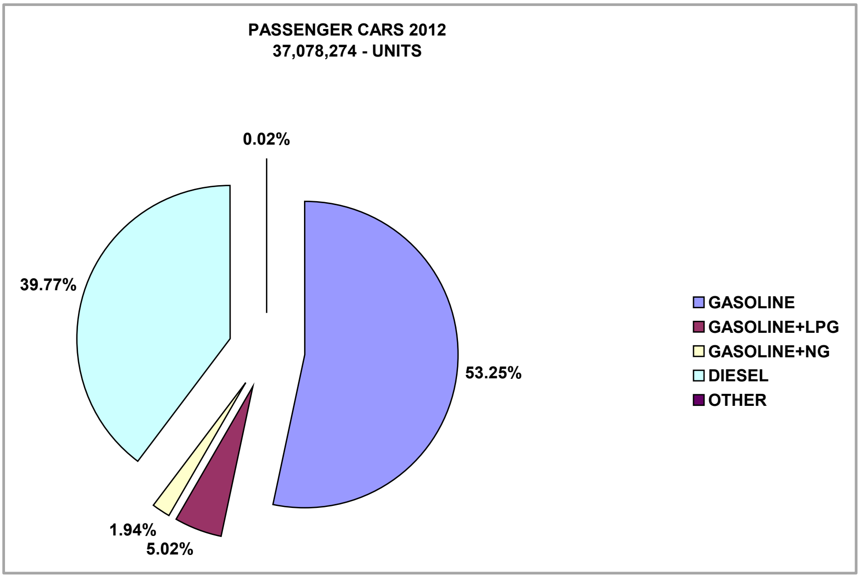

Fig. 6 Types of Fuel Used by Passenger Cars in 2012
Source: ACI – Autoritratto 2012

Besides, diesel-fueled vehicles can employ up to 7% of biodiesel; gasoline-fueled vehicles can employ gasoline containing oxygenated bio-fuels where oxygen may amount to 3.7%.

Policies and Legislation

In the long and very long term (2030–2050), Italy subscribes to the spirit of the European Roadmap 2050 for a low-carbon economy, which 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, biofuels, and the capture and storage of carbon dioxide (CO_2).

Italian Law has adopted two European directives: Renewable Energy Directive (2009/28/EC) and Fuel Quality Directive (2009/30/EC). Under Italian Law 2009/99 (of July 23, 2009) and in accordance with European Specification EN590:2009, the Italian Government has given permission for diesel fuel to contain biodiesel fuel (FAME) in a percentage of up to 7% as other European County. 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-source- as 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 traffics in urban areas.

Implementation: Use of Advanced Motor Fuels

Figure 7 shows the distribution of alternative fuels used in Italy in 2012. LPG and biodiesel are the primary sources 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 *tert*-butyl ether (ETBE), derived from bioethanol. In 2012, the amount of bio-ETBE used in gasoline was 120 kilotons (kt), and the amount used in bio-ethanol was 0,317 ktons.

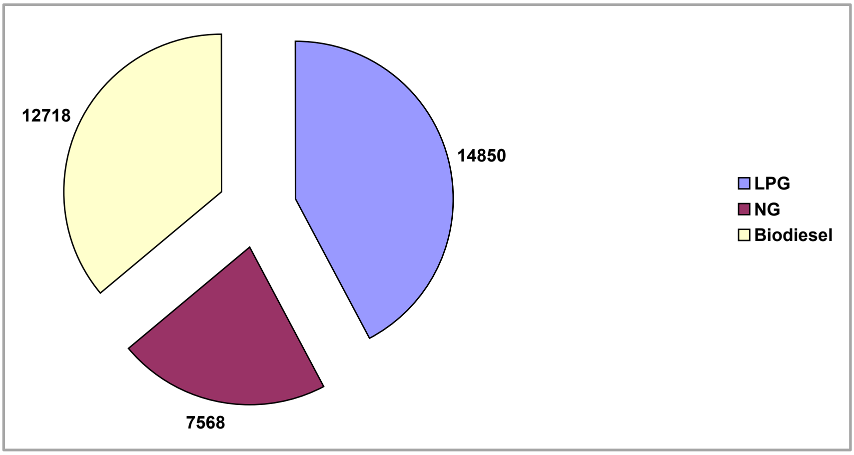

Fig. 7 Alternative Motor Fuels Used for Transportation in 2012 (10^9 kcal)
(Source: Ministry for Economic Development, 2012, National Energy Balance)

At the end of 2013, there were 996 natural gas stations in the country, as well as a fleet of more than 700,000 cars that use natural gas. 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 natural gas 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 1.8 million LPG-fueled cars in 2012.

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 and high-quality bio-fuels. The project is the first in the world designed to convert a conventional refinery into a bio-refinery, utilizing 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 existing facilities of Venice refinery that was implemented starting in the second quarter of 2013 and completed by the end of that year. Biofuel production will start in the second quarter of 2014 and grow progressively as new facilities enter into operation. The new facilities 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 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. Building 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, Eni has completed in 2013 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). Starting operation with the Oil In occurred 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 gasoil without generating coke or fuel oil, for which the market is constantly declining.

Outlook

Italy has confirmed the 2020 target of 10% for biofuels, which, in terms of the costs to the system, could reach about €1 billion annually (extra-cost estimate compared with the use of fossil fuels) To reach this in Italy target, here are the yearly minimum increases in the percentage of energy to be derived from biocomponents:

- From January 1 to December 31, 2007: 1%
- From January 1 to December 31, 2008: 2%
- From January 1 to December 31, 2009: 3%
- From January 1 to December 31, 2010: 3.5%
- From January 1 to December 31, 2011: 4%
- From January 1 to December 31, 2012: 4.5%
- From January 1 to December 31, 2013: not defined
- From January 1, 2014: 5%
- From 2015 through 2019: not yet defined

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

In the short run, the 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. This is why European Directive 28/2009 on this matter will be reviewed in 2014. 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.

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- http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/annuario-statistico.html
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Benefits of Participation in the AMF IA

In Italy, information on AMF 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 23.3% of total energy consumption in Japan. Of this transportation sector energy consumption, passenger transport is responsible for 62%, and freight transport is responsible for the other 38%. Energy for transport in Japan depends mostly on imported oil (Figure 1).

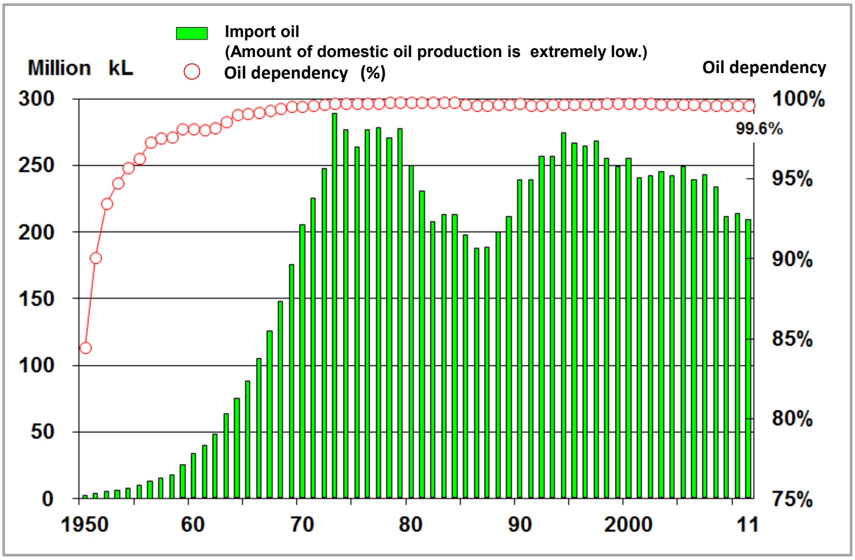

Fig. 1 Transition of Crude Oil Imports and Oil Dependency in Japan [1]

Figure 2 shows the energy sources used in the transportation sector [2]. Oil-related energy accounts for 97.9% 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.

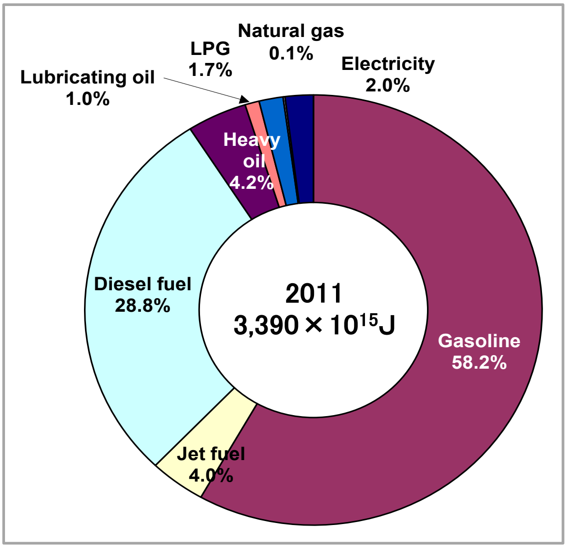

Fig. 2 Energy Sources Used in the Transportation Sector in 2011

Table 1 Current Penetration of Low-Emission Vehicles in Japan

Vehicle Type	Methanol [3]	CNG [4]	Hybrid [5]	EV [6]	Vehicle Registration [7]
Passenger Vehicle	–	1,548	2,016,691	13,266	39,922,526
Truck LD MD + HD	576	5,483 18,683	11,118	11	5,896,100
Bus	–	1,560	738	15	226,047
Special Vehicle	–	3,833	4,245	30	1,654,739
Small Vehicle	–	11,483	–	8,940	–
Total	**576**	**42,590**	**2,032,792**	**22,262**	–

(LD, MD, HD = light, mid, and heavy duty)

Policies and Legislation

In May 2006, Japan's Ministry of Economy, Trade and Industry (METI) developed a new national energy strategy, which set two major targets for the transportation sector to achieve by 2030. One is to reduce its dependence on oil to 80%, and the other is to improve its energy efficiency by 30%.

The most effective short-term strategy for reducing energy consumption and increasing energy security is to improve fuel economy, so more stringent fuel economy standards were introduced. For a long-term strategy, METI is taking a comprehensive approach to significantly reduce energy consumption and reduce oil dependence. In December 2006, the Ministry announced its next-generation vehicle fuel initiative, which focuses on the further development and introduction of four technologies: (1) biofuel, (2) clean diesel fuel, (3) next-generation battery, and (4) fuel cell/hydrogen-based technologies.

Although the basic energy plan for Japan was revised in June 2010, after the Great East Japan Earthquake on March 11, 2011, major discussions began to focus on establishing a new plan. The discussion arose out of deep reflections on the enormous damage to the national livelihood, to the regional economies, and to the environment that resulted from the accident at Fukushima Daiichi Nuclear Power Station, which occurred in the wake of the earthquake.

Implementation: Use of Advanced Motor Fuels

Liquefied Petroleum Gas (LPG)

Japan's LPG market is the sixth largest in the world and has a long history. The main merit of LPG is that it costs less than gasoline. Its use in vehicles in Japan has conventionally focused on taxis, which quickly accumulate mileage. However, in recent years, great progress has been made in the energy savings of gasoline, making the cost benefits of LPG smaller. The taxi industry, in particular, is continuing to shift toward using hybrid vehicles (HEVs) and other environmentally friendly cars [8, 9]. Furthermore, because the scale of the taxi market is decreasing, automotive LPG consumption has also been decreasing since 2008. Sales of LPG vehicles are also low. Moreover, research and development designed to improve energy efficiency and performance were delayed. As a result, the performance of LPG vehicles fell behind that of gasoline vehicles. However, this situation has begun to change with the launch of an LPG vehicle equipped with an electronically controlled fuel injection system [10] and of a dual-fuel hybrid vehicle that can use both gasoline and LPG [11]; both were converted from gasoline models.

Natural Gas

Terms like "shale gas" and "unconventional natural gas" have started to appear in articles virtually every day — evidence that the world is currently undergoing a natural gas boom. There are 240 years' worth of proven natural gas reserves — far more than crude oil reserves. The hope is to have a long-term and stable supply of natural gas.

Because of the realization of the availability of natural gas, the adoption of natural gas vehicles has been accelerating around the world. In Japan, natural gas has conventionally been used in trucks, buses, and other vehicles used for urban transportation. However, now fleets of large trucks (25-ton gross vehicle weight or GVW) have started to use natural gas. Currently, Japanese automakers have not been manufacturing or selling large natural gas trucks for domestic use. Consequently, Kyodo, a company specializing in natural gas conversions, teamed up with an engine conversion company called HKS to develop a natural gas version of the Giga, a large truck manufactured by Isuzu Motors Limited. So far, these companies have produced slightly fewer than 40 of these trucks.

Isuzu Motors Limited started launching a new heavy-duty CNG truck in 2015, and it is also focusing on developing natural gas trucks, including trucks that operate on liquefied natural gas (LNG) and have natural gas engines with higher efficiency.

Although CNG is used in heavy-duty vehicles in Japan at this time, it is hoped that LNG, which has an energy density roughly three times higher than that of CNG, will be used as a fuel for long-distance heavy-duty vehicles (Figure 3).

Fig. 3 Heavy-Duty CNG Truck in Japan

Hydrogen

Research on hydrogen engines has a long history. Similar to fuel cells, hydrogen engines are a power source with zero fuel-derived carbon dioxide (CO_2) emissions. At the same time, these engines are capable of using mature basic technologies, such as existing production equipment and auxiliary devices. Consequently, hydrogen engines are considered to have the potential for low-cost implementation, and research on how to accomplish this is under way at universities, research institutes, and automakers around the world. Issues associated with the engines include suppressing abnormal combustion caused by the high ignitability of the fuel, developing countermeasures for the high level of nitrogen oxides (NO_x) emissions that result when the engines are operated at high power, and improving thermal efficiency. Recent research focuses on direct injection as a means of resolving these issues.

In Japan, reports on hydrogen engines were published by the group of Tokyo City University and the National Traffic Safety and Environment Laboratory (NTSEL), Mazda, and Kinki University. Mazda announced a method of improving thermal efficiency in homogeneous-charge, premixed combustion; it focuses on the practicality of a rotary engine using hydrogen as the fuel.

Dimethyl Ether (DME)

Field tests on two 3.5-ton, DME, gull-wing trucks (Figure 4) built by the Isuzu Advanced Engineering Center and registered for commercial use (green license plates) are continuing [12]. The test vehicle in the Kanto region completed the field test at the end of July 2011 after driving a total of 100,000 km. As of the end of February 2012, the test vehicle in the Niigata region had been driven a total of 95,000 km, and the project was finished in 2013.

The standardization of DME as a fuel is under discussion in ISO/TC28/SC4/WG13. This working group (WG) is debating the quality of DME as a base fuel, including one for automotive use. Discussions have moved from the Committee Draft (CD) phase to the Draft International Standard (DIS) phase (ISO CD16861: DME Fuel Quality). Furthermore, WG14 has performed round-robin tests of the five analysis methods. Discussions on the creation of the DIS are continuing. A series of studies on the quality of automotive DME fuel is due to start.

Fig. 4 DME Truck in Japan

Bioethanol

The main effort in Japan to use biofuel occurred under the Project for Developing Soft Cellulosic Resources Utilization Technology, which was run by the Ministry of Agriculture, Forestry and Fisheries (MAFF). It ended in 2012. The project has been succeeded by three Model Demonstration Projects of Local Biofuel Use [13]. Other examples of biofuel projects include one in the Okinawa prefecture; it supplied approximately 40,000 kL of E3 in 2012. As of April 2013, E3 is available in 46 service stations in Japan [14]. The Japanese Ministry of the Environment also constructed a bioethanol production facility at Miyako-jima. It ended trial operations in 2011 and later was restarted; Japan Alcohol Corporation is the designated managing entity, with operations carried out by the city government [15]. On November 30, 2012, an emissions reduction methodology involving switching from fossil fuels to bioethanol was approved by the Domestic Credit Certification Committee; it enabled application of the Japan Verified Emission Reduction System [16]. As of May 2013, the number of service stations selling biogasoline blended with ethyl tertiary butyl ether (ETBE) had increased by 11% to 3,440 across the whole of Japan [17].

Biodiesel

In 2012, there were changes to biodiesel fuel quality standards. On March 30, 2012, Japan amended its diesel quality control law when METI issued Ordinance 26. Previously, in the quality assurance (QA) items for B5 diesel, an increase in the acid number had been recognized as a measure of oxidation stability. In this old method, the acid number was measured after a certain period when the sample fuel was held at a constant temperature and bubbled with oxygen. The increase from the initial value was then calculated by the ΔTAN (total acid number) method. This measurement method was changed in the new 2012 law. The sample fuel is placed in a sealed container, pressurized with oxygen, and heated. The relationship between time and internal pressure is recorded, and the time taken for the internal pressure to drop by a maximum of 10% is now used to evaluate oxygen stability (i.e., the PetroOXY method). Its standard value is 65 minutes or more.

Outlook

Some ongoing activities, including those related to the outlook for advanced motor fuels covered in the New National Energy Strategy developed by METI in May 2006, are listed here:

- By 2020, reexamine the regulation on the upper blending limit for oxygenated compounds that contain ethanol, with goals of (1) speeding up improvements to the biomass-derived fuel supply infrastructure through the use of environmental and safety countermeasures in gas stations and (2) prompting the automobile industry to accept 10% ethanol mixed gasoline. Moreover, strive to spread the use of diesel cars, the exhaust of which, terms of emissions, is no worse that of gasoline cars. This effort is also important with regard to the use of gas-to-liquid (GTL) technologies because a related goal is to promote the use of GTL technologies by the middle of 2010.
- Examine (1) the existing support for regional efforts designed to expand domestic bioethanol production and (2) the development of support for importing biomass-derived fuels, such as bioethanol. Promote the supply of new fuels, such as biomass-derived fuels. Improve economic efficiency by promoting the development of highly efficient ethanol production and GTL technologies.
- Promote the dissemination of electric and fuel cell vehicles, which are already about to be put into practical use. Also work on the intensive technical development of next-generation batteries and fuel cell vehicles. Establish a safe, simple, efficient, and low-cost hydrogen storage technology. Promote the development and practical application of next-generation vehicles.

Since the Great East Japan Earthquake on March 11, 2011, there were major discussions about establishing a new basic energy plan for Japan. The new plan was approved in a Cabinet meeting on April 11, 2014.

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Benefits of Participation in the AMF IA
One can find out a lot of the latest information on the use of advanced motor fuels throughout the world by studying the activities being carried out under the AMF Implementing Agreement. Understanding what is going on in the field of motor fuels in various countries is important for stakeholders (e.g., policy makers, industries).

Republic of Korea

Introduction

In Korea, all city buses (more than 38,000) use natural gas (Figure 1), and all taxis use liquefied petroleum gas (LPG). However, it is now mandatory that all diesel fuel contain 2.0% bio-diesel fuel (i.e., BD2). There is no policy on bio-ethanol (BE) use.

The Korean Government discussed future scenarios on how to introduce BD and create a long-term road map. 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 by 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 specified 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 two-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 BE will reach 5% in 2020, as a result of an incremental increase in the mixing ratio associated with the new renewable energy sources each year. Also, the Ministry of Trade, Industry and Energy (referred to in a subsequent paragraph) announced that the quality standards should be to ensure the proper quality of renewable energy sources, 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 liquefied natural gas (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 natural gas 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 rest 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.

Biodiesel has been used as an automotive fuel in Korea since 2002. After a few years of demonstration, the Ministry of Trade, Industry and Energy 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 biodiesel 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 new 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, BE5 and BD5 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 2.0–3.0% would be reviewed. In the second step from 2018 to 2020, BE5 and BD5 would be introduced. The final step from 2020 to 2023 would be the BD7 and BE7 era. The introduction of biogas (BG) beginning in 2017 is also being considered.

Additional References

- www.kpetro.or.kr/

Spain

Introduction

Almost all of the oil and gas used in Spain is imported, with less than 1% being domestically produced (Figure 1). In 2013, oil imports decreased with respect to the previous year. Mexico became the first oil supplier of crude oil (15.9%), followed by Russia (14.0%), Saudi Arabia (13.8%), and Nigeria (12.5%). These four countries represented almost 60% of total Spanish imports in this period. The decrease in imports from Organization of the Petroleum Exporting Countries (OPEC) continued, and a policy of supply diversification was maintained. (For instance, in December 2013, 23 different crude oils were imported from 17 countries.)

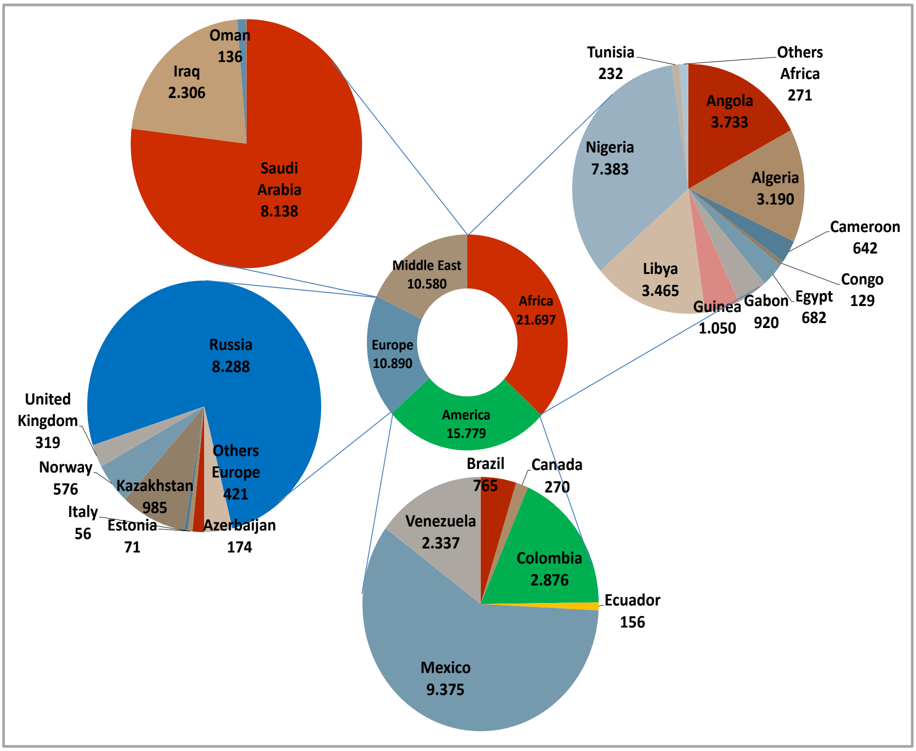

Fig.1 Oil Imports in 2013 (kt)

(Source: Corporación de Reservas Estratégicas [CORES])

With regard to the external trade of oil products, total imports amounted to 14,329 kt (a decline of about 13.2% from the previous year), while exports reached 18,547 kt. The total physical balance of the external trade of oil products in 2013 resulted in a net export balance of 4,218 kt (Figure 2).

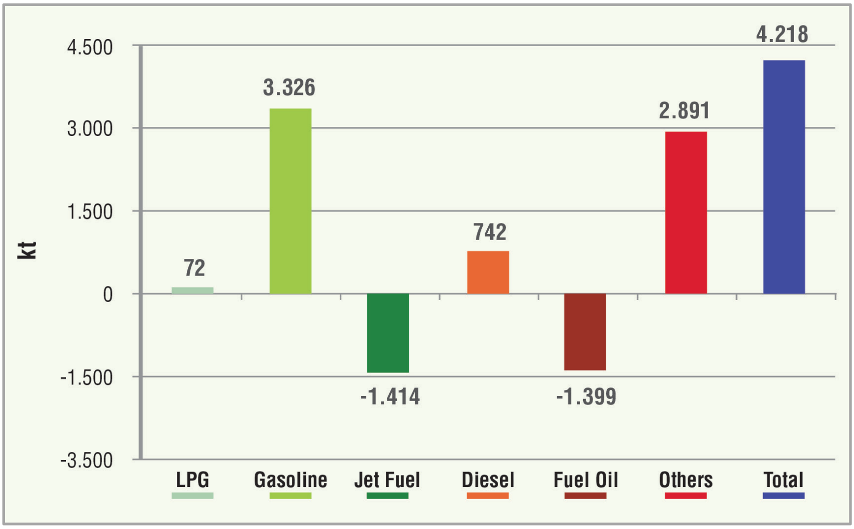

Fig. 2 Imports and Exports of Oil Products in 2013
(Source: CORES)

After peaking in 2007, total fuel consumption in Spain has continued to shrink as a result of the continuing economic crisis there. Gasoline consumption continues to lose its market share in favor of diesel (Figure 3).

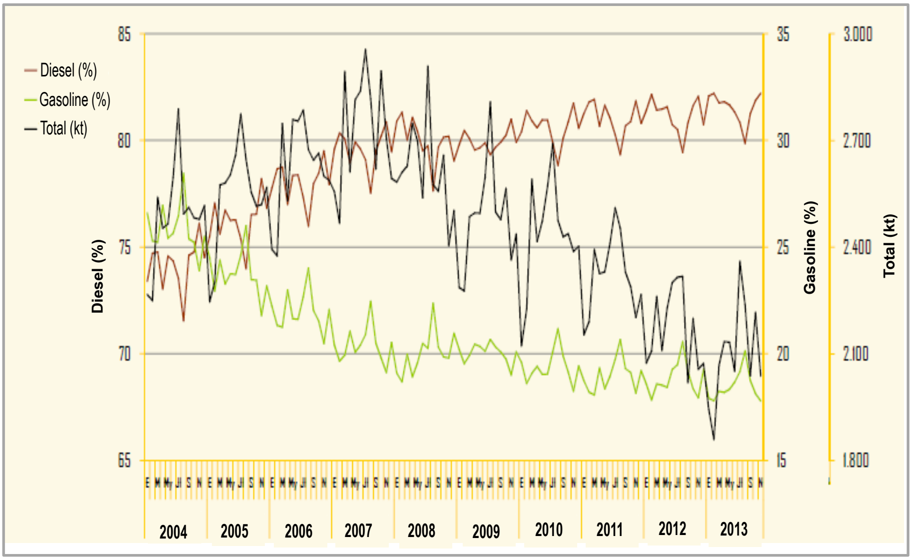

Fig. 3 Gasoline and Diesel Consumption, 2004–2013
(Source: CORES)

Policies and Legislation

Biofuel Use Targets

Because the tax exemption for biofuels expired on December 31, 2012, the only legal incentive for biofuel consumption in Spain since 2013 has been the blending mandate. This obligation requires all operators to sell a specific percentage of biofuels each year. However, the target for 2013 and coming years was revised to a lower level by Law 11/2013 in order to support entrepreneurs and boost economic growth and job creation. Thus, the overall energy-based obligation for biofuel consumption was reduced from 6.5% in 2012 to 4.1% in 2013; the biodiesel-specific obligation was reduced from 7.0% to 4.1%; and the bioethanol-specific mandate reduced the obligation from 4.1% to 3.9%. The 2013 obligations are repeated here:

- Overall mandate: 4.1,
- Biodiesel mandate: 4.1, and
- Bioethanol-specific mandate: 3.9.

Transposition of the Renewable Energy Directive (RED) into a National Regulation

Royal Decree 1597/2011 transposed sustainability criteria established in the Directive 2009/28/EC (RED) into a national regulation and defined Spain's national scheme for verification of compliance. Sustainability was to have been required as of January 2013, but a delay in implementation was approved by means of Law 11/2013. The date for meeting sustainability requirements will be established by a resolution that will be published at least 8 months before it is enforced. A transitory period will begin then and last until the verification system is fully in place.

Biodiesel Production Quota System

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. A Resolution of the Directorate General for Energy Policy and Mines (a unit of the Ministry of Industry, Energy and Tourism) was issued in November 2013; it included a provisional list of fatty acid methyl ester (FAME) facilities eligible for two years. The definitive list will be approved by means of a Resolution of the Secretary of State of Energy.

Technical Fuel Specifications

Royal Decree 1088/2010 (which modifies Royal Decree 61/2006) contains specifications on gasoline and diesel fuel, the use of biofuels, and other matters. It established the obligation, until December 31, 2013, of supplying, to all petrol stations, gasoline having at least the lowest octane index, with less than 5% bioethanol in terms of volume and less than 2.7% of oxygen in terms of mass. (This so-called “protective petrol” is intended to be used in the oldest vehicles, which are not prepared to operate on fuel with a higher bioethanol content.) A Ministerial Order dated December 26, 2013, extended this obligation until December 31, 2016.

Implementation: Use of Advanced Motor Fuels

In 2013, consumption of alternative fuels (mainly biofuels) decreased as a consequence of a lower blending mandate; the percentage barely reached 5% of total consumption (Figure 4).

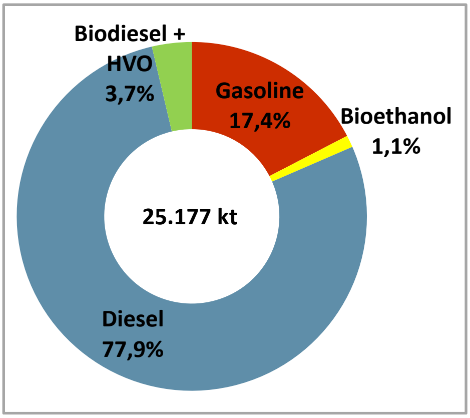

Fig. 4 Percentages of Alternative Fuel Use
(Source: CORES)

Monthly biofuel consumption is shown in the following chart (Figure 5).

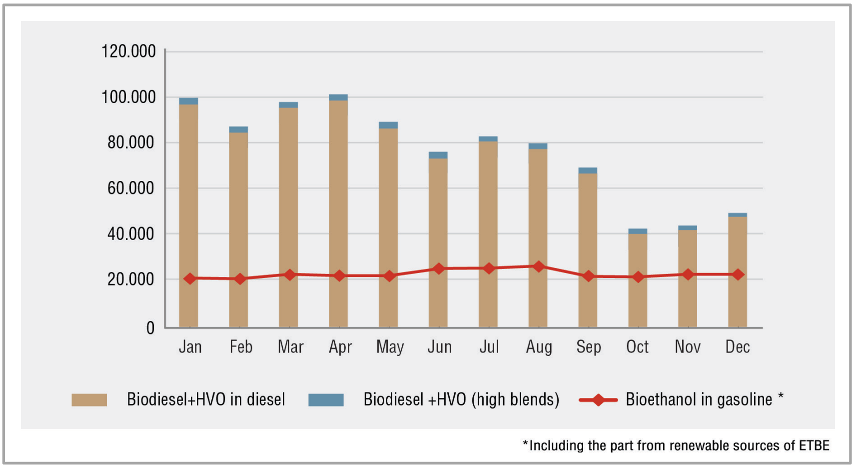

Fig. 5 Monthly Biofuel Consumption
(Source: CORES)

The monthly shares of biofuels in diesel and in gasoline (in terms of mass) are shown in Figures 6 and 7, respectively.

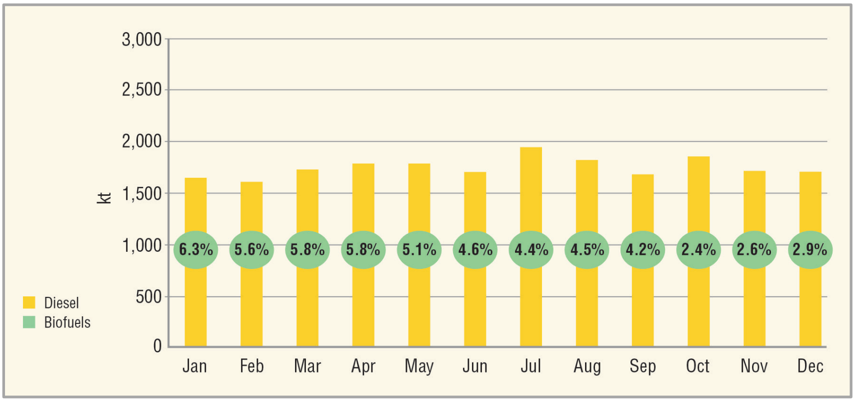

Fig. 6 Monthly Share of Biofuels in Diesel
(Source: CORES)

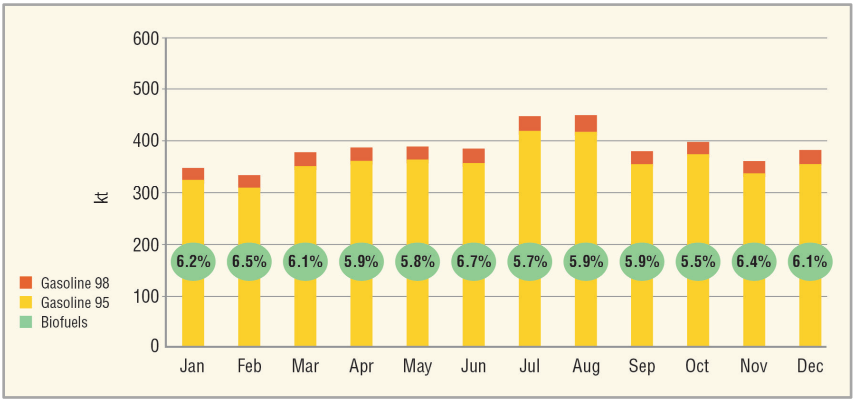

Fig. 7 Monthly Share of Biofuels in Gasoline
(Source: CORES)

The current number of vehicles capable of using other alternative fuels (liquefied petroleum gas or LPG, natural gas) is shown in Figure 8.

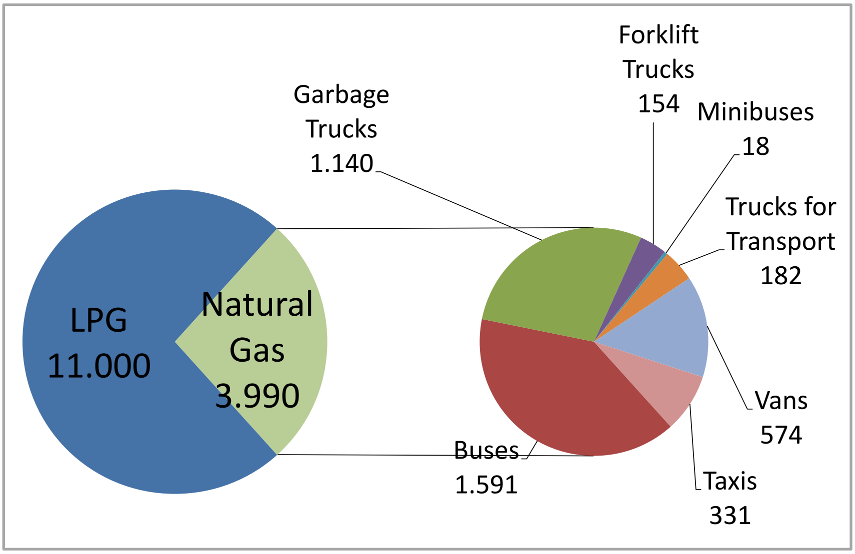

Fig. 8 Number of Vehicles That Could Use LPG and Natural Gas
(Source: Instituto para la Diversificación y Ahorro de la Energía [IDAE])

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 kt of oil equivalent (ktoe) in 2020. On the one hand, the amount of 400 ktoe corresponds to biofuels in gasoline (bioethanol and bio-ethyl *tert* butyl ether [ETBE]). On the other hand, the amount of 2,313 ktoe corresponds to biofuels in diesel (mainly FAME and hydrotreated vegetable oil [HVO], which achieved significant market penetration in 2013).

References

- CORES: Corporación de Reservas Estratégicas, www.cores.es
- IDAE: Instituto para la Diversificación y Ahorro de la Energía, www.idae.es

AMF 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

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.

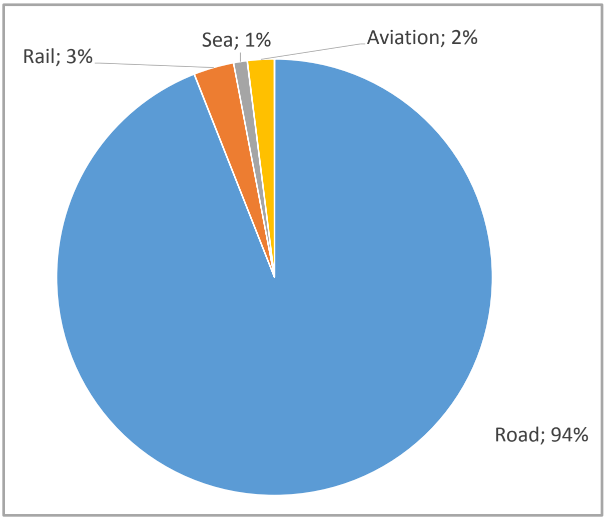

Fig. 1 Share of Energy Use among Different Transport Modes in 2012

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.

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.

**Information presented in this 2013 report was current at the time of preparation. Information for calendar year 2013 will be presented in the 2014 Annual Report.*

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.

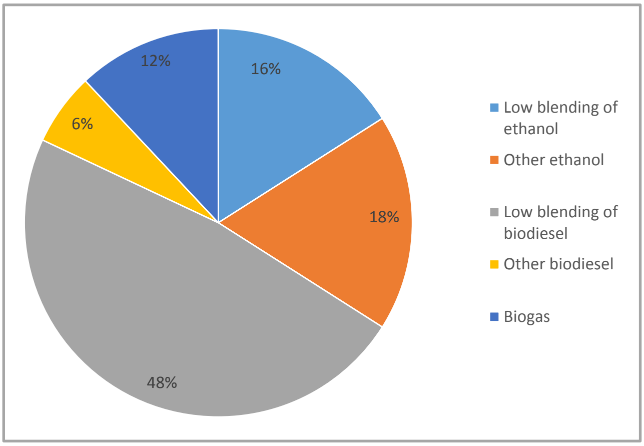

Fig. 2 Share of Alternative Fuel Use in 2012

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[30] 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 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

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

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.

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

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.

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.

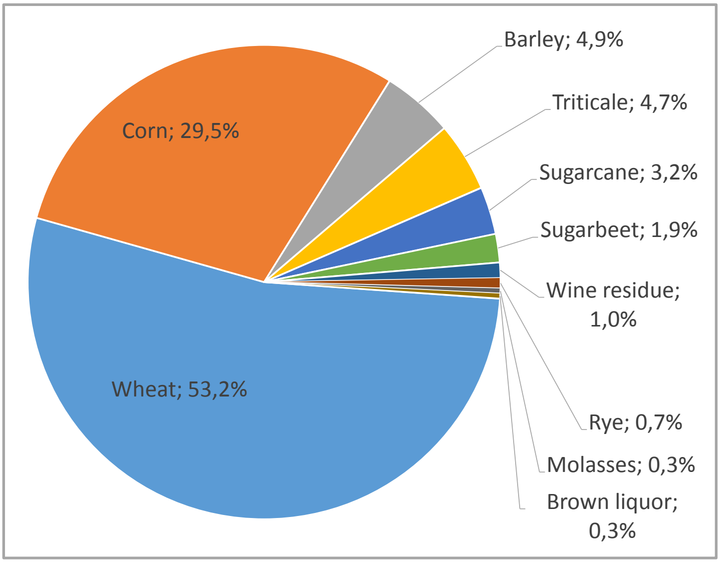

Fig. 3 Ethanol Feedstocks

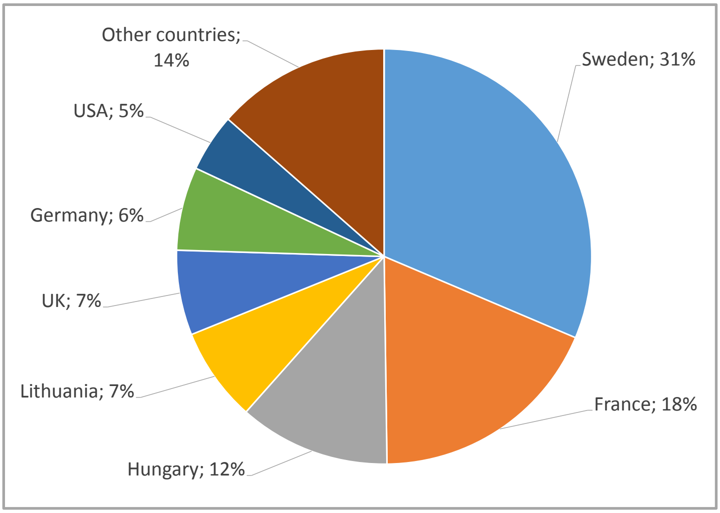

Fig. 4 Countries of Origin for Ethanol Feedstocks

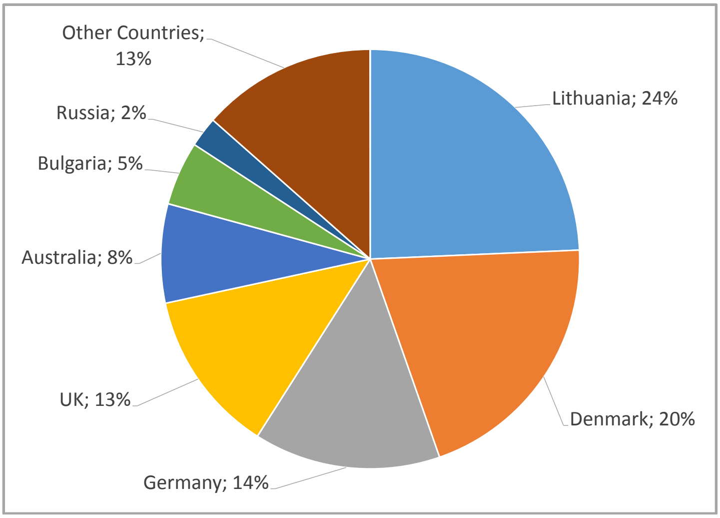

Fig. 5 Countries of Origin for FAME Feedstocks

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.

Additional References

- Executive Summary of the Commission on Fossil-Free Road Transport (http://www.sou.gov.se/content/1/c6/23/07/47/74abda62.pdf)
- Analys av marknaderna för biodrivmedel (2013): ES 2013:08, Statens energimyndighet (www.energimyndigheten.se)
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Switzerland

Introduction

Final total energy consumption in Switzerland in 2012* amounted to 882,280 terajoules (TJ), of which 34% was transport fuels [1]. Compared to 2011, transport fuel consumption increased by 1.1% (aviation fuels +6.1%, diesel +2.6%, and gasoline –3.5%). All fossil fuels were imported. The share of biofuels was very small (0.27% of total transport fuels) at 819 TJ in 2012, but this represented a 14% increase from 2011 [2]. The increase was mainly due to higher sales of biodiesel. Figures 1–3 show consumption in terms of mode of transportation, shares of energy sources in energy consumption, and the development in gasoline and diesel Consumption by motor vehicles in 2003–2012, respectively.

In 2012, 334,000 passenger cars were newly registered. This represented a rise of 2.2% in the total amount of passenger cars; the number reached 4.25 million [3], of which 87% had gasoline engines, and 22% had diesel engines. The percentage represented by other propulsion systems was 1% (28,090 hybrid, 1,758 electric, 12,118 other). The average age of the passenger car fleet was 8.2 years [4].

Within the last 10 years (through 2012), the consumption of transport fuels (minus aviation fuel) increased by only by 4.2%. In the same period, the number of cars (all types) rose by 15%. Use of gasoline decreased by 22%, and use of diesel increased by 72%. 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 800% in this 10-year timeframe, but it represented a very low percentage of the overall motor fuel demand, increasing from 0.12% to 0.27%.

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.

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* *Information presented in this 2013 report was current at the time of preparation. Information for calendar year 2013 will be presented in the 2014 Annual Report.*

Policies and Legislation

Energy Strategy 2050

In 2011, the Federal Council and Parliament decided that Switzerland would withdraw from the use of nuclear energy on a step-by-step basis [5]. The existing five nuclear power plants 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, as part of its new Energy Strategy 2050, 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. As a result of the new decision to move away from nuclear power and of various other profound changes that have been occurring for a number of years (particularly in the international energy arena), 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. The Parliament will start the debate over Energy Strategy 2050 and the new Energy Act in 2014. The important targets/measures that motor fuels are expected to meet/adopt are to (1) adopt carbon dioxide (CO_2) emission regulations, (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, and it will be 80% in 2014 and 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 [6]. 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 litre (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 three 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

This label 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 (litres 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.

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 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 per kilogram [10].

Mineral Oil Tax Exemption for Biofuels

Switzerland is the first country worldwide 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 [10].

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

Biodiesel and Pure Vegetable Oil (PVO) Fuel

The consumption of biodiesel fuel in Switzerland amounted to about 12.4 million L in 2012 (+21%) (Table 1). In the 10 years up through 2012, consumption increased by 700%. Compared to consumption of fossil-fuel-based motor fuels, however, the amount was still very low, representing a share of 0.17%. Then in 2012, the consumption of PVO fuel significantly decreased again (i.e., –23% with respect to 2011). 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, 2003–2012 (in 1,000 L/yr) [2, 11]

Year	Biodiesel (1,000 L)			PVO Fuel (1,000 L)		
	National Production	Imports	Total	National Production	Imports	Total
2003	2,324	18	2,342	145	–	145
2004	3,158	104	3,262	313	–	313
2005	6,180	181	6,361	529	–	529
2006	8,717	116	8,833	845	–	845
2007	9,756	113	9,869	1,846	–	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

Bioethanol

Since 2008, there has been no facility in Switzerland that produces bioethanol (Table 2). In 2012, the entire volume of bioethanol that was used as a motor fuel was imported from Norway. It is possible that the closing of

Swiss bioethanol producer Borregaard Schweiz in 2008 affected consumption in 2009; there was a large drop in that year. Since then, the demand for bioethanol has been recovering, and 2012 sales reached a new maximum. Until 2010, only Alcosuisse (a Profit Center of the Swiss Alcohol Board) was allowed to import and sell ethanol. The government cancelled its activities related to the trade of bioethanol and opened the market to the private economy in the autumn of 2010. In 2012, 49 fuel stations provided E85, and 90 fuel stations provided E5.

Table 2 Consumption of Bioethanol Fuel, 2005–2012[a] (in 1,000 L/yr) [11]

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

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

Biogas and Natural Gas

In 2012, the total amount of biogas produced in Switzerland was much higher than the amount used as a motor fuel:

Parameter	Production or Use Values	
	TJ (terajoule)	Tons of Oil Equivalent (TOE)
Total national biogas production	3,750	89,567
Direct use for power and heat generation	3,426	81,829
Upgraded as motor fuel	324	7,739
Direct use in cars	2	48
Feed in natural gas grid	322	7,691
Use as motor fuel in cars	140	3,344
Other uses (heating, cogeneration)	56	1,338
Upgraded biogas not sold	126	3,009

Only 44% of the upgraded biofuel and only 3.8% of the total biofuel produced were used as a motor fuel. With regard to upgraded biogas, not all of it can be sold because of its higher price. As it is fed into the natural gas grid, it is used as a general fuel for heating. Table 3 shows the use of biogas and natural gas as a motor fuel since 2009.

Table 3 Use of Biogas and Natural Gas as Motor Fuels (via gas grid and directly at fuel pump), 2009–2013 (in 1,000 kg/yr) [13]

Year	Upgraded Biogas as Feed in Gas Grid	Upgraded Biogas Used as Motor Fuel in Cars	Other Uses	Use as Feed in Natural Gas Used as Motor Fuel	Total Gaseous Motor Fuels	Share of Biogas Used as Motor Fuel in Total Amount of Gaseous Motor Fuels (%)
2009	3,152	2,349	56	10,373	12,722	19
2010	4,505	3,002	839	12,080	15,082	20
2011	6,350	3,210	601	12,051	15,711	20
2012	6,915	3,005	1,197	11,830	14,835	20
2013	9,981	3,462	3,348	11,599	15,060	22

Energy Research

The Swiss government supports energy research in the amount of 200 million CHF each year. Also, in support of Energy Strategy 2050, the Swiss Parliament is granting an additional total of 200 million CHF toward launching and building the capacity of seven Swiss Competence Centers for Energy Research (SCCERs) between 2013 and 2016. Two SCCERs are relevant to advanced motor fuels: one for research on “efficient concepts, processes, and components in mobility” and the other for the same in “biomass.”

The targets of energy research are described in *Energy Concept 2013–2016* [14]. 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 [15] covering 20 topical areas. In the areas of “biomass and wood energy,” “combustion and cogeneration,” and “transport,” here are some areas of ongoing research related to advanced motor fuels:

- Influences of biocomponents (fatty acid methyl esters or FAME) on the emissions and exhaust systems of heavy-duty (HD) diesel engines [16]
- Development of a novel, micro-thermal gas-quality sensor for detecting the composition of methane-rich gases for feed-forward control of engines [16]
- System modeling to assess the potential of decentralized biomass-combined heat and power (CHP) plants to stabilize the Swiss electricity network with increased fluctuating renewable power generation [16]
- Renewable energy sources in the future energy supply (RENERG^2) [16]
- Characterization of high-boiling-point/synthetic fuels for homogeneous charge compression ignition (HCCI) and partially stratified diesel engine combustion by means of optical experiments and global reaction models [16]
- Three-dimensional (3D) Computational Reactive Fluid Dynamics (CRFD) models for low-CO_2/low-emission mixing controlled combustion of biogenic/synthetic fuels in engines based on detailed reaction kinetics [16]
- Metal-nanoparticles and other non-legislated emissions from cars with blended gasoline and alcohol fuels [16]
- Distributed production of ultra-pure hydrogen from woody biomass [17]
- Predictions of the complex coupling of chemistry and hydrodynamics in fluidized-bed methanation reactors used to produce synthetic natural gas (SNG) from wood [17]
- Novel system for the direct fermentation of pretreated lignocellulosic material to ethanol in a single reactor [17]

- Harmonization and extension of bioenergy-related ecobalances [17]
- Methane losses from biogas plants [17]

Outlook

The Federal Council estimated that the potential amount of biofuels that could be produced in the medium term is 76 million L. This equals 1% of Swiss annual fuel consumption.

If Swiss policy would heavily encourage the use of biomass for local energy production, biofuels could have an 8% share in total motor fuels until 2020. To achieve this, all biomass-based products and by-products would have to be used [18].

Other than the support for tax exemptions and tax reductions, there is no strong political support for using biofuels in the transportation sector at present. In 2008, the SFOE published a position paper [19]. There were four main messages in this document.

1. The production of biofuels from waste is preferred for ecological reasons.
2. New technologies in biofuel generation and agricultural production systems can improve the acceptance of biofuels.
3. Quotas for blending are not regarded as being reasonable because they are opposed to more rational uses of biofuels (e.g., in heat-operated CHP plants).
4. Food production has priority over fuel production with regard to the limited areas for agricultural production in Switzerland.

These messages were also supported in a recently published study [20] that showed that although many biofuels based on agricultural products help to reduce greenhouse gas emissions, they have drawbacks with regard to other environmental concerns (e.g., acidified soils and nutrient surpluses in lakes and rivers due to intensive fertilization). Thus, most biofuels just shift the environmental impacts, emitting fewer greenhouse gases but resulting in more growth-related pollution in agricultural land. Only a few biofuels result in a better overall ecobalance than does petrol. Biogas from residues and waste materials is especially good (depending on the source material) — it can have up to a 50%-lower negative environmental impact than does petrol. With regard to different biofuels, ethanol-based fuels tend to result in a better ecobalance than oil-based fuels; however, the results depend very much on the frame conditions (e.g., manufacturing method and technology used).

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

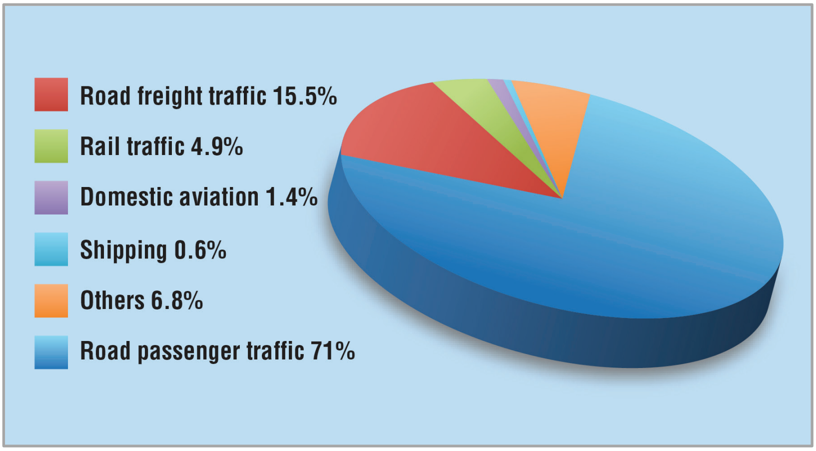

Fig. 1 Transportation Sector: Percentages of Modes of Transport in Terms of Energy Consumption in 2012 [21]

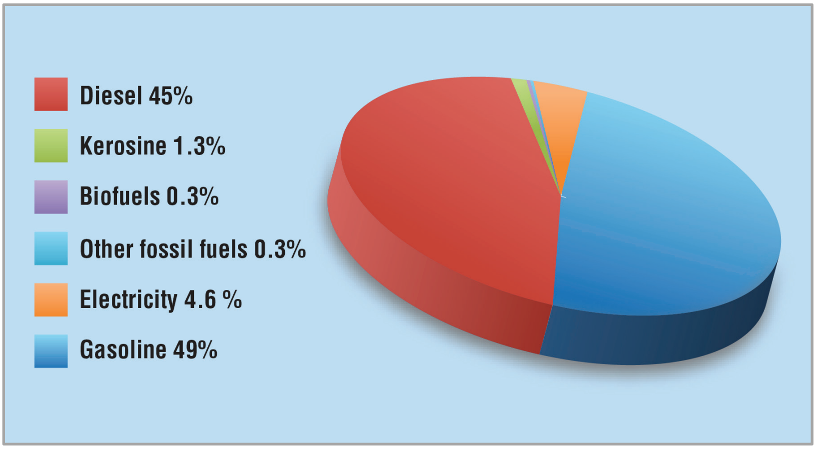

Fig. 2 Transportation Sector: Shares of Energy Sources in Energy Consumption in 2012 [21]

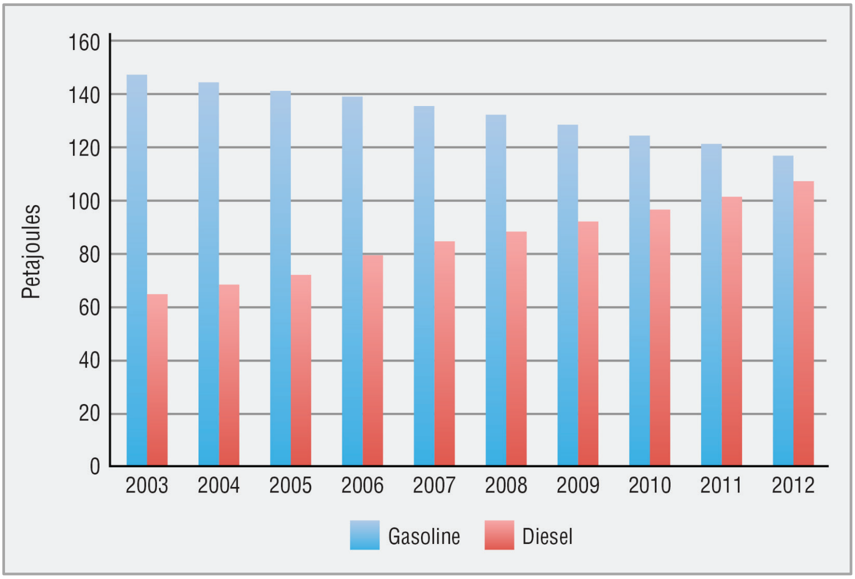

Fig. 3 Development in Gasoline and Diesel Consumption by Motor Vehicles, 2003–2012 [21]

Thailand

Introduction

Thailand has limited indigenous oil reserves and heavily imports the total energy consumption of 1.42 trillion baht (US$43,030 million) in 2013, which is a 2.0% decrease from the previous year. The final energy consumption of Thailand covers all energy supplied to the final consumer for all energy uses, and it rose by 2.59% in 2013 [1], where petroleum products represent the major part of the energy consumption, as shown in Figure 1. Figure 2 shows that, of the fuel types, diesel fuel used in the transportation and industrial sectors is the most consumed, accounting for 40.2% of petroleum consumption in transportation sector for Thailand in 2013. Diesel consumption is followed by consumption of ethanol blend, jet fuel, CNG and LPG, as also shown in Figure 2.

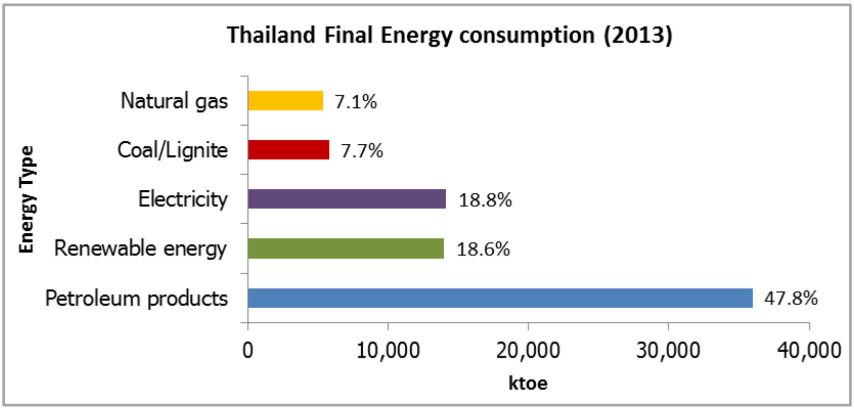

Fig. 1 Thailand Energy Consumption in 2013 [1]

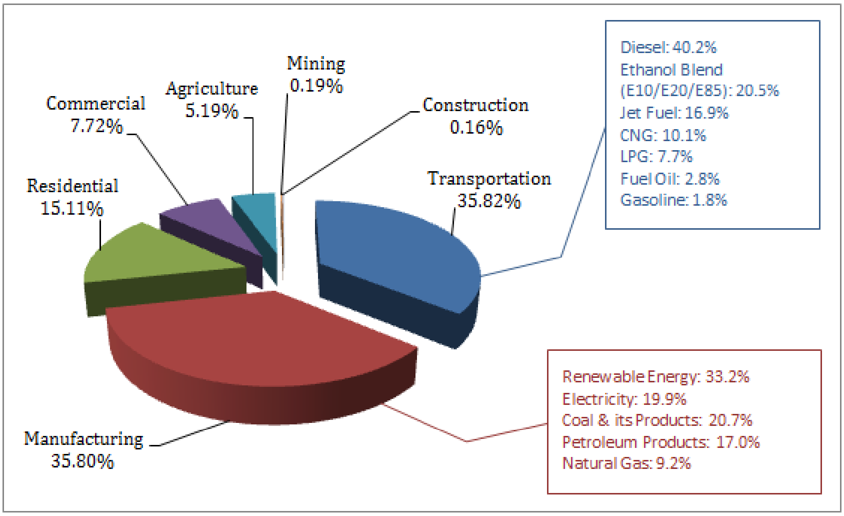

Fig. 2 Final Energy Consumption by Economic Sector in 2013 [2]

The increase in environmental concerns regarding climate change and air pollution caused by the transportation sector and the need for the diminution of oil imports have led to various approaches to resolve the problem, such as promotion of biofuels, natural gas vehicles (NGVs), and electric vehicles (EVs). Biofuel usage is one of the key measures to mitigate these problems while giving rise to an alternative energy substitute for conventional fossil fuels. With a campaign and incentives launched by the government, ethanol and biodiesel production in Thailand in 2013 rose to 958 and 1,038 million liters, respectively [3,4], reflecting a 46.48% 15.85% increase compared with those in 2012.

A total of 3,633,822 new vehicles were registered in 2013. By the end of 2013, Thailand had 34,624,406 vehicles. Among these, gasoline vehicles accounted for 24,189,984 units; diesel vehicles, 8,639,255 units; mono-fuel liquefied petroleum gas (LPG) vehicles, 25,732units; bi-fuel or dual-fuel LPG and gasoline or diesel vehicles, 1,107,077 units; mono-fuel compressed natural gas (CNG) vehicles, 62,652 units; bi-fuel or dual-fuel CNG and gasoline or diesel vehicles, 328,191 units; and EVs, hybrids, non-fuel and other vehicles, 271,515 units [5].

Policies and Legislation

Thailand energy demand, forecasted by the Energy Ministry, is expected to increase from 75,214 ktoe in 2013 to 99,838 ktoe in 2021. The Thai government plans to accelerate alternative energy consumption by revising the production and consumption of renewable energy. The government, therefore, assigned the Energy Ministry to establish a Renewable and Alternative Energy Development Plan (AEDP) that will reach 25% renewable resource consumption in 10 years, called AEDP 2012–2021 [6]. The goal is to identify the framework and direction for developing renewable energy in Thailand with the following six strategic issues:

1. Promoting the community to collaborate in producing and consuming renewable energy.
2. Adjusting incentives on investment from the private sector to a level appropriate to the situation.
3. Amending the laws and regulations to benefit renewable energy development.
4. Improving the energy system infrastructure for transmission lines and power distribution lines, including development toward a Smart Grid System.
5. Applying public relations to build up comprehensive knowledge within the country about the new energy policies.
6. Promoting research as a mechanism to develop an integrated renewable energy industry.

Use of renewable energy for the transportation sector as a substitute for fossil fuel is one of the key driving technologies to achieve the goal of AEDP 2012–2021. According to this document, the government had planned to terminate octane 91 regular gasoline sales by October 1, 2012, but that requirement was postponed to January 1, 2013 (see additional discussion in “Implementation: The Use of Advanced Motor Fuel,” under the “Bioethanol” topic). Moreover, the selling price of ethanol blend E20 is to be lower than that of 95 octane E10 (95 gasohol), that is, 4.95 baht/L ($0.15/L) (as of December 2013), and the market value of E20 is to be higher than that of 91 octane E10 (91 gasohol), that is, at least 0.50 baht/L ($0.02/L). These incentive measures are to be implemented to encourage the expansion of E20 service stations. Nonetheless, a public relations campaign to improve understanding of the E10, E20, and E85 ethanol blends is still required.

To promote energy conservation and E85 use, manufacturing of eco-cars and E85 cars is being supported in Thailand. Automobile manufacturers can claim an excise tax reduction of 50,000 baht ($1,554) for each E85 car and a reduction of 30,000 baht ($932) for each eco-car. Furthermore, the requirement of E85 vehicle procurement for official government use has been proposed. A state incentive plan to boost the ethanol demand has also been deployed, and it includes application of an E85 conversion kit to old cars and motorcycles and modification of diesel engine vehicles so that they can be fueled by ED95 (a blend of 95% ethanol and 5% ignition improver, used in modified diesel engines).

Ethanol is a significant substitute for gasoline in Thailand, and its total production capacity is expected to increase to 9 million L/day in 2021, compared to the current total production capacity of 4.19 million L/day, by increasing production yield of the first-generation raw material, including sugarcane and cassava (Table 1).

In addition to conventional feedstocks, other alternative crops are being commercially promoted, such as sweet sorghum. Furthermore, laws and regulations will need to be amended to support ethanol free trade in the future, such as an exemption from the Liquor Act for ethanol production for fuel use, and amendment of the Excise Tax Act to support ethanol exports.

With regard to fuel for diesel vehicles, biodiesel is a major diesel substitute, and its total production capacity is expected to rise from current value of 1.69 million L/day to 7.2 million L/day in 2021. Currently, a key raw material for biodiesel production is palm oil. By 2021, palm plantation area will increase to 0.88 million hectares, as shown in Table 1, and production capacity of crude palm oil will increase to not less than 3.05 million tons/year, from 1.94 million tons/year in 2013 [16].

Table 1 Expected National Average Production of Cassava, Sugarcane, and Palm in 2021

Feedstock/Raw Material	Planting Area (million hectare)	Average Production (tons/ hectare/year)	Annual Production (million tons/ year)
Sugarcane	1.12	93.75	105
Cassava	1.12	31.25	35
Palm	0.88	20.0	17.6

Integrated management (i.e., palm cultivation, palm oil extraction, consumable vegetable oil production, biodiesel production, and related industries such as product import, export, and R&D) would reduce cost and generate value added for the biodiesel supply chain.

The proportion of biodiesel blend sold in Thailand is well managed with regard to the quantity of domestic palm oil production. Nevertheless, the biodiesel (fatty acid methyl ester, also called FAME) standard needs to be revised in preparation for the proportional improvement of biodiesel blend previously from 5% to the maximum value of 7% (currently varying from 3.5% to 7%).

"The Future New Fuel for Diesel Substitution" is one of the key strategic measures of AEDP 2012–2021, aiming at commercializing a second-generation renewable diesel fuel produced by hydrogenating a vegetable oil feedstock. The use of refinery-based hydrogenation processes to produce a synthetic-hydrogenated vegetable oil, called biohydrogenated diesel or BHD, is driven by several issues, including some technical considerations over the properties and effects of first-generation FAME biodiesel.

Implementation: The Use of Advanced Motor Fuel

The AEPD 2012–2021 of the Ministry of Energy specifies a biofuel goal of 19.2 million L/day (44% fossil fuel replacement) in 2021, consisting of 9.0 million L/day of ethanol; 7.2 million L/day of biodiesel; and 3.0 million L/day of BHD.

Thailand's government policy on alternative energy as a national agenda encourages the production and use of alternative fuels for vehicles and the use of biofuels — such as gasohol (E10, E20, and E85) and biodiesel — to enhance energy security and to reduce tailpipe pollution, greenhouse gases, and other pollutants. In 2013, domestic biofuel supply (excluding exports) reached 1,887 million liters, accounting for 6.5% of fuel consumption for gasoline engines (gasoline, as well as gasohol E10, E20, and E85) and high speed diesel (HSD) consumption (Table 2).

Table 2 Domestic Biofuel Production in 2012 and 2013 [3,4]

Types of Biofuel	2012	2013	
	Million Liters	Million Liters	Difference (%)
Ethanol	654	958	46.5
Biodiesel	896	1,038	15.8

Bioethanol

In Thailand, molasses-based ethanol dominates ethanol production, reaching 2.6 million L/day of installed production capacity in 2013, up 13.0% from an average of 2.3 million L/day in the previous year. The sole sugarcane-based ethanol plant operates at around 0.2 million L/day. In 2013, the number of operating ethanol plants increased to 21 plants, with total production capacity of 4.2 million L/day, rising from 20 plants with production capacity of 3.3 million L/day in 2012. The new ethanol plants are cassava based. In 2013, three new cassava-based ethanol plants were being constructed, with total production capacity of 1.3 million L/day. Meanwhile, cassava-based ethanol plants are operating at 1.4 million L/day, a 75.0% increase compared to that in 2012 [9].

Although the government planned to terminate octane 91 regular gasoline sales by October 1, 2012, five out of the total six refineries were not ready to shift from octane 91 regular gasoline production to gasohol production by October 2012. Consequently, termination of octane 91 regular gasoline production was postponed to January 1, 2013, as mentioned previously.

In 2012, ethanol consumption increased to 577 million liters because of an increase in the consumption of gasohol (octane 91 E10, as well as octane 95 E10, E20, and E85) driven by a bigger price difference between octane 91 regular gasoline, following the government policy to promote gasohol consumption. The retail prices were 6–8 baht/L (\$0.19–0.25/L) less expensive for octane 91 E10 gasohol, 8–11 baht/L (\$0.25–0.34/L) less expensive for E20 gasohol, and 20–22 baht/L (\$0.62–0.68/L) less expensive for E85 gasohol [10]. In addition, the number of E20 and E85 service stations increased from 1,310 and 68 stations in 2012 to 1,940 and 252 stations, respectively, by the end of 2013 [11].

Biodiesel

Unblended biodiesel (B100) in Thailand is currently produced from palm oil industry-derived feedstock —for example, crude palm oil, refined bleached deodorized palm oil, palm stearin, and free fatty acids of palm oil. Production of B100 production is determined by domestic demand for blended biodiesel, as well as supply of raw material, with currently compulsory use of biofuel B7 since January 1, 2014. Thailand does not import or export B100; however, it does export crude palm oil [9].

Because of the increased demand from mandatory B5 use and growing diesel consumption, B100 consumption for HSD blending has grown from 2.42 million L/day in 2012 to 2.88 million L/day in 2013, an increase of 19% [12]. Fourteen (B100) plants are in operation in Thailand (as of 2012). The active producers have a current production capacity of 5.2 million L/day or 1,898 million L/annum [7].

Outlook

In a 20-year period (1990–2010), according to the 20-Year Energy Efficiency Development Plan (2011–2030) of Ministry of Energy, energy consumption in Thailand continuously increased at an annual average rate of 4.4%. In the following 20-year period, from 2011 to 2030, if there is no energy conservation and efficiency improvement or no significant reform of the industrial sector and transportation system, energy demand under the business-as-usual scenario will increase to 151,000 ktoe, accounting for an annual average growth rate of 3.9%.This estimate assumes that the gross domestic product will grow at an annual average rate of 4.2% [13]. Thai government therefore set the target to reduce energy intensity by 25% in 2030, compared with that in 2005, or equivalent to reduction of final energy consumption by 20% in 2030.

Thailand is a net energy importer, chiefly because of oil, with imports amounting to 900 billion baht ($28 billion) a year. According to the International Energy Agency’s forecast, Thailand's net oil imports will rise to 1.5 million barrels/day by 2035 [14], increasing from 0.87 million barrels/day in 2013 [8]. High oil prices provide a continuing impetus for switching to alternative fuels for the transportation sector, particularly bioethanol, biodiesel, and other advanced biofuels. Hence, research and development projects on advanced fuels, as well as advanced technologies, have been carried out to achieve the goal, focusing on BHD (hydrogenated/hydrotreated vegetable oil). The research and development scheme on BHD includes conducting engine tests and establishing a quality testing standard, targeted to produce 3.0 million L/day of BHD.

For natural gas vehicles, production and utilization of compressed bio-methane gas (CBG) from biomass/energy crops for the transportation sector have been promoted. In the AEDP Plan (2012–2021), CBG consumption is targeted to be 1,200 ton/day by 2021. And CBG is expected to replace CNG consumption in the transportation sector by 5%. One CBG project has been established in the Chiang Mai province of northern Thailand. The compressed biogas is produced from swine manure and Napier grass, with a design CBG production capacity of 2,160–3,000 tons per year. This fuel can replace 2.2 million liters of diesel per year [15]. Biogas process upgrading is very important for utilization of biogas as CBG. It helps improve gas quality and fulfill the requirements of gas appliances. Furthermore, biogas upgrading can enhance its heating value.

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Benefits of Participation in the AMF IA

Thailand benefits in a number of ways by participating in the AMF IA. Through participation, Thailand has opportunities to promote a domestic R&D project through the AMF scheme and participate in 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 research and development, establish international linkage or contacts, exchange knowledge, and better develop ideas for creating or modifying the national energy development plan.

United States

Introduction

The U.S. Energy Information Agency (EIA) estimates that the total U.S. transportation energy consumption in 2013 was approximately 26.78 quadrillion Btu (a level that has remained little changed since 2008[31]), and projects that the 2014 total will be just under this level, at 26.72 quadrillion Btu.[32] [33] Over 90% of this energy consumption arose from petroleum-based fuels — gasoline and diesel (some 12 million barrels per day) — with almost the entire remainder being ethanol blended into gasoline at 10%, with about 95% of U.S. gasoline currently being such blends.[34]

The U.S. net dependence on foreign oil has dropped from approximately 60% of U.S. petroleum use in 2005 to around 32% at the end of 2011, with 2014 imports preliminarily estimated at 28% and 2015 projections at 27%.[35] These large reductions are 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.[35]

Policies and Legislation

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

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31 See http://www.eia.gov/forecasts/aeo/er/early_consumption.cfm. Note: These are EIA's preliminary estimates for 2013.

32 See http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=7-AEO2014ER&region=0-0&cases=ref2014er-d102413a.

33 All EIA projections in this report, unless otherwise noted, are from *the Annual Energy Outlook 2014 Early Release* and its "Reference Case."

34 Ibid. EIA shows only 910 trillion Btu of this as being renewable fuel (http://www.eia.gov/totalenergy/data/monthly/pdf/sec2_11.pdf), including ethanol. This estimate appears low since 16 trillion Btu of the total is estimated to be motor gasoline, 95% of which contains 10% ethanol, and 6.0 trillion Btu is diesel fuel, some of which contains renewable components (http://www.eia.gov/oiaf/aeo/tablebrowser/#release=AEO2014ER&subject=0-AEO2014ER&table=2-AEO2014ER&region=1-0&cases=ref2014er-d102413a).

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

The Energy Policy Act of 1992 (EPAct 92) requires that certain centrally fueled fleets (federal, state, and alternative fuel provider fleets, such as utility companies) acquire light-duty alternative fuel vehicles as most of their new vehicle acquisitions. 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 such technologies as alternative-fueled 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 provides manufacturers, trade associations, national fleets, government agencies, and other stakeholders with coordinated strategies and resources they can leverage to implement effective petroleum reduction practices. Clean Cities also provides 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 348 million gallons of gas equivalent (MGGE) in 2012 (most recent data), about the same amount as 2011. Over half of the savings comes from natural-gas-powered vehicles, most frequently a city bus. The savings come from approximately 400,000 vehicles tracked by the Clean Cities coalitions. Note that the consumption quoted by Clean Cities is mainly by fleet vehicles that are in an area tracked by a Clean Cities coalition partner. The U.S. federal government does not have an active role in the majority of these fleet operations.

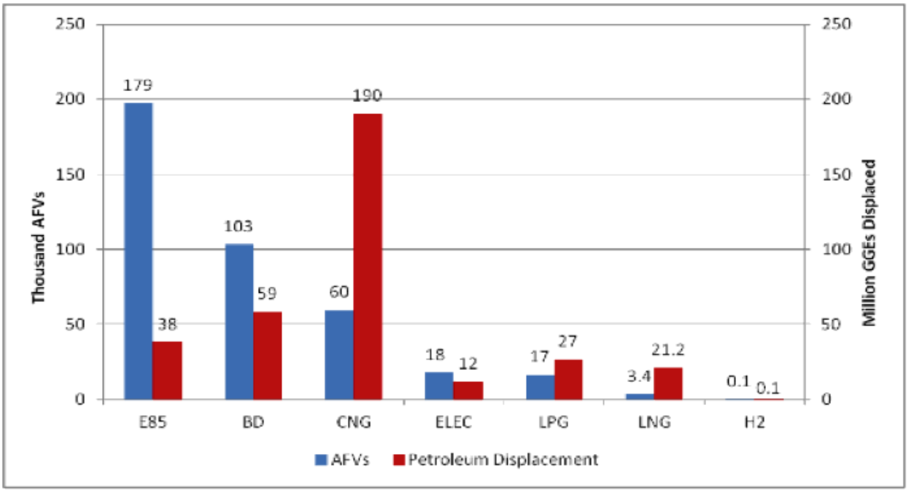

Fig. 1 Clean Cities 2012 Data for Advanced Fuel Vehicles (AFVs) and Petroleum Displacement[36]

More information on the Clean Cities program can be found at www.cleancities.energy.gov.

EPA Requirements under the Renewable Fuels Standard
The primary driver of renewable fuel use in the United States is the Renewable Fuel Standard (RFS), adopted in 2005 and expanded in 2007 (RFS2), which requires that increasing volumes of renewable fuel be used in motor fuels.

In 2013, the U.S. Environmental Protection Agency (EPA) issued a proposed rulemaking for the 2014 volume requirements of renewable fuels,[37] proposing the *reduction* of both total volume requirements and requirements for specific categories, compared to volumes originally proposed in 2010. Total renewable fuels requirements were reduced from a mandated 18.15 billion gallons per year (ethanol equivalent) in 2013 to 16.55 billion gallons per year actual volume, and the proposed volume for 2014 is 15.21 billion gallons per year. The reduction in volumes is due to a number of factors. The EPA cited reduced market fuel volumes (for example, gasoline consumption declined from 18.67 quad Btu/year to

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36 See http://www.afdc.energy.gov/uploads/publication/2012_metrics_report.pdf.
37 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 ends January 28, 2014).

15.84 quad Btu/year over the period 2007–2013), the ethanol blend wall (combining the factors of market acceptance and availability of E15 gasoline blends and limited availability and acceptance of E85), and limited production of biodiesel and other advanced biofuels. Cellulosic ethanol requirements were reduced from a previously mandated 1.75 billion gallons per year in 2014 to a proposed 17 million gallons per year, citing lack of production capacity. Much of the U.S. cellulosic ethanol production is scheduled to start in 2014, making 2014 volumes somewhat uncertain. Biomass-based diesel is proposed at 1.28 billion gallons per year, citing under-utilization of capacity due to feedstock cost and uncertainty regarding tax credits for 2014. The comment period for this proposed rulemaking ended January 28, 2014, and final regulations will be issued in spring 2014.

The EPA divides renewable fuels into several categories for regulation purposes, some of which are nested. Cellulosic biofuel is fuel derived from biomass by enzymatic conversion and fermentation, by pyrolysis, or by gasification, with cellulosic ethanol dominating the category. Biomass-based diesel is mainly traditional FAME (fatty acid methyl ester) 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/.

Implementation

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. Natural gas production in the United States has increased steadily in recent years[38] and is projected to continue to increase in future years. Accompanying this increase in the production of natural gas, the production of crude oil and natural gas liquids has also grown. Crude oil production is expected to grow at 0.8 million

[38] U.S. Energy Information Administration, *Short Term Energy Outlook*, January 7, 2014.

barrels per day through 2016, then level off, and begin to slowly decline after 2020. The share of total U.S. liquid fuels consumption met by net imports peaked at more than 60% in 2005 and fell to an average of 33% in 2013. The EIA expects the net import share to decline to 25% in 2015, which would be the lowest level since 1971. U.S. petroleum imports are expected to then slowly increase to 32% by 2040. Natural gas production is expected to continue growing through 2040, with a 56% increase between 2012 and 2040. This increase will be absorbed by electrical power generation, industrial use, vehicle use, and liquefied natural gas (LNG) exports.[39] Figure 2 shows the steady increases in production and decreases in net imports for the period 2005–2015 for U.S. natural gas and crude oil.

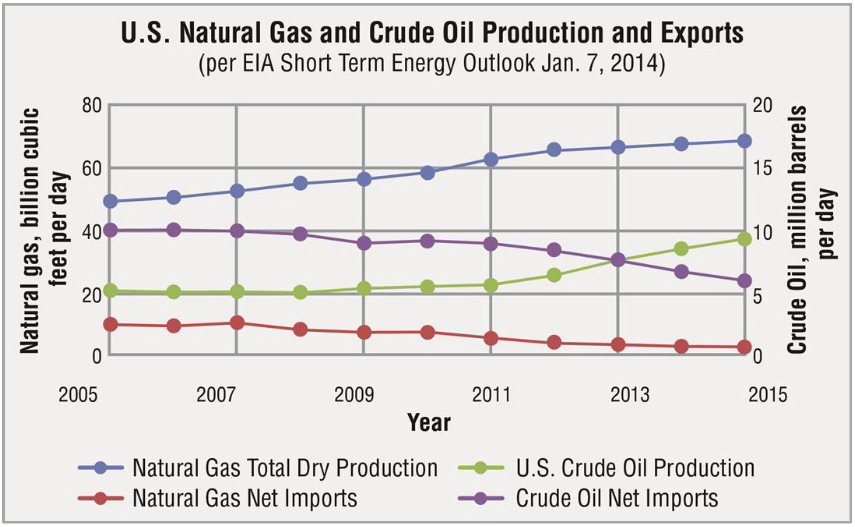

Fig. 2 U.S. Natural Gas and Crude Oil Production from 2005 to 2015[40]

The large increase in U.S. production has changed the balance of oil shipments in the United States, resulting in the need for some pipeline reversals and increasing shipments of crude oil by rail. The Keystone XL pipeline was intended to move Canadian crude to the U.S. Gulf Coast, but when completed, the pipeline will also be able to transport U.S.-based crude to the Gulf Coast. In addition, some companies are applying for LNG export licenses to help correct regional mismatches in natural gas production,

[39] U.S. Energy Information Administration, *Annual Energy Outlook 2014: Early Release Overview*, December 16, 2013.
[40] Op cit., *Short Term Energy Outlook*, 2014.

infrastructure, and consumption and to allow sale to higher-priced foreign markets.

Natural gas use for transportation is expected to grow in the coming decades, mainly in the heavy-duty vehicle sector. The problems surrounding the use of natural gas as a motor fuel are mainly infrastructure related, rather than research related. Figure 3 reproduces EIA's projection for the growing use of compressed natural gas (CNG) and LNG in various transportation applications.[41]

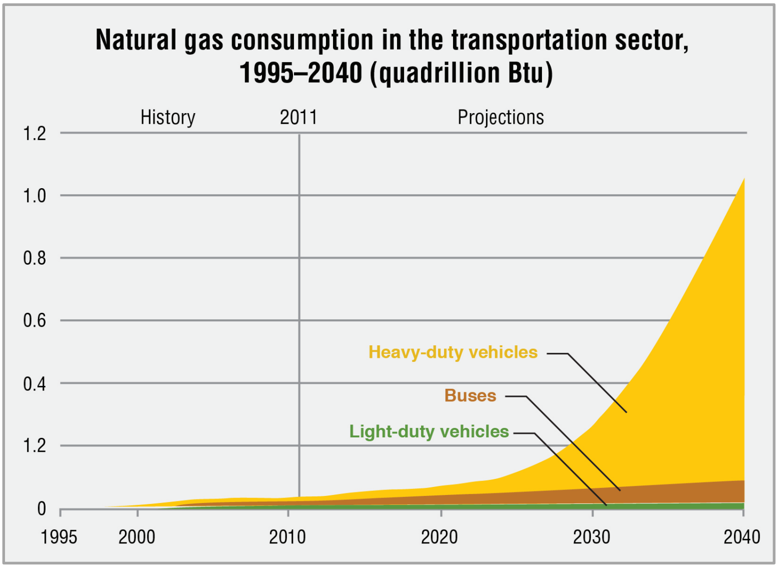

Fig. 3 Consumption of Natural Gas by Light- and Heavy-Duty Vehicles and Buses for the Period 1995–2040

CNG is also under consideration for railroads, and evaluation programs are under way at GE Transportation, Electro-Motive Diesel, BNSF, Union Pacific, CN, Clean Energy Fuels, Chart Industries, Westport Innovations, Waste Management, and many other firms.[42] Large-scale deployment is likely to develop slowly because of LNG logistics, the high investment required for fuel tender cars and delivery infrastructure, the distributed nature of the U.S. rail industry, and the long life cycle of rail equipment.

41 U.S. Energy Information Administration, *Annual Energy Outlook 2013*, May 2, 2013.

42 William Vantuono, "Experts Weigh in on LNG," *Railway Age*, http://www.railwayage.com/index.php/mechanical/locomotives/experts-weigh-in-on-lng.html, Sept. 6, 2013 (on-line).

Current natural gas pricing in the United States could offer an average of up to a $200,000 savings per locomotive per year.

Use of Advanced Motor Fuels

In 2012, the first commercial production of cellulosic ethanol in the United States came on-line. Although the volume was still very small (less than 1 million gallons), several facilities came on-line in 2013, and several more are projected to be added in 2014. The EPA projects 61–123 million gallons of cellulosic ethanol production in 2014,[43] although its prior projections (based largely on what aspiring producers predicted they would produce) have proven to be overly optimistic. The EPA has identified five commercial-scale cellulosic biofuel plants, four of which will produce ethanol and one of which will produce gasoline and diesel, along with numerous pilot-scale plants that are structurally complete and in the process of start-up.[44]

At this time, 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 2,391 stations selling FFV fuel in the United States by the end of January 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 down to 51% ethanol to be used as FFV fuel.[45] There is, however, no legal barrier to marketing blends of even lower than 51% for use in FFVs. As noted above, some marketers are offering lower blends year-around through blender pumps.

For biomass-based diesel, EPA projects that 1.28–1.6 billion gallons will be sold in the United States in 2014.[46]

In 2011, the EPA revised its regulations governing conversion of conventional vehicles to alternative fuels, making it easier for conversion systems for natural gas and propane to get approval for vehicles older than

43 U.S. Environmental Protection Agency, op. cit., p. 71736.
44 Ibid.
45 See http://ethanol.cttstest.nrel.gov/afdc/fuels/ethanol_e85_specs.html.
46 U.S. Environmental Protection Agency, op. cit., p. 71765.

two years. This revision has resulted in many more AFV conversion systems being registered with the EPA.

The record for electric vehicles in 2013 continues to be mixed, partly as a result of various setbacks that include equipment suppliers going out of business and monthly vehicle sales numbers fluctuating up and down. But the trend continues to be upward: U.S. electric vehicle sales, including all-electric, plug-in hybrid, and extended-range electric vehicle sales topped 96,000 in 2013.[47]

The table below provides the counts of alternative fuel refueling stations, including private stations, in the United States according to the U.S. DOE's Alternative Fuels Data Center.[48] Updated information, with a breakdown by state, can also be accessed at http://www.afdc.energy.gov/locator/stations/. Individual station locations can also be accessed on the Alternative Fuels Data Center site.

Table 1 Counts for U.S. Alternative Fuel Refueling Stations by Type in 2012 and 2013

Year	B20	CNG	E85	Electricity	H2	LNG	LPG	Total
2012	675	1107	2553	13392	58	59	2654	20498
2013	757	1263	2639	19410	53	81	2956	27159

As can be seen from the table, the total number of alternative fueling stations in the United States increased by more than 30% between 2012 and 2013. This mainly reflects an increase of over 40% in the number of electric vehicle charging stations.[49]

Advanced Fuels and Engines

The DOE Vehicle Technologies Office sponsors research in fuels and advanced combustion engines for the purpose of displacing petroleum-derived fuels, better matching of engines and fuel characteristics, and increasing engine and vehicle efficiency. This research covers a very broad range of fuel, engine, and vehicle technologies, and the brief summary

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47 See http://www.electricdrive.org/index.php?ht=d/sp/i/20952/pid/20952.

48 See http://www.afdc.energy.gov/data/search?q=stations#10332.

49 This growth in the total number of refueling sites is somewhat misleading because the electric recharging numbers generally reflect an individual charger outlet for a single auto, in most cases a Level 2 charger that requires some 1–2 hours to recharge. The other types of stations shown may include multiple dispensers and can refuel many more vehicles in shorter periods.

provided here will focus on fuels and fuel effects and is based upon recent DOE annual program reports.[50, 51] Fuels can affect combustion and efficiency by altering in-cylinder mixing of fuel and air, by enabling a higher compression ratio through high octane, and by causing chemical effects on important properties, such as burning velocity and ignitability.

Much of the research studying 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.,[52] ethanol blends were found to outperform high-octane gasoline relative to knock-limited spark timing at high loads, thus both allowing higher loads and improved fuel economy. In several studies[53], 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 reported a significant margin for further engine optimization by spark advance, compression ratio increase, and engine downsizing for blends of ethanol in gasoline from 51% to 85%, such as 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 is still preliminary, HCCI or PCCI engines will likely not benefit from higher octane fuels. They may 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.

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

51 U.S. Department of Energy Vehicle Technologies Office, *Advanced Combustion Engine Research and Development 2012 Annual Progress Report*, DOE/EE-0872, December 2012.

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

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

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 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 there exist detailed kinetic mechanisms. 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 development of new fuels from initial concepts, laboratory research and development, and pilot and demonstration plant phases. Research areas include feedstock, algae, biochemical conversion, and thermochemical conversion for both fuels and high value chemicals.[54]

The Bioenergy Technologies Office has estimated the potential for the conversion of one billion tons of biomass per year. Various pricing and yield assumptions predict the potential for producing from 20 to 70 billion gallons per year of advanced biofuels by 2022.[55] Other highlights[56] 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.

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[54] U.S. Department of Energy Bioenergy Technologies Office, *Peer Review 2013*, May 20–23, 2013.

[55] U.S. Department of Energy, *2011 US Billion-Ton Update: Biomass Supply for a Bioenergy and Bioproducts Industry*, R.D. Perlack and B.J. Stokes (leads), ORNL/TM-2011/224, Oak Ridge National Laboratory, Oak Ridge, TN, August 2011.

[56] U.S. Department of Energy Bioenergy Technologies Office, *Bioenergy Successes*, www.eere.energy.gov.

Outlook

The EIA projects the dependence ratio for U.S. petroleum imports will continue to decline to about 25% in 2015 and then rise to 32% in 2040 for the same reasons identified in the introduction for the decline since 2005.[57]

High oil prices provide a continuing impetus for switching to alternative fuels, particularly natural-gas-based fuels, as U.S. natural gas prices have been dropping because of a new supply from shale gas and enhanced recovery at conventional fields. The EIA projects steady increases in the use of CNG in both freight trucks and transit buses from the present through 2030, followed by rapid increases between 2030 and 2040 (although it projects CNG use in light-duty vehicles to remain at 18–20 trillion Btu/year through 2040).[58] The EIA has not included LNG in its projections as its use has been limited to date, but the private sector is investing substantial resources on the expectation that a market will develop.

In addition, as noted above, changes to EPA regulations governing conversions of vehicles to gaseous fuels (primarily natural gas and propane) are likely to result in substantial increases in use of these fuels (mainly natural gas with a limited number of propane vehicles). Moreover, the California Air Resources Board has initiated a rulemaking to similarly reform its regulations so as to facilitate such conversions, which is likely to take effect in late 2013 or 2014.

A number of companies have introduced advances in technology for liquefied petroleum gas (LPG) use in light-, medium-, and some heavy-duty applications and are offering additional models incorporating the advances. The EIA projects transportation use of LPG to increase steadily in the future, a change from previous years when declines had been projected.[59]

The principal U.S. advanced fuel, ethanol, however, is expected to continue being constrained in 2014 by the challenges associated with blending over 10% in gasoline, as well as by concerns about misfueling and compatible systems, among other issues. In fact, EIA projects domestic ethanol production to be unchanged in 2014 at 0.85 mmbpd and to increase slowly to 0.95 mmbpd by 2040.[60]

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57 See http://www.eia.gov/forecasts/aeo/er/executive_summary.cfm.

58 See Transportation Sector Energy Use by Fuel Type Within a Mode, Reference Case. EIA AEO2014ER.

59 See Transportation Sector Energy Use by Fuel Type Within a Mode, Reference Case. EIA AEO2014ER.

60 See Petroleum and Other Liquids Supply and Disposition, Reference Case. AEO2014ER.

While FFV fuel has not taken off to date, the next few years could be “make or break” years for it because of the combination of high gasoline prices, RFS2 requirements, and constraints on meeting those requirements by additional low-level blends. At the same time, station owners have expressed some reluctance to install new FFV refueling systems because of the loss of the excise tax credit, making the FFV fuel more expensive; moreover, where FFV dispensing has been installed, sales have been disappointing, often leaving such investments unrecouped. The EIA projects FFV fuel use (based on average blend of 74% ethanol) to grow from about 18 trillion Btu in 2013 to nearly 100 trillion in 2018 and 450 trillion in 2029.[61]

An interesting development in 2012–2013 has been the expressed interest of automakers in offering FFVs optimized for use of a higher than E15 blend (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 so as to essentially offset the lower energy content of the ethanol.

Additional References

- Alternative Fuels & Advanced Vehicle Data Center, www.afdc.energy.gov
- Energy Information Administration 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/
- EERE Info Center, http://www1.eere.energy.gov/informationcenter
- Bioenergy Feedstock Information Network, http://bioenergy.ornl.gov/
- Biomass R&D Initiative, www.biomass.govtools.us

[61] See Transportation Sector Energy Use by Fuel Type Within a Mode, Reference Case. EIA AEO2014ER.

Benefits of Participation in the AMF IA

The United States Department of Energy's Vehicle Technologies Program is an active participant in the AMF annex through the Fuels and Lubricants subprogram. The United States Government benefits from participation through several means. One major benefit is the ability to leverage finances and technical expertise on research programs of mutual interest. United States Government researchers also benefit from the ability to maintain contact with international experts and interact in research and policy discussions. Many of the countries participating in the AMF are facing the same fuel issues as the United States and are active in international import and export markets for fuels, renewable fuels, and fuel components on the world market. Mutual cooperation has proven beneficial in the past and should continue to do so in the future.

3

Ongoing AMF Annexes

3.a
Overview of Annexes

Ongoing Annexes in 2013

Annex Number	Title	Operating Agent
28	Information Service and AMF Website (AMFI) and Fuel Information	Dina Bacovsky
35-2	Particulate Measurements: Ethanol and Butanol in DISI Engines	Debbie Rosenblatt
38-2	Environmental Impact of Biodiesel Vehicles	Norifumi Mizushima
39-2	Enhanced Emission Performance of HD Methane Engines (Phase 2)	Magnus Lindgren
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	Jukka Nuottimäki
44	Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels	Fan Zhang
45	Synthesis, Characterization and Use of Hydro Treated Oils and Fats for Engine Operation	Benjamin Stengel
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	Jukka Nuottimäki

Recently Completed Annexes

Annex Number	Title	Operating Agent
41	Alternative Fuels for Marine Applications	Ralph McGill

The final report on the recently completed Annex 41 is published on the AMF website. In addition, printed copies of the Annex 41 report are available upon request.

3.b
Annex Reports

Annex 28: Information Service and AMF Website

Project Duration	January 28, 2004 – Continuous
Participants **Task Sharing** **Cost Sharing**	 No task sharing Austria, Canada, China, Denmark, Finland, France, Germany, Israel, Italy, Japan, South Korea, Spain, Sweden, Switzerland, Thailand, United States
Total Budget	43,000 € for 2013 ($59,244 US) 47,000 € for 2014 ($64,751 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 e-mail alert system to disseminate information about the latest issues.
- 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 should cover 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 is not expected to cover information on fuel resources, fuel production, or greenhouse gas emissions. Different organizations are working together in close cooperation to build an AMF guidebook that will be accessible electronically on the AMF website.
- Update the AMF website to provide information on issues related to transportation fuels, especially those associated with the work being done under the Implementing Agreement of Advanced Motor Fuels. The website, in addition to providing public information, has a special password-protected area that is used to for storing and distributing internal information for Delegates, Alternates, and Operating Agents on various topics (e.g., strategies, proposals, decisions, Executive Committee meetings of the AMF Implementing Agreement, etc.).

Results and Reports/Deliverables

- In 2013, four electronic newsletters were published: one in March, in June, in October, and in December (Figure 1).
- The Alternative Fuels Information System is now available on the AMF website.
- The AMF website was updated frequently with information from Annexes and Executive Committee meetings.

ADVANCED MOTOR FUELS
IEA-AMF
March 2013, issue no. 1/2013
AMFI Newsletter

The AMFI Newsletter is prepared for the members of the Implementing Agreement on 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 WORGETTER, BIOENERGY 2020+
- Nuwong CHOLLACOOP, MTEC
- Päivi Aakko-Saksa, VTT

Editing by Päivi Aakko-Saksa, VTT, and Dina Bacovsky, BIOENERGY 2020+.
The AMFI Newsletter is available online at: www.iea-amf.org

New AMF Website online (go to website)

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AMFI Newsletter, March 2013 – Page 1(13)

ADVANCED MOTOR FUELS
IEA-AMF
June 2013, issue no. 2/2013
AMFI Newsletter

Göteborg Energi
GoBiGas

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Editing by Päivi Aakko-Saksa, VTT, and Dina Bacovsky, BIOENERGY 2020+.
The AMFI Newsletter is available online at: www.iea-amf.org

Visit to the GoBiGas biomethane production facility (under construction) during AMF ExCo 45

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AMFI Newsletter, June 2013 – Page 1(14)

ADVANCED MOTOR FUELS
IEA-AMF
October 2013, issue no. 3/2013
AMFI Newsletter

U.S. monthly biodiesel production
million gallons
109 million gallons previous peak in December 2011
111 million gallons May 2013
eia
120
100
80
60
40
20
0
Jan-09
Jan-10
Jan-11
Jan-12
Jan-13

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Checking by Ralph McGill, FEEC and Päivi Aakko-Saksa, VTT.
The AMFI Newsletter is available online at: www.iea-amf.org

U.S. biodiesel production reached a record level in May 2013
more

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AMFI Newsletter, October 2013 – Page 1(15)

ADVANCED MOTOR FUELS
IEA-AMF
December 2013, issue no. 4/2013
AMFI Newsletter

The AMFI Newsletter is prepared for the members of the Implementing Agreement for Advanced Motor Fuels of the International Energy Agency (IEA/AMF).
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The AMFI Newsletter is available online at: www.iea-amf.org

AMF ExCo members visiting the 3CV test lab in Santiago, Chile
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Fig. 1 AMF Newsletters Published in 2013

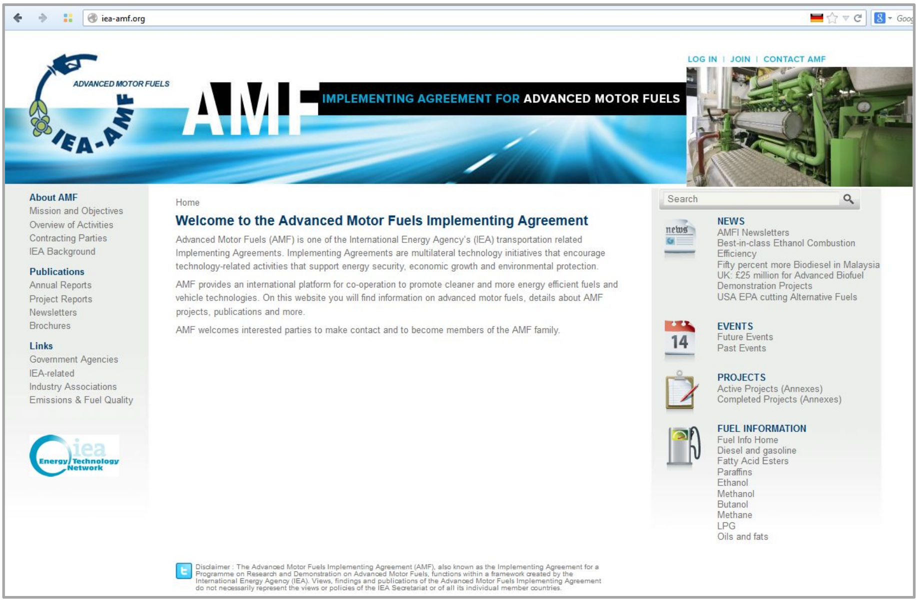


Fig. 2 Screenshot of the AMF Website

Future Plans

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

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

Project Duration	November 2010 – May 2014
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Finland, United States No cost sharing
Total Budget	~225,000 € ($310,000 US)
Operating Agent	Debbie Rosenblatt Environment Canada Email: Debbie.Rosenblatt@ec.gc.ca

Background

As renewable fuel mandates are enacted and revised throughout the world, and as fuel economy standards get more demanding, a need has arisen to better understand the synergies between the fuels proposed to meet cleaner domestic renewable energy production goals and the technologies that can result in 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) engines with turbocharged spark ignition (SI). Emissions of particulate matter (PM) are not currently a problem associated with gasoline engines; however, the PM associated with DISI engines have been shown to be greater than those associated with port fuel-injected gasoline engines or compression-ignition engines with diesel particulate filters. As PM emission regulations have been becoming more stringent, it has become necessary to ensure that interactions that result from efforts to use renewable energy and to improve energy efficiency do not have 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 their impacts on the design and effectiveness of after-treatment systems, it has become important to understand how particulates form from 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. There is also only a limited amount of data on PM emissions that can result from the use of butanol blends in DISI engines. 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) with the direct injection of gasoline-injected fuels. Steady-state engine dynamometer tests as well as transient chassis dynamometer vehicle tests were conducted. The strategy was to evaluate the impact of ethanol and isobutanol on emissions from DISI engines operating under various 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 using a 2.2-liter (L), in-line, four- cylinder, 16-valve DISI engine under idle conditions and at 25%, 50%, and 75% load at 2,000 revolutions per minute (rpm). The fuels tested were gasoline, E10, E85, and iso-butanol-16 (iB16). The particle number and size distribution was determined by using a scanning mobility particulate sizer, and soot morphology was determined by using a transmission electron microscope.

Canadian Project Activities

Environment Canada's (EC's) Emissions Research and Measurement Section (ERMS) conducted chassis dynamometer tests on a model year 2012 flex-fueled 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 the New European Driving Cycle (NEDC) at 22°C and at –7°C with an engine exhaust particle sizer (EEPS). The fuels tested included gasoline, E10, and E85.

In addition, chassis dynamometer tests were conducted and particle measurements were taken 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 fueled with gasoline and splash blends of E10, E15, E20, and an iB16 blend. Two transient drive cycles FTP-75 and US06 (aggressive driving) were used at ambient test temperatures of 22°C and –18°C.

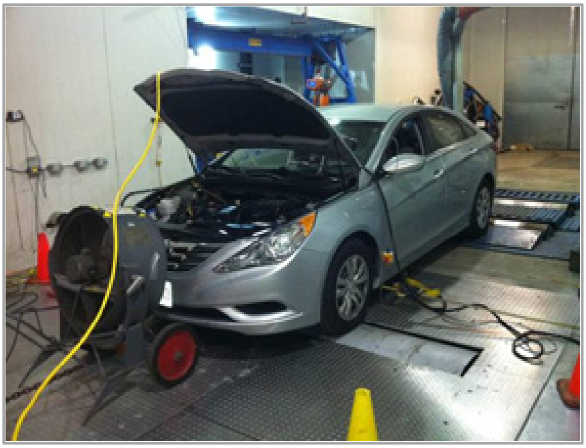


Fig. 1 Vehicle Emissions Testing on Environment Canada's Chassis Dynamometer

Three Canadian universities (University of Alberta, University of British Columbia, and University of Toronto) studied the particle number and size distribution with a scanning mobility particulate sizer, the particle density with a centrifugal particle mass analyzer, and the soot particle morphology with a transmission electron microscope. Data were collected from a 2.0-L, four- cylinder, DISI engine fueled with gasoline and ethanol-blended fuels (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 tests were conducted at two ambient temperatures: 23°C and –7°C. Measurements were taken over the transient NEDC. Particulate size distributions were measured with an electrical low-pressure impactor (ELPI).

China Project Activities

The China Automotive Technology and Research Center (CATARC) is conducting chassis dynamometer tests on several DISI vehicles running on gasoline and ethanol blends. Both gaseous and particulate emissions are being measured. The information resulting from this research will be presented in Annex 44: Research on Unregulated Pollutant Emissions of Vehicles Fueled with Alcohol Alternative Fuels.

Participants

- Canada: Environment Canada, Emissions Research and Measurement Section (ERMS)
- Canada: University of Alberta, University of British Columbia, and University of Toronto
- China: China Automotive Technology and Research Center (CATARC)
- Finland: VTT Technical Research Centre of Finland
- United States: Argonne National Laboratory

Time Schedule

This Annex is scheduled to be completed in May 2014.

Results/Key Messages

This Annex demonstrated the potential for E85 to mitigate particulates 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 can be realized from using 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 revealed significant differences in the levels of particulates produced as a result of using different fuels at different load/speed combinations. E85 resulted in significantly lower particulate levels than did any of the other fuels tested. The iB16 fuel resulted in levels slightly above those that resulted from using the other fuels at 75% load conditions and resulted in levels slightly below them at 25% load conditions. At 50% load, iB16 resulted in significantly higher particulate levels than did the other fuels.

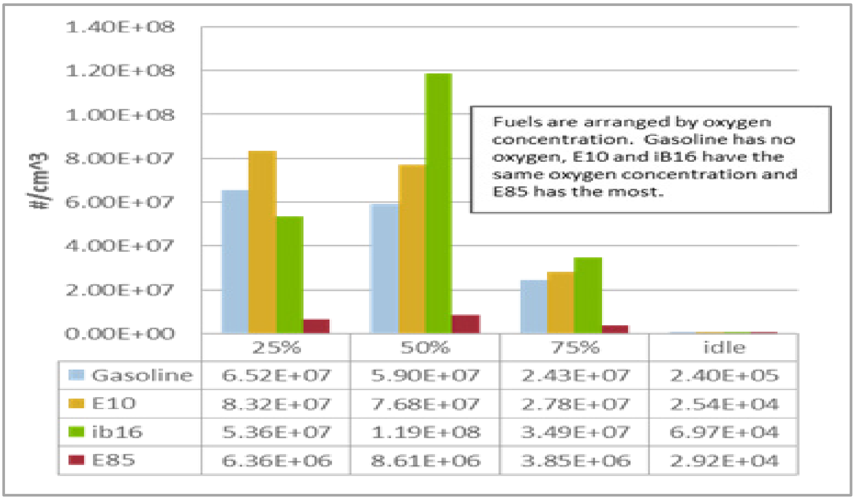


Fig. 2 Total Particulate Concentrations (#/cm^3): 2.2-Liter DISI Engine

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

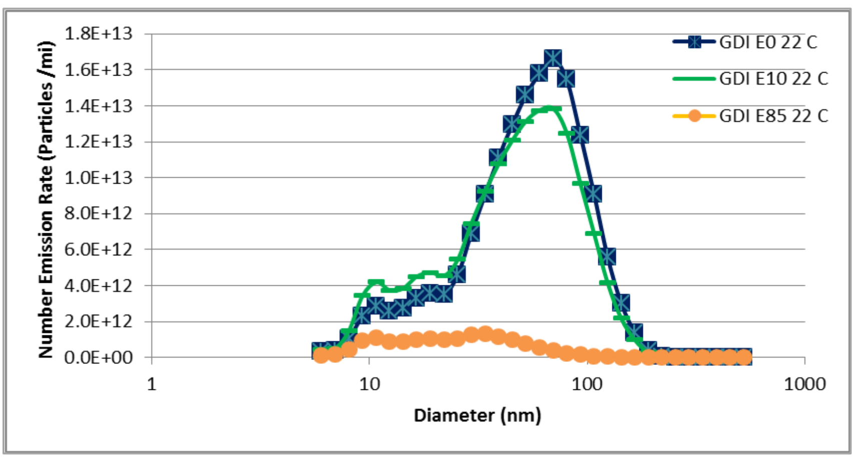


Fig. 3 Particle Size Distributions mi) for DISI Vehicle Running on E0 and E85 over FTP-75 Driving Cycle

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

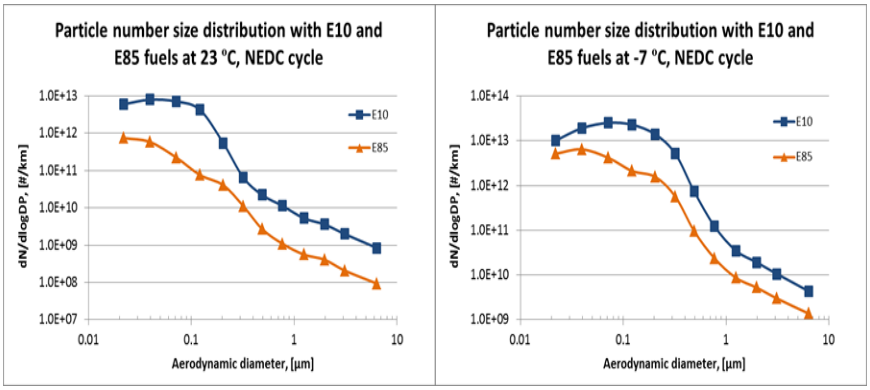


Fig. 4 Particle Size Distributions (/km) for DISI Vehicle Running on E10 and E85 over the NEDC at Various Ambient Temperatures

Publications

- Chan, T., E. Meloche, J. Kubsh, D. Rosenblatt, R. Brezny, and G. Rideout, 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.
- 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, D. Rosenblatt, and G. Rideout, 2013, "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, Portland, Ore., Sept. 30–Oct. 4.

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 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. This Sub-task 2 of Annex 35 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 Implementing Agreement studies related to alcohol fuels. The presentation not only highlighted the impacts of alcohol fuels on particles from DISI engines (Annex 35, Sub-task 2) but also provided preliminary results from the other current Annexes that focus on alcohol fuels:

- Annex 43: Performance Evaluation of Passenger Car Fuel and Power Plant Options
- Annex 44: Research on Unregulated Pollutant Emissions of Vehicles Fueled with Alcohol Alternative Fuels
- Annex 46: Alcohol Application in Compression Ignition Engines

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

Future Plans

Canada, China, and Finland, as participants in Annex 44, will provide data in support of Annex 44's Research on Unregulated Pollutant Emissions of Vehicles Fueled with Alcohol Alternative Fuels. The objective of this research is to establish measurement methods and limits for unregulated pollutants by examining how unregulated pollutants from vehicles are influenced by measurement methods, automotive technologies, alcohol contents, ambient temperatures, test cycles, and other test parameters. Both DISI and port fuel-injected vehicles are included in this study, and particulate masses 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: Performance Evaluation of Passenger Car, Fuel, and Power Plant Options. The objective of Annex 43, as operated by VTT Technical Research Centre of Finland, is to enable the development and comparison of different fuel options by developing benchmark data on fuel efficiency, engine efficiency, and tailpipe emissions for a variety of vehicle makes and models, with an emphasis on the differences among alternative engine technologies. Then particulate emissions from DISI engines fueled with E85 and E10 can be compared with emissions that result from different vehicle technologies and fuel options.

In supplemental test programs, Canada will investigate the impacts of emission control technologies, such as gasoline particulate filters, and different alcohol fuels, with the objective of discovering any synergistic effects that the technologies and alcohol fuels might have 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, USA
Total Budget	95,000 € ($124,450 US)
Operating Agent	Norifumi Mizushima 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 will be recycled. As a result of this potential, efforts to promote the production and use of BDF have taken place all over the world.

On the other hand, today's diesel vehicles are adapted to the latest emission regulations and already incorporate leading-edge technologies with precise electronic control systems designed to reduce exhaust emissions. These technologies provide benefits for vehicles fueled with ultra-low-sulfur diesel (ULSD). So if BDF was used in diesel vehicles with these advanced technologies, the exhaust emissions would not be as low as they are when ULSD is used, since the emission properties of the two fuels are very different from each other. The exhaust emissions from the vehicles might even get worse if BDF was used.

Nevertheless, BDF is promoted because it is highly effective in reducing GHG emissions. So in the development of BDF vehicles, the possibility of increasing harmful exhaust emissions is a concern that must be addressed. In this context, research on the emission characteristics of the latest vehicles fueled with BDF must be done.

Purpose and Objectives

The use of BDF vehicles has progressed in many countries. For example, in Kyoto City, Japan, route buses and refuse trucks fueled 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 the portable emission measurement system (PEMS) are conducted on a new diesel vehicles adapted to the latest emission regulations equivalent to EURO V level regulations (during Phase 1 of this Annex) and EURO VI level regulations (during Phase 2 of this Annex). These test diesel vehicles are not customized for BDF operation. 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 BDF).

In addition, the Japanese heavy-duty diesel vehicles that meet the latest emission 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 on emission levels cannot be ignored, the real-world fuel economy should 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 these tasks continue to progress.
- Tests use the latest heavy-duty diesel vehicle that complies with the Japanese 2009 regulations (Figure 1).
- Chassis dynamometer tests are conducted on the latest heavy-duty diesel vehicle fueled 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 are conducted with the latest heavy-duty diesel vehicle fueled 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 (complies with Japanese 2009 regulations)

Participants

Finland, Germany, Sweden, United States, Canada, 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 driving and eco-driving) with ULSD, first-generation BDF (FAME), and next-generation BDF (HVO) were finished.
- Test data from on-road driving were analyzed.
- An engine bench with an engine that is the same as the one mounted on the test vehicle was set up and prepared for evaluating the combustion and emission characteristics of BTL (Figure 2).

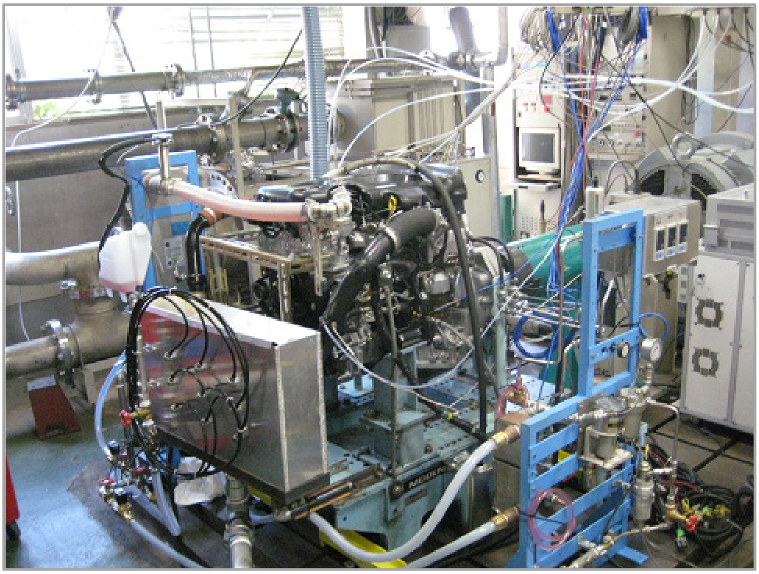


Fig. 2 Test Engine

Success Stories

This Annex can provide data on real-world emissions from the latest heavy duty-vehicles (Euro VI level) fueled with various BDFs. Based on the results of this Annex, measures will be developed to counter the exhaust emissions from BDF vehicles. The measures will be considered when a policy for introducing biofuel into the market is being developed.

Annex 39: Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines

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, European Commission Directorate General for Energy (DG Energy)
Total Budget	325,000 € ($430,000 US)
Operating Agent	Magnus Lindgren Phone: +46 70 361 50 26 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 (Intergovernmental Panel on

Climate Change [IPCC] 2007[62]). 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 the Annex 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.

[62] Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, 2007. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor, and H.L. Miller (eds.), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Activities

The first phase of the Annex 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 AMF 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 ExCo 45.
- Elaborate and present a technical report for AMF.
- 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
- European Commission DG Energy via Bioenergy Implementing Agreement
  - Cost share
- ANGVA
  - Provide information on natural gas vehicles in Asia and on compressed natural gas (CNG) consumption in Asia

- Canada and Finland
  – Provide test results on methane-fueled HDVs participating in national programs

Time Schedule

Table 1 shows the schedule.

Table 1 Schedule

	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															●

DDF = diesel dual fuel; SI = spark ignition; Q1, 2, 3, 4 = first, second, third, fourth quarter

Results/Key Messages

Phase 1 of the project resulted in the report *Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines*, a literature study that focuses on diesel dual fuel (DDF) concepts and highlights their potential to achieve low exhaust emissions and improved engine efficiency (compared to spark ignition [SI] methane engines). The first phase of the project was finalized in May 2010.

Phase 2 consists of measuring the performance of and emissions from dedicated methane and dual-fuel engines. In addition to the measurements taken in Sweden, information has been contributed by the cost-sharing participants Germany, Japan (LEVO and JGA), and Bioenergy IA (DG Energy). The contributions from the task-sharing participants Canada and Finland have not yet been reported. The final report will also contain information from ANGVA on gas consumption and the post-conversion of petrol/diesel engines to gas/DDF engines in Asian countries.

The following conclusions can be made from the initial literature review:

- Although the reasons for using methane are different in different countries, the main ones are to mitigate carbon dioxide (CO_2) emissions, mitigate toxic emissions, and access low-cost fuels.
- Both the engine and after-treatment technologies need further development.
- Converting from diesel to DDF is a very attractive option.
- No test method is available for DDF.

Current results from Phase 2 are summarized as follows:

- DDF concepts (DDF, methane-diesel)
  - It is difficult for concepts, if implemented, to meet Euro V/VI emission standards in dual-fuel mode.
  - Diesel replacement depends on load conditions.
  - Concepts are not suitable for low-load, start/stop driving in dual-fuel mode.
  - Concepts do not offer the potential for reduction in global warming in dual-fuel mode compared with diesel mode (unless biogas is used).
- Dedicated gas engines (SI)
  - They have no problem complying with Euro V/Enhanced Environmentally-friendly Vehicle (EEV) emission standards.
  - The efficiency of these engines is lower (than that of diesel engines), especially with regard to lean mixes.
  - The lean-mix concept is operating mostly on $\lambda 1$ (stoichiometric combustion).

Publications

- 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.
- Final report expected in May/June 2014.

Success Stories

This Annex has contributed to work being done under the framework of the UNECE Working Party on Pollution and Energy to develop a test procedure that will enable the homologation of dual-fuel engines within the Euro VI regulation.

The evaluation of various technologies for dual-fuel operation has shown that some of them result in higher methane emissions than initially anticipated. By taking the results from this Annex into account in future work, a possible 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, this concept needs to be monitored for 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 members through the common fund • AMF nonmembers: Czech Republic, Greece, Netherlands, Norway
Total Budget	40,000 € ($55,356 US) • Task-sharing AMF budget: 10,000 € ($13,839 US) • Swiss contribution: 10,000 € ($13,839 US) • Continuation AMF budget: 20,000 € ($27,678 US)
Operating Agent	Jan Czerwinski AFHB (Laboratory for Exhaust Gas Control) University of Applied Sciences, BFH-TI, Biel, 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 all the living cells or cell cultures to the aerosol; this results in a simultaneous superposition of all toxic effects from all active components.

In several instances,, 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 investigation in Annex 42 focuses 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, mass, 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 results 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 members.

Activities

International Activities

Several toxicologists, biologists, and medical doctors are investigating the toxic influences of vehicle exhaust emissions (Figures 1 and 2). 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 bio-toxicological testing procedure, more worldwide testing activities need to take place. Several European countries declared their interest in participating in the European Union (EU) -funded project EngToxNet: a round-robin program for validating toxicological procedures.

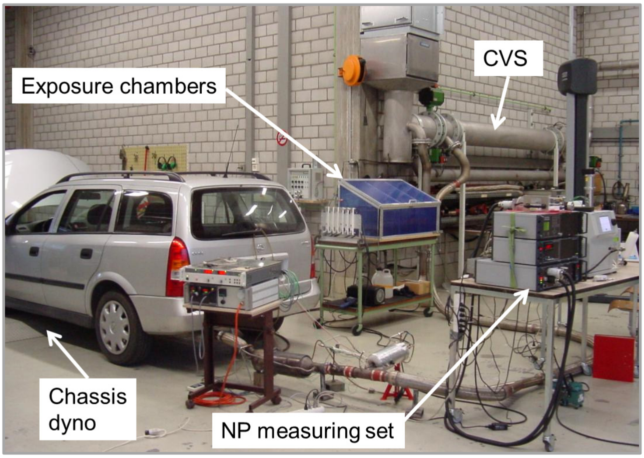


Fig. 1 Exposure Tests on a Diesel Passenger Car
(CVS = constant volume sampling; NP = nanoparticle)

Present Annex:

- Contact different research groups
- Collect information
- Prepare annual information report
- Coordinate with cooperating agents
- Send report to AMF

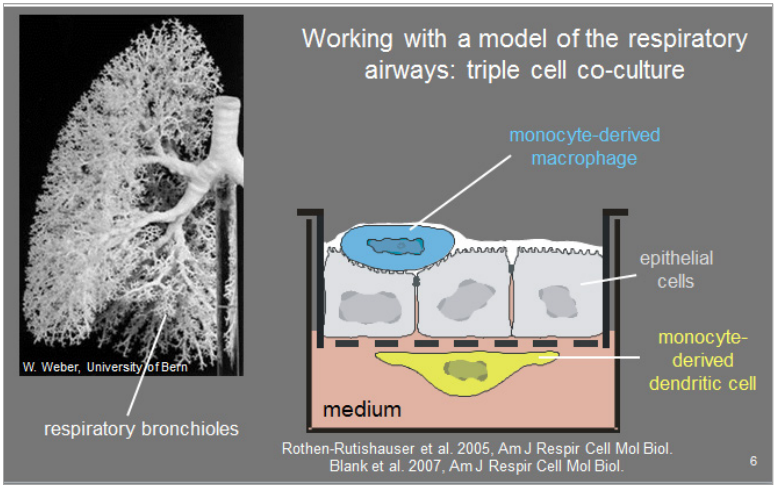


Fig. 2 Structure of the Lung and the Triple-Cell Model

Participants

All AMF members

Time Schedule

November 2010 – May 2015

Results/Key Messages

- Provide information and enable knowledge exchange (three annual reports: Information Report for 2010/2011, AFHB B315, Sept. 2011; Information Report for 2012, AFHB B344, Oct./Nov. 2012; Information Report for 2013, AFHB B370, Oct./Nov. 2013)
- Help coordinate future activities
- AMF homepage: http://iea-amf.org/content/projects/annexes/42

Publications

EngToxIn reports, see “Results” sections

Success Stories

The Annex helps disseminate information on health effects and raises the scientific community’s consciousness of them. It fosters progress in protecting the environment, especially in highly populated areas, and protecting working places. It could lead to further improvements in research and policies in the future.

Annex 43: Performance Evaluation of Passenger Car, Fuel, and Power Plant Options

Project Duration	January 2011 – May 2014
Participants	
Task Sharing	Canada, China, Finland, Japan, Sweden, United States
Cost Sharing	No cost sharing
Total Budget	~450,000 € ($622,755 US)
Operating Agent	Jukka Nuottimäki VTT Technical Research Centre of Finland Email: jukka.nuottimaki@vtt.fi

Background

Major de-carbonizing actions need to occur in the road transport sector. However, no single solution can address this challenge. Multiple technologies need to be studied in order to determine the alternatives best-suited for each given set of boundary conditions. The consideration of energy efficiency is becoming more important. Downsizing engines, switching to diesel fuel, and opting for hybridization can all contribute to fuel efficiency. Renewable energy can be introduced, either through biofuels or through electricity from renewable sources.

Passenger cars make up 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, to improve the possibility of making the most appropriate choices among the many available options. The numbers of technology options available for both powertrain alternatives and fuel alternatives are increasing. Unbiased data sanctioned by the International Energy Agency (IEA) on the performance (energy use and emissions) of new technologies is needed by decision makers at all levels.

Purpose and Objectives

The core of the study consists of benchmarking a set of passenger car makes and models that offer multiple options for power plants and fuels. The project will also 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 the duty cycle and ambient temperature to be modulated 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 market-specific type-approval conditions and driving cycles.

The primary objective of the project is to produce comparable information about different power plant options with regard to fuel efficiency, energy efficiency, and tailpipe emissions. By using selected vehicle platforms and basically performing "internal" comparisons among power plant options, the vehicles themselves can be "nullified." This approach emphasizes the differences in alternative engine technologies rather than the differences in 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 in this Annex in 2013 concentrated 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.

Method Development

Agreement on common test protocols was essential for this project, and this work was done in 2011. The purpose of common test protocols is to ensure that the baselines for test results will be comparable; however, participant-specific test conditions were also allowed and encouraged.

Data Collection

Japan and the United States are participating in this Annex by sharing existing data. Due to different test protocols, these data are not directly comparable with other experimental test results. However, the data from Japanese and American participants were accepted because the information supplements the test matrix, providing valuable data on hybrid powertrains and liquefied petroleum gas (LPG) as a fuel.

Experimental Work

Canada, China, Finland, and Sweden have conducted experimental work for this Annex in a laboratory environment by using chassis dynamometer and emission measurement equipment. The test vehicles used represent passenger car types that are typical in 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 awaiting supplementation. Canada plans to finish the tests and to submit a sub-report early in 2014.

Data Assessment

Data will be evaluated in two steps. The first evaluation on end-use performance will be done by each individual participating country on vehicles in the tested vehicle model's family. The second evaluation will be done when the Final Report is being prepared; it will use all the information generated. The second phase will combine the well-to-tank data on test fuels with the end-use performance data to provide information on the complete fuel cycle.

Information Dissemination

Information will be disseminated at AMF Executive Committee (ExCo) meetings, in the Final Report, and possibly also at suitable conferences. A short summary of the project idea and of the Finnish test results will be presented at the Fisita 2014 conference.

Participants

Policy-Related Participants

Finnish Transport Agency, New Energy and Industrial Technology Development Organization (NEDO), Organization for the Promotion of Low Emission Vehicles (LEVO), Swedish Energy Agency, Swedish Road Administration Agency, and Tekes – The Finnish Funding Agency for Innovation

Industrial Participants

European Batteries, Gasum, Neste Oil, Nikki Co. Ltd., and St1

Academia and Testing Laboratory Participants

Argonne National Laboratory, AVL MTC Motortestcenter AB, Beijing Institute of Technology, China Automotive Technology and Research Centre, Environment Canada, National Traffic Safety and Environment Laboratory (NTSEL), and VTT Technical Research Centre of 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 are expected to be delivered early in 2014, and the Final Report is scheduled to be ready by summer 2014 (Table 1).

Table 3 Planned Project Time Schedule (Q = quarter)

	2011				2012				2013				2014	
	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2	Q 3	Q 4	Q 1	Q 2
Preparations, test protocols														
Vehicle measurements														
Reporting, sub-reports														
Final report														

Results/Key Messages

The preliminary results indicate that no single solution could address all the challenges of road transport. Instead, there seem to be pros and cons with regard to the tested fuel and powertrain alternatives, with the best choice for using them depending on the particular operating environment. Electric vehicles are an energy-efficient option under various driving conditions, but they suffer from having a limited driving range. In addition, the well-to-wheel carbon dioxide (CO_2) emissions of electric vehicles, among the available powertrain options, seem to be most sensitive to upstream energy production. In other words, the most suitable option seems to depend on driving conditions and user needs. However, the preliminary results also indicate that sophisticated fuels may help to reduce tailpipe emissions and well-to-wheel CO_2 emissions from traditional vehicles.

Publications

The Final Report is planned to be published in the summer of 2014. A short summary of VTT's test results will be presented at the Fisita 2014 conference; the title of the presentation is "Performance Evaluation of Passenger Car, Fuel and Power Plant Options."

Success Stories

The outputs from 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 makes recommendations for road transport in the future.

Future Plans

At AMF's ExCo Meeting 43 in Zürich, VTT was tasked with two action items:

- Action Item 9: Prepare a pre-proposal on fuel and technology alternatives for heavy duty vehicles to be presented at ExCo Meeting 44
- Action Item 12: Prepare a proposal analyzing alternative fuel and powertrain options for commercial light-duty vehicles to be presented at ExCo Meeting 44

VTT combined these requests into one proposal, which was accepted as Annex 49 at ExCo Meeting 45 in Gothenburg. This new Annex 49 is based on the work done in Annexes 37, 38, 39, and 43. Therefore, the findings from this study will supplement the work that is going to be carried out under Annex 49.

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

Project Duration	July 2012 – June 2014 (2 years)
Participants **Task Sharing** **Cost sharing**	 China, Canada, Finland, Sweden, Israel, Switzerland China, Sweden, Finland
Total Budget	80,000 € ($103,000 US)
Operating Agent	Fan Zhang Beijing Auto Test Lab China Automotive Technology and Research Center (CATARC) Email: zhangfan@catarc.ac.cn

Background

The gradual depletion of petroleum resources throughout the world has made the need to develop alternative energy sources more urgent. Alcohol fuels have the advantage of coming from a wide range of sources. They 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, petrochemicals, 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.

As a result of the reductions in the emission limits on regulated pollutants, emissions of unregulated pollutants in the vehicle exhaust have attracted increasing 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 complete combustion of the fuel. Unfortunately, however, more unregulated pollutants, such as polycyclic aromatic hydrocarbons (PAHs), aldehydes, and ketones, may be emitted. These substances stimulate strong negative reactions in sensitive recipients. They could also have genetic toxicity and cause carcinogenic activity, which can significantly affect human health. This issue is an important factor that could hinder further development of alcohol alternative fuels.

As a result of these concerns, we need to investigate the unregulated pollutant emissions from vehicles fueled 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 main purpose of this project is to obtain the unregulated pollutant emission levels of alcohol-fueled vehicles and to gradually establish both measurement methods and limits for these emissions. In addition, research focuses on examining the influences that measurement methods, automotive technologies, the alcohol content of fuels, ambient temperatures, test cycles, and other relevant factors have on emissions of unregulated pollutants from vehicles.

Activities

Researchers in China conducted emission tests on a chassis dynamometer by using a gasoline direct-injection (GDI) vehicle fueled with gasoline, E10, E20 (gasoline with 10% and 20% ethanol, respectively), M15, and M30 (gasoline with 15% and 30% methanol, respectively). 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 pollutant emissions from the vehicle. The measurement results for methanol, formaldehyde, acetaldehyde, acetone, benzene, toluene, xylene, and other unregulated pollutant emissions at 25°C were quantitatively determined and are still being analyzed. In addition, evaporative emission tests were conducted by using a port fuel injection (PFI) vehicle fueled with gasoline, E10, and M15. HPLC and GC-MS were used to measure the unregulated emissions.

Researchers in Sweden conducted a review of the literature on the low blending of alcohol fuels in passenger cars. The report was finalized in October 2013 and has already been delivered as a task-sharing contribution for Annex 44. The report discusses both regulated and unregulated emissions and experiences related to the use of alcohol fuels. Its focus is on methanol.

Researchers in Finland conducted emission tests on the 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 (by using GC), aldehydes (2,4-dinitrophenylhydrazine [i.e., DNPH] by using HPLC), and particulate masses were measured. The driving cycles were cold-start NEDC and hot-start FTP-75 (U.S. Environmental Protection Agency [EPA] Federal Test Procedure).

Researchers in Canada conducted emission tests on a model year 2012 Ford Focus flex-fueled vehicle with a 2.0-liter wall-guided GDI engine. Test cycles included FTP-75, US06 (an aggressive, high-speed, high-load cycle), and a limited set of NEDC. All tests were conducted at 25°C. In addition, FTP-75 tests were performed at ambient temperatures of –7°C and –8°C. Analysis is ongoing. In addition to regulated pollutant emissions, unregulated pollutant emissions of CO, nitrogen oxides (NO_x), HC, and carbon dioxide (CO_2) were collected by using HPLC and GC-FID (flame ionization detection) for compounds such as acetaldehyde, formaldehyde, acetone, benzene, and toluene. 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 both regulated pollutant emissions and unregulated ones (focusing on formaldehyde and acetaldehyde). All tests were performed in a 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.

Participants

- China Automotive Technology and Research Center (CATARC)
- Canada's CanmetENERGY
- VTT Technical Research Centre of Finland (VTT)
- Swedish Transport Administration (STA)
- Israeli Ministry of National Infrastructure, Energy and Water Resources
- Swiss Federal Office of Energy (SFOE)

Time Schedule

The estimated duration of the project is two years, beginning in July 2012. The main breakdown of the schedule is as follows:

- Preparation of project: July – September 2012
- Literature survey: October – December 2012
- Measurements with methanol fuels: January – December 2013
- Measurements with ethanol fuels: March 2013 – March 2014
- Final report: April – June 2014

Results/Key Messages

China

The test results from China on a light-duty gasoline vehicle using alcohol fuels indicate that the transient emissions of formaldehyde, acetaldehyde, toluene, propylene, and 1,3-butadiene have the highest peak under the conditions that occur during the first acceleration. Then, with the catalyst lights off, the emission values gradually decrease to nearly zero and remain there until the end of the driving cycle. At both low and normal ambient temperatures, as the proportion of alcohol in the fuel increases,

- The level of CO_2 in the exhaust emissions remains basically the same;
- The levels of HC, CO, and methane (CH_4) decrease slightly;
- The level of NO_x increases slightly; the levels of unburned methanol, formaldehyde, and acetaldehyde increase proportionally; and
- The levels of benzene, toluene, ethylene, propylene, 1,3-butadiene, and isobutene decrease slightly.

The levels of both regulated and unregulated pollutant emissions are significantly higher in the low ambient temperature than in the normal ambient temperature. The difference in the levels of HC emissions that occur during the entire process of the evaporative emission tests of E10, gasoline, and M15 fuels is slight. Although there is a difference in the level of unregulated pollutant emissions in the diurnal test of the three fuels, this difference is very small. Figure 1 shows the unregulated pollutant emissions during the NEDC at –7°C when ethanol fuels are used.

VTT Technical Research Centre of Finland

Figure 2 shows the unregulated pollutant emissions during the cold-start NEDC using ethanol fuels. The test results show that formaldehyde and acetaldehyde emissions were higher when E85 and E100 were used than when E10 was used, particularly when E85 was used at a temperature of –7°C. During the cold-start NEDC, particulate matter (PM) emissions were generally low (below 7 mg/km). The PM level at –7°C was clearly higher than that at +23°C. PM emissions decreased with an increasing ethanol content in the fuel. PM emissions were low (i.e., below 1 mg/km) when both fuels and cars were used during the hot-start FTP-75.

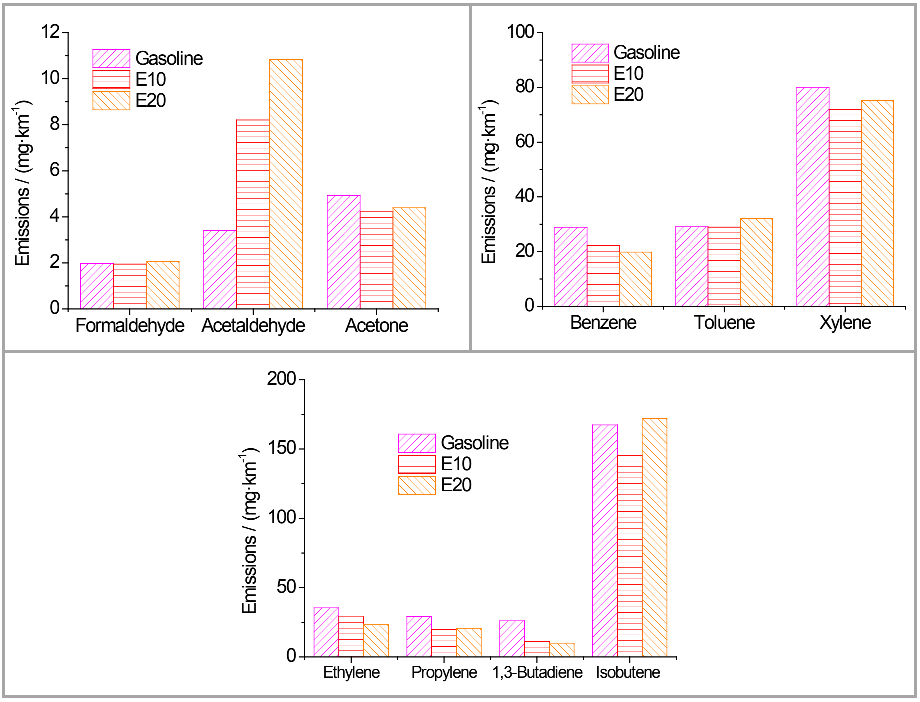


Fig. 1 NEDC: Unregulated Pollutant Emissions (ethanol fuels at –7°C)

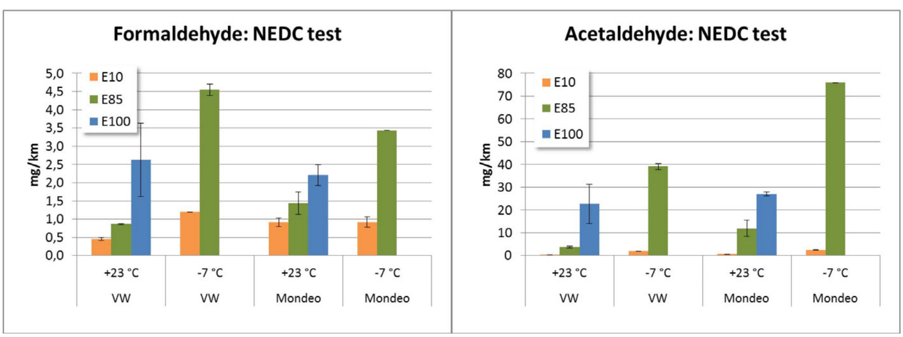


Fig. 2 Cold-Start NEDC: Unregulated Pollutant Emissions (ethanol fuels)

Sweden

The final report on the literature review shows that reliability in the projects that used low-level blends of methanol was good. Few problems were experienced. For example, phase separation under normal conditions was not observed. Material compatibility also has generally not been an issue. Most engine and fuel system components that were inspected were in good condition. However, these results do not mean that problems of this kind would not occur if modern cars and/or certain car models were used. These problems would be of particular concern if the blending level were raised from the current level of 3% allowed in the European Union.

This study identified a couple of areas in which there are gaps in the knowledge if methanol was introduced in the market at a larger scale. There is a general a lack of experience with regard to running modern cars on methanol blends. Although the blending level maximum is 3% in the European Union today, it is not known if the practical limit could, in fact, be raised without requiring any vehicle modifications. Gaps in knowledge have also been identified with regard to unregulated pollutant emissions that could pose a health hazard. For example, modern vehicles should be used to characterize PAH emissions at low temperatures and perhaps under several other driving conditions not covered under current certification test cycles.

Publications

The final report is expected to be published before the end of 2014.

Future Plans

Switzerland is going to start specific research and will contribute its information as part of the Annex 44 task sharing before the planned end of the Annex in June 2014.

Annex 45: Synthesis, Characterization, and Use of Algae-HVO and eFAME for Engine Operation

Project Duration	March 2013 – February 2014 (prolonged to September 2014)
Participants **Task Sharing** **Cost Sharing**	 Canada, Denmark, Finland, Germany, United States No cost sharing
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 for the upcoming decades, even though the costs for oil will increase. However, as a result of emissions from internal combustion engines and limited oil stocks, it is necessary to conduct research on alternative fuels. One promising approach is to substitute fossil fuels with renewable fuels. The European Union has established the 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 mainly for blending with fossil diesel. However, increased FAME blends can lead to the dilution of lubrication oil, thereby resulting in shorter intervals between oil changes. Furthermore fouling can occur, which leads to damage of high-pressure injection pumps.

One promising alternative is the use of hydrotreated vegetable oil (HVO) as a diesel substitute. The HVO shows very similar characteristics compared with conventional diesel and results in reduced exhaust emissions. Further research is needed in order to reduce the high production costs of HVO. Simultaneously, the production method for FAME must be improved to decrease costs.

Purpose and Objectives

The goal of the project is to analyze the use of algae-HVO, NExBTL, FAME, and enzymatic FAME (eFAME) as diesel substitutes in EURO-VI diesel passenger car engines. Fuel analyses will provide information about characteristic values such as heating value, cetane number, and so forth. Engine tests will be carried out focusing on fuel impacts on combustion, emissions, and the efficiency of exhaust after-treatment systems. Furthermore, the fuels will be analyzed, and their production costs and sustainability compared.

Activities

A literature review was conducted focusing 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 using a EURO-VI passenger car diesel engine with state-of-the-art exhaust after-treatment. The test bench was completed with measurement equipment for in-cylinder pressure measurements, emission measurement, as well as engine data and engine control unit (ECU) data recording. 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 reference diesel (EN 590), NExBTL, and FAME. In addition, Denmark performed a cost/quality analysis that shows the relation of cost and quality for several alternative fuels compared with standard EN 590 diesel.

Participants and/or Experts' Meetings

- University of Rostock, Institute of Piston Machines and Internal Combustion Engines (academia, Germany)
- Danish Technological Institute (industry, Denmark)
- Neste Oil (industry, Finland)
- Canada's CanmetENERGY and Environment Canada (industry, Canada)
- Solazyme (industry, USA)

Time Schedule

The time schedule for this project is presented in Table 1.

Table 1 Time Schedule for Annex 45

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																			

Results and Reports/Deliverables

Engine tests were performed for diesel, HVO, and FAME. The analysis of pressure traces and heat release rates showed a significantly shorter ignition delay for HVO (Figure 1), which is caused by its higher cetane number. However, FAME seems to shift the operation maps of the ECU. This can be attributed to its low heating value, which makes it difficult to analyze the direct influences on combustion.

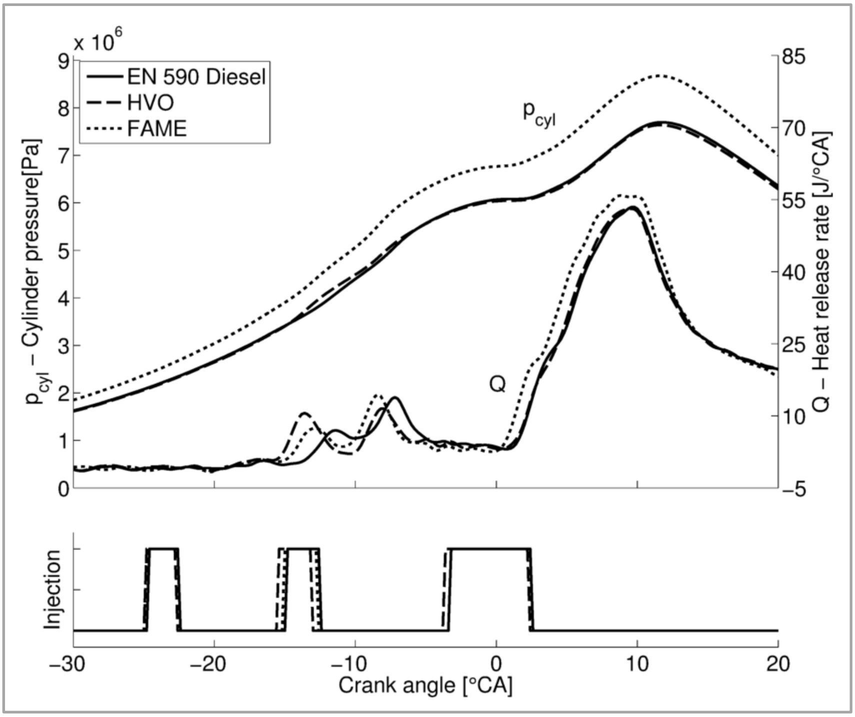


Fig. 1 Cylinder Pressure, Heat Release Rate, and Injection for HVO, FAME, and Reference Diesel (EN 590), n = 2,000min^{-1}, p_{me} = 9 bar

All exhaust emissions were clearly reduced with the use of HVO (Figure 2). HVO is supposed to vaporize earlier, leading to better mixture formation and decreased emissions. Furthermore, the absence of aromatics and polyaromatics inhibits the formation of soot particles (see FSN = Filter Smoke Number). Operation with FAME showed an even higher reduction of emissions except for nitrogen oxides (NO_x). Soot emissions are reduced due to the oxygen content in the fuel, which leads to increased soot oxidation.

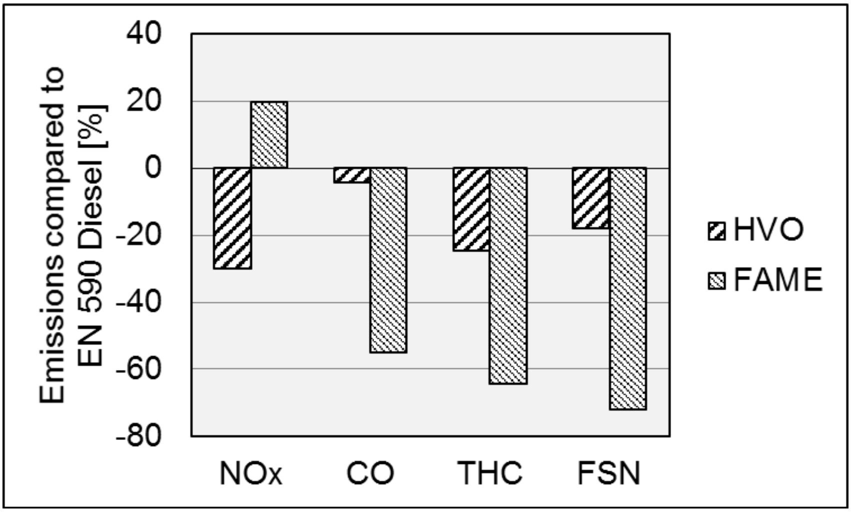


Fig.2 Reduction of Emissions with the Use of HVO and FAME

Research carried out at the Danish Technological Institute (Figure 3) provides an overview of the quality and costs of different biofuels in relation to diesel. It should be noted that HVO showed a higher quality, but at a higher cost. Methylesters showed a lower quality index and higher costs. The production of straight vegetable oil (SVO) is less expensive than diesel production; however, this fuel is of a much lower quality.

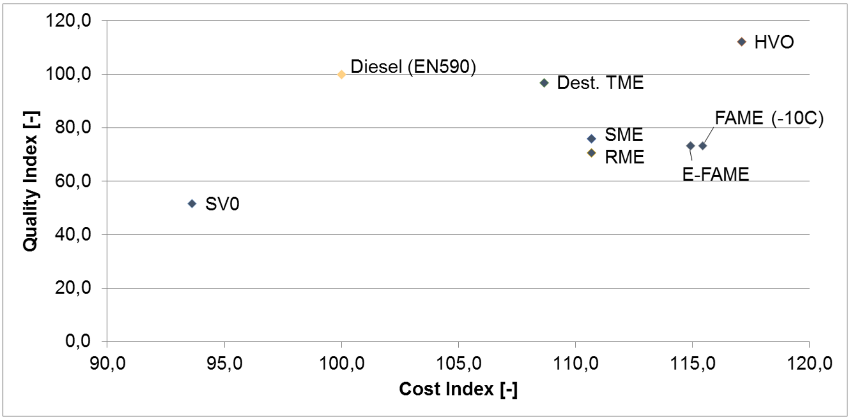


Fig.3 Quality/Cost Analysis of Several Alternative Diesel Fuels

Publications

Stengel, B., Sadlowski, T., and Wichmann, V., 2013, “HVO-Kraftstoffe in EURO-VI-Motoren,” presented at 7. Rostocker Bioenergieforum, Rostock, Germany, June 20–21, 2013.

Planned Publications:

- Stengel, B., Sadlowski, T., and Wichmann, V., 2014, “Influences of HVO and FAME on Combustion and Emissions in EURO-VI Diesel Engines,” to be presented at 2nd International Conference of the Cluster of Excellence Tailor-Made Fuels from Biomass, Aachen, Germany, June 16–18, 2014.
- Stengel, B., Sadlowski, T., and Wichmann, V., 2014, “Einflüsse von HVO und FAME auf die Verbrennung und Emissionen moderner PKW-Dieselmotoren,” to be presented at 8. Rostocker Bioenergieforum, Rostock, Germany, June 19–20, 2014.
- Abstracts for further presentations have already been submitted. It is anticipated that the final report will be published by the end of 2014.

Annex 46: Alcohol Application in CI Engines

Project Duration	March 2013 – February 2015
Participants **Task Sharing** **Cost Sharing**	 Denmark, Finland, Sweden No cost sharing
Total Budget	~300 k€ ($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 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 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** **Cost sharing**	 Japan, Korea, Sweden, Thailand No cost sharing
Operating Agent	Dr. Mitsuharu Oguma National Institute of Advanced Industrial Science and Technology (AIST) mitsu.oguma@aist.go.jp

Background

Although the price of crude oil has come down and is stable, it is imperative that continuous energy security remain a major worldwide goal. With a view toward that objective, expectations are high that dimethyl ether (DME) could reduce the environmental impacts from vehicles and reduce world dependence on oil. Currently, DME is produced from coal and natural gas. If the techniques for producing DME by using synthetic gases either from waste paper fluid (black liquor) or from unused wood (including thinned wood) could be improved, a dramatic reduction in well-to-tank greenhouse gases would be achieved, and DME could become the most attractive next-generation biofuel.

AMF investigated the potential of DME as an alternative fuel for diesel engines through some annexes (e.g., Annexes XIV, XX, and XXVII) from 1997 to 2004. There was no market for DME for vehicles at that time, but the investigation resulted in some supposition that such a market would be established in the near future.

Currently in China, a market for DME for vehicles has developed, and production capacity has reached 13 million tons. In Shanghai, a field test of 10 city buses in a commercial bus line that are running on DME is being conducted now. Also, Sweden is now operating a bio-based DME project, and 14 DME trucks will run in the field test. In Japan, two DME trucks are running (with business license plates), with the goal being to develop technical regulations for DME vehicles. The situation in Japan has changed, and commercialization of DME fuel is being accelerated.

The International Organization for Standardization (ISO) has started to discuss standardization of DME fuel through Standard TC 28/SC 4/WG 13 from 2007. The proposer of this new annex is a convener of Working Group (WG) 13. The scope of DME standardization covers three use categories: (1) as a feedstock for home and industrial use, (2) as a blend stock with liquefied petroleum gas (LPG), and (3) as an alternate for diesel fuel for power systems, including those in vehicles. WG 13 has draft values for DME fuel specifications, but they are not for the final DME product that is used in vehicles; they are for the base fuel that can be used in various applications. Thus, it is still necessary to standardize DME specifications for vehicles, and now is the time to do it, in a new annex of AMF that will consider the current situation with regard to DME fuel commercialization.

Purpose and Objectives

The subject of this proposed Annex 47 is the "Reconsideration of DME Fuel Specifications for Vehicles." The basic specifications will be based on the draft values found in Specification ISO/TC 28/SC 4/WG 13 (shown in Table 1). The main issues to be investigated by the annex are as follows:

- Effect of fuel impurities on DME diesel engine systems
- Effect of additives (e.g., lubricity improver, odorant, if any) on DME diesel engine systems

Table 1 DME Fuel Specifications for Base Fuel (Draft Values in ISO/TC 28/SC 4/WG 13)

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

Participants will individually investigate the effects of fuel impurities and additives on DME diesel engine systems and/or DME vehicles in their country, then share their data and opinions with each other. Some critical issues, such as limits on the hydrocarbon number (up to C_4 currently) and the use of odorant, will be discussed to get a consensus among participants. The information will be referenced in discussions of the standardization of DME fuel specifications for vehicles (as a final fuel), which will be proposed as a new work item under specification ISO/TC 28/SC 4/WG 13 in the near future. Examples of items to be investigated are as follows:

- A materials immersion test will evaluate the effects of fuel specifications on the tolerance of materials used in fuel supply and injection systems.
- An engine performance and emission test will evaluate the effects of fuel specifications on engine performance and on emission characteristics.
- A durability test will evaluate the effects of fuel specifications on the durability of the engine system.
- An operating agent will interview DME vehicle developers in Sweden, Korea, and China and discuss with them the effect of fuel impurities on DME diesel engine systems.
- Emission tests will be performed with fuel-grade DME, if necessary.
- A draft of DME fuel specifications will be established for the proposal of an ISO new work item.

Participants

- **Japan**
  - National Institute of Advanced Industrial Science and Technology (AIST)
  - Isuzu Advanced Engineering Center, Ltd.
  - DENSO Corporation
- **Sweden**
  - Swedish Transport Administration (STA) (Sweden)
  - 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

- Interview and discussion: March–June 2014
- Engine testing to investigate the effect of impurities on emissions from DME-powered diesel engine: July–December 2014
- Discussion of DME fuel specifications for vehicles: January–June 2015
- Preparation of draft DME fuel specifications for ISO new work item proposal: June–October, 2015
- Preparation of final report: October–November 2015
- Follow-up on the ISO's discussion: December 2015

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

Project Duration	October 2013 – April 2015
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Denmark, Finland, Israel, United States Canada, Denmark, United States
Total Budget	• Canada – $24,000 US • Denmark – $10,000 US • US DOE – $120,000 US
Operating Agent	Ralph McGill Fuels Engines and Emissions Consulting Email: rnmcgill@chartertn.net

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 practicality 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, present possibly more feasible utilization of available energy, but to date such fuels have been typically more expensive to produce than CNG and LNG. Electricity derived from natural gas offers a fourth candidate for fueling vehicles, especially with the current emergence of electric vehicles (EVs) and 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 fueling the vehicle, which introduces extra cost and fuel efficiency losses.

Production of synfuels, on the other hand, will likely result in energy loss in the synthesis conversion process. Some of this expense, however, will likely be offset in part by the elimination of other costs, such as simpler transport of fuels, higher vehicle efficiencies, and so forth. Synthetic fuels derived by natural gas 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 ability for the fuels to often be delivered through existing pipeline infrastructure.

Using natural gas to generate electricity for use in EVs also presents unique benefits, including power generation and transmission through power lines rather than pipelines, ongoing development of charging infrastructure, and favorable vehicle efficiencies. New EVs with improved range and fuel economies have been regularly introduced in recent years such that much momentum is building worldwide in this market segment.

For such benefits of natural gas–derived fuels to be realized, the resultant fuels would have to be produced, delivered, and used in vehicles at prices competitive with petroleum-based fuels. Balancing these trade-offs on an economical basis will help drive the selection of fuels for road transportation. In addition to cost, emphasis should be placed on the environmental benefits, energy use, and energy security that each fuel pathway can offer to a particular nation.

Purpose and Objectives

Together with partners, a value proposition study will be conducted to investigate different pathways of natural gas used in on-road vehicles to assess the advantages and disadvantages of the various options. Aspects include, but are not limited to, cost, life-cycle emissions, energy consumption, and societal implications. The goal is to identify the most cost-effective and technically feasible way to utilize natural gas in transportation, with the potential to emerge into the mainstream market, rather than maintaining a niche market in many countries.

Activities

Main Activities

The team will first establish what fuel pathways will be investigated, and general descriptions of each pathway will be provided, including foreseeable opportunities and barriers. While many possible fuel pathways originating from natural gas exist, only approximately 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.

Since viability of different natural gas–derived fuel pathways is likely to vary across different geographic settings, the project team will conduct a number of country-specific case studies that will present ranges of natural gas reserves, production levels, consumption levels, import levels, and infrastructure levels. Natural gas reserves will likely be a dominating factor in determining how viable production and distribution of fuel could become. Furthermore, countries with large reserves may have already established traditional and synthetic natural gas operations. However, countries that heavily import and consume natural gas may also have a strong distribution network that could facilitate greater use of natural gas in road transport.

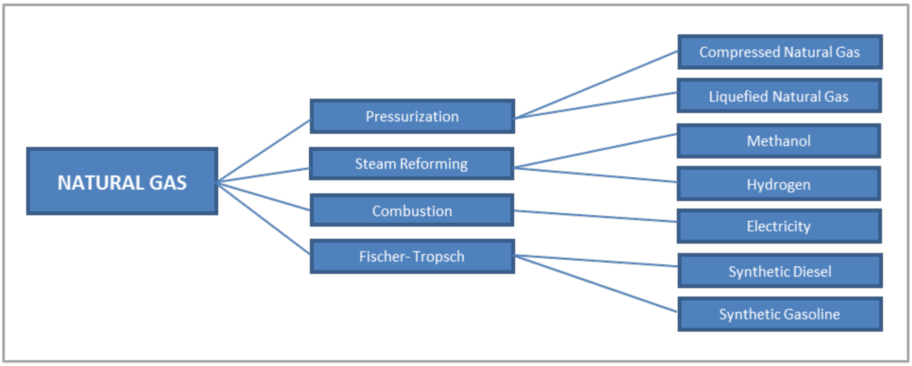


Fig. 1 Breakdown of Fuel Pathways

Life-cycle emissions will also be compared across each natural gas pathway investigated in this study. These emissions are expected to vary across fuel pathways due to differing upstream operations, fuel production and transport, and vehicle operation (dependent on engine design). Also, the composition of natural gas 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 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 include:

- Scenario matrix (accounting for every combination of fuel pathway and case study)
- Key modeling assumptions
- Vehicle design (e.g., drivetrain, light- or heavy-duty)
- Market (e.g., fuel prices, infrastructure presence)
- Regulatory (e.g., incentives, tax credits)
- Emission factors
- Life-cycle analysis (LCA) model boundaries
- Cost/benefit components
- Production and upstream activities
- Cost of vehicle ownership

- Purchase price
- Operating cost
- Fuel/electricity cost
- Maintenance cost
- Environmental/societal impacts
- Greenhouse gas (GHG) emissions
- Energy security
- Necessary modeling tools
- Vehicle simulation
- Emissions model

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 natural gas pathways appear to be 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, conclusions will be drawn on which pathways should be considered more heavily for production of transportation fuels due to economic or environmental benefits.

Sub-Activities

Sub-activities, to be completed by task-sharing countries, include the following:

- 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

None planned.

Participants and/or Experts' Meetings

Representatives from participating countries will convene for status meetings on a biannual basis in coordination with planned International Energy Agency-Advanced Motor Fuels (AMF) Executive Committee (ExCo) Meetings.

Time Schedule – October 1, 2013–April 30, 2015

Results and Reports/Deliverables

The results and major deliverable of this annex/task will be a final report detailing the costs and benefits associated with each natural gas pathway investigated in this study. The report will also include conclusions and recommendations on which pathways appear to be most economically and technically feasible with regard to use, different modes of road transportation, and variations between nations. In addition to cost information, results on environmental impacts and potential implications to energy security will be provided.

Progress on milestones will be presented at AMF ExCo Meetings.

Publications/Newsletters

Other than the IEA-published final report, the project team may pursue publications in non-IEA journals and/or venues, provided approval by all participating countries.

Rights and Obligations of Participants

This annex is both cost-shared and task-shared.

Cost sharing participants:

- Canada/Canmet: $24,000 US
- Denmark – DTU: $10,000 US
- U.S. DOE: $120,000 US

Task sharing participants:

The United States will lead the execution of this Annex, which includes preparation of case studies development, modeling framework and simulation, technical analysis, and deliverable preparation.

Canada, China, Denmark, Finland, and Israel are responsible for:

- Providing data for modeling and analysis inputs specific to the case study countries, and
- Reviewing respective country profiles and final analysis results.

Management

(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, therefore, is responsible for the management and for the leadership of 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.

(c) Operating Agent's meetings;
The Operating Agency 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) above);
N/A

(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, newsletters.
The Operating Agent will submit a final report to the participants of the ExCo as the single deliverable for this Annex.

Admission, Participation, and Withdrawal of Participants

No special provisions outside those already indicated in the main body of the Implementing Agreement.

Information and Intellectual Property

No special provisions outside those already indicated in the main body of the Implementing Agreement.

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 1.5 years, until April 30, 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 Implementing Agreement.

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

Project Duration	July 2013 – June 2015
Participants	
Task Sharing	Canada, Chile, China, Denmark, Finland, Israel, Japan, Korea, Sweden, Thailand
Cost Sharing	No cost sharing
Total Budget	~900,000 € ($1,245,510 US)
Operating Agent	Jukka Nuottimäki VTT Technical Research Centre of Finland Email: jukka.nuottimaki@vtt.fi

Background

Transport needs major de-carbonizing actions. However, there is no single solution that could solve this challenge. To gain optimum results, all transport sectors should be taken into consideration. Because resources of advanced and carbon-neutral fuels are scarce, information on the usability of alternative fuels and technologies and their impact on energy consumption and emissions in a given transport task is needed. In addition, an overall assessment of these alternatives and their full fuel-cycle performance will provide insight into where certain technologies are best utilized and thus lead to "optimal allocation" of various alternatives.

Purpose and Objectives

This project aims to deliver comparable data on commercial light- and heavy-duty vehicle tailpipe emissions and energy consumption.

This study provides information on alternative fuels and vehicle technologies, well-to-wheel energy consumption, emissions, and costs to supplement the information already gathered in Annexes 37, 38, 39, and 43.

In combination with the information gathered in previous Annexes 37, 38, 39 and 43, the goal of this study is to gain further knowledge on the optimum allocation of alternative fuels and technologies for road transport. Several governments are developing road maps for the introduction of alternative and carbon neutral fuels. For example, Sweden is striving for a vehicle fleet independent of fossil fuels, and Finland has set a very ambitions biofuels target of 20% by 2020. This project will strongly support the development of deployment strategies for alternative fuels and energies.

Activities

The project will proceed similarly to that in Annex 43. This means that several laboratories will contribute to a common pool of test data by running tests according to jointly defined test programs and test protocols.

Therefore, the development of common test procedures among research partners will be a key element. At least one common test cycle should be used for all vehicle categories. The project will consist of eight work packages:

WP 0. Collection and consolidation of existing data

WP 1. Development of common test procedures and protocols

WP 2. Vehicle testing

Three different vehicle categories, including several alternative fuel and vehicle technologies, will be tested. The parameters to be varied include fuel composition, driving cycle, payload (0, 50, and 100%), and environmental conditions (ambient temperature).

WP 3. Aggregation of well-to-tank information

Information based on the test fuel matrix and information gathered in Annexes 37 and 43 will be used.

WP 4. Regional information on transportation sectors' energy options

Information from project participants on regional challenges and opportunities that drive the development of energy options in transportation sectors and impacts on the available fuel selection will be used. This regional information will also shed light on potential of various alternative technology options in different regions.

WP 5. Full fuel-cycle evaluation (integration of WP2 and WP3)

Well-to-wheel fuel consumption, energy efficiency, and emissions will be evaluated.

WP 6. Life-cycle cost analysis
The analysis will include how alternative fuel and vehicle technology, together with operation of the vehicle, influences life-cycle costs. The objective is to find a cost-effective way of reducing emissions and energy consumption in a given vehicle use.

WP 7. Coordination of the project, synthesis, and reporting
The project will include administrative coordination, communication with the AMF Executive Committee (ExCo), synthesis of the data, compilation of the final report, and dissemination of the results.

WP 1 was finalized in 2013; however, WP 0 will continue in 2014, along with other project activities.

Participants

Policy
Finnish Transport Agency; Danish Energy Agency; Israel Ministry of National Infrastructure, Energy & Water Resources; Natural Resources Canada; Organization for the Promotion of Low Emission Vehicles (LEVO); Swedish Road Administration Agency; and The Finnish Funding Agency for Innovation (Tekes).

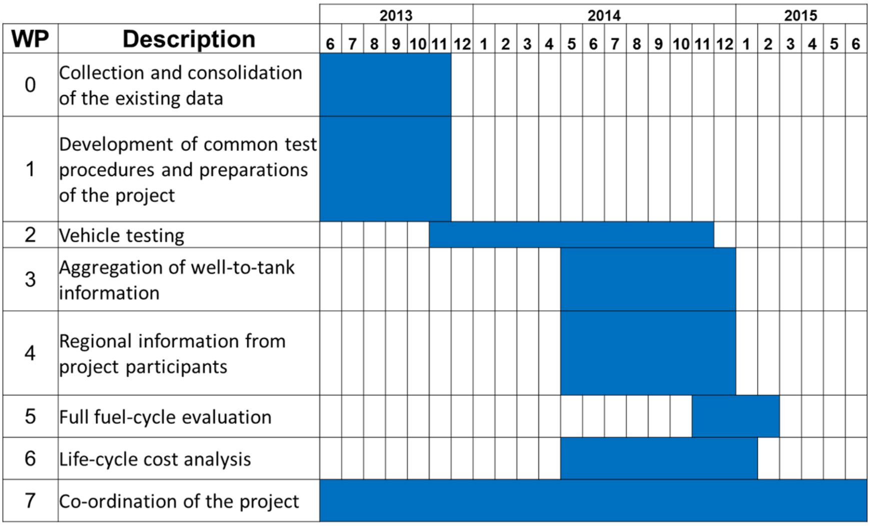
Industry
Gasum; Neste Oil; UPM; PTT Public Company Limited; and St1.

Academia and Test Laboratories
AVL MTC Motortestcenter AB; Centro Mario Molina Chile; China Automotive Technology and Research Centre (CATARC); Environment Canada; Danish Technological Institute; Korea Automotive Technology Institute (KATECH); National Traffic Safety and Environment Laboratory, Japan (NTSEL); Vehicle Control and Certification Center (3CV); and VTT Technical Research Centre of Finland.

Time Schedule

The time schedule for this project is presented in Table 1.

Table 4 Time Schedule for Annex 49



Results/Key Messages

WP 1, development of common test procedures and protocols, was completed during the reporting period as planned. WP 1 defined the test methods and minimum requirements for emissions to be measured. The work of WP 1 also included the minimum requirements for one baseline test fuel and mandatory reporting requirements for the test results. Figure 1 shows the World Harmonized Vehicle Cycle (WHVC), which was chosen as the common test cycle in the vehicle-testing phase (WP 2).

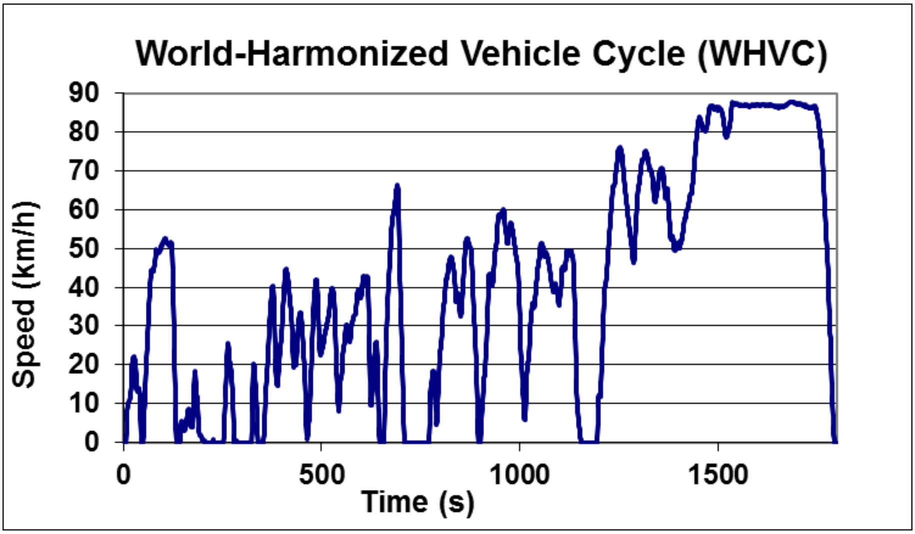


Fig. 1 World Harmonized Vehicle Cycle

Publications

The results of this project are expected to be reported in 2015.

Success Stories

This study started in the middle of summer 2013, and, therefore, most of the time in the reporting period was used in preparation and buildup of the project. However, the project has already attracted the participation of many AMF member states. Such a large number of project participants will help disseminate project outcome both within and outside the AMF community.

4 Further Information

4.a
AMF Executive Committee (ExCo) Meetings

ExCo 45, May 28–30, 2013, Gothenburg, Sweden

The 45th Meeting of the AMF ExCo was held on May 28–30, 2013, in Gothenburg, Sweden. There were 42 participants, a total that includes Poland and the Methanol Institute as Observers, as well as the Chair of the Hydrogen Implementing Agreement (IA). The discussions revealed the following important findings:

- The shale gas revolution in North America will most probably also affect the transportation sector, with regard to both the direct use of natural gas (NG) and the use of NG-derived liquid fuels.
- Light-duty gas vehicles perform well, but, as pointed out by Annex 39, improvements are needed with regard to actually getting methane into heavy-duty (HD) gas vehicles.
- Interest in methanol, from both fossil and renewable sources, is increasing again, so AMF should include methanol on its agenda.
- The electrification of vehicles is moving slower than anticipated, which amplifies the need for sustainable, clean-burning fuels for internal combustion (IC) engines.
- AMF recognizes the need for a broader approach to transport, as outlined in the preliminary proposal for new IEA-level activities associated with "energy-efficient and intelligent transport systems."
- The EU policy on biofuels suggests limiting their production from edible feedstock, so there will be more focus on other substrates that involve more challenging conversion processes and probably also on end-use aspects.
- Most of the BRICS (Brazil, Russia, India, China, and South Africa) countries are still catching up in dealing with higher traffic volumes, which is posing a global challenge with regard to fuel supplies and emissions control.

Membership

- **Israel** joined AMF as a Contracting Party on January 20, 2013.
- The Petroleum Authority of Thailand (PTT) took over from Thailand's National Science and Technology Development Agency (NSTDA) as a Contracting Party, effective April 1, 2013.
- **Australia** withdrew, effective at the end of December 2012.
- **Poland** was invited to join AMF as a Contracting Party.
- The **Methanol Institute** was invited to join AMF as a Sponsor.

Work Program

Current Annexes

- **Annex 28:** Information Service and AMF Website (AMFI). As part of this Annex, a new fuel information system is under development; the review of fuel information is almost complete, and parts of it are already on the AMF website (www.iea-amf.org). The European Committee for Standardization (CEN) gave permission to AMF to directly cite standards as required for fuel information. The new website is on line, and users will be redirected from the old website to it.
- **Annex 35:** Particulate Measurements: Ethanol and Butanol in DISI Engine. Work is almost complete; an extension until May 2014 was granted in order to include the work of China. The report is due in December 2014.
- **Annex 38:** Environmental Impact of Biodiesel Vehicles – Phase 2. The work scope will be expanded to evaluate the mechanisms of the increase in nitrogen oxides (NOx) emissions in biomass-to-liquid (BTL) vehicle operations; for this purpose, an extension of Annex 38 until mid 2014 was granted.
- **Annex 39:** Emission Performance of HD Methane Engines – Phase 2. The inclusion of a task-sharing contribution from the Swedish Gas Technology Center has significantly increased this annex's budget. The contribution (data) from the Asia Pacific Natural Gas Vehicles Association (ANGVA) did not materialize, and an offer by the EU Joint Research Center (JRC) to contribute has not yet been confirmed. First results were presented; further input on task sharing is expected soon.
- **Annex 41:** Alternative Fuels for Marine Applications. The final report awaits acceptance by the Annex 41 participants. It was decided to quickly disseminate the report, since the implementation of alternative marine fuels is developing dramatically. Updates in this sector will be reported through the AMF newsletter. The annex was closed.
- **Annex 42:** Toxicity of Diesel Exhaust and Particles from IC-Engines. All Delegates were asked to notify the Operating Agent of experts that are dealing with this issue in their own countries. The annex was extended until the end of 2014.

- **Annex 43:** Performance Evaluation of Passenger Car Fuel and Powerplant Options. Work is almost complete. The final annex report is due in December 2014.
- **Annex 44:** Research on Unregulated Pollutant Emissions of Vehicles Fueled with Alcohol Alternative Fuels. Work has been progressing well. Israel was accepted as a new participant.
- **Annex 45:** Synthesis, Characterization, and Use of Hydrotreated Oils and Fats for Engine Operation. Turkey will not be able to carry out the fuel analyses, so the Operating Agent is searching for a substitute. Those involved in Bioenergy Task 34 on Pyrolysis are interested in joining, but not all participants have agreed to use pyrolysis oil in their test engines. Finland and Israel were accepted as new participants.
- **Annex 46:** Alcohol Application in CI Engines. Work will be carried out in collaboration with the Combustion IA. A work program was set up; VTT Technical Research Centre of Finland (VTT) and DTU Space, Technical University of Denmark, have started work. Currently, only ethanol blends are being tested, but the work program can still be adjusted to accommodate other fuels such as methanol. New participants are still welcome.

New Annexes

- **Annex 47:** Reconsideration of DME (Dimethyl Ester) Fuel Specifications for Vehicles. AIST (Japan) will be the Operating Agent. Confirmed participants are Japan, Korea, Sweden, and Thailand.
- **Annex 48:** Value Proposition Study on Natural Gas Pathways for Road Vehicles. FEEC (USA) will be the Operating Agent. Confirmed participants are Canada, China, Denmark, Finland, Israel, and the United States.
- **Annex 49:** COMVEC – Fuel and Technology Alternatives for Commercial Vehicles. VTT (Finland) will be the Operating Agent. Confirmed participants are Canada, China, Finland, Japan (LEVO), Korea, Israel, Sweden, Thailand, and the United States.

Extension Process

It was decided to request an extension of the AMF for another five years, starting in March 2015. The required documents shall be prepared through the Secretary (for the End of Term Report) and by the team of Chairs (for the Strategic Plan), with contributions from Delegates and Operating Agents, as appropriate.

Administration

- The **terms and conditions for sponsors** were accepted as proposed and were distributed by the Secretary.
- The **AMF legal text** was revised and altered. The final document will be disseminated and accepted through a written procedure.
- Difficulties arose in dealing with information needed for the **Transparency database**. AMF does not constitute a legal entity, so it is not clear how payments to AMF should be cited in the Transparency database. Because this is probably an issue that applies to all IAs, the Secretary will work with the IEA Secretariat to find a solution.
- AMF welcomed its **new desk officer, Alex Körner**, who gave a webinar presentation on his work.
- The **provision of services through Anne Lechartier** was discussed. AMF agreed to make a one-time financial contribution to help enable IEA find a permanent solution. AMF will not make another contribution in 2014.
- The draft of the **Annual Report 2012** was accepted. All feedback will be integrated, and the final report will be published by June 30, 2013.

Liaisons with Other IAs

The Bioenergy IA cooperates with AMF in Annex 39, and the Combustion IA participates in AMF Annex 46. The Bioenergy IA and AMF held their ExCo meetings in parallel in Denmark in May 2014; the meetings included a joint workshop and study tour.

Next Meetings

- ExCo 46: November 2013 in **Chile**
- ExCo 47: May 2014 in **Denmark**
- ExCo 48: Fall 2014 in **Israel** (tentative)
- ExCo 49: March 2015 in **South Korea** (tentative)

ExCo 46, November 19–21, 2013, Santiago, Chile

The 46th Meeting of the AMF ExCo was held November 19–21, 2013, in Santiago, Chile. There were 24 participants, including Chile, Norway, Brazil, and Uruguay as Observers. There were two main topics at the meeting: (1) outreach to South America, including a seminar organized with Centro Mario Molina (of Chile), and (2) preparations for extending the AMF IA. The discussions revealed the following important findings (worldwide trends as well as more local trends):

- Energy efficiency is important around the globe, and 50% engine efficiency can be reached. Also, a vehicle's configuration plays a big role in the overall efficiency achieved.

- Future fuels will include conventional fuels, NG, NG-derived gas-to-liquid (GTL) fuel, methanol, dimethyl ester (DME), and all kinds of biofuels, including ethanol and BTL/HVO (hydrotreated vegetable oil); in addition, there is electrification. The picture is changing every year.
- A broad range of fuels is needed, with the requirements being most stringent for aviation purposes (liquid fuels required), less stringent for marine purposes, and most flexible for road transport.
- DISI engines have much higher emissions of smaller particles than do diesel engines with diesel particulate filters (DPFs); their use calls for gasoline particulate filters.
- The International Council on Clean Transportation (ICCT) found that real-life carbon dioxide (CO2) emissions are, on average, 25% higher than car manufacturers say they are; this finding calls for revisions in test procedures.
- In South America, harmonization and standardization in all different vehicle classes are important; the improvement of fuel quality is important for enabling low-emission technologies.
- Nonroad mobile machinery (NRMM) is a significant contributor to pollutants. For example, in the Greater London area, it is responsible for 12% of NOx emissions and 15% of particulate matter (PM) emissions.
- The sale of flexible fuel vehicles (FFVs) in Sweden has dropped dramatically due to EURO 6 regulations and disappearing advantages to customers.

Extension of the Implementing Agreement

At the last ExCo meeting (45), the decision had been made to apply for a five-year extension of the IA. A process was started to define the strategic direction and the scope that AMF should have. A survey was carried out in September 2013 to define common areas of interest for the Contracting Parties. A core group (ExCo Chair and Vice-Chairs, Heads of Subcommittees, Secretary) spent two days in face-to-face discussions in October 2013.

The resulting draft Strategic Plan was disseminated to all Contracting Parties and the Annex Operating Agents for feedback. The revised Strategic Plan was presented at the ExCo 46 meeting, and a significant part of the meeting was dedicated to the related discussion. Agreement was reached on the vision, mission, and scope of AMF. The Head of the Strategy Subcommittee will finalize the document by the time of ExCo 47.

For the End of Term report, the Secretary had prepared a concept, which was accepted by the ExCo. The Secretary will send requests to the Operating Agents and the Delegates for contributions (e.g., for success stories or on impacts that the AMF is having). This document will be prepared in parallel with the Annual Report, and both documents will be approved at ExCo 47.

Collaboration within the Energy Technology Network

The plans for cooperation with other IAs will be described in the new Strategic Plan. The Combustion, HEV, and Bioenergy IAs are already closely collaborating. The Bioenergy IA and AMF will hold their ExCo meetings in parallel in Denmark in May 2014; the meeting will include a joint workshop and study tour. Participating countries in Bioenergy Task 37 have asked AMF to collaborate on a brochure on methane for transportation. Discussions on how this can be done best are ongoing.

Information on the new IA on Gas and Oil Technologies (GOT) was presented via a deck of slides provided by the GOT Chair. GOT showed a strong interest in Annex 48, as did IEA headquarters. The Vice-Chair for Transport of the Working Party on End-Use Technologies (EUWP) provided an update on EUWP and Transport Contact Group (TCG) activities, including the efforts to set up a new IA to deal with systemic issues of transport.

The AMF **desk officer Alex Körner** presented an update on IEA Secretariat activities via webinar.

Seminar on "Cleaner and More Efficient Public Transport"

Chile had arranged for a seminar in which — apart from the AMF Delegates and Observers — 15 national experts also participated. The focus was chosen in consideration of the needs of Chile and especially of Santiago, where about 6,000 buses will be replaced by new ones in the coming years. A sound basis for procurement decisions is still lacking, however. AMF experts contributed their knowledge in several presentations.

Membership

During the ExCo meeting and the seminar, strong areas of common interest to AMF and Chile were identified. **Chile** was invited to join AMF as a Contracting Party.

Next Meetings

- ExCo 47: May 20–23, 2014, in Copenhagen, **Denmark**
- ExCo 48: October 27–31, 2014, in Jerusalem, **Israel** (tentative)
- ExCo 49: March 9–13, 2015, in Gwangju, **South Korea,** in conjunction with the International Symposium on Alcohol Fuels (ISAF) conference (tentative)

Work Program

- **Annex 28:** Information Service and AMF Website (AMFI) The old website was completely turned off. The new one is being used frequently (e.g., by Chile to promote advanced motor fuels). Fuel information is almost complete for 2013, but new content will be added in 2014.
- **Annex 35:** Particulate Measurements: Ethanol and Butanol in DISI Engine. China might withdraw from Annex 35 and move its contribution to Annex 44 so as to not further delay the final report. This will be decided by email by the annex participants. The final report is due in May 2014.
- **Annex 38:** Environmental Impact of Biodiesel Vehicles – Phase 2. Progress is on schedule. BTL fuel use will be tested December through February. A draft report is due for distribution at ExCo 47.
- **Annex 39:** Emission Performance of HD Methane Engines – Phase 2. Denmark will move its task-sharing contribution from Annex 39 to Annex 49 so as to not delay the final report of Annex 39 due in mid 2014).
- **Annex 42:** Toxicity of Diesel Exhaust and Particles from IC-Engines. The third report has just been finalized. New interesting contacts could be the Health Research Institute (United States), University of Aarhus (Denmark), and Centro Mario Molina (Chile).
- **Annex 43:** Performance Evaluation of Passenger Car Fuel and Powerplant Options. Work was extended five months until May 31, 2014, in order to integrate all results.
- **Annex 44:** Research on Unregulated Pollutant Emissions of Vehicles Fueled with Alcohol Alternative Fuels. Work has been progressing well, and many results are already available. The final report is due in 2014.
- **Annex 45:** Synthesis, Characterization, and Use of Hydrotreated Oils and Fats for Engine Operation. The delivery of enzymatic fatty acid methyl ester (e-FAME) fuel has been delayed, and so far, it has been impossible to deliver algae HVO fuel. The Operating Agent will contact the participants and ask for an extension of the annex until September 30, 2014.
- **Annex 46:** Alcohol Application in CI Engines. Scania helped to arrange for obtaining the fuels. Clariant and Oxiteno are providing additives. Testing has just started. A workshop is planned for late 2014 to report on test results and prepare a common report.
- **Annex 47:** Reconsideration of DME Fuel Specifications for Vehicles. The Operating Agent will organize face-to-face meetings with the participants and report on these specifications (and, if possible, on the International Organization for Standardization [ISO] draft standard at the next ExCo meeting.

- **Annex 48:** Value Proposition Study on Natural Gas Pathways for Road Vehicles. IEA headquarters has indicated interest in collaborating with this annex. It is also a possible topic for collaboration with GOT. There will be a meeting on the role of NG in transport at IEA. The Operating Agent will soon send a request for specific contributions to the participants.
- **Annex 49:** COMVEC – Fuel and Technology Alternatives for Commercial Vehicles. Participants are in the final stage of setting up the work program. Data collection has started, but it is difficult to collect data because the test method has not yet been defined.

4.b
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4.b.i.
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4.c
AMF Publications in 2013

Annex 42: Toxicity of Exhaust Gases and Particles from IC Engines – International Activities Survey (EngToxIn)

- Toxicity of Exhaust Gases and Particles from IC-Engines – International Activities Survey (EngToxIn). Third information report for IEA Implementing Agreement AMF, Annex 42, international activities. October/November 2013.
- Annexes to 2013 report.

Annex 41: Alternative Fuels for Marine Applications

- Alternative Fuels for Marine Applications. May 2013.

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 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, advancements 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 fueling 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.

Di-methyl 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. Di-methyl ether 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 fueling 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 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 their heavy-duty diesel buses to run this biofuel blend.

The RED95 Ethanol-Diesel project is a three-year joint project of NEOT, ST1, VTT, Scania, HSL, and Helsingin Bussiliikenne Oy concentrating on environmental impacts and energy consumption of waste ethanol-powered buses. The aim is to demonstrate that ethanol can be utilised as bus traffic fuel, thereby significantly reducing peri-urban emissions and greenhouse gases. Since November 2013, two ethanol-powered buses are 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- 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 as well be used as a pure fuel 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 which can be produced from biomass gasification. The resulting Fischer-Tropsch fuels, when compared to standard diesel fuels, can reduce NO_x, CO_2, and PM. 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)

Flex fuel vehicles are capable of safely handling various fuels, ranging from gasoline to high-ethanol-content blends. The fuel system in a flex fuel 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 alternative fuels, due to the lower energy content of ethanol.

Fuel Cell Vehicle (FCV)

A FCV is a type of hybrid that uses a hydrogen-powered fuel cell to produce electrical energy, which then power electric motors that drive the vehicle. Fuel cell vehicles 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 our 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.

Hydrotreated vegetable oil (HVO)

HVO is a biobased 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 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 over 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 ICEs, as an alternative to gasoline. Liquefied petroleum gas also can 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 ground water 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. Natural gas is not only less expensive than gasoline, but it also contributes to lower GHG emissions and smog-forming pollutants. Current gasoline and diesel vehicles can be converted to run on natural gas.

Natural Gas Vehicle (NGV)

NGVs are alternative fuel vehicles that use compressed or liquid natural gas, which are much cleaner-burning when compared to traditional fuels. Current vehicles can be converted to run on natural gas, and is a popular trend among fleet vehicles. The only new OEM NGV available in the U.S. market is the Honda Civic GX CNG — 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.

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 are 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)

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

Plug-in hybrid electric vehicle (PHEV)

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 (MPI)

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

Rapeseed methyl ester (RME)

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 well-to-wheel concept takes into account all of the emissions created from the initial energy source to the end system for the desired mode of transport. For instance, an electric vehicle will create lower GHG emissions, when compared directly to a gasoline-powered vehicle. If the electricity used to charge the electric vehicle came from a combustion power plant and other transmissions of power were taken into account, it 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, Univ. of Applied Sciences, Biel-Bienne, Switzerland
AIST	Advanced Industrial Science and Technology (Japan)
AMF	Advanced Motor Fuels
AMF-IA	Implementing Agreement-Advanced Motor Fuels
AMFI	Advanced Motor Fuels Information
ANGVA	Asia Pacific Natural Gas Vehicles Association
ANR	Agence Nationale de la Recherche (The French National Research Agency)
AVF	Advanced Fuel Vehicle
BD	biodiesel
BD2	biodiesel 2%
BDF	biodiesel fuel
BE	bioethanol
BE5	5% bioethanol, 95% gasoline
bioSNG	synthetic natural gas made of renewable resources
Bio-ME	biomaterials and energy
BIO	10% biofuel, 90% diesel
BTL fuel	biomass-to-liquid fuel
CD	committee draft
CEA	French Alternative Energies and Atomic Energy Commission (commissariat à l'énergie atomique et aux énergies alternatives)
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
DIS	Draft International Standards
DISI	Direct Injection Spark Ignition
DME	di-methyl ether
DOE	U.S. Department of Energy (United States)
E5	an ethanol fuel mix of 5% ethanol and 95% gasoline
E10	petrol containing 10 vol-% ethanol
E85	85% ethanol/15% gasoline fuel blend
EC	Environment Canada, European Commission
ECU	engine control unit
ED95	an 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
EV	electric vehicle
EVE	Electric Vehicles Systems Programme
ExCo	Executive Committee
FAME	conventional esterified biodiesel; fatty acid methyl ester
FCV	fuel cell vehicle
FFV	flex-fuel vehicles
FUI	Fond Unique Interministériel (France), France-UK-Ireland
GC-MS	gas chromatography-mass spectrometry
GDI	gasoline direct injection
GHG	greenhouse gas
GTL	gas-to-liquid
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
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
METI	Ministry of Economy, Trade, and Industry (Japan)
MS	mass spectroscopy
MTBE	methyl tertiary-butyl ether
NEDC	New European Driving Cycle
NG	natural gas
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)
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)
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	A high-concentration ethanol fuel (similar to E85), manufactured from biowaste (helps to reduce CO_2 emissions); sold by St1
RME	rapeseed methyl ester
SAE	Society of Automotive Engineers
SFOE	Swiss Federal Office of Energy
SI	spark ignition
Tekes	the Finnish Funding Agency for Technology and Innovation
TGAP	taxe générale sur les activités polluantes (a French tax on polluting activities)
TIC	taxe intérieure sur la consommation (a French tax on consumption)
TransSmart	Smart Mobility Integrated with Low-carbon Energy
UNECE	United Nations Economic Commission for Europe
USD	U.S. dollars
VELROUE	Véhicule Utilitaire Léger hybride bi mode (France)
VTT	VTT Technical Research Centre of Finland
WP	work package
WTW	well-to-wheel

Units of Measure

baht/L	Thai currency per liter
DKK	Danish krone (currency)
Euro(s)	EU currency
g	gram(s)
GWh	gigawatt-hour(s)
hL	hectoliter(s)
kg	kilogram(s)
kL	kiloliter(s)
km	kilometer(s)
kt, kton	kiloton(s)
kt/a	kilotons per year (annum)
ktoe	kiloton 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
mmbpd	million barrels of oil per day
Mt	mega-tonnes
Mt/a	mega-tonnes per year (annum)
Mtoe	mega tonnes of oil equivalent
PJ	Peta-joules (1×10^{15} joules)
t/a	tons per year (annum)
TJ	terajoule(s)
tonne	metric ton
TWh	terawatt-hour(s)
€/a	euro per year (annum)
€/hL	euro per harvest-liter