Dr. NILS-OLOF NYLUND
VTT Technical Research Centre of Finland

40 YEARS OF AMF COLLABORATION

Working for sustainable transport

Technology Collaboration Programme
by iea

Author

The author of this short history of AMF is **Dr. Nils-Olof Nylund**, Senior Advisor at VTT Technical Research Centre of Finland. Dr. Nylund is well familiar with AMF, as he was the Finnish Delegate to AMF from 1990 – 2020, and in addition, served the Committee as Chair or Vice Chair for some 20 years.

The author would like to acknowledge the AMF Delegates for their contributions to this history, and in particular, the contributions from **Walter Mauritsch** of Austria, **Rachel Martins Henriques, Paula Isabel da Costa Barbosa** and **Angela Oliveira da Costa** of Brazil, **Debbie Rosenblatt** of Canada, **Lena Huck** and **Birger Kerckow** of Germany and AMF's Secretary **Dina Bacovsky** and **Kerstin Brunbauer**.

SUMMARY

IEA's Technology Collaboration Programme on Advanced Motor Fuels (AMF) celebrates its 40th Anniversary in 2024. This is the motivation to compile a document summarising the evolvement, activities and achievements of AMF. Starting as "Alcohol and Alcohol Blends as Motor Fuels", evolving through "Alternative Motor Fuels" to becoming "Advanced Motor Fuels", while keeping its original acronym, AMF takes a comprehensive approach towards clean, sustainable and energy efficient transport. Starting with activities related to fuels for road vehicles, AMF now also covers non-road mobile machinery, shipping and aviation, with the focus moving towards those modes of transportation, which are difficult to electrify.

AMF is a successful platform for international collaboration. As of 2024, AMF has 14 member countries and 16 contracting parties, representing the Americas, Asia and Europe. Over the years, 56 AMF Tasks or projects have been completed. Currently there are five Tasks running, bringing the total to 63. A wealth of data and information has been collected, generated, compiled and disseminated. AMF runs a well organised information system which, among other things maintains the AMF website, enables downloading of AMF Task reports as well as special reports, produces Annual Reports and newsletters, and maintains the AMF Fuel Info System, a comprehensive data bank on fuel characteristics.

In 2023, an internal survey on the accomplishments and added value of AMF was conducted. The contracting parties are very satisfied with AMF and its activities and recognise its value. The members value the truly international network of experts, the engagement of multiple countries around the globe, sharing information and best practices, pooling resources and the capacity to set up timely research tasks. AMF is appreciated for its ability to generate unbiased data on various motor fuels, and AMF results have been used to formulate international standards as well as national transport policies.

CONTENT

BACKGROUND

Transport over the years

Motorised transport has been around for some 140 years, starting with Daimler's Reitwagen motorcycle and Benz's three-wheeler Patent Motorwagen in mid-1880s. Consequently, the need for motor fuels goes as far back as this. The story goes that when the Bertha Benz, the wife of Carl Benz, demonstrated her husband's tricycle on a long-distance trip (100 km); she had to buy fuel at pharmacies.

We have come a long way since those days. The internal combustion engine (ICE) has become an integral part of modern society, serving most modes of transport as well as agriculture, forestry, construction and mining. Currently there are close to 1.5 billion road vehicles in the world[1], and transport fuels are readily available almost everywhere.

Today electrification of road transport is progressing rapidly in industrialized countries, especially regarding passenger cars and commercial vehicles for urban services. In fact, there has always been a competition between technologies. In the early 1900s, the competition was between ICEs, electric cars and steam driven cars. After the invention of the electric starter and development of refuelling infrastructure, the ICE car won the race.

ICE vehicles are proven to be successful due to efficient hydrocarbon fuels because of their high energy density, easy storage and easy refuelling. Liquid fuels (and in some cases also liquefied gas) will fuel long-haul trucks, mobile machinery and ocean-going ships for many years to come. Refuelling a truck with diesel fuel, fossil or renewable, at a rate of 70 litre/min means transferring energy with a power of 40 MW, not achievable with other energy carriers.

[1] https://hedgescompany.com/blog/2021/06/how-many-cars-are-there-in-the-world/

When contemplating alternative energies for transport, several factors should be considered, e.g., regional differences in energy supply and infrastructure as well as the requirements of the various end-use sectors. Both electrification and the use of renewable fuels can reduce greenhouse gas emissions from transport. The preferred solution can vary from country to country, e.g., in Brazil, biofuels play a major role in the government's strategy to decarbonise transport.

Figure 1 illustrates the hierarchy of applications when it comes to the need for liquid fuels. Electrification should first be implemented where it is most feasible, e.g., in urban surroundings. The realization should be made that no single energy carrier alone can meet the needs of all modes of transport.

However, the use of ICE powered vehicles running on conventional fuels also creates problems. Less sophisticated engines running on low quality fuels emit significant amounts of pollutant emissions. This is still a major problem in many developing regions. California was the forerunner in air pollution control, and started regulating vehicle emissions already in the 60's. Today pollutant emissions can be tackled by sophisticated engine and aftertreatment technology in combination with high quality fuels.

As for carbon dioxide (CO_2) emissions, the culprit is not the ICE itself, but rather the burning of carbon containing fossil fuels. Renewable fuels, that is biofuels as well as e-fuels based on renewable electricity, can deliver significant reductions of greenhouse gas emissions considering the whole fuel cycle (well-to-wheel).

Hierarchy of applications

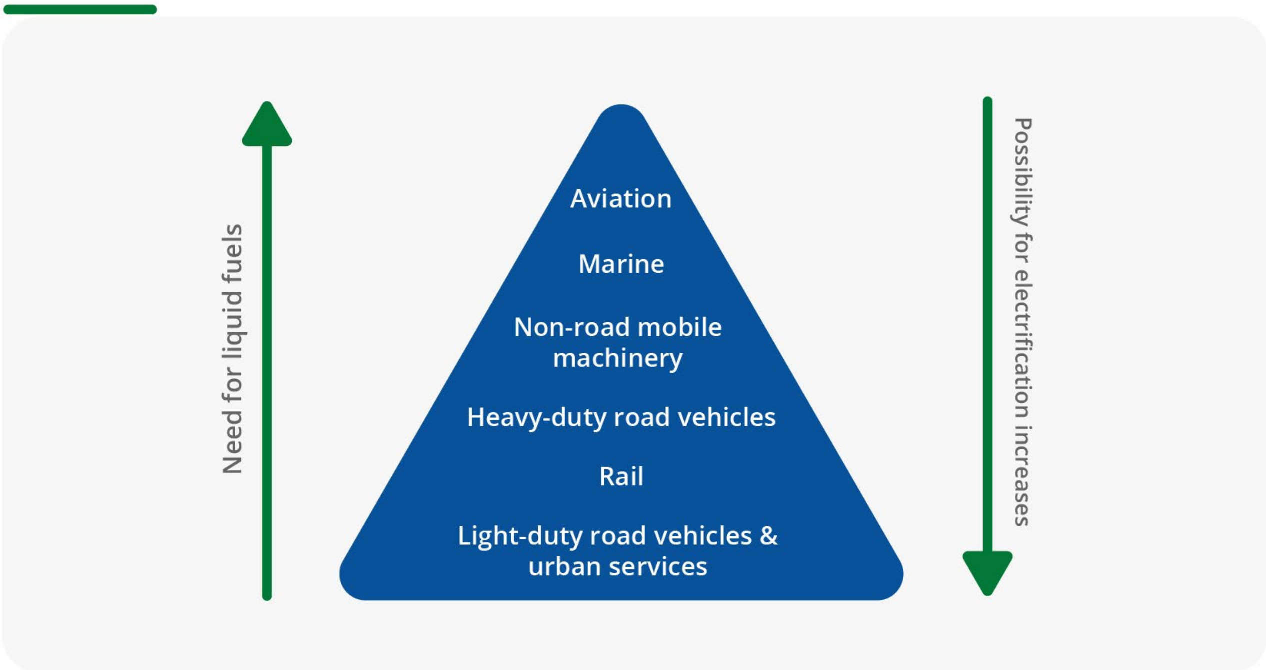


Figure 1: *The hierarchy of end-use applications[2]. Adapted from "Future propulsion systems in transport. Final report of the working*

[2] Alternative propulsion for the transport of the future (in Finnish), https://julkaisut.valtioneuvosto.fi/handle/10024/77976

One challenge here is that often (e.g. in the EU) vehicle emission regulations consider CO_2 tailpipe emissions only, not giving any credit to the use of renewable fuels. If the requirement would be zero tailpipe CO_2 emissions, the only options to meet this requirement are electricity, hydrogen and ammonia. Hydrogen can be used in fuel cells as well as in ICEs, and ICEs can, at least in principle, run on ammonia. However, ammonia will most probably not be a viable alternative for road-going vehicles or mobile machinery.

As fuels can have an impact on both pollutant and greenhouse gas emissions, the work of the IEA Advanced Motor Fuels (AMF) Technology Collaboration Programme (TCP) will contribute to emission reductions both today and in the future.

Projections of fuel use

The world needs to move away from fossil fuels. Notwithstanding, in August 2023 IEA reported that world oil demand is scaling record highs, boosted by strong summer air travel, increased oil use in power generation and surging Chinese petrochemical activity. Global oil demand is set to expand by 2.2 mb/d to 102.2 mb/d in 2023, with China accounting for more than 70 % of growth[3]. The Agreement from the COP28 UN Climate Change Conference in Dubai in December 2023 signals "Beginning of the End" of the fossil fuel era[4].

The degree of electrification of transport is growing in many countries, this is a fact[5]. However, there is significant inertia in the legacy vehicle fleet and the infrastructure serving it, and thus there will be a need for ICEs and motor fuels for many years to come. Passenger cars are typically scrapped after some 20+ years of service, ships after 40+ years of service. As previously stated, some modes of transport and some vehicle categories are challenging when it comes to electrification. In addition, the readiness to implement electric vehicles and the construction of the needed infrastructure also varies significantly by region.

Figure 2 shows IEA's projection of transport fuel use up to the year 2030 in the Net Zero Emissions by 2050 Scenario (NZE)[6]. NZE is a normative IEA scenario that shows a pathway for the global energy sector to achieve net zero CO_2 emissions by 2050. In this scenario, total transport energy demand drops by 9 % from 2022 to 2030 because of increased energy efficiency and increased use of electricity. Correspondingly the share of oil drops from 91 % to 78 %, and the shares of biofuels and electricity increase from 4 % to 10 % and from 1 % to 7 % respectively.

[3] https://www.iea.org/reports/oil-market-report-august-2023
[4] https://unfccc.int/cop28
[5] https://www.iea.org/reports/global-ev-outlook-2023
[6] https://www.iea.org/reports/global-energy-and-climate-model/net-zero-emissions-by-2050-scenario-nze

Energy consuption in transport by fuel in the Net Zero Scenario, 1975-2030

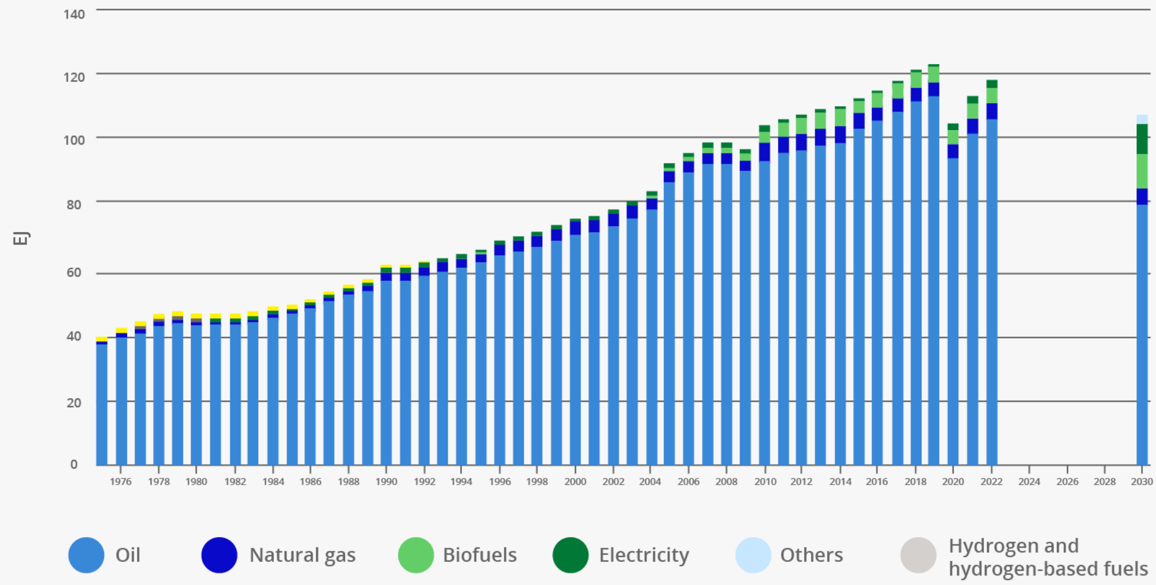


Figure 2: *IEA's projection of transport fuel usage up to the year 2030 in the Net Zero Emissions by 2050 Scenario (NZE).*

Also, energy companies make projections into the future, e.g., ExxonMobil. In its 2023 Global Outlook the company, which is known for its conservative views, projects transport fuel usage up to the year of 2050[7]. The energy demand for light-duty vehicles is expected to peak before 2030, whereas all other transport sectors show increased energy consumption towards 2050. Aviation shows the strongest relative growth. Figure 3 shows the total demand of oil. A sensitivity analysis for electrification of passenger cars was carried out. If all new passenger cars from 2035 were full electric vehicles, this would reduce oil demand by some 15 % in 2050 compared with a more moderate penetration of electric vehicles.

For electricity and other energy carrier options, the carbon intensity of the power generation or fuel production determines the overall greenhouse gas emissions. For the future, in order to reduce the climbing GHG emissions, continuing to implement renewable energy is a must.

[7] https://corporate.exxonmobil.com/what-we-do/energy-supply/global-outlook#Keyinsights

Oil ex biofuels demand back to '10 levels in sensitivity'
MBDOE

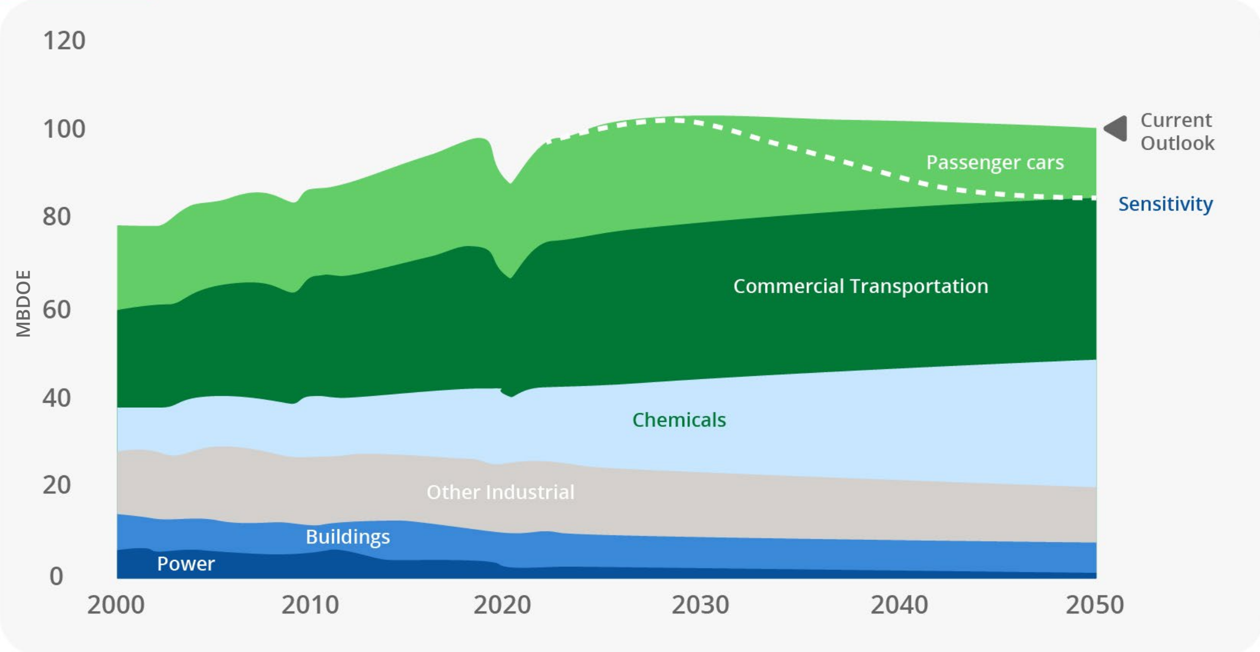


Figure 3: *ExxonMobil's projection of oil demand up to the year 2050. The dotted red line shows the estimated impact of 100 % sales of electric passenger cars from 2035 onwards*

International Energy Agency (IEA)

The International Energy Agency (IEA) was founded in 1974 to ensure the security of oil supplies[8]. Energy security remains a central part of its mission, but today's IEA has a wider mandate to focus on a full range of energy issues, including climate change and decarbonisation, energy access and efficiency, investment and innovation, and ensuring reliable, affordable and sustainable energy systems.

The IEA was created in response to the 1973-1974 oil crisis when an oil embargo by major producers pushed prices to historic levels and exposed the vulnerability of industrialized countries to dependency on oil imports. The newly created autonomous Agency was hosted at the OECD in Paris with an initial mandate for oil supply security and policy co-operation. This included setting up a collective action mechanism to respond effectively to potential disruptions in oil supply as well as develop energy conservation policies.

Taking an all-fuels, all-technology approach, the IEA recommends policies that enhance the reliability, affordability and sustainability of energy. It examines the full spectrum of issues including renewables, oil, gas and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand-side management, and much more.

[8] https://www.iea.org/about

Since 2015, the IEA has opened its doors to major emerging countries to expand its global impact, and deepen cooperation in energy security, data and statistics, energy policy analysis, energy efficiency, and the growing use of clean energy technologies.

Technology Collaboration Programme (TCP)

Technology cooperation started in 1975[9]. The Technology Collaboration Programme activity supports the work of independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues. The experts in these collaborations work to advance the research, development and commercialization of energy technologies. The scope and strategy of each collaboration is in keeping with the IEA Shared Goals of **energy security, environmental protection and economic growth**, as well as **engagement worldwide** (IEA's Three E's).

Within the TCP network, there are currently eight different themes, one of which is dealing with transport. The five programmes in the transport sector are:

- Advanced Fuel Cells (AFC TCP)
- Advanced Materials for Transportation (AMT TCP)
- Advanced Motor Fuels (AMF TCP)
- Sustainable Combustion (Combustion TCP)
- Hybrid and Electric Vehicles (HEV TCP)

Other TCPs falling under the heading of renewable energy, Bioenergy (Bioenergy TCP) and Hydrogen (Hydrogen TCP), have some activities which also relate to transport.

IEA Technology Collaboration Programmes *involve over* ***6 000 experts worldwide*** *who represent nearly* ***300 public and private organizations*** *located in* ***55 countries****, including many from IEA Association countries such as China, India and Brazil.*

The breadth of the analytical expertise in the ***Technology Collaboration Programme*** *is a unique asset to the global transition to a cleaner energy future.*

[9] https://www.iea.org/about/technology-collaboration

ADVANCED MOTOR FUELS (AMF) TCP

Foundation

AMF was initiated in 1984 as "The Implementing Agreement for a Programme of Research, Development and Demonstration on Alcohol and Alcohol Blends"[10]. The original signatories (Contracting Parties) were:

- The Department of Energy, Mines and Resources, **Canada**
- The National Swedish Board for Technical Development, **Sweden**
- The Ministry of New Zealand, **New Zealand**
- The Department of Energy, **United States of America**

The scope of activity was defined as follows:

"The Programme to be carried out by the Contracting Parties within the framework of this Agreement shall consist of co-operative research, development, demonstration and exchanges of information regarding alcohol and alcohol blends as motor fuels."

An Annex of the Agreement defines activities more in detail:

"Background. The growing need for saving petroleum derivates in transportation has led to the development of more energy-efficient cars and to the investigation of the potential for replacing petroleum derivates partly or totally by alcohol. In order to increase the use of alcohol as motor fuel, there is a need for establishing the conditions for its use under a broad range of operating and climatic conditions. A state-of-the-art review and a thorough systems analysis approach to the technologies required for alcohol fuel production and application are necessary for that purpose."

[10] International Energy Agency. Implementing Agreement for a Programme of Research, Development and Demonstration on Alcohol and Alcohol Blends as Motor Fuel. Paris, December 13th, 1984.

Key issues pointed out here are petroleum substitution, operability in various conditions and a holistic approach to fuel production as well as end use. Emission control, whether pollutant emission or emissions of greenhouse gases, is not mentioned. AMF was meant to work on fuels with methanol, ethanol and other oxygenated hydrocarbons.

The listed objectives were:

1. To collect, classify and comment on data obtained by international experience in the generation and use of alcohol and alcohol blends as motor fuels
2. To collect guidelines that could be used in choosing national strategies for replacing motor fuels in whole or part by alcohol
3. To obtain appropriate proposals for relevant developments in this field, and to identify the potential need for future evaluation, analysis and development programmes

The work plan included the following items:

- International Technology Survey of the state-of-the-art technology including:
  - **- Technologies of alcohol production from biomass, urban waste, gas, coal and peat**
  - **- Alcohol fuel specifications**
  - **- Application technologies**
- Identification of New Co-operative R&D Projects

The Agreement stated that the work of AMF should be carried out as jointly-funded activities. Although the Agreement was officially signed in December 1984, AMF held its first two ExCo meetings before the actual signing, in Ottawa, Canada, in May 1984 and in Stockholm, Sweden, in November 1984. AMF's first Chair, Gene Ecklund of the US Department of Energy, served the Committee from 1984 to 1988. At the time of writing this brief history of AMF, AMF Chair number 12, Jesper Schramm of DTU, Denmark, sits at the wheel.

Part of the original Agreement text is in fact relevant now 40 years later. However, focus has shifted over the years, and the scope has been widened to encompass more fuel alternatives[11].

Over the years, AMF has kept the same acronym, which to begin with pointed to alcohol fuels. In 1990, the name was changed to Alternative Motor Fuels, to also make it possible to work on, e.g., gaseous fuels. In 1999 the scope was again widened, and the new name Advanced Motor Fuels made it possible to encompass, e.g., reformulated fuels (fuels modified for reduced pollutant emissions).

The scope of AMF covers fuels that:

- **Have positive impact on GHG emissions**
- **Have positive impact on criteria/air pollutant emissions**
- **Are cost-efficient to produce**
- **Are efficient to use in engines**
- **Have been sustainably produced**

[11] https://www.iea-amf.org/

Internationally, there are several fuels-related organisations. However, these organisations are normally solely focused on a specific fuel or group of fuels — for example, alcohols, natural gas, liquid petroleum gas, and synthetic fuels. Often there are commercial interests behind these groups. AMF has the ambition to achieve a position as an internationally recognised, technology-neutral clearinghouse for fuels related information.

To start with, AMF had a focus on cars, and soon after, heavy-duty road vehicles were included. In 2001, the first project on mobile machinery was initiated. Work on marine fuels commenced in 2011, and aviation fuels became a part of the work programme in 2021.

AMF has thus developed from an activity focusing on fuel substitution for passenger cars, through a period with a focus on reduction of pollutant emissions towards reduction of greenhouse gas emissions and improved efficiency in general, and new types of fuels for heavy-duty road vehicles, mobile machinery, marine applications and aviation. Reduction of pollutant emissions was very topical in the 1990s. Oxygenated fuels and gaseous fuels could provide emission benefits compared to conventional petrol and diesel. Since those days, engine and exhaust after-treatment technologies for road vehicles have improved significantly, and current vehicles running on high quality fuels can deliver ultra-low pollutant emissions.

This is accentuated by Figure 4, showing the development of European limit values for nitrogen oxides and particulates for heavy-duty on-road engines[12]. Going from Euro I to Euro VI the limit value for nitrogen oxides has been reduced by 95 % and the one for particulates by 98 %. In practice advanced diesel engines apply urea SCR catalyst for control of nitrogen oxides and wall-flow particulate filters for control of particulate emissions. At the time of the writing, Euro VII, calling for even lower emissions, is being finalised. The same kind of development also has taken place in, e.g., Japan and North America.

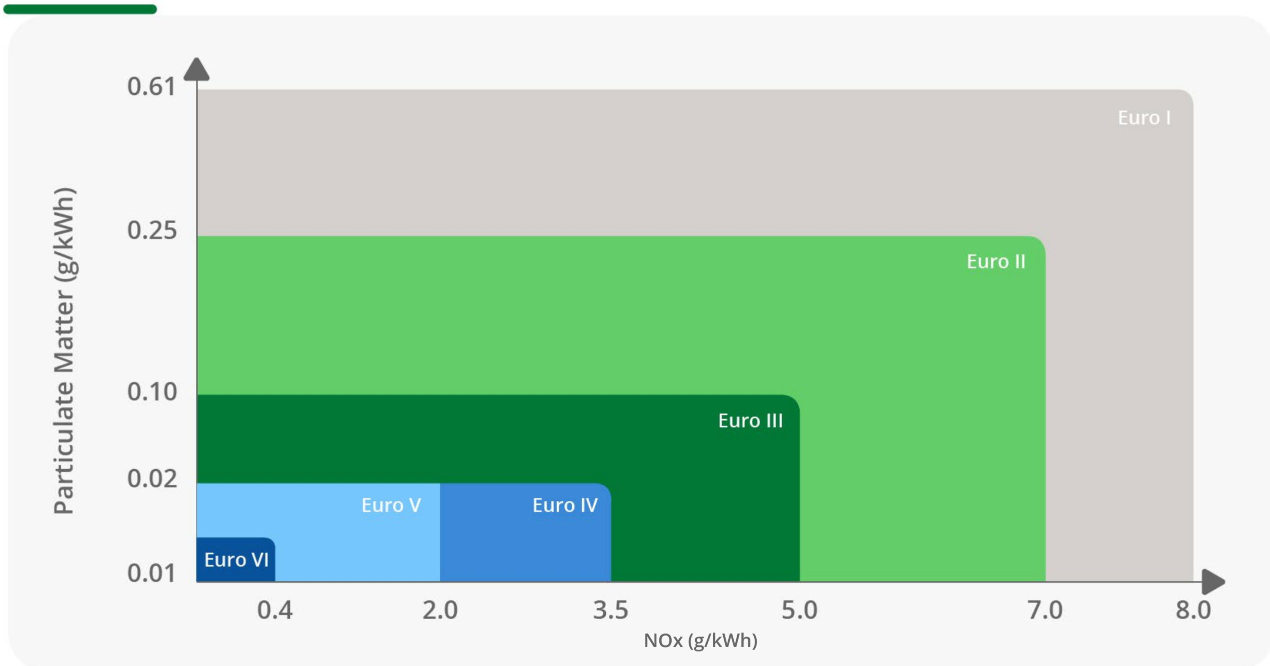


Figure 4: *Development of European heavy-duty engine limit values for nitrogen oxides and particulates*

[12] https://mhf.uk.com/wp-content/uploads/2021/10/euro-VIa.png

Starting with a membership of the four constitutive countries in 1984, membership has grown to 14 member countries and 16 contracting parties (Japan has designated three contacting parties). The geographic coverage is ample: Americas (Brazil, Canada, United States), Asia (China, India, Japan, Korea) and Europe (Austria, Denmark, Finland, Germany, Spain, Sweden, Switzerland). The newest addition to the AMF family is Brazil, the second largest producer of biofuels in the world, the US being the largest one[13].

AMF provides a platform for exchange between representatives of a wide range of organisations, with different backgrounds and national priorities.

AMF brings together top experts in this area, across countries and contintents;

Connects with non-OECD countries;

Share experiences; and

Provides a cost-efficient way to achieve international cooperation.

Added value from AMF's 2023 internal survey

Current work period / Strategic Plan 2020 – 2024

Technology Collaboration Programmes normally operate in five-year periods. At the end of each period, an End-of-Term report highlighting the achievements is produced, as well as a Strategic Plan for the upcoming period.

The current work period of AMF TCP covers the years 2020 – 2024. Thus, producing the End of Term Report and creating a new Strategic Plan coincide with the 40th anniversary of AMF. The new Strategic Plan and the extension of AMF TCP will eventually be approved by IEA's Committee on Energy Research and Technology (CERT).

[13] https://www.statista.com/statistics/274168/biofuel-production-in-leading-countries-in-oil-equivalent/

In the current Strategic Plan, AMF's vision and mission are defined as follows:

VISION:

Advanced motor fuels, applicable to all modes of transport, significantly contribute to a sustainable society around the globe. More specific, AMF brings stakeholders from different continents together for pooling and leveraging of knowledge and research capabilities in the field of advanced and sustainable transport fuels.

Our cooperation enables an exchange of best practices. With our broad geographical representation, we are able to take regional and local conditions into consideration when developing policy briefs and facilitating deployment of new fuel and engine technologies.

MISSION:

The mission of AMF is to advance the understanding and appreciation of the potential of advanced motor fuels towards transport sustainability. We provide sound scientific information and technology assessments facilitating informed and science-based decisions regarding advanced motor fuels on all levels of decision-making.

AMF HAS THE FOLLOWING OBJECTIVES:

- Expand our network and continue our fruitful contributions to R&D
- Strengthen the collaboration with other topically closely related TCPs
- Continue to involve industry in our work
- Encourage activities on all modes of transport and assess the optimum allocation of different fuels"

AMF is not a static institution, and this is reflected in a shift of focus.
The current Strategic Plan states:

The AMF group understands that the progress in electric vehicles challenges ICE vehicles to operate with even better efficiency, lower GHG emissions and close to zero local air pollutant emissions. While maintaining our broad scope, AMF will focus on sectors that are difficult to electrify, such as heavy-duty vehicles, ships and aviation. For these sectors, AMF will strive to identify the best available technologies and their impacts and costs. AMF also desires to pursue synergy with EVs and electrification (such as plug-in hybrid electric vehicles and range extenders).

The proposed work programme for 2020 – 2024 listed the following topics:

FUELS:

• Performance evaluation (energy efficiency, GHG and air quality) of new fuels and technology platforms
• Focus on fuels substituting diesel (including substitution of marine fuels)
• (Pre) studies on emerging fuels (such as e-fuels, ammonia and alternative aviation fuels)

VEHICLES:

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

SYSTEM ANALYSIS:

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

COMMUNICATION AND DISSEMINATION:

• Provide information on AMF publications on the AMF website
• Provide information on advanced motor fuels on the AMF website and through the AMF newsletter
• Organize topical workshops for exchanging information and deepen understanding

AMF Tasks (earlier called Annexes) can be cost shared, task shared or carried out as a combination of these two modes. AMF rules stipulate that three contracting parties are needed to start up new Tasks. New Tasks can be generated either top-down (the initiative coming from the Executive Committee) or bottom-up (some contracting party or research institute coming up with a theme with a general interest). It is up to the contracting parties to decide which technical Tasks to take part in. All contracting parties are participating in the continuous Task 28 taking care of AMF's information and communication activities.

It is quite an accomplishment that AMF has been able to reinvent itself and stay current with all of the changes in motor fuels and with the progress of electrification.

From AMF's 2023 internal survey

AMF Executive Committee

> *A well-functioning and active Executive Committee (ExCo) is an indispensable asset to AMF. The atmosphere of the Committee is exceptionally good and relaxed, which makes cooperation easy.*

The AMF ExCo typically meets twice a year, the location circulating from country to county. Figure 5 shows the AMF ExCo enjoying the possibility to test drive heavy-duty trucks in conjunction with the spring 2019 meeting in Sweden (ExCo 57). COVID 19 meant that AMF held virtual and hybrid meetings, but the fall 2023 meeting (ExCo 66) was again a physical meeting in Leipzig, Germany.

For ExCo 51, which was held at Argonne National Laboratory, Illinois, USA, in May 2016, Dr. Yutaka Takada of LEVO, Japan compiled a document of the social side of AMF's first 50 ExCos, accentuating the good spirit of the group. The plan is now to have this document updated to cover the first 40 years of AMF ExCos.

Figure 5: *AMF's ExCo visiting Scania's test facility in Södertälje, Sweden, in May 2019. Notice all the happy faces!*

The agenda of an AMF ExCo meeting typically consists of the following elements:

- **hosting county presentations, possible technical excursion**
- **subcommittee meetings**
- **informal discussions on Tasks and new ideas**
- **wrap-up with the formal meeting where decisions are taken**

AMF's Chair and Vice Chairs are chosen in such a way that the three major regions active within AMF are represented, that is the Americas, Asia and Europe.

AMF has set up two subcommittees, "Membership and Outreach" and "Strategy and Technology". Figure 6 shows AMF's current management structure.

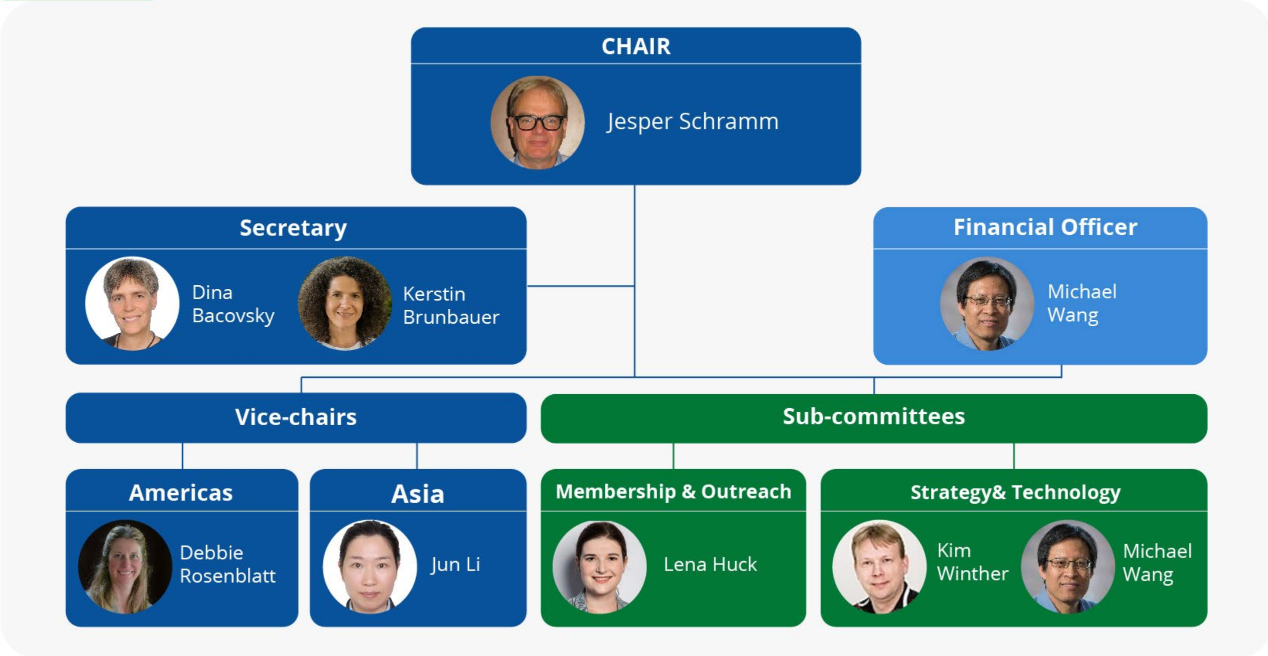


Figure 6: *The management structure of AMF.*

Occasionally joint workshops are arranged with other TCPs and organisations. This was the case for ExCo 66 held in Leipzig in October 2023, where IEA Bioenergy's Task 39 (Biofuels to Decarbonize Transport) and AMF jointly arranged a workshop and a site visit under the title "Expert workshop on renewable fuels".

Services provided by AMF, e.g., in the form "AMF Information Service and Website" and the impact of AMF (assessed in AMF's 2023 internal survey) will be described later in the text.

AMF constitutes an international stakeholder group that enables generating new information and sharing lessons learned from different countries.

AMF provides a global perspective for energy carriers in the transportation sector.

In general, AMF defines relevant research topics with a strong international focus;

Provides networking and allows us to achieve critical mass; and

Creates a good climate for cooperation.

AMF is outstanding in its strive to communicate Task results and in the Task generation and implementation within the TCP family. AMF is a well-established source of reliable information.

From AMF's 2023 internal survey

Snapshot of AMF's work programme over the years

Over the years, 58 projects have been completed. Currently there are five Tasks running, bringing the total to 63. Way back two Tasks received a number, but were never initiated, resulting in a small glitch in the numbering. Information on the Tasks and most Task reports can be found on AMF's webpage[14].

The five ongoing (January 2024) Tasks are:

- **TASK 65**: Powertrain options for non-road mobile machinery
- **TASK 64**: E-Fuels and End-Use Perspectives
- **TASK 62**: Wear in Engines using Alternative Fuels
- **TASK 61**: Remote Emission Sensing
- **TASK 28**: Information Service and AMF Website

AMF, unlike some other TCPs, conducts tangible projects, with a start and end date. One exception is Task 28, Information Service and AMF Website, which is a continuously running activity. In addition to handling dissemination, Task 28 also provides a fast-track platform for issues of common interest, e.g., producing special reports and white papers on topical issues. A recent example is the special report "Ammonia Application in IC Engines".

Characteristic for AMF also is generating new first hand experimental data on fuel and vehicle performance. This is made possible by quite an impressive list of laboratories involved in the work of AMF.

The Tasks of AMF can be classified in a several ways, e.g.:

- projects collecting and refining existing data
- projects generating new data
- projects focused around one specific fuel or types of fuels
- projects focused on specific applications (light-duty road, heavy-duty road, mobile machinery, marine, aviation)
- projects comparing various fuels and vehicle technologies
- projects dealing with development of measurement technologies and standards
- projects related to policy and deployment
- communication and dissemination

A map of AMF's Tasks is presented in Annex 1.

[14] https://www.iea-amf.org/content/projects/map_projects

LABORATORIES THAT HAVE PRODUCED NEW DATA FOR AMF

- CanmetEnergy, Natural Resources Canada, **Canada**
- AEA Technology/ETSU, **UK**
- Argonne National Laboratory, **USA**
- AVL MTC AB, **Sweden**
- Battelle Memorial Institute, **USA**
- China Automotive Technology and Research Centre (CATARC), **China**
- Danish Technological Institute (DTI), **Denmark**
- Emissions Research and Measurement Section Environment and Climate Change Canada, **Canada** (formerly Environment Canada)
- National Institute of Advanced Industrial Science and Technology (AIST), **Japan**
- National Traffic Safety and Environment Laboratory (NTSEL), **Japan**
- Oak Ridge National Laboratory (ORNL), **USA**
- PTT Public Company Limited, **Thailand**
- Rostock University, **Germany**
- Swiss Federal Laboratories for Materials Science and Technology (EMPA), **Switzerland**
- Swedish Environmental Research Institute (IVL), **Sweden**
- Technical University of Denmark (DTU), **Denmark**
- TNO Automotive, **the Netherlands**
- University of Applied Sciences Bern (AFHB), **Switzerland**
- Vehicle Control and Certification Center (3CV), **Chile**
- VITO, **Belgium**
- VTT Technical Research Centre of Finland, **Finland**
- West Virginia University, **USA**

It is not possible to start describing the merits in detail of 60+ projects. In the following, some groups of projects are listed, and some individual projects are highlighted. In some cases, Tasks could well be placed under multiple headings. E.g., Task 36, Measurement Technologies for Emissions from Ethanol Fuelled Vehicles – METEV, can be put under ethanol specific activities or under test methodology related activities.

Scanning through the matrix of projects the following numbers can be picked out, keeping in mind that the classification is not unambiguous:

- **Measurement methodology and standards: 9 Tasks**
- **Alcohols and other oxygenates: 8 Tasks**
- **Biodiesel fuels and renewable diesel: 5 Tasks**
- **Emerging fuels: 5 Tasks**
- **Performance of fuels for heavy-duty vehicles: 5 Tasks**
- **Communication and dissemination: 5 Tasks (with one standing Task)**
- **Natural gas: 4 Tasks**
- **Performance of fuels for light-duty vehicles: 4 Tasks**
- **Implementation and policy: 4 Tasks**
- **Non-road mobile machinery: 3 Tasks**
- **Marine and aviation fuels: 3 Tasks**
- **Fuel additives, lubricants and engine wear: 3 Tasks**
- **Environmental and climate impacts: 2 Tasks**
- **Fuel production: 2 Tasks**
- **Infrastructure: 1 Task**

Although only two Tasks are placed in the category of environmental and climate effects, one must remember that most of the experimental Tasks have produced data on both greenhouse gas emissions and pollutant emissions.

The themes of the 63 AMF Tasks demonstrate that the topic of alternative and advanced motor fuels has been addressed in a comprehensive and diverse way. The project matrix also displays a renewal and shift of focus over time.

THE FIRST FIVE TASKS

Alcohol fuels fired up AMF's engine in 1984 - 1990

The two first Tasks of AMF dealt with collecting, classifying, and commenting on international experience related to alternative fuels. Task 1 focused on alcohols and alcohol blends, whereas Task 2 already dealt more broadly with alternative fuels. Task 1 produced a comprehensive report in two volumes, whereas Task 2 produced newsletter type reports called TRENDS. The Operating Agent or Task Manager for the two first Tasks was Claës Pilo from Sweden, who also served as Secretary for AMF between the years 1998 and 2010.

The two next Tasks were run by Canada, Task 3 reporting on field trials with alcohol fuels in diesel engines, opening work on heavy-duty vehicles, and Task 4 reporting on the production of alcohols and other oxygenates from fossil fuels and renewables. Within AMF's project portfolio, the projects looking specifically at fuel production are rather rare, as focus of AMF's activities has been on end-use of fuels. However, links between feedstock, fuel processing and end-product quality has been touched upon in several projects. Task 5, Performance evaluation of alternative fuel/engine concepts was the first Task to generate new experimental AMF data.

AMF provides unbiased engine and vehicle experimental data/ information.

From AMF's 2023 internal survey

ACTIVITIES BY FUEL

Alcohols and other oxygenates

In addition to the initial Tasks described above, **alcohol fuels** have later been covered in several Tasks, e.g., Task 35 "Ethanol as a Fuel for Road Transportation", Task 36 mentioned above, Task 44 "Research on Unregulated Pollutants Emissions of Vehicles Fuelled with Alcohol Alternative Fuels", Task 54 "GDI Engines and Alcohol Fuels" and Task 56 "Methanol as Motor Fuel".

The topic of alcohols specifically for diesel engines was dealt with in e.g., Task 26 "Alcohols and Ethers as Oxygenates in Diesel Fuel" and Task 46 "Alcohol Application in CI Engines". Task 18 "Future Greener Diesel Fuels" covered oxygenates for diesel fuels.

Biodiesel fuels and renewable diesel

Various aspects of **biodiesel** fuels and renewable diesel have been investigated, from vehicle performance to biological hazards arising from the use of animal fats. The list of projects includes, e.g., Task 13 "Emission performance of selected biodiesel fuels", Task 30 "Bio-safety Assessment: Animal Fat in Biodiesel", Task 34 "Analysis of Biodiesel Options," Task 38 "Environmental Impact of Biodiesel Vehicles" and Task 45 "Synthesis, Characterization and Use of Hydrotreated Oils and Fats for Engine Operation".

Natural gas

Natural gas (methane) has been the focus in several projects, both from a system and from a vehicle performance point of view, e.g., Task 6 "State-of-the-art Report on Natural Gas as a Motor Fuel" Task 39, "Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines" Task 48 "Value Proposition Study on Natural Gas Pathways for Road Vehicles" and Task 51 "Methane Emission Control".

Emerging fuels

The definition here is fuels that can be seen in the horizon, i.e., fuels which are not yet (fully) commercialised.

In the late 1990s, two projects looked at the feasibility of **DME** as a motor fuel, namely Task 14 "Feasibility of DME as a Fuel in Diesel Engine", and Task 20 "DME as an Automotive Fuel II". Eventually, Task 47 "Reconsideration of DME Fuel Specifications for Vehicles", contributed to the creation of an ISO standard for automotive DME. Task 19 "New Fuels for New Engines" dealt with fuel requirements for new combustion schemes" (e.g., Homogenous Charge Compression Ignition HCCI).

Of the ongoing projects, Task 64 "**E-Fuels** and End-Use Perspective", is covering information exchange on the production and application of different e-fuels as well as the corresponding regulatory framework and standards.

Ammonia is covered in the special report "Ammonia Application in IC Engines" as well as in Task 60 "The Progress of Advanced Marine Fuels".

ACTIVITIES BY END-USE SECTOR

Performance of fuels for light-duty road vehicles

Task 5, Performance evaluation of alternative fuel/engine concepts started a long row of projects generating first-hand AMF data. Typically, the performance of alternative fuels and alternative fuel vehicles is checked against conventional petrol and diesel technology. Other projects on this group include Task 12 "Particulate Emissions from Alternative Fuelled Vehicles", Task 22 "Particulate Emissions at Moderate and Cold Temperatures Using Different Fuels", and Task 43 "Performance Evaluation of Passenger Car Fuel and Powerplant Options".

Synchronisation of in-lab chassis dyno methods and on-road routes used in vehicle performance testing has been very useful.

From AMF's 2023 internal survey

Performance of fuels for heavy-duty vehicles

The course of action here resembles that used for light-duty vehicles, with the exception that the reference point in this case is diesel. Projects in this category include e.g., Task 17 "Real Impact of New Technologies for Heavy-Duty Vehicles", Task 37 "Fuel and Technology Alternatives for Buses", Task 49 "COMVEC - Fuel and Technology Alternatives for Commercial Vehicles" and Task 57 "Heavy Duty Vehicle Evaluation". Alternative fuels covered include biodiesel and renewable diesel, gaseous fuels and also additive treated ethanol.

Non-road mobile machinery (NRMM)

The NRMM sector is responsible for between 10 and 25 % of national diesel consumption and significantly contributes to overall pollutant emissions. Consequently, in this this category of projects, focus is on diesel substitution. However, Task 25 "Fuel Effects on Emissions from Non-Road Engines", also looked at the performance of alkylate petrol in small spark-ignited engines. In Task 50 "Fuel and Technology Alternatives in Non-Road Engines", although actual machine testing was done with diesel vehicles, the report also discusses alternative technologies such as gaseous fuels, hybridisation and full electrification. AMF's newest Task, Task 65 and named "Powertrain Options for Non-Road Mobile Machinery", takes the subject of mobile machinery back on the table.

Marine and aviation

The first activity on marine fuels was Task 41 "Alternative Fuels for Marine Applications - Future Marine Fuels Study". The current Strategic Plan of AMF calls for activities on marine and aviation fuels. Task 41 got a follow-up in Task 60, The Progress of Advanced Marine Fuels. AMF's first opening towards aviation fuels is Task 63 "Sustainable Aviation Fuels"..

FUEL ADDITIVES, LUBRICANTS AND ENGINE WEAR

Task 16 "Biodegradable Lubricants", looked at e.g., environmental benefits of BioLubes. Task 52 "Fuels for Efficiency" had an element dealing with friction modifier additives. The ongoing Task 62 "Wear in Engines Using Alternative Fuels," is striving to minimise adverse effects of using alternative fuels.

TEST METHODOLOGY AND STANDARDS

AMF has carried out several activities specifically related to development, refinement and use of test methodology. Sometimes such activities have been embedded in more general projects.

- **Task 10** "Characterisation of New Fuel Qualities" studied the real ignition quality of new diesel qualities.
- **Task 29** "Evaluation of Duty cycles for Heavy-Duty Urban Vehicles", researched methods to best depict the performance of city buses.
- **Task 33** "Particle Emissions of 2-S Scooters" and **Task 42** "Toxicity of Exhaust Gases and Particles from IC-Engines - International Activities Survey", looked at the sampling and characterisation of aerosols.
- **Task 36** specifically researched measurement technologies for exhaust from ethanol vehicles.
- **Task 53** "Sustainable Bus Systems" developed a methodology for setting requirements for clean and energy efficient busses for use in tendering process for public transport operators in developing regions like in South America.

  Real driving emissions have been dealt with in two projects, **Task 55** "Real Driving Emissions and Fuel Consumption", and in the still ongoing **Task 61** "Remote Emission Sensing".
- **Task 27** "Standardization of Alternative Fuels", dealt with standardization of alternative fuels in general.

As already mentioned, Task 47 "Reconsideration of DME Fuel Specifications for Vehicles", contributed to the creation of an ISO standard for automotive DME.

Task 39 "Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines", contributed to the inclusion of dual-fuel gas engines in European Euro VI emission certification.

Through two-way communication between AMF experts and standardisation bodies (ASTM, CEN, ISO, DIN) in which they are active, knowledge contributes to work of both organisations. AMF has been the world leading information platform for performance data on alcohol fuels, DME standards and HDV emissions. E.g., AMF has contributed to the details of the DME fuel standard and Euro VI certification of dual-fuel.

ENVIRONMENTAL AND CLIMATE IMPACTS

Two Tasks, Tasks 7 "Comparison of Relative Environmental Impacts of Alternative and Conventional Fuels" and Task 40 "Life Cycle Analysis of Transportation Fuel Pathways" relate to environmental and climate impacts on a general level. It should be noted that most experimental Tasks involving engine and vehicle testing produce data on pollutants as well as on greenhouse gas emissions, and some contain life cycle analysis.

Although not a focal point of AMF, a few Tasks have touched upon health effects, toxicity and genotoxicity of exhaust from various combustion systems and fuels, and even the fuel itself. On this list we find e.g., Tasks 30, 33, 35 and 42. In addition to regulated pollutant emissions and carbon dioxide, in AMF's emission measurements also components like formaldehyde, BTEX (benzene, toluene, ethylbenzene, xylenes), PAH (polyaromatic hydrocarbons as well as particulate size distribution are frequently analysed.

FUEL PRODUCTION

Although the original scoping document of AMF encompasses feedstock as well as fuel processing, these topics have not been in the focus of AMF. However, two Tasks have dealt specifically with these themes, namely Task 4 "Production of Alcohols and Other Oxygenates from Fossil Fuels and Renewables" and Task 31 "Production and use of Synthetic Vehicle Fuels Made by Fischer-Tropsch Technique". The impact of feedstock on fuel characteristics was covered in, e.g., Task 34 "Analysis of Biodiesel Options", which in its Phase II also looked at algae as feedstock for biodiesel. AMF has had good cooperation with Bioenergy TCP, and the two TCPs have teamed up in certain activities.

INFRASTRUCTURE

One Task, Task 11 "Forecasting and Planning Tools for Alternative Fuels and Related Infrastructure" has focused solely on infrastructure for alternative fuels.

IMPLEMENTATION AND POLICY

The first activity in this field was Task 15 "Implementation Barriers of Alternative Fuels" in the 1990s. Later AMF cooperated with Bioenergy TCP as well as with the Hybrid and Electric Vehicle (HEV) TCP on matters related to implementation and policy. Task 21 "Deployment Strategies for Hybrid, Electric and Alternative Fuel Vehicles", a joint exercise of AMF and HEV in 2000 – 2002, was one of the first joint activities within the TCP network. A more recent activity, Task 58 "Transport Decarbonisation", carried out by AMF and Bioenergy TCPs and with support from the European Commission, looked at the role of renewable fuels in transport decarbonisation. Task 59 "Lessons learned from Alternative Fuels Experience", collected experiences from six AMF Member Countries and concluded that long-term and comprehensive policies are needed for success.

Lessons Learned from Alternative Fuels Experience feed into ongoing policy activities to decarbonize sectors like aviation, inland shipping and non-road machinery.

From AMF's 2023 internal survey

COMMUNICATION AND DISSEMINATION

A priority for AMF has always been communicating its results and findings. It started with the two information-type Tasks of AMF, Task 1 and 2. Communication activities then moved from Sweden to the Netherlands and was handled by Innas and Martijn van Walwijk (later Secretary to HEV TCP) in two Tasks, Task 9 "Automotive Fuels Information Service" and Task 24 "Advanced Motor Fuel Information Exchange". As of 2004, communication and dissemination activities are handled in a standing activity, Task 28 "Information Service and AMF Website". This activity, which originally was handled by Finland and Päivi Aakko-Saksa, is now by run by BEST - Bioenergy and Sustainable Technologies GmbH in Austria and AMF's Secretary Dina Bacovsky. Task 28 will be described in greater detail later in the report.

Synchronisation of in-lab chassis dyno methods and on-road routes used in vehicle performance testing has been very useful.

From AMF's 2023 internal survey

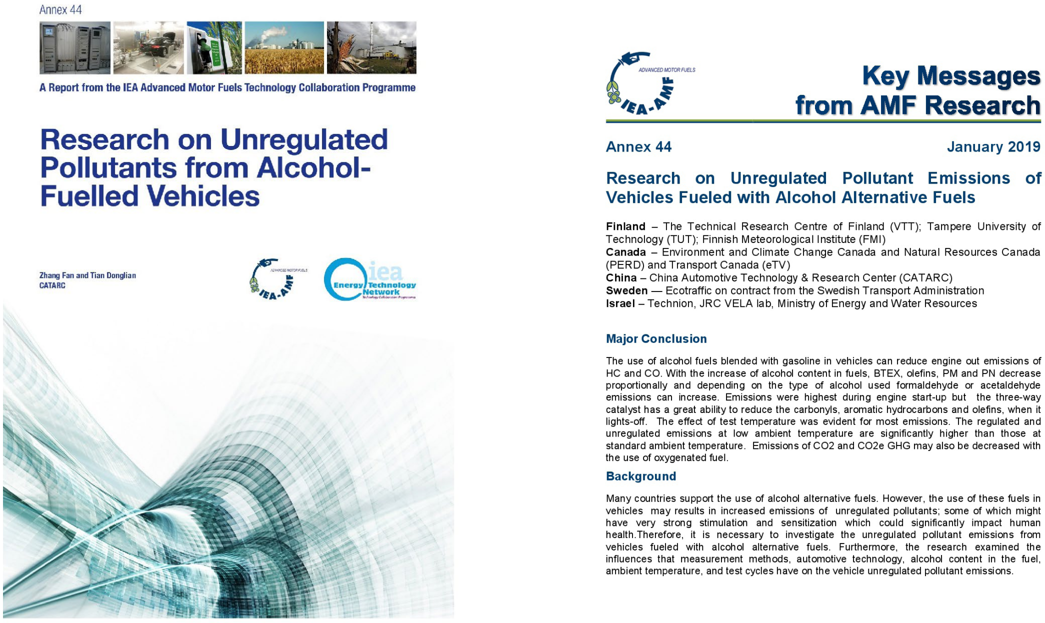
A CLOSER LOOK AT AMF PROJECTS

As previously sated, choosing only a few examples and highlights out of 60+ projects is challenging. There are various types of projects, and the focus of AMF has shifted over the years. It is impossible to use a single metric to evaluate the value and impact of AMF Tasks. The following is a presentation of all in all 14 Tasks which can be deemed to depict the versatility of AMF and its extensive project base.

When appropriate, AMF accentuates the merits of advanced motor fuels. In addition, AMF also rings the bell in case there are some concerns. Examples of the latter case are, e.g., nanoparticles and methane slip from gas vehicles, excessive nitrous oxide emissions from certain exhaust after-treatment technologies and engine wear caused by the use of alternative fuels.

A standardised AMF report format was introduced some 10 years ago. The idea with this was making AMF project reports clearly identifiable. At that time AMF also introduced a two-pager with key messages for each completed Task. The aim is to deliver a short synopsis on what has been done, main results, key messages and recommendations. Figure 7 shows examples of a report cover page and a key messages leaflet.

Final reports for each of the 14 Tasks discussed and other Tasks may be found at the AMF website.


Annex 44

A Report from the IEA Advanced Motor Fuels Technology Collaboration Programme

Research on Unregulated Pollutants from Alcohol-Fuelled Vehicles

Zhang Fan and Tian Donglian
CATARC

Key Messages from AMF Research

Annex 44 January 2019

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

Finland – The Technical Research Centre of Finland (VTT); Tampere University of Technology (TUT); Finnish Meteorological Institute (FMI)
Canada – Environment and Climate Change Canada and Natural Resources Canada (PERD) and Transport Canada (eTV)
China – China Automotive Technology & Research Center (CATARC)
Sweden — Ecotraffic on contract from the Swedish Transport Administration
Israel – Technion, JRC VELA lab, Ministry of Energy and Water Resources

Major Conclusion

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

Background

Many countries support the use of alcohol alternative fuels. However, the use of these fuels in vehicles may results in increased emissions of unregulated pollutants; some of which might have very strong stimulation and sensitization which could significantly impact human health.Therefore, it is necessary to investigate the unregulated pollutant emissions from vehicles fueled with alcohol alternative fuels. Furthermore, the research examined the influences that measurement methods, automotive technology, alcohol content in the fuel, ambient temperature, and test cycles have on the vehicle unregulated pollutant emissions.

Figure 7: *Examples of an AMF report cover and key messages leaflet (Task 44).*

TASK 1:
Alcohols and Alcohol Blends as Motor Fuels (1984 – 1987)

STARTING UP BY DISTILLING INFORMATION

- Task Manager: SDAB, Sweden

This first co-operative project within AMF had as objectives:

- to collect, classify, and comment on data obtained by international experience in the generation and use of alcohols and alcohol blends as motor fuels;
- to collect guidelines that could be used in choosing national strategies for replacing motor fuels in whole or in part by alcohols and
- to obtain appropriate proposals for relevant developments in this field and to identify the potential need for future evaluation, analysis and development programmes.

The project resulted in a comprehensive report printed in 2000 copies and distributed worldwide. The Executive Summary (Vol I) has two main chapters 1) “State-of-the-art summary” of technical, environmental, and economic data in Vol II and 2) “Conclusions and Guidelines” summarizing analyses, evaluations and assessments of a policy character contained in Vol II and expressing the consensus, that is, the essence of the study as agreed upon by the representatives of the participating countries.

Participants in this first Task were Canada, Japan, New Zealand, Sweden and USA.

Activities continued in Task 2 in the form TRENDS newsletters.

TASK 5:

Performance evaluation of alternative fuel/engine concepts (1990 – 1995)

NOW AMF STARTS DELIVERING ITS OWN FIRST-HAND DATA

- **Task Manager: VTT Technical Research Centre of Finland, Finland**

Task 5, dealing with passenger cars, was the first subtask to generate new experimental data. The objective of the task was to generate information on the emission potential of alternative motor fuels in severe operating conditions and to evaluate new emission measurement methods. The work was carried out in three phases, Engine Tests (preliminary phase), Vehicle Tests and Addendum of Diesel Vehicles. The work was carried out as a cost shared operation. Participants were Belgium, Canada, Finland, Italy, Japan, the Netherlands, Sweden and USA.

The test matrix was quite comprehensive. Testing commenced with three test engines installed in a climatic engine test chamber. The vehicle tests included 143 different vehicle/fuel/temperature combinations. FTP type emission tests were run on 14 vehicles fuelled with different petrol compositions, methanol (M50 and M85), ethanol (E85), LPG, CNG and diesel. Both regulated and unregulated emission components were measured using the most up-to-date emission measurement technology.

The results indicated that the three-way catalyst equipped petrol vehicles of that era could be considered rather clean. Diesel was comparable with petrol in the case of carbon monoxide and hydrocarbon emissions. M85 delivered low emissions in warm conditions, but unburned methanol was a problem in the warm-up phase. Natural gas and LPG are inherently clean fuels which were found to deliver low emissions in all conditions.

Task 5 was a good example of international cooperation. US Department of Energy was helpful in arranging a monofuel M85 engine from a test car at Argonne National Laboratory to be tested at VTT. US DOE also helped to get hold of factory built FFV type M85 vehicles and TNO of the Netherlands helped with vehicles on gaseous fuels.

Task 5 paved the way for many more experimental Tasks to follow.

TASK 12:

Particulate Emissions from Alternative Fuelled Vehicles (1996 – 1998)

CLOSER LOOK AT EXHAUST PARTICULATES

- **Task Manager: ETSU/AEA Technology, UK**

Less sophisticated vehicles can have high particulate emissions, both regarding mass and number of particles. In the mid-1990s, the health impacts of vehicle particulate emissions were of great concern, particularly in the impact of the smaller sized particles.

Switching to alternative fuels was seen as one answer for reduction of particulate emissions. Task 12 studied the methods available for measuring particulate size and chemical composition for low emission vehicles and provided a basic set of measurements for three vehicle/fuel combinations.

The first phase of Task 12 consisted of:

- a review of the current state of knowledge on the health impacts of vehicle particulate emissions;
- a survey of previous particulate emissions measurement work on alternative-fuelled vehicles, with a focus on experimental method and inconsistencies between results;
- development of an improved particulate collection technique for use in the experimental work

The actual experiments for the Task were carried out on the following vehicle/fuel combinations:

- Euro II light-duty van run on “clean” diesel, e.g. Greenergy City Diesel
- state-of-the-art LPG bi-fuel light-duty van;
- state-of-the-art dedicated CNG light-duty van

The LPG (Liquefied Petroleum Gas) and CNG (Compressed Natural Gas) vehicles produced remarkably low particulate emissions, in terms of both mass and the number of particles present. Under most conditions, the mean size of the particles was similar to those of petrol vehicles, tested in parallel projects. However, very small particles were found under certain conditions, especially at higher engine speed and load. Task 12 thus pointed out that looking just at particulate mass is not enough, also particulate numbers and size distribution should be taken into account. It was speculated that in the case of gaseous fuels, the engine oil could contribute to small particulates and high particulate number emissions, and in the case of CNG, even carry-over from the compressor oil.

Later, direct injected petrol engines (GDIs) were found to produce high particulate number emissions, and nowadays in Europe, for direct injected petrol as well as diesel vehicles both particulate mass and numbers are regulated.

The participants in Task 12 were Belgium, Canada, Finland, the Netherlands, United Kingdom and USA.

Task 22, Particulate Emissions at Moderate and Cold Temperatures Using Different Fuels, by VTT Technical Research Centre of Finland, followed up the work with a wider test vehicle selection and testing also at low temperatures. In this case, a dedicated factory built mono-fuel CNG car delivered particulate mass and numbers practically nil in all conditions.

TASK 21:
Deployment Strategies for Hybrid, Electric and Alternative Fuel Vehicles (2000 – 2002)

COOPERATION WITHIN THE TCP NETWORK

- **Task managers: Engineering Office Muntwyler, Switzerland and INNAS, the Netherlands**

The market introduction of clean vehicle technologies needs strategies that include the identification of steps, target groups and stakeholders. AMF teamed up with HEV TCP in one of the first formal joint activities between TCPs. Within HEV, the project was designated Task 8.

The Task, among other things, identified distinctive steps in the deployment of new vehicle technology:

- Fleet tests are a first testing of the reliability and application of advanced vehicle technologies, focus is on technical performance
- Demonstration programmes with a broader audience are the first step of the market introduction of hybrid, electric and alternative fuel vehicles in niches. The programmes address acceptance issues, behavioural changes and motivation
- Government support and regulations targeted at the framework conditions of the vehicle market prepare the mass market for hybrid, electric and alternative fuel vehicles
- Widespread efforts that address as many stakeholders as possible to both increase the acceptance of new technologies and prepare a favouring framework for a successful market introduction

The report defines a marketable product, specifically with respect to the highly competitive vehicle market. In this case "marketable includes":

- licensing, compliance with national technical standards
- a purchasing process with reasonable conditions for the customer
- the reliability and safety of the technology
- easy access to fuels or other forms of required energy
- service facilities within a reasonable distance
- trained staff at the service facilities
- availability of driving lessons (if necessary)
- access to information on performance, operation, best application of the vehicle

Under the heading main finding the report states, pointing out governments as the key actors:

- Governments are not the only stakeholders, but they play the key role not only by actively implementing promotion measures, but also by being responsible for the framework in which a market for alternatively fuelled vehicles must succeed.
- Governments are not always aware of their own roles in the transportation market. A transformation to sustainable transport needs a high steering capacity and high technical and financial resources.

The joint Task was supported by Austria, Finland, Italy, Japan, the Netherlands, Sweden Switzerland and USA.

TASK 28:
Information Service and AMF Website (2004 onwards)

COMMUNICATING AMF'S RESULTS TO THE BROAD AUDIENCE

- **Task manager: BEST - Bioenergy and Sustainable Technologies GmbH, Austria**

Task 28 is the only continuously running AMF Task. Before Task 28 was established in 2004, information and dissemination were handled more in a case-by-case manner. All contracting parties of AMF are part of Task 28, and the costs of the activity are covered from the membership fees of AMF.

The overall objective of Task 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. Task 28 is an essential part of AMF's service package.

The listed activities are:

- Review relevant sources of news on advanced motor fuels, vehicles, and energy and environmental issues in general. News articles are provided by experts in the Americas, Asia, and Europe.
- Publish three electronic newsletters per year (on average) on the AMF TCP website and use an email alert system to disseminate information about the latest issues.
- Run an Alternative Fuels Information System that provides concise information on alternative fuels and their use for transport. The system covers information on the performance of cars, effects of fuels on exhaust emissions, and compatibility of fuels with the needs of the transportation infrastructure.
- Update the AMF TCP website to provide information on issues related to transportation fuels, especially those associated with the work being done under the AMF TCP. In addition to providing public information, the website has a password-protected area for storing and distributing internal information for Delegates, Alternates, and Task Managers on various topics (e.g., strategies, proposals, decisions, and Executive Committee meetings of the AMF TCP).
- Since 2020, additional activities also include distributing news on social media.

AMF's website and the connected Fuel Information contain a wealth of information. Information on completed and running projects as well as downloadable reports are easily found on the website. Figure 8 shows the opening page of the website. The headings under publications are:

- Special reports
- Annual reports
- Project reports
- Country reports
- Newsletters
- Brochures

Task 28 also provides a platform to carry out activities of common interest in an efficient and swift way. Special reports that have been produced within Task 28 are:

- Standardization Outlook
- Status and outlook for biofuels, other alternative fuels and new vehicles
- Ammonia Application in IC Engines
- Air quality implications of transport biofuel consumption

The report "Status and outlook for biofuels, other alternative fuels and new vehicles" was a bestseller of its time, as it was downloaded more than 50,000 times from AMF's website.

The Fuel Information System is a very comprehensive data bank for information on end-use related aspects of various types of motor fuels (Figure 9). The Fuel Information System was set up by Päivi Aakko-Saksa of VTT Technical Research Centre of Finland. Going down into the system one can find very detailed information on a specific fuel. One of the newest additions to the system is ammonia, an emerging fuel which could play a role in the marine sector in the in the future.

The general description of ammonia as a motor fuel reads as follows:

> *"Ammonia is currently being investigated as a fuel mainly for maritime transportation. Ammonia can be considered as a so called "electro-fuel" since it can be produced from nitrogen (from air) and hydrogen (through electrolysis of water). The electricity could be produced from wind, solar, or from other sustainable sources. Ammonia burns without production of carbon dioxide during combustion. However, there is almost no knowledge about the behaviour of ammonia in a combustion engine. Ammonia has a relatively low calorific value, and on top of that, characteristics like low cetane number and low flame speed make it difficult to apply in combustion engines. Therefore, it is necessary to carry out investigations on how to improve the applicability of ammonia for combustion engines. Fuel cells for ammonia use are available."*

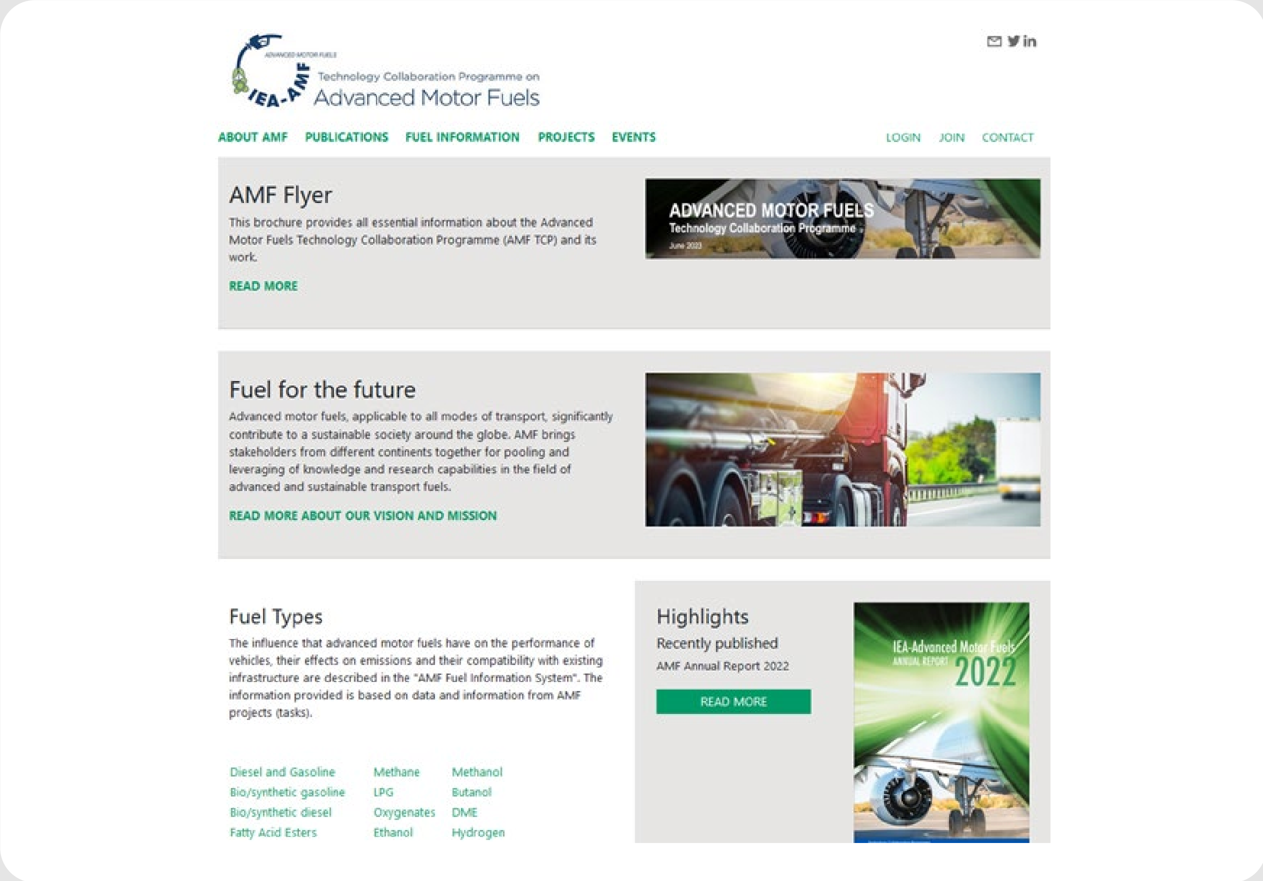


Figure 8: *The opening page of AMF's website (https://www.iea-amf.org/).*

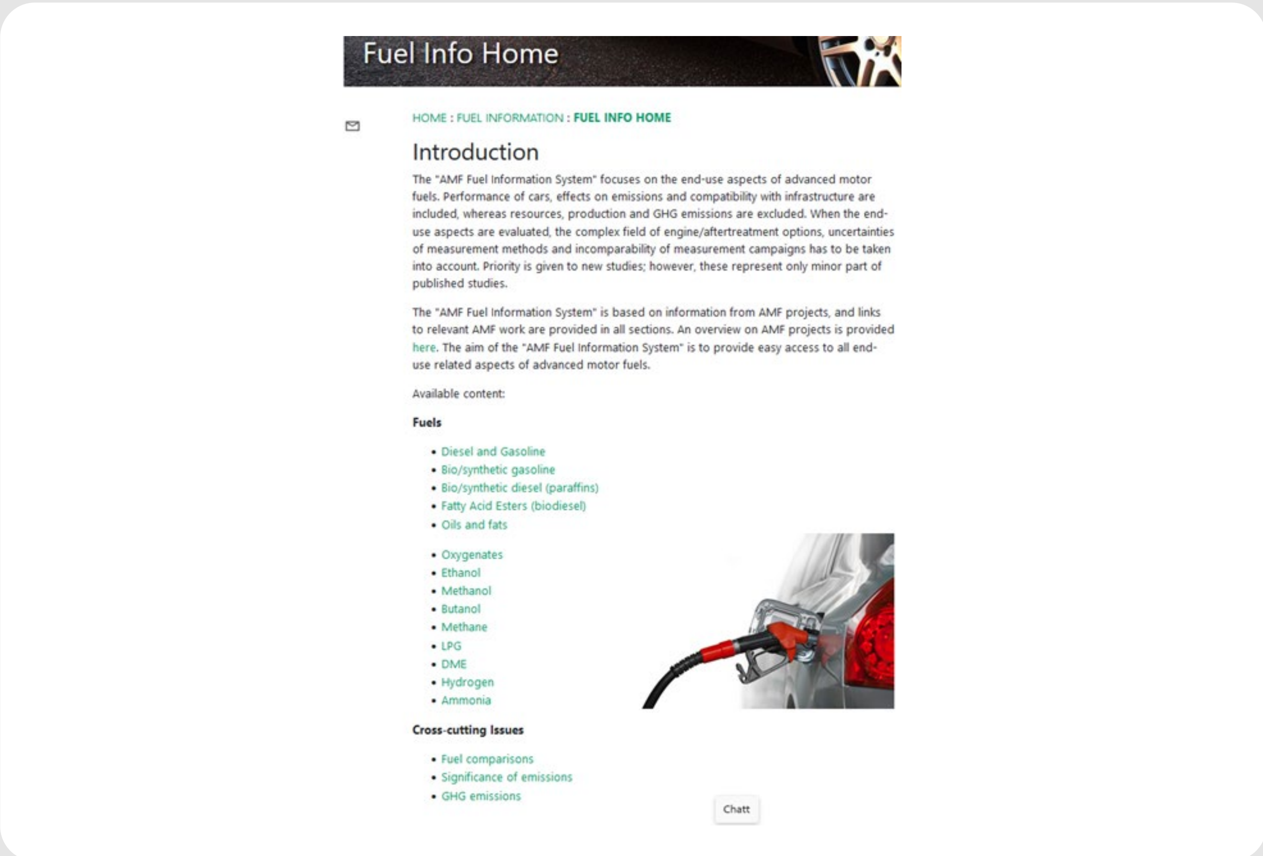


Figure 9: *The starting page of the Fuels Information System (https://www.iea-amf.org/content/fuel_information/fuel_info_home).*

AMF strives to publish three newsletters every year. An ample geographic representation is achieved by having experts in the Americas, Asia, and Europe proving input for the newsletter.

A wealth of information can also be found in AMF's Annual Reports. Each Annual Report covers topical issues, describes progress of the work programme and the Tasks, and delivers country reports from the individual member countries. The country reports provide valuable information on progress and policies all around the globe.

Anyone can subscribe to receive AMF's newsletter at:

https://iea-amf.org/content/publications/newsletters

In a nutshell, Task 28 serves the following objectives:

- provides information on AMF TCP itself, with an outreach function to parties which might be interested to join the cooperation
- collates and disseminates information on transportation fuel alternatives, both from general sources and from AMF's own research activities
- provides detailed fuel specific information in the Fuel Information System, with a focus on end-use aspects
- provides a platform for special activities, such as producing special reports on topical issues

Important findings from research - if properly communicated - will influence politics and be integrated in the political debates via governmental organisations.
Within the TCP family, AMF is outstanding in its strive to communicate Task results and in the generation and implementation of Tasks.
AMF provides a comprehensive list of fuel-related policy and technology trends in each country.
AMF Tasks and e.g., Country Reports have contributed to policy and decision making.
AMF has helped to resolve information asymmetry.

From AMF's 2023 internal survey

TASK 30:
Bio-safety Assessment: Animal Fat in Biodiesel (2004 – 2006)

ALLEVIATING SAFETY CONCERNS

- **Task manager: AFTCAN, Canada**

This was a kind of deviant activity in AMF's normal project portfolio, but of high relevance at that time.

The United Kingdom was afflicted with an outbreak of Bovine spongiform encephalopathy (BSE, also known as "mad cow disease"), and its human equivalent variant Creutzfeldt–Jakob disease (vCJD), in the 1980s and 1990s. Over four million head of cattle were slaughtered in an effort to contain the outbreak, and 178 people died after contracting vCJD through eating infected beef.

Biodiesel is produced from vegetable oils as well as animal fats. The goal of the study on bio-safety assessment of biodiesel was to determine what, if any, animal and public health risks and environmental exposure issues might result from using animal fats for biodiesel fuel, particularly those materials specified at higher risk for transmissible spongiform encephalopathy. The outcome of the study was relieving, as the study concluded that biodiesel made from specified risk material tallow, such as tallow potentially contaminated with bovine BSE, poses negligible risk to human and animal health.

Participants in this Task were Canada, Finland and USA.

TASK 39:
Enhanced Emission Performance and Fuel Efficiency for HD Methane Engines (2010 -2014) &

TASK 51:
Methane Emission Control (2013 -2018)

REMOVING OBSTACLES FOR METHANE AS A MOTOR FUEL

- **Task managers: Swedish Transport Administration (STA), Sweden (Task 39) and**
- **Technical University of Denmark (DTU), Denmark (Task 51)**

Methane is one of the most widespread alternative fuels, and it has found applications in road vehicles, light and heavy, as well as in the marine sector. Methane can be of fossil (natural gas) or biogenic origin (biomethane, which is cleaned-up biogas). Methane is an inherently clean-burning fuel, and the absence of carbon-to-carbon bonds leads to soot-free combustion. If methane can be burned with the same efficiency as diesel fuel in a diesel engine, this would result in a reduction of approximately 25 % in tailpipe carbon dioxide emissions. Biomethane again, depending on the feedstock, can deliver substantial reductions in well-to-wheel greenhouse gas emissions.

However, methane slip can be a problem in using methane as a transportation fuel. Methane emissions can occur throughout the whole fuel chain, upstream, during refuelling, boil-off from LNG tanks and also in engine exhaust. Methane slip into the exhaust can easily nullify the benefits of methane's lower carbon intensity compared to e.g., diesel fuel.

Task 39 was split in two phases. The first phase was a literature study and to describe engine and after-treatment technology for methane fuelled engines used in heavy-duty vehicles. The second phase of the project involved vehicle testing in Canada, Finland and Sweden. The vehicle testing was carried out based on a Task sharing agreement. In addition, Japan, Germany and IEA Bioenergy TCP contributed by cost sharing.

Three different combustion systems were evaluated; stoichiometric spark-ignition, diesel dual-fuel (gas fed into the intake manifold) and High-Pressure Direct Injection (HPDI), where both the pilot diesel and methane are injected directly into the combustion chamber.

The conclusions of the testing were as follows:

- spark-ignited stoichiometric engines
  - very low pollutant emissions and low methane slip
  - energy consumption was considerable higher than for diesel engines
- diesel dual-fuel (gas injected into the intake manifold)
  - **very difficult to meet mandatory emission standards (Euro V, Euro VI) with technology available at that time**
  - **diesel replacement very much dependent upon load conditions and is not meeting expectations**
  - **due to the methane slip, total emissions of greenhouse gases might be higher in dual-fuel mode than for vehicles operating on diesel fuel**

- HPDI

  – promising technology, but still in the development phase

  – not possible to verify the performance of the second-generation system which was scheduled for a launch in 2014 - 2015[15]

When the project started it was not possible to obtain EU or ECE type approval certificate for heavy- duty engines using two different fuels simultaneously (diesel and methane gas). Vehicles using this type of technology could only be accepted in EU Member States based on national exemptions (waiver).

However, after pressure from EU Member States and the industry work started within the frame of "World Forum for Harmonisation of Vehicle Regulation" (WP 29) by the Working Party on Pollution and Energy (GRPE). The actual work was carried out by the informal group Gaseous Fuelled Vehicles (GVF), with the main objective to modify the ECE Regulation 49 (Emissions from Heavy Duty Engines) to also include approval procedure for dual-fuel technology according to Euro VI emission requirements. The final result is found in the Commission Regulation No 133/2014 of 31 January 2014, amending Directive 2007/46/EC, Regulation (EC) No 595/2009 and Regulation (EU) No 582/2011.

So, Task 39 both pinpointed the weaknesses of simple diesel dual-fuel engines as well as to some extent contributed to the inclusion of engines using two fuels simultaneously in the European emission regulations.

Task 51 was partly based on the experience of Task 39, Task 51 with the goal of improving engine-out methane emissions, methane catalyst efficiency, and methane emissions from other parts of the vehicle. The task also continued to follow up on any information about methane heavy-duty vehicle (HDV) fleets, thus adding to the data already available.

Task 51 had the following work packages:

- WP 1: Application of Natural Gas in Combustion Engines
- WP 2: Fundamental Investigations of Methane Combustion
- WP 3: Methane Emissions from Parts of the Vehicle Other Than the Engine and Exhaust System
- WP 4: Natural Gas Application in Light-Duty Vehicles (LDVs)
- WP 5: Natural Gas Application in Heavy-Duty Vehicles
- WP 6: Natural Gas Application in Marine Engines

The Task was thus divided into generic and application specific actions.

[15] Volvo has since successfully implemented HPDI technology, as demonstrated in the measurements of Task 57, Heavy-duty vehicle evaluation

The conclusions of this study were:

The most important mechanisms behind unburned methane emissions from natural gas engines could be identified. These include misfire/bulk quenching, wall quenching, crevice volumes, post oxidation and valve timing/overlap (see Figure 10). Particularly low-pressure dual-fuel engines (gas injected into the inlet manifold) are associated with high values of methane emissions. Mixing of hydrogen into natural gas has shown emission and operation advantages. Different oxidation catalyst concepts (e.g., Rh/zeolite catalyst) have shown to be promising for exhaust after treatment. Finally, engine exhaust is found to be the major source of methane slip from NG vehicles.

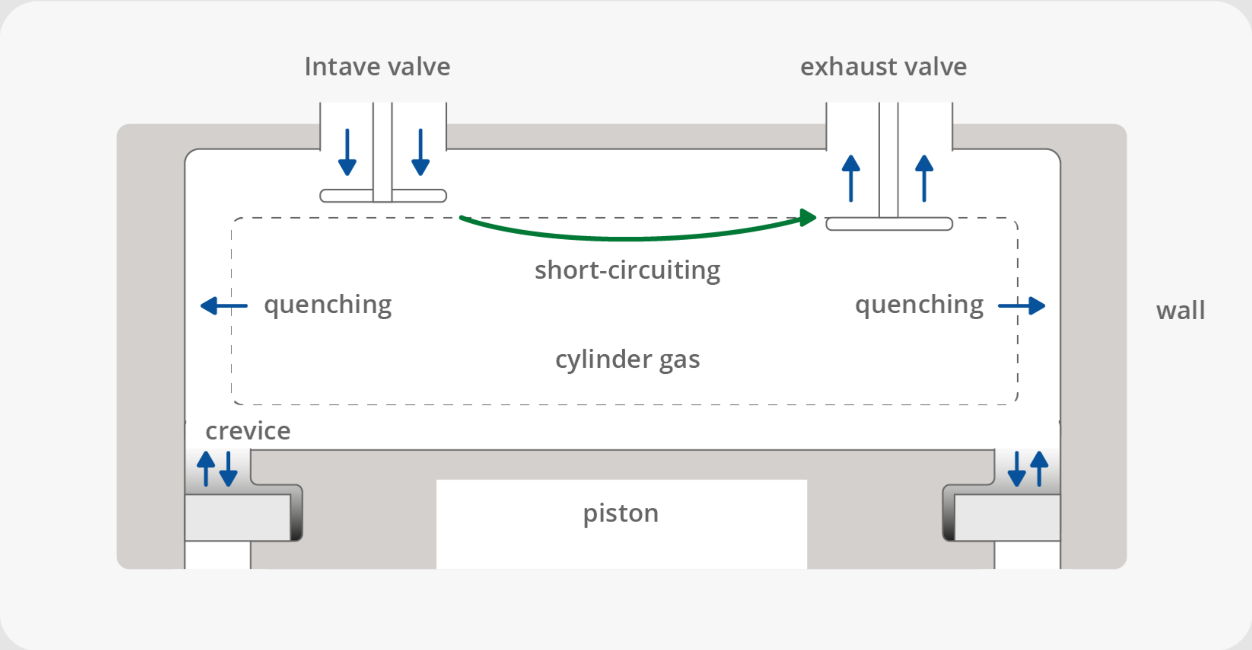


Figure 10: *Methane slip sources in a combustion chamber*

TASK 47:
Reconsideration of DME Fuel Specifications for Vehicles (2013 – 2015)

STANDARDISATION OF NEW FUEL ALTERNATIVES

- **Task manager: National Institute of Advanced Industrial Science and Technology (AIST), Japan**

Dimethyl ether (DME) is considered as an alternative fuel for diesel engines. DME is commonly used as aerosol propellant for example in deodorants, perfumes and air fresheners. DME is an excellent fuel for diesel combustion process as it ignites readily and has no carbon-to-carbon bonds. However, it is a gaseous fuel and requires a mild pressure to keep it in a liquid form. Low lubricity and viscosity call for modifications to the injection system on the engine. Fuel use of DME is not commercial today, but field testing has been carried out in e.g., China, Japan and Sweden.

ISO started to discuss standardisation of DME fuel in TC28/SC4/WG13 from in 2007. The Task manager of Task 47, Dr. Mitsuharu Oguma of AIST is convenor of the WG13. Use of DME is foreseen for three cases: 1) feedstock for home and industrial use, 2) blend stock with LPG and 3) alternative for diesel in power systems, including vehicles. WG13 had a draft value of DME fuel specifications. However, it was not considered to adequately cover DME as a vehicle fuel.

Participants investigated the effect of fuel impurities and additives on DME diesel engine systems and/or DME vehicles in their country individually, and then shared the data and opinion with each other. Especially, some critical issues such as limit of hydrocarbon number (up to C4 currently) and use of odorant were discussed to gain a consensus among participants. The research agenda covered, e.g.:

1. **Materials immersion test**: To evaluate the effects of fuel specifications on tolerance of materials for fuel supply and injection system.
2. **Engine performance and emission test**: To evaluate the effects of fuel specifications on engine performance and emission characteristics.
3. **Durability test**: To evaluate the effects of fuel specifications on durability of engine system.

ISO published its specifications and test methods for DME, ISO16861:2015, in 2015. This general specification is not fully covering DME as a motor fuel, and lubricity needs further attention, e.g., a revision of "Residue after evaporation" for lubricity improver. It is challenging to standardise lubricity testing using High Frequency Reciprocating Rigs (HFRR), and further work is needed. The Japanese Industrial Standard (JIS) for DME will also be revised. Although the AMF Task closed in 2015, a new campaign of round robin testing commenced in 2016. ISO TC28/SC4 working groups WG13 and WG14 are continuing discussions DME specifications.

Participants in the Task were Japan, Korea, Sweden and Thailand.

TASK 49:
COMVEC - Fuel and Technology Alternatives for Commercial Vehicles (2013 – 2016) &

TASK 57:
Heavy Duty Vehicle Evaluation (2018 – 2021)

DELIVERING TRUE PERFORMANCE DATA FOR TRUCKS AND BENCHMARKING ALTERNATIVE FUELS

- **Task Manager: VTT Technical Research Centre of Finland**

Commercial goods vehicles, light-, medium- and heavy-duty vehicles, together, represent some 30 % of the total energy used in transport, and are the second largest segment after passenger cars. Therefore, this vehicle category is important, not only for its contribution to economic activities, but also for its share of energy use and emissions.

The 2017 IEA report "The Future of Trucks: Implications for Energy and the Environment" stated that road freight transport makes up 32 % of the total transport-related energy demand. In addition, the report found that road freight transport primarily uses petroleum-derived fuels, which account for more than 97 % of the sectoral final energy usage[16].

The purpose and objective of Task 49, COMVEC, was to develop common test procedures for comparison of commercial heavy- and light-duty vehicles' tailpipe emissions and energy consumption and to verify actual vehicle performance. One of the key questions was: will new vehicles really deliver low pollutant emissions as promised. Task 49 also looked at energy and emissions from a well-to-wheel perspective and presented cost estimates for alternative technologies.

In combination with the information gathered in previous Tasks (e.g., 37, 38, 39, 43), the goal of COMVEC was to determine optimum allocation of alternative fuels and technologies for road transport. Several governments were developing road-maps for the introduction of alternative and carbon neutral fuels, and the Task was aimed at supporting development of deployment strategies for alternative fuels and energies.

In the "COMVEC" project, eight partners from four continents teamed up to generate performance data (energy efficiency, exhaust emissions) for commercial vehicles:

- **Canada**: Emissions Research and Measurement Section (ERMS) of ECCC
- **Chile**: Center for Control and Vehicle Certification (3CV), Ministry of Transport and Telecommunications of Chile
- **China**: CATARC
- **Denmark**: DTI

[16] https://www.iea.org/reports/the-future-of-trucks

- **Finland**: VTT
- **Japan**: National Traffic Safety and Environment Laboratory (NTSEL)
- **Sweden**: AVL MTC
- **Thailand**: PTT Research and Technology Institute

Altogether, 35 different vehicles were tested on chassis dynamometers, with vehicles ranging from light commercial vehicles (vans) to heavy-duty vehicles for trailer combinations. In addition, one engine installed in an engine dynamometer was tested. The World Harmonised Vehicle Cycle (WHVC) was used in vehicle testing by all partners, and the World Harmonized Transient Cycle (WHTS) for engine testing.

The fuels and technologies covered in the study were:

- light-duty commercial vehicles on petrol, diesel, bi-fuel CNG, bi-fuel LPG and electricity
- trucks (medium- and heavy-duty) on diesel, biodiesel, renewable diesel, dedicated CNG, dual-fuel CNG and ethanol (with ignition improver)

The emission certification of the vehicles tested ranged from Euro III (~model year 2000) to Euro VI/EPA 2010 (model year 2010 +).

Only Euro VI delivered actual low emissions. Relative to mass, larger vehicles are more energy efficient than smaller ones, and spark-ignited engines are less efficient than compression-ignited (diesel) engines (Figure 11).

The Task listed e.g., the following messages:

- Euro VI vehicles perform extremely well (for NOx emissions)
- Going from Euro III to Euro IV or Euro V vehicles does not necessarily deliver real emission benefits; one should leapfrog directly to Euro VI or to US 2010 regulations to obtain real-life low emissions
- Heavy-duty Euro VI/EPA 2010 engines are so clean that any effect of the fuel on pollutant emissions will be negligible
- The carbon intensity of the fuel or the energy carrier is decisive for well-to-wheel CO_2 emissions, not vehicle technology.
- CO_2 assessment should be carried out on a well-to-wheel basis and not only look at tailpipe CO_2 emissions
- Euro VI (alternatively US/EPA 2010) in combination with a renewable fuel is a good option for the local environment as well as the climate

Participants in the Task were Canada, Chile, China, Denmark, Finland, Japan, Korea, Sweden and Thailand. In addition, Norway, contributed financially to the work.

Specific energy consuption - MHVC

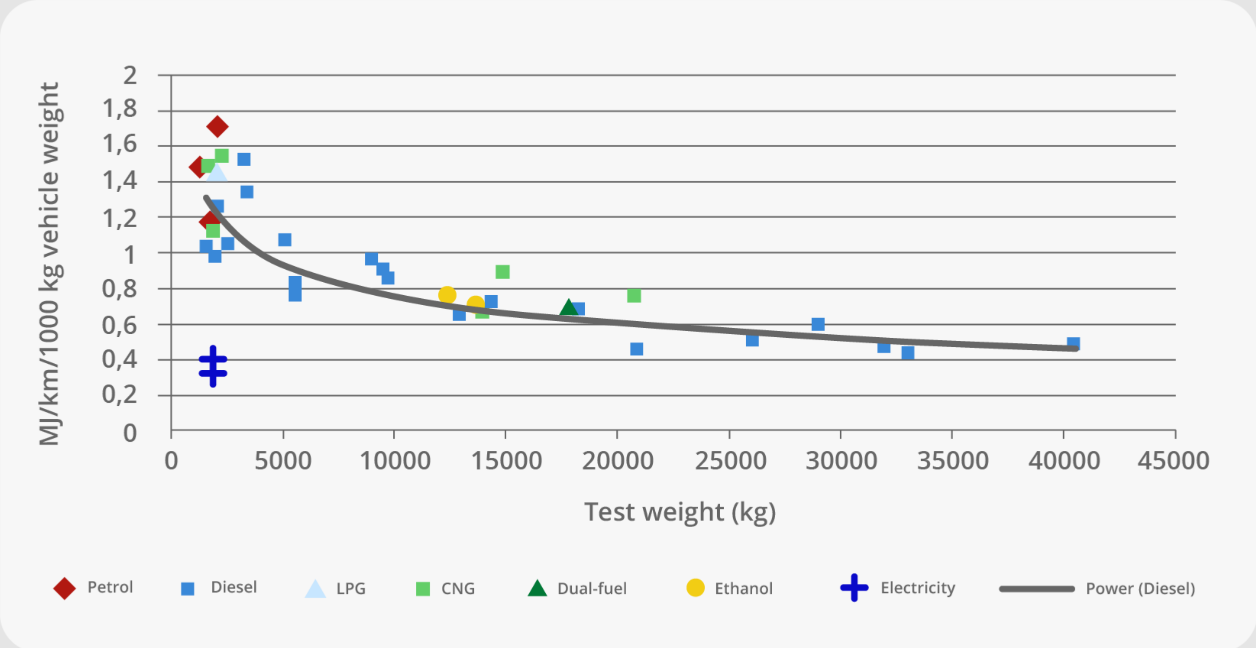


***Figure 11:** Specific energy consumption by fuel.*

Task 49 evaluated both current and older vehicles in various sizes, whereas Task 57, Heavy Duty Vehicle Evaluation, looked at contemporary vehicles. With a focus on energy efficiency of the heaviest truck segment, Task 57 was the first project to combine chassis dynamometer measurements, on-road measurements and simulations. The objective of Task 57 was to present a snapshot of the performance of contemporary vehicles as well as to present projections of performance up to the year 2030. The technologies tested were diesel, spark-ignited methane (CNG, LNG), high-pressure direct injection (HPDI) methane (LNG) and additive treated diesel.

Task 57 carried out testing of a total of 17 medium- heavy-duty trucks (energy consumption, and emissions) on chassis dynamometers and in some cases also in on-road conditions. In addition, vehicle simulation methods were developed for modelling energy consumption and CO_2 emissions. Vehicle testing was done in Canada, Chile, Finland and Sweden, and simulations of vehicle performance in Finland and Korea.

Task 57 also encompassed a joint activity with IEA Hybrid and Electric Vehicles (HEV) TCP for evaluation of energy consumption and CO_2 emissions with different powertrains and fuel options on typical long-haulage vehicle.

Results of regulated emissions showed that all engine concepts tested, independent of fuel type, are capable of reaching emissions clearly below the legislative target values. However, testing revealed that nitrous oxide (N_2O) emissions might be problematic for vehicles equipped with specific selective catalytic reduction (SCR) systems. N_2O can make a significant contribution to CO_2eqv emissions. On the positive side, all tested methane engines (stoichiometric SI and HPDI dual-fuel) had relatively low CH_4 emissions, especially in comparison with older lean-burn engines and port-injected dual-fuel engines, so clear progress has been made.

The various vehicle technology and fuel options were compared against the HDV CO_2 emission reduction targets set by EU at the time of writing the report, -15 % in 2025 and -30 % in 2030 relative to 2019[17]. The observations here are as follows. If CO_2 regulations are based on tailpipe CO_2, 2025 targets can be met with several technologies, but as from 2030, the options would basically be limited to electric and fuel cell vehicles (or ICE vehicles running on hydrogen). On the other hand, if assessment would be on a WTW basis, the door for renewable fuels would be left open.

Some of the key findings of Task 57 were:

- HDV CO_2 regulations that focus on tailpipe emissions constitute a barrier for further development of alternative fuelled trucks. This could result in a halt in development of clean and efficient engines for vehicles dedicated to alternative fuels, resulting in a preference to use drop-in fuel in the legacy fleet and electrification for new trucks entering the market. This type of legislation will have an impact on the prospect to use sustainably produced fuels in the future.
- State-of-the-art diesel trucks reach approx. 45 % engine thermal efficiency on typical long-haul operation. With the use of renewable fuel, the well-to-wheel (WTW) GHG emissions and energy consumption can be very low.
- State-of-the-art trucks are clean. Independent of fuel and combustion process pollutant emissions are low.
- New SI and HPDI methane fuelled trucks have significantly lower CH_4 emissions compared to previous generations.

Participants in Task 57 were Canada, Chile, Finland, Japan (LEVO), Republic of Korea and Sweden.

[17] EU has since tightened the targets for HDV CO_2 emissions reductions, 45% from 1 January 2030, 65 % from 1 January 2035 and 90 % from 1 January 2040 onwards, with no provisions for taking renewable fuels into account, https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_763

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

CLOSER LOOK AT NRMM PERFORMANCE

- **Task manager: Swedish Transport Administration, Sweden**

Non-road mobile machinery (NRMM) is used to produce food, feed, and industrial material. In addition, NRMM play an important role in logistics. The NRMM sector is responsible for between 10 and 25 % of national diesel consumption and significantly contributes to GHG emissions, but perhaps most of all, to pollutant emissions.

In many cases, NRMM uses technology originally developed for on-road heavy-duty vehicles. However, emission regulations for NRMM, at least in earlier days, lagged significantly behind those for on-road vehicles. In addition, there has been much less attention to alternative fuels in the case of NRMM.

The first AMF activity on mobile machinery, Task 25, took place in 2001 – 2003. By 2014, it was time to return to the subject as technology and emission performance had changed substantially. The focus of the new Task 50 was on agricultural machinery (tractors) and construction equipment (road vehicle like machinery, excavators, wheel loaders etc).

Firstly, the Task evaluated the efficiency and emission performance of different engine technologies, looked at fuel specifications and machinery applications including engine load cycles. A second objective was to develop emission factors for inventories of non-road mobile machinery in the participating countries and investigate potential spill-over from road vehicle technology. Assessment of retrofit of the legacy fleet on fuel efficiency and emissions was a third objective. Also, hybridisation and electrification were covered in reviewing possible technology options.

As in the case of Task 57, Task 50 combined laboratory testing, testing in the field ("real driving emissions") and simulations. The institutes that carried out measurements or provided data were:

- **Canada**: Emissions Research and Measurement Section (ECCC)
- **Finland**: VTT
- **Sweden**: AVL MTC
- **Switzerland**: Federal Department of Economic Affairs
- **Germany**: ifeu

Compared with on-road vehicles, especially old non-road mobile machinery are high emitters of pollutant emissions. However, Task 50 demonstrated that the latest emission class, EU Stage V, results in extremely low emissions during real world operation of non-road mobile machinery. The recommendation is, when possible, to leapfrog directly from less sophisticated technology to Stage V. Alternatively, if sulphur free diesel can't be guaranteed, leapfrogging to Tier 3/Stage IIIA would be the best option. Renewable and advanced drop-in fuels are a viable option to reduce GHG and regulated emissions from both new and existing machinery.

Quite like in the case of on-road vehicles in Task 49, there was a significant spread in NOx emissions also for NRMM, by emission certification category and by power (Figure 12). Renewable diesel was found to deliver significant reduction in particulate mass emission, up to some 50 %.

The key findings from the project were summarised as follows:

- Non-road mobile machinery fulfilling emission class Stage V delivered extremely low regulated emissions in real world operation
- Countries that can guarantee sulphur free (less than 15 ppm) diesel should leapfrog directly to Stage V emission regulation to get real-life low emissions
- If sulphur free diesel can't be guaranteed then Tier 3/Stage IIIA gives the best emission performance
- The regulated emissions of non-road mobile machinery are first and foremost determined by the emission control technology, not the fuel
- Notwithstanding, clean burning fuels like paraffinic diesel can deliver significant reductions in regulated emissions and exhaust toxicity, especially in less sophisticated engines
- CO_2 assessment should be carried out on a well-to-wheel basis, in addition to tailpipe CO_2 emissions
- For selected applications, electrification with low-carbon electricity shows promising potential for reducing both air pollutants and GHG emissions
- Electrification is unlikely to be able to replace the need for renewable fuels in the foreseeable future
- Stage V in combination with a renewable fuel is a good option for the local environment as well as the climate
- Procurement requirements and environmental zones can assist in reducing local pollutants

Largely the findings and conclusions of Task 50 on NRMM coincide with those of Task 49 regarding on-road vehicles.

Participants in Task 50 were Canada, Finland, Germany, Sweden and Switzerland.

NOx- Emissions from NRMM-measurments in Sweden, Finland, Switzerland and Canada, All data

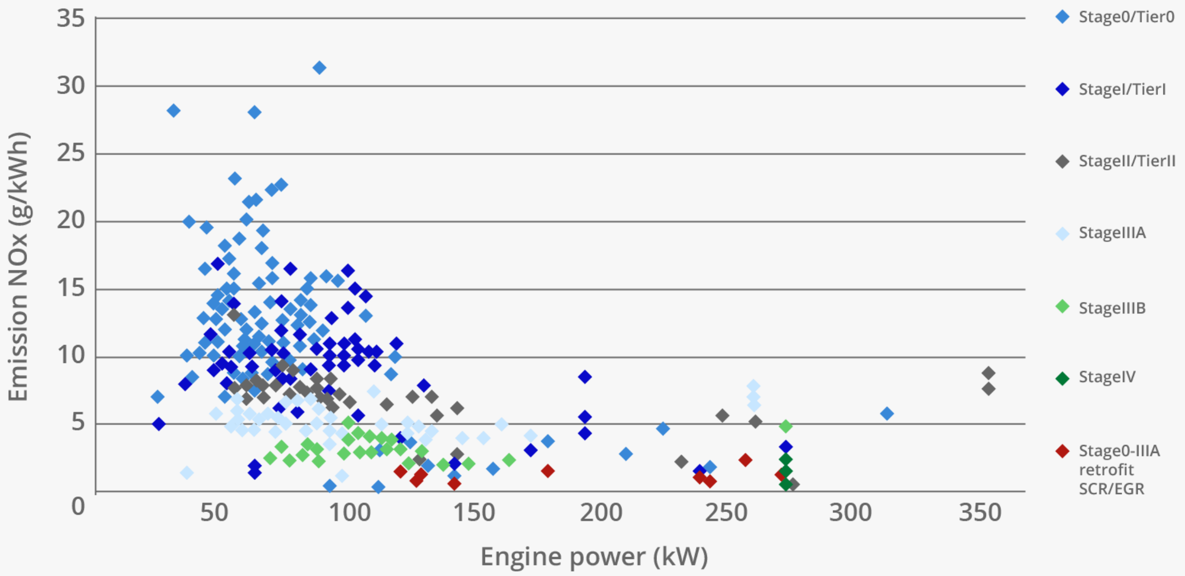


Figure 12: *NO_x emission factors for NRMM. The data is divided by emission standards (colours) and old machinery retrofitted for NO_x reduction.*

TASK 53:
Sustainable Bus Systems

PROVIDING TOOLS FOR EFFECTIVE BUS SERVICE PROCUREMENT

- **Task manager: Ministry of Transport and Telecommunications of Chile**

Many countries still rely on buses as the main element of public transport system. This is especially true for countries in development. Some of the biggest cities in Latin American are facing the renewal of their bus fleet. As an example, Santiago de Chile will initiate replacing part of its bus fleet, and Sao Paulo in Brazil is expected to renew around 15.000 older buses. These processes are in the focus of a massive introduction of energy efficient, low-polluting and soot-free buses, beyond the actual Euro V emission standard (mandatory in Brazil and Chile) and Euro III (mandatory in other countries in the region). In this context, advanced technologies require appropriated characterisation of their advantages in terms of emissions, operational costs and fuel economy in comparison with conventional diesel buses, considering that these are still the backbone of public transport systems.

The availability of appropriate test procedures that represent the actual operational conditions in urban areas in developing countries will facilitate the evaluation and identification of technology options with lower emissions and operational costs. Thus, the main objective of Task 53 was to develop a methodology for setting requirements for clean and energy efficient buses for use in tendering process for public transport operators in developing regions, including guidance and recommendations to control and follow up the buses in operation. The requirements shall be adopted to local conditions and verify the effects in real driving conditions in developing cities. Also, methodology to assess emission stability over time has been considered. Only new OEM products were considered, thus no retrofit solutions.

Task 53 comprised of four components:

1. The design of a driving cycle and test procedures which represent the operating conditions of buses in the Santiago public transportation system

2. The development of a laboratory-testing program for buses with advanced technologies in Santiago and in Europe

3. Testing of eight buses using the Santiago Bus Cycle and reference cycles, four buses (Diesel Euro V, two Euro VI diesel, one battery electric) at the 3CV laboratory of the Chilean Ministry of Transportation and Telecommunication's and four buses (two Euro VI diesel, one Euro VI CNG and one battery electric) at VTT Technical Research Centre of Finland, and the simulation of the behaviour of different bus technologies using the Autonomie vehicle modelling software

4. The preparation of recommendations both for the use of the Santiago bus cycle, and for the test procedures which Ministry of Transport and Telecommunications of Chile carries out during the evaluation and selection of bus technologies that will enter the fleet of Santiago's public transport.

The key findings from the project were summarised as follows:

- An evaluation of the operational conditions of urban bus systems in developing countries must be undertaken as they may be different to those used internationally to evaluate buses.
- The emissions of a Euro VI bus measured with the Santiago Bus Cycle are different to the results seen with the conventional cycles, especially in NOx. However, emissions from the Euro VI bus were still very low in comparison with Euro III buses.
- The energy consumption is higher in the Santiago bus cycle than in the Braunschweig cycle; up to 60 % higher for the same Euro VI diesel bus.
- Battery electric buses consume less than a quarter of the energy that a diesel bus requires per kilometre under the Santiago bus cycle conditions.
- The developed methodology will allow the fleet renewal with Euro VI buses and the progressive introduction of electric buses, and this will result in the highest possible reductions in energy consumption, operating cost and emissions
- On the Chilean side the Task was carried out in cooperation by the Ministry of Transport and Telecommunications and Centro Mario Molina Chile. They were awarded the 2018 Climate and Clean Air Award for Enabling Policy, for their joint efforts to implement policy to reduce diesel air pollution[18].

Figure 13: *Recipients of the 2018 Climate and Clean Air Award for Enabling Policy.*

The participants in Task 53 were Canada, Chile, Finland, Israel, Sweden and the United States.

[18] https://www.ccacoalition.org/news/2018-climate-and-clean-air-awards

TASK 58:
Transport Decarbonisation

DEMONSTRATING THE IMPORTANCE OF RENEWABLE FUELS IN TRANSPORT DECARBONISATION

- **Task manager: BEST - Bioenergy and Sustainable Technologies GmbH, Austria**

It can be said that renewable fuels provide a fast track to transport decarbonisation. This is especially true for drop-in type fuels, which do not require modifications to the vehicles or to the infrastructure.

There are renewable fuel mandates in place in many countries and regions, either expressed as required renewable energy share or reduced fuel carbon intensity.

Task 58 was a joint exercise by AMF and Bioenergy TCP, with strong support from the European Commission. The purpose of the project was to draw the big picture of how advanced renewable transport fuels (i.e., advanced biofuels and renewable liquid and gaseous transport fuels of non-biological origin) can contribute to the decarbonisation of the transport sector.

The key question brought to the table was:

How much can advanced renewable transport fuels contribute to the decarbonization of the transport sector? The target audience was first and foremost policy makers.

The project comprised five work packages:

1. **Key strategies in selected countries**

   Task participants from Brazil, China, Finland, Germany, Japan, Sweden and the United States provided detailed descriptions of GHG emissions from their road transport sectors and shared scenarios of how their countries intend to reduce these emissions.

2. **Fuel production technologies and costs**

   A number of experts from within the IEA Bioenergy TCP and the AMF TCP networks provided descriptions of biomass feedstock availability, technology status, biofuel production costs, future feedstock costs, future fuels GHG emissions, the role of policy, and engine and fuel compatibility.

3. **Country assessments**

   Experts at VTT assessed the possible future development of vehicle stocks of all kinds for Brazil, Germany and Sweden and calculated the future energy demand and associated GHG emissions. Scenarios were developed to show the effect of pushing the use of biofuels and e-fuels to the limits. This was compared to the national targets for GHG emissions from the transport sector.

4. **Implementation barriers**

   Results from AMF Task 59 regarding implementation barriers for advanced biofuels are summarized.

5. **Recommendations to policy makers**

The Task produced a total of five reports:

- Summary Report
- Key Strategies in Selected Countries
- Production Technologies and Costs
- Scenarios and Contributions in Selected Countries
- Deployment Barriers and Policy Recommendations

In addition, the Task arranged a workshop in Brussels, Belgium, on November 18th, 2019, presenting all results and a webinar entitled "The Contribution of Renewable Fuels to Road Transport Decarbonisation" on November 17th, 2020.

The project ended up with the following conclusions:

- Bringing the GHG emissions of the road transport sector down to zero by 2050 cannot be achieved by one measure alone.
- Countries that deploy a set of different measures such as reducing transport demand, improving vehicle efficiency, and adding renewable energy carriers such as biofuels, e-fuels, renewable electricity and renewable hydrogen have the best chances to meet ambitious decarbonisation goals.
- The assessment shows that biofuels contribute most to decarbonisation now and up to 2030, 2040, or even 2050, depending on the country. In Germany, efficiency gains become the main contributor after 2030, and in Finland and Sweden the impact of biofuels remains largest until around 2040 when the use of electric vehicles takes over. In Brazil, biofuels remain the largest contributor until 2050.

The policy recommendations read as follows:

- **Long term and stable policy frameworks are essential to foster growth of renewable transport fuels. An appropriate policy portfolio would include measures to "level the playing field" by removing fossil fuel subsidies and putting effective carbon pricing mechanisms in place. The portfolio also includes specific targets for low-carbon fuels, and mechanisms to ensure that the fuels are competitive in the transport market, along with a stringent, evidence-based sustainability governance regime.**
- **Additional measures are needed to promote fuels which are not yet fully commercialised, including mandatory obligations for deployment of emerging biofuels, dedicated financial mechanisms and instruments to facilitate technological development, subsequent market deployment, and targeted support for RD&D.**

Participants in this project were the Contracting Parties of IEA Bioenergy from Brazil, the European Commission, Finland, and USA, the Contracting Parties of AMF from China, Finland, Germany, Japan, Sweden, and USA, and AMF Annex 28 and AMF Annex 59. All parties provided in-kind contributions, except for the European Commission that also provided 80,000 USD to finance the work of experts.

ADDED VALUE AND IMPACT

Added value and impact can be assessed in various ways, and often the results are more qualitative than quantitative. Added value of IEA's TCP collaboration in general, as well as for AMF, arise from, e.g.:

- **Strong working relationships**
- **Pooling resources**
- **Sharing data, information, knowledge and expertise**
- **Frequent communication**
- **Increasing visibility**

AMF's ExCo, with delegates representing governments and decision makers as well scientists and investigators from academia and research institutes work together in the field of transportation fuels defining where additional information is needed, setting up common research agendas, sharing best practices and communicating key findings and messages.

AMF ambition to achieve a position as an internationally recognised, technology-neutral clearinghouse for un-biased fuels related information has been successful. The ExCo has members from 14 different countries and all in all 16 contracting parties. This broad representation is a guarantee that the activities of AMF have a truly international dimension.

In AMF, pooling takes place for information and data (e.g., country reports included in AMF's Annual Reports) as well as for research capabilities. At least 22 laboratories and institutes have generated experimental data for AMF. The record in collaboration was set by Task 49, COMVEC, in which all in all 8 laboratories in as many countries generated new engine and vehicle performance data for 35 commercial vehicles. However, there are also other ways to contribute, and some partners in cooperation have contributed with desk studies.

AMF is sharing and communicating its results and information in general through Task 28, Information Service and AMF Website. Almost all information generated by AMF, e.g., Annual Reports, Special Reports, Project (Task) Reports, Fuel Info and Newsletters, are available for downloading for the broad audience.

Working under the umbrella of IEA and its Technology Collaboration Programme adds credibility to the activities, as IEA constantly monitors the performance of individual TCPs. IEA is highlighting the value of work within its Technology Collaboration Programme, thus increasing visibility of the individual TCPs. On several occasions, AMF has had the opportunity to interact with the IEA Secretariat, providing input for various studies. The most recent example is the special report "Air quality implications of transport biofuel consumption".

Achievements and impact reported to the IEA

TCPs have to apply to IEA's Committee on Energy Research and Technology (CERT) for a continued mandate on a regular basis, in the case of AMF every five years. Key elements in this process are producing an End-of-Term report highlighting the past achievements, as well as a Strategic Plan for the upcoming period. The latest AMF End-of-Term Reports (EoT) cover the periods 2010 – 2014 and 2015 – 2019.

2010 – 2014 End-of-Term Report

The 2010 – 2014 report highlighted the following achievements:

Success stories of AMF contributions to technology evolution:

- **Task 33** contributed to basic research on particle emissions of small two-stroke engines and clarified reduction measures.
- **Task 35** found that high-level ethanol-blended fuels result in the most efficient engines and least emissions and explored their impacts on particle emissions.
- **Task 36** provided the scientific base for measurement methodologies and standards for ethanol-fueled vehicles.
- **Task 39** opened up the process for engines using dual-fuel technology to be included in the scheme for UNECE/EV emission-type approvals (EURO VI).

Success stories of AMF contributions to technology deployment:

- **Task 37** provided a solid base for choosing technologies and fuels for city buses.
- **Task 43** evaluated the performance of light-duty vehicles using various fuels and powertrains.
- **Task 49** is evaluating the performance of commercial vehicles.

Relevance to policy making:

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

The report also stated:

> *"AMF's work has had an impact on national policies on transportation fuels and on industrial decisions. An example of this occurred in Finland and Sweden. Comprehensive work on technology and fuel options for buses (Task 37), done by the AMF TCP working with the Bioenergy TCP and involving the participation of nine countries plus the European Commission, has guided the procurements of buses and bus services in many places around the world."*

2015 – 2019 End-of-Term Report

The 2015 – 2019 report states, noting the important role of the Executive Committee and the new practice to deliver concise key messages:

> *"Technology gaps and barriers to deployment are continuously being identified and discussed during ExCo meetings, especially in the Strategy & Technology Sub-committee. Whenever feasible, gaps and barriers identified are addressed through a task. Cooperative research on advanced motor fuels and demonstration of fuels, vehicle technologies and after-treatment technologies are being performed in almost all technical tasks as part of their work program. Finally, all AMF tasks result in final reports and the "Key Messages" synthesis documents, and both are published on the AMF website. In addition, several tasks have produced scientific publications."*

The 2015 – 2019 report also listed some key achievements:

- The newsletters produced under Task 28 serve to inform national audiences of AMF member countries and are translated into Japanese.
- Task 48 provides an overview on how to use natural gas and biogas and their derivatives in road transport.
- Task 49 demonstrates the need to leapfrog from Euro IV or V to Euro VI emission standards to achieve real-life low emissions by motor vehicles.
- The driving cycle for buses in Santiago developed as part of AMF´s Task 53 Sustainable Bus System was officially adopted by the Chilean Government. All new bus models that are coming to the bus market in Santiago must be tested under this cycle as part of the process of homologation. Task 53 benefitted from exchange of researchers and adopting best practices.
- Results on fuel efficiency and tailpipe emissions acquired from several tasks on various fuels feed into the international emission model that Sweden maintains.
- Fuel and powertrain producers provide fuels or vehicles to AMF tasks and in turn their products have been evaluated and benchmarked against others.
- AMF delegates for Finland and Sweden have been/are involved in elaborating strategies on renewable transport fuels, using information from AMF tasks as a basis.

The 2015 – 2019 EoT Report also commented on an internal survey carried out in 2018. It was noted that delegates state that face-to-face ExCo meetings have provided the opportunity for in-person interactions. Cooperation among participating members has been very good, and an active and extensive network has been formed.

Task progress and final reports have been very informative and useful, along with the AMF newsletter and the annual report.

The next EoT is due in 2024, as a part of the request for extension process.

Consequently, this report is not available to date.

Internal assessment 2023

SET-UP

In mid-2023, a new internal survey among the delegates was carried out. The objectives with the survey were twofold, to obtain feedback on the added value and usefulness of AMF cooperation, and to obtain input for the directions of the next AMF Strategic Plan.

The 2023 survey encompassed, e.g., the following questions related to the relevance and performance of AMF:

How important are the current strategic objectives of AMF for you/your country?

- 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
- Expand our network and continue our fruitful contributions to R&D
- Strengthen the collaboration with other topically closely related TCPs
- Continue to involve industry in our work
- Encourage activities on all modes of transport and assess the optimum allocation of different fuels

How important is AMF work in the following areas for research in your country?

- **Performance aspects of fuels and vehicles**

  – e.g., local emissions/air quality, energy efficiency, GHG emissions, real driving emissions, wear in engines

- **Fuels and end-use sectors**

  – e.g., fuels replacing petrol, diesel, kerosene and heavy fuel oil, gaseous fuels, e-fuels

  – light-duty vehicles, heavy-duty vehicles, off-road and mobile machinery, shipping, aviation

- **System analysis**

  – e.g., LCA/GHG emission data on various fuels, methodology of accounting for CO_2 emissions, fuel standards, market barriers to the deployment of alternative fuels, decarbonisation roadmaps and policy advice

The Contracting Parties were also asked to list past success stories of AMF, what AMF has been especially good at and to provide a statement why participation in the AMF TCP has been beneficial.

RESPONSE TO THE SURVEY

The following presents a summary of the responses to the survey, with a focus on past and current activities.

Why has participation in the AMF TCP has beneficial (comments country by country):

- *AMF provides a platform for exchange between representatives of a wide range of organisations, with different backgrounds and national priorities. The discussions allow us to reflect on different approaches to similar societal challenges and motivate us to activate national stakeholders for Task participation.*
- *By participating in the AMF TCP, we can leverage its vast natural resources, technological capabilities, and commitment to sustainability to drive advancements in advanced motor fuels, foster economic growth, and contribute to a greener and more sustainable transportation sector.*
- *The contacts in other countries knowing what issues and priorities other countries are concerned with, collaboration with other countries, knowing how AMF fuels work has impacted policies, regulations in other countries.*
- *Cooperative research among different countries.*
- *As a major provider of shipping services, marine engines and fuel processing technology our country benefits from strong ties with the global end-user. Being a small nation, our country cannot focus on all areas, such as e.g., automobile production, for which we need collaborations. AMF has brought us closer to decision making worldwide and to obtain first-hand technical insight.*
- *AMF provides an international stakeholder group which enables generating new information and share lessons learned from different countries. It gives a global perspective for energy carriers in the transportation sector.*
- *Take part in international developments in the area of advanced motor fuels. Quintessentially, international collaboration amongst researchers is beneficial to society as a whole. The decarbonisation of the transport sector is key to reaching our climate goals, hence AMF TCP plays an important role generating knowledge that will help us reach these goals.*
- *Keep up to date on AMF in other countries. Enhancing the value of our organisation through international cooperation*
- *Valuable to present fuel and energy-related information in Korea and to share statistics and policies of other countries. It is also good to have an opportunity to explain our country's position in international policies on fuel and energy.*
- *Cost efficient way to achieve international cooperation*
- *The AMF TCP is a pioneer in researching and describing novel fuels and their application, benefits, and effects in terms of efficiency and emissions. AMF is a unique source of information and a platform for international exchange of experience and cooperation.*
- *Technical information exchange and network development.*

Strategic objectives:

The current strategic objectives are in line with the views of the delegates. For the two first questions related to the strategic objectives, 100 % of those who responded deemed these themes being of high or medium priority. The conclusion can be drawn that the delegates use data from AMF to feed into decision making, and that networking, pooling and conducting cooperative R&D are deemed valuable.

For work related to the optimum allocation of different fuels, high and medium priority totals 96 %.

As for cooperation with related TCPs, high and medium priority totals to 91 %, and cooperation with industry correspondingly to 77 %. In the case of AMF, industry involvement has mostly been in the form of providing test fuels and test vehicles, not in the form of monetary contributions, which might compromise objectivity. Industry representatives have every now and then been invited to ExCo meetings as observers to share their views on transport related issues. In addition, the ExCo has made technical excursions to various companies, fuel producers as well as vehicle manufacturers.

Performance aspects, types of fuels and end-use sectors

Regarding performance aspects of fuels and vehicles GHG emissions and carbon negative fuels are given highest priority, followed by energy efficiency. Lowest priority is given to wear in engines.

As for types of fuels, kerosene substitution (aviation fuels) and e-fuels are given highest priority, gaseous fuels and petrol substitution lowest. Of the end-use sectors, aviation, shipping and heavy-duty vehicles are given the highest scores for priority. Lowest rating is for non-electrified rail.

The following presents some verbal comments to the success of AMF. Comments can also be found embedded in the text throughout the report.

AMF success regarding regulations, policy making and decision making:

- *Task 59: Lessons Learned from Alternative Fuels Experience - feeds into ongoing policy activities to decarbonize sectors like aviation, inland shipping and non-road machinery*
- *AMF Tasks and e.g., Country Reports have contributed to policy and decision making*
- *AMF has helped to resolve information asymmetry*
- *AMF Tasks have contributed to the general acceptance of alternative fuels, especially biofuels, impact on the county's progressive biofuels obligation*
- *AMF data is used as a reference when determining exhaust regulation for LDV and HDV.*
- *Market surveillance regarding alternative fuels, information then used in developing strategies and policy advice on the national level*
- *Important findings from research properly communicated will influence politics by being integrated in the political debates via governmental organisations*

Examples of where results of AMF Tasks are reflected in technical standards or international standards harmonisation activities:

- *AMF has conducted extensive research and provided insights into the technical aspects of producing, blending, and utilising biodiesel (FAME) as a sustainable transportation fuel, as a result, AMF's research has influenced the development of technical standards related to biodiesel production and use*
- *Synchronisation of in-lab chassis dyno methods and on-road routes used in vehicle performance testing*
- *Two-way communication as AMF experts are active in standardisation bodies (ASTM, CEN, ISO, DIN), knowledge is brought into work in both directions*
- *DME fuel standard, Euro VI certification of dual-fuel engines*

What has been the most valuable contribution/achievement of AMF?

- *AMF provides a platform for exchange between representatives of a wide range of organisations, with different backgrounds and national priorities*
- *Overall, the most valuable contribution of the AMF program lies in its efforts to accelerate the development and adoption of advanced motor fuels as part of a comprehensive approach to address energy security, reduce greenhouse gas emissions, and promote sustainable mobility*
- *By fostering collaboration, sharing knowledge, and providing policy guidance, the AMF program has been instrumental in driving the transformation of the global transportation sector towards a more sustainable future*
- *AMF has been the world leading information platform for performance data on alcohol fuels, DME standards and HDV emissions*

What has AMF been especially good at?

- *AMF is outstanding in its strive to communicate Task results and in the Task generation and implementation within the TCP family*
- *AMF has been particularly good at conducting impactful research, facilitating international collaboration, providing policy guidance, promoting advanced motor fuel technologies, and raising awareness about sustainable transportation solutions*
- *Connecting with non-OECD countries, sharing experiences*
- *Bringing together top experts in this area, across countries and continents*
- *Providing unbiased engine and vehicle experimental data/information*
- *It's all good. The AMF has public confidence, so the material it publishes is reliable*

To summarise, the contracting parties are very satisfied with AMF and its achievements. Things that pop up in the recent survey are, e.g.:

- *formation of a truly international network of experts*
- *good sprit within the AMF group*
- *engagement of multiple countries, including non-OECD countries*
- *sharing information and best practices, pooling resources, leveraging*
- *setting up timely research tasks*
- *ability to generate unbiased data on various motor fuels*
- *making AMF results visible*
- *creating data and information that goes into decision making*

QUO VADIS AMF?

The world is ever changing, and therefore AMF has to change with it. Change means, among other things, a shift in focus over time.

Projections on future fuel use were presented in the beginning of this report. It is obvious that we will be needing fuels up to the year 2050 and even beyond, so there is a general justification for AMF to continue working for more sustainable transport. There will still be a need for collecting and processing data, generating performance data for new alternatives, sharing best practices and networking.

In 2023, DNV states as follows[19]:

> *"In 2022, the transport sector accounted for 62 % of the world's total oil consumption. Out of this, approximately 80 % was allocated to powering road vehicles, while the remaining portion was distributed relatively evenly between aviation and maritime usage. Despite the increasing adoption of electricity, sustainable aviation fuels (SAF), hydrogen, and ammonia across road, aviation, and maritime transport, the transport sector will continue to be the leading consumer of oil. By 2050, oil will still represent 50 % of the global transport sector energy demand, underscoring its persistent significance.*
>
> *The path to achieving decarbonization is evident: electrify what can be electrified; what cannot be electrified in the near-term should transition to sustainable advanced biofuels; and get ready for the widespread adoption of hydrogen-based new fuels, which should extend from local and regional systems to a global system starting in 2035."*

[19] https://www.dnv.com/article/transport-in-transition-247014

DNV lists reasons why oil will be used in transport for years to come:

- **Cost Competitiveness**: Oil is currently cost-effective due to its widespread production and availability
- **High Energy Density**: Gasoline, diesel, and kerosene have energy densities over three times higher than liquid ammonia and liquid hydrogen
- **Infrastructure**: The existing transportation infrastructure, including tankers, pipelines, refineries, and gas stations, is heavily oriented towards oil-based fuels
- **Processing for Transport**: Oil transportation requires no significant pre- or post-processing, unlike hydrogen and e-fuels
- **Storage**: Crude oil can be stored almost indefinitely with minimal loss in tanks or barrels.

One can make a note that most of these features, cost competitiveness excluded, also apply to liquid drop-in type renewable fuels.

Figure 14 presents DNV's view on electric, hybrid and alternative fuel solutions towards 2050. Choice of technology depends on the power level required as well as on the need for autonomy.

One could say that AMF's way of thinking corresponds to that of DNV: electrify what easily can be electrified and promote sustainable fuels for those applications which combine high power and high autonomy. However, AMF has to keep in mind that the preconditions for electrification varies from country to country and region to region, and some countries prioritise biofuels over electrification in transport decarbonisation.

Electric, hybrid and alternative fuel solutions towards 2050

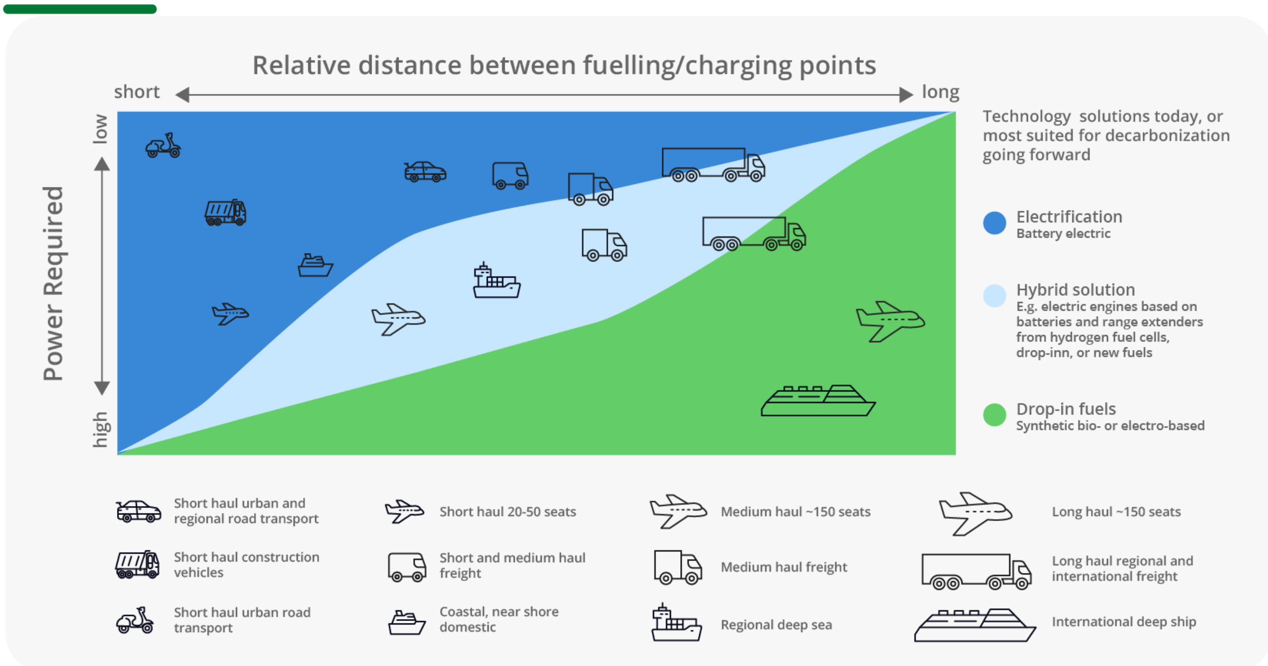


Figure 14: *DNV's view on electric, hybrid and alternative fuel solutions towards 2050*[19].

[19] https://www.dnv.com/article/transport-in-transition-247014

Outlook for ICEs

The ICE is a rather efficient energy converter, it's affordable and reliable, and current ICEs with sophisticated exhaust after-treatment systems can deliver extremely low pollutant emissions.

In 2015, the Finnish engine manufacturer Wärtsilä achieved a Guinness World Records title for the most efficient 4-stroke diesel engine with its Wärtsilä 31 medium-speed engine[20]. Fuel consumption minimum is 165 g/kWh, which translates into a shaft efficiency of some 51%. AMF Task 57 demonstrated that the engines of current heavy-duty trucks achieve 45% efficiency in typical long-haul operation. In 2016, the US SuperTruck program set an efficiency target of 55% for heavy-duty engines, a number requiring waste heat recovery[21].

US Department of Energy states that PEM fuel cell systems for transportation can reach a system efficiency of 53 to 58%[22]. This means that ICEs can be almost as good as fuel cells for system efficiency. In automotive systems, ICEs can be complemented with hybrid systems, to boost efficiency in part load and transient conditions.

So, the ICE is quite efficient and affordable, why has it then been blacklisted occasionally? Two main reasons, the first one being CO_2 emissions, which relate to the use of fossil fuels, not the ICE itself. Secondly, high real-life emissions, a result of engine and vehicle manufacturers trying to cut corners. The so-called Dieselgate surfaced in 2015, showing that some manufacturers cheated in emission testing[23].

These two topics are on the agenda of AMF. AMF is trying to promote low-carbon and carbon neutral fuels. However, if vehicle CO_2 emissions are evaluated from a tailpipe perspective only, as typically is the case in vehicle CO_2 emission regulations, carbon containing renewable fuels, whether biofuels or e-fuels, are in trouble. The only fuels that can deliver zero tailpipe CO_2 emissions in an ICE are ammonia and hydrogen.

Task 57 pointed out that focusing on tailpipe emissions constitutes a barrier for further development of renewable fuels and alternatively fuelled trucks.

E.g., the EU is heading for extremely stringent vehicle CO_2 regulations. For passenger cars and light-duty commercial vehicles, from 2035 onwards, the EU fleet-wide CO_2 emission target for both cars and vans is a 100% reduction, meaning 0 g CO_2/km[24].

However, the proposal has raised some opposition both in member countries and in the automotive industry. A proposal to continue allowing the registration of new cars with combustion engines even after 2035, provided they run "exclusively on CO_2 neutral fuels", is now on the table[25]. "CO_2 neutral" fuels means "renewable fuels of non-biological origin" (RFNBOs), as defined in the EU's Renewable Energy Directive (REDII)[26].

[20] https://www.wartsila.com/media/news/02-06-2015-new-wartsila-31-engine-achieves-guinness-world-records-title
[21] https://www.greencarcongress.com/2016/03/20160302-supertruck.html
[22] https://www.hydrogen.energy.gov/fuel_cells.html
[23] https://www.bbc.com/news/business-34324772
[24] https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co$_2$-emissions-vehicles/co$_2$-emission-performance-standards-cars-and-vans_en
[25] https://www.euractiv.com/section/transport/news/eu-considers-watering-down-co$_2$-neutrality-standard-for-efuels/
[26] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.328.01.0082.01.ENG&toc=OJ:L:2018:328:TOC

According to the Directive, the GHG savings from the use of RFNBOs shall be at least 70 %. The proposal to include RFNBOs in the vehicle CO_2 regulations increases the requirement for savings to 100 %. It should be noted that advanced biofuels and RFNBOs are treated unequally.

In 2023, the European Commission proposed a revision of the Regulation on CO_2 emission standards for heavy-duty vehicles[27]. If adopted, the proposal would introduce new, stronger CO_2 emission standards for heavy-duty vehicles from 2030 onwards and extend the scope of the Regulation to cover smaller trucks, city buses, long-distance buses and trailers. The proposed reductions are 45 % in 2030, 65 % in 2035 and 90 % in 2040, relative to 2019.

To stimulate faster deployment of zero-emission buses in cities, the European Commission also proposes to make all new city buses zero-emission as of 2030. Renewable fuels are not a part of the proposed HDV CO_2 regulation, and the motivation is that renewable fuels are better used in other sectors than on-road vehicles[28].

It is true that there are some alternatives for on-road vehicles. But try to envision what would happen if this zero tailpipe CO_2 spreads to NRMM and marine engines. Electrification, hydrogen and ammonia would be very challenging in many applications.

In the so called "Dieselgate" scandal , the automotive industry shot itself in the foot, losing credibility. To patch shortcomings in the certification procedures, much attention is now given to real driving emissions (RDE). RDE and catching gross polluters has been the topic of two AMF Tasks, Tasks 55 and 61. In addition, RDE was embedded e.g., in Tasks 53 and 57. As the Swedish delegate to AMF and Past Chairman put it: "You get what you inspect, not what you expect" (meaning that only solid data describes true performance). Fortunately, measurements on new vehicles show that RDE are well controlled and are not a major concern anymore.

Alternative and renewable fuels

Although there are some uncertainties of the role of renewable fuels in road transport in the long run, there will be an increasing demand for renewable fuels in shipping and aviation as demonstrated by Figure 14, and probably also in the NRMM sector. And as for road transport, not every continent is going in the same direction for vehicle CO_2 regulations as Europe. In Brazil, electromobility plays a secondary or tertiary role in the government´s strategy to decarbonise the transport sector, behind biofuels from primary and secondary sources.

Renewable fuels are taken into account when calculating emission inventories, and this is naturally a good thing. However, if stringent vehicle CO_2 regulations lead to a situation in which the offering of ICE vehicles fades away, in the long run, there will fewer and fewer vehicles being able to use renewable fuels. As the automotive sector is putting massive effort in developing electric vehicles, dedicated alternative fuel vehicles (e.g., FFV, vehicles on gaseous fuels) will be severely hit, as the resources for technical development are limited.

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27 https://climate.ec.europa.eu/eu-action/transport/road-transport-reducing-co$_2$-emissions-vehicles/reducing-co$_2$-emissions-heavy-duty-vehicles_en
28 https://ec.europa.eu/commission/presscorner/detail/en/qanda_23_763
29 see, e.g., https://www.epa.gov/vw/learn-about-volkswagen-violations

A fair way to treat renewable fuels is to use well-to-wheel assessment, that is to consider emissions and energy use over the full fuel cycle. Even better would be full life cycle assessment (LCA), considering also the full cycle of materials. This should also apply to vehicle CO_2 regulations. If renewable fuels are to be taken into account in vehicle CO_2 regulations, mechanisms to secure that the vehicles that get a CO_2 credit actually run on low carbon or renewable fuels.

Renewable fuels are sometimes classified by feedstock or by technology, where in fact, classification should be based on performance, e.g., overall reduction of GHG emissions and implications on land use.

Europe has put limitations on biofuels, e.g., by capping some feedstocks and listing "good" feedstocks and is favouring certain technologies, electrification first and foremost, and then, e.g., RFNBO over biofuels. Currently there are more sticks than carrots for the biofuels business. This is a rather strange situation as the climate impacts of fossil fuels are regulated to a significantly lesser degree. Frequently changing regulations and rules makes life hard for investors. Thus, Europe does not constitute an example on how to build confidence in biofuels.

E.g., Brazil and USA, on the other hand, are examples on countries with a favourable policy towards biofuels.

Here AMF has a role to play. Assess various energy carriers on a well-to-wheel basis or even better on a life cycle basis, demonstrate environmental performance and cost effectiveness. Continue collating information on policies and regulations in the member countries and highlight examples of successful policies and implementation.

The general interest in gaseous fuels, namely methane, seems to be fading, at least in the on-road sector. In the segment of light-duty vehicles, the offering of vehicles has dropped dramatically. There are still a handful manufacturers offering heavy-duty trucks, whereas in the case of city buses, the game has been lost to electric buses.

Cleaned-up biogas, that is bio-methane, is a drop-in substitute for fossil natural gas. Bio-methane is one of the least questioned biofuels, and some bio-methane pathways even display a negative GHG balance in avoiding methane that would otherwise leak into the atmosphere. Bio-methane could have a great potential but is limited by the vehicle fleet being able of using it.

Way ahead

As stated, and also underlined by the 2023 internal survey, there is a solid justification to continue the work of AMF. Neither fuels nor the ICE are going away in the near future, and transport decarbonisation cannot only rely on electrification. AMF must have a truly international approach, not focusing, e.g., on what is mainly happening in Europe and North America. Conditions vary from region to region and country to country.

The 2020 – 2024 work programme already started a shift towards hard-to-electrify sectors, that is heavy-duty road, NRMM, shipping and aviation, and this shift can be expected to continue.

Emerging fuels such as e-fuels (RFNBO), ammonia and hydrogen for ICEs should be kept on AMF's radar screen. AMF has made some efforts in the direction of "best use of alternative fuels", and this theme should probably be strengthened, with more system level studies. Cost is an important factor and should be embedded in the assessments.

The 2023 survey listed engagement of multiple countries, sharing information and best practices, pooling resources, leveraging, setting up timely research tasks, ability to generate unbiased data on various motor fuels, making AMF results visible and creating data and information that goes into decision making as added value of AMF. This is a solid foundation to build on.

LIST OF FIGURES

Annex 1.
Map of Tasks

TABLE 1.
AMF TCP work on comparisons of advanced in different transport sectors

Fuels for cars	Fuels for heavy duty vehicles	Non-road fuels	Marine fuels	Aviation
Task 56: Methanol as Motor Fuel	Task 57: Heavy Duty Vehicle Evaluation	Task 65: Powertrain options for non-road mobile machinery	Task 60: The Progress of Advanced Marine Fuels, report	Task 63: Sustainable Aviation Fuels, report
Task 54: GDI Engines and Alcohol Fuels	Task 53-2: Sustainable Bus Systems (Phase 2) Task 53-1: Sustainable Bus Systems (Phase 1)	Task 50: Fuel and Technology Alternatives in Non-Road Engines	Task 41: Alternative Fuels for Marine Applications, report	
Task 52: Fuels for Efficiency	Task 51: Methane Emission Control	Task 33: Particle Emissions of 2-S Scooters, report		
Task 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options	Task 49: COMVEC – Fuel and Technology Alternatives for Commercial Vehicles	Task 25: Fuel Effects on Emission from Non-Road Engines, report		
Task 22: Particulate Emissions at Moderate and Cold Temperatures Using Different Fuels, report	Task 37: Fuel and Technology Alternatives for Buses, report			**Lubricants**
Task 12: Particulate Emissions from Alternative Fuelled Vehicles (CNG, LPG), report	Task 17: Real Impact of New Technologies for Heavy-Duty Vehicles			Task 16: Biodegradable Lubricants -Diesel, report -Gasoline, report
Task 5: Performance evaluation of Alternative Fuel/ Engine Concepts, report	Task 8: Heavy-duty Vehicles on Alternative Fuels			

TABLE 2.
AMF TCP general work on advanced motor fuels

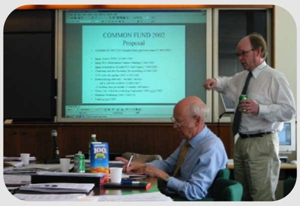
Life cycle, efficiency, feedstocks	Significance of emissions	Measurement methods	Strategies	Information Services, Fuel standards
Task 64: E-fuels and End-use Perspectives (ongoing)	Task 55: Real Driving Emissions and Fuel Consumption	Task 62: Wear in Engines using Alternative Fuels (ongoing)	Task 59: Lessons Learned from Alternative Fuels Experience	Task 28, 24, 9, 2 AMFI Newsletters
Task 52: Fuels for efficiency	Task 42: Toxicity of Exhaust Gases and Particles from IC-Engines – International Activities Survey, report	Task 61: Remote Emission Sensing (ongoing)	Task 58: The Role of Advanced Renewable Transport Fuels in Decarbonising the Transport Sector in 2030 and beyond	Task 27: Standardization of Alternative Fuels -Phase 1, report -Phase 2, report
Task 40: Life Cycle Analysis of Transportation Fuel Pathways, report	Task 7: Comparison of Relative Environmental Impacts of Alternative and Conventional Fuels, report	Task 36: Measurement technologies for Emissions from Ethanol Fuelled Vehicles, report	Task 21: Deployment Strategies for Hybrid, Electric and Alternative Fuel Vehicles, report	AMF Annual Reports
Task 34: 1. Analysis of Biodiesel Options, report 2. Algae as a Feedstock for Biofuels, report		Task 29: Evaluation of duty-cycles for Heavy-Duty Urban Vehicles, report	Task 15: Implementation Barriers of Alternative Fuels, report	AMF End of Term Report 2009-2015
Task 19: New Fuels for New Engines		Task 3: Diesel Field Trials and Diesel Field Trials Analyses	Task 11: Forecasting Tools for Alternative Fuels and Related Infrastructure	

ExCo 9, Tokyo, Japan,
November 1988
Chair: Shinichi Nahayama (Japan)

ExCo 22, Rovaniemi, Finland,
January 1998
Chair: Ben van Spanje (NL)

ExCo 23, Tokyo, Japan,
October 1998
Chair: Ben van Spanje (NL)

ExCo 24, Espoo, Finland,
June 1999
Chair: Nils-Olof Nylund (Finland)



ExCo 27, Milano, Italy,
May 2002
Chair: Nils-Olof Nylund (Finland)

ExCo 28, Paris, France,
March 2003
Chair: Nils-Olof Nylund (Finland)

ExCo 30, Sao Paulo, Brazil,
October 2004
Chair: Steve Goguen(USA)

ExCo 31, Prague, Czech Republic,
November 2005
Chair: Steve Goguen (USA)

ExCo 32, Beijing, China,
October 2006
Chair: Steve Goguen (USA)

ExCo 35, Vienna, Austria,
May 2008
Chair: Steve Goguen (USA)

ExCo 36, Osaka, Japan,
December 2008
Chair: Nils-Olof Nylund (Finland)

ExCo 39, Ottawa, Canada,
May 2010
Chair: Nils-Olof Nylund (Finland)

ExCo 40, Thessaloniki, Greece,
November 2010
Chair: Nils-Olof Nylund (Finland)

ExCo 41, Karlsruhe, Germany,
May 2011
Chair: Jean-Francois Gagné (Canada)

ExCo 43, Zürich, Switzerland,
May 2012
Chair: Jean-Francois Gagné (Canada)

ExCo 44, Beijing, China,
October 2012
Chair: Nils-Olof Nylund (Finland)

ExCo 45, Gothenburg, Sweden,
May 2013
Chair: Sandra Hermle (Switzerland)

ExCo 47, Copenhagen, Denmark,
May 2014
Chair: Nils-Olof Nylund (Finland)

ExCo 48, IEA/Paris, France,
November 2014
Chair: Sandra Hermle (Switzerland)

ExCo 51, Chicago, USA,
May 2016
Chair: Magnus Lindgren (Sweden)

ExCo 53, Helsinki, Finland,
June 2017
Chair: Magnus Lindgren (Sweden)

ExCo 56, Delhi, India,
October 2018
Chair: Magnus Lindgren (Sweden)

ExCo 61, webmeeting,
May 2021
Chair: Jesper Schramm (Denmark))

ExCo 64, Aalborg, Denmark,
hybrid meeting, October 2022
Chair: Jesper Schramm (Denmark)

Dr. NILS-OLOF NYLUND
VTT Technical Research Centre of Finland

40 YEARS OF AMF COLLABORATION

Working for sustainable transport

Technology Collaboration Programme on Advanced Motor Fuels