European Commission

STRIA Roadmap on Low-emission Alternative Energy for Transport (ALT)

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Electric batteries are now seen as a viable option for many road vehicles. However, aviation, waterborne transport and certain heavy-duty road vehicles are likely to rely on combustion engines and liquid fuels for the foreseeable future.

In order to decarbonise the transport sector it is therefore essential in the short- and medium-term to increase the use of renewable energy sources and improve the overall energy efficiency of the transport system. This will have the benefit of not only reducing greenhouse gases but also pollutants that are responsible for poor urban air quality.

Nevertheless, increasing the share of alternative low emission energy in the transport sector poses a number of technical and environmental challenges.

The development of a new generation of powertrains will require research and innovation efforts to be focused on a step change in technology. One that allows greater and more efficient use of alternative energies to reduce greenhouse gases. For energy production, research and innovation efforts will need to focus on novel low emission alternative energies based on renewable and sustainable sources.

The Strategic Transport Research and Innovation Agenda (STRIA) Roadmap for Low-emission Alternative Energy for Transport focuses on renewable fuels production, alternative fuel infrastructures as well as the impact on transport systems and services of these technologies for road, rail, waterborne transport and aviation.

The following alternative fuels fall under this roadmap:

- Methane-based fuels (e.g. Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Bio-methane and E–gas). All transport modes can use it, with the exception of aviation.
- Propane and butane based fuels (e.g. Liquefied Petroleum Gas (LPG) and BioLPG), used only in road transport.
- Alcohols, Ethers and Esters (e.g. Ethanol, Butanol, Methanol, Ethanol-based blend of 95 % (ED95)). All transport modes can use it, with the exception of aviation.
- Synthetic paraffinic and aromatic fuel (e.g. Hydrotreated Vegetable Oil (HVO) and Gas to Liquid (GTL)). All transport modes can use it, including aviation.
- Hydrogen (e.g. CH2, LH2, NH_3). All transport modes can use it.

These factsheets are available on the TRIMIS portal (https://trimis.ec.europa.eu), and aim at providing a summary of the main features and targets identified in each of the seven STRIA Roadmaps.

Current Developments

Light duty vehicle technology and the fuels it uses are driven by tailpipe emission limits as well as fleet average CO_2 tail pipe targets. EU emission standards apply to all motor vehicles and limits the permissible tailpipe emissions of CO, HC, NOx, PM and PN. Current Euro 6 standards came into force in 2013. Very effective after-treatment devices such as the Three Way Catalysts (TWC) for most gasoline vehicles and oxidation catalysts combined with a Lean NOx Trap (LNT) and / or Selective Catalytic Reduction (SCR) as well as a Diesel Particulate Filter (DPF) for diesel vehicles have become a necessary additional expense to auto makers to meet emissions standards. These systems, especially the diesel after-treatment systems, can be costly (about 15% of the car cost), which could become another driver to push the development of alternatively fuelled powertrains. With electrification however, comes a new challenge of low temperature exhaust systems for reducing NOx and oxidising PM/HC/CO, CH_4 for hybrid vehicles running at a lower speed and load.

Consequently, research focuses on new high efficiency, low polluting combustions systems that work well in combination with increased levels of vehicle electrification. These include Homogeneous Charge Compression Ignition (HCCI), Cold Air Intake (CAI), Partially Premixed Combustion (PPC) and others, but essentially they share the aim of efficient combustion at lower temperatures to reduce engine out NOx emissions and are therefore captured under the broad category of Low Temperature Combustion (LTC) systems. Improving combustion systems, taking into account the potential of alternative fuels should be a priority, together with the development of hydrogen fuel cell electric powertrains. This will enable deep decarbonisation and low pollutant emission across all transport modes. In addition, research into control systems, new materials and manufacturing processes, improved modelling, simulation and testing, life cycle analysis will enable to even greater benefits from the use of alternative fuels.

Heavy-duty road vehicles (trucks and buses) are predominantly powered by diesel engines currently. This is a consequence of the superior fuel efficiency and low end torque compared to SI engines resulting in better operating characteristics. The heavy-duty vehicle sector is characterised by many different vehicle categories, technologies, sizes and weights, as heavy-duty vehicles are typically customised for specific clients and uses. This range of different vehicle combinations makes it difficult to estimate important parameters such as fuel consumption and CO_2 emissions in a reliable and cost-effective manner.

Current research activities in the ICE based powertrains HDV sector focus strongly on improving fuel consumption for lower cost of operation of the complete vehicle. For the powertrain this focuses on reducing waste energy as well as high efficiency, low polluting combustions systems. These combustion systems are available in various formats and have a large number of names (HCCI, CAI, PPC, LTC and others), but essentially share the aim of efficient combustion at lower temperatures to reduce engine out NOx emissions and are therefore captured here in Low Temperature Combustion systems (LTC). Research into a number of different alternative fuels is ongoing (including DME, ED95, NG) and for OEMs the focus is strongly focused on developing cost-effective system solutions integrating varying levels of electrification with combustion engines depending on typical duty cycles the product will experience. Hydrogen buses projects have flourished across Europe over the past ten years and there are early commercial buses on offer. Hydrogen trucks demo-projects are currently ongoing.

Waterborne transport, from recreational craft to large ocean-going cargo ships, is driven primarily by diesel engines, using mainly heavy fuel oil (HFO), which tends to be high in sulphur, and middle distillate fuel (MGO). The waterborne transport sector has internationally recognised standards that define the characteristics of fuel oils and what they can contain, so as to be suitable for use on-board ships (ISO 8217:2017 being the most widely used standard). The 2017 update of this standard (previously 2012) included new grades of distillate fuel which allow up to 7% blend of the biofuel Fatty Acid Methyl Esters (FAME).

As with other sectors, there is no silver bullet solution to decarbonisation. It is likely that halving carbon emissions will require a range of options, including new fuel sources and raising technical and operational efficiencies. Short-term measures include incentivising speed reduction and optimisation, which will have the largest impact, as well as strengthening the Energy Efficiency Design Index (EEDI), incentivising early adoption of low carbon technologies, developing carbon intensity guidelines for all marine fuels, and research into innovative technologies and low carbon fuels, as well as deployment of available low carbon fuel options. Mid- and long-term measures are to develop zero emission solutions and fuels, such as high power marine fuel cells and hydrogen / ammonia fuel, as well as build upon the short-term measures and develop market-based mechanisms to incentivise substantial emissions reductions.

Current research activities in waterborne transport are concentrated on combustion systems to reduce emissions and fuel consumption. This includes research on dual-fuel engines (gasoil/diesel and natural gas) and advanced fuel injection systems to reduce emissions while maintaining or improving energy efficiency. Partially pre-mixed (and other forms of low temperature) combustion systems combined with exhaust gas recirculation and waste heat recovery are also topics of research for the same reasons. Methane leakage throughout the fuel supply and storage chain could (partly) offset GHG emissions and requires further research. More recently, hydrogen has made an appearance in the landscape of alternative fuels for waterborne transport applications, either as a possible blend with existing gaseous and liquid fuels, or as the sole fuel in combination with a fuel cell and electric powertrain.

Aviation – Efforts made through technological progress and operational improvements have significantly improved the energy efficiency of air transportation. However, even with the most radical technological progresses, the efficiency gains will not offset the expected traffic growth or allow achievement of the challenging commitments for decarbonisation made by the aviation industry by 2020 and 2050. A global market-based mechanism has been agreed by Member States to ICAO's Committee for Aviation Environmental Protection, which aims to address international aviation emissions, called the Carbon Offsetting and Reduction Scheme for International Aviation (CORSIA). Under CORSIA, the aviation sector will need to maintain international aviation CO_2 emissions at or below 2020 level.

In order to mitigate the cost of offsetting CO_2 emissions to comply with sectoral climate policies such as CORSIA, the aviation industry may reduce its CO_2 emissions directly through improvements in airframe and engine technologies, more efficient aircraft and ground operations and the use of sustainable alternative jet fuels (AJF). Low-carbon synthetic fuels produced from renewable sources are expected to play a key role in meeting aviation sector decarbonisation targets in 2050. Today the vast majority of commercial aviation flights use Jet-A1 (also known as kerosene). Due to the high cost of aircrafts and the long fleet replacement time, and also to limit infrastructure changes, the aviation sector is likely to rely in future when looking for greener substitutes on liquid fuels similar to kerosene up to 2050 and possibly beyond. All of the alternative jet fuels currently certified or under development are 'drop-in' fuels, which can be blended at a limited percentage into conventional kerosene whilst meeting existing specifications. Sustainability of alternative jet fuel production processes depends upon the feedstock and method of production. Drop-in fuels could also be produced from electric power, known as power-to-liquid (PTL) or directly from sunlight.

Pure electric options to fly planes, like battery-based and hydrogen fuel cell-based solutions, remain to this day limited. Hydrogen is in fact making an entry into aircrafts as an additional fuel which will be used to power certain applications via a fuel cell.

Rail strategies favour further electrification, but there are routes where electrification is not economically viable. On these routes, locomotives using ICE and fuelled with alternative fuels can play a role. Alternatively, an electric train solution can be implemented consisting of a battery-based solution (for short distance) or hydrogen fuel cell based solution (for long distance). To meet increasingly ambitious emissions reductions and efficiency gains, rail transport is considering the use of alternative fuels such as liquefied natural gas (LNG), liquid biofuels and synthetic fuels in trains running with ICEs, and battery and hydrogen fuel cell based solutions in electric trains, and also looking at improvements in energy efficiency and weight reductions.

Biodiesel (FAME) could also be an alternative fuel. However, existing diesel traction engines running with blends in excess of B30 can lead to increased fuel consumption and decreased power, and higher maintenance costs. LNG and biomethane (LBG) offer reductions of particulate matter emissions and tailpipe GHG emissions, but the WTW GHG emissions of LNG depend largely on the levels of methane slip and source of the gas. This technology is considered for new locomotive development rather than for retrofitting of existing ones, due to the extra-space needed for LNG tanks.

Key Research and Innovation Pathways

Reducing GHG emissions in transportation consists of two main elements, namely:

1. The availability of cost-effective sustainable low carbon alternative energy / fuels (well-to-tank - WTT)
2. Improved efficiency in real world utilisation (tank-to-wheel - TTW)

This roadmap deals with the potential impact of alternative fuels on the latter, as well as their potential impact on emissions affecting air quality. Decarbonisation will depend on the full well-to-wheel implications of alternative fuel use, and will need to rely on low carbon and renewable fuels, while alternative fossil-derived fuels could help address in the interim air quality and energy diversification issues. A high-level summary of key elements of a R&I agenda in relation to the different alternative fuels considered is the following:

Alcohols and ethers:

- Optimal levels of alcohols and ethers to maximise WtW emissions savings
- Optimise injection, combustion and aftertreatment
- Downsizing / rightsizing and hybridisation
- Bi-fuel octane on demand engine
- Control aldehyde emissions
- High temperature fuel cells

Methane:

- Direct injection in SI engines
- Lean combustions and controlled auto-ignition
- Aftertreatment to avoid methane slip e.g. exhaust gas recirculation
- Methane slip and leakage in supply chain
- High temperature fuel cells

Synthetic paraffinic and aromatic fuels:

- Optimal levels of SPFs to maximise WtW emissions savings
- Appropriate levels of aromatics

Hydrogen:

- Fuel cell materials, architectures, balance of plant components, manufacturing techniques
- Hydrogen production technologies, storage and refuelling infrastructure

Strategic Transport Research and Innovation Agenda

The Strategic Transport Research and Innovation Agenda (STRIA) outlines future transport research and innovation priorities to decarbonise the European transport sector.

STRIA is one of five interlocking dimensions set out in the Energy Union strategy that provides a framework to achieve EU energy and climate goals. It supports the vision of a clean, connected and competitive European transport system.

In coordination with Member States and transport stakeholders, STRIA aims to set out common priorities to support and speed-up the research, innovation and deployment process leading to radical technology changes in transport.

STRIA builds on and integrates seven thematic transport research areas:

- Connected and automated transport (CAT);
- Transport electrification (ELT);
- Vehicle design and manufacturing (VDM);
- Low-emission alternative energy for transport (ALT);
- Network and traffic management systems (NTM);
- Smart mobility and services (SMO); and
- Transport infrastructure (INF).

STRIA is also the interface between other relevant sectors such as energy and information and communication technology.

About TRIMIS

The Transport Research and Innovation Monitoring and Information System (TRIMIS) supports the implementation and monitoring of STRIA and its seven roadmaps. TRIMIS is the analytical support tool for the establishment and implementation of STRIA, and the Commission's instrument for mapping technology trends and research and innovation capacities in the transport field, as well as monitoring progress against the targets set for all the transport sectors.
TRIMIS is an open-access information system to map and analyse technology trends, research and innovation capacities, as well as monitor progress in the transport sector.

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