ADVANCED MOTOR FUELS
IEA-AMF

Key Messages from AMF Research

Annex 43 — October 2016

Performance Evaluation of Passenger Car, Fuel and Powerplant Options

Operating Agent: VTT Technical Research of Finland Ltd
Partners: USA, Sweden, China, Canada, Japan

Main Conclusions

In the overall synthesis, **the electric drive proved to be the best option.** It was still better than any fossil fuel internal combustion engine (ICE) option, even when the electricity was assumed to contain the EU28 average carbon footprint. **The best ICE engine option was a compression ignition (CI) engine using a fully renewable HVO-type of fuel**, followed by a spark-ignition (SI) engine on biomethane, as a close contender. The **lowest combined score was attributed to SI/gasoline and SI/LPG.** Fuels with **high amounts of renewable contents help to reduce well-to-wheel (WTW) CO_2 emissions**, in a meaningful way. Furthermore, **use of more sophisticated fuels is still well justified, as they help to reduce tailpipe emissions**. However, this study was limited to Euro 5, whereas **use of the more stringent Euro 6 level technology may change this claim**, at least to some extent. Thus, **re-assessment is highly advisable, in the future**.

Background

Major de-carbonizing is needed in road transport, but there is no single solution that can solve the challenge. Instead, multiple technologies must be considered to find the best alternatives for each set of boundary conditions. Moreover, the importance of energy efficiency is increasing. Renewable and carbon-free energy can be introduced with biofuels or via electricity from renewable sources. Passenger cars constitute the majority of on-road vehicles, and for those, several new viable fuel and powerplant options are available, such as SI engines that employ high concentration ethanol fuel or biomethane. Furthermore, new biobased synthetic (parafinnic) diesel fuels have come to the market. Additionally, the number of electric-only cars being offered is steadily rising, with almost every OEM having at least one model in their product portfolio. Since the number of individual vehicle types, makes, and models is very large, the evaluation of future options is quite challenging. The goal of this research project was to deliver first-hand primary data for this type of assessment, envisioning that it could improve the opportunities of making appropriate choices amongst the several available options. Furthermore, as the number of available options is increasing for both powertrain technology and fuels, unbiased data, sanctioned by the IEA, on the performance (energy use and emissions) of new technologies was needed for decision makers, at all levels.

Research Protocol

The data in this assessment was either the result of tests specific to this study (CHN, SWE, CDN, FIN), or came from other suitable pre-existing available data (USA, JPN). Therefore, the used test protocols and duty-cycles were not 100 % harmonized, as most of the tests were made using the European type approval procedure (NEDC), with some data having been acquired using other types of approval cycles (US, Japan). Additionally, the Artemis cycles were labelled as being “more representative” of driving.

The fuel options included gasoline, without ethanol (or methanol) as low blends (E5, E10, M15), high concentration ethanol (E85) and compressed methane (CNG/CBG). For CI engines, regular mineral oil-only diesel fuel was used, without any biocomponent, or as a low blend of the conventional biodiesel FAME (B7), or similar vegetable oil. Furthermore, a paraffinic, fully synthetic and renewable diesel fuel (HVO) completed the fuel matrix. Most of the tests were run at +23 °C, with some additional ones at +5 and -7 °C. Altogether, 27 different cars representing eight platforms were involved. First, an evaluation of the end-use performance (TTW) was done, and then the data was combined with the WTT data from the JRC test fuel study (2014) to provide information on the complete fuel cycle (WTW). Fig. 1 depicts the results.

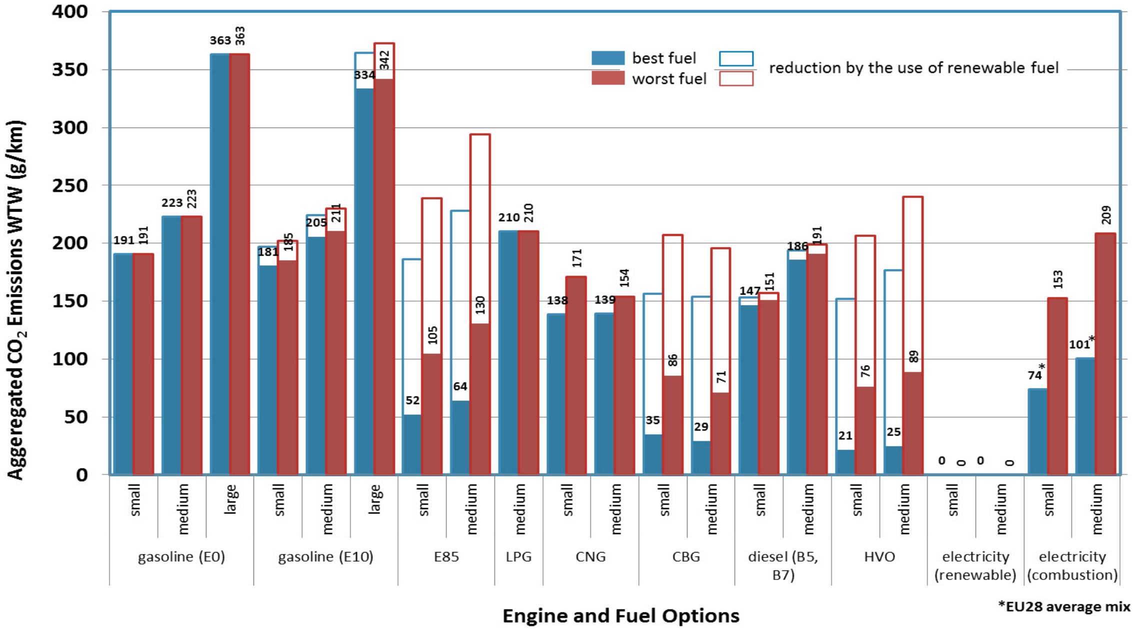

Fig.1: Aggregated well-to-wheels (WTW) CO_2 for the “best” and ”worst” fuel pathways.

In the overall analysis and in trying to look at all of the options from as many standpoints and perspectives as possible, a scoring scheme was developed in the synthesis phase, based on five dimensions: 1) energy efficiency (25 %), 2) well-to-wheel (WTW) CO_2 emissions (25 %), 3) (harmful) local exhaust emissions (composite of five) (25 %), 4) sensitivity to cold ambient temperatures (15 %) and 5) driving range with one fill-up of fuel/energy (10 %). The % figure is the weighting of each dimension.

Key Findings

A high WTW CO_2 emissions rate is the major flaw of present-day motor fuels based only on mineral oil. However, with the right kind of fuel, ICE remains as a viable option. For example, an SI engine with a simple and robust three-way catalyst, meets even the most stringent emission regulations and allows the use of renewable energy via biomethane, with low harmful emissions and good low temperature response. With CI engines, better efficiency is at hand, but at the offset the control of NOx emissions is much more complicated. Furthermore, paraffinic, fully synthetic renewable diesel fuels, known as HVO, allow for very high amounts of renewable contents in the fuel, accompanied by positive effects on exhaust emissions. The high efficiency of the electric powertrain ascertains that the WTW CO_2 emissions rate remains low, even if the electricity used is not 100 % renewable; however, with current state-of-the-art batteries, the range is short and costs are high.