Annex 43: Performance Evaluation of Passenger Car Fuel and Powerplant Options (CARPO)

Project Duration	January 2011–June 2016
Participants **Task Sharing** **Cost Sharing**	 Canada, China, Finland, Japan, Sweden, United States None
Total Budget	~€450,000 ($622,755 US)
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Purpose, Objectives, and Key Question

Major de-carbonizing actions need to take place in the road transport sector. There is no single solution for solving the de-carbonization challenge. Multiple technologies must be considered in order to find the alternatives that are best suited for each given set of boundary conditions.
The core of the study consisted of benchmarking a set of passenger car makes and models that offer multiple options for fuels and powerplants. Another project goal was to demonstrate the differences in efficiency that arise from engine types and sizes by testing engines with different power outputs offered on the same vehicle platform.

The test matrix allowed for modulation of the duty cycle and ambient temperature in order to obtain more application-specific and environment-specific data. To make the assessment as realistic as possible, the evaluation was based on a set of different operating conditions and duty cycles. This varying of conditions is important, since previous experience has shown that cars tend to be optimized to type-approval conditions and common driving cycles.

The primary objective of the project was to produce comparable information about different powerplant options with regard to fuel efficiency, energy efficiency, and tailpipe emissions. By using selected vehicle platforms and by basically performing “internal” comparisons between powerplant options, the vehicles themselves can be “nullified.” This approach emphasized the differences between alternative engine technologies, rather than the differences between car makes and models. Full fuel cycle performance was calculated by combining well-to-tank (WTT) data for various fuels generated in Annex 37.

Activities

The data used in this assessment were either the result of tests specific to this study (China, Sweden, Canada, or Finland), or came from other suitable pre-existing available data (United States, Japan). Therefore, the test protocols and duty cycles used were not 100% homogeneous, as most of the tests were conducted using the European type approval procedure (New European Driving Cycle [NEDC]); some data were acquired using other types of approval cycles (United States, Japan).

The fuel options included gasoline, without ethanol (or methanol) as low blends (E5, E10, and M15), high-concentration ethanol (E85), and compressed methane (compressed natural gas/compressed biogas [CNG/CBG]). For compression ignition (CI) engines, regular mineral-oil-only diesel fuel was used, without any bio-component, or as a low blend of the conventional biodiesel fatty acid methyl acid (FAME) (B7), or other similar vegetable oil. A paraffinic, fully synthetic and renewable diesel fuel (hydrotreated vegetable oil [HVO]) completed the fuel matrix. Most of the tests were run at +23°C; some additional ones were run at +5 and −7°C. Altogether, 27 different cars representing 8 platforms were involved. First, an evaluation of the end-use performance (tank-to-wheel [TTW]) was conducted, and then the data were combined with the WTT data from the Joint Research Centre (JRC) test fuel study (2014) to provide information on the complete fuel cycle (well-to-wheel [WTW]). Figure 1 depicts the results.

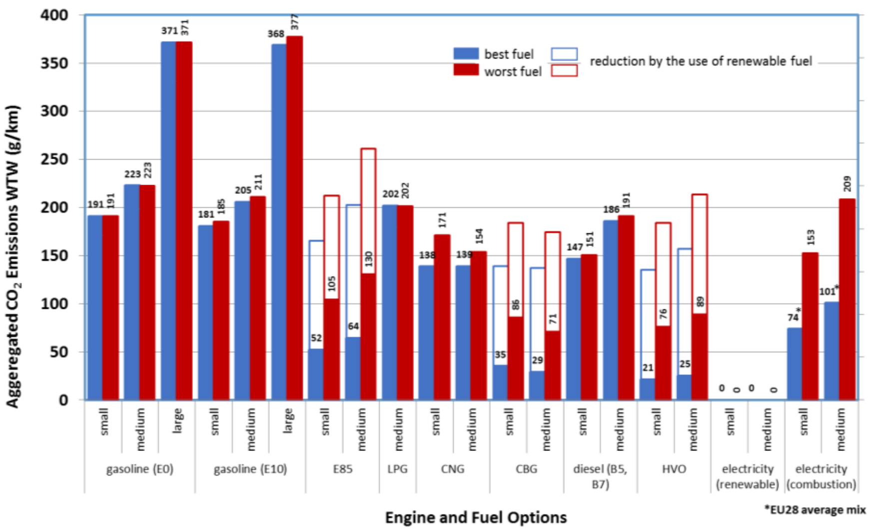

Fig.1 Aggregated WTW CO_2 for the “Best” and “Worst” Fuel Pathways

Key Findings

A high WTW carbon dioxide (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, the internal combustion engine (ICE) remains a viable option. For example, a spark ignition (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. While CI engines have better efficiency, the control of nitrogen oxides (NO_x) 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.

Main Conclusions

In the overall synthesis, the electric drive proved to be the best option. It was still better than any fossil fuel ICE option, even when the electricity was assumed to contain the European Union (EU)28 average carbon footprint. The best ICE engine option was a CI engine using a fully renewable HVO-type of fuel, followed by an SI engine on bio-methane, as a close contender. The lowest combined score was attributed to SI/gasoline and SI/liquefied petroleum gas (LPG). Fuels with high amounts of renewable contents help to reduce WTW CO_2 emissions significantly. Furthermore, the 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, future assessment is highly advisable.

Publications

Nuottimäki, J., J. Laurikko, and N.-O. Nylund, 2014, “Performance Evaluation of Passenger Car, Fuel and Powerplant Options,” Paper F2014-CET-040, published in *Proceedings of 2014 FISITA World Automotive Congress*, Maastricht, Belgium, June.

Laurikko, J. (ed.), 2016, *Performance Evaluation of Passenger Car, Fuel and Powerplant Options*, Research Report VTT-R-00892-16.