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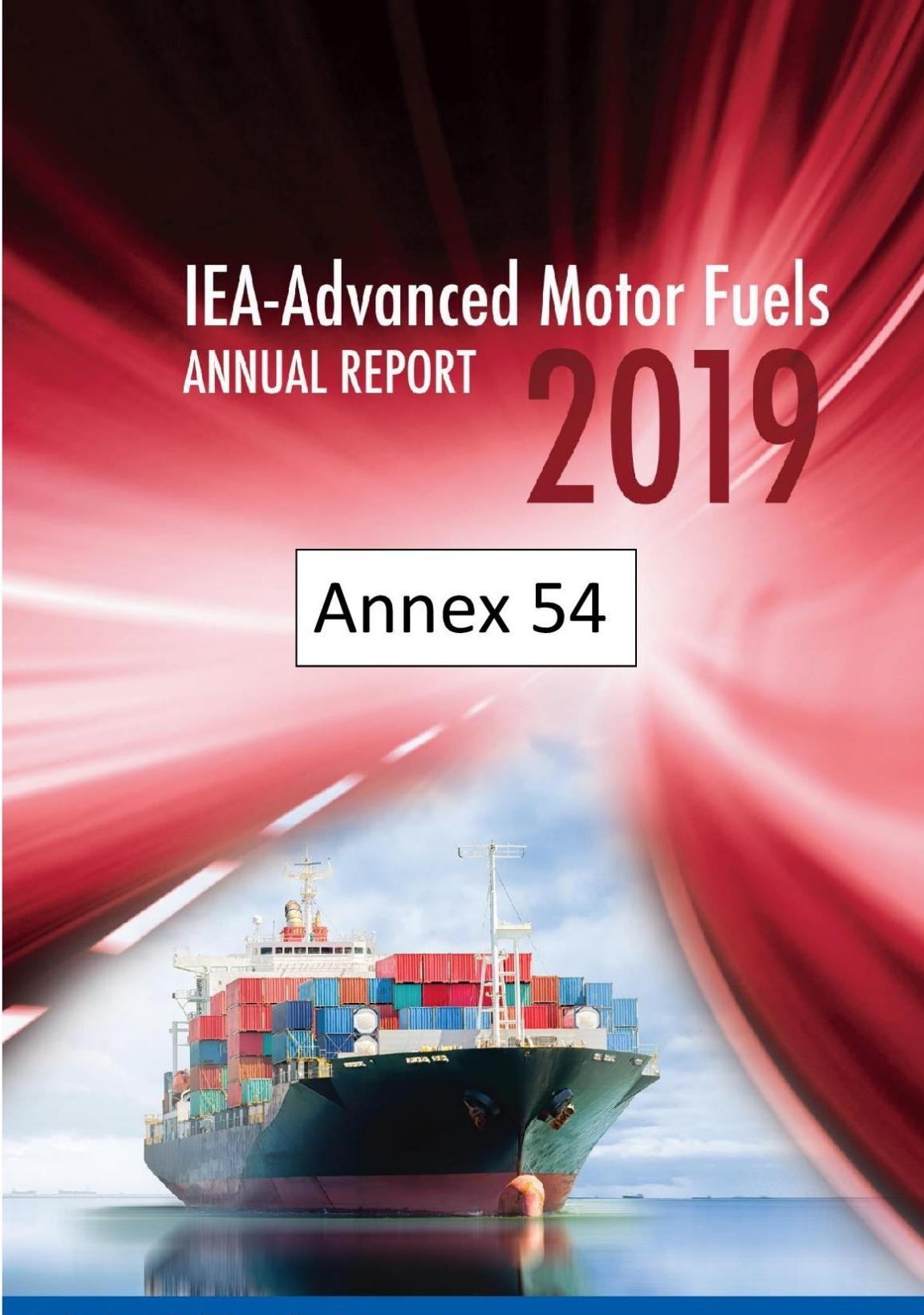
Annex 54



Technology Collaboration Programme
by IEA

Annex 54: Gasoline Direct Injection Engines and Alcohol Fuels

Project Duration	April 2016 - April 2019
Participants **Task Sharing** **Cost Sharing**	 Canada, Germany, Israel, Switzerland, United States No cost sharing
Total Budget	~€350,000 (~$400,000 US)
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Purpose, Objectives, and Key Questions

Under certain conditions, gasoline direct injection (GDI) may increase particle emissions in comparison to port fuel injection (PFI) engine technologies. Both gasoline particulate filters (GPFs) and alcohol fuel blends, such as E85, have shown the potential to reduce particulate matter (PM) emissions from GDI vehicles.

The objective of Annex 54 was to determine the impacts of alcohol fuels on emissions from GDI engines. In addition to information on combustion processes, the annex focused on gaseous and PM emissions, along with the potential for secondary organic aerosol (SOA) and genotoxic formation. The fuels investigated included ethanol blends (E10 to E85, and E100), methanol blends (M56), and butanol blends. The impact of GPFs and start-stop operation on emissions from GDI vehicles was also investigated.

Activities

Experiments were carried out at the Emissions Research and Measurement Section of Environment and Climate Change Canada.[1] Two light-duty vehicles—one GDI, with and without GPF, and one PFI—were tested on a chassis dynamometer with low-level ethanol blends at 25°C and −7°C.

[1] Araji, F. and Stokes, J., "Evaluation of Emissions from Light Duty Trucks with and without the Use of a Gasoline Particulate Filter," SAE Technical Paper 2019-01-0971, 2019.

Studies conducted at the Institute of Engineering Thermodynamics (LTT) Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) in Germany provided fundamental investigations of mixture formation and soot formation in an optically accessible GDI engine using laser-based diagnostics. Further characterizations of PM were conducted in the exhaust gas duct of a metal GDI engine. E20, E85 fuel blends and other model fuel mixtures (iso-octane and toluene) and butanol mixtures (Bu20) were studied.

Research conducted under an Israeli-European cooperation between the Technion–Israel Institute of Technology and the Joint Research Centre of the European Commission (JRC) was commissioned by the Ministry of Energy, State of Israel. Emissions tests were conducted with three vehicles, two GDI and one PFI, fueled with gasoline, methanol (M56), and E85.

Switzerland's contribution was provided by the following organizations: Paul Scherrer Institute; University of Applied Sciences Northwestern Switzerland; University of Applied Sciences Bern; and Swiss Federal Laboratories for Materials Science & Technology (Empa).

GDI vehicles, some equipped with GPFs, were tested with ethanol blends (E0, E10, E85) and butanol blends (E10/Bu15 and Bu30). Testing in a smog chamber allowed for a comparison of PM and the genotoxic potential and the SOA formation potential of GDI and diesel vehicles.[2,3]

Through the U.S. Department of Energy's Oak Ridge National Laboratory, a light-duty vehicle equipped with a GDI engine and start-stop operation was tested. Three fuels were evaluated: E0, E21, and iso-butanol (iBu12).[4]

Although Chile was not formally a participant in this annex, relevant findings from studies led by the Centro Mario Molina (CMMCh) were included as supporting information.[5]

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[2] EmGasCars, Research of Nanoparticles and of Non-Legislated Emissions from GDI Cars in the Primary Emissions and Secondary Gas and Particle Formation from Vehicles Using Bioethanol Mixtures.

[3] Comte, P., et al., "GASOMEP: Current Status and New Concepts of Gasoline Vehicle Emission Control for Organic, Metallic and Particulate Non-Legislative Pollutants," Final Scientific Report of the CCEM-Mobility Project 807.

[4] Storey, J., et al., "Characterization of GDI PM during Vehicle Start-Stop Operation," SAE Technical Paper 2019-01-0050, 2019, https://doi.org/10.4271/2019-01-0050.

[5] Gramsch, E., et al., 2018, "Variability in the Primary Emissions and Secondary Gas and Particle Formation from Vehicles Using Bioethanol Mixtures," *Journal of the Air & Waste Management Association*, 68:4, 329-346, DOI: 10.1080/10962247.2017.1386600.

Key Findings

- Alcohol fuel blends had generally beneficial effects on both gaseous and PM tailpipe emissions of GDI vehicles.
- The GDI engines equipped with GPFs were effective in reducing PM and particle number (PN) emissions. Some of these results showed PN emissions that could meet the European regulatory limit of 6.0 X 10E11 particles/km.
- A smog chamber study suggested that the rate of secondary pollutant formation in the atmosphere would be slower from GDI vehicles using alcohol blended fuels, thus representing a positive impact on air quality.
- Using the toxicity equivalents approach for eight polycyclic aromatic hydrocarbon (PAH) compounds, the genotoxic potential of the emissions from select GDI vehicles were observed to be higher than a diesel vehicle equipped with a particle filter. It is suggested that catalysed GPFs would reduce the genotoxic potential to that of diesel vehicles.
- The effects of start-stop operation on one GDI vehicle with gasoline alcohol blends were minor and suggested that additional stops and starts after catalyst heat-up would not add significantly to emissions.
- Observations from an optically accessible single cylinder GDI engine showed that soot is formed in fuel rich regions with incomplete evaporation of fuel droplets remaining from the injection event.

Main Conclusions

Ethanol is the most widely used biofuel around the globe. In addition to reducing greenhouse gas emissions, ethanol, generally has beneficial effects on both gaseous and PM tailpipe emissions. Fuel-efficient GDI engines tend to have high PM emissions compared to diesel engines equipped with diesel particulate filters, however, both the use of ethanol as a blending component and GPFs can alleviate this issue. This annex contributed to the understanding of particle formation in GDI engines as well as mitigation.

Publications

Rosenblatt, D., Karman, D. “GDI Engines and Alcohol Fuel.” Annex 54 – A Report from the Advanced Motor Fuels Technology Collaboration Programme,” Annex 54 Final Report, March 2019.