IEA AMF Task 57 HDV Performance Evaluation

IEA AMF Webinar 21.10.201
### IEA AMF Task Main Info

| Task Number and Title | Task 57  
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<tbody>
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<td><strong>HDV Performance Evaluation</strong></td>
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<tr>
<td>Operating Agent (institution)</td>
<td>VTT LTD Finland</td>
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<tr>
<td>Start and End Date</td>
<td>October 2018 - May 2021</td>
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<tr>
<td>Participants</td>
<td>Canada, Chile, Finland, Japan, Republic of Korea, Sweden</td>
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<td>Task Sharing</td>
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<td>Cost Sharing</td>
<td>Japan and Sweden</td>
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<tr>
<td>Total Budget</td>
<td><del>€610,000 (</del>$671,000 US)</td>
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| Project Leader (name and email) | Petri Söderena  
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IEA AMF Task 57 HDV Performance Evaluation

Objective and key questions

• Provide information for political decision making, OEM’s, transport sector and NOG’s by investigating the current performance of HDV’s on laboratory and on-road and future pathways (fuels and technology) for ICE powered vehicles to achieve ever more stringent climate and air quality targets

• The overall activity covers three time dimensions:
  • Legacy vehicles and a reference backwards through completed AMF Annexes (Annex 37: buses and 49: HDV’s)
  • Current performance of the best-available-technology HDVs using conventional and alternative fuels
  • Joint activity with Hybrid Electric Vehicle (HEV) TCP to bring an insight how different HDV’s powertrain and fuel (fossil and renewable) options perform against the CO₂ emission regulations in 2025 and 2030 perspective
IEA AMF Task 57 HDV Performance Evaluation

Project content

- Testing on chassis dynamometer
  - Canada, Chile, Finland and Sweden
- Testing with PEMS in on-road conditions
  - Canada, Finland and Sweden
- One year continuous on-road NOx concentration monitoring
  - Finland
- HD vehicle simulation
  - Description of Heavy-duty vehicle Emission Simulator (HES) in Korea
  - Modelling and simulation of High Capacity Transport vehicles in Finland
- Future projection with HEV TCP for energy consumption and CO2 emission analysis in WTW and WTT basis for typical long-haul operation

The original project plan constituted of nine work packs listed below:

- WP 0: Collection and consolidation of existing data
- WP 1: Agreement on common test procedures and protocols
- WP 2: Vehicle chassis dynamometer testing
  - Contemporary diesel vehicles as well as alternative fuel vehicles in different vehicle categories
- WP 3: Vehicle on-road testing with PEMS
  - Contemporary diesel vehicles as well as alternative fuel vehicles in different vehicle categories
- WP 4: Vehicle on-road NOx concentration monitoring
  - Contemporary diesel vehicles as well as alternative fuel vehicles
  - NOx concentration monitoring during normal operation
- WP 5: HD vehicle simulation
  - Description of a simulation model developed in Korea
  - Simulation model for high capacity transport vehicles fuel consumption analysis
- WP 6: Aggregated test results
  - Analysis and comparison of chassis dynamometer and on-road test results generated within the Annex
- WP 7: Future projections of heavy-duty vehicle performance
  - Aggregating available data from similar studies such as US Super Truck programs and European counterparts
  - Cooperation with HEV TCP for future projection of heavy-duty vehicle CO2 emissions and energy consumption
  - Mirroring of performance against legislative targets
- WP 8: Co-ordination of the project, synthesis and reporting
  - Administrative co-ordination, communication with the IEA AMF ExCo, synthesis of data, compilation of the Final Report and dissemination of the results
IEA AMF Task 57 HDV Performance Evaluation

Project methods

• Common testing procedure and protocol
  • On chassis dynamometer: WHVC* imitating WHTC** testing procedure i.e. cold start cycle following hot start cycle
  • On-road PEMS testing: Following Euro VI ISC*** requirement
  • Targeting half of the maximum payload
  • Typical regional fuels i.e. EN590 diesel, ULSD and Chile diesel

• Additional testing based on participants
  • Chassis dynamometer testing
  • On-road PEMS testing
  • For example: different fuel blends and test cycles

*World Harmonized Vehicle Cycle, **World Harmonized Transient Cycle used in Euro VI engines type approval, *** Euro VI HDV’s In-service conformity
### IEA AMF Task 57 HDV Performance Evaluation

#### Project testing activities

<table>
<thead>
<tr>
<th>Country</th>
<th>Tested vehicles</th>
<th>Emission class</th>
<th>Chassis</th>
<th>Engine</th>
<th>Tested fuels</th>
<th>CD</th>
<th>PEMS</th>
<th>Other testing</th>
<th>On-road</th>
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<tbody>
<tr>
<td>Canada</td>
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<td>EPA 2010</td>
<td>Rigid 4x2</td>
<td>6.7L CI 7.7L CI</td>
<td>ULSD B20</td>
<td>WHVC</td>
<td>ISC</td>
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<td>Finland</td>
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<td>Tractor 4x2 Tractor 6x2 Tractor 4x2 Tractor 4x2 Rig 6x2 Tractor 4x2 Rig 6x2 Rig 6x2</td>
<td>13L SI 13L SI 13L CI 13L CI HPDI 13L CI 11L CI 13L CI 13L CI HPDI</td>
<td>CNG, CNG** LNG EN590, HVO*** LNG&amp;EN590 ED95 EN590, HVO*** EN590 LNG&amp;EN590</td>
<td>All trucks WHVC HDVPerE All trucks ISC HDVPerE All trucks WHVC HDVPerE 44 ton</td>
<td>NOx monitoring NOx monitoring NOx monitoring</td>
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<td>All trucks WHVC All trucks ISC</td>
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*Commercial diesel in Chile, **Low methane number gas (MN approx. 77), ***EN15940 HVO
Aggregated results
Aggregated results - WHVC

Energy consumption

• In energy consumption (EC) wise vehicle GVW is the most effective factor – increased GVW reduces specific EC
• For the EC the combustion process has second highest effect
  • Compression ignition engines in general have lower energy consumption
    • Diesel and ED95 engines have similar efficiency
    • HDPI-LNG engine has slightly lower efficiency compared to diesel, roughly 4 to 7 % higher
• SI-LNG/CNG engines have some 15 to 30 % higher EC compared to diesel
Aggregated results - WHVC

CO2 emissions

- Similarly as with EC the most dominant factor in CO2 emissions is the vehicle GVW – increase in GVW reduces CO2 emissions
- New methane fueled engines utilize the favorable carbon intensity of methane. Advantage over diesel in CO2 emissions
  - HPDI-LNG engines offer in the best case around 20 % lower CO2 emissions
  - SI-LNG/CNG engines deliver a reduction from -6% to +3% compared to diesel, depending on the vehicle, driving cycle and load
- ED95 engine produces roughly similar CO2 emissions as diesel
- High CO2,eqv emissions are observed with some SRC technologies due to high N2O emissions
Aggregated results - WHVC

NOx and PM emissions

- NOx emissions depend on the specific technology in each vehicle
  - However, new compression ignition engines (diesel and HPDI-LNG) with SRC are capable close to zero NOx emissions (around 1 mg/kWh)

- PM emissions are low with all Euro VI and EPA 2010 vehicles
  - Euro VI SI-methane, HPDI-LNG, ED95 and diesel
  - EPA 2010 diesel

- Chile 2015 emission regulation based on Euro V
Aggregated results – On-road
Energy consumption, CO2 and NOx emissions

• It should be noted that on-road testing is more pass or fail type testing method and accurate comparison is rather difficult as driving conditions may not be the same (route, traffic, loading, weather)

• In general, energy consumption wise similar trends as in chassis dynamometer
  • Higher GVW has the highest effect on specific EC
  • Trucks with compression ignition engines have lower energy consumption
    • Diesels lower than HPDI-LNG
  • NOx emissions spread over wide spectrum with all powertrains
    • However, emission values below the limit value
Aggregated results – WHVC

Comparison against the previous study

• In IEA AMF Annex 49 ”COMVEC” performed in 2014-2016 Euro VI and EPA 2010 diesel and Euro VI CNG trucks with various test mass was measured on chassis dyno

• Results of diesel trucks suggest that there has been clear improvement in energy consumption from Euro IV to Euro VI
  • At the same time pollutant emissions are reduced remarkably

• Results within Euro VI class (pre vs. post MY2016 trucks) suggest that there is no noticeable improvement taken place
HCT simulation
HCT simulation

- With each studied vehicle combination increase in GVW reduces the specific CO2 emissions
- The calculated fuel consumption and work data indicate average efficiency of about 46% at the engine level in this specific driving route between Helsinki to Oulu (around 600 km)
Future projection with HEV TCP for energy consumption and CO2 emission – WTW and WTT analyzes
Future projection with HEV TCP

WTW and WTT analyzes

• Based on CD results of AMF Task 57 and simulations of HEV TCP
  • The WTT data needed for this stems from the newest version of the JEC Well-to-Tank report v5
• Energy consumption and CO2 emissions were analyzed both on TTW (end-use or tailpipe) and WTW (overall impact) basis
  • Estimations and demonstrations from US Super Truck II* and H2020 LONGRUN** programs were used for estimating the future ICE efficiency

* US Super Truck II
** LONGRUN
Future projection with HEV TCP
WTW and WTT analyzes
Summary and key message
Summary and key message

• Heavy-duty truck engines operating with diesel process (i.e. compression ignition and diffusion combustion) have a clear advantage in efficiency compared to powertrains with spark-ignition engines
  • Up to - 17 % ... - 25 % less consumed energy vs. SI-engines depending on the average loading of the cycle/mission – the higher the loading the lower difference

• New engine options, dual-fuel LNG-diesel and ED95 ethanol, provide interesting options for the future
  • Dual-fuel LNG-diesel powertrain can provides close to 20 % less CO₂ tailpipe emissions compared to diesel
  • ED95 ethanol powertrain provides similar efficiency and CO₂ emissions compared to diesel

• In tailpipe CO₂ emissions SI-methane HDV engines provide slightly lower to slightly higher emissions depending on the engine loading in the specific cycle/mission
  • - 6 %...+3 % vs diesel in chassis dynamometer and even up to 8 % lower emissions in the measured on-road routes
Summary and key message

• Regarding local emissions, all the powertrain options are capable of low emissions
  • Powertrains equipped with SCR are capable of ultra low NO\textsubscript{x} emissions in hot operation conditions, even as low as 1 mg/kWh on powertrain basis
  • Engines equipped with particulate filter are capable on PN and PM emissions clearly under the emission limit values
  • In best case, SI-methane engines without particulate filter are also capable on PN and PM emissions under the limit value
    • Other SI-methane truck measured gave PN emissions under and another clearly over the limit value

• N\textsubscript{2}O emissions in CO\textsubscript{2} equivalence basis can be relative high in engines equipped with SCR – adding up to 7 % (Euro VI D) compared to CO\textsubscript{2} emissions
  • Not dependent on the fuel, but the chemistry used in the SCR and the exhaust gas temperature

• CH\textsubscript{4} tailpipe emissions are not a problem for the new generation methane powertrains, spark-ignited and direct injection dual-fuel
  • Adds less than 1 % to CO\textsubscript{2} equivalence basis compared to CO\textsubscript{2} emissions
Summary and key message

• HDV CO₂ 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 dedicated 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
  • Moreover, neglecting tools that are already available hinder remarkably successful achievement of the GHG targets

• Based on the simulations within Annex 57 increasing gross vehicle weight rating (GVWR) from some 60 up to 90 tons could reduce CO₂ emissions per ton-kilometre of cargo by up to 40%
  • Thus, HCT offers an effective way for reducing specific energy consumption and CO₂ emissions
Thank you for attention!