“Trends and insight in heavy-duty vehicle electrification”

Results of the IEA-IA-HEV Annex XII on “Heavy-duty hybrid vehicles”

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Operating Agent IEA-IA-HEV Annex XII
Outline

» Introduction IEA-IA-HEV: Annex XII - Heavy-duty Hybrid Vehicles

» Classification of heavy-duty vehicles

» Driving forces for electrification of heavy-duty vehicles

» Benefits & Barriers for electrification of heavy-duty vehicles

» Some conclusions
**Mission**: As independent and customer-oriented research organization, VITO (± 600 employees) provides innovative technological solutions as well as scientifically based advice and support in order to stimulate sustainable development and reinforce the economic and social fabric of Flanders.

**Active in Sustainable Technologies in the field of**:

- **Energy**
  - Smart grids & integration of (PH)EV’s
  - Batteries & ultracapacitors
- **Environment**
- **Materials**
- **Remote sensing**

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More information: [bluways.com](http://bluways.com)
IEA–IA–Hybrid & Electric Vehicles

» International Energy Agency (IEA) : www.iea.org

» Implementing Agreement (IA) : Hybrid & Electric Vehicles (HEV)
  » Information source on hybrid & electric vehicles
  » More information : www.ieahev.org (newsletter, ...)

» Some running IA-HEV Annexes (task groups) 1994 - today :
  » Annex I: Information Exchange
  » Annex X: Electrochemical Systems
  » Annex XI: Electric Cycles
  » Annex XII: Heavy-Duty Hybrid Vehicles
  » Annex XIII: Fuel Cells Vehicles
  » Annex XIV: Market deployment of Evs & HEVs : “Lessons Learned”
  » Annex XV: Plug-in Hybrid Electric Vehicles, …
IEA–IA–HEV : Annex XII : Heavy-Duty Hybrid Vehicles

» Objective
  » Report the current status of the heavy-duty hybrid vehicles “playing field”. Besides a general description of the current heavy-duty hybrid vehicle situation, the status report will also focus on emerging hybrid vehicle technologies and market trends.

» Activities
  » Collect and organize information on heavy-duty hybrid vehicles technologies and market potential
  » Share and disseminate knowledge in participating countries

» Period : from 01/01/2007 until 30/11/2010

» 6 Participating countries : Belgium (VITO), Canada (NRCan), Finland (Aalto University), Switzerland (HESS), The Netherlands (Agency NL), United States (NREL)

» Website Annex XII: http://ieahev.vito.be
» Operating Agent : VITO (BE), contact : carlo.mol@vito.be
IEA–IA–HEV : Annex XII : Heavy-Duty Hybrid Vehicles

» Structure of Annex XII
  » Subtask I: Heavy-Duty Hybrid Vehicle Technologies
    » Technology oriented subtask
    » Study on components, systems and configurations
  » Subtask II: Heavy-Duty Hybrid Vehicle Market Situation, Trends and Potential
    » Market oriented subtask
    » Study on market potential in different applications: costs vs benefits
  » Subtask III: General Information Gathering and Dissemination
    » Support subtask I and II, write end report
    » Full end report only available for participating countries
    » Dissemination to broader public: website, papers, presentations, …

HEV (hybrid) (electric & hydraulic)
PHEV (plug-in hybrid)
EV (all electric)
Classification

- Important to setup a classification on heavy-duty vehicles because they all have its own specific requirements, driving cycle and other boundary conditions -> big impact on potential of electrification for vehicles suitable for the application.
<table>
<thead>
<tr>
<th>Main categories</th>
<th>Sub categories</th>
</tr>
</thead>
</table>
| Bus                             | • city  
• regional  
• long distance                                                                  |
| Truck                           | • city distribution/delivery truck  
• regional distribution  
• inter- and national transport                                                   |
| Mobile workmachines             | • Construction, mining, and earth moving: loaders, excavators, dumpers, bulldozers, etc.  
• Agriculture and forestry: tractors and their accessories, harvesters, forwarders, etc.  
• Transportation of goods and material handling: forklifts, straddle carriers, RTGs, terminal tractors, etc.  
• Municipal or janitorial machines: gardening, cleaning, etc. |
Driving forces for electrification

» Economical: fuel cost reduction, ...
» Ecological: reduce global and local impact on the environment
» Technical: performance, comfort, ...
» Legislation: emission standards, ...
» Government: oil independency, strategic energy plans (EU Renewable Energy Directive), ...
Benefits for electrification of heavy-duty vehicles

» In case of “electrification” of powertrain, majority of heavy-duty vehicles are hybrid electric systems, fewer hydraulic systems, PHEV and EV

» Increase energy efficiency and reduce fuel consumption in hybrid system (ICE+EM) through:
  » unloading harsh transient operations from ICE
  » downsizing ICE
  » regenerative braking
  » meeting auxiliary power demand (avoid idling)

» When vehicle is grid-connected (PHEV and EV) further benefits are:
  » Electricity: multiple energy sources possible when charging (oil independency, more renewable energy)
  » Integration in smart grid environment offers new business opportunities (impact on TCO)
  » Reduce Local Impact: zero emission and no noise
Barriers for electrification of heavy-duty vehicles

» Added cost for electrification versus benefits
» Diverse market with a lot of different types of vehicles and applications in smaller production volumes compared to passenger car market
» Reliability of new technology is very important in heavy-duty vehicles ("working horses") – no downtime allowed
» Procurement procedures, …

» Matching the right vehicle with the right application (driving cycle, …) = major challenge

» Choice of the right powertrain has a very big impact, but there are other parameters to take into account for higher energy efficiency
Parameters for optimizing heavy-duty vehicles & Results

» Hybrid and Electric powertrains (fuel savings reported in a broad range from -5% up to -50% depending on application)

» But also technology improvements besides powertrains are crucial for fuel savings:
  » Eco-driving (-8%)
  » Low-friction tires (-3%)
  » Lightweight materials
  » Aerodynamics
    » Platform for Aerodynamic Road Transport (www.part20.eu)
Trends and insight – Hybrid & Electric Trucks

» Market still in prototype / demonstration phase
» Most studies show technological benefits, but data on added cost/benefits ratio difficult to find
» Potential benefits very dependant on application (driving cycles, …)
  » applications with a lot of start/stop cycles -> brake energy recuperation
  » applications with high demand of auxiliary units e.g. garbage trucks
  » urban areas: EV’s local zero emission – no noise - city distribution trucks
Trends and insight – Hybrid & Electric Trucks

» Example: Renault Premium Distribution Hybris

» Test-case in Lyon (FR) as garbage truck

» Test-case at Coca-Cola Belgium as distribution truck

» < 20 km/h – Electric drive

» Up to 20% of fuel saving depending on usage with a potential target up to 30% with the use of an electrical PTO and additional battery to run the refuse compactor

» Power and torque with electrical engine during starting phase

» Idle shutdown

» Energy recovery during slowing down and braking phases

» Positive feedback on driving behaviour
For long-haul trucks: focus of research on ICE optimization (exhaust heat recovery, ...), biofuels, lightweight materials, electrification of auxiliary systems, overall energy management (thermal and electrical) to reduce fuel consumption and CO2 emissions, ...

EU-FP7:
- EE-VERT
- HEATRECAR
- ...

**Analysis of Vehicle Energy Flows (Heavy Duty Example)**

- From the total amount of fuel used (at 100km/h), the energy flows are as follows:

  - Combustion
  - Ancillaries
  - Transmission Loss
  - Roll Resistance
  - Aero Drag

- Fuel Energy Loss
- Exhaust Heat Recovery? Split Cycle? 85%
- Electric & Variable Ancillaries? 5%
- Automated Manual Transmissions? 5%
- Low Resistance & Single Wide Tyres? 10%
- Aero Packs? “Teardrop” Trailers Platooning? 15%

(Under body ~ 1/3)

Source: Risoe analysis
**Trends and insight – Hybrid & Electric Buses**

» Hybrid & Electric Buses on the market:
  » Long distance buses: see long-haul trucks remarks
  » City buses: number of hybrid buses growing worldwide
  » Ex.: New York City Transit bus fleet
    » 12 month period study showed 34% to 40% higher fuel economy over the baseline diesel units operating under similar driving conditions

» Also hybrid versions in articulated city buses

*Figure 7. Orion VII bus with BAE Systems HybriDrive hybrid propulsion system*
Hybrid & Electric Buses on the market: Trolleybuses
  + All electric drive (local zero emission & noise)
  Examples in countries like Switzerland, Germany, Italy, the Netherlands, …
  + Brake energy recuperation in overhead lines (15 to 35%)
  + Dual-mode possible
  + Up to 220 passengers
  - Visual aspect & investment cost
Trends and insight – Mobile Work Machines

» Hybrid & Electric Mobile Work Machines on the market:
  » Separate chapter in paper due to even more diverse market
**Some conclusions**

- Heavy-duty vehicles market is very diverse with very specific applications/drive cycles and this in relative small production numbers

- Matching the right vehicle with the right application = challenge

- Market of heavy-duty hybrid vehicles is still more or less in prototype/demonstration phase, except for some applications (e.g. city buses)

- Technical results (lab- and real life fieldtests) show substantial benefits on e.g. fuel consumption, but not yet enough market data available on the added cost vs benefits (ROI)

- Electrification of heavy-duty vehicles has a lot of potential, but …
Some conclusions

» Further research needed for next generation of heavy-duty hybrid vehicles to get to mass market:
  » European Green Car Initiative (EGCI) & American Recovery and Reinvestment Act (ARRA)
  » EU FP7 - Hybrid Commercial Vehicle (HCV), USA - 21st Century Truck Program, Super Truck Class 8 Trucks, …

» Information dissemination is crucial:
  » IEA-IA-HEV : Annex XII - Heavy-duty Hybrid Vehicles (International)
    » www.ieahev.org & http://ieahev.vito.be
  » Hybrid User Forum (Europe)
    » http://wp1173759.wp202.webpack.hosteurope.de/www/wordpress2/
  » Hybrid Truck Users Forum (USA)
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BESWA - Lentedag 19 mei 2011
Trends and insight in heavy-duty vehicle electrification
Demonstration has been reinforced with more vehicles: 3 12 m buses, 3 18 m buses and 3 small buses to be operated in various cities in enlarged Europe. In terms of trucks it is expected to have 3 trucks of about 12 tons and at least 3 delivery vehicles (about 6 tons) to be tested/demonstrated in various locations with different topographical and climate conditions.

Many different hybrid vehicles will be developed and tested by:
- Volvo, IVECO, Altra, DAF, Solaris, …

Advanced second generation hybrid electric powertrain vehicles:
- Development of high-efficient hybrid systems/components for mass market introduction
- Cost reduction of 40%
- Fuel consumption reduction of 30%
HCV – Hybrid Commercial Vehicles

HCV Demonstrators

1. Volvo, Sweden, Gothenburg, CityBus
2. Volvo, Sweden, Gothenburg, CityBus
3. Volvo, Holland, CityBus
4. IVECO-Altra, Italy, 5 ton, Genoa, Bus
5. IVECO-Altra, Italy, 6 ton, Van/Cab
6. IVECO-Altra, Italy, 3.5 ton Turin Van
7. Solaris, Pforzheim, Germany
8. Solaris, Poland, Customer Bus
9. Solaris, Poland, Customer Bus
11. DAF, England, 7.5 ton truck
12. DAF, Holland, 7.5 ton truck
Collaborative effort between U.S. Government & heavy-duty vehicle industry

Top R&D Priorities:
- reliability of the hybrid drive unit
- system cost
- energy storage system reliability & cost
- demonstrated ability to meet 2007 heavy-duty vehicle emissions requirements
- a target 60% improvement in fuel economy when compared with that of today’s conventional non-hybridized heavy-duty vehicles.

http://www1.eere.energy.gov/vehiclesandfuels/about/partnerships/21centurytruck/
ARRA – Hybrid & Electric Trucks

» American Recovery and Reinvestment Act (ARRA)
» 48 projects ($2.4 billion USD) in batteries & EVs announced Aug-2009
  » $229 million for battery production (Johnson Controls; supplies Azure Dynamics)
  » $39.2 million to develop & deploy 400 electric vehicle delivery trucks with a 100-mile range (Navistar, Inc.)
  » $10 million to develop and deploy 100 electric vehicle light- and medium-duty trucks and vans (Smith Electric Vehicles)
  » $62.8 million for increasing the capacity to manufacture hybrid systems for the commercial truck market (Allison-Transmission)
  » $89.3 million to expand manufacturing of existing electric drive power electronics components for both passenger and commercial vehicles (Delphi Automotive Systems)
Information Exchange

» IEA-IA-HEV: Annex XII - Heavy-duty Hybrid Vehicles (International)
   » www.ieahev.org & http://ieahev.vito.be

» Hybrid User Forum (Europe)
   » http://wp1173759.wp202.webpack.hosteurope.de/www/wordpress2/
   » a forum which brings together (potential) users of hybrid buses, hybrid trucks and hybrid delivery vehicles with vehicle manufacturers.

» Hybrid Truck Users Forum (USA)
   » HTUF is a national, multi-year, user-driven program to speed the commercialization of medium- and heavy-duty hybrid and high-efficiency technologies. It is operated by CALSTART in partnership with the U.S. Army’s National Automotive Center (NAC), with project support from the Hewlett Foundation and the Department of Energy. HTUF has been very successful in helping launch the first production of hybrid trucks and is credited with cutting up to two years from product development. HTUF has helped create the first markets and is now working to get purchase incentive funding.