Heavy Duty Gas Engines integrated into Vehicles

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Project partners:
1 - AVL - AVL List GmbH - AT
2 - BWR - Borgwarner Ludwigsburg GmbH - DE
3 - BOSCH - Robert Bosch GmbH - DE
4 - DAI - Daimler AG - DE
5 - DINEX - Dinex Ecocat OY - DK
6 - FPT - FPT Industrial S.p.A. - IT
7 - IDIADA - Idiada Automotive Technology S.A.- ES
8 - IVECO - Iveco Espana SL - ES
9 - MAN - MAN Truck & Bus AG - DE
10 - POLIMI - Politecnico di Milano - IT
11 - RCD - Ricardo UK Limited - UK
12 - SAG - SAG Motion GmbH - AT
13 - TNO - Nederlands organisatie voor toegepast natuurwetenschappelijk onderzoek - NL
14 - TUG - Technische Universiteat Graz - AT
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16 - UASE - Hochschule Esslingen - DE
17 - UNR - Uniresearch BV - NL
18 - VOLVO - Volvo Technology AB - SE
19 - VIF - Virtual Vehicle Research Center - AT

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Executive summary

This document is the initial version of the HDGAS Exploitation Plan. It is to a large extent based on the Description of Work of HDGAS. It shall explain the methodology behind the exploitation of project results as well as list exploitable results, etc.

The Exploitation Plan comprises the following elements:
- Initial list of exploitable results from the project, including partner responsible
- Target market and means of exploitation
- Timeline for the exploitation of each result
- IPR protection

The initial Exploitation Plan has been shared with the Executive Board. It will be updated during months 18, 25 and 36. The final version will be published in month 36.
The Exploitation Plan is meant to assure maximum benefit of the HDGAS project results.

Deliverable Approval Process

A deliverable review and approval process has been agreed upon. The reason behind this process is to ensure highest quality of deliverables and independent reviewing and cross-checking of quality deliverables.

The lead participant as identified in Annex I is responsible for technical quality, content and format as well as on time delivery / reporting of expected delays. All deliverables shall be ready in a first draft 30 days prior to the delivery to the EC.

Work Package leaders are responsible for checking the quality of the reporting and whether the report is consist with and “fits” into the Work Package.

Next to this, each and every deliverable will be reviewed by another partner. This process ensures that the deliverable fits with the DoW/project objectives and fulfils expectations of all WPs.

The coordinator (AVL) will ultimately approve all deliverables and Uniresearch makes sure it is delivered on time to the EC.

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1 Introduction

HDGAS aims to develop and demonstrate advanced powertrain concepts for dual-fuel and optimised for pure natural gas operation engines, integration thereof into heavy duty vehicles and proof compliance with Euro VI standards (EU6RDE) and fuel economy targets currently under definition. The targeted Technology Readiness Level is TRL6/7, i.e. system prototype demonstration in operational environment. The HDGAS consortium comprises all key stakeholders needed to develop, demonstrate and market the LNG technology in the medium duty and heavy duty vehicle markets.
The draft plan for the exploitation of the project results (or roadmap towards full implementation in 2020), HDGAS's position in this respect and the subsequent steps are explained in this document.

Since the HDGAS DoW already contains extensive information on exploitable results, including partner responsible, this document (i.e. the DoW) was the starting point for drafting this initial Exploitation Plan.
In addition an excel overview of all results and products has been started. It is work in progress at the moment (April 2016/M12) and all partners will completely update it. Filling and completing this excel file together with all partners will be the core method towards the exploitation of results of HDGAS.

The final Exploitation Plan will draw on this inventory of results filled by all partners. It will be published in month 36.

2 Exploitation strategy

2.1 Exploitation plan and steps needed to bring about the impact

2.1.1 Key project outputs and pillars of the project

HDGAS targets for step-changes in vehicle costs, vehicle performance and vehicle/engine availability. The achievement of these targets will facilitate the deployment of heavy-duty natural gas (NGVs) and dual fuel vehicles (DFVs) and will facilitate investments in infrastructure and the deployment of the LNG/CNG stations as financial and operational risks are lowered and the return on investment and payback times are favorable.

Key HDGAS outputs are summarized in table 1.

Table 1 Specific expected impacts under topic GV-7-2014 and key outputs of the project

Specific impacts	Key outputs of the project (products and services)
Achieve advanced non-hybrid powertrain concepts for heavy duty vehicles (either dual-fuel or optimised for pure natural gas operation) respecting post-2020 emission limits under real driving conditions and during the entire engine lifetime.	Two advanced LNG vehicle fuel systems (D2.5) - a LNG fuel tank with a low pressure fuel feed system - a LNG fuel tank with a high pressure fuel feed system Two types of dual fuel engines - a high pressure direct injection engine (D6.5) - a low pressure port injected engine (D5.4) Two types of natural gas engines (D4.4) - a spark ignition lean burn combustion system - a spark ignition stochiometric combustion system Four new exhaust gas aftertreatment systems will be defined and designed (D3.3) to meet the full range of NG and Dual Fuel engines: - High Pressure Dual Fuel (NO_x, CH4 + PM control) - Low Pressure Dual Fuel (NO_x, CH4 + PM control) - Lean DI NG (CH4 + NO_x control) - Stoichiometric DI NG (CH4 control) The developed powertrains will be: - adequate combinations of dual fuel and natural gas engines with optimised combustion processes, variable compression ratios, advanced engine control, dual fuel operation, optimised fuel injection systems, adaptive systems and sensors to monitor and control different fuel qualities and advanced after-treatment systems suited for different market segments and applications - capable to achieve post-2020 emission limits under real driving conditions and during the entire engine lifetime
Achieve at least 10% lower CO_2-equivalent emissions (i.e. including unburned methane and N_2O) than the best vehicles on the market in 2013 using the same fuel (natural gas for pure methane engines, diesel in the case of dual fuel systems)	Three demonstration vehicles (D4.5, D5.6 and D6.6) will be built based on the developed engines, LNG vehicle fuel systems, other powertrain components and aftertreatment systems. The performance of the demonstration vehicles and underlying powertrain technologies will be validated through: Individual testing by the OEMs Testing by independent bodies (MTC in Sweden, TÜV Süd in Germany and JRC/Ispra in Italy) according to the WHDC test procedures and PEMS approaches (D7.1) Accelerated aging test procedures (see below). All demonstration vehicles need to comply with the Euro VI standards and need to meet the CO_2/km emissions targets currently under definition. Proof fuel economy of the developed engines/vehicles and the compliance with EU6RDE through individual testing and independent testing (D7.1, D7.2)

There are four pillars in the project:

- A group of partners of HDGAS will develop advanced LNG vehicle fuel systems. These partners will experience the improvements made in the fuel system. After each integration and testing into a demonstrator vehicle, they decide between adoption and exploit or, if needed, further improvement. These partners profit from first-hand experience.
- Three engines will be developed - two dual fuel engines and one natural gas engine. The engines will be exploited by each OEM individually, via their own routes to exploitation, or, if necessary, be recommended for further improvements.
- Another group of partners in the consortium will develop the exhaust aftertreatment systems further. Decisions will be taken on a case-by-case basis on whether to turn a new feature into a commercial feature or make further improvements.
- The three HDGAS OEM partners MAN, IVECO and VOLVO, all of which are manufacturers of heavy-duty vehicles will integrate the above mentioned tank system, the three engines and the aftertreatment technologies into demonstration vehicles and together with AVL test them during the project. Independent testing will be done too. The OEMs will disseminate matured results of the tests. The products will make their way into mass manufacturing if successful.

The order of the pillars is also the order in time: implementing commercial features takes some time, and OEMS will only have their vehicles tested by the end of the project.
The academic partners in the consortium will also use the results of the project in enhancing their curriculum. However, the focus in the project will be on the three pillars mentioned above.

The Exploitation plan aims to strengthen and speed up the market uptake of all project outputs by developing an exploitation strategy for all outputs and by supporting the partners involved with further exploitation activities during the different stages of the project.

The main objective of the HDGAS exploitation strategy is to ensure a broad adoption and exploitation of the HDGAS engine and aftertreatment technologies, tank system, standards and demonstrator vehicles.

2.2 Specific exploitation

2.2.1 Exploitation from project point of view

The HDGAS strategy to deliver project innovations to the market is built on the following pillars:

- Provide iterative refinement and maturation of the proposed technology: The work plan consists of several innovation cycles – each of them consisting of the following phases: requirement elicitation, concept phase, technology development and finally an evaluation. This approach enables a focus on industry needs and a successive refinement and maturation of the proposed technology according to the project targets.
- Provide innovations in line with industry (value chain) expectations: The HDGAS consortium provides a complete value chain (distributed over the consortium partners). Project results will provide the opportunity for the partners to identify the respective needs and support integration of the proposed technology into their core business.
- Provide innovations in line with and integrated into existing technology available in the market: The HDGAS consortium comprises technology and tool providers for key technologies (e.g., SAG, BWR, BOSCH, and AVL). These partners will reinforce the proposed technology with respect to feasibility and will integrate the most promising results into their technology portfolio and commercial products.

2.2.2 Exploitation from partner point of view

The HDGAS consortium is a broad consortium in which all key stakeholders are represented, such as developers/manufacturers of key components (engines, LNG tanks, fuel feeding systems and aftertreatment systems), system integrators and all European OEMs with NG and DF vehicles in their portfolio. In table 2 an overview of the new knowledge, expected major exploitable results (= innovations) and credible path(s) to deliver the innovations to the market (= routes to exploitation) are presented.

Table 2 shows the cooperation within the consortium, the integration of new knowledge and the commitment to deliver these innovations to the markets. The HDGAS project has great potential to contribute to the innovation capacity in the emerging/developing LNG vehicle sector and to strengthen the competitiveness and growth of the (involved) companies in this sector. The lowering of the vehicle costs will increase the deployment of heavy-duty natural gas (NGVs) and dual fuel vehicles (DFVs). The standardization of the refueling and tank system will allow full compatibility of vehicles and infrastructure and will increase both the number of vehicles and the deployment of infrastructure.

Table 2 New knowledge, expected major project results (innovations) and individual route(s) to exploitation

Partner	New knowledge and expected major project results	Route to exploitation (R2E)
SAG based on specs / standards of the OEMS	**New generation LNG fuel tanks** (TRL6/7) with improved thermal insulation, optimised new pressure handling systems (low and high pressure) that meet future truck engines demands and the technical requirements (e.g. pressure level, volume, weight, interfaces) and (safety) standards for application in heavy duty vehicles (trucks and buses)	PCT patents on IP or Proprietary knowhow R2E via joint development projects with OEMs, developing application specific products/solutions R2E through the sales of equipment and fueling systems
FPT, RCD, BWR, IVECO	Advanced stoichiometric and lean burn **direct spark ignition natural gas engines and powertrains (TRL6/7)** suited for heavy duty vehicles that meet improved fuel economy targets and EU6RDE	PCT patents on IP or Proprietary knowhow R2E via joint projects/engineering contracts with OEMs developing application specific products/ solutions and through sales of components, engines and powertrains
VOLVO, AVL, BOSCH	Advanced **high pressure gas injection engine and powertrain (TRL6/7)** suited for heavy duty vehicles that meet fuel economy targets and EU6RDE	PCT patents on IP or Proprietary knowhow R2E via joint projects/engineering contracts with OEMs developing application specific products/ solutions and through sales of components, engines and powertrains
MAN, IDIADA	Advanced low pressure **dual fuel port injected engine and powertrain (TRL6/7)** suited for heavy duty vehicles that meet improved fuel economy targets and EU6RDE	PCT patents on IP or Proprietary knowhow R2E via joint projects/engineering contracts with OEMs developing application specific products/ solutions and through sales of components, engines and powertrains
RCD, DINEX	New generation of **exhaust aftertreatment systems** and low emission technologies (TRL6/7) natural gas and dual fuel engines for medium and heavy duty trucks and buses based on new catalyst compositions and their combinations, also with DPF technology (FSCR)	PCT patents on IP or Proprietary knowhow. R2E via joint development projects with OEMs, developing application specific products/solutions R2E through the sales of EATS and catalysts
POLIMI, UEF	Knowhow of **methane catalysers** and aftertreatment processes for natural gas and dual fuel engines	R2E is that of research centres commercialising expertise and knowhow through consultancy services and third party research contracts
TNO	Knowhow of **accelerated aging procedures** for evaluating, methane catalysers and aftertreatment processes for natural gas and dual fuel engines	R2E is that of a research centre commercialising expertise and knowhow through consultancy services and third party research contracts
TUG,	Knowhow to carry out assessments of the	R2E is that of research centres commercialising

UASE	proposed technology combinations and quantification of their environmental impacts along the entire Tank-to-Wheel chain	expertise and knowhow through consultancy services and third party research contracts
ViF	Knowhow to carry out simulations for fueling process, especially for impact of the vapour collapse on the entire process.	R2E is that of research centres commercialising expertise and knowhow through consultancy services and third party research contracts
DAI, IVECO, MAN, VOLVO	Knowhow to specify and integrate a standardized LNG tank and fueling systems as well as optimized natural gas and dual-fuel engines and powertrains and new generation aftertreatment systems into trucks and buses (TRL6/7)	PCT patents on IP or Proprietary knowhow. R2E through the sales of LNG fuelled trucks and buses via their existing worldwide sales networks, starting in Europe, one of the triad markets

At a certain stage, the deployment of vehicles and infrastructure will strengthen each other, induce more and more collaborative research and development efforts for improved components, products and services, and to achieve further cost efficiencies, attract more and more investments and investors. When the pay-back time of the incremental vehicle cost is close to or less than two years and the network of LNG/CNG stations expands, more and more fleet owners will switch to LNG powered vehicles as the cost of ownership of these vehicles is significantly lower than for diesel powered vehicles.

2.2.3 Market Entry

Market entry is the next step. The participating OEMs are well positioned in the CNG and LNG bus and truck markets. DAI, IVECO and VOLVO are active in the medium duty and heavy duty LNG truck market[1], *i.e.* Daimler Econic LNG (Engine: M906 LAG, 279 hp, EEV), Iveco Stralis LNG (Engine: Iveco Cursor 8, 330 hp, EEV) and Volvo FM MethaneDiesel LNG (Engine: 7 or 13 litre, up to 460 hp, Euro V Diesel). Since the HDGAS consortium comprises all key stakeholders needed to develop and demonstrate the LNG fuel tank, engine and aftertreatment technology and to market in the different vehicle segments, there is a vested interest in bringing the technologies through to series production. The supply/value chain (see figure on the right) is in place. To reach maximum impact, the market drivers need to be in place and each stakeholder of the supply/value chain needs to be satisfied, *i.e.* supply a high number of parts, components and vehicles and earn a reasonable margin. The key market driver for the heavy duty vehicle segments comes directly from Cost of Ownership considerations as the market is cost driven. Fuel costs are responsible for about 30% of total operating costs[2]. Fuel economy is therefore the major cost driver for operators or fleet owners. The introduction of the new LNG long haul trucks will be made in countries with already developed LNG infrastructure as the UK, The Netherlands, Spain and Sweden. Fleet owners with environmental profile and high mileage trucks are the ideal first customers. Initially it is important to create good examples of attractive business cases and satisfied customers. This experience will then be used to extend the technology to a wider range of applications. Broad market introduction requires close collaboration with LNG providers and filling station operators to develop and roll out LNG fueling infrastructure in the Member States and along all major transport corridors in Europe.

Other activities in the market entry phase are: a) further optimizing of LNG components and systems, b) ramp-up of the production capacity to increase volumes and to lower COGS (Cost of Goods Sold), and c) application development amongst others to broaden the LNG vehicle/engine portfolio.

The HDGAS project leads to a breakthrough for the emerging LNG medium and heavy duty truck market. The capability to offer long distance heavy-duty natural gas (NGVs) and dual fuel vehicles (DFVs) complying with EU6RDE emission standards with attractive fuel economy and favourable Cost of Ownership (CoO) will persuade

[1] http://www.ngvaeurope.eu/trucks

[2] Commercial vehicles and CO2, ACEA, European Automobile Manufacturers Association, 2010

fleet owners to shift to LNG powered vehicles. The increase of LNG fueled vehicles is closely related to the increase of the deployment of LNG infrastructure. Based on a positive business case calculation more and more fleet owners will shift part of their fleet to LNG fueled vehicles (snowball effect). All relevant stakeholders (OEMs, energy, producers of reference sites) are needed to plan and start ramp up activities. This could be encouraged by a low taxation policy.

2.3 IPR management and ownership of results

2.3.1 IPR management

Exploitation of the project results also entails supporting activities for IPR protection.

The WP Leaders will play an important role in this step as they coordinate the technical work in the WPs (including contribution to reporting) and are able to identify IPR issues and opportunities. Any issues arising will be discussed in the Executive Board (EB), consisting of the WP leaders. The EB will prepare any IPR issues that should be decided by the General Assembly (GA). The GA is the highest operational body, also for IPR issues.

The Consortium Agreement specifies how intellectual property rights (IPR) are managed in this project. The general rule will be that knowledge will be the property of the participants generating it. The Consortium Agreement specifies the management of intellectual property rights (IPR) in more detail and will include mechanisms for management of IPR issues (see below).

2.4 Knowledge management and protection

In the HDGAS project, valuable knowledge and also (technical) solutions will be developed by various partners. In order to avoid any problems related to IP issues within the consortium, special attention is paid to the specific IP paragraphs in the Consortium Agreement (EUCAR model Horizon 2020). These IP paragraphs in EUCAR Horizon 2020 deal with (joint) ownership and possible transfer of the IP and the access rights for project partners and affiliates. Generally, each partner will own its new IP and other results generated in the project (Results) and, obviously, its existing knowledge and IP (Background). Other partners will get access rights to Results and Background whenever needed for the performance of their tasks in the project or for the use of their own Results. In accordance with the Grant Agreement, all partners have listed their included Background in the Consortium Agreement.

When a certain IP is identified to be attractive for the future business opportunities of the partner(s involved), the necessary steps are taken to protect that IP. Patent application may follow the procedures already in use by the partner(s). The WP leader will be informed at the earliest possible stage and he/she will bring forward the IP protection initiative in the Executive Board. In order to secure the research and business interests of all partners involved, any issue that might arise from the patenting initiative during the project will be dealt with by the General Assembly, which consists of one representative of each partner, chaired by the representative of the Coordinator (the PM). In the case of jointly owned new IP, the procedures for patenting, use and licensing will proceed along the regulations described in the Consortium Agreement. The access rights to be concluded will be in accordance with the Grant Agreement and will assure effective use of each other’s newly-generated results and pre-existing IP in the exploitation phase after the project.

3 Methods and results

This document is the initial Exploitation Plan. It comprises the following elements in table format, taken from the DoW of HDGAS: key outputs of HDGAS (table 1) and an initial list of exploitable results/products from the project, including partner responsible and IPR protection (table 2).

This information is based on the Description of Work (DoW) of HDGAS. Next to the Exploitation Plan the final list of results is being inventorised in an excel file. I will be completely updated by month 18 for all HDGAS exploitable results/products. This will necessitate an exercise in which all HDGAS partners participate. Next to that, the file can give information on e.g. the target market and the means of exploitation for each product, as well as setting out the timeline and the IPR protection. This excel file will be a living document with an official update and presentation plus discussion at M18 (next General Assembly meeting in Munich, Germany).

This initial Exploitation Plan has been shared and discussed with the Executive Board and it has been agreed that the accompanying excel file (living document) will be updated by all partners between M12-18. The Exploitation Plan will thus be updated at months 18, 25, and 36 (M36 = submission of the Exploitation Plan, final version).
This current document comprises the initial version of the Exploitation Plan. The final version will be published in month 36.
The Exploitation Plan is meant to assure maximum benefit of the HDGAS project results.

4 Discussion and Conclusions

N/A

5 Recommendations

N/A

6 Risk Register

N/A

6.1 References

N/A

7 Acknowledgment

The author(s) would like to thank the partners in the project for their valuable comments on previous drafts and for performing the review.

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#	Partner	Partner Full Name
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17	UNR	Uniresearch B.V.
18	VOLVO	Volvo Technology AB
19	ViF	Kompetenzzentrum – Das Virtuelle Fahrzeug, Forschungsgesellschaft mbH

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Appendix List

N/A