TECH DAY 2017
NATURAL GAS TECHNOLOGIES

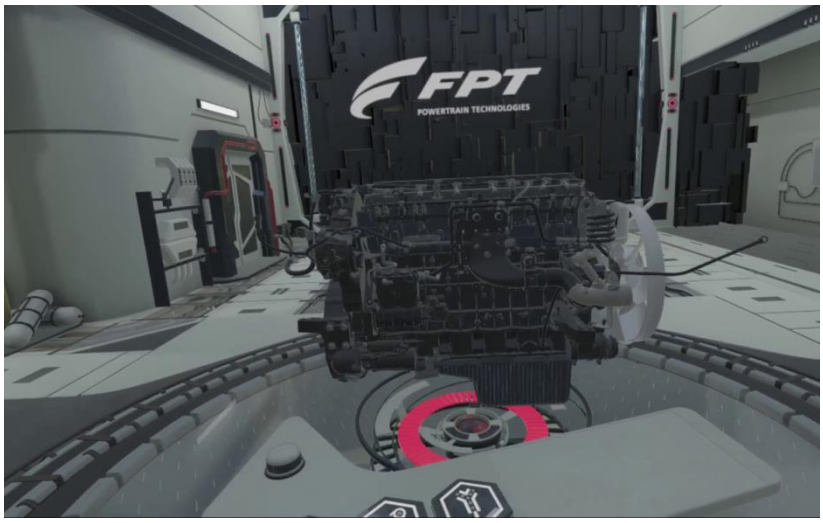
FACT SHEET

FPT TECH CUBE: DISCOVERING TECHNOLOGIES OF THE FUTURE

Turin, October 30, 2017

Throughout its history, FPT Industrial has always put the **greatest effort in the research and development of the best technological applications**. On the occasion of its first Tech Day, FPT Industrial has put together some of its best developments in the Tech Cube, installed at Industrial Village. Beside the **Virtual Reality experience**, visitors can discover **mock-ups and applications** to get a deeper knowledge of FPT Industrial present and future technological challenges and improvements.

Cursor 13 NG Virtual Reality Experience



The experience has been developed to allow users **to discover the new FPT Industrial Cursor 13 Natural Gas engine** in a way not possible through standard multimedia supports. For example, 360-degree view is not only from the outside of the engine, but it is possible also inside of it. At the same time, users can discover the real time operation of the specific NG features, such as the stoichiometric combustion, **injection swirl-angle**, high-temperature resistant materials and the **3-way catalyst**. Thus, the Immersive VR technology will be used by FPT Industrial not only for commercial presentation, but also for **training sessions with customers**.

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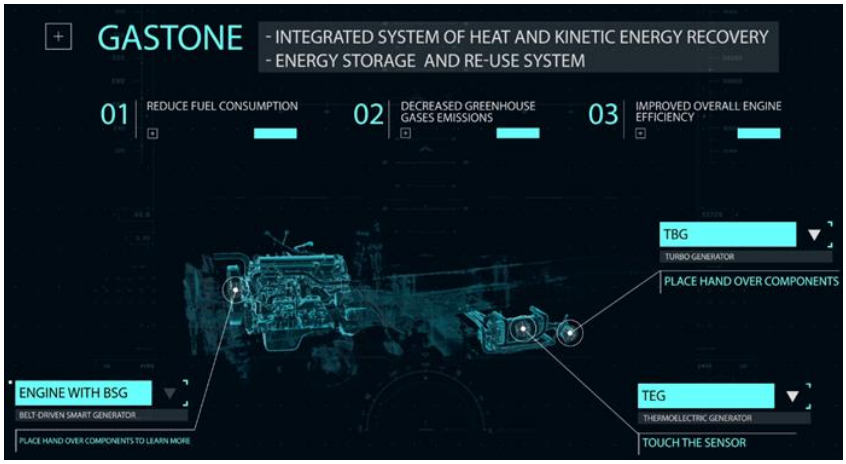
The **immersive Virtual Reality** experience presents an artificial environment that replaces users' real-world surroundings convincingly enough that they are able to suspend disbelief and fully engage with the created environment.

In order to generate a positive user engagement, the experience offers:

- **Continuity of surroundings**: there is the possibility to look around in all directions and have continuity of the environment. The experience is settled in a futuristic R&D testing center;
- **Conformance to human vision**: visual contents are conform to real elements, so that, for example, objects in the distance are sized appropriately to our understanding of their size and distance from us. Motion parallax ensures that the view of objects changes appropriately as our perspective changes;
- **Freedom of movement**: users can move normally within borders of the environment;
- **Physical interaction**: users are able to interact with objects in the virtual environment similarly to the way they do with real life ones;
- **3D audio**: to increase VR immersion the real sound of the engine is emulated and it changes according to users' position.

The hardware which provides the experience is the **HTC Vive**, using the SteamVR software which renders the virtual environment. It also offers a precise, 360-degree controller and headset tracking, realistic graphics, directional audio and HD haptic feedback.

GASTone



FPT Industrial was involved in the last four years in the **GASTone project**, funded by the **European Commission**. The GASTone project is a high efficient energy conversion concept, based on the integration of energy recovery devices, energy storage and engine auxiliaries' electrification on an FPT Industrial **Cursor Natural Gas Euro VI engine** for On-Road vehicles.

The energy recovery strategy was based on two mainstreams:

- **Recovery of kinetic energy**, thanks to the adoption of a Belt-driven Smart Generator (BSG)
- **Recovery of the waste heat** following an energy cascading approach, with a Thermo-Electric Generator (TEG) operating at high temperature and subsequent Turbo Generator (TBG).

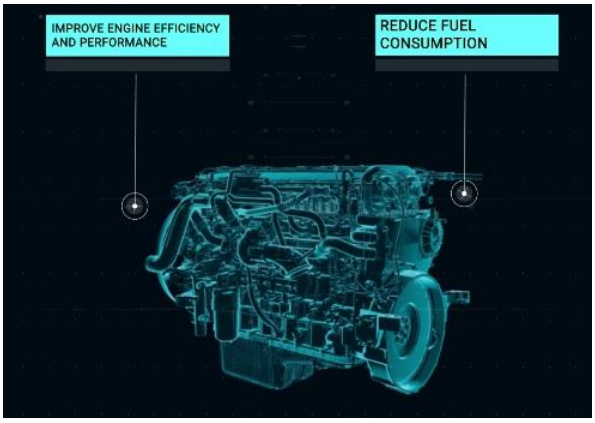
The FPT Industrial Cursor NG Euro VI engine is integrated with:

- TEG downstream the catalyst
- TBG downstream TEG
- BSG, in lieu of current alternator
- DC/DC converter to manage three voltage levels (12V, 24V, 48V)
- Dual Layer Capacitor to store the energy produced
- Water pump and a Low Temp. circuit for correct cooling of the e-devices

Thus, the main tasks of FPT Industrial were the mechanical integration and installation of all proto components on the engine, as well as the control system development for the management of the electronical devices. Furthermore, test bench activities were held in **FPT Industrial R&D facilities**, in order to verify the expected benefits of the new technologies adopted, in terms of fuel consumption, Greenhouse Gas emissions reduction and improved engine efficiency.

Hi-eNG – High efficiency Natural Gas

The aim of the Hi-eNG project is the development of a highly innovative low pressure direct injection, positive-ignition combustion system for the next generation of Heavy Duty Natural Gas engines. The brake **thermal efficiency improvement**, the reduction in Greenhouse Gas emissions, the Torque and rated Power of the Hi-eNG, when compared to baseline engine, all have an **improvement of 10%**.



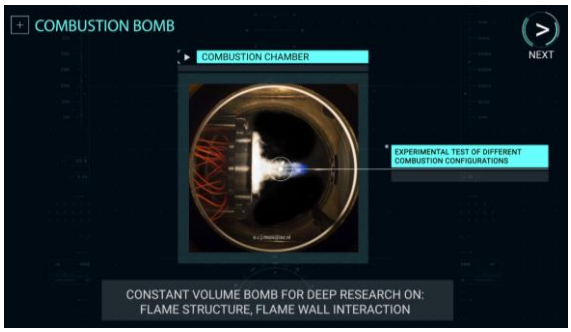
The engine development has been strongly supported by state-of-the-art simulation tools for hardware selection and optimization, as well as by a single cylinder engine for testing and calibration. The engine has a **specific cylinder head** featuring a pentroof combustion chamber with tumble intake ports, and it is designed for optimal positive ignition combustion. The low pressure (up to 50 bar) gaseous fuel direct injection system brings also many advantages, such as an higher specific engine power output and a better and more flexible control of fuel mixture, that takes to an overall pollutant emission reduction during transient operations, contributing significantly to a better fuel economy. The high pressure cooled EGR circuit helps in reducing the throttling losses at part load, while the Variable Valve Timing uses a cam-phaser technology in order to achieve the best phasing conditions and the optimal volumetric efficiency and turbulence level. Finally, the **Corona Ignition** system guarantees optimal **mixture ignition and enables** the adoption of high EGR rates. All these new components are integrated thanks to the FPT Industrial specific control system strategies.

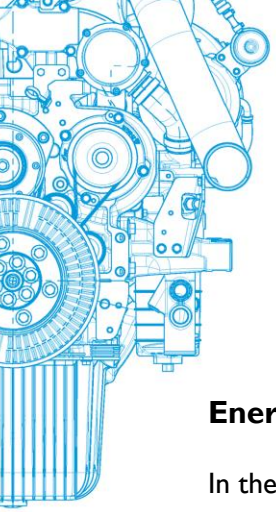
Single Cylinder High Engine Efficiency

FPT Industrial is putting a strong focus on the fundamental research **to achieve the 50% brake thermal efficiency for Diesel engines**. Combustion efficiency, as a major field of improvement, is being tackled by combining highly advanced research tools with virtual simulation and engine tests.

Three main tools for detailed research on the identified fields are utilised to reach the thermal efficiency target:

- **Combustion bomb** for fundamental research and simulation calibration - Constant volume bomb allows for deep research on flame structure and flame wall interaction. Results are used as input to build the next generation combustion simulation model.
- **Combustion simulation** for virtual combustion development - Investigation of different combustion configurations (compression ratio, injection modulation, piston bowl shape) with front loaded simulation activities in order to reduce the number of engine tests.
- **Single cylinder engine for combustion validation** - A single cylinder engine is used for physical combustion validation. Research topics include air handling, fuel injection, combustion and multi-fuels. The modularity of the single cylinder engine allows for quicker variation of combustion relevant components.





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Energy Management

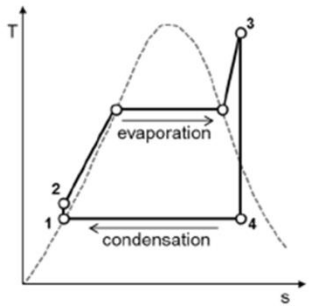
In the transport sector, the reduction of Real Driving Emissions and fuel consumption of heavy duty on-road haulage is one of the main challenges. Fuel efficiency and emissions reduction interact with each other and vary with the specific vehicle application and operating conditions. The challenge is, therefore, to **develop new strategies for flexible engine and emissions control** capable to interact with the vehicle systems, for each application and mission, in order to maximize the potential efficiency of the individual sub-systems.

The main objective of such **Energy Management project** is to achieve fluids consumption reduction (diesel and urea), whilst keeping the vehicle within the legal limits for pollutant emissions. The approach relies on three stages targeting the improvement of the control strategy:

a) **direct optimization of the control of the main components** (engine, exhaust after-treatment, transmission, waste heat recovery, e-drive) to maximize their performances;
b) **integrated powertrain energy manager** to coordinate the different energy sources and optimize their use depending on the current driving situations;
c) providing a **more comprehensive understanding** of the mission (GPS predictive, mission-based learning), so that the different energy sources can be planned and optimized on a long term.

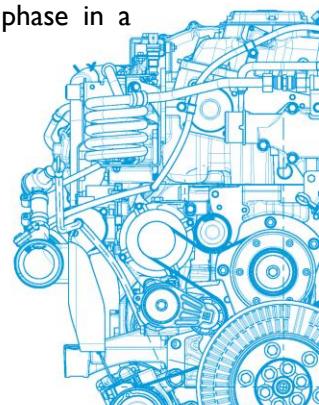
Waste Heat Recovery System

FPT Industrial collaborated into the development of a Waste Heat Recovery system, applied to an Iveco Stralis. The system, together with the vehicle, was put under **several experimental tests** in order to **optimize both the components and the performance**. The hardware and the FPT Industrial's control system were designed together with the target to decrease the complexity and improve the system modularity, while using a safety approach that led to a better confidence in roads' measurements. First results on the IVECO Stralis Euro VI truck indicate a **fuel economy gain from 2.6% to 3%**, depending on tested mission profiles.



The Waste Heat Recovery is a version of the **Rankine cycle**, familiar from steam power plants. A working medium passes through several changes of state in a closed circuit in order to convert heat energy into mechanical energy in a thermodynamic process. Starting at state **1**, the pressure of the initially liquid medium is increased adiabatically by a pump. It is then heated, evaporated, and superheated in an evaporator (**2** to **3**).

The now gaseous medium is fed into an expansion machine in which it is adiabatically expanded (**3** to **4**), which results in mechanical work. It is then condensed back into the liquid phase in a condenser (**4** to **1**), thus closing the loop.



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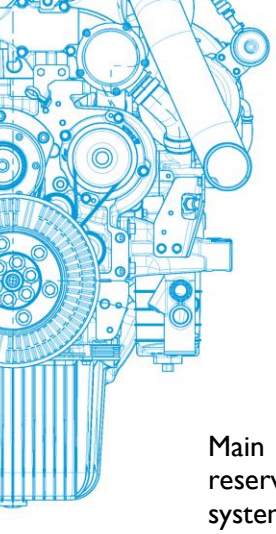

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Main components like exhaust evaporator, exhaust by-pass valve, high pressure feed pump and reservoir tank are located in a compact box placed directly after the exhaust after-treatment system, depending on customer needs.

Waste Heat Recovery for Commercial Vehicles main features

- Engine: Cursor 11, 476 hp, Euro VI
- Vehicle: IVECO Stralis Hi-Way
- Closed Organic Rankine Cycle (ORC) system
- Mechanical energy recovery
- Expander type: Axial Piston
- Heat source: Exhaust Heat
- System pressure: less than 40 bar
- Adapted vehicle cooling system
- Optimized for highest performance during real work operation

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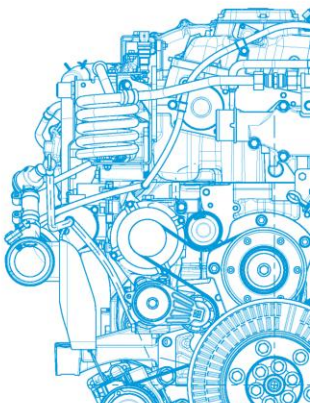

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