Results from the automotive use case being implemented in InComEss

On vehicles equipped with an internal combustion engine, around 70-75% of the fuel chemical energy is lost as waste heat and around half of it is wasted in the exhaust system. Recovering even a small amount of this huge power can have a valuable impact on vehicle's energy management. In particular the exhaust system runs along the entire car length, so it is suitable to create a distributed energy generation/harvesting to power-supply and monitor different sensors or small actuators along the vehicle. Thermoelectric modules (TEMs) that, exploiting the Seebeck effect, directly convert thermal to electrical energy, are the suitable candidate for the application, being compact and robust. The advantages are in terms of vehicle energy management, but also, and mainly, in cabling reduction and layout simplification.

For the automotive demonstrator a thermoelectric generator (TEG) is directly applied on the external skin of a Jeep Renegade rear muffler (see fig.1).

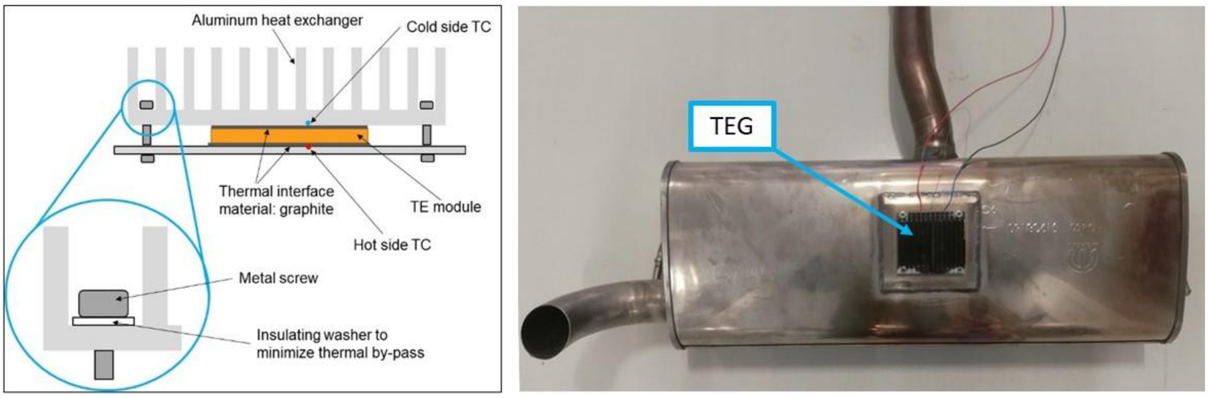

Fig.1 – Left: schematic layout of TEG; right: Jeep Renegade muffler with integrated TEG

The TEG harvested energy is used to power-supply the car's Fuel Level Sensor (FLS) and the electronic devices developed in the project: the Power Conditioning Circuit (PCC, SMRT, WP6), the monolithic Super Capacitor (SC, TAU, WP4) and the Wireless Sensor Node (WSN, AIMEN, WP6). Data coming from the FLS are collected and transmitted, via Bluetooth, by the WSN to the IoT gateway. The IoT gateway displays the fuel level and transmits data to the Internet, on a monitoring website that collects and reports recorded data (see fig.2).

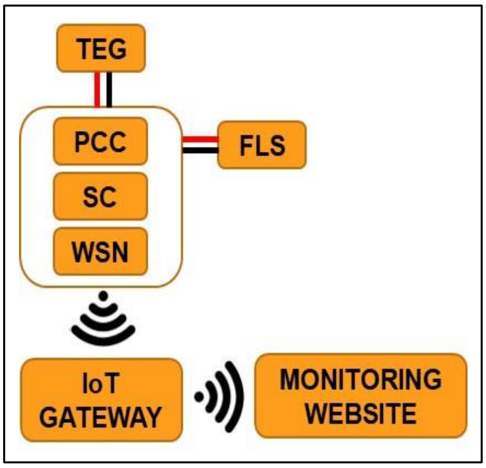

Fig.2 - Scheme of energy and data management

Preliminary tests have been run to characterize the TEMs and they indicate that polymeric modules are not ready yet for

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the automotive application since their power output is not sufficient to power-supply the entire system. For this reason, a commercial inorganic TEM with dimensions and thermal characteristics similar to those of the polymeric module has been employed as a backup solution, integrated into the same position originally designated for the polymeric module.

In order to validate the entire system, the muffler has been connected to a burner that can be controlled in terms of exhaust gas mass flow and temperature reproducing exactly the same thermal output coming from the engine. A fan with a proper air duct has been used to reproduce the air flow due to vehicle's motion that cools down the TEG cold side. The system has been tested and validated in three different working/driving conditions: steady state @ 50 km/h, steady state @ 90 km/h, FULL LOAD @ 50 km/h. For each working point 5 fuel levels have been reproduced: EMPTY; ≈1/4; ≈1/2; ≈3/4; FULL.

The entire system has been successfully validated: for all working points the TEG has been able to generate an output voltage in the range of ≈ 1.1÷1.5 V and an electrical power in the range of ≈ 370÷600 mW in a compact and easy-to-install solution (see table 1). These electric parameters are large enough to power-supply the Power Conditioning Circuit, the Wireless Sensor Node, the Fuel Level Sensor and to charge-up the super-capacitor. FLS data have been successfully collected and transmitted by the WSN to the IoT gateway and then to an internet monitoring website where they are recorded and monitored (see fig.3).

Table 1 - Validation experimental results

Exhaust gas mass flow	Exhaust gas T @ rear muffler	Measured muffler skin T (TEM Thot)	Air flow speed	Measured TEM Tcold	TEG output voltage	TEG output current	TEG harvested power
Vehicle driving conditions: steady state @ 50 km/h							
65 kg/h	330°C	162°C	14 m/s	102°C	1.12 V	339 mA	380 mW
Vehicle driving conditions: steady state @ 90 km/h							
98 kg/h	390°C	197°C	25 m/s	120°C	1.27 V	382 mA	485 mW
Vehicle driving conditions: FULL LOAD @ 50 km/h							
238 kg/h	465°C	237°C	14 m/s	144°C	1.50 V	398 mA	597 mW

Then the muffler with integrated TEG has been subjected to vibrational fatigue on a Road Simulation Bench (RSB). The validation has been repeated after the RSB test and experimental results showed that real life vibrations have no impact on system performance.

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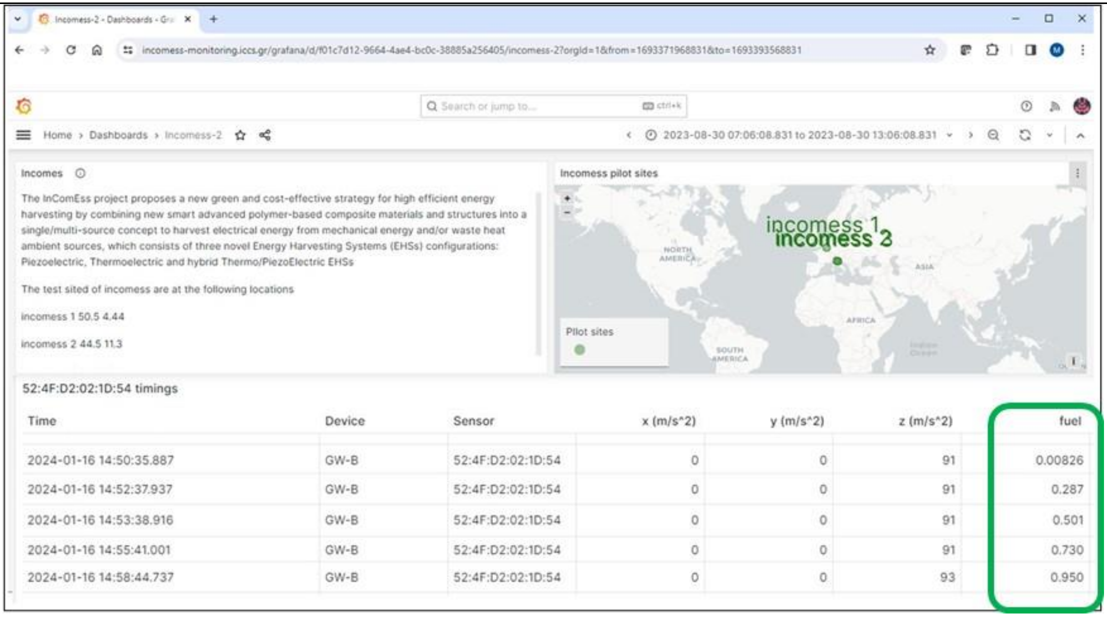

Fig.3 – Screenshot from monitoring website: fuel level data highlighted in the green box

For this particular study case it can be estimated that around 6 meters cabling is saved because the FLS does not need to be connected to the vehicle's battery and ECU for power-supply and data management. With multiple distributed energy harvesting sources to be connected to different sensors (tire pressure sensor, parking sensor, etc.) it is possible to estimate that hundreds meters of cabling could be saved.

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Details

Project title: INnovative polymer based COmposite systeMs for high efficient Energy Scavenging and Storage

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