FEMAG-C
Flexible Ecological Multipurpose Advanced Generator - Car
**DESCRIPTION (1/2)**

**FEMAG-C** is a technology framework enabling the use of fuel cells in on-board electric generators for electric vehicles, allowing for improved range, reduced weight and zero emissions.

**FEMAG-C** consists of plug-in serial hybrid electric power train, with scalable and redundant architecture, capable to convert and control the electric power in accordance to preset strategies, conceived to reduce the control requirements of PEMFC, and to improve its efficiency and lifetime.
A low pressure metal hydride system stocks the hydrogen safely, with independent hydrogen sensors wired to automatically shutdown the system upon leak detection.

FEMAG-C is also a platform for the development of Internal Combustion Engine (ICE) plug-in serial hybrid off-highway vehicles.
SIMPLIFIED ELECTRICAL ARCHITECTURE

#1 PEMFC

#1 Intelligent DC-DC Converter

Lithium Ion Polymer Battery Pack

Electric motor Power supply

#2 PEMFC

#2 Intelligent DC-DC Converter

= Energy Flow direction
Hydrogen Storage
- 6 Ovonics@work 940sl tank
- Metal hydride low pressure storage
- Excess heat from fuel cells used for hydrogen release

Hydrogen conversion
- 2 Ballard MK1020ACS PEM Fuel cell stacks
- 46 cells per stack
- 50Amps 32V with no significant degradation
- 1,6 kW nominal power
- 45-60% LHV Efficiency
DC-DC Converter

- 24-50V input voltage
- 30-60V output voltage
- 50A maximum current output
- 86-93% electrical conversion efficiency

![DC-DC Converter efficiency graph](image-url)
Smart controller

- Intelligent loading of fuel cells with preset ramps for longer lifecycle
- Independent control of fuel cells
- Battery charge and discharge management
- Scalable architecture
Battery Pack

- 3 EIG M4820 Lithium Ion Polymer batteries
- 48V 60Ah Total nominal capacity=2880Wh
- 3C recommended discharge rate
- 10C maximum discharge rate
- Recommended charge 2h -> 30A
- Maximum possible charge 1h -> 60A
SYSTEM WORK LOGIC

The controller follows the vehicle load requirements separating the loads on the Fuel Cells and the batteries keeping the Fuel Cells as much at steady state as possible: the battery provide the peaks and the cells recharge the battery in the lows.

The system supports multiple storage systems (supercondensers, different discharge batteries, etc), which are not necessary in this case due to the small size of vehicle.
SYSTEM ARCHITECTURE WITH ONE FUEL CELL AND SUPERCAPACITORS
FEMAG-C can control hybrid systems with Petrol Engine, Biofuel Engine or Fuel Cells

FEMAG-C : Hybrid Generator
for Small-Size Electric Vehicles
VEHICLE : SYSTEM PERFORMANCE

- Up to 12 kWh capacity
- 85 kg weight
- 40-55% LHV efficiency to electric motor

- 3 kW nominal power
- 10 kW peak power
- Instantaneous start-up
- Improved fuel cell lifetime
## POWERTRAIN: PERFORMANCE AND COMPARISON

<table>
<thead>
<tr>
<th>FEATURES</th>
<th>FEMAG-C</th>
<th>Lithium-Ion Battery</th>
<th>Pb-Gel Battery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volume (l)</td>
<td>140</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>85</td>
<td>140</td>
<td>175</td>
</tr>
<tr>
<td>Usable energy (kWh)</td>
<td>12</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Volumetric energy density (Wh/l)</td>
<td>86</td>
<td>100</td>
<td>36</td>
</tr>
<tr>
<td>Gravimetric energy density (Wh/kg)</td>
<td>141</td>
<td>100</td>
<td>29</td>
</tr>
</tbody>
</table>
### HYDROGEN STORAGE PERFORMANCE COMPARISON

<table>
<thead>
<tr>
<th>STORAGE SECTION</th>
<th>Metal hydrides</th>
<th>Compressed H2 Tanks</th>
<th>Chemical Hydrides</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usable energy (with 50% fuel cell efficiency of FEMAG-C)</td>
<td>8400 Wh</td>
<td>8400 Wh</td>
<td>8400 Wh</td>
</tr>
<tr>
<td>Storage tank weight</td>
<td>39 Kg</td>
<td>17,1 Kg</td>
<td>8,4 Kg</td>
</tr>
<tr>
<td>Gravimetric energy density</td>
<td>215 Wh/Kg</td>
<td>490 Wh/Kg</td>
<td>1000 Wh/Kg</td>
</tr>
</tbody>
</table>
In September 2010 DAIMLER BENZ will deliver 100 plug-in electric Smart vehicles to private customer for a full test in Rome.
The vehicle will go on public sale in 2013.
1. Car manufacturers are currently concentrated on batteries development.
2. Batteries are becoming more and more competitive.
3. Hydrogen has performance advantages over batteries but the H2 chain infrastructure needs to be agreed and implemented.
4. The hydrogen storage is still a critical point for automotive acceptability.
5. Fuel cells are still undergoing heavy technological development and their mass market will not start soon. Conversely, their potential is still mostly inexploited.
6. The FEMAG-C experience will be used to develop an Internal Combustion Engine (ICE) plug-in serial hybrid off-highway vehicle based on petrol or biofuels.
THANK YOU!

Giuseppe Leo Guizzi  Faculty of Engineering University of Rome
Tor Vergata

Alfredo Picano  LABOR

Filippo Ugolini  AGT Engineering