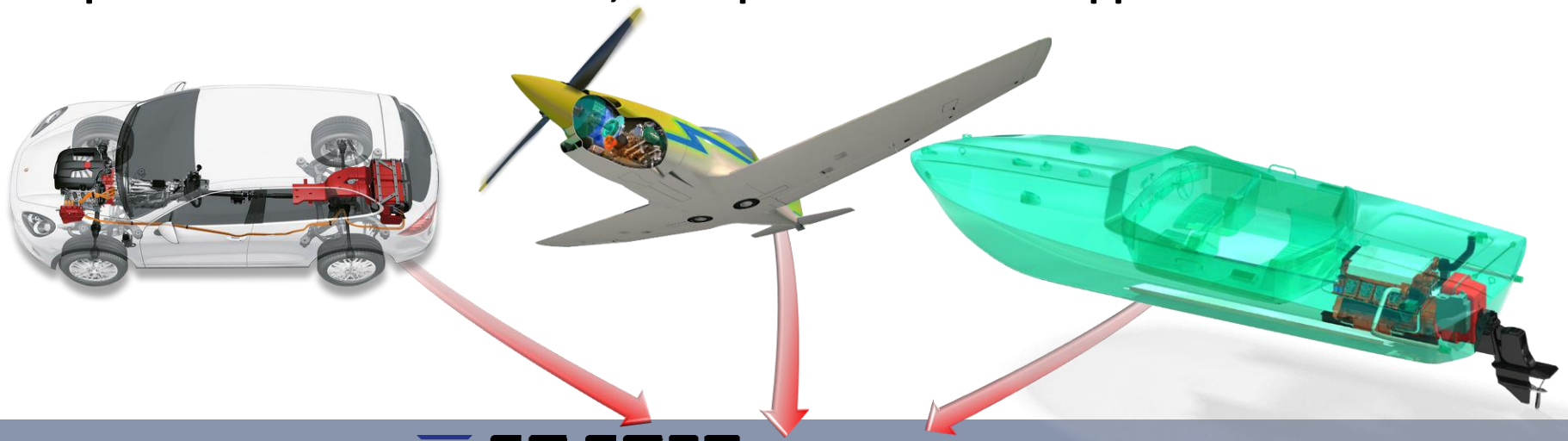
Company Presentation

- **EFESTO, founded in 2012, headquarters in Paris, France, is a spin-out arm of FIDIA Group (www.fidia.com) world leader in the design, manufacture and commercialization of Numerical Controls, CAD/CAM Software, Power Electronics and High Speed Milling Systems for automotive, aerospace and energy industries.**
- **EFESTO's mission is to deliver best in class propulsion technology in the respect of the environment and the nature. Efesto is active in the design and development of turn key hybrid and full electric power trains and power units for automotive, aerospace and marine applications.**



In 2015 three enterprises and one university joined their competencies in order to develop and market hybrid propulsion solutions for automotive, aerospace and marine sectors.

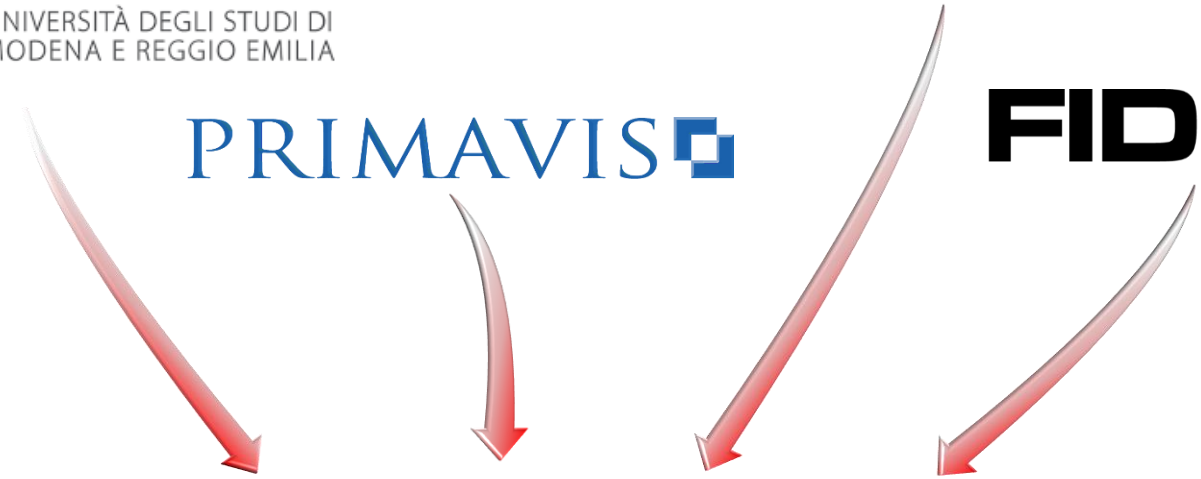
UNIVERSITAS STUDIORUM MUTINENSIS ET REGIENSIS 1175

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

EFESTO

PRIMAVIS

FIDIA



Best in class Series and Parallel Hybrid Power Trains

The three partner companies and the university have complementary know-how and expertise in their respective fields

EFESTO: development, engineering and production of innovative highly efficient inverters, converters, vehicle control units, electric motors and software. www.efesto.fr

PRIMAVIS mission is to develop and to sell best in class internal combustion engines based on a split cycle supercharged direct injection patented architecture. www.primavis.eu

FIDIA: world leader in the design, manufacture and commercialization of Numerical Controls, CAD/CAM Software, Power Electronics and High Speed Milling Systems for automotive, aerospace and energy industries. www.fidia.com

UNIMORE is located in the heart of one of Europe's most dynamic regions, which is world-renowned for its production of mechanical parts, engines, sports cars (e.g. Ferrari and Maserati) and has a significant experience in ICE simulations and development. www.unimore.it

Products

1. Automotive Range Extender and pure electric/hybrid power train

2. Parallel Hybrid System for Light Aircraft

3. Hybrid Power Units for Sail Boats and Motor Boats

4. Hybrid Motorcycle Ibex Quattro70

5. Parallel Hybrid Power Train for Ice Racing Prototype Car

Automotive Range Extender

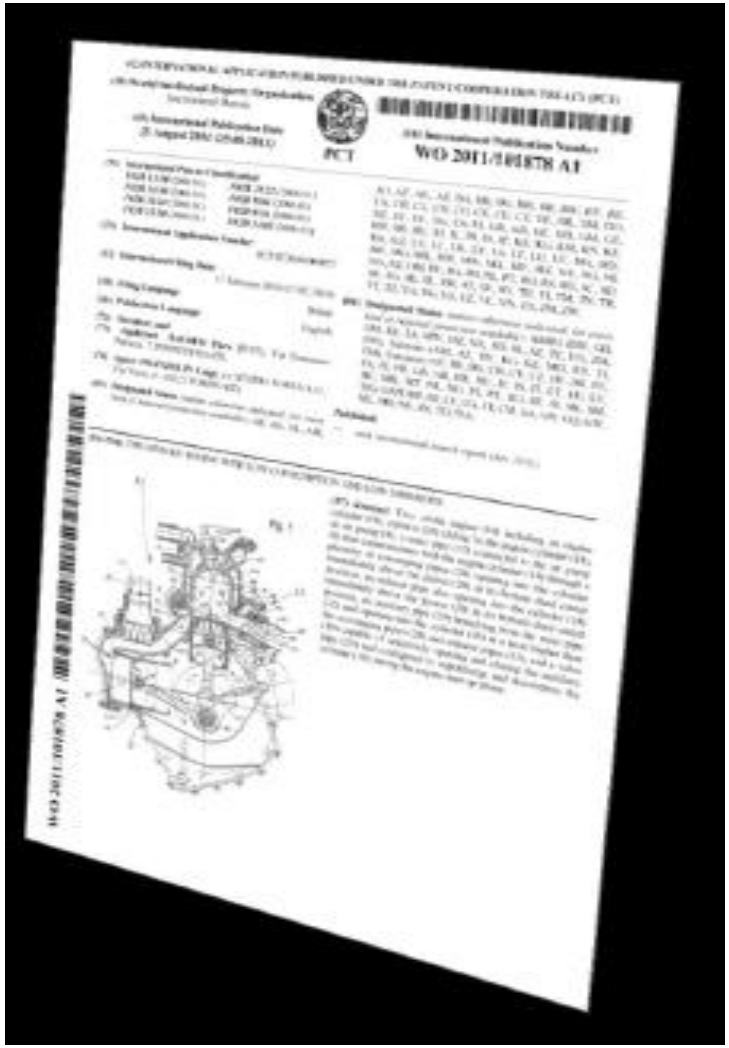
23 kW @ 4000 rpm - total weight 55 kg based on Primavis Split Cycle Internal Combustion Engine

The Internal Combustion Engine

PRIMAVIS offers a range of solutions based on the Patent WO/2011/101878 titled “Two Stroke Engine with Low Consumption and Low Emissions”, studied to achieve

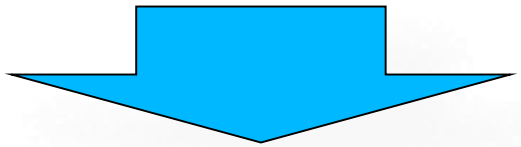
- **High efficiency**
- **High specific power**
- **Very compact dimensions**
- **Low weight**
- **Simplicity, low production costs**
- **Extremely good NVH**

Mono and multicylindrical configurations, from15 kW to 180 kW, have been studied



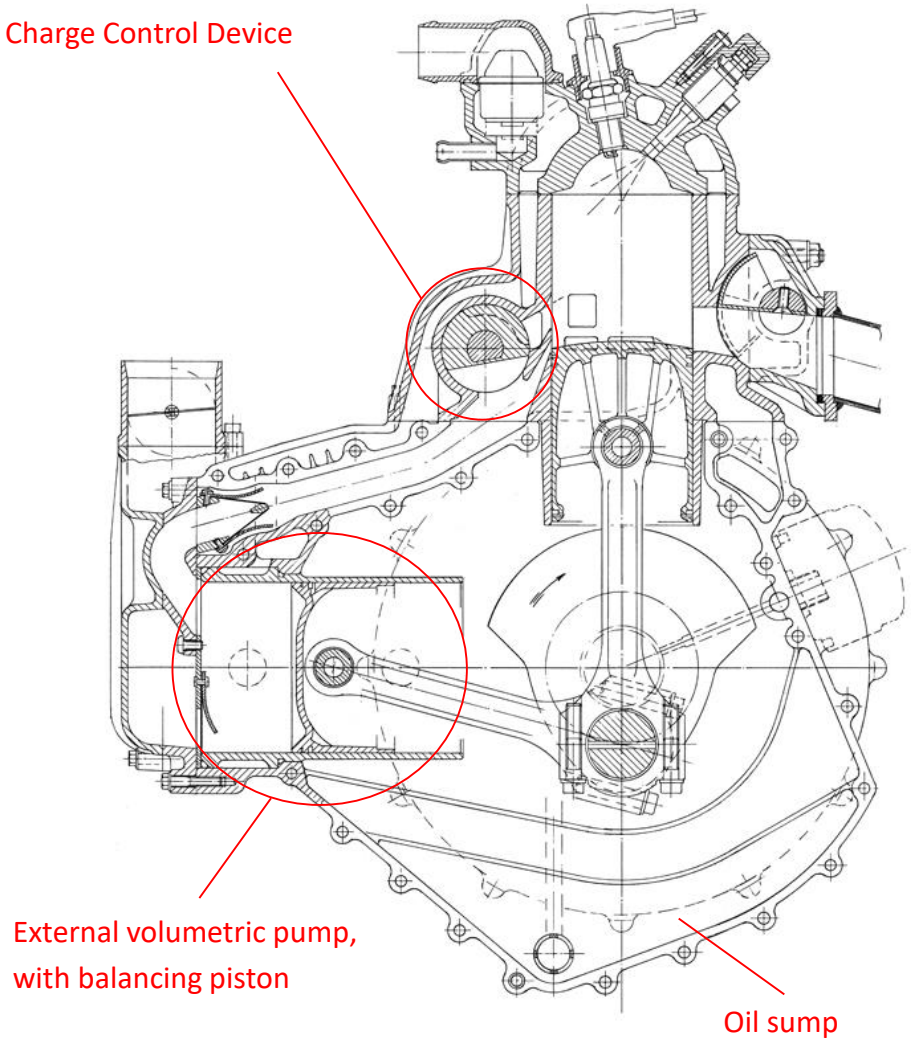
The Internal Combustion Engine

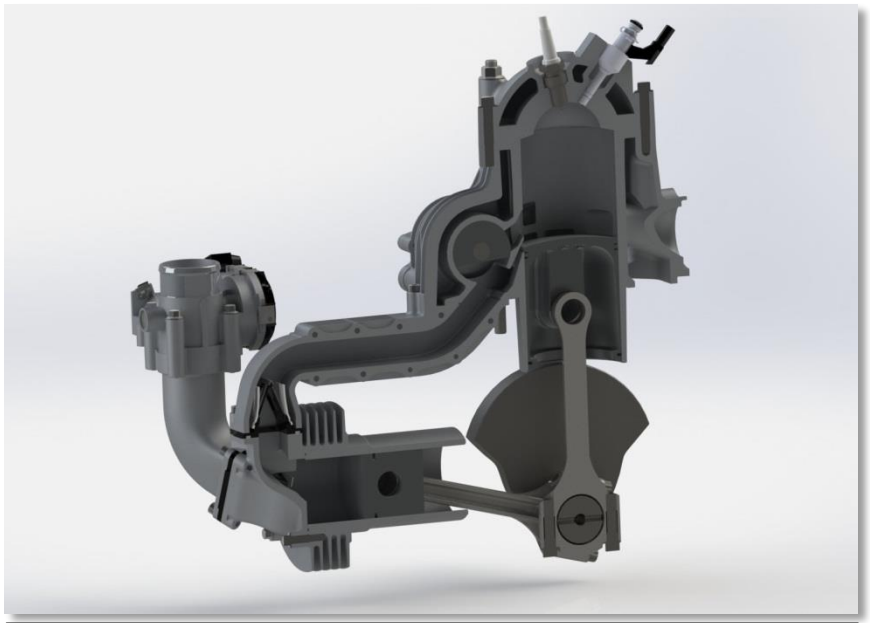
- One combustion process every crankshaft revolution (modern Two Stroke)
- Air supply realised by external volumetric pump, with possibility of supercharging by patented CCD (control charge device)
- High pressure direct fuel injection system
- Lubrication system “Four Stroke like” (lubrication oil not mixed with fuel and not burned during the combustion process)
- Liquid cooling
- Possibility of internal EGR
- Possibility to function with several fuels (gasoline, CNG, LPG and also diesel, if required)

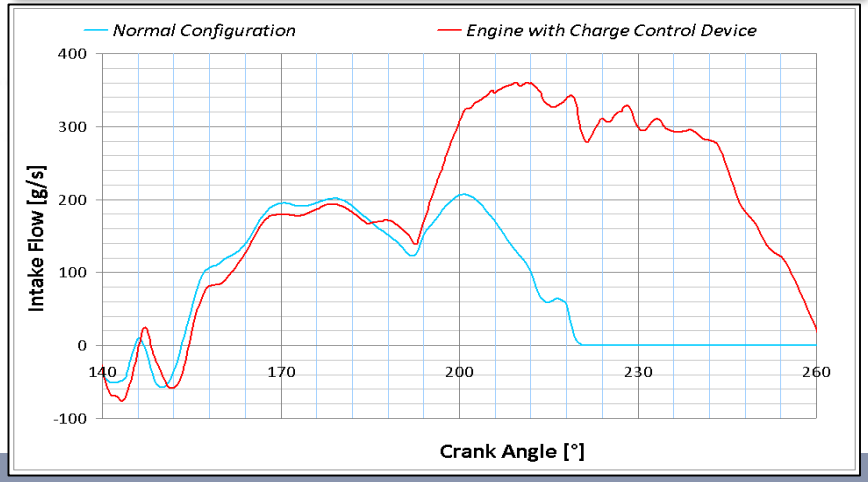


Innovative clean Split Cycle Two Stroke engine, no drawback of standard solutions

Layout of the complete solution
Primavis GDI engine represented



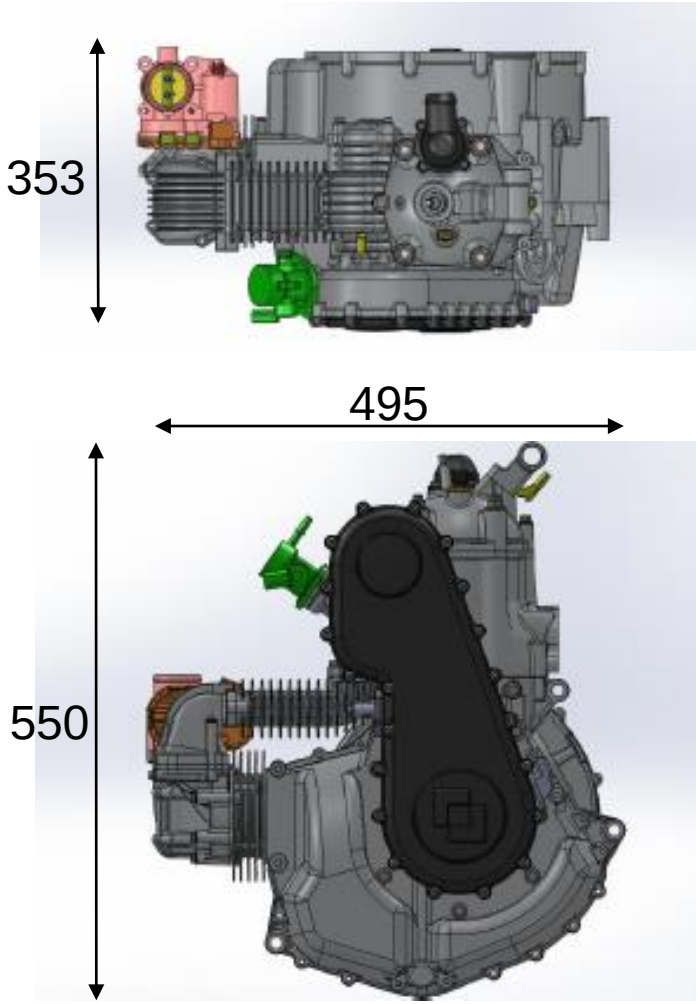




Range extender main features

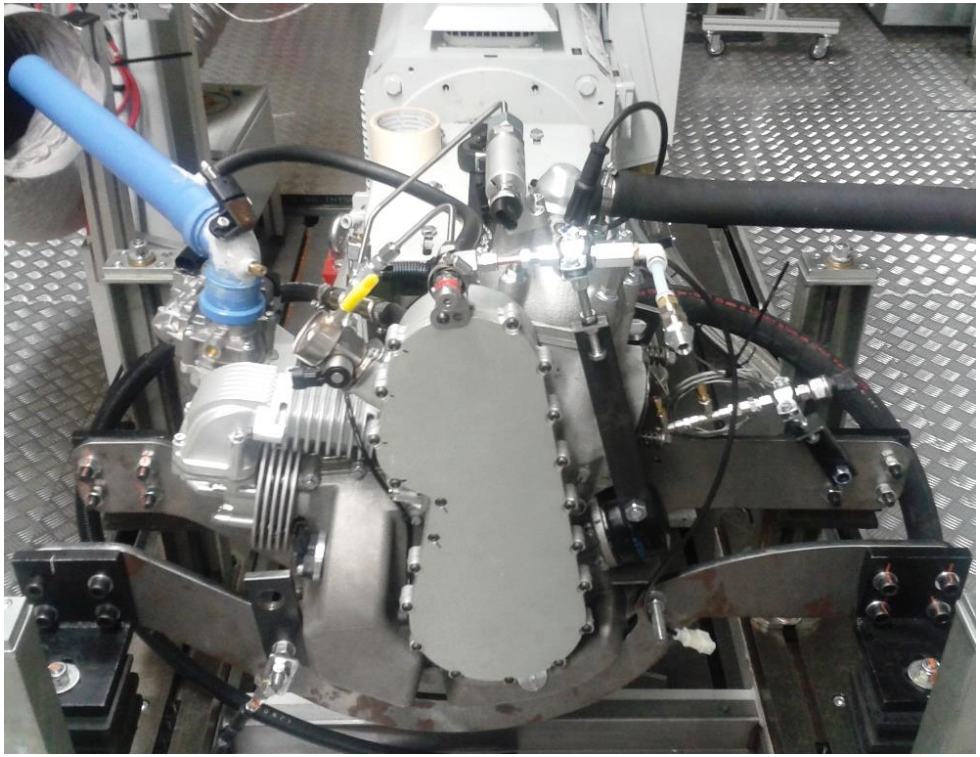
- **Monocylindrical supercharged, Gasoline Direct Injection**
- **500 cc displacement (34 kg)**
- **250 g/kWh best BSFC**
- **PMSM starter-generator, external rotor (21 kg)**
- **23 kW@4000 rpm power output**
- **55 kg total weight***

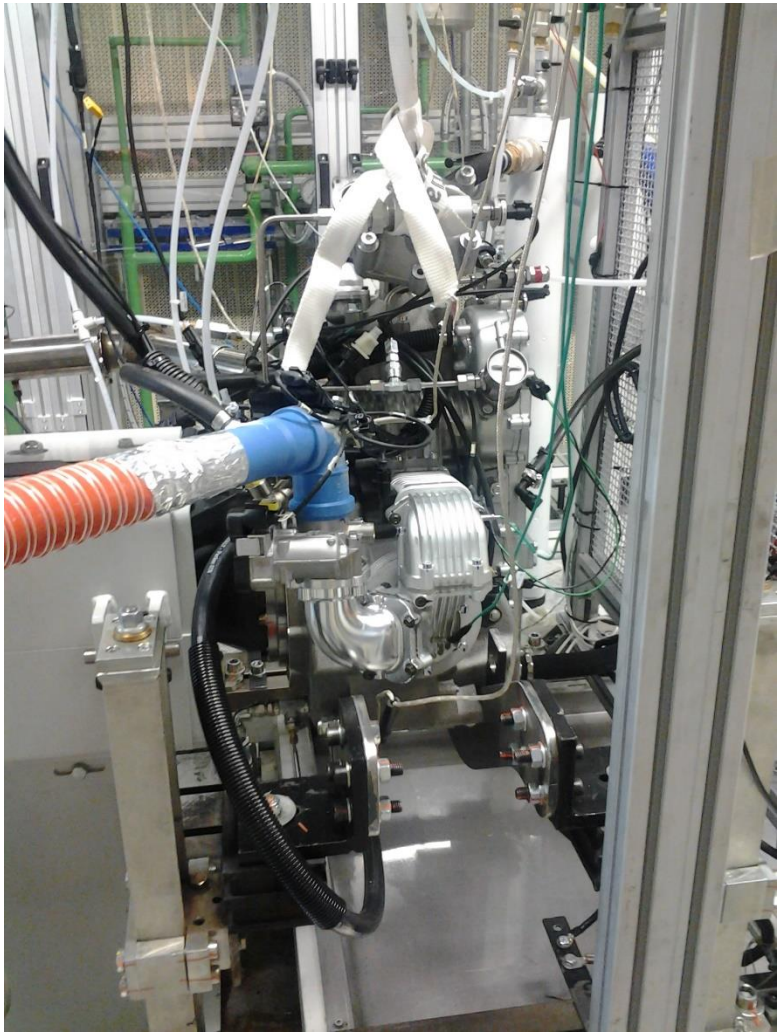
* 46 kg version available with EMRAX 228 (12 kg) Electric motor (see page 16)



Bench test installation

Several tests have been carried on the Primavis GDI internal combustion engine since 2015.





Primavis Engine installed on UNIMORE bench test

Electric power train components

Efesto develops complete turn key electric or hybrid power train based on the following components:

- **Efesto AC/DC inverters**

- **PMSM electric motors**

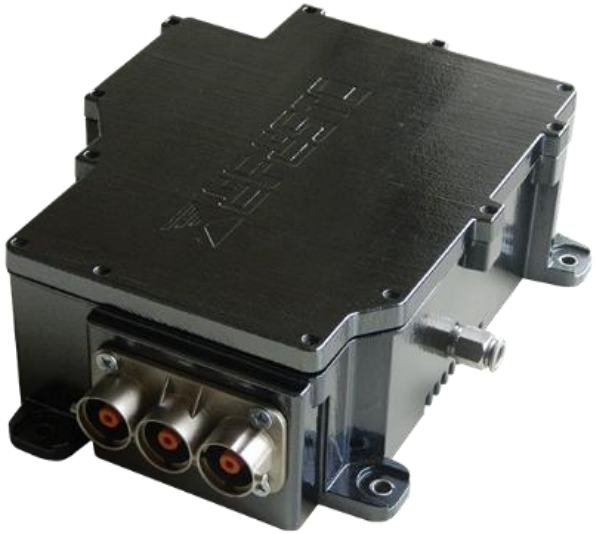
- **Efesto Vehicle control unit**

- **DC/DC converters**

- **On board battery charger**

- **Lithium-ion battery pack**

EFESTO has developed a line of very compact and efficient AC/DC inverters for full electric, series and parallel hybrid configurations



GCU 50/400

50 kW - 4.5 kg inverter for recharging the Li-ion battery pack

MCU 100/400

100 kW - 7 kg inverter for controlling the traction electric motor

Efesto Inverters Technical Specification

MAIN FEATURES	GCU-MCU50/400	GCU-MCU100/400
Maximum Rating		
Electrical output power	50 kW	100kW
Output current	283 Arms	566 Arms
Efficiency	97.0%	
Continuous Rating		
Electrical output power	35 kW	70kW
Output current	200Arms	400 Arms
Efficiency	97.5%	
Electrical Parameters		
Operating battery voltage	100 - 450 Vdc	
Diagnostic	CAN BUS interface	
Switching frequency	Up to 25 kHz	
CAN interface version	2.0b	
Short-circuit protection (IEC 947-4-1)	Type 1 & 2	
Over-current protection	Yes	

GCU-MCU 50 MECHANICAL DATA

Length **270 mm / 10.6 in**
Width **215 mm / 8.5 in**
Height **85 mm / 3.4 in**
Weight **4,5 kg / 9,9 lb**
Volume **4,93 lt**

GCU-MCU 100 MECHANICAL DATA

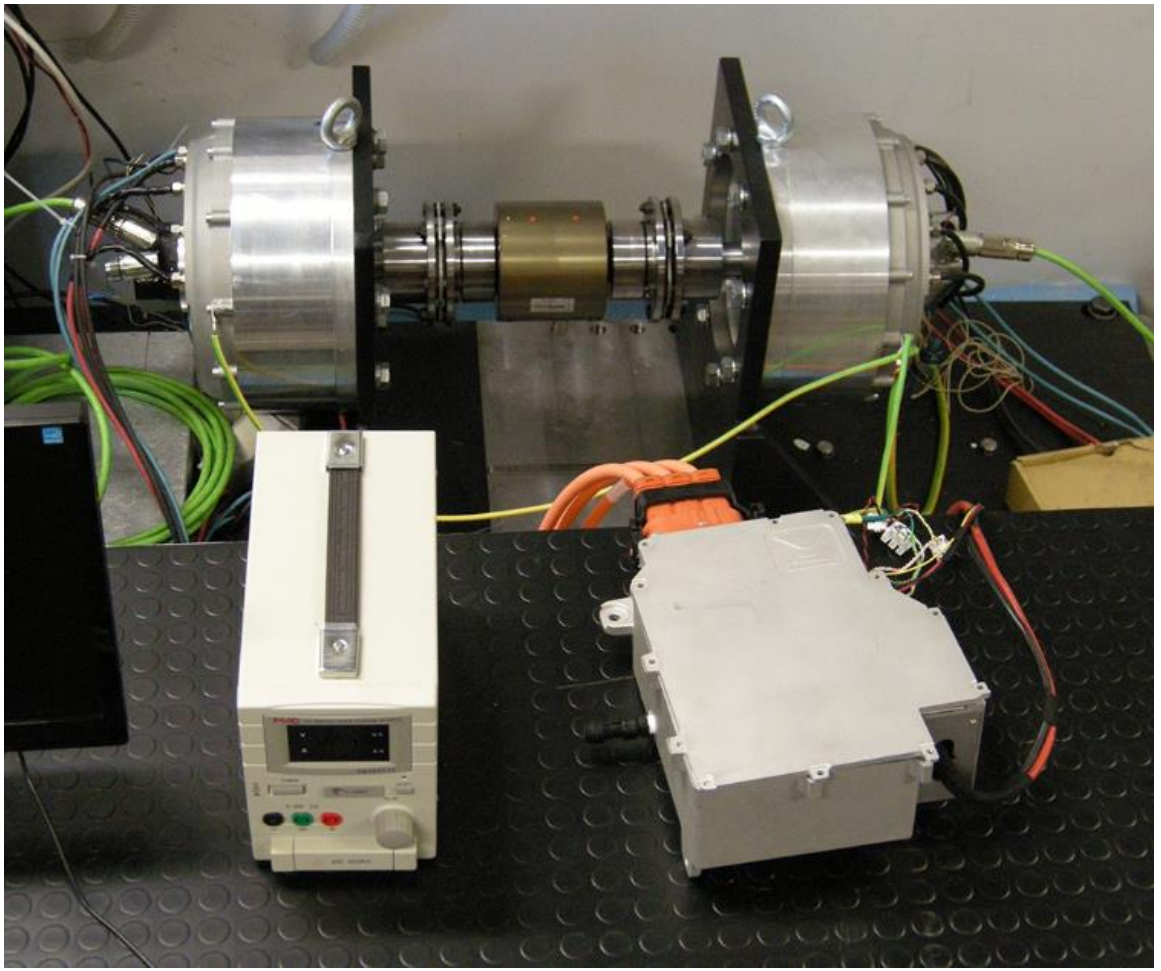
Length **270 mm / 10.6 in**
Width **315 mm / 12.4 in**
Height **85 mm / 3.4 in**
Weight **7 kg / 15 lb**
Volume **7,23 lt**

ENVIRONMENT AND COOLING DATA

Operating conditions **-40°C to 125°C**
Coolant temperature **-10°C to 95°C**
Coolant type **50/50 glycol-water**
Protection **Waterproof, dustproof**

Efesto Electric Motor Starter-Generator

- PMSM starter-generator
- External rotor
- Surface mounted magnets
- Liquid cooling
- Itegrated cooling circuit with ICE and Power Electronics
- Directly connected to ICE crankshaft
- Parameter as Generator at nominal speed
  - Output power 30 kW
  - Nominal current 130 Arms
  - Efficiency 95%



50 kW inverter and two 30 kW electric motors connected trough torquemeter in a test bench back to back configuration in EFESTO R&D centre

Traction Electric Motors Technical Specification

TECHNICAL DATA	EMRAX 228	EMRAX 268
Weight [kg]	12.3	20.3
Diameter ø / width [mm]	228/86	268/91
Battery voltage range [Vdc]	50-600 HV/50-450 MV/24-150 LV*	50-600 HV/50-400 MV/24-130 LV*
Peak motor power [kW]	100	200
Continuous motor power [kW]	35-55	50-100
Maximal rotation speed [RPM]	5500 (**6500 peak)	4000 (**5000 peak)
Maximal motor torque [Nm]	240	500
Continuous motor torque [Nm]	125	250
Motor efficiency [%]	93-98%	93-98%
Maximal motor current* **	240 HV/340 MV/900 LV*	240 HV/360 MV/1000 LV*
Continuous motor current [Arms]	115 HV/160 MV/450 LV*	125 HV/180 MV/500 LV*
Torque / motor current [Nm/1Aph rms]	1.1 HV/0.75 MV/0.27 LV*	2.0 HV/1.4 MV/0.5 LV*

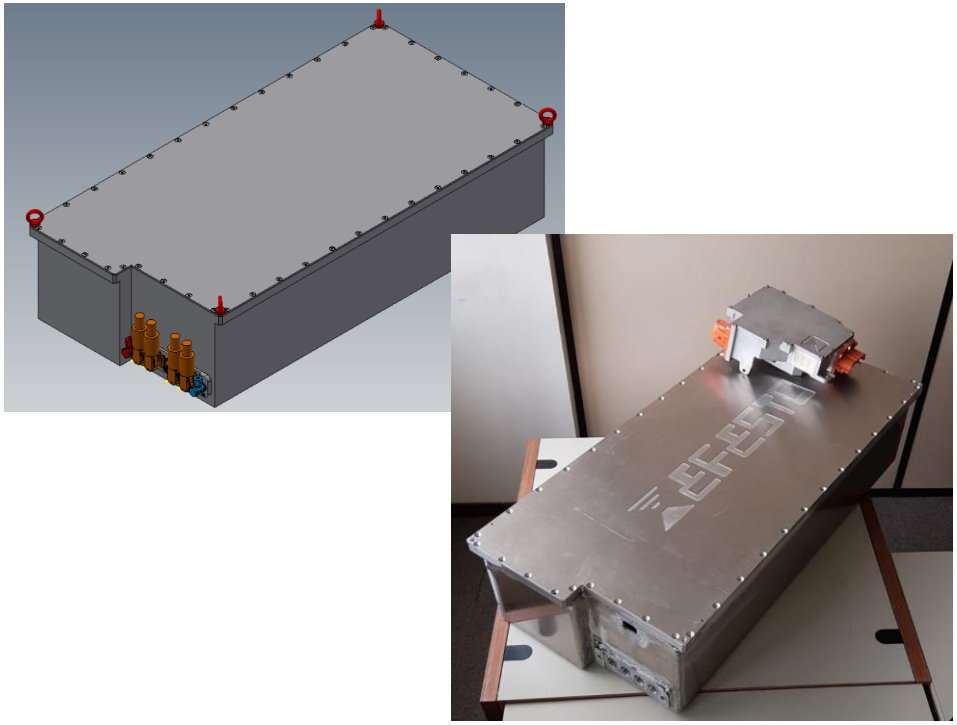
Efesto custom design battery pack

Li-ion batteries pack

Efesto design and produce custom batteries packs based on client's requirements.

The battery pack can be designed with air or liquid cooling system and the BMS is connected trough an high speed CAN BUS line to the proprietary Efesto Vehicle Control Unit

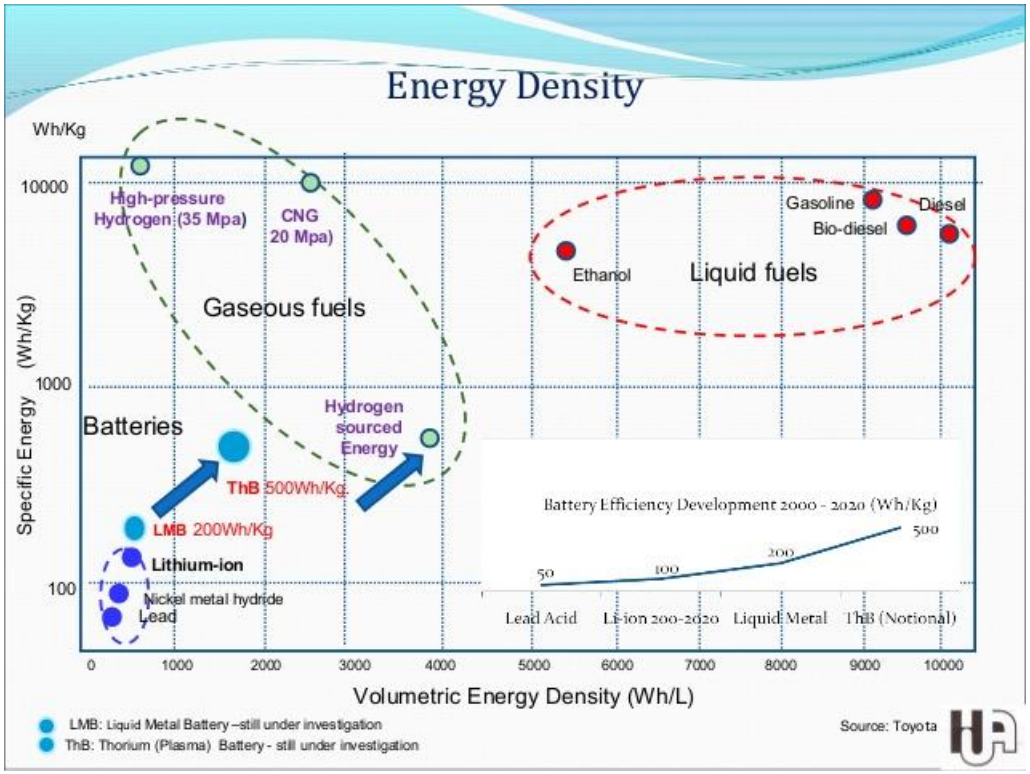
View of the High voltage battery pack developed for the Efesto hybrid motorcycle presented at Eicma 2019.



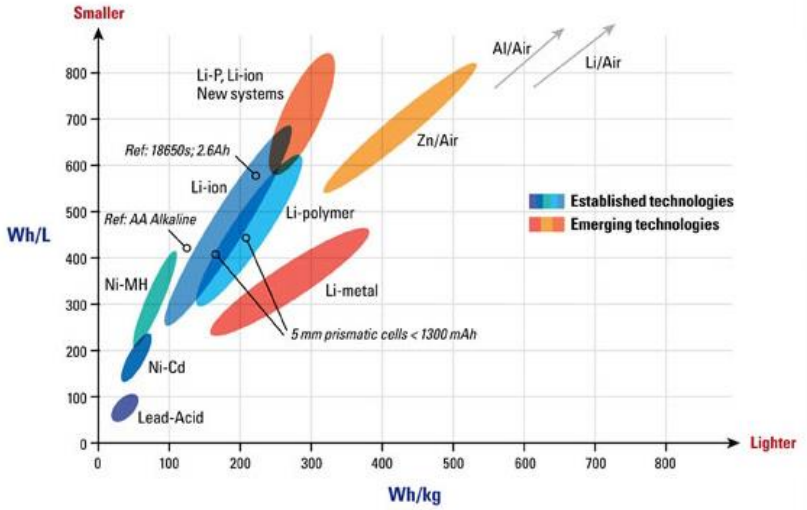
Customized mechanic for installation in restricted space and air circulation. It's been increased mechanical strength for harsh on board environment.

Battery Energy Density Trend

The battery energy density is constantly improving thanks to massive R&D investments of different industries



In the chart above it is possible to observe the battery energy density trend constantly improving

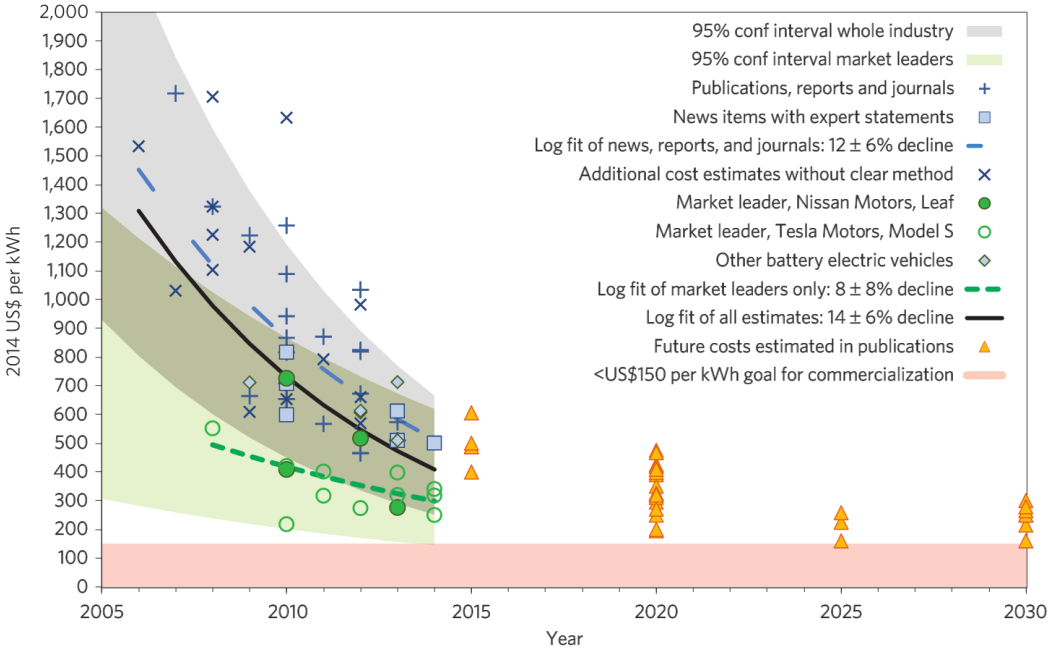


Source Oregon University

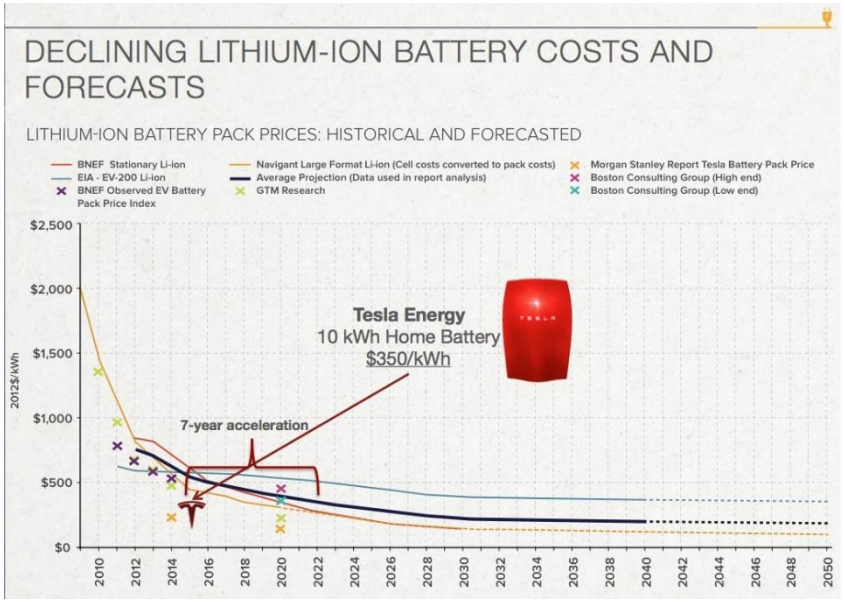
As shown in the chart above, today the actual available energy density with Li-ion battery pack is around 200 Wh/kg, but is forecast to almost double in the near future.

Li-ion Battery Price Trend

The battery price is constantly reducing thanks to massive R&D investments of different industries



Source Clean Technica.com



Source Rocky Mountain Institute

EFESTO defines, according to the final customer request, the technical specifications of the batteries and can supply the assembled battery pack including the Battery Management System (BMS) if requested.

In June 2015 at the Paris Air Show in Le Bourget, Efesto, in collaboration with CFM, presented the first parallel hybrid unit ever installed on a light airplane

51st INTERNATIONAL
PARIS AIR SHOW
LE BOURGET
JUNE 15 - 21, 2015
51e SALON INTERNATIONAL
DE L'AÉRONAUTIQUE ET DE L'ESPACE
PARIS LE BOURGET
15 - 21 JUIN 2015

CFM Dardo airplane

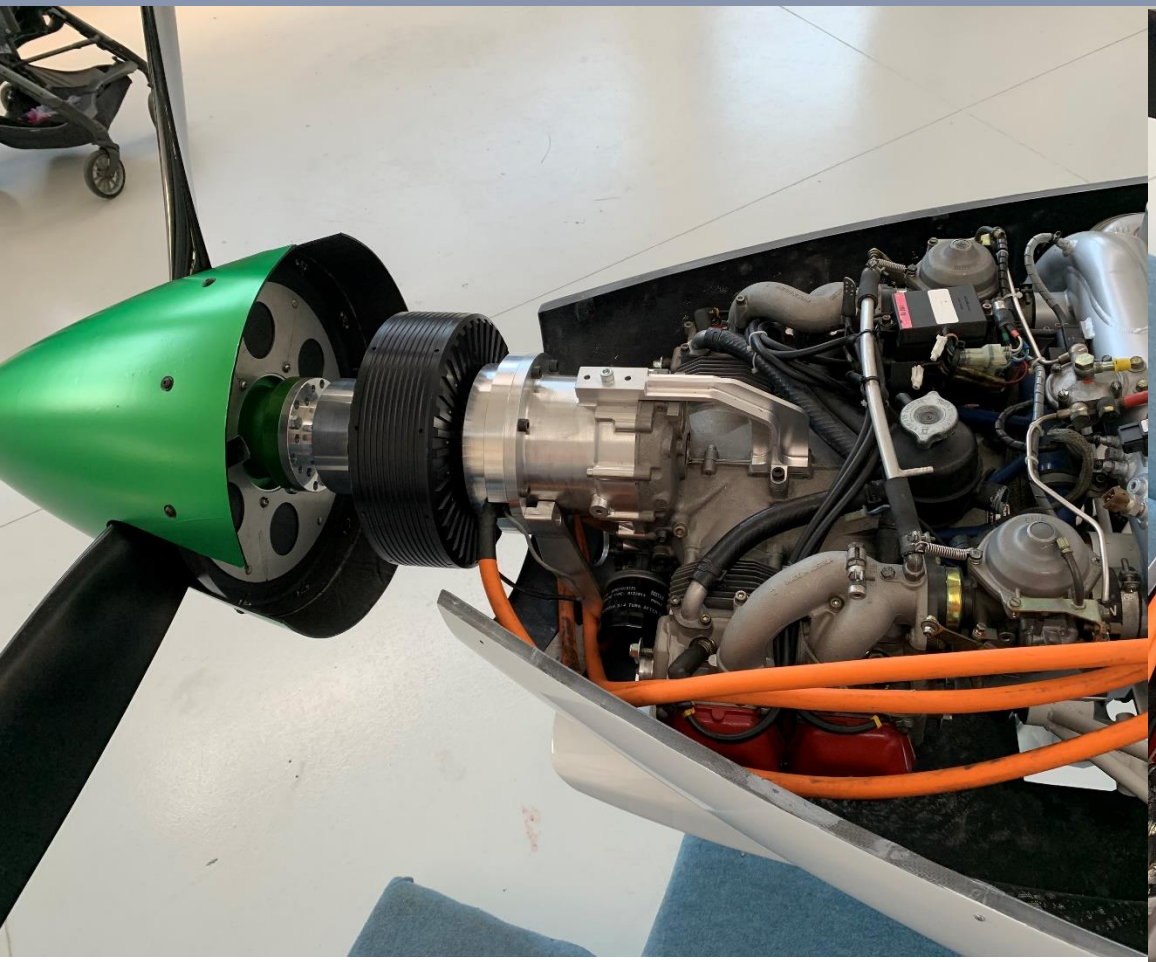
Parallel Hybrid System for Light Aircraft
Power Unit description

The hybrid power unit develops up to 100 kW power in pure electric flight and over 200 kW in boost mode combining the power of the Rotax 914 to the power of the Emrax 268 Electric motor.

- The parallel hybrid system is installed on the Rotax 914.
- A new gearbox developed by Efesto with a clutch inside replaces the Rotax original gearbox.
- A 60 kW permanent magnet electric motor is mounted directly on the propeller shaft.
- The inverter is installed behind the Rotax, a 30 kg battery pack is installed at the rear of the plane.
- Total added weight 57 kg.

Side view and top view of the hybrid power unit installation on the Dardo

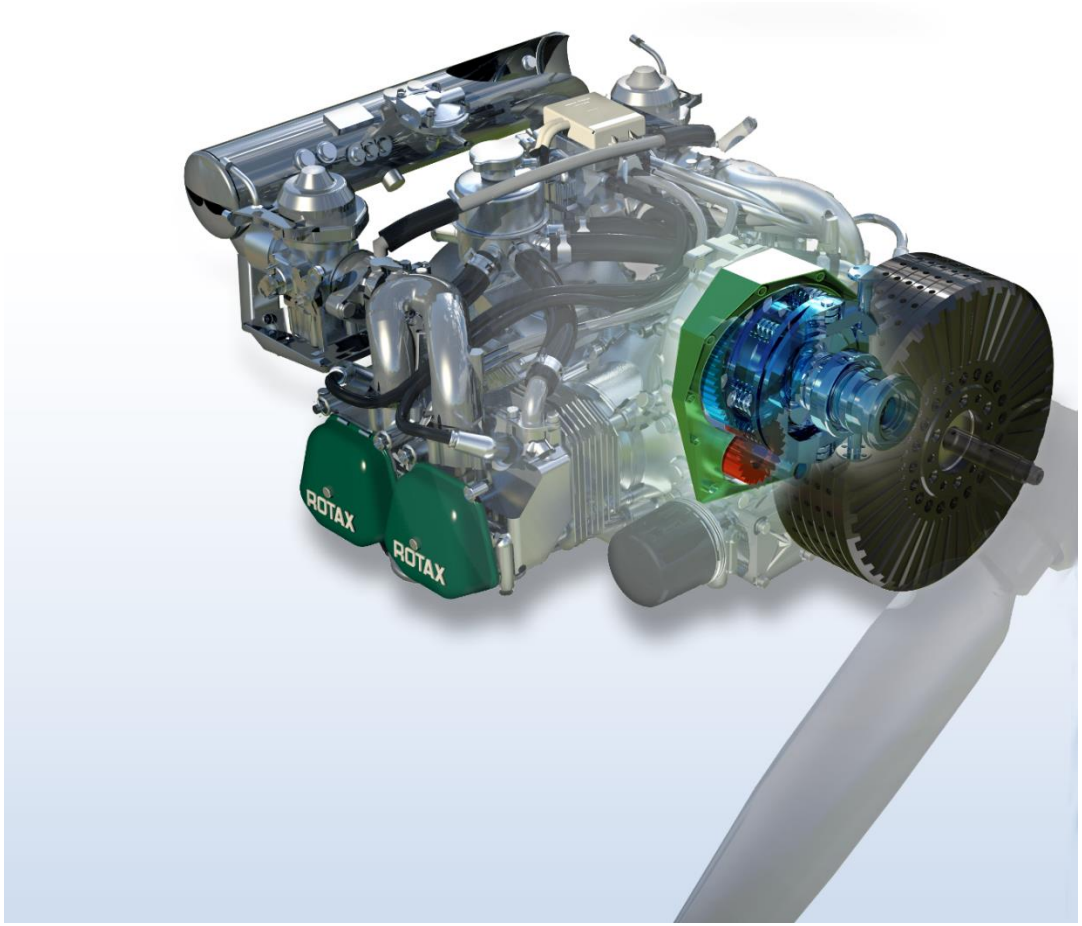
Friedrichshaffen aero show 2022



Friedrichshaffen aero show 2022

Parallel Hybrid System for Light Aircraft
System Operation Modes

The Hybrid Unit allows to operate the airplane in different operating modes



1. **Normal Mode: ICE only drives the propeller**
2. **Pure Electric Mode: the electric motor only drives the propeller**
3. **Boost Mode: ICE and electric motor simultaneously drive the propeller**
4. **Starter Mode: the Electric motor starts the ICE**
5. **Generator Mode: the Electric motor as generator charges the Power Pack Lithium Polymer Battery**

Hybrid Power Units for Motor Boats

in collaboration with

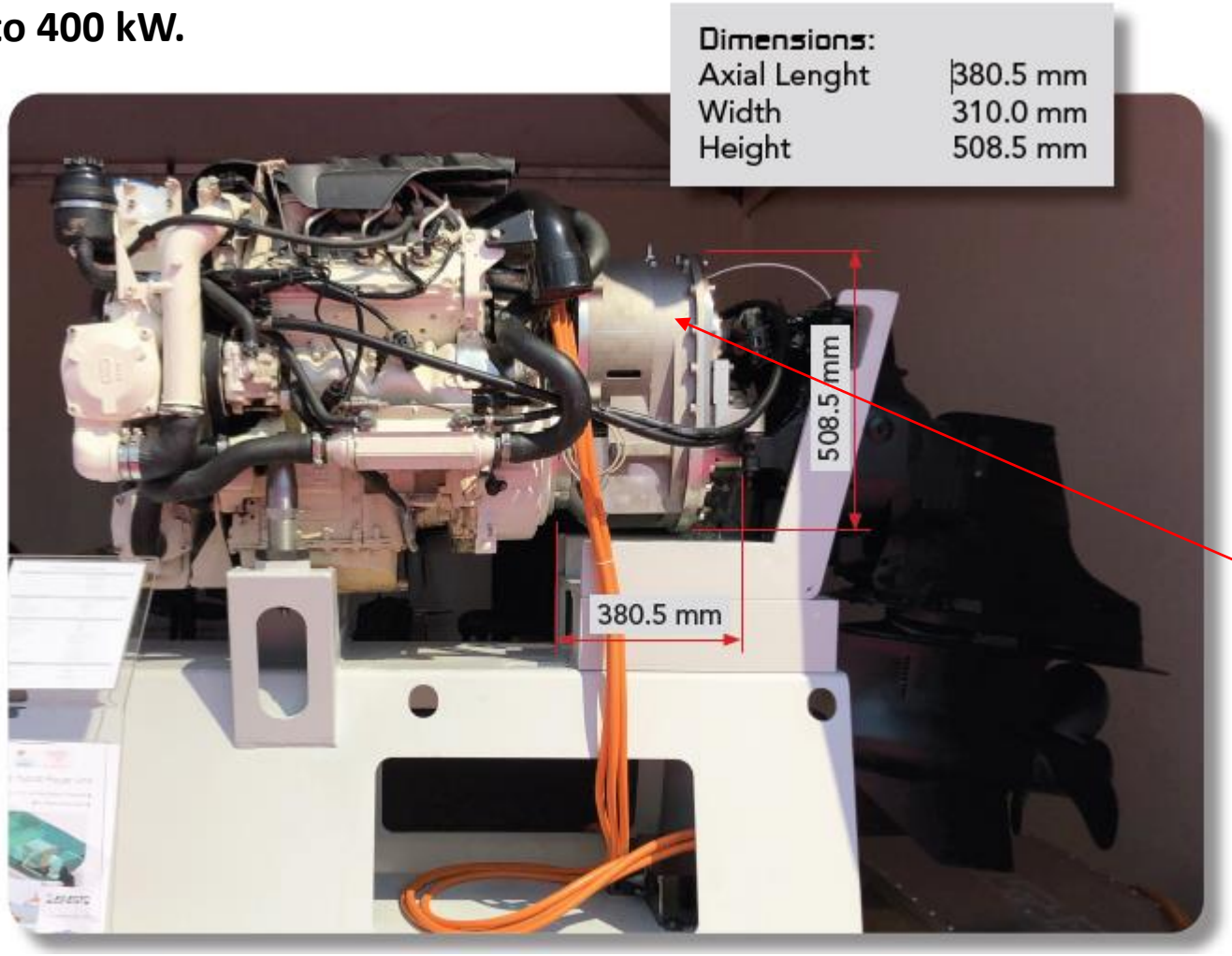
In September 2021 at the Cannes Boat Show, Efesto presented a parallel hybrid unit to be installed on the inboard motor boat

Hybrid Power Units for Sail Boats

Lithium-ion battery pack – Internal combustion engine – Efesto Power Unit

Hybrid Power Unit installation

The Efesto Hybrid Power Unit can be installed on any gasoline and diesel engines with a power up to 400 kW.

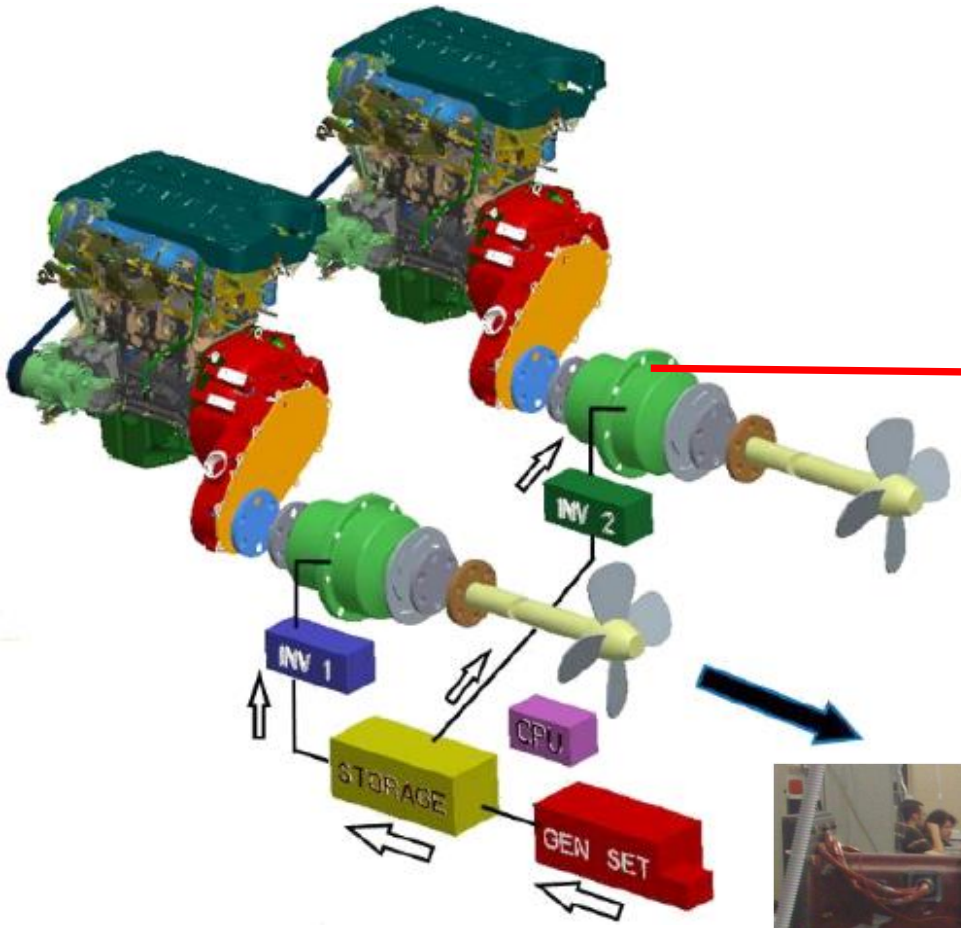


Hybrid Power Unit views and details

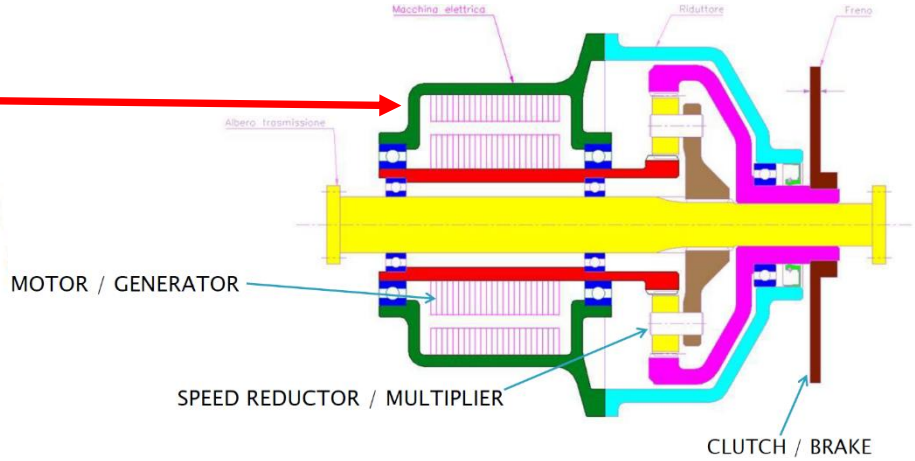
The double shaft with gears architecture allows to use the electric motor always at its optimal speed, independently from the internal combustion engine maximum rpm

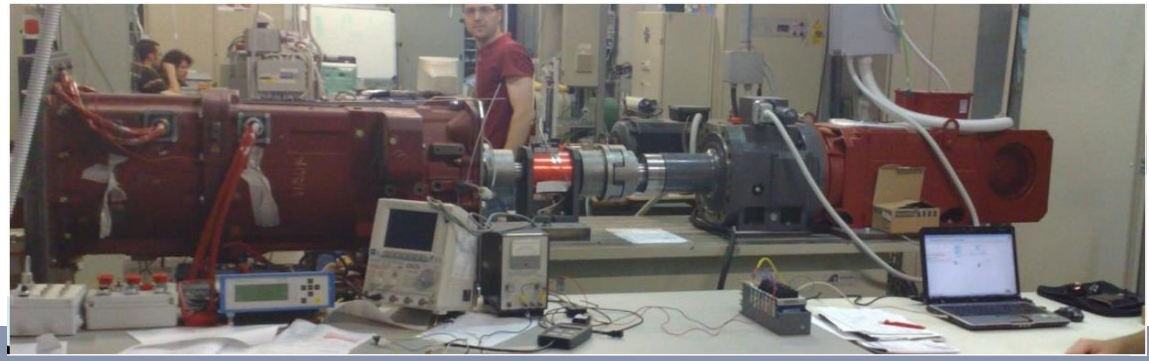
The hybrid power unit fits in to an axial space of only 380 mm.
The hybrid power unit is compatible with the original stern drive shaft.
The Mercury ICE has been moved forward in order to accomodate the hybrid power unit.

Hybrid Power Unit for Yachts



Efesto is developing an Hybrid transmission for mega-yachts based on a planetary gearbox architecture.





For high power requirements it is possible to mount two motors in twin configuration. Continuous power over 400 kW per axis, peak power over 600 kW per axis. Motors total weight 84 kg

Mechanical	
Type:	Axial flux motor / generator
Casing diameter:	348 mm
Axial length:	107 mm
Dry mass:	41,0 kg (AC) / 41,5 kg (CC) / 42 kg (LC)
Stator cooling:	air (IP21) / combined (IP21) / liquid (IP65)
Mounting:	Front: 6x M10 threaded holes Back: 10x M8 threaded holes

Electrical	
Maximal battery voltage:	800 (HV) / 800 (MV) / 420 Vdc (LV)
Peak power (at 4500 RPM):	380 kW
Continuous power*:	up to 210 kW
Peak torque:	1000 Nm
Continuous torque*:	up to 500 Nm
Efficiency:	92-98%

Parallel Hybrid Power Train for Ice Racing Prototype Car

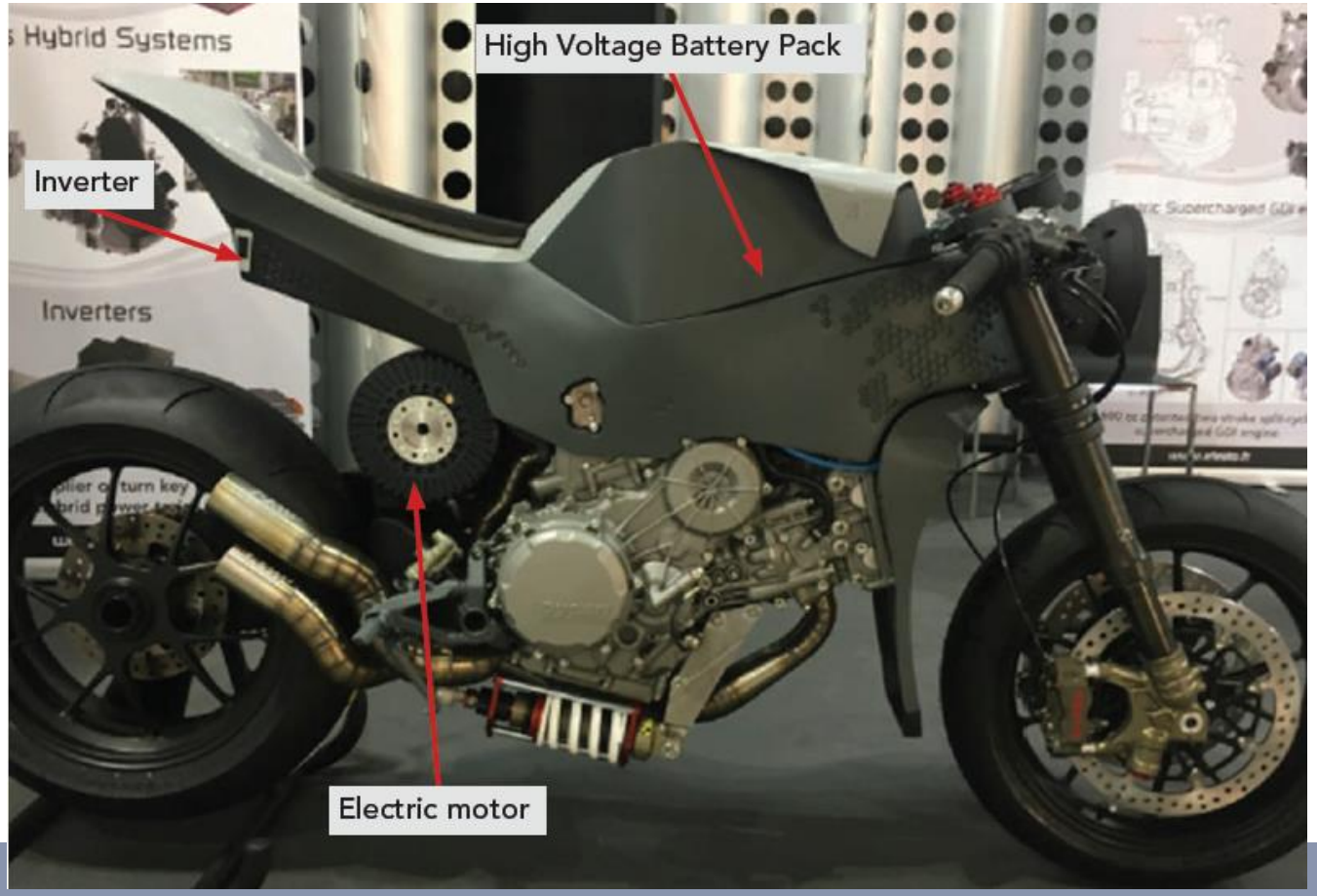
Efesto in collaboration with Diad Group (www.diadgroup.com) is developing the first ice racing prototype car with a parallel hybrid power train.

The DS3 prototype has 367 kW on the rear axis from the internal combustion engine and 200 kW on the front axis from the PMSM Emrax 268 electric motor(*). Total power 567 kW

(*) see tech specs at page 18

Ibex Quattro70 hybrid motorcycle

Presented at the EICMA show in Milan in November 2018, the Ibex Quattro70 features 225 HP (155 HP ICE + 70 HP electric motor) continuous power and 257,4 Nm (107,4 Nm ICE + 150 Nm electric motor) continuous motor torque .



Ibex Quattro70 hybrid motorcycle

Operating modes:
A mode-selector located on the handlebar allows using the bike in four different operating modes:

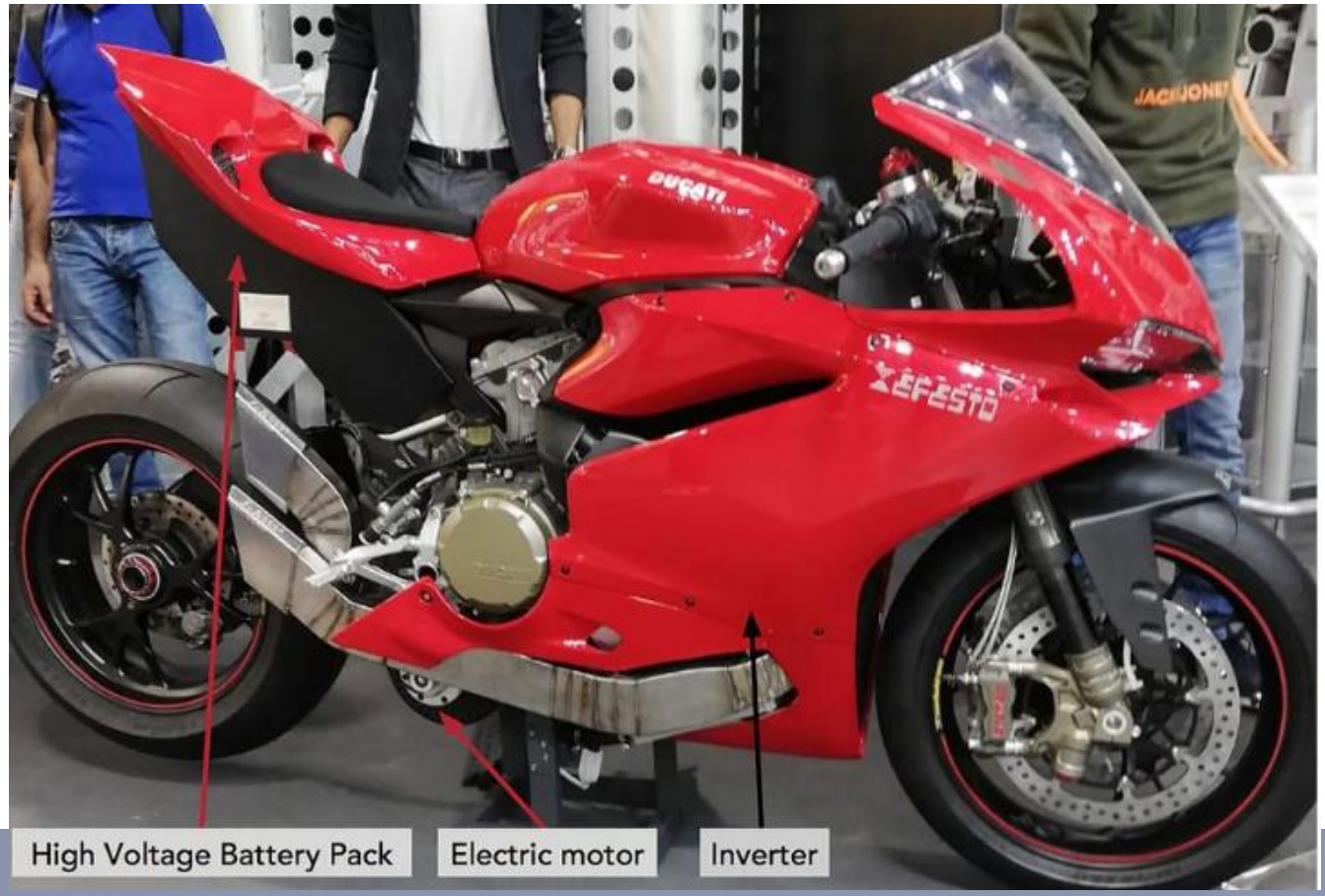
- **Pure thermic**
- **Pure electric (up to 70 HP)**
- **Boost mode**
- **Custom mode**

Patented anti-spinning and anti-wheeling electric control system
Patented counter rotating electric motor.

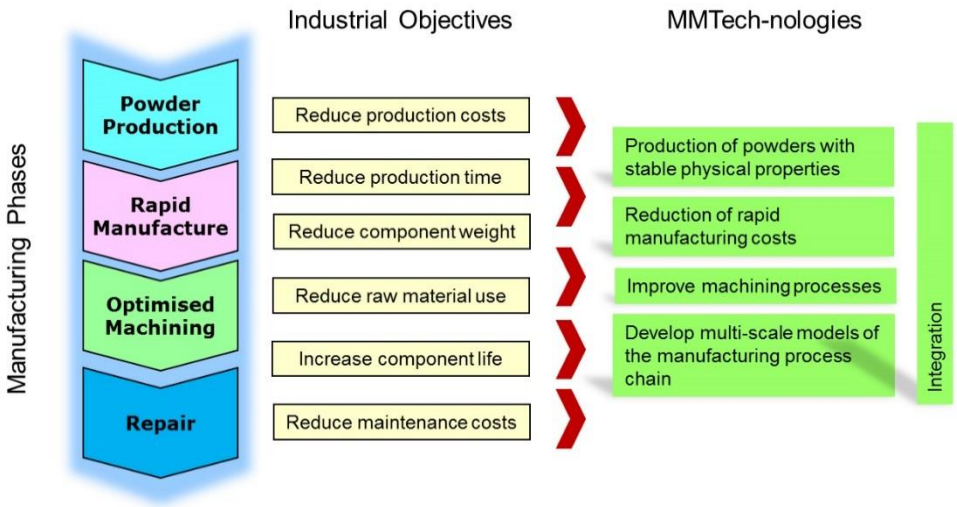
Total motorcycle weight 211 kg

Autonomy in pure electric 50-70 Km.

Unveiled at the EICMA show in Milan in November 2019, the Efesto 200NOVANTANOVE is the first functioning hybrid motorcycle ever presented. The bike features 300 HP (200 HP ICE + 100 HP electric motor) continuous power and 300 Nm (150 Nm ICE + 150 Nm electric motor) continuous motor torque .



During the project the most critical components of turbine and ICE will be produced in gamma titanium aluminides (γ-TiAl) by an additive manufacturing/milling process



A scientific approach based on the sustainable introduction of titanium aluminide alloy, γ-TiAl: a promising advanced material for aerospace applications.

Efesto is a core member of the Consortium MMTECH, a multinational coalition of enterprises focused on the development and application of a new generation of materials for high temperature applications (turbochargers, aerospace turbines, rockets). http://mmtech-nology.com/

The MMTech project is focusing on the development of technologies and methodologies which have the potential to save cost and time across the whole aircraft lifecycle, including design, production, maintenance, overhaul, repair and retrofit.

It will investigate the steps needed to certify the new technologies for use on planes.

The scientific target is based on the sustainable introduction of titanium aluminide alloys in the gamma phase, known as gamma titanium aluminides or γ-TiAl.

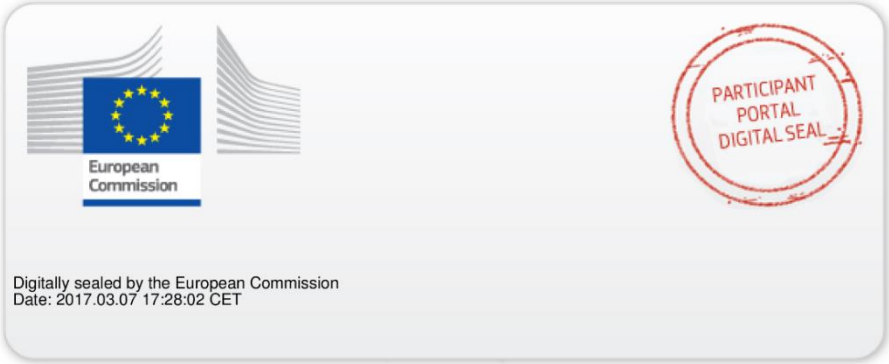
This is a promising material for aerospace (but also high-end automotive) applications because is performs well at the high temperatures found in engines and is lighter than the nickel alloys which are currently in use.

However, it is extremely brittle at low temperatures and so is hard to work with.

SKY'S THE LIMIT FOR THE HYBRID AEROPLANE

Efesto is a core member of the Consortium BLU-SPARK, an international consortium of enterprises developing, manufacturing and commercialising the first hybrid airplane and the most compact and powerful hybrid power unit module for light airplanes, conceived to be installed as retrofit kit in operative light airplanes, contributing to the overall reduction of gases emissions and offering to the customers unsurpassed flying safety, increased performances, fuel savings and emissions abatement. https://www.blu-spark.eu/

Certificate delivered by the European Commission,
as the institution managing Horizon 2020,
the EU Framework Programme for Research and Innovation 2014-2020



We remain at your disposal for any further information
You can join us at the following addresses: