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Electric, hybrid and hydrogen buses for public transport

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Abstract

Ept is a productive reality able to give a significant contribution to the research of innovative technological solutions for implenting safe and low emissions transportation systems. The value of ept's activity, the quality and the innovation level of its solutions, have caught the interest and the attention of many operators in its target market.

Electric, Hybrid, Hydrogen, Bus

1 Introduction

The company ECOPOWERTECHNOLOGY (Ept s.a.) was founded in 1999, with the aim of solving the current problems of air and noise pollution in downtown and communities Ept has made a big effort in developing and manufactoring low emission public transport systems. To accomplish the above said goal, Ept s.a. is involved in the following activities:

- Electric bus production.
- Hybrid bus production with a multi-fuel microturbine.
- Hydrogen bus production together with PROTON MOTOR (intentional project).

1.1 Strong point

Solid **know how**. Background of ept's engineers in their previous experiences in the following fields:

- **Robotics**.
- **FMS** (*Flexible Manufacturing System*).
- **FAS** (*Flexible Assembly System*).

Collaboration with californian and german companies inspired by the same philosophy:

- Research of innovative technologies to realize safe and low emisson transportation systems.

Ept belongs to a team of worldwide highly qualified companies involved in a constant R&D of innovative solutions. ept's team and solutions aim to win a tough challenge:

- To ensure mobility with the comfort and the performances of worldclass vehicle and the total respect of environment.
  No more dust, benzene, noise and bad smells.

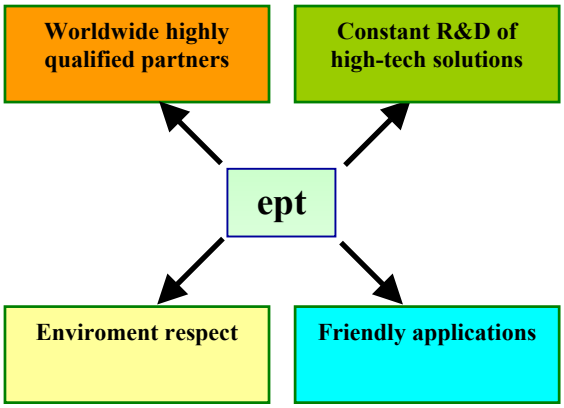

Figure1: Ept phylosophy

Ept's target markets are:

- Public Bodies
- Regional and Provincial Administration, munipalities
- National Park, Archeological sites.

2 The Torino Project

Since 16th June 2003 the STAR-1-LINE is working with pure electric buses. This line was born from the need and political will to connect 5 town parking areas to the heart of the city of Torino, in order to increase the use of public transport in the areas characterized by high traffic density, also considering the decisions of the town Government, to increase the number of roads included in the limited access area.
In the first phase of the line test (summer 2003), the buses could be used only by cardrivers who parked their cars in one of the parking areas included in the "park and ride system".
Since autumn 2003, under request by the citizens, the line is open to all passengers with a normal ticket; so even if the line maintains the shuttle function to connect the parking areas (drivers who use the parking areas travel for free on line STAR1), line STAR1 has become an integration and an alternative line to those already existing in the centre of Torino.

2.1 The Route Map of STAR1

The length of the line is almost 7 km one way. It is circular and crosses the town heart; along the line route we find important areas such as two hospitals, several universities, many museums, pedestrian areas, the Justice Palace and several touristic places. The terminals or headlines are next to the Justice Palace and new railway- and underground-station on one side and on the other side next to a hospital.

Figure2: Torino's Monuments

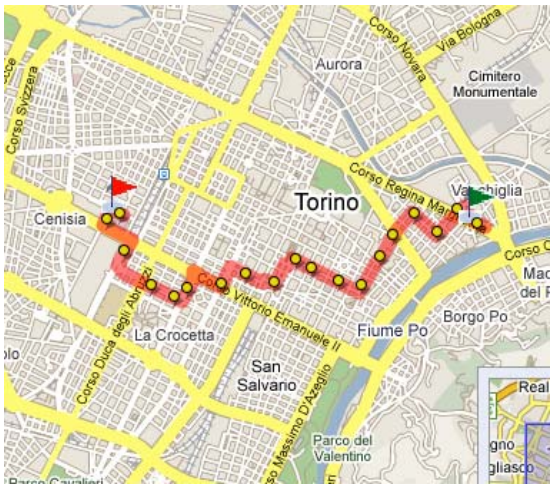

Figure3: Star1 path corso Regina Margherita (Ospedale Gradenigo) - via Cavalli (Palagiustizia)

Figure4: Star2 path corso Bolzano - corso Cairoli

Since 2008 because of the positive experience with line STAR1 the Municipality of Torino opened a second line through the centre of the city: the line STAR2 with the same items as STAR1 and intersecting the STAR1 and other important public transport lines.
The two lines form a flat cross with two diagonals across the city, each line is ca. 6 to 7 km one way.

23 electric buses are operating on these two lines from 7:00 to 20:00 with a frequency of about every 10 minutes a bus.

3 ELFO "The pure electric"

ELFO is a bus based on an electric traction system:

- Air riding suspension.
- Three phase asynchrony motor of 120 KW.
- Battery management system.

It offers:

- High driving comfort.
- Dynamic performance comparable to conventional buses.
- Monitoring of electrical parameter.
- High reliability (in Torino after 5 year operation more than 98%).

The outstanding peculiarity of ELFO is the innovative fast inductive method of charge.
The inductive power transfer (IPT) charge system, is provided to Ept by Wampfler, the German strategical partner.

The modern concept of automotive traction are characterised by:

- Zero Emission.
- High Energy Efficiency.
- Quiet operation.
- High Driving Comfort.
- Freedom of range as with internal combustion engines...

IPT Charge provides charging of batteries:

- Contactless intervention free.
- Power can be transfered across air gaps of several centimeters.
- Supply of electrical energy without any electrical or mechanical contact.
- Charging under all weather conditions.

ELFO can be **charged fast during its stops**, without requiring skilled workers and with a more effective routes management.

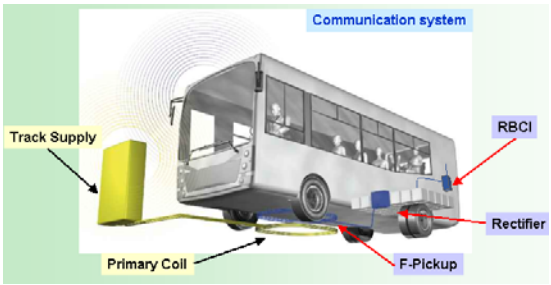

Figure5: Wampfler IPT Concept

Practically: ELFO parks on a platform and lowers on to a powerfull primary coil connected to the track supplier by feeding cables. A pick up rectifier unit is laid on the bus. Through the airgap between the coils occurs by induction the fast recharging of the batteries (5-7 min for 30 min drive).

3.1 Working principle

The energy transfer occurs without contact between one on the ground (Primary Coil) and one sensor (Secondary Coil or Pick-up) mounted on board the vehicle.
The primary circuit (Primary Coil) is fed with alternating current at high frequency (20kHz) by a Power System (Track Supply) with electronic control. On pick-up, when appropriately overlooking the primary circuit, it induces an alternating voltage. A rectifier device static (Rectifier) provides direct current to the batteries.
The power regulation is achieved by the Power System on the primary circuit to the ground, under the supervision of a unit on board the vehicle (RBCI - Remote Battery Interface Unit), interfaced with the unit BCU (see description Traction System) through the control signals (Pilot) and the data line (J1850), provided by the standard SAE 1772. It's always the unit BCU (Battery Care Unit) to determine the proper implementation of the charging profile.
Track Supply (ground) and RBCI (on-board the vehicle) communicate via a radio transmission system for short-haul.

3.2 BMS (Battery Management System) Software

The system BMS (Battery Management System), is software control of the batteries, which can monitor several critical parameters including:

- Diagnostic of batteries (voltage, charge, residual charge and temperature).
- SOC Forecast (according to the residual charge).
- Decrease of maintenance costs.
- Diagnostic and Repair of incidental faults.
- Optimization of traction driver system's performance as a function of the exploitations request.

3.3 Technical Items

Table1: Ept ELFO technical data.

Structure	Support shell in stainless steel with low floor	
Body	Stainless steel and fiberglass	
Outfitting	City bus	
Seating capacity	Seated Standing Service Total	11/14 30/27 1 42
Axles	2, the rear axles is the driving axle.	
Steering	Power steering ZF 8090 (1:15.2 ratio) with re-circulation.	
Suspension	Fully pneumatic with electronic control, kneeling.	
Wheels	17.5", twinned rear wheels.	
Tires	225/75 R17,5	
Brakes	Disk brakes, pneumatic-hydraulic command.	
Dimensions	Length Width Height Pass Minimum swing-out radius	7480 mm 2260 mm 2800 mm 3930 mm 7500 mm
Weights	Tare Fully loaded Maximum	7500 kg 10500 kg 11500 kg
Traction batteries	Lead-Gel, with regulation valve.	
	Rated voltage Capacity C5 Composition Cooling	336 V 180 Ah 56 x 6V 180 Ah in series Enforced air
Static converter	Three-phase vector inverter IGBT.	
	Incoming voltage Outgoing voltage Efficiency Cooling	250-450 Vdc max 120 kW > 95% with liquid
Electric engine	Three-phase asynchronous	
	Maximum power Continuous power Maximum torque Maximum speed Cooling	120 kW (162 HP), at 1800 rpm 65 kW 650 Nm, from 0 to 1800 rpm 7200 rpm With liquid
Reducer	Fixed ratio, integrated to the engine, with parking brake.	
Transmission	Propeller shaft	
Differential	5,57:1 ratio	
Auxiliary electric system	24V, negative grounded.	
	DC/DC Converter Batteries	100 A 2 x 12V 180Ah
On-board battery charger	6,6 kW, 230 Vac supplì.	
Performance	Fully loaded.	
	Maximum speed Maximum slope Acceleration 0-30 km/h Acceleration 0-50 km/h Specific consumption (at 30km/h)	70 km/h 22%, fino a 18 km/h 7 sec 18 sec 0,6 kWh/km

Figure6: Ept ELFO photograph

4 The Brescia Project

Brescia is an industrial city in northern Italy with a medieval centre. Buildings from the Celtic, roman and medieval time in white marble are characterizing the historical centre.

Figure7: Brescia – Piazza Loggia

The city government wanted a bus line connecting seven car parks, situated outside the city centre, to lead into the historical centre and heart of the city, which has reduced car access and partly pedestrian areas. The city of Brescia wanted buses which are noiseless, vibration free and very low in emission regarding dust in gram per horse power. This in order to preserve in the best way the historical patrimonies.

Figure8: Brescia – Castello

The city of Brescia ordered in 2000 four Ept hybrid buses with an electric engine and a micro turbine powered by methane.

5 HORUS the Hybrid bus with multi-fuel micro turbine

The concept is based on a pure electric bus by using just the electricity for the traction. A second component is the micro turbine which provides the necessary energy for the traction in sophisticated coordination with the batteries.

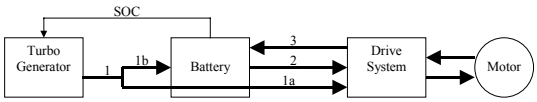

Figure9: Horus architecture

Just the batteries feed the traction till their loading status reaches a 75%. The micro turbine will switch on automatically by fulfilling two tasks at the same time: on the one hand they provide the energy directly to the electric motor; on the other hand they load the batteries till they reach a loading status of 90%. Having reached this stage the micro turbine will switch off automatically again and the bus will continue to run as a pure electric bus by just using the energy from the batteries.

An extraordinary battery management system with a high sophisticated software coordinate and check all the operations which happen between the batteries the micro turbine and guarantee a full automatic operation by providing the traction with energy.

Lowest emissions, noiseless and vibration free: with the new generation of these hybrid busses the emissions are kept very low and they are almost noiseless. Moreover these vehicles are extremely vibration free which may be important for historic buildings and ancient downtowns.

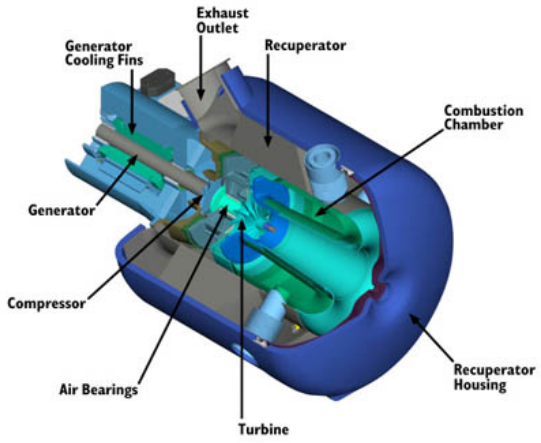

Figure10: Capstone Micro-turbine C30

Considering above advantages it is now possible to replace successively diesel busses from the urban environment with the hybrid busses which guarantee an ecologic environment, almost emission free and they prevent human beings from the stress of noise.

The micro-turbine (see figure 10) is a multi-fuel turbine which means that gas as CNG and LPG, biogas and diesel can run this engine. The advantage furthermore is that the emissions are very low as the fuel is burnt under such high temperature that almost all emissions are destroyed as well.

The micro turbine runs with 96'000 rpm (rotations per minute).

Table2: Horus emission g/bhp-h (gram/ british horse power-hour)

	Turbine fed by Diesel				*Turbine fed by LPG*				*Turbine fed by CNG*			
	Emissionen g/bhp-h				Emissionen g/bhp-h				Emissionen g/bhp-h			
	NO_x	HC	CO	PM	NO_x	HC	CO	PM	NO_x	HC	CO	PM
Horus	**0,75**	**0,3**	**0,4**	**0,01**	**0,53**	**0,42**	**0,18**	**0,004**	**0,26**	**0,42**	**0,41**	**0,004**
EEV	2,68	0,53	4,02	0,027	2,68	0,53	4,02	0,027	2,68	0,53	4,02	0,027

The above shown results are in comparison with the EEV norms, the HORUS is already according the norms Euro 5 – 6.

The model HORUS is a super-low-floor bus with a length of 8 m, 11 seats and 31 standing places () with an urban operating range of about 250 – 300 km, depending on road conditions, inclines etc., - an ideal City-bus for big cities with the possibility to reach the peripheral areas. The bus is also constructed in a version of 10.50 m length.

The acceleration from 0-30 km/h is 9 seconds, from 0-50 km/h 25 seconds at full load.

The maximum speed is 70 km/h.

The maximum incline reaches up to 19% at a speed of 13 km/h fully loaded.

The consumption at a constant speed in a flat urban environment of 30 km/h (without stop and go) is about 0,6 kWh / km.

According to ECE84 (Euro norms for diesel busses) the consumption was measured to 0,9 kWh / km. Both measurements were made with 2/3 of a full loading capacity.

Figure11: Ept Horus Photograph

6 HHORUS the hydrogen bus with electric engine and fuel cell

In cooperation with Proton Motor, Germany, the Ept hybrid bus is transformed in Hydrogen bus. The microturbine of the HORUS is replaced by a fuel cell. This fuel cell is powered by hydrogen and is recharching automatically the batteries when their load is under 75%.
The hydrogen is stored in 5 tanks of 148 l each under a pressure of 350 bar.
The bus is operating like the hybrid bus HORUS, starting as a pure electric bus (like ELFO). When the loading status of the batteries falls under 75% the fuel cell will upload the batteries.
We can imagine the HHORUS in a 8,00 m and 10,50 m version operating between Oslo and Stavanger on the "Norwegian Hydrogen Corridor", as well as at the Olympic Games in London, Great Britain, and in Soci, Russia.

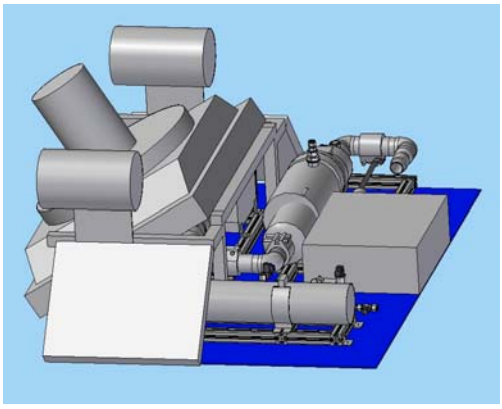

Figure12: Ept H-Horus System

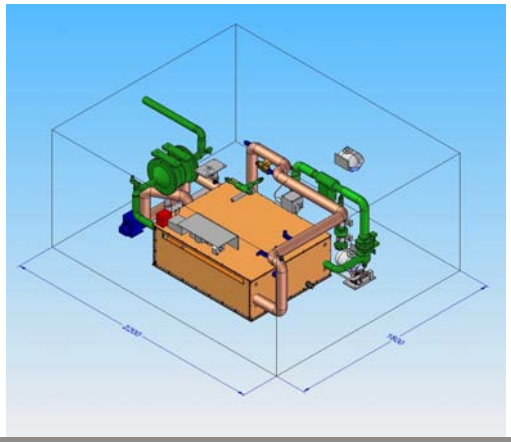

Figure13: Ept H-Horus FC detail

Figure14: Ept H-Horus project

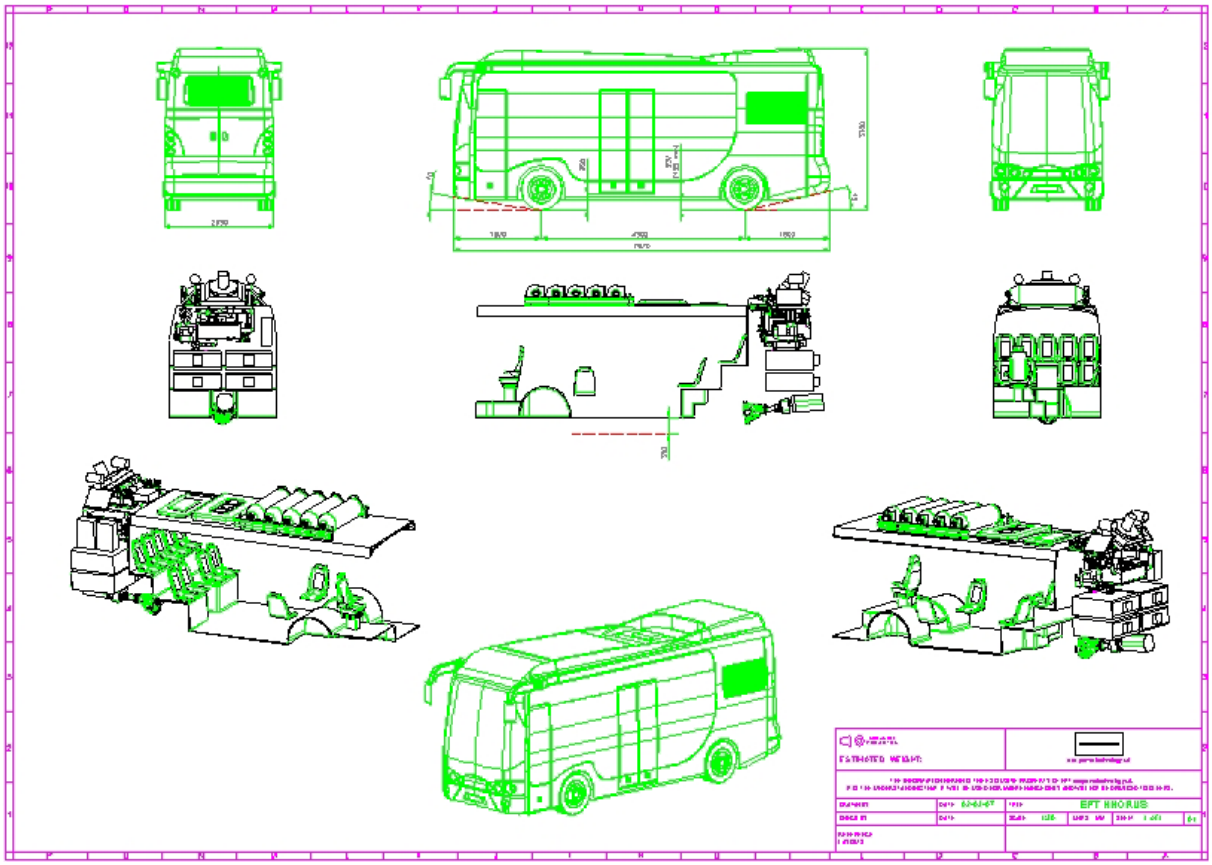

Figure15: Ept H-Horus technical design

Table3: Ept H-Horus main data

Dimension L x W x H	m	8,00 x 2,35 x 3,00
Passenger + Driver Including Seated	n° n°	45 12 (incl. 1 wheel-chair)
Rated power drive system	kW	65
Rated power fuel cells	kW	30
Max. speed	km/h	70
Max. gradeability	%	19
Battery buffer		Gellified lead
Hydrogen storage		5 x 148 lt @ 350 bar
Autonomy	km	> 250

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