P-MOB

Integrated Enabling Technologies for Efficient Electrical Personal Mobility

7 Partners, 4 Member States:

CRF	Centro Ricerche Fiat (IT)
MAZEL	Mazel Ingegneros (ES)
Integra	Integrare (IT)
USFD	University of Sheffield (UK)
SIE	Siemens (DE)
Polimodel	Polimodel (IT)
MGM	Magnomatics (UK)

Instrument: STREP **Duration: 3 Years**

Support: 2.788 M€

CRF CENTRO RICERCHE FIAT · MAZEL GROUP · INTEGRA.re renewable energies · The University Of Sheffield. · SIEMENS · POLI MODEL · Magnomatics

Problems and Objectives

Problem

- ❑ EU: 80% of the population live in cities
- ❑ World:> 50% living in megalopolis
- ❑ Urban congestion primarily due to large vehicles with a single occupant on board
- ❑ Cost - energy consume – noxious emissions – GHG – raw materials
- ❑ New competition of a world already moving electrically

Objectives

Safe and ergonomic small vehicle addressing personal mobility needs having:

- ❑ Distributed powertrain solutions (optimisation of the drive train as a whole)
- ❑ Ultralight structure
- ❑ Advanced aerodynamic solutions
- ❑ V2G+I technologies
- ❑ On board solar cells
- ❑ state of the art ICT technology for energy flow management and connectivity.

Needed Power to drive an ideal vehicle

$$P_{total} = \underbrace{P_{kin} + P_{grade}}_{\text{Partial Regeneration}} + P_{air-drag} + P_{friction}$$

$$P_{kin} = d(KE)/dt = d(1/2Mv^2)/dt = Mav$$

M = mass of vehicle

$$P_{grade} = d(PE)/dt = Mgv\sin q$$

Sinq = inclination of road

$$P_{air-drag} = \tfrac{1}{2}\rho C_x S v^3$$

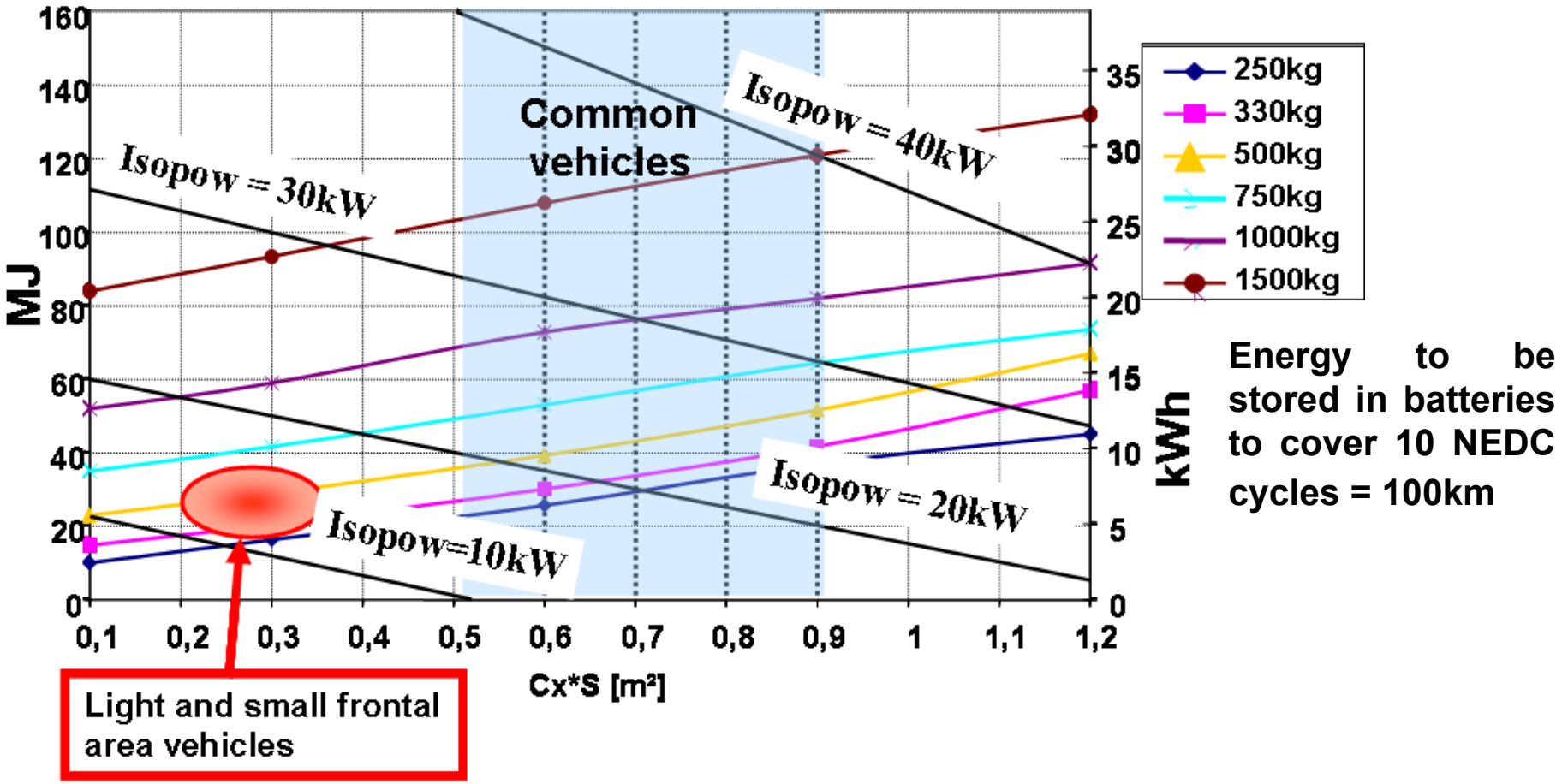
ρ=air density, **S = frontal area,**
Cx= aero resistance

$$P_{friction} = \mu Mgv$$

μ=Tyre Rolling Resistance,
v =velocity, g = acc.gravity

Internal losses PWT + 4 parameters to control: Mass, frontal area, aero drag, TyreRR

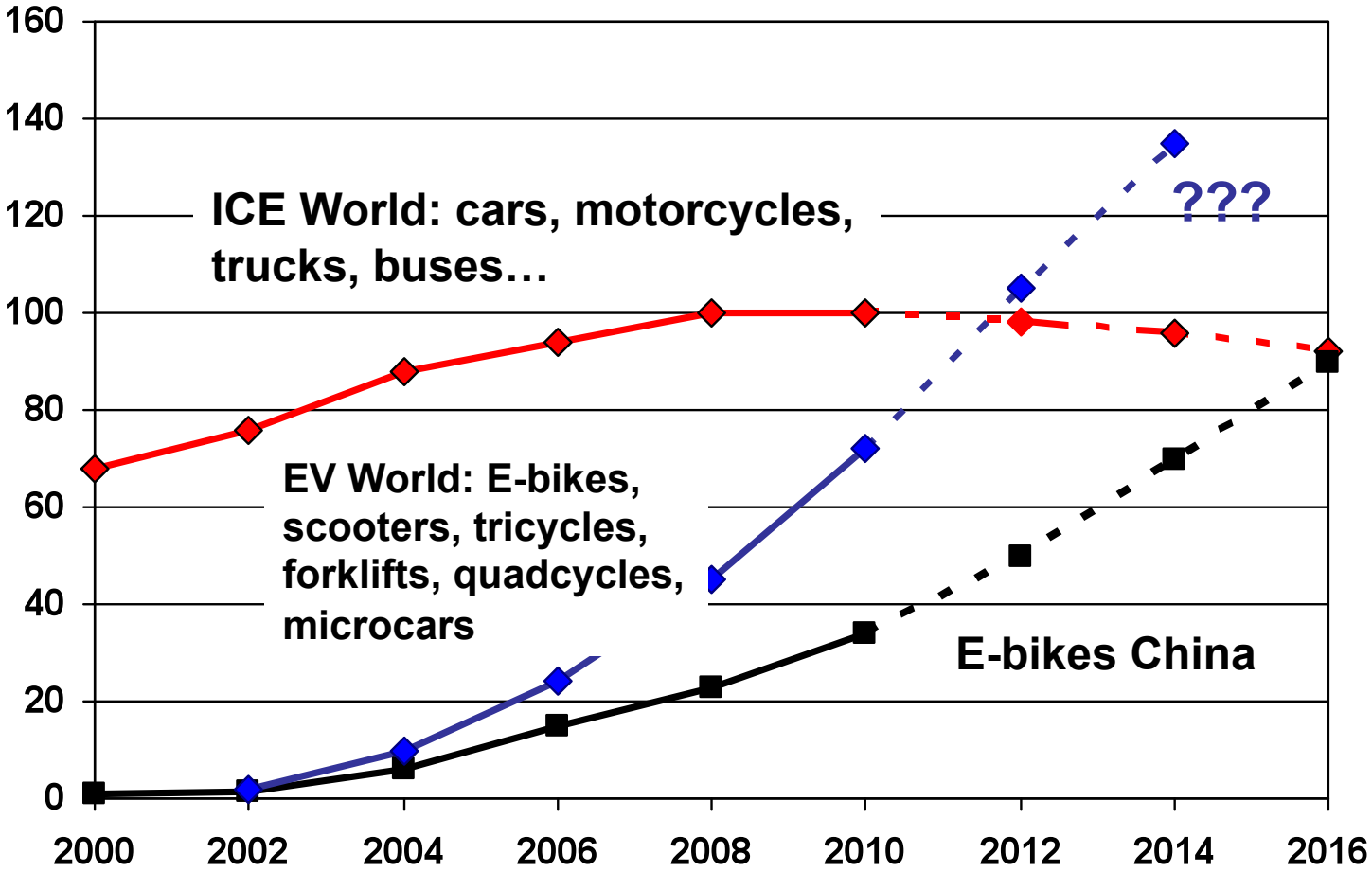
Small frontal area and low aero-drag



Energy to be stored in batteries to cover 10 NEDC cycles = 100km

An Isopower line is the total nominal power required at the e-motors to reach 120km/h of the NEDC cycle (note: peak power is 2-3 times the nominal power).

A world already moving electrically!



ICE cars continue to increase, ICE motorcycles already decreasing. By 2020 > 2 Billion motor vehicles (two-wheels, cars, trucks) on the roads. By 2020 the production of E-means is likely to reach 200 millions/year!

Energy per typology of EV

Type	LEVs (E-Bike) Speed limit	LEVs (other) Speed limit	Micro Cars NEDC	Small Cars NEDC	Mid size Cars NEDC	Large Cars NEDC
Weight kg	20-50	50-300	300 -700	700 -1100	1100-1500	1500-2000
Energy kWh/100km	1-2	2-3	4-9	9-12	12-18	18-25
Kg/100km of Li-ion battery pack level (180Wh/kg)	6 -11	11-17	23-50	50-67	67-100	100 -139

Sales of LEVs (e-bicycles, e-scooters and other two-wheelers) is already driven by lower purchase prices, low cost of operation and lack of harmful emissions.

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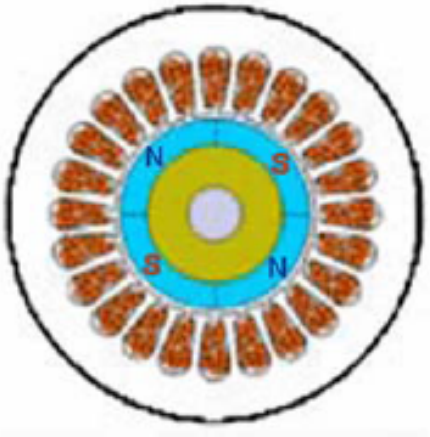
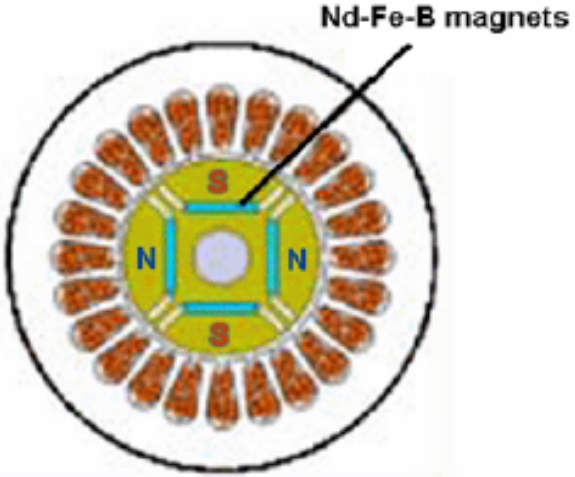
The new focus is on micro and small cars!!

PM for more efficient motors

Surface Permanent Magnet

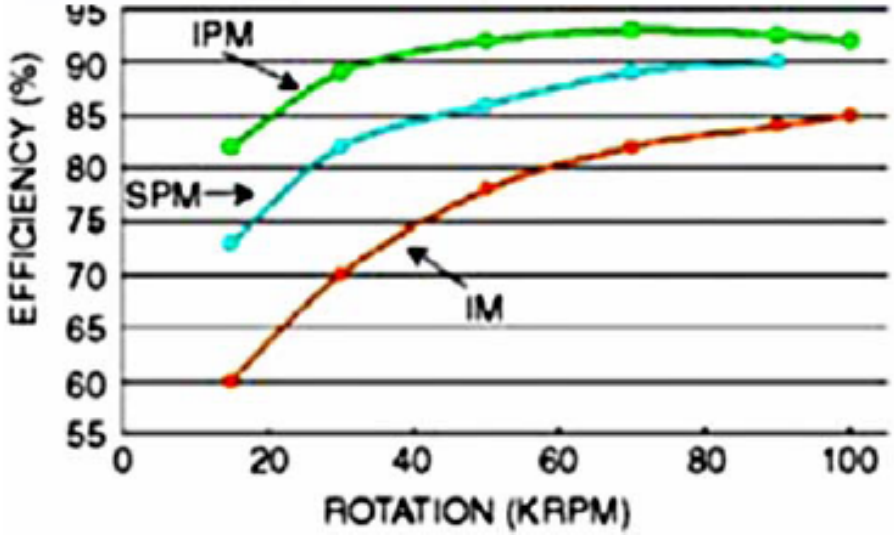


Interior Permanent Magnet



- High-performance Nd-Fe-B sintered magnets are playing an increasingly important role in automobile and electric appliances driven by the issues of energy saving and efficiency.

- In an *air-conditioner compressor motor* Inserted permanent magnet rotor has better efficiency than a surface mounted rotor.



Y. Matsuura. *J. Magn. Magn. Mater.* 303 (2006).

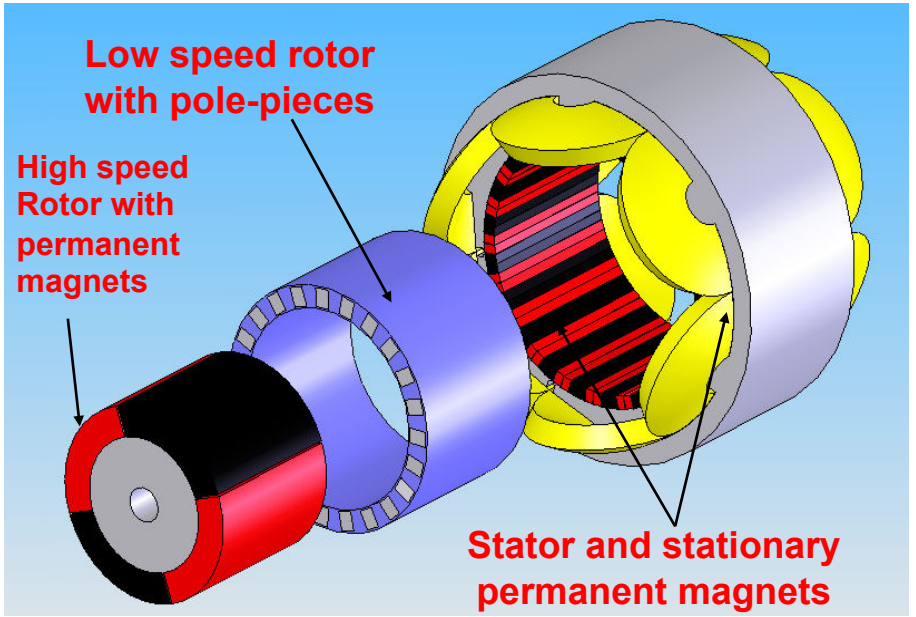
P-MOB: Motor innovation

Electric drives based on PM design with integrated gearing and integrated electronic drive

High torque, low speed at wheel

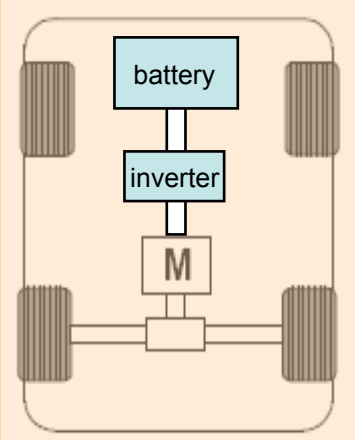
To reduce gearing and improve drive train efficiency, torque density has to be significantly increased.

The novel pseudo direct-drive PM machine integrates a “magnetic gear” in the machine and hence increases torque density by a factor of (4~10)



Univ.Sheffield-Magnomatics

Problems of conventional EV Power train

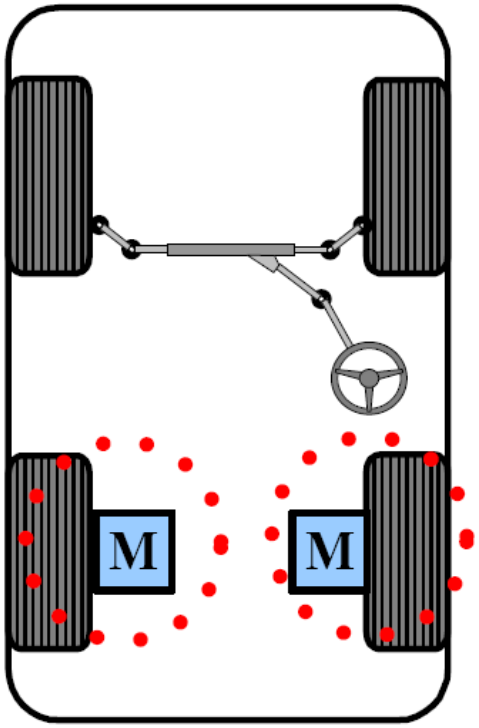


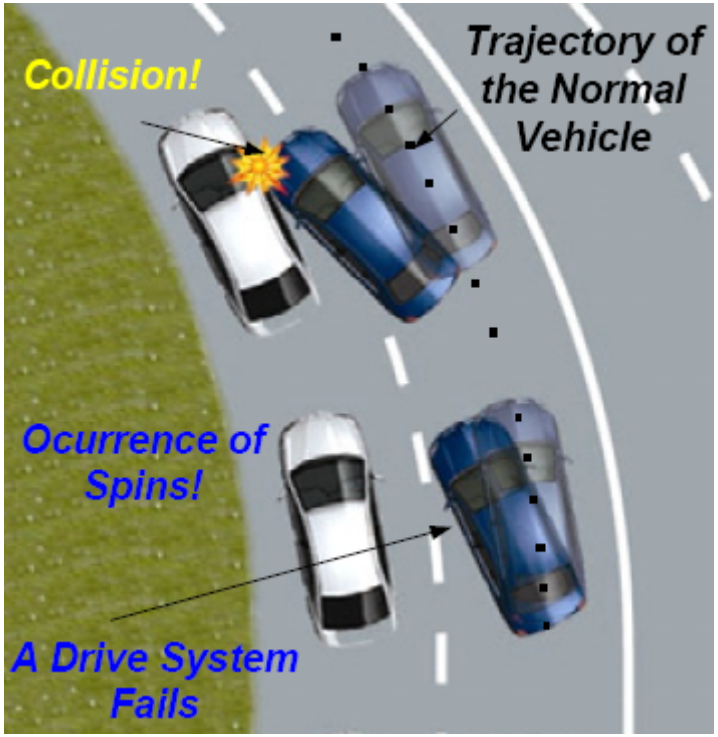
- Centralised mass distribution affects vehicle dynamic performance and constitutes a safety concern.
- Transmission losses in cables and gear box reduce the system efficiency
- Cable weight increases the total vehicle mass which in turn increases power rating of the propulsion system.
- High EMI pulses due to dynamic peak current produce interference to control electronics and pose a serious threat to their operation.
- Unshielded low frequency electromagnetic field may cause health hazard to passengers.
- Single point failure will lead to complete loss of traction power, and potential accidents
- High DC-Link voltage increases the cost and complexity of the energy storage, reduces their efficiency and reliability and further deteriorate EMI as voltage stress and dv/dt increase

And Low efficiency, complex and costly cooling

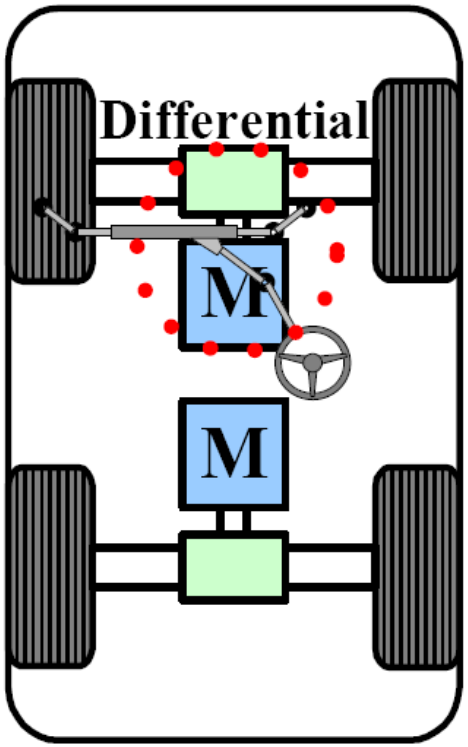
Two motors EV Power train

- Distributed front or rear in-wheel drives can alleviate some problems of centralised power train architectures, **but safety becomes a serious concern**
- In the event of a single drive failure, a spin centred around failed drive may induce accidents
- Traction torque cannot be distributed in the front and rear wheels according to the weight shift during acceleration and braking





Fail-safe power train architecture



The distributed traction system for next generation of EVs can be made fail-safe. The key features of the fail-safe scheme are:

Inherently fault-tolerant ---- failure in one drive will not significantly affect the vehicle performance

Fail-safe --- no spin or complete loss of power will take place

Freedom in distribution of traction torque according to weight shift, --- further improvement in traction efficiency

Moderate high efficiency in energy recovery

Improved traction control on low friction road and safety enhancement

On-board “Smart” Photovoltaic

Conservative average daily energy produced by on-board solar cells in Torino* with existing technologies could be as much as 1.8 kWh/day (657 kWh/year).

Mid size EV 657kWh/(150Wh/km)= 4380 km/year

Small size EV 657kWh/(130Wh/km)= 5053 km/year

Micro EV 657kWh/(80Wh/km)= 8212 km/year

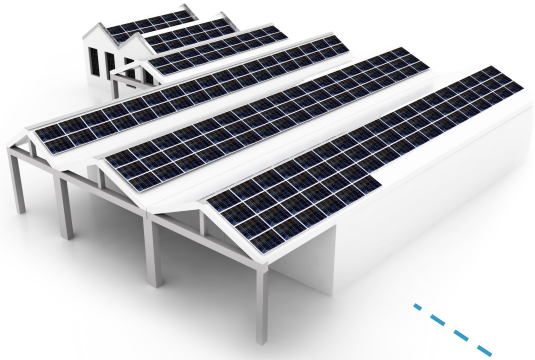
*Average annual insulation 3.8kWh/m^2/day

The Goal is to produce > 2kWh/day on the annual average insulation of South Europe 5kWh/m^2/day.

P-MOB: V2G+I

Wind Plant

PV Plant



PV House

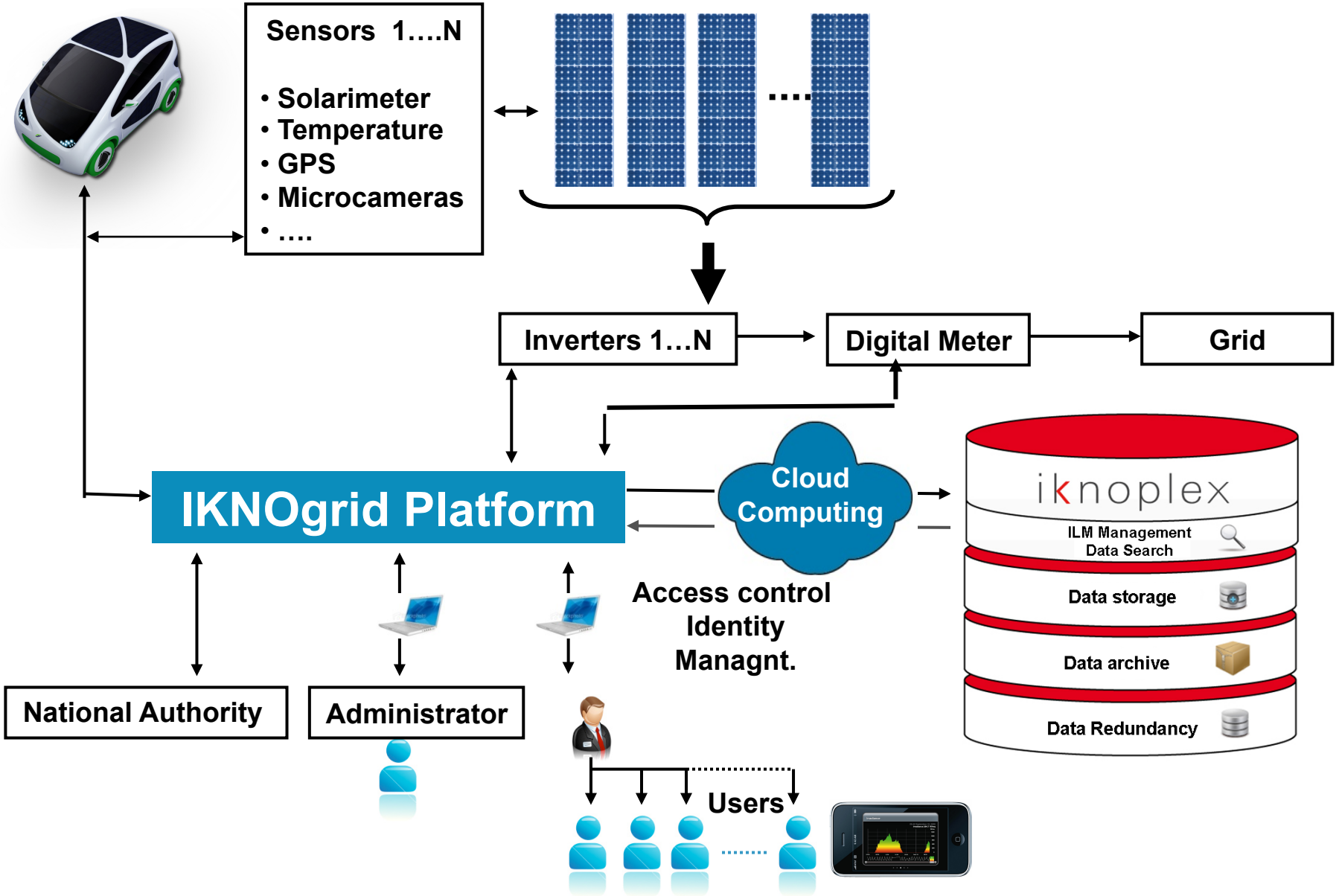
E-Car

Remote Control System

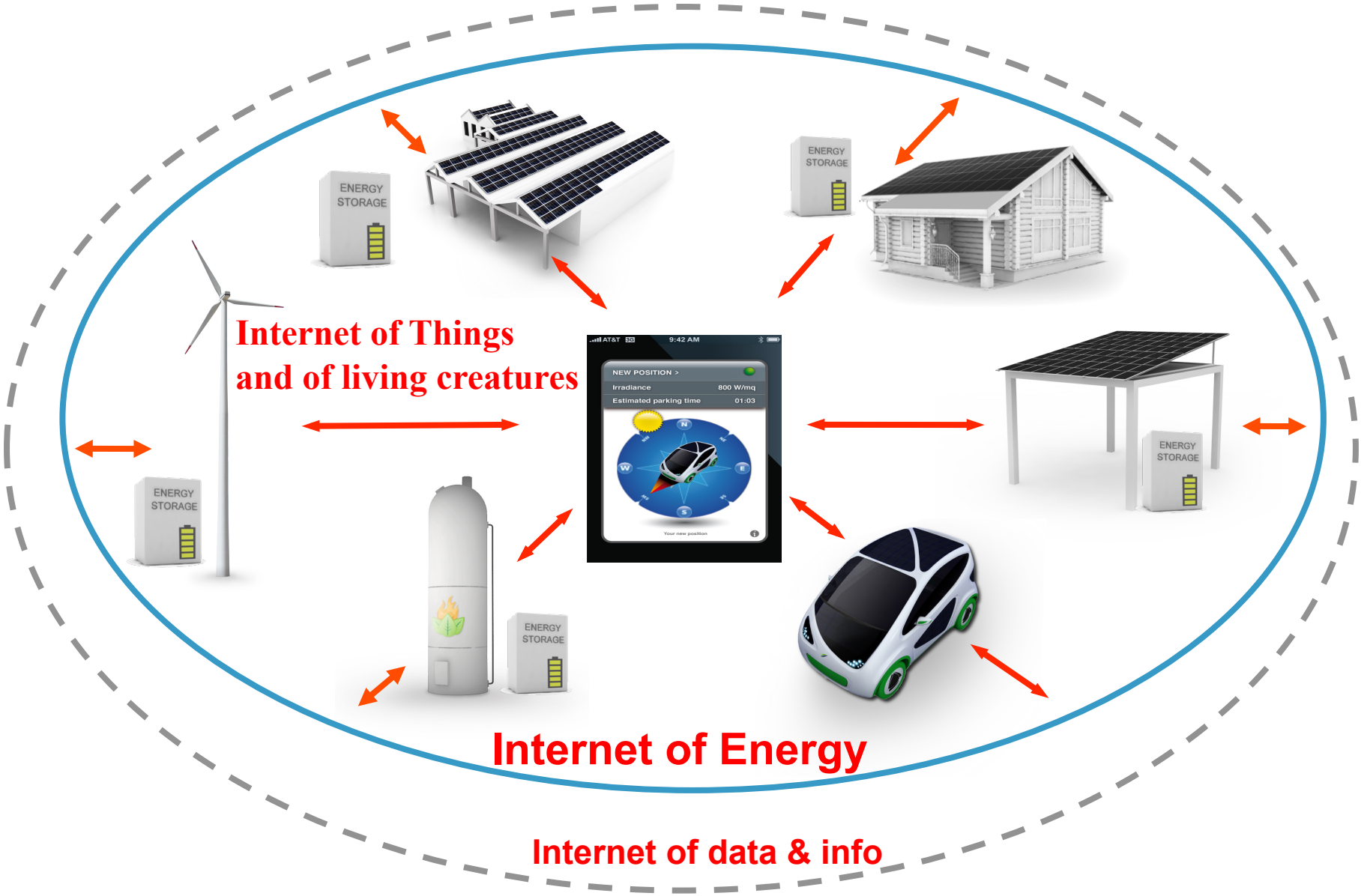
On computer

On a smart phone

Architecture



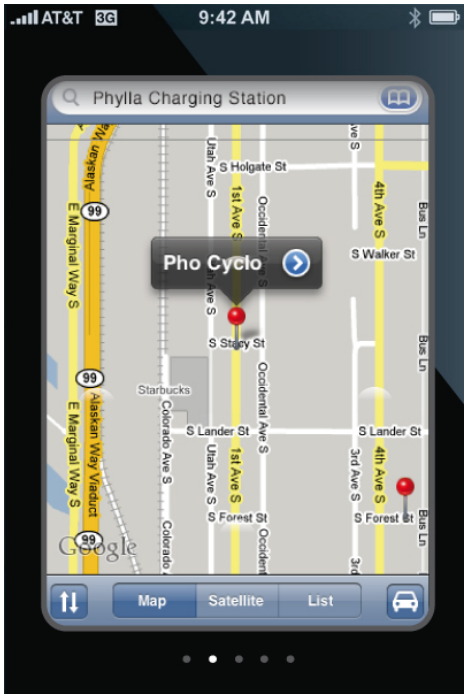
V2G+I: Web Centric Embedded Platform

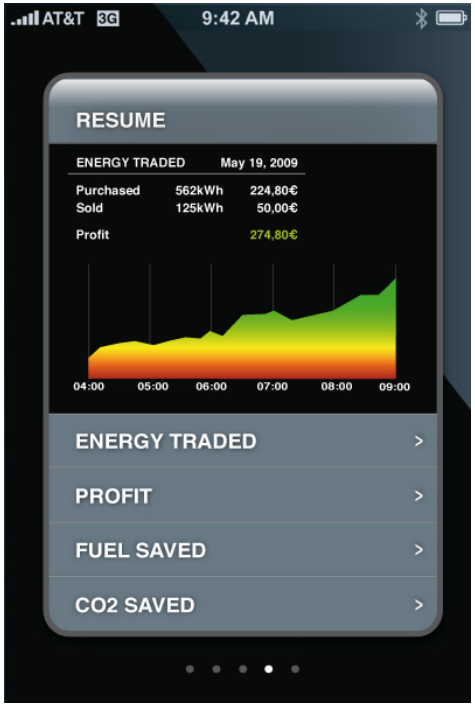


CENTRO RICERCHE FIAT

P-MOB: V2G+I

INTEGRA re renewable energies





P-MOB Project: Workpackages

WP n°	Work package title	Type of activity	Lead participant	Other participants
1	**Detailed specifications**	MGT	**CRF**	all
2	**E-vehicle structural parts development**	RTD	**Polimodel**	Mazel,CRF
3	**Photovoltaic Integration**	RTD	**Integrare**	CRF, Polimodel, Mazel
4	**Electrical drive train**	RTD	**U.Sheffield**	CRF, Mazel, Magnomatics, Polimodel
5	**Vehicle to Grid integration**	RTD	**Siemens**	USFD, CRF, Integrare
6	**Vehicle assembling and testing**	DEMO	**Mazel-CRF**	CRF, POLIMODEL, Siemens, USFD, Integra
7	**Life cycle analysis**	RTD	**CRF**	All
8	**Project management**	MGMT	**CRF**	All

P-MOB : Summary of expected outputs

The project addresses the design and development criteria of EVs basic building blocks such as:

- Overall system optimisation **based on two PM motors** for enhanced efficiency of the Drive train,
- **Implementation of Advanced V2G+I**
- **On board V2G multifuctional charger for V2G**
- **Low weight and aerodrag** body,

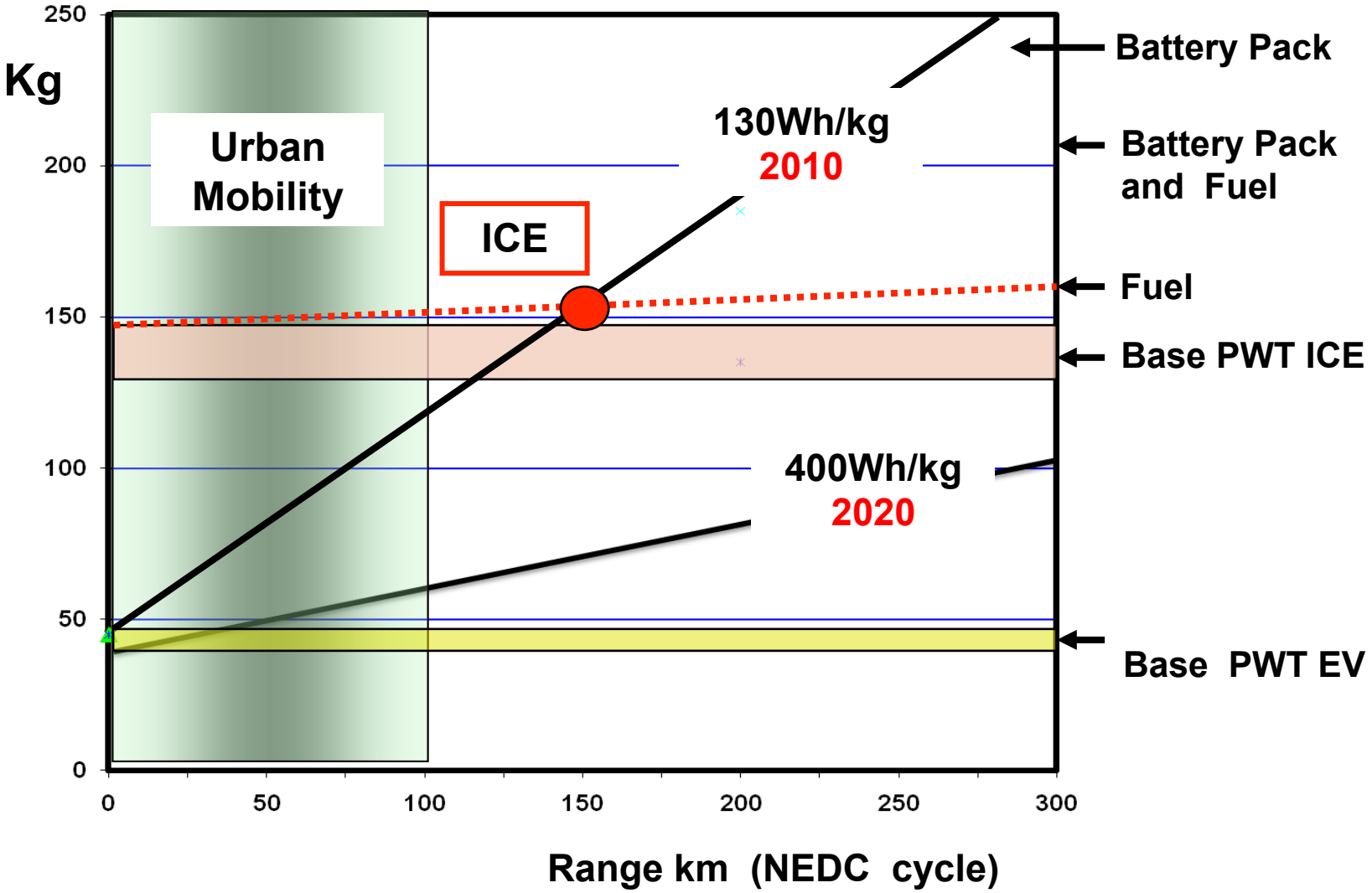
- **Solar panels distributed on both horizontal and vertical surfaces** with smart adaptive electronic for a continuous optimization of the output under shadowing

- Solar output to battery load optimised adapting coupling

- **Finalisation** trough a demo vehicle for urban mobility integrating the proposed concepts.
- Guidelines, IPR and experience upon which to build a world-leading EU position to track and exploit the global uptake of FEV mobility.

Weight of PWT: system to system comparison

1000kg car



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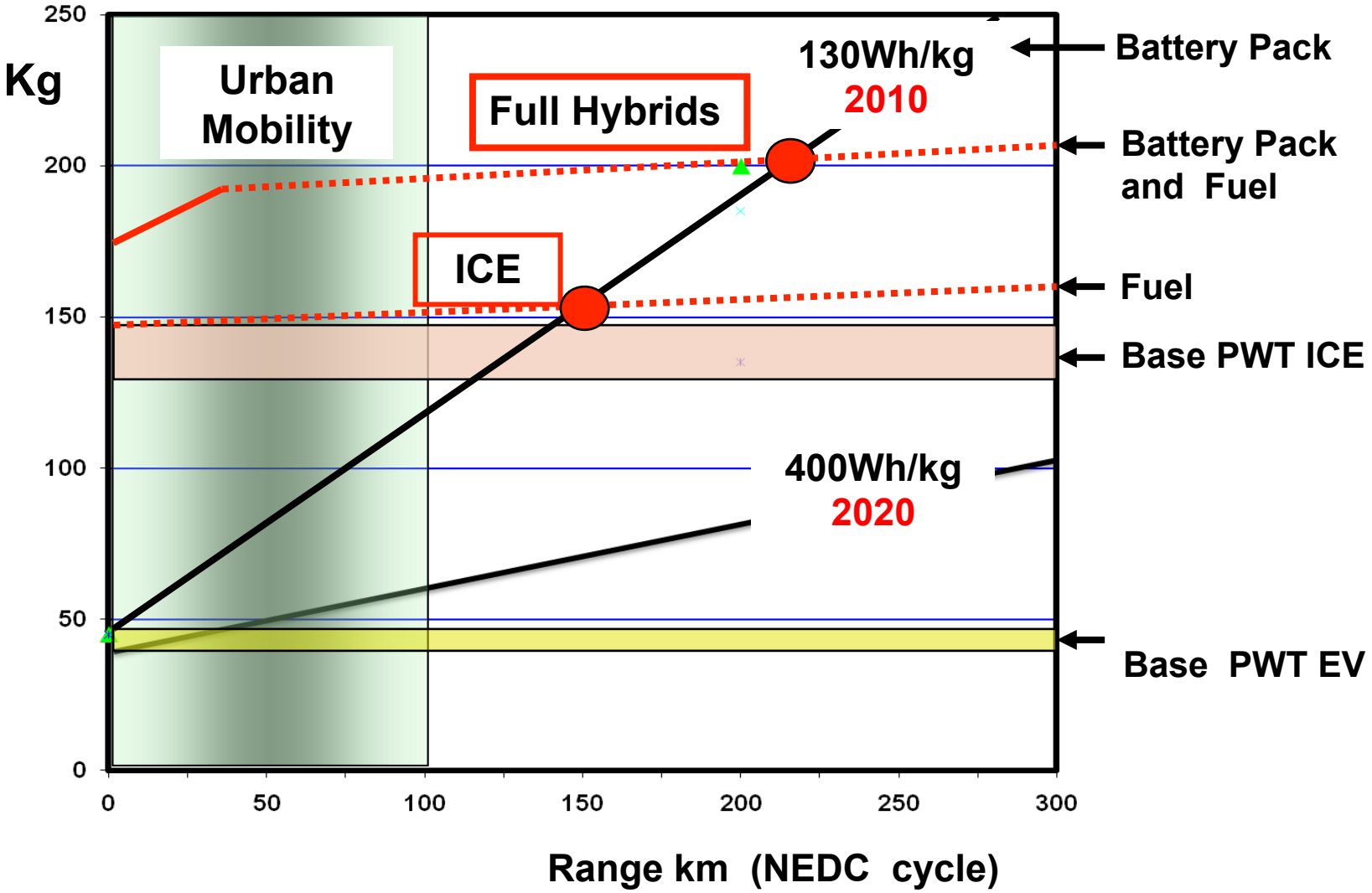
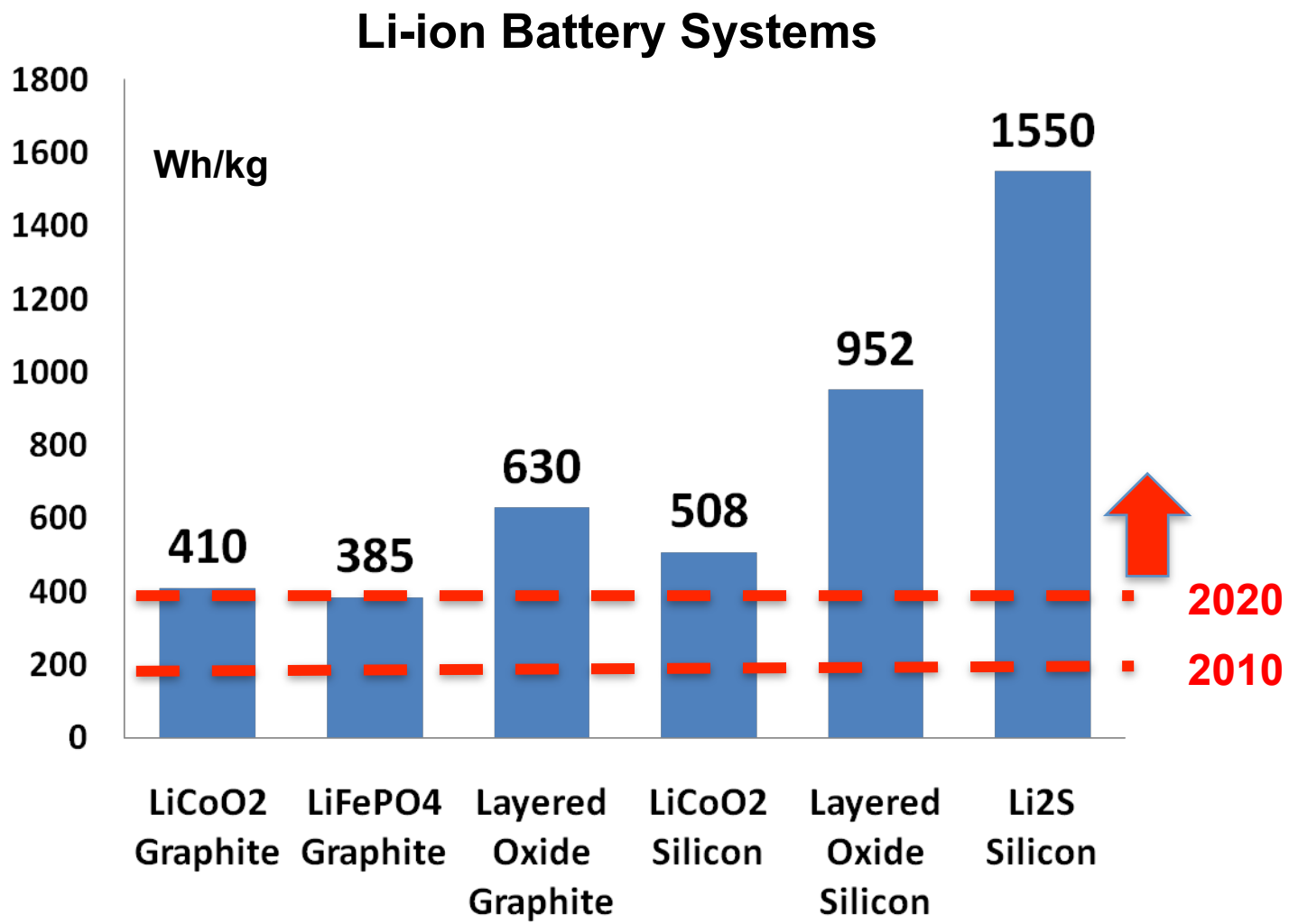




Comparison of theoretical specific energy for different types of Li-ion batteries.

Nanostructured Lithium Sulfide/Silicon demonstrated at 600Wh/kg. ACS, Yang. **Nanostructured SnC/Li_2S demonstrated at 1100Wh/kg Scrosati, Rome.**

P-Mob does not need a Range Extenders

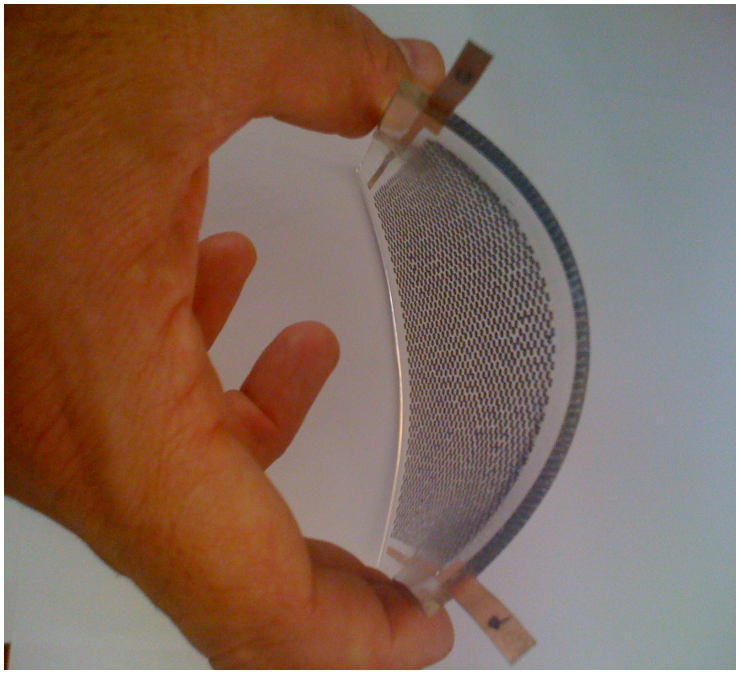
Type Use	Micro 400-700 kg	Small 700-1200 kg	Mid 1200-1500 kg	Large 1500-2000 kg
2010 Urban mobility	No RE	No RE	No RE	2-5kWe Can avoid RE
2010 *Long range	No RE	2-5kWe RE Can avoid RE	****5-10 kWe RE**	****8-20 kWe RE**
2020 Urban mobility	No RE	No RE	No RE	No RE
2020 Long Range	No RE	No RE	2-5 kWe RE Can avoid RE	****4-10 kWe RE**
2030 Long Range	No RE	No RE	No RE	2-5kWe RE Can avoid RE

With a RE the hypothesis is that the peak power is delivered to the wheels from the accumulators and that the RE charges the accumulators at a quasi constant regime.

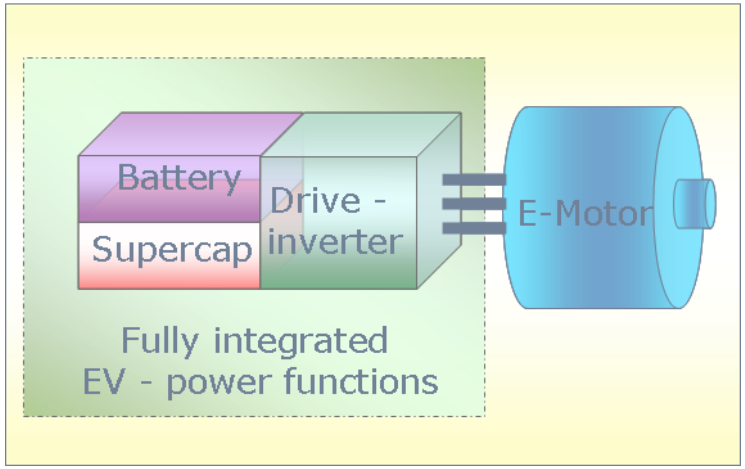
* Long range is intended > 200km (for Micro EVs < 200km). E-cars have already been demonstrated with a range >400km with a single charge without RE. The RE is intended to reduce the overall cost of the PWT and time of recharge.

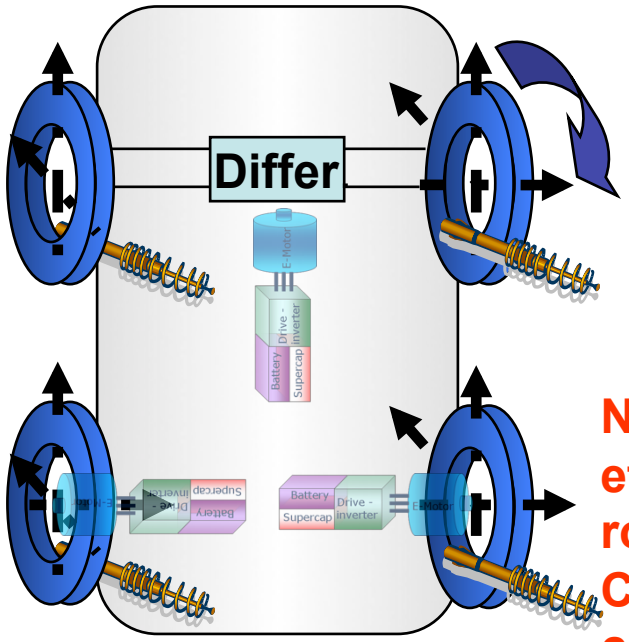
** In competition first with full hybrid than with Plug-in full Hybrids.

Low weight and low cost flexible materials for both Silicon crystalline and thin film PV technologies



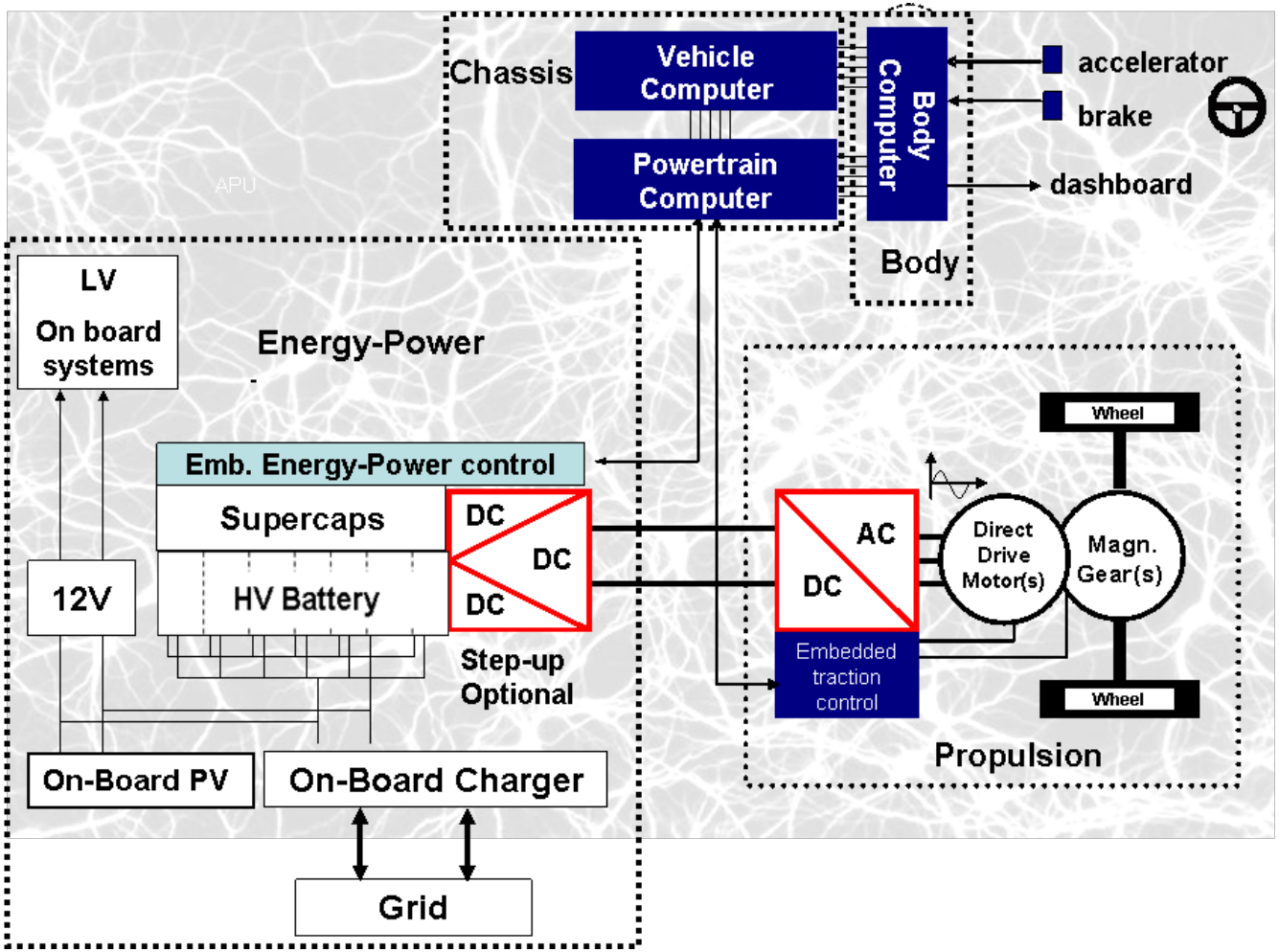
Three motors and Modular traction unit





- Modular traction unit will be a key building block of EV power trains
- Development of high power dense, highly reliable and highly integrated traction drive unit capable of high efficiency over wide operating range is fundamental and key to realisation of advanced EV power train architectures
- Modularity and flexibility for different markets and products
- Mass production and standardisation help improve product quality and reliability, and reduce cost

No liquid cooling necessary. Fail safe, high efficiency on energy recovery, high mechanical robustness, simplified control algorithms. Convenient solution for micro, small and midsize cars competing in cost with the four wheels drive (without differential).


Chassis
Vehicle Computer
Powertrain Computer
Body Computer
accelerator
brake
dashboard
Body
LV
On board systems
Energy-Power
Emb. Energy-Power control
Supercaps
HV Battery
DC
DC
DC
12V
Step-up Optional
On-Board PV
On-Board Charger
Grid
AC
DC
Embedded traction control
Direct Drive Motor(s)
Magn. Gear(s)
Wheel
Wheel
Propulsion