International Workshop on Energy Storage in the Grid
Low, Medium and Large Scale Requirements

Barcelona, 8th - 10th January 2014

EV-Grid Concept

Electrical Architecture & Technologies, research tools

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Photographies Source: INRETS, IFSTTAR

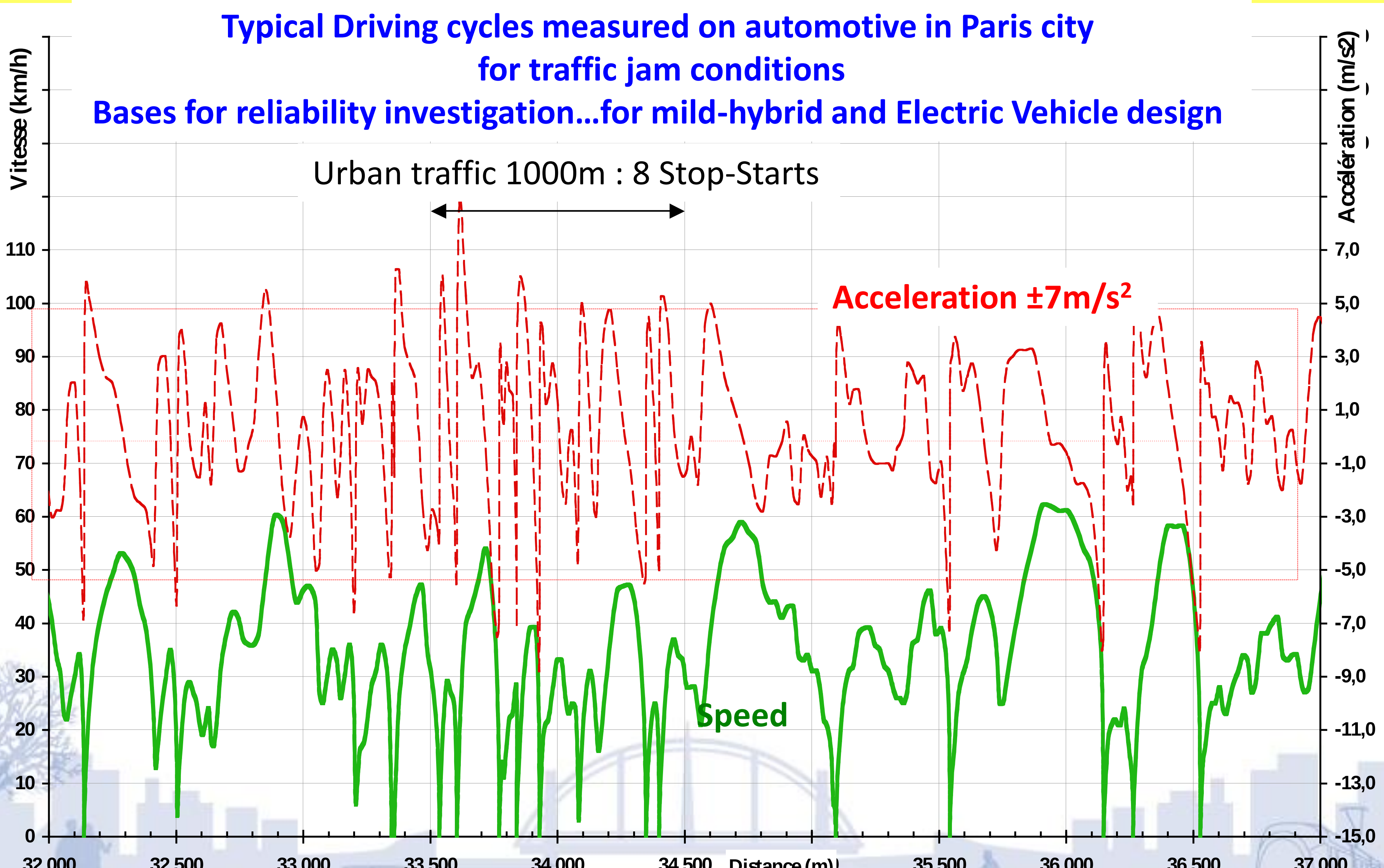
Contents

Synergy between Renewable Energy and Transportation Systems

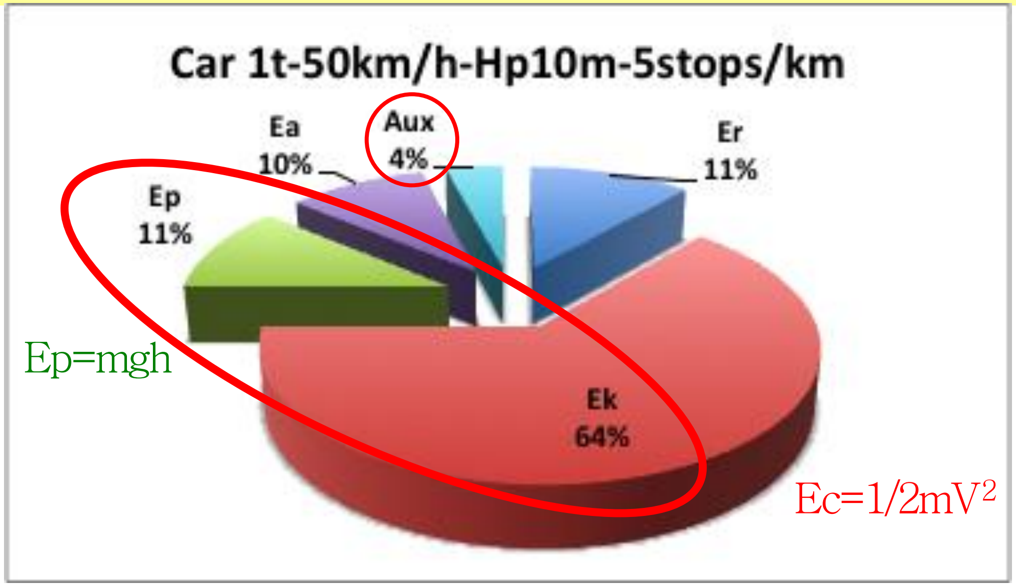
- Reduce energy consumption and pollutant emission

- Increase efficiency, reliability, durability and service quality

Why Energy Storage System
Automotive driving in urban mission profile

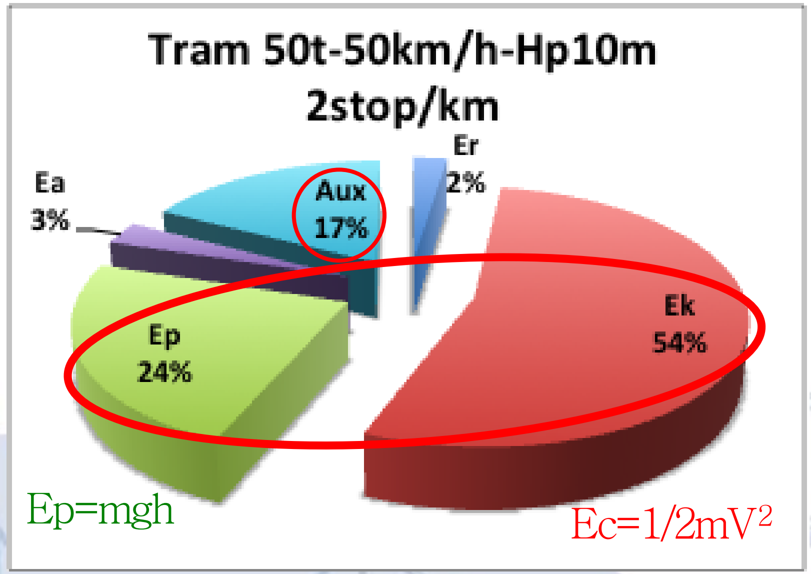


Energy in City Mobile applications: Kinetic & Potential Energy



Car energy consumption
in traffic city:
120Wh/km if 1 stop/start/km
244Wh/km if 5 stop/start/km
50 to 75% can be saved in theory
30 to 50% could be in practical
by using regenerative braking
(Leaf EV data: 155-212Wh/km)

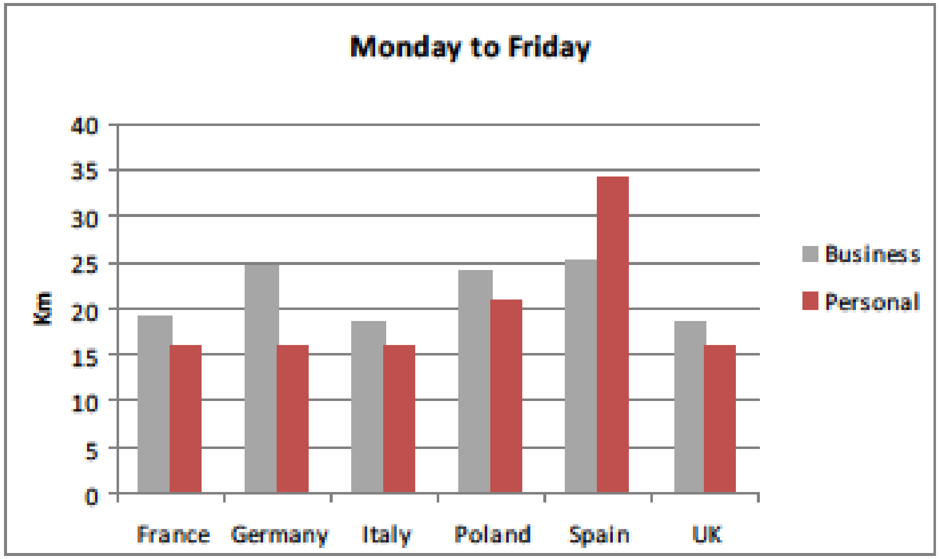
Energy comsumption: $\sum E = R.V + D.V^2 + 1/2mV^2 + Mgh + Aux.\&Comfort$

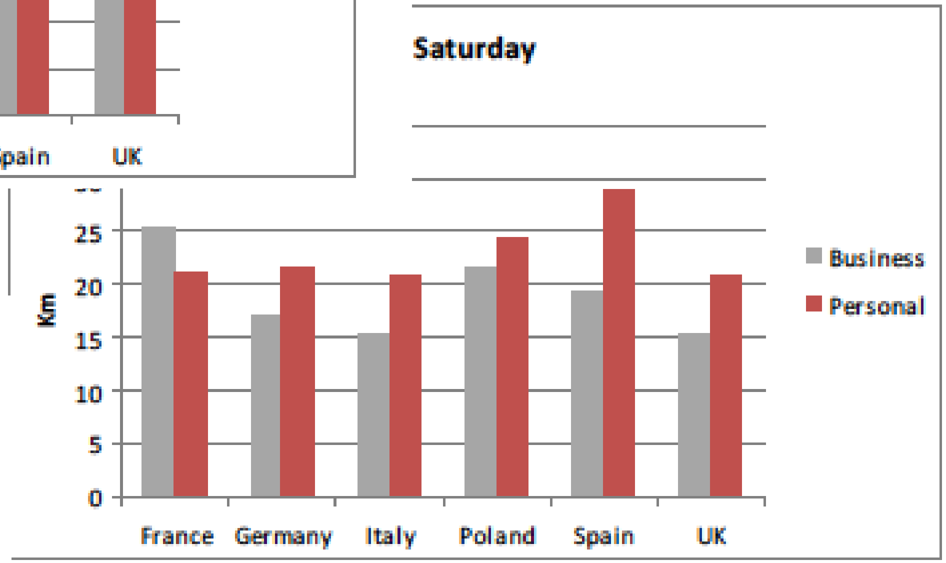


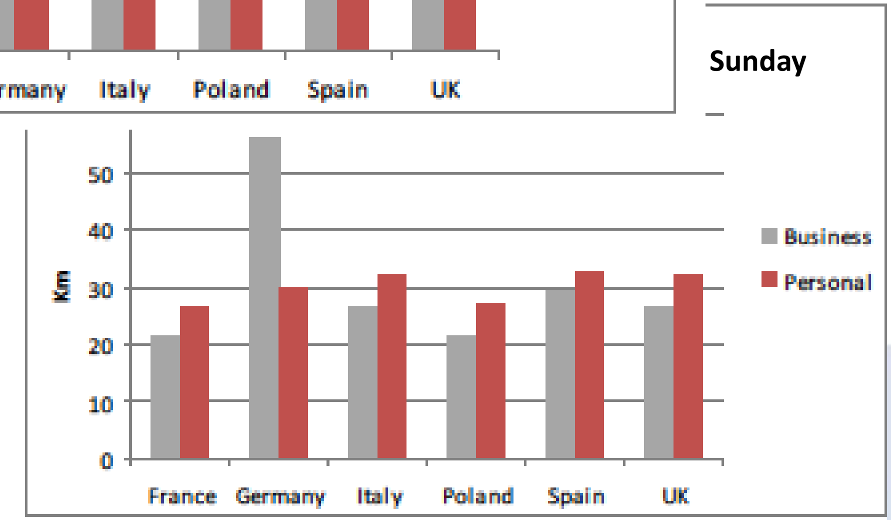
Tramway energy consumption
in traffic city:
5,8kWh/km if 2 stop/start/km, 10m elevation
75% can be saved in theory
about 40% in practical
by using regenerative braking

Average trip distance (kms) By trip purpose

Source: Driving & parking patterns of EU drivers a mobility review, JRC-EU2012







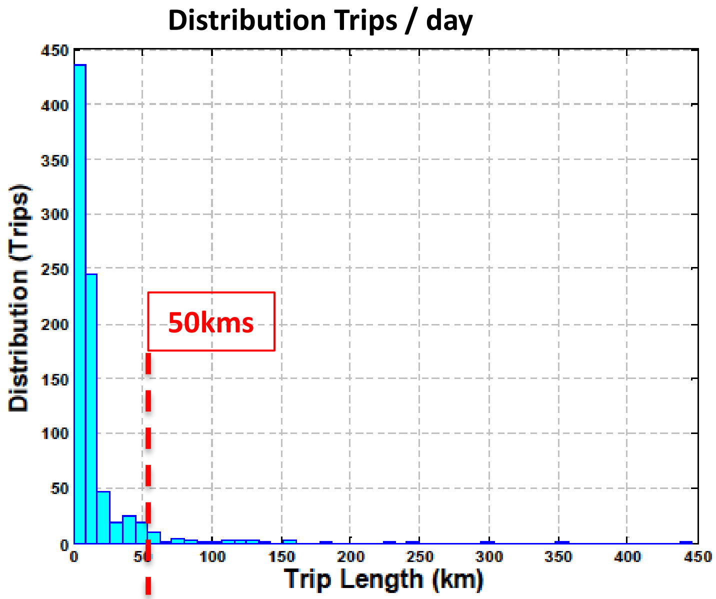
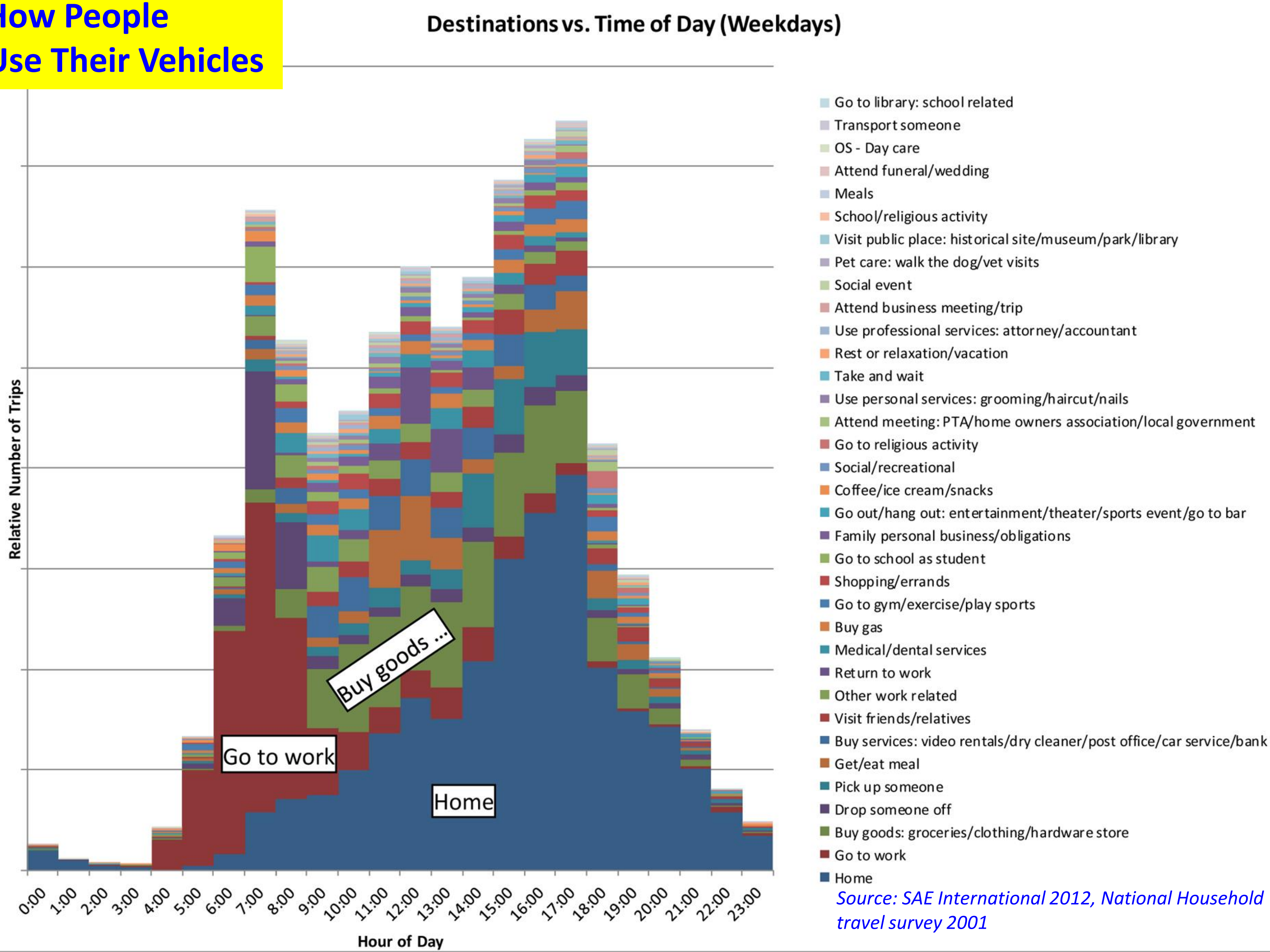


Figure 88: Distribution of trip lengths among the CarChip-logged data by trip

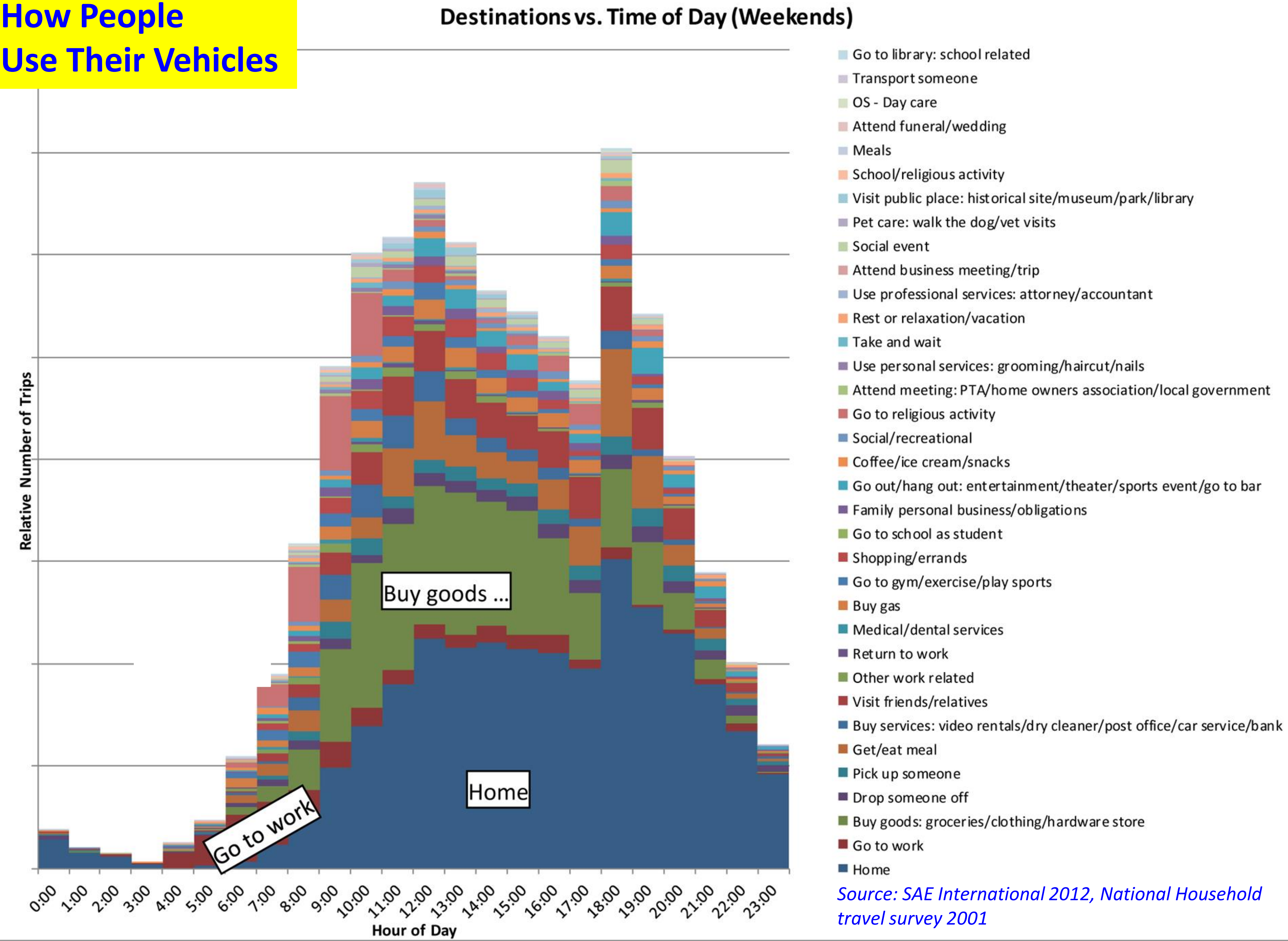
Source: I.Berry, Thesis-MIT-USA2010, National Household travel survey 2001

How People Use Their Vehicles



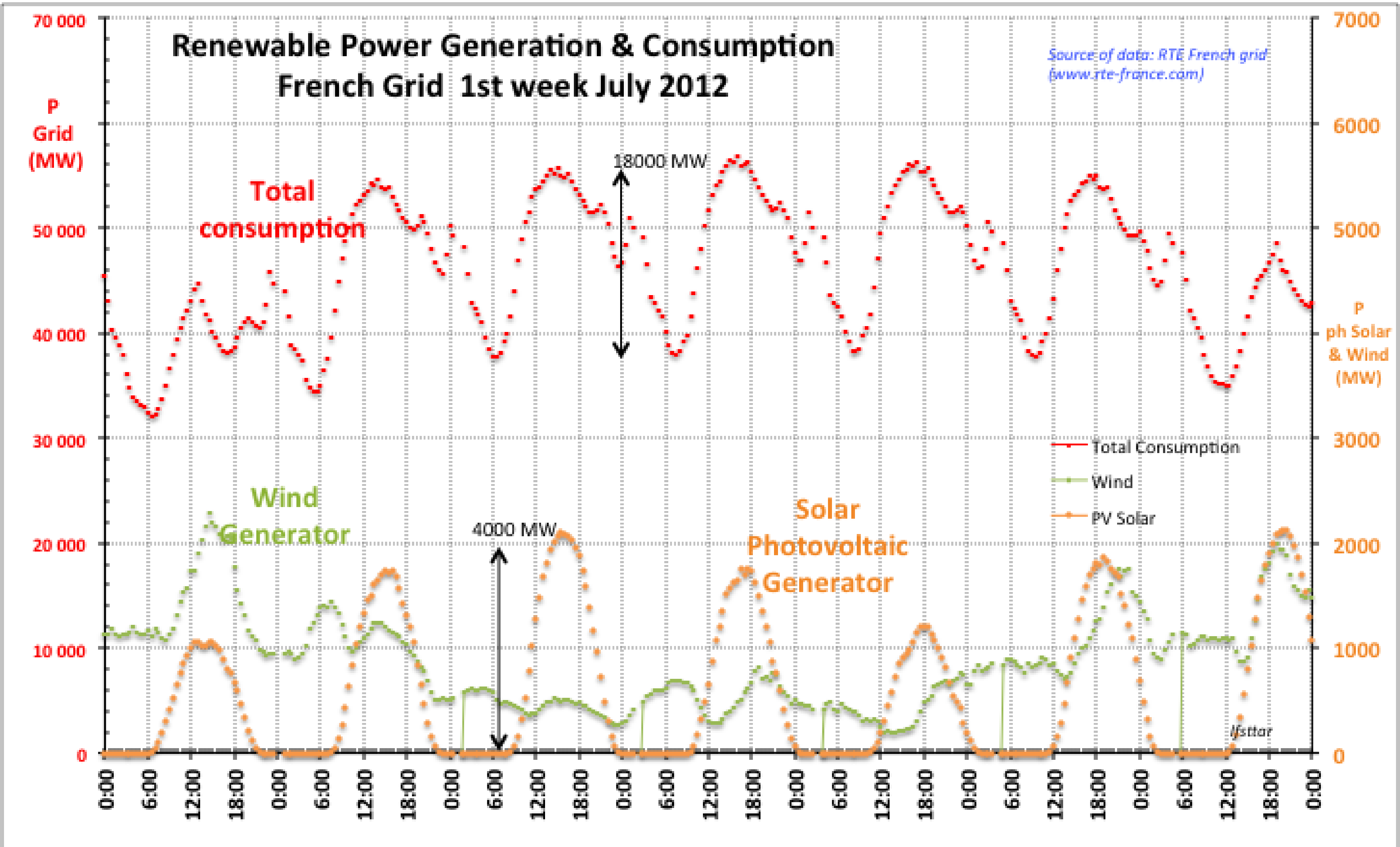
Source: SAE International 2012, National Household travel survey 2001

How People Use Their Vehicles



Source: SAE International 2012, National Household travel survey 2001

Renewable energy, uncertain production and time gap between consumption and production require Energy Storage System



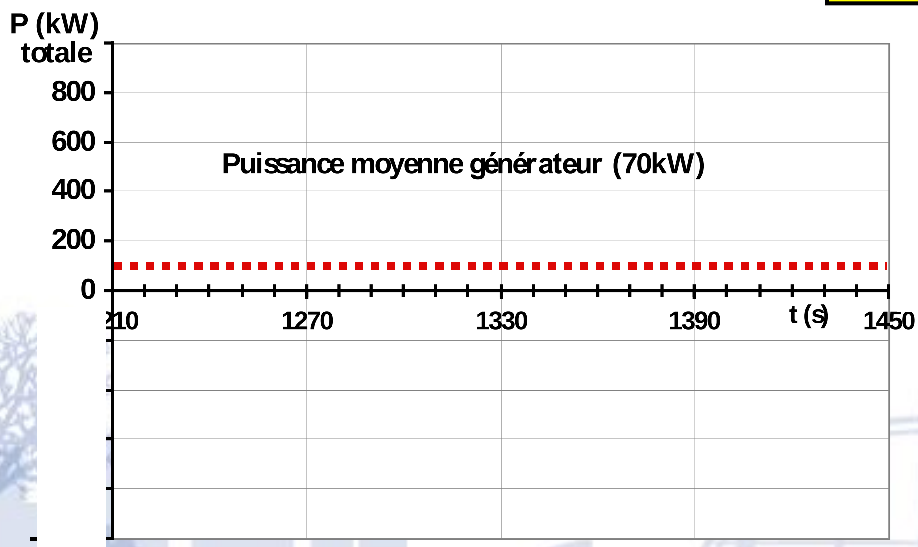
Why Energy Management from generation to electrical vehicle: traction and renewable conditions

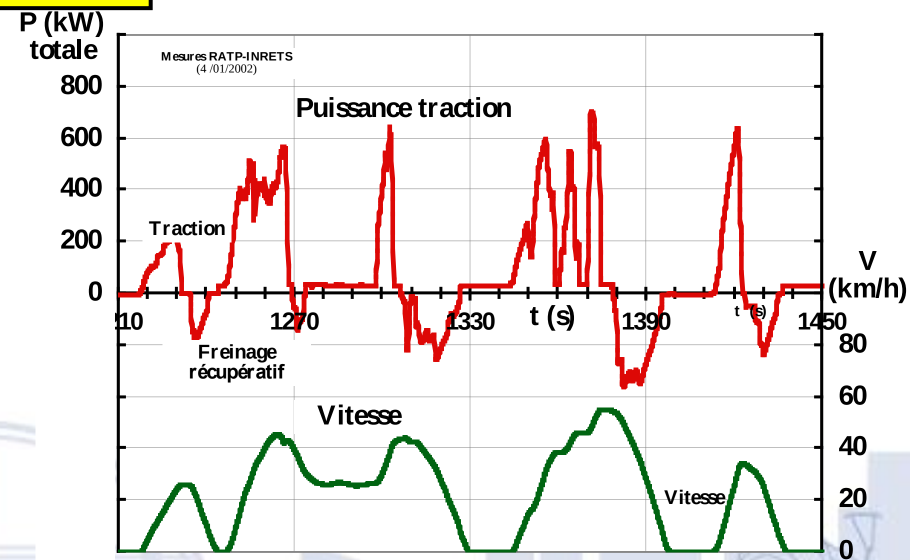
- sizing of generator and infrastructure on average power: “down sizing“
- manage energy from renewable source to EV and to GRID
- reduction of consumption: regenerative energy

Average Power Used for moving
(ex. tramway : 70kW)

Buffer Energy Storage

Traction peak power
(ex. tramway: 800kW à 1MW)





“Vehicle electrification Level…today status“

From ICE to EV, impact on energy storage technology

Rated Electrical Parameters	Stop Start	Mild Hybrid	Full Hybrid	Recharg. Hybrid	Full Electric	Electric Range Extender
Energy storage	No 12V battery Reinforced Or SCap	100-150kJ 0,04kWh **SCap?**	1-2kWh	4-5kWh **Batteries**	20-30kWh	16kWh
Electrical Power	2kW peak	10-15kW	60kW	60kW	80kW	111kW
Vehicle Example	BMW, VW PSA, Nissan …	48V German Carmakers Agreement 2011	1,8kW (NiMH) Prius 2002 0,94kWh Insight	4,4kWh Prius3 2011 27kW-80kg 3kWh-25kms-85kmh	24kWh (li-ion) Leaf 90kW-	16kWh (li-ion) Ampera -198kg -60kms
Prospective Market 2020 *Source: actus ?*	? ≠30%	? ≠10%	? ≠10%	? ≠10%	? ≠1-2%	?

Source: NREL, Toyota,…

To remenber the market : 19Mcars-EU27 2011, 80Mv-Worlsd

Electric vehicles, today status !
On board energy storage and recharging power

Vehicle	Class	Battery (kWh)	type	Fast recharging	Motor (kW)	type	Weight No-load
Smart fortwo	2 seats	17,6	Li-ion-wc*	AC-22kVA	55	PM	1000
Fiat 500e	Mini-compact	24	Li-ion-wc	AC-7kVA	83		1000
Mitsub. i-MiEV	Compact	16	Li-ion-wc	DC-50kW	47	PM	1000
Nissan Leaf	Compact	24	Li-ion-la-wc	DC-50kw	80 / 109	SM	1474
Tesla S (85kWh)	Large car	85		DC-120kW			2108
Tesla S (60kWh)	Large Car	60		DC-120kW			
Honda Fit/Jazz	wagon	20	Li-ion-wc		100	PM	
Ford Focus e	Sub-compact		Li-ion-wc		107		1473
Renault ZOE	Compact	25	Li-ion-wc	AC-43kVA	65 / 88	Srwired	1562
Bolloré BlueCar	Compact	30	LMP	AC-7kVA	45		1120
Smith-Newton	Truck-Bus	80		AC-43kVA	120	Induction	4432/11990
	Truck-Bus	120		AC-43kVA	120	Induction	4432/11990

**wc: water cooled assited*

Urban Energy consumption close to 100Wh/km

Electric Vehicle Batteries: state of the art cathode chemistry

(Total 2011, about 29GWh produced including phone, labtop,…)

Source: Avicenne 2011

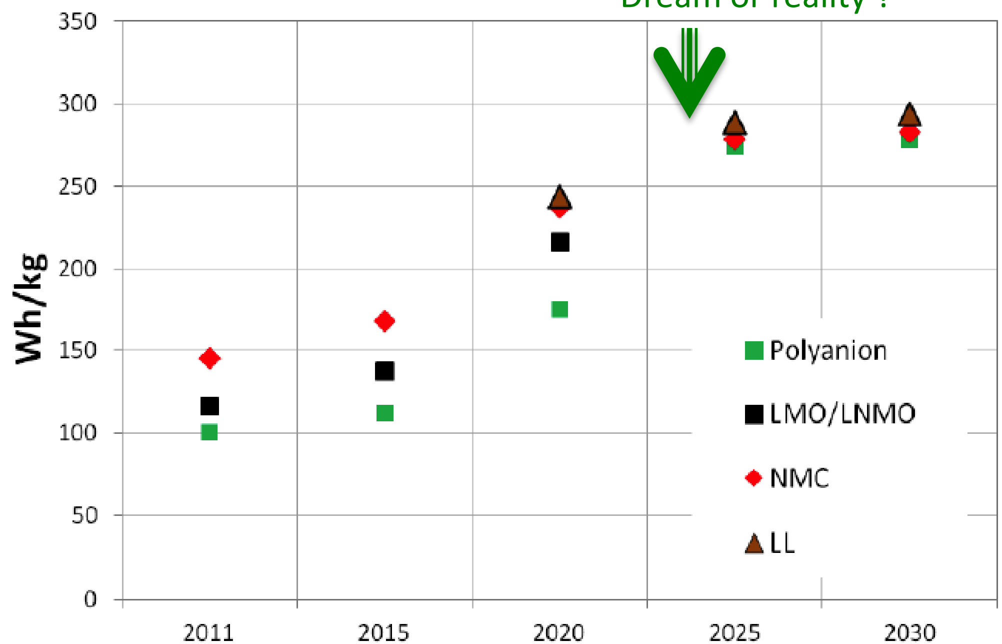
Cathode active material name	Material	Abbreviation	Short form	Maturity for EV?
Lithium cobalt oxide	$LiCoO_2$ (60%Co)	LCO	Li-cobalt	Used in the original Tesla car but rejected on safety concern grounds by series car OEMs
Lithium manganese oxide	$LiMn_2O_4$	LMO	Li-manganese or spinel	Already in series car (e.g. Leaf, Volt, iMiEV)
Lithium iron phosphate	$LiFePO_4$	LFP	Li-phosphate	Already in series car (e.g. Fisker EV)
Lithium nickel manganese cobalt oxide	$LiNiMnCoO_2$ (10-20% Co)	NMC	NMC	Used in consumer goods and EV prototypes
Lithium nickel cobalt aluminium oxide	$LiNiCoAlO_2$ (10-20% Co)	NCA	NCA	Already in series car (e.g. plug-in Prius)

Electric Vehicle battery expected road map

	Current	2015	2020	2030	Post 2030
Energy Density	100Wh/kg	150Wh/kg	250Wh/kg	500Wh/kg	700Wh/kg
Volumetric energy density	250Wh/l	400Wh/l	600Wh/l	1000Wh/l	1500Wh/l
Cost	1300$/kWh	400$/kWh	270$/kWh	130$/kWh	70$/kWh

New Technologies

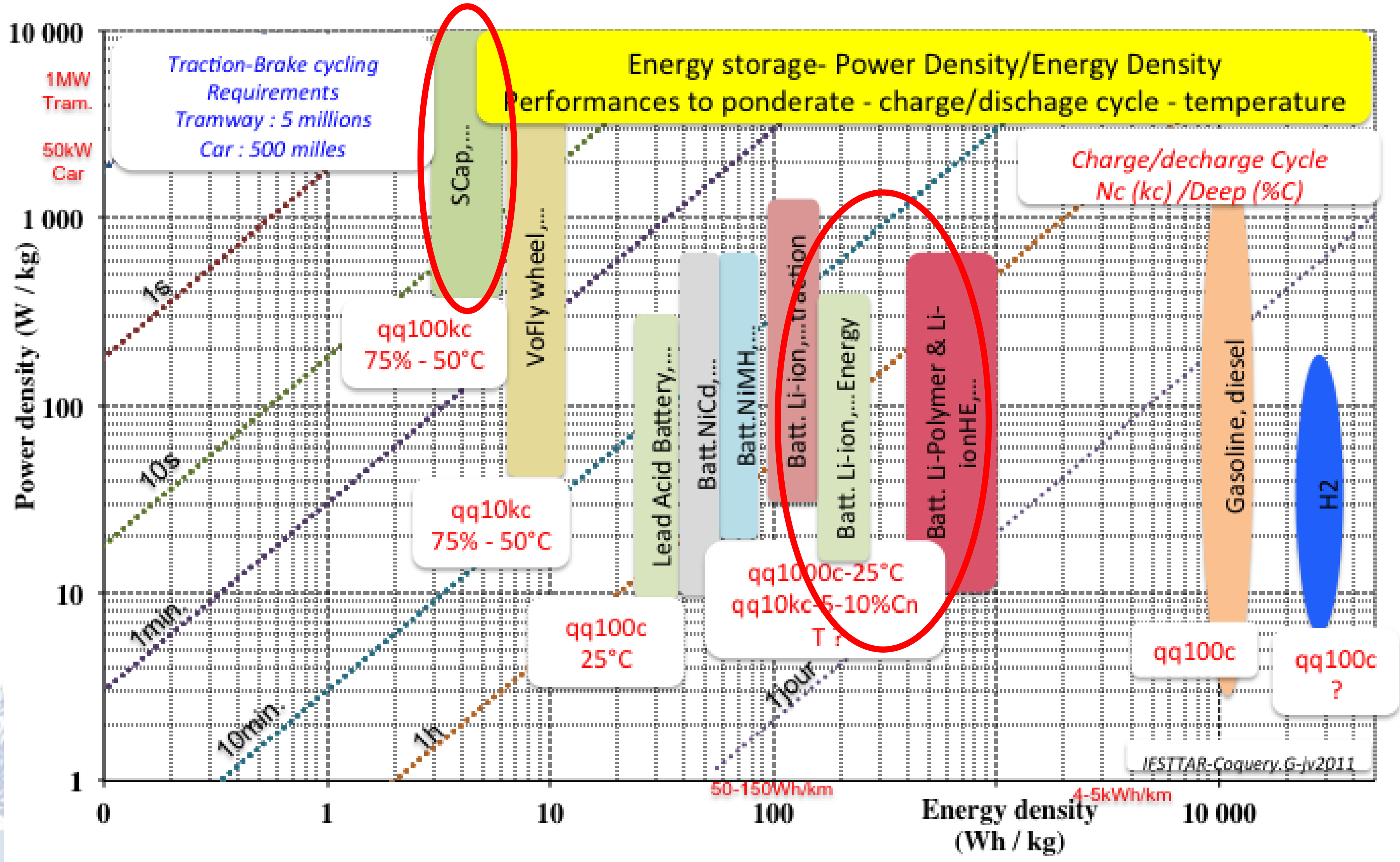
50kWh
400kms autonomy
Dream or reality ?



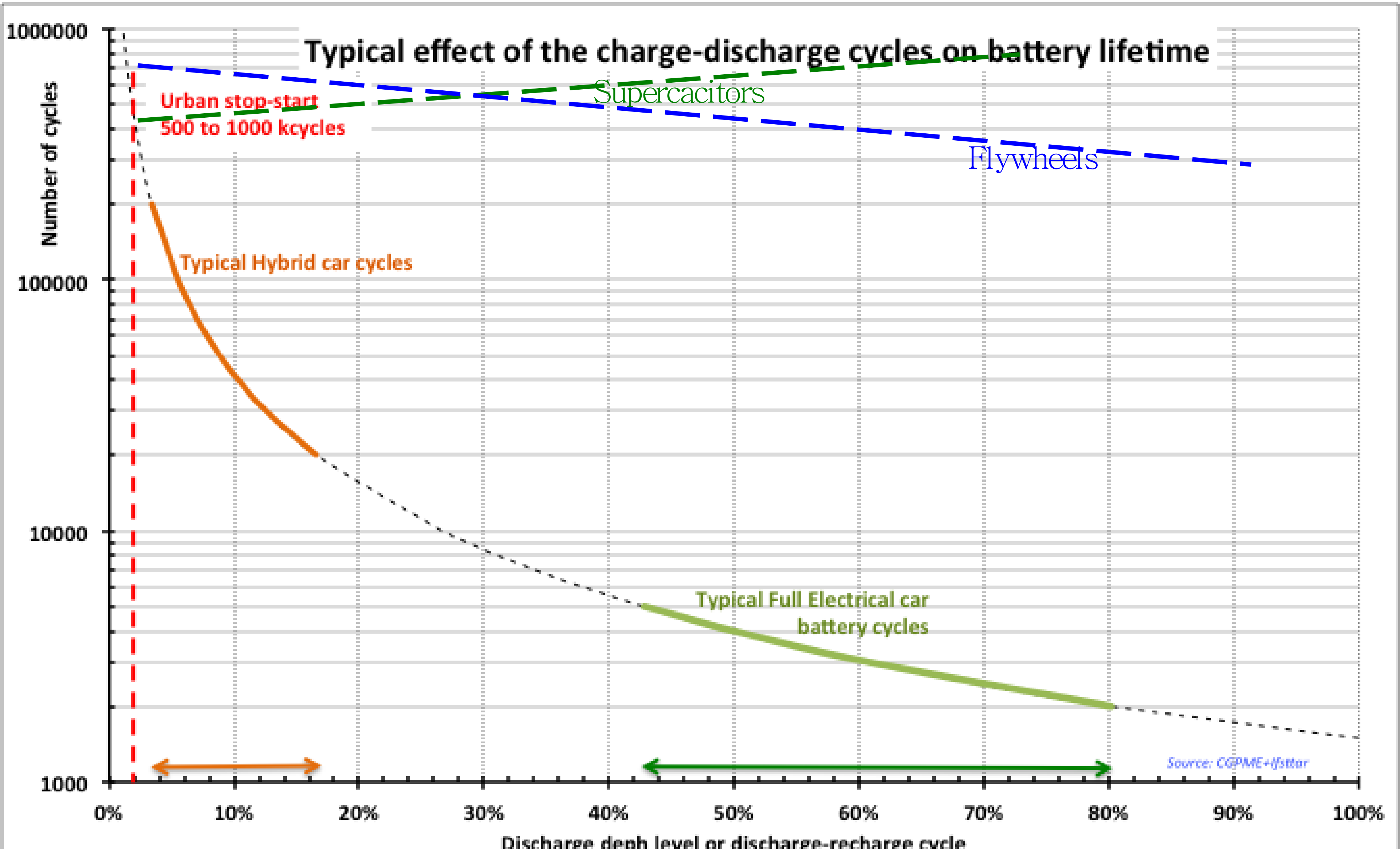
Other chemical solutions are investigated NMC, LMO,…

Source: French Ambassy Japan 2010

Battery/Supercapacitor – Energy/Power – Efficiency/Reliability
Status of the art



Choice of the energy storage technology
Impact of charge-discharge cycles…on battery



Methodology for lifetime & reliability characterisation…no reliability model today ?

Summary of the general test plan proposed :

-1 – Initial measurements
- -dimensions, weight,

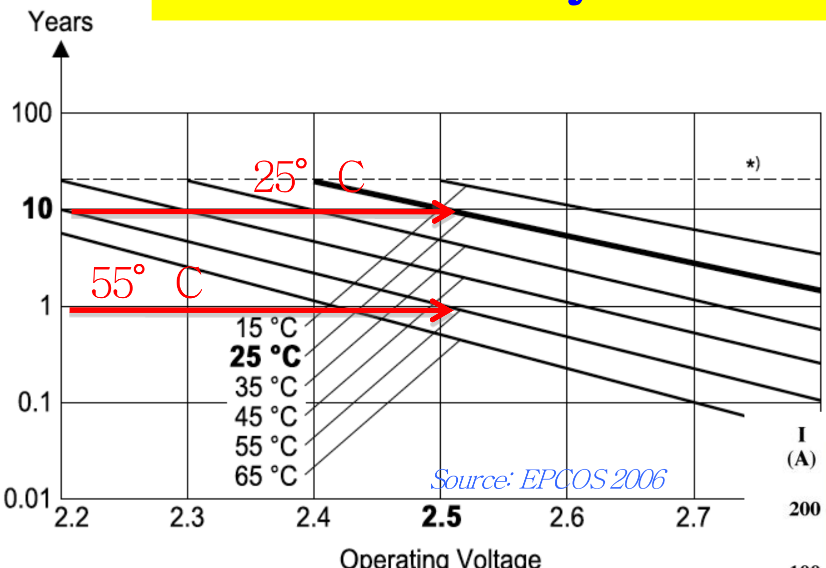
-2 -Static tests or stabilised conditions (vs U, T, I)
- -Calendar tests, leakage current under static voltage (or floating conditions)
- -DC method : discharge tests
- -Z or impedance spectroscopy method

-3 -Dynamic tests or cycling or pulse conditions (vs U, T, P, t)
- -Thermal cycling test (based on environmental conditions)
- -Current cycling tests (based on vehicle mission profile)
- -Power cycling tests (repetition of the exact working conditions)
- -Short-circuit tests (cell, module, bank with circuit protection)

Monitoring of the test conditions:
- external access : Isc, Ut, Tt, Tc (.t terminal, .c case)
- internal access : Uei, Tei (ei: electrode i…)

needs to be install by the manufacturer

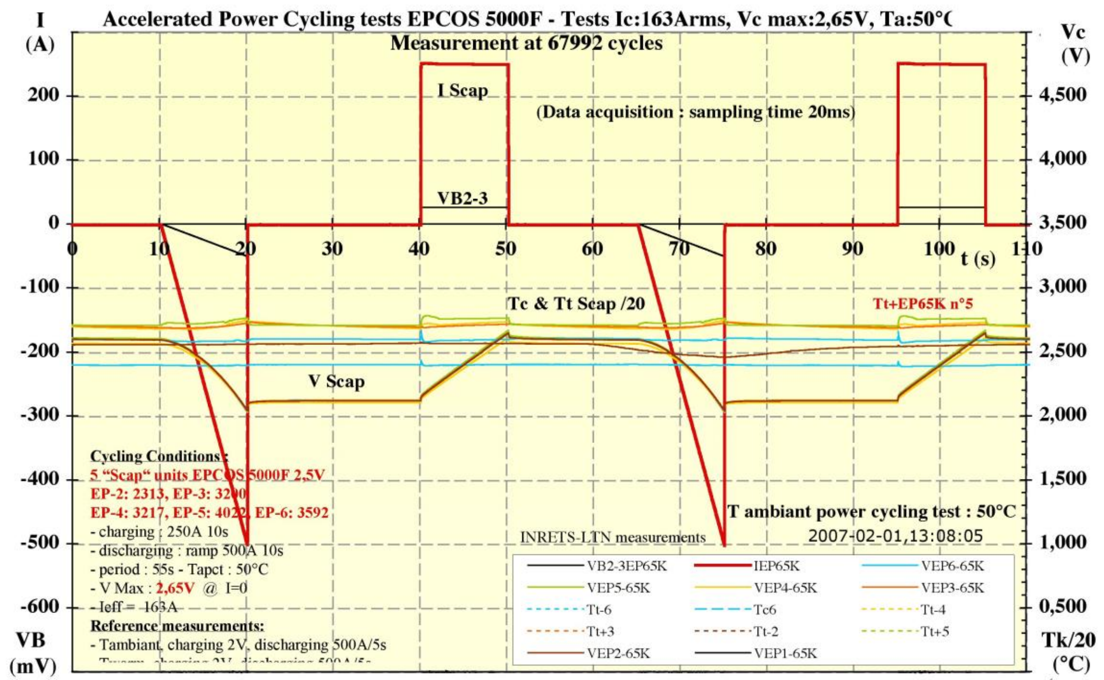
Reliability: influence of the working conditions



Lifetime 10 years (at V_R = 2.5 VDC and T_{op} = 25 °C)

*) Note: The lifetime is shown up to 20 years. An expanded lif
is additionally influenced by deviations of lifetime parameter
to fatigue mechanisms of capacitor materials.

Voltage, Temperature, Current
During operating time
(cycling ageing)

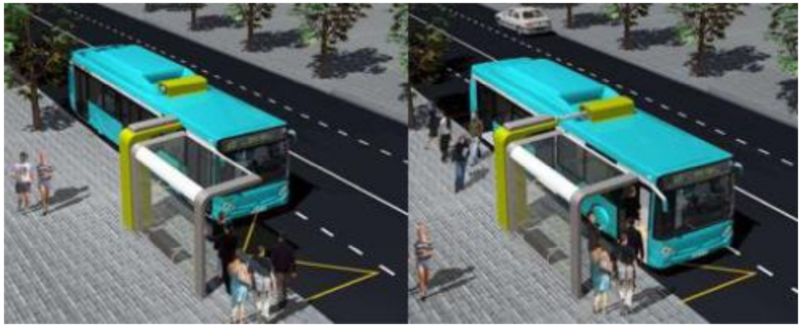


Voltage & Temperature
At waiting status
(calendar ageing)
Homogenous temperature
Eyring model: $td(T,U) = A.\, e^{(U'/kT)}$

Non-homogenous temperature
Thermal cycling
Current cycling

Electromobility: local energy delivering by high power way

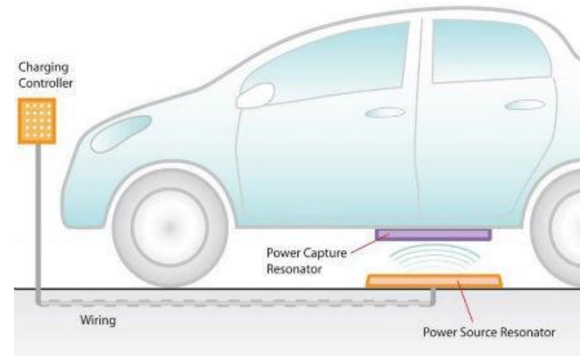
- Fast recharge in stop station
- Dynamic energy transfer



WATT system, PVI France

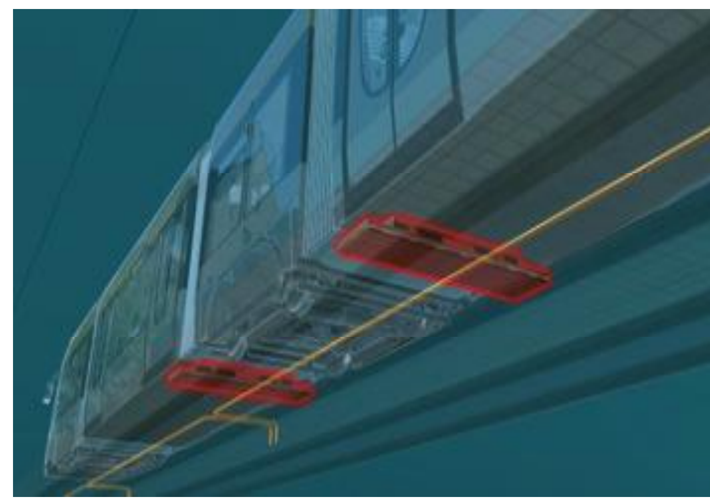
Proterra, USA

Alstom, Bordeaux, France



BMW/Delphi/Siemens

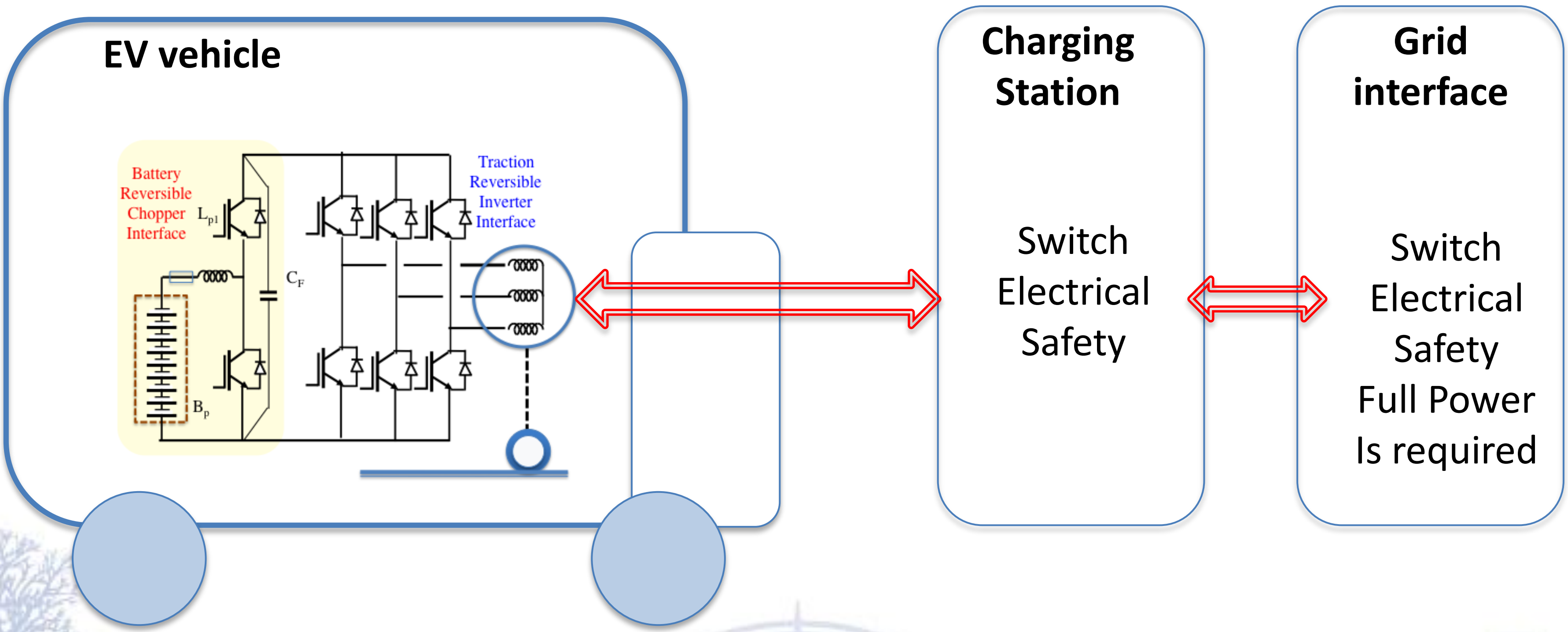
Capabus, USA/China



PRIMOVE –Bombardier

Fast charging station to EV
AC 22kVA & 43kVA

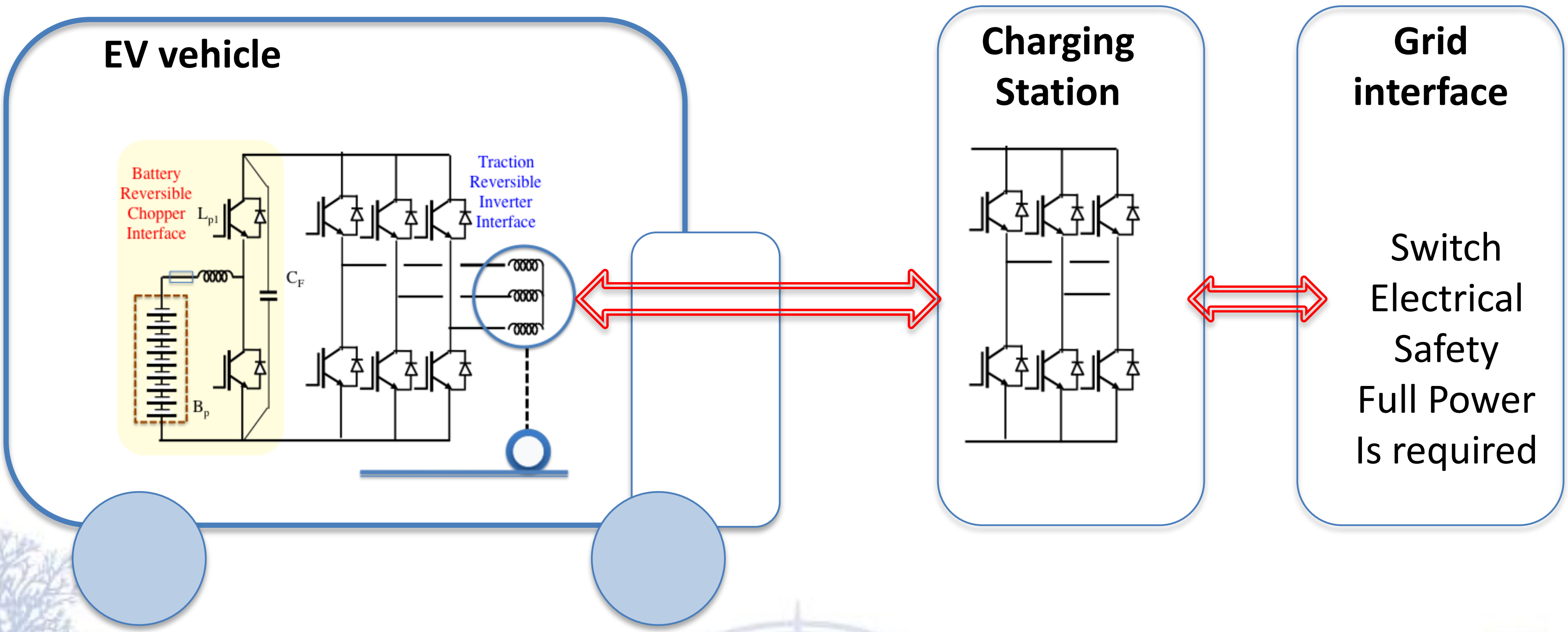
The today normal mode is non reversible architecture
Only Grid to EV



The EV converter assume the respect of the rules on Quality and Safety

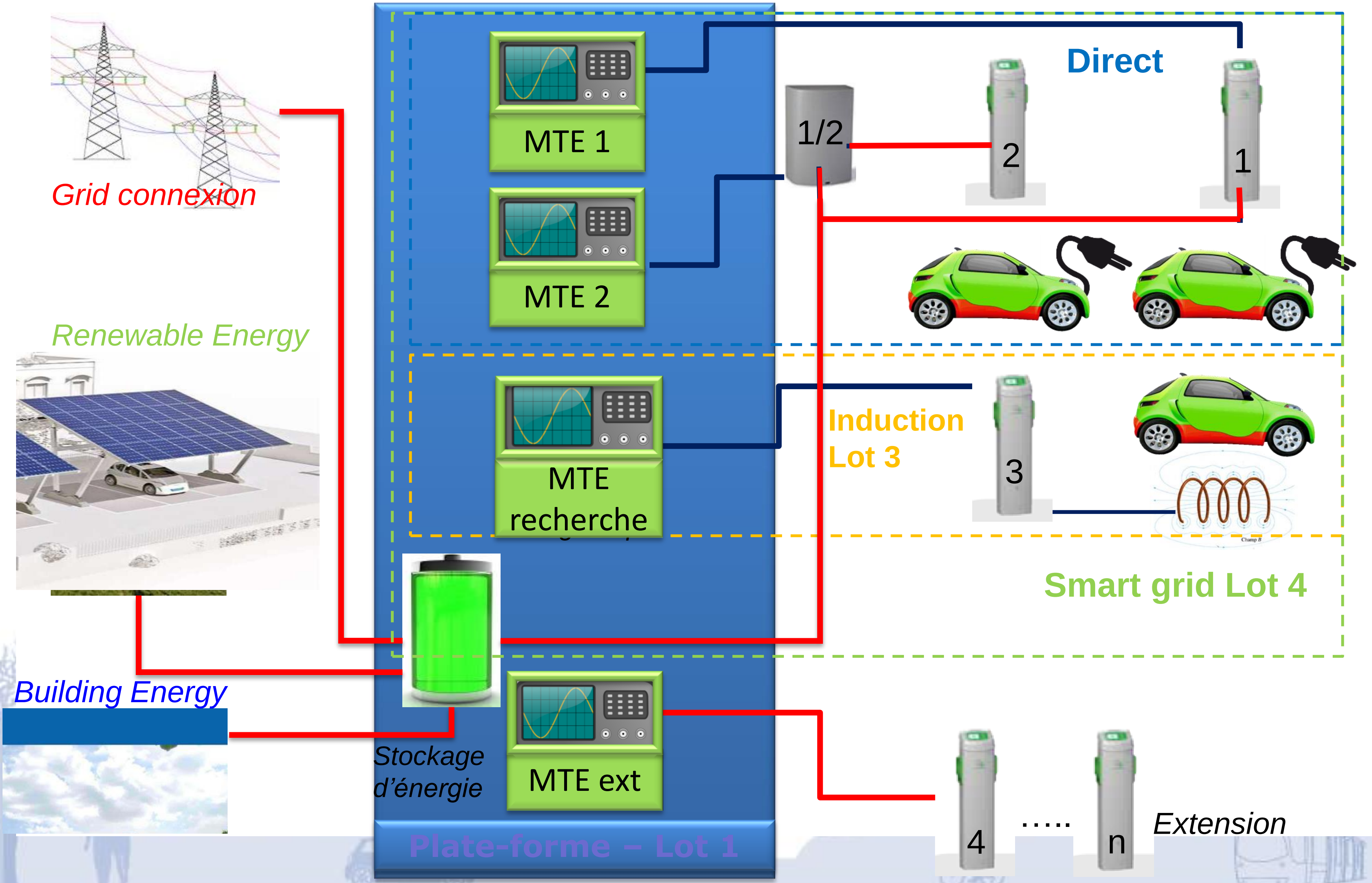
Fast charging station to EV
DC 50kW … 120kW

Today the reversible mode is working… Grid to EV to Grid



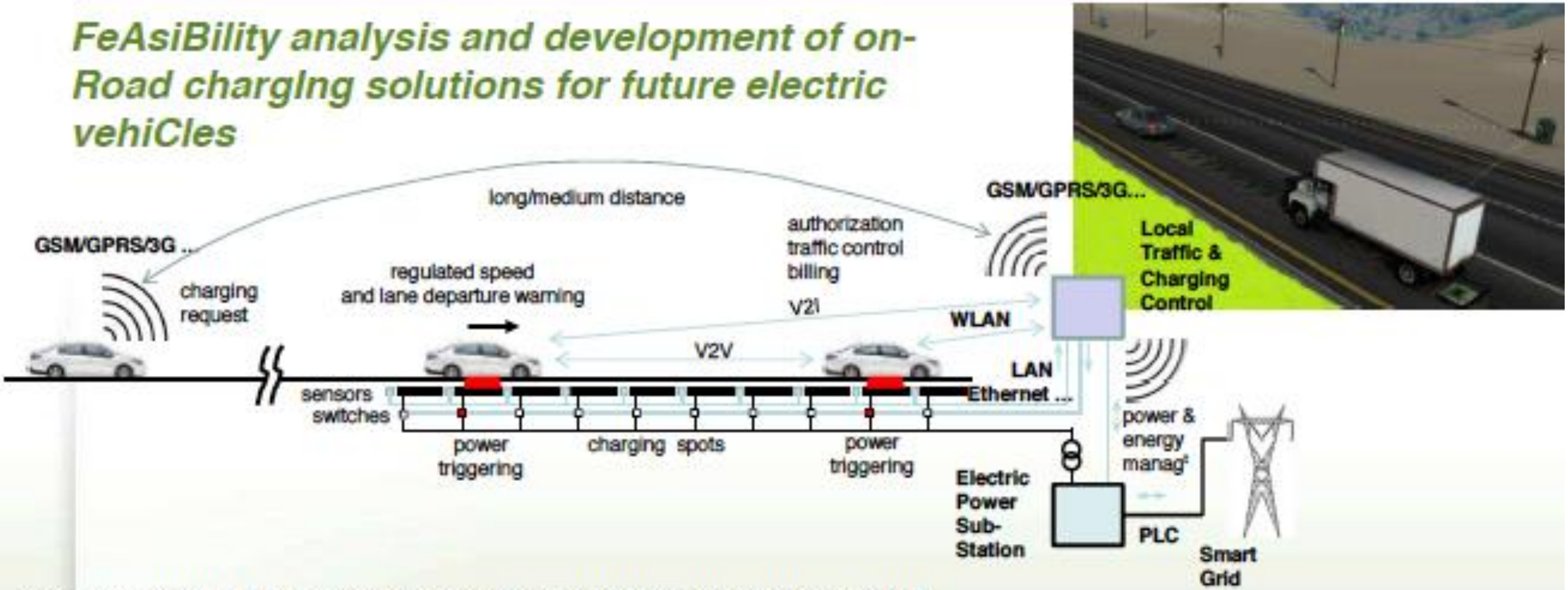
The Charging station converter assume the respect of the rules on Quality and Safety

Plateform for test on fast charging station AC & DC
Energy management ...grid - charging station - vehicle



Projet européen FABRIC

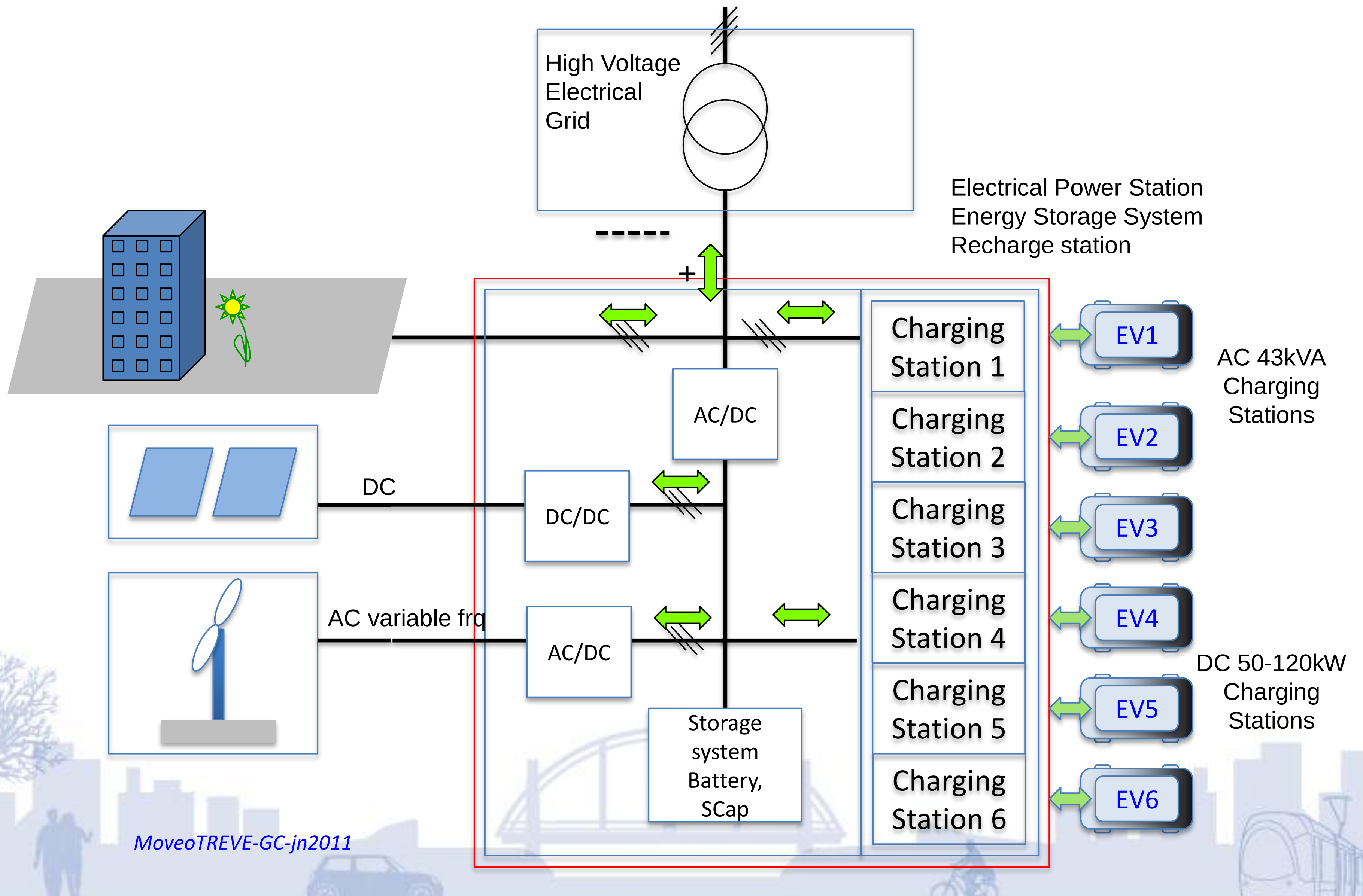
FeAsiBility analysis and development of on-Road chargIng solutions for future electric vehiCles



- Coordinateur : ICCS (Grèce) ; 26 partenaires dont **VeDeCoM**
- Pays : <u>Italie</u>, Belgique France, Allemagne, Grèce, Pays-Bas, Espagne, Suède, Royaume Uni
- VeDeCoM : Subvention **887 k€**/ Coût total : 1182 k€

incluant IFSTTAR, IFP Énergies nouvelles, Renault, PSA Peugeot Citroën, ParisTech, ... avec Qualcomm halo, sanef

Electrical architecture for EV & HEV Urban Recharge Service Station Coupling to renewable energy generators



EV scenario to help Grid to solve winter peak days demand
Power ∆ (Pmax-Pmin) is about 20GW during 24h00
Basic hypothesis…just to discuss

Data based on the French status:

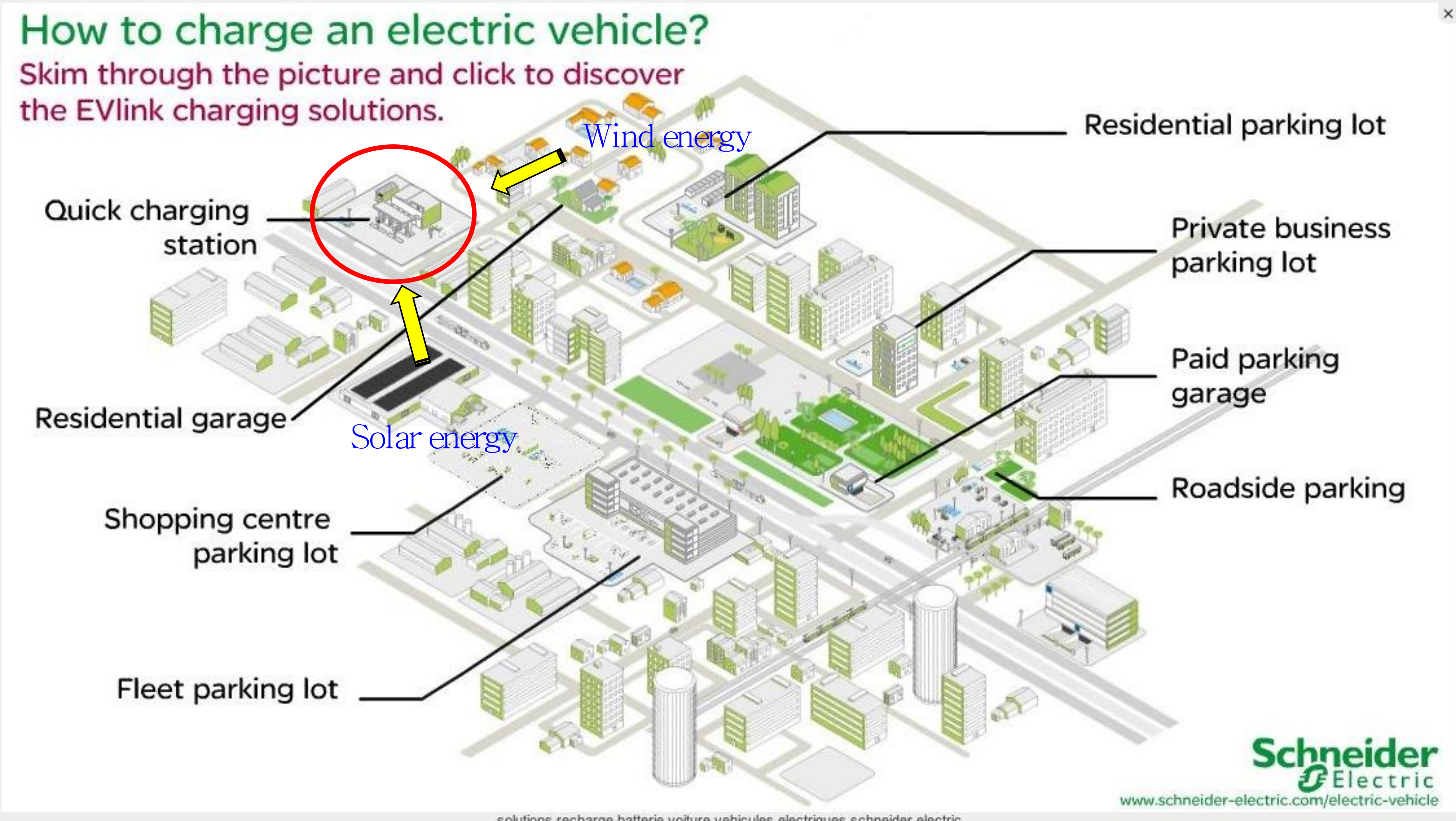
- About 105GW installed, 80 to 95GW required peak power each winter day
- Hypothesis 1 million EV car 2020 ?

Solution1: 25kWh/car…∑25GWh…
if free offer for Grid is 10% = 2,5GW during 1h

Solution2: 50kWh/car…∑50GWh…
If free offer for Grid is 20% = 10GW during 1h

EV storage combined with hydraulic storage could contrubute to save the Grid stability and energy delivering

Electromobility in the City: EV Stations-service as energy storage



Energy Storage Technologies for EV-Grid concept
Synergy electro-mobility to renewable energy and Grid
Synthesis and prospective

- **Energy status analysis ratio : Peak power / Average power**

> 10 for tramway (without climatic equipt.), > 3 for electrical substation

> 3 to 5 due to car stop in urban traffic

> Energy renewable production / power needs, PV production 100% day light /0% night

-

Electrical buffer storage devices will allow Energy Management

- efficiency improvement (braking regenerative energy, reduction of line losses),
- full electrical braking for LRT and LRV-EV/HEV to save energy and particles emission
- **down sizing of electrical substation and grid connexion**
- partial autonomy for infrastructure cost reduction (free crossroad, existing tunnel,…)

Key technologies and system approach:

- buffer energy storage devices,… **reliability law is the key knowledge to get…**
- integrated semiconductor functions (converter),
- appropriate software and high level data communication between grid and users

-- **local energy management in the frame of micro-smart grid**

- **reduce peak power on the grid for charging station**

Efficiency+Reliability+Safety+Cost = Energy storage system required

Thank you for your attention

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Electromobility: Battery interface voltage for traction

Power electronic converter assume :

Voltage-current adaptation for traction

And power sharing between Scap and Battery for highest reliability-efficiency