Session
The development of electric mobility in Italy: plan and government incentives, the most advanced experiences and new trends in supply

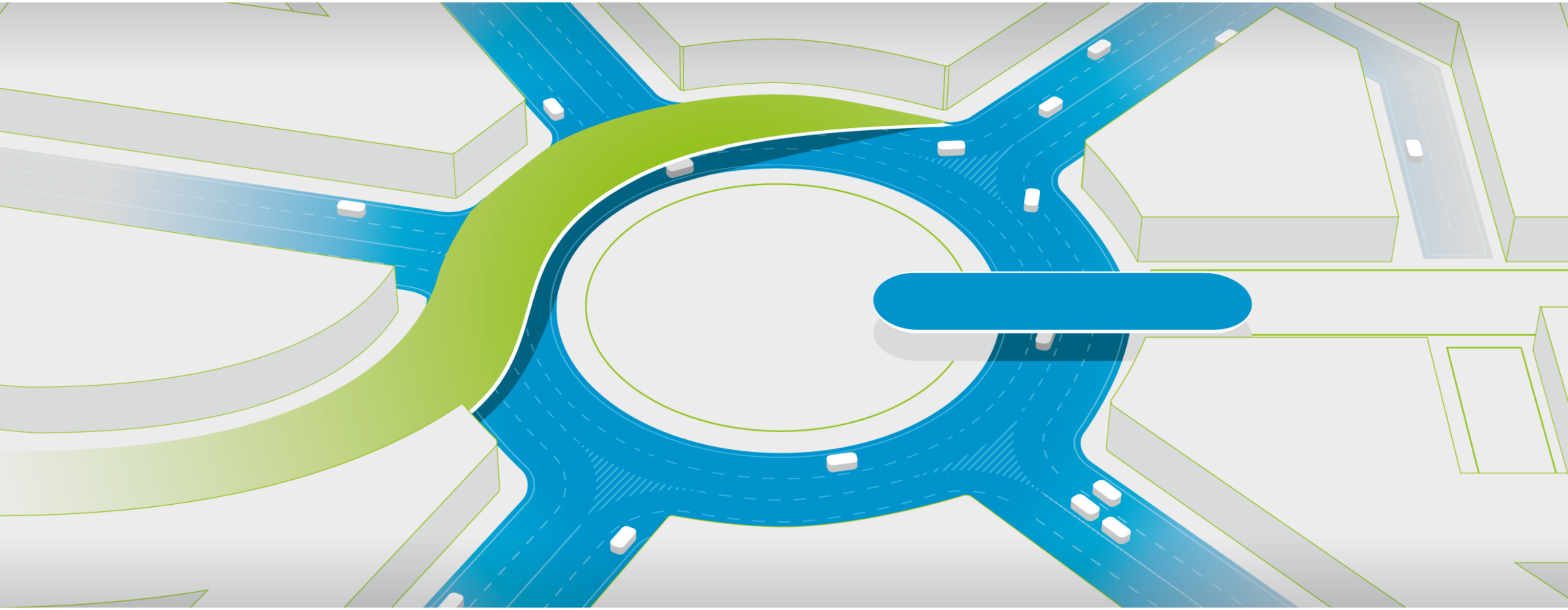
Range of competitiveness of road FEV :

mobility of passengers and freight transport analysis, performances and possible solutions

Ambito di competitività dei veicoli elettrici su strada: analisi di mobilità di persone e del trasporto merci, prestazioni e possibili soluzioni.

Torino - I, Thursday - 26th of September 2013, p.m.

eCo-FEV combining infrastructures for efficient electric mobility



eCo-FEV

Sept. 2012- May 2015

Presented by:
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EcO-FEV EU project working group, Politecnico di Torino

Torino – I , Lingotto, 26th of Sept. 2013

This project is co-funded by the European Union

Aims

1. Analysis of typical travels of vehicles (passengers/freight), on the basis of the international mobility beside specific national or local
2. Area of competitiveness of FEV on the base of the analysis of demand
3. Performances and limitations on the supply side: autonomy, batteries, power, performances, consumptions
4. Recharging possibilities most suitable on the bases of the previous items
5. Consequent choices, with examples of di UC (use case) of the EcOFEV
6. Possible technical solutions.

Premise: why?

Some figures, at European level (EU White Book on transports of 2001 [COM/2001/0370 def.]) estimated dependence on black oil at the 98%; in the USA it was estimated at 96% in the same period, reduced to 93.2% in 2010 [US Transportation Energy Data Book 2011, Ed30]). The White book on Transport Systems of 2011 reports a figure of 96% in EU.

Demand of motorised mobility is nearly constant the last 2-3 years, but expressed in different ways in the last decades (urban contexts)

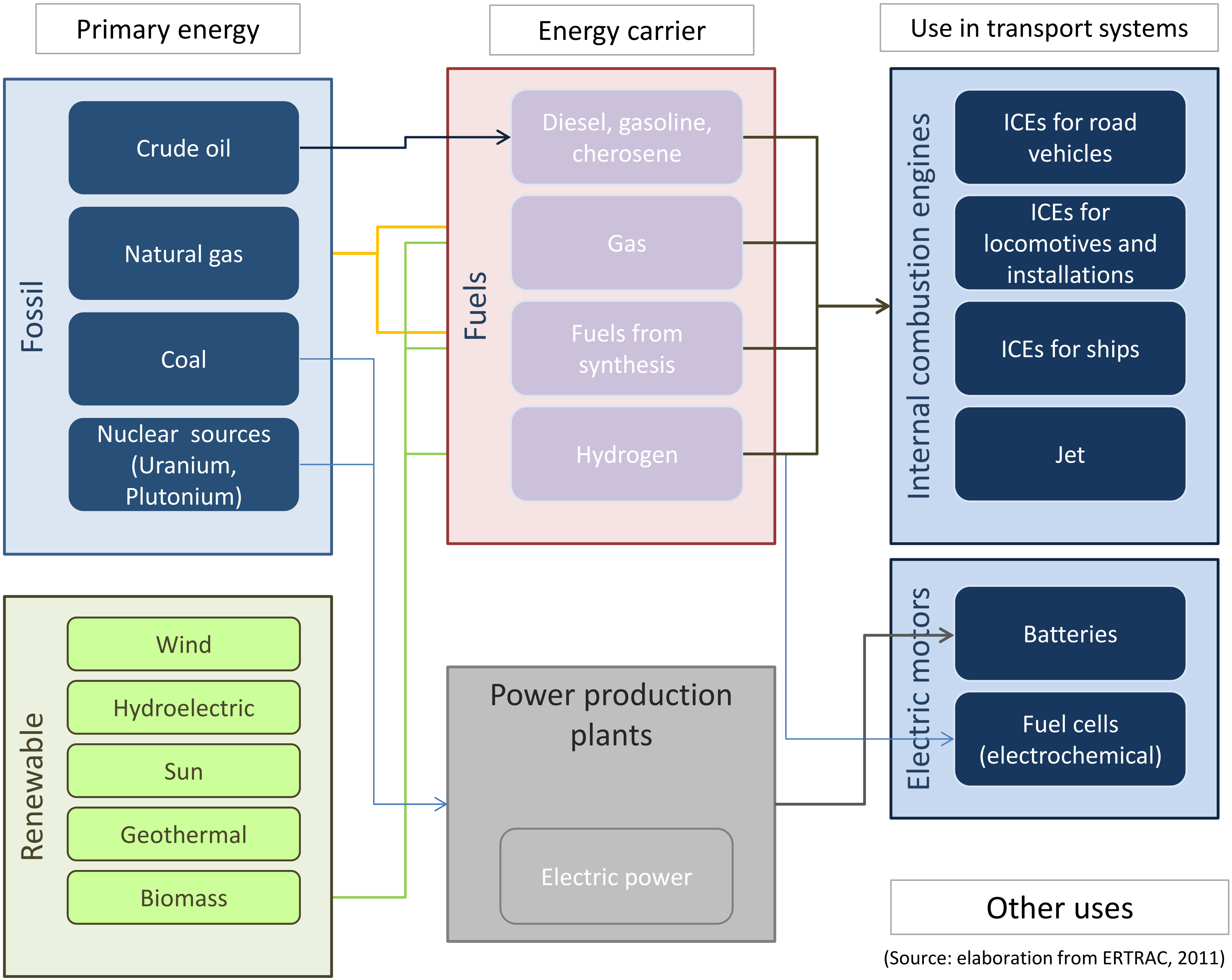
The electrification of road transport is considered a key element in EU and worldwide for reducing the near-monopoly of black oil in this field and, consequently, local greenhouse gas (GHG) emissions generated by internal combustion engines, largely used at present for the whole travels.

WHITE PAPER

Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system

Brussels, 28.3.2011 - COM(2011) 144 final

"17. The challenge is to break the transport system's dependence on oil without sacrificing its efficiency and compromising mobility."



(Source: elaboration from ERTRAC, 2011)

Analysis of typical travels of vehicles (passengers/freight), on the basis of the international mobility beside specific national or local

Average distances covered in Italy

Starting from different samples, the following studies individuate comparable results:

AVERAGE DAILY VEHICLE DISTANCE [km]	
ISFORT	35,1
PoliTO[1]	34,8
«5T» (Turin ITS centre)	32,1
CNIT/MIT 2004[2]	33,8
PoliMI[3]	38,7

AVERAGE VEHICLE TRIP LENGHT [km]		
	URBAN	EXTRA URBAN
ISFORT	4,7	25
PoliTO[1]	6,2	14,4
5T	4,6	11,9

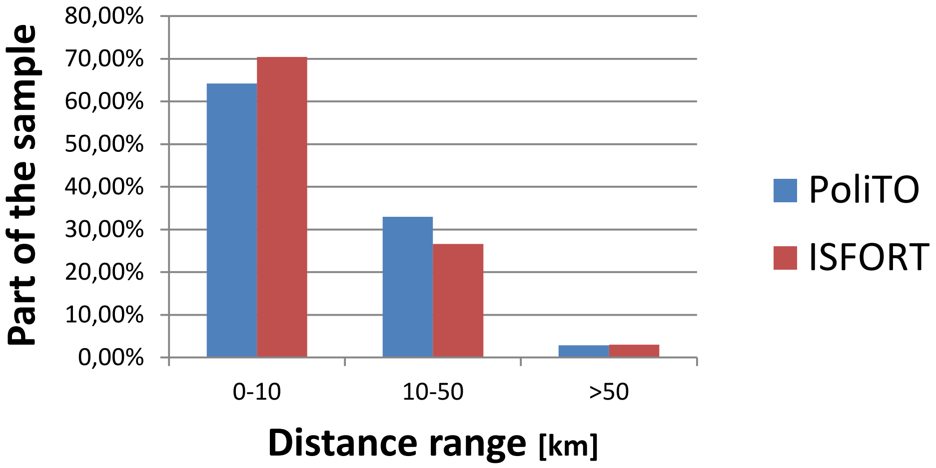
Sources:

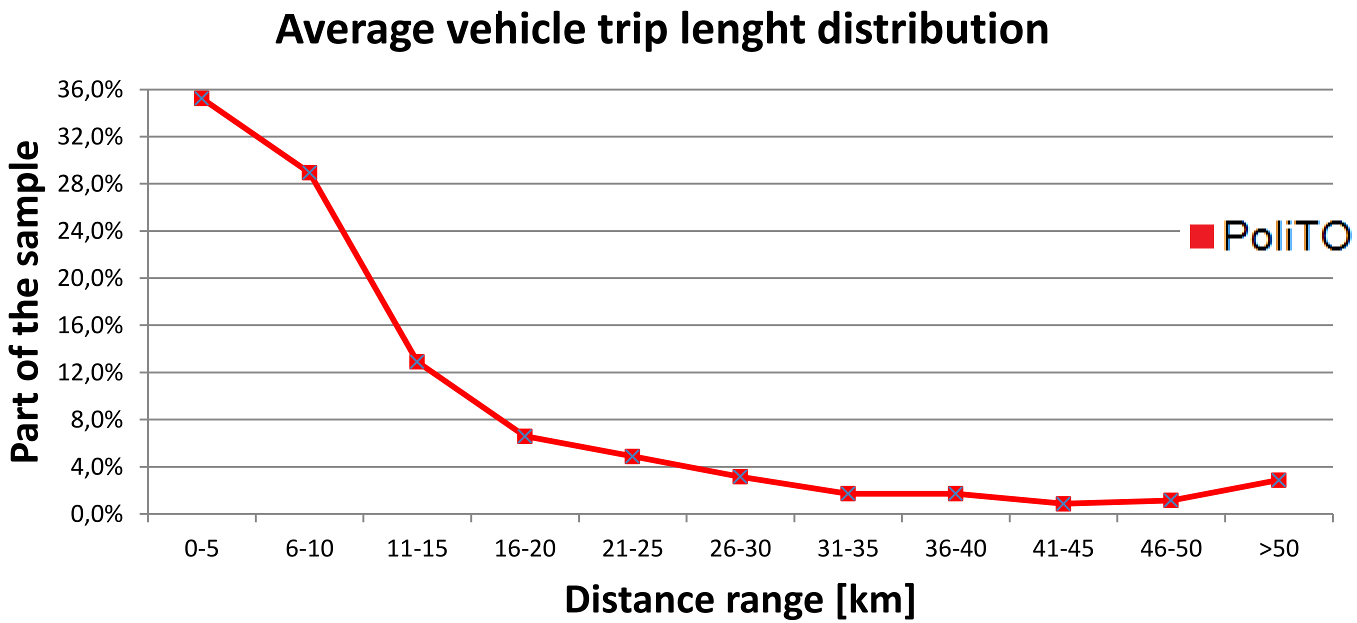
(1) POLITECNICO DI TORINO, Dept. DIATI-Transport. Eng., *Indagine su mezzi di trasporto e mobilità motorizzata per il personale del Politecnico di Torino*, Risultati salienti, 2013

(2) MINISTERO DELLE INFRASTRUTTURE E DEI TRASPORTI, *Conto nazionale delle infrastrutture e dei trasporti*, 2004

(3) S. CASERINI, C. PASTORELLO, P. GAIFAMI, L. NTZIACHRISTOS, *Impact of the dropping activity with vehicle age on air pollutant emissions*, 2013

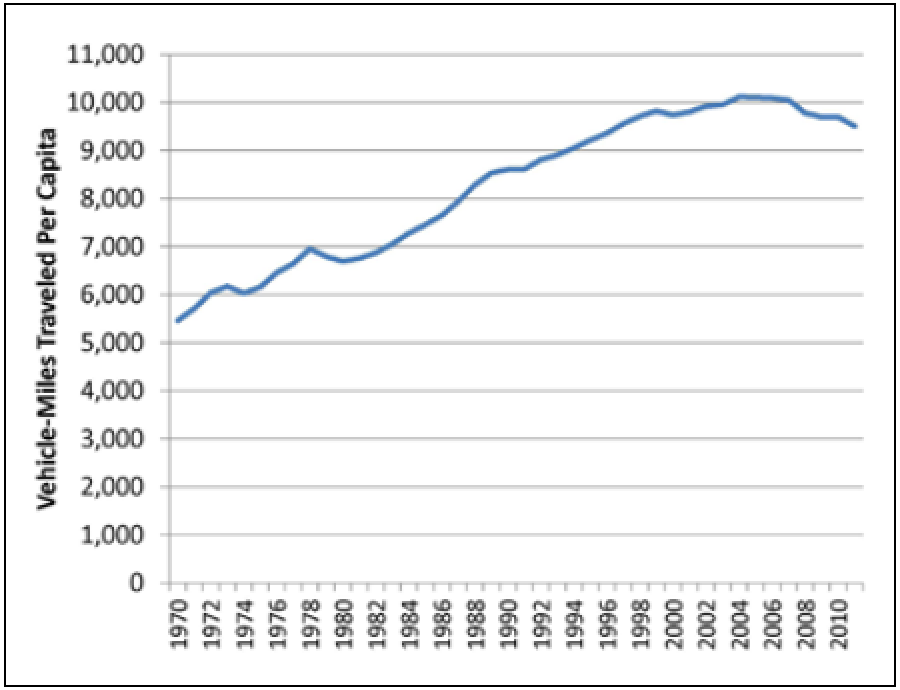
Distribution of daily travels (working days)





Comparison between Italy and USA trends

After a period of continuous growth of the road transports, a period of stabilisation or inflection of the demand is showed also in the USA



Source: FRONTIER GROUP and U.S. PIRG EDUCATION FUND, Transportation and the new generation – Why young people are driving less and what it means for transportation policy, 2012

Average daily vehicle distances are higher than Italian and generally European ones, on values next to 30 miles (about 48 km)

	Number of daily vehicle trips (per driver)	Average vehicle trip length (miles)	Daily vehicle miles of travel (per driver)
1990	3.3	8.9	28.5
1995	3.6	9.1	32.1
2001	3.4	9.9	32.7
2009	3.0	9.7	29.0

Source: S.C. DAVIS, S.W. DIEGEL, R.G. BOUNDY, *Transportation Energy Data Book: edition 31*, 2012

Freight transport in Italy

AVERAGE DAILY DISTANCES [km]			
	OWN ACCOUNT	FOR HIRE	GLOBAL
CONFETRA[(1)]	48,8	165,1	118,6
Ministero dell'Ambiente[(2)]	36,6	133,2	102,5
Autostrade per l'Italia[(3)]	-	-	100,6

Data from "Autostrade per l'Italia" indicate that almost half of the heavy vehicles (48%) covers a distance less than 50 km

Sources:

(1) CONFETRA, *Trasporti interni ed internazionali per titolo di trasporto e classe di percorrenza*, 2003

(2) MINISTERO DELL'AMBIENTE E DELLA TUTELA DEL TERRITORIO E DEL MARE, *Il trasferimento modale sui grandi assi di scorrimento*, 2013

(3) Autostrade per l'Italia, *Il traffico sulla rete del gruppo autostrade, valori a consuntivo*, 2012

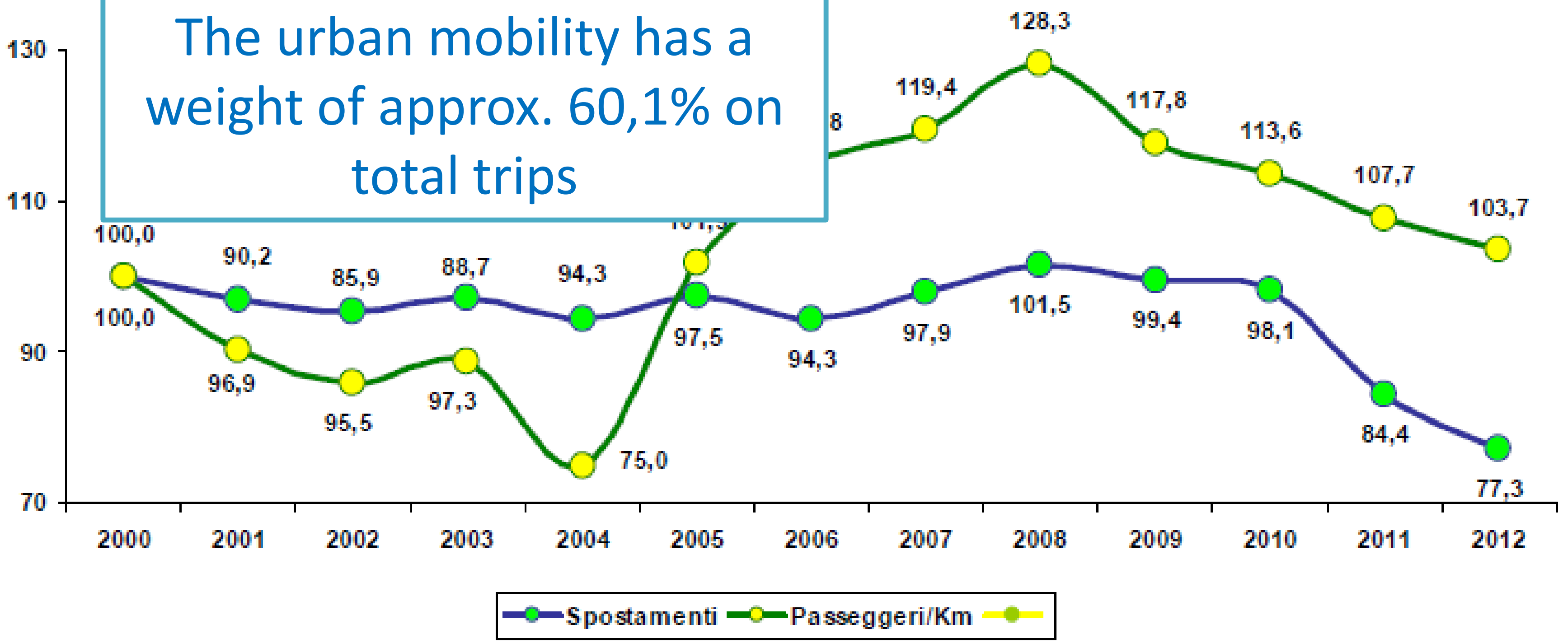
Mobility demand trend in Italy (2000-2012)

	2012	2011	2010	2009	2008	2007	2000
Spostamenti **totali** in un giorno medio feriale	97,5	106,6	123,8	125,4	128,1	123,5	126,2
Passeggeri*km **totali** in un giorno medio feriale	1.261,2	1.302,2	1.381,4	1.432,8	1.561,0	1452,0	1216,2

Fonte: Isfort, Osservatorio "Audimob" sulla mobilità degli italiani

(valori assoluti in milioni)

The urban mobility has a weight of approx. 60,1% on total trips



Fonte: Isfort, Osservatorio "Audimob" sulla mobilità degli italiani

Motorized mobility in Italy

Trips distribution for motorized vehicles in URBAN mobility (% values)

	2012	2011	2010	2007
Public transport	15,1	13,5	12,9	11,5
Car	**79,7**	**79,4**	**80**	**81**
Motorcycle / moped	5,2	7,1	7	7,6

Trips distribution for motorized vehicles in EXTRA-URBAN mobility (% values)

	2012	2011	2010	2007
Public transport	13,0	14,8	13,9	12,6
Car	**84,7**	**83,0**	**83,0**	**83,9**
Motorcycle / moped	2,2	2,2	3,1	3,4

Source: ISFORT, ANAV, ASSTRA, *Una leva per la ripresa – 10° rapporto sulla mobilità in Italia*, 2013

- Area of competitiveness of FEV on the base of the analysis of demand
- Performances and limitations on the supply side: autonomy, batteries, power, performances, consumptions
- Recharging possibilities most suitable on the bases of the previous items

Private transport

Freight transport

Public transport and multimodal mobility

- Area of competitiveness of FEV on the base of the analysis of demand
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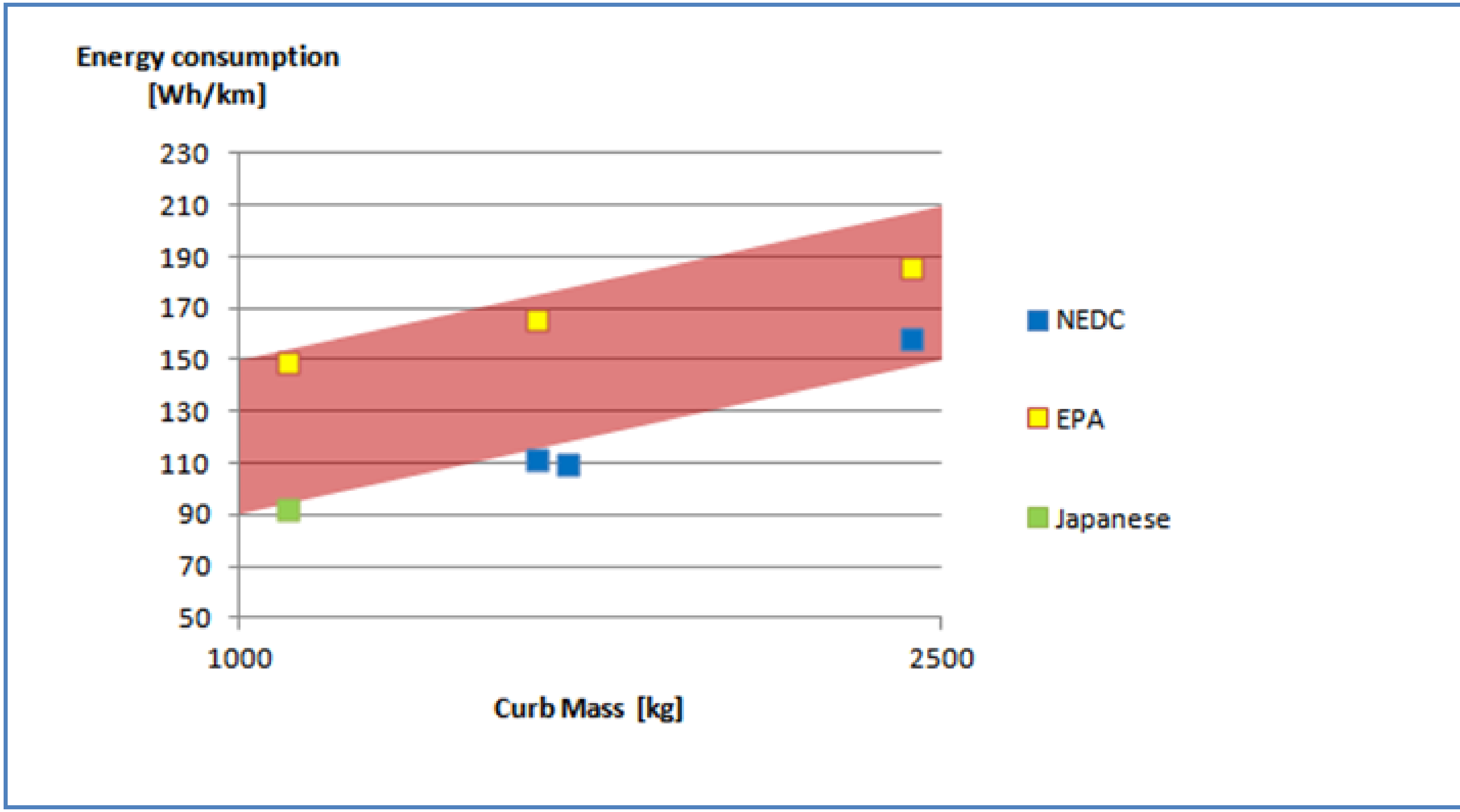
Private transport



Full electric cars energy consumption range according to three driving cycles
[elabor. by Politecnico di Torino, Filidoro, 2013]

Curb mass [kg]	Energy consumption [Wh/km]	Maximum driving range [km] given the charging speed specified in the line below	
		Slow charging: 220 V, 16 A, maximum power≈3.5 kW	Mode 2 charging: 220 V, 30 A, maximum power≈7kW
1000	150	187	373
1500	170	165	329
2000	190	147	295
2500	210	133	267

Maximum obtainable driving range, eight-hour charging
[elabor. by Politecnico di Torino, Filidoro, 2013]

The calculation does not take into account the limits caused by the batteries admissible size though. The two types of charging methods would need respectively a 30 kWh and a 60 kWh battery pack. Recalling the Li-ion batteries characteristics, that would correspond to 200÷300 kg and 400÷600 kg respectively. Definitely it would not be possible to afford 500kg-heavy batteries in a vehicle with a total mass of 1000 kg. Small to medium electric cars are typically featured by a 20÷30 kWh battery pack. As a consequence is possible to notice that the limit on the maximum driving range between charges is not imposed by the charging methods, even if fast charging is not considered, but from the size of the batteries.

Road tests performed by specialized magazines always show real consumptions to be higher than the one obtained through standard driving cycles, particularly NEDC.

There is no direct way of measuring the State Of Charge of a Li-Ion battery indeed. There are indirect ways of estimating it, but each suffers from limitations.

The electric cars designed in recent years show that is affordable to have approx. up to 20% of the curb weight given by batteries.

		Driving range [km] given the charging speed specified in the line below			
Curb mass [kg]	Energy consumption [Wh/km]	3.5 kW	7 kW	AC three-phase charging: 400 V, 30 A, max. power≈20 kW	DC fast charging: 400 V, 125 A, maximum power≈50kW
1000	150	[illegible]	[illegible]	67	167
1500	170	[illegible]	[illegible]	59	147
2000	190	[illegible]	[illegible]	53	132
2500	210	[illegible]	[illegible]	48	119

Obtainable driving range, half-hour charging
[elabor. by Politecnico di Torino, Filidoro, 2013]

		Charging time [min] given the charging speed specified in the line below			
Curb mass [kg]	Energy consumption [Wh/km]	3.5 kW	7 kW	20 kW	50 kW
1000	150	90	45	16	6
1500	170	102	51	18	7
2000	190	114	57	20	8
2500	210	126	63	22	9

Charging time needed to obtain a 35 km driving range
[elabor. by Politecnico di Torino, Filidoro, 2013]

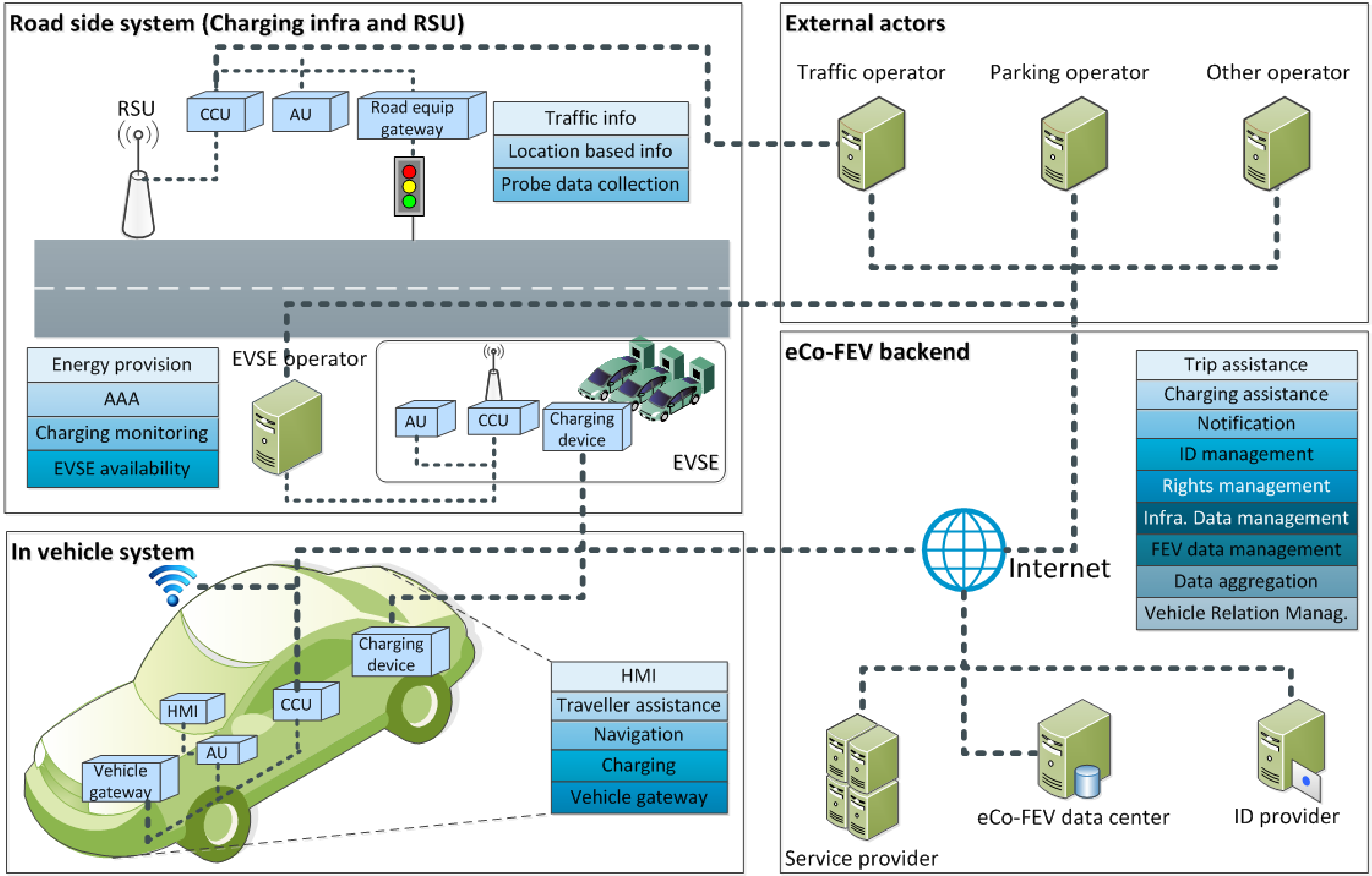
BATTERY RE-CHARGING

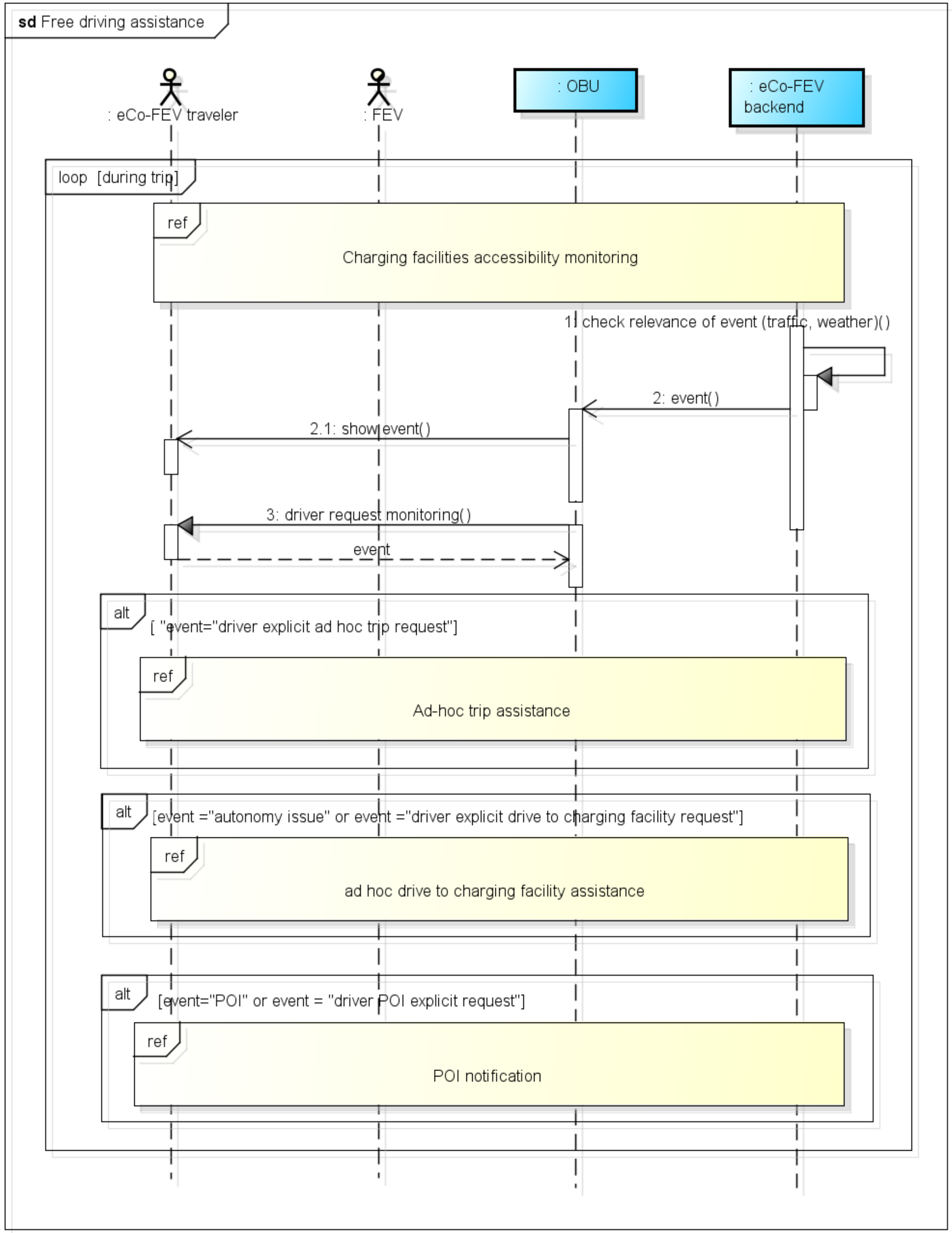
A. Conductive charging

B. Inductive contactless charging (contactless implicit)

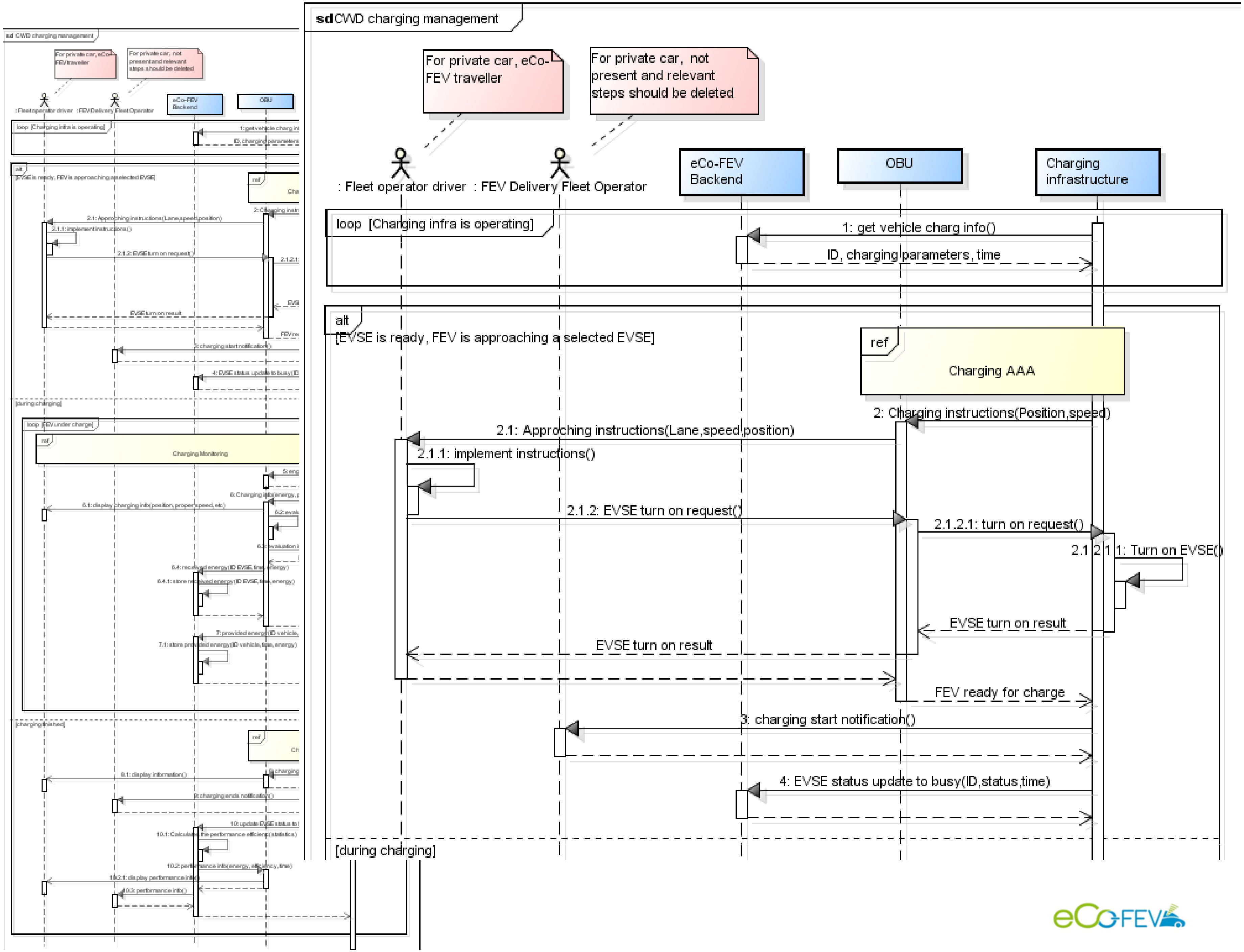
both of them can be

1. either motionless or in motion (e.g. inductive charging in motion);
2. either driverless or while driving (e.g. inductive charging while driving).


Road side system (Charging infra and RSU)
RSU
CCU
AU
Road equip gateway
Traffic info
Location based info
Probe data collection
Energy provision
AAA
Charging monitoring
EVSE availability
EVSE operator
AU
CCU
Charging device
EVSE
External actors
Traffic operator
Parking operator
Other operator
eCo-FEV backend
Trip assistance
Charging assistance
Notification
ID management
Rights management
Infra. Data management
FEV data management
Data aggregation
Vehicle Relation Manag.
Internet
In vehicle system
Charging device
CCU
HMI
AU
Vehicle gateway
HMI
Traveller assistance
Navigation
Charging
Vehicle gateway
Service provider
eCo-FEV data center
ID provider



sd Free driving assistance
: eCo-FEV traveler
: FEV
: OBU
: eCo-FEV backend
loop [during trip]
ref
Charging facilities accessibility monitoring
1: check relevance of event (traffic, weather)()
2: event()
2.1: show event()
3: driver request monitoring()
event
alt
["event="driver explicit ad hoc trip request"]
ref
Ad-hoc trip assistance
alt
[event ="autonomy issue" or event ="driver explicit drive to charging facility request"]
ref
ad hoc drive to charging facility assistance
alt
[event="POI" or event = "driver POI explicit request"]
ref
POI notification


sd CWD charging management
For private car, eCo-FEV traveller
For private car, not present and relevant steps should be deleted
: Fleet operator driver
: FEV Delivery Fleet Operator
eCo-FEV Backend
OBU
Charging infrastructure
loop [Charging infra is operating]
1: get vehicle charg info()
ID, charging parameters, time
alt
[EVSE is ready, FEV is approaching a selected EVSE]
ref
Charging AAA
2: Charging instructions(Position,speed)
2.1: Approching instructions(Lane,speed,position)
2.1.1: implement instructions()
2.1.2: EVSE turn on request()
2.1.2.1: turn on request()
2.1.2.1.1: Turn on EVSE()
EVSE turn on result
EVSE turn on result
FEV ready for charge
3: charging start notification()
4: EVSE status update to busy(ID,status,time)
[during charging]

- Area of competitiveness of FEV on the base of the analysis of demand
- Performances and limitations on the supply side: autonomy, batteries, power, performances, consumptions
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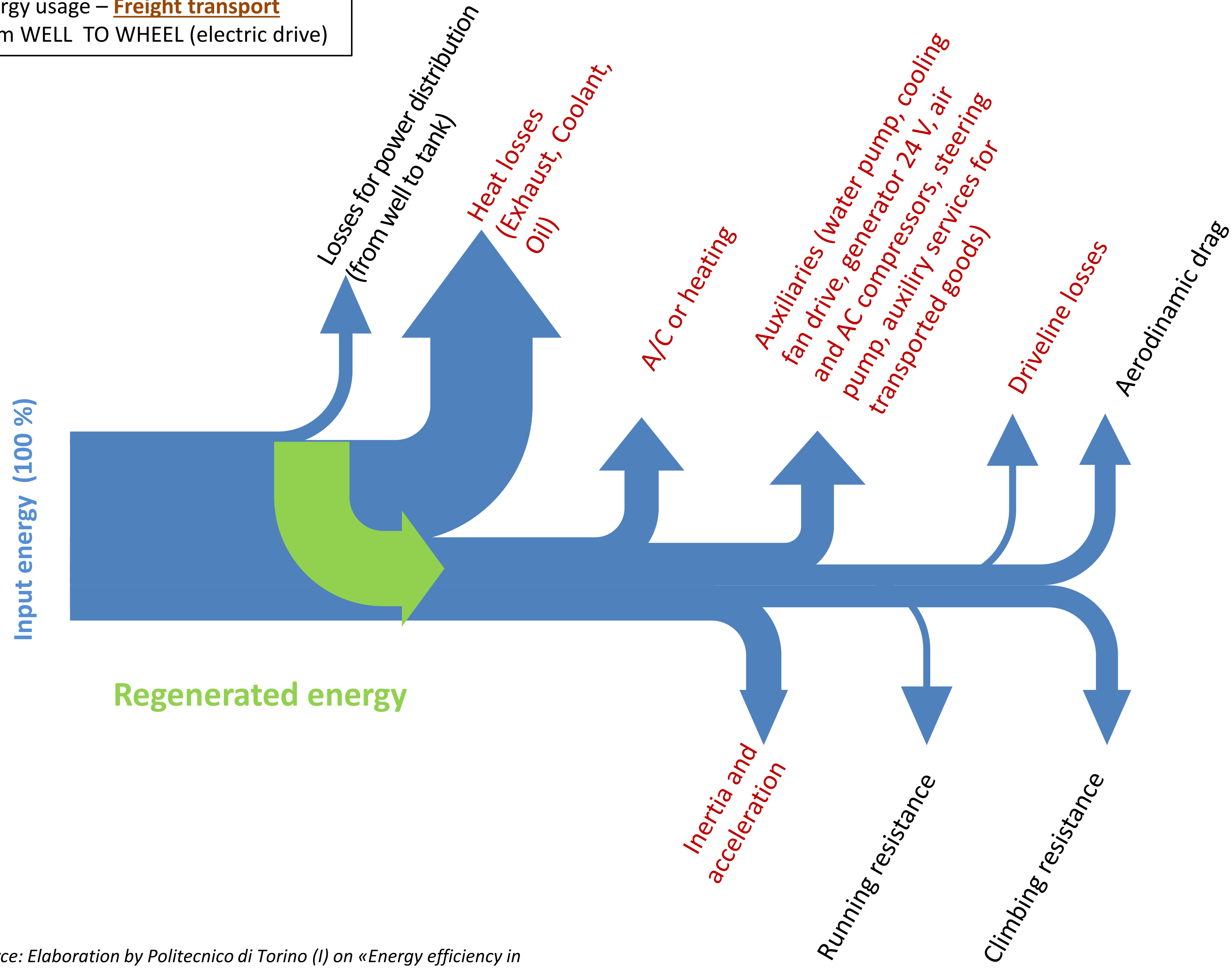
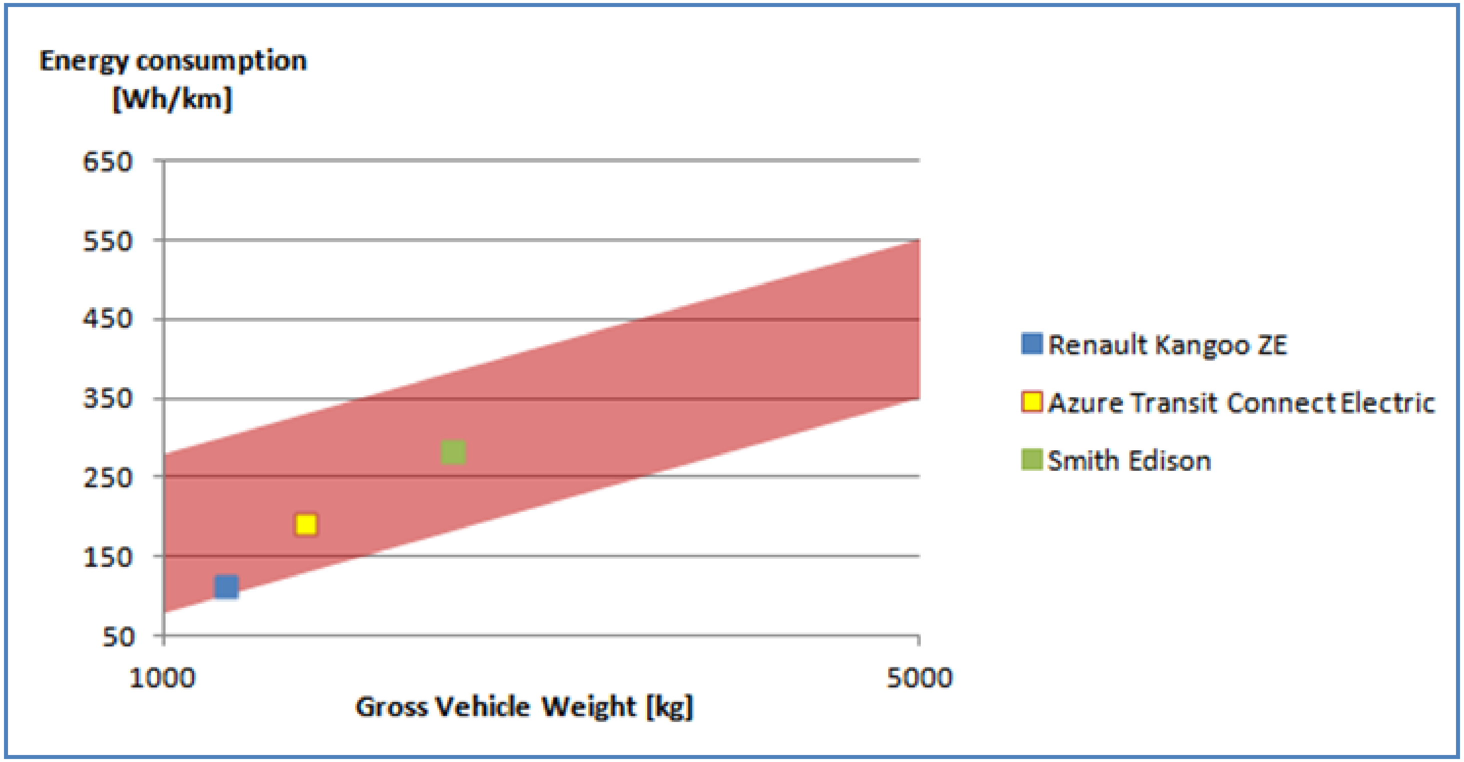
Freight transport

Energy usage – **Freight transport**
From WELL TO WHEEL (electric drive)



Source: Elaboration by Politecnico di Torino (I) on «Energy efficiency in public transport systems: what is the next stop on the line»? (F. Burkhart), Public Transport International n° 5, Sep-Oct 2012



Full electric light commercial vehicles energy consumption estimation, with some examples

Payload conditions!

		Maximum driving range [km] obtainable through the charging speed in the line below		
Gross Vehicle Weight [kg]	Energy consumption [Wh/km]	3.5 kW charging	7 kW charging	20 kW charging
1300	300	93	187	533
2000	350	80	160	457
3500	450	62	124	356
5000	550	51	102	291

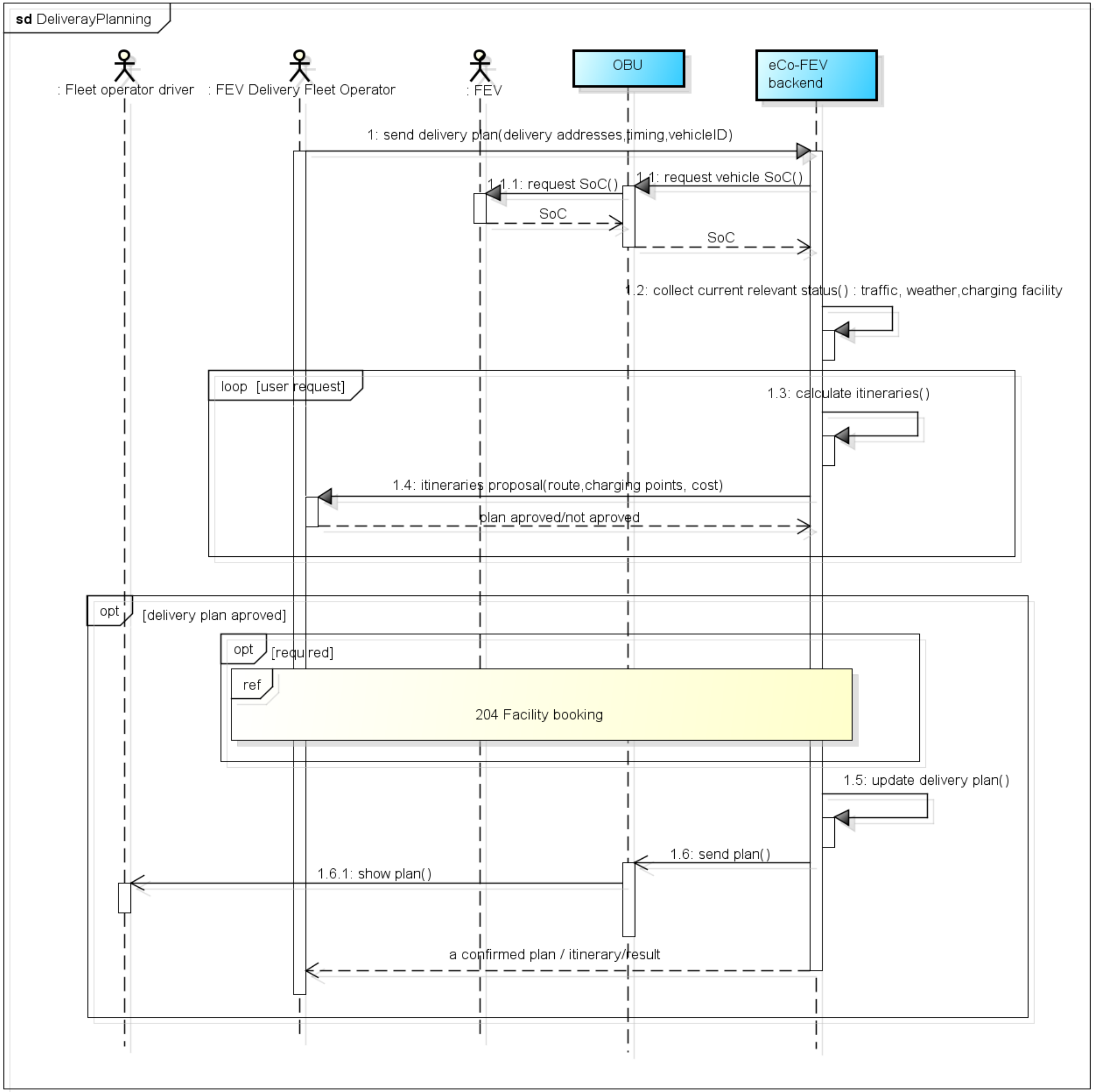
Maximum obtainable driving range, eight-hour charging

The calculation does not take into account again the limits caused by the batteries admissible size

		Charging time [min] given the charging speed specified in the line below			
Gross Vehicle Weight [kg]	Energy consumption [Wh/km]	3.5 kW	7 kW	20 kW	50 kW
1300	300	180	90	32	13
2000	350	210	105	37	15
3500	450	270	135	47	19
5000	550	330	165	58	23

Charging time needed to obtain a 35 km driving range

The calculation does not take into account again the limits caused by the batteries admissible size



sd DeliverayPlanning
: Fleet operator driver
: FEV Delivery Fleet Operator
: FEV
OBU
eCo-FEV backend
1: send delivery plan(delivery addresses,timing,vehicleID)
1.1: request vehicle SoC()
1.1.1: request SoC()
SoC
SoC
1.2: collect current relevant status() : traffic, weather,charging facility
loop [user request]
1.3: calculate itineraries()
1.4: itineraries proposal(route,charging points, cost)
plan aproved/not aproved
opt [delivery plan aproved]
opt [required]
ref
204 Facility booking
1.5: update delivery plan()
1.6: send plan()
1.6.1: show plan()
a confirmed plan / itinerary/result

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Public transport and multimodal mobility

Main features:

- Fixed path
- Known distances
- Known and usually necessary stops
- Scheduling of activities (driver’s rest) at terminals/depots

Though:

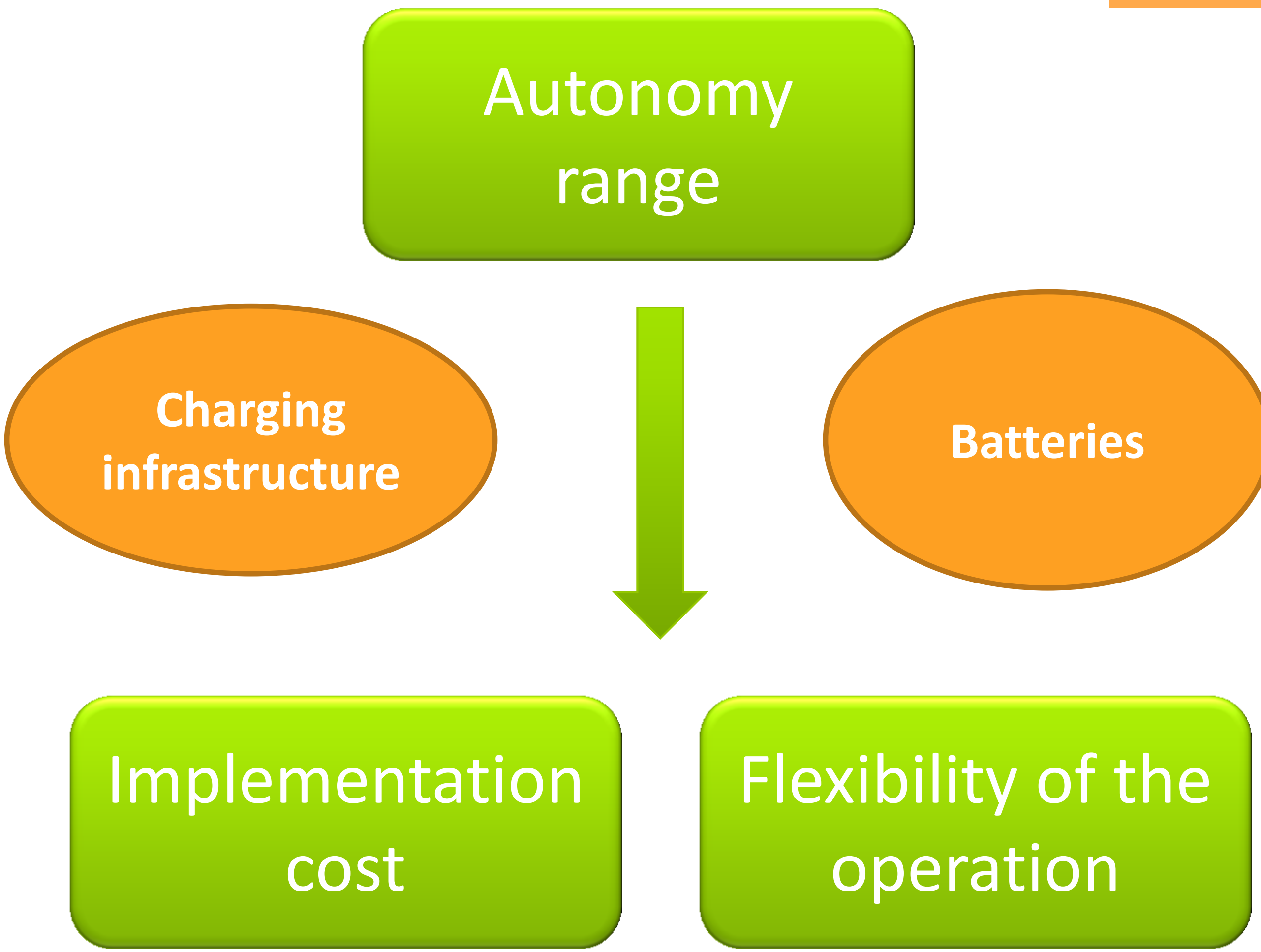
- Variability of the mass
- Possible aging effects on batteries
- Transport for a public service (no risks, no nearly-empty SOC allowed)

Factors driving change towards electrification of public transport

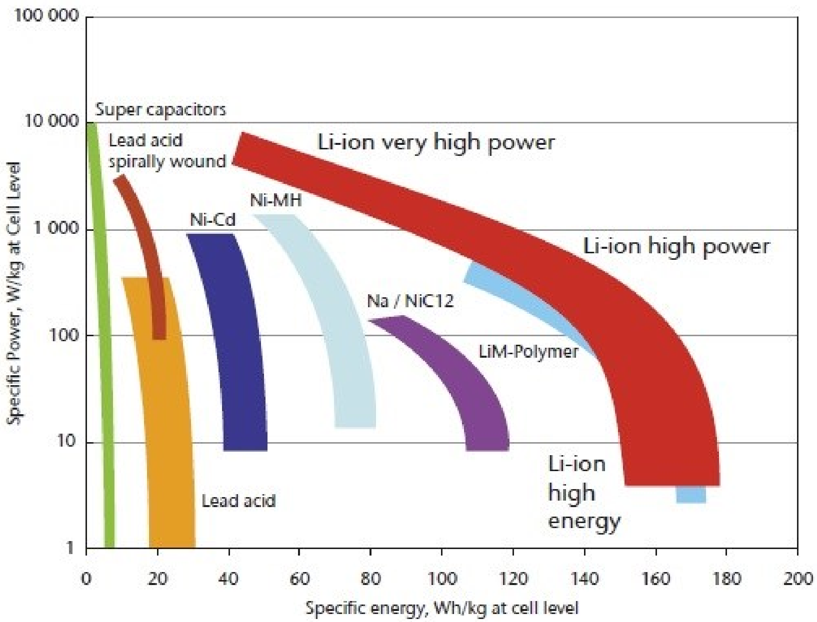
Global → Local → Technical

Global	Local	Technical
Environmental issues and oil depletion	Pressure to improve quality of city life	Sustainable technology with low running costs

Factors limiting change towards electrification of public transport



Electric energy storage element



- Specific energy
- Cycle life
- Purchasing costs
- Opportunity charging

⇩

- Sizing of the storage element

Most used
- Li-iron phosphate
- Li-titanate
- Super capacitors

Electric bus typologies and energy consumption

Trolley bus
(Non autonomous)

Battery bus
(Autonomous, partially autonomous)

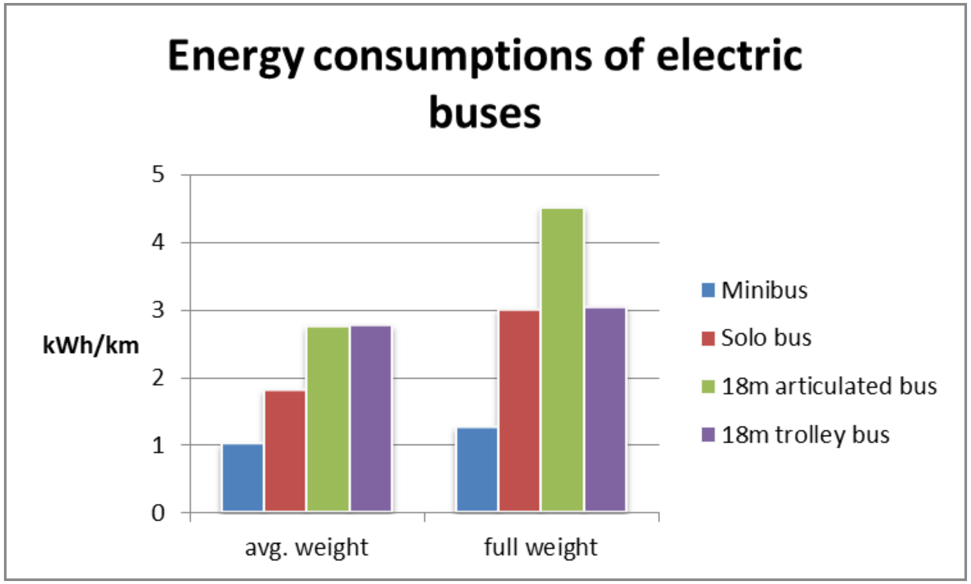
Capabus
(Partially autonomous)

- Dimensions
  - Number of passengers
  - Avg. energy consumption
- Energy storage element
  - Autonomy range
  - Charging time
  - Purchasing cost
- Charging devices on board
  - Adaptation to infrastructure

Electric bus typologies and energy consumption

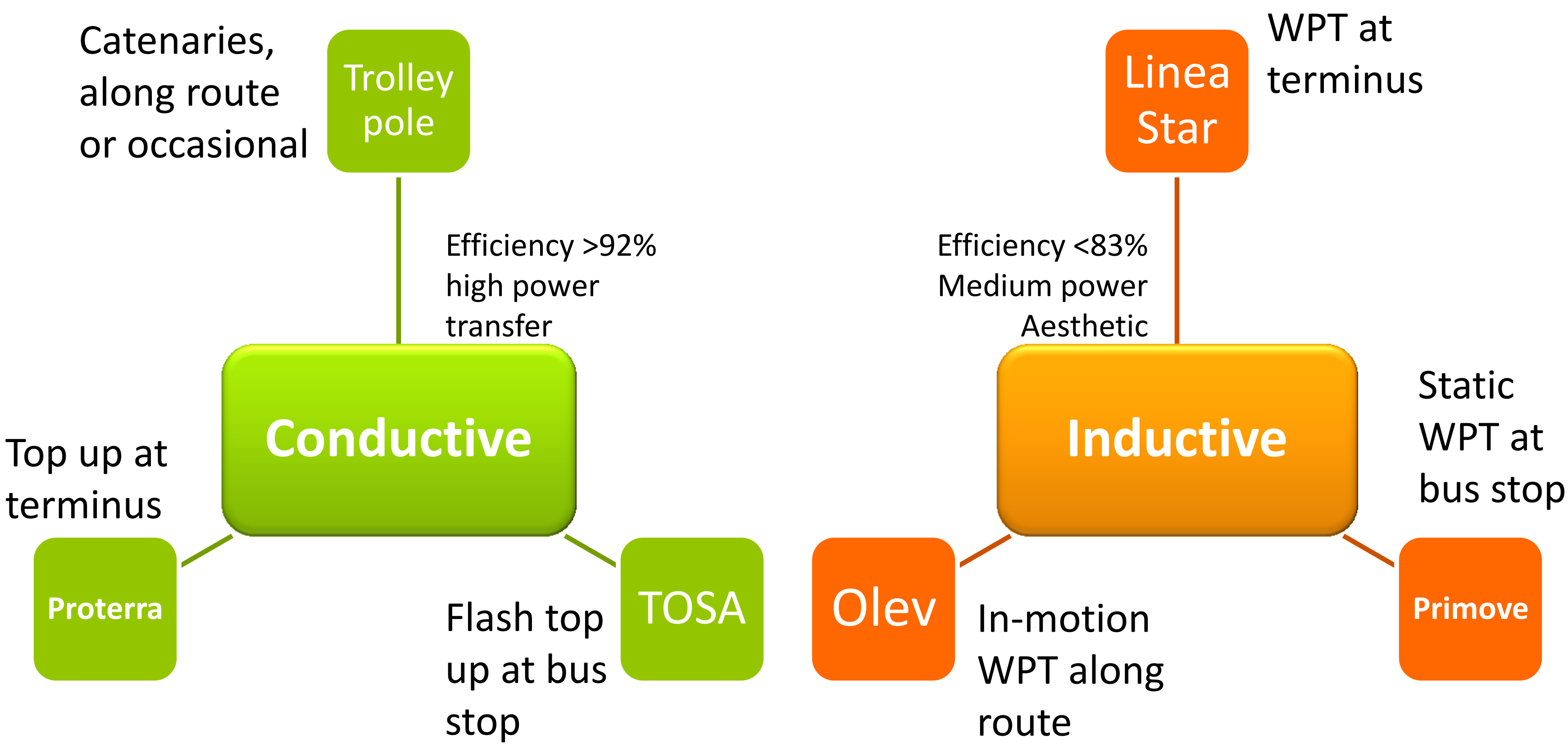
For given traffic and route, energy consumption is mainly influenced by :

- Vehicle mass
- Auxiliary devices



Exemplary consumption value: 1kWh/km

Investigated charging technologies and infrastructure systems



Linea Star study case: example

[source: some data were provided by GTT, Spring-Summer 2013]

Current bus characteristics:

- 7.48m, 34 passengers
- 8750-11500 kg
- Pb-gel batteries, 60.4 kWh, 1790 kg
- Three phase asynchronous motor (max 120kW, 65kW)

Route:

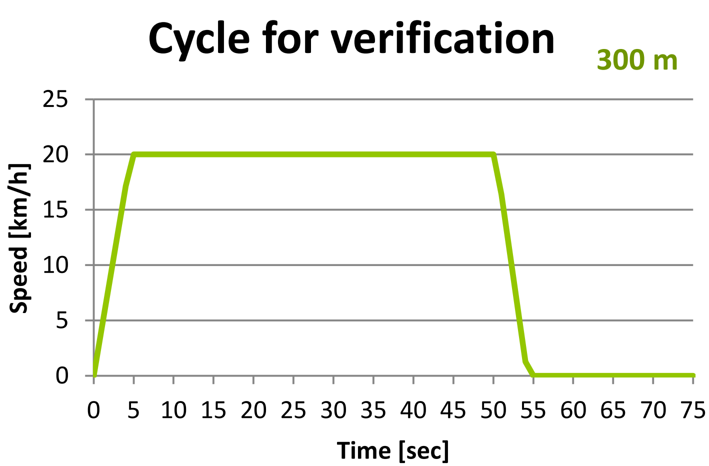
- Turin city center,6km
- Total of 120km/day

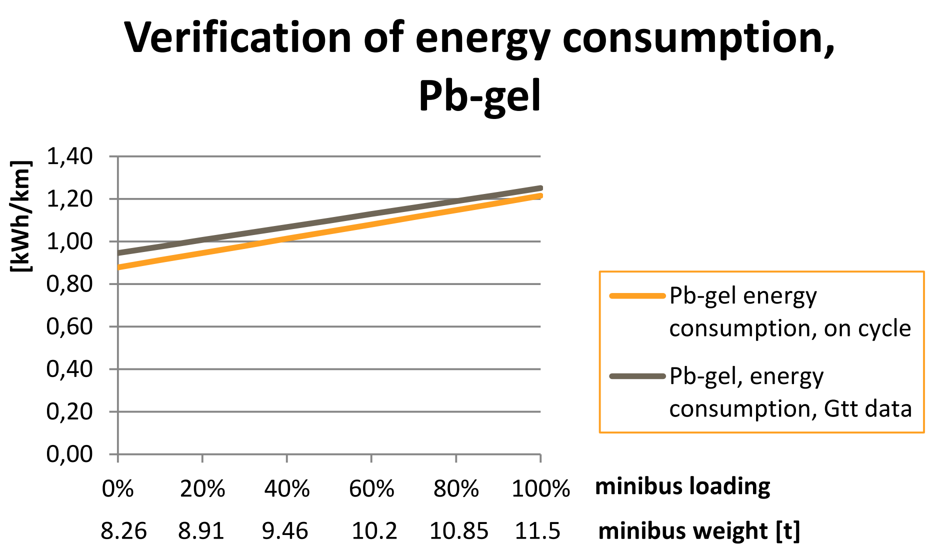
Inductive charging at terminus:

- Efficiency 70%
- Power transfer ≤40kW
- 10-15 minutes

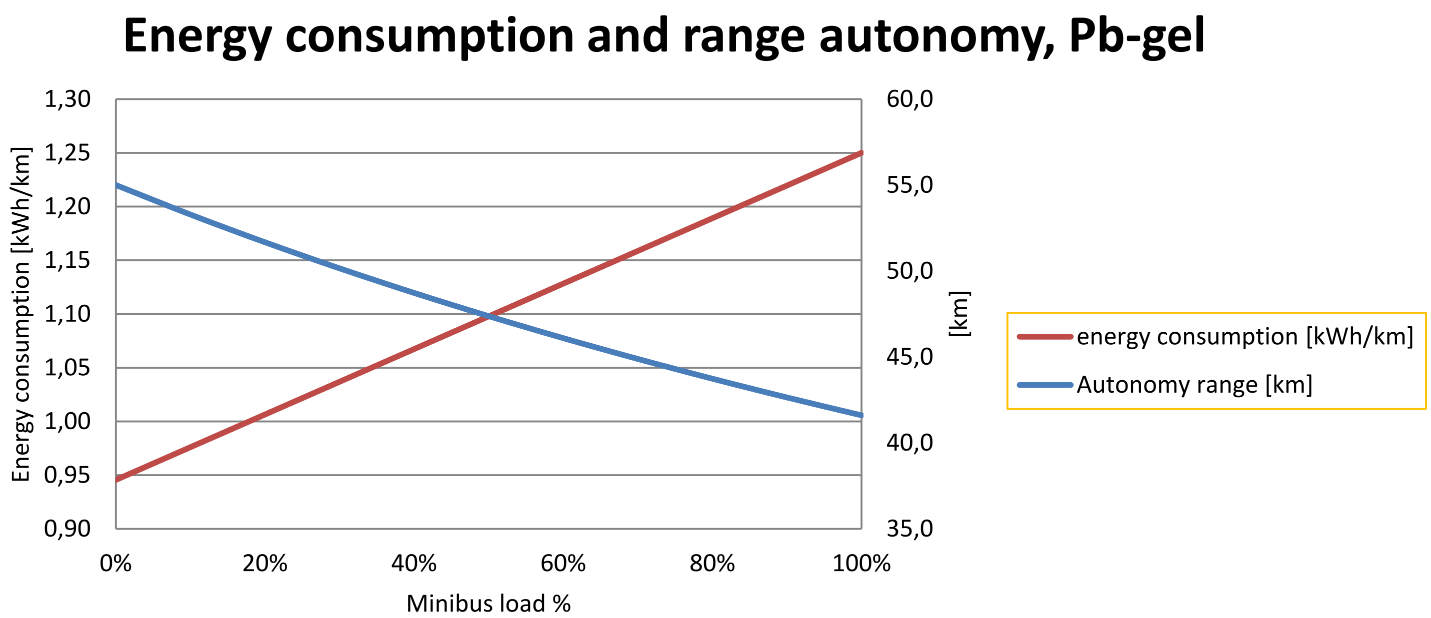
Linea Star study case - current status

Pb-gel batteries	Data given by GTT
Full load energy consumption	1.25 kWh/km
Weight effect on energy consumption	0.094 kWh/km*ton



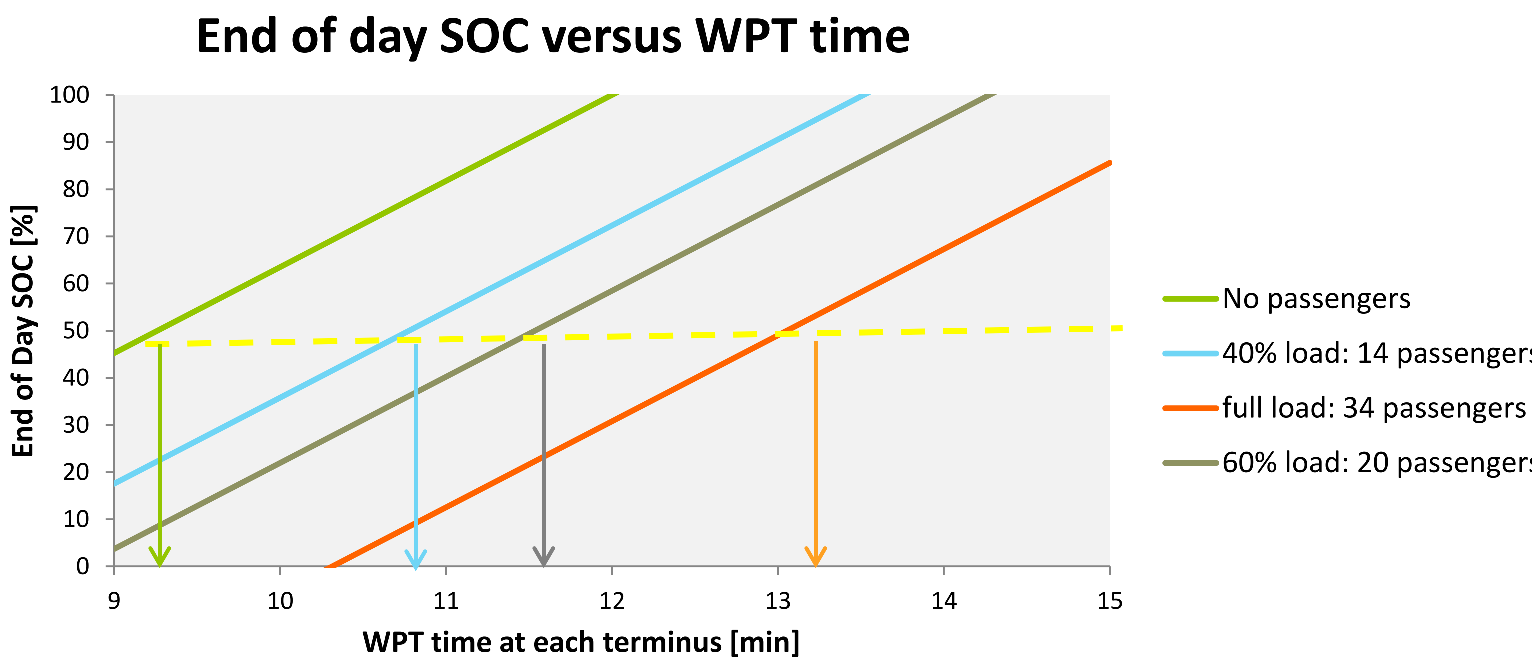


Linea Star study case - current state



40% loading	14 passengers	9.56 ton	1.07 kWh/km	49 km
60%	20 passengers	10.2 ton	1.13 kWh/km	46 km

Linea Star study case - current state



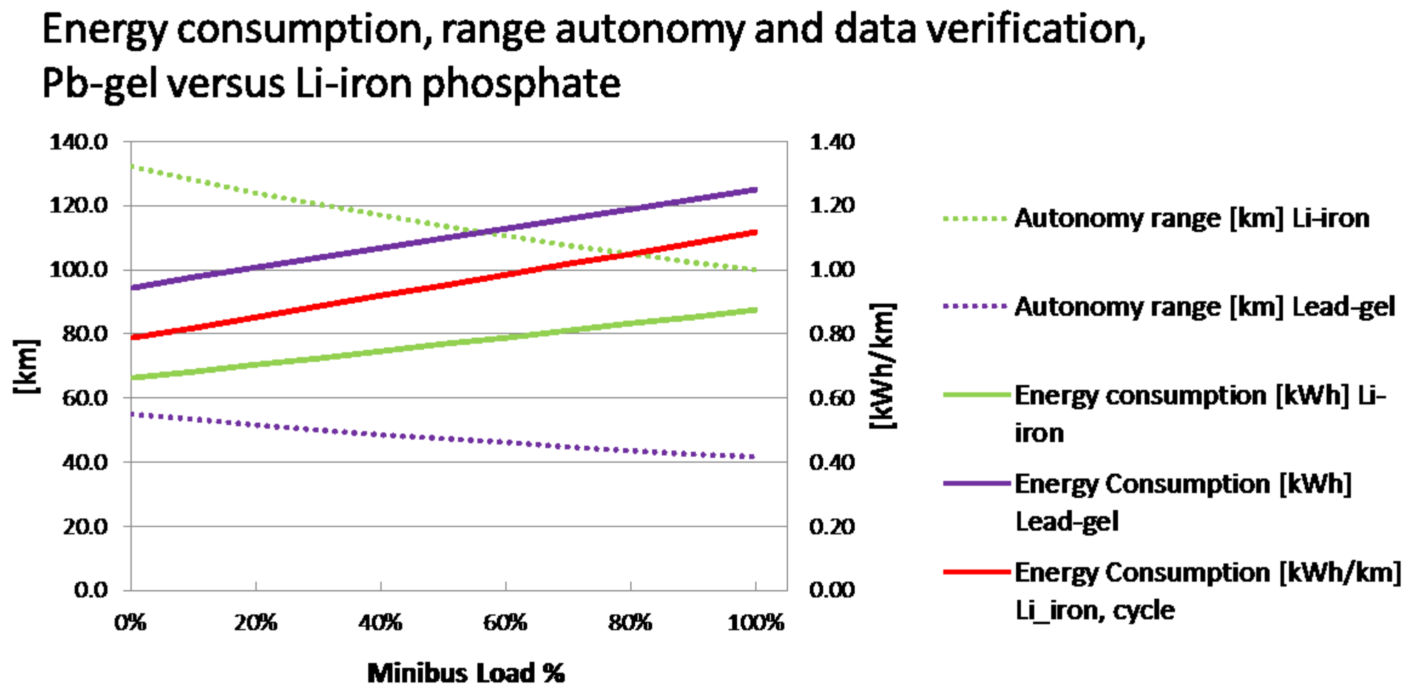
- Pb-gel useful SOC: 40-90 %

- 6km route
- 20 journeys
- 19 stops

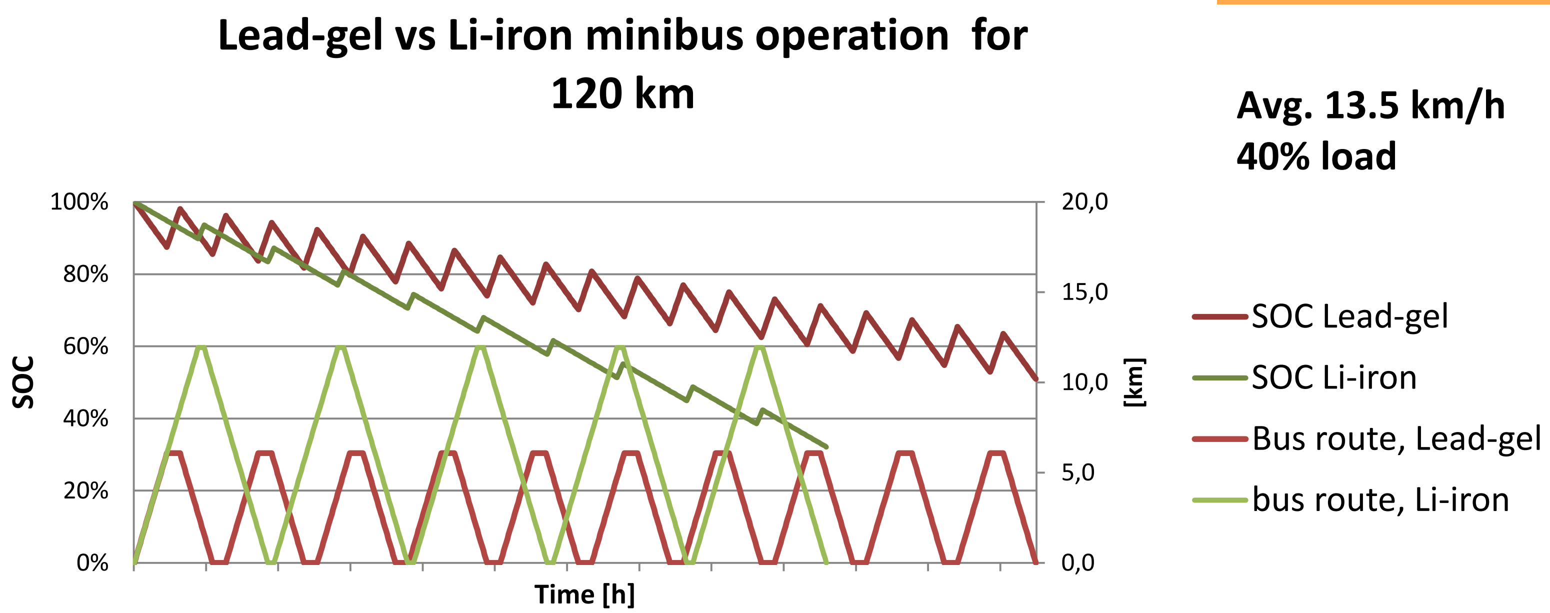
Linea Star study case - Li-iron phosphate versus Pb-gel batteries

- Weight reduction (778 kg)
- Improvements in regenerative braking

→ **-30% energy consumption**

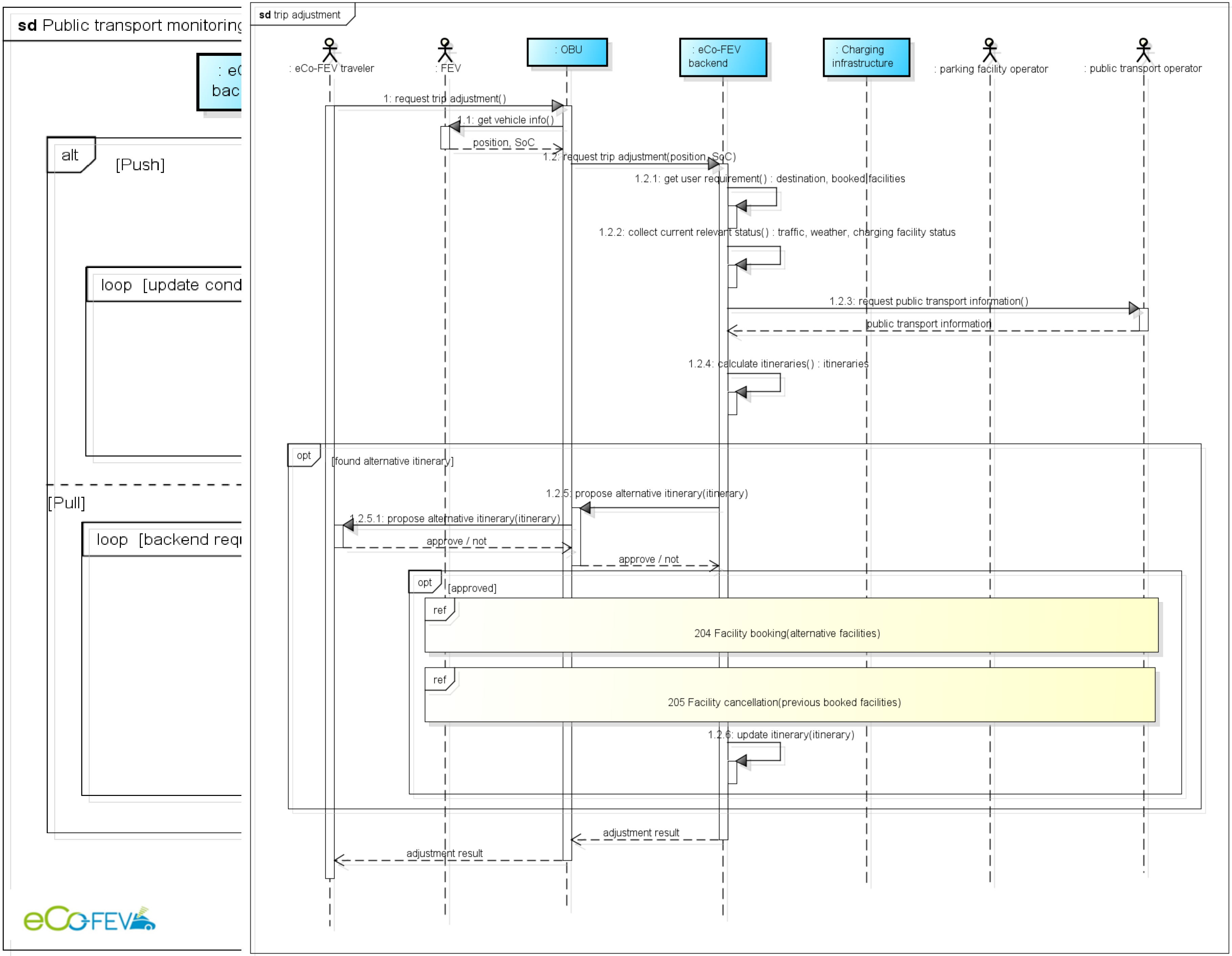


Linea Star study case - Li-iron phosphate versus Pb-gel batteries



- Lead-gel (9.56 ton, 1.07 kWh/km): 20 journeys of 6km each with 19 stops of 11’ for inductive charging

- Li-iron (8.78 ton, 0.75 kWh/km): 10 journeys of 12km each with 9 stops of 5’ for inductive charging


sd Public transport monitoring
: e
bac
alt
[Push]
loop [update cond
[Pull]
loop [backend requ
eCoFEV
sd trip adjustment
: eCo-FEV traveler
: FEV
: OBU
: eCo-FEV backend
: Charging infrastructure
: parking facility operator
: public transport operator
1: request trip adjustment()
1.1: get vehicle info()
position, SoC
1.2: request trip adjustment(position, SoC)
1.2.1: get user requirement() : destination, booked facilities
1.2.2: collect current relevant status() : traffic, weather, charging facility status
1.2.3: request public transport information()
public transport information
1.2.4: calculate itineraries() : itineraries
opt
[found alternative itinerary]
1.2.5: propose alternative itinerary(itinerary)
1.2.5.1: propose alternative itinerary(itinerary)
approve / not
approve / not
opt
[approved]
ref
204 Facility booking(alternative facilities)
ref
205 Facility cancellation(previous booked facilities)
1.2.6: update itinerary(itinerary)
adjustment result
adjustment result

Conclusions: FEV

- A market compliant with urban motorised personal mobility and other specific cases (freight distribution, < 5 t – GVW; Public Transport)
- Conditioned by use, with preferences for known paths: actual autonomy and foreseenable SOC, recharging organisation and scheduling (e.g. PT)
- Inductive charging can be a good solution, especially in some conditions
- EV conditioned by flexible use → PHEV
- Heavy masses and long distances → traditional and alternative fuels

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