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BUS & COACH SECTOR

## Needs and consequences for the electricity supply in case of plug-in electro-mobility

Raf Ponnette, research coordinator Sustainable Energy  
Electrical Devices, EnergyVille-VITO



- EnergyVille
  - Energy research with link to e-mobility
- Electrification of public transport
  - Trends & roadmaps : technology & market
- Activities in Europe
  - Research & demonstration projects



**EnergyVille** unites the Flemish research institutes KU Leuven, VITO and imec for research on **sustainable energy and intelligent energy systems**. Our researchers deliver expertise to industry and cities on energy efficient buildings and intelligent networks – such as smart grids and advanced heat nets.

Our work on smart grids includes **e-mobility energy supply infrastructure**. It is our vision that electric vehicles will become active participants in the smart grids and markets of the future.



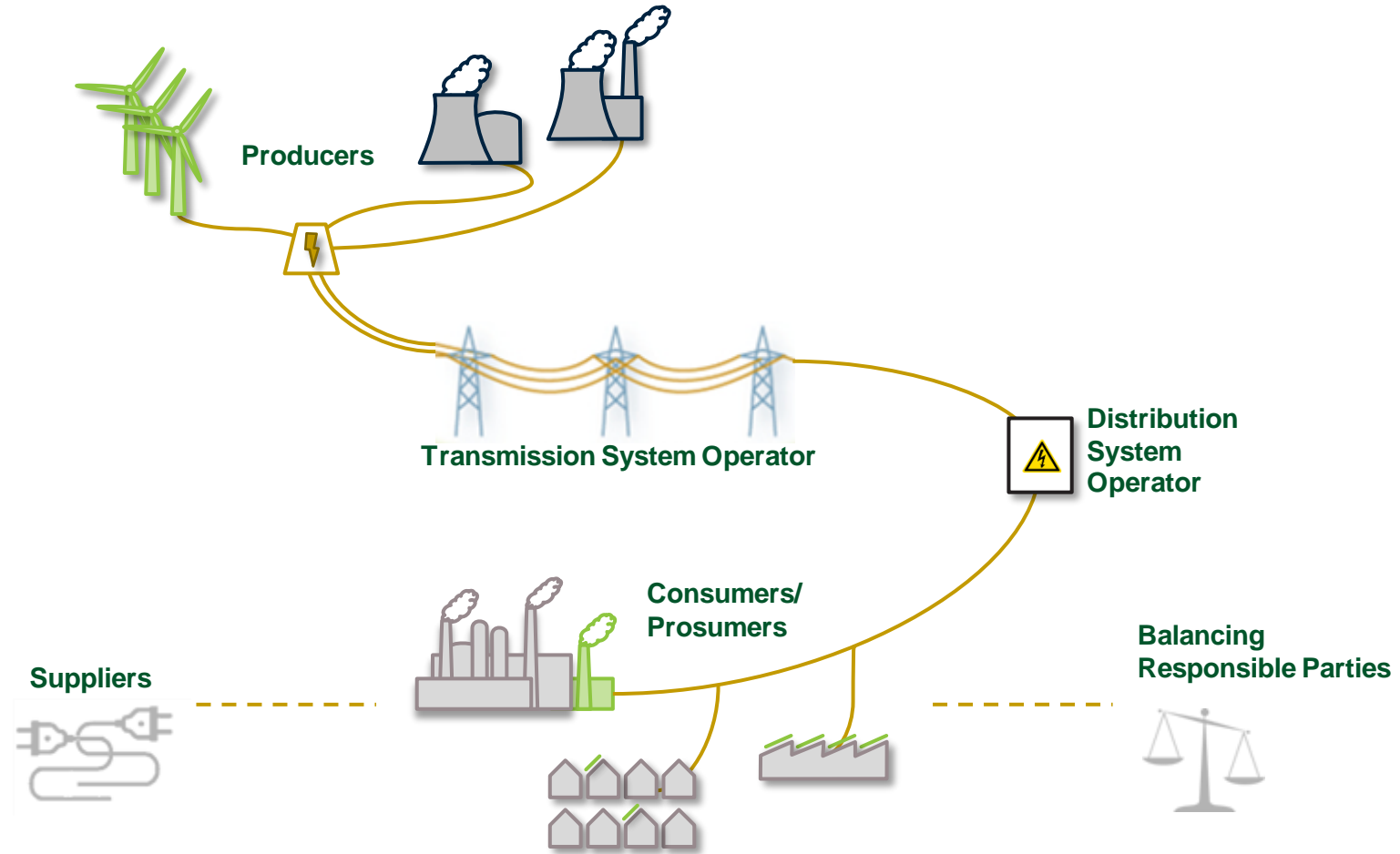
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## E-Mobility & Electric Supply

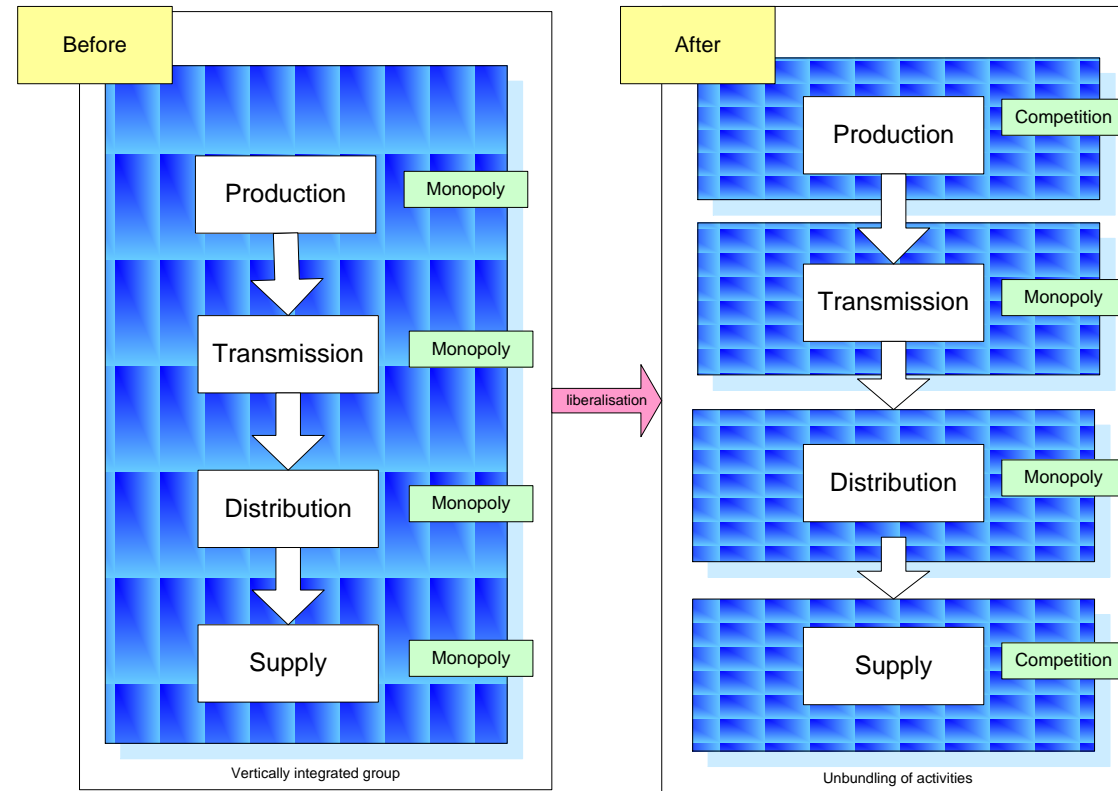
- Electric transport of persons and distribution of goods will be the preferred mode in cities (the dominant mode in 2050)
  - increases quality of life (reduction of NO<sub>x</sub>, PM, SO<sub>2</sub>, VOCs)
  - increases quality of service (predictability of cost, reliability)
- Electric vehicles will become pro-active and cooperating components that connect and disconnect to the grid
  - increases potential of renewable energy sources
  - increases effective use of grid infrastructure
- E-mobility charging infrastructure will be tightly integrated with
  - the electricity distribution grids
  - public transport energy infrastructure for energy & mobility services

# Electricity System : Stakeholders



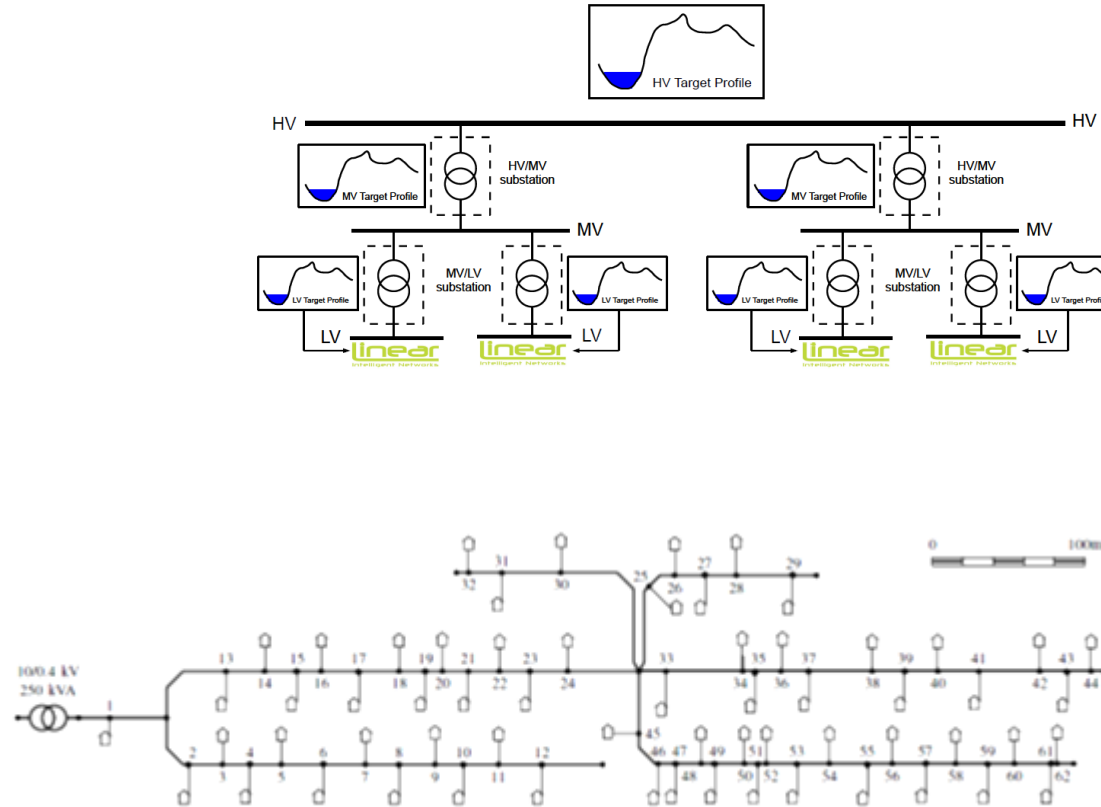
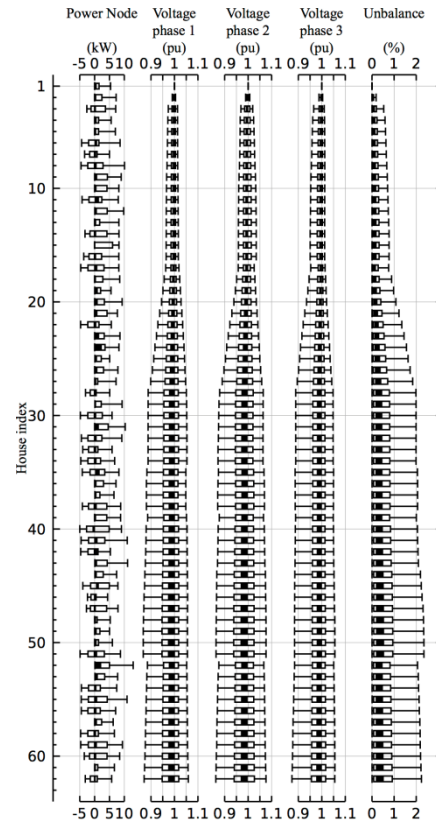
# Energy Market : context and background

- Liberalisation energy markets across Europe
- Vertical unbundling of generation, transmission and supply





- 3 phase grid impact



# Grid buffering

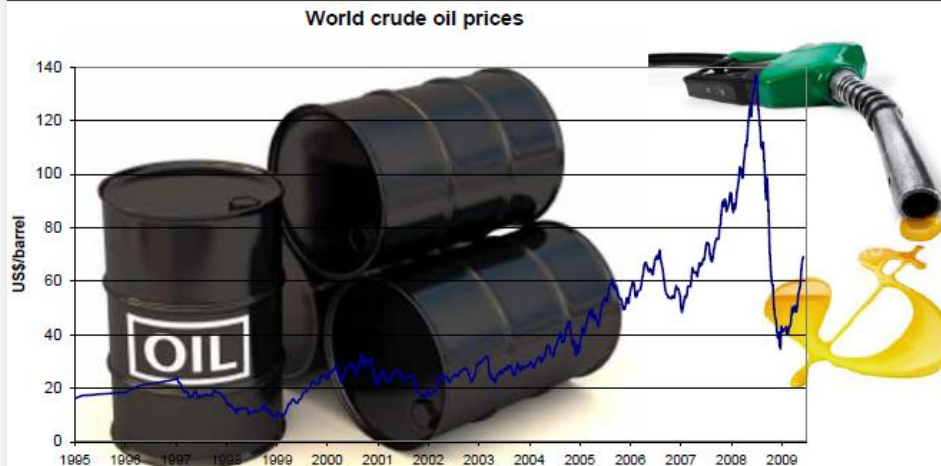
- Small footprint storage system feeding trams, metro and light rail networks
    - Increased recovery of brake energy
    - Peak power reduction
- ➡ **Reduction of Energy Bill**
- ➡ **Increased network capacity**





- EnergyVille
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## *Driving forces for electrification*



- » Economical : fuel cost reduction, ...
- » Ecological : reduce global and local impact on the environment
- » Technical : performance, comfort, ...
- » Legislation : emission standards, ...
- » Government : oil independency, strategic energy plans (EU Renewable Energy Directive), ...

# Electrification of “light-duty” transport

## GoPedelec!



GoPedelec!  
Go easy!

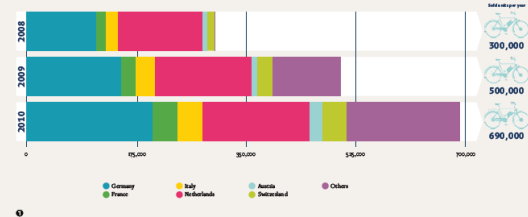
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GoPedelec 1

MARKET

MARKET DEVELOPMENT OF PEDELECS AND E-BIKES IN EUROPE



There's hardly any more controversial subject than sales figures for pedelecs. These numbers are from *Zweiradfahrerverband (ZFV)* in Germany. ZFV has given a total for 900,000 units for 2010. Other sources such as the *Strom (Electric Bike) Worldwide Report* by Frank Janssen estimate that the total market was already reached for 2010, and gives 1.1 million units for 2010. Because pedelecs do not have to be registered and because they are also often imported from Europe under various different customs codes, nobody can give exactly what the sales figures are. But it is still clear that it is already very easy, and it is ever increasing.

### Growth with a tailwind Pedelecs expand in sales and turnover

In 2010 sales of pedelecs exceeded the one million mark in Europe. What had been promised by steadily increasing numbers since 2008 had become reality. The market for electric two-wheelers is in top gear with ever more countries joining the pedelec bandwagon. It's not just unit sales which are growing, but also the turnover per bicycle is also increasing thanks to increased quality expectations from customers.

NewsMonday

Pedelecs are enjoying rapid sales, especially in their largest European markets: Germany, the Netherlands and, since 2009, Austria. A market report in the trade magazine *Bike Europe* stated that for 2010, sales of electric bikes in Europe had exceeded the one million mark. For 2015, 3 million are expected. Among these sales of electric two-wheelers the majority are pedelecs. The entry of new players with high production capacity into the pedelec market also promises well for further rise in sales. Companies from the auto supply sector such as *Bosch* (2008) and *Brose* (2011) have given as reasons for their actions the future potential of e-mobility.

Sales of electric bikes in Europe have now exceeded the one million units mark.

With growing acceptance of pedelecs they are increasingly replacing bicycles.

PEDELEC BESTSELLER

Since 2008 the sales of pedelecs have been increasing rapidly, often by 50% or more per year. The growth in unit sales in the Netherlands has been the most consistent, and this is at the same time the most mature market. Here it has been determined that as acceptance of pedelecs has increased they have displaced sales of conventional bikes. This increasing self-confidence for pedelecs is seen across Europe. While unit sales of bikes overall reduced slightly in 2009/10 because of the harsh winter and wet summer, pedelecs notched up another increase.

The figures illustrated in Figure 1 from the *Zweiradfahrer Verband (ZFV)* are a very conservative estimate. They do not reflect European import numbers, which implies considerably higher unit figures. China alone

14 GoPedelec

### Market sectors with potential

Many people think of the bicycle as rather limited in transport capacity. But unnoticed by most of the population of Europe and many other regions worldwide, a very interesting new category of bike has been evolving.



**The Redfish:** As the name suggests this springs from the baker's delivery bike, and it has become a much-loved family vehicle in the Netherlands. With a pedelec drive it will also spread to hillier parts of the world.



**Endgame public:** For those who need to carry even more children than will fit in a Redfish the solution is the GoGak. There's a store of room in the GoGak for eight children to be safe and comfortable. It makes the kindergarten run child's play.



**Flat, like:** Worldwide, according to *Farsight* estimates, there are already over 100,000 pedelecs in daily use in bike fleets. As pointed out here for pizza delivery in China, but also for postal deliveries, for couriers, for taxicab service vehicles etc...

**Not all that new, but still with huge potential:** hire pedelecs are increasingly available as personal public transport, for an extended range around stations. Especially in urban areas this can lead to better transport connections and acceptance of the personal public transport concept.

GoPedelec 11

### PUBLIC CHARGING INFRASTRUCTURE

### Pedelecs – public charging infrastructure Doing the right thing

Almost the whole world is well provided with private charging infrastructure, because just about every main power socket is suitable for recharging pedelecs: via the mains charger which are usually supplied along with the bikes.

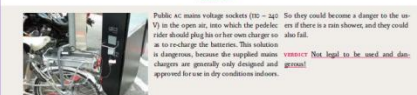
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With this in mind one could say that there is no need at all for a public charging infrastructure. And this conclusion is apparently justified, because the pedelec has caught on really over recent years – without any such infrastructure. But you can also look at it another way: the pedelec might have caught on even faster if there had been a suitable public infrastructure. Because it is a very high level of investment and can then very quickly lose its attractiveness and value.

Electricity company houses, mayors and tourism heads have to make as 'promoters' centers in front of a public charging station with partners who use it or are standing their own offerings and who are happy to take on the extra business.

Ensure that both and restaurants are provided with cycle-friendly structures. So here a half pedelec which should help with any design making about infrastructure:

EXAMPLES



Charging at AC main sockets in waterproof lockers which fulfill the requirements of "dry indoors". Have the user plug in the charger and battery, and then, once parked, remove them. If the lockers are located outside it is also worth remembering that most batteries should be charged below 10 degrees Celsius.



# Electrification of “heavy-duty” transport



## Final Report

### Task XII - “Heavy-duty hybrid vehicles”

2007 – 2010

#### Authors

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© EVS-25 Shenzhen, China, Nov. 5-9, 2010  
The 25th World Battery, Hybrid and Fuel Cell Electric Vehicle Symposium & Exhibition

## Trends and insight in heavy-duty vehicle electrification

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**Abstract**—This paper describes the results from Annex XII “Heavy-duty hybrid vehicles” of the International Energy Agency (IEA) Implementing Agreement on “Hybrid and Electric Vehicles” (IA-HEV). Since 1993, this Implementing Agreement has provided a platform to exchange knowledge, experience and strategies among the member states on the latest developments in hybrid and electric vehicles, mostly passenger cars. Because heavy-duty vehicles have specific technical requirements and economic boundary conditions compared to the passenger car market, a dedicated Annex was started in 2007 and will run until the end of 2010. Six countries (Belgium, Canada, Finland, Switzerland, the Netherlands and the United States) are participating to collect and share relevant information on the latest technical and market developments in “electrified” trucks, buses and mobile work machines. This information will broaden the insight in the existing applications of heavy-duty vehicles electrification and can provide essential information for future heavy-duty hybrid vehicle deployment projects. *Copyright Form of EVS25.*

**Keywords**—Heavy-duty hybrid vehicles, Vehicle electrification, Trucks, Buses, Mobile Work Machines

## Classification


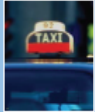

» Important to setup a classification on heavy-duty vehicles because they all have it's own specific requirements, driving cycle and other boundary conditions -> big impact on potential of electrification for vehicles suitable for the application



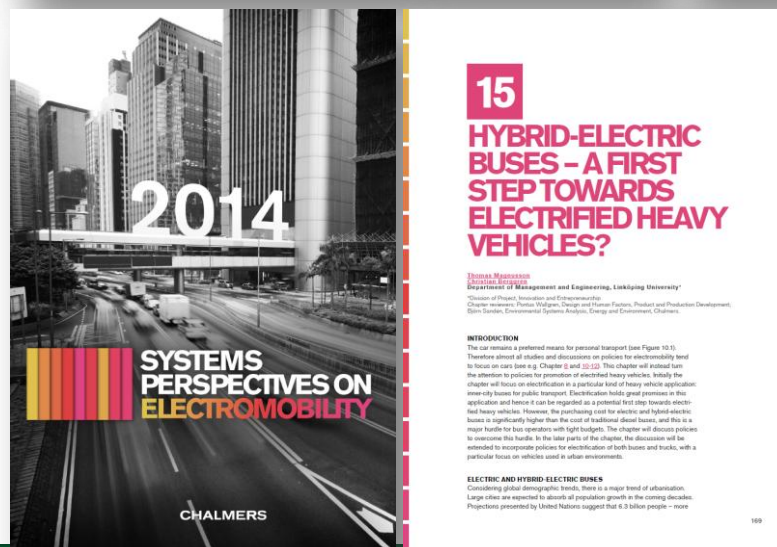
# Electrification of “public” transport



Figure 19: Key components of public mobility services

Public mobility infrastructure		Service offering characteristics	
Public transport		Quality	<ul style="list-style-type: none"> <li>■ Accessibility, operating hours, punctuality, reliability, frequency, network coverage</li> <li>■ Sufficient capacities in peak periods</li> </ul>
			<ul style="list-style-type: none"> <li>■ Rail (regional, sub-urban, metro, light rail, tram)</li> <li>■ Buses (regional, urban buses &amp; trolleybuses, BRT)</li> <li>■ Ferries, Personal Rapid Transit</li> </ul>
			<ul style="list-style-type: none"> <li>■ Car &amp; bike sharing</li> <li>■ Car &amp; bike rental</li> <li>■ Taxi &amp; limousine service</li> <li>■ Etc.</li> </ul>
Public individual transport		Safety and Security	<ul style="list-style-type: none"> <li>■ Exploitation safety performance, security and perception of security</li> <li>■ Emergency medical and police services</li> </ul>
			<ul style="list-style-type: none"> <li>■ Real-time information, planning, booking and payment</li> <li>■ Comfort, speed, congestion freeness</li> </ul>
Parking infrastructure		Convenience	<ul style="list-style-type: none"> <li>■ Energy efficiency and alternative engines</li> <li>■ Air quality and noise neutrality, climate neutrality</li> </ul>
			<ul style="list-style-type: none"> <li>■ Park + Ride facilities</li> <li>■ Bike + Ride facilities</li> <li>■ Bike garages and parking boxes</li> <li>■ Etc.</li> </ul>
		Sustainability	<ul style="list-style-type: none"> <li>■ Financial attractiveness for users, meeting social and distributional objectives</li> <li>■ Cost efficiency of operators, PT incentives</li> </ul>

Source: Arthur D. Little



## 15 HYBRID-ELECTRIC BUSES – A FIRST STEP TOWARDS ELECTRIFIED HEAVY VEHICLES?

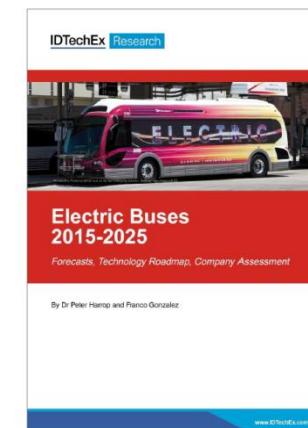
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Chairman of the Board, Innovation and Entrepreneurship  
Chairman of the Board, Future Vehicle Design and Future Urban Product and Production Development  
Chairman, Environmental Systems Analysis, Energy and Environment, Chalmers

**INTRODUCTION**  
The car remains a preferred means for personal transport (see Figure 10.1). Therefore almost all studies and discussions on policies for electromobility tend to focus on cars (see e.g. Chapter 2 and 10.2). This chapter will instead turn the attention to policies for promotion of electrified heavy vehicles. Initially the chapter will focus on electrification in a particular kind of heavy vehicle application: zero-emission buses for public transport. Electrification holds great promise in this application and hence it can be regarded as a potential first step towards electrified heavy vehicles. However, the purchasing cost for electric and hybrid-electric buses is significantly higher than the cost of traditional diesel buses, and this is a major hurdle for bus operators with tight budgets. The chapter will discuss policies to overcome this hurdle. In the later parts of the chapter, the discussion will be extended to incorporate policies for electrification of both buses and trucks, with a particular focus on vehicles used in urban environments.

**ELECTRIC AND HYBRID-ELECTRIC BUSES**  
Considering global demographic trends, there is a major trend of urbanization. Large cities are expected to absorb all population growth in the coming decades. Projections presented by United Nations suggest that 6.5 billion people – more

## Read Electric Buses 2015-2025

[idtechex.com/research](http://idtechex.com/research)



## Electric Buses 2015-2025

Forecasts, Technology Roadmaps, Company Assessment

Industrial and commercial electric vehicles will be a similar market to cars but innovating faster and frequently more profitable for all in the value chain.

Electric buses are based on various types of hybrid and pure electric powertrain. We find Chinese pure electric winning and fuel cells losing, hybrids in-between as the bus market passes \$100 billion in 2025.

[www.idtechex.com/buses](http://www.idtechex.com/buses)



## Storage for Hybrid Busses



# Electrification of public transport

- Which type of “e-bus” ?
  - Hybrid, Plug-in Hybrid, Battery, Fuel Cell ?
  - Battery : big battery or small battery + opportunity charging ?
- Need for charging infrastructure networks but which type ?
  - normal or fast charging ?
  - conductive or wireless charging or battery swapping ?
  - static or dynamic charging ?
  - ...



- Not easy for public transport authorities/operators to make a good choice
- It all depends on the use case which combination is the best investment

## Criteria

- Total Cost of Ownership (capex – opex)
- Reliability (time table)
- Comfort
- Impact on public space in urban areas
- Impact on the electricity network
- Future proof investment ? Flexibility, Legislation, Standards, ...
- People acceptance : customers, drivers, ...

# How much energy is needed ? EV Monitoring, Remote Sensing & Control

On-board logger

GPS

GPRS

Data storage capacity

CAN interface

Wifi

On-board preprocessing

Collects data :

Electricity consumption

Trajectory characteristics

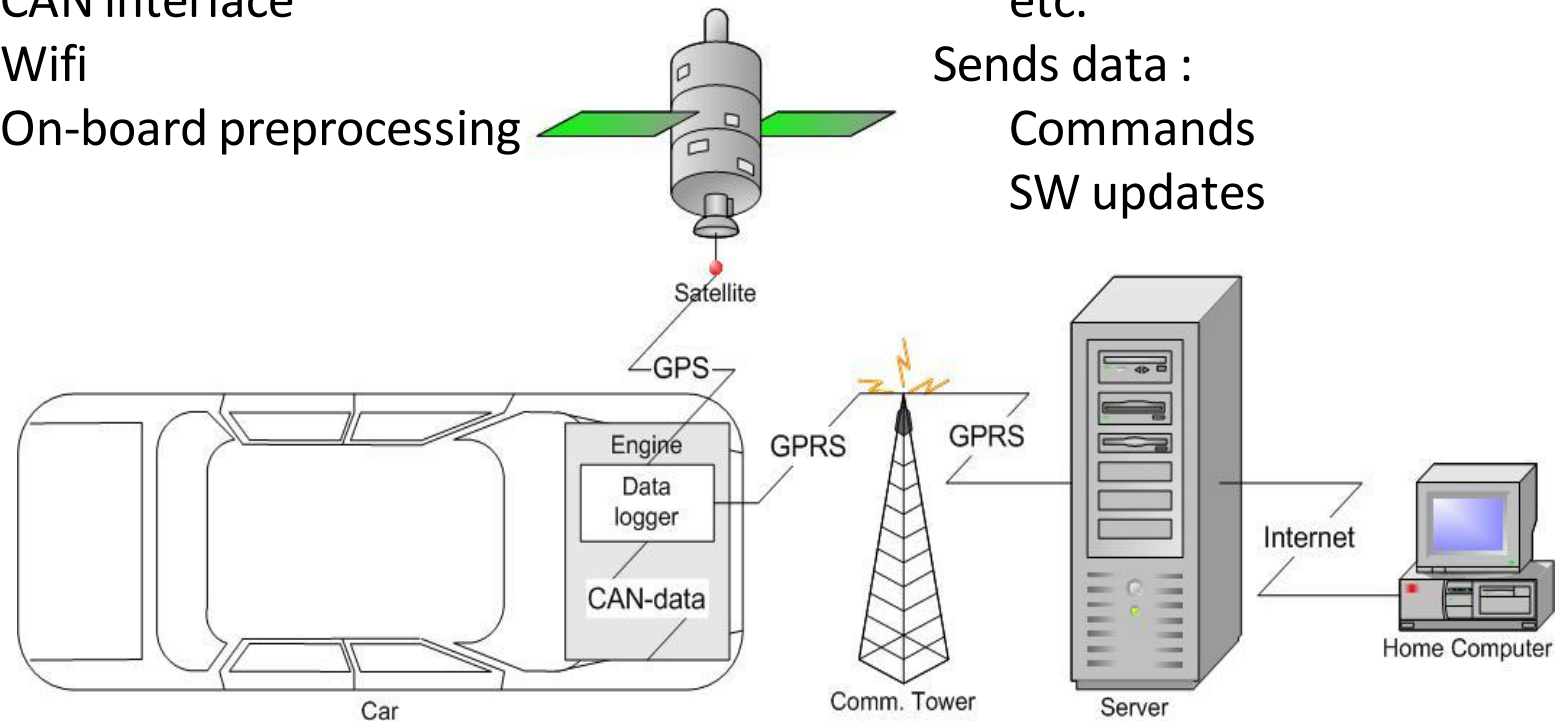
State of Charge

etc.

Sends data :

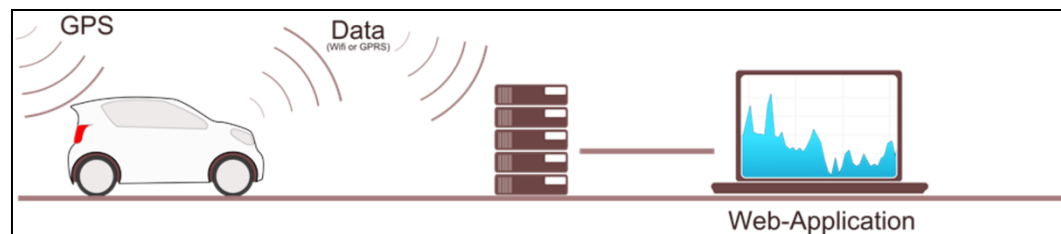
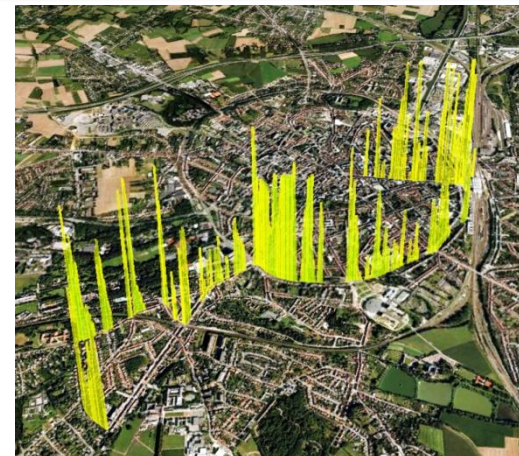
Commands

SW updates





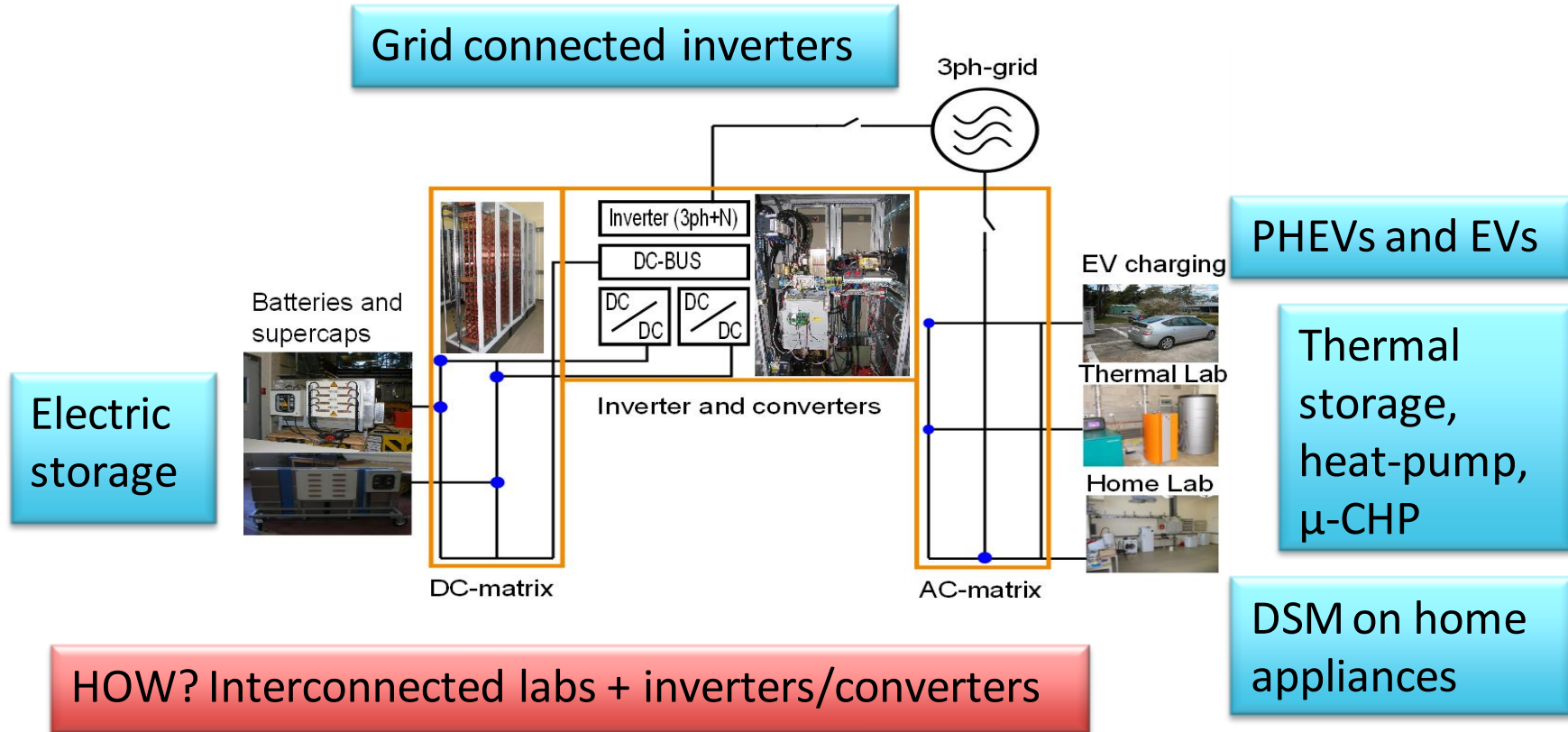
# Monitoring public transport & special EVs





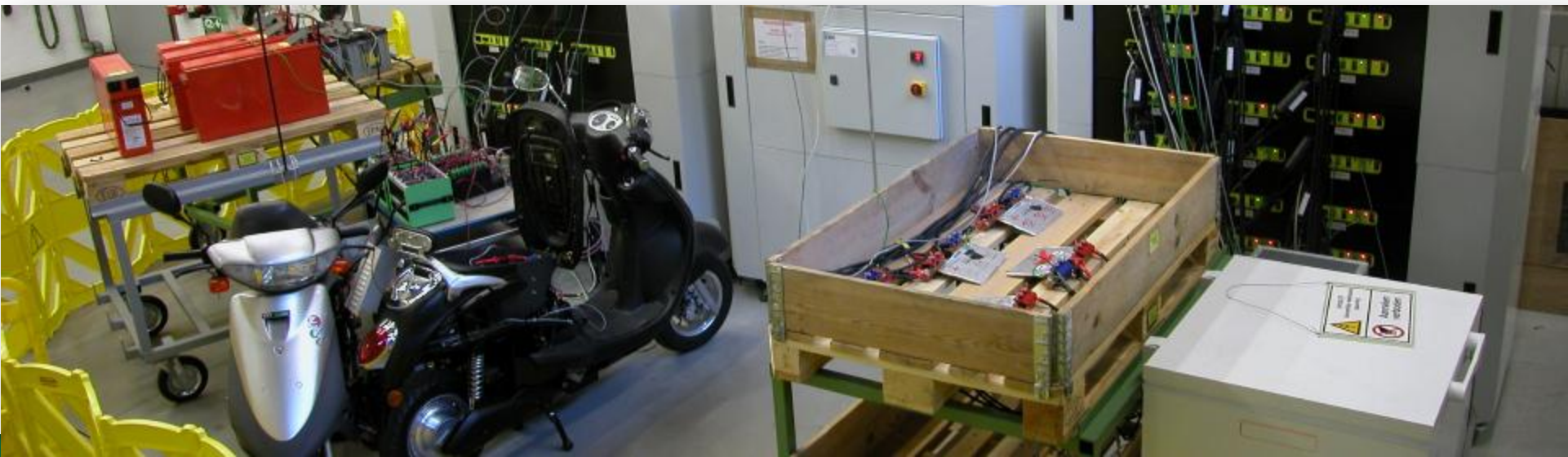
# What is the impact of additional electric loads (EV) on the grid ? VITO Smart Grid Testplatform

Goal: Test environment for different Smart Grid research topics



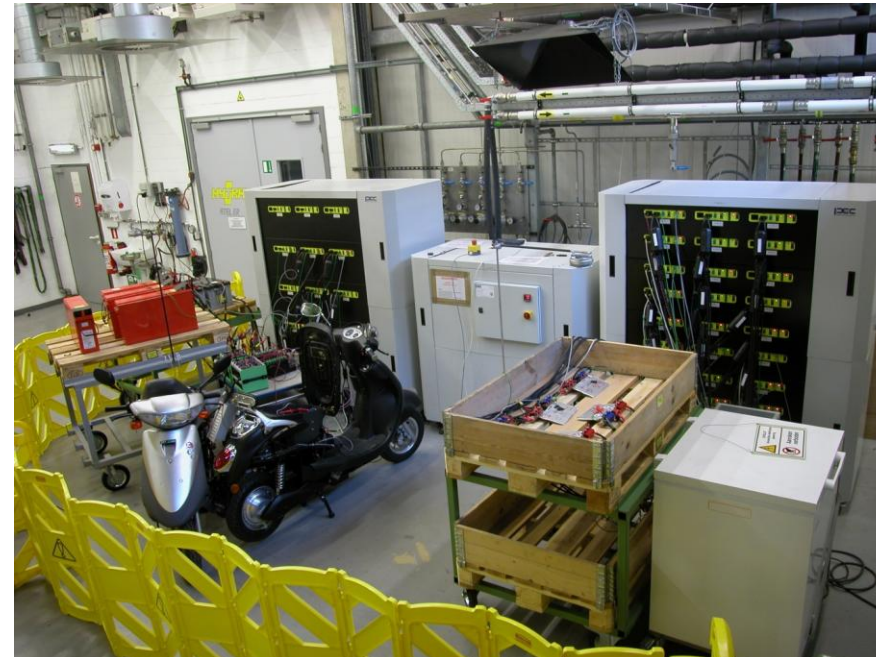
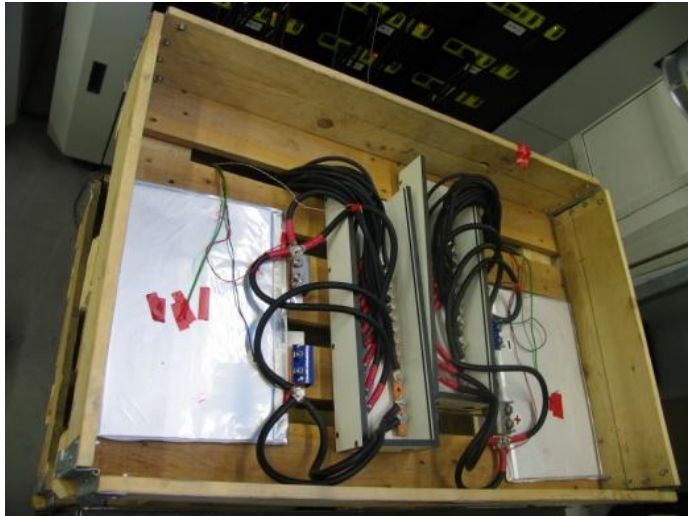
# Which batteries do I need and how long can I use them ?

- Performance and lifetime testing of commercial and prototype batteries and ultra-capacitors
- Development of custom application-based efficient test protocols
- Evaluation of battery systems
  - Business case
  - Technical and legal standards



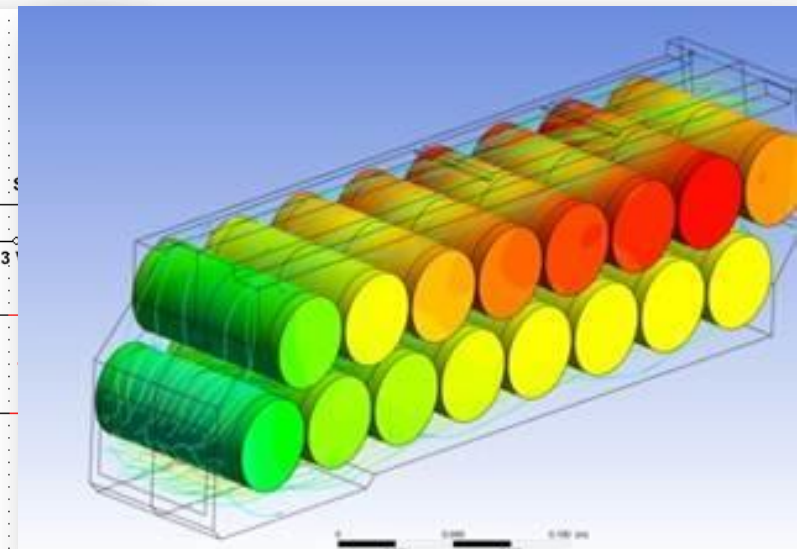
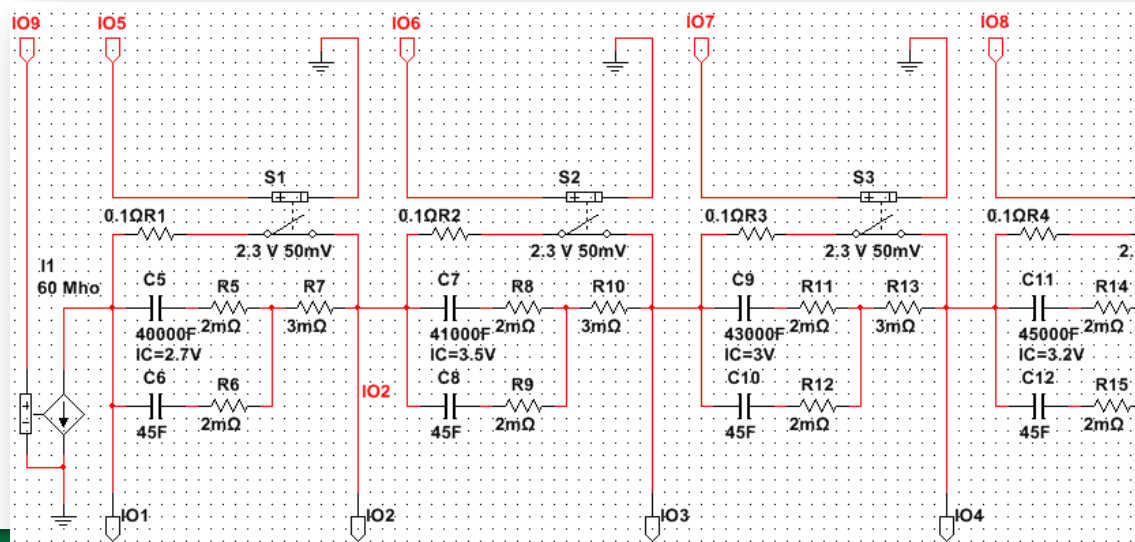
## Battery and supercaps test facilities

- 2 X 24 channel (6V, 50A) cell test station.
  - 2 X 12 channel (80V, 50A) battery/UC test station.
  - 1 X 1 channel (15V, 400A battery test station
  - Controllable loads combined with inverters
- 
- 150 kW turning DC load
  - 90 kW converter

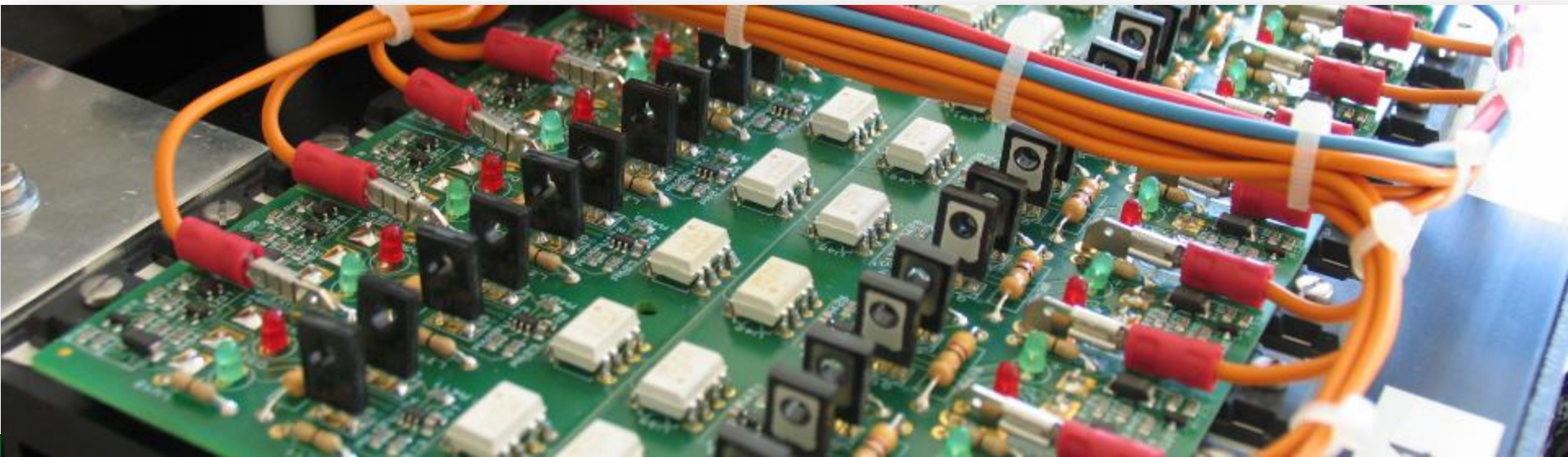




- Battery characterization
- Battery modelling
  - Lumped parameter electrical modelling
  - Thermodynamic modelling
- Modelling and prediction of aging



- Insulation monitoring (DC-safe<sup>®</sup>)
- Voltage monitoring (CellSense<sup>®</sup>)
- Dynamic cell balancing (patent pending)
- SoC/SoH estimation (patent pending)





- EnergyVille monitoring technology is used to control the world's largest PEM fuel cell (Solvay Antwerp)
- EnergyVille developed a braking energy recuperation system used by Van Hool



- EnergyVille
  - Energy research with link to e-mobility
- Electrification of public transport
  - Trends & roadmaps : technology & market
- Activities in Europe
  - Research & demonstration projects

- Increasing interest in clean transport from governments (EU, national and city level) & PTA



## DIRECTIVES

### DIRECTIVE 2014/94/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 22 October 2014 on the deployment of alternative fuels infrastructure (Text with EEA relevance)

THE EUROPEAN PARLIAMENT AND THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty on the Functioning of the European Union, and in particular Article 91 thereof,

Having regard to the proposal from the European Commission,

After transmission of the draft legislative act to the national parliaments,

Having regard to the opinion of the European Economic and Social Committee <sup>(1)</sup>,

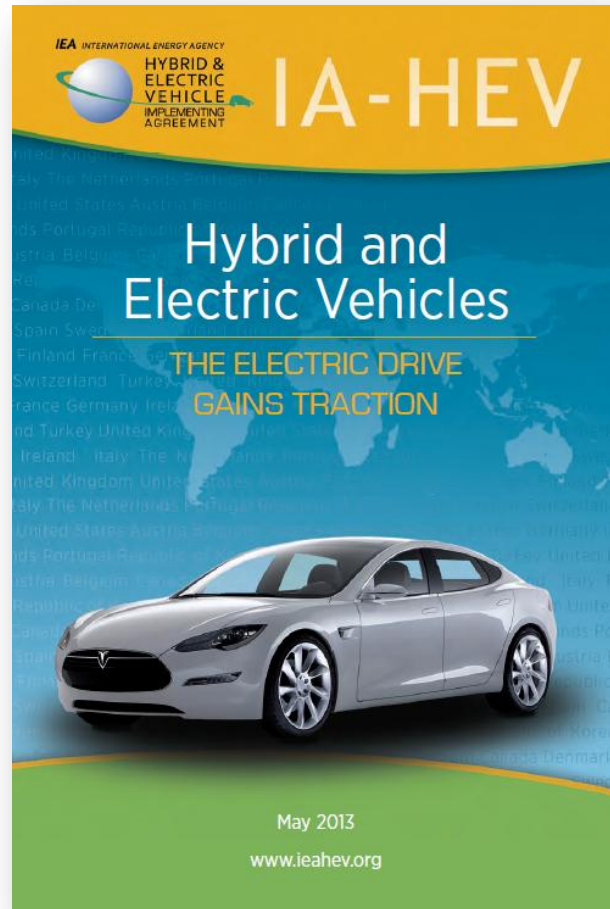
Having regard to the opinion of the Committee of the Regions <sup>(2)</sup>,

Acting in accordance with the ordinary legislative procedure <sup>(3)</sup>,

Whereas:

- (1) In its Communication of 3 March 2010 entitled 'Europe 2020: A strategy for smart, sustainable and inclusive growth', the Commission aims at enhancing competitiveness and energy security by a more efficient use of resources and energy.
- (2) The Commission's White Paper of 28 March 2011 entitled 'Roadmap to a Single European Transport Area — Towards a Competitive and Resource Efficient Transport System' called for a reduction in the dependence of transport on oil. This needs to be achieved by means of an array of policy initiatives, including the development of a sustainable alternative fuels strategy as well as of the appropriate infrastructure. The Commission's White Paper also proposed a reduction of 60 % in greenhouse gas emissions from transport by 2050, as measured against the 1990 levels.
- (3) Directive 2009/28/EC of the European Parliament and of the Council <sup>(4)</sup> sets a market share target of 10 % of renewable in transport fuels.

- Hybrid buses are getting more and more “standard”



## CHAPTER 14 – BELGIUM

### Hybrid, electric, and fuel cell buses

Hybrid, electric, and fuel cell buses received extra attention in Belgium during 2012. Such vehicles were the focus of some major decisions by local public transport companies in the country's various regions to increase the electrification of the bus fleets. Testing was conducted and some large orders were placed for hybrid, electric, and fuel cell buses.

De Lijn in Flanders placed an order for 386 new buses that amounted to €93 million (US \$121 million). A mix of alternative drivetrains is represented in the new bus orders: 3 fully electric buses, 5 fuel cell buses, and 123 hybrid buses (Fig. 14.5).



Fig. 14.5 De Lijn is heavily investing in creating a clean bus transport fleet. (Image courtesy of EVTeLab platform.)

MIVB in Brussels announced that it will no longer purchase diesel buses beginning in 2015 and is looking for alternative bus drivetrains. Compressed natural gas (CNG) buses are certainly an option, but MIVB will also investigate using electric buses to replace diesel buses. MIVB tested an electric bus from BYD at the end of 2012.



- Fuel cell buses : High V.LO-City project



On 6 December 2012, the Fuel Cell Hydrogen Joint Undertaking (FCH JU) which supported a study on the alternative powertrain technologies available for buses in Europe in 2012-2030, officially presented the main outcomes. The study was conducted by McKinsey & Company and over 40 companies and government organisations participated.

With Europe's commitment to reduce CO2 emissions by 80% by 2050, road transport can account for 95% in CO2 reduction.

The study considered available powertrain technologies including hydrogen and electric buses (opportunity and overnight electric buses) and the results were drawn based on environmental, performance and economic criteria.

Van Hool's Manager and High V.LO-City project Coordinator Paul Jenné presented the project objectives to introduce zero emission and highly-efficient fuel cell buses in existing public transport fleets (Flanders, Liguria and Aberdeen). The project is co-funded by the EU's Fuel Cell Hydrogen Joint Undertaking (FCH JU). Van Hool supplier has also contributed to the study.

The FCH JU will launch a next phase study to examine in further details the uptake of the hydrogen fuel cell technology in European public transport fleets and invites public authorities, transport operators and bus manufactures to participate.

More information is available [here](http://highvlocity.eu/).

## Urban buses: alternative powertrains for Europe



A fact-based analysis of the role of diesel hybrid, hydrogen fuel cell, trolley and battery electric powertrains

- More information : <http://highvlocity.eu/>



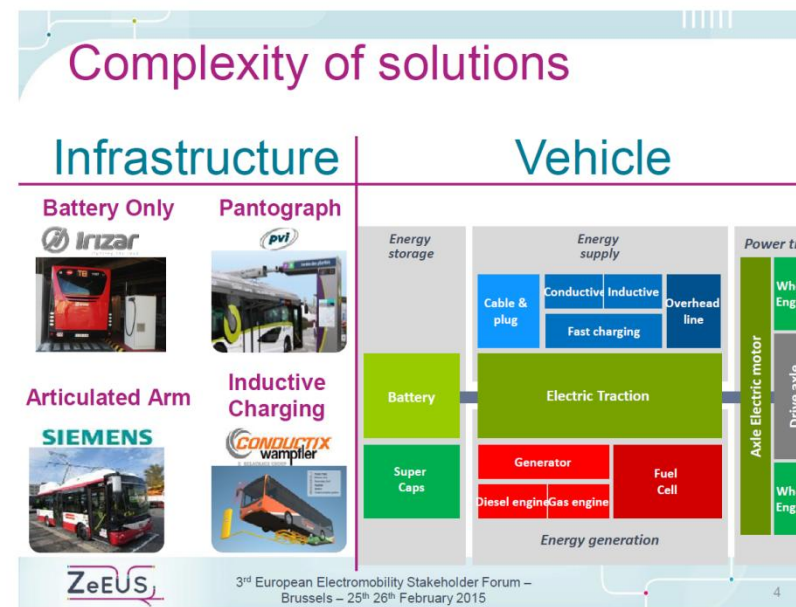
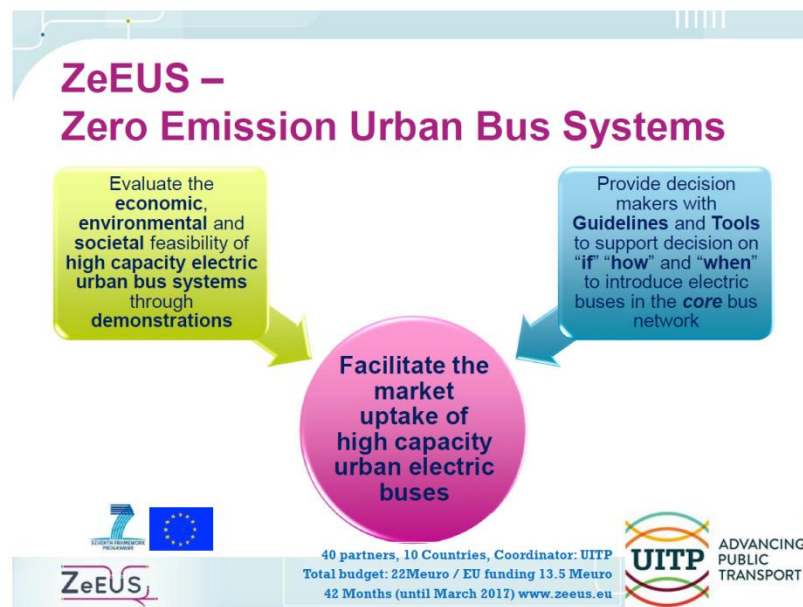
## Activities in Europe

- Battery electric buses : EBSF (2008-2012)




- More information : <http://www.ebsf.eu>

- Battery electric buses : ZeEUS project (until 2017)



- Battery electric buses : ZeEUS project (until 2017)

## ZeEUS Demonstrations



**Core Demonstration**

- Barcelona, Bonn, Cagliari, London, Münster, Plzen, Stockholm

**~35 electric buses**

- 12 meters, articulated, double-deckers
- Plug-in Hybrid, Full-electric, Battery Trolleys

**Energy supply modes:**



- plug-in, conductive, inductive, overhead

**Fast and slow charging strategies**

- Overnight (depot)
- Opportunity (terminals, bus-stops)

**Observed / Monitored Demos**

- 60 contacts already!

**Legend:**  
 Core Demonstrations  
 Observed Demo

**ZeEUS**  
 3<sup>rd</sup> European Electromobility Stakeholder Forum – Brussels – 25<sup>th</sup> 26<sup>th</sup> February 2015

## ZeEUS Demo information & plan

Barcelona	Stockholm	Muenster	Plzen	London	Barcelona	Cagliari	Bonn
2	8	5	2	3	2	4	6
Full electric	Plug-in	Full electric	Full electric	Plug-in	Full electric	Battery Trolley	Full electric
12m	12m	12m	12m	Double Deck	18m	12m	12m
IRIZAR	Volvo	VDL	Skoda	Alexander Dennis	SOLARIS	VOSSLOH / VAN-HOO	SOLARIS
Overnight charging only at the depot	Overnight at depot Fast at Terminals (pantograph)	Fast charging at end stations and at depot	Overnight at depot Fast at Terminals	Inductive charging at end stations slow charging at bus depot	Overnight at depot Fast at Terminals (pantograph)	During service and at Ospedale Marino terminal (catenary)	Overnight charging at the bus depot
Test on different lines with different characteristics	One line completely electrified	One line completely electrified Stationary battery	Operation started on different line	Central city line	High frequency central city line (5 to 6 min)	New bus line Off contact operations: 1.5 km in city center 4.5 km through natural reserve	Tested on most relevant lines of Bonn network
Mild	Hemiboreal	Continental	Continental	Oceanic	Mild	Mediterranean	Continental

**Timeline:** 2014, 2015, 2016

**ZeEUS**  
 3<sup>rd</sup> European Electromobility Stakeholder Forum – Brussels – 25<sup>th</sup> 26<sup>th</sup> February 2015



- Battery electric buses : ZeEUS project (until 2017)

## ZeEUS: Networking Stakeholders 1/2

ZeEUS is the **main** EU activity about the **introduction** of electric urban bus systems in European City Bus Networks

### ZeEUS National Observatory

- Monitor of EU/world/National activities: *on-going pilots, demonstrations, tenders, regulations, new technological or behavioral developments, electricity domain actions impacting eBus*
- Link with the **UITP FTSO WG**

### ZeEUS Observed Demonstrations

Provide **Detailed information and evolution** about the demo

### ZeEUS Monitored Demonstrations

Select **KPI** within the ZeEUS database  
**Data collection and evaluation** following ZeEUS methodology

### ZeEUS User Group

Interested in eBuses but in **"thinking phase"**

**Contact me if you want to propose an Observed / Monitored Demo or you wish to be in the ZeEUS User Group**



3<sup>rd</sup> European Electromobility Stakeholder Forum –  
Brussels – 25<sup>th</sup> 26<sup>th</sup> February 2015

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## ZeEUS - Guidelines & Tools for Pre-Commercial Support 2

Support decision makers to decide **if, how and when** to introduce electric bus systems in the Public Transport network

### Funding schemes, tools, procurement guidelines

- Interaction with EIB and other funding entities
- Update of UITP tender structure including eBus

### Regulatory frame

- Link with EU Directive on **"Deployment of alternative fuels infrastructure"**
- Guidelines for including electric buses infrastructure in **National Policy Frameworks** (NPF)

### Introduction of electric Buses in urban fleets

- Recommendations for urban / spatial planning
- Operational concepts** and **migration scenarios**

### ZeEUS Vision

### ZeEUS Electrification Roadmap

### Training for drivers and maintenance staff

### Education


modules and workshops for **university**  
eBus module of the **UITP Training** about buses



3<sup>rd</sup> European Electromobility Stakeholder Forum –  
Brussels – 25<sup>th</sup> 26<sup>th</sup> February 2015


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- Battery electric buses : ZeEUS project (until 2017)



**Strategy for optimised interaction with the power grid**

- Optimised overnight charging
- High number of charging points
- Charging strategy
- Business / contractual models with energy providers



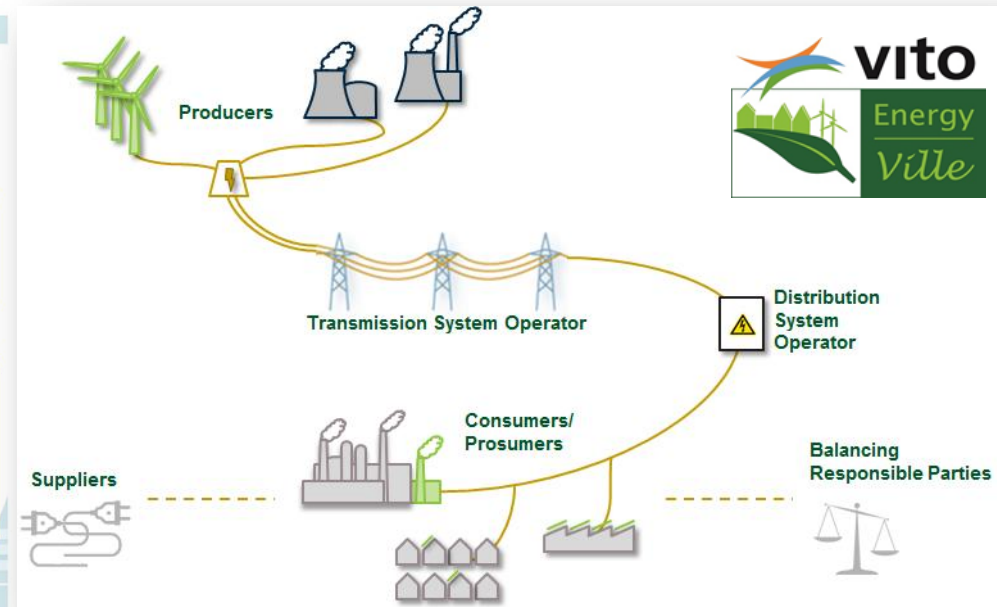
**Strategy for re-using existing PT power network** for fast charging at bus-terminal / stop

Existing European public transport energy distribution network as low-cost basis to set-up rapidly a charging infrastructure for urban passenger and freight

*EBSF Electrification Study pt.2*  
available on [www.ebsf.eu](http://www.ebsf.eu)

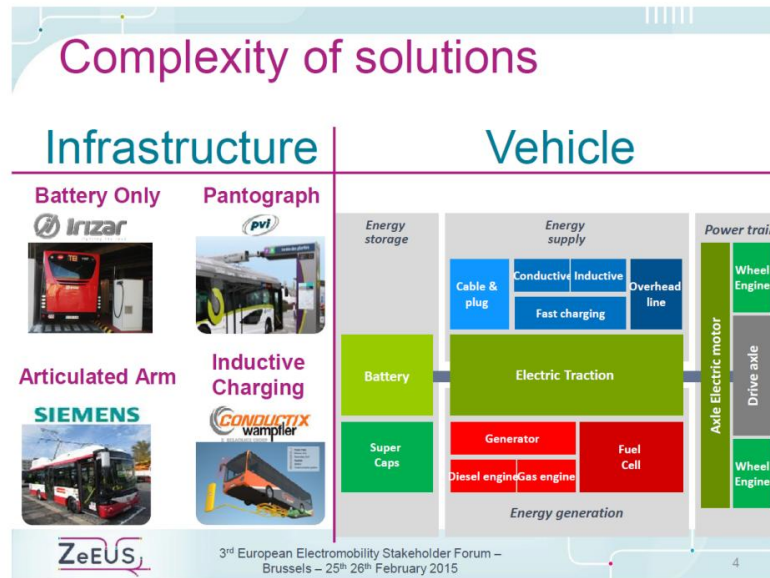
**ZeEUS**

3<sup>rd</sup> European Electromobility Stakeholder Forum – Brussels – 25<sup>th</sup> 26<sup>th</sup> February 2015



- More information : <http://zeeus.eu>

- Charging infrastructure for Battery electric buses
- Need for charging infrastructure networks but which type ?
  - normal or fast charging ?
  - conductive or wireless charging or battery swapping ?
  - static or dynamic charging ? ....
- What's the impact on the electricity grid and on the battery itself ?





- Charging infrastructure for Battery electric buses
- Battery swapping stations



## Smart Grid Support for Electric Vehicles: China

20 May 2013

China has taken the lead in total EV charging capacity, having the most equipment for EV charging/battery swap.

- 243 standard stations for charging/battery swap and
- 13283 AC charge spots has been established and put into use by State Grid.



## Power Supply Technology & Construction of EV Network in China

20 May 2013

### Interconnection project between Suzhou, Shanghai and Hangzhou

➤ 9 charging/battery swap stations in 5 service areas in 3 highways are involved in the preliminary stage of the project, and the operational system are built at the same time.

➤ The service of charging/battery swap between Suzhou, Shanghai and Hangzhou in different provinces.



Charging/battery swap station in  
Baiyanghu Service area



Charging/battery swap station in  
Fengjing Service area



Charging/battery swap station in  
Jiaxing Service area



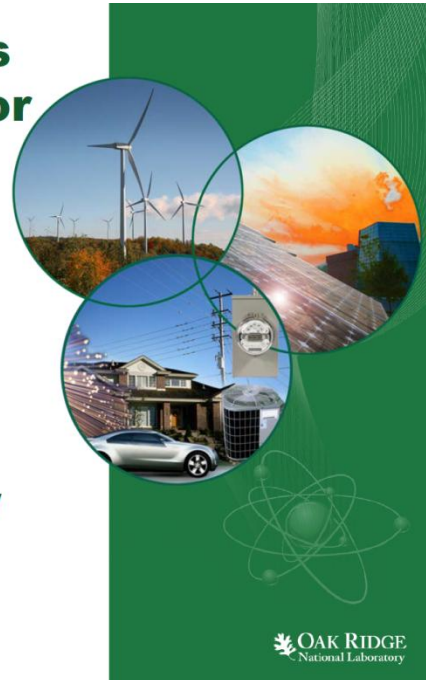
- Charging infrastructure for Battery electric buses
- Wireless charging projects are gaining interest

## Task 26: Wireless Power Transfer for Electric Vehicles Information Update

P.T. (Perry) Jones

Oak Ridge National Laboratory  
Vehicle Systems Research

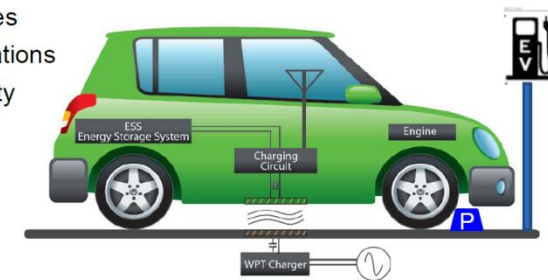
ORNL is managed by UT-Battelle  
for the US Department of Energy



## Task Objective

The **objective** of this new task on WPT for EVs will:

- **Address interoperability and comparison of standards** in various countries (JARI, SAE, ISO/IEC) which may include:
  - Power transfer levels
  - Center frequency operation
  - Alignment and Component location
  - Safety issues
  - Communications
  - Data security



OAK RIDGE  
National Laboratory

- Wireless charging projects outside of Europe

## Activities in Asia

South Korea – KAIST launches road-charged electric buses. August 2013



Source: <http://inhabitat.com/kaist-launches-first-wirelessly-charged-electric-buses-in-south-korea/>

Frequency	20 kHz
Power Transfer Levels	100 kW
Wireless Mode	dynamic

Japan – Toyota tests wireless charging system. February 2014



Source: <http://chargedevs.com/newswire/toyota-begins-testing-wireless-charging-system/>

Frequency	85 kHz
Power Transfer Levels	2 kW
Wireless Mode	static

Technology licensed from WiTricity

## Activities in North America

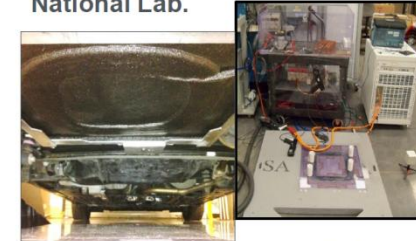
Utah – WAVE's electric buses top off at bus stops. October 2013



Source: <http://www.wired.com/2013/10/utah-ev-bus/>

Frequency	23.4 kHz
Power Transfer Levels	50 kW
Wireless Mode	static

Tennessee – WPT system development at Oak Ridge National Lab.



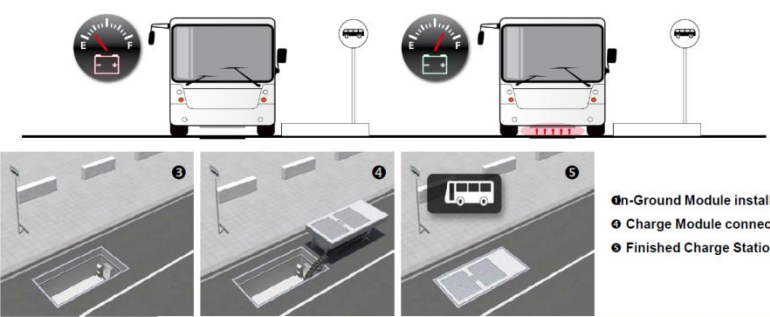
Source: PT Jones of ORNL. April 28, 2014.

Frequency	23 kHz
Power Transfer Levels	6.6 kW
Wireless Mode	static & dynamic




## • Wireless charging projects in Europe : some examples


### Wireless high power opportunity charging



1 In-Ground Module installed  
2 Charge Module connected  
3 Finished Charge Station



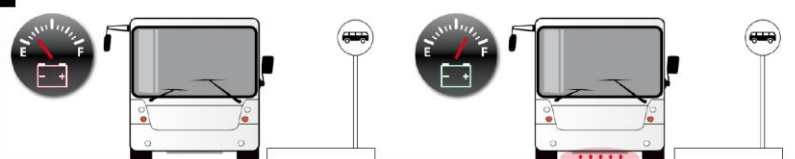
1 Track Supply  
2 Primary Coil  
3 Secondary Coil  
4 Rectifier  
5 Battery  
6 Communication System



### Opportunity Charging with Proov-IPT®

#### Use Opportunities to Become Competitive

- Onboard energy storage is reduced to a minimum to gain a higher payload and/or passenger space. Short but frequent re-charging is required, e.g. at bus stops.
- Even if charging opportunities are less frequent and only possible at large intervals, onboard energy storage capacity can be reduced significantly compared with just overnight plug-in charging.
- This results in a significant reduction of weight and increases vehicle efficiency and payload.
- No worries about cables and plugs to handle.
- Safe and reliable operation even in areas with public access.
- Insensitive to dirt and dust and protected from vandalism




3 days operation in the public area

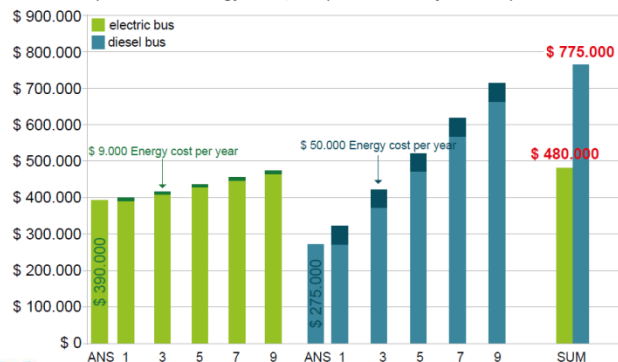
That's all you see....



- Wireless charging projects in Europe : some examples

## Cost Saving Operations ... an Economic Boost

Operating cost comparison\*: electric vs. diesel propulsion (in US \$)  
Acquisition and energy costs, compared over 10 years of operation



\* Extrapolation = costs per passenger mile x average annual mileage (50,000 Miles)  
1 passenger mile by electric bus = 0.19 US \$, 1 passenger mile by diesel bus = 1.00 US \$  
ANS= Acquisition cost, SUM = Sum total  
Sources: Technology Review 2011, Bahninfo.de 2011, Dresdner Verkehrsbetriebe 2011, Optare 2012

## OVER 50 E-BUSES IN OPERATION INCLUDING UTRECHT, LONDON, GLASGOW...

Genoa, Italy | since 2002

Type of vehicles / Manufacturer:

Electric buses 120 kW Motor / EcoPower Technology s.r.l.

Energy storage:

Lead-Gel battery 180 A

Vehicle weight: Empty approx. 7,5 t / Max. approx. 10,2 t

Charging power per load point: 60 kW

Number of vehicles: 8



Den Bosch, Netherlands | since 2012

Type of vehicles / Manufacturer:

Volvo 7700 (converted to electrical / Bluekens Truck & Bus BV)

Energy storage:

120 kW LiFePo<sub>4</sub> batteries

Vehicle weight: 12.0 t (empty weight)

Charging power per load point: 120 kW (2 modules of 60 kW)

Number of vehicles: 1



Turin, Italy | since 2003

Type of vehicles / Manufacturer:

Electric buses 120 kW Motor / EcoPower Technology s.r.l.

Energy storage:

Lead-Gel battery 180 A

Vehicle weight: Empty approx. 7,5 t / Max. approx. 10,2 t

Charging power per load point: 60 kW

Number of vehicles: 23



Milton Keynes, Great Britain | since 2013

Type of vehicles / Manufacturer:

Electric buses 120 kW / WrightBus

Energy storage:

Lithium batteries

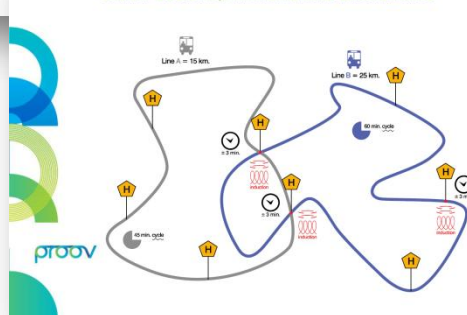
Vehicle weight: 12.0 t (empty weight)

Charging power per load point: 120 kW (2 modules of 60 kW)

Number of vehicles: 8



## SMART LOGISTIC, FINANCIAL GRID ENGINEERING




- Flemish Living Lab Electric Vehicles



*EVS28*  
*KINTEX, Korea, May 3-6, 2015*







**Flemish Living Lab Electric Vehicles**  
**3 years of real-life experiences!**

**Mol Carlo**  
*Mol Carlo, VITO, Boeretang 200, 2400 Mol (Belgium), [carlo.mol@vito.be](mailto:carlo.mol@vito.be)*

**Flemish Living Lab Electric Vehicles**

Facilitate and accelerate the innovation and adoption of electric vehicles in the Flemish region → Set up an open “real-life” innovation platform in which innovations can be tested by representative end users in their own living and working environment

- Call has been set up in 2010 by Flemish Government
- 5 different Platforms have been approved & running in period 2011-2015
- > 70 partners = mainly industry and also research institutes, public bodies
- Total Budget : 27 m€ (16,25 m€ funding)
- Open test infrastructure : electric vehicles, charging infrastructure, ICT, data monitoring, testpopulation, ...

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- Flemish Living Lab Electric Vehicles

**Flemish Living Lab Electric Vehicles**

401 Electric Vehicles

861 charging points (bikes & cars) at 163 locations

> 200 cities

200 families

1000 individuals

Testpopulation

EVS 28

**Flemish Living Lab Electric Vehicles**

move know

CAN and/or GPS

privacy levels

surveys

Datamonitoring

> 2.600.000 km

driving and charging behaviour

VITO data logging

On-board data logger

GPS + CANbus

GPS

Back-end at VITO

Processed data to VITO Ai / Powerdata server

GPS

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## • Flemish Living Lab Electric Vehicles

**Flemish Living Lab Electric Vehicles**

Results from the research projects per theme

Final conference – Flemish Living Lab Electric Vehicles

Open innovation platform – Electric Mobility

Brussels - 1 december 2014

Flanders State of the art

AGENDA

- 0. Introduction – Living lab
- 1. Electric vehicles
- 2. Charging infrastructure
- 3. Real life test population
- 4. Energy services
- 5. Mobility services
- 6. International fora
- 7. Panel debate

More information : [www.livinglab-cv.be](http://www.livinglab-cv.be)

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**Electric Vehicles**

Commercial vehicles vs Own developed vehicles




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**Electric Vehicles**

Own built electric vehicles : heavy-duty

- 40\* Van – Punch Ford Transit connect EV
- 2\* e-Trucks
- 3\* Full electric Bus – Van Hool A308E
- 1\* Fuel cell bus – HD6



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- Flemish Living Lab Electric Vehicles
- Wireless charging project in Bruges

## Electric buses

A308E	
Type	Low floor, midi bus
Bus length	9,4 m
Capacity	18 seats and 38 standing
Range	Continuous – on a dedicated line
Conductively charging	140 kW
Inductively charging	200 kW
Battery pack energy content	Li Ion (LTO) 34.8kWh



Introduction in Bruges mid 2015

## Inductive charging Li Ion (LTO) battery pack

Primove Pick up



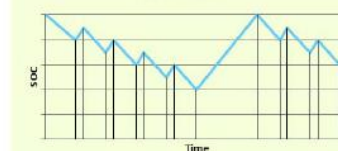
**BOMBARDIER**  
the evolution of mobility

Battery pack



**trineuron**  
a division of amtel

### SOC vs time

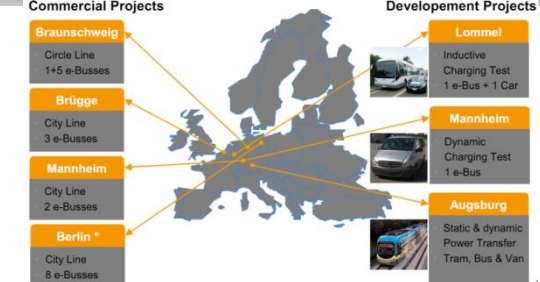


### Commercial Projects

<b>Braunschweig</b>
Circle Line
1+5 e-Busses
<b>Brügge</b>
City Line
3 e-Busses
<b>Mannheim</b>
City Line
2 e-Busses
<b>Berlin *</b>
City Line
8 e-Busses

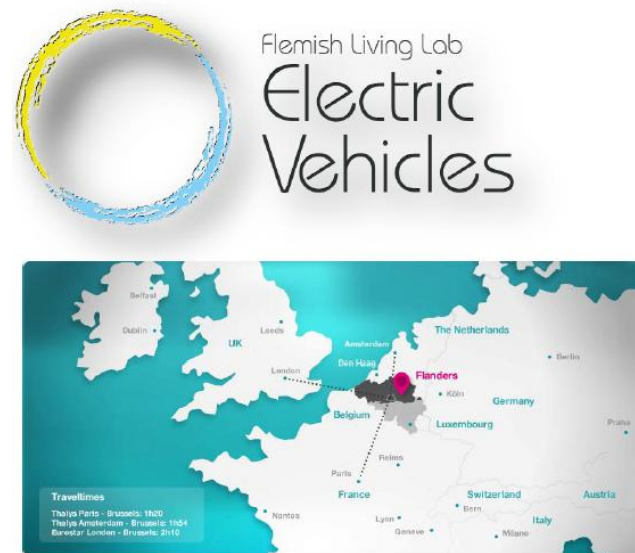
### Development Projects

<b>Lommel</b>
Inductive Charging Test
1 e-Bus + 1 Car
<b>Mannheim</b>
Dynamic Charging Test
1 e-Bus
<b>Augsburg</b>
Static & dynamic Power Transfer
Tram, Bus & Van





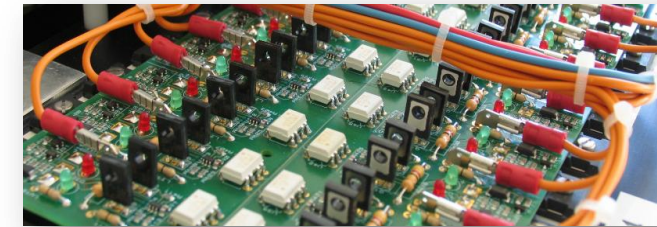
- Flemish Living Lab Electric Vehicles



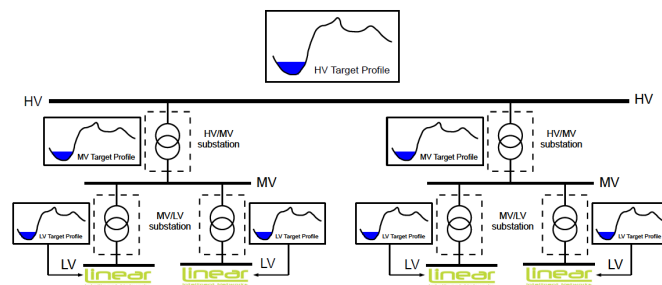
- More information :
  - [www.livinglab-ev.be](http://www.livinglab-ev.be)
  - <http://www.livinglab-ev.be/content/presentations-final-conference-are-available-online>



- Performance & lifetime tests of batteries and supercapacitors
- Battery management systems  
Supercaps balancing
- Battery state of health analysis & prediction
- Cooling system design

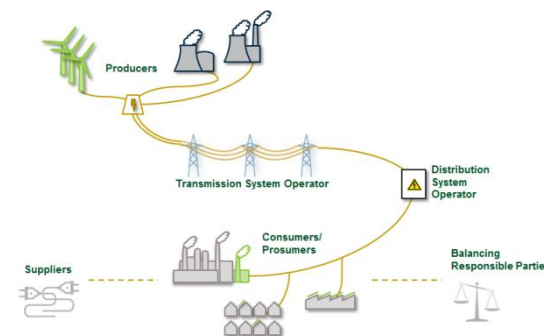
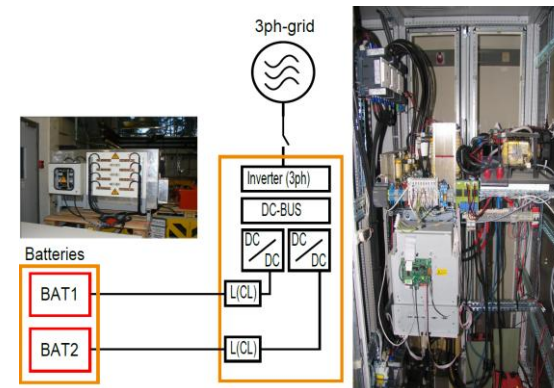


- Grid & Bus friendly  
Charging Infrastructure



- Energy market &  
E-bus business models

- Field monitoring of e-busses  
& environmental impact





# Questions? → Contact

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Visit our website: [www.vito.be](http://www.vito.be)



## Selection of publications

- Grietus M., De Ridder F., Coenen P., Weyen D. and Martens A. Evaluation of an on-site cell voltage monitor for fuel cell systems. International Journal of Hydrogen Energy, doi:10.1016/j.ijhydene.2008.07.017, 2008.
- Grietus Mulder; Noshin Omar; Stijn Pauwels; Filip Leemans; Bavo Verbrugge; Wouter De Nijs; Peter Van den Bossche; Daan Six; Joeri Van Mierlo. "Enhanced test methods to characterise automotive battery cells", Journal of Power Sources, 196(23), 10079-10087, 2011.
- Jeroen Tant, Frederik Geth, Daan Six, Peter Tant, Johan Driesen, "Multi-Objective Battery Storage to Improve PV Integration in Residential Distribution Grids", IEEE Transactions on Sustainable Energy, 4(1), 182-191.
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- Machiels, N.; Leemput, N.; Geth, F.; Van Roy, J.; Buscher, J.; Driesen, J., "Design Criteria for Electric Vehicle Fast Charge Infrastructure Based on Flemish Mobility Behavior," Smart Grid, IEEE Transactions on , vol.5, no.1, pp.320,327, Jan. 2014
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- Everts J., Krismer F., Van den Keybus J., Driesen J., Kolar J.W.: " Optimal ZVS Modulation of Single-Phase Single-Stage Bidirectional DAB AC–DC Converters," IEEE Transactions on Power Electronics. , ISSN 0885-8993, 2014
- Leemput N., Geth F., Claessens B., Van Roy J., Ponnette R., Driesen J.: " A Case Study of Coordinated Electric Vehicle Charging for Peak Shaving on a Low Voltage Grid," IEEE PES Innovative Smart Grid Technologies Europe edition:3, Berlin, Germany, October 14-17, 2012
- De Craemer K., Vandael S., Claessens B., Deconinck G. 2013. An Event-Driven Dual Coordination Mechanism for Demand Side Management of PHEVs. IEEE Transactions on Smart Grid. Institute of Electrical and Electronics Engineers (), ISSN 1949-3053
- Vandael, S., Claessens, B., Hommelberg, M., Holvoet, T., Deconinck, G. (2012). A scalable three-step approach for demand side management of plug-in hybrid vehicles. IEEE Transactions on Smart Grid, 4 (2), 720-728.