busworld academy

KNOWLEDGE PLATFORM
FOR THE WORLDWIDE
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

Scope

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

Energyville – Smart Cities, Smart Grids

vito vision on technology | KU LEUVEN | imec

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.

SMART GRIDS FLANDERS

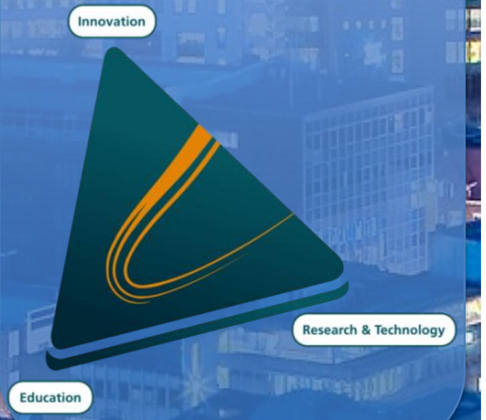
GSGF Global Smart Grid Federation

Energy Ville

CC Benelux

eit Knowledge & Innovation Community

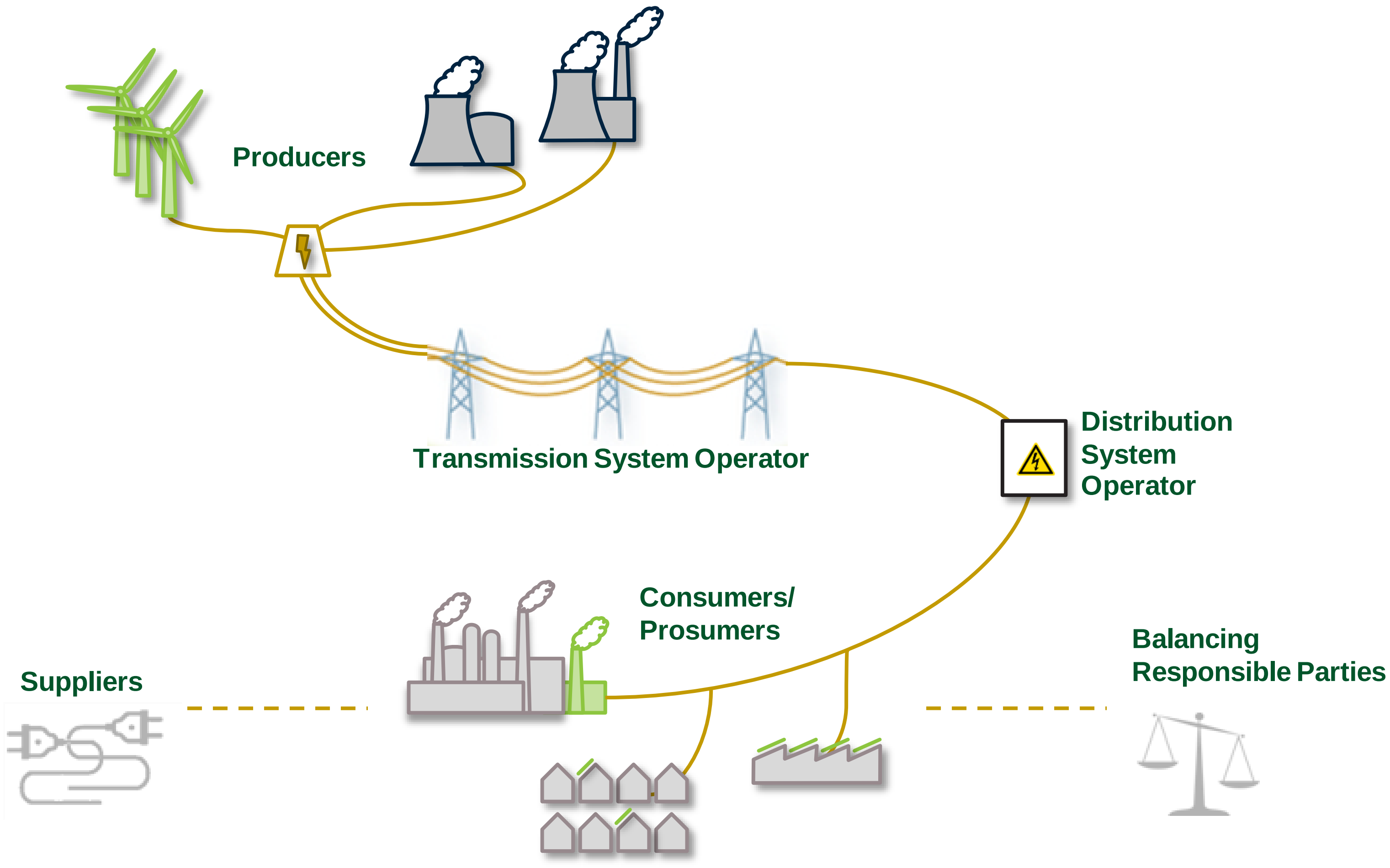
KIC InnoEnergy



E-Mobility & Electric Supply

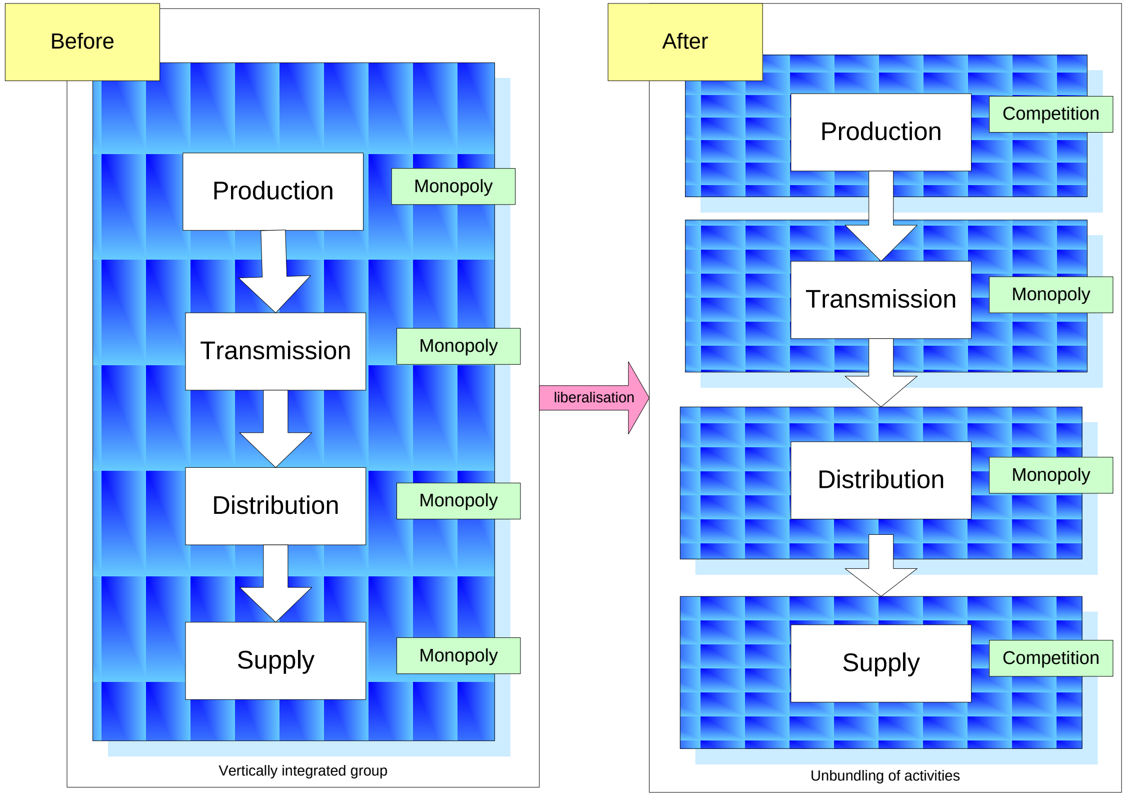
- Electric transport of persons and distribution of goods will be the preferred mode in cities (the dominant mode in 2050)
  - increases quality of life (reduction of NOx, PM, SO_2, VOCs)
  - increases quality of service (predictability of cost, reliability)
- Electric vehicles will become pro-active 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



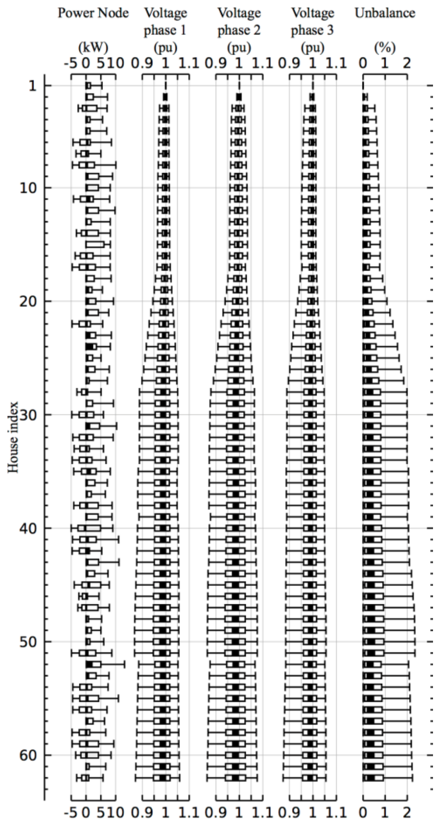
Energy Market : context and background

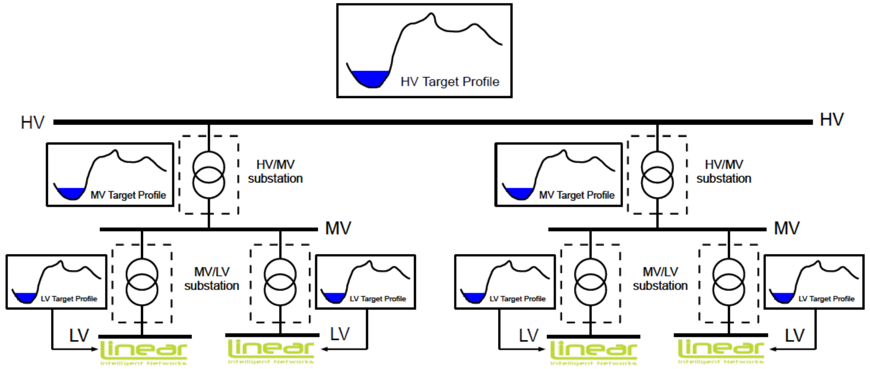
- Liberalisation energy markets across Europe
- Vertical unbundling of generation, transmission and supply

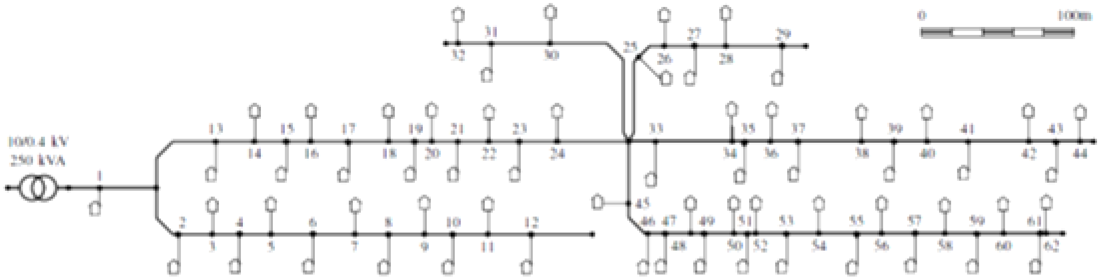


Grid Impact of PHEV Charging

- 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**

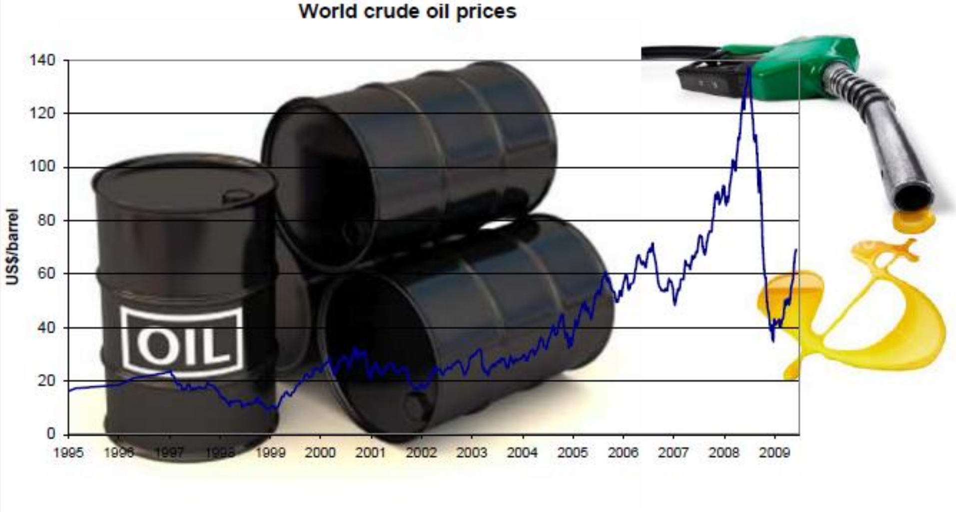
➡ **Increased network capacity**

Scope

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

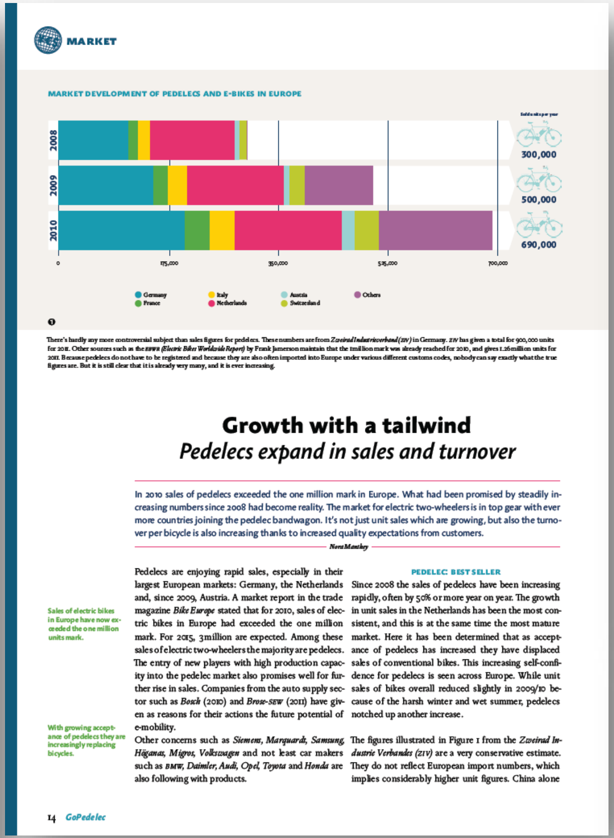
Electrification of transport

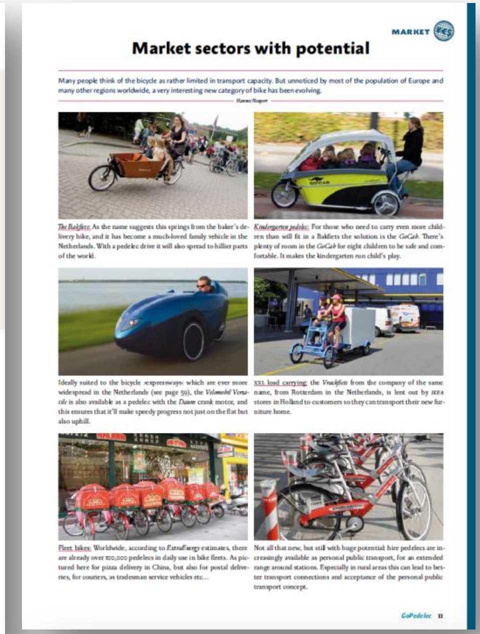
Driving forces for electrification

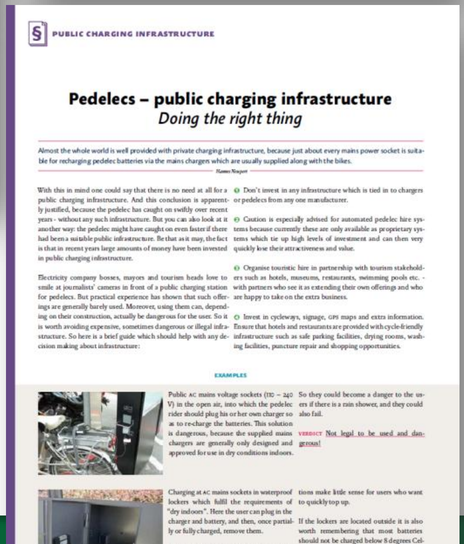


- Economical : fuel cost reduction, …
- Ecological : reduce global and local impact on the environment
- Technical : performance, comfort, …
- Legislation : emission standards, …
- Government : oil independency, strategic energy plans (EU Renewable Energy Directive), …

Electrification of “light-duty” transport







Electrification of "heavy-duty" transport

IEA INTERNATIONAL ENERGY AGENCY
HYBRID & ELECTRIC VEHICLE IMPLEMENTING AGREEMENT

Final Report

Task XII - "Heavy-duty hybrid vehicles"

2007 – 2010

Authors

- Carlo Mol, VITO (Belgium)
- Michael O'Keefe, NREL (USA)
- Arie Brouwer, NL Agency (the Netherlands)
- Jussi Suomela, Aaltoo University (Finland)
- Carol Burelle, NRCan (Canada)
- Alex Naef, Hans-Jörg Gisler, HESS (Switzerland)
- Martijn van Walwijk, IA-HEV Secretary-General

© 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

Carlo Mol[1], Michael O'Keefe[2], Arie Brouwer[3] and Jussi Suomela[4]

[1] VITO (Flemish Institute for Technological Research), Boeretang 200, Mol, 2400, Belgium
[2] National Renewable Energy Laboratory, 1617 Cole Blvd., Golden, Colorado, USA
[3] NL Agency, Postbox 8242, 3503 RE Utrecht, The Netherlands
[4] Aalto University, School of Science and Technology, Postbox 15500, FI-00076, Aalto, Finland
E-mail: carlo.mol@vito.be

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

IEA INTERNATIONAL ENERGY AGENCY HYBRID & ELECTRIC VEHICLE IMPLEMENTING AGREEMENT

- 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

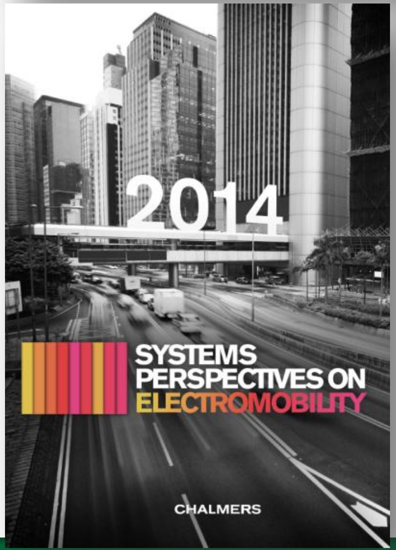
Public mobility infrastructure

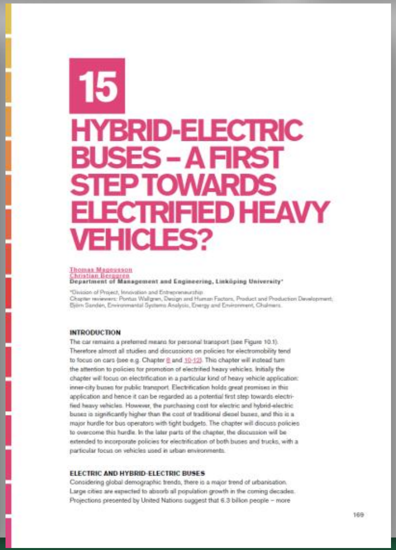
- Public transport
  - Rail (regional, sub-urban, metro, light rail, tram)
  - Buses (regional, urban buses & trolleybuses, BRT)
  - Ferries, Personal Rapid Transit
- Public individual transport
  - Car & bike sharing
  - Car & bike rental
  - Taxi & limousine service
  - Etc.
- Parking infra-structure
  - Park + Ride facilites
  - Bike + Ride facilites
  - Bike garages and parking boxes
  - Etc.

Service offering characteristics

- Quality
  - Accessibility, operating hours, punctuality, reliability, frequency, network coverage
  - Sufficient capacities in peak periods
- Safety and Security
  - Exploitation safety performance, security and perception of security
  - Emergency medical and police services
- Conve-nience
  - Real-time information, planning, booking and payment
  - Comfort, speed, congestion freeness
- Sustain-ability
  - Energy efficiency and alternative engines
  - Air quality and noise neutrality, climate neutrality
- Afford-ability
  - Financial attractiveness for users, meeting social and distributional objectives
  - Cost efficiency of operators, PT incentives

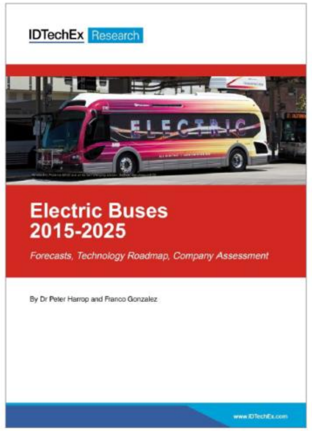
Source: Arthur D. Little





Read Electric Buses 2015-2025

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

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

Electrification of public transport

Criteria

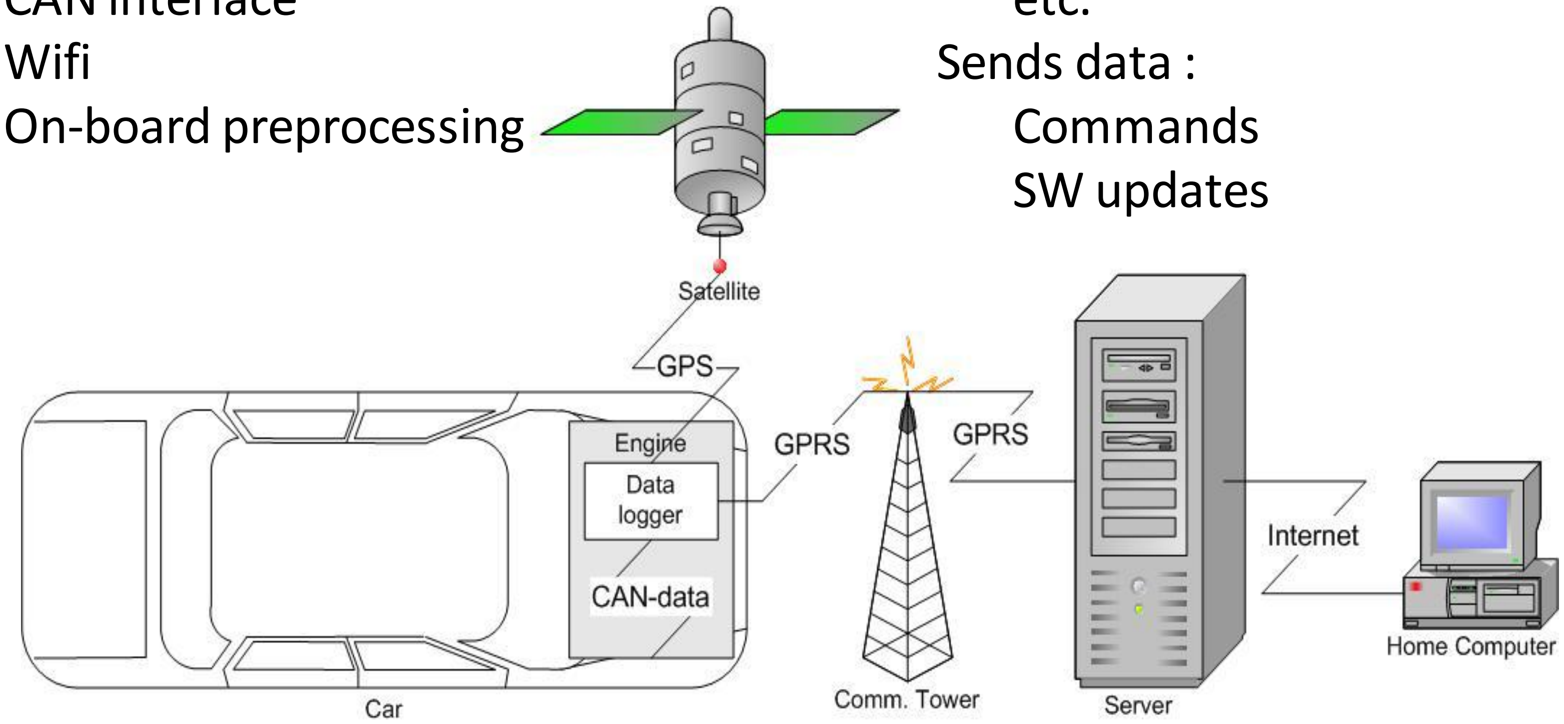
- Total Cost of Ownership (capex – opex)
- Reliability (time table)
- Comfort
- Impact on public space in urban areas
- Impact on the electricity network
- Future proof investment ? Flexibility, Legislation, Standards, …
- People acceptance : customers, drivers, …

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

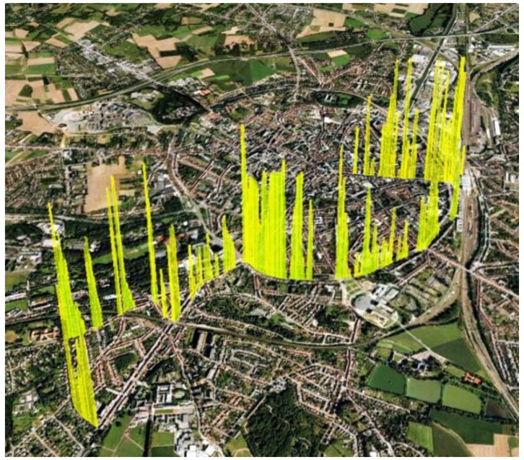
On-board logger
- GPS
- GPRS
- Data storage capacity
- CAN interface
- Wifi
- On-board preprocessing

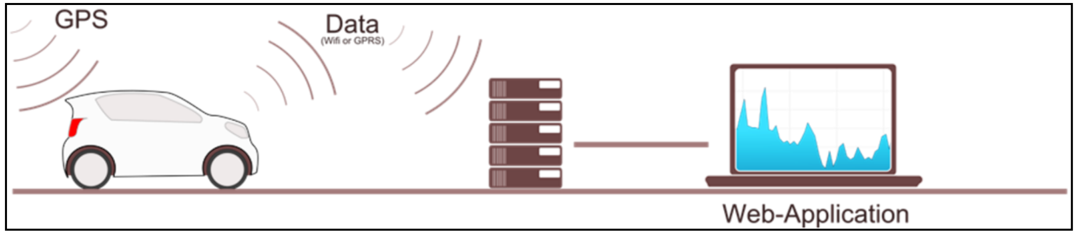
Collects data :
- Electricity consumption
- Trajectory characteristics
- State of Charge
- etc.

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

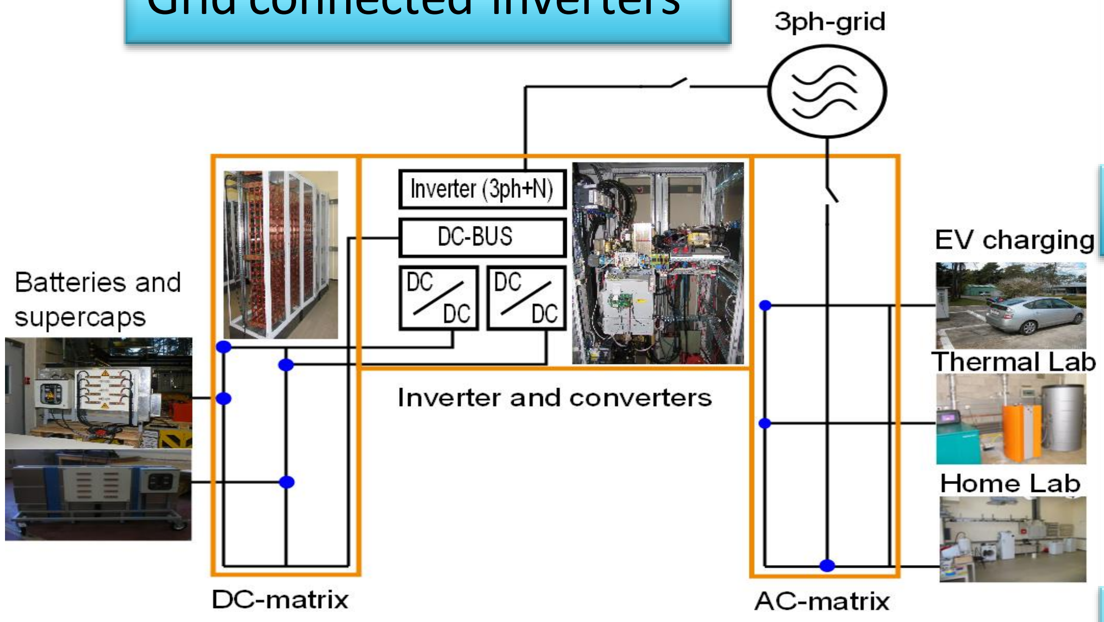
Grid connected inverters

Electric storage

PHEVs and EVs

Thermal storage, heat-pump, μ-CHP

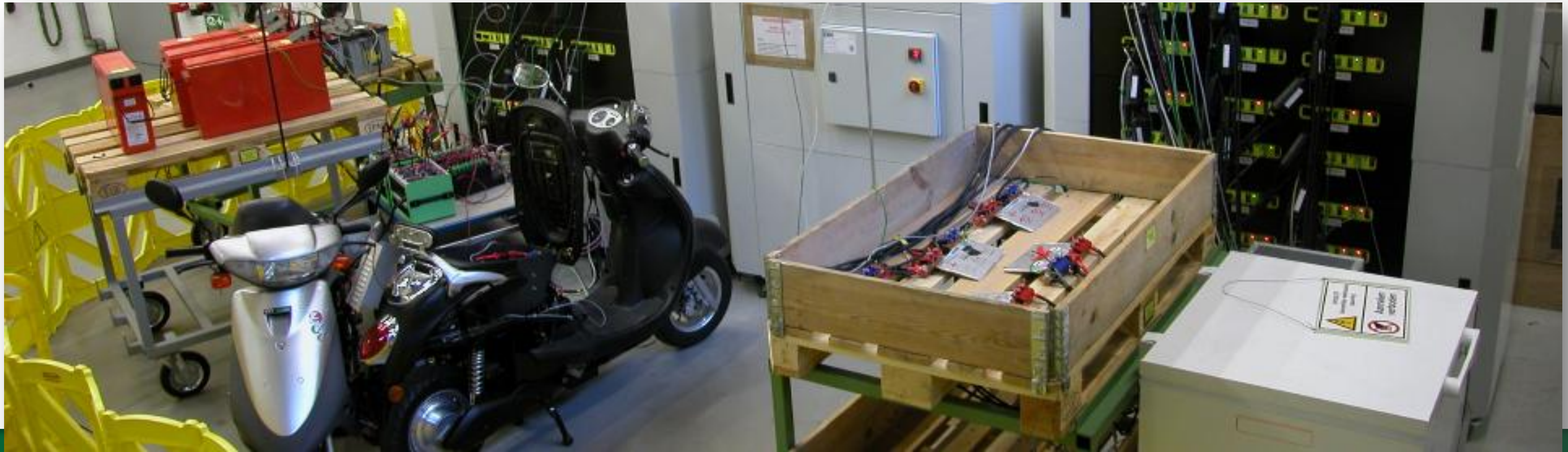
DSM on home appliances



HOW? Interconnected labs + inverters/converters

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

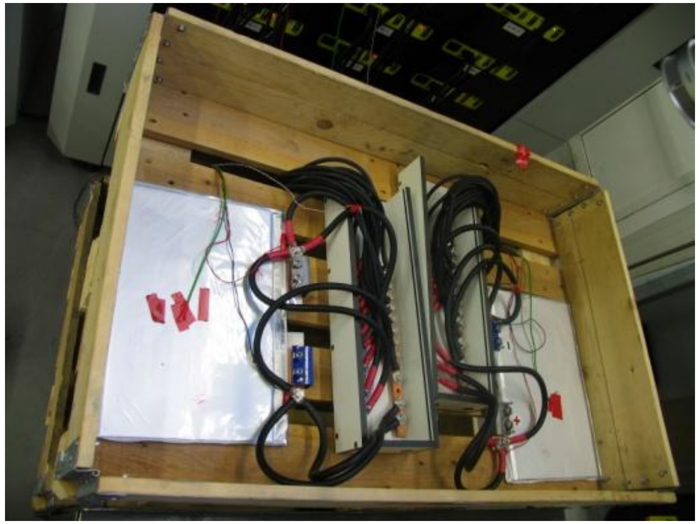
- Performance and lifetime testing of commercial and prototype batteries and ultra-capacitors
- Development of custom application-based efficient test protocols
- Evaluation of battery systems
  - Business case
  - Technical and legal standards



Battery and supercaps test facilities

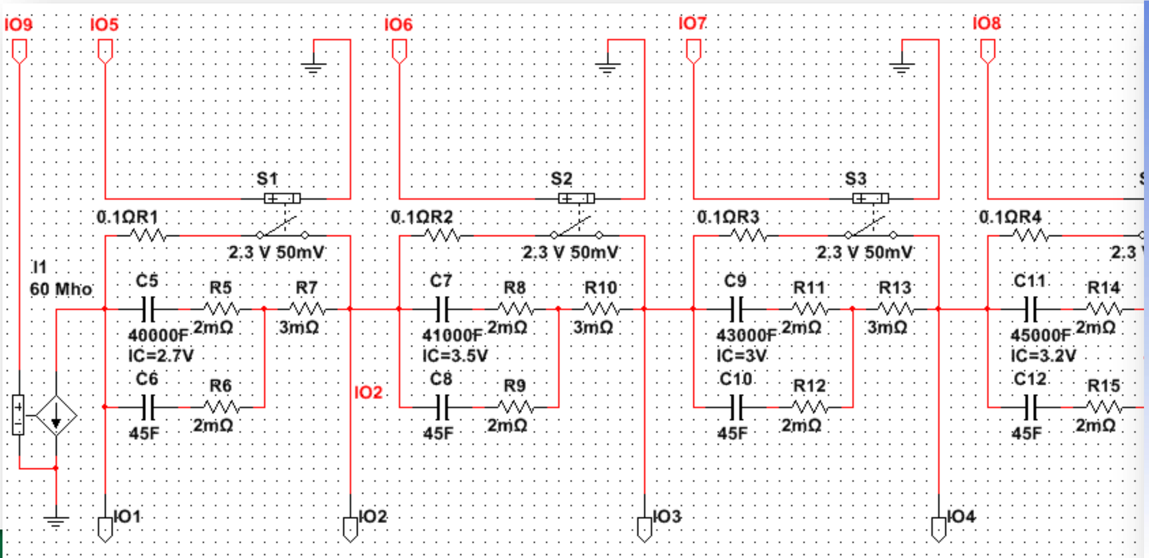
- 2 X 24 channel (6V, 50A) cell test station.
- 2 X 12 channel (80V, 50A) battery/UC test station.
- 1 X 1 channel (15V, 400A battery test station
- Controllable loads combined with inverters

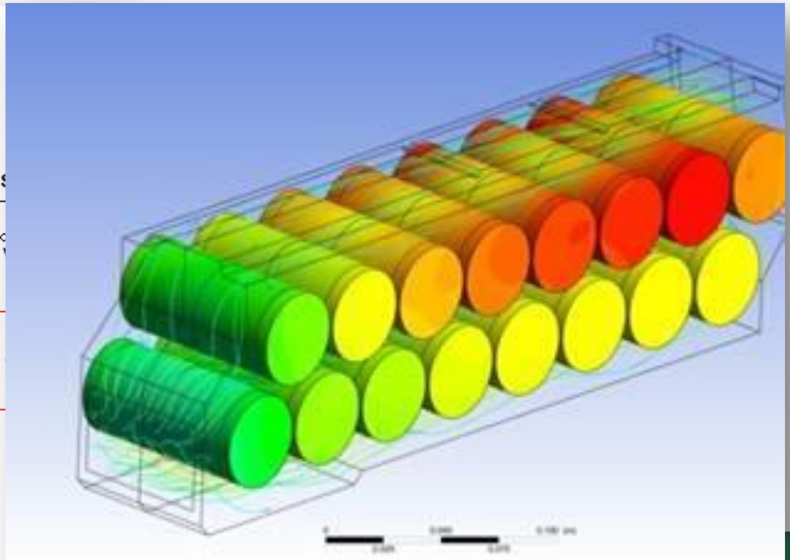
- 150 kW turning DC load
- 90 kW converter



Battery modelling

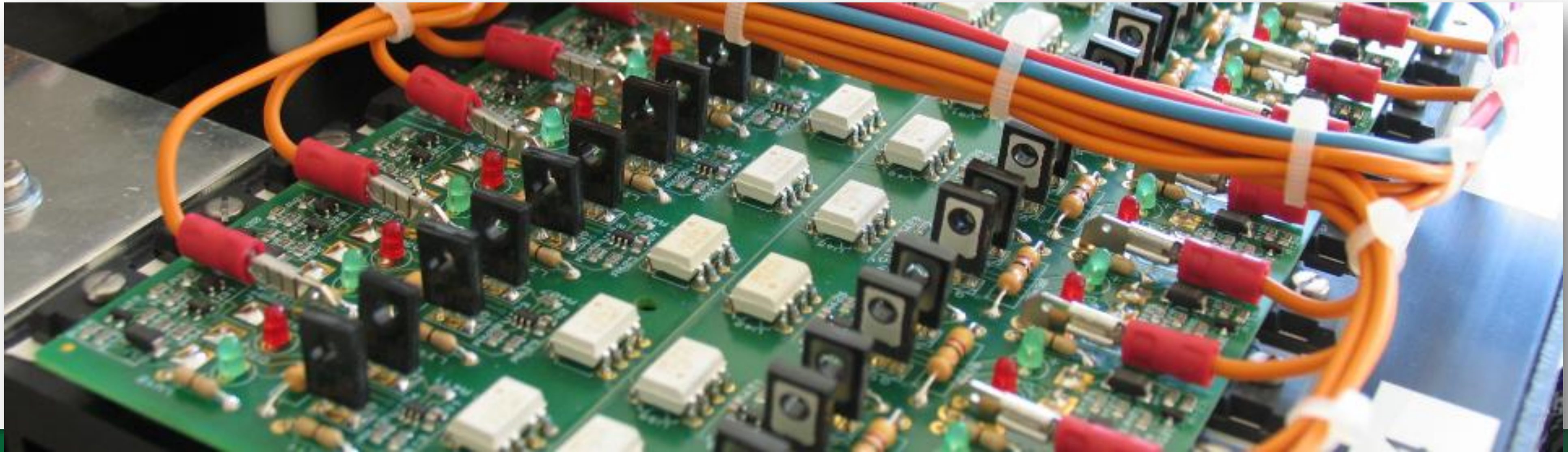
- Battery characterization
- Battery modelling
  - Lumped parameter electrical modelling
  - Thermodynamic modelling
- Modelling and prediction of aging





Battery Management System development

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



Storage Experience

- EnergyVille monitoring technology is used to control the world's largest PEM fuel cell (Solvay Antwerp)

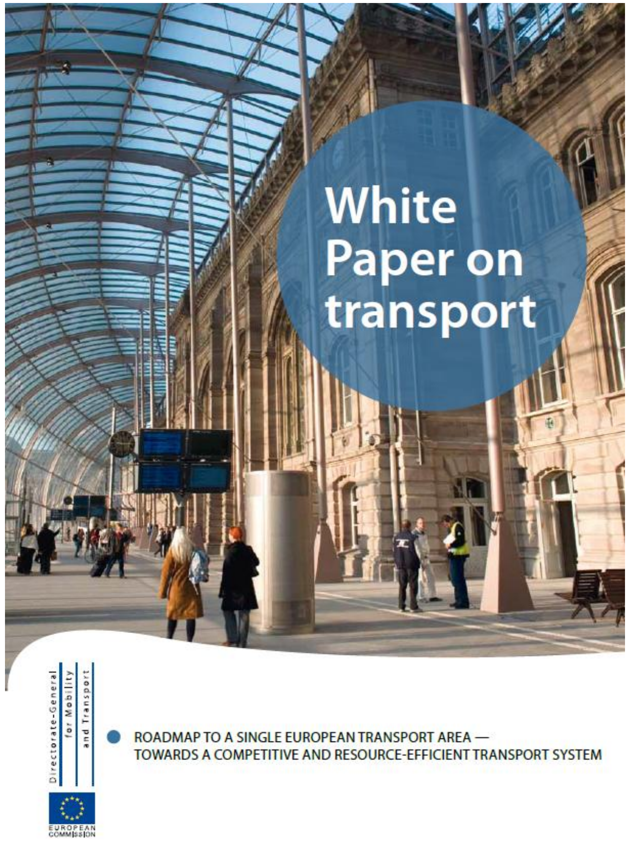
- EnergyVille developed a braking energy recuperation system used by Van Hool

Scope

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

Activities in Europe

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



28.10.2014 EN Official Journal of the European Union L 307/1

I

(Legislative acts)

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 (1),

Having regard to the opinion of the Committee of the Regions (2),

Acting in accordance with the ordinary legislative procedure (3),

Whereas:

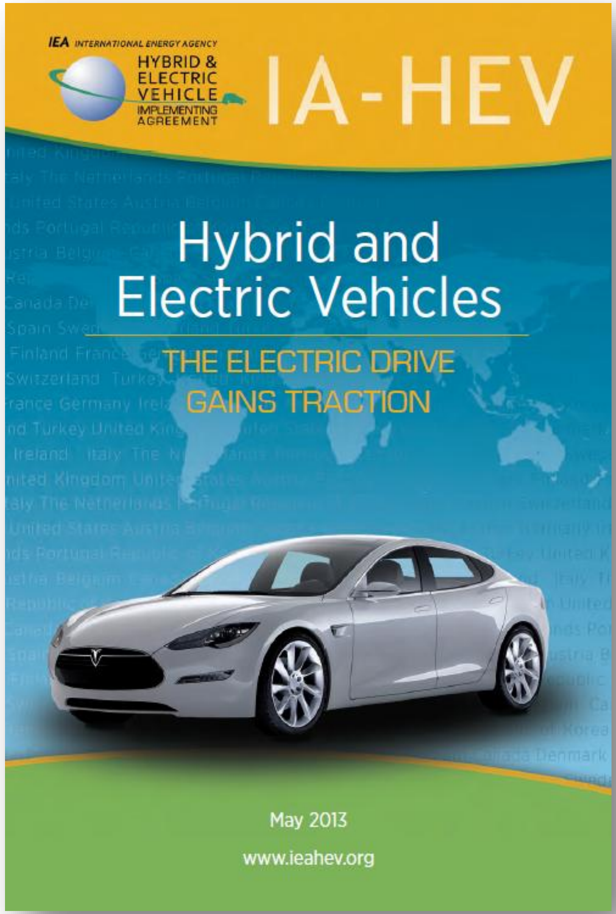
(1) In its Communication of 3 March 2010 entitled 'Europe 2020: A strategy for smart, sustainable and inclusive growth', the Commission aims at enhancing competitiveness and energy security by a more efficient use of resources and energy.

(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 (4) sets a market share target of 10 % of

Activities in Europe

- 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 a creating a clean bus transport fleet. (Image courtesy of EVTecLab 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.

Activities in Europe

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

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

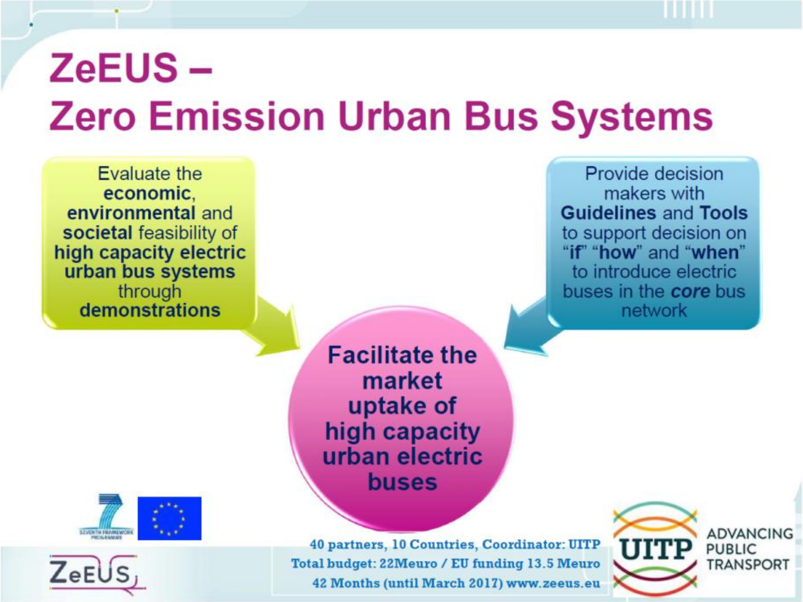
Activities in Europe

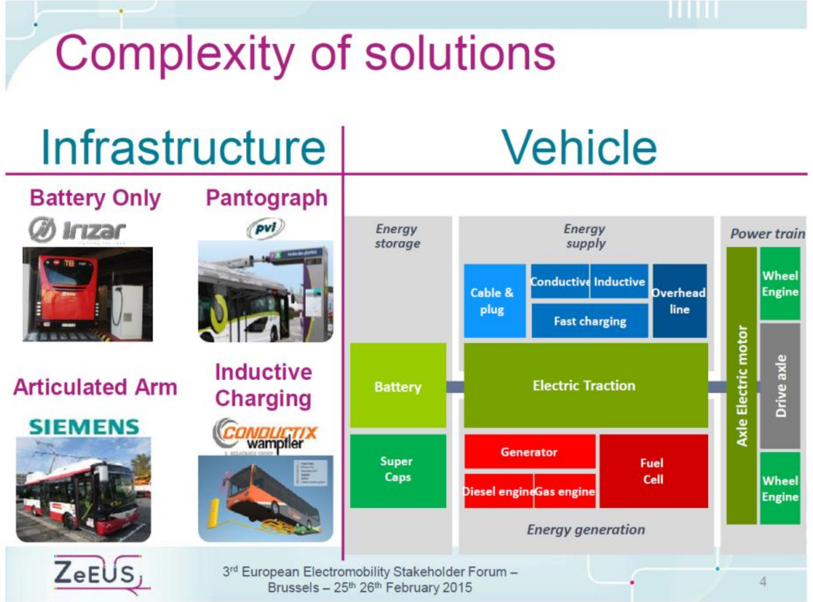
- Battery electric buses : EBSF (2008-2012)

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

Activities in Europe

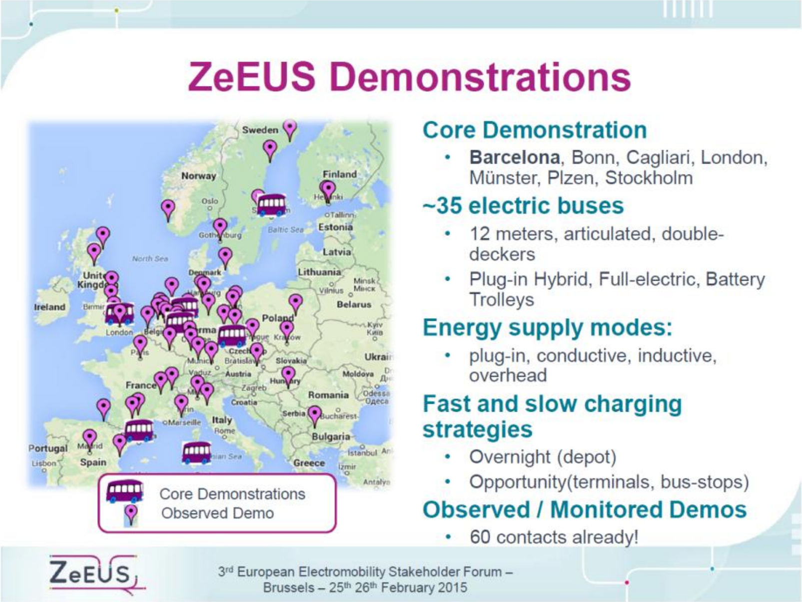
- Battery electric buses : ZeEUS project (until 2017)

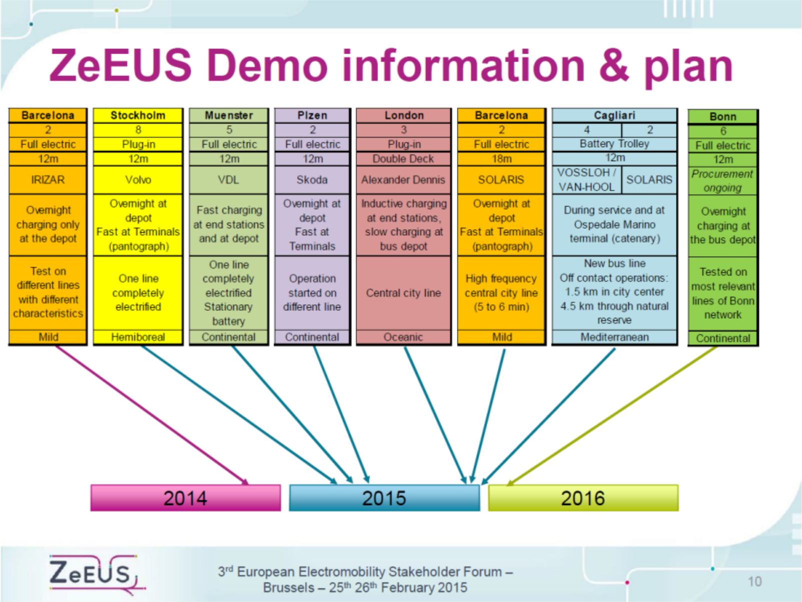




Activities in Europe

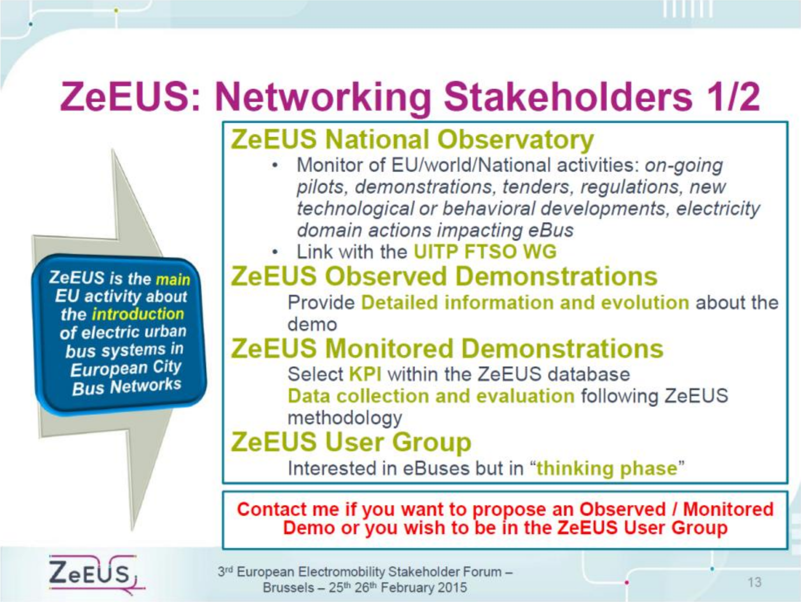
- Battery electric buses : ZeEUS project (until 2017)

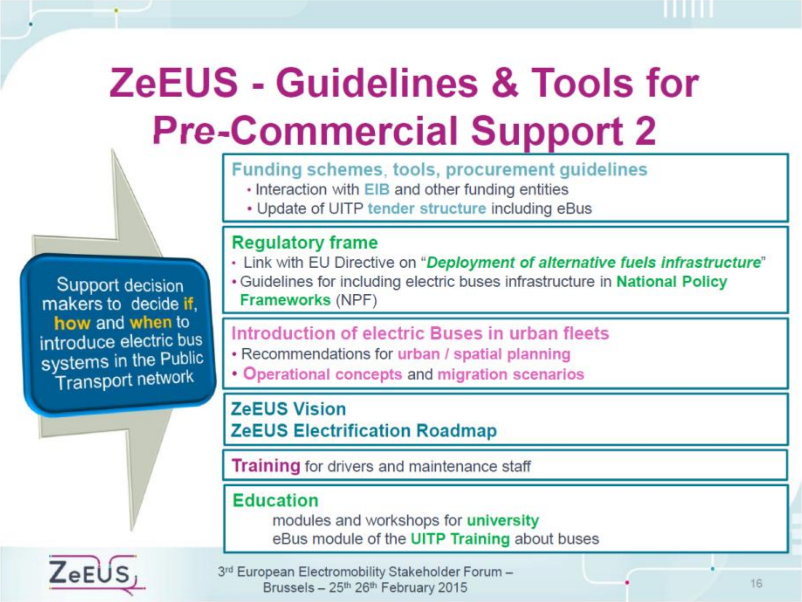




Activities in Europe

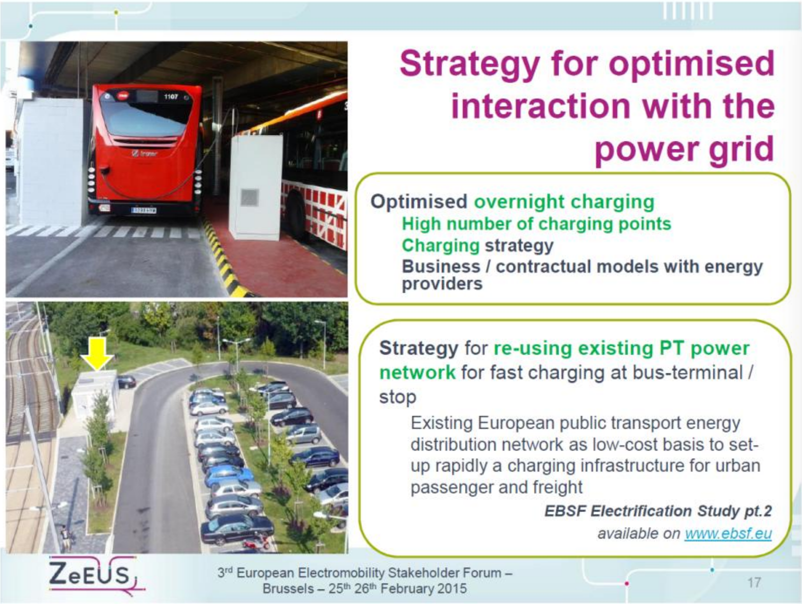
- Battery electric buses : ZeEUS project (until 2017)

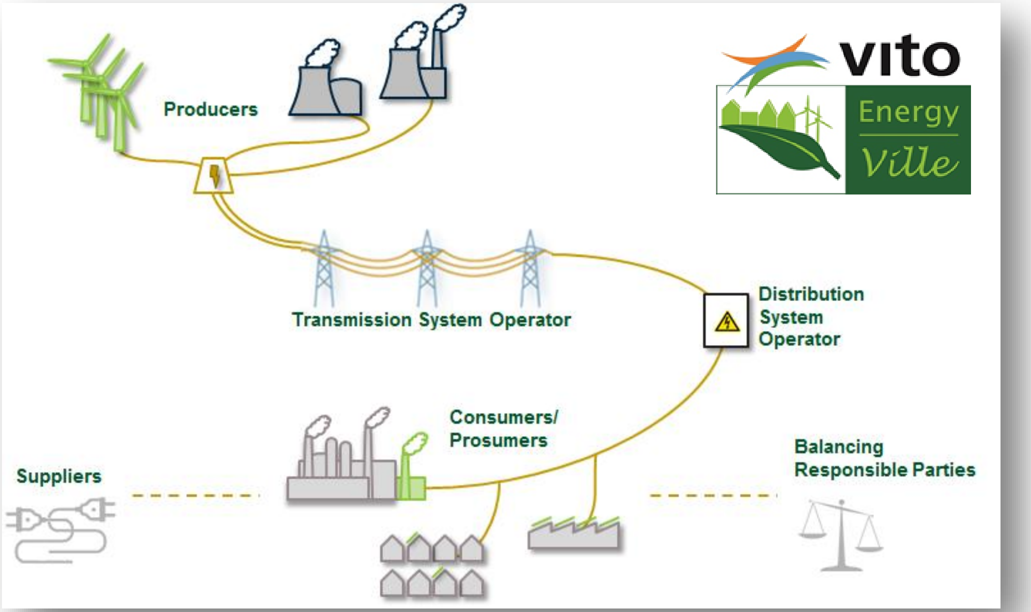




Activities in Europe

- Battery electric buses : ZeEUS project (until 2017)

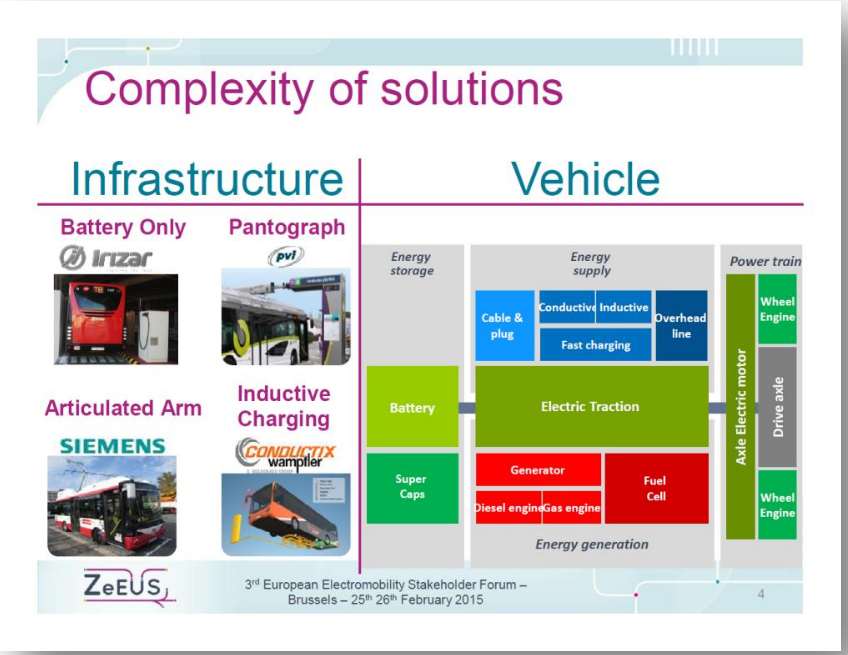




- More information : http://zeeus.eu

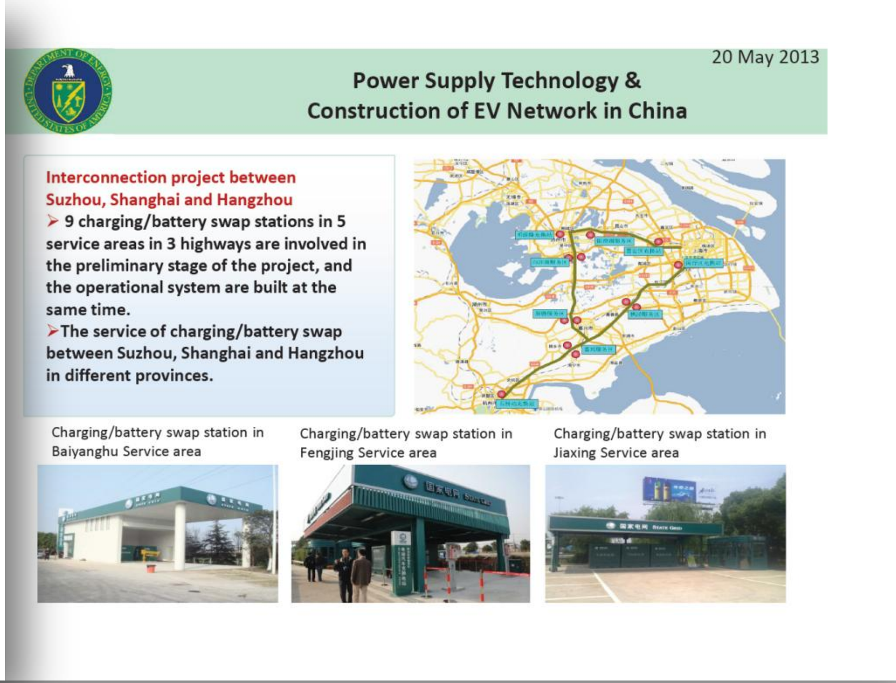
Activities in Europe

- ## 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 ?



Activities in Europe

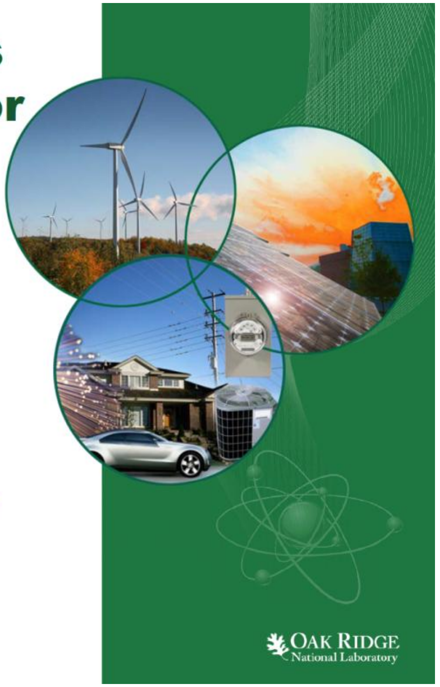
- Charging infrastructure for Battery electric buses
- Battery swapping stations



Activities in Europe

- 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

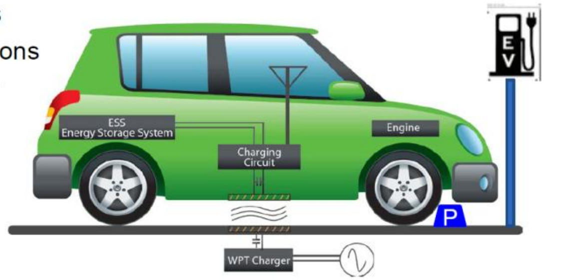
Oak Ridge National Laboratory
Vehicle Systems Research

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

Activities in Europe

- 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

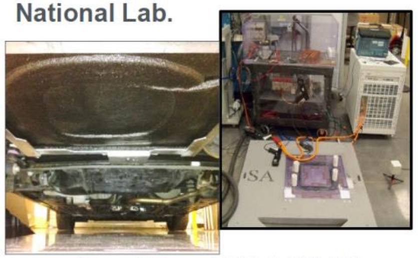
Activities in North America

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.

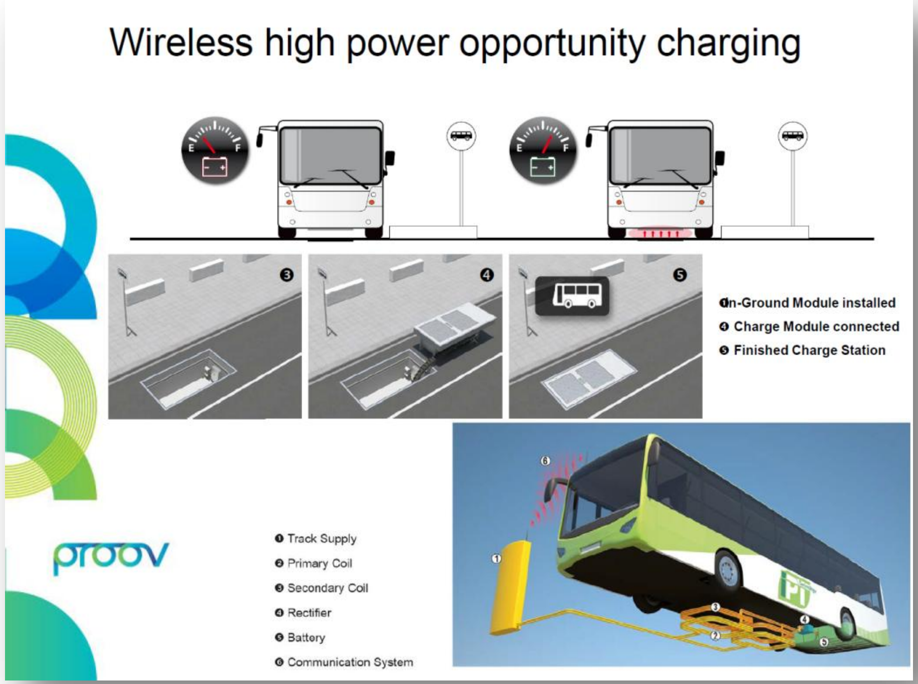


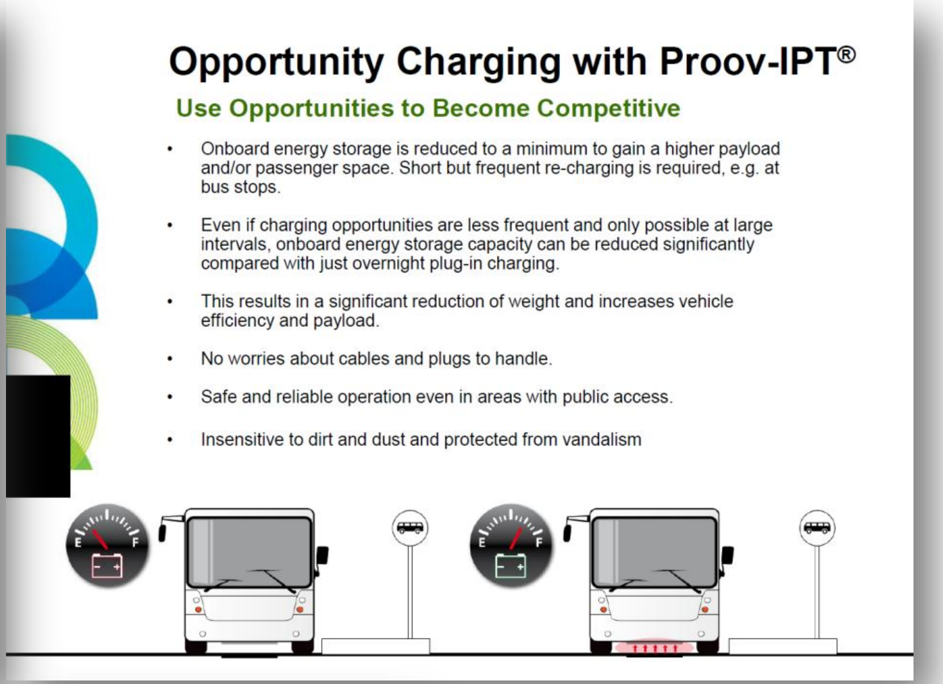
Source: *PT Jones of ORNL. April 28, 2014.*

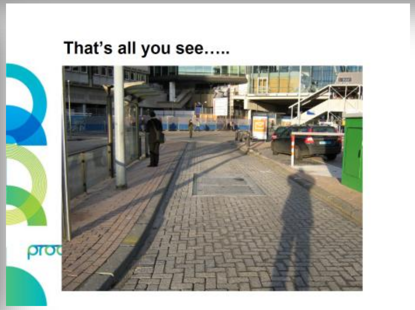
Frequency	23 kHz
Power Transfer Levels	6.6 kW
Wireless Mode	static & dynamic

Activities in Europe

- Wireless charging projects in Europe : some examples

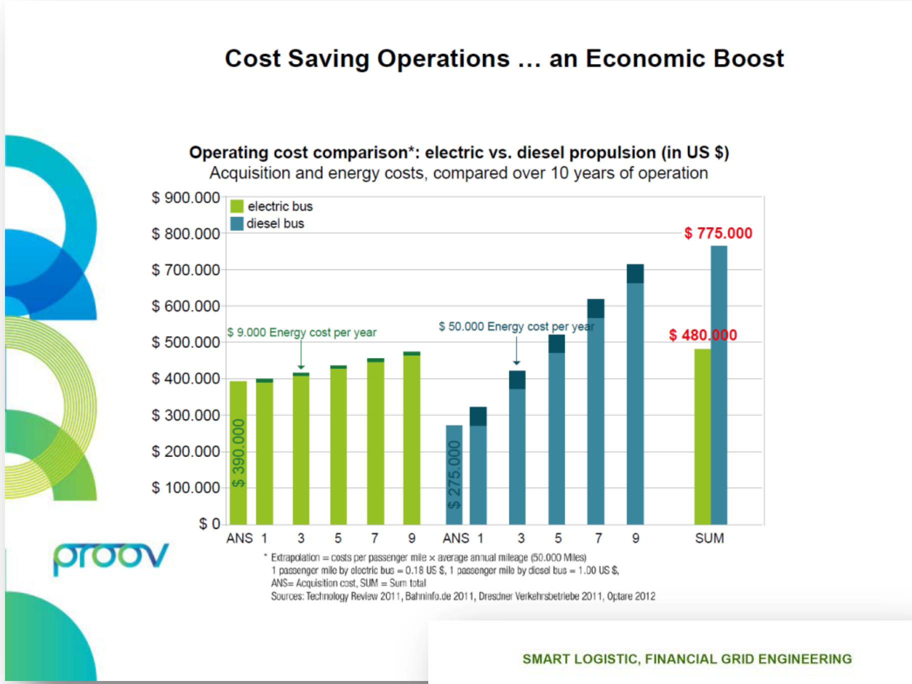


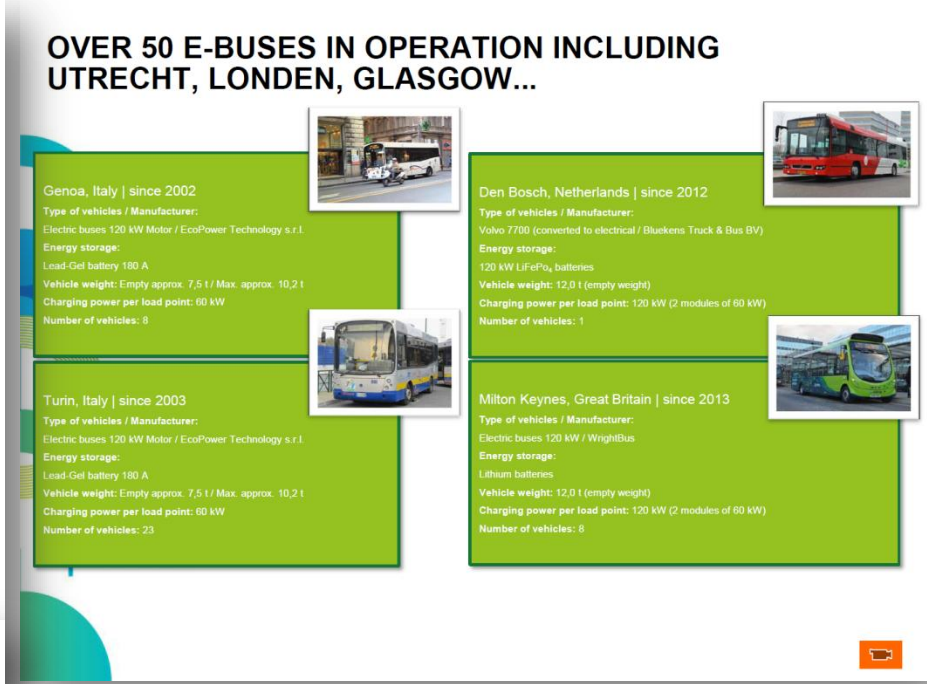


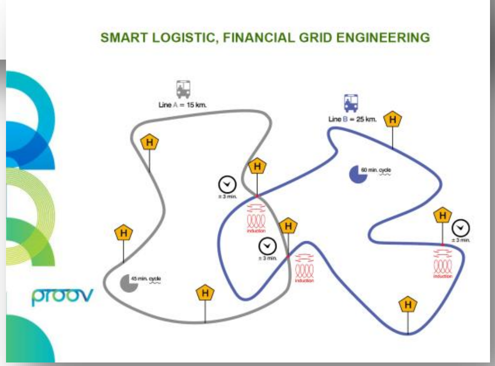


Activities in Europe

- Wireless charging projects in Europe : some examples







Activities in Europe

- Flemish Living Lab Electric Vehicles

EVS28

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

vito
vision on technology

Flemish Living Lab Electric Vehicles

EVS28

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

Flanders State of the Art

EVA Elektrische Voertuigen in Actie

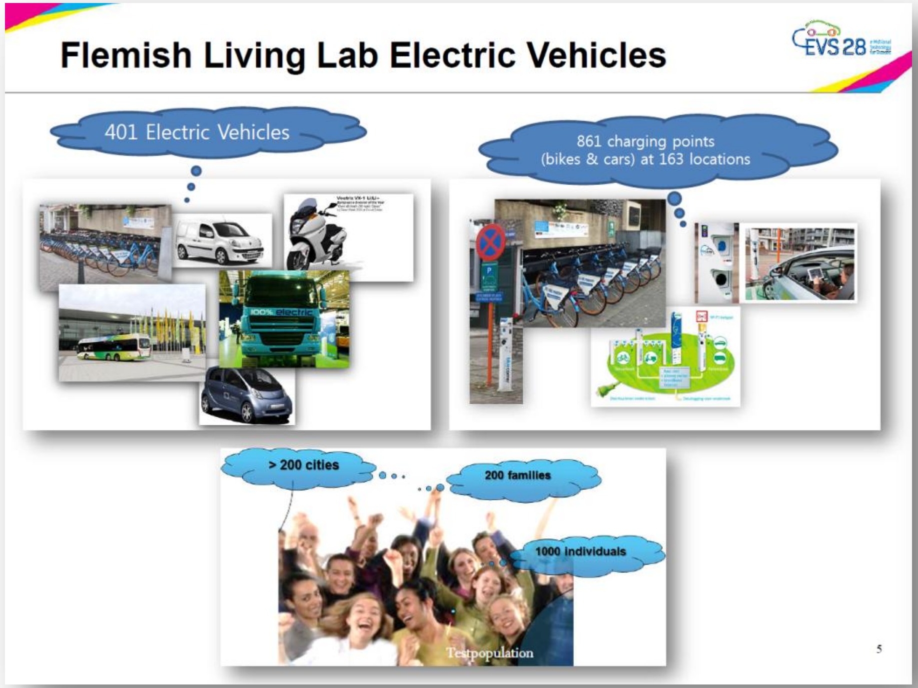
iMove OLYMPUS eVTecLab

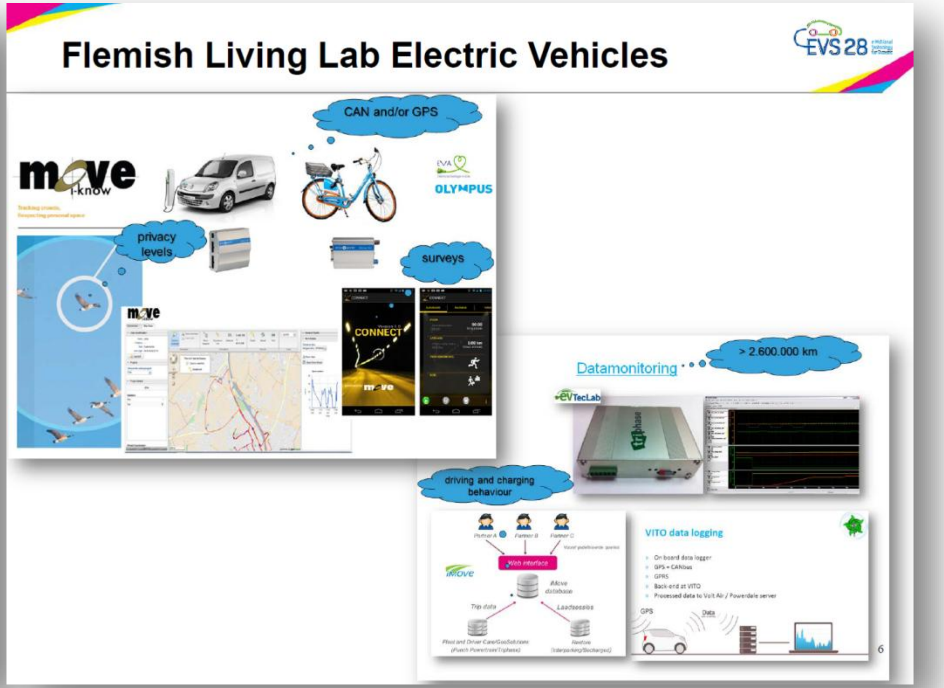
- Call has been set up in 2010 by Flemish Government
- 5 different Platforms have been approved & running in period 2011-2015
- > 70 partners = mainly industry and also research institutes, public bodies
- Total Budget : 27 m€ (16,25 m€ funding)
- Open test infrastructure : electric vehicles, charging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

4

Activities in Europe

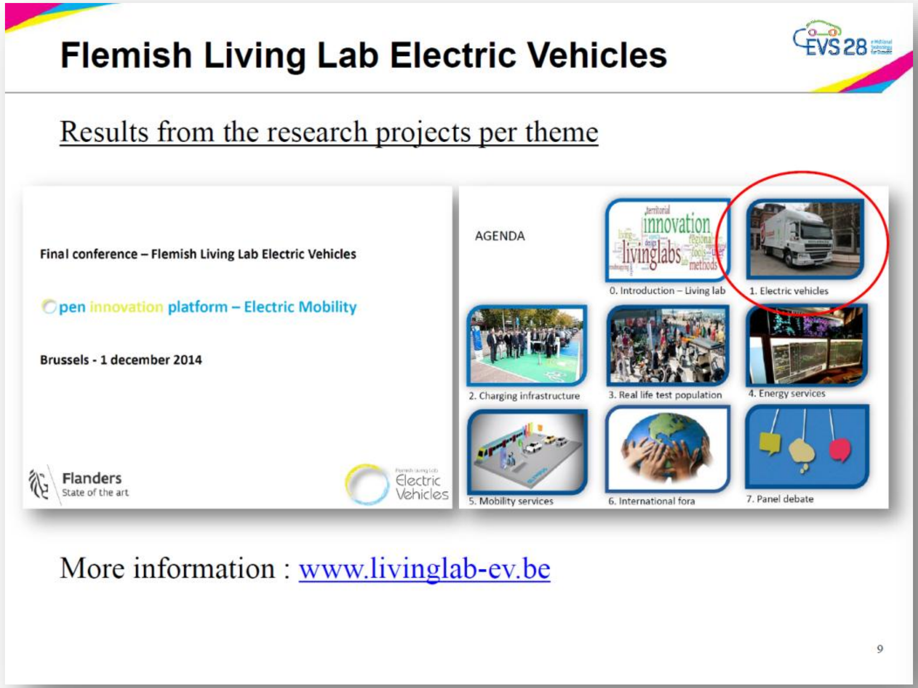
- Flemish Living Lab Electric Vehicles

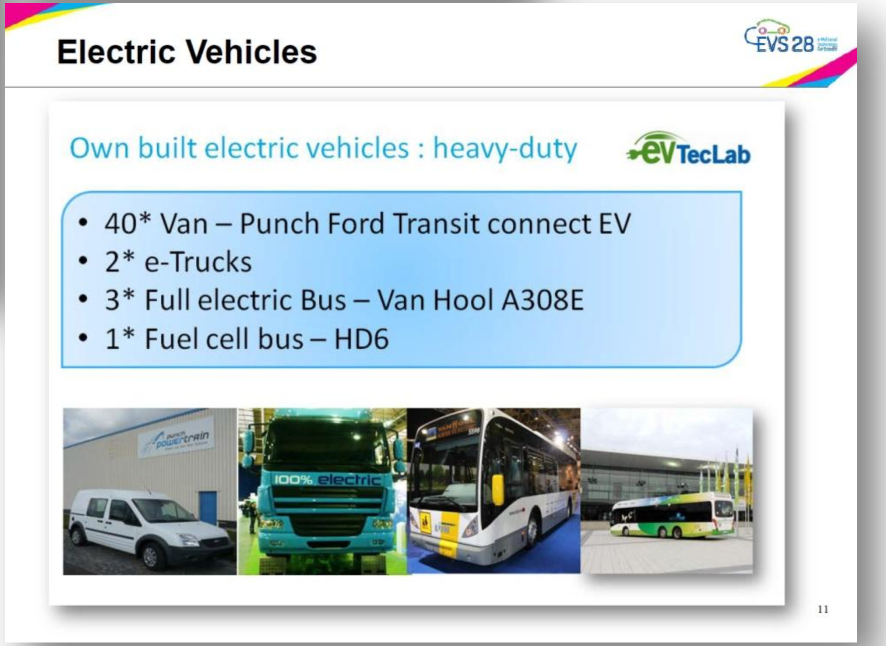




Activities in Europe

- Flemish Living Lab Electric Vehicles





Activities in Europe

- 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

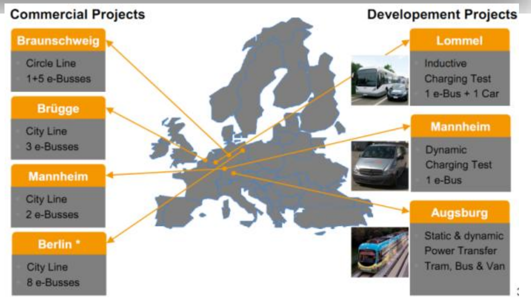
Inductive charging
Li Ion (LTO) battery pack

Primove Pick up

BOMBARDIER
the evolution of mobility

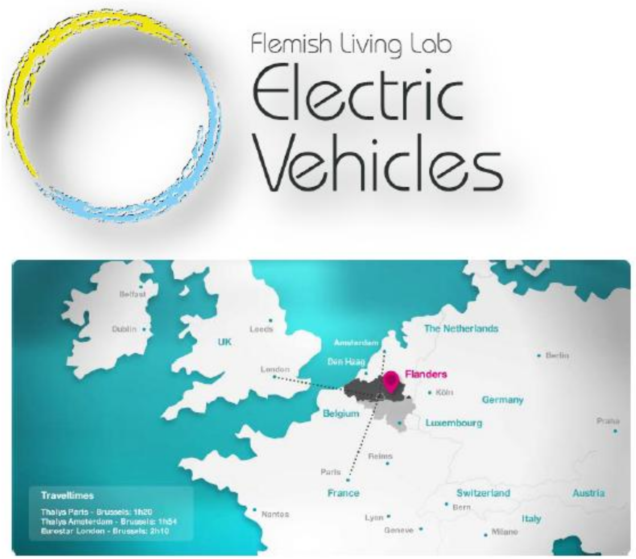
Battery pack

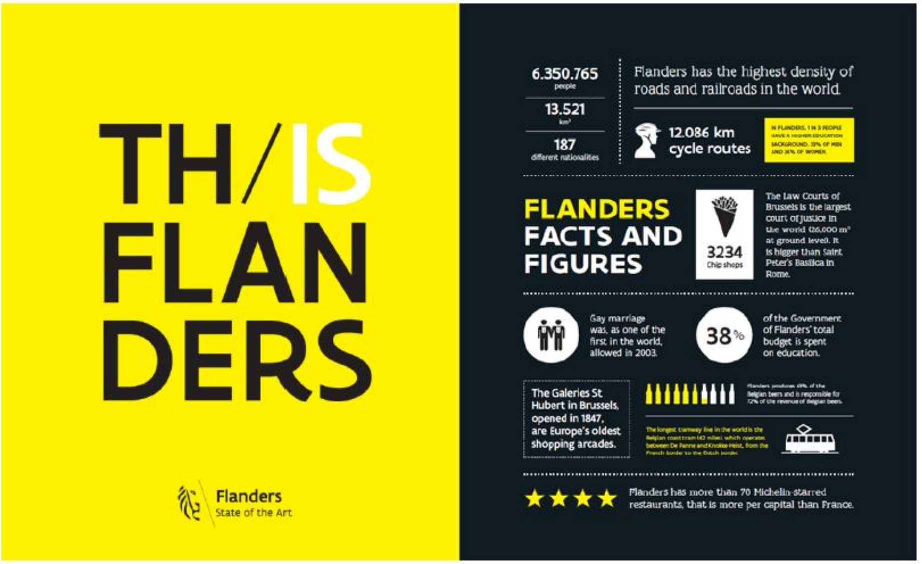
trineuron
a division of emrol



Activities in Europe

- Flemish Living Lab Electric Vehicles





- More information :
  - www.livinglab-ev.be
  - http://www.livinglab-ev.be/content/presentations-final-conference-are-available-online

EnergyVille's e-bus technology and services offerings

- Performance & lifetime tests of batteries and supercapacitors

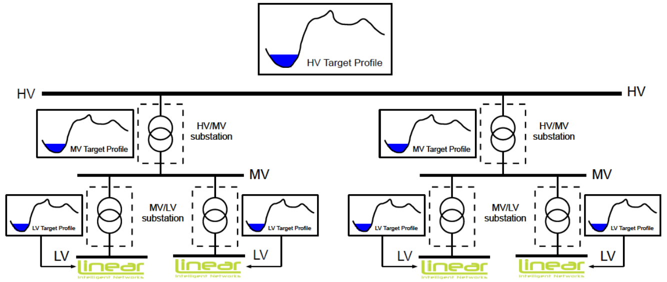
- Battery management systems
  Supercaps balancing

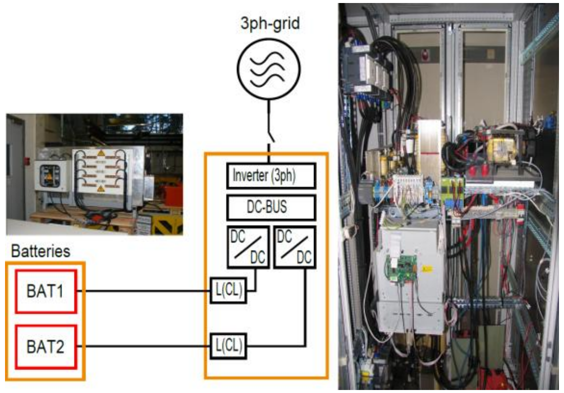
- Battery state of health analysis & prediction

- Cooling system design

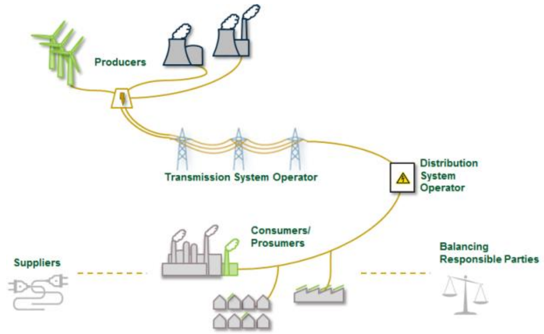
EnergyVille's e-bus technology and services offerings

- Grid & Bus friendly Charging Infrastructure

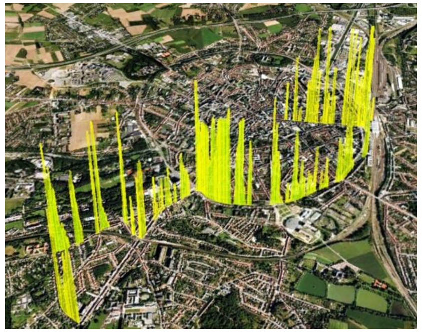




- Energy market & E-bus business models



- Field monitoring of e-busses & environmental impact



Questions? → Contact

Raf Ponnette

EnergyVille - *partnership VITO, KULeuven, imec*

EnergyVille: Thor Park 8300, 3600 Genk, België

VITO: Boeretang 200, 2400 Mol, België

Mobile +32 478 470355

raf.ponnette@energyville.be

raf.ponnette@vito.be

Visit our website: www.energyville.be

Visit our website: 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.
- Grietus Mulder, Noshin Omar, Stijn Pauwels, Marcel Meeus, Filip Leemans, Bavo Verbrugge, Wouter De Nijs, Peter Van den Bossche, Daan Six, Joeri Van Mierlo, “Comparison of commercial battery cells in relation to material properties”, Electrochimica Acta, 87, 473-488, 2013.
- Dominguez-Benetton X., Sevda S., Vanbroekhoven K., Pant D. (2012). The accurate use of impedance analysis for the study of microbial electrochemical systems. Chem. Soc. Rev. 41(21):7228-46.
- Grietus Mulder, Daan Six, Bert Claessens, Thijs Broes, Noshin Omar, Joeri Van Mierlo; “The dimensioning of PV-battery systems depending on the incentive and selling price conditions”; Applied Energy 111 (2013)
- Clement-Nyns, K.; Haesen, E.; Driesen, J., "The Impact of Charging Plug-In Hybrid Electric Vehicles on a Residential Distribution Grid," Power Systems, IEEE Transactions on , vol.25, no.1, pp.371,380, Feb. 2010
- 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
- Van Roy, J.; Leemput, N.; Geth, F.; Salenbien, R.; Buscher, J.; Driesen, J., "Apartment Building Electricity System Impact of Operational Electric Vehicle Charging Strategies," Sustainable Energy, IEEE Transactions on , vol.5, no.1, pp.264,272, Jan. 2014
- De Brabandere, K..; Bolsens, Bruno; Van den Keybus, J..; Woyte, A.; Driesen, J.; Belmans, R., "A Voltage and Frequency Droop Control Method for Parallel Inverters," Power Electronics, IEEE Transactions on , vol.22, no.4, pp.1107,1115, July 2007
- Engelen K., De Breucker S., Tant P., Driesen J.: "Gain Scheduling Control of a Bidirectional DC-DC Converter with Large Dead-Time," IET Power Electronics, 2013
- 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.