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 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.
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, SO2, 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

- Producers
- Transmission System Operator
- Distribution System Operator
- Consumers/Prosumers
- Suppliers
- Balancing Responsible Parties
Energy Market: context and background

- Liberalisation of 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

  ![Image of trains]

  - Reduction of Energy Bill
  - Increased network capacity

  ![Image of trains at station]
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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
Electrification of “public” transport

Figure 19: Key components of public mobility services

<table>
<thead>
<tr>
<th>Public mobility infrastructure</th>
<th>Service offering characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Public transport</strong></td>
<td><strong>Quality</strong></td>
</tr>
<tr>
<td>- Rail (regional, sub-urban, commuter, light rail, tram)</td>
<td>- Accessibility, operating hours, punctuality, reliability, frequency, network coverage</td>
</tr>
<tr>
<td>- Buses (regional, urban buses &amp; trolleybuses, BRT)</td>
<td>- Sufficient capacities in peak periods</td>
</tr>
<tr>
<td>- Ferries, Personal Rapid Transit</td>
<td></td>
</tr>
<tr>
<td><strong>Public individual transport</strong></td>
<td><strong>Safety and Security</strong></td>
</tr>
<tr>
<td>- Car &amp; bike sharing</td>
<td>- Exploitation safety performance, security and perception of security</td>
</tr>
<tr>
<td>- Car &amp; bike rental</td>
<td>- Emergency medical and police services</td>
</tr>
<tr>
<td>- Taxi &amp; limousine service</td>
<td></td>
</tr>
<tr>
<td>- Etc.</td>
<td></td>
</tr>
<tr>
<td><strong>Parking infrastructure</strong></td>
<td><strong>Convenience</strong></td>
</tr>
<tr>
<td>- Park &amp; Ride facilities</td>
<td>- Real-time information, planning, booking and payment</td>
</tr>
<tr>
<td>- Bike &amp; Ride facilities</td>
<td>- Comfort, speed, congestion friendliness</td>
</tr>
<tr>
<td>- Bike parking and parking boxes</td>
<td></td>
</tr>
<tr>
<td>- Etc.</td>
<td></td>
</tr>
<tr>
<td><strong>Sustainability</strong></td>
<td><strong>Sustainability</strong></td>
</tr>
<tr>
<td>- Energy efficiency and alternative engines</td>
<td>- Energy efficiency and alternative engines</td>
</tr>
<tr>
<td>- Air quality and noise neutrality</td>
<td>- Climate neutrality</td>
</tr>
<tr>
<td><strong>Affordability</strong></td>
<td><strong>Affordability</strong></td>
</tr>
<tr>
<td>- Financial attractiveness for users, meeting social and distributitional objectives</td>
<td>- Cost efficiency of operators, PF incentives</td>
</tr>
</tbody>
</table>

Source: Arthur D. Little

Read Electric Buses 2015-2025

Electric Buses 2015-2025

Forecast, 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 $160 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
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

HOW? Interconnected labs + inverters/converters

PHEVs and EVs

Thermal storage, heat-pump, μ-CHP

DSM on home appliances
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
Battery Management System development

- Insulation monitoring (DC-safe®)
- Voltage monitoring (CellSense®)
- 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
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Activities in Europe

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

• Hybrid buses are getting more and more “standard”
Activities in Europe

• Fuel cell buses: High V.L.O-City project

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

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Activities in Europe

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Activities in Europe

- Battery electric buses: ZeEUS project (until 2017)

More information: [http://zeeus.eu](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
Activities in Europe

• Wireless charging projects outside of Europe
Activities in Europe

• Wireless charging projects in Europe: some examples

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. Little or 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.
Activities in Europe

- Wireless charging projects in Europe: some examples
Activities in Europe

- Flemish Living Lab Electric Vehicles

**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

**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, test population, …
Activities in Europe

• Flemish Living Lab Electric Vehicles
Activities in Europe

• Flemish Living Lab Electric Vehicles

Results from the research projects per theme

More information: www.livinglab-ev.be

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
Activities in Europe

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

<table>
<thead>
<tr>
<th>Electric buses</th>
<th>Inductive charging Li Ion (LTO) battery pack</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type</strong></td>
<td>Primove Pick up</td>
</tr>
<tr>
<td><strong>Bus length</strong></td>
<td>Battery pack</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td>SOC vs time</td>
</tr>
<tr>
<td><strong>Range</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Conductively charging</strong></td>
<td>Bombardier</td>
</tr>
<tr>
<td><strong>Inductively charging</strong></td>
<td>trineuron</td>
</tr>
<tr>
<td><strong>Battery pack energy content</strong></td>
<td>Li Ion (LTO) 34.8kWh</td>
</tr>
</tbody>
</table>

Introduction in Bruges mid 2015
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

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Selection of publications

- Grietse 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.
- 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
- De Craemer K., Vandaels S., Claessens B., Deconinck G. 2013. An Event-Driven Dual Coordination Mechanism for Demand Side Management of PHEVs, IEEE Transactions on Smart Grid.IEEE Transactions on Smart Grid. Institute of Electrical and Electronics Engineers (I), ISSN 1949-3053