Integration of electric transportation with smart grids

Kari Mäki

"Will a smarter grid lead to smarter end users – or vice versa"
IEA EGRD Meeting
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Oslo, Norway

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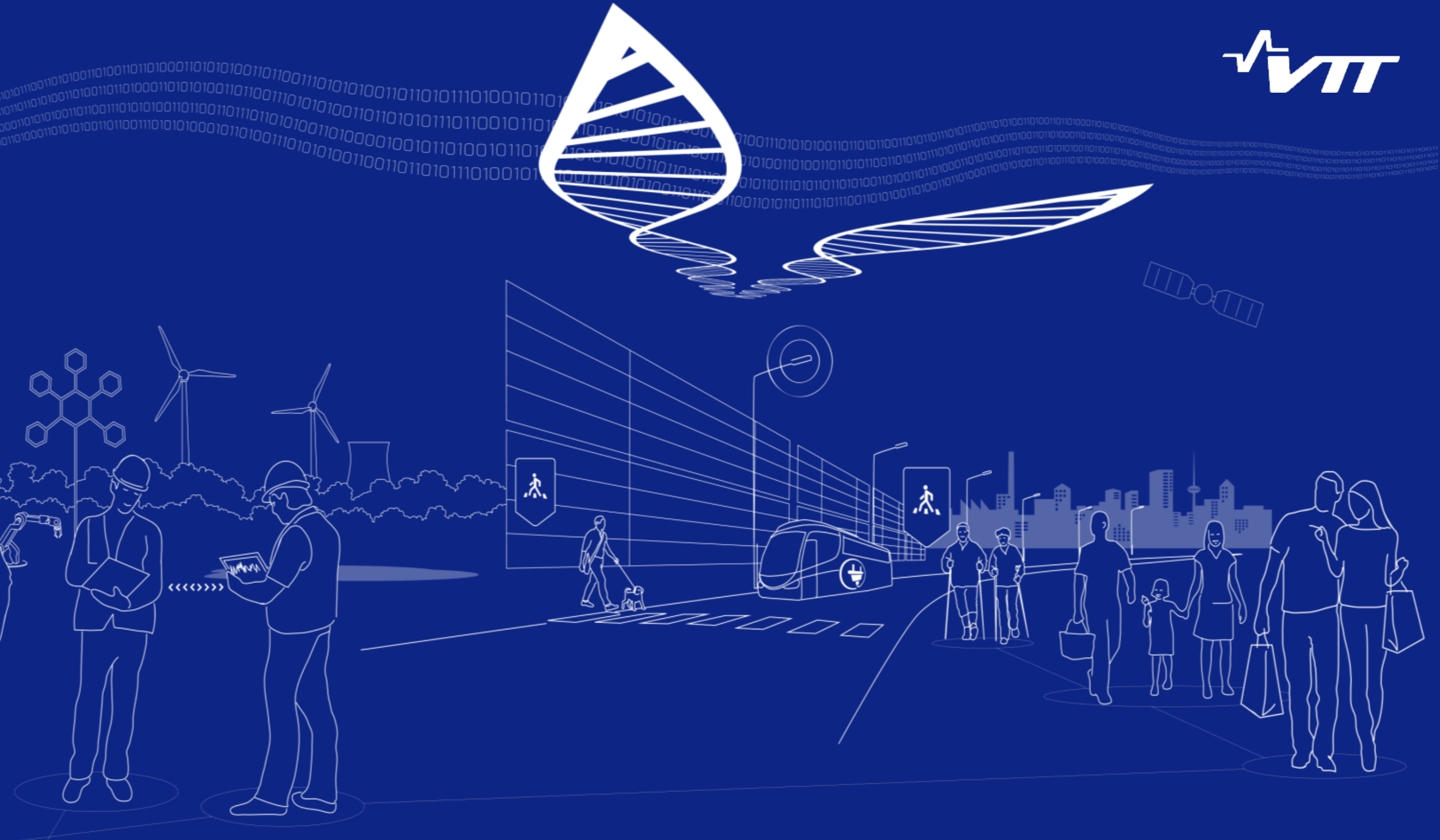


VTT briefly

VTT – Technology for business

VTT Technical Research Centre of Finland Ltd is the leading research and technology company in the Nordic countries. We provide expert services for our domestic and international customers and partners, and for both private and public sectors. We use 4,000,000 hours of brainpower a year to develop new technological solutions.

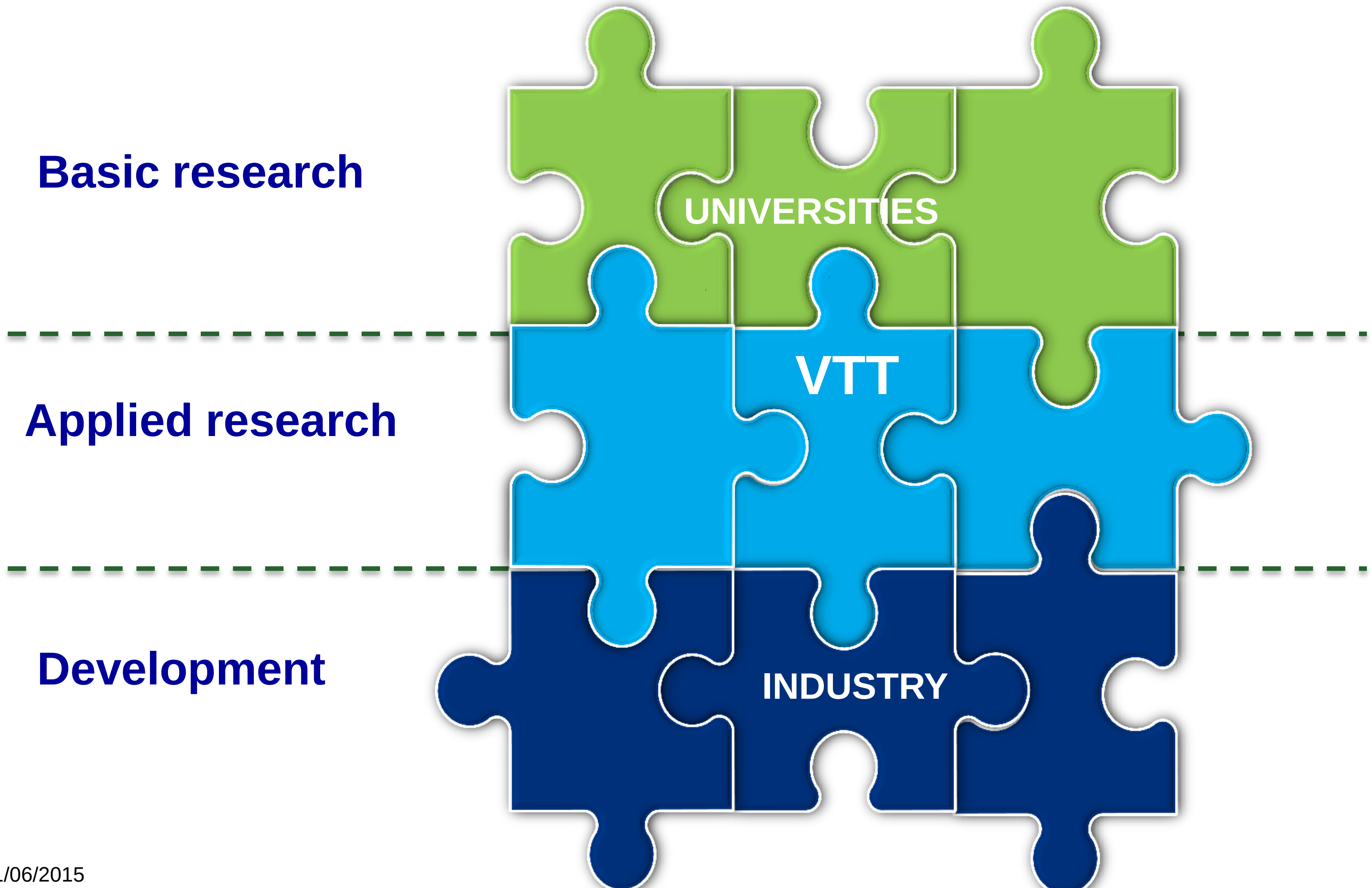
We develop new smart technologies, profitable solutions and innovative services. We cooperate with our customers to produce technology for business and build success and well-being for the benefit of society.

VTT is a non-profit organisation and a crucial part of Finland's innovation eco-system. VTT operates under the mandate of the Ministry of Employment and the Economy.

- Turnover 277 M€ (VTT Group 2014), personnel 2,600 (VTT Group 1.1.2015)
- Unique research and testing infrastructure
- Wide national and international cooperation network

*) Source: Roles, effectiveness, and impact of VTT, VTT & Technopolis Group, 2013

VTT's status as performer of R&D work



VTT's research projects

1 Commercial activities

- Commercial activities performed according to direct demand from customers.

Impact:

- Building competitiveness for VTT's customers through world-class research and innovation services

2 Joint projects

- Research projects jointly funded by VTT, companies, research financers (*) and/or other research parties.

Impact:

- More efficient technology transfer
- Foundation for new innovations and political decision-making

3 Self-financed research

- Technology-based strategic research projects

Impact:

- Developing VTT's own competitiveness and acquiring knowledge and expertise to meet future customer needs

(*) R&D funding possibilities for example

- Tekes (The Finnish Funding Agency for Technology and Innovation)
- EU projects

VTT's strategic research portfolio

Bioeconomy transformation

- Sustainable use and refining of bio-based raw materials
- Industrial biotechnology and green chemistry
- Process and manufacturing technologies
- Bioeconomy business ecosystems

Low-carbon economy

- Energy efficient solutions for industry, built environment, and transport
- Renewable energy sources
- Nuclear energy: safety and waste management
- Energy systems and modelling

Clean environment

- Clean water cycles on demand
- Industrial ecology and life cycle design
- Waste refineries, material recovery, and recycling
- Substitute material solutions

Horizontal research: Business and services – Innovation methods and policies – Safety and security – User and customer understanding

Digital world

- High-performance microsystems and sensing solutions
- Printed intelligence
- Scalable digital service economy
- Internet of Things (IoT)

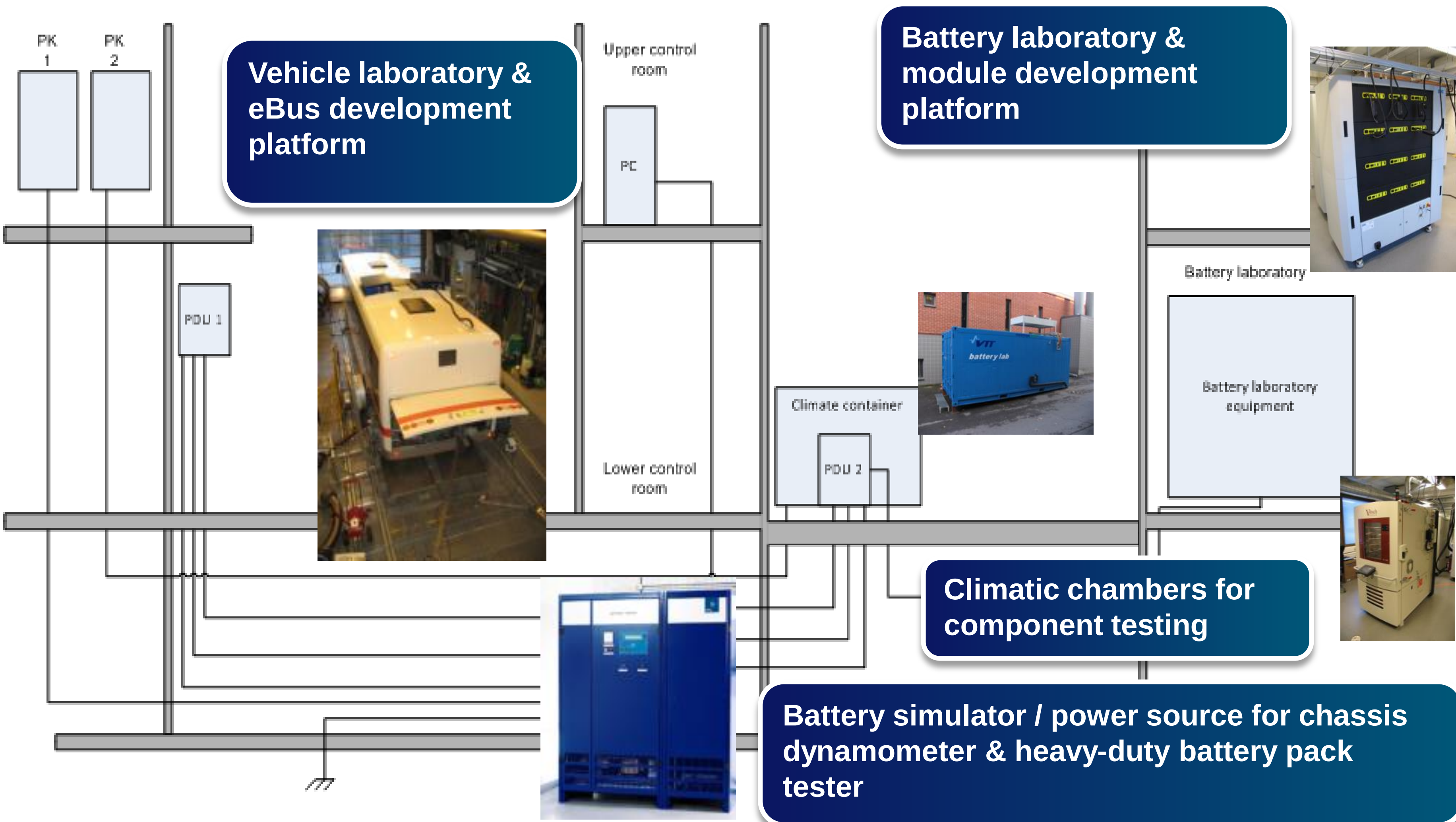
Resource efficient production systems

- Eco-efficient machines
- Resource efficient processes
- Simulation based design
- Global production and services

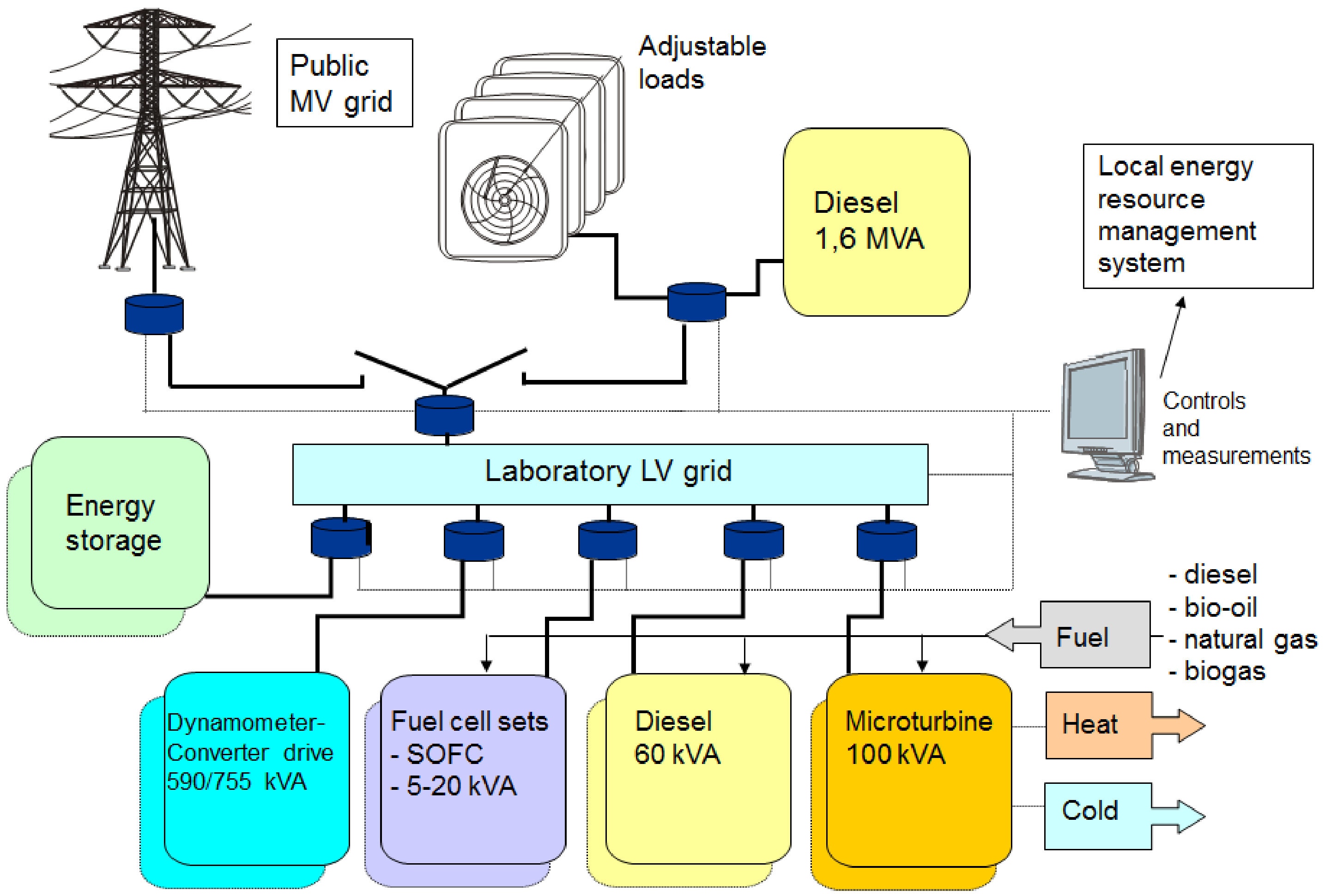
Health and wellbeing solutions

- Diagnostics
- Food products and health
- ICT for health
- User-driven spaces and environments

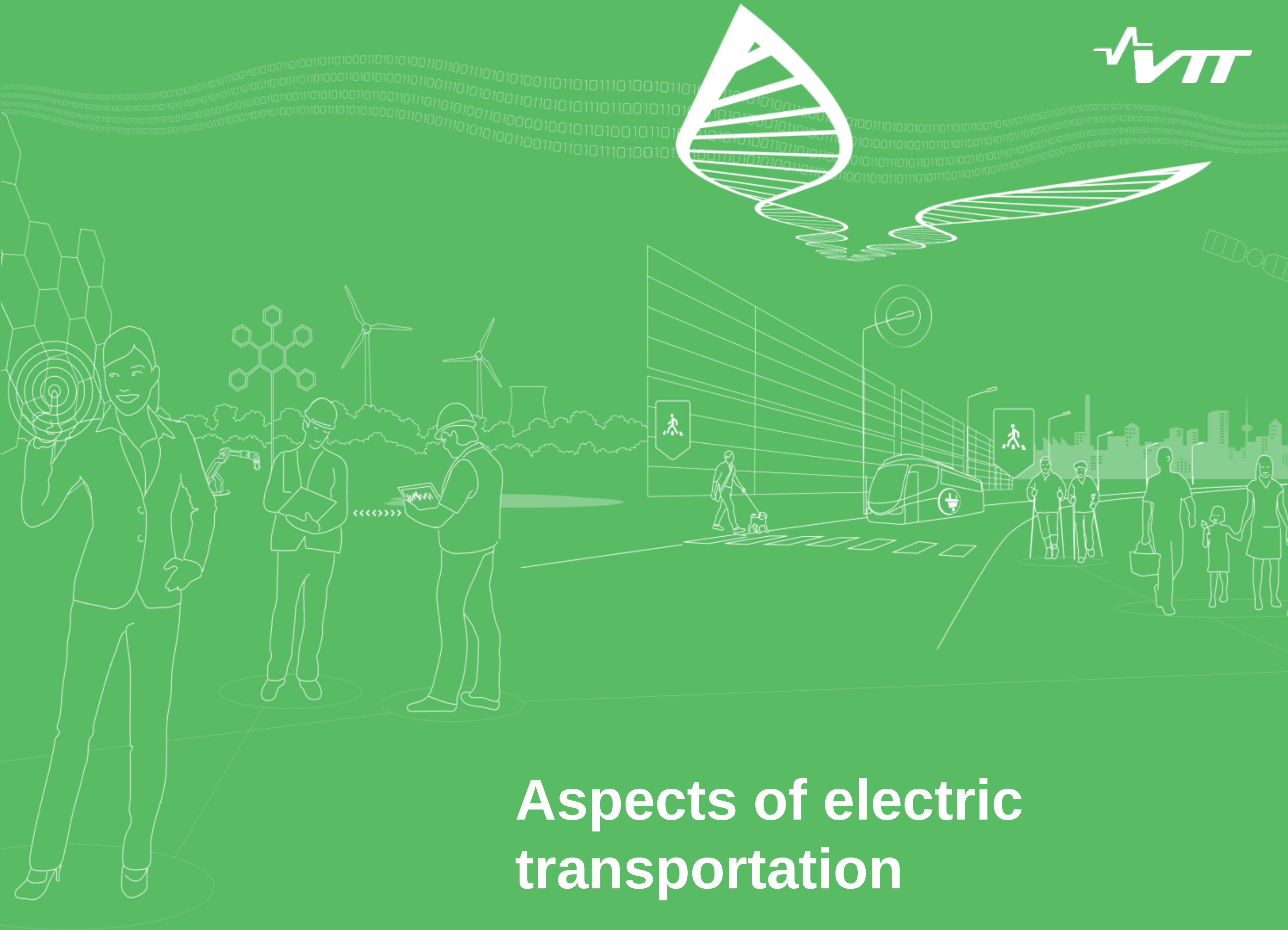
VTT has integrated research capabilities for electric vehicle R&D



… as well as Smart Grid research environments



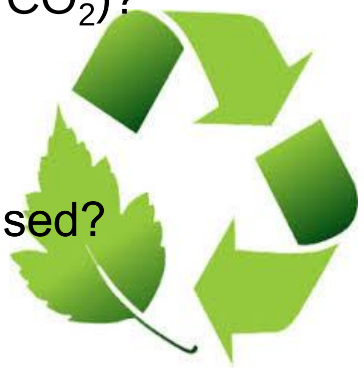
- Integration between electric vehicle, battery and smart grid labs is in progress!



Aspects of electric transportation

Questions to be asked

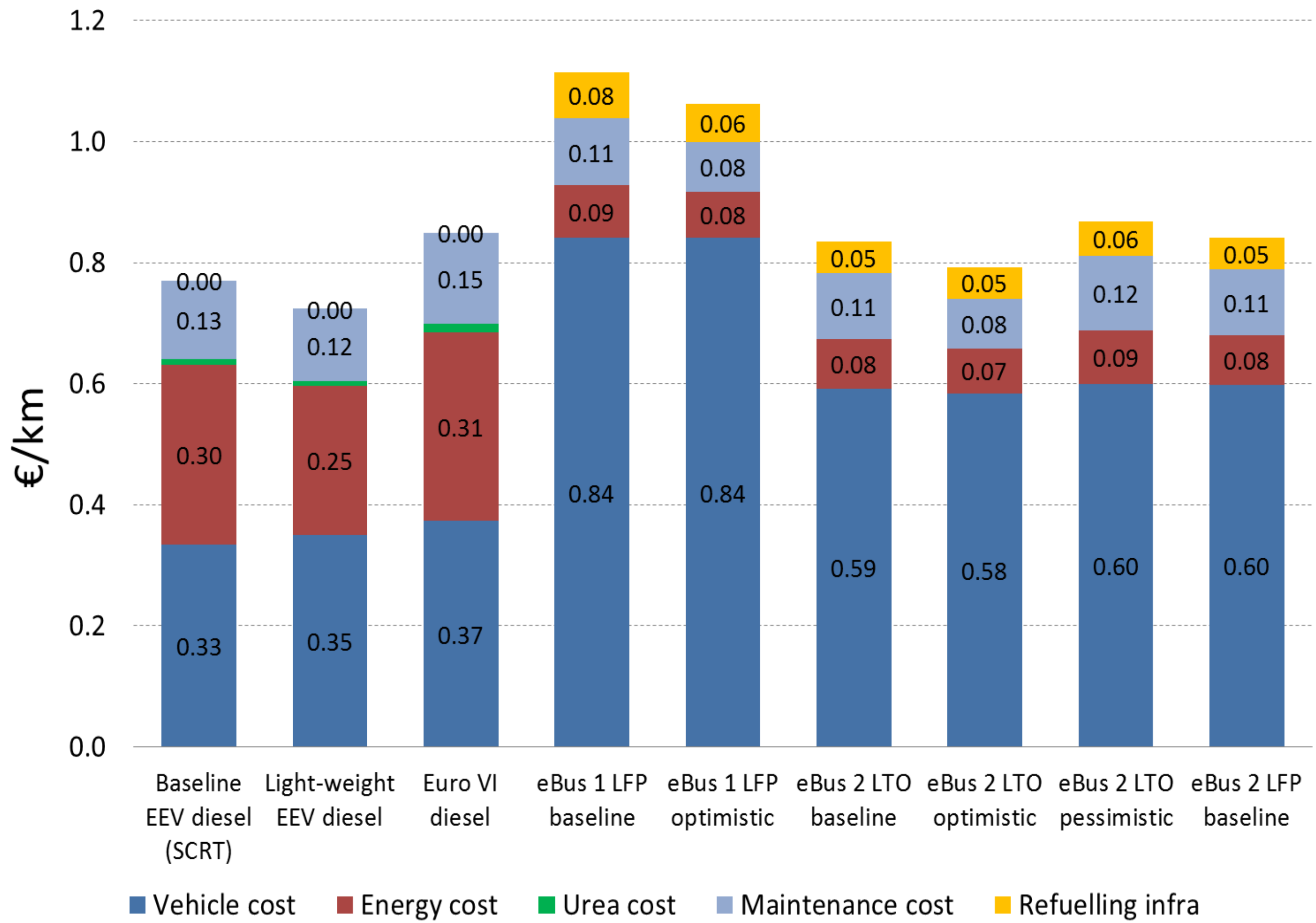
- From the car owner's or fleet operators' point of view:
  - Which vehicles provide best fuel and overall economy?
  - Ensuring high reliability, availability and productivity of the system
- From the point of view of decision makers and those responsible for transport services and procurement:
  - Which vehicles actually deliver low emissions (regulated, CO_2)?
- And the practical issues…
  - How should the charging infrastructure for EV's be organised?
  - How to facilitate the adoption of the new technologies?



Why are electric buses attractive?

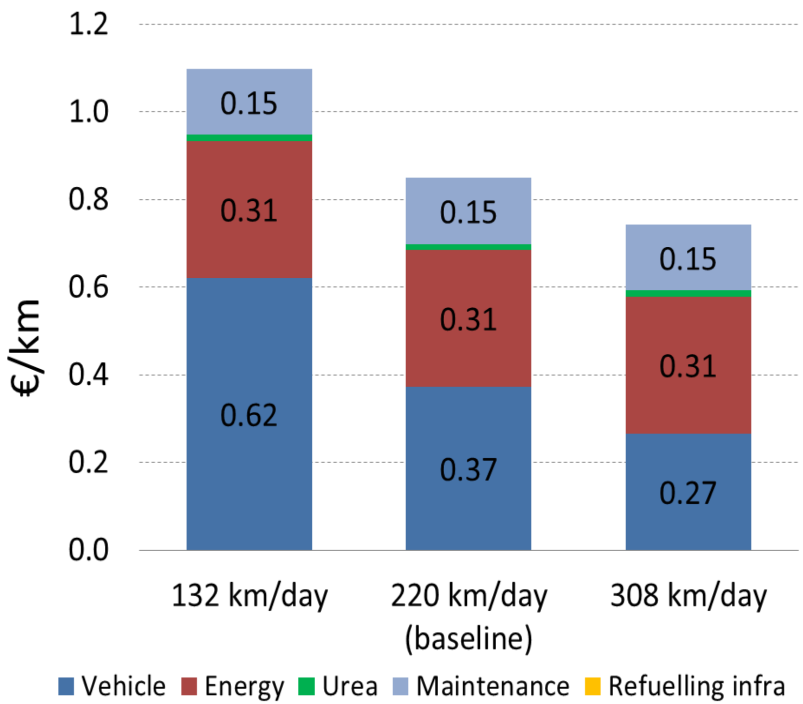
- City buses are the ideal case for e-mobility:
  - Fixed route length
  - Fixed schedule
- High utilisation rate
  - Low energy cost
  - Possibility for profitability
- No local emissions
- Quiet
- High passenger comfort
- Multimodality potential (rail, tram)
- What about the total cost of ownership?

Total ownership costs of electric buses – Espoo case

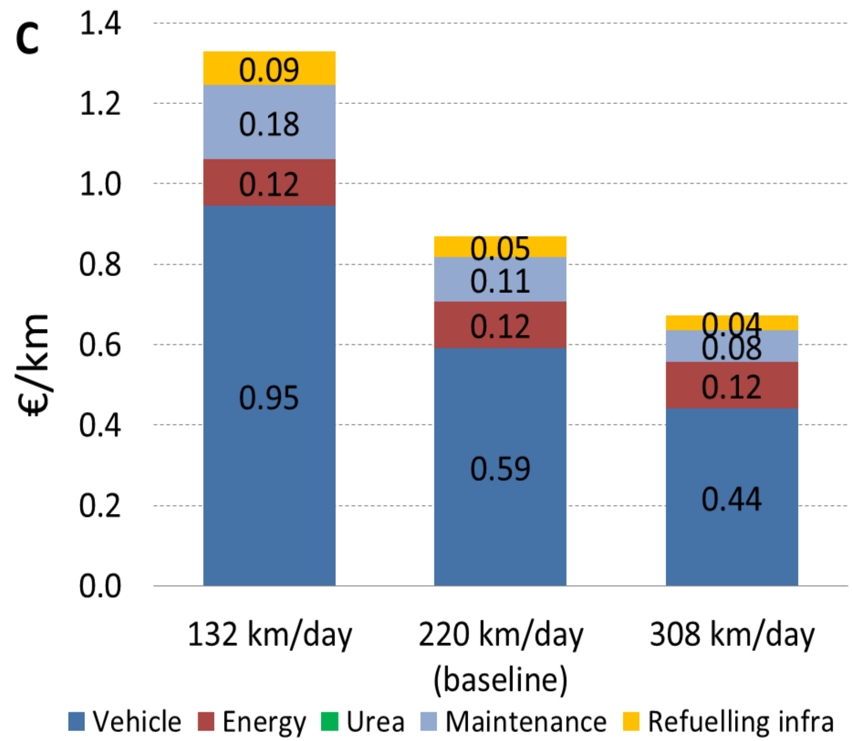


Ref: M. Pihlatie et al, Fully electric city buses – the viable option, IEEE IEVC 2014, Florence 17-19 December, DOI: 10.1109/IEVC.2014.7056145

Effect of daily mileage - sensitivity



Euro 6 diesel

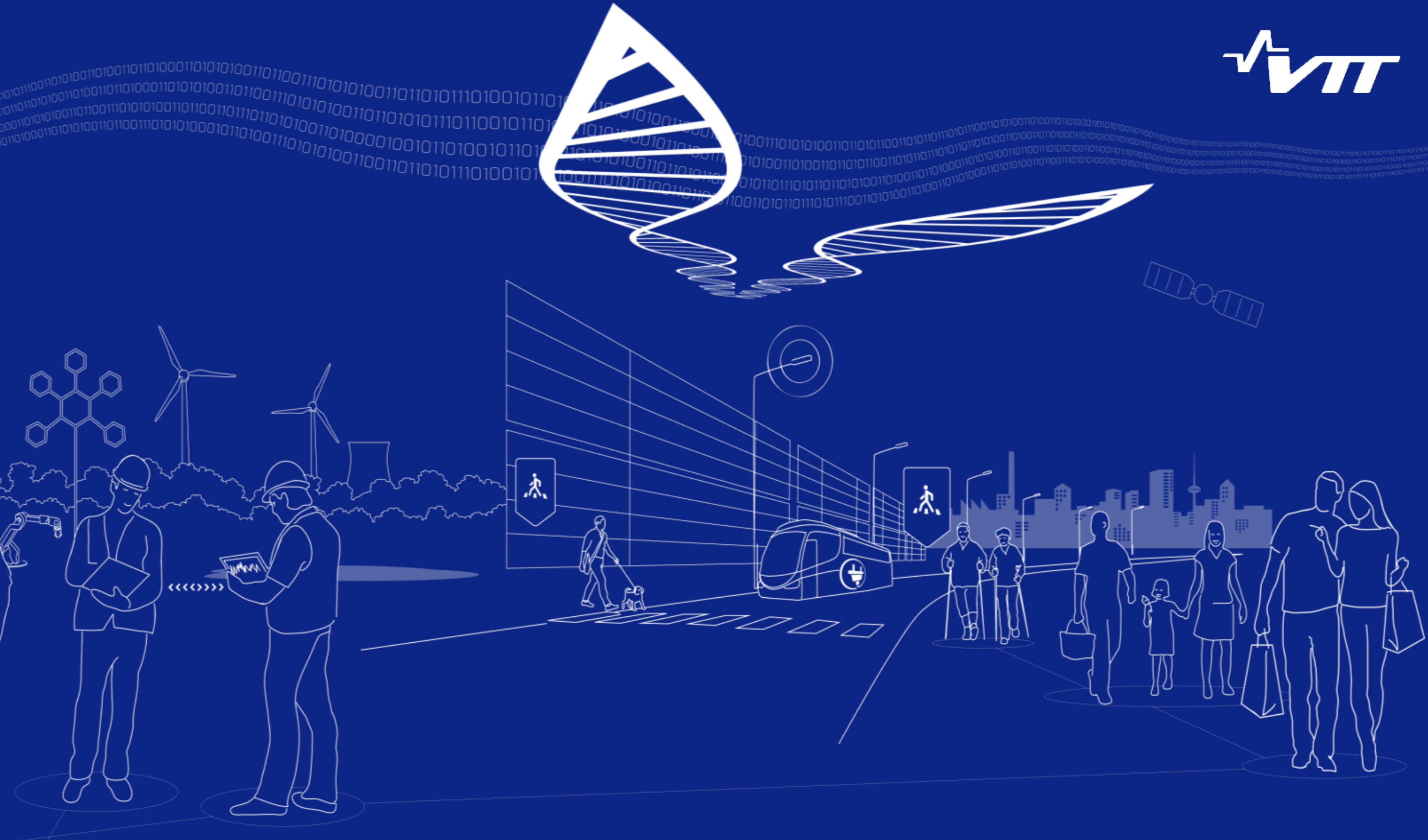


eBus Type 2 LTO

Message to take: it is economical to maximise the mileage of the electrical vehicle fleet

What about other modes of urban transport?

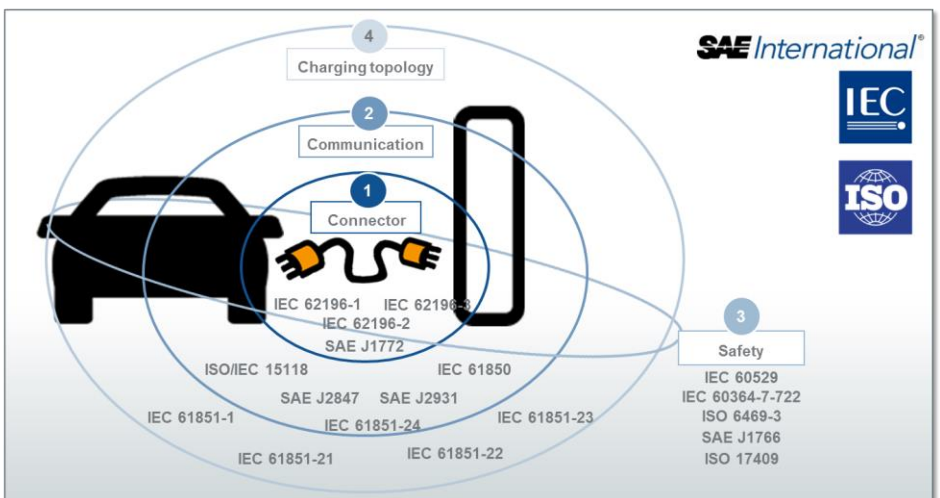
- Techno-economic viability for electrification of <u>commercial fleets</u> is highest (high utilisation rate of capital-intensive components)
  - Buses are the backbone of many public transport systems
  - Urban deliveries, logistics and freight
  - Utility vehicles and machinery (refuse, maintenance, ..)
  - Taxis and other passenger vehicles
- Huge impact of urban transport on local air quality
- Fuel efficiency is important for operational costs
- Potential synergies and value to be addressed
  - Shared charging infra

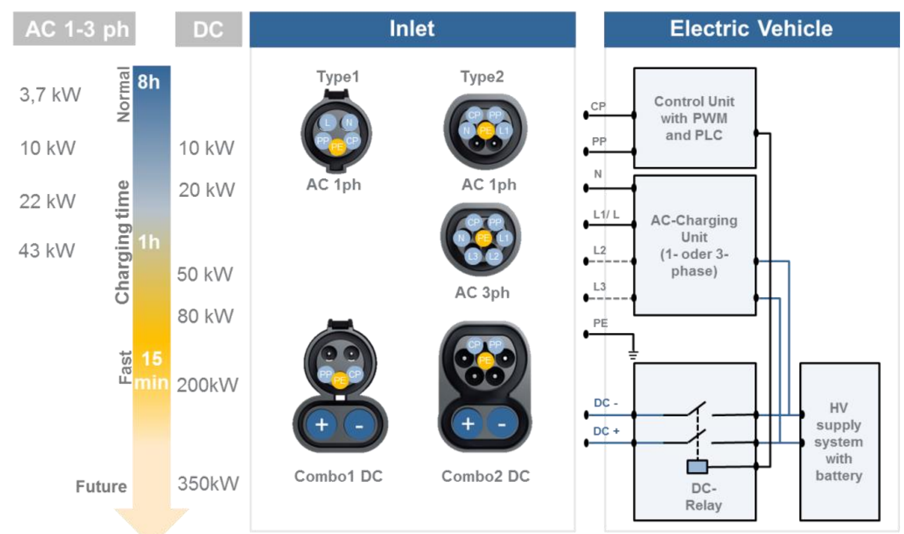


Charging systems

Charger is the interface

- Charger has a crucial role as it defines the interface between electric network and e-mobility application
  - Defines quality impacts and behaviour towards grid
  - Defines information exchange and functionalities
  - Impacts the lifetime of the battery
  - Provides the communication interface
  - Manages the most important safety concerns





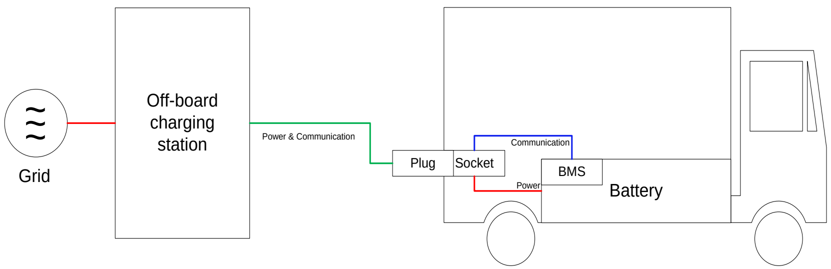
Charging concepts

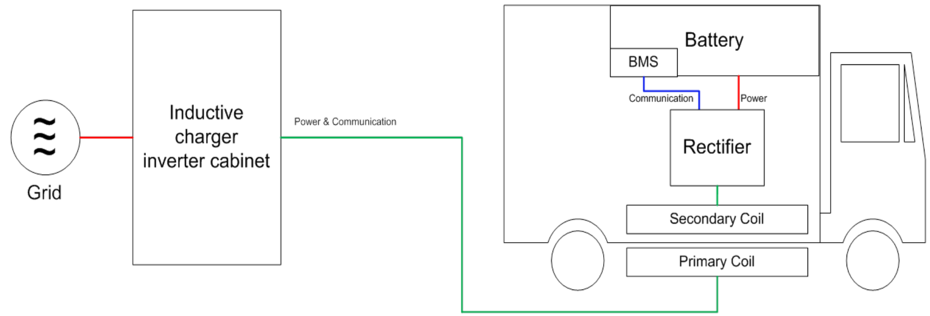
Charging concept	Infrastructure costs	Vehicle costs	Operation costs	Concept feasibility
1. Overnight charging in the depot	Low, Chargers only in the depot	High, Large battery capacity	High, low battery lifetime, high energy consumption	Possible in demonstrational phase
2. Overnight charging + fast charging during the day	Moderate, Chargers both in the depot and terminals	Moderate, slightly smaller battery capasity	Moderate, slightly longer battery lifetime, additional costs if extra buses and drivers needed	Possible in demonstrational phase, parking space in bus terminals limits in wider scale use
3. Opportunity charging (automatic high-power charging)	High, expensive charging systems in terminals	Moderate, small battery, expensive technology depending on system	Low, no changes into normal bus operations	Feasible only as a large system where there are enough vehicles to take advantage of the investment

Potential charging methods

Charging with cable & socket

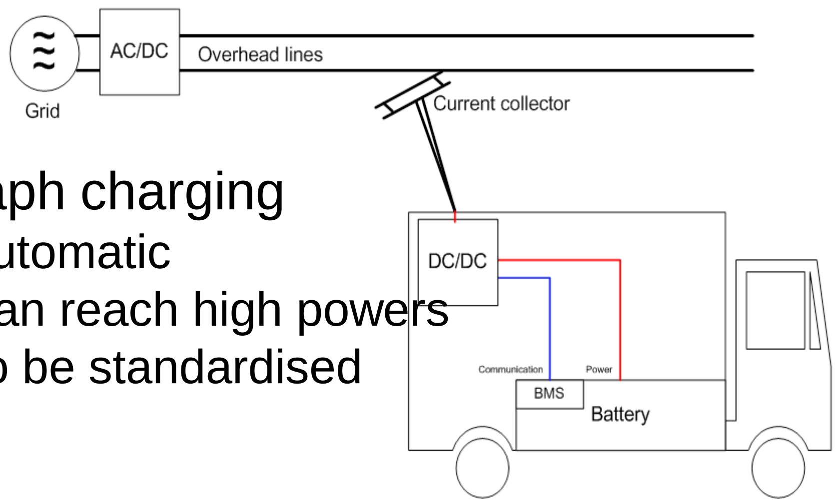
- Manual operation
- Partly standardised, low power





Inductive charging

- Contactless
- Automatic
- Can reach high powers
- Not standardised



Pantograph charging

- Automatic
- Can reach high powers
- To be standardised

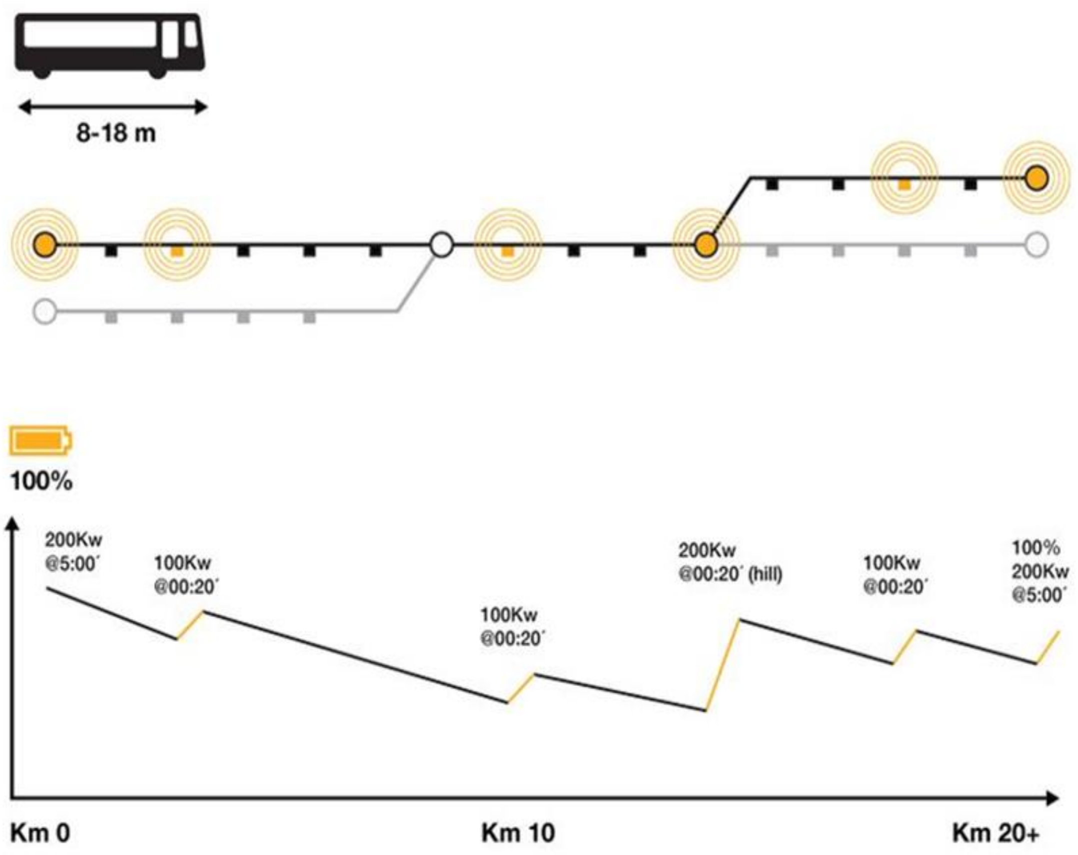
Siemens

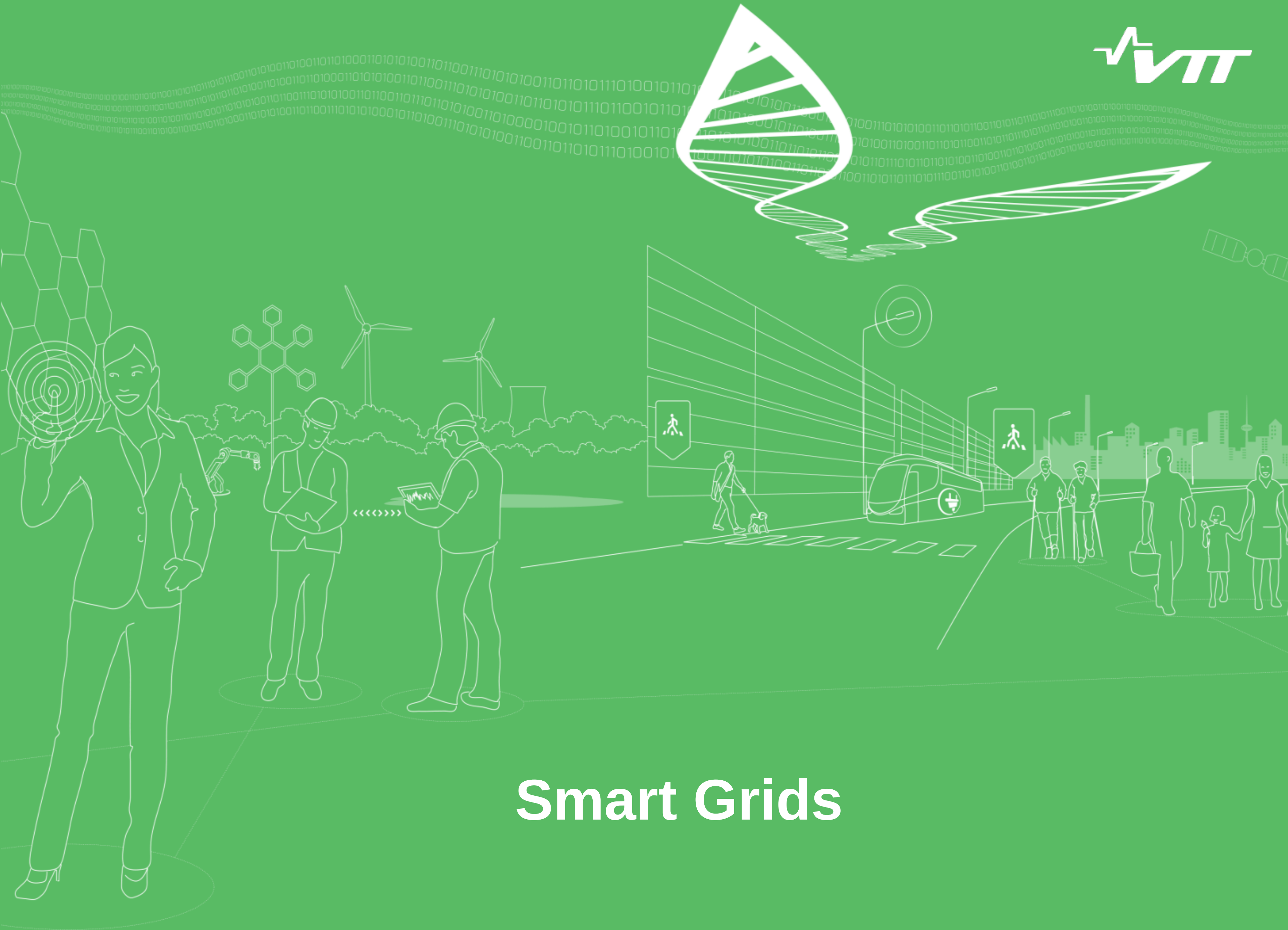
ABB

Conductix

Opportunity charging

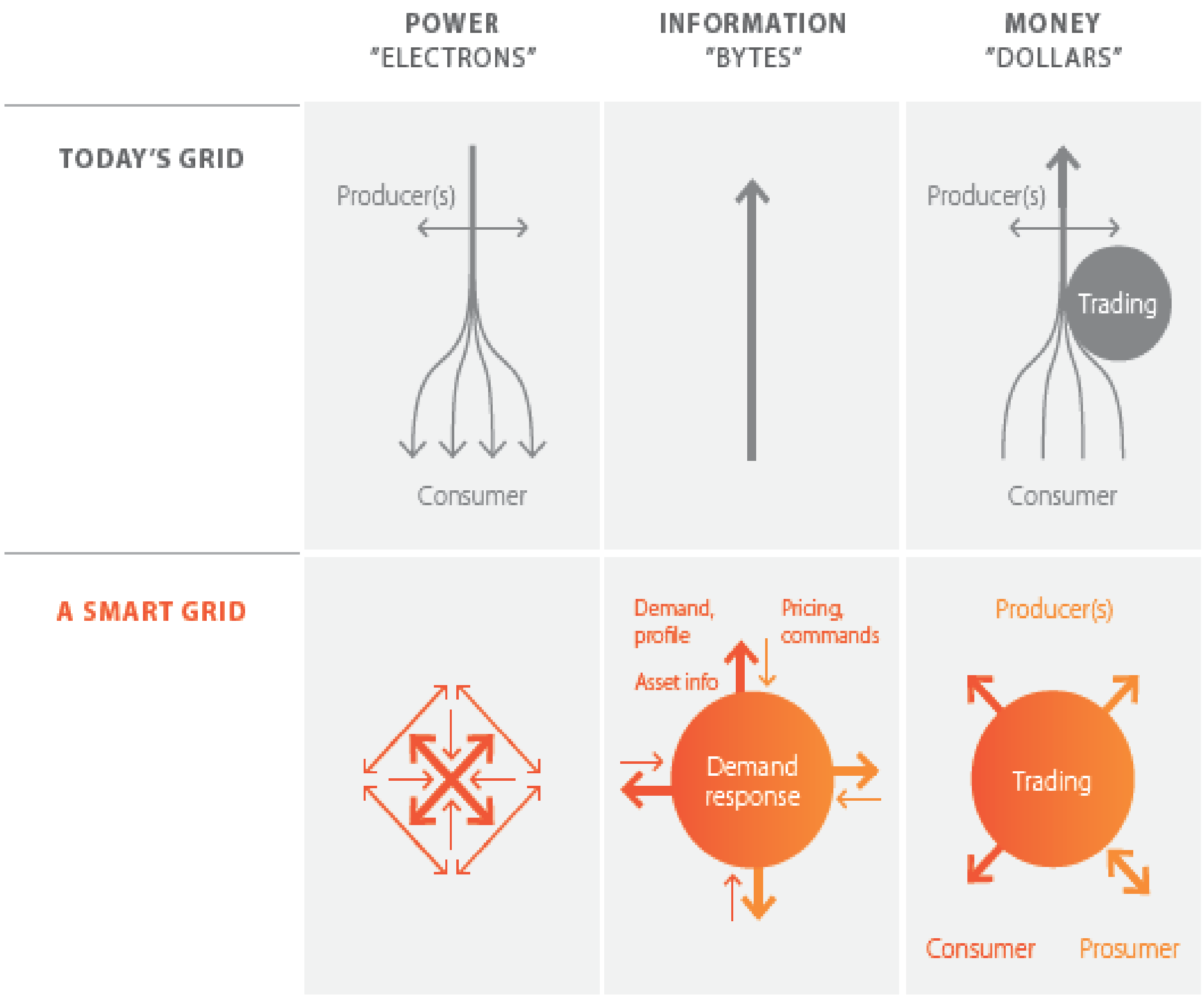
- Charging in bus terminals and at some points along the bus line
- Battery is always used in the middle area of state of charge →
    - Extended battery lifetime
    - Extra capacity always available in case that one charging would fail
- Multiple random-operated quick-charging points across grid: needs good integration and planning





Smart Grids

Smart Grid

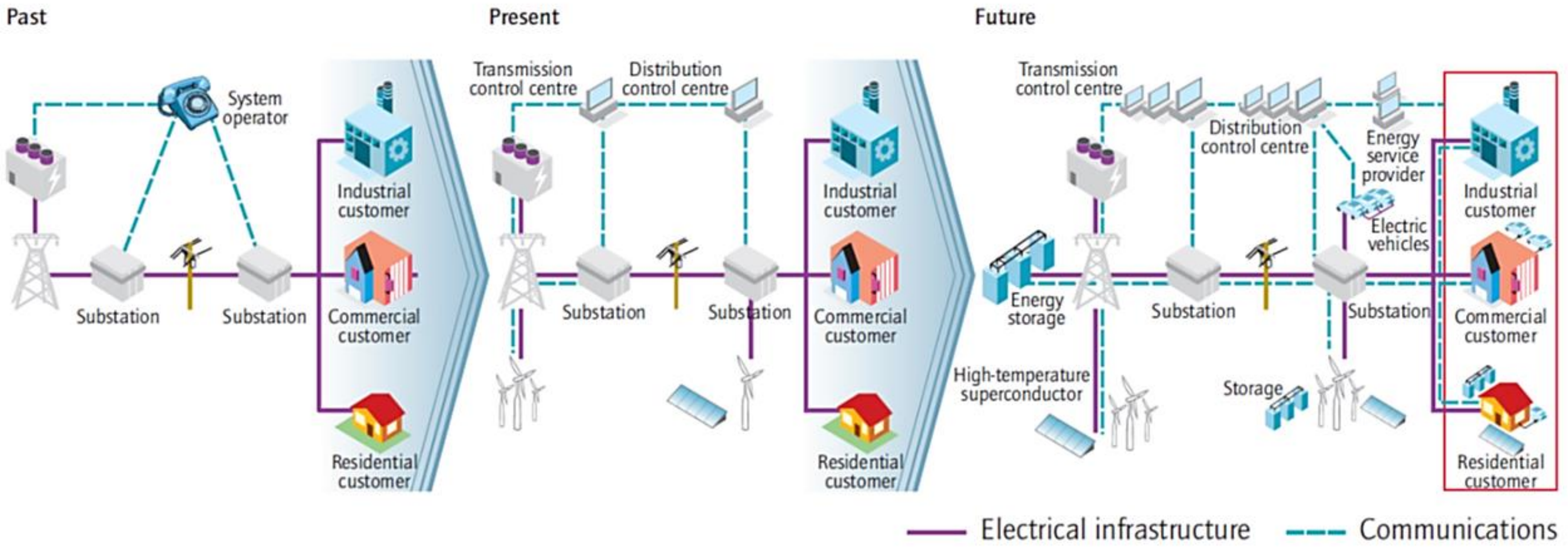


National SGEM research program by CLEEN, Finland.

Key drivers for Smart Grids

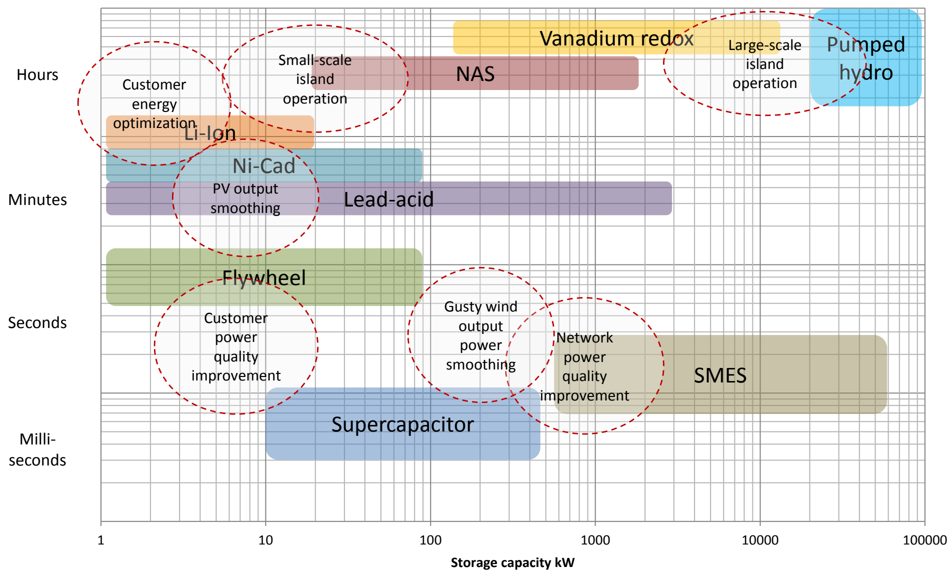
- **Accommodating** renewable energy resources
- **Flexibly** integrating and controlling variety of active components
- **Enabling** platform for new businesses
- **Introduction** of electric mobility
- **Providing** better reliability and quality of service
- **Better** involving individual users

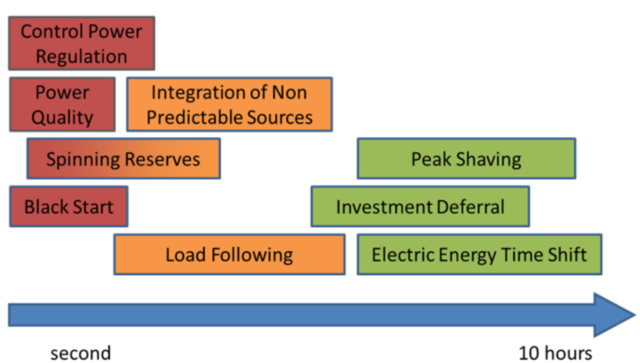
Key component: Integrated communication

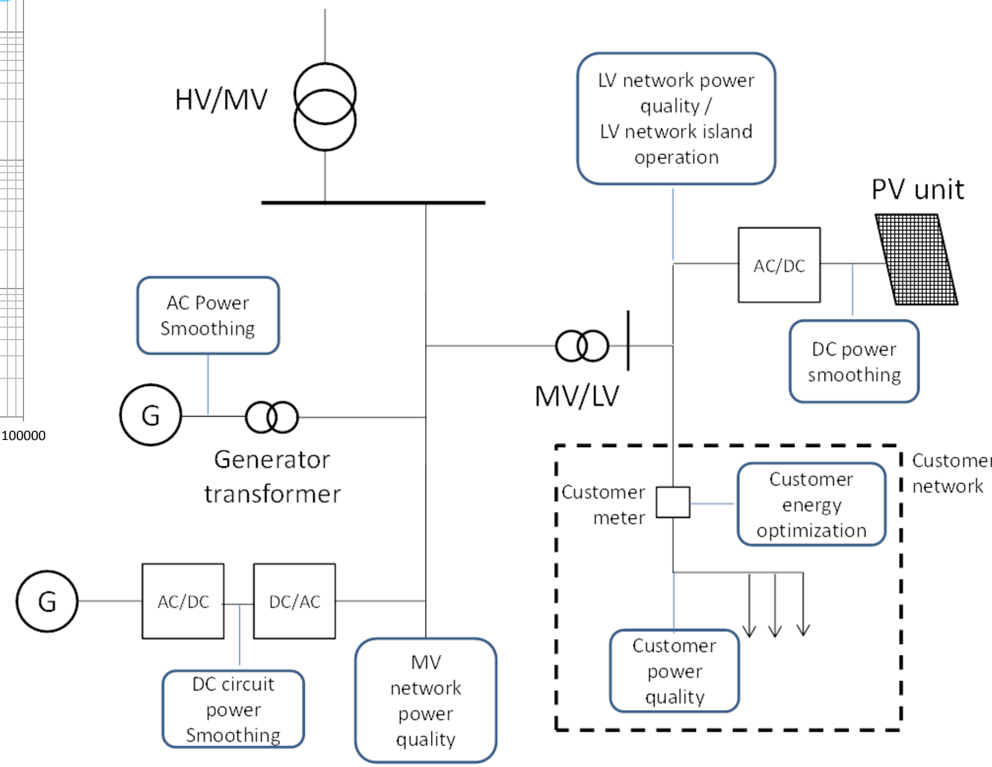


IEA Technology Roadmap: Smart Grids.

High expectations for energy storages

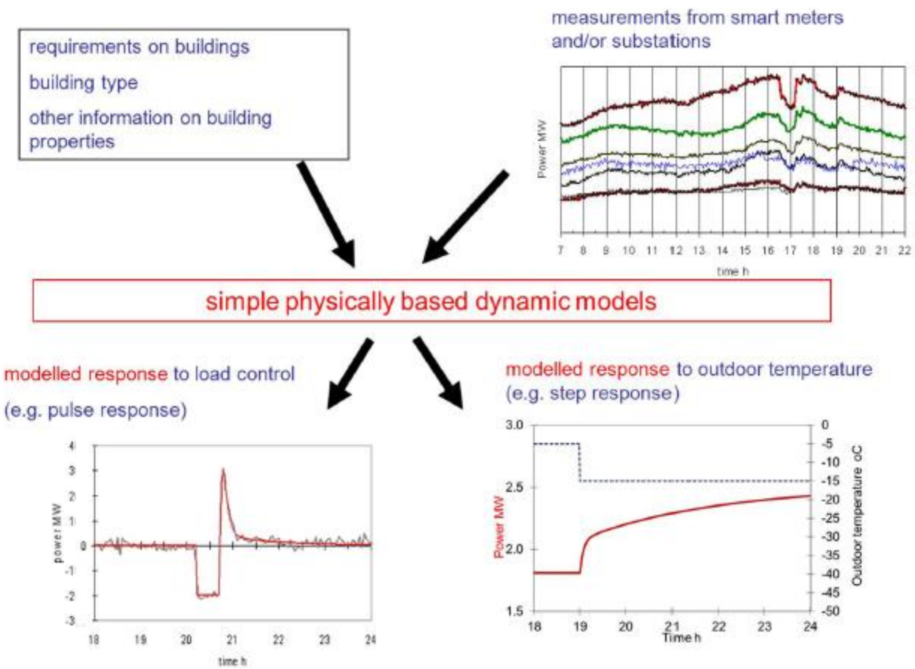


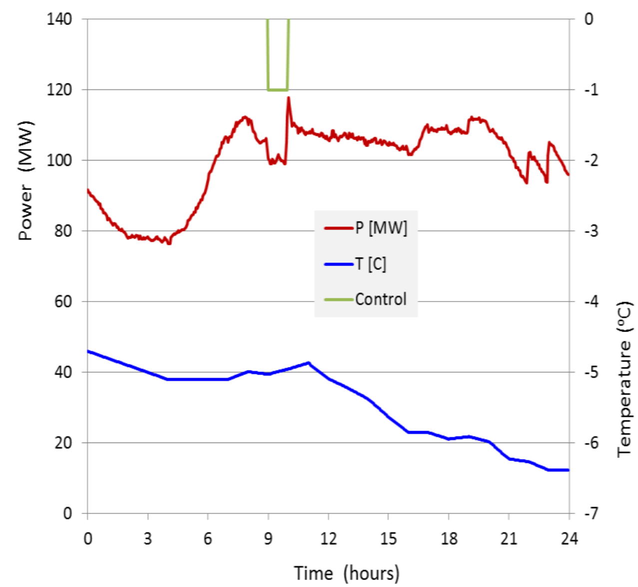




Demand response – involving the customer side in control chains

- Controllability of loads offers new tool for grid management and market operation purposes
- Essential to understand the customer behavior and processes





Electric mobility integration in smart grids

- **Storage** on wheels...

... or rather a perfect means of **Demand response?**

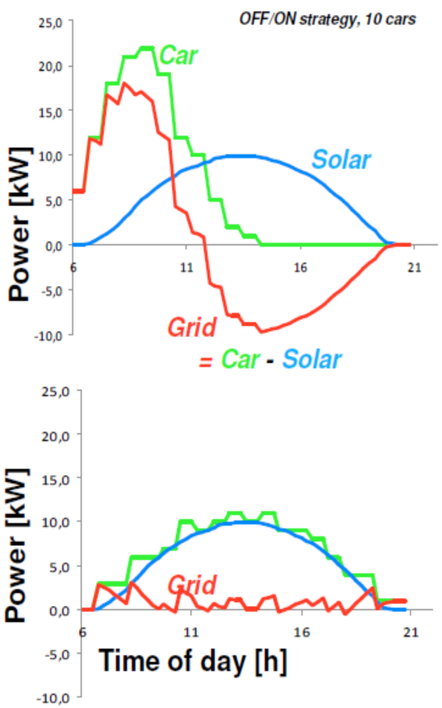
- with **communication** and control implemented!

- Controllable EV charging can be utilized intelligently towards energy markets, local grid as well as individual customer
  - Straightforward use for load control
  - Communication and control interfaces available
  - Efficient localization of control actions
  - Integration with PV output power
  - Customer level optimization methods

  ... BUT always in line with the actual need:

  Mobility (customer needs / availability)

  ... AND respecting **Battery lifetime**



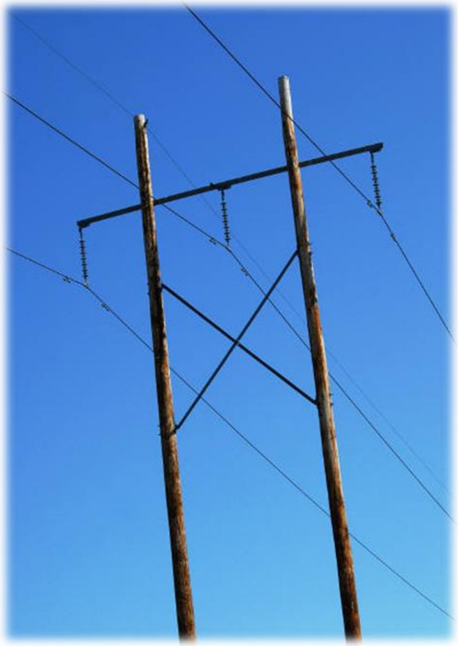
Picture by: CEA INES

Electric mobility integration in smart grids

- Distribution network planning perspectives
  - Traditional “grid as a service channel” approach:
    - Interface ordered and dimensioned according to peak power
    - Very robust way of managing

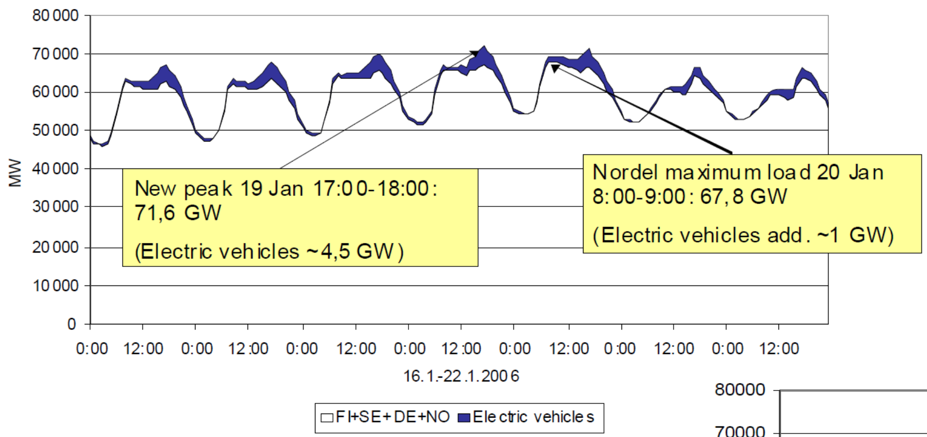
...or...

  - More flexible co-operation approaches:
    - Controllable charging power according to network status
    - Avoidance of peak powers
    - Economic synergies
  - Network regulation plays an important role in managing charger interfaces

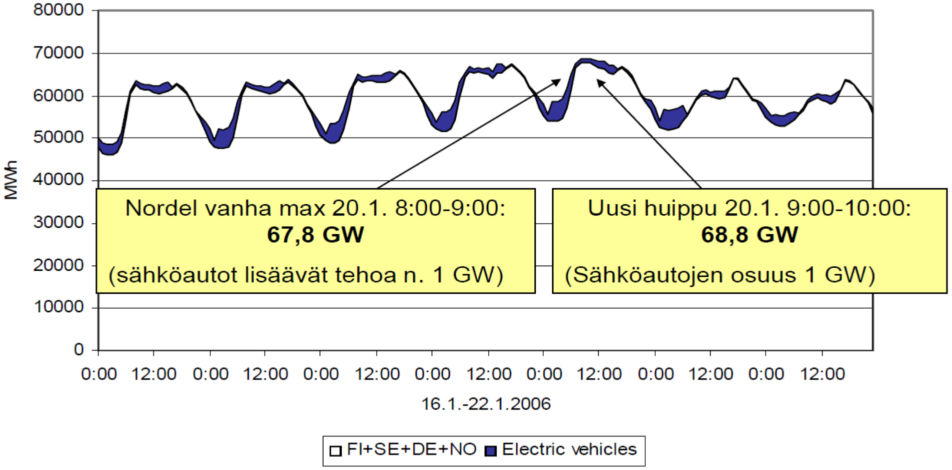


Electric mobility integration in smart grids

- On the system level, the actual impact of EVs is not crucial
  - Local problems can be faced especially in weak LV grids

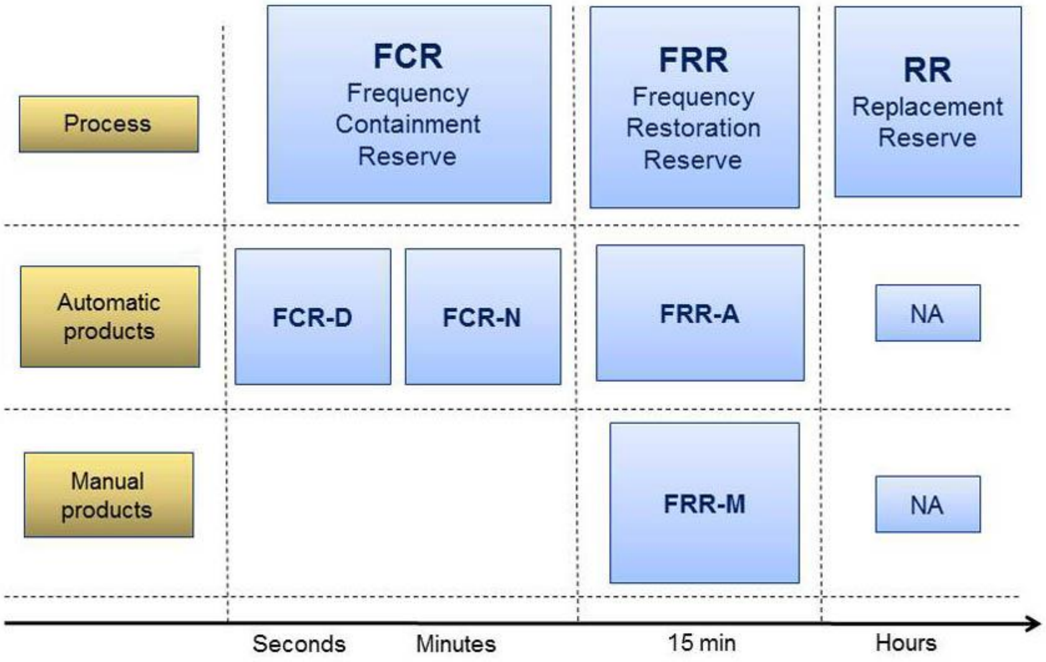


5 million EVs in Nordic countries; worst and best scenarios

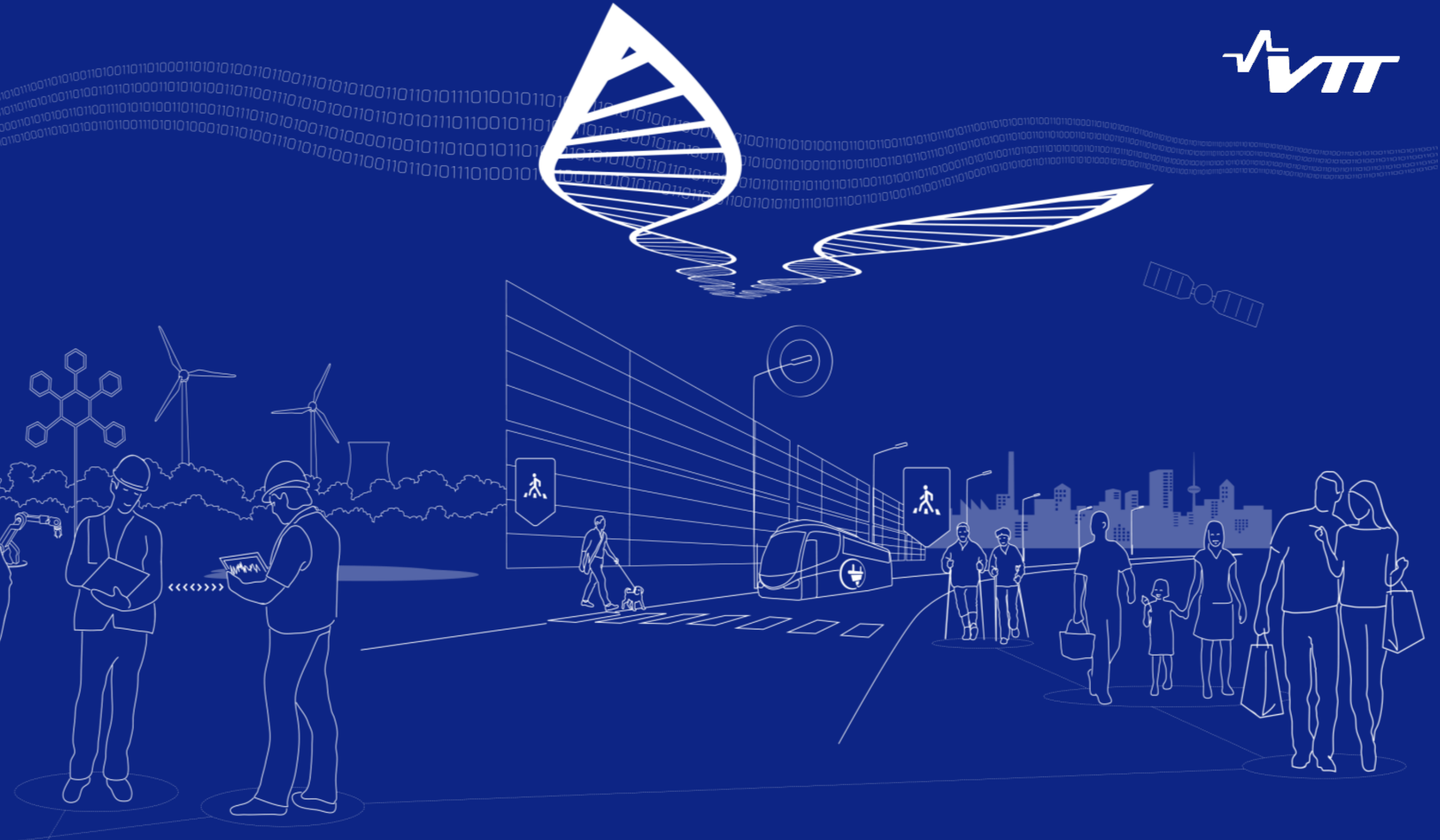


Flexibility has a value..

- Controllable flexibility will have an increasing value
- Aggregating individual EVs can form significant entities
- Control can be based on local logics or communication
  - Communicating and managing masses of small EVs still challenging



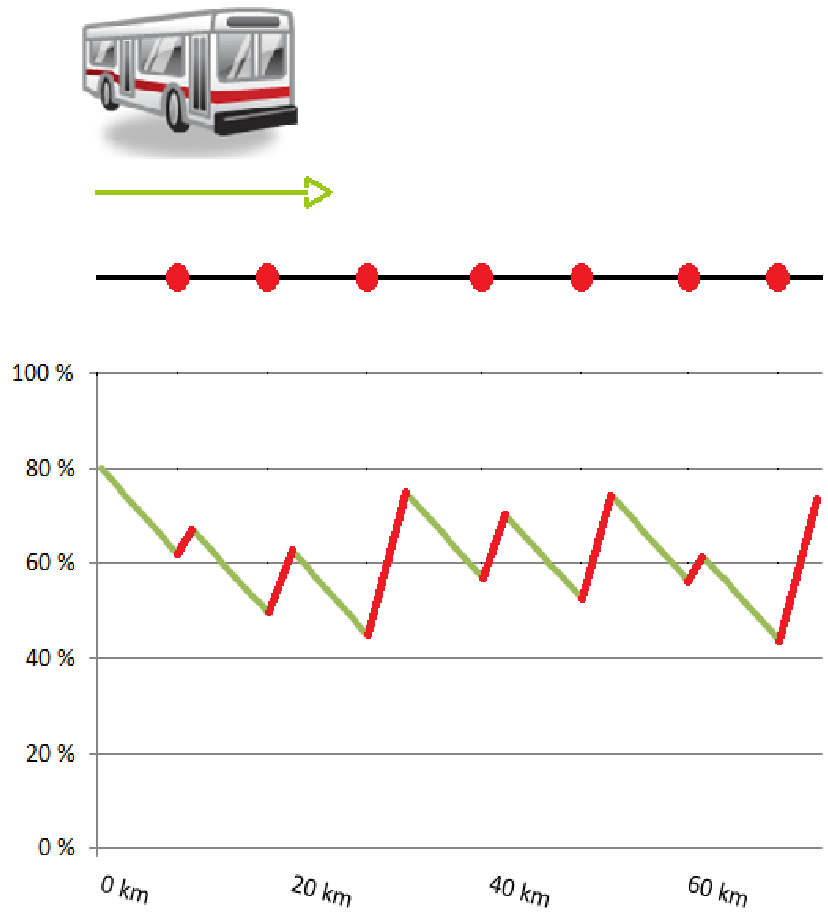
Fingrid reserve types



Integrated approaches

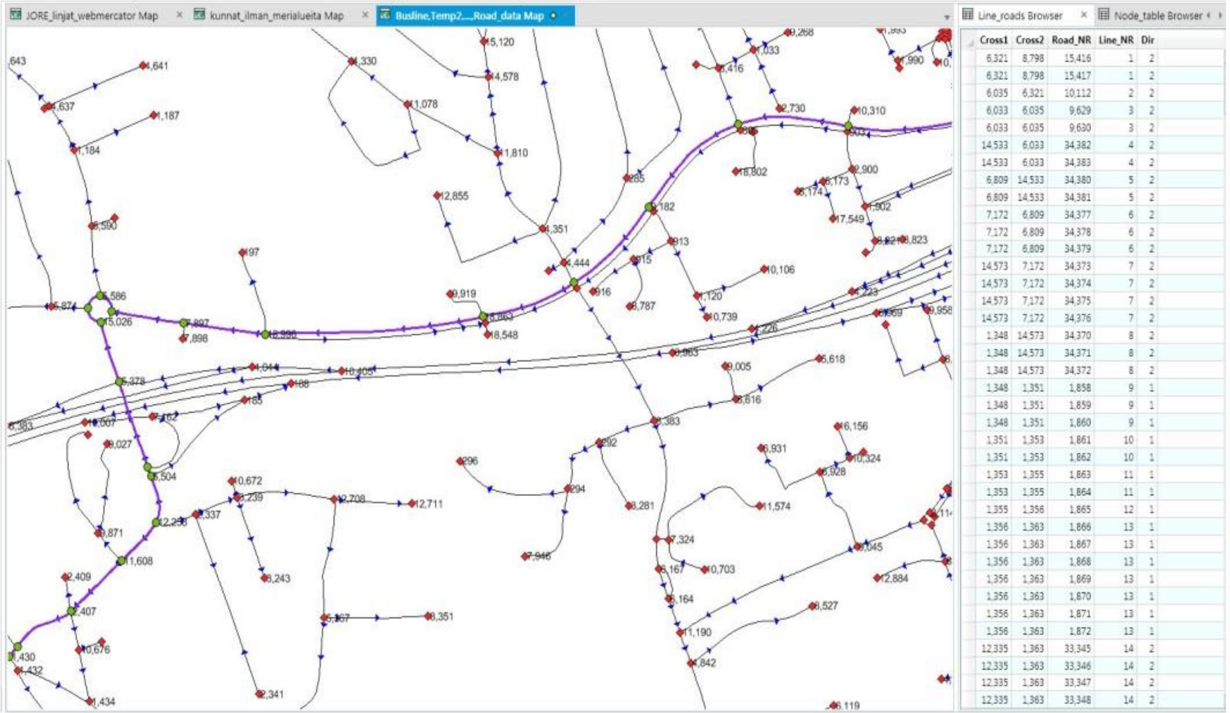
Opportunity charging planning

- Integrated approach on opportunity charging
  - Bus lines and operational data
  - Electric bus data
  - Distribution network data
- Tools have been developed to enable joint studies



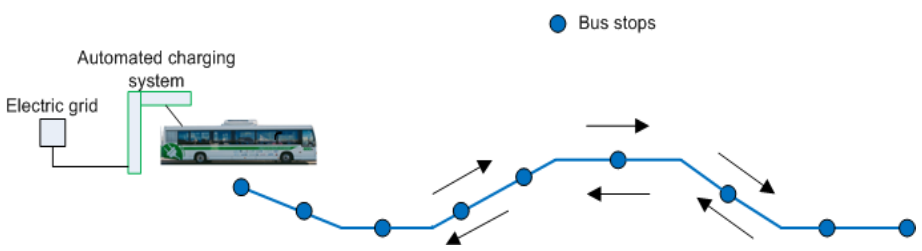
Opportunity charging planning

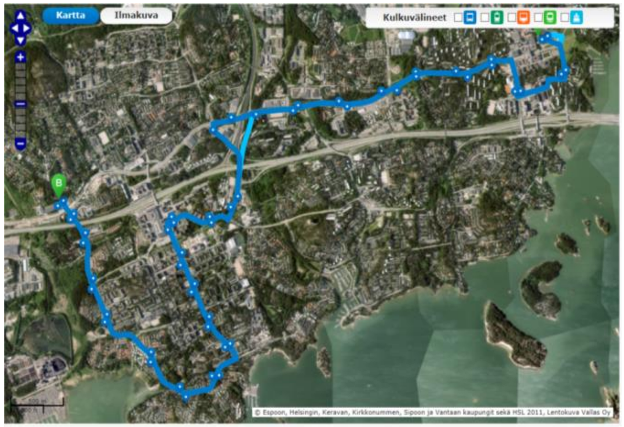
- An application based on GIS system has been developed
- Utilizes existing data for traffic, bus lines, electric bus, distribution network etc.
- For integrated planning of electric bus infrastructure



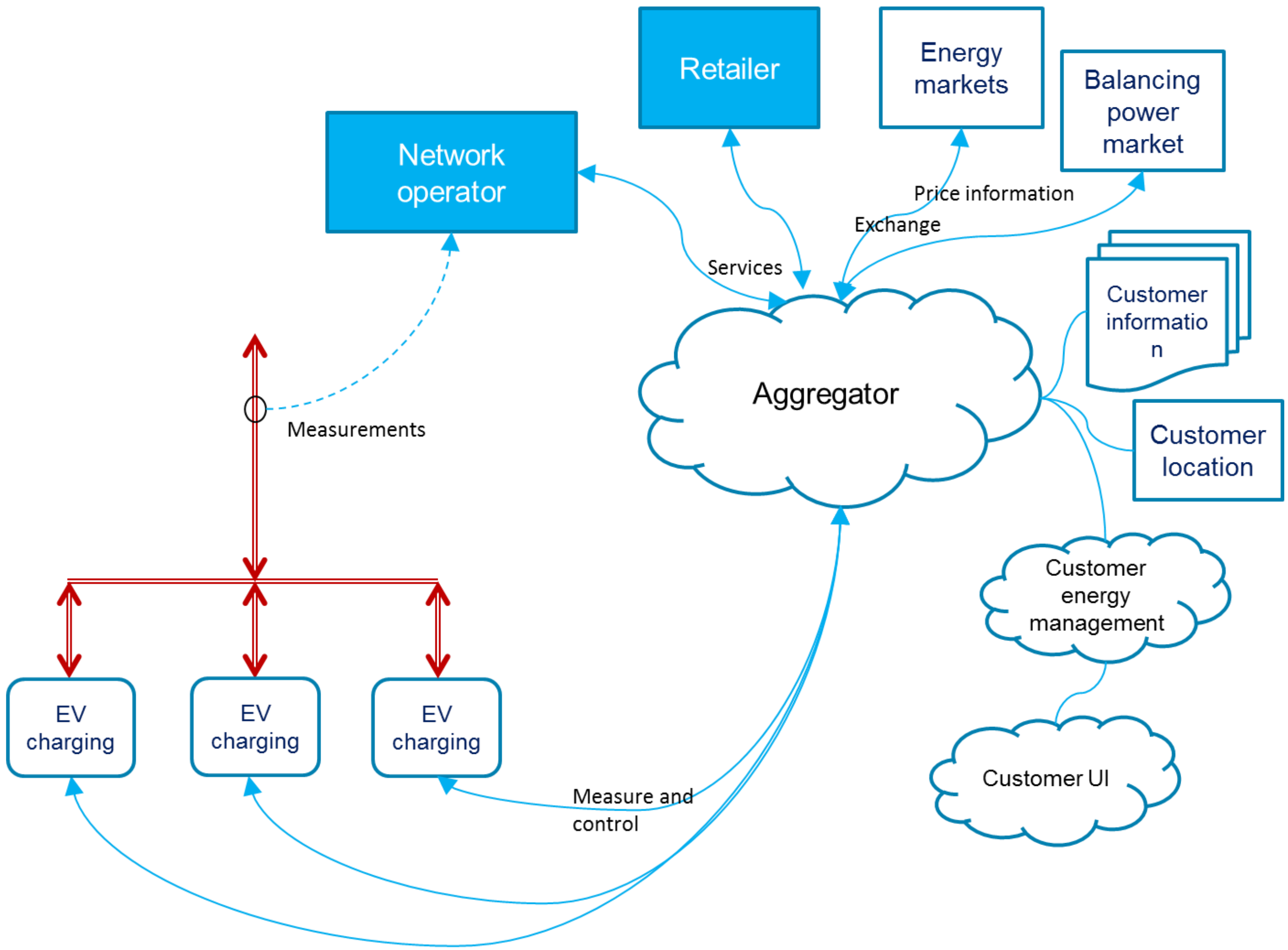
Opportunity charging planning in real circumstances

- Objective: Dimension a battery for opportunity charged eBus operating in HSL bus line 11 (in Espoo) and discuss about the cost and lifetime
- Assumptions
  - Charger in Tapiola, Espoo is 250 kW, 8 minutes of charging after each roundtrip
  - One roundtrip is 20 km in distance
  - The eBus consumes 1 kWh/km during summer and 1,5 kWh/km during winter



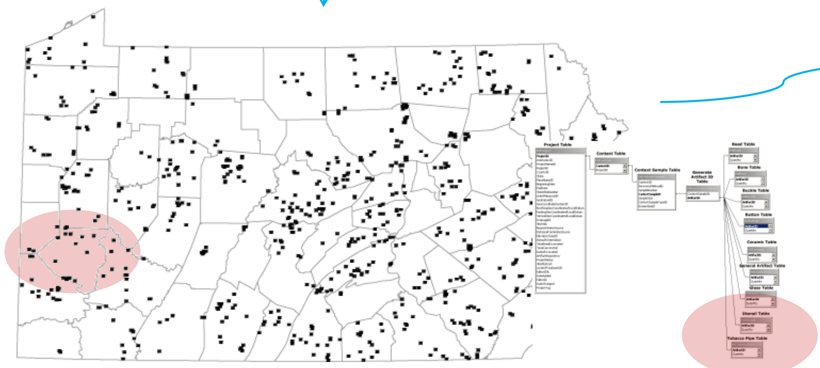


Aggregator business logics



Aggregator business logics

1. Message from network operator:
”Reduce load or increase generation
Area: x
Power: 5 MW
Time: following 4 hrs”



2. Aggregator identifies the customers on the area and their control possibilities

3. Aggregator calculates the possibilities of fulfilling the network operator request

4. Response to the network operator (confirmed or denied)

Aggregator maintaining the customer lcoation and customer information database

5. Control signals to the required customers

6. Monitoring of the customer state – reallocation of control if needed. Control service on area is maintained same during reallocation.

7. Releasing customer controls after the network service time is fulfilled or service relased by the network operator.

Aggregator business logics: the bus depot case

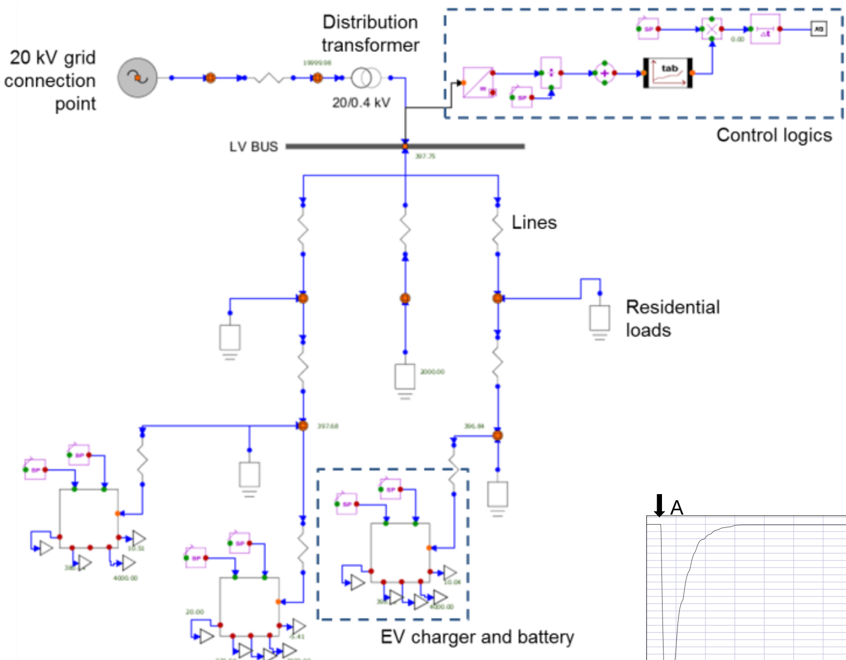
- Assume an operator of bus depot charging for a fleet of electric buses in a big city
  - Buses are mainly charged through the night
  - Charging can be controlled as long as battery lifetimes are not affected and buses are available in the morning as agreed
  - The operator also supplies the charging energy for fleet operator

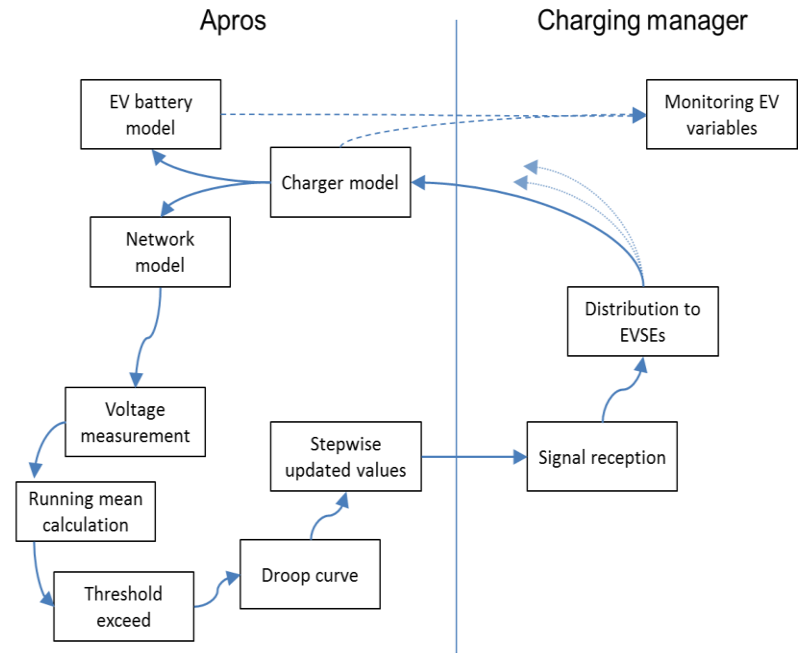
Aggregator business logics: the bus depot case

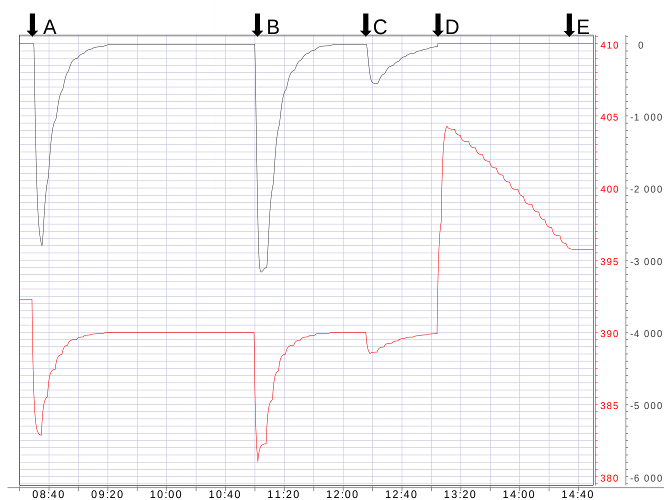
- Now the depot operator can offer different services:
  - Ancillary services like voltage control, quality improvement, dip mitigation for local distribution network operator
  - Balancing services for energy retailers, aggregators and balance responsible parties
  - Services for system operator, for instance system balancing market bidding or fast reserves
  - Smoothing services for producers of intermittent renewable energy
  - Conduct it's own operation on energy market for retailing the charging energy

… as long as constrictions of battery lifetime, vehicle availability, etc. are respected!

Voltage control case simulated

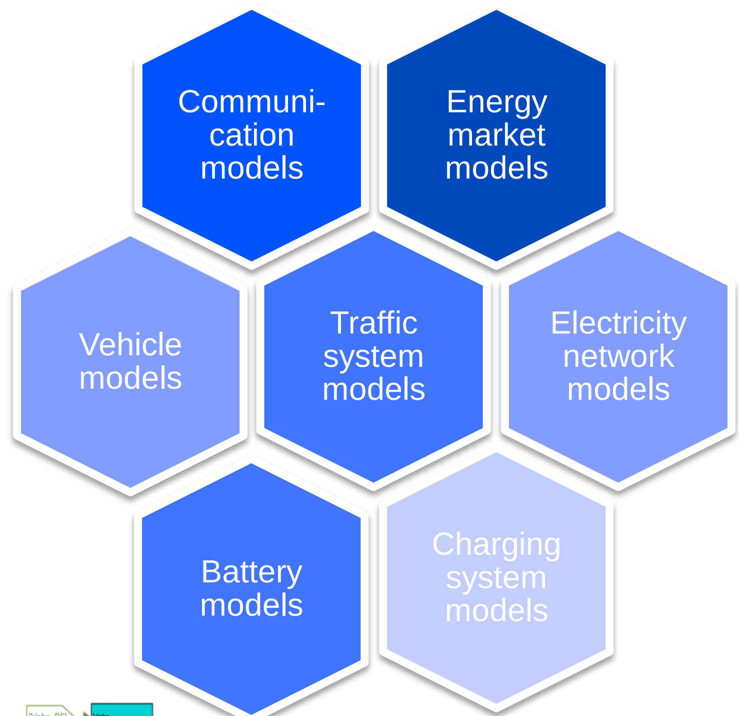


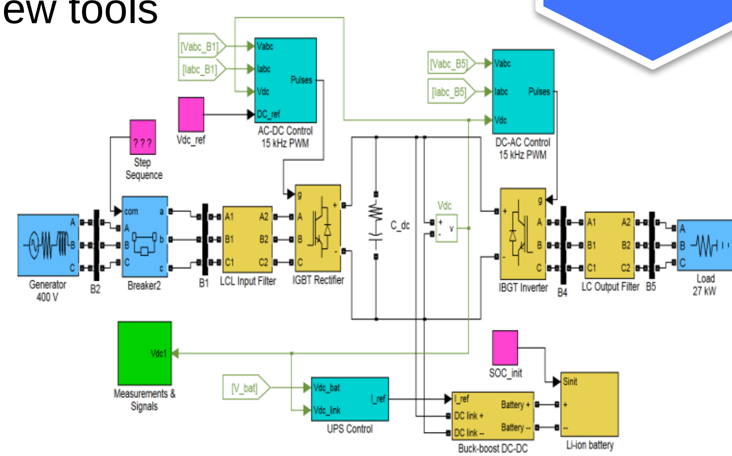


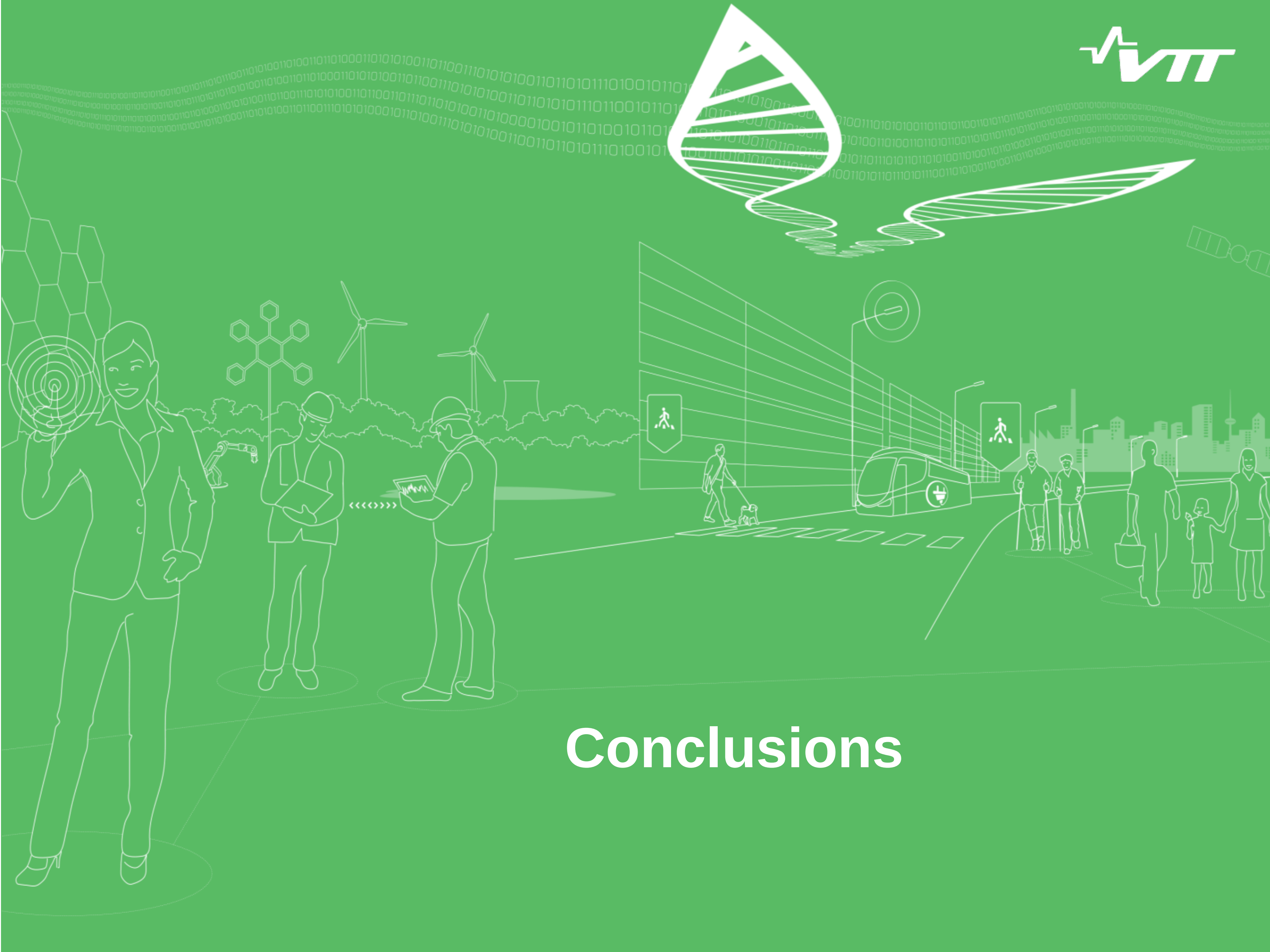


Development of joint simulation environments

- Main challenges
  - Different objectives, different timescales, different levels of details
  - Interfaces and syncing of data
  - Correct level of modelling for different cases
  - Infrastructure boundaries – who is the eventual user?
- Main attributes
  - Scalable, flexible, easy to use
  - Provides platform for new tools







Conclusions

Conclusions

- Electric transport systems are fast emerging
  - Electric city buses highly interesting
- Putting transport and power systems in the same study gives an interesting integrated approach
- EV charging sets especially local challenges, on system-wide level impacts seem more minor
- EV charging represents a good means of demand response
- A charging operator could offer different services
  - Potential for new business models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