Smart Grid, Renewables, Electric Mobility: Challenges and Potential of an Integrative Approach

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Overview

- Karlsruhe Institute of Technology – KIT
- European Energy Policy Targets
- Electric Mobility
- Projects on E-Energy and ICT for Electric Mobility
- Implications
- Summary

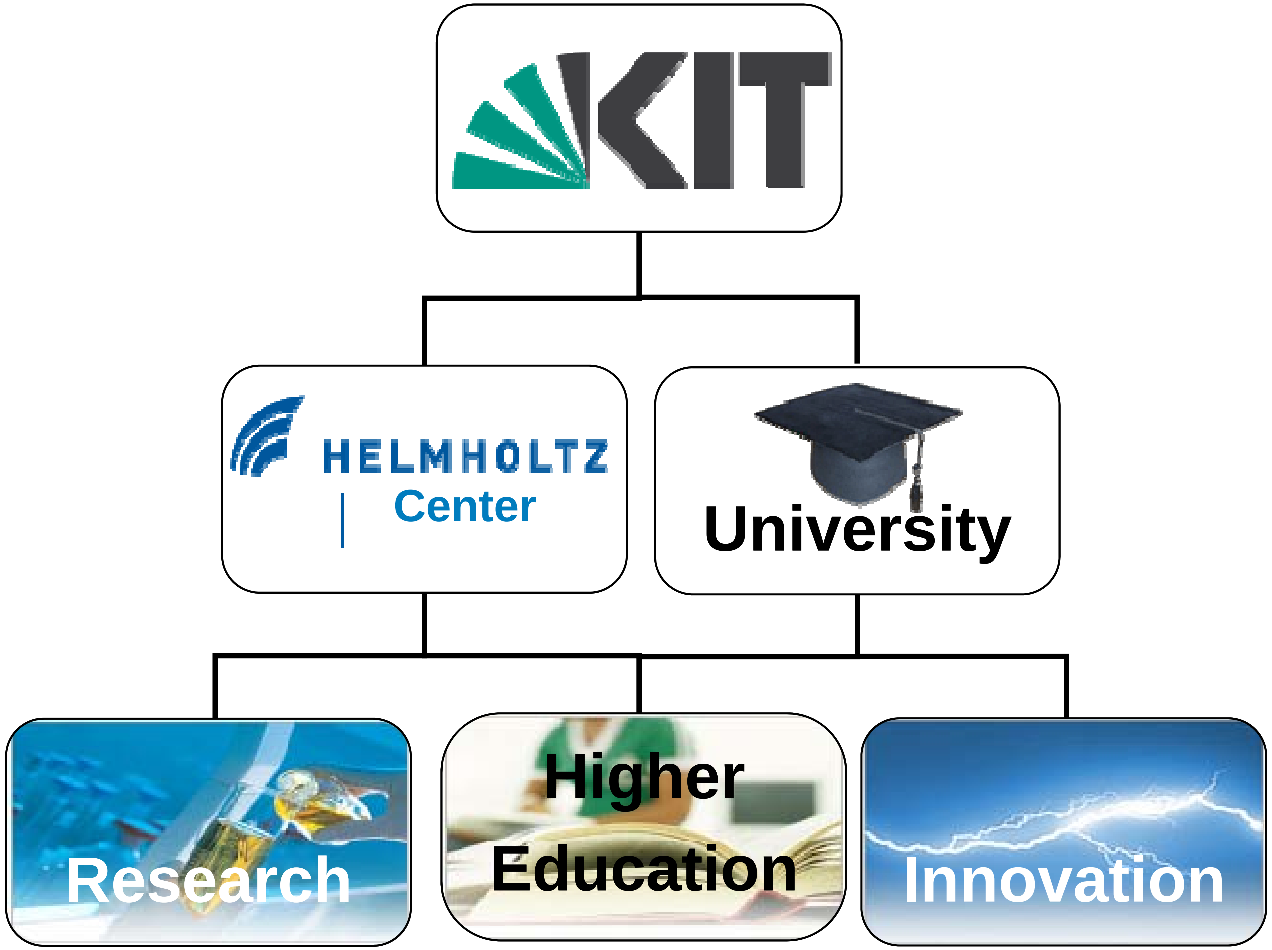
Karlsruhe Institute of Technology
Merging a University And a Research Center

One Entity, Two Missions, Three Tasks

One Entity

Two Missions

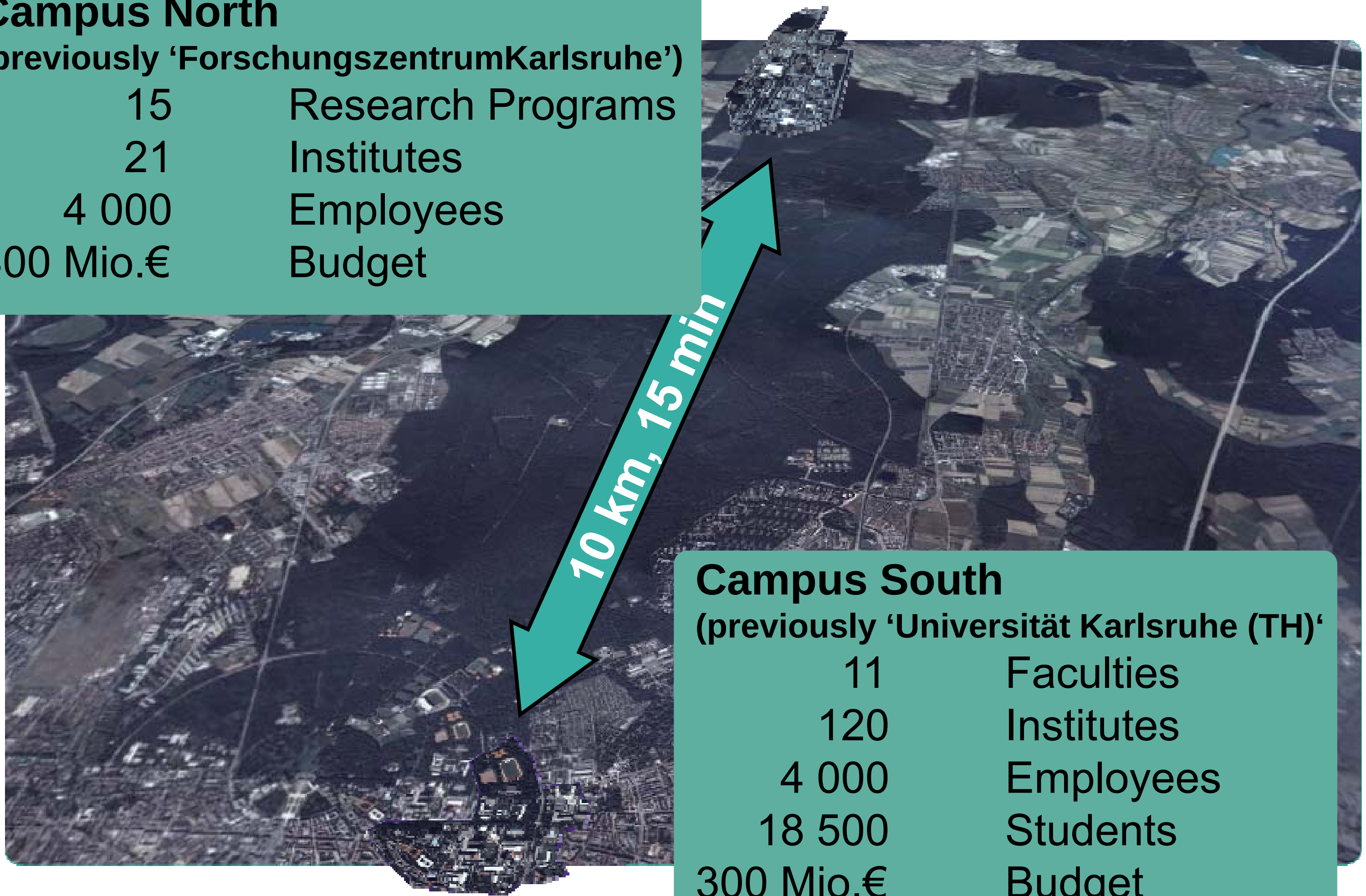
Three Tasks



Two major locations

Campus North
(previously 'ForschungszentrumKarlsruhe')

15	Research Programs
21	Institutes
4 000	Employees
400 Mio.€	Budget



Campus South
(previously 'Universität Karlsruhe (TH)'

11	Faculties
120	Institutes
4 000	Employees
18 500	Students
300 Mio.€	Budget

Restructuring Research: Competence Portfolio

30 Fields of Competence Bundled into 6 Areas of Competence

Matter and Materials

- Elementary Particle and Astroparticle Physics
- Condensed Matter
- Nanoscience
- Microtechnology
- Optics and Photonics
- Applied and New Materials

Earth and Environment

- Atmosphere and Climate
- Geosphere and Risk Management
- Hydrosphere and Environmental Engineering
- Constructed Facilities and Urban Infrastructure

Applied Life Sciences

- Biotechnology
- Toxicology and Food Science
- Health and Medical Engineering
- Cellular and Structural Biology

Systems and Processes

- Fluid and Particle Dynamics
- Chemical and Thermal Process Engineering
- Fuels and Combustion
- Systems and Embedded Systems
- Power Plant Technology
- Product Life Cycle
- Mobile Systems and Mobility Engineering

Information, Communication, and Organization

- Algorithm, Software, and System Engineering
- Cognition and Information Engineering
- Communication Technology
- High-Performance and Grid Computing
- Mathematical Models
- Organization and Service Engineering

Technology, Culture, and Society

- Cultural Heritage and Dynamics of Change
- Business Organization and Innovation
- Interaction of Science and Technology with Society

KIT – Centers, Focuses and Schools

KIT-Centers	KIT-Focuses	KIT-Schools
Energy	COMMputation	KSOP
NanoMicro	Humans and Technology	School of Energy
Elementary Particle and Astroparticle Physics	Mobility Systems	⋮
Climate and Environment	Optics and Photonics	School of xyz

Research at KIT – A twofold approach

- "top-down"

KIT-Centers and KIT-Focuses

- Strategic approach
- Project-based structures
- Increase of international visibility
- Answer to requests of major societal interest

- "bottom-up"

Fields and Areas of Competence

- People-based structures
- Availability of a broad range of competences
- Communication platform for the exchange of know-how
- Starting point for new projects

European Energy Targets:

Strategic Energy Targets 20-20-20:

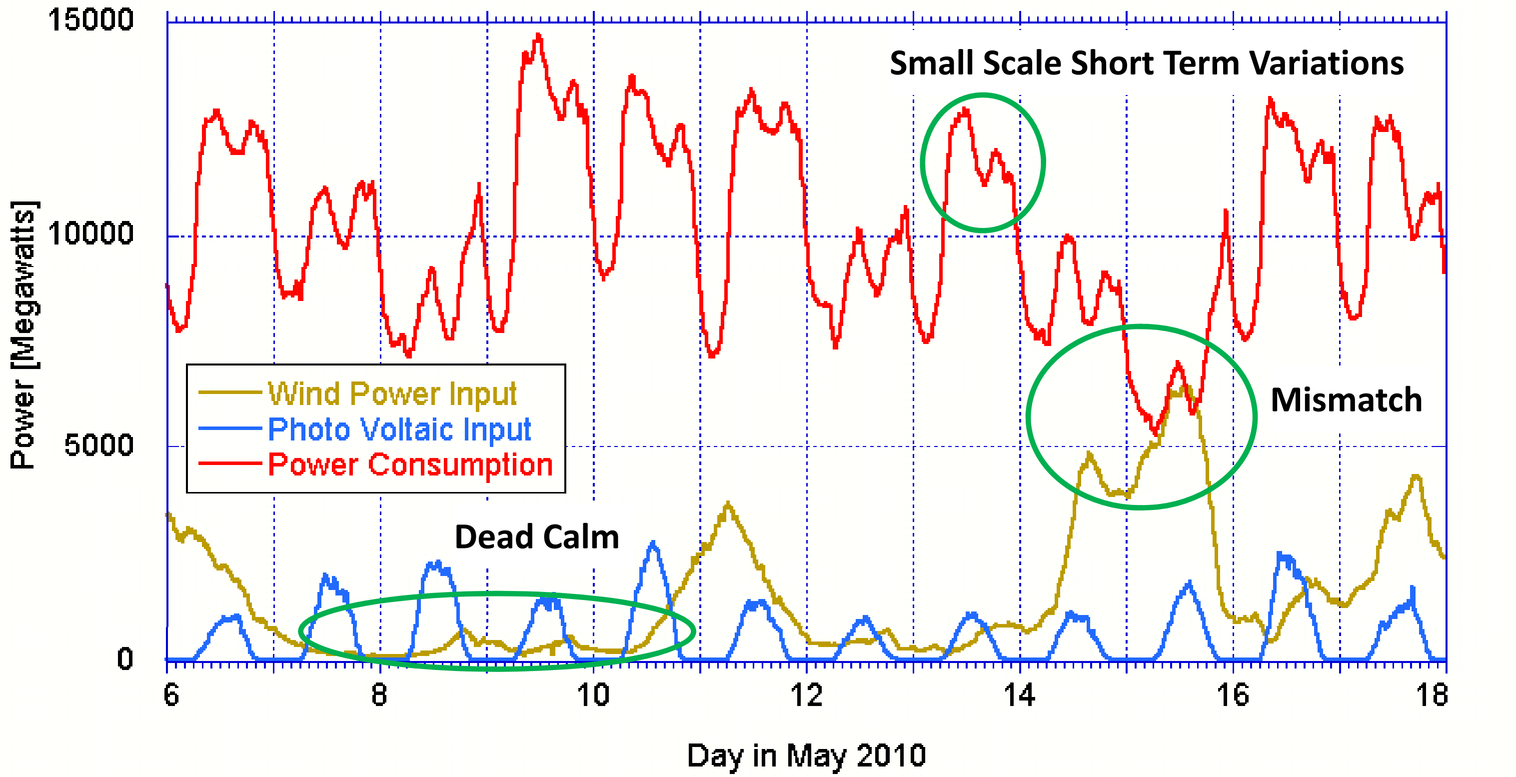
March 2007:
EU's leaders endorse an integrated approach to climate and energy policy:

- Combat climate change and increase the EU's energy security while strengthening its competitiveness.
- Transform Europe into a highly energy-efficient, low carbon economy.
- Kick-start this process by a series of demanding climate and energy targets to be met by 2020:
  - Reduce EU greenhouse gas emissions at least 20% below 1990 levels.
  - Increase share of renewables to 20% of EU energy consumption
  - Improve energy efficiency to reduce primary energy consumption
  - by 20%.

More ambitious targets of Germany:

30% renewables by 2020, 50% by 2030, 80% (??) by 2050

Problems:
Fluctuations – in demand and supply



- Variations at different time scales, only partially predictable
- How to deal with fluctuations? → demand and supply management
- How to compensate for a „dead calm"??

Management of the power grid

Power grid needs a steady balance between demand and supply.

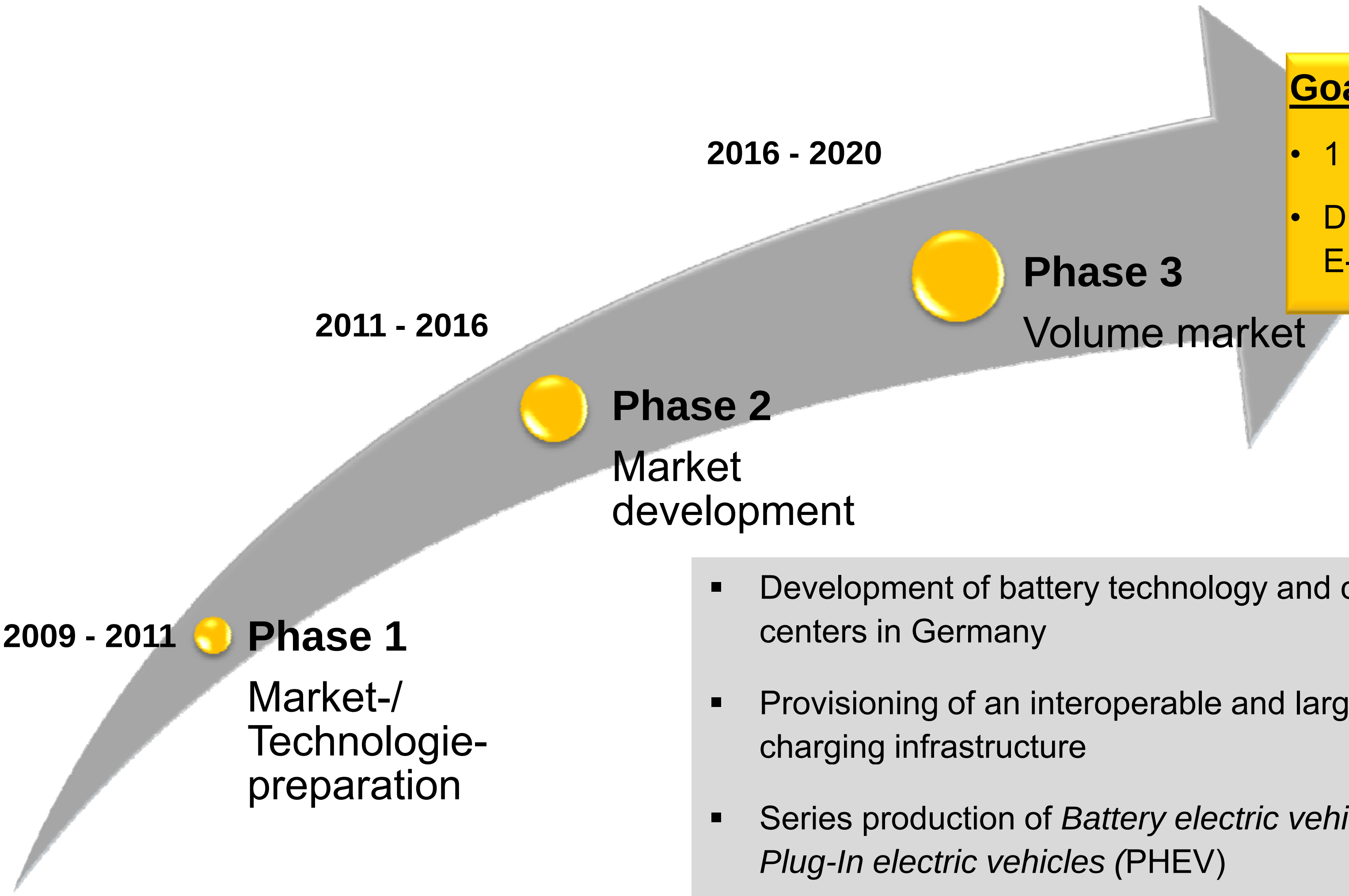
- Traditional assumptions of energy management and control:
  - Demand cannot be controlled
  - Electricity cannot be stored
- Standard control using spinning reserve, balancing power (primary, secondary, minute, hour,..)
- Future energy management
  - Discover and exploit degrees of freedom for demand (and supply) management.
  - Develop new ways of storing (electric) energy.

⟹ Strong need for intelligent demand and supply management to increase the reliability of power supply in spite of fluctuating uncontrollable generation of power from renewable sources.

Electric Mobility

- First electric vehicle in 1892
- Advantage: no time consuming manual start of engine
- Invention of electric starter => since 1920 almost only internal combustion engines (ICEs)
- Since around 1990 increasing revival of electric vehicles.
- Major push: Economic crisis and climate change lead to strong demand for GHG-reduction and increasing use of renewable energy.
- In 2009 economic incentive packet II in Germany invests 500 Mio€ into research and development of technologies for electric mobility (infrastructure, ICT for EM, battery research)
- In 2009 National German development plan for electric mobility

German national development plan for electric mobility



Goal for 2020:

- 1 Mio. E-Vs in DE
- DE is lead market for E-Mobility

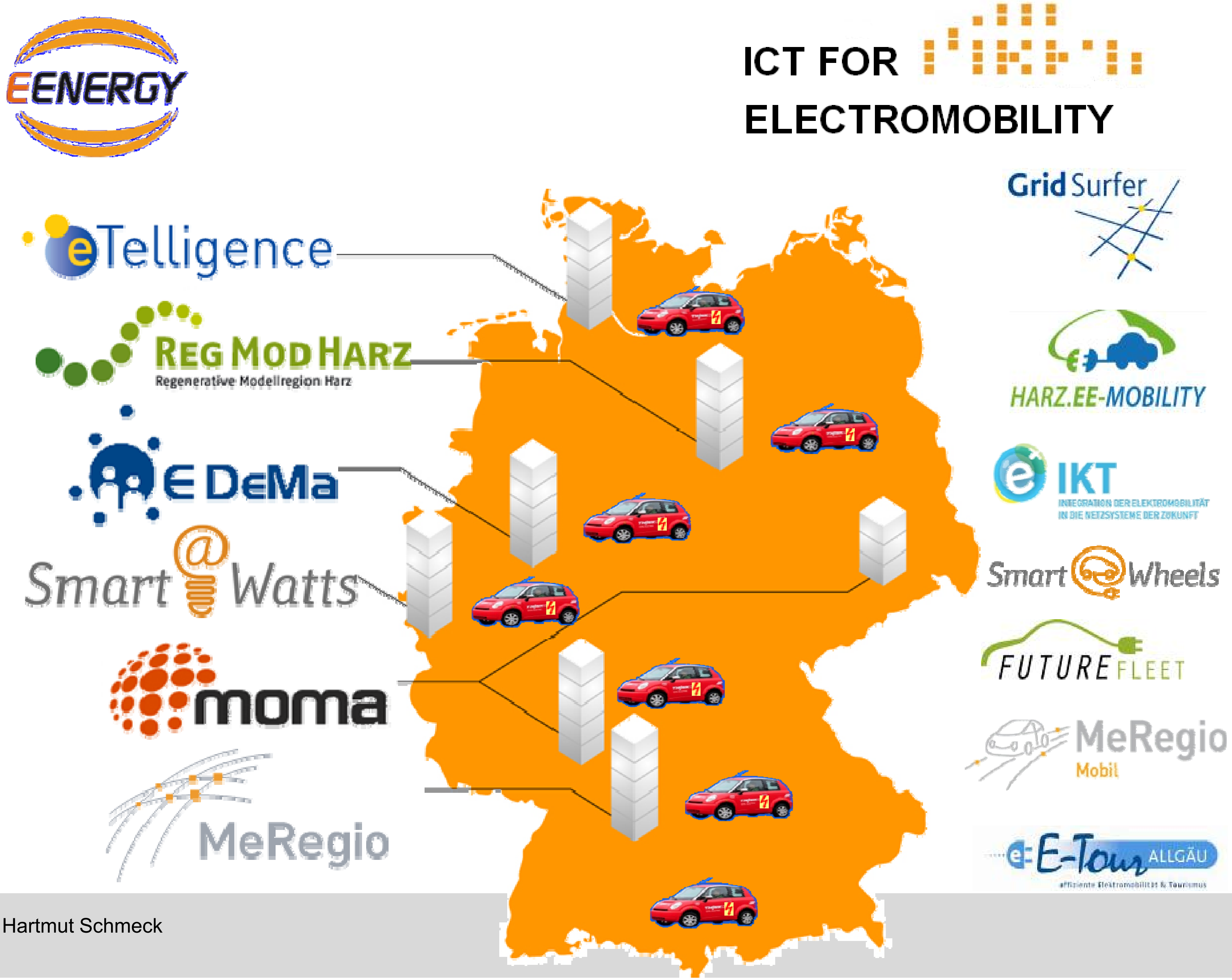
2030:
6 Mio EVs

- Development of battery technology and competence centers in Germany
- Provisioning of an interoperable and large-scale charging infrastructure
- Series production of *Battery electric vehicles* (BEV) and *Plug-In electric vehicles (*PHEV)
- Development of business models

Related German Federal Funding Programs

- **E-Energy** (2008-2012, 60 Mio.€, 6 "model regions")
  Combining **energy technology** with **market mechanisms** and **ICT** in all parts of the energy value chain in order to improve the efficiency of the energy system and reduce GHG emissions
- **Economic incentive package II** (2009 – 2011, 500 Mio €)
  - **ICT for electric mobility**
    (7 projects associated with E-Energy program)
  - 8 **model regions for electric mobility**:
    install infrastructure and bring EVs on the road
  - Research on **electric storage** systems (batteries,…)
- In the following:
  - Project **MeRegio**: ("Moving towards Minimum Emission Regions", e-Energy)
  - Project **MeRegioMobile** (ICT for Electric Mobility)

Germany's way to an Internet of Energy



MeRegio

Moving towards Minimum Emission Regions

Gefördert durch das Bundesministerium für Wirtschaft und Technologie

KIT Karlsruhe Institute of Technology

Research Question / Scenario

Energy Technology

- Smart Metering
- Hybrid Generation
- Demand Side Management
- Distribution Grid Management

Energy Markets

- Decentralized Trading
- Price incentives at the power plug
- Premium Services
- System Optimization

ICT

- Real-time measurement
- Safety & Security
- System Control & Billing
- Non Repudiable Transactions

Pilot Region with ~ 1000 Participants (Freiamt + Göppingen)

5 chairs at KIT:
Energy Economics, Informatics, Telematics, Management, Law

Objectives

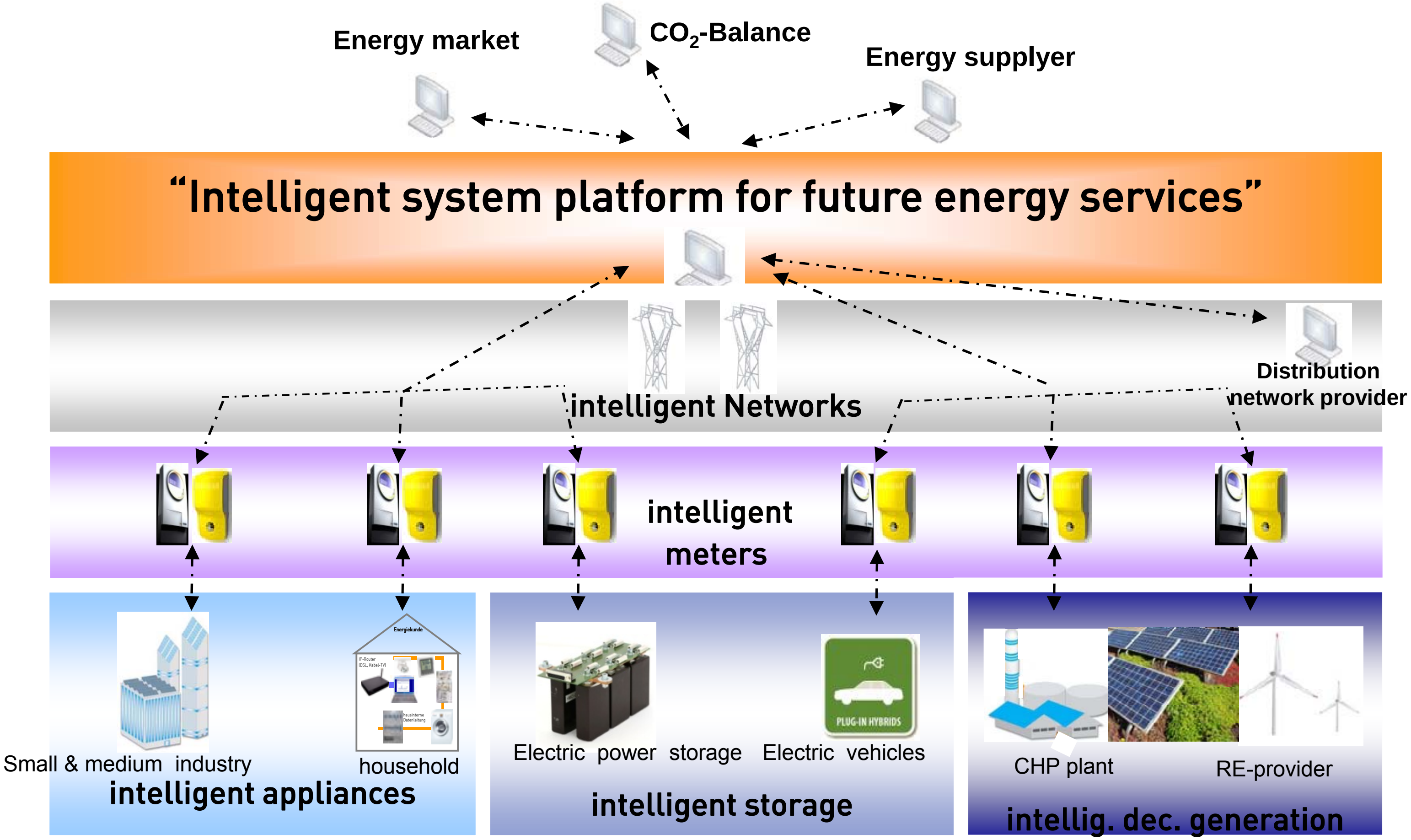
- Optimize power generation & usage from producers to end consumers
- Intelligent combination of new generator technology, DSM and ICT
  - Price and control signals for efficient energy allocation
  - Combined Heat and Power
- MeRegio-Certificate: Best practice in intelligent energy management

Partners

KIT Karlsruhe Institute of Technology, EnBW, ABB, IBM, SAP, systemplan ENGINEERING

MEREGIO system view

- Intelligent system platform
- Central element for integration in the model region.



4 Phases of MeRegio

Phase 1 — Q4/ 2009 – Q2 / 2010

Measure & Respond

- Insights on consumer response to dynamic price signal
- Hour-based price signal for testing sensitivity of standard demand profile

➡ Price elasticity

Phase 2 — Q3/2010 – Q2/ 2011

Control

- Control of consumers and decentral producers using control boxes and complex price and control signals

➡ First local optimisation; testing control methods for intelligent components

Phase 3 — Q2 – Q3 / 2011

Storage

- Combining (partially) flexible consumption und storage of decentrally generated power
- Testing interaction of components and preparation for market entry

➡ Simulation of grid events, bottlenecks, management

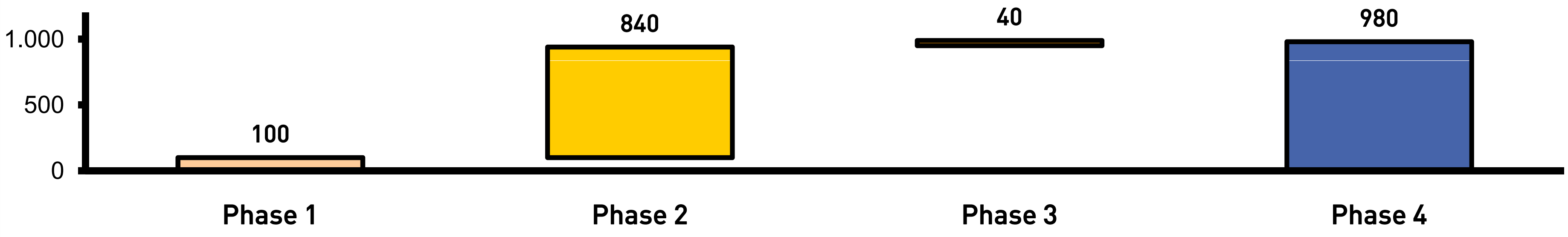
Phase 4 — Q3 / 2011 to Q2 / 2012

Market place

- Automatic interconnection of interested participants (consumer, producer) via market place.
- MeRegio certification

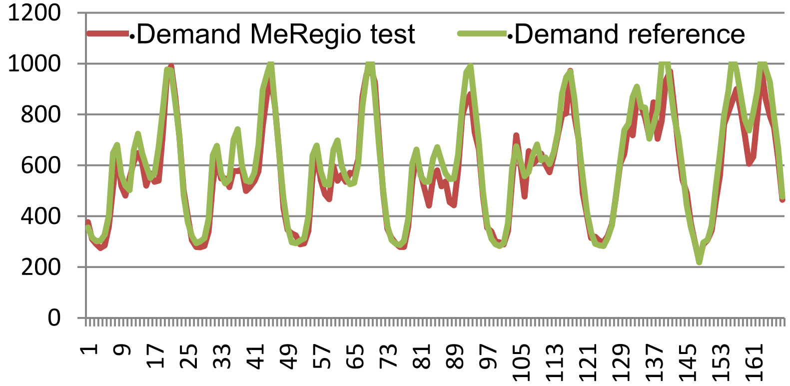
➡ Offering different roles / degrees of freedom for participating in energy trading

Number of test customers

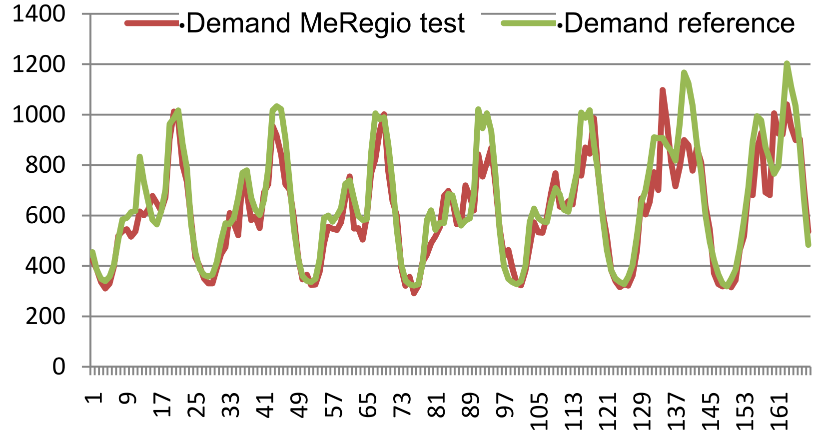


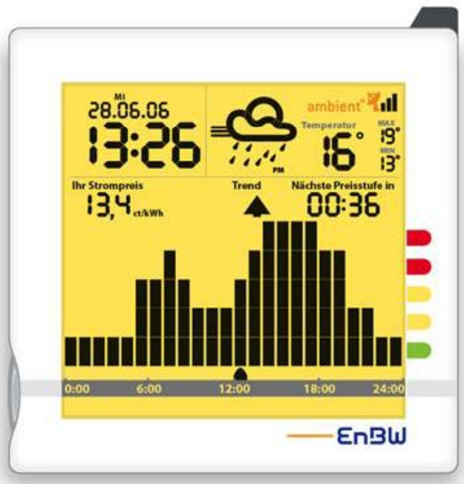
Phase 1 of MeRegio: First results on user response

- **Demand profile before testing**

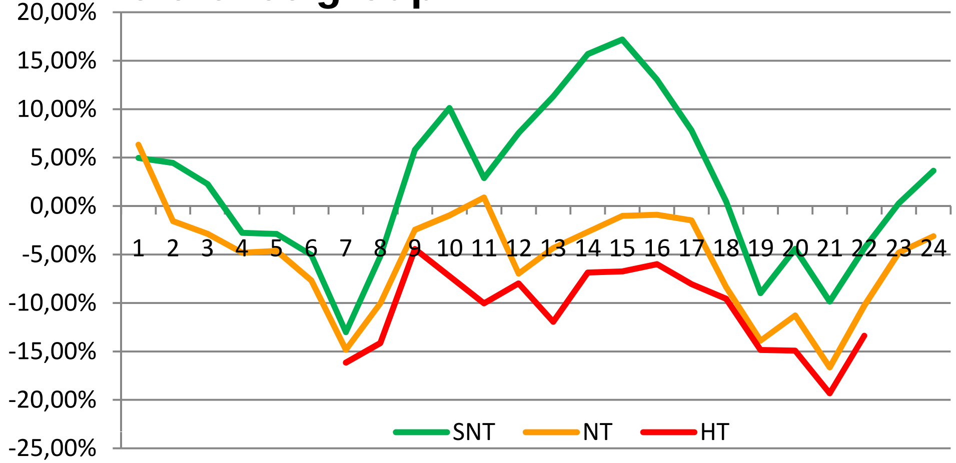


- **Demand profile during testing**





- **Relative changes compared to reference group**



MeRegio Mobil

ICT for Electromobility

Gefördert durch das
Bundesministerium für Wirtschaft und Technologie

KIT Karlsruhe Institute of Technology

Research Question / Scenario

[source: EnBW AG]

Methodology

- Computer Simulations
- Field trial with about 50 BEV
- Living Lab

11 chairs at KIT: Electrical Engineering (2), Energy Economics, Informatics (5), Telematics, Management , Law

Objectives

- Intelligent & efficient integration of electric vehicles into the grid
- Technology assessment & feasibility under real life conditions
- Seamless integration into MeRegio pilot region
- Center of competence at KIT (demo and research lab)

Partners

KIT Karlsruhe Institute of Technology
EnBW
Stadtwerke Karlsruhe – Versorgung mit Verantwortung
Bosch
SAP
Fraunhofer ISI
Daimler
Opel

Classification of electric vehicles

- Micro hybrid:
  - No electric engine
  - Recuperation: recovering braking energy
  - Automatic start / stop
  - Fuel savings of 5% to 10 %
  - Additional cost of about 430 € (for electric servo and high performance ignition)
- Mild hybrid:
  - Larger battery and an electric engine, supporting the ICE
  - Results in reduced cylinder capacity and corresponding fuel savings
  - Icremental costs of around 1500 to 2000 €
  - Example: Mercedes S400 Hybrid

Classification of electric vehicles (2)

- Full hybrid:
  - Similar to mild hybrid, but larger batteries and engine, allowing electric driving
  - Incremental costs around 2500 to 3000 €
  - Efficiency gains around 25% to 40%
  - Examples: Toyota Prius, VW Touareg, BMW ActiveHybrid X6, Porsche Cayenne, Mercedes ML 450

Classification of electric vehicles (3)

- Plug-in Hybrid (PHEV):
  - Similar to full hybrid
  - Allows external recharging of battery
  - 50 % of driving should be electric
  - Incremental costs around 3200 to 7300 €
  - Efficiency gains around 40% to 60%
  - Examples: Toyota Prius PHV, many more at http://phevs.com/indexGalleries.html

Classification of electric vehicles (4)

- Full electric, battery electric vehicle ((B)EV):
  - Electric engine only , no ICE
  - Significantly reduced number of moving parts
  - Extra costs of at least 15.000 €
  - Significantly reduced driving range (100 – 200 km)
  - Higher weight due to larger battery
  - Long charging times (2 to 8 hours)
  - Examples: many EVs available or announced (smart ed, Mini E, eVito, eMIEV, Ampera, Think, …)









Effects of electric vehicles (EVs) on power grid

- Germany, 2008 (mobility survey):
  - Average daily car usage < 1 h, 94% of trips < 50 km
  - Average net capacity of currently available EVs: 20 KWh
- At 1 Million BEVs (German objective for 2020): available storage capacity of ~ 20 GWh
- At charging/discharging power of 3.7 KW: ~ 3.7 GW potential power
- Consequently: **high demand** for power, potentially also **high supply** (if power feedback is possible)
- Average time for charging:
  - Single phase 3.7 KW: 5 to 7 hours.
  - Three phase 10 KW: ~ 2 hours (but high risk of grid overload!)
- Potential of **high flexibility for load shifting**, but also potential of **high peak load**!
- Using intelligent control leads to high potential for stabilizing the grid.

Uncontrolled Charging of EV

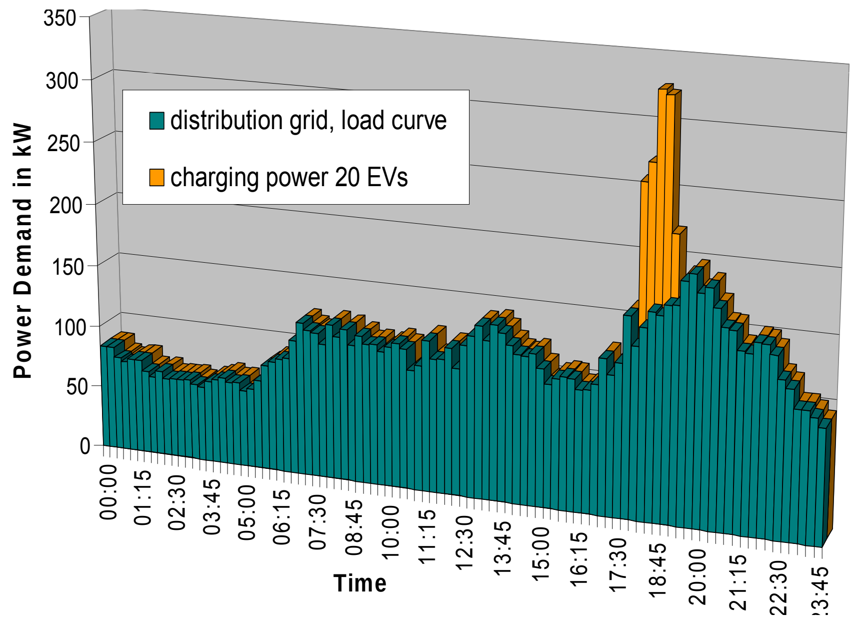
Simulation:

Distribution Grid:

- rural german area
- ~100 households

Electric Vehicles:

- 20 EVs at grid segment
- power demand = 10KW
- charging after last trip
- high simultaneity expected in the evening



Conclusion:

- Even a small rate of Electric Vehicles could strongly affect the power demand of a distribution grid.
- Increasing stress of grid equipment expected, overload is possible

Integration Strategies: Load Balancing Potential

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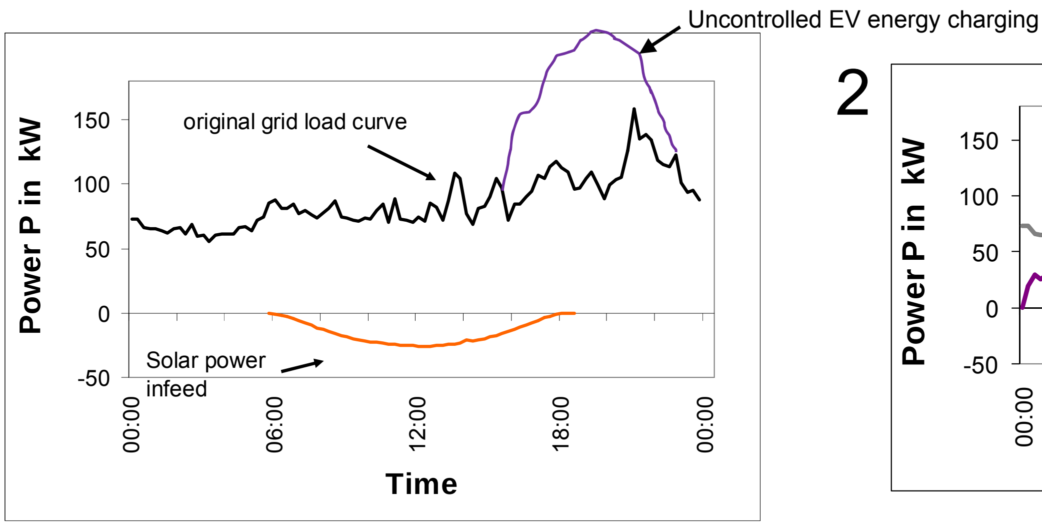

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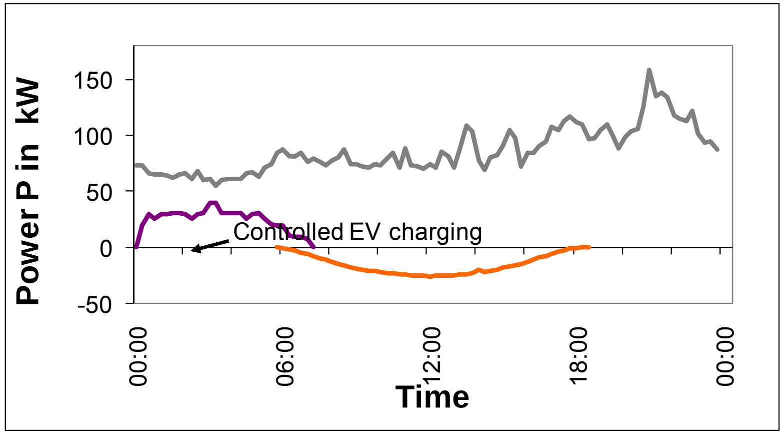

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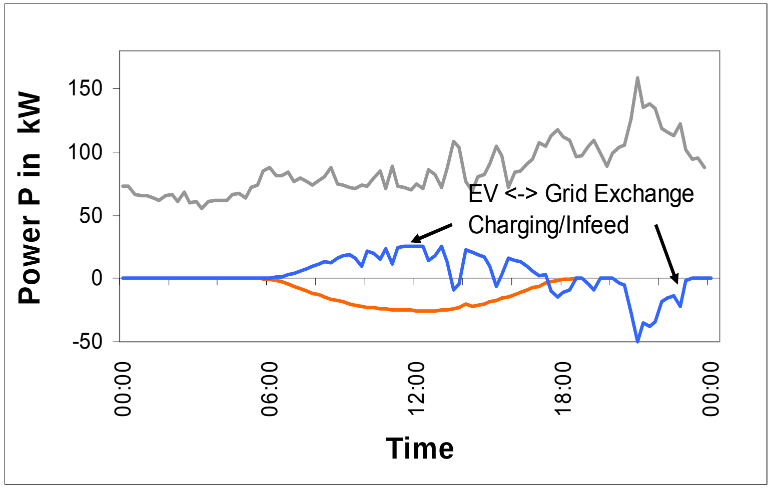

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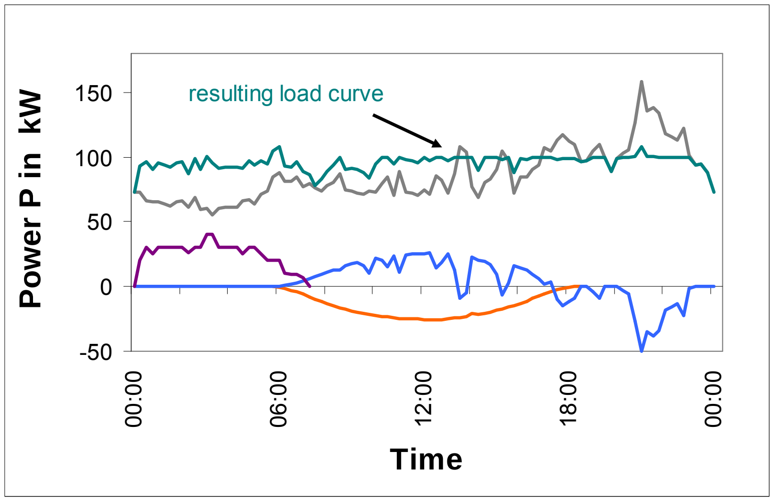

„Smart Home“ – e-Mobility Lab at KIT
Testing smart integration of EVs into the (local) grid

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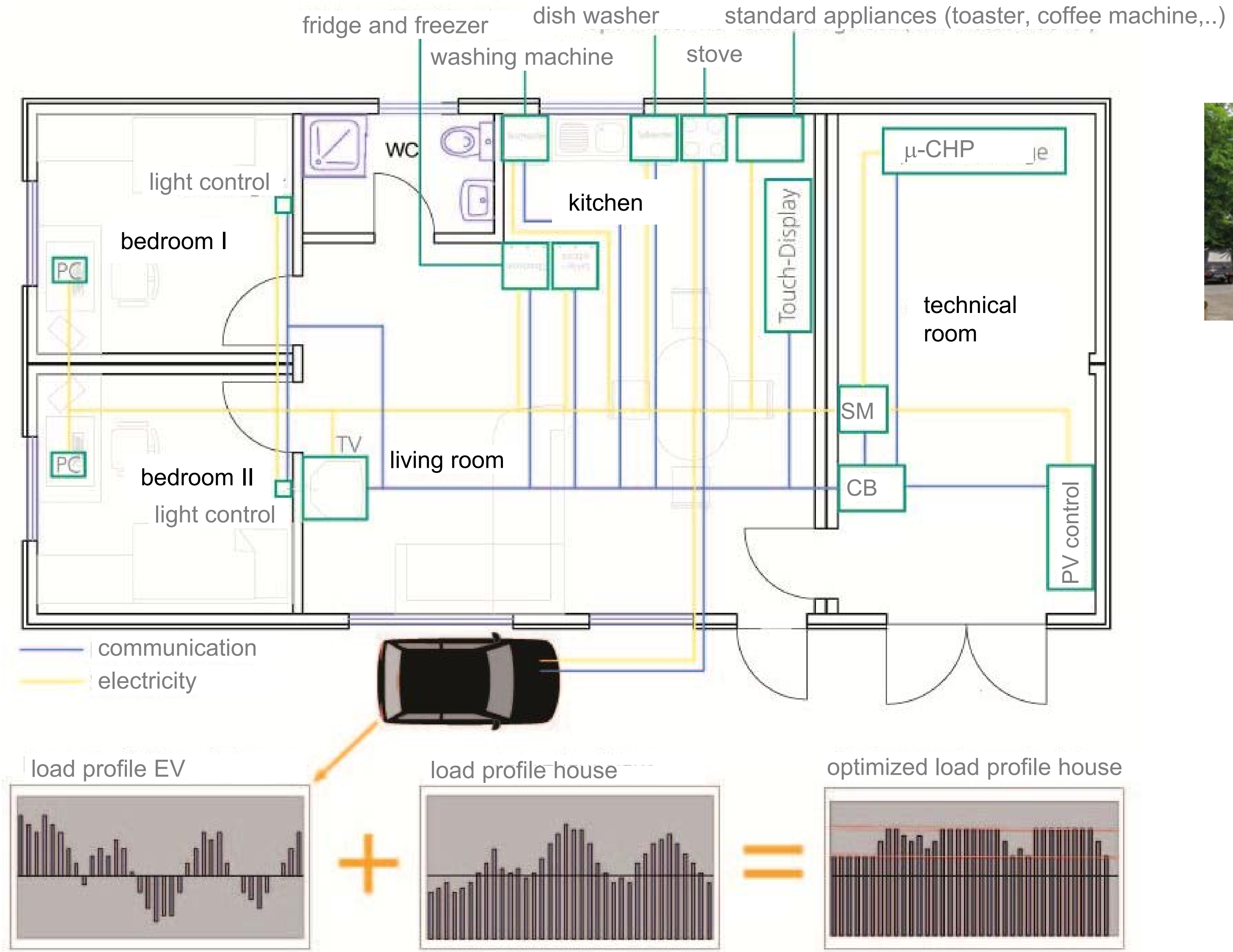
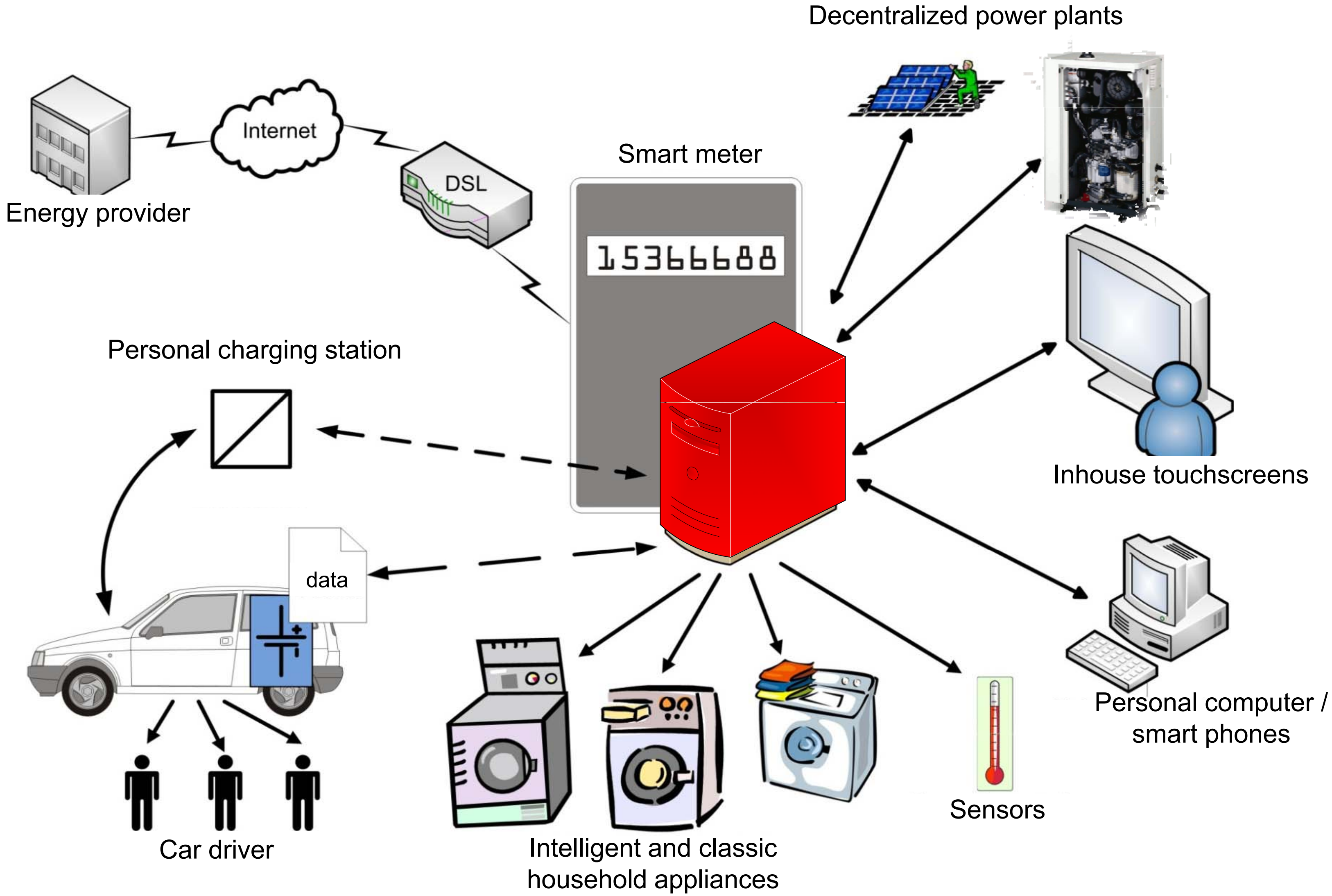
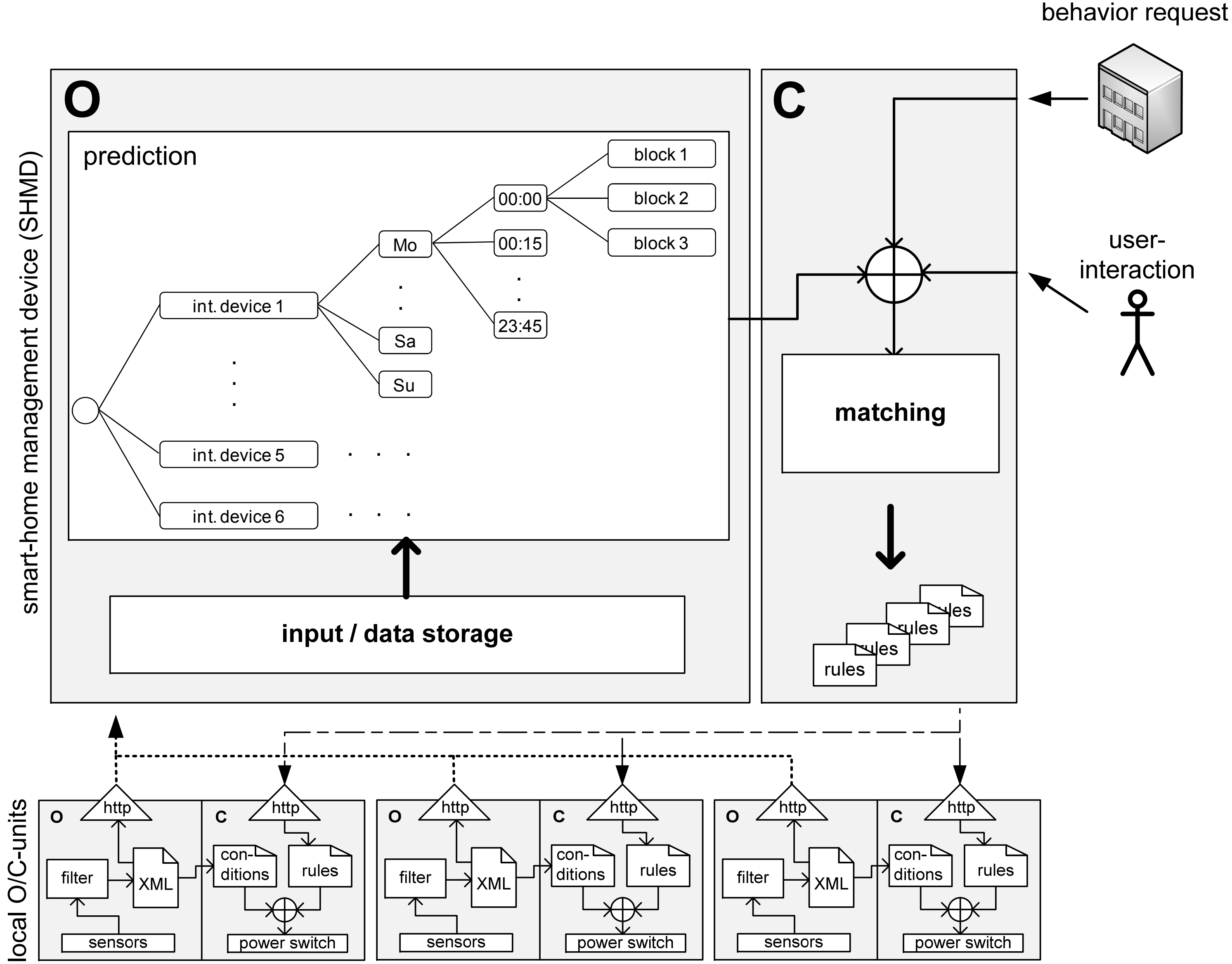


Smart home lab - structure



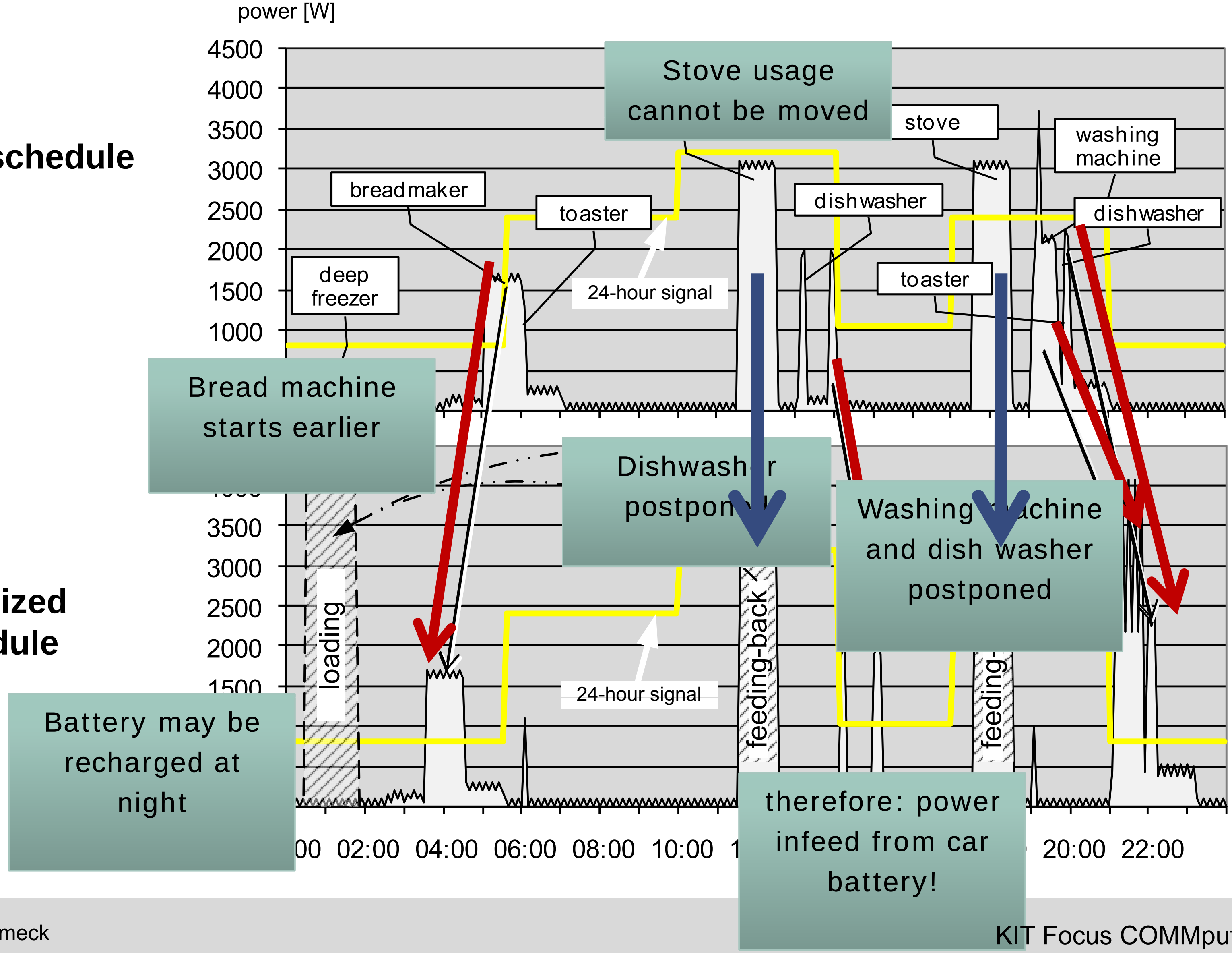
O/C-Architecture for DSM



Intelligent demand management

Original schedule

Optimized schedule



Challenges of Electric Mobility

- Battery charging infrastructure needs **standardization** and **interoperability** (at private, public, semi-public charging stations)
- Need of **incentives** (regulations?) for leaving recharging control to external provider (otherwise, EVs will lead to severe problems!)
- Effective bidirectional control of batteries needs **knowledge on “next drive”** → privacy protection problems?
- Limited range of BEVs needs new **energy-aware services**, e.g.:
  - remaining driving distance
  - energy-optimized routing and driving
  - reservation of next charging station (coordination and booking)
- Exploit potential of effective **system services** utilizing virtualized storage.
- **Security and safety issues**
  - Denial of service attacks, viruses, worms – all the problems known from data communication networks.
  - Validity of billing for bidirectional charging?

Implications for "Smarter Cities"

- EV''s need **charging stations**
  - **Private**: at home (garage, what about apartment buildings???)
  - **Public**: at public parking lots
    - Locations?
    - Users?
    - Roaming problems
  - **Semi-public:** restricted range of users, special contract
    - Company employees
    - Private parking garages
    - Sports arena visitors
    - Shopping centers

- Studies show that ***public charging is not really needed*** (but very expensive).

Implications for “Smarter Cities”

- **Limited driving range** → strong need for **new mobility** concepts
  - **Multi-modal mobility**
    - BEVs for short trips (94% are below 50 km!!)
    - Switching between different mobility modes for long range trips
      e-bikes – e-cars – buses – trains – planes - ….
  - **Mobility as a service**
    - Car-sharing
    - Public transport
- **“Green City”** concept
  - Regions with “E-traffic only”
  - Municipal services, delivery services with e-traffic only
  - Combinations of BEVs and Hydrogen-Infrastructure
    (public transport)
  - Utilization of BEVs for stabilizing the power grid **(system services)**

Implications for "Everybody"

- **"When to use your dishwasher?":**
  - Learn to adjust your power demand to specific profiles (which might be changing frequently).
  - Agree to have the devices in your smart home managed by some third party ("your personal power agent").
  - Specify your constraints for guaranteed personal comfort levels.
  - Learn how to reduce your energy consumption.

- **"When and how to use or recharge your electric vehicle?"**
  - Learn to cope with "range anxiety" .
  - Have your vehicle plugged in as long as possible.
  - Agree to have your BEV used for stabilizing the grid.
  - Get used to "mobility as a service" and resulting multi-modal mobility.

Summary

- Power generation from renewable sources needs ICT for new approaches to energy management.
- Electric vehicles will generate significant capacity for power storage – leading to additional demand and supply of power.
- Potential flexibility of power demand and supply should be exploited in “smart” homes and enterprises.
- Integration of EVs into smart home environments allows for intelligent balancing of power demand and supply and for new power system services.
- An “Internet of Energy” will have to cope with similar safety and security problems as the “Internet of Data”.
- Pervasive use of ICT in our vicinity is inevitable but need not reduce our personal comfort .

Thanks for your attention!

Questions?

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