Smart Grid, Renewables, Electric Mobility:
When To Use Your Dishwasher or Recharge Electric Vehicles?

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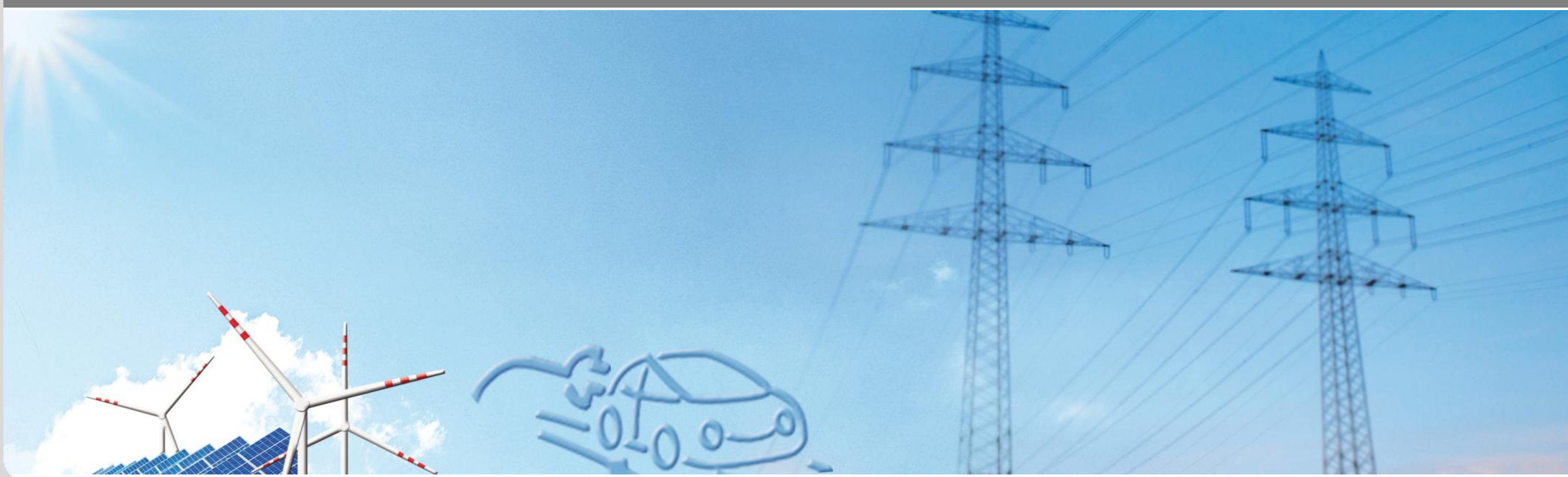


Overview

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

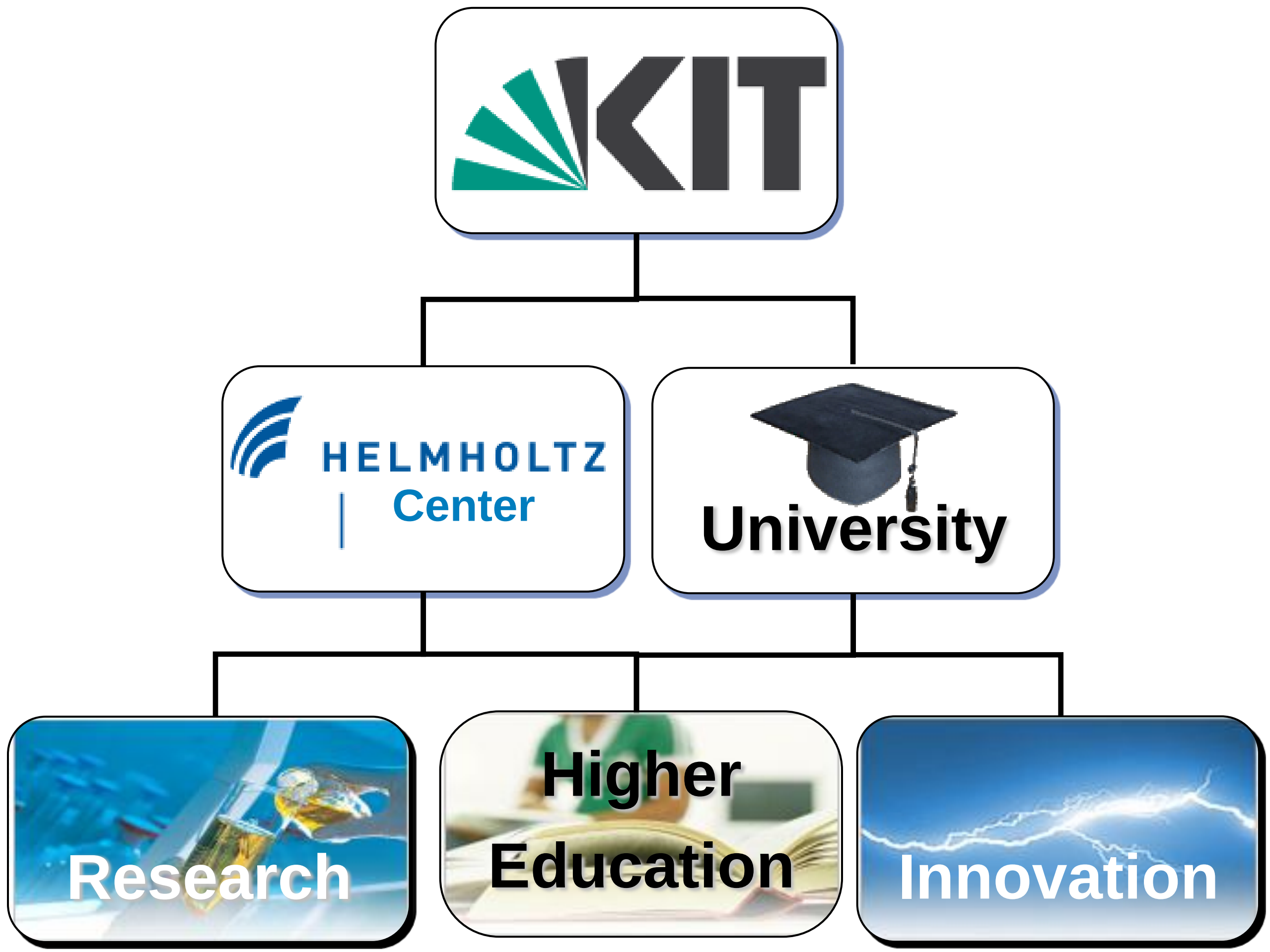
Karlsruhe Institute of Technology
Merging a University And a Research Center

One Entity, Two Missions, Three Tasks

One Entity

Two Missions

Three Tasks



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:

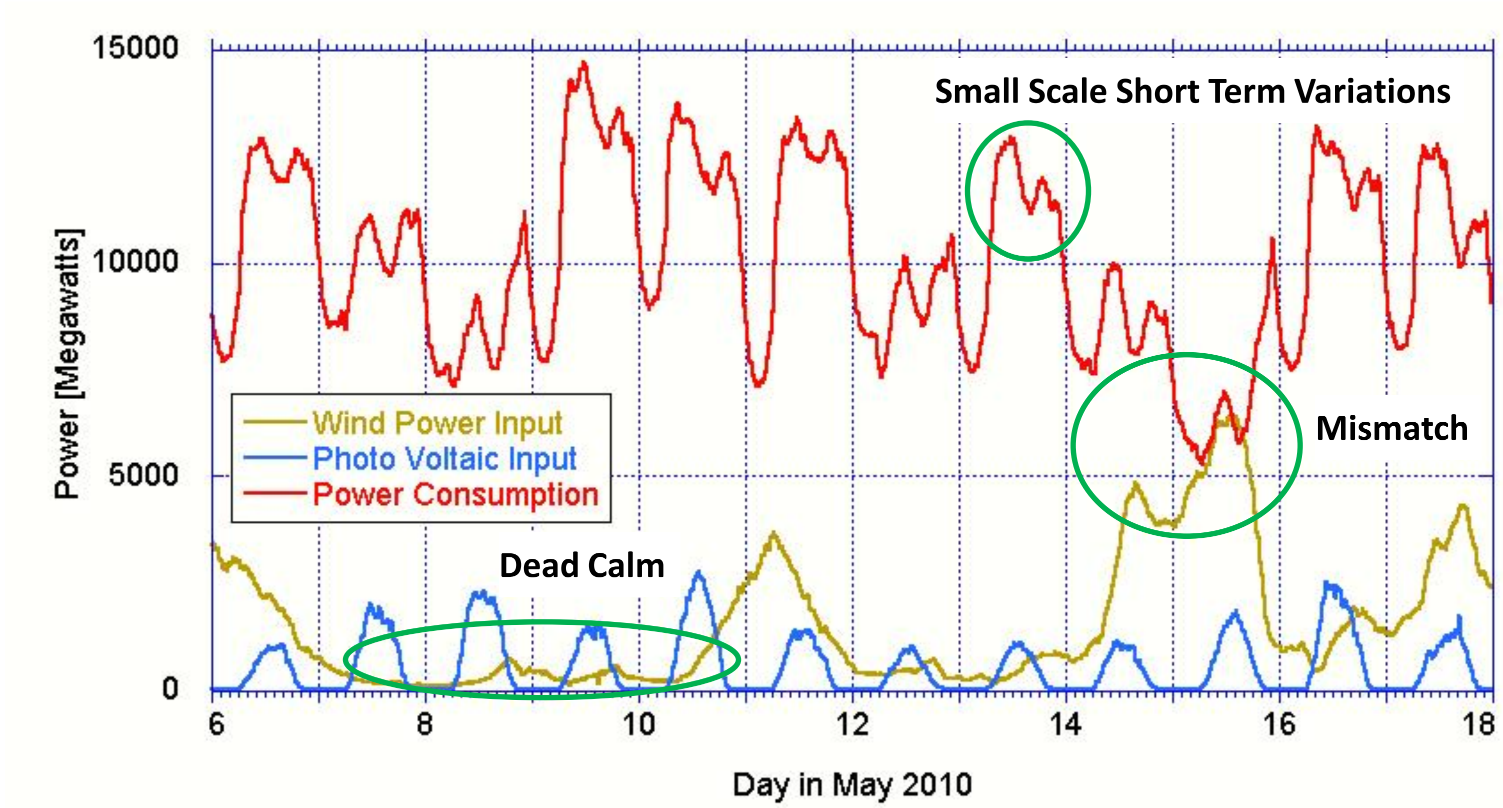
March 2007:
EU's leaders endorse an integrated approach to climate and energy policy:

- 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.

$\Rightarrow$ 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

2009 - 2011 **Phase 1**
Market-/ Technologie-preparation

2011 - 2016 **Phase 2**
Market development

2016 - 2020 **Phase 3**
Volume market

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

EENERGY

ICT FOR
ELECTROMOBILITY

eTelligence

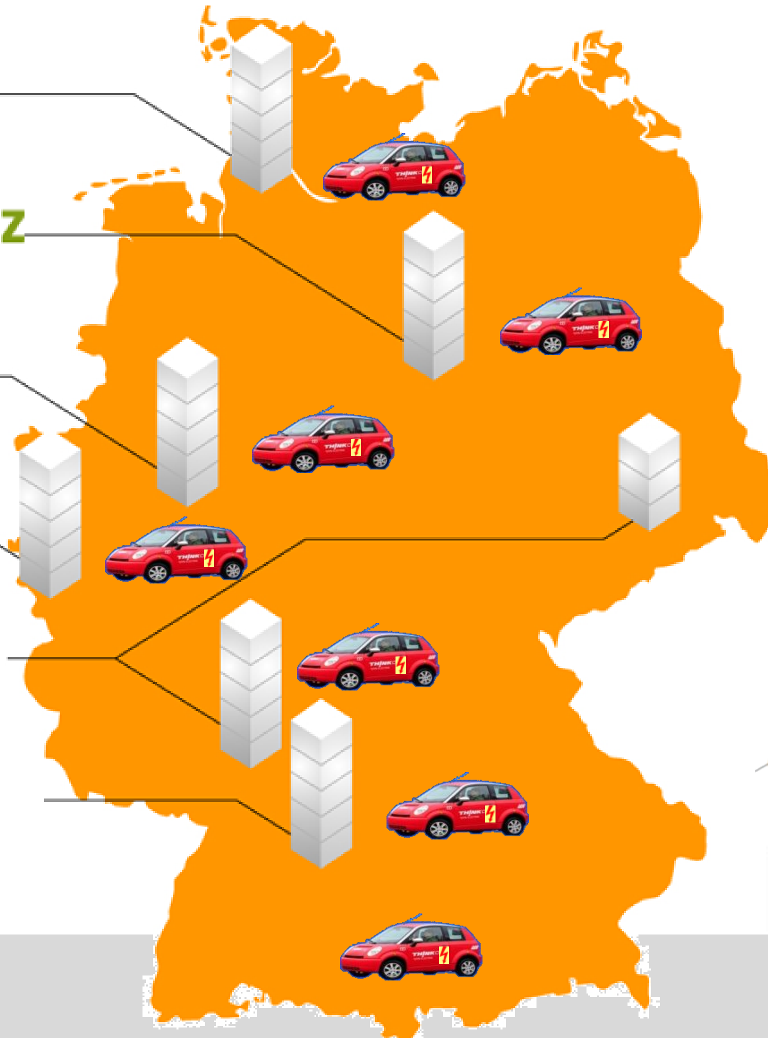
RegModHarz
Regenerative Modellregion Harz

E DeMa

Smart Watts

moma

MeRegio



Grid Surfer

HARZ.EE-MOBILITY

IKT
INTEGRATION DER ELEKTROMOBILITÄT IN DIE NETZSYSTEME DER ZUKUNFT

Smart Wheels

FUTURE FLEET

MeRegio Mobil

E-Tour ALLGÄU
effiziente Elektromobilität & Tourismus

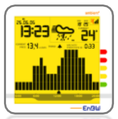
Gefördert durch das Bundesministerium für Wirtschaft und Technologie

Moving towards Minimum Emission Regions

MeRegio

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

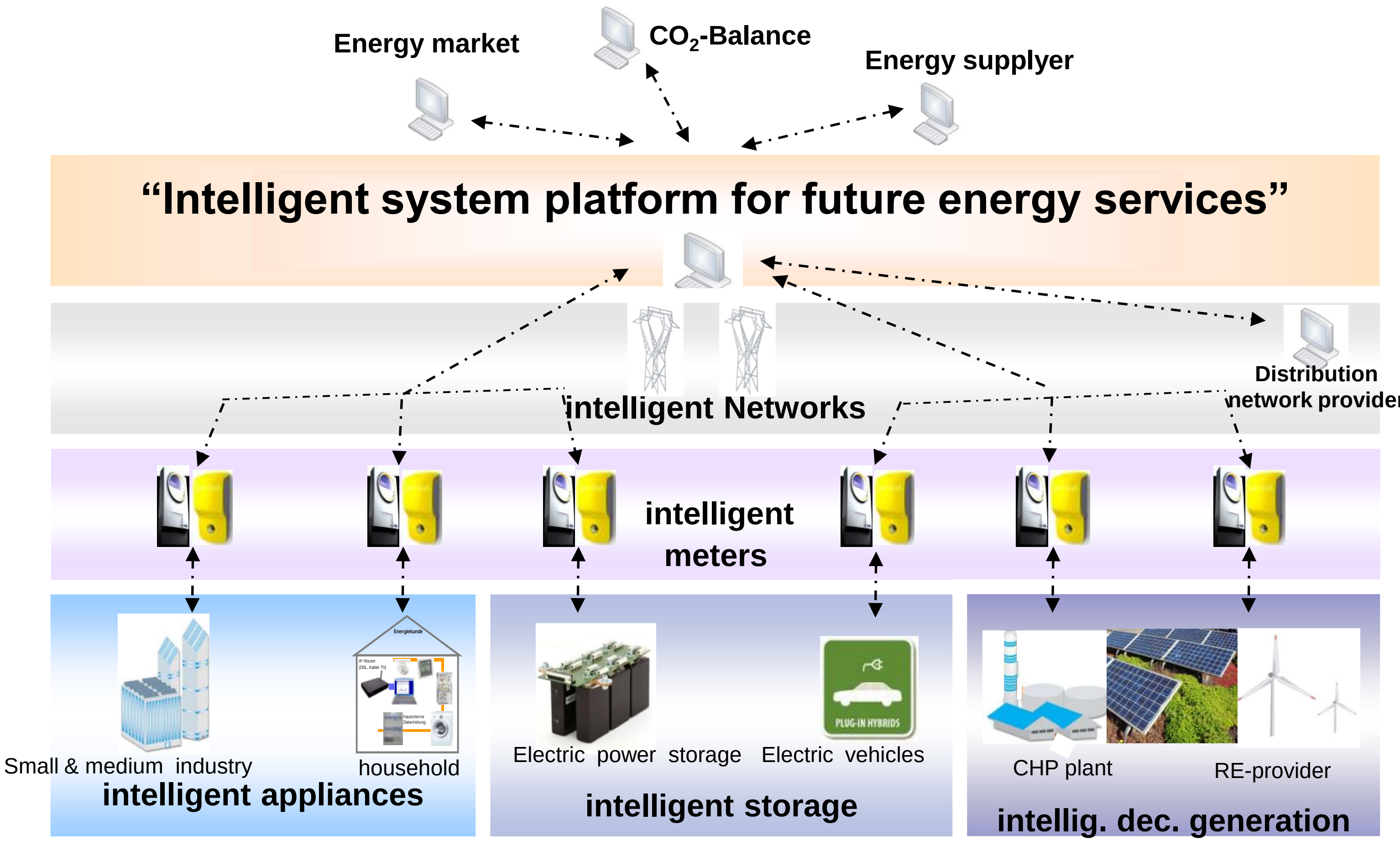
Objectives
- Optimize power generation & usage from producers to end consumers
- Intelligent combination of new generator technology, DSM and ICT
  - Price and control signals for efficient energy allocation
  - Combined Heat and Power
- MeRegio-Certificate: Best practice in intelligent energy management

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	Phase 2 Q3/2010 – Q2/ 2011	Phase 3 Q2 – Q3 / 2011	Phase 4 Q3 / 2011 to Q2 / 2012
Measure & Respond	**Control**	**Storage**	**Market place**

Phase 1 – 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 – 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 – Storage

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

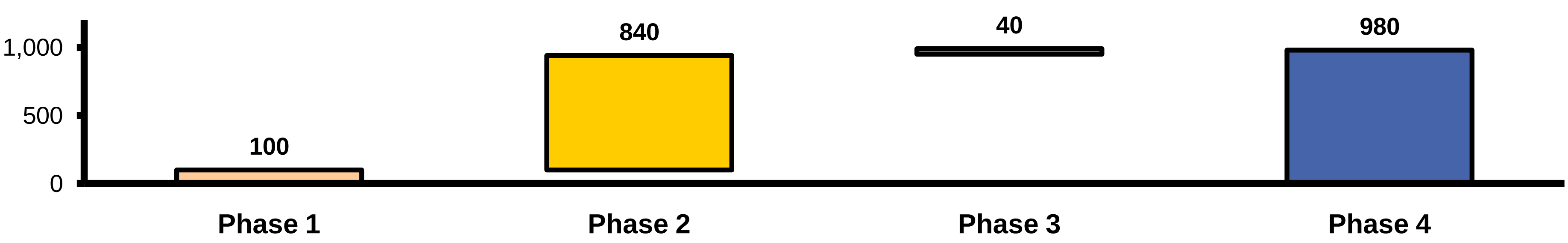
➡ Simulation of grid events, bottlenecks, management

Phase 4 – Market place

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

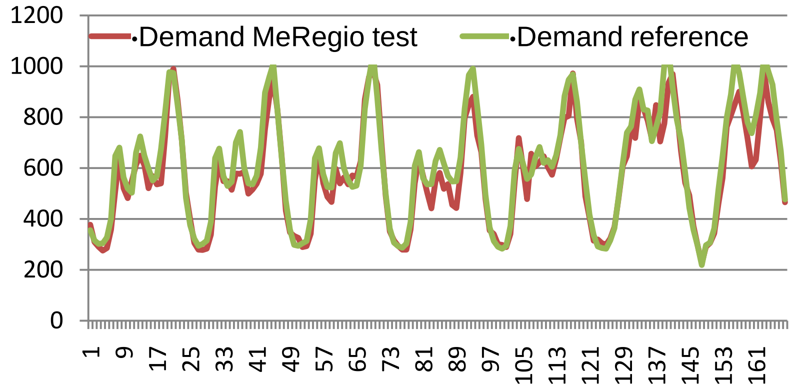
➡ Offering different roles / degrees of freedom for participating in energy trading

Number of test customers

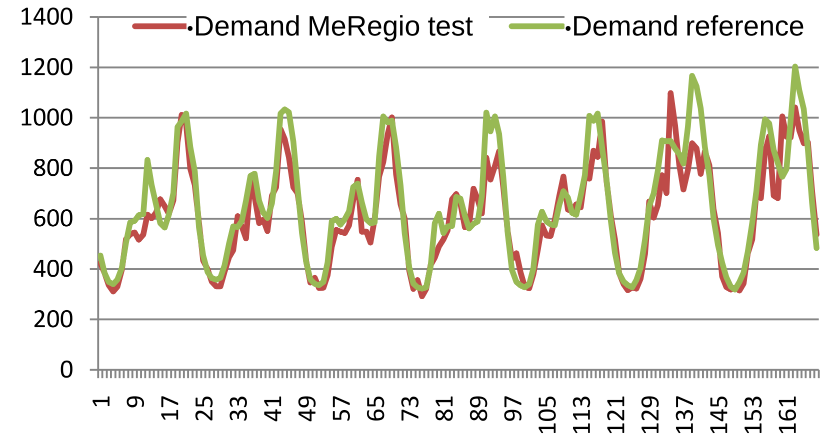


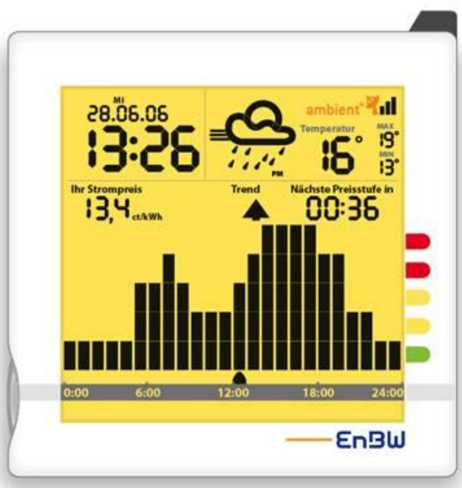
Phase 1 of MeRegio: First results on user response

- **Demand profile before testing**

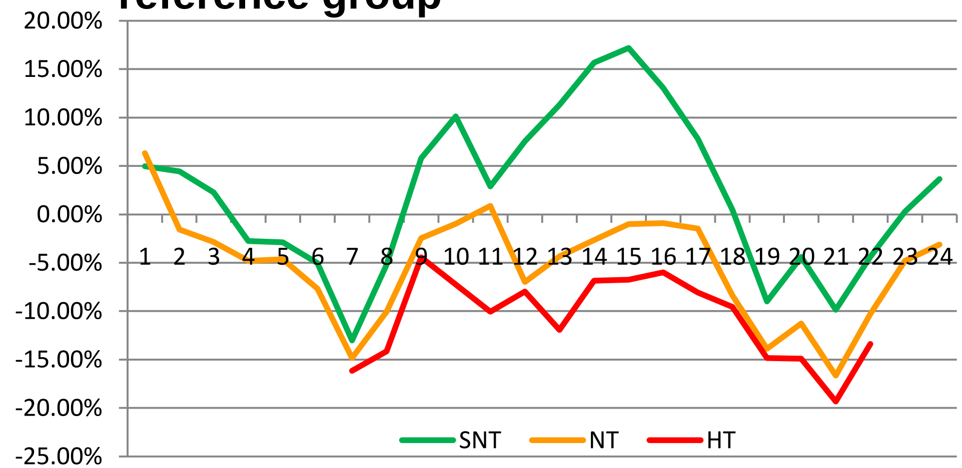


- **Demand profile during testing**





- **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

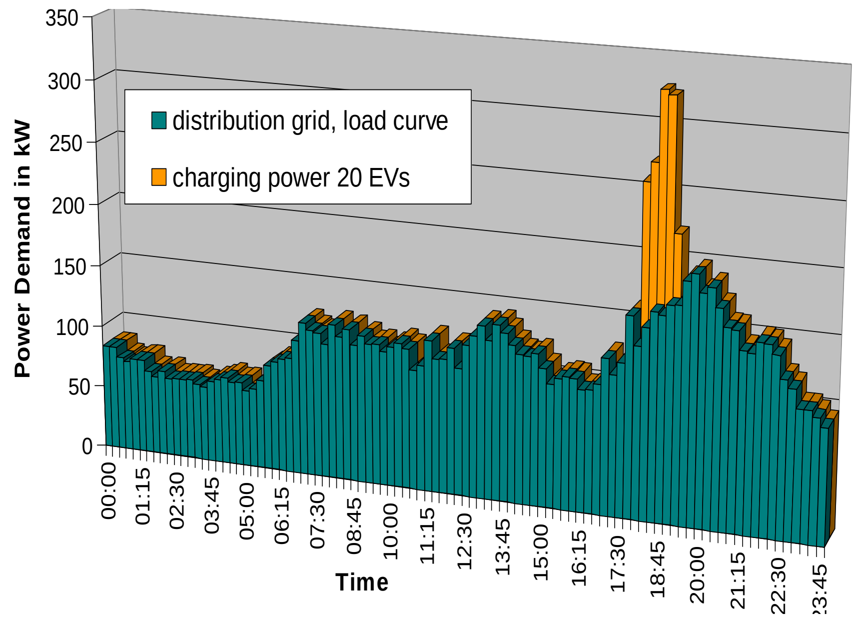
- Germany, 2008 (mobility survey):
  - Average daily car usage < 1 h, 94% of trips < 50 km
  - Average net capacity of currently available EVs: 20 KWh
- At 1 Million BEVs (German objective for 2020):
  available storage capacity of ~ **20 GWh**
- At charging/discharging power of 3.7 KW: ~ **3.7 GW** 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

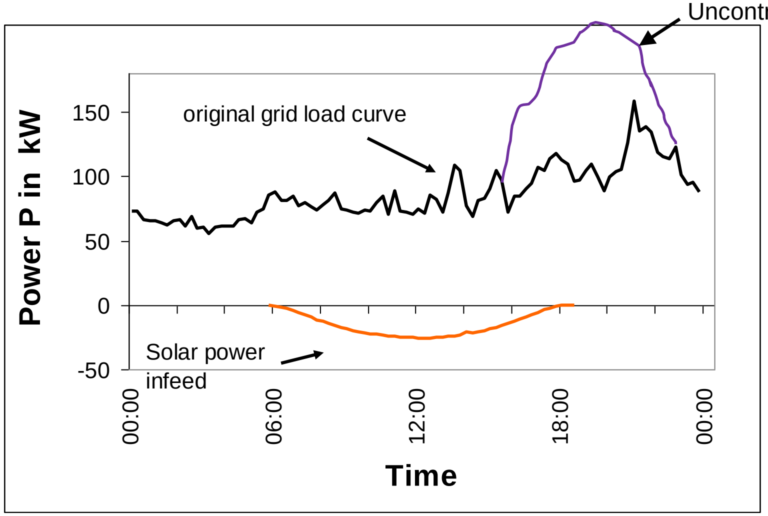
Electric Vehicles:
- 20 EVs at grid segment
- power demand = 10KW
- charging after last trip
- high simultaneity expected in the evening



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

1



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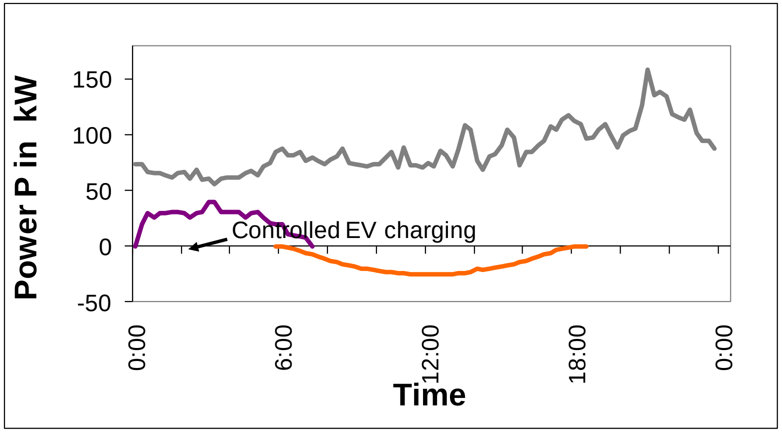

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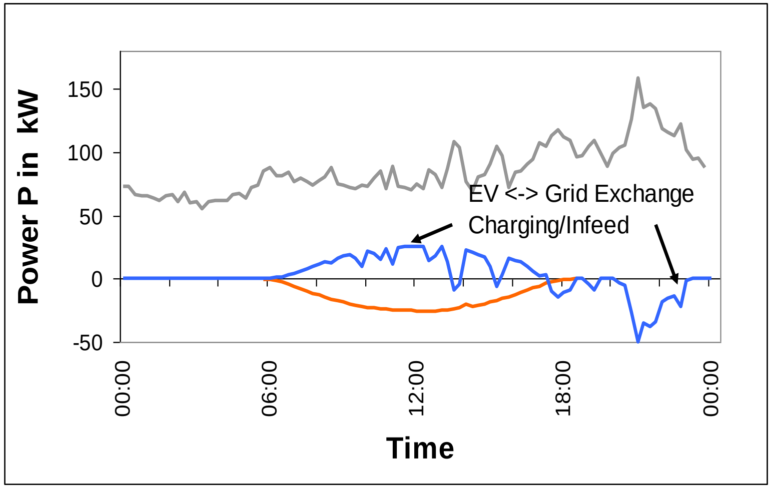

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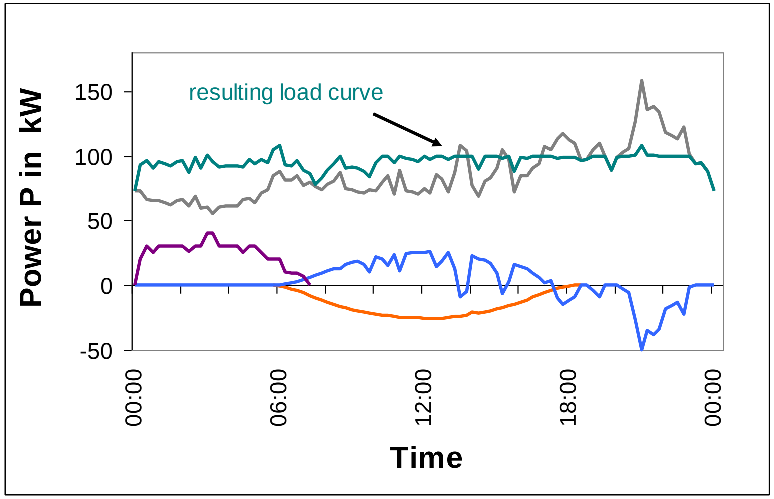
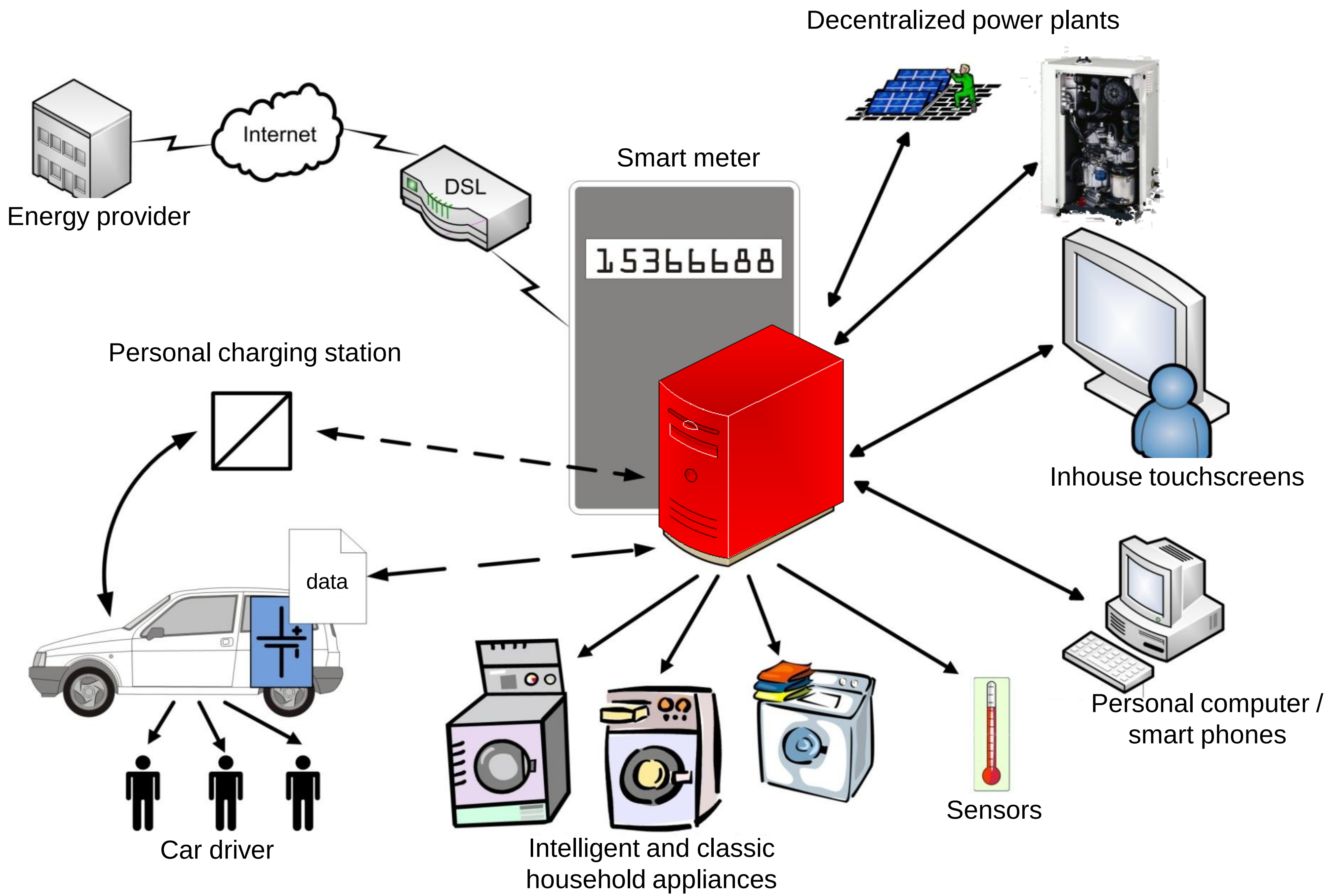
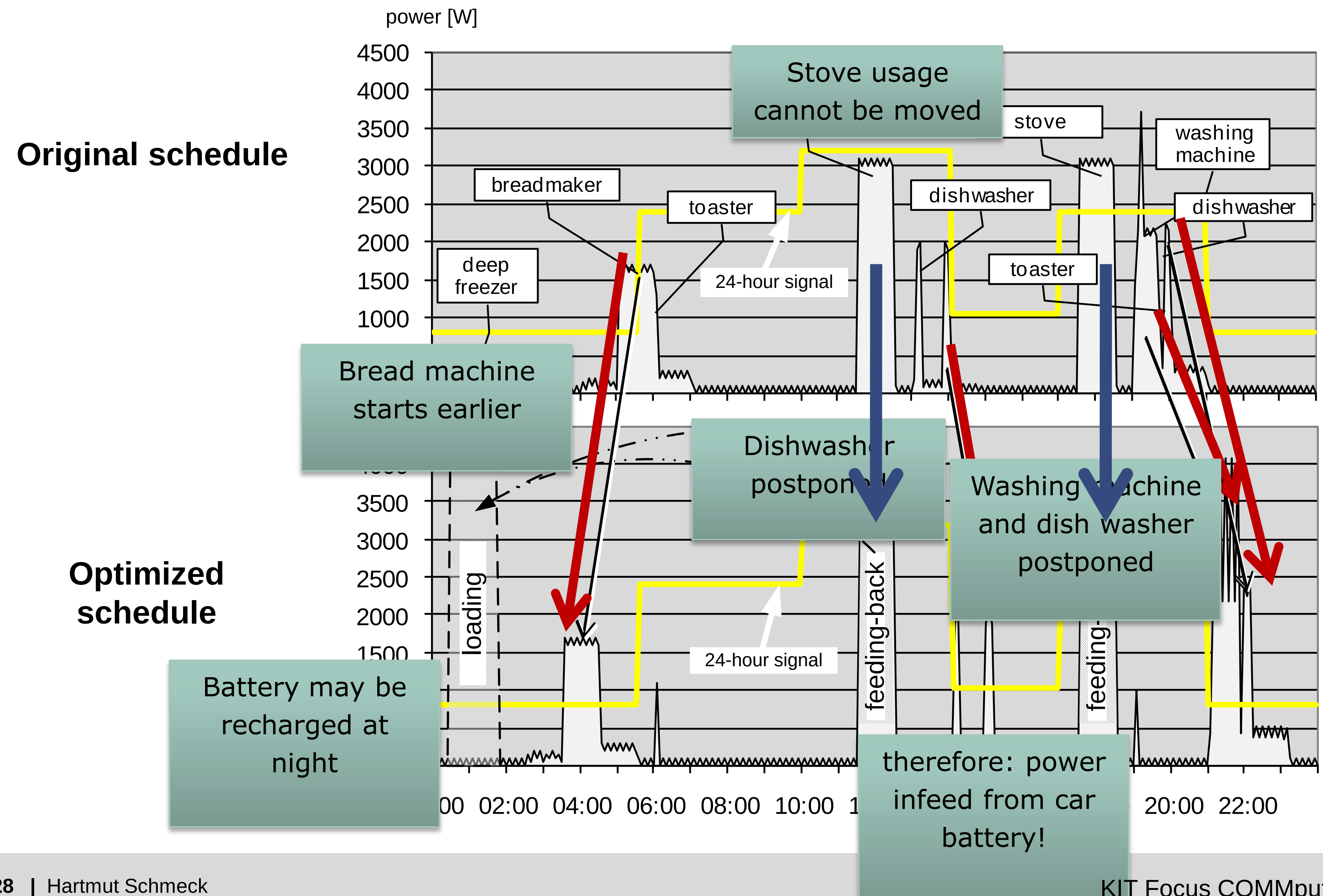


„Smart Home“ – e-Mobility Lab at KIT
Testing smart integration of EVs into the (local) grid

Smart home lab - structure



Intelligent demand management



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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