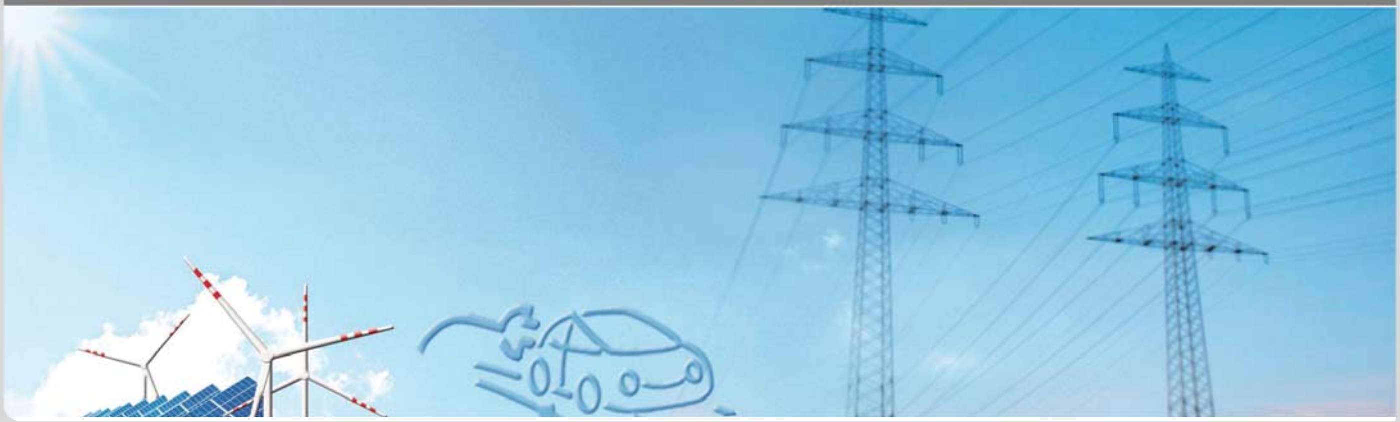
Challenges for ICT in Smart Energy and Electric Mobility

Hartmut Schmeck
Institute AI(FB) + KIT Focus COMMputation
Research Center for Information Technology – FZI

INSTITUTE FOR APPLIED INFORMATICS (AND FORMAL DESCRIPTION METHODS) - IAI - AIFB



European Energy Targets:

Strategic Energy Targets 20-20-20:

March 2007: EU targets to be met by 2020:

- 20% reduction of EU greenhouse gas emissions.
- 20% share of renewables of overall EU energy consumption
- 20% increase in energy efficiency.

More ambitious targets of Germany:

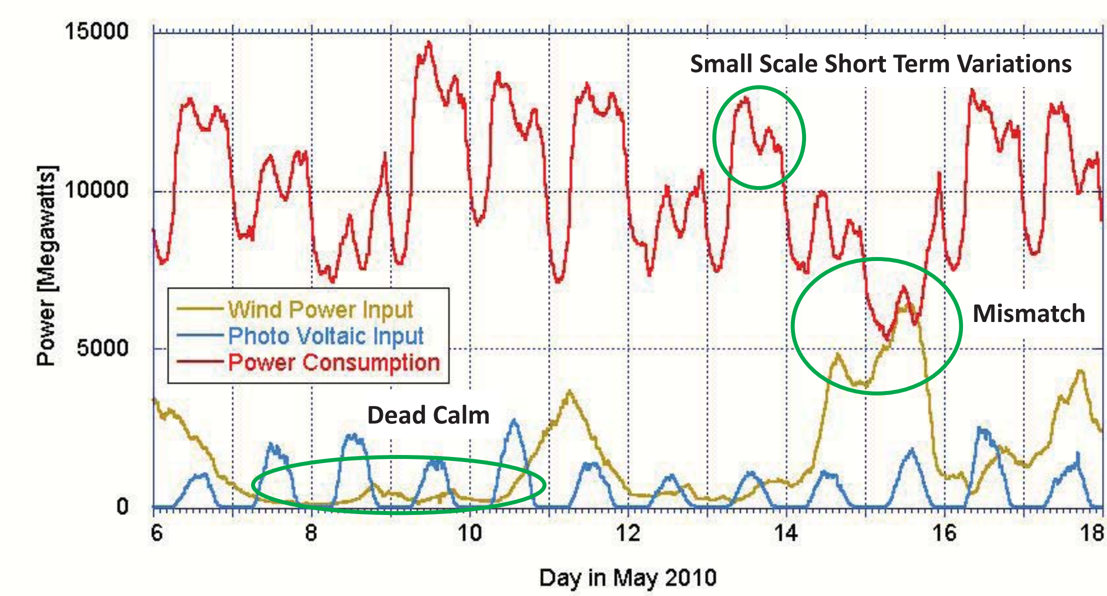
Fall 2010:

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

Spring 2011: "Energiewende"

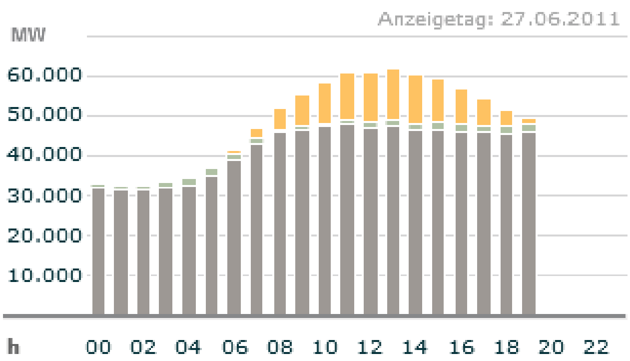
Highly accelerated replacement of nuclear power with renewables (by 2022)

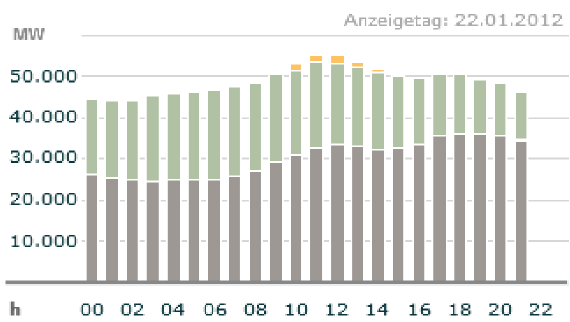
Problems:
Fluctuations – in Demand and Supply



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

Problems:
Power Generation on 27.6.2011, 22.1.2012

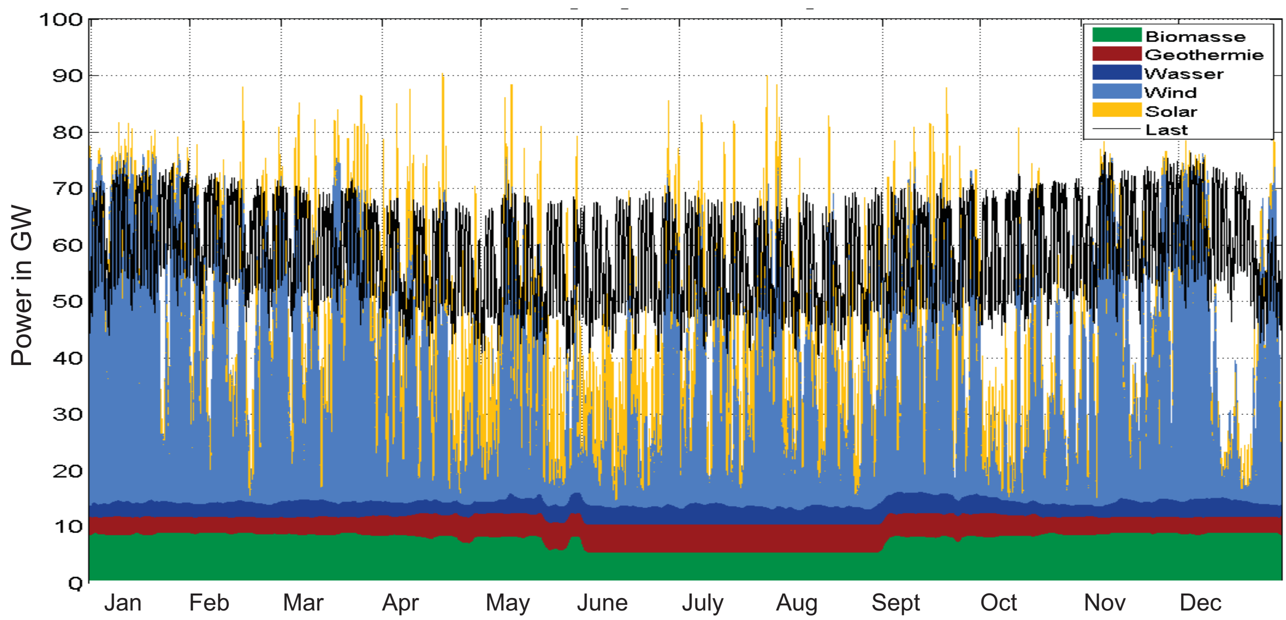




- 27.6.: PV 12 GW, wind 2 GW (peak), nuclear 10,3 GW (steady)
- 22.1.: PV . 1,8 GW, wind 22 GW (peak), nuclear 5,7 GW (steady)

(source: http://www.transparency.eex.com/de/)

Study on Energy Situation 2050 (Meteorological Base Year 2007)



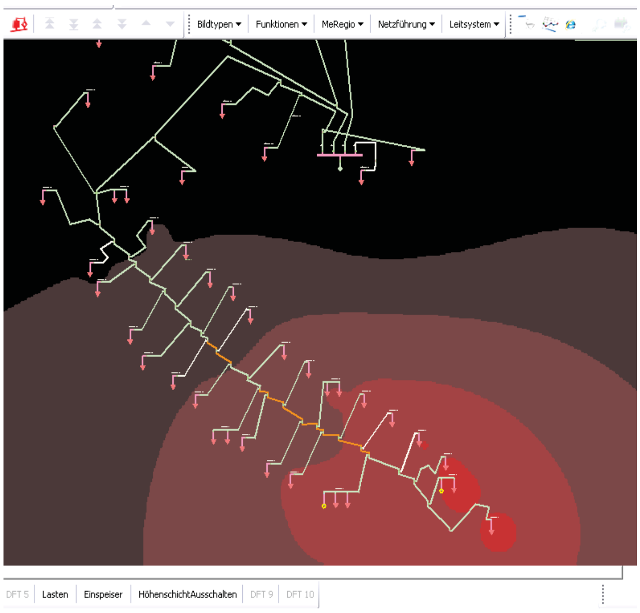
Source: Fraunhofer IWES

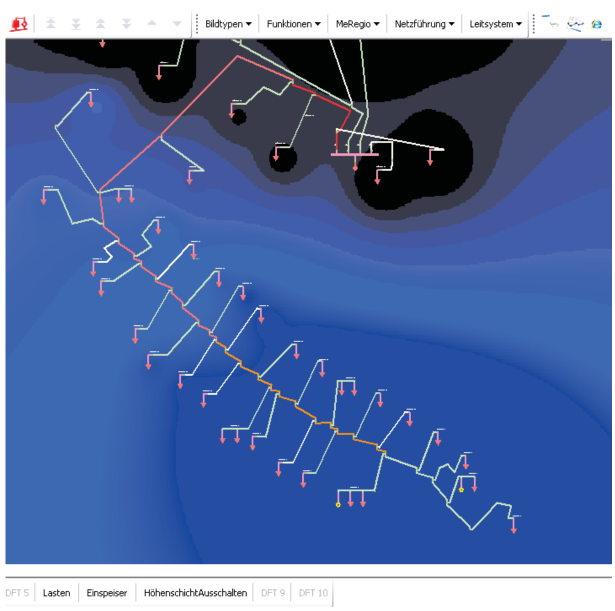
Problems due to decentralization: bottlenecks in the low voltage distribution grid

Local voltage increase due to PV power infeed

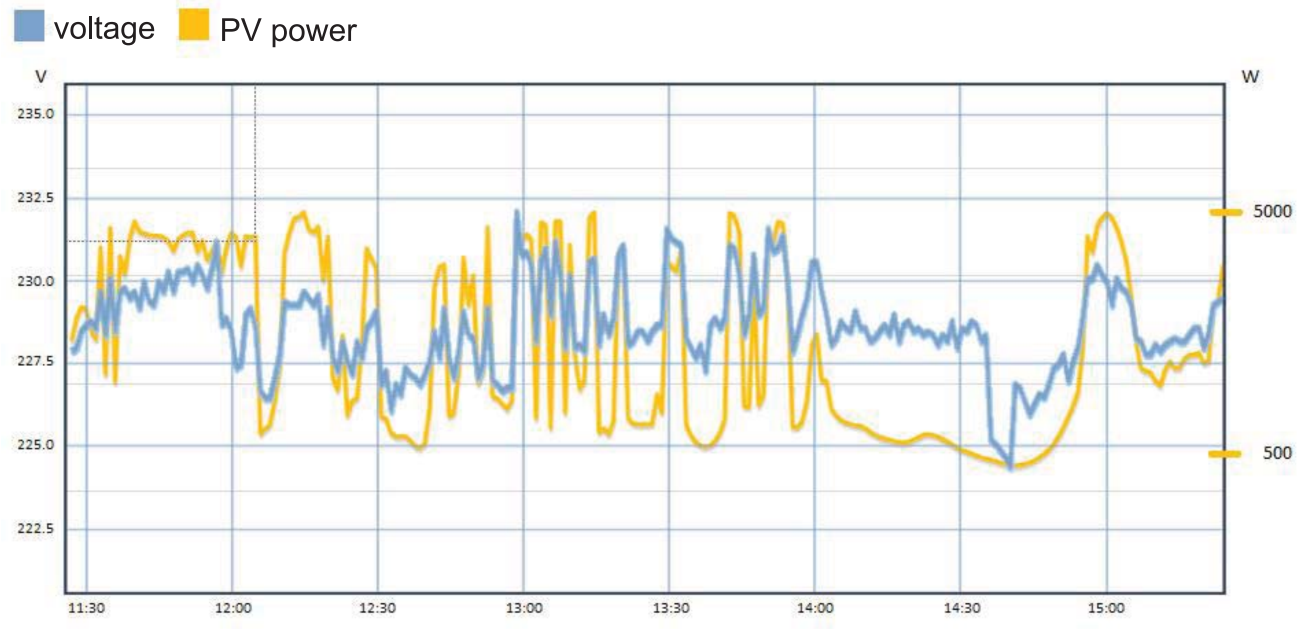
Local voltage decrease due to EV charging

These visualizations are a result of E-Energy project MeRegio.





Impact of PV power input on voltage in the low power grid



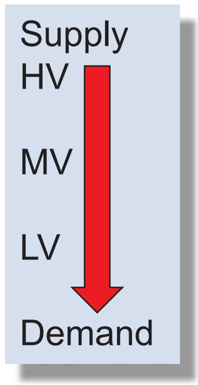
Problem: all PV panels of one segment are in sync!

Energy Management: Balancing Demand and Supply

Traditional:

- Demand cannot be controlled.
- Electricity cannot be stored.

→ **Principle: Supply follows demand**
(Spinning reserve: Primary, secondary, …)

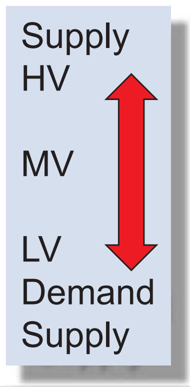


Future:

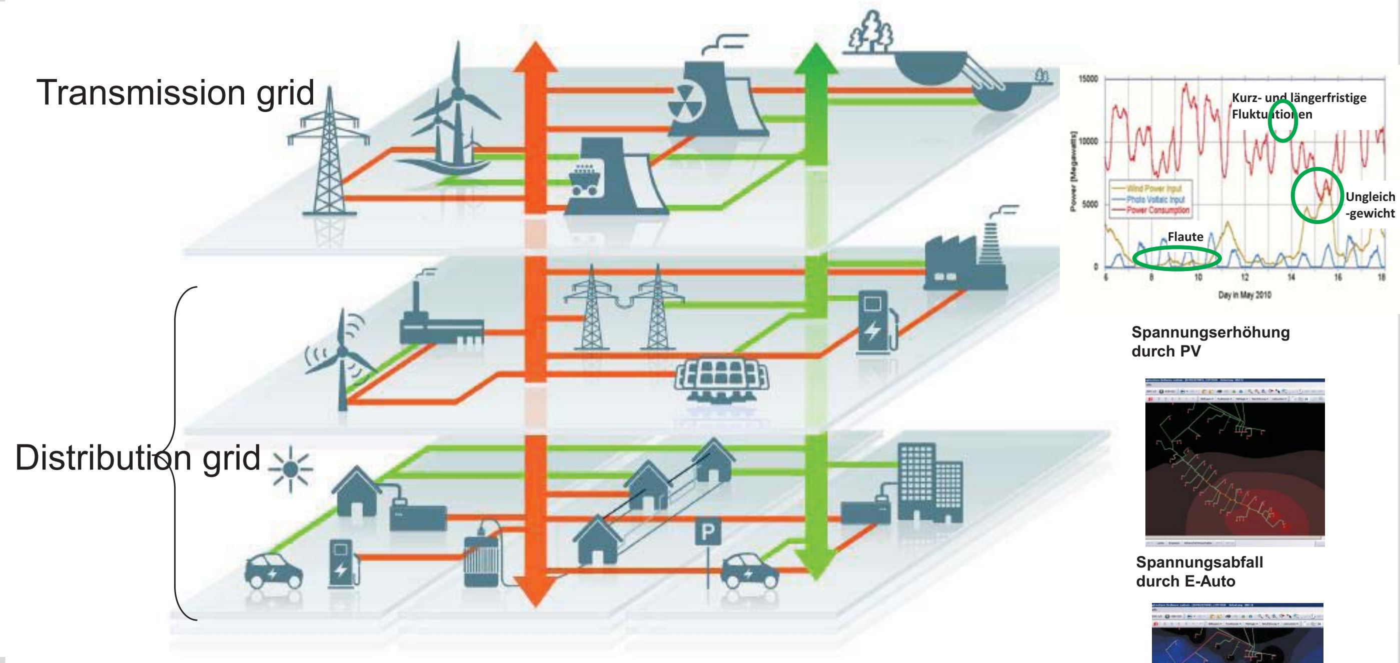
- Supply only partially controllable and decentralized
- **Potential reversal of power flow**

→ **New Principle:**
Demand has to follow supply!

→ **Requires more flexible demand**

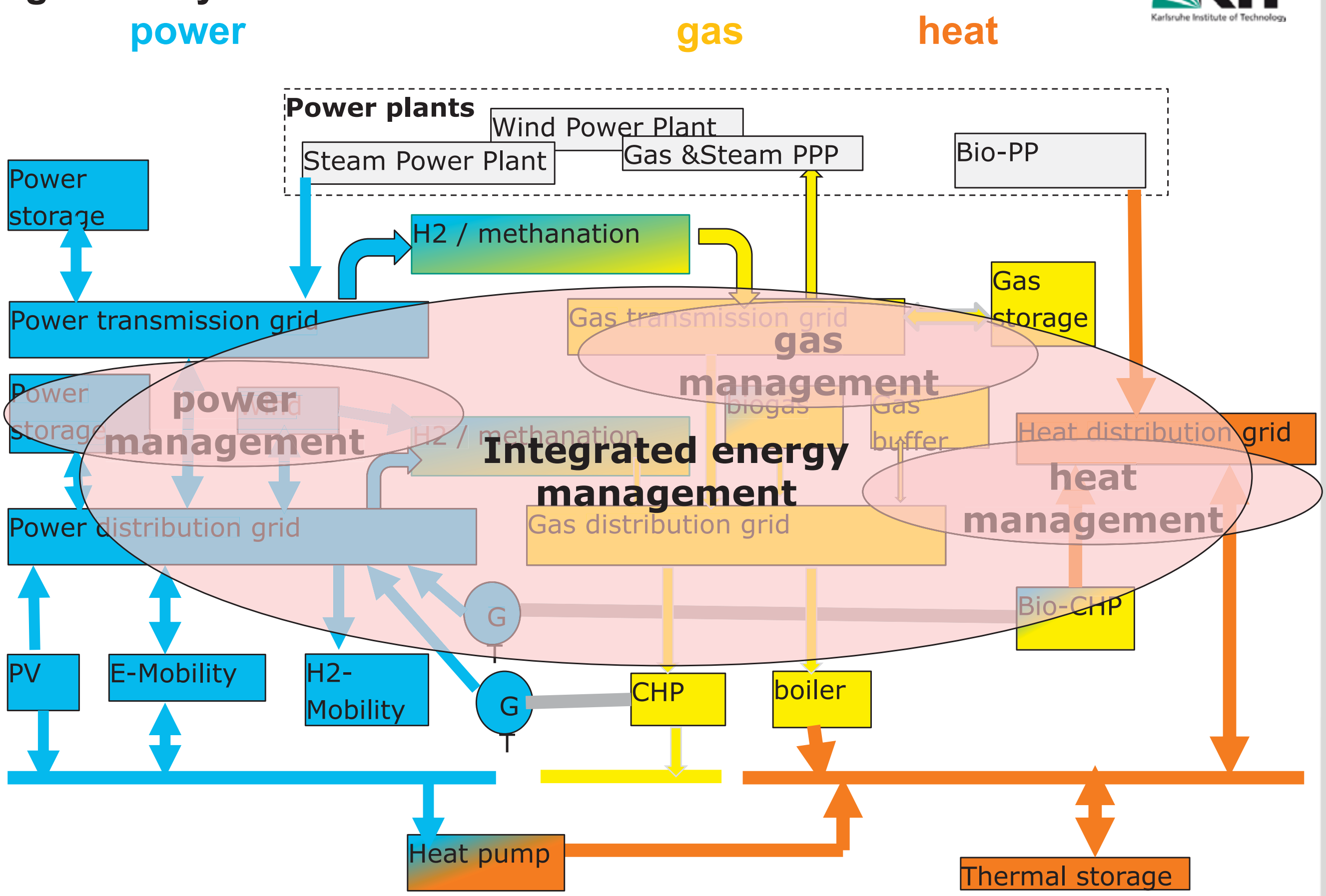


Integrated Future Energy System



Energy flow (electricity)
Information flow
(Energy Information Network with distributed system intelligence)

Integrated Hybrid Grids



Integrated Energy Management Systems

- **Balancing demand and supply** within each grid
- **Energy conversion** in between gas, power, and heat
  - „**real conversion**“ of power to gas
    e.g. by electrolytic methods (H_2) and methanation in order to consume overflow of power supply from wind power plants
  - „**virtual conversion**“ of power to gas in bivalent systems
    e.g. by switching between gas boiler and electric boiler
- **Interoperability** of energy management systems for power, gas, and thermal grids (→ standardized interfaces?)
- **Integrated energy information grid with distributed system intelligence** in order to increase the efficiency, flexibility, and stability of the combined grids.

Tomorrow’s Energy Management

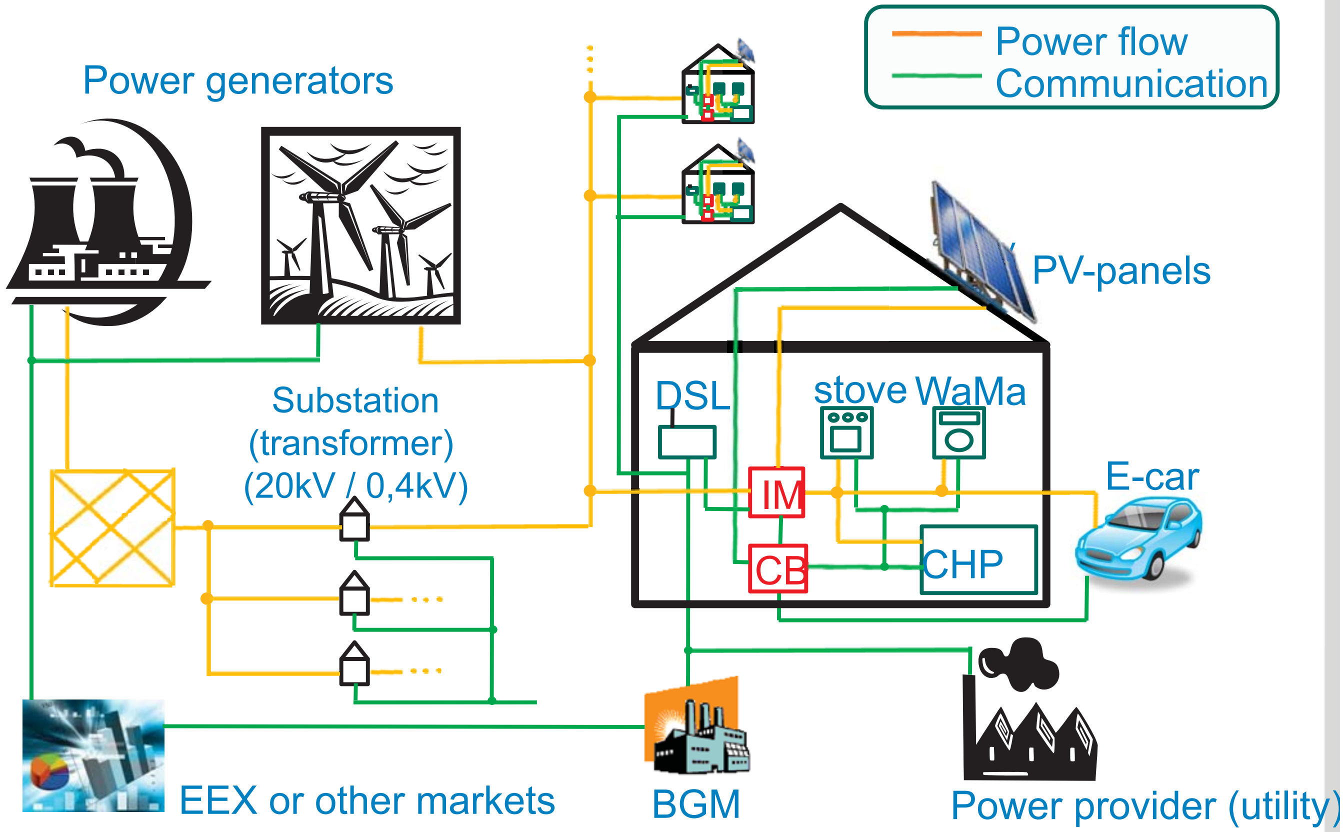
Challenges

- Discover and exploit degrees of freedom and leeway for demand (and supply) management.
- Need for autonomic/organic/MAS energy management without reducing personal comfort or industrial productivity
- Develop new ways of storing (electric) energy
  - Batteries
  - Power to gas to power
  - Virtual storage

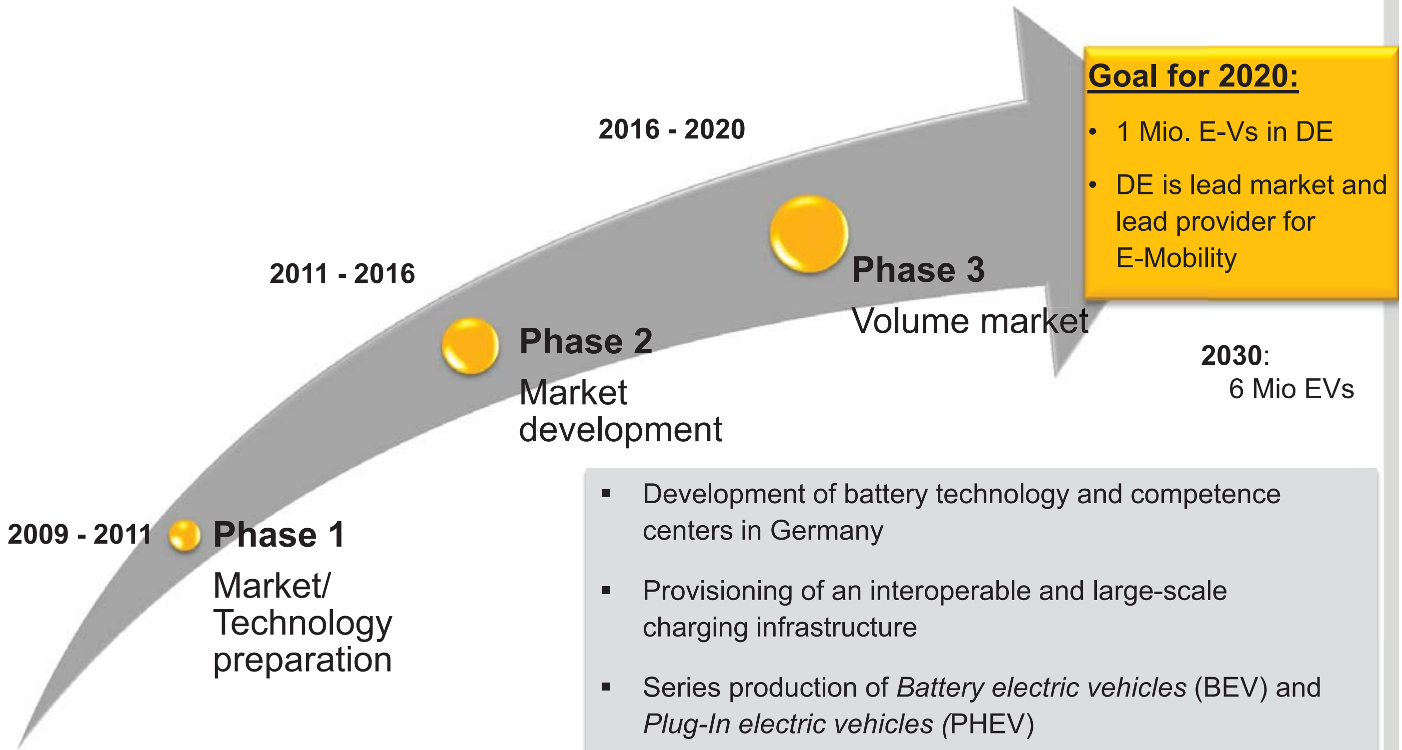
⇒ Strong need for intelligent demand and supply management to increase the reliability of power supply in spite of fluctuating, decentralized and uncontrollable generation of power from renewable sources.

⇒ Strong need for **load flexibility** and **load shifting**

Where should "system intelligence" be located?
What do we have to communicate?



German national development plan for electric mobility

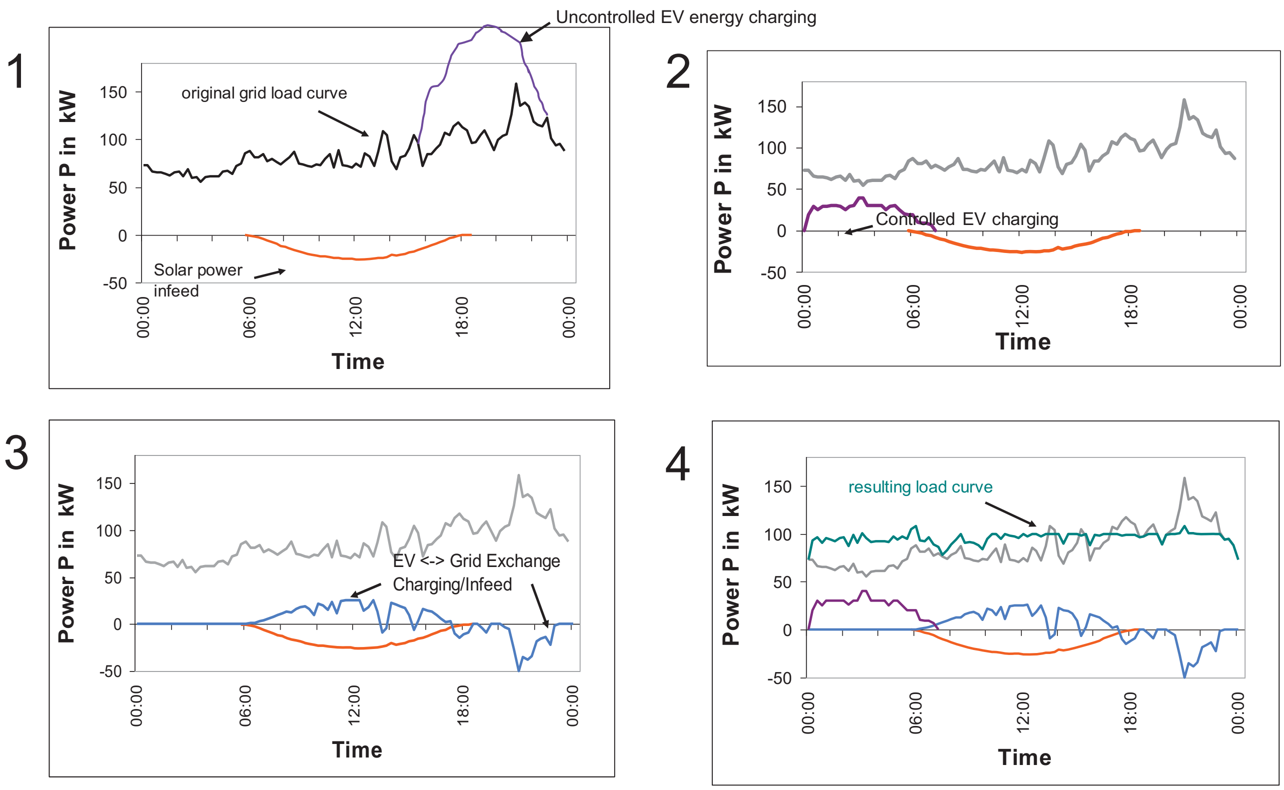


- Development of battery technology and competence centers in Germany
- Provisioning of an interoperable and large-scale charging infrastructure
- Series production of *Battery electric vehicles* (BEV) and *Plug-In electric vehicles* (PHEV)
- Development of business models

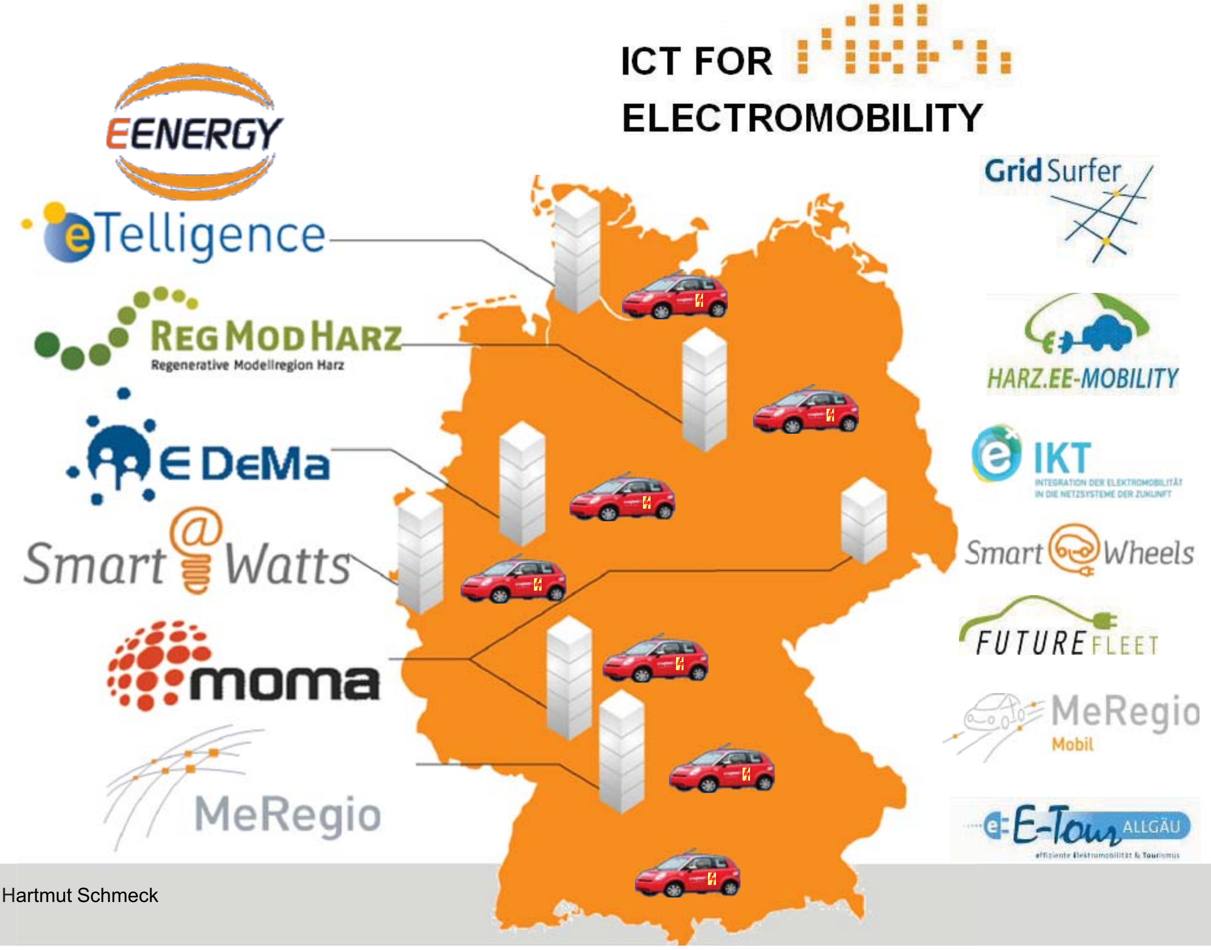
Effects of electric vehicles (EVs) on power grid

- Typical mobility in 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**!
- **Intelligent control leads to high potential for stabilizing the grid.**

Integration Strategies: Load Balancing Potential



Germany's way to an Internet of Energy



MeRegio — Moving towards Minimum Emission Regions

Gefördert durch das Bundesministerium für Wirtschaft und Technologie

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 — EnBW
ABB, IBM, SAP
systemplan ENGINEERING

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

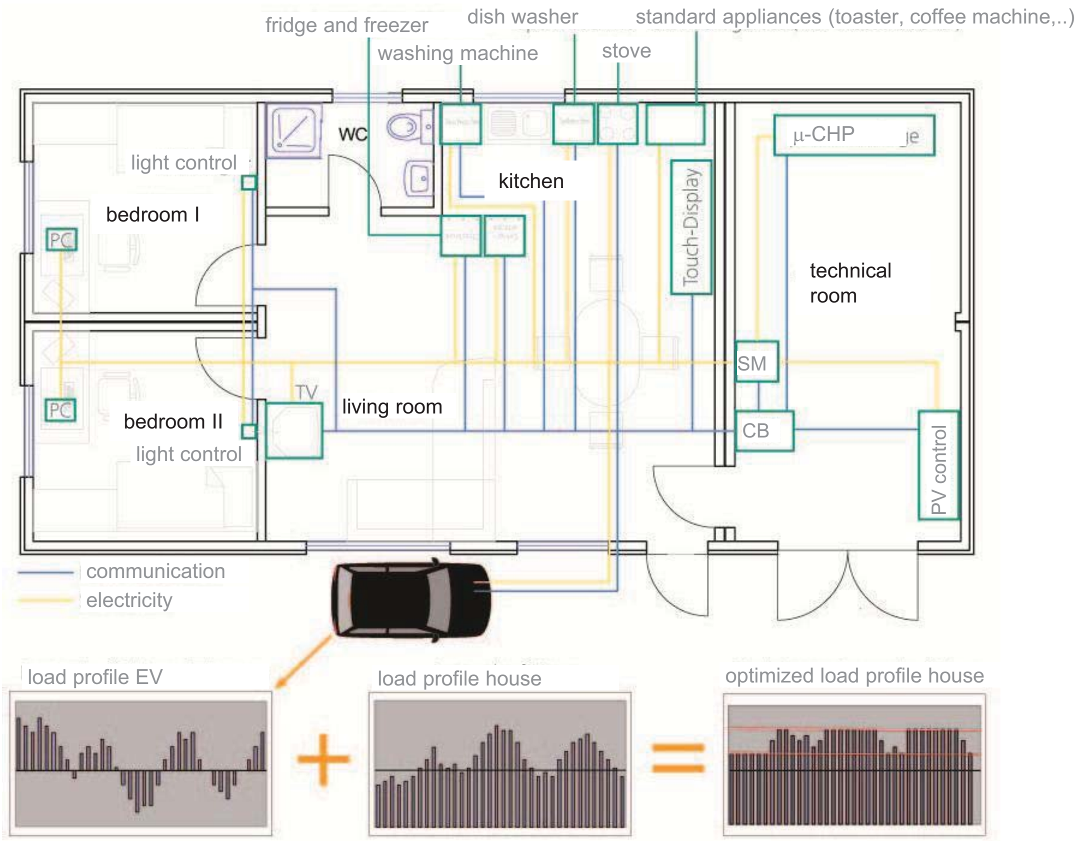
Stadtwerke Karlsruhe, Bosch, SAP

Fraunhofer ISI, Daimler, Opel

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

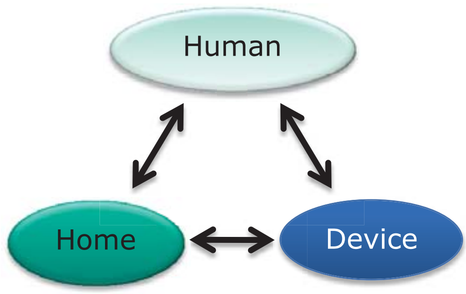
KIT Karlsruhe Institute of Technology

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

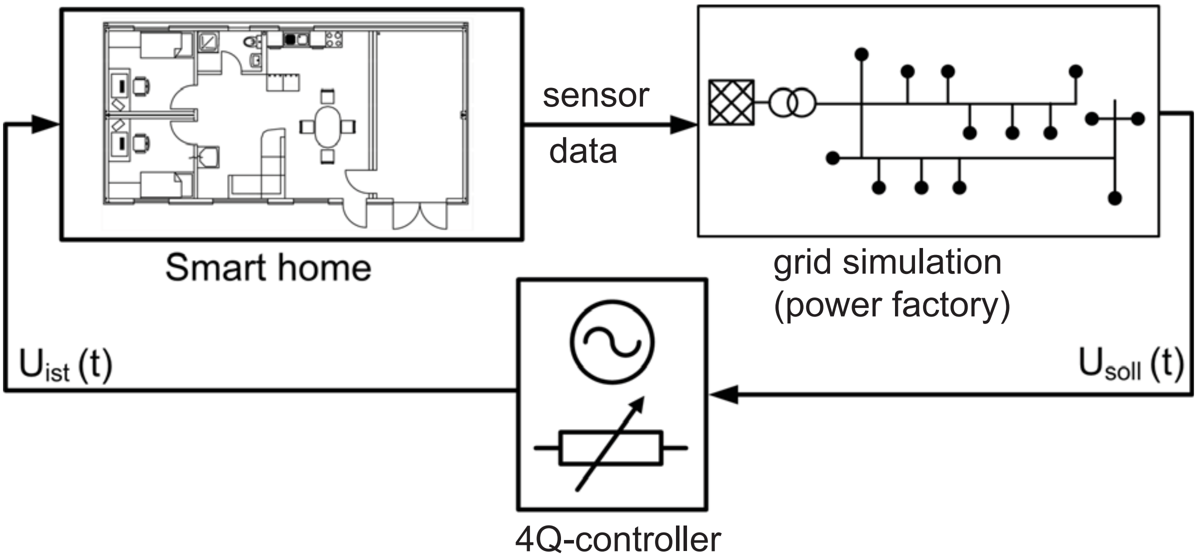


Smart Home Scenario

- **Intelligent appliances**
  - Communicate with central control and with each other.
  - Know (and communicate) their current state.
  - May respond to control.
- **Electric car**
  - Connected to the home as a mobile storage
  - Bidirectional utilization (charging/discharging)
  - Large consumer/supplier
- Decentralized power generation (**PV/CHP**)
- **PCM** elements in ceiling (cooling)
- Simulation component (“**4-Quadrant amplifier**”)
- Reduced but effective interaction between human, home management, and devices
- Discover and exploit degrees of freedom for energy control



Hardware in the Loop Simulation

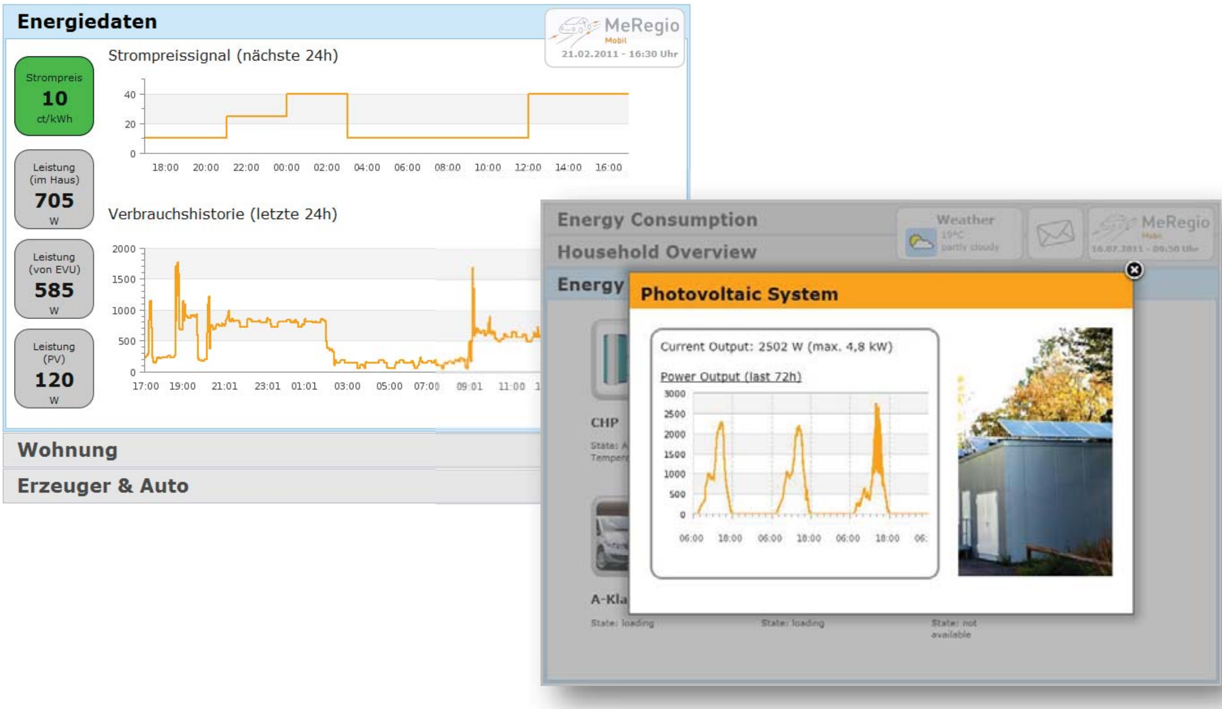


Human – System Interaction: Energy Management Panel

Transparent information on energy consumption

Discover and specify degrees of freedom for use of appliances

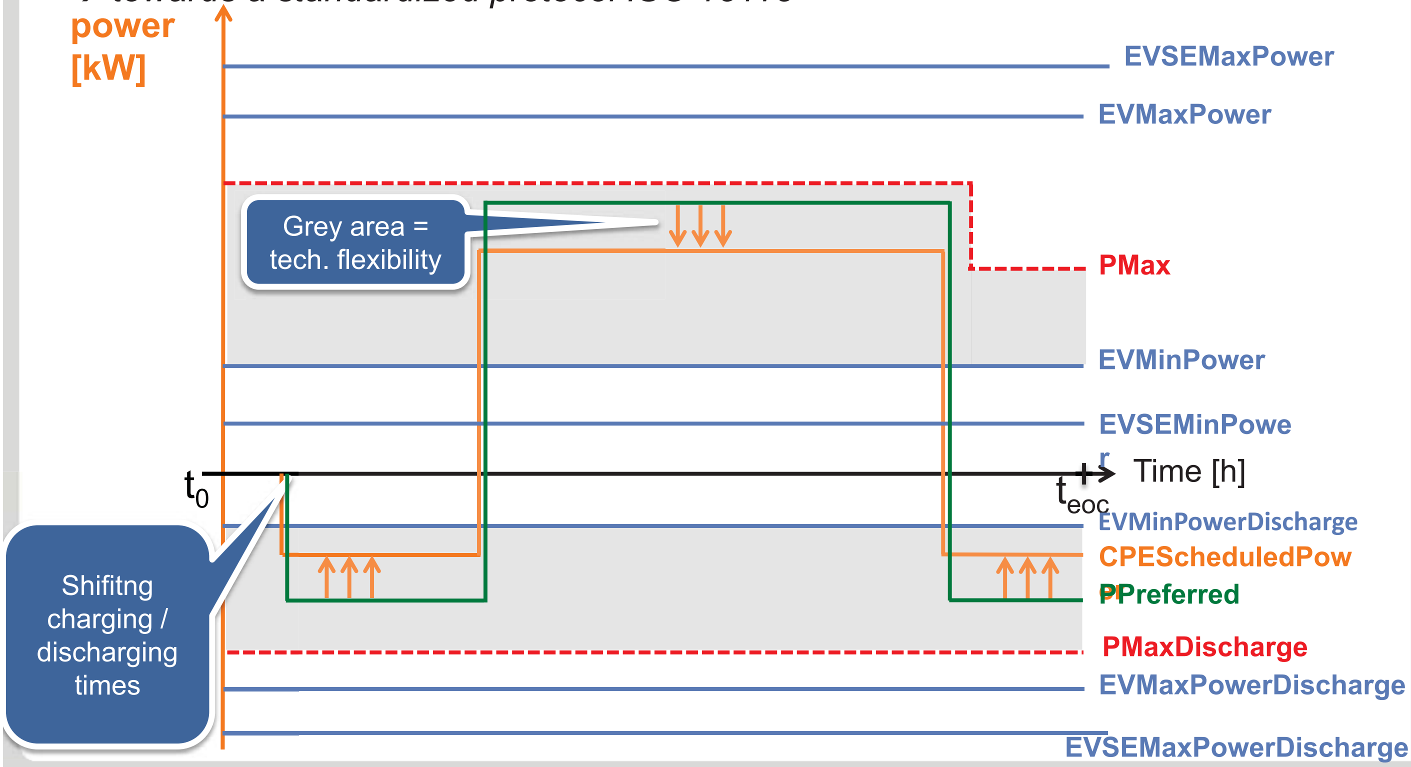
Energy Management Panel – EMP



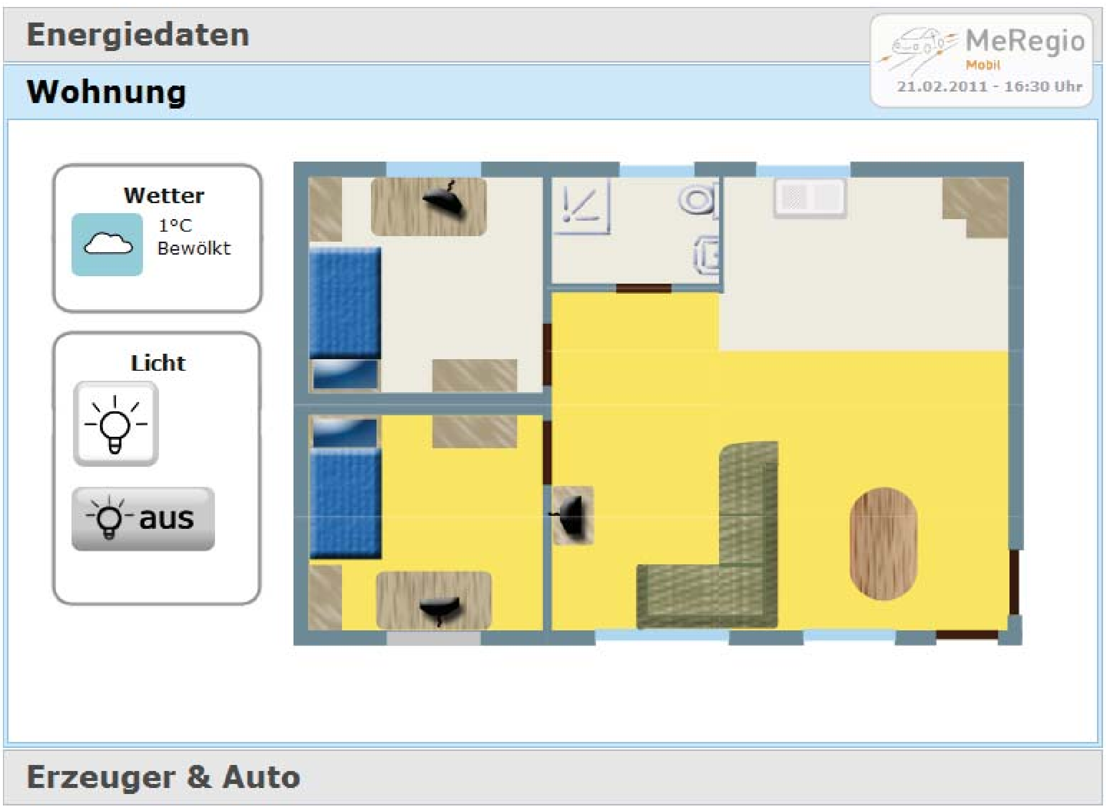
Energy Management Panel

Optimized battery charging for EVs *(Marc Mültin)*

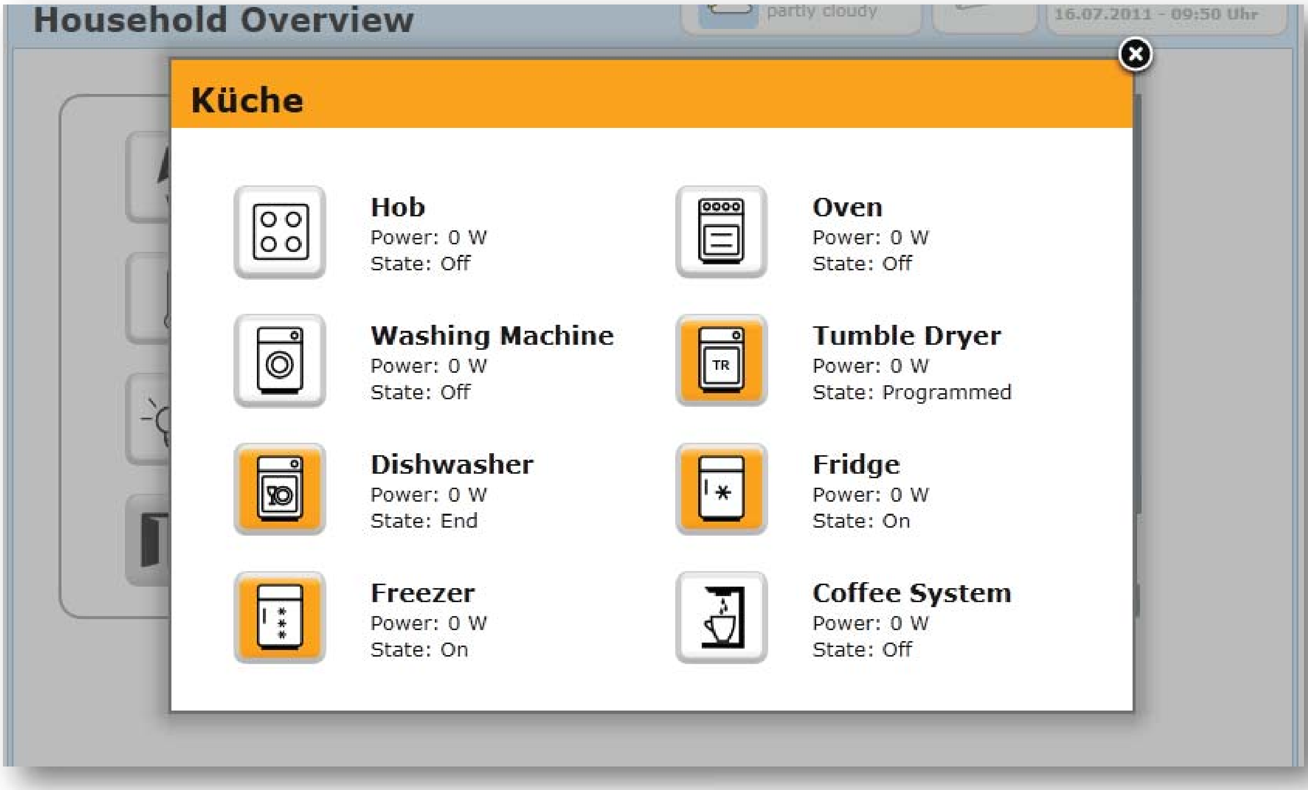
Constrained by power grid, charging station, EV, and user (driver)
→ *towards a standardized protocol ISO 15118*



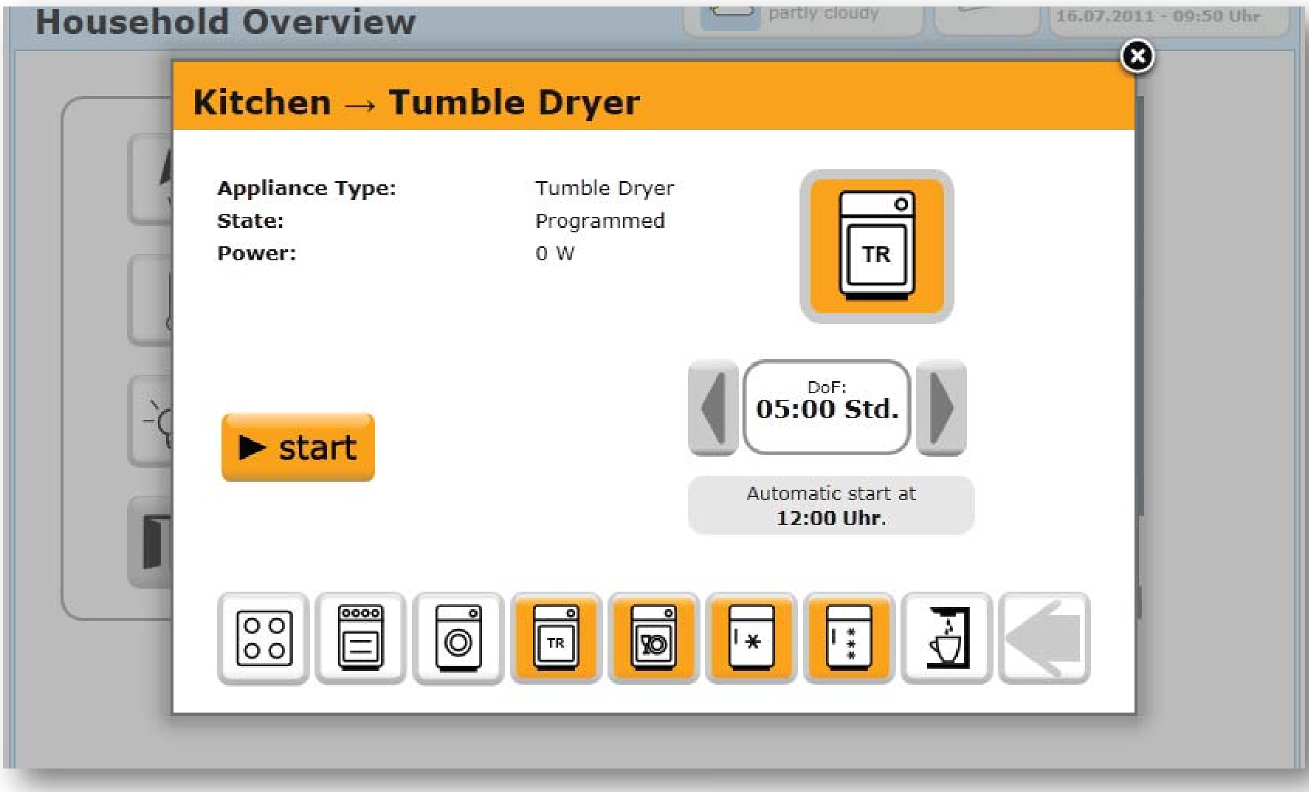
Energy Management Panel



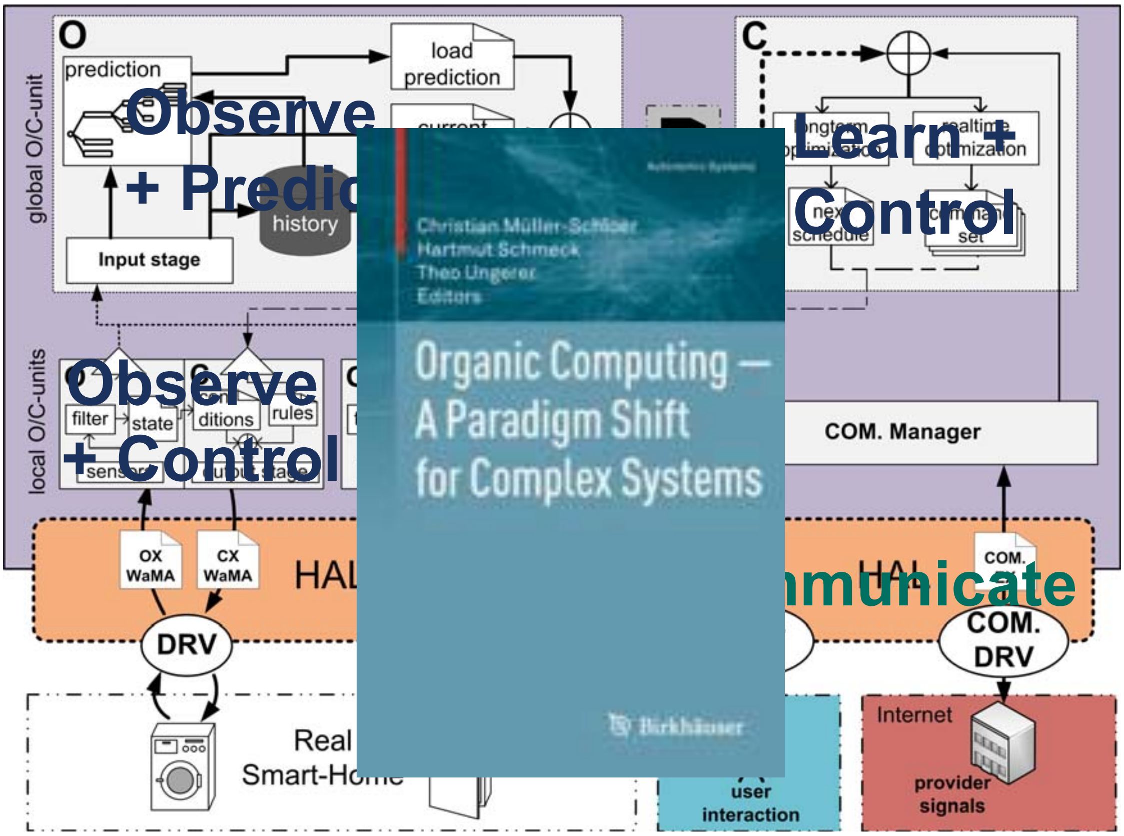
Energy Management Panel



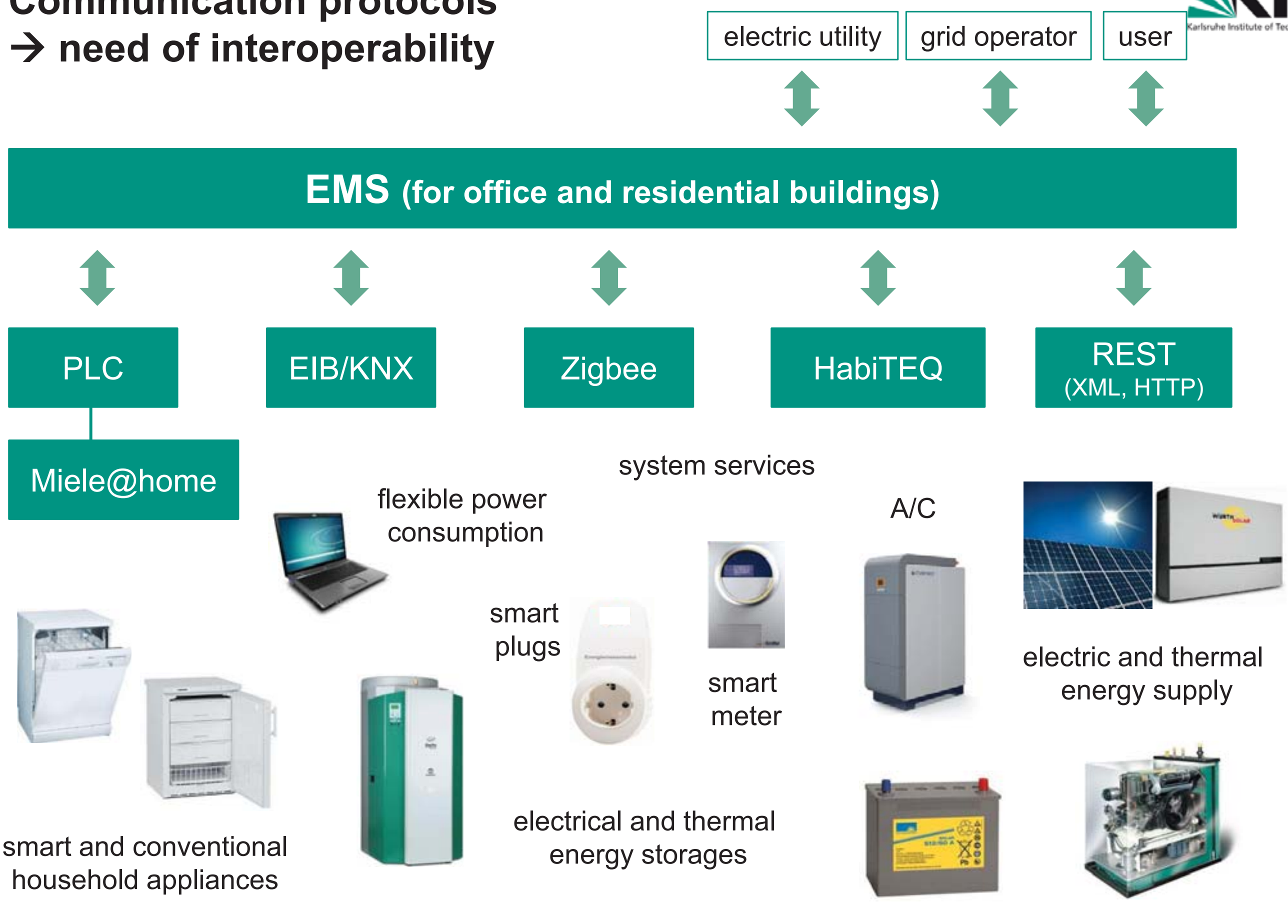
Energy Management Panel



Energy Management System – EMS



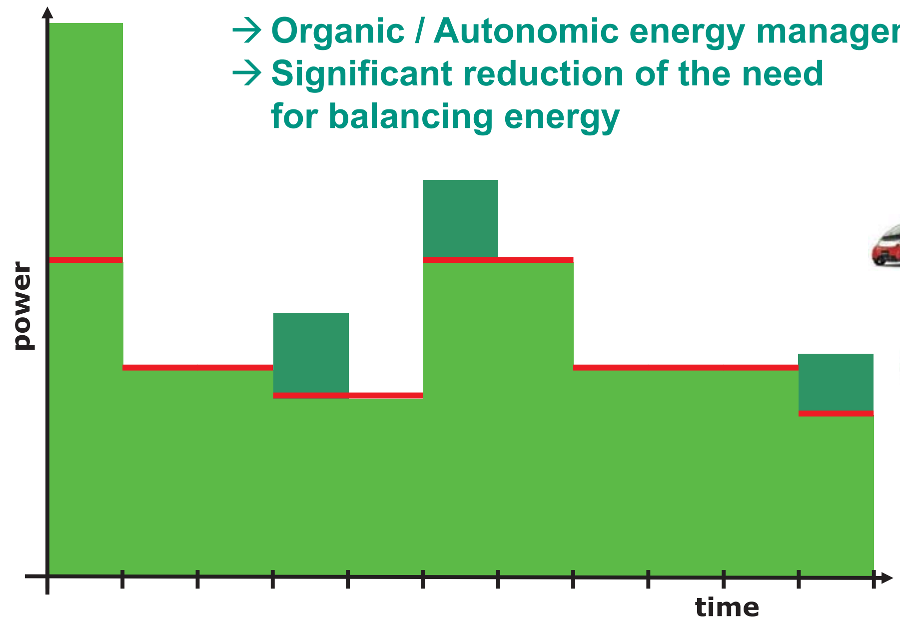
Communication protocols → need of interoperability

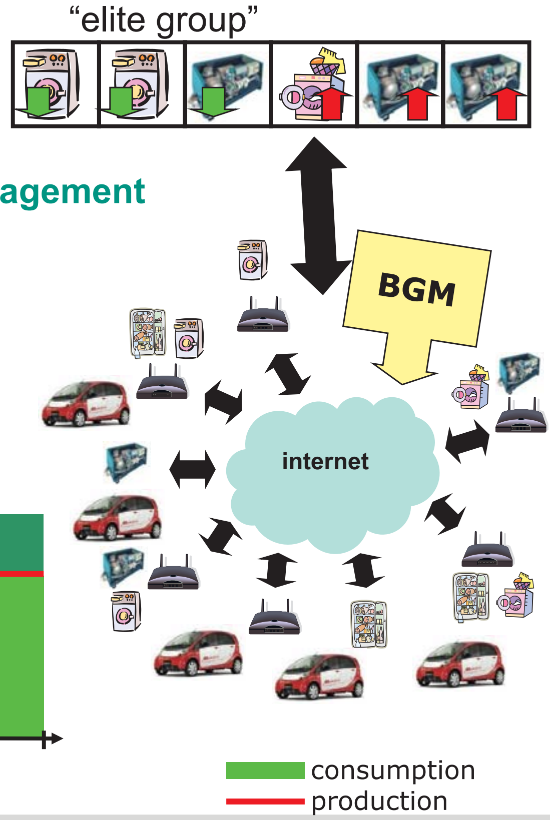


Controlled self-organizing energy management

- Shift imbalances to a later point
- Handle device restrictions decentralised

→ **Organic / Autonomic energy management**
→ **Significant reduction of the need for balancing energy**





Challenges for ICT

- Energy information network with distributed system intelligence
- Design of appropriate distributed architectures
- Observation, prediction, learning of energy load profiles
- MM-Interfaces for discovering degrees of freedom for energy loads
- State estimation and control (appropriate combination of control theory, power engineering, and informatics)
- Design of distributed power system services (controlling active and idle power, phase shifts)
- Distributed optimization under real-time constraints and with reduced data availability (privacy concerns)
- Security and safety issues
- …

Final remarks

- Tomorrow's energy system needs an integrating approach to energy management.
- Essential role of ICT to cope with fluctuation of power supply and large scale decentralization.
- Self-organization of autonomously acting energy agents will be essential, but needs adequate methods to guarantee stability
- Electric vehicles will generate significant capacity for power storage and for flexible demand.
- An "Internet of Energy" will have to cope with similar safety and security problems as the "Internet of Data".

→ Fascinating challenges for ICT, we will have to deliver solutions!

Thanks for your attention!

Questions?

!!!!!!!!!!!CfP!!!!!!!!!!!CfP!!!!!!!!!!!CfP!!!!!!!!!!!CfP!!!!!!!!!!!CfP!!!!!!!!!

Secure Autonomous Electric Power Grids Workshop

http://sites.google.com/site/saepog/

10 September 2012, Lyon, France

Collocated with the **Sixth IEEE International Conference on Self-Adaptive and Self-Organizing Systems (SASO 2012)** (http://saso2012.univ-lyon1.fr)

Important Dates:

Submission of papers and demonstration abstracts: **13 July 2012**

Contact Address

Prof.Dr. Hartmut Schmeck
KIT Campus South
Institute AIFB
76128 Karlsruhe
Germany

hartmut.schmeck@kit.edu
Phone: +49-721 608-44242
Fax: +49-721 608-46581

www.aifb.kit.edu

www.commputation.kit.edu

http://meregio.forschung.kit.edu/english/

http://meregiomobil.forschung.kit.edu/english/

www.fzi.de

www.e-energy.de/en   www.ikt-em.de/en