Energy Informatics - Computer Science for Power and Energy Systems of the Future

Martin Sachenbacher and Martin Leucker

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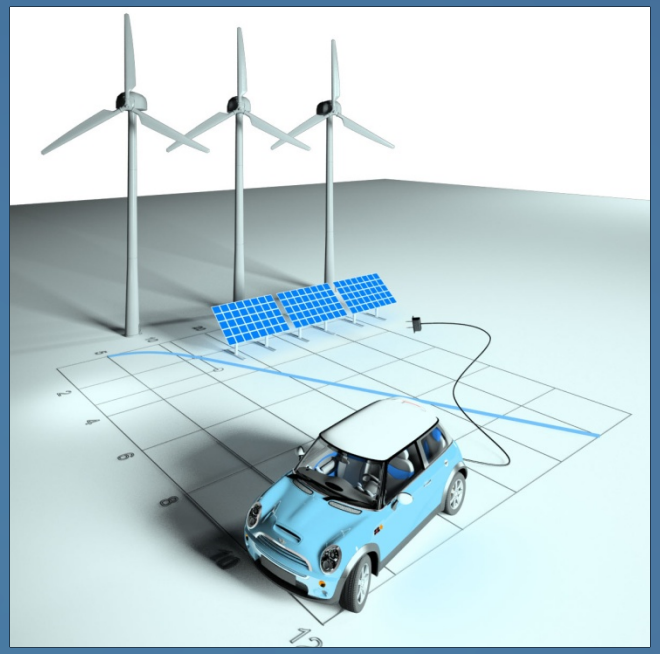


Energy Informatics?

The application and adaption of the large body of achievements in Informatics for addressing the challenges in the Energy Domain.

Reducing energy consumption

- Of buildings - SmartHouses
- Of computer systems – Green IT
- Of (Embedded) Systems

How to reduce energy consumption?

- Analyse and Optimize energy consumption of
  - Buildings,
  - Computers,
  - All kind of systems

  using modeling, analysis, and optimization techniques meanwhile standard in computer science
- Optimize energy consumption using ICT by
  - Monitoring,
  - Diagnosis, and
  - Planning

  Again – with techniques from computer science actually deployed in the final system

Expansion of Renewable Energy: DESERTEC

Expansion of Renewable Energy: Small Producers

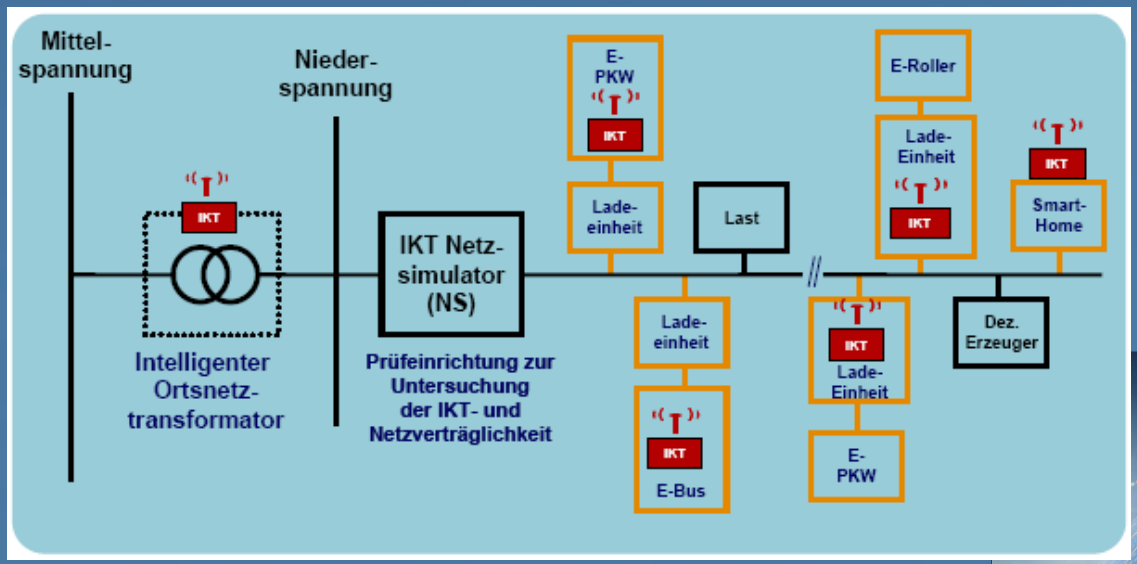
Farmer transforms into an
Energy Farmer managing an Energy Farm

Martin Leucker

Challenge: Renewable Energy Buffering

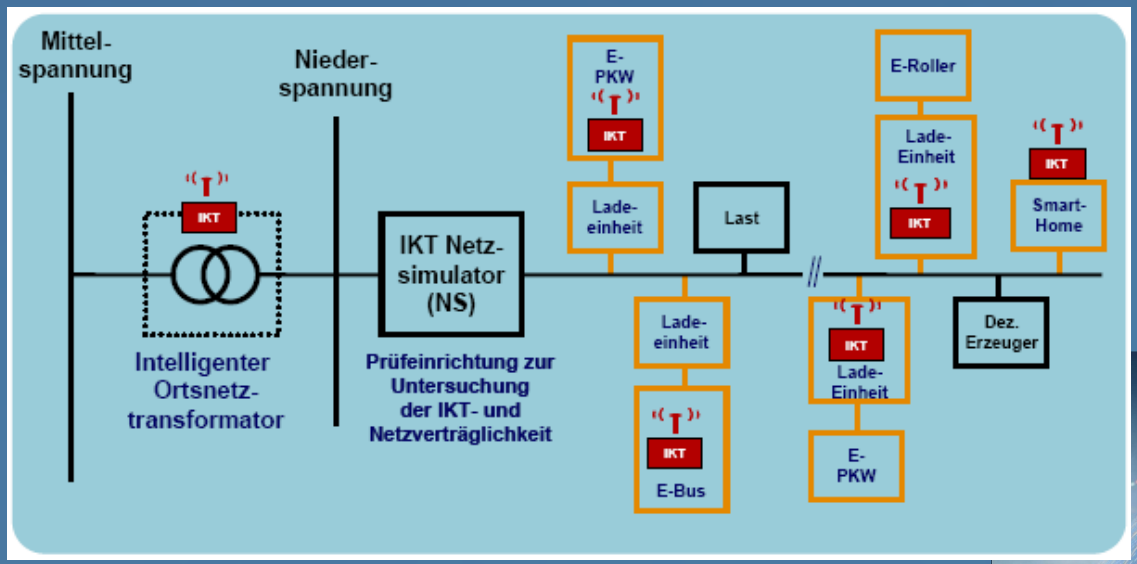
- Energy supply becomes increasingly fluctuating/uncertain due to weather-dependent energy sources (wind and solar power)

Goal: shift peak demands by integrating storage devices in grid to store energy in an optimal manner.



Challenge: Risk Analysis - Trust?

How to model and analyze the reliability of producers?



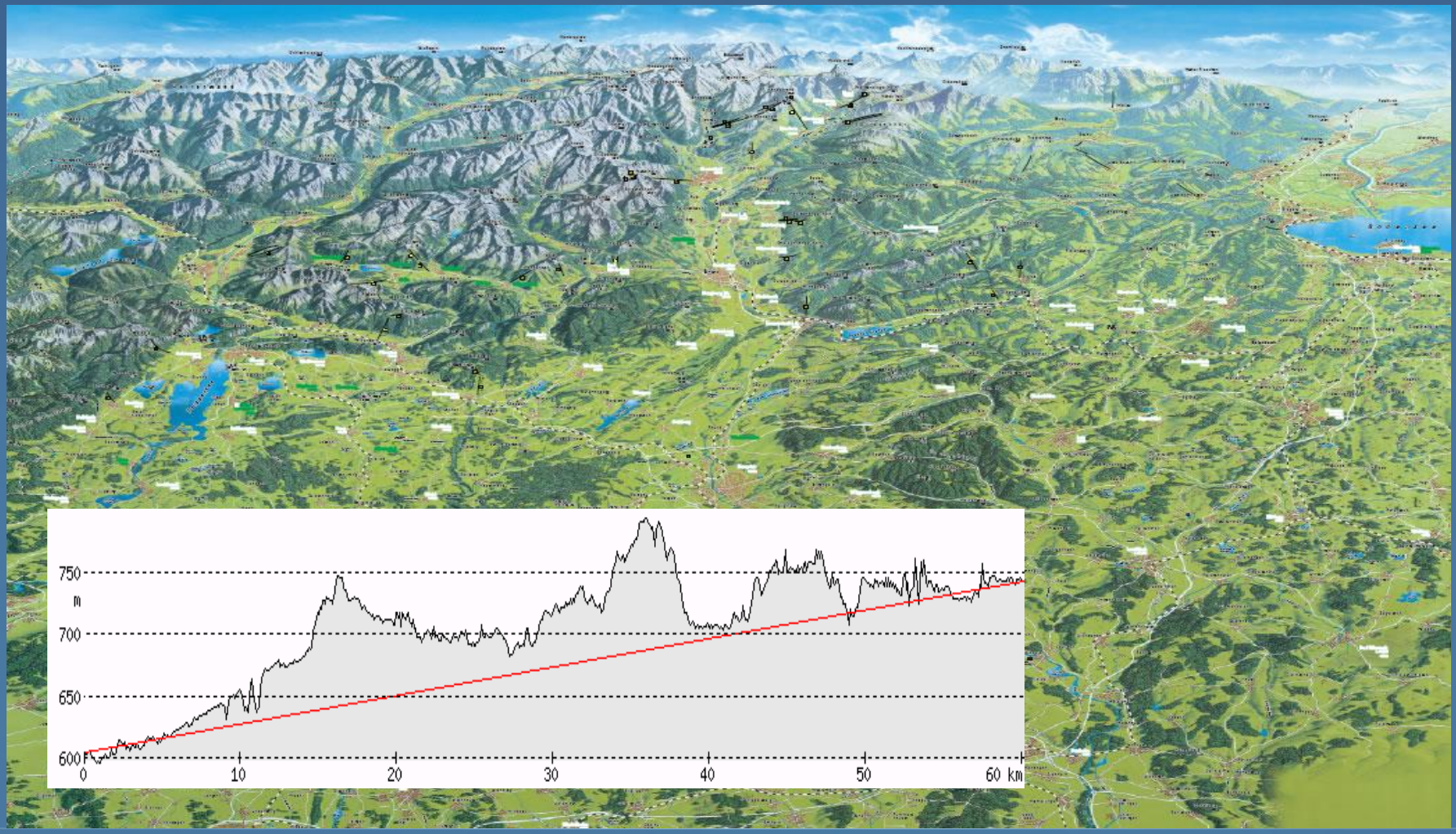
Germany‘s National Electrical Mobility Plan

- Bring one million electrical vehicles (EVs) to the streets by 2020
- Reduce carbon emissions and dependency on fossil resources
- Information & communication technology (ICT) plays major role
  - Demand-oriented power production
  - Supply-oriented power consumption
  - „Prosumers“ buy and sell energy

E-Tour Allgäu Project

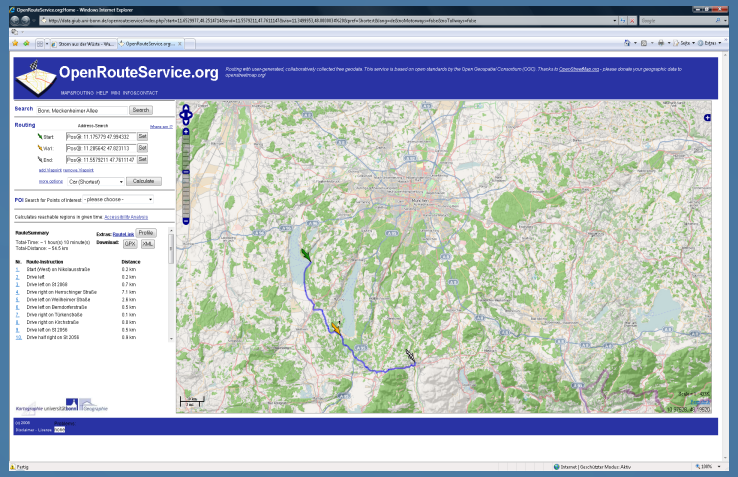
- Show how sustainable electrical transportation using local and renewable energy can be realized in a rural, touristic region
- Diverse fleet of 30 EVs, operated and monitored under typical modes of usage (e.g., commuting to nearby Munich)
- Funding: 5,8 MEuros, duration: 2009-2011

Allgäu Model Region



Challenge: Cruising Range Prediction and Energetic Route Optimization

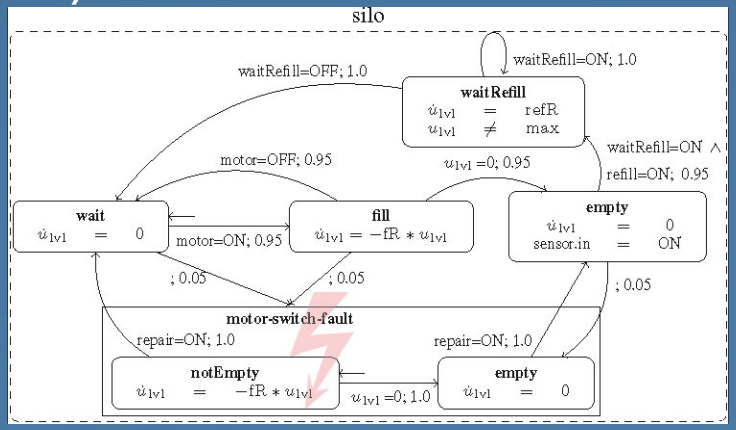
- Limited battery capacity (100-150 km), recharging takes hours
- Goal: accurately predict energy consumption for specific route segments, perform energy-based route optimization
  - Depends on distance and elevation profile, traffic conditions, weather, battery state, vehicle dynamics, driver behavior, etc.
  - Reason from mixed discrete-continuous and stochastic models

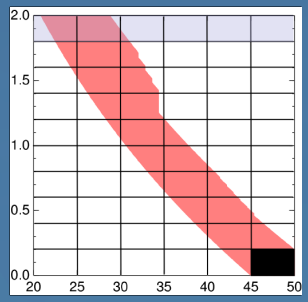


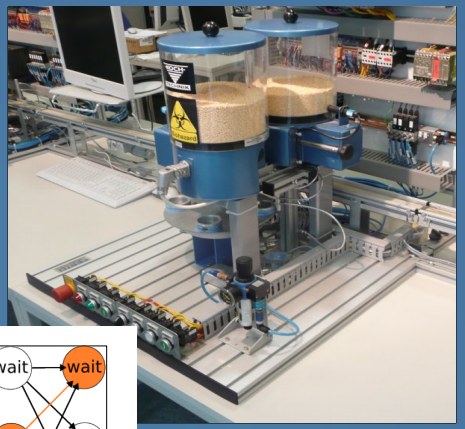
Reasoning with Hybrid Constraint Models

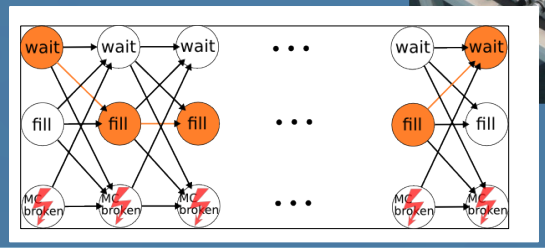
(Maier Sachenbacher CPAIOR 2008, PHM 2009)

- Model discrete-continuous systems with HyPHCA (Hybrid Probabilistic Hierarchical Constraint Automata)
- Discretize continuous part using PHAVer (Polyhedral Hybrid Automaton Verifier)
- Find solutions using constraint solver (Toulbar2, GeCode, …)



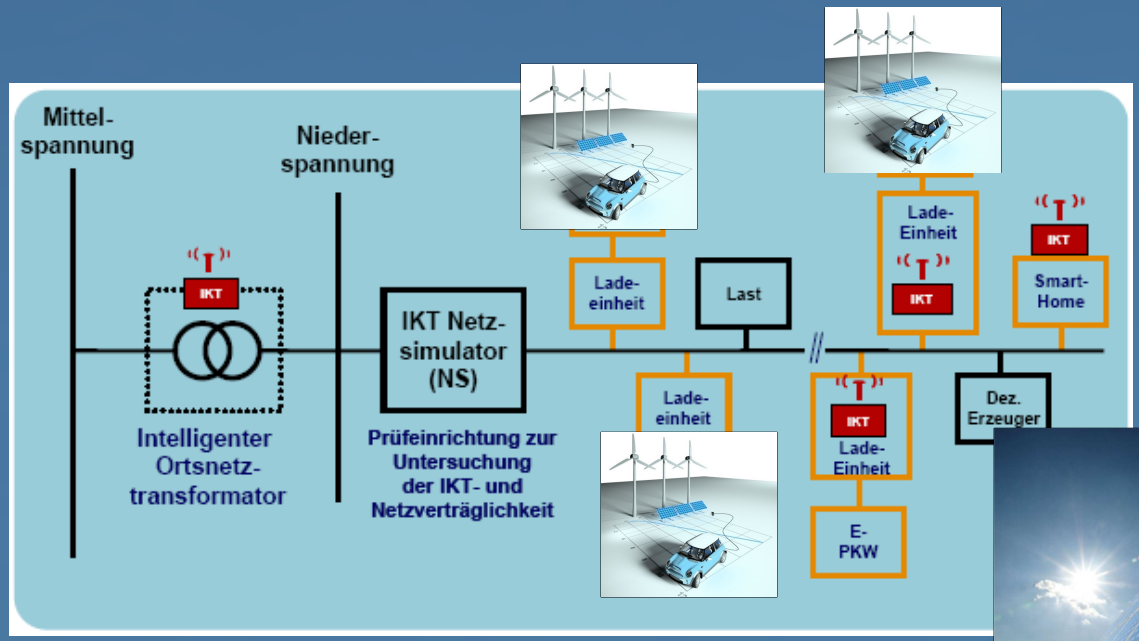






Challenge: Renewable Energy Buffering

- Goal: shift peak demands by integrating Electric Vehicles in the power grid to store energy



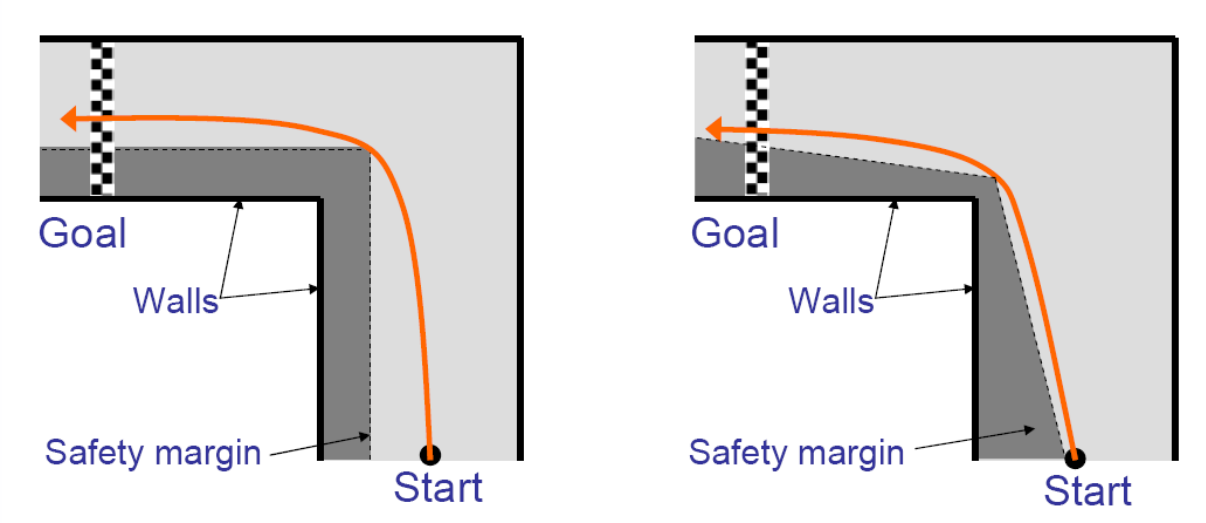
Optimal Energy Buffering under Constraints on Probability of Failure

- Goal: Maximize storage effectiveness, while minimizing mobility risk
  - Given model of physical battery behavior and stochastic model of human car usage (when will the car be driven)
  - Compute control strategy that maximizes effectiveness of energy buffering, but keeps mobility risk (possibility that user cannot drive car because of insufficient charge) below a certain threshold

- Promising approach: Iterative risk allocation for model-predictive control with a joint chance constraint (Ono Williams AAAI 2008)
  - Finds control strategy that maximizes expected performance in dynamic system with uncertainty, while constraining that probability of failure is below an upper bound (pfail < 0.01)

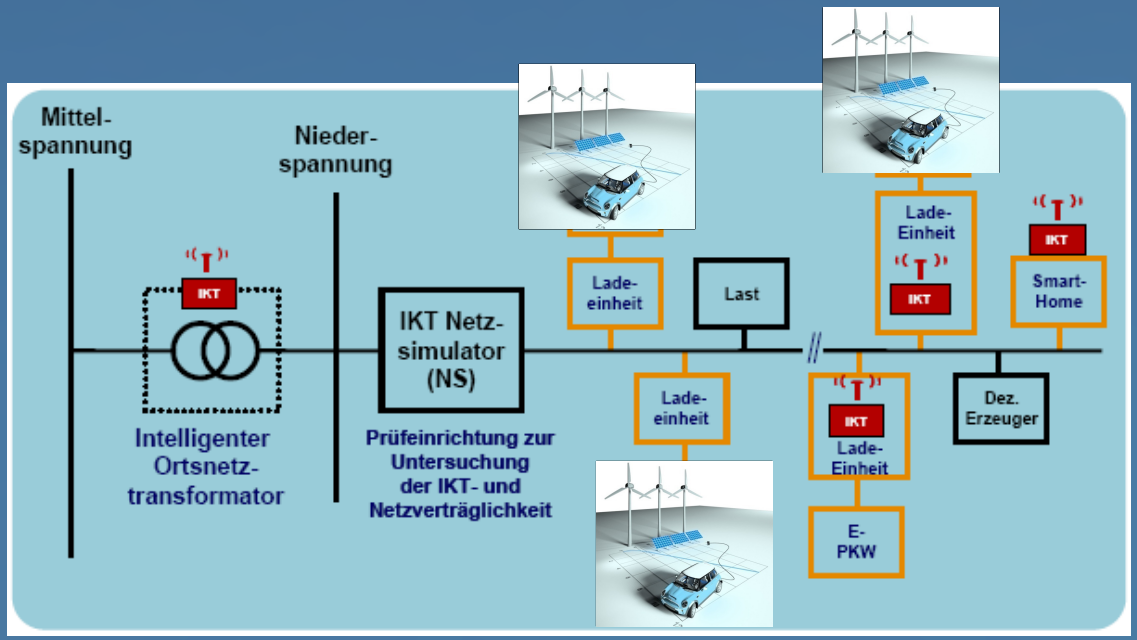
Iterative Risk Allocation (Ono Williams AAAI 2008)

- Dynamic system x(t+1) = Ax(t) + But with uncertainty (disturbance, …)
- Find u1 … ut with probabilistic guarantee pfail < 0.01 (chance constraint)
- Iterative algorithm:
  - compute best control strategy using current risk allocation
  - decrease/increase risk where constraint is inactive/active

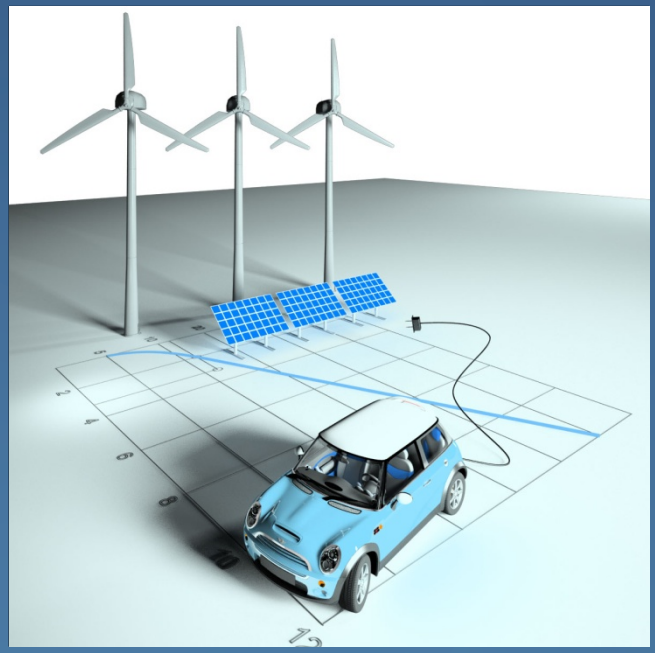


Challenge: Fully automatic markets

The Electric Vehicle has to sell and buy energy automatically – on a dynamically changing market place



Conclusions



Some challenges of the energy domain

- Reducing energy consumption
- Energy Production
  - Volatile renewable energy production
  - Large number semi-trustable energy producers
- Shift towards Electro mobile vehicles

- ICT can help to address these challenges by using
  - *Modeling*
  - *Analysis, and*
  - *Optimization*