Current and future challenges of the electricity supply system:

Economic analyses in the context of Smart Grids

PhD results presentation

Natalie Prüggler

PhD Seminar, SS 2013
Klagenfurt, 10.-11.04.2013

Outline

- **Motivation**
- **Economic research areas & papers**
- **Presentation of papers**
  - **Research question**
  - **Methodology**
  - **Main results & lessons learnt**

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Motivation$_1$: **Drivers**

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- Upcoming **challenges in the electricity supply system due to**:
  - Climate change, CO_2 emissions and its negative effects on health and environment *(UN (2009))*
  - Shortage in conventional resources, especially oil & natural gas *(IEA (2010));* nuclear phase-out
  - Continuously rising energy/ electricity demand *(EC (2009))*
  - Old generation infrastructure, high decommissioning rates *(Kjärstad, Johnsson (2007))*
  - Awareness of import dependencies *(e.g. EEA (2010))*
- Therefore, increased penetration of **electricity produced by renewable sources** (wind, solar, small-scale hydro, biomass, etc.) *(e.g. Haas et al. (2011))*

Motivation$_1$: Drivers

- **Properties of electricity** *(Erdmann, Zweifel (2006))***:**
  - Electricity flows, is hardly storable, immediately needs to be delivered
  - Production corresponding to demand
  - Distribution over mashed electricity grids
  - Generation and transmission capacities need to meet peak demand at any point in time
- **Renewable electricity generation:**
  - Often distributed, far from densely populated areas, connected to remote grid areas
  - Wind & solar needs to be balanced to guarantee security of supply, especially in periods of low demand

Motivation$_2$: <u>**Grid challenges**</u>

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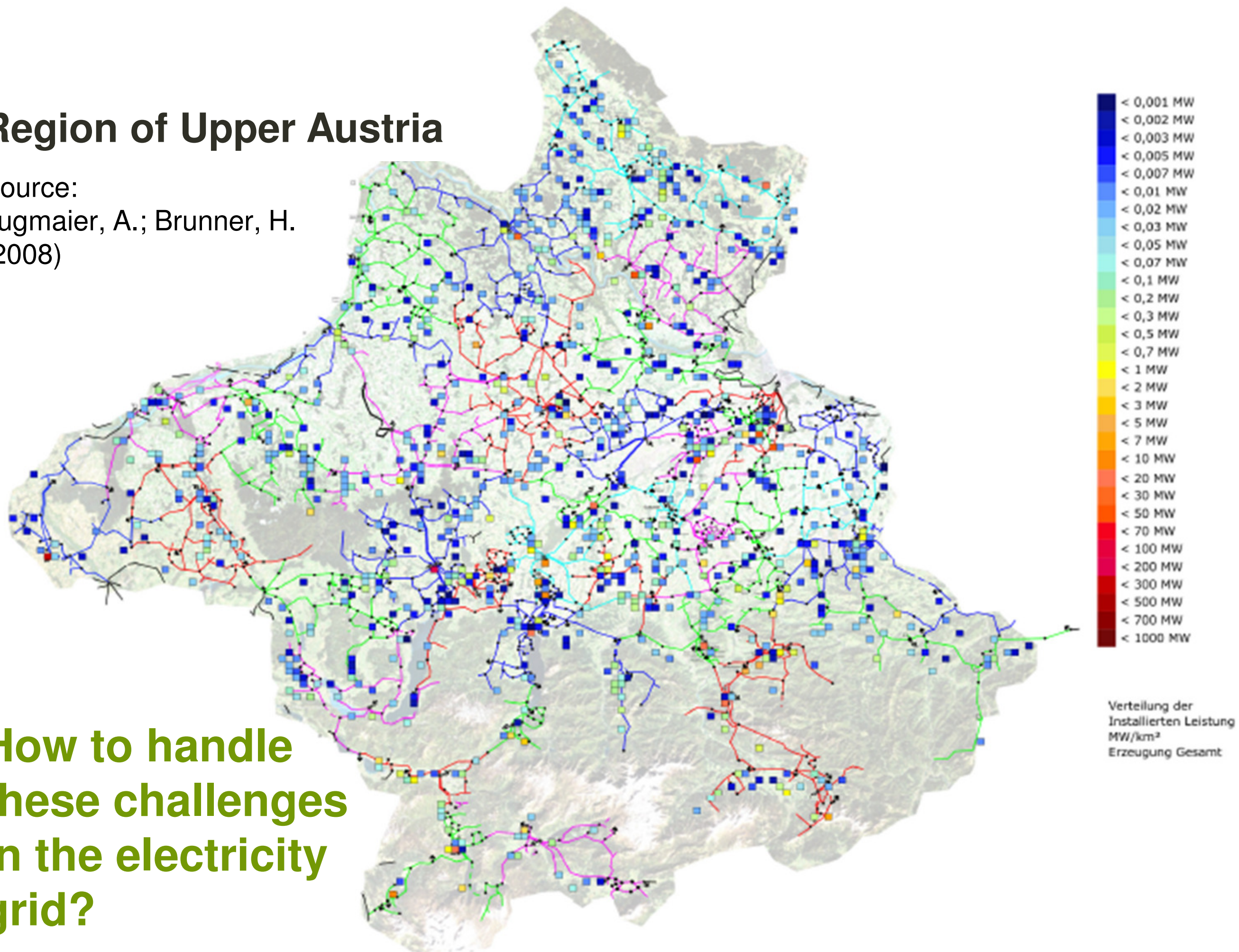
Region of Upper Austria

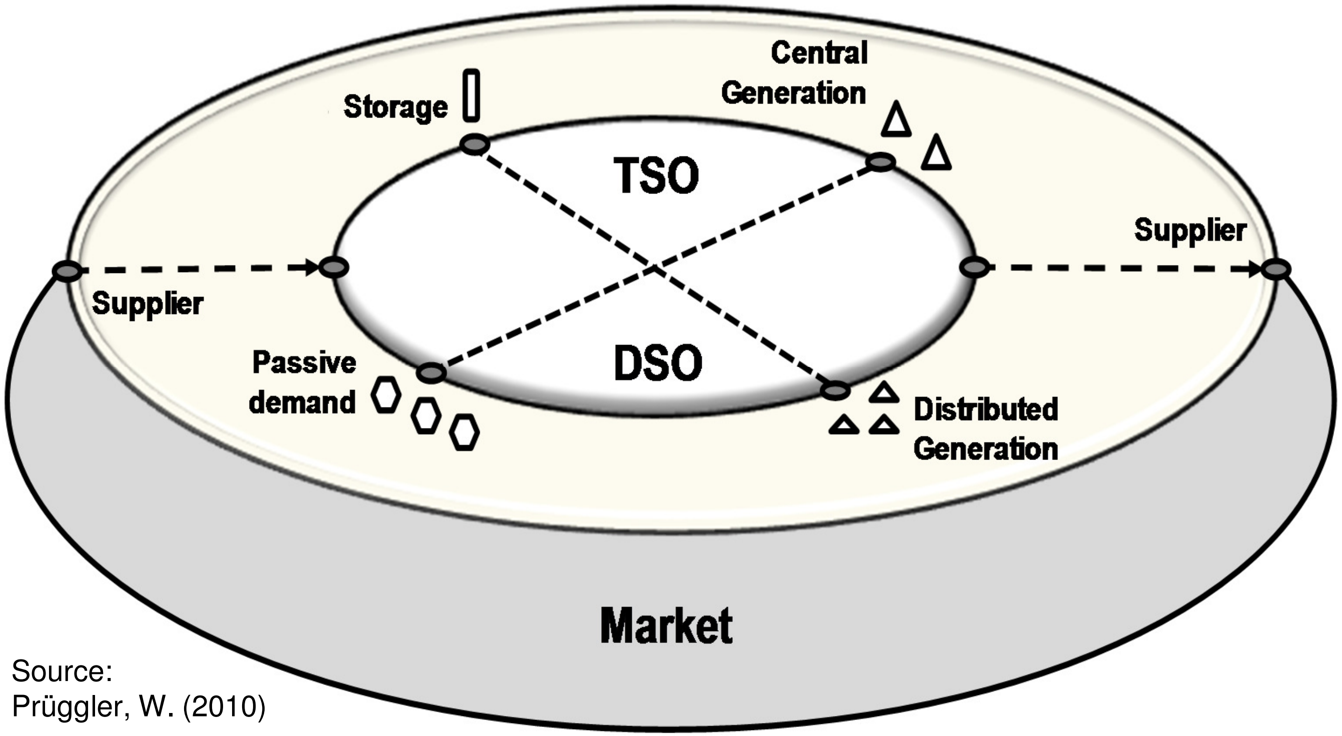
Source:
Lugmaier, A.; Brunner, H.
(2008)



How to handle these challenges in the electricity grid?

Motivation$_3$: **Possible solution**

- Change from the passive system, …



Source:
Prüggler, W. (2010)

Motivation$_3$: Possible solution

- … to an intelligent system, which makes the active participation of players, innovative grid operation, smart applications and alternative market options feasible: A **Smart Grid**.

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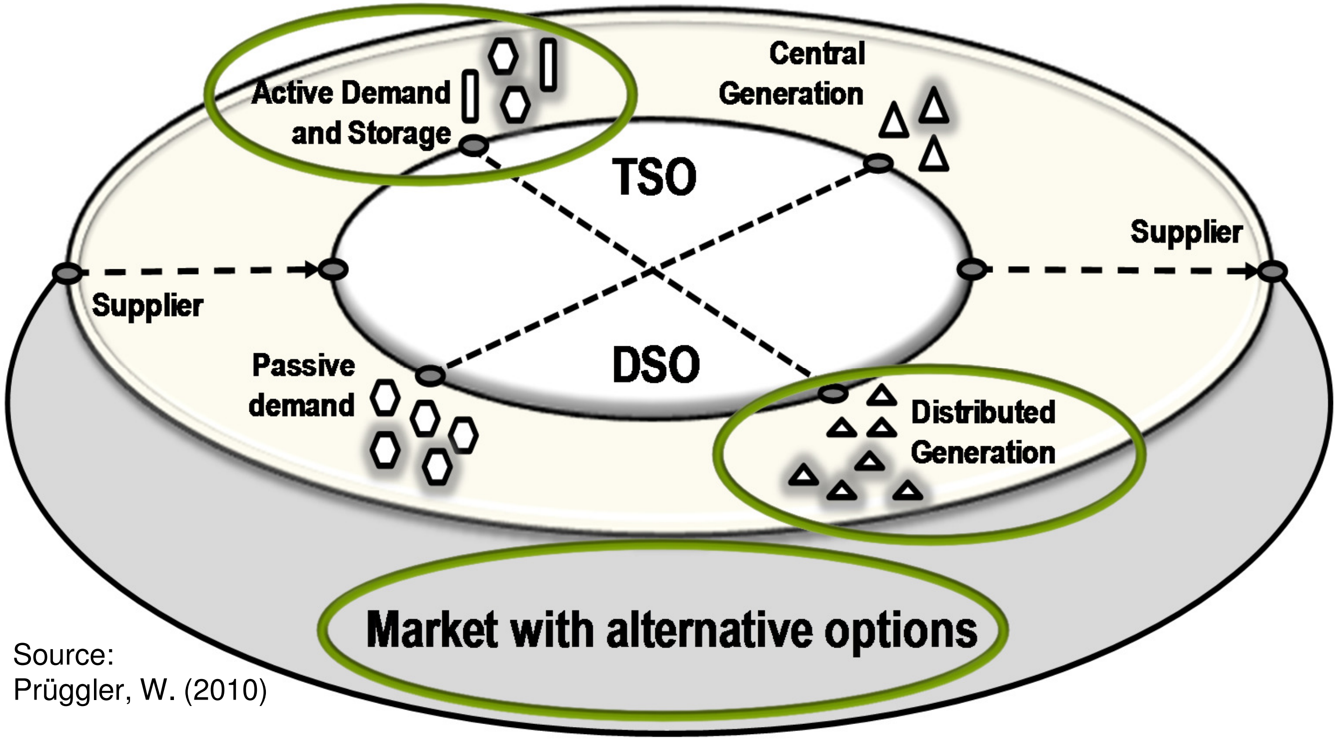

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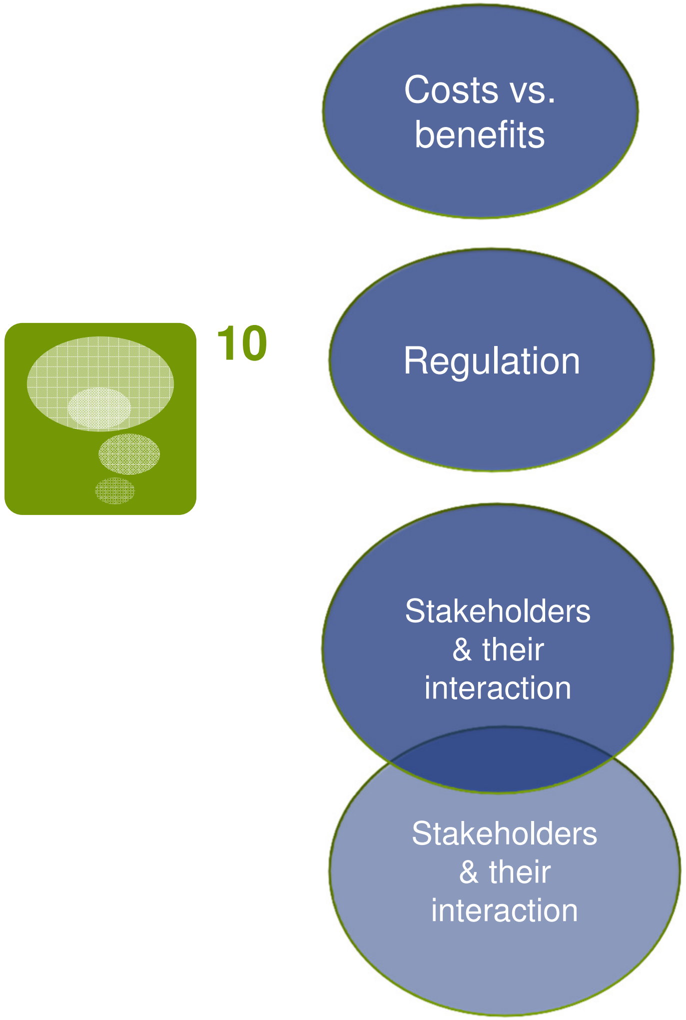
Economic research areas & papers



- Paper 1: **A Cost-based approach to evaluate future grid structure options.** Prüggler; DER Journal, 8 / 1 (2012)
- Paper 2: **Grid regulation in Austria: smart grids incentives or disincentives?** Prüggler, Bremberger; e&i 10/2011
- Paper 3: **Storage and Demand Side Management as power generator's strategic instruments to influence demand and prices.** Prüggler, Prüggler, Wirl; Energy 36 (2011)
- Paper 4: **Economic potential of Demand Response at household level – Are Central-European market conditions sufficient?** Prüggler; under review @ Energy Policy

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Costs vs. benefits

Paper 1: Question

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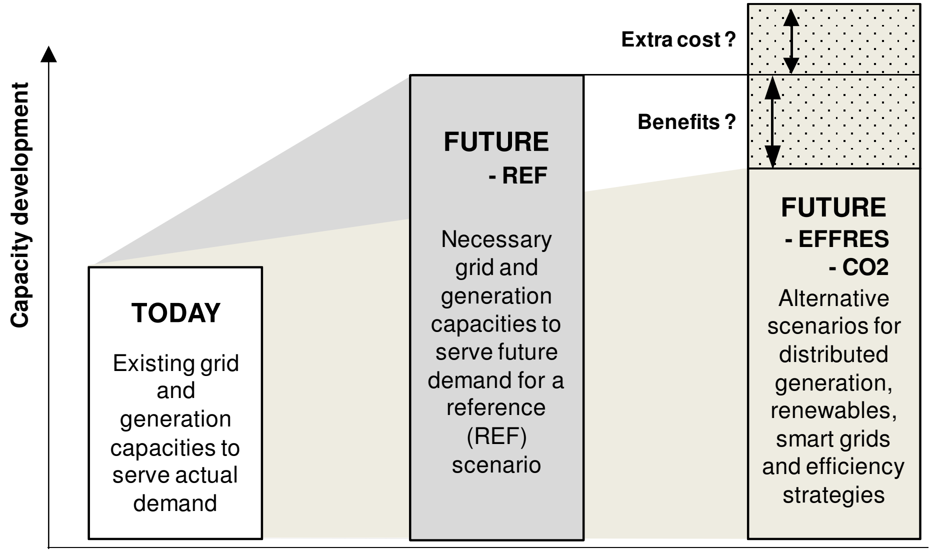
Which scenarios of the grid structure (as e.g. Smart Grid) in Austria are possible or necessary dependent on different generation mixes and how does their level of costs look like compared to a reference scenario?



Source:
Prüggler, W. (2010)

Paper 1: Methodology

- Identification of possible solutions (technical scope): ***„Active distribution grid“***; state-of-the art voltage control methods → might be less capital-intensive
- Different generation scenarios until 2050
- Calculation/ derivation of
  - generation capacity costs per technology
  - Import capacity cost
  - Future grid investments: Reference (REF) vs. ‚Smart‘ Scenario
- Derivation of cost indicator **to make costs comparable & summable** → all costs per **MW of cumulated installed capacity** in each year

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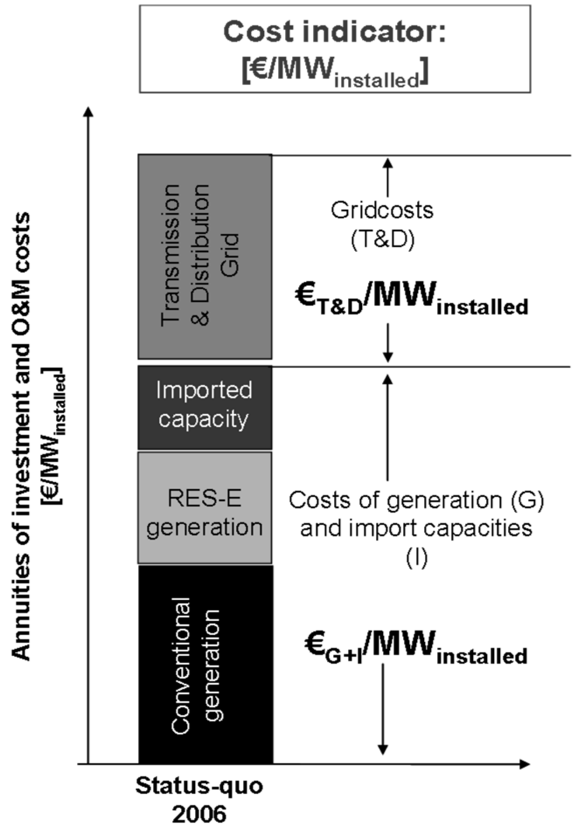


Own depiction.

Paper 1: Results

- The level of the resulting additional grid costs compared to the resulting annual costs for generation or import capacities is **low** and **do not have exceptional weight** if considering the whole electricity supply system
- Highest cost impact in overall system:
  - **Renewable capacities** (not considering technological learning)
  - **Import capacities** → high effect, if no additional efficiency and/or peak load shifting measure successfully implemented

Regulation

Paper 2: Question

- Conventional grid enhancement vs. ‚active distribution grids‘ → if less costly → should be reflected in **lower grid tariffs** for consumers
- Grid operators = **natural monopolies** → respective incentives in regulation needed, s.t. they
  - Choose most cost-efficient grid infrastructure investment *(Joskow, Tirole (2005))*
  - Participate in & contribute to innovation processes *(Bauknecht (2011))*

Is the current regulatory regime in Austria able to provide sufficient incentives for distribution grid operators to invest in innovative grid structure options, especially, if this requires less capital-intensive investments?

Paper 2: Methodology

- Detailed analysis of incentive mechanism:
  - **(Kind-of) price-cap mechanism → cost reduction path**
  - **Analysis of carry-over mechanism:**
    - Allows grid operators to retain 50% of extraordinary cost savings as additional profits
  - **Identification of Rate-of-Return element:**
    - Allowed interest on invested capital dependent on asset base, which is in turn dependent on
      - → asset base (t-1) and
      - → new investements (t) – depreciation (t)
  - **Discussion of power of mechanism to incentivice less capital-intensive grid options:**
    - Based on the assumption of the information-asymmetry-problem *(Joskow (2005)):*
      - → Private information of grid operator about true capital costs
      - → **bargained WACC > WACC on market** (different risk structure)

Paper 2: Results

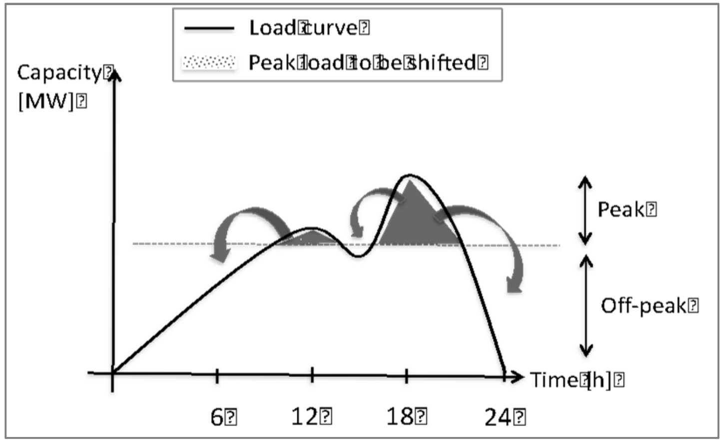
- Less capital needed → to be invested elsewhere (market; generation technology; ...)
  - If assumption holds → grid operator needs to be compensated for ‚**loss in interest**‘ by regulation to create adequate incentives

- **In current regulatory regime:**
  - Cost pressure only until cost reduction path
  - „Power“ of carry-over mechanism: Giving away 50% of cost savings = sufficient incentive? → case study analyses necessary
  - Rate-of-return element (Averch-Johnson-effect/ „gold-plating“)
  - No innovation incentives „per se“ existing
  - Alternative grid options in demonstration status → development of real costs (OPEX vs. CAPEX) still not clear

Paper 3: Question

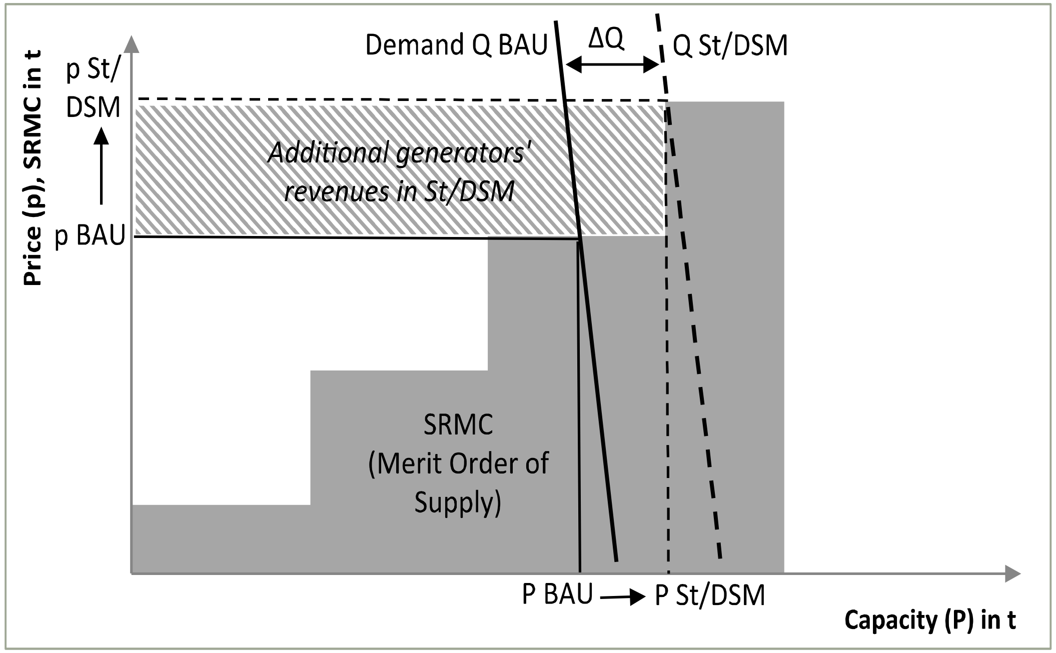
- Developments in electricity supply system:
  - Role of storage (compare known gaming practices, *e.g. Green, Newbery (1992))*
  - Role of Demand Side Management (DSM)
  - Role of new actors, e.g. ‚aggregators', who aggregate consumers' load or generation

Whether and to what extent can a non-regulated power generation company with a dominant share of generation capacity influence hourly demand and prices by strategically applying either storage technologies or automated DSM?



Own depiction.

Paper 3: Methodology



Own depiction.

- **Case study application – Ontario, CA – descrete price jumps:**
  - Dominant power generator (70% generation)
  - Data from Ontario electricity market
  - xls model

Paper 3: Results

- **Formal framework**:
  - Results: → Storage: **yes**, → DSM restrictions: **no**
- **Ontario application**:
  - Results: → storage and DSM: **yes**

- Assumptions of perfect forecast – however, these results are feasible without sophisticated optimization
- Ontario = transparent market, DMS strictly regulated (not duty of generators)
- In general, as long as DSM = “load shifting” programms (within allowed hours): might be easy for utilities to hide such behaviour
- Willigness of consumers to participate is required
- Results show there is potential for misuse → could lead to higher prices, higher electricity bills for customers
- **Market surveillance & regulation needed!** (countries in fledgling stages of DSM, storage, etc.)

Stakeholders & their interaction

Paper 4: Question

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- DSM ... shifting household (HH) loads with intelligent applications

Source: Verbund, NTP Aggregator WS, 25.01.2012

- **Does it really pay?**
- For suppliers/ aggregators and of course consumers?

Examine potential monetary benefits vs. costs of the (automated) DR case:

Spot-market oriented load aggregation and shifting under Central European market conditions

Stakeholders
& their
interaction

Paper 4: Question

Consumers‘ willingness to pay:

- Willingness to pay for Energy Management System:

  → **max. 4 EUR/month accepted** (*MoMa (2012)*)

  – Expected cost savings from dynamic pricing programs (*Paetz et al (2012)*)

    → **65-120 EUR/year of participation**
    → **already accounting for needed investments**

Cost of technical infrastructure:

- Investment cost: **ca. 1000 EUR** (*Meisl et al. (2012)*)

Paper 4: Methodology

- Perspective of supplier/ aggregator:
  - Buy electricity as cheap as possible for as many of his household (HH) customers as possible

  - to shift loads of aggregated customers
    - → from a particular number of hours with highest prices
    - → to hours with lowest prices each day
    - → seize peak - offpeak price spreads

- Case study with
  - Austrian electricity market data
  - **3 HH**- ; **1 heat pump**-load profile; **1 e-car**-charging profile

Paper 4: Results

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- Results for realistic level of load shifting potential (2% load shifting/hour and 12 activated hours/day):
  - **HH cost savings:**
    - *< 1 EUR/year* (6.5 EUR/year @ 15%)
  - **Heat pump cost savings:**
    - ***4.4 EUR/year*** **(33 EUR/year @ 15%)**
    - ***110 EUR/year*** **(@ 50%)**

- Results of best observed case (10 years lifetime, i = 2 and 12 hours of activation/day):
  - **HH NPV:** *8 EUR (2%), 58 EUR (15% load shifting)*
  - **Heat pump NPV:**
    39 EUR (2%), 295 EUR (15%), **985 EUR (50%)**

- **At Central-European market conditions general potential for broad implementation of DR mechanisms as demonstrated is restricted to significant loads.**

- **From the economic point of view Central European market conditions are not sufficient to make DR at household level beneficial, except the application to heat pumps**

Thank you for your attention!

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