Value and granularity of ICT and smart meter data in demand response systems

Workshop, Dauphine University Paris

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UNI FREIBURG

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Renewable Energies as instrument of environmental sustainability

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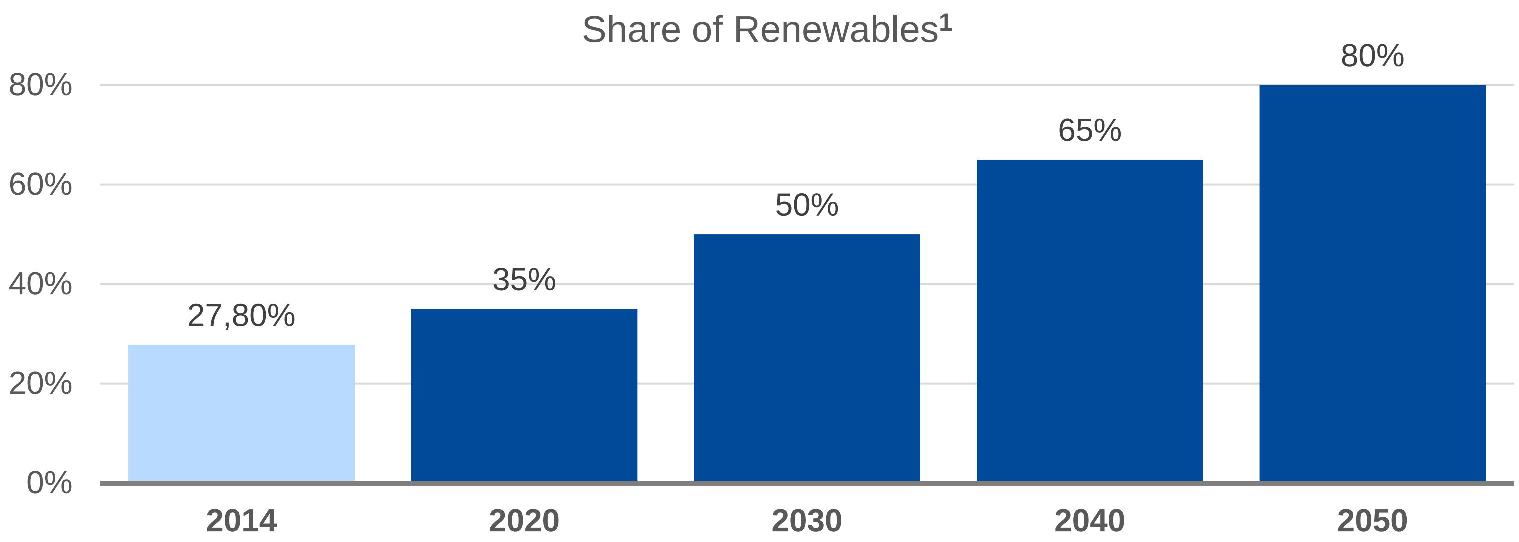
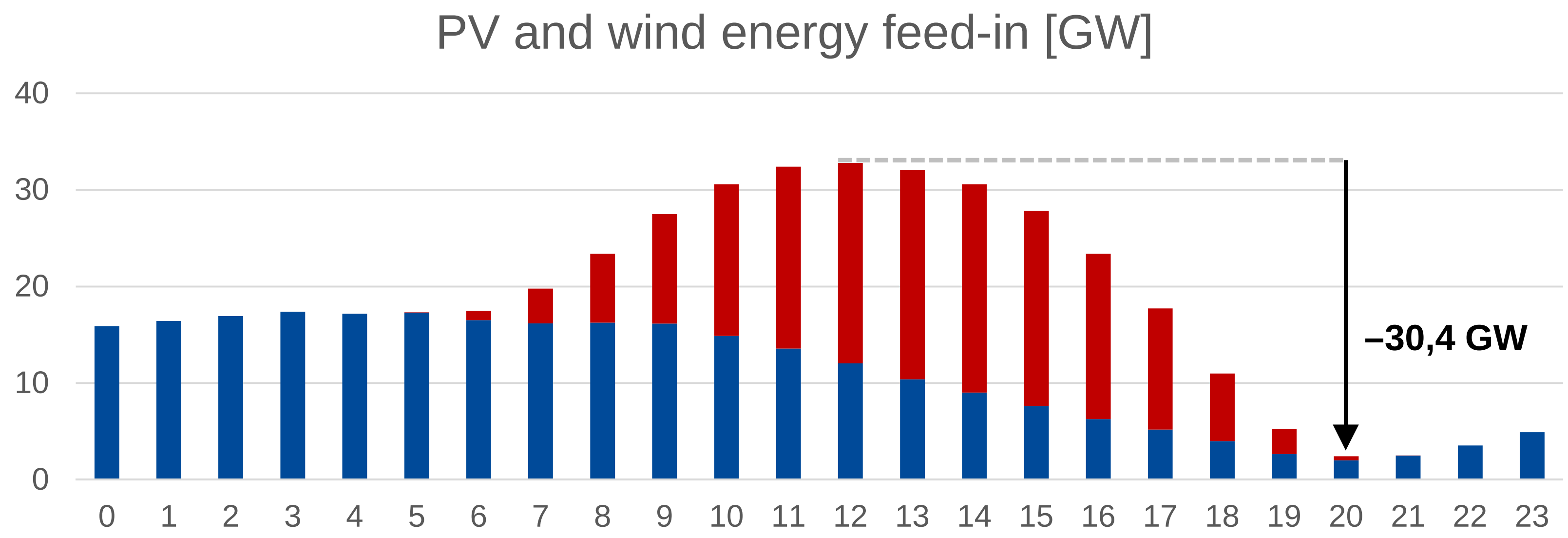
- Environmental sustainability has been identified as a prioritized societal goal
- Europe has set targets for renewables to make up 20% of the total electricity generation by the year 2020
- USA planned 26% less greenhouse gas emissions by the year 2025 **(Pre-Trump Era)**
- **Germany[1] is planning 35% of renewables by the year 2035** and 65% by the year 2050



Challenges of Integrating Renewables into the electricity system

Challenges

- Physical constraints apply as „Demand = Supply“ for maintaining network stability
- Demand and Generation do not necessarily match
- **High fluctuation in the generation** may compromise network stability

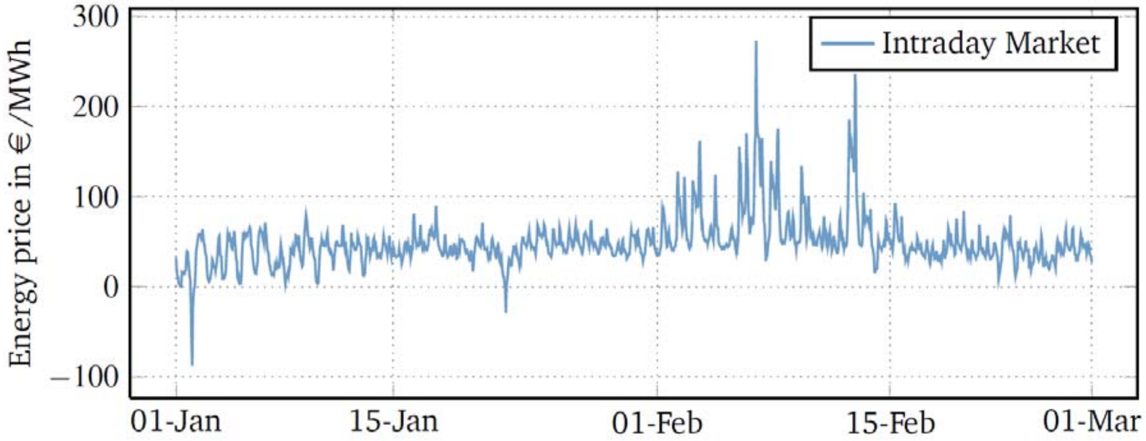


1. EEX Transparency, Daten für 10. Mai 2015

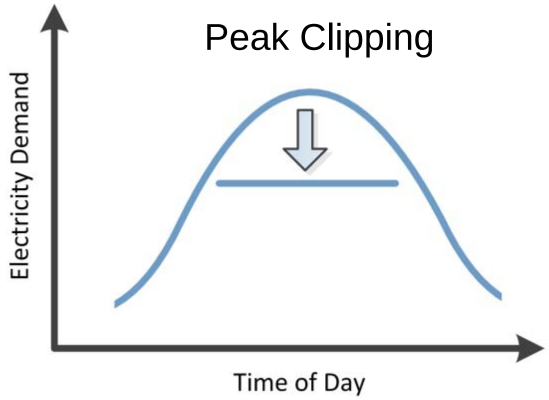
Demand Response Management

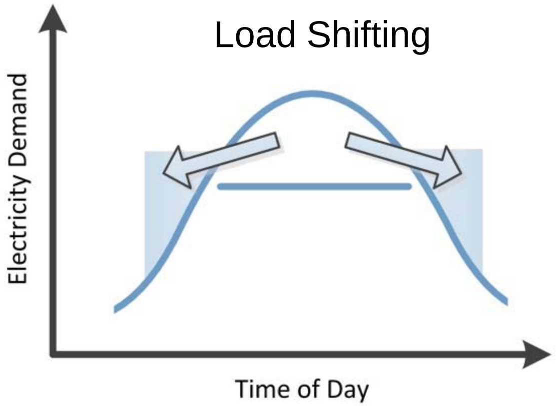
High Fluctuations in Generation leads to highly volatile markets

Problem:
Highly Volatile
Electricity Prices



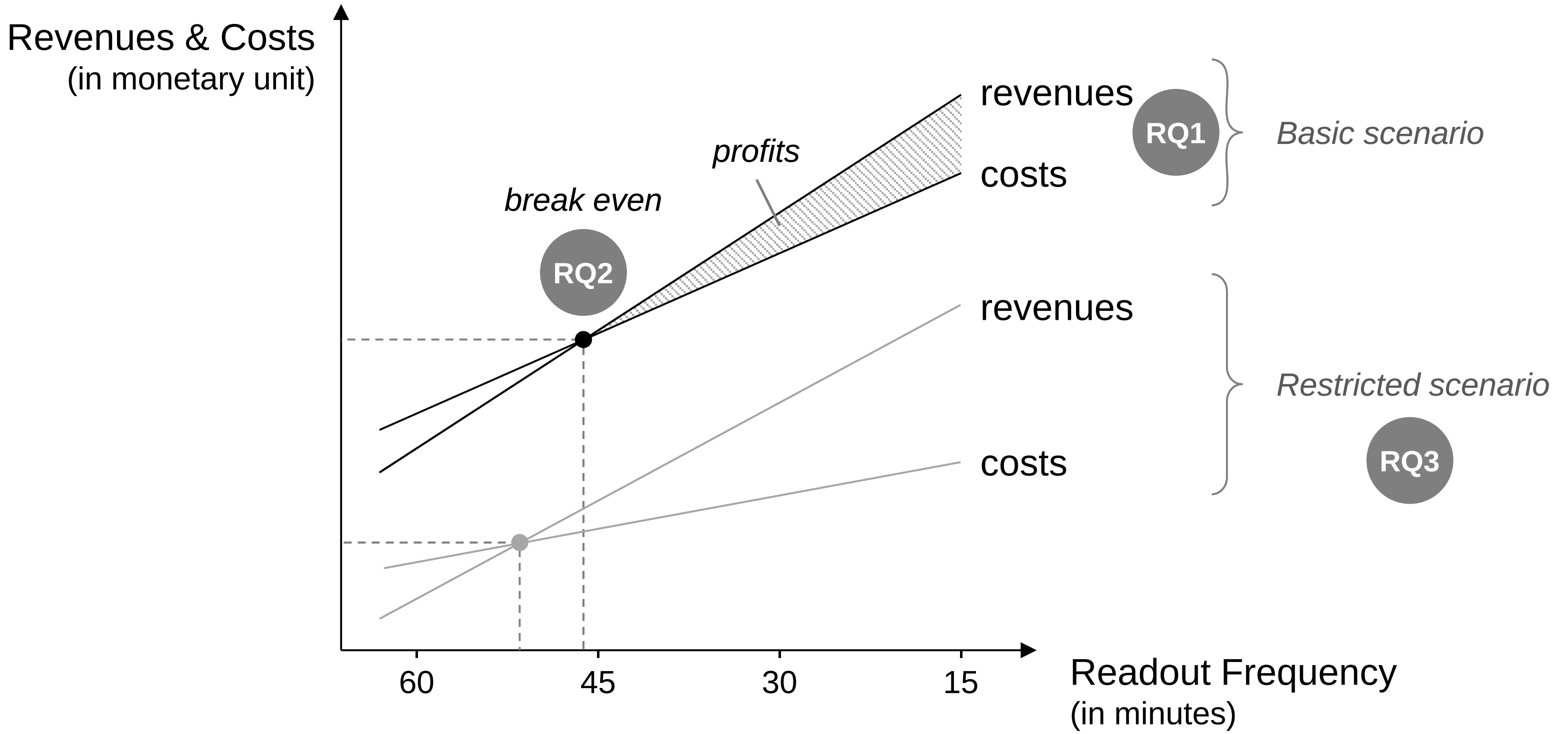
Demand Side Management:
Matching Demand
and Supply in Grid





Demand Response Management

- Retailers can realize savings from optimizing their electricity procurement
- The integration of demand response into the electricity market is still not well understood
- *„There is a lack of understanding costs and benefits of demand response“*
- Trade-off between ICT deployment and economic benefits are unexplored

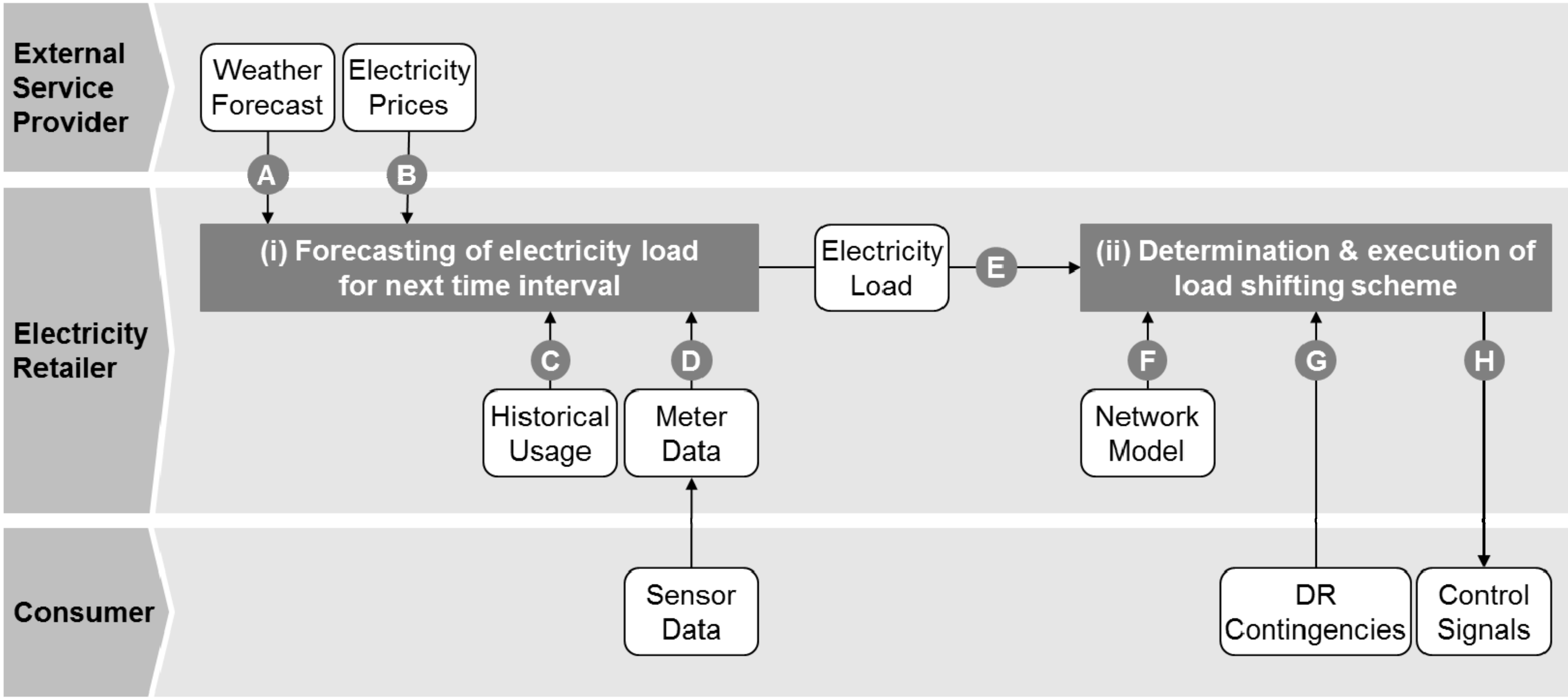


Agenda

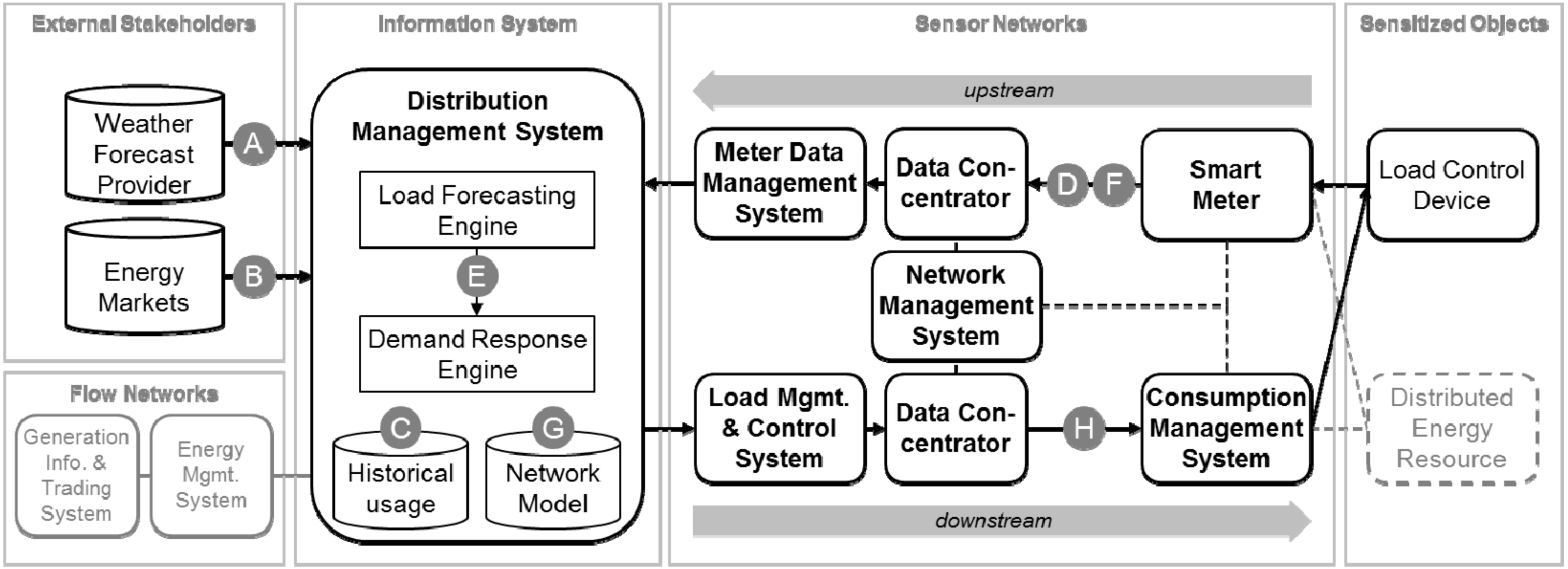
1. System Architecture of a Demand Response System
2. Cost-Value Model
3. Findings
4. Conclusion

Information Flow

- Demand Response (DR) adoption is driven by the reailer
- Assumption: Incentive-based DR system
- Consumers communicate their maximal shift duration and power volume to the retailer



IS Architecture of the DR System



Legend: A Weather Forecasts B Electricity Prices C Historical Usage Data D Current Usage Data
E Electricity Demand F DR Contingencies G Network model H DR Control Signals

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Model Assumptions

- Demand Response integrated on a distribution level
  - Implicitly impose requirements by power grid
- Consumers own and install devices that can be remotely controlled for load shifting
- Focus on single electricity retailer (not consumers)
  - Aggregated Demand Response potential instead of controlling individual devices
  - Change in demand does not affect prices
- Only IT and communication costs (incl. personnel)

- No grid-related costs
- No costs for support, processes and integrating in existing IT infrastructure

Value of Information

- We define the value of information for Demand Response as the electricity retailer's profit per meter readout

$$IV(f) = \frac{r - c}{T}$$

f	readout interval (in minutes)
r	total annual saving potentials
c	total annual running costs for DR infrastructure
T	total number of annual meter readouts for all meters

Modeling IS Costs: Investments

Investment Costs	▪ Procuring and installing components according to number of smart meters and read-out frequency
Operating Costs	▪ Costs for maintenance, personnel, energy, … ▪ $c_{OP} = \underbrace{c_{SM} \cdot x_{SM}}_{\text{Smart meters}} + \underbrace{c_C \cdot x_C}_{\text{Concentrator}} + \underbrace{c_{IS}}_{\text{IS}}$
Communication Costs	▪ Costs for exchanging control signals ▪ $c_{COM,DR} = \underbrace{\beta_{GSM}}_{\text{GSM meters}} \cdot \underbrace{v}_{\text{Data/MB}} \cdot \underbrace{c_{GSM}(v)}_{\text{Costs/MB}} \cdot \underbrace{365}_{\text{Days p.a.}}$

Modeling IS Costs: Operating Costs

Investment Costs

- Procuring and installing components according to number of smart meters and read-out frequency

Operating Costs

- Costs for maintenance, personnel, energy, …
- $c_{OP} = \underbrace{c_{SM} \cdot x_{SM}}_{\text{Smart meters}} + \underbrace{c_C \cdot x_C}_{\text{Concentrator}} + \underbrace{c_{IS}}_{\text{IS}}$

Communication Costs

- Costs for exchanging control signals
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Modeling IS Costs: Comm. Costs

Investment Costs

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Communication Costs

- Costs for exchanging control signals
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Modeling System Costs: Running Costs

Investment Costs

- Procuring and installing components according to number of smart meters and read-out frequency

Operating Costs

Communication Costs

Total running costs:

$$c = \underbrace{c_{OP}}_{\text{Operating Costs}} + \underbrace{c_{COM,DR}}_{\text{Control Signals}} + \underbrace{c_{COM,UD}}_{\text{Meter Readout}}$$

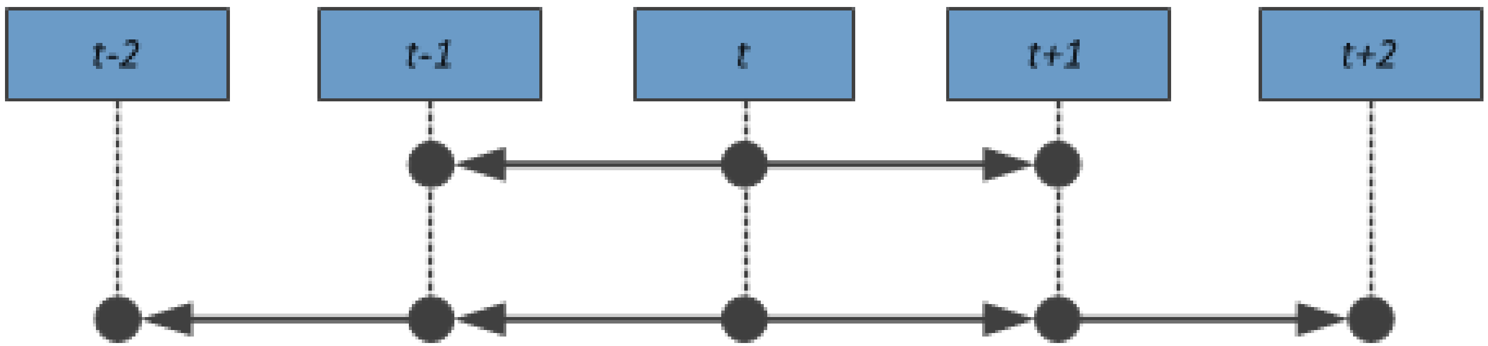
Modeling Saving Potentials

- Minimizing retailer's expenditures

$$r = \min_{q_F(t), q_A(t)} \sum c_F(t) q_F(t) + c_A(t) q_A(t)$$

- Energy purchase according to demand

$$q_F(t) + q_A(t) = D(t) + \sum \pm DR_j(t, \pm i)$$



- Linear optimization problem with further constraints

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Simulation Scenario

- 143,000 households and 77,000 commercial customers (corresponds to an annual energy consumption of 1,000 GWh)

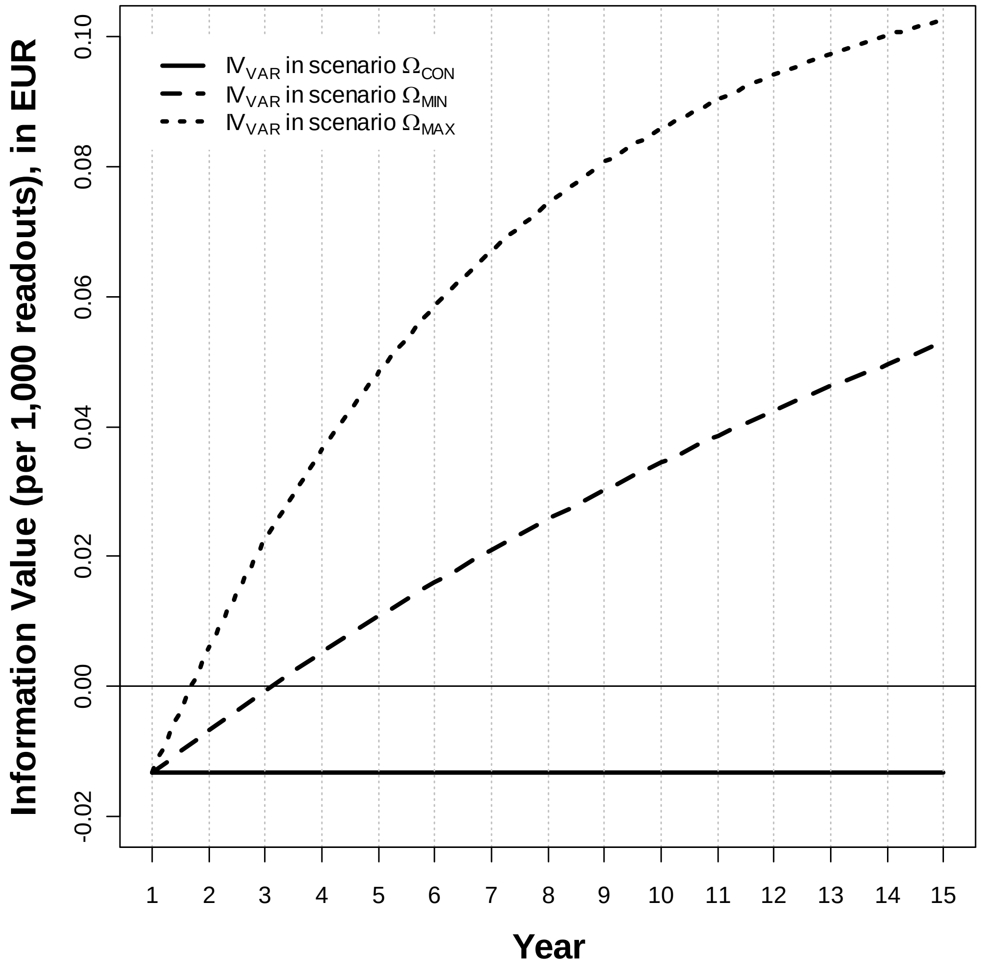
- 220,000 smart meters
  - 126,000 communication modules PLC
  - 54,000 communication modules GSM (= 20 %)

- Hardware costs of smart meter:
  - 95 EUR incl. GSM communication module
  - 80 EUR incl. PLC communication module

- Communication prices GSM: logarithmic function depending on volume

- Readout interval of meters: 60 (basis), 30, 15, 10 minutes

IT-related run costs of smart meter data

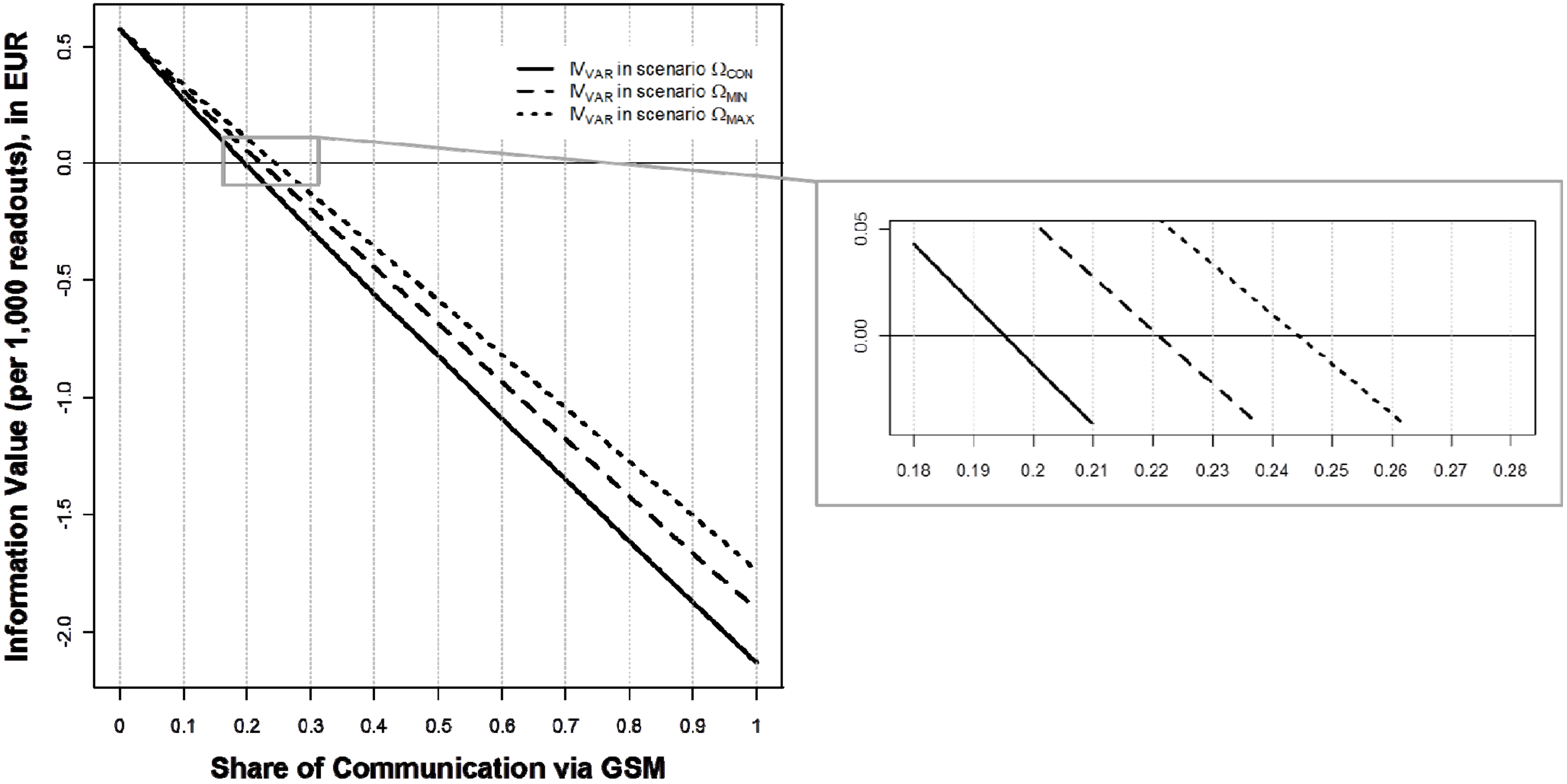


- Evaluation of the cost-value model across tress scenarios
  - GSM communication prices stay constant
  - GSM communication prices decrease annually by 5%
  - GSM communication prices decrease annually by 15%

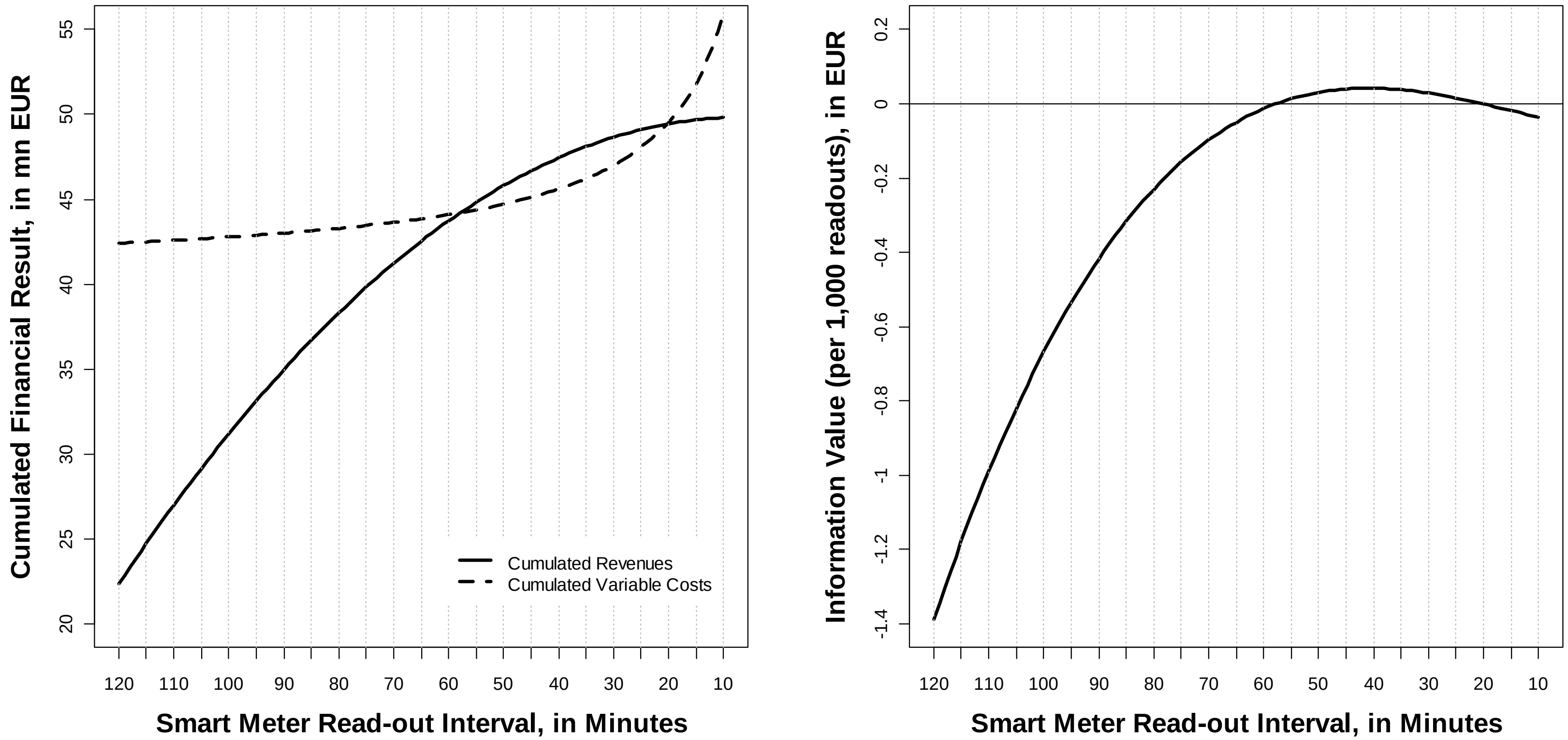
- If communication costs stay constant, we obtain a negative net present value, due to the immense roll-out costs

Break-Even Analysis: Share of GSM-based meters

- Sensitivity analysis: Which parameters need to the adjusted in order to obtain a profitable solution



Optimal read-out frequency for smart meter data



- Information-value is positive, if the read-out frequency is the range between 21 and 57 minutes
- Optimal read-out frequency is 41 minutes

Optimal Roll-out Strategy

- How can the retailer maximize his profit by reducing the number of smart meter deployments?

	Read-out interval 15 minutes *Base*	**Read-out interval 15 minutes** *Restricted*	**Read-out interval 60 minutes** *Base*	**Read-out interval 60 minutes** *Restricted*
Share of HH/CC	100%/100%	0.66%/25%	100%/100%	0.98%/32.6%
Total annual consumption	1000 GWh	209 GWh	1000 GWh	258 GWh
Number of smart meters	219.781	20.172	219.781	25.758
NPV	-22.45 M €	0.98 M €	-22.37 M €	0.89 M €

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Conclusion & Limitations

- Savings from a DR system significantly exceed its running costs
- More granular smart meter data does not necessarily result is higher profits due to ICT costs
- A positive return can be achieved if the read-out occurs every 21-57 minutes
- Restricting the DR system to large-scale consumers may produce a positive NPV

- Consumers participate in the DR system without getting compensation
- Business case of the intermediaries need to be explored in detail