EcoGrid EU
Quantitative Results

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Presentation by:
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EcoGrid EU in Brief

- EU funded FP7-Energy project (total budget: 21 million €)
- A large scale demonstration of a real-time market place for distributed energy resources (DER)
- ICT systems and innovative market solutions enable small-scale consumers to offer TSOs additional and more efficient balancing services
- A demonstration in a real power system with more than 50 % renewable energy
- Preparation for a fast-track towards European real-time market operation of renewable energy sources and demand response
The Fundamental Idea of EcoGrid

The market concept allows regulation of price signals without direct measurement of the individual DER response.

*DER = Distributed Energy Resources
EcoGrid is an example of a real-time market that can be implemented in the context of existing power markets.

EcoGrid supports the need for direct control options on a very short time scale.
2000 Participating Customers in the Demonstration

**Static Control**
- 200 households with smart meters
- No access to specific information
- Must move their energy consumption on their own

**Manual Control**
- 500 households with smart meters
- Receiving simple market price information

**Automatic Control**
- 700 automated households with Siemens equipment and smart meters
- All houses have heat pumps or electric heating – responding autonomously to price signals

**Aggregated automatic Control**
- 500 automated households with IBM-Green Wave Reality equipment and smart meters
- All houses have heat pumps or electric heating – responding to control signals

**Smart Businesses**
- Up to 100 costumers with smart meters
- Including small business and public customers
- Connected smart appliances – responding to control signals
Why a new model for evaluation?

- Experimental groups not comparable to the control group due to differences in group composition in terms of
  - Heating systems (type, wood stoves)
  - Usage (Holiday houses)

- Market model is mostly nonlinear
  - Models systems response, but not statistically treatable

- Therefore a purely linear model was used
Most important facts about the model

- Differentiated model
  - changes in consumption, not consumption for statistical reasons

- Influence from future and past
  - Day ahead because of the agent listening to forecast
  - RTP up to a certain time back
  - Weather up to a certain time back

- Sample output

<table>
<thead>
<tr>
<th></th>
<th>reference</th>
<th>manual</th>
<th>IBM dir.el</th>
<th>IBM HP</th>
<th>Siemens d.e+ HP</th>
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<tbody>
<tr>
<td>rt_lag1</td>
<td>-0.001***</td>
<td>0.002</td>
<td>-0.032***</td>
<td>-0.054***</td>
<td>-0.175***</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.005)</td>
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<tr>
<td>rt_lag2</td>
<td>0.003</td>
<td>-0.001</td>
<td>-0.083***</td>
<td>-0.074***</td>
<td>-0.183***</td>
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<tr>
<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.005)</td>
<td>(0.005)</td>
<td>(0.006)</td>
</tr>
<tr>
<td>rt_lag3</td>
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<td>-0.004</td>
<td>-0.056***</td>
<td>-0.030***</td>
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<td></td>
<td>(0.004)</td>
<td>(0.004)</td>
<td>(0.006)</td>
<td>(0.005)</td>
<td>(0.006)</td>
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</tbody>
</table>
Sample reaction

- Although linear, not always the same reaction to the same price due to influence from the past
Hourly Response

<table>
<thead>
<tr>
<th></th>
<th>Increasing RTP [kW]</th>
<th></th>
<th>Decreasing RTP [kW]</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Best</td>
<td>Average</td>
<td>Worst</td>
<td>Best</td>
</tr>
<tr>
<td>Reference</td>
<td>0,0306</td>
<td>0,0017</td>
<td>0,0000</td>
<td>-0,0323</td>
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<tr>
<td>Manual</td>
<td>0,0166</td>
<td>0,0013</td>
<td>0,0000</td>
<td>-0,0170</td>
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<tr>
<td>Siemens</td>
<td>0,3177</td>
<td>0,0147</td>
<td>0,0000</td>
<td>-0,2101</td>
</tr>
<tr>
<td>All households</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>connected by</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IBM</td>
<td>0,1413</td>
<td>0,0089</td>
<td>0,0000</td>
<td>-0,1329</td>
</tr>
</tbody>
</table>

No comparison feasible because of

- Group composition
- Degree of automation (simply blocking heat sources vs. home automation)
Manual Customers

- Tested in detail with very extreme control signals
- Results for (for high prices)
  - Reference group used for qualitative behavior
  - manual group (red) and reference group (blue)
Very high prices – customers claiming to use the FBS
Very low price – customers who claimed to use the FBS
Industrial Customers

- 13 customers
- 11 with more than 50 days of data
- Overall DR

<table>
<thead>
<tr>
<th></th>
<th>Max negative DR (KW)</th>
<th>Max positive DR (KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Industrial DR</td>
<td>-57,147</td>
<td>61,058</td>
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</tbody>
</table>
## Industrial Customers

<table>
<thead>
<tr>
<th>Installation Type</th>
<th>Max negative DR (KW)</th>
<th>Max positive DR (KW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manure Mixer</td>
<td>-19,872</td>
<td>19,874</td>
</tr>
<tr>
<td>Manure Mixer</td>
<td>-10,799</td>
<td>10,799</td>
</tr>
<tr>
<td>Pallet Jack Charger</td>
<td>-1,796</td>
<td>1,792</td>
</tr>
<tr>
<td>Pallet Jack Charger</td>
<td>-2,329</td>
<td>4,194</td>
</tr>
<tr>
<td>Pallet Jack Charger</td>
<td>-3,746</td>
<td>5,503</td>
</tr>
<tr>
<td>Forklift Charger</td>
<td>-4,059</td>
<td>4,932</td>
</tr>
<tr>
<td>Forklift Charger</td>
<td>-0,294</td>
<td>0,32</td>
</tr>
<tr>
<td>Forklift Charger</td>
<td>-2,602</td>
<td>2,609</td>
</tr>
<tr>
<td>Forklift Charger</td>
<td>-7,343</td>
<td>7,299</td>
</tr>
<tr>
<td>Forklift Charger</td>
<td>-12,231</td>
<td>12,231</td>
</tr>
<tr>
<td>Forklift Charger</td>
<td>-3,569</td>
<td>3,962</td>
</tr>
</tbody>
</table>
Load Reduction (Increase of Energy Efficiency)

- Heating involved

- HDDs in Denmark – bias towards EcoGrid EU

<table>
<thead>
<tr>
<th>Heating Season</th>
<th>11/12</th>
<th>12/13</th>
<th>13/14</th>
<th>14/15</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDDs</td>
<td>2431</td>
<td>2852</td>
<td>2157</td>
<td>2229</td>
</tr>
</tbody>
</table>

- Therefore linear approach (consistent with e.g. 3e houses)

- Also important as the billing year is not the calendar year and historic data is therefore also aligned
Validation: ANCOVA

- Analysis of Covariance (ANCOVA) tells us whether two linear models are statistically distinguishable or not.

- Linear model for
  - Historic data of different groups
  - Experimental data of different group

- Comparisons
  - Time of the experiment with the time before
  - Different groups
Results (percentages)

<table>
<thead>
<tr>
<th>Group</th>
<th>Change in $Q_{\text{base}}$ [-]</th>
<th>Change in $Q_{\text{therm}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>-3</td>
<td>2.1</td>
</tr>
<tr>
<td>Manual</td>
<td>-2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Semi Automated</td>
<td>-3.1</td>
<td>-0.3</td>
</tr>
<tr>
<td>Automated</td>
<td>-2.8</td>
<td>-0.1</td>
</tr>
</tbody>
</table>

- But statistically insignificant

- Possible reasons
  - Siemens Hardware in turn used 30W (~300 kWh/y)
  - Reduction measures in the first half of project (e.g. change to LED) not noticeable here
Thank you for your attention

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Austria
Bornholm – a Unique Test-site

Demonstration in a `real´ system with 50% RES

High variety of low carbon energy sources

Several demand & stationary storage options

Interconnected with the Nordic power market

Strong political commitment & public support

Operated by the local municipal owned DSO, Østkraft

Eligible RD&D infrastructure & full scale test laboratory
EcoGrid EU is a large scale demonstration of a real-time market place in a power system with a broad mix of distributed energy resources. Approx. 2,000 pilot test customers.

Power Generation

- 36 MW Wind Power
- 16 MW CHP (biomass)
- 2 MW Biogas
- 5 MW Photovoltaic (solar)

Demand side/Storage options

- Intelligent control of household appliances
- Heat Pumps with Smart Grids applications
- Electricity storage in district Heating

Distributed Energy Resources on Bornholm