International Conference on Energy Systems Integration

Flexible Industrial Demand Supporting Cost Effective Integration of Renewables

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Challenges of decarbonisation of European power system

- Degradation in utilization of generation and network infrastructure
- Limited ability to integrate renewable generation
Key objectives

Cost-effective transition to a low-carbon European power system

Rising cost of electricity – impact on competitiveness of the European Industry

Bring together the EU industrial and renewable energy community - create win-win context
  - Formulate business models
  - Develop tools to facilitate their adoption
  - Quantify the potential benefits for the European power system and industrial consumers
  - Formulate regulatory and policy recommendations
IndustRE – targeted 6 countries in Europe:
• Belgium – France – Germany - Italy – Spain - UK
• Combined these represent:
  • >60% EU population
  • 80% of EU wind and PV capacity
• Industrial sectors targeted in IndustRE
  • Chemicals
  • Non-ferrous metals
  • Steel
  • Cold storage
  • Water treatment
Share of EU industrial demand per country

Share of industrial electricity consumption
## Case Studies

<table>
<thead>
<tr>
<th>Sector</th>
<th>Country</th>
<th>Flexibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paper</td>
<td>Belgium</td>
<td>Electric / gas boiler identified as main source of flexibility</td>
</tr>
<tr>
<td></td>
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<td>Overcapacity of pulpmill factory</td>
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<tr>
<td>Steel</td>
<td>Italy</td>
<td>Thermal buffer in induction furnace</td>
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<tr>
<td>Cold Storage</td>
<td>UK</td>
<td>Thermal buffer in cold storage, emergency generators</td>
</tr>
<tr>
<td>Water treatment</td>
<td>Germany</td>
<td>Switching between electricity and gas with multiple sources of flexibility</td>
</tr>
<tr>
<td>Cold storage</td>
<td>France</td>
<td>Thermal buffer</td>
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<tr>
<td>Chemicals</td>
<td>Germany</td>
<td>Overcapacity of liquefaction process</td>
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<tr>
<td>Non-ferrous</td>
<td>Germany</td>
<td>Thermal buffer in induction furnace</td>
</tr>
</tbody>
</table>

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Quantification of whole system value of industrial demand flexibility

**Benefits across multiple system sectors:**
- Generation system (incl. conventional and renewable generation)
- Transmission network
- Distribution network

**Benefits across multiple timescales:**
- Long-term investment planning
- Short term scheduling
- Real-time balancing
Overall modelling approach

Future scenarios 2030 horizon

Sensitivity studies

Generation, Transmission and Distribution Investment Optimisation

G+T+D infrastructure assessment

Stochastic Optimisation

Operational assessment

Flexible Industrial demand

System benefits of industrial demand flexibility

Inflexible Industrial Demand

Share of industrial electricity consumption

- Albania
- Austria
- Belgium
- Bosnia and Herzegovina
- Bulgaria
- Croatia
- Czech Republic
- Denmark
- Estonia
- Finland
- France
- Germany
- Greece
- Hungary
- Ireland
- Italy
- Latvia
- Lithuania
- Luxembourg
- Netherlands
- Norway
- Poland
- Portugal
- Romania
- Serbia
- Slovakia
- Slovenia
- Spain
- Sweden
- Switzerland
- United Kingdom

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Benefits for European power system

- Increased utilisation of renewables and low-cost generation
- Reduction in network reinforcement
- Reduction in peak generation capacity

Cost savings (€bn/year)

<table>
<thead>
<tr>
<th>α = 1%</th>
<th>α = 5%</th>
<th>α = 10%</th>
<th>α = 20%</th>
<th>α = 50%</th>
<th>α = 1%</th>
<th>α = 5%</th>
<th>α = 10%</th>
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<tbody>
<tr>
<td>30% RES</td>
<td>0.2</td>
<td>0.4</td>
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G CAPEX | T/I CAPEX | OPEX

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Utilisation of industrial demand flexibility

<table>
<thead>
<tr>
<th>Country</th>
<th>FID utilisation</th>
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<tbody>
<tr>
<td>Albania</td>
<td>10%</td>
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<tr>
<td>Austria</td>
<td>15%</td>
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<tr>
<td>Belgium</td>
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<td>Bulgaria</td>
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<td>Croatia</td>
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<td>Czech Republic</td>
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<td>Denmark</td>
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<td>Estonia</td>
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<td>Finland</td>
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<td>France</td>
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<td>Hungary</td>
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<td>Ireland</td>
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<td>Italy</td>
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<td>Latvia</td>
<td>10%</td>
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<td>Lithuania</td>
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<td>Luxembourg</td>
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<td>Netherlands</td>
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<td>United Kingdom</td>
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Benefits for European distribution networks

Cost savings (%)

Greatest share of industrial load and low demand growth

Lowest share of industrial load and high demand growth

Belgium, France, Germany, Italy, Spain, UK

α=1%, α=5%, α=10%, α=20%, α=50%
Flexible industrial consumer market model

Objective function:
Minimise overall electricity cost for flexible industrial consumer

Operational constraints of flexible industrial consumer

Prices of energy, balancing and capacity services

- Energy procured by industrial consumer in the energy market
- Volume of balancing services offered by industrial consumer
- Reduction of peak demand of industrial consumer

Case studies with actual demand profile and flex capacity
Benefits for flexible industrial consumer

Need for fundamental reform of market and regulatory framework

Cost savings (£/year)

<table>
<thead>
<tr>
<th>Belgium</th>
<th>France</th>
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Need for fundamental reform of market and regulatory framework

30% RES

Energy | Balancing | Generation | Transmission | Distribution

60% RES
Main findings: System perspective

- Multiple value streams of industrial demand flexibility for the European power system:
  - Reduction in system operation costs by providing balancing services (reserves, frequency response) and enabling higher utilisation of renewable and cheaper energy sources and
  - Reduction in generation and network investments by limiting peak demand levels and limiting the required generation flexibility
- System cost savings become more significant under higher renewable generation levels
- Value of industrial demand flexibility varies across different European countries
Main findings: Industry perspective

- Multiple revenue streams for demand flexibility for the European industrial consumers:
  - Energy cost savings by adjusting electricity consumption patterns to the temporal variation of energy prices
  - Revenues from provision of balancing services (reserves, frequency response)
  - Revenues from provision of capacity services (generation, transmission and distribution level)
- Total cost savings and revenues become more significant under higher renewable generation levels
- Need for fundamental reform of market and regulatory framework to remunerate the multiple provided services in a cost-reflective way
Business Models identified for FID /1

Available tools

- Flexible demand only
- + contract with offsite VRE
- + contract with onsite VRE

Variable Renewable energy (VRE)

Flexible Industrial Demand (FID)

Energy costs
Network and other regulated costs
System services

Savings

Revenues

Business Model

Strategy 1
Strategy 2
Strategy N

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# Business Models identified for FID

## Available tools

<table>
<thead>
<tr>
<th>能量成本 (Energy costs)</th>
<th>灵活需求 (Flexible demand only)</th>
<th>+合同与离场VRE (contract with offsite VRE)</th>
<th>+合同与 onsite VRE (contract with onsite VRE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>客户价格响应 (Supplier price response)</td>
<td>市场价格响应 (Market price response)</td>
<td>长期电力供应 (Long-term electricity supply)</td>
<td>长期电力供应 (Long-term electricity supply)</td>
</tr>
<tr>
<td>网络和其它规制成本 (Network and other regulated costs)</td>
<td>浮动费率网络费率 (ToU network tariff)</td>
<td></td>
<td>水量费率响应 (Volumetric tariff response)</td>
</tr>
<tr>
<td>系统服务 (System services)</td>
<td>调整供应和服务 (Balancing provision and other services)</td>
<td></td>
<td>双边调整供应 (Bilateral balancing provision)</td>
</tr>
</tbody>
</table>

## Savings
- 能源成本 (Energy costs)
- 网络和其它规制成本 (Network and other regulated costs)

## Revenues
- 系统服务 (System services)

## Authors:

[Imperial College London](https://www.imperial.ac.uk)

[Comillas Pontificia University](https://www.comillas.edu)

[IndustRE](https://www.industre.eu)
Key Market/Policy Recommendations

• Harmonize flexibility mechanism and products across EU markets
  • Level playing field – trading of flexibility cross-border

• Energy and Capacity Market access
  • Improve access and participation of small and large industries in wholesale electricity markets (day-ahead and intraday markets)
  • Ensure level playing field for flexible industrial demand into these markets

• Ancillary services
  • Promote active network access / management by DSOs
  • Apply marginal pricing contracting balancing energy instead of pay-as-bid (also supported by National Grid); Reduce procurement horizons to closer to real time

• Tariff design
  • Establish cost-reflective network tariffs

• Carbon benefits of flexibility
• Option value of flexibility
Detailed project results:
www.industre.eu/downloads/category/project-results
International Conference on Energy Systems Integration

Flexible Industrial Demand Supporting Cost Effective Integration of Renewables

Goran Strbac, Roberto Moreira, Dimitrios Papadaskalopoulos, Danny Pudjianto, Predrag Djapic, Fei Teng

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