The electricity supply system of the EU is characterised by a high reliability.

How to choose the level of an interruption?

Historically: duration, redundancy criteria (N-1), LOLP

Balance investments in reliability with reduced costs due to fewer outages.

Requires knowledge of socio-economic costs of interruptions.

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Estimating the socio-economic costs of electricity supply interruptions

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Focus

• Objective: to spur discussions on interruptions and their costs
• Social dimension: not only industries, also citizens
• Costs: direct vs. indirect, how to share them between stakeholders
• Case studies: to showcase the different types of interruptions
• Evolution: impact of increased shares of renewables
• Beyond kWh: services rather than electricity
• Modelling approaches & databases: minor focus
• International cases: putting the EU in context
Characterising Interruptions

Types of end-users: hospital vs. industrial plant vs. household

Time of occurrence: weekday vs. weekend, winter vs. summer

Duration: instant losses (PC files) vs. time-dependent losses (food)

Advance notification: e.g., elevator; regular outages: notifications not as important any longer -> lower immediate cost, but less confidence in system

Perceived reliability level: vulnerability conflict -> higher perceived reliability leads to higher vulnerability in case of outage

Source of the outage: failure in network vs. failure in power plant
Composition of Costs

- Consumers have no choice to choose tariff depending on reliability
- No market mechanism to derive the value of the cost of interruption
- Utilities/TSOs lack balanced incentives to engage in investments

**Direct:** Infrastructure

**Indirect:** Production outage

**Macro-economic long-term:** Change in investments, e.g., choice of business location

### Households

Only partly material -> costs such as fear, inconvenience, loss of leisure time

-> Willingness-to-Pay (WTP)

### Industry/Commerce

1. Output
2. Loss of productivity
3. Damage
4. Labour
5. (Loss in reputation)
Quantifying the Costs

**Surveys/Interviews**
- Willingness to Pay (WTP)
- Willingness to Accept (WTA)
- Choice experiment
- e.g., winter, WTP is 1/3 higher in Austria

**Production-function**
- Estimates welfare costs across different sectors, durations, times
- e.g., lost production, reduced convenience
- Uses statistical information

**Market behaviour**
- Revealed preferences/expenditures
- e.g., backup facilities, insurances, interruptible contracts
- US: 170 GW of backup generators

**Case studies**
- List and monetise effects of outage
- Surveys after interruption
Case Study - Cyprus: Isolated & vulnerable

- 11 July 2011: 98 containers of ammunitions exploded at naval base
- 650 MW power plant damaged
- >50% of total capacity of Cyprus
- No interconnections -> rolling blackouts
- Temporary units installed
- Price increase of 36% for consumers
- Restoration: €220 million, finished in 2013

<table>
<thead>
<tr>
<th>Households*</th>
<th>2011 1st half</th>
<th>2011 2nd half</th>
<th>2012 1st half</th>
</tr>
</thead>
<tbody>
<tr>
<td>€/kWh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2011 1st half</td>
<td>0.205</td>
<td>0.241</td>
<td>0.278</td>
</tr>
</tbody>
</table>

Vasilikos power plant
Case Study - Italy: Timing Matters

- 3 AM, 28 September 2003: 2 transmission lines from Switzerland to Italy were cut off due to storm
- Almost all of Italy without power for 12 hours
- Nuit Blanche in Rome: annual overnight festivities -> hundreds of people trapped in underground trains
- 110 trains cancelled
- 30,000 people stranded on trains across Italy
- Heavy rain: many people sleeping in train stations and on the streets
Integrating Renewables (RE) through Smart Grids (SG)

Distributed RE + Storage
- Same reliability level possible
- E.g., small hydro: black-start capable
- Germany: loans/subsidies for PV storage
- Distribution of costs for grid access requires consideration

Smart Grids
- Increasing RE -> SG
- Self healing, able to contain outage and minimise its duration and cost
- New sources of flexibility (demand-side)

Demand-side management
- SGs: minimise outage cost through prioritising loads (hospitals /industry)
- Not necessarily limited to consumer groups, but also within one group
- 50% of household demand not instantly required

Regulation
- Currently mostly primary assets rewarded, not performance based
- Few of the EU28 have created strong regulatory support for demand response
Looking Forward

Calculating the economically optimal interruption levels

- Required to know the value society places on supply security
- Dependent on time, duration, service
- Initial estimate may be less arbitrary then, e.g., Loss of Load Propability (LOLP)
Need for a consistent approach
# International context: examples from Sub-Saharan Africa

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Senegal</th>
<th>Nigeria</th>
<th>Sub-Saharan Africa</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of electrical outages in a typical month</td>
<td>25.8</td>
<td>26.3</td>
<td>10.7</td>
<td>8.6</td>
</tr>
<tr>
<td>Duration of a typical electrical outage (hours)</td>
<td>2.3</td>
<td>8.2</td>
<td>6.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Losses due to electrical outages (% of annual sales)</td>
<td>5.1</td>
<td>8.9</td>
<td>6.7</td>
<td>4.8</td>
</tr>
<tr>
<td>Percent of firms owning or sharing a generator</td>
<td>90.7</td>
<td>85.7</td>
<td>43.6</td>
<td>31.6</td>
</tr>
<tr>
<td>Proportion of electricity from a generator (%)</td>
<td>30.8</td>
<td>47.5</td>
<td>13.8</td>
<td>7.1</td>
</tr>
<tr>
<td>Percent of firms identifying electricity as a major constraint</td>
<td>57.5</td>
<td>75.9</td>
<td>50.3</td>
<td>39.2</td>
</tr>
</tbody>
</table>
Looking Forward

Modelling Tools
Modified version of tools like APOSTEL, OSeMOSYS or PLEXOS can optimise extent of interruptions by minimising socio-economic costs

Proposed Vision / Next Steps
• Consistent investigation of VoLL across EU-28
• Standardised database for aggregating costs
Thank you for your attention

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