Solidarity Measures: Assessment of Strategic Gas Storage Coordination Among EU Member States on EU Natural Gas Supply Resilience

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- Context
- Methodology
- Results and Conclusions
Can energy security be enhanced by solidarity among EU member states in response to natural gas supply crises?
The EU goal of carbon neutrality by 2050 is going to require a significant system transformation.

Natural gas today is the second largest-primary energy source in the EU.

Pathway to net zero (Source: IEA, 2021)

Total EU energy mix
- 25%

Electricity generation
- 20%

Heat generation
- 37%

Role of gas in the EU energy system in 2017 (Sesini et al., 2021)
Gas Storage in the EU

- Dual role
  - Market value (flexibility)
    - Commercial storage
      - Declining indigenous production
  - Insurance value
    - Strategic storage
    - Storage Obligation (9 Member States) vs Strategic Storage (2 Member States)
      - Heavy import dependence
      - Little diversification of sources

Mandatory storage security of supply interventions in the EU by type (Source: CEER, 2014)
Research Goal

LITERATURE GAP

Natural Gas Supply Disruption

Natural Gas Storage

NOVELTY

<table>
<thead>
<tr>
<th>Definition</th>
<th>Contribution</th>
</tr>
</thead>
<tbody>
<tr>
<td>HILP (“high-impact, low-probability” events): mega-disasters where the market is unable to meet demand and policy intervention is required</td>
<td>Absent in the literature</td>
</tr>
<tr>
<td>Strategic storage: pre-fixed volume of gas taken out of the market</td>
<td></td>
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<tr>
<td>Solidarity: cooperation of Regional Risk Groups</td>
<td></td>
</tr>
<tr>
<td>Resilience: ability of supply chain to respond to unexpected events and maintain continuity of operations</td>
<td>Absent in terms of strategic storage</td>
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</table>
HILP Model

- Linear programming optimization modelling the natural gas supply chain
- Stochastic approach with a short-term optimization framework (i.e., 7 days) based on real-world data (i.e., Burian).

Basic HILP model structure
HILP Model: Structure

- Illustrative model structure:

- Event (e1, e2, e3, probability)

- Supply (Extraction, LNG)

- Demand

- Demand + Storage

- Member State

- Natural gas flow

- HILP event

- Disrupted flow
HILP Model: Network Structure

Illustrative network structure:

## HILP Model: Stochastic Formulation

\[
\text{min} \quad \text{total system costs}
\]

\[
\text{s.t.} \quad \text{Constraints:}
\]
- Demand
- Resource availability
- Storage capacity
- Infrastructure capacity
- LNG port capacity

<table>
<thead>
<tr>
<th>First stage variables</th>
<th>Second stage variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount of stored natural gas</td>
<td>Natural gas transmission</td>
</tr>
<tr>
<td>Amount of natural gas withdrawn from storage</td>
<td>Natural gas production</td>
</tr>
<tr>
<td></td>
<td>Natural gas supplied through LNG terminals</td>
</tr>
</tbody>
</table>
HILP Model: Applications

- Cold spell (validation)
- HILP
- Solidarity

Focus: Coordinated strategic storage for energy security

Method: HILP model based on full Natural Gas Supply Chain Model

Eastern gas supply risk group: 1 (a) Ukraine as in EU Regulation 2017/1938. Includes: Bulgaria, Czech Republic, Germany, Greece, Croatia, Italy, Luxembourg, Hungary, Austria, Poland, Romania, Slovenia, Slovakia
Solidarity: Scenarios

- **Two-stage stochastic optimization-based linear programming minimum cost with increase temporal and geographical scope.**
- **Solidarity and Regional Risk Groups in case of HILP**

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### Disruption scenarios

<table>
<thead>
<tr>
<th>Scenario Assumption</th>
<th>Reference Scenario</th>
<th>Ukraine disruption Scenario</th>
<th>Russia disruption Scenario</th>
<th>Norway disruption Scenario</th>
<th>North Africa disruption Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Origin of loss of gas transmission</strong></td>
<td>-80% from Russia</td>
<td>-100% from Ukraine</td>
<td>-100% from Russia</td>
<td>-100% from Norway</td>
<td>-100% from North Africa</td>
</tr>
<tr>
<td><strong>Gas reserve</strong></td>
<td>No strategic storage</td>
<td>With strategic storage</td>
<td>With strategic storage</td>
<td>With strategic storage</td>
<td>With strategic storage</td>
</tr>
</tbody>
</table>

RR = EU Regional Risk Groups MS
Solidarity: Supply Mix

✓ Use of strategic storage is favoured

Natural gas supply mix at European level comparison (%)

Production: 56% Pre-Disruption, 13% Burian, 19% Disruption Day 1, 19% Disruption Week 1

Import: 53% Pre-Disruption, 19% Burian, 9% Disruption Day 1, 19% Disruption Week 1

LNG: 28% Pre-Disruption, 24% Burian, 25% Disruption Day 1, 23% Disruption Week 1

Storage: 32% Pre-Disruption, 16% Burian, 18% Disruption Day 1, 35% Disruption Week 1
### Solidarity: Systems Costs

- Solidarity reduces up to 15% total system costs

<table>
<thead>
<tr>
<th></th>
<th>Disruption without and with Strategic Storage</th>
<th>Reference scenario and disruption with Strategic Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL COSTS</td>
<td>-12.7</td>
<td>-14.82</td>
</tr>
<tr>
<td>PRODUCTION COSTS</td>
<td>-7.67</td>
<td>-9.13</td>
</tr>
<tr>
<td>TRANSPORT COSTS</td>
<td>-8.2</td>
<td>-10.45</td>
</tr>
<tr>
<td>LNG COSTS</td>
<td>-42.56</td>
<td>-69.57</td>
</tr>
<tr>
<td>STORAGE COSTS</td>
<td>1.9</td>
<td>-44.25</td>
</tr>
</tbody>
</table>

Cost efficiency between scenarios without and with strategic storage at European level comparison at disruption week 1 (%).
Strategic storage depletion during a seven-day emergency at European level (%).

**Solidarity: Resilience**
**Conclusions**

- There is a strong interplay between LNG and storage during emergencies.
- Non-market based measure could be a cost-effective alternative to market-based ones, highlighting the reliability and insurance value of strategic storage benefitting overall system costs.
- Solidarity among member states during HILP significantly lessens the impact of the event in terms of costs and increases system resilience.

Hence, it points out how in an increasingly interconnected EU energy market and system, the role of strategic storage and solidarity should gain traction in the path towards an Energy Union.
Thank you!