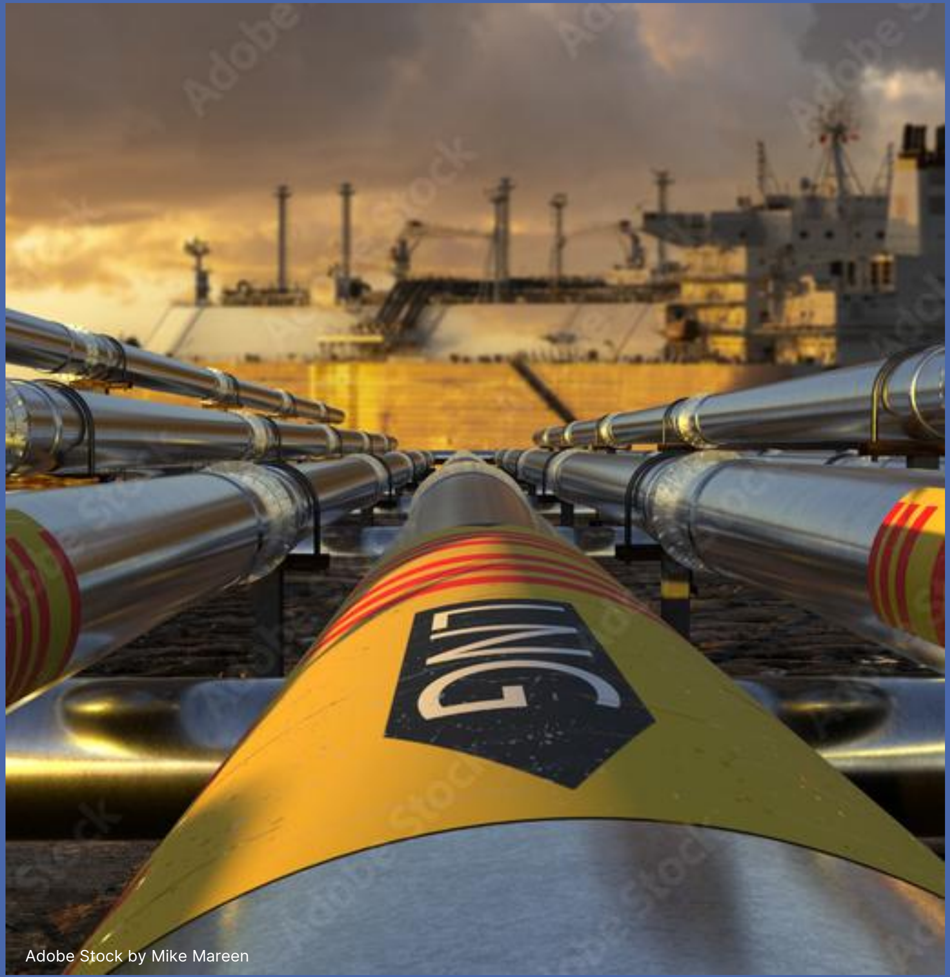
CBS DEPARTMENT OF ECONOMICS · COPENHAGEN SCHOOL OF ENERGY INFRASTRUCTURE · TECHNISCHE UNIVERSITÄT BERLIN · E&R

REASSESSING THE EU'S LNG IMPORT EXPANSION

Geopolitical Dependencies, Energy Security, and Climate Goals after the Russian Invasion of Ukraine

IAEE Paris 2025



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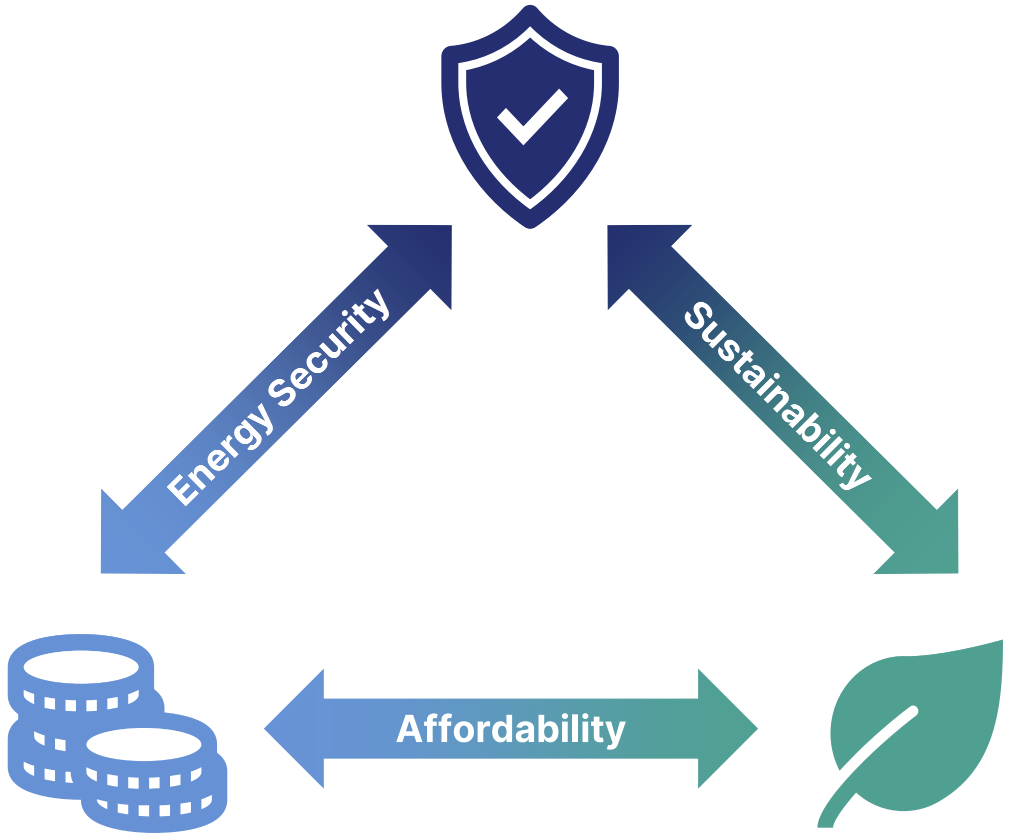
Johannes Giehl, Flora v. Mikulicz-Radecki, Maike Kalz, Mathilde Roger
CSEI and TUB-ER

The energy crisis showed the vulnerabilities of Europe's Energy System

Analysis of gas supply combining network modelling with policy analysis

- Geopolitical tensions put a spotlight on security relevance of energy policy
- Expansion of LNG terminals to ensure short-term supply.
  - Member states fast-tracked LNG terminals with public investment and regulatory flexibility
  - Capacity rose from 2,780 to 3,480 TWh/a by 2024.
- Expansion risks fossil lock-in and EU's climate goals
- South-East Europe remains vulnerable due to limited interconnection, energy poverty, and fewer alternatives to Russian gas
- The study evaluates whether LNG expansion was/is necessary and how it affects regional resilience —particularly in Eastern and South-Eastern Europe—

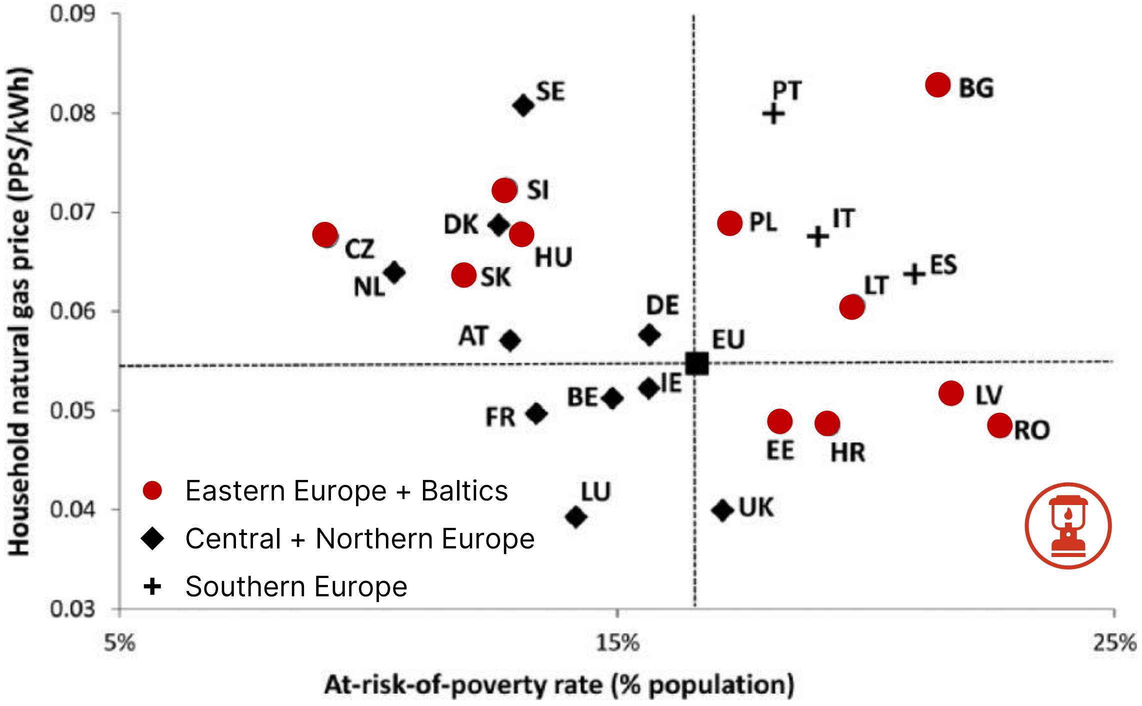


How to evaluate the LNG expansion and the impact on supply

Gas Network Modelling

- **Pre-2022 literature**
  - Focused on Europe's vulnerability to Russian gas supply disruptions
  - Emphasised the need for infrastructure development, including LNG and pipelines [1-5]
- **Recent studies**
  - Examine trade-offs between energy security and climate goals
  - Findings showing LNG and Caspian pipeline gas can replace the Russian supply [6-7]
- **What's new?**
  - Updated and higher resolution of reginal data
  - Focus on Eastern European countries

Energy Poverty and Eastern Europe



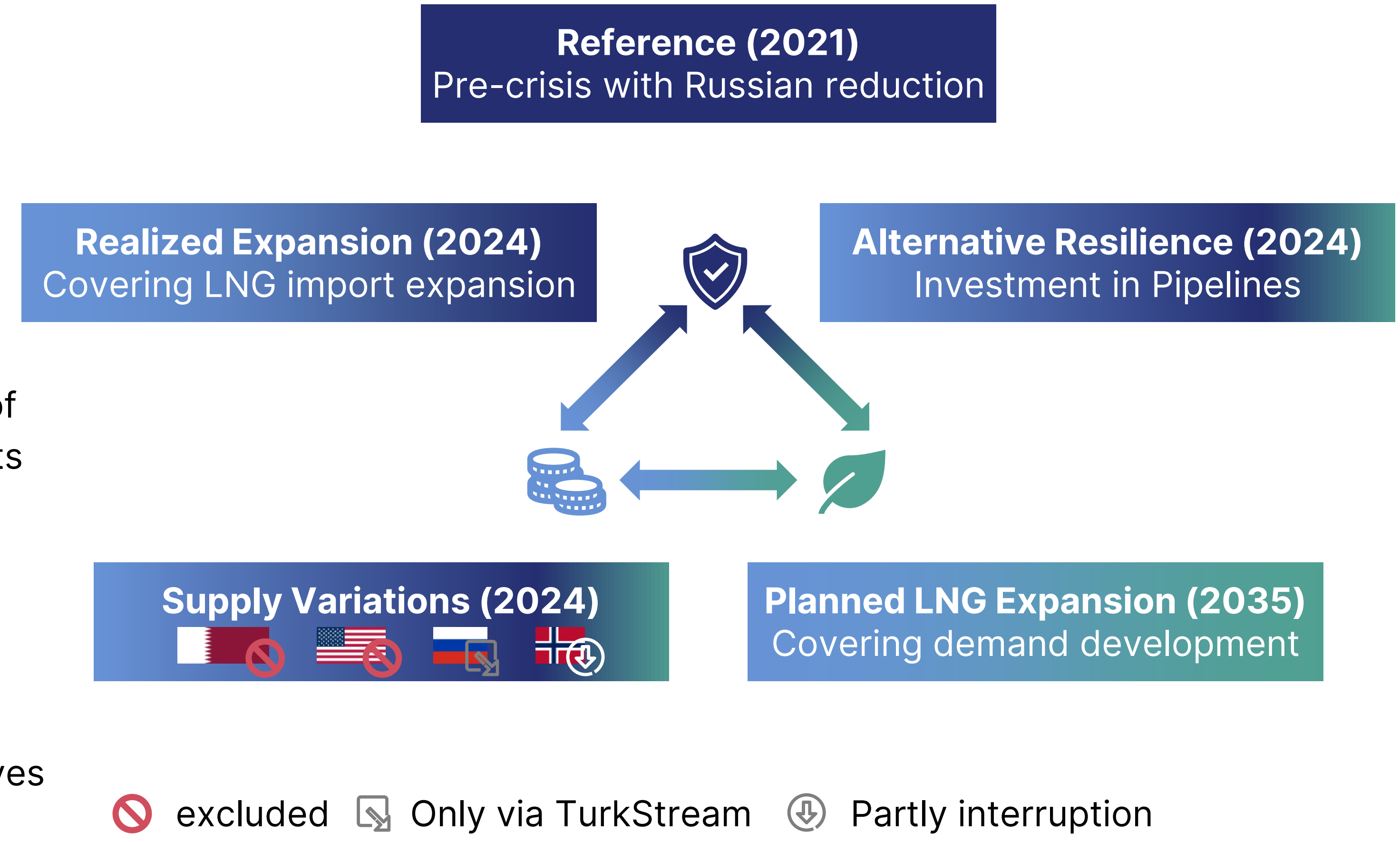
Household natural gas versus at-risk-of-poverty rate by **Bouzarovski et al.** (2015)

[1] Richter and Holz (2015), [2] Holz et al. (2016), [3] Deane et al (2017), [4] Sziklai et al. (2020), [5] Eser et al. (2019), [6] Neumann and Zwickl (2024), [7] Barner et al. (2025), [20] Bouzarovski et al. (2015)

Five scenarios to analyze supply security, affordability, sustainability

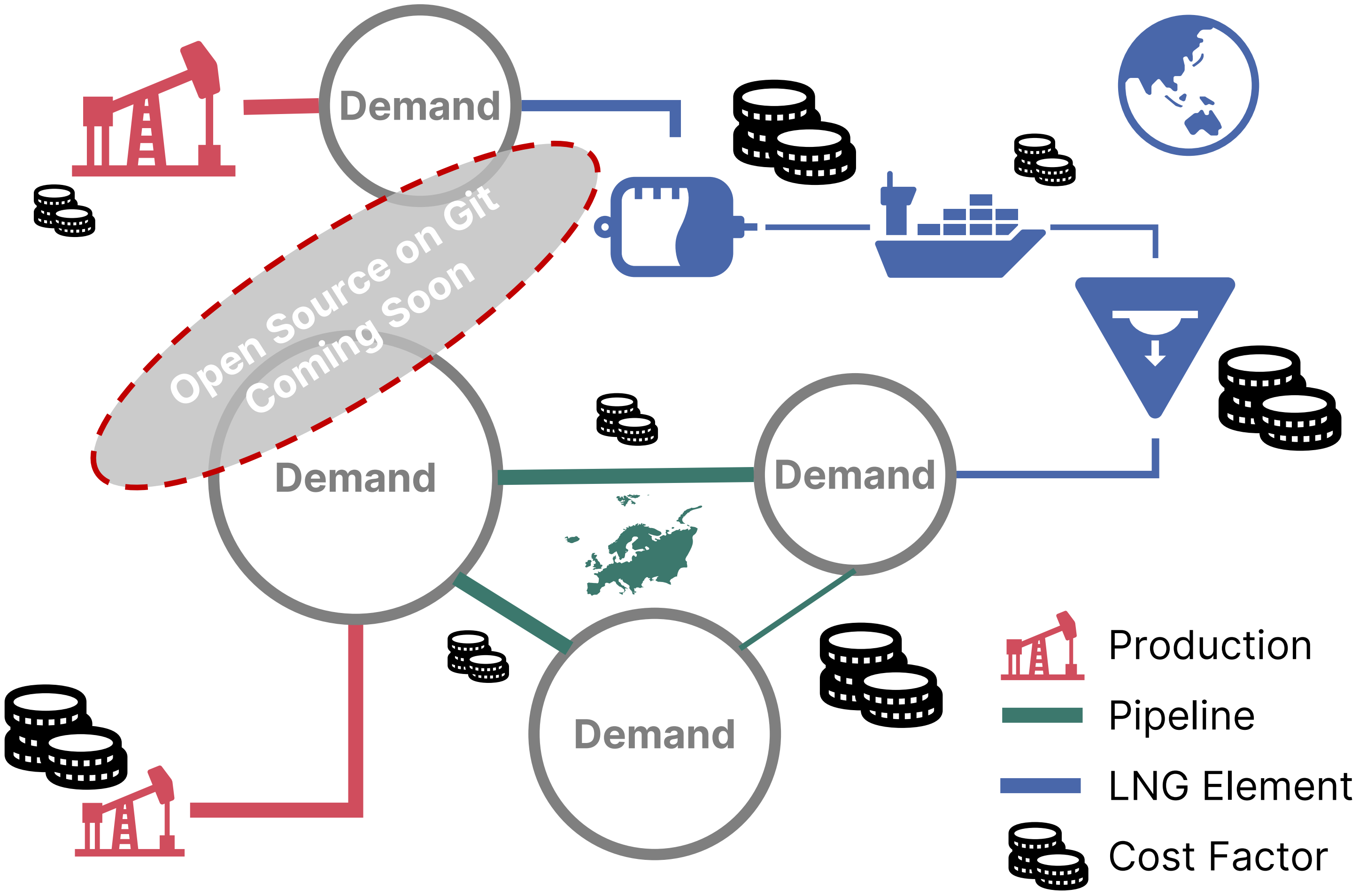
A qualitative analysis based on the gas network model results

- **Security of Supply [8-13]**:
  - Reduction of dependence on Russia
  - Introduced new geopolitical and infrastructural vulnerabilities
- **Affordability [14-19]**:
  - Global markets access but higher price volatility
  - Capital-intensive infrastructure is, with the risk of stranded assets and uneven regional investments
- **Sustainability [8, 21-24]** :
  - LNG's lifecycle emissions
  - Long operational lifespan of LNG terminals risks carbon lock-in
  - Diversion of resources from renewable alternatives



The European Gas Infrastructure in context of global gas transportation

Mixed Integer Linear Programming to identify cost optimal global supply

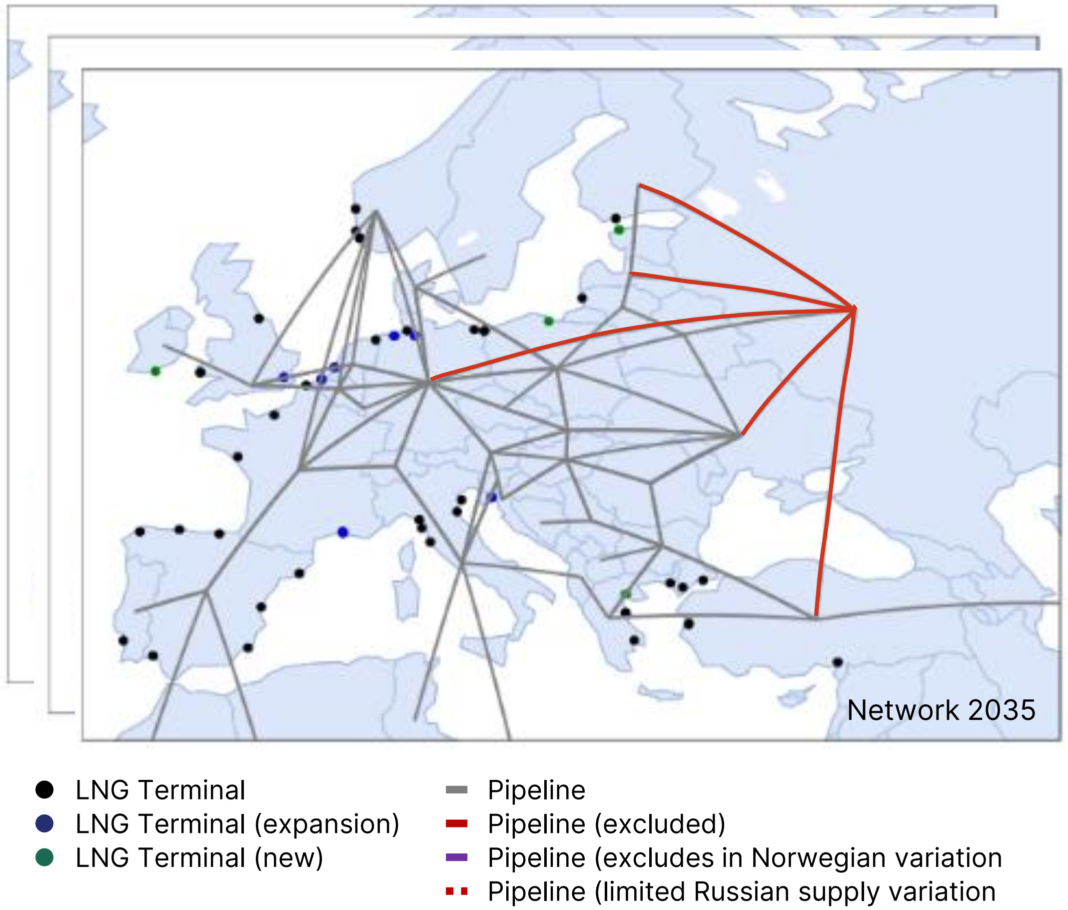


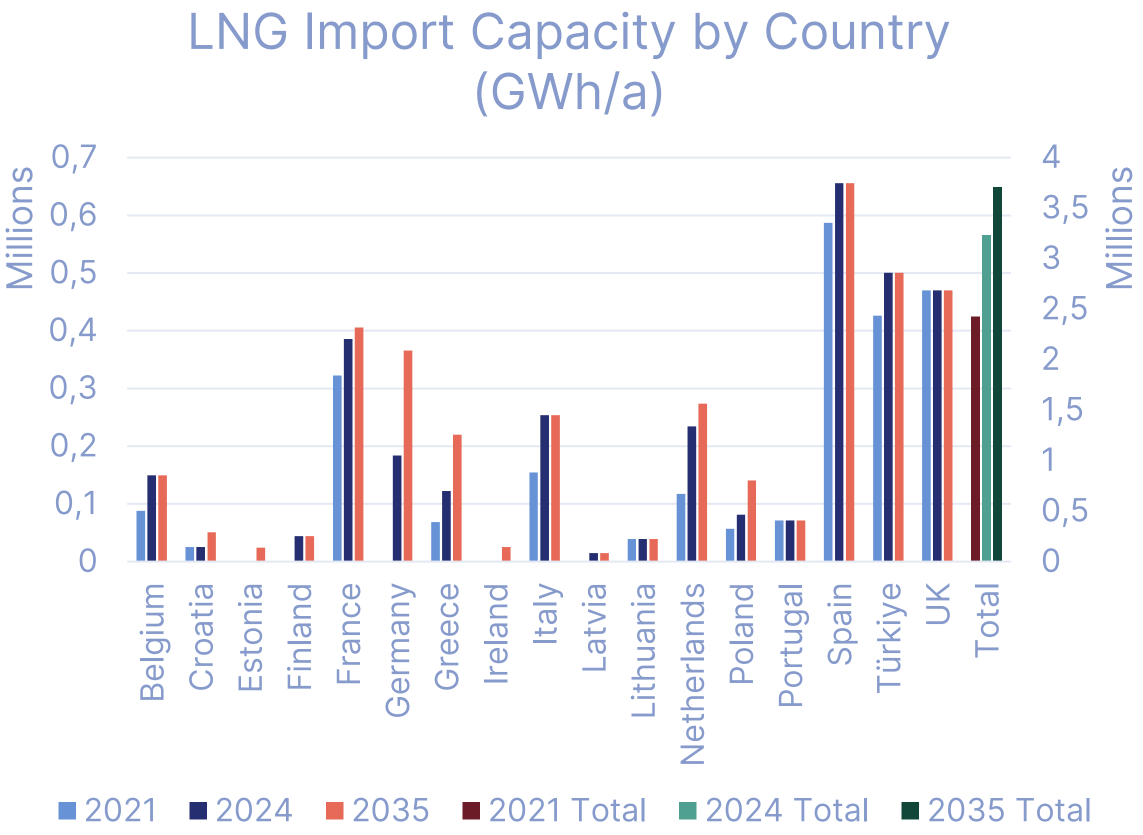
Cost Component	Value	Unit
LNG shipping cost	0.0805	€/GWh/km
Liquefaction cost	8530.35	€/GWh
Regasification cost	8530.35	€/GWh
Panama Canal fee	2217.89	€/GWh
Suez Canal fee	950.00	€/GWh
Pipeline transport cost	1.71	€/GWh/km
Pipeline investment cost	0.51	€/GWh/km/year
Production Cost	Regional Value	€/GWh

[6] Neumann and Zwickl (2024), [25] Panama Channel (2025), [26] Suez Channel (2025),
[27] Eiselt et al (2007), [28] Molnar (2022), [29], DE (2024)

National nodes and net transfer capacities represent Europe's gas grid

From pre-war over the current expansion to 2035 LNG infrastructure

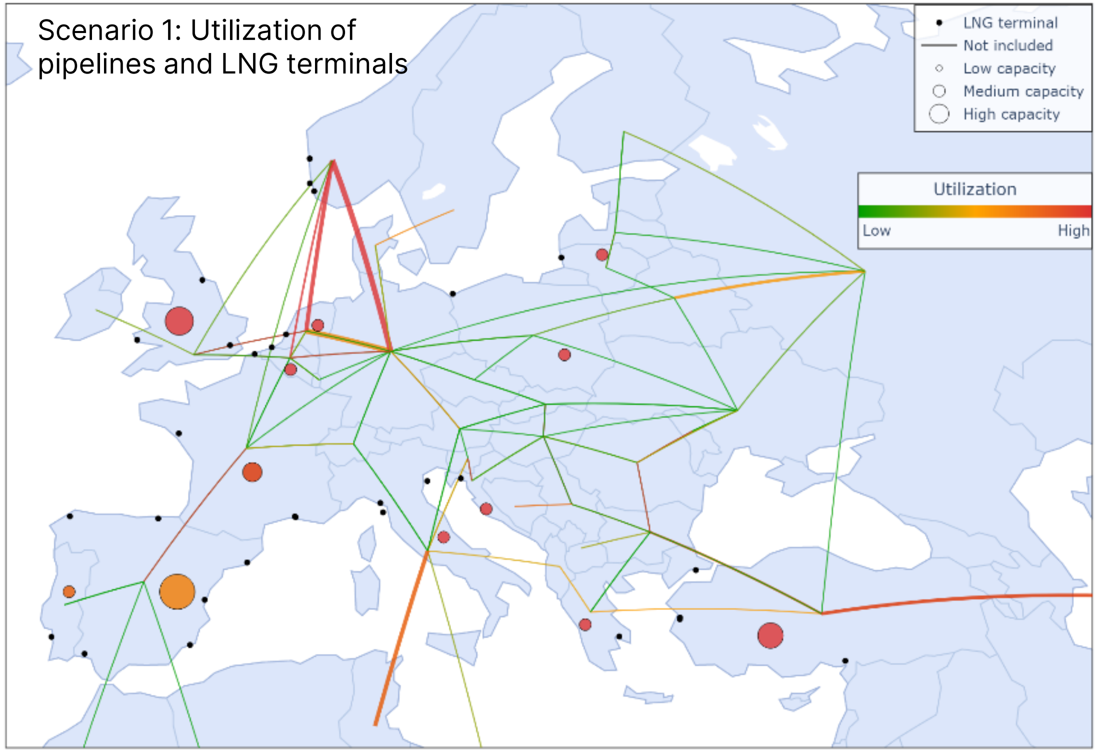




[30] ENTSO-G (2025), [31] ENTSO-G (2025), [32] ENTSO-G (2025), [33] GEM.wiki (2025), [34] Sea Distance (2025), [35] Energy Institute (2025), [36] GIE (2025), [37] IEA (2024)

A Fragile Foundation for Gas Security with High Risk and Low Flexibility

Reference Scenario (2021)



- Supply **reliant on Russian pipelines**; full independence not feasible.
- **Limited flexibility** and severe chokepoints (e.g. NO–DE/NL, NL–DE, FR–ES).

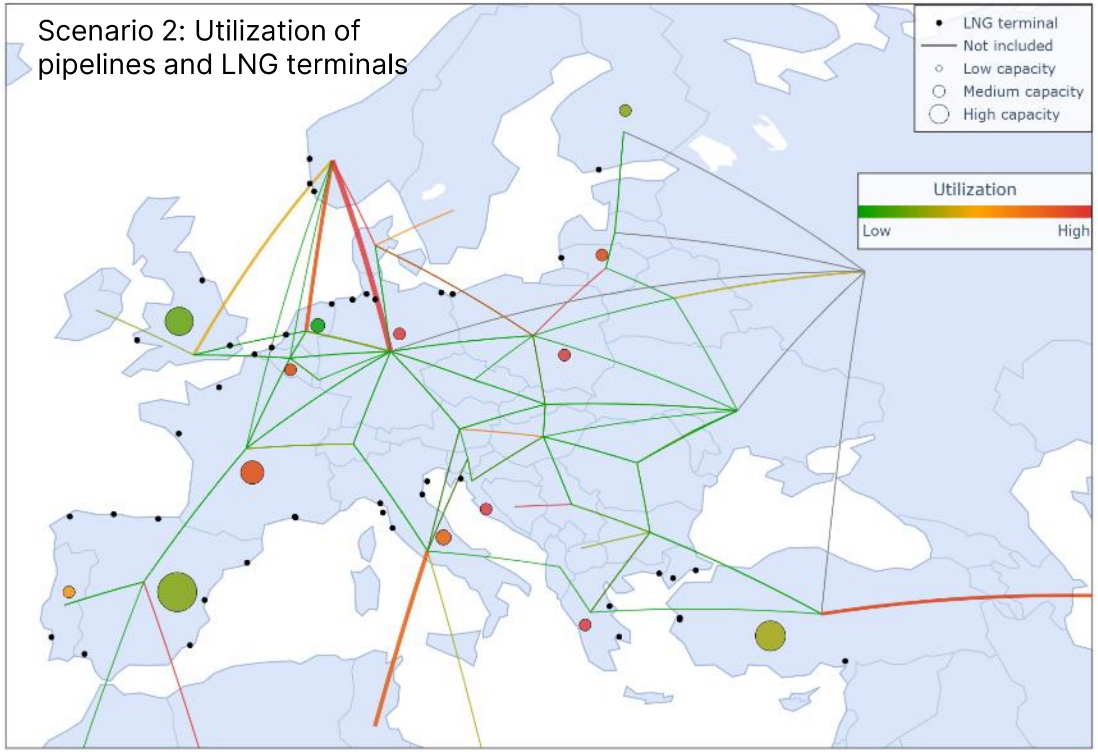
- Price stability based on **fragile assumptions** (uninterrupted Russian flows).
- No structural overinvestment, but **regional imbalance** limited system efficiency.
- **Lack of integration reduced cost-effectiveness**; supply could not flow to where it was most needed.

- Emissions relatively low due to **pipeline dominance** (incl. Russian gas).
- **No demand reduction**, no LNG lock-in yet, but no decarbonisation cushion either.

- Full dependence on **Russian gas**, especially in Southeast and Northeast.
- **No LNG access in Finland**, limited diversification options.
- Severe **infrastructure constraints** (e.g. limited interconnectors to the West).
- **High vulnerability** to supply shocks and price volatility.

Crisis-Driven Resilience with Secured Supply, Uneven Outcomes

Realized Expansion Scenario (2024)



- Fully **secured supply** despite the loss of Russian gas.
- **High LNG flexibility**, but overcapacity in peripheral terminals (ES, PT, TR).
- **Security driven by demand reduction**, not infrastructure.

- Moderate price effects; **Central and Eastern Europe** benefit from expanded infrastructure.
- Some **LNG terminals underutilised** → risk of sunk costs.

- Emissions decline **driven by demand-side reduction**.
- **Overcapacity** risks future fossil lock-in.

- **Supply secured**, but regional stress persists.
- Poland & Baltics **heavily rely on LNG**, terminals near capacity.
- **Southeast limited by grid**, dependent on Turkish inflows.
- **Slight price relief** in PL/UA, but energy poverty remains structurally unresolved.

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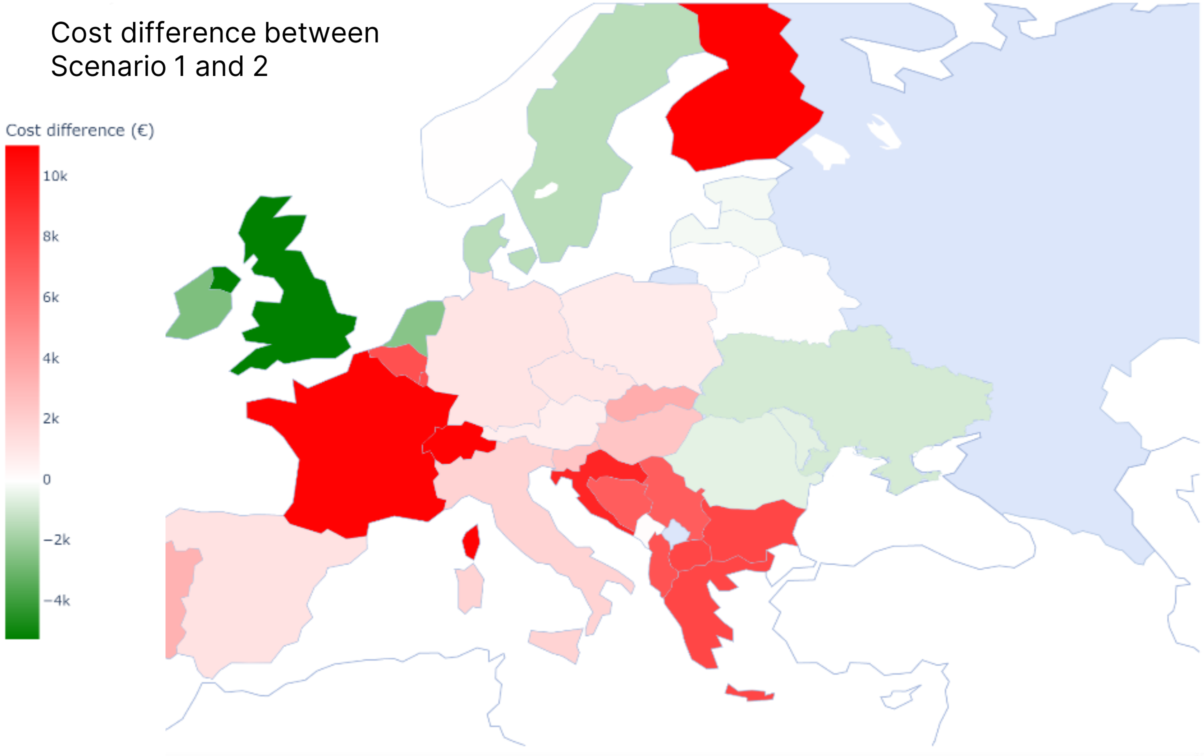

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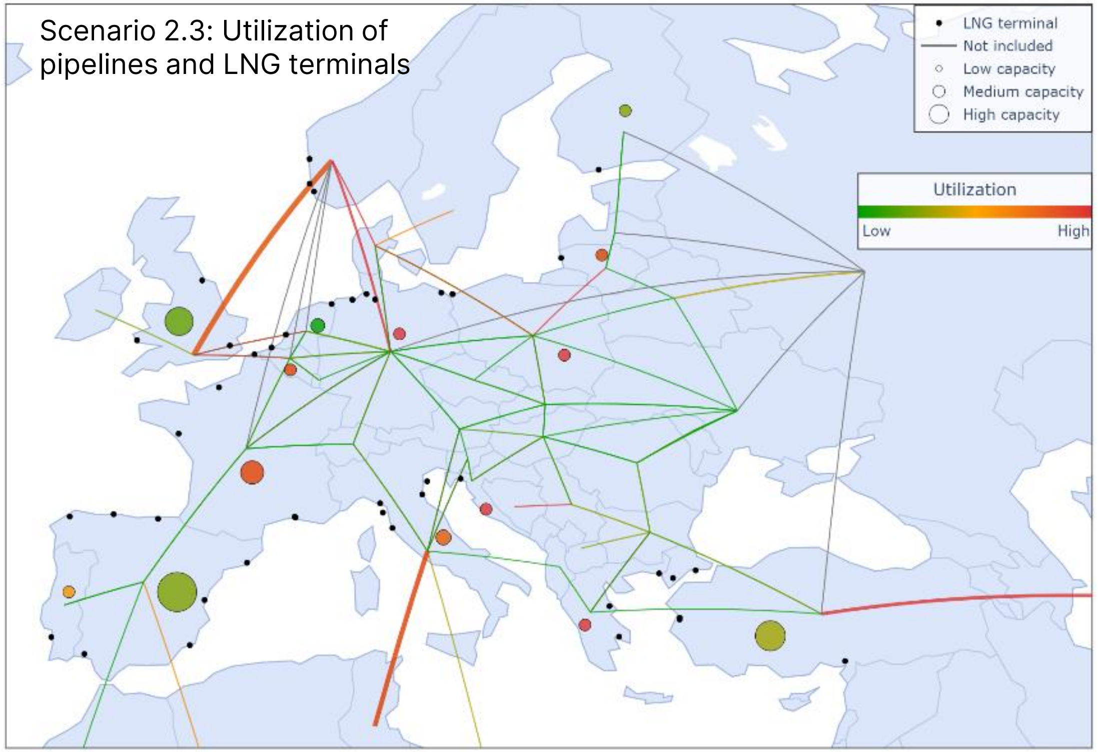
Norwegian Pipeline Loss Strains the System

Realized Expansion Scenario (2024) with interruption of pipeline gas flows from Norway



Supply remains secure but system is more stressed.

- Loss of Norwegian pipeline flows **increases reliance on LNG**, especially in DE and PL.
- More **complex rerouting and higher utilisation** of southern corridors.

- **Mixed economic effects**.
- Slight **price increases** in NL, ES, Southeast Europe due to loss of pipeline advantage.
- Greater burden on LNG import infrastructure raises **cost volatility**.

- Higher LNG share **increases lifecycle emissions** slightly.
- Loss of Norwegian pipeline gas (low GHG intensity) **worsens carbon footprint regionally**.

- Increased LNG **burden on DE/PL infrastructure**.
- Southeast faces **price rise** due to rerouting and longer supply chains.
- Vulnerability to **pipeline loss** with limited fallback option.
- Confirms **pipelines are more effective** for Eastern Europe than LNG expansion.

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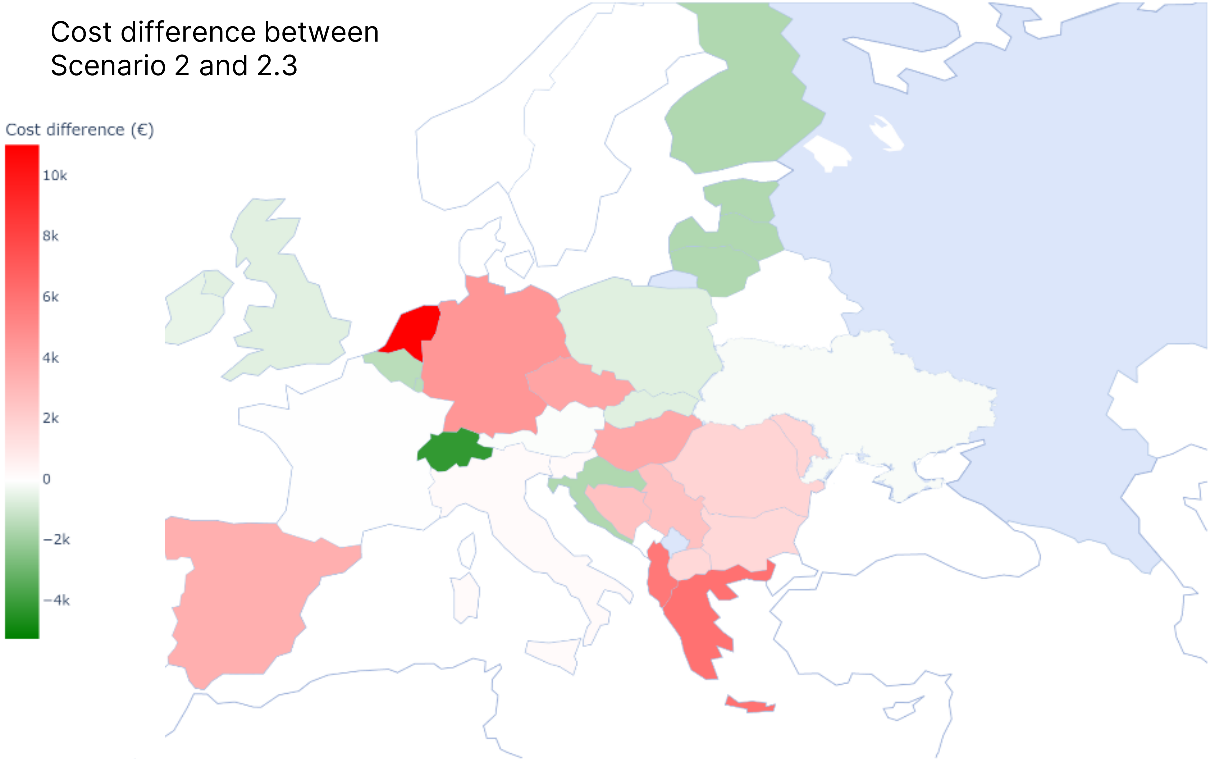
Cost difference between Scenario 2 and 2.3



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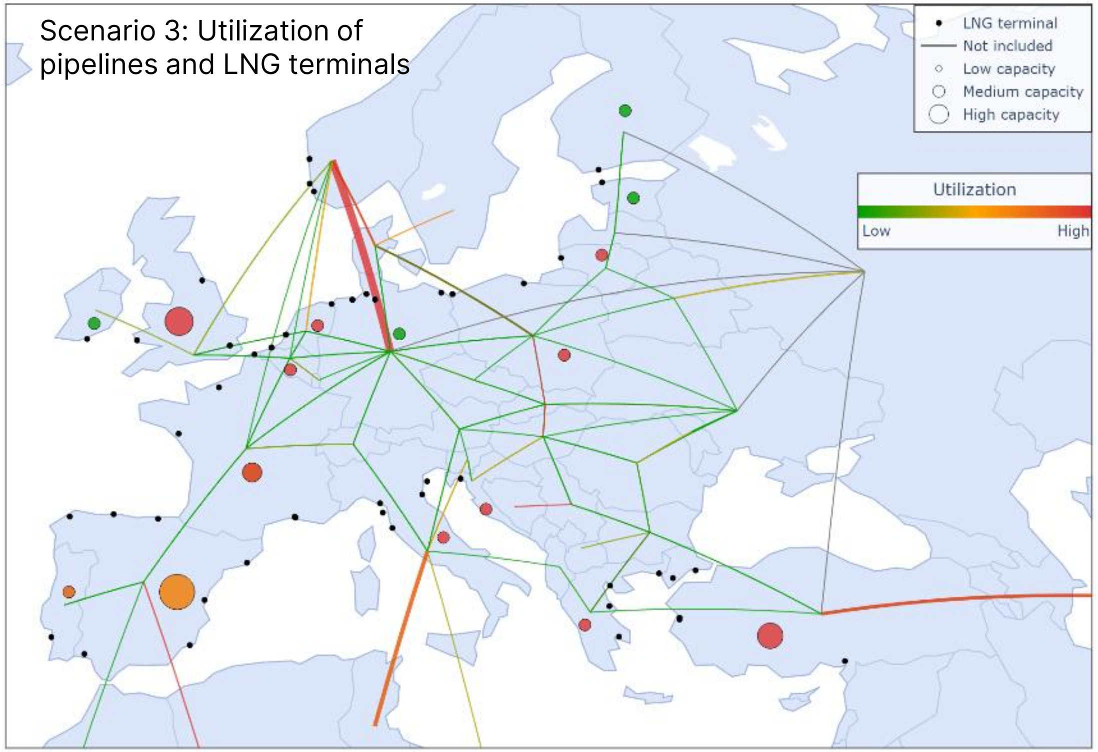
Efficiency Through Integration – Better Balance Without Expansion

Alternative Resilience Scenario (2024) with targeted investment in the infrastructure



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- **Less LNG** use reduces lifecycle emissions.
- Aligns better with **EU climate goals**.
- **No additional lock-in** from new terminals.

- Internal pipeline reinforcements **improve eastward flow**, especially via Poland.
- **Stress on LNG terminals in Eastern Europe decreases**, as pipeline capacity absorbs more volume.
- More **balanced gas distribution**, lower regional congestion.
- **Prices fall or stabilise** in Eastern and Southeastern Europe.
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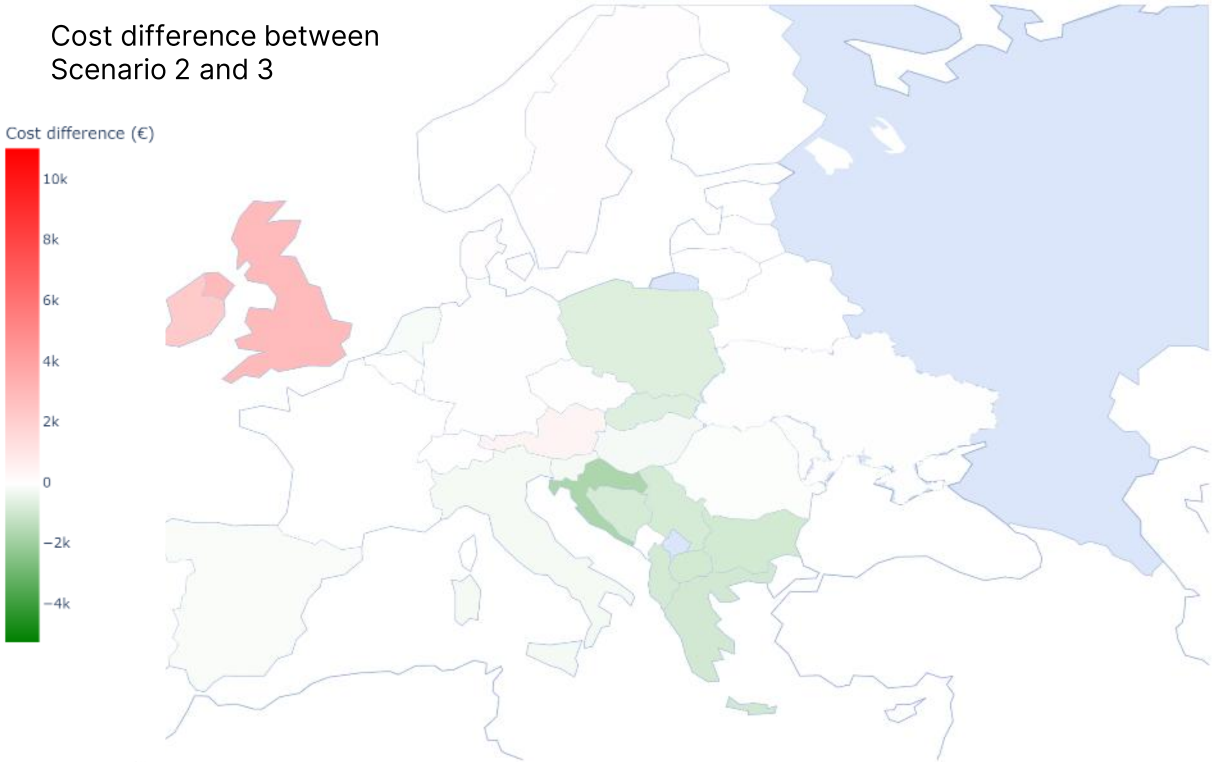

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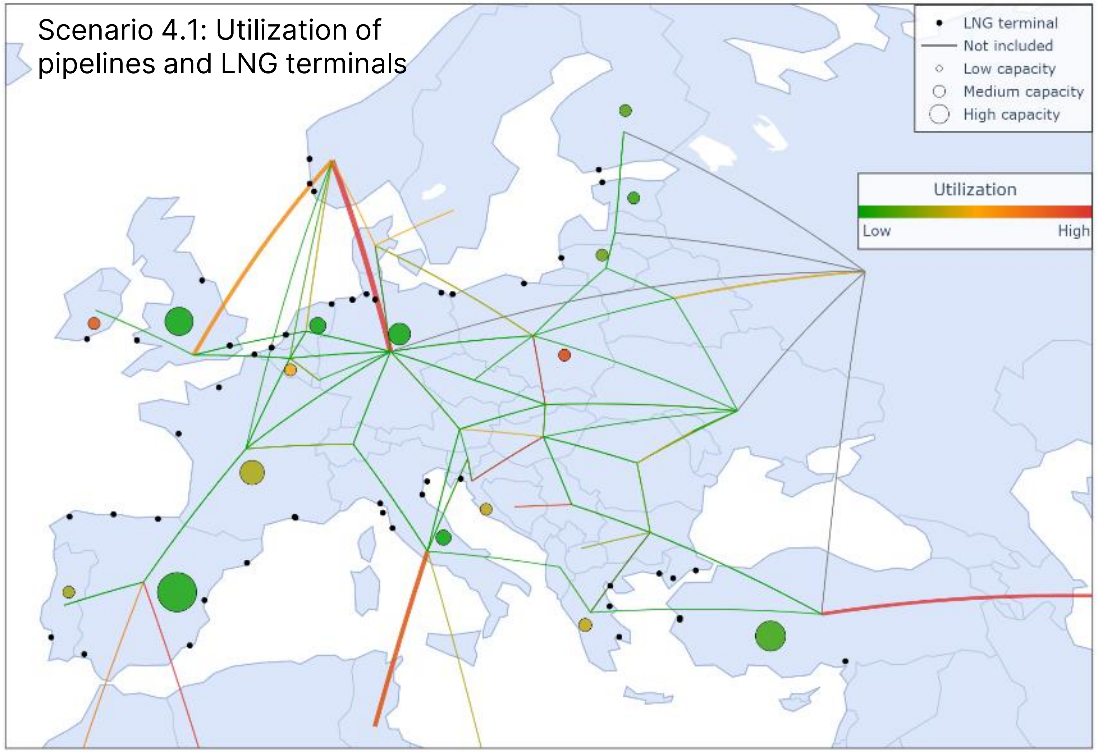
Stable System with Persistent Structural Imbalances

Planned LNG Expansion Scenario (2035) with demand from the IEA Stated Policies Scenario



- **Supply secured**, but regional disparities remain.
- Overcapacity coexists with stress in Eastern Europe.

- **Prices fall** in most regions, but less so in the East.
- Overbuilt LNG terminals lead to **sunk cost risk**.

- **Emissions decline** only moderately.
- Stated policies **insufficient for deep decarbonisation**.
- **Lock-in risk remains** high due to long-term LNG contracts.

- Supply secure, but Eastern Europe sees **limited price relief**.
- **Grid fragmentation** limits access to unused LNG capacity.
- **Infrastructure stress** persists in PL, Baltics, Southeast.
- **Energy poverty unchanged**; price drops don't reach vulnerable groups.
- **Reveals inequality in access and utilisation**, despite EU-wide capacity surplus.

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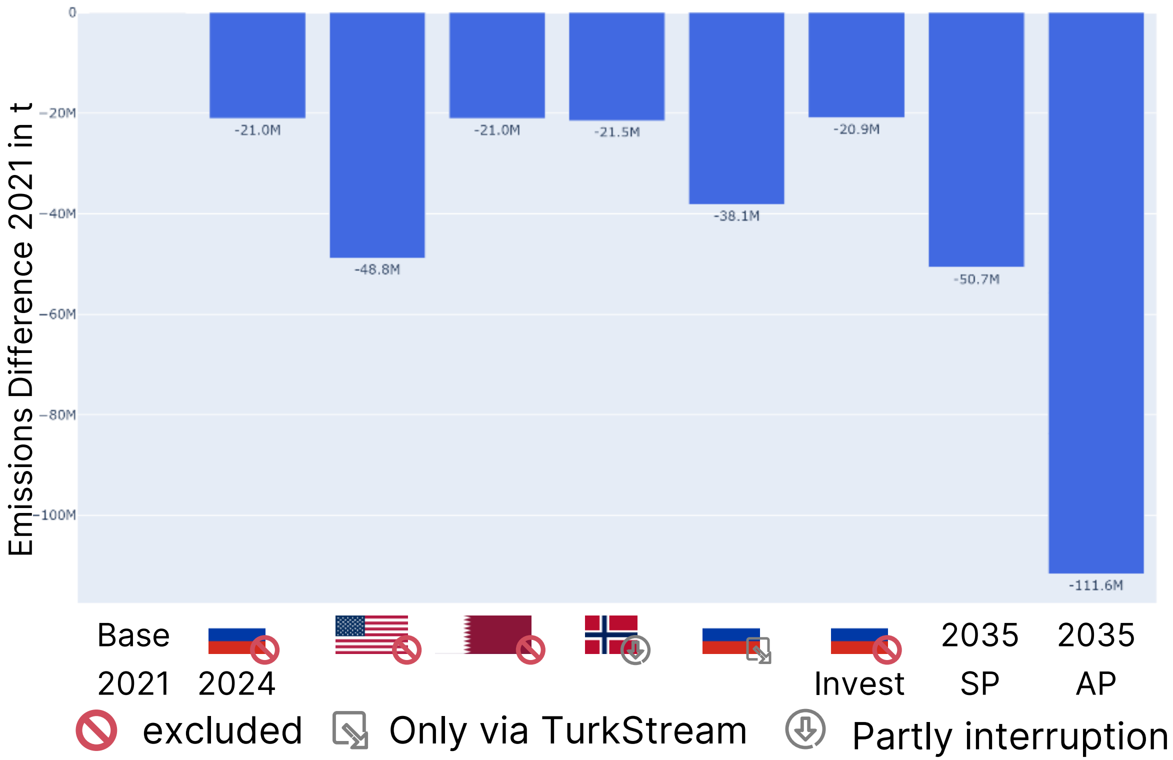

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The analysis highlights the need for spatially, integrated planning

Limitations & Conclusions

- **Model focus**
  - Calculation on annual level does not show operational bottlenecks
  - No consideration of full market behaviour and long-term contracts
  - Cost estimates are simplified
  - Assumes rational infrastructure use up to 100% per year
  - No factors such as politics, delays or social opposition
- **The effects of global emissions**
  - Simplified assessment uses averages for the whole of Europe
  - No scenario with endogenous minimisation
  - Hydrogen and long-term repurposing options not covered
- **Energy poverty and Eastern Europe**
  - Effects are discussed qualitatively based on regional access and price signals
  - No economic analysis based on current data
- **Reducing demand is crucial for achieving**
  - energy security
  - affordability and economic efficiency
  - Sustainability
- **Supply without any Russian gas in Europe is possible**
  - LNG ensured short-term supply and increased resilience
  - LNG expansion created regional disparities, overcapacity and risks of fossil lock-in
- **Reinforcing the pipeline provides more balanced outcomes**
  - Reaching emission reductions
  - Cost-efficient supply and transition
- **Eastern and Southeastern Europe**
  - Remains structurally disadvantaged
  - Benefit more from internal infrastructure coordination than from global LNG markets

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The Gas Infrastructure Model

Single time step deterministic cost minimization

Objective:

- Minimize total cost of gas supply

$$Min \sum_{(i,j)\in E} x_{ij,Commodity} * c_{var,ij,Commodity}$$
$$+ x_{ij,Commodity} * c_{trans,ij,Commodity}$$
$$(+ new_{ij,Commodity} * c_{new,ij,Commodity})$$

s.t:

- Kirchoff's 1st law

$$\sum_{(i,j)\in E} x_{ij,commodity} - \sum_{(k,i)\in E} x_{ki,commodity}$$
$$= S_{i,commodity}$$

- Capacity Constraint

$$x_{ij,commodity} \leq cap_{ij,commodity}$$

Variables:

- $x_{ij,Commodity}$ = flow per edge
- $new_{ij,Commodity}$ = new capacity per edge

Parameters:

$S_{i,commodity}$ = Demand / Supply at node i
$cap_{ij,commodity}$ = Capacity of edge i,j for
$c_{var,ij,Commodity}$ = production cost of edge i,j
$c_{new,ij,Commodity}$ = construction cost of edge i,j for each commodity
$c_{trans,ij,Commodity}$ = transportation cost of edge i,j

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- The Gas Infrastructure Model will be available soon open source: Giehl et al. (2025): CSEI's Gas Infrastructure Model, https://github.com/CSEI-EU/gas_infrastructure_model using the Branch IAEE_Paris_2025 for the data of the presentation.