Energiewirtschaftliches Institut an der Universität zu Köln

Model-based analysis of market integration and congestion in the European gas market

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Infraday
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Motivation

- Potentially large investment requirements in the European gas market

  (1) Rising import dependency requires additional capacities

  (2) Third Energy Package: Improving competition requires enhancing physical market integration

  (3) Security of supply scares: Mitigation of risks through increased interconnection

- European Recovery Plan, Trans-European Networks, 10Year-Network Development plans by TSOs & ENTSO-G
- Lack of coherent investigation of investment requirements

Motivation

- Study initiated by European Regulators‘ Group for Electricity and Gas (ERGEG), prepared by the Institute of Energy Economics at the University of Cologne (EWI):

  *Model-based Analysis of Infrastructure Projects and Market Integration in Europe with Special Focus on Security of Supply Scenarios**

- European-wide, model-based, top-down approach

*http://www.ewi.uni-koeln.de/ERGEG-Study.303.0.html

Agenda

1. Theoretical Background

2. Model-based Approach

3. Selected Results

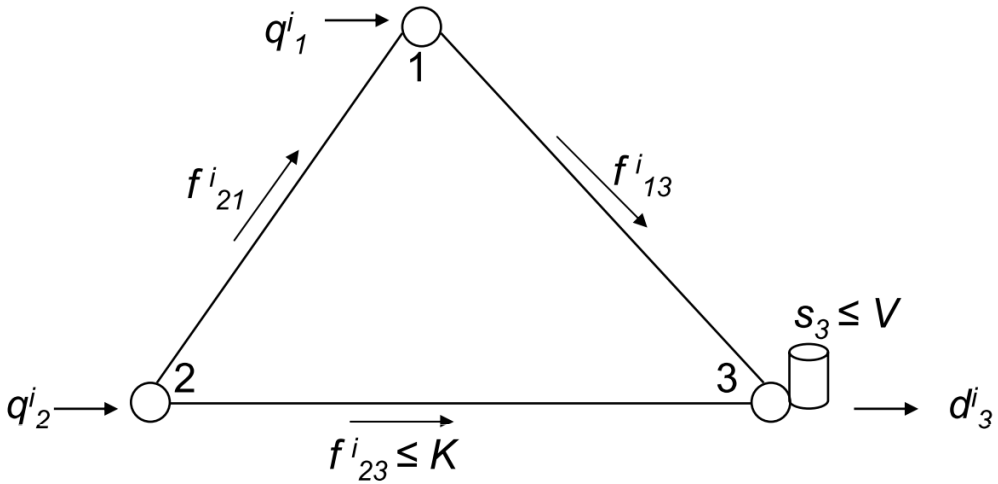
Literature

Capacity Valuation and Investments in Gas Markets:

- Small literature on infrastructure valuation in interconnected gas grids (Cremer/Laffont EER 2002)
- Generally based on approaches from electricity grids:
  - LMP (Schweppe 1988)
  - Congestion Pricing (Hogan, J Reg Econ 1992)

- EWI Working Paper: Extension of Cremer/Laffont approach with inclusion of temporality / storages

Simple grid with storages – Problem Setup



Welfare Optimization Problem:

$$
\begin{aligned}
SW \quad = & \sum_{t=0}^{1} \frac{1}{(1+i)^t} \Big[\\
& + \left(S(d_3^t) - p_3(d_3^t) d_3^t\right) \\
& + \left(p_3(d_3^t) d_3^t - p_1(q_1^t) q_1^t - p_2(q_2^t) q_2^t - c_{13}(z_{13}^t) l_{13} - c_{21}(z_{21}^t) l_{21} - c_{23}(z_{23}^t) l_{23}\right) \\
& + \left(p_1(q_1^t) q_1^t - C_1(q_1^t) + p_2(q_2^t) q_2^t - C_2(q_2^t)\right) \Big] \\
& - c_{storage}(s_3) - G - H
\end{aligned}
$$

Simple grid with storages – Optimality Conditions

Optimality conditions:

$$P_3^t \leq P_2^t + c_{23}^{transport} + \eta_{23}^t$$

Shadow cost of the pipeline capacity constraint

$$P_3^{t+1} \leq (P_3^t + c^{storage})(1+i) + \lambda$$

Shadow cost of the storage capacity constraint

Application to Analysis of Transport Infrastructures

- Investigation of physical market integration / investment requirements -> Where do we identify congestion?

$$P_B^t \leq P_A^t + c_{AB}^{transport} + \eta_{AB}^t$$

i. Capacity Constraint not binding:

$$\eta_{AB}^t = 0 \quad \Leftrightarrow \quad P_B^t - P_A^t \leq c_{AB}^{transport}$$

ii. Capacity Constraint associated with shadow cost:

$$\eta_{AB}^t > 0 \quad \Leftrightarrow \quad P_B^t - P_A^t > c_{AB}^{transport}$$

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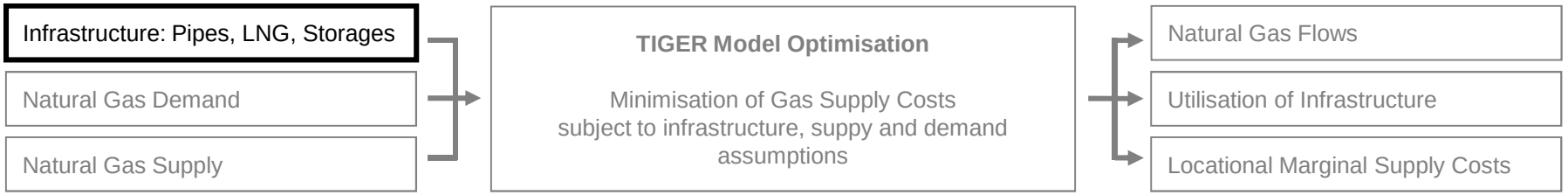
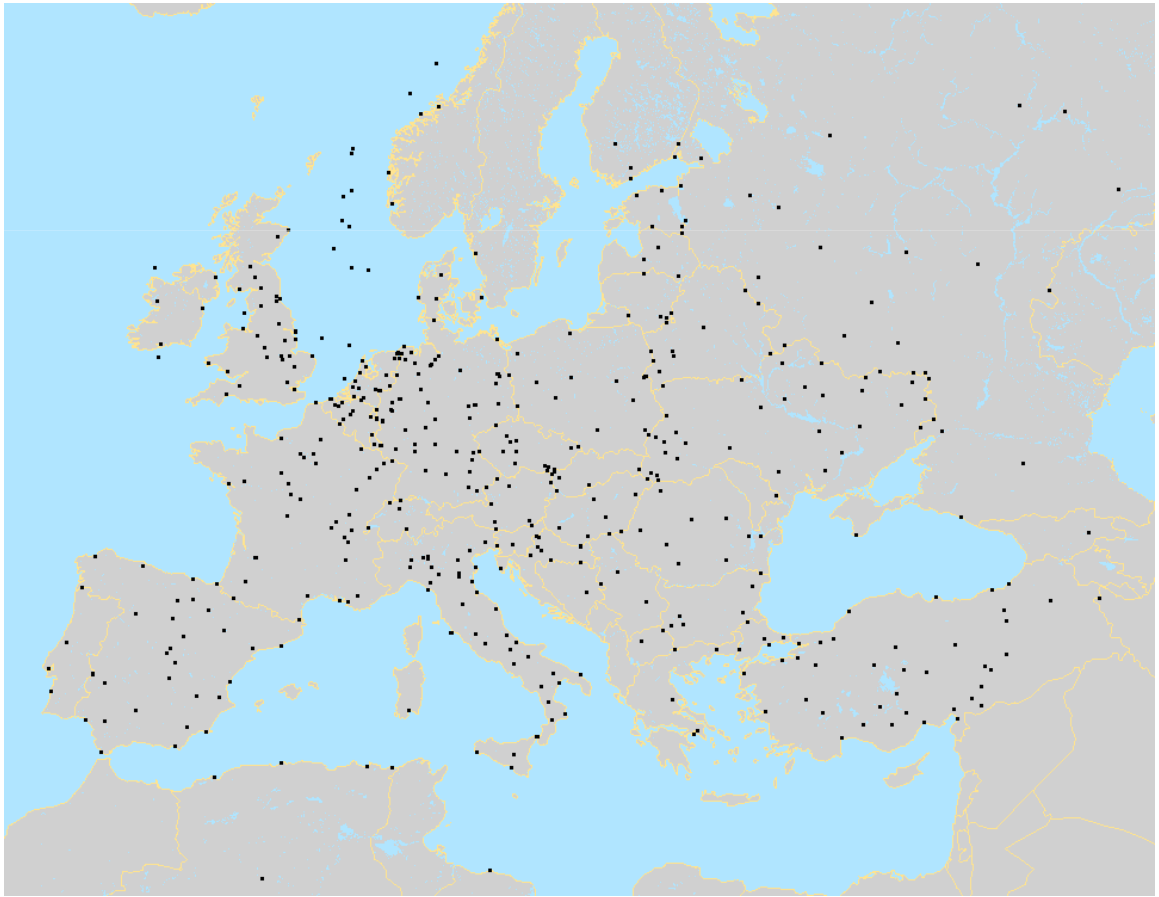
European Infrastructure Model



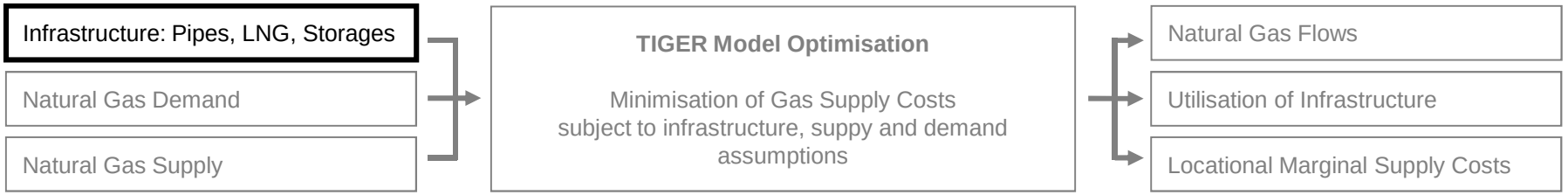


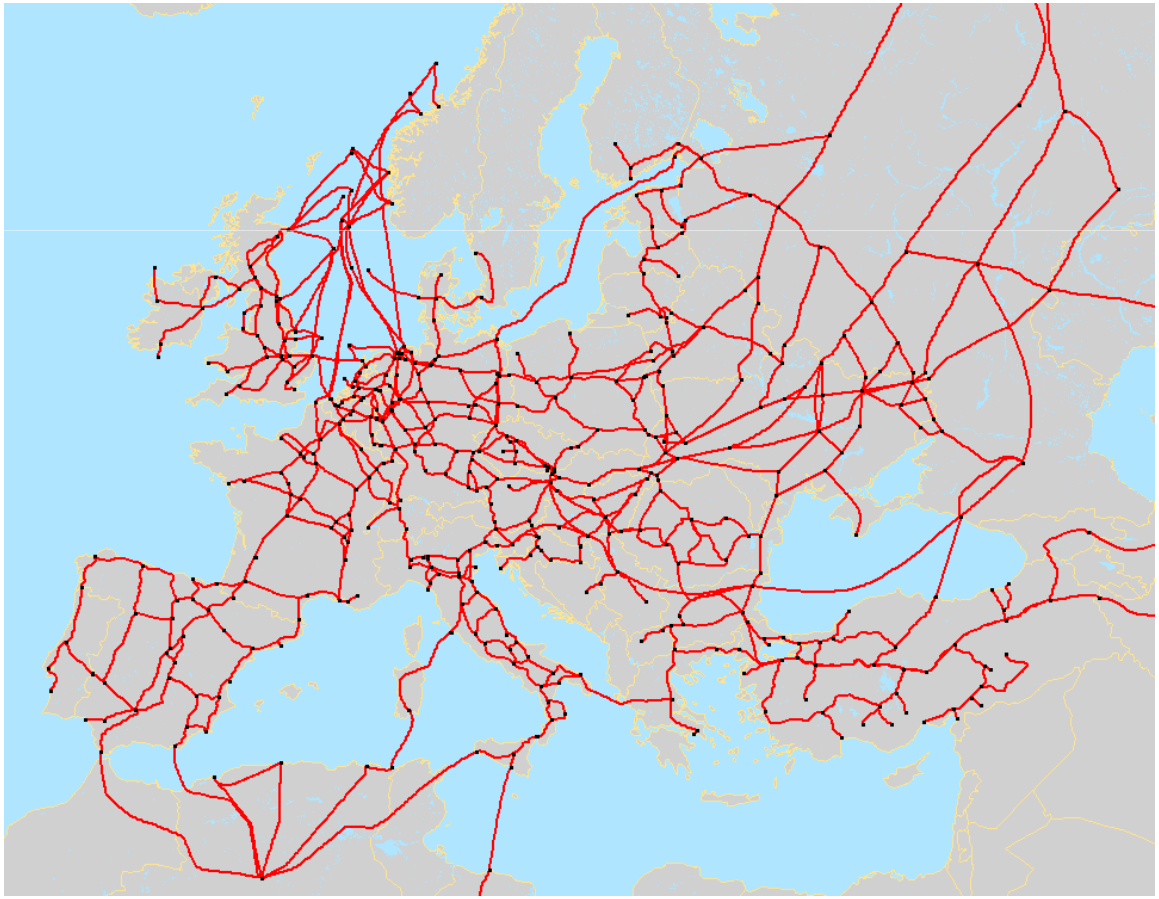
Geocoded Database:

Coverage >EU-27

>600 Nodes

European Infrastructure Model





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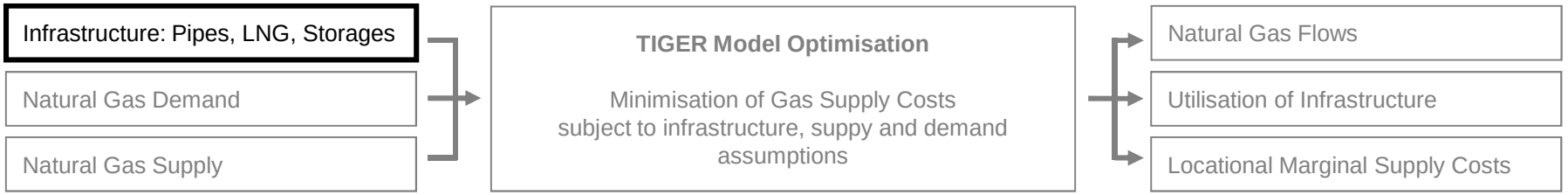
>600 Nodes

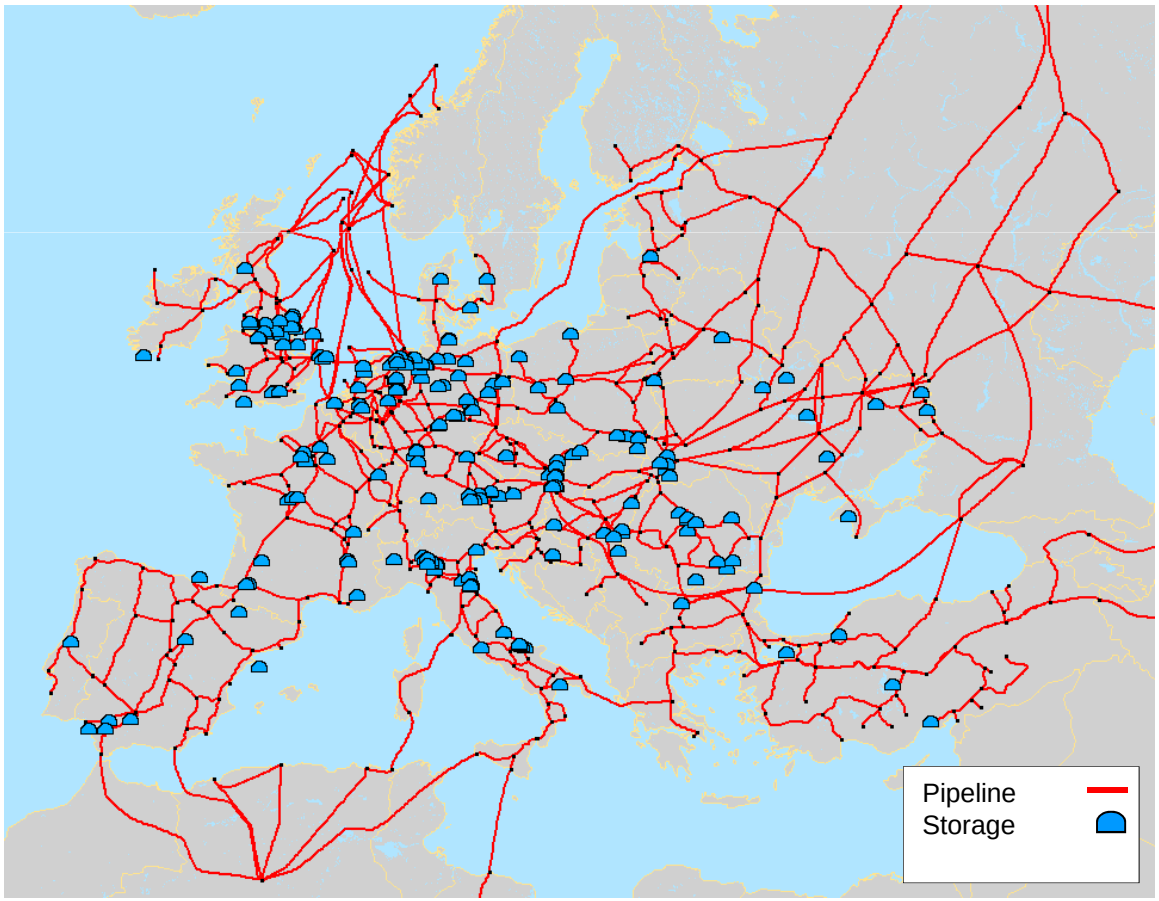
>900 Pipelinesections*

- Based on TSO Maps
- Capacity / Pressure / Diameter
- Nearly all Entry-Points
- Major Exit Points
- Border point capacities

**including projects*

European Infrastructure Model





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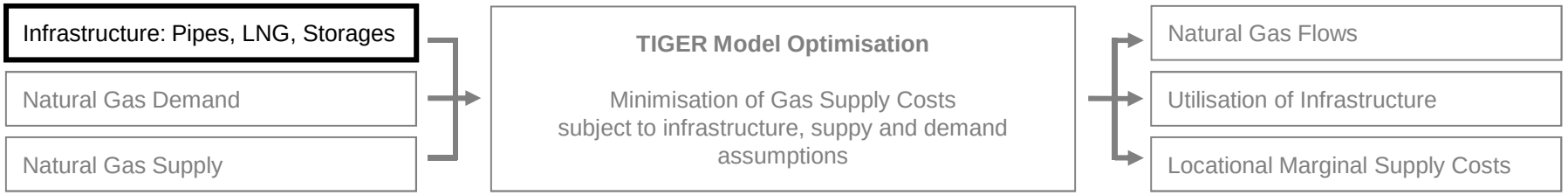
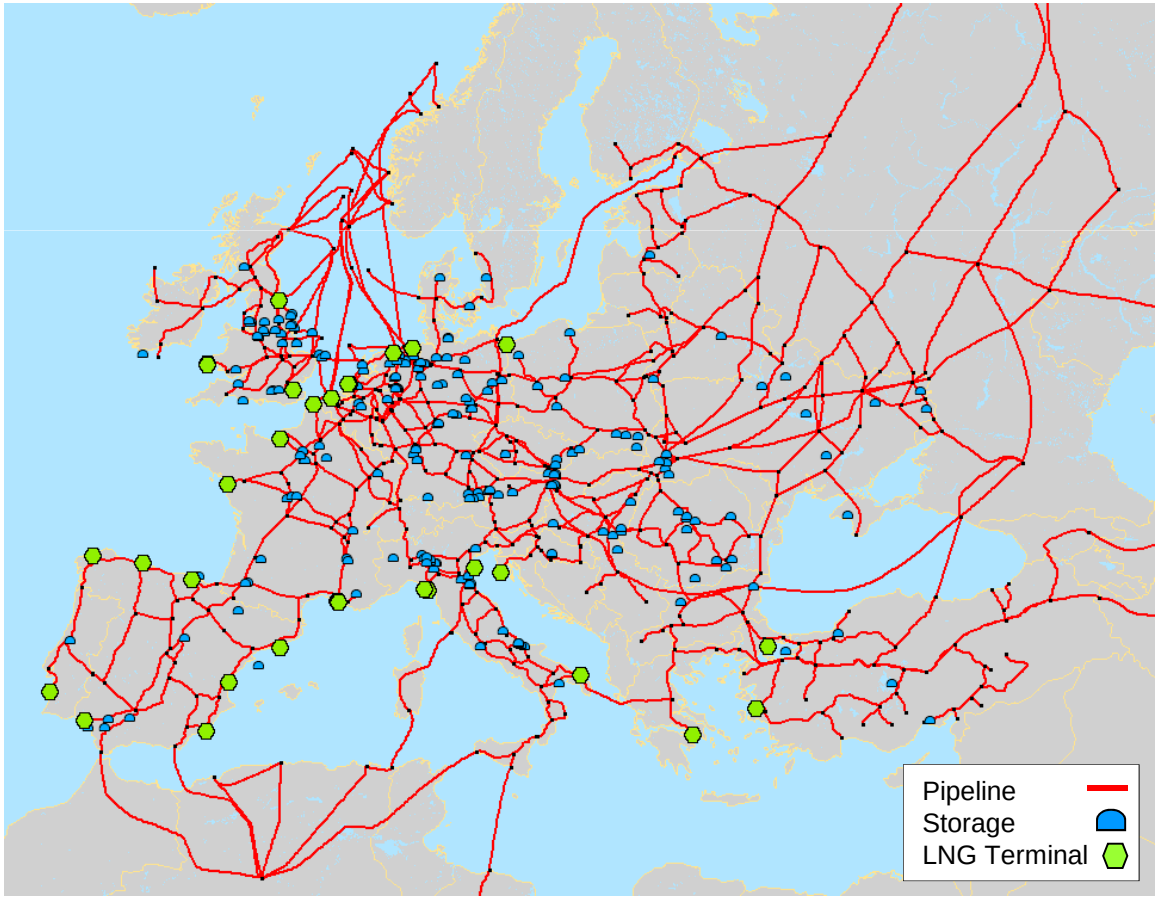
>200 Storages*

- Type
- Max. injection / withdrawal
- Working Gas Volume

**including projects*

European Infrastructure Model





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- Border point capacities

>200 Storages*

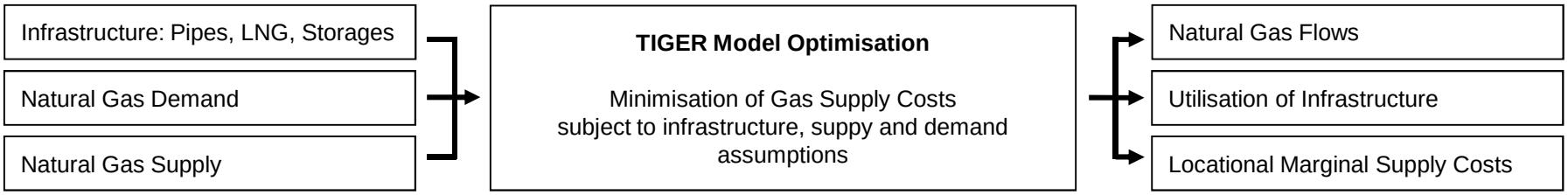
- Type
- Max. injection / withdrawal
- Working Gas Volume

>30 Terminals*

- Max. hourly / annual capacity
- LNG Storage Capacity

**including projects*

Approach for Analysis



- Scenario(s) on gas supply / demand / infrastructures:
  - Based on data from European Commission / ERGEG / TSOs

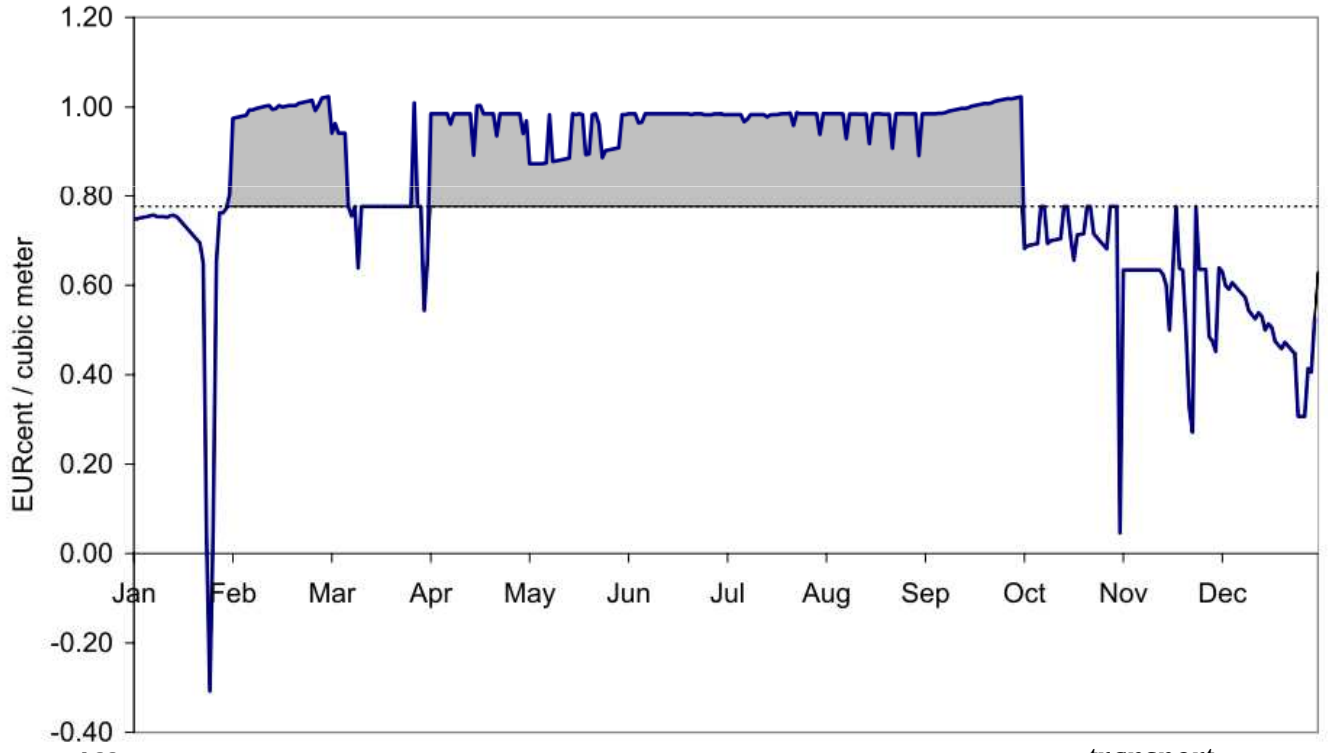
- Scenario Variations:
  - Major Pipeline Projects (Nord Stream II, South Stream, Nabucco)
  - Relative LNG Prices: LT equilibrium vs. “LNG Glut“

Agenda

1. **Theoretical Background**
2. **Model-based Approach**
3. **Selected Results**

Approach for Analysis

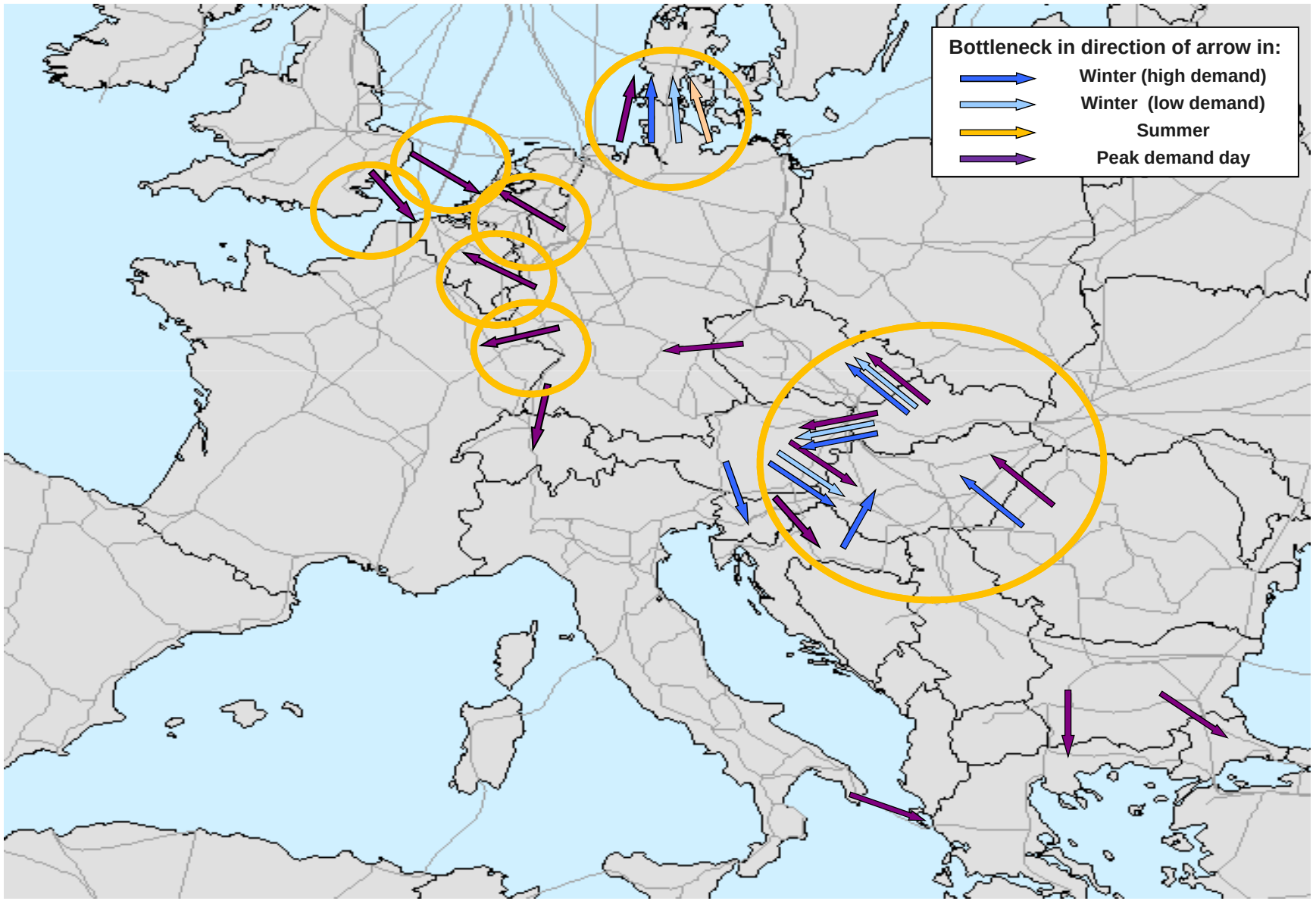
- Computation of Locational Marginal Supply Costs
- Investigation of existence of congestion between selected nodes (pipeline routes / between countries)



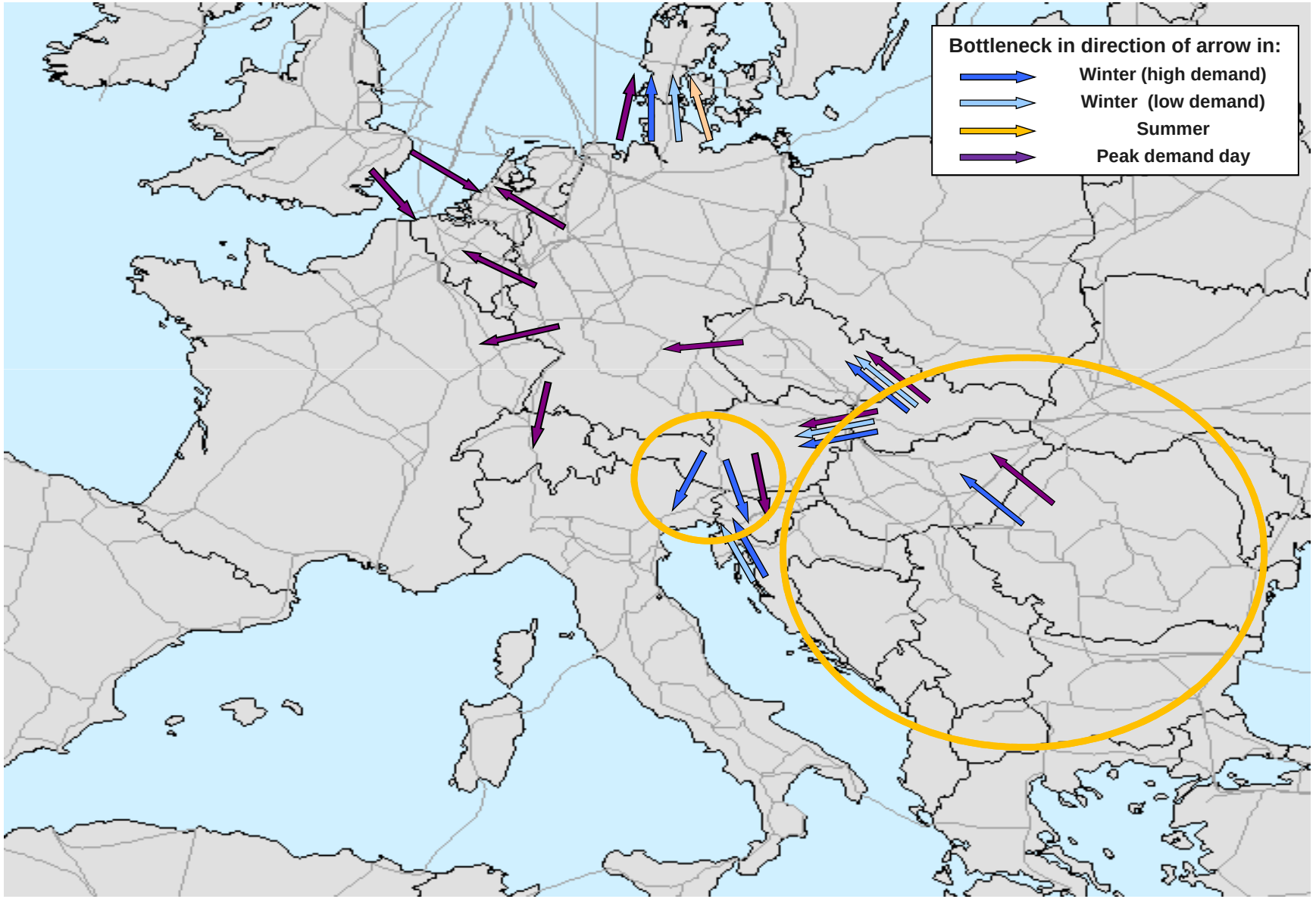
Price Difference $(P_B - P_A)$ ····· Transport Cost $(c_{AB}^{transport})$

Cost of Congestion (η_{AB})

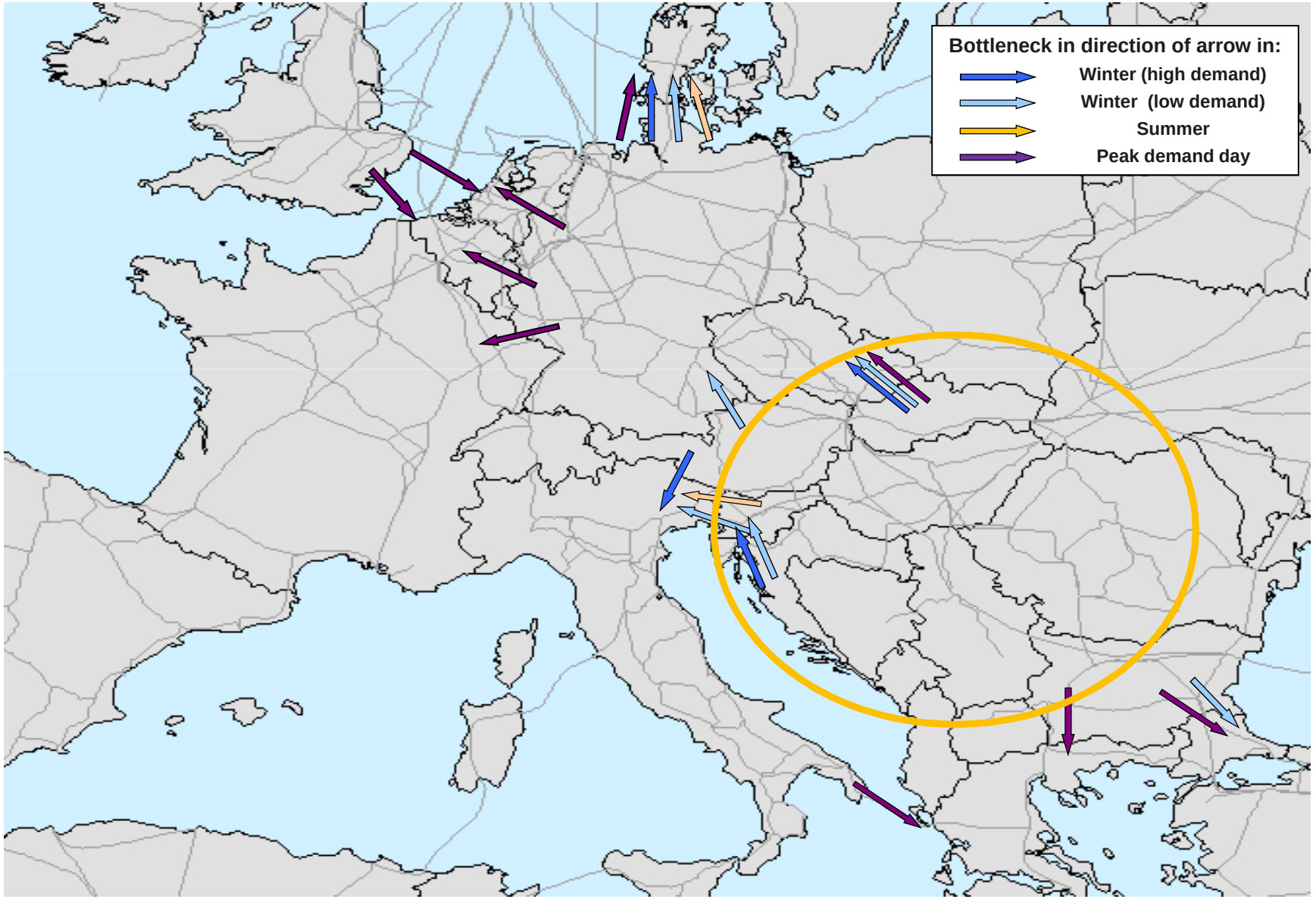
Identified Congestion in Reference Scenario



Effects of Nabucco?



Effects of South Stream?



Findings

- Generally, with all assumed infrastructure projects being included (TYNDP by TSOs), European gas market, especially in Western Europe, well integrated physically
- Some severe bottlenecks (into Denmark, Eastern Europe, especially import capacity into Hungary)
- Further congestion in Western Europe, especially into France, Belgium, Netherlands on days of very high demand due to limited peak storage capacities (and potentially very high demand volatility) there
- Nabucco and South Stream increase physical market integration in Eastern Europe significantly
- Full results on Security of Supply Simulations

-> Study Download: http://www.ewi.uni-koeln.de/ERGEG-Study.303.0.html

Conclusion

- Theoretical framework from electricity grid analysis suitable starting point for valuation of infrastructures in gas markets
- Model-based approach with Europe-wide infrastructure model allows analysis for European gas market
- Identification of possible congestion in simulated efficient market -> possibly further congestion caused by market inefficiencies (especially congestion management and capacity allocation)
- Study focused on congestion identification -> question of efficient amount of investment? (scope for further research)

Thank you for your attention!

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Selected EWI publications on natural gas topics

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