Designing a model for the cost-optimal decommissioning and refurbishment investment decision of gas networks

CANCEL

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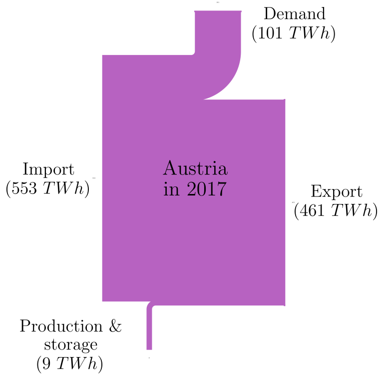
Outline

Current situation of (natural) gas in Austria

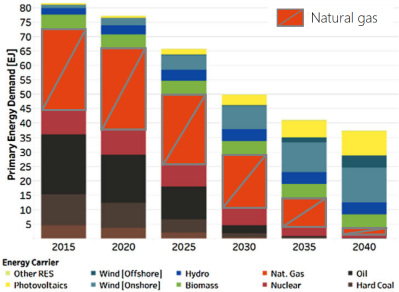
- Area-wide transmission and distribution network infrastructure (≈ 46 000 km)
- Supply of 1,245,000 households and 103,000 companies (incl. industry)
- Important transmission route from east (i.e., gas import) to west (i.e., gas export) and seasonal gas storage
- Defossilization and related (natural) gas demand reduction in line with Austrian and European decarbonization pathways



Holzmann, A. & Strimitzer, L. (2019) *Netzeinspeisung von erneuerbarem Gas.*

Consensus between science and policymakers on natural gas

”Our results suggest that, globally, a third of oil reserves, **half of gas reserves** and over 80 per cent of current coal reserves **should remain unused** from 2010 to 2050 in order to meet the target of 2.0 ℃.” McGlade, C. & Ekins, P. (2015) *Nature 517(7533), 187-190.*



Source: Auer et al. (2020) *e&i, 137(7), 346-358.*


KLEINE ZEITUNG

Startseite › Wirtschaft

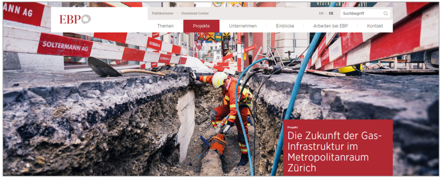
Bund und Länder einig | Heizen in Österreich künftig ohne Öl & Gas

Nun ist es fix: Für Kohle- und Ölheizungen kommt in Österreich spätestens 2035 das Aus, für das Ende der Gasheizungen fassen Bund und Länder das Jahr 2040 ins Auge.

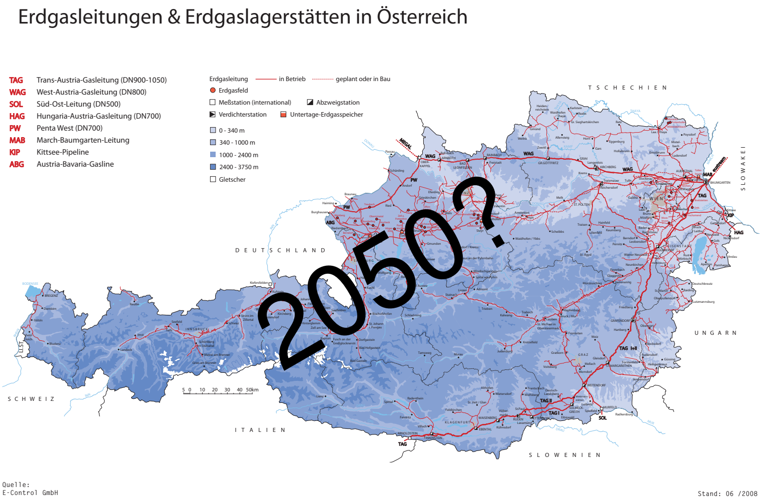
17.49 Uhr, 19. April 2021

ARTIKEL MERKEN

(top) Kleine Zeitung; (bottom) EBP



Reliability of gas supply against the risk of stranded assets



This work's scope (system analysis)

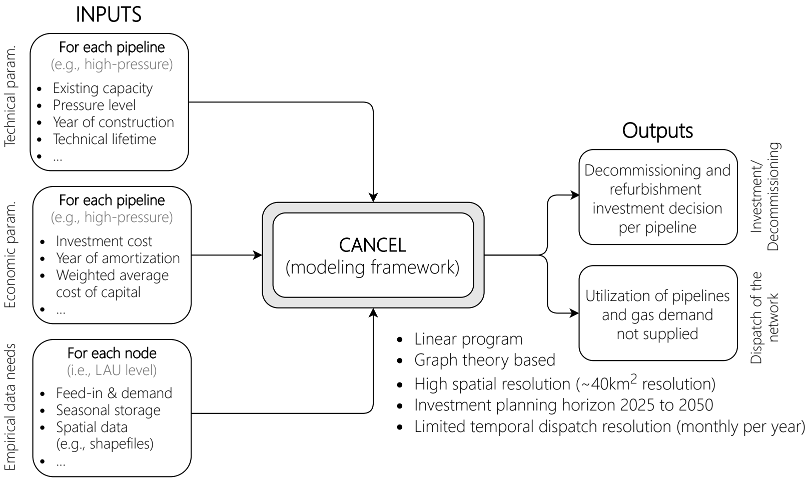
Main research question:

- How does the cost-effective transmission and distribution gas network in Austria until 2050 look like?
- What impact does the expected decline in gas demand as a result of the defossilization of the provision of energy services have on the decision of decommissioning and refurbishment investments of gas pipelines at the local levels in Austria?

Core objective:

- The cost-effective development of the existing gas networks (incl. transmission and distribution network levels) in Austria until 2050.
- In particular, the development encompasses the decision of decommissioning and refurbishment investments of gas pipelines at the community level.

Overview of the modeling framework



- Linear program
- Graph theory based
- High spatial resolution (~40km^2 resolution)
- Investment planning horizon 2025 to 2050
- Limited temporal dispatch resolution (monthly per year)

Mathematical formulation (1/3)

Type	Description	Unit
Set and Index		
$p \in \mathcal{P} = \{1, \ldots, P\}$	Pipeline for gas transport, index by p	
$n \in \mathcal{N} = \{1, \ldots, N\}$	Node of the gas network, index by n	
$l \in \mathcal{L} = \{1, \ldots, L\}$	Gas network level (e.g., high-pressure), index by l	
$y \in \mathcal{Y} = \{1, \ldots, Y\}$	Years, index by y	
$m \in \mathcal{M} = \{1, \ldots, M\}$	Months, index by m	
Decision Variables (Selection)		
Capex	Capital expenditures	EUR
Opex	Operational expenditures	EUR
Revenues	Revenues generated by gas supply	EUR
$\gamma_{p,l,y}$	Capacity of pipeline p at l in y	MW, GW
$q^{dem}_{n,l,y,m}$	Gas demand supplied at n and l in y and m	MWh, GWh
$q_{p,l,y,m}$	Quantity of gas transported at p and l in y and m	MW, GW
$\Pi_{p,l,y}$	Book value of pipeline p at l in y	EUR

Mathematical formulation (2/3)

Type	Description	Unit
Parameters (Selection)		
$\gamma_{p,l,y}^{pre}$	Pre-existing capacity of pipeline p at l in y	MW, GW
$d_{n,l,y,m}^{max}$	Maximum gas demand at n and l in y and m	MWh, GWh
$q_{n,l,y,m}^{fed}$	Quantity of gas fed at n and l in y and m	MW, GW
c_{l}^{inv}	Specific refurbishment investment costs at l	EUR/MW/km
$\Pi_{p,l,y}^{pre}$	Book value of pre-existing pipeline p at n in y	EUR
$y_{p,l}^{inv}$	Year of refurbishment/decommissioning per p and l	1
ω	Weighted average cost of capital	%
i	Interest rate (for calculating the net present value)	%

Mathematical formulation (3/3)

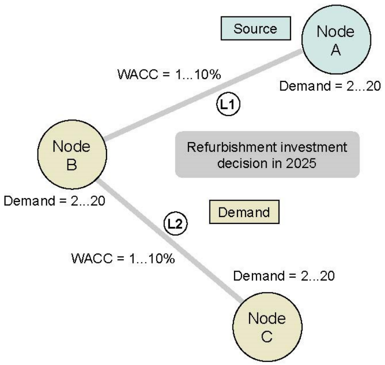
Objective function:

$$\min_{x}\left(\underbrace{Capex + Opex}_{\text{Assets/pipelines}} - \underbrace{Revenues}_{\text{Demand coverage}} + \underbrace{Purchase}_{\text{Storage}}\right)$$

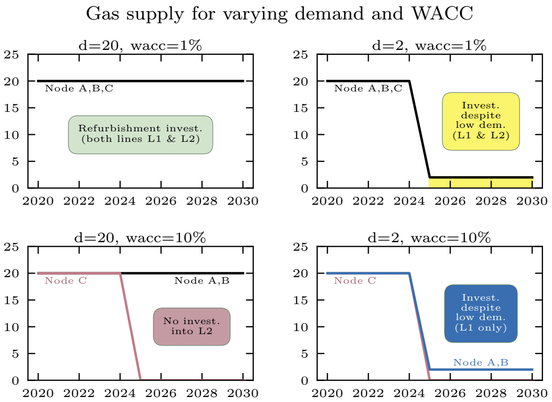
Demand constraint:

$$\underbrace{q^{dem}_{n,l,y,m}}_{\text{Supplied}} \leq \underbrace{d^{max}_{n,l,ym}}_{\text{Total}} \iff q^{dem}_{n,l,y,m} + \underbrace{q^{dem,not}_{n,l,y,m}}_{\text{Not supplied}} = d^{max}_{n,l,ym}$$

Test and verification of the model by different demands and wacc

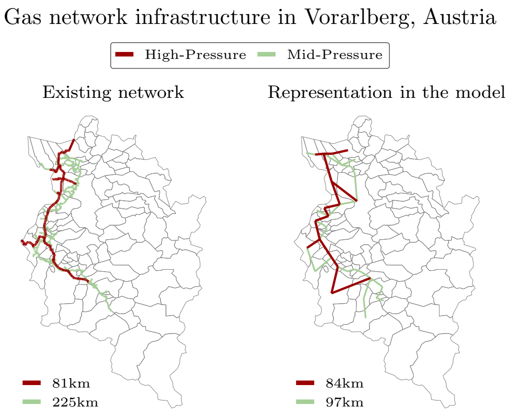


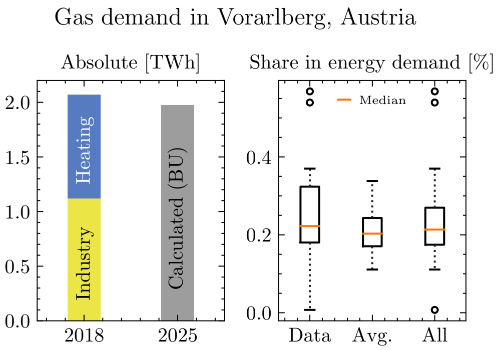
(a) Simplified gas network topology



(b) Four different cases (high/low demand and wacc)

Case example: Vorarlberg's gas network until 2050

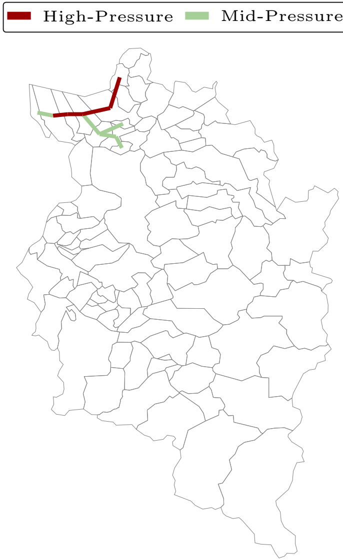




Sources: Vorarlberger Energienetze and Energiemosaik Austria

Type	Decline	2050
Res.	linearly	0
Serv.	8%	12%
Ind.	4%	36%

(a) Gas demand development



Input		Output	
Model run	Demand constraint	Network	Result
1	$q^{dem}_{n,l,y,m} \leq d^{max}_{n,l,ym}$	Cost-optimal without ensured supply	Demand supplied ($\overset{*}{\mathbf{q}}^{dem}_{n,l,y,m}$)
2	$q^{dem}_{n,l,y,m} = \overset{*}{\mathbf{q}}^{dem}_{n,l,y,m}$	Cost-optimal without ensured supply (CO)	Nodal shadow price ($\lambda^{CO}_{n,l,y,m}$)
3	$q^{dem}_{n,l,y,m} = d^{max}_{n,l,ym}$	Cost-optimal with ensured supply (ES)	Nodal shadow price ($\lambda^{ES}_{n,l,y,m}$)

Table: Model runs and related demand constraint variation used to obtain cost-optimal demand supplied and nodal shadow prices

Conclusions and further work

- Large parts of gas network are decommissioned under assumed gas demand developments
- High shares of unsupplied gas demand under cost-optimality of gas networks
- Detailed analysis of gas demands at the community level (incl. their energy services covered)
- Comparison of gas networks w/ unsupplied demand constraints
- Shadow prices at the nodal level (i.e., community level) provides an estimate of the costs necessary to economically substitute natural gas with alternatives