Towards unified framework for district heating resilience

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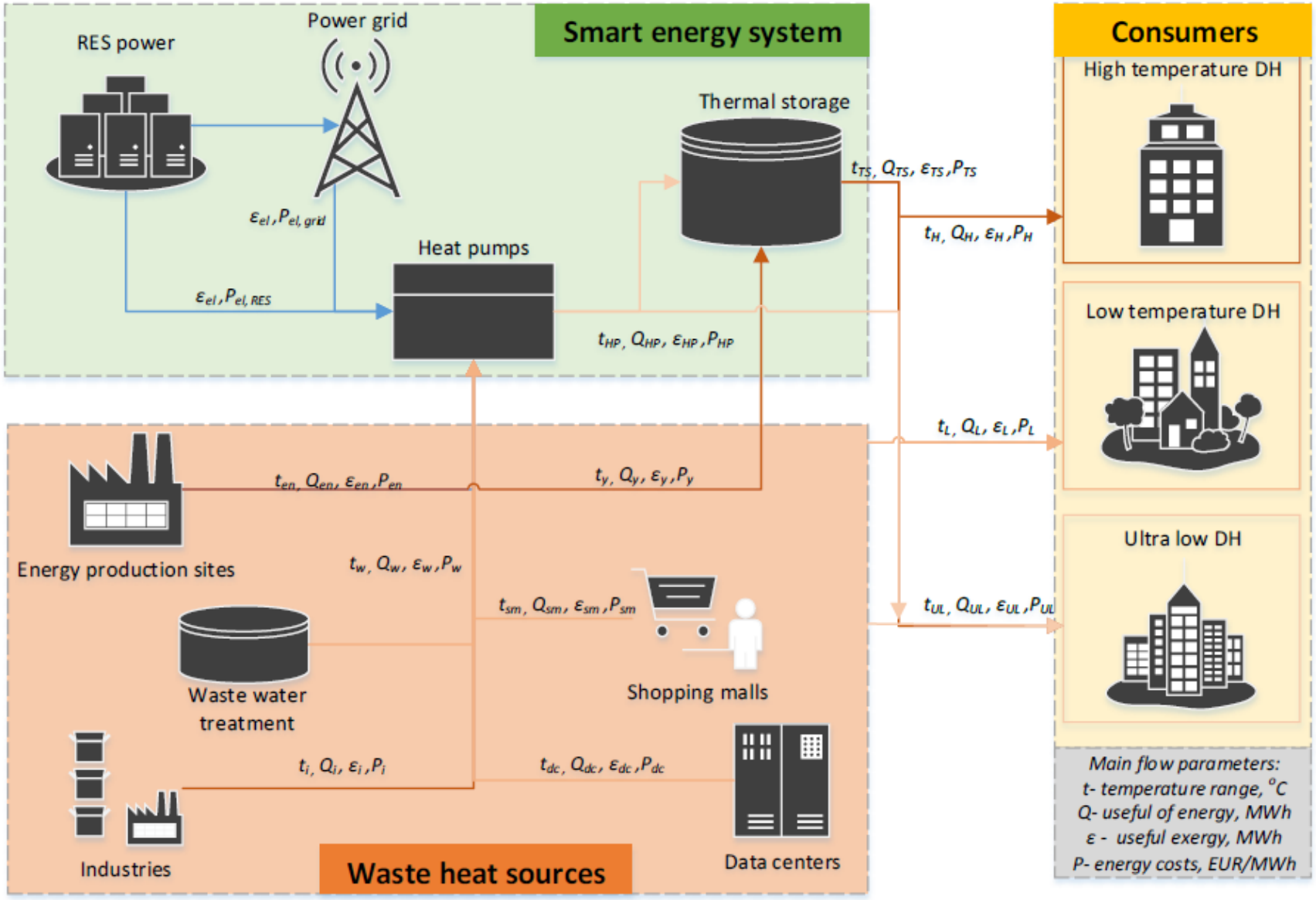
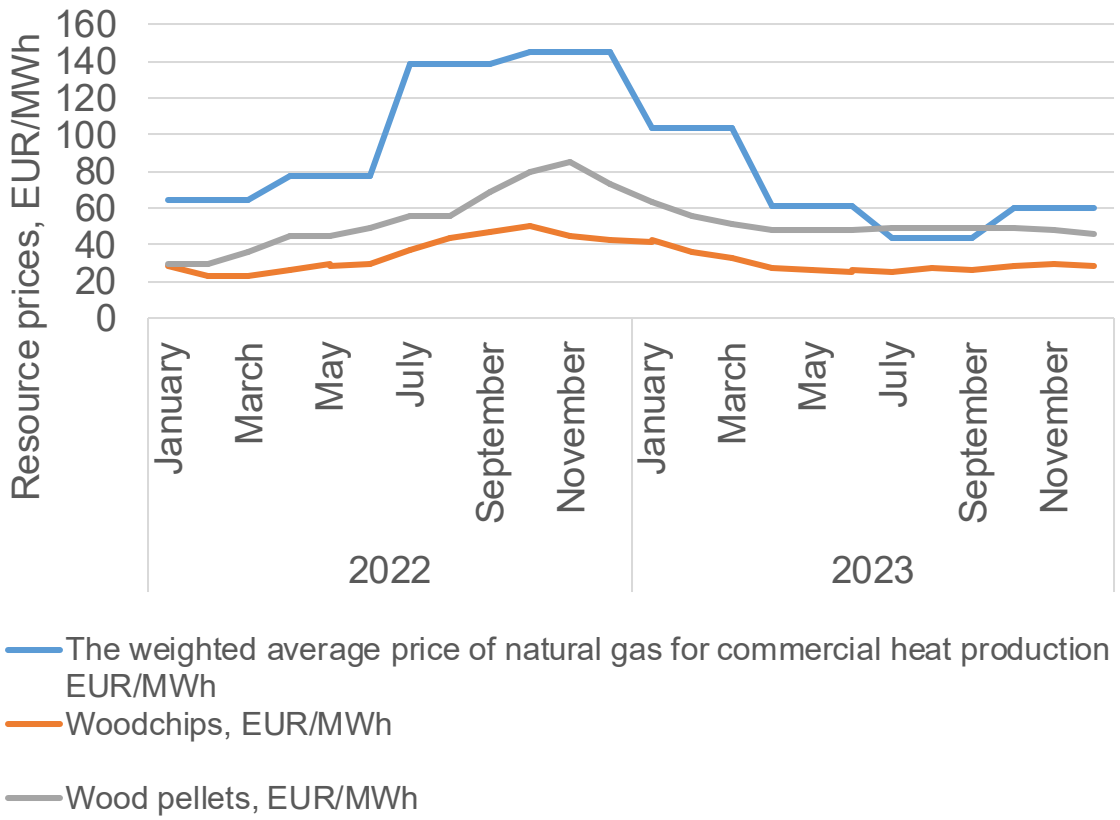
CONECT 2024
FLPP FUNDAMENTAL AND APPLIED RESEARCH PROJECTS
15-17 May 2024 I Riga, Latvia

Future role of district heating (DH) systems

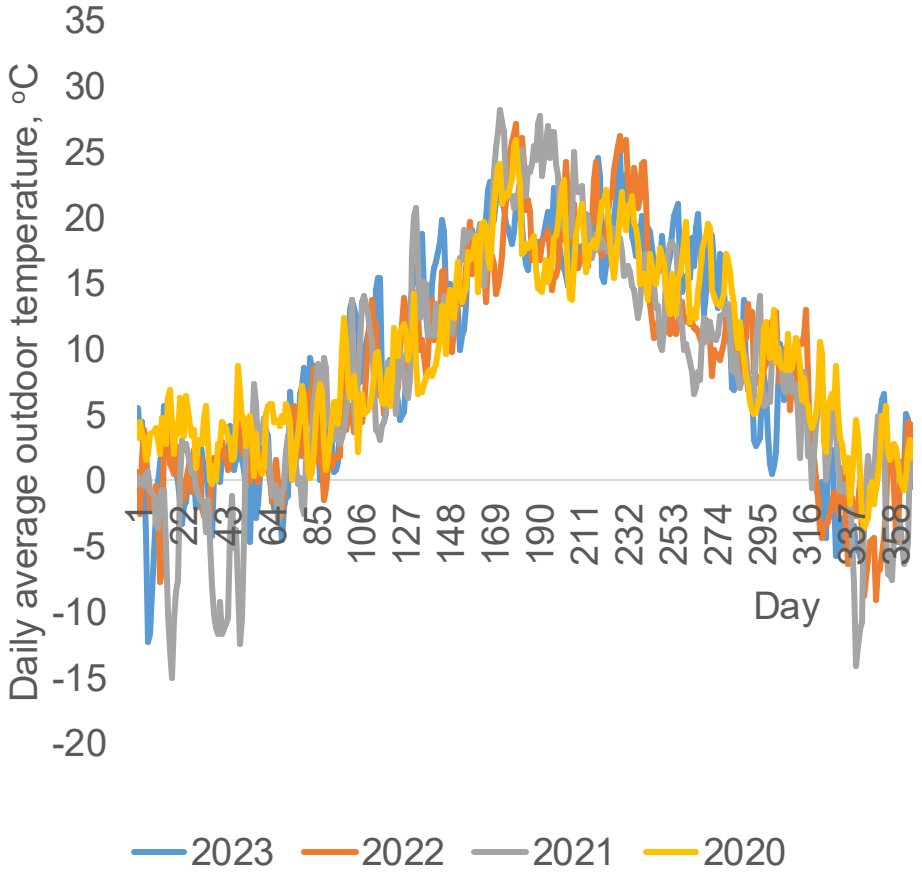


Factors impacting DH operation. Examples

Fuel prices



Outdoor temperature



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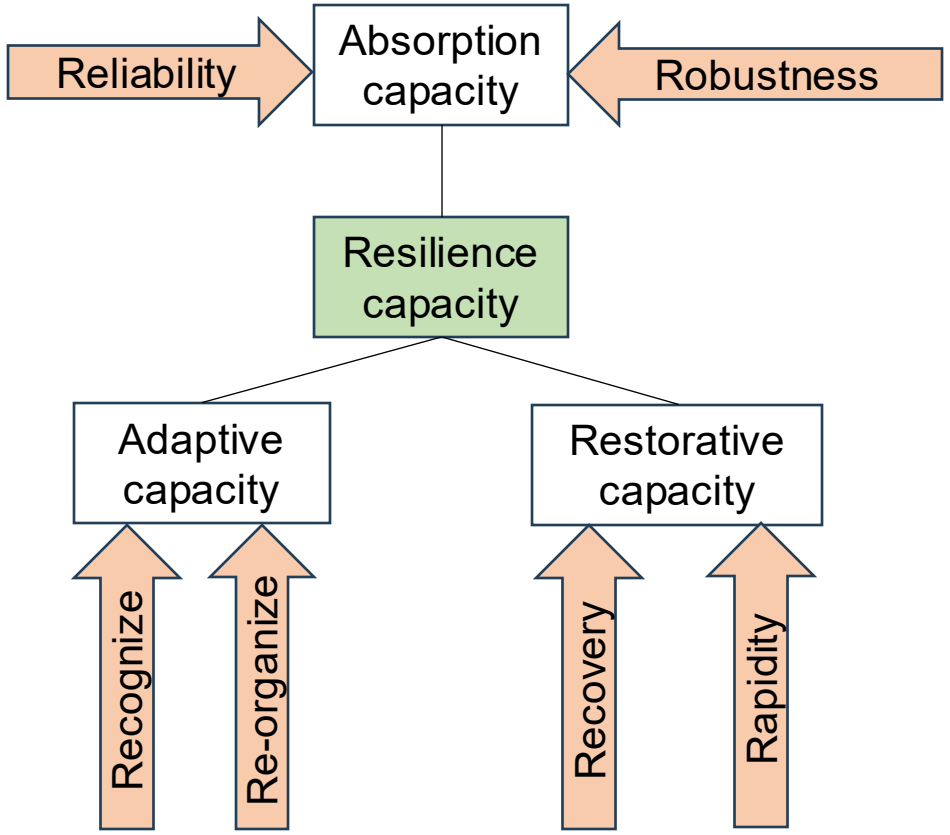
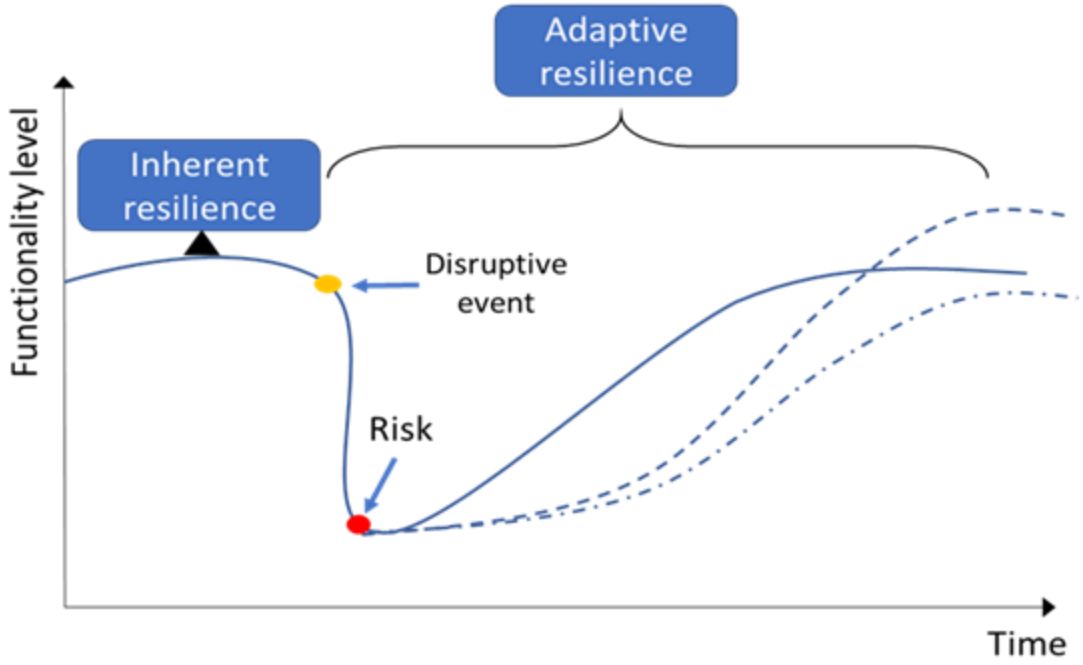
General framework of resilience assessment

Resilience *- ability/capacity of a system in resisting, absorbing, buffering and recovering from effects of hazards in a timely and efficient manner*



Source: R. Francis and B. Bekera, "A metric and frameworks for resilience analysis of engineered and infrastructure systems," Reliab. Eng. Syst. Saf., vol. 121, pp. 90–103, 2014



Source: Feofilovs, Maksims. Dynamics of Urban Resilience to Natural Hazards. PhD thesis. Rīga: [RTU], 2020. PP 179

Research questions

What are the focus areas, methods and impacting factors analyzed in energy system resilience assessments?

How far the heat supply resilience is included in the energy system resilience analyses?

What are the focus areas in DH resilience, security, and flexibility assessments?

Methodology

Energy system resilience assessment

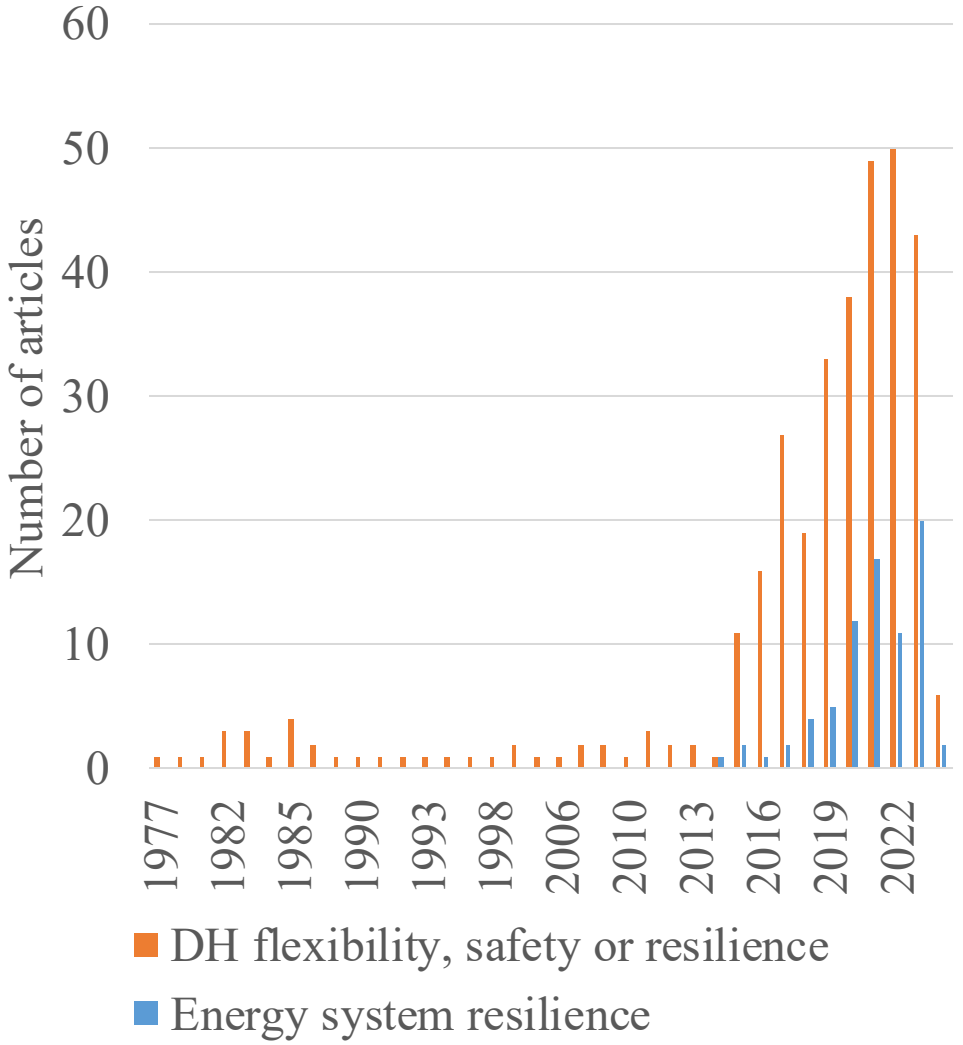
Keywords
TITLE-ABS-KEY
“**energy system resilience**”

District heating resilience assessment

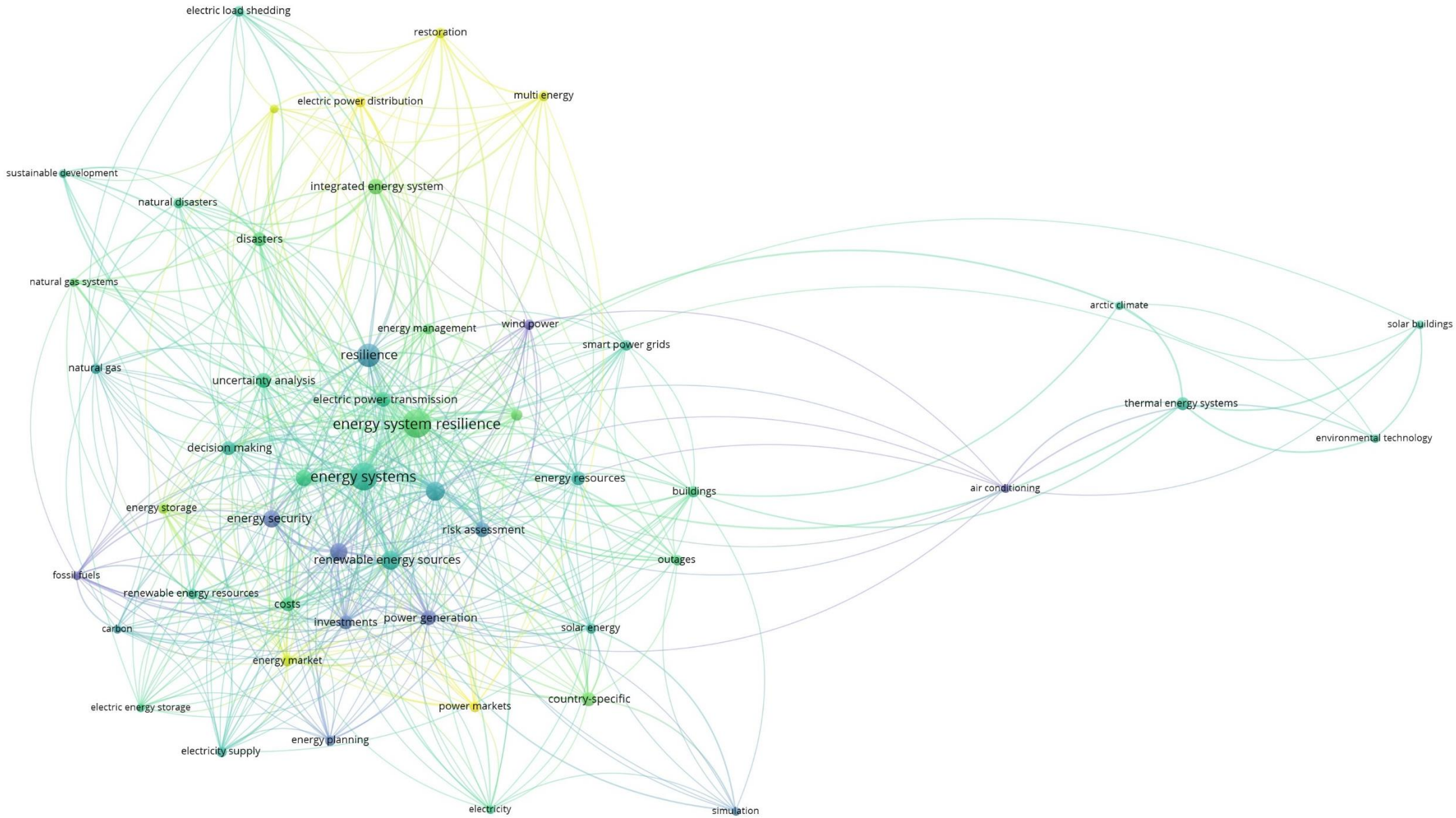
Keywords
TITLE-ABS-KEY
(“**district heating systems**”) AND
TITLE-ABS-KEY
(“**safety**” OR “**flexibility**” OR “**resilience**”)

Quantitative literature review

- 333 papers on «DH resilience, safety and flexibility»
  - 2 with «DH resilience»
  - Mostly from Denmark
- 77 papers on «Energy system resilience»
  - Mostly from USA, China



Energy system resilience keyword network analyses



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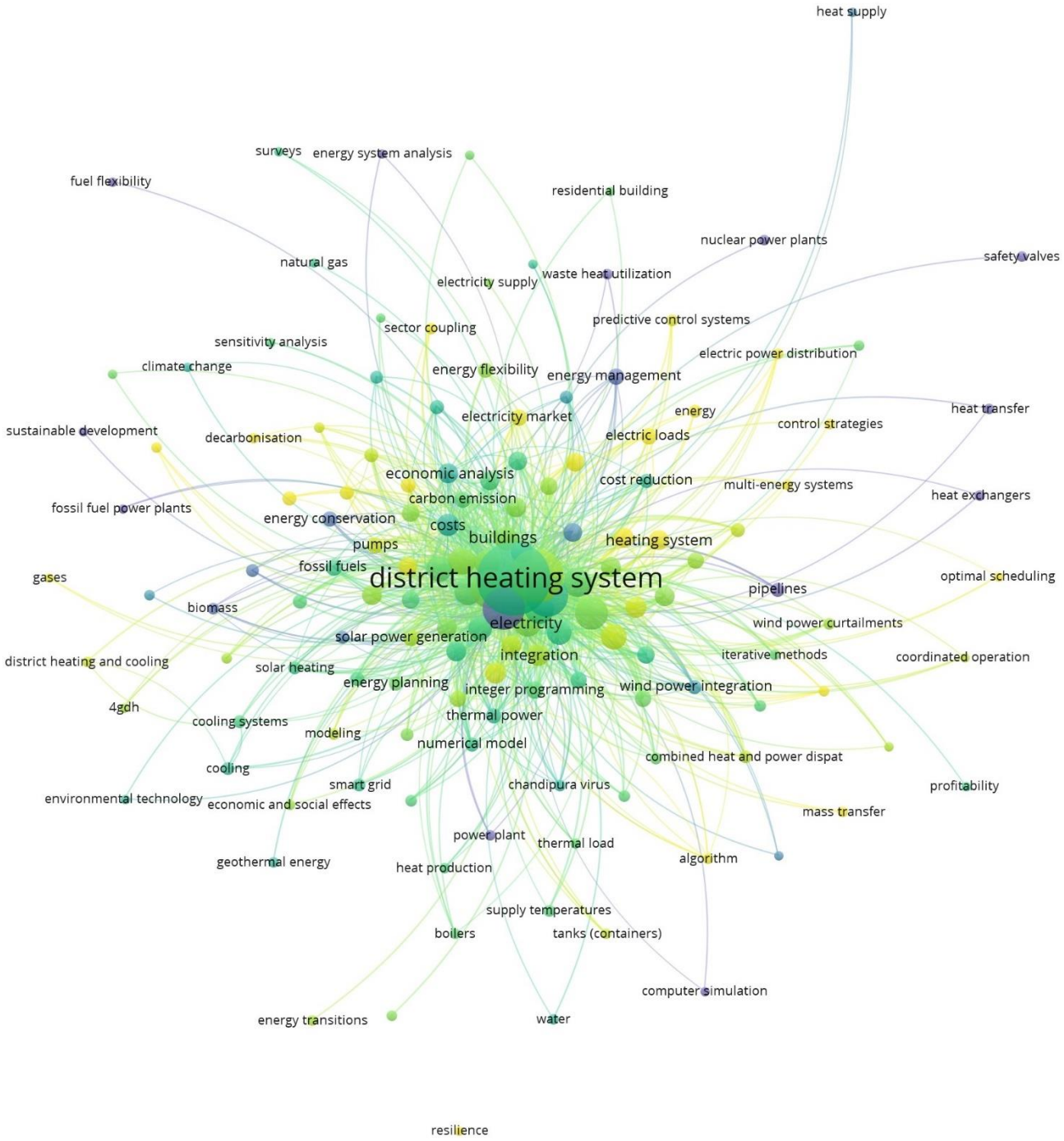
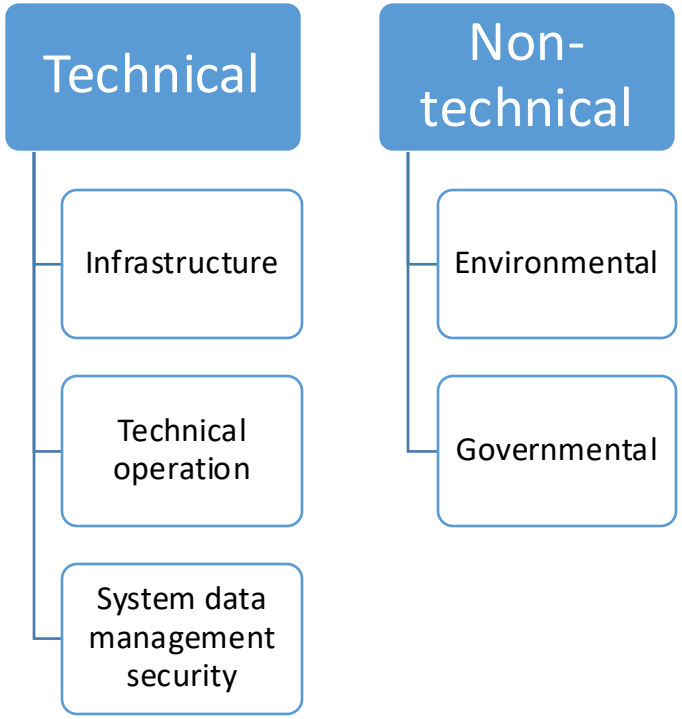
DH assessment keyword network analyses



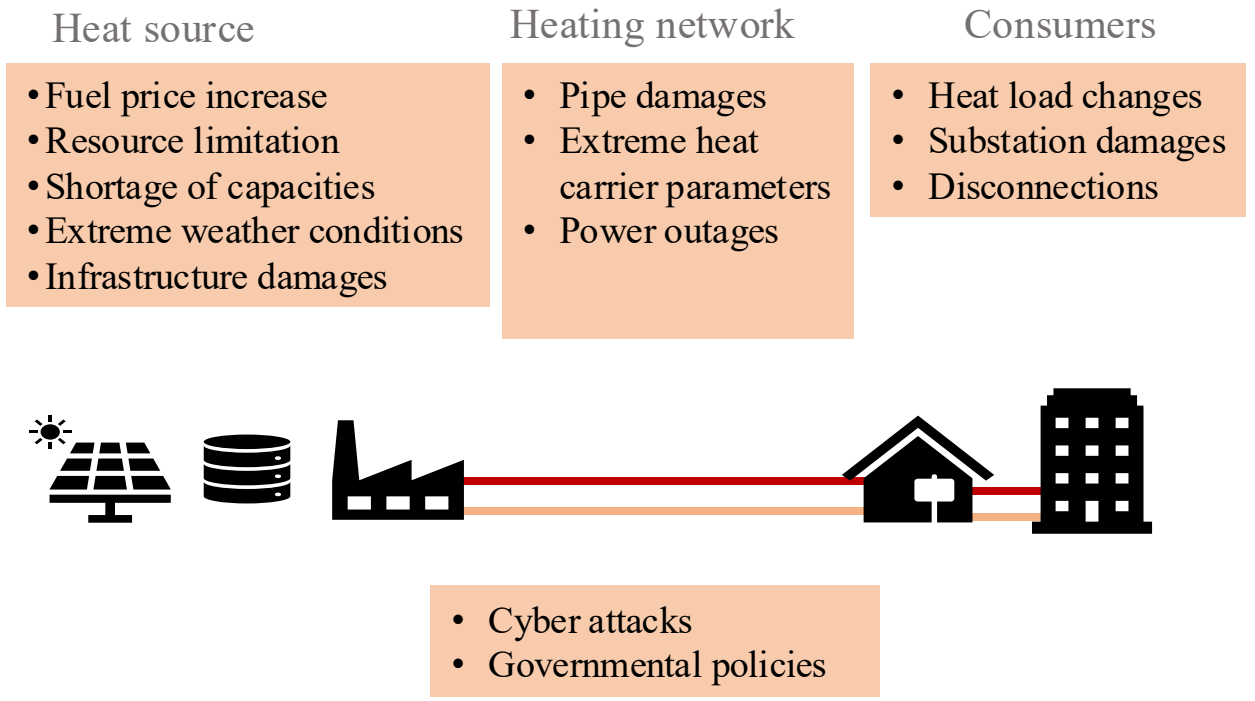
Qualitative literature review

Threats to smart grids



Source: A. O. Otuoze, M. W. Mustafa, and R. M. Larik, "Smart grids security challenges: Classification by sources of threats," J. Electr. Syst. Inf. Technol., vol. 5, no. 3, pp. 468–483, Dec. 2018,

Threats to district heating systems



Quantification methods of resilience

Energy system resilience

absorptive capacity	additional costs to improve the productivity	recovery ratio
adaptability ratio	performance difference between stable and disrupted operation	sum of energy costs and energy lost due to disruption
stability index of a system	resilience index	the utilization ratio of available capacity

DH resilience/safety/flexibility

Failure simulation models	Feasible service life method
Hydraulic analyses	Functional reliability index
Agent based modelling	

Conclusions

- The energy sector becomes more complex. Therefore, the research on **optimal operation of energy systems**, associated risks and potential solutions should significantly increase.
- The quantitative literature review shows that current research on energy systems **resilience is focusing mainly on the secure operation of power systems**. The thermal energy supply has not been fully integrated.
- There is a wide range of, research focusing on **the flexible, vulnerable, cost-optimal, and secure operation of DH** but mainly analyzing the operation of **separate heating system elements.**
- There is **a need for a fundamental generic quantitative and quality approach for resilience** assessment that would be usable and useful across various scopes or sectors in a consistent manner

Acknowledgement

The research has been done within Fundamental and Applied Research Project **“Resilience Metrics for District Heating Systems: A Comprehensive Framework (DH INERTIA)”** project No. lzp-2023/1-0039, funded by the Latvian Council of Science.

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