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District heating resilience under high energy price shocks

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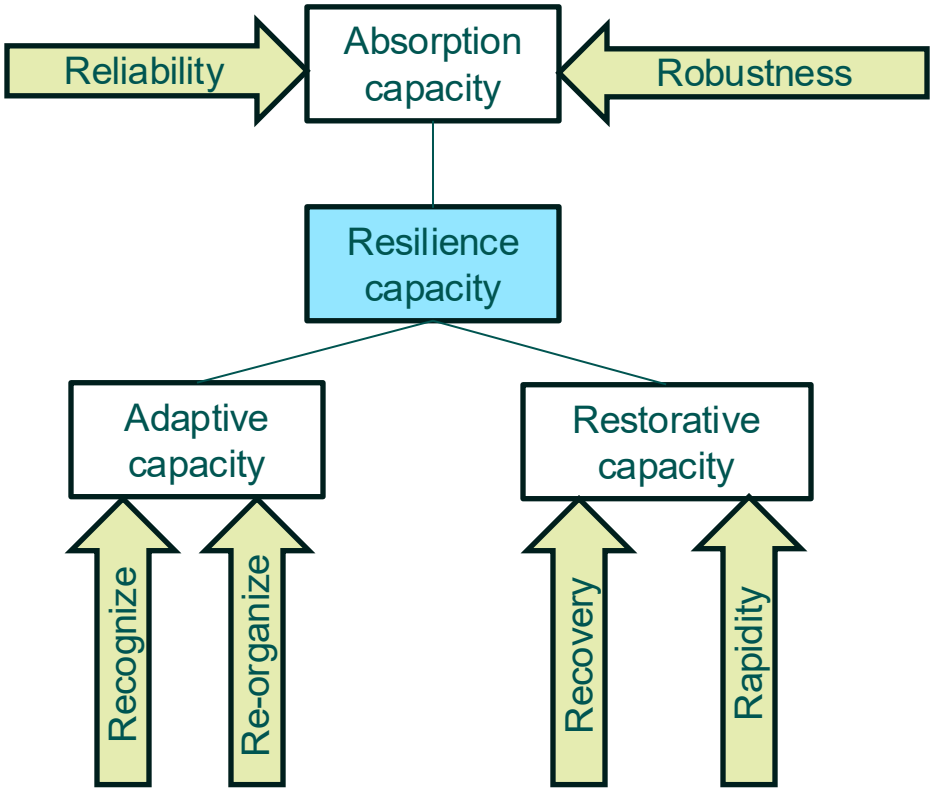
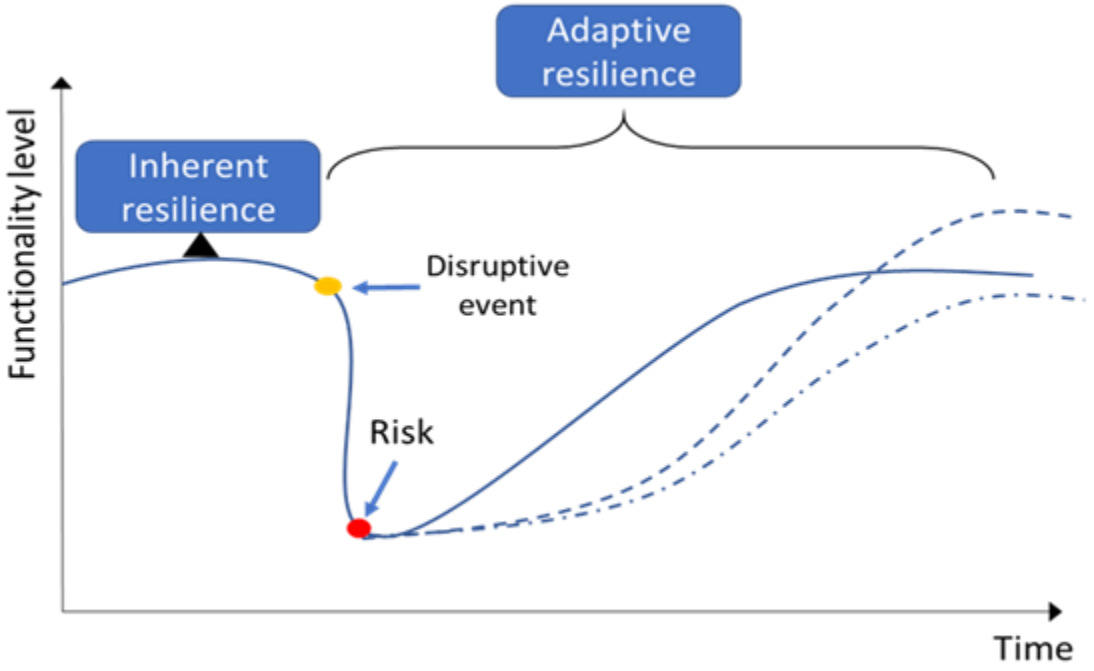
RTU IESE

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*

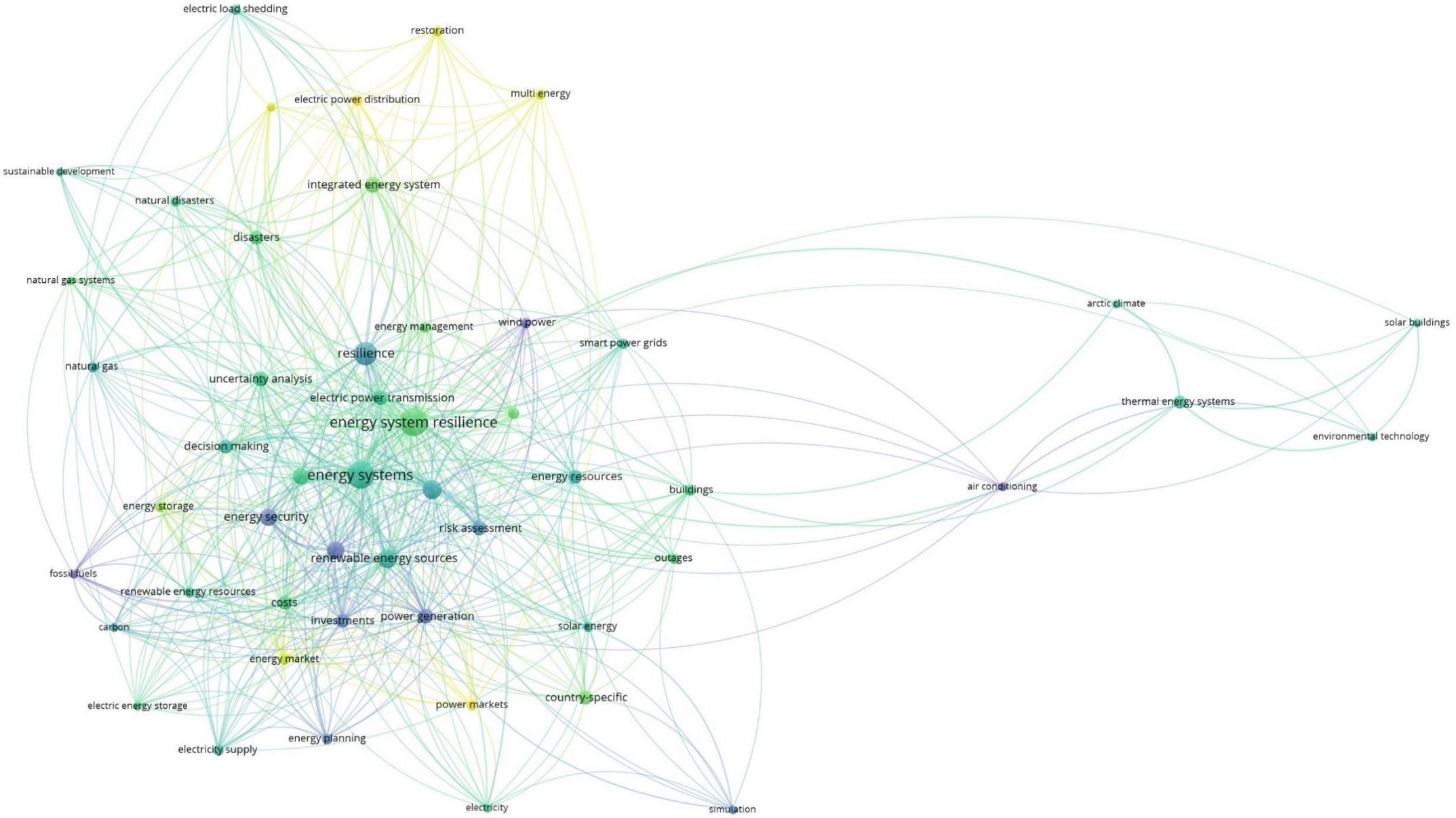


Source: R. Francis and B. Bekera, "A metric and frameworks for resilience analysis of engineered and infrastructure systems," Reliab. Eng. Syst. Saf., vol. 121, pp. 90–103, 2014

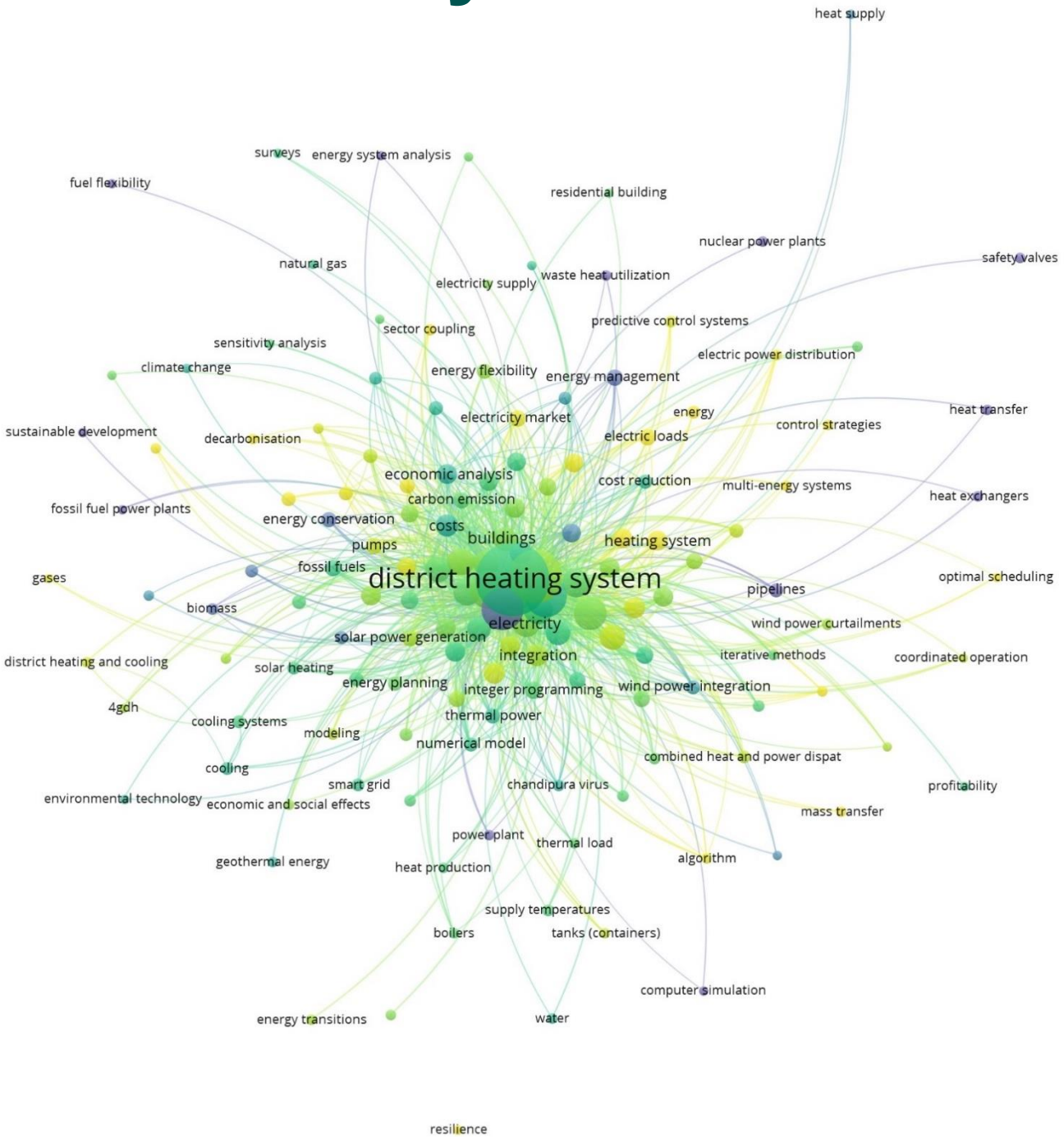


Source: Feofilovs, Maksims. Dynamics of Urban Resilience to Natural Hazards. PhD thesis. Rīga: [RTU], 2020. PP 179

Current research on energy system resilience



DH assessment keyword network analyses



Threats to district heating systems

Heat source

- Fuel price increase
- Resource limitation
- Shortage of capacities
- Extreme weather conditions
- Infrastructure damages

Heating network

- Pipe damages
- Extreme heat carrier parameters
- Power outages

Consumers

- Heat load changes
- Substation damages
- Disconnections

- Cyber attacks
- Governmental policies

Research questions

How the heat price changed during extreme resource price fluctuations?

How do different heat production technologies and fuel mixes impact the recovery time and economic performance of DH systems?

What are the key factors that determine the resilience of DH systems in maintaining affordable heat prices?

Methodology

Main input data

- Selection of 12 different DH systems in Latvia;
- Heat prices from January 2021 to April 2024;
- Main operation data for 2021-2023

Resilience factor*

$$\rho_i(S_p, F_r, F_d, F_o) = S_p \frac{F_r}{F_o} \frac{F_d}{F_o}$$

- Speed recovery factor;
- Original system performance level;
- Performance level immediately post-disruption;
- The performance level after an initial post-disrup
- Perfo level after recovery;

Resilience index

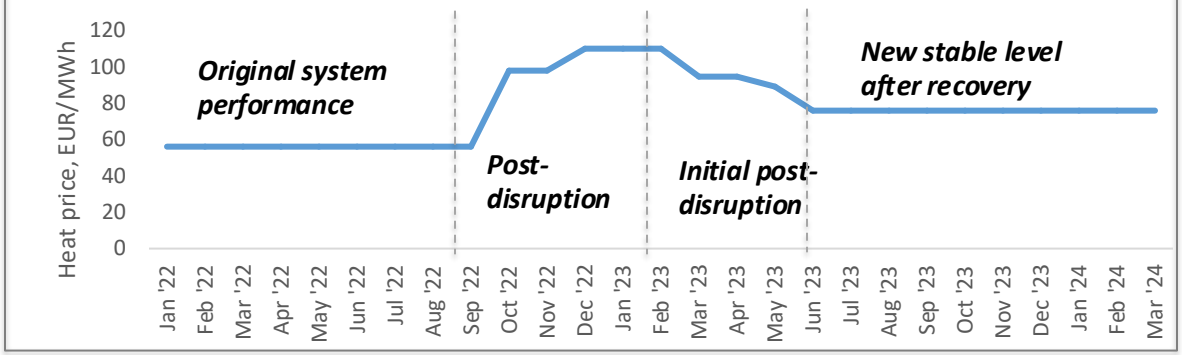
- Includes 4 dimensions: technical, social, environmental and economic;
- Determining 10 criteria in total;
- Normalizing criteria values;
- Calculating resilience index according to the composite i

Adaptive resilience

Inherent resilience

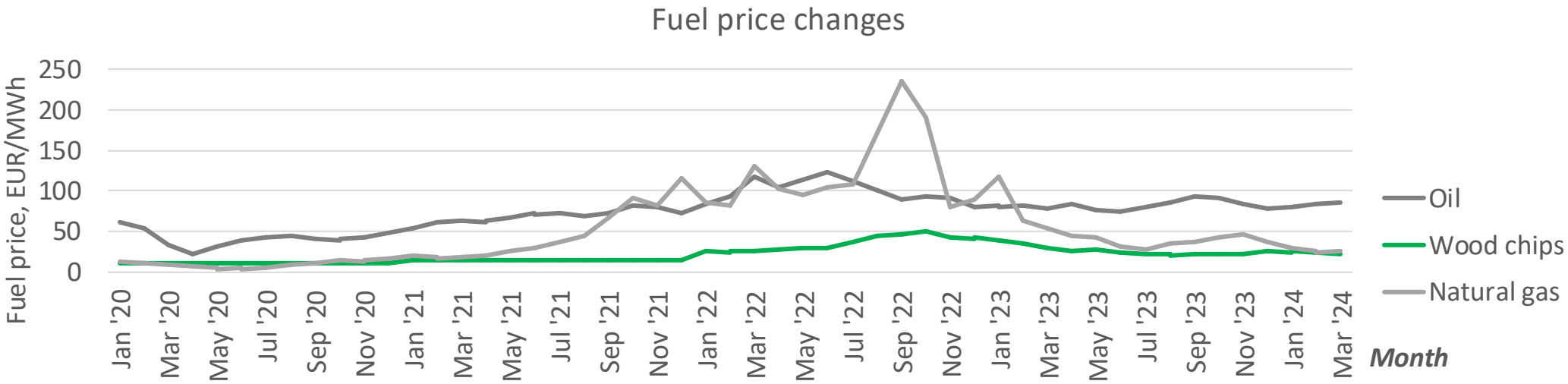
Heat price assessment → Heat price resilience assessment → Identification of impacting factors → Resilience index determination

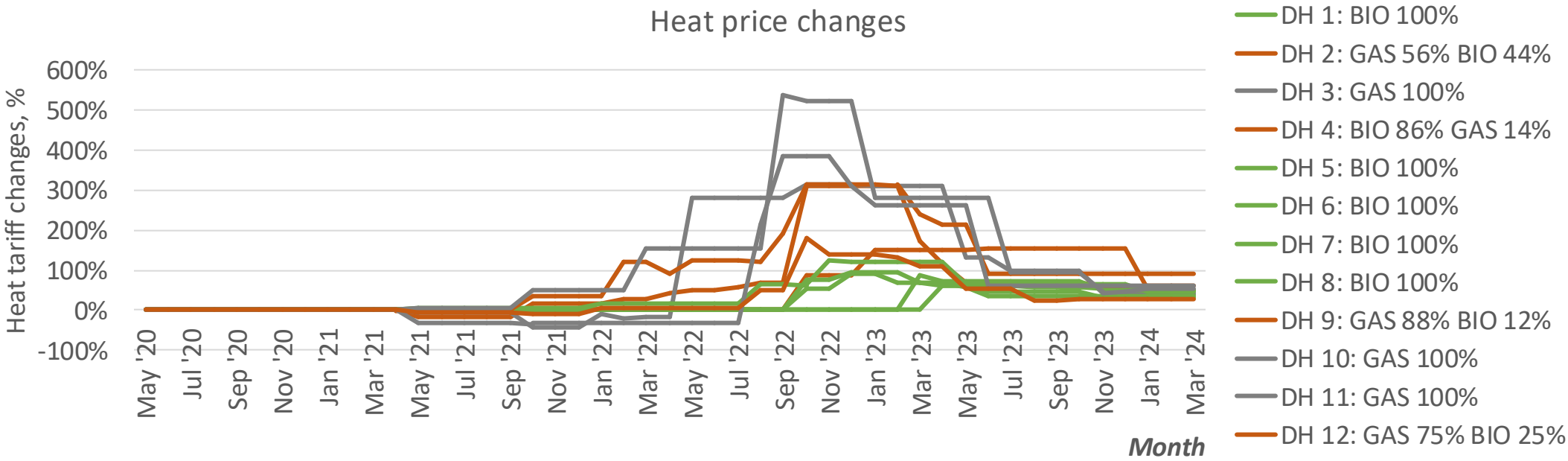
Heat price assessment



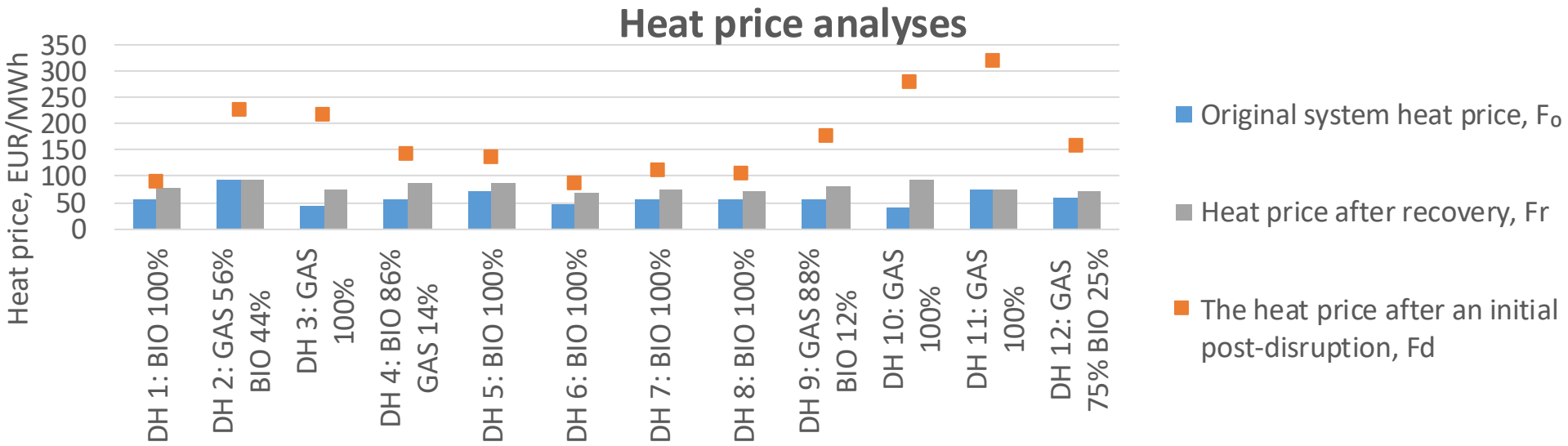
*Francis R., Bekera B. A metric and frameworks for resilience analysis of engineered and infrastructure systems, Reliability Engineering & System Safety, 121,2014, 90-103

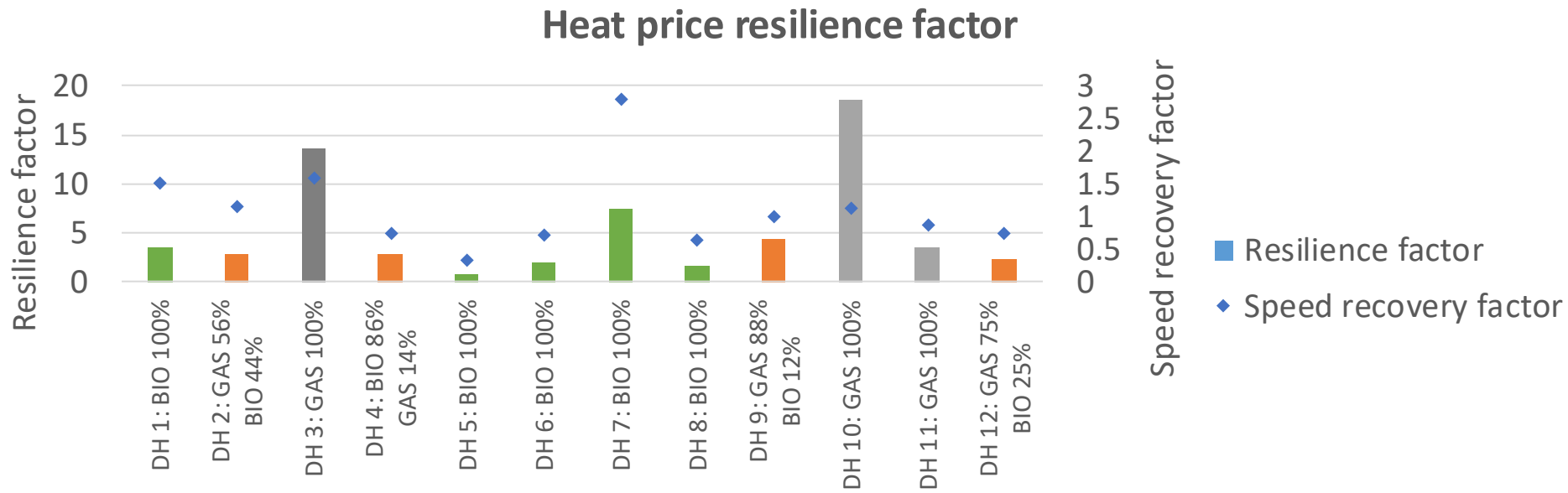
Heat price assessment





Heat price resilience assessment





DH resilience impacting factors (v1.0)

Economic dimension

- Profit/losses, EUR/MWh
- Production costs, EUR/MWh
- Affordability of heat tariff, EUR/MWh
- Investments in infrastructure, EUR/MW
- Workforce costs, EUR/MWh

Technical dimension

- Diversification of production, HHI^*_P
- Diversification of resources, HHI_R
- Heat losses, MWh/km
- Thermal storage capacity, m^3

Environment dimension

- Renewable energy share, %
- GHG emissions, t/MWh
- Particulate matter emissions, kg/MWh

Social dimension

- Municipal energy management system.
- Tax on fossil fuel
- Taxes on emissions
- Wage competitiveness in the region

*Herfindahl-Hirschman Index (HHI)

Values of impacting factors

Type	Criteria	DH 1: BIO 100%	DH 2: GAS 56% BIO 44%	DH 3: GAS 100%	DH 4: BIO 86% GAS 14%	DH 5: BIO 100%	DH 6: BIO 100%	DH 7: BIO 100%	DH 8: BIO 100%	DH 10: GAS 100%
Tech1	Diversification of production, HHI_P, %	0.51	0.23	0.47	0.27	0.86	0.90	0.52	0.51	0.11
Tech2	Diversification of resources, HHI_R, %	0.87	0.50	0.58	0.47	0.87	0.84	1.00	0.85	0.97
Tech3	Heat losses, MWh/km	411.81	340.40	554.04	447.98	324.63	353.80	570.55	365.44	964.14
Tech4	Heat accumulation tank volume, m3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.50
Env1	Heat produced with renewable resources, %	93%	58%	28%	82%	93%	100%	100%	100%	1%
Env2	GHG Emissions, kg/MWh	15.988	3.855	156.835	37.219	10.143	0.447	0.000	0.000	0.428
Env3	Particulate matter, kg/MWh	3.95	2.85	0.01	0.04	0.03	0.04	0.05	0.01	0.01
Eco1	Company Profit and Losses, EUR/MWh	5.64	29.51	1.90	0.00	0.00	0.00	6.40	0.53	0.00
Eco2	Amount investments, EUR/MW	6462	128539	80945	22126	216893	56848	38969	0	63669
Eco3	Affordability of heat energy tariff	21.02	17.35	9.96	11.52	14.88	17.25	12.02	15.29	14.78
Eco4	Production cost, EUR/MWh	56.53	79.34	82.72	57.18	47.53	59.54	39.74	55.58	251.60
Eco5	Workforce, worker per GWh	0.54	0.43	0.46	0.55	0.43	5.98	0.54	0.18	4.23
Soc1	Tax for emissions, EUR/MWh	0.11	0.65	11.49	0.95	0.12	0.02	0.02	0.12	2.52
Soc2	Salary/salary in region, EUR	1.16	1.28	1.34	1.74	1.01	0.87	2.13	1.00	0.83

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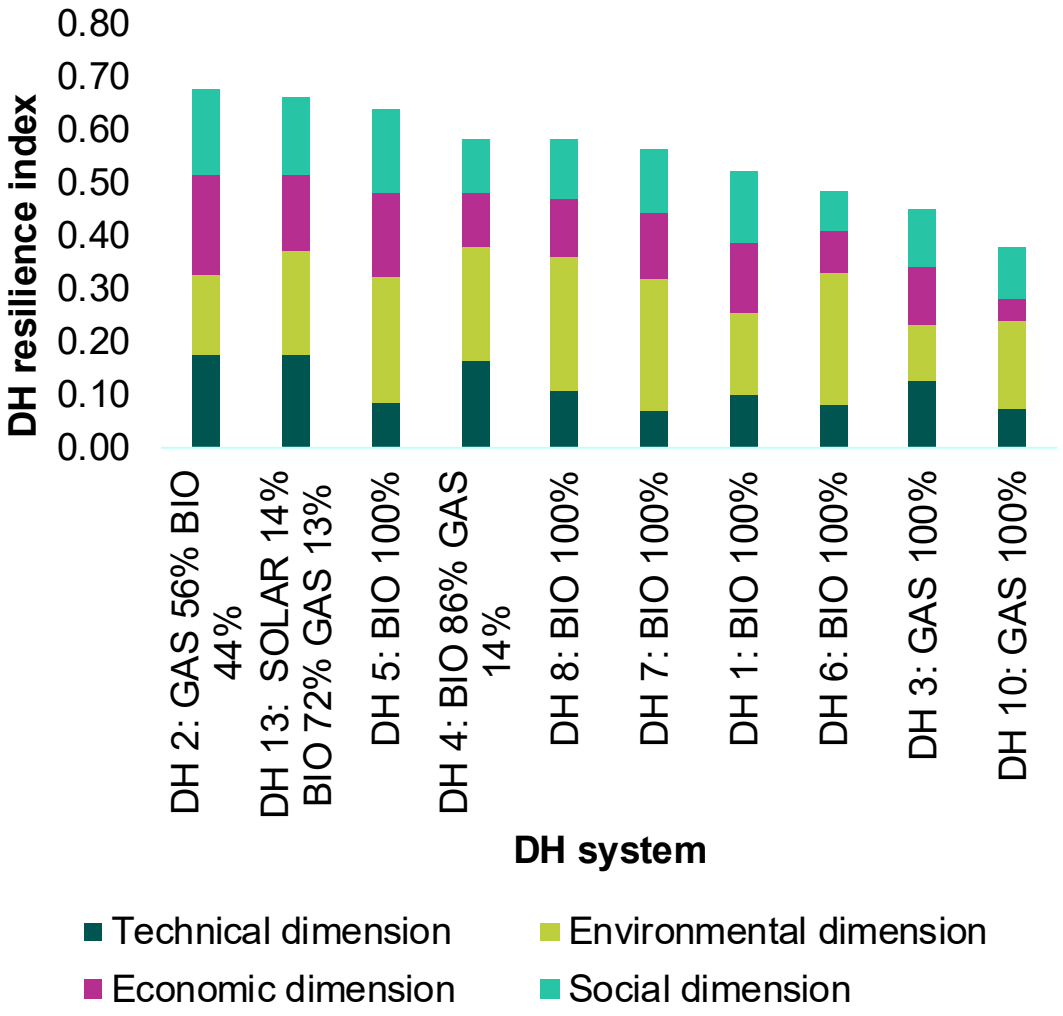
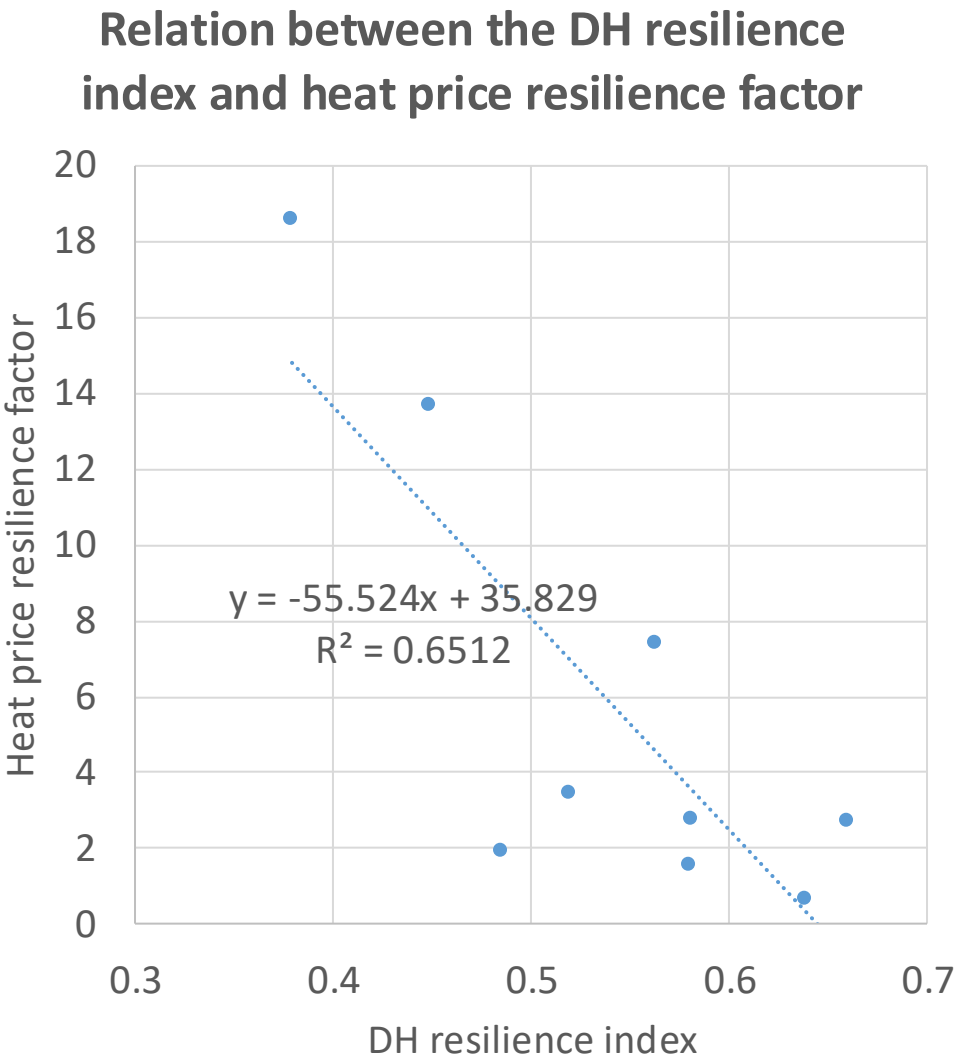
DH Resilience index





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Conclusions

- Research focuses on the **economic resilience of DH systems** by analysing the heat price fluctuations and **identifying potential impacting factors** for more resilient operations.
- Current research on energy systems **resilience focuses 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 **DH's flexible, vulnerable, cost-optimal, and secure operation** but mainly analysing the operation of **separate heating system elements.**
- The analysis reveals that **biomass-based DH systems effectively mitigated extreme heat price increases**, however, the heat tariffs for these systems are higher at current stable energy price levels than before the energy crisis.
- The varying resilience index among DH systems with similar energy mixes suggests that **additional factors significantly influence the resilience of these systems**.
- The developed **DH resilience index could serve as a metric** to evaluate the DH system's resilience to economic changes

Contact me

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