15TH IEA HEAT PUMP CONFERENCE
MAY 26–29, 2026 | HOFBURG
VIENNA 2026
DECARBONISATION THROUGH INNOVATION

Datacenters – Valuable heat providers for decarbonisation?

Andreas MELTZER[a], Christian DIENDORFER[a], Heinz NUSSER[a]

a Decision Advisory Group GmbH, Postgasse 8b, 1010 Wien, Austria, +43 6764411128, andreas.meltzer@decision-advisory.com, www.decision-advisory.com

Abstract

This study evaluates the techno-economic feasibility of datacenter waste heat recovery using heat pumps, with focus on liquid-cooled systems that provide stable heat streams at elevated temperatures. The objective was to quantify the levelised cost of heat under uncertain boundary conditions, identify dominant cost drivers, and assess the potential of thermal energy storages to reduce overall costs.
A scenario-based modelling framework was applied, integrating technical data from industry partners with projections of future energy and carbon price developments. Uncertainty was explicitly represented to generate cost ranges instead of deterministic outcomes. Key parameters included heat pump investment costs, electricity prices, achievable full-load hours, target heat temperature, and distance to heat demand. The resulting cost ranges were benchmarked against alternative heat supply options.
The results showed that liquid-cooled datacenters can provide economically competitive heat, particularly for applications requiring supply temperatures below 70 °C. Temperature lifts to approximately 130 °C remain feasible under favourable conditions. Sensitivity analysis revealed that electricity prices and capital expenditure exert the strongest influence on cost outcomes, while short-term thermal energy storage can reduce costs by improving utilisation of available waste heat.
The findings underline the potential of datacenter waste heat as a decarbonised heat source and highlight substantial context dependence. Future research should incorporate more detailed cooling system representations, location-specific conditions, and the potential of flexible heat pump operation to further reduce costs.

Selection and/or peer-review under the responsibility of the organizers of the 15th IEA Heat Pump Conference 2026.

Keywords: Datacenter; LCOH; waste heat reuse; heat pumps; business case; uncertainty; TES

1. Introduction

Application of heat pumps to recover waste heat from datacenters offers a promising chance to drive decarbonisation in various sectors. Future electricity consumption of datacenters is projected to grow rapidly.[1], [2], [3] Currently, a significant share of the generated waste heat remains mostly unused and is released to the atmosphere.[4] However, waste heat reuse already gains momentum (e.g. reinforced by European legislation) and datacenters already serve as valuable heat providers in certain applications.[5], [6], [7] Given technological advancements, fluctuating energy prices, and emerging applications for waste heat utilisation, it is essential to systematically account for uncertainty in the economic analysis of datacenter waste heat recovery using heat pumps. We identified significant uncertainties in the business case of datacenter waste heat reuse, determined ranges for the levelised cost of heat at different target temperature levels and assessed the economic advantages of thermal energy storage systems.

2. Methodology

The applied methodology combines data from datacenter operators, construction companies, and heat pump manufacturers with scenario-based modelling of future energy prices and CO_2 costs. Building on the Decision Quality framework, the model incorporates uncertainty explicitly, allowing the derivation of cost ranges rather than single-point estimates. [8], [9], [10], [11], [12], [13]

Key parameters considered include:

- Waste heat temperature (focus: liquid cooling at ~55 °C),

- Weighted average cost of capital (8%)
- Lifetime (15 years)
- Heat pump investment costs (250,000-1,000,000 €/MW_{th}),[14], [15]
- Electricity costs including grid fees and taxes (130-170 €/MWh),[16]
- Distance to heat demand and necessary pipeline investments (0-1 km),
- Full load hours and annual operating profiles.

The levelized cost of heat (LCOH) was calculated for waste heat recovery with heat pumps. To determine the LCOH, the annuity for the investments, costs for system integration, and heat pipelines as well as OPEX for energy supply and operations and maintenance were considered. The LCOH for the waste heat reuse were benchmarked against the cost of conventional and alternative thermal energy sources, like natural gas, hydrogen, biomethane, biomass, and electric boilers, that were mainly compiled from literature and industry data.

3. Results

Depending on the technical set up of datacenters, we can differentiate between air-cooled rather low temperature systems and liquid-cooled systems with typically higher waste heat temperature levels. Figure 1 shows the typical temperature levels of air- and liquid-cooled datacenters. In this study, we focused on a liquid cooled datacenter type that typically offers useable waste heat streams of 55°C. The figure shows different possible applications for this waste heat temperature level. According to our analysis, increasing the temperature up to 130°C using heat pumps can be economically and technically viable, offering the possibility to supply heat to district heating (DH) systems, drying processes and industry.

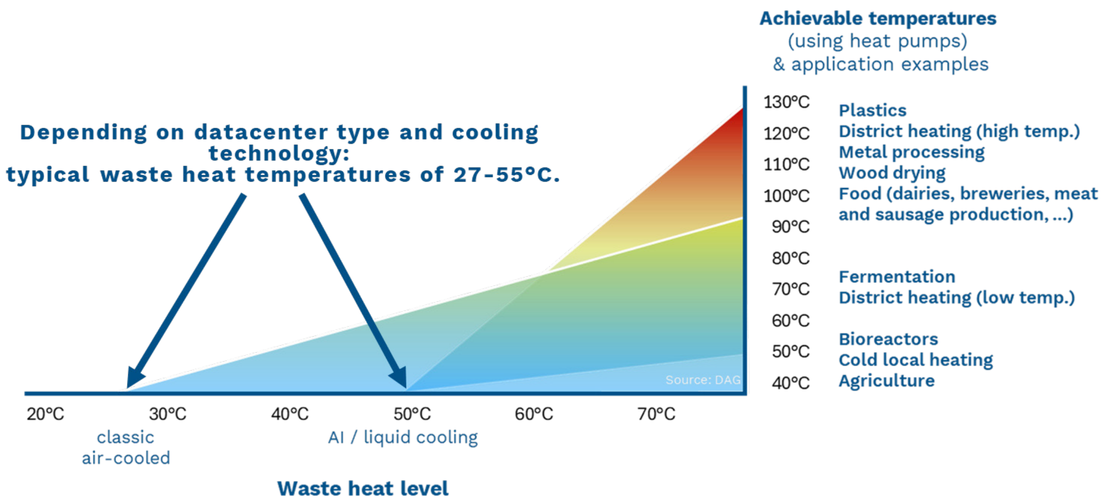

Figure 1: Datacenter cooling technologies and economically reachable end temperatures with application examples. Mainly based on [30]

3.1. Levelised cost of heat and uncertainties

We found that the utilisation of waste heat from datacenters can be competitive from an economic perspective, especially when temperature levels lower than 70°C are required. As the competitiveness of the heat source is always dependent on the cost of alternatives, we compared the use of waste heat with other energy sources, such as natural gas, hydrogen, and electric boilers. As indicated in **Error! Reference source not found.**, there is a broad range concerning the LCOH of most energy sources. The competitiveness mostly depends on investment and electricity costs, as well as the required temperature level.

Our results demonstrate that waste heat utilisation from datacenters can be competitive, particularly for applications requiring low temperature levels. As can be seen in the figure, liquid-cooled datacenters may outperform alternatives such as biomethane or electric boilers. Natural gas remains cost-effective, but rising CO_2-related costs and volatile price developments may reduce its long-term competitiveness. Biomass can be a competing heat source due to comparably low costs, especially if higher temperatures are required. Green hydrogen is, as of today, not a financially attractive option.

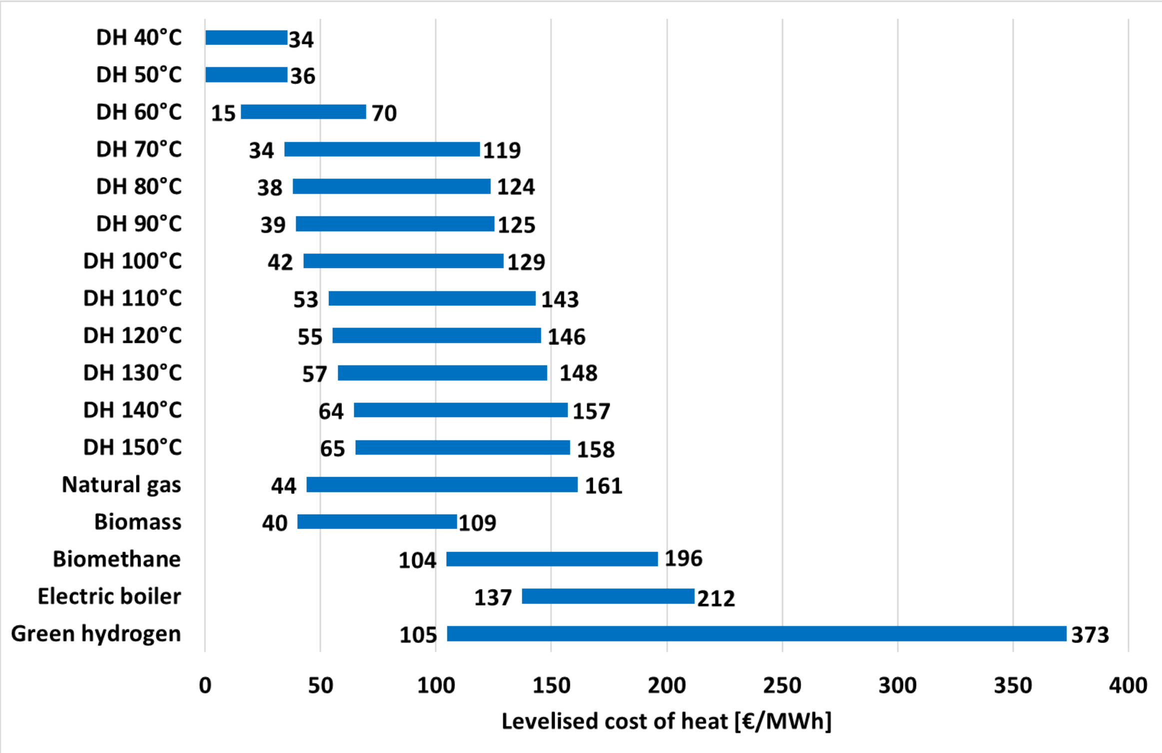

Figure 2: Ranges of levelised cost of heat of different energy sources. For minimum and maximum values all uncertain parameters in the business case were set to minimum and maximum, respectively. "DH" refers to the use of datacenter waste heat in district heating (DH) systems using heat pumps for temperatures ≥60°C. (Note, that for efficient heat transfer from the condenser side of the heat pump to the heat sink, a temperature level of 5-10°C above the target temperature for the DH might be necessary). The range for alternative energy sources is mainly based on energy cost forecasts and costs for related investments (such as gas-fired burners).[14], [15], [31], [32]

We conducted a thorough sensitivity analysis to estimate factors with the highest influence on the LCOH. By defining minimum, base, and maximum values for uncertain or project specific parameters, we were able to identify ranges for the LCOH of datacenter waste heat reuse in different circumstances. The overall ranges when if the most optimistic/pessimistic circumstances are assumed are depicted in Figure 2. To identify the effect of individual parameter changes, we created so called tornado charts. To estimate the influence of a single parameter on the overall LCOH, all parameters were set to “base” and only one parameter was changed to its minimum/maximum value. This procedure was applied to all uncertain/volatile parameters, leading to the respective deviation from the base case. The results for those individual parameter changes are depicted in Figure 3. The chart shows that the uncertainty concerning future electricity costs and CAPEX for the heat pump has the highest effect on the LCOH, followed by the distance to the offtaker and the number of full-load hours. The broad ranges emphasize the necessity of evaluating LCOH on a case-by-case basis, taking into account local and project-specific conditions.

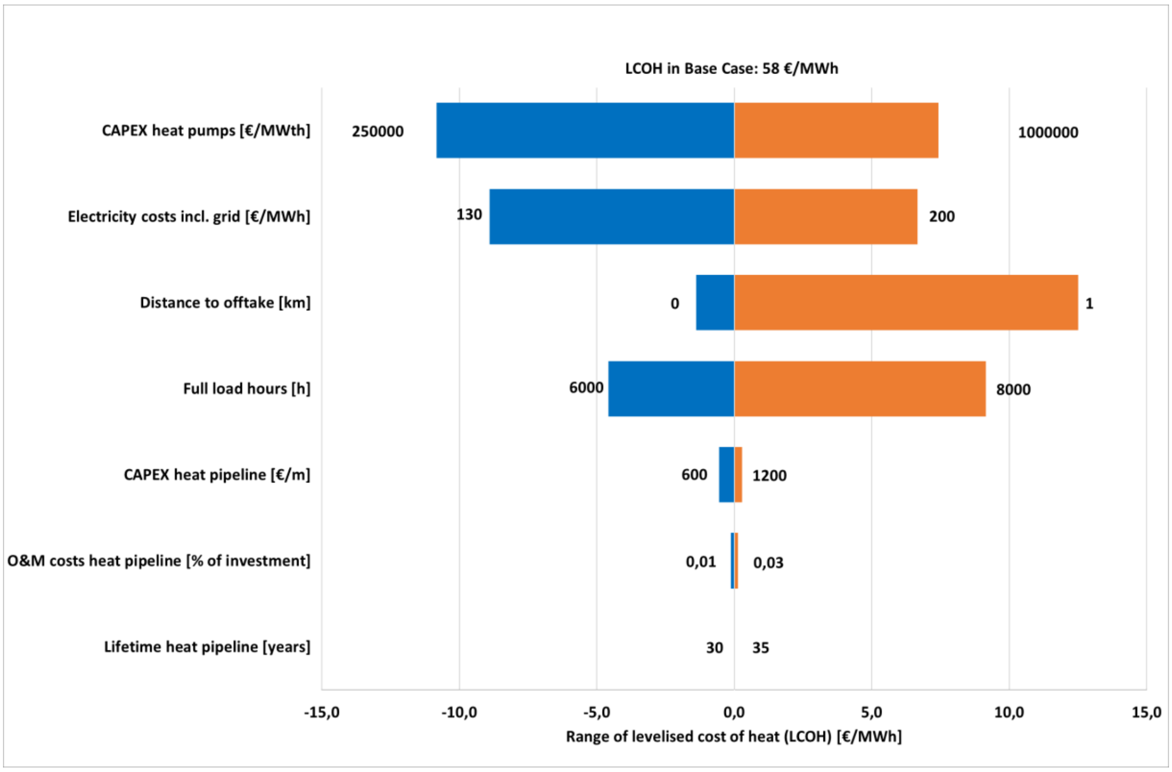

Figure 3: Main drivers of the levelised cost of heat in datacenter waste heat recovery using heat pumps to lift heat from 55°C to 70°C. The length of the bars indicates the deviation of the levelised cost of heat when the respective minimum and maximum assumptions (indicated on left and right side of the bars) are applied instead of the baseline assumptions. Hence, the uncertainties regarding actual heat pump CAPEX, electricity cost, pipeline costs to offtakers and full load hours of the system have relatively high impacts on the business case of waste heat reuse.

3.2. Thermal energy storage systems and their effect on LCOH

A thermal energy storage (TES) can be beneficial when there is a mismatch between heat supply and demand. Due to data protection issues, the available data for datacenter load curves (the heat supply side) are very limited. In the literature, typically only oversimplified daily load curves are supplied that show a load increase during noon/in the afternoon due to the energy consumption of cooling systems. However, this load curves are not representative, as expert statements indicate that the actual load curves are highly dependent on weather conditions, cooling systems and workloads in the datacenter. Hence, for our study we assumed a steady waste heat flow, which is, according to expert judgement, a good approximation considering the liquid cooled datacenter type analysed in this study.

The heat demand can vary heavily between different applications. Ideally, there is a constant heat demand over the year, which is beneficial from an economic point of view. In practice, we often see variable heat demands (daily and seasonal variability in district heating for example). To estimate the potential advantages of a TES, we applied the load curve of a typical Austrian commercial building.[17] The exemplary heat demand curve is depicted in Figure 4 and shows a high seasonal variation. We used this load curve for calculating potential benefits, when a TES is implemented. The advantages stem from a higher quantity of heat that can be supplied to offtakers with the same waste heat recovery system at the datacenter. Figure 5 indicates the LCOH of waste heat reuse for a system without storage and with 1-day, 7-day, and 30-day storage, respectively. It can be seen that the short-term storages reduce the overall LCOH, as significantly more heat can be supplied at a relatively low rise in CAPEX. On the other hand, long-term TES is, in this specific setup, not beneficial from an economic point of view.

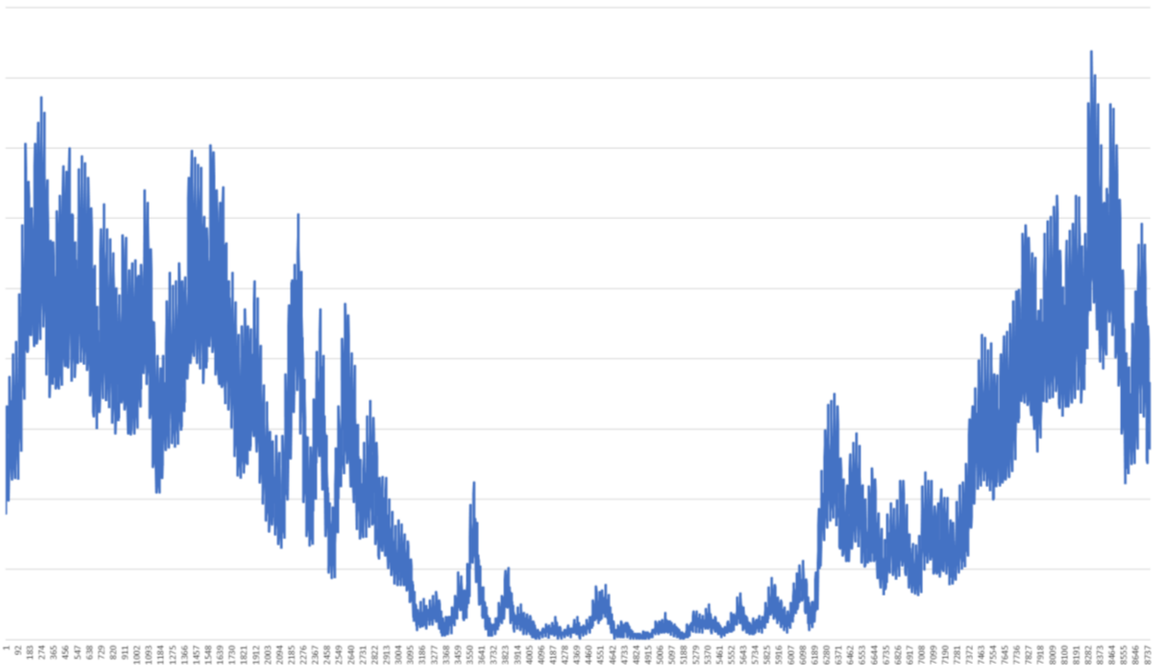

Figure 4: Annual heat demand curve of a typical commercial building in Austria.[17]

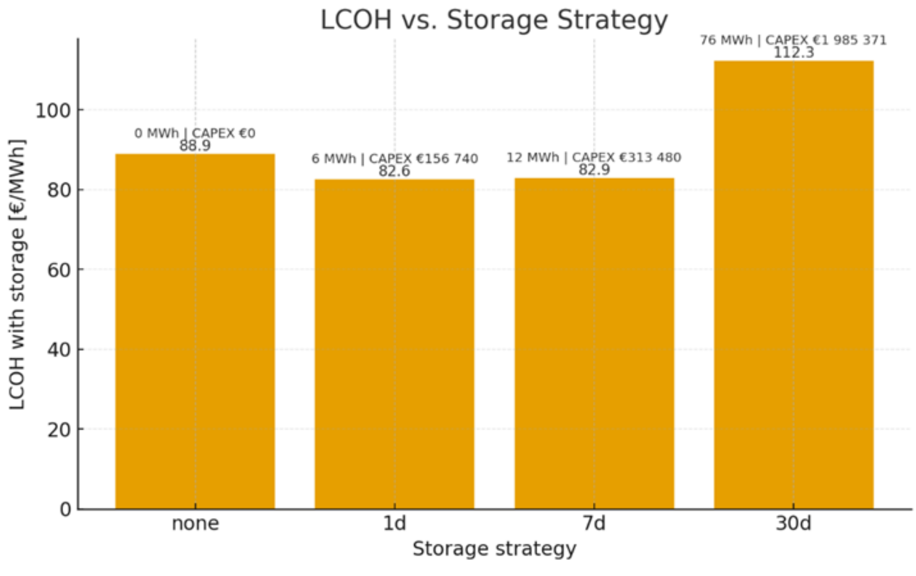

Figure 5: LCOH without TES and with different TES capacities. CAPEX for TES were assumed based on own data.

4. Discussion and Conclusion

The findings emphasize that the reuse of datacenter waste heat can be beneficial from an economic point of view and competitive in comparison to other heat sources. In particular waste heat of liquid-cooled datacenters holds potential due to the typically high temperature levels that enable temperature lifts to 100°C and more using heat pumps. The evaluation of sensitivities stressed the importance of context-specific business case analysis.

While the presented analysis offers important insights into uncertainty in the application of heat pumps for waste heat reuse of datacenters, several limitations must be acknowledged:

The integration of heat exchangers in datacenter systems is complex. Several technical alternatives exist for heat dissipation, especially depending on the datacenter cooling set up. The detailed integration of heat exchangers was not considered in the model. The achievable temperatures therefore indicate a maximum potential. In practice, depending on the system setup, it must be expected that targeted heat pump outlet temperatures need to be assumed to be 5–10 °C higher in order to enable efficient transfer via heat exchangers into a district heating system or an industrial heat process.

Location-specific factors such as climatic conditions, electricity prices, and local infrastructure can have a significant impact on the business case of waste heat utilisation with heat pumps. Therefore, these aspects should be represented as accurately as possible in future models. The strong dependence of LCOH on electricity prices (due to the electricity required by the heat pump) underscores the potential of making waste heat utilization economically viable through access to low-cost electricity, for example via power purchase agreements (PPAs). We also see strong technical developments regarding heat pump technologies and system costs. These developments might lead to prospectively lower LCOH for the implementation of waste heat reuse systems and enable waste heat reuse in many contexts.

Furthermore, we found that the addition of short-term TES can lead to lower LCOH. Literature and the findings of our analysis indicate that even lower LCOH can be realised with lower electricity costs, which could be achieved with flexible heat pump operation (e.g. levelling the temperature in the TES during periods of low electricity prices).[18], [19], [20], [21], [22], [23], [24], [25], [26], [27], [28], [29] Although current papers partly consider this issue, future scientific effort is recommended to obtain a clear picture on the potential cost reductions. As the economic feasibility is highly context-dependent, datacenter cooling and waste heat reuse concepts should be developed that can be economically viable under a wide range of boundary conditions. Future research should address this question in more detail.

References

[1] J. Aljbour and T. Wilson, “Powering Intelligence - Analyzing Artificial Intelligence and Data Center Energy Consumption,” 2024.

[2] T. Li *et al.*, “Powering the Data-Center Boom with Low-Carbon Solutions China’s Perspective and Global Insights Authors and Acknowledgments Contacts Copyrights and Citation,” 2024. [Online]. Available: https://rmi.org/insight/

[3] M. Buck and B. / Brussels, “Why Data Centres Should Feature Prominently in the Clean Industrial Deal Short-term actions to expand data centre capacity in Europe for advanced AI development and industrial innovation, while ensuring rising electricity demand is met with new renewable energy,” 2024. [Online]. Available: https://dirox.com/post/deepseek-v3-the-open-source-ai-revolution

[4] C. Kulemann, P. Husi, and R. Gürber, “Abwärmenutzung von Rechenzentren – Potenzialstudie und Empfehlungen für Betreiber und Gemeinden,” 2023.

[5] X. Yuan, Y. Liang, X. Hu, Y. Xu, Y. Chen, and R. Kosonen, “Waste heat recoveries in data centers: A review,” Dec. 01, 2023, *Elsevier Ltd*. doi: 10.1016/j.rser.2023.113777.

[6] C. Zhang, H. Luo, and Z. Wang, “An economic analysis of waste heat recovery and utilization in data centers considering environmental benefits,” *Sustain Prod Consum*, vol. 31, pp. 127–138, May 2022, doi: 10.1016/j.spc.2022.02.006.

[7] Bytes2Heat, “Best-Practice- Übersicht Von inspirierenden Projekten zur Abwärmenutzung aus Rechenzentren lernen.” Accessed: Apr. 14, 2025. [Online]. Available: https://bytes2heat.com/static/files/20240403_BP%C3%9C_V2404_deu.pdf

[8] C. Spetzler, H. Winter, and J. Meyer, *Decision Quality: Value Creation from Better Business Decisions*. Wiley, 2016.

[9] Daniel Kahneman, *Schnelles Denken, langsames Denken*. Siedler Verlag, 2012.

[10] Paul Papayoanou, *Game Theory for Business: A Primer in Strategic Gaming*. Probabilistic Publishing, 2010.

[11] P. Tetlock, D. Gardner, and J. Neubauer, *Superforecasting – Die Kunst der richtigen Prognose*. Fischer, 2016.

[12] P. Nutt, *Why Decisions Fail: Avoiding the Blunders and Traps That Lead to Debacles*. Berrett-Koehler, 2002.

[13] R. Lum, *4 Steps to the Future: A Quick and Clean Guide to Creating Foresight*. Vision Foresight

Strategy LLC, 2016.
[14] C. Diendorfer *et al.*, “KLIMANEUTRALITÄT ÖSTERREICHS BIS 2040: BEITRAG DER ÖSTERREICHISCHEN INDUSTRIE,” 2021. Accessed: Apr. 14, 2025. [Online]. Available: https://www.bmk.gv.at/dam/jcr:0ac604d1-7928-492f-991a-4845dce78c27/Begleitstudie_Endbericht.pdf
[15] Bytes2Heat, “Bytes2Heat-Tool v.2.2.” Accessed: Apr. 14, 2025. [Online]. Available: https://www.bytes2heat.de/static/files/20240527_B2H_Wirtschaftlichkeitstool_V2.2_final.xlsb
[16] BDEW, “BDEW Strompreisanalyse.” Accessed: Jan. 08, 2026. [Online]. Available: https://www.bdew.de/service/daten-und-grafiken/bdew-strompreisanalyse/
[17] O. Ruhnau, L. Hirth, and A. Praktiknjo, “When2Heat Heating Profiles,” Time series of heat demand and heat pump efficiency for energy system modeling. Accessed: Nov. 17, 2025. [Online]. Available: Time series of heat demand and heat pump efficiency for energy system modeling.
[18] C. Montagud-Montalvá, E. Navarro-Peris, T. Gómez-Navarro, X. Masip-Sanchis, and C. Prades-Gil, “Recovery of waste heat from data centres for decarbonisation of university campuses in a Mediterranean climate,” *Energy Convers Manag*, vol. 290, Aug. 2023, doi: 10.1016/j.enconman.2023.117212.
[19] F. Wegener, “Utilizing Data Centre Excess Heat in District Heating Networks A Techno-Economic Assessment of Seasonal Thermal Energy Storage Integration in Finland,” 2024.
[20] H. Du, X. Zhou, N. Nord, Y. Carden, P. Cui, and Z. Ma, “A new framework for evaluating and enhancing the performance of district heating systems integrated with data centres using short-term thermal energy storage,” *Energy*, vol. 319, Mar. 2025, doi: 10.1016/j.energy.2025.134934.
[21] H. Li, J. Hou, T. Hong, Y. Ding, and N. Nord, “Energy, economic, and environmental analysis of integration of thermal energy storage into district heating systems using waste heat from data centres,” *Energy*, vol. 219, Mar. 2021, doi: 10.1016/j.energy.2020.119582.
[22] M. Köfinger *et al.*, “Simulation based evaluation of large scale waste heat utilization in urban district heating networks: Optimized integration and operation of a seasonal storage,” *Energy*, vol. 159, pp. 1161–1174, Sep. 2018, doi: 10.1016/j.energy.2018.06.192.
[23] I. Keskin and G. Soykan, “Optimal cost management of the CCHP based data center with district heating and district cooling integration in the presence of different energy tariffs,” *Energy Convers Manag*, vol. 254, Feb. 2022, doi: 10.1016/j.enconman.2022.115211.
[24] Q. Huang, S. Shao, H. Zhang, and C. Tian, “Development and composition of a data center heat recovery system and evaluation of annual operation performance,” *Energy*, vol. 189, Dec. 2019, doi: 10.1016/j.energy.2019.116200.
[25] E. Oró, V. Depoorter, N. Pflugradt, and J. Salom, “Overview of direct air free cooling and thermal energy storage potential energy savings in data centres,” *Appl Therm Eng*, vol. 85, pp. 100–110, Jun. 2015, doi: 10.1016/j.applthermaleng.2015.03.001.
[26] Z. He, T. Ding, Y. Liu, and Z. Li, “Analysis of a district heating system using waste heat in a distributed cooling data center,” *Appl Therm Eng*, vol. 141, pp. 1131–1140, Aug. 2018, doi: 10.1016/j.applthermaleng.2018.06.036.
[27] M. Wahlroos, M. Pärssinen, J. Manner, and S. Syri, “Utilizing data center waste heat in district heating – Impacts on energy efficiency and prospects for low-temperature district heating networks,” *Energy*, vol. 140, pp. 1228–1238, 2017, doi: 10.1016/j.energy.2017.08.078.
[28] V. Dvorak, V. Zavrel, J. I. Torrens Galdiz, and J. L. M. Hensen, “Simulation-based assessment of data center waste heat utilization using aquifer thermal energy storage of a university campus,” *Build Simul*, vol. 13, no. 4, pp. 823–836, Aug. 2020, doi: 10.1007/s12273-020-0629-y.
[29] W. Zheng, K. Ma, and X. Wang, “TE-Shave: Reducing Data Center Capital and Operating Expenses with Thermal Energy Storage,” *IEEE Transactions on Computers*, vol. 64, no. 11, pp. 3278–3292, Nov. 2015, doi: 10.1109/TC.2015.2394381.
[30] K. Hamid *et al.*, “Potential evaluation of integrated high temperature heat pumps: A review of recent advances,” *Appl Therm Eng*, vol. 230, Jul. 2023, doi: 10.1016/j.applthermaleng.2023.120720.
[31] L. Eltrop, “Leitfaden feste Biobrennstoffe,” 2014. Accessed: Apr. 14, 2025. [Online]. Available: https://mediathek.fnr.de/leitfaden-bioenergie/book/book05.pdf#:~:text=von%20501%20bis%201,Entaschung%20und%20werden%20teilweise%20als
[32] “Hydex.” Accessed: Apr. 14, 2025. [Online]. Available: https://e-bridge.de/kompetenzen/wasserstoff/h2index/#:~:text=Der%20Hydex%20ist%20ein%20t%C3%A4glich%20ver%C3%B6ffentlichter%20kostenbasierter%20Spotmarktindex,Wasserstoffproduktion%20ohne%20Kapitalkosten%2C%20Transport-%20und%20Vertriebskosten%20in%20Deutschland.