ENGINEERING TOMORROW

Article | Danfoss Climate Solutions — District Energy

End-to-end efficiency in urban buildings:
Comparing the future-proof potential of district heating and hydrogen heat sources

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As urbanization intensifies around the world, efficiently heating our cities' buildings—responsible for 28% of all global energy-related CO_2 emissions—is an essential task. That begs the question: What are the most resilient, energy-efficient, and climate-friendly heat supply systems? Hydrogen is positioned as a future-proof energy carrier capable of decarbonizing urban energy systems. This article argues, however, that despite the potential of hydrogen to deliver clean heating, there are major efficiency drawbacks—and that, ultimately, district energy is significantly more efficient and has a much lower environmental footprint in both the short and long term.

Infrastructure, efficiency, and resilience: Why are we comparing hydrogen-based heat supplies with low-temperature district energy?

Decarbonization can be achieved in many ways. However, different approaches have different costs, environmental effects, and impacts on energy efficiency—parameters that are intrinsically linked in an applied supply system. In other words, the higher a system's efficiency is, the lower a system's operating costs, environmental impact, and primary energy need becomes. The key to achieving high energy efficiency is minimizing the number of energy conversion processes occurring in a system—and matching the supplied energy to the demanded energy quality.[1] This is particularly important when considering building heating demands—which is an energy demand that does not require high quality energy.

The Hydrogen Council, a lobby organization for major oil and gas producers [1], promotes hydrogen as a viable and cost-effective means to decarbonize the heat supply in buildings currently heated by natural gas—by repurposing the existing natural gas infrastructure rather than developing new infrastructures. This idea is shared in several reports from countries such as the Netherlands [2, 3], Germany [4, 5], the United Kingdom [6], and Europe [7, 8].

While the idea of repurposing natural gas grids is indeed appealing, research has shown that most of the components in existing natural gas grids are unable to cope with a large concentration of hydrogen in the gas supply [5]. In fact, the maximum allowable blending of hydrogen in the gas supply in 2020 could be found in France at just 6% [9]. Due to this incompatibility, an extensive renovation of the existing natural gas infrastructure—from transmission lines to the end users' gas installations—would be necessary to enable a widespread rollout of hydrogen.

An alternative to hydrogen-based heat supply in urban areas could be modern, low-temperature district heating—an infrastructure designed to distribute centrally-produced heat to one or more locations via a pipe network [10–12].

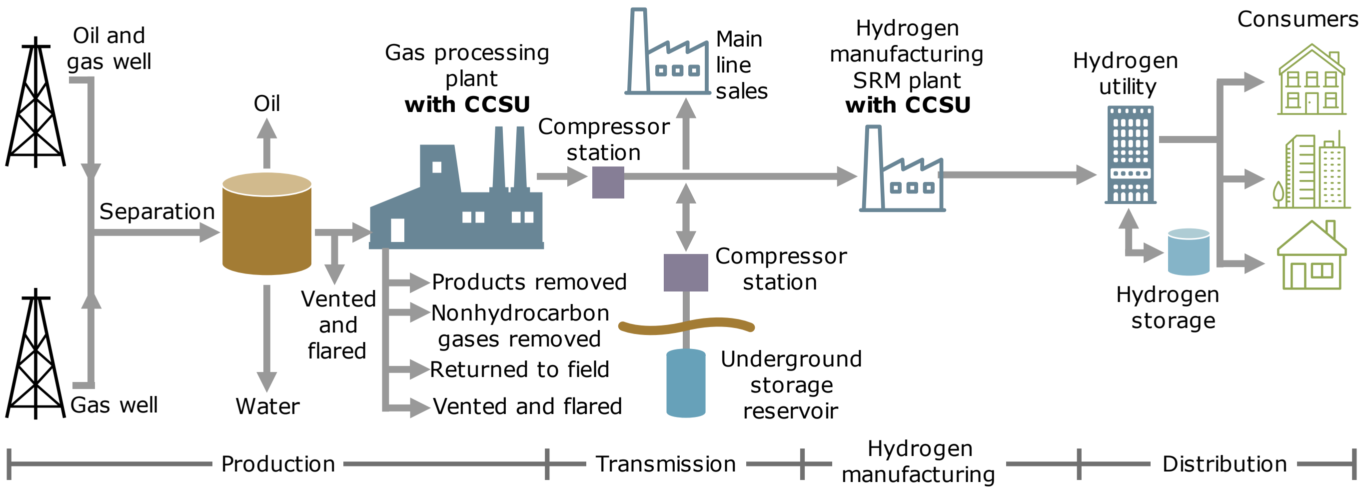
In this article, we compare blue and green hydrogen with district heating for building heating demands based on two key parameters: energy intensity and global warming potential (GWP). The hydrogen industry promotes blue hydrogen as transitional—therefore, this article considers blue district heating (natural gas-based) as a transitional alternative. This end-to-end energy chain comparison of the two different kinds of energy carriers highlights the large inefficiencies associated with manufacturing a high-quality energy carrier, hydrogen, for low-quality energy demands. As both supply solutions aim to solve a basic need of meeting building heat supply demands—and both require extensive infrastructures to be built—a long-term lock-in effect must be considered. That means it is particularly important to prioritize energy efficiency to minimize both the environmental footprint and the cost of establishing future renewable energy systems.

Methodology

This article intends to evaluate the energy intensity and GWP of a future energy system that utilizes blue energy, decarbonized natural gas, or renewable energy for meeting the heat demands of buildings. The analysis is based on examining the energy supply chain from primary energy input to the end user of the heat. For blue energy systems, the system boundary extends from the gas field development to the heat-consuming buildings [Figure 1]. In renewable energy systems, the system boundary extends from the point where the renewable power enters the power transmission grid to the heat-consuming buildings [Figure 2].

Figure 1. Blue energy-based systems: hydrogen above and district heating below. Adaptation of U.S. Energy Information Administration figure on natural gas production and delivery [13].

Blue hydrogen – From source to sink



Blue district heating – From source to sink

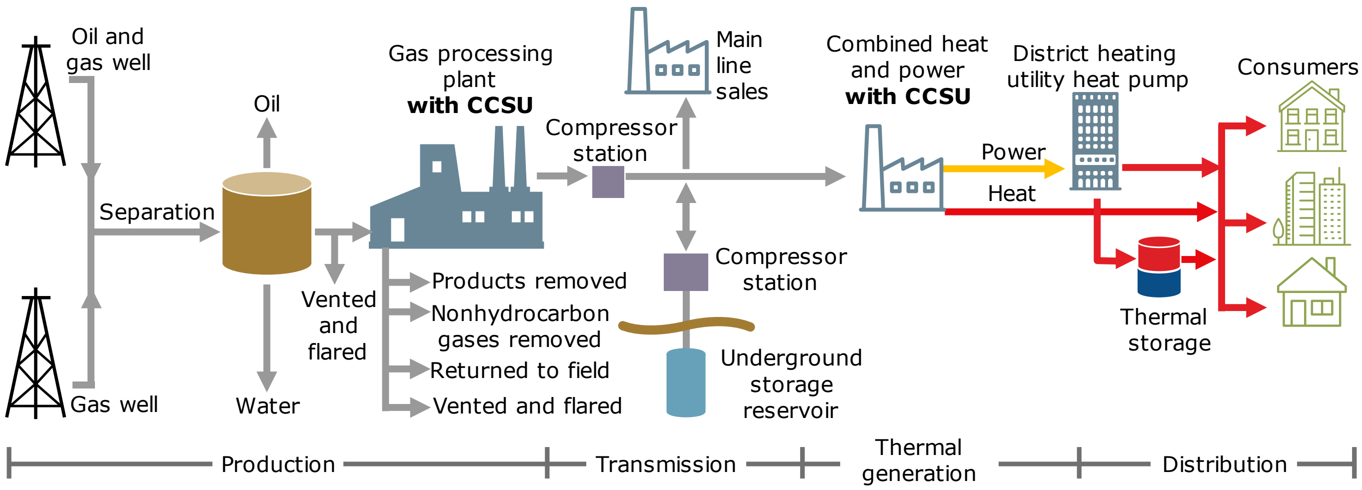
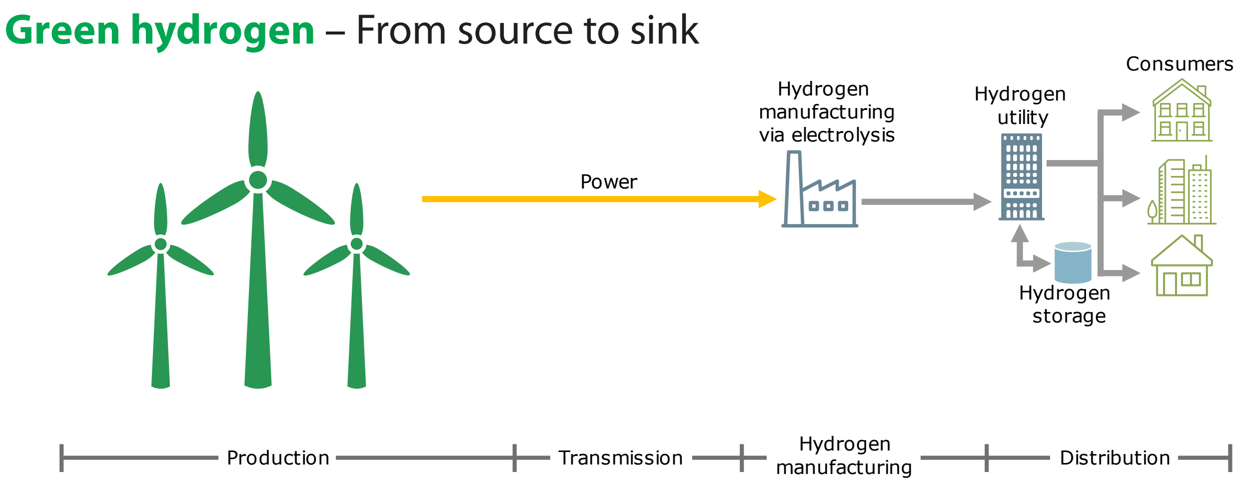
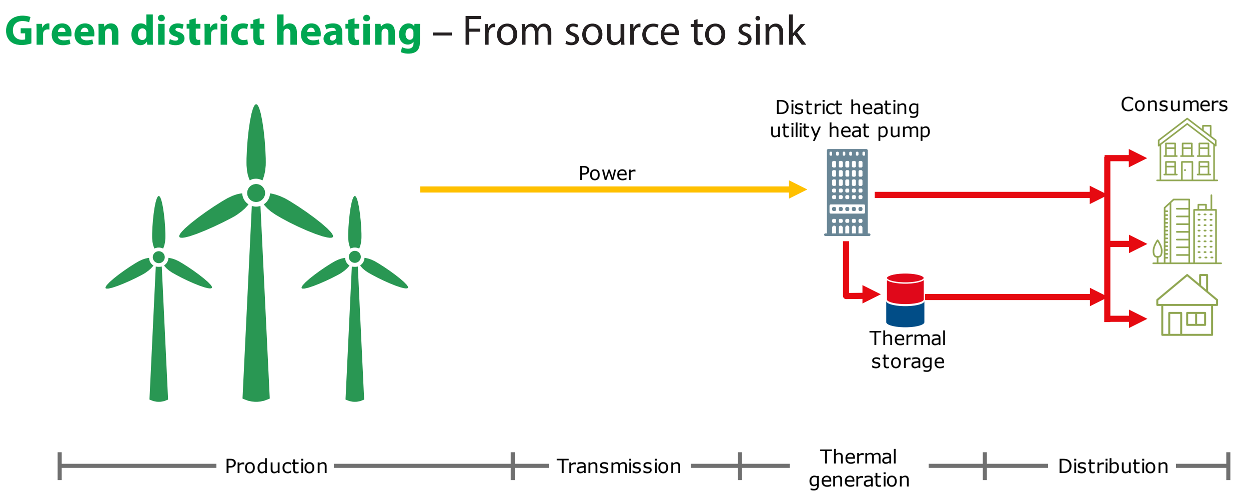


Figure 2. Green energy-based systems: hydrogen above and district heating below.





When estimating the overall supply system efficiency and GWP, the efficiency and fugitive emission of each step is estimated based on a literature review.

Results

While several different thermal sources would generally supply district heating, this analysis assumes that both heat supply systems are based on the same primary input. This simplification enables one-to-one comparison of the primary energy demands of district heating and hydrogen-based heat supply systems. The Sankey diagrams visualize the main results of the study, the primary energy demands, the energy efficiencies along the supply chain, and the value of matching the supplied energy quality with the demanded energy quality.

A comparison of the Sankey diagrams for the blue hydrogen scenarios [Figures 3 and 4] show that the superiority of blue district heating originates from its ability to capture waste heat from primary fuel conversions and incorporate ambient heat—via heat pumps—into the heat supply. Utilizing waste and ambient heat greatly reduces the primary energy demand compared to the blue hydrogen alternative, as a consequence of the lower primary energy demand there is significantly lower short and long-term GWP potential from the district heating alternative [Table 1].

In the green scenarios [Figures 5 and 6], the ability of district heating systems to utilize ambient heat through heat pumps results in significantly lower primary energy demand compared to the green hydrogen alternative.

A. Sankey diagrams: Blue energy systems

Figure 3. Energy flow diagram for the blue hydrogen scenario.

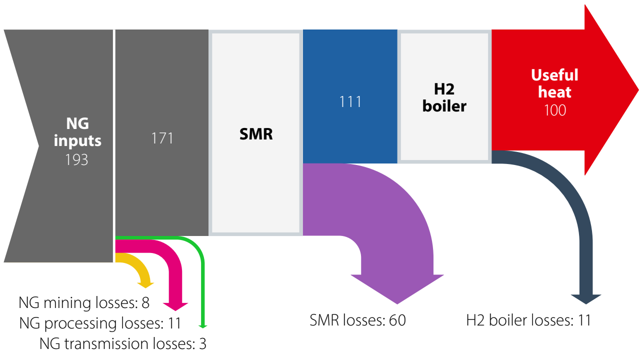
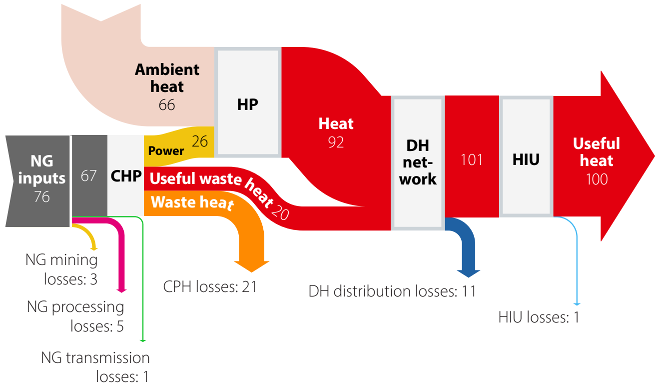


Figure 4. Energy flow diagram for the blue district heating scenario.



B. Global warming potential of blue energy systems

Table 1. GWP of 100 units of useful heat from different heat supply systems.

GWP of natural gas scenarios	CH_4 emissions per 100 useful energy units	CO_2 emissions per 100 useful energy units	GWP potential of greenhouse gas emissions								
			Year 0			Years 0 to 20 average			Years 0 to 100 average		
			CH_4	CO_2	Combined	CH_4	CO_2	Combined	CH_4	CO_2	Combined
Average GWP potentials at given years from utilization:			**120**	**1**	-	**86**	**1**	-	**34**	**1**	-
NG boiler (reference)	3,1	104,3	372	104	477	267	104	371	106	104	210
Blue hydrogen	4,2	22,6	503	23	526	361	23	383	143	23	165
Blue district heating	1,6	8,9	198	9	207	142	9	151	56	9	65

C. Sankey diagrams: Green energy systems

Figure 5. Energy flow diagram for the green hydrogen scenario.

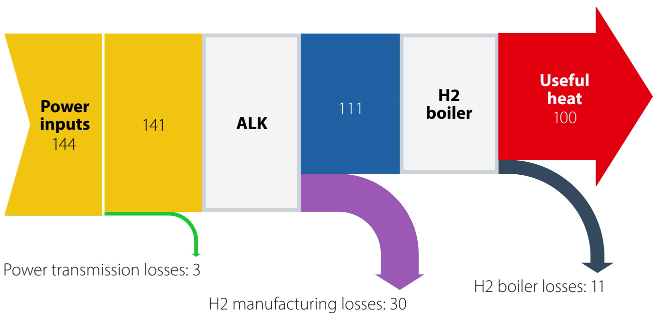
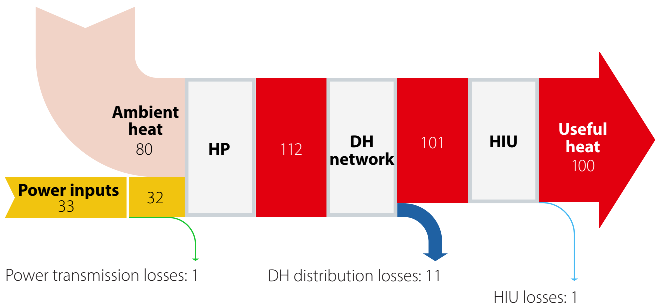


Figure 6. Energy flow diagram for the green district heating scenario.



District heating proves to be more energy efficient and resilient

Conclusions

Due to the inherent energy losses of a hydrogen-based energy system, the logical utilization of hydrogen in future decarbonized energy systems would be in hard-to-electrify sectors such as industrial processes requiring high-temperature heat [14] and the potential long-term storage of excess renewable power. However, for building heating demands, district heating supply systems would have significantly higher primary energy efficiency compared to a hydrogen-based heat supply system.

Like recent studies on the role of hydrogen in future energy systems [15–17], the results of this analysis underscore the efficiency shortcomings of using hydrogen to fulfill heat demands in urban areas. From an energy efficiency perspective, district heating would vastly outperform a hydrogen-based heat supply system—and in realized systems, the advantages of district heating become even greater due to its ability to integrate any locally-available surplus heat or renewable energy sources. Unlike leakages in flammable gas distribution networks, the leakages in district heating networks are generally gradual—slowly developing and non-hazardous. Plus, district heating systems are very robust and can usually operate with leakages until repairs can be done. The combination of the heat source agnostic nature of district heating and its robustness make it an exceptionally resilient infrastructure, as is explained in [19].

While direct utilization of hydrogen for building heating demands is vastly inferior compared to district heating, there are important synergies to be explored. With proper planning, future hydrogen manufacturing for hard-to-decarbonize sectors can become an important source of heat for district heating systems. If realized, district heating would benefit from access to a stable, low-cost waste heat and the hydrogen manufacturing company would benefit from a secondary revenue stream—making the overall energy system much more cost and energy efficient.
A detailed description of the above analysis is found in [19].

[1] Kahya D. Unearthed today: Why oil companies want you to love hydrogen. Unearthed 2020. *https://unearthed.greenpeace.org/2020/12/08/unearthed-today-why-oil-companies-want-you-to-love-hydrogen/ (accessed December 14, 2021).*

[2] Rongé J, François I. Use of hydrogen in buildings BatHyBuild study. 2021.

[3] Van den Broeck Y, François I, Martens A. A Flemish Hydrogen Strategy - 2025-2030. Turnhout: 2020.

[4] Hennig E. Decarbonising Buildings: the Role of Hydrogen Hydrogen Blending: Overview of Different Approaches. COGEN EUROPE Power & Heat Boost Webinar Decarbonising Buildings: Role of Hydrogen 2021.

[5] Cerniauskas S, Jose Chavez Junco A, Grube T, Robinius M, Stolten D. Options of natural gas pipeline reassignment for hydrogen: Cost assessment for a Germany case study. International Journal of Hydrogen Energy 2020;45:12095–107. *https://doi.org/10.1016/j.ijhydene.2020.02.121.*

[6] Great Britain. Department for Business E& IStrategy. UK Hydrogen Strategy. London: 2021.

[7] Haeseldonckx D, D'haeseleer W. The use of the natural-gas pipeline infrastructure for hydrogen transport in a changing market structure. International Journal of Hydrogen Energy 2007;32:1381–6. *https://doi.org/10.1016/j.ijhydene.2006.10.018.*

[8] Minett S. Benefits of Hydrogen & CHP for Buildings. COGEN EUROPE Power & Heat Boost Webinar Decarbonising Buildings: Role of Hydrogen 2021.

[9] IEA. Current limits on hydrogen blending in natural gas networks and gas demand per capita in selected locations. Current Limits on Hydrogen Blending in Natural Gas Networks and Gas Demand per Capita in Selected Locations 2020. *https://www.iea.org/data-and-statistics/charts/current-limits-on-hydrogen-blending-in-natural-gas-networks-and-gas-demand-per-capita-in-selected-locations (accessed December 14, 2021).*

[10] Lygnerud K, Werner S. Implementation of Low-Temperature District Heating Systems. 2021: 2021.

[11] Schmidt D, Kallert A. Future low temperature district heating design guidebook: Final Report of IEA DHC Annex TS$_1$. Low Temperature District Heating for Future Energy Systems. Frankfurt Am Main: 2017.

[12] Lund H, Werner S, Wiltshire R, Svendsen S, Thorsen JE, Hvelplund F, et al. 4th Generation District Heating (4GDH). Energy 2014;68:1–11. *https://doi.org/10.1016/j.energy.2014.02.089.*

[13] U.S. Energy Information Administration (EIA). Natural gas explained - Delivery and storage of natural gas. Webpage Article 2021. *https://www.eia.gov/energyexplained/natural-gas/delivery-and-storage.php (accessed December 15, 2021).*

[14] Papadis E, Tsatsaronis G. Challenges in the decarbonization of the energy sector. Energy 2020;205. *https://doi.org/10.1016/j.energy.2020.118025.*

[15] Baldino C, O'Malley J, Searle S, Christensen A. Hydrogen for heating? Decarbonization options for households in Germany in 2050. 2021.

[16] Baldino C, O'Malley J, Searle S, Christensen A. Hydrogen for heating? Decarbonization options for households in the European Union in 2050. 2021.

[17] Gerhardt N, Bard J, Schmitz R, Beil M, Pfennig M, Kneiske T. Hydrogen in the Energy System of the Future: Focus on Heat in Buildings. Hannover: 2020.

[18] Gudmundsson O, Thorsen JE. Source-to-sink efficiency of blue and green district heating and hydrogen-based heat supply systems. Smart Energy 2022;6:100071. *https://doi.org/10.1016/j.segy.2022.100071.*

[19] Gudmundsson O. White paper: Designing a resilient district energy infrastructure. Nordborg, 2022. *https://assets.danfoss.com/documents/latest/207344/BE424741808063en-000101.pdf*

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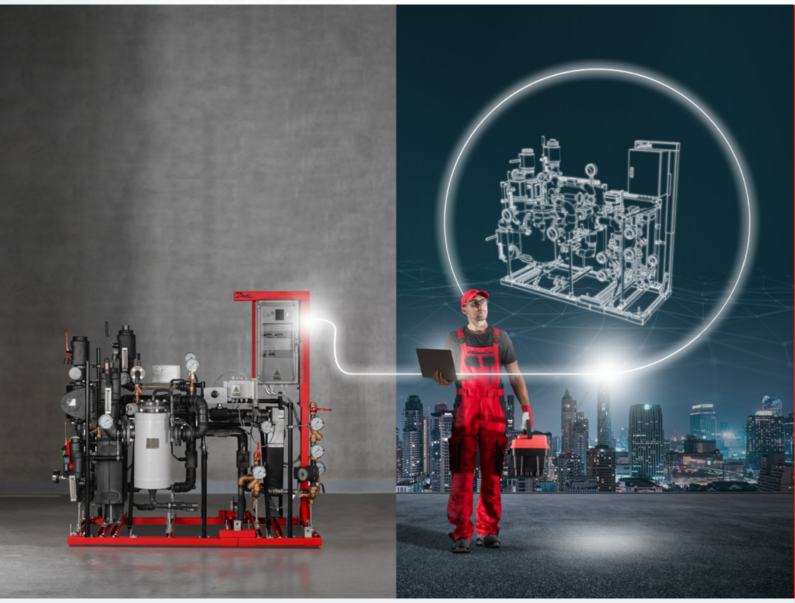

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