MARKET STATUS, INCENTIVES AND POLICIES IN DENMARK

Technical Report of the IEA DHC TS3 “Hybrid Energy Networks”, subtask A “Technologies and synergy potential”, WP2 “Experiences with hybrid energy networks based on large-scale heat pumps”: *Market status, incentives and policies in Denmark*.

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Content

1 Danish market for heat pumps in district heating

1.1 Market development

The website www.heatpumpdata.eu contains a map showing the location of all known large-scale heat pumps connected to district heating networks in Denmark together with an associated list. Each heat pump icon has its main properties stated in an info box such as rated themal power, type of heat souce, commissioning year etc. The list and map are updated regularly to include the latest heat pumps commissioned.

Figure 1 shows the development of district heating heat pump capacities in Denmark until end of 2022. There was a significant increase of these capacities during 2020 due to an incentive scheme ending by the end of the same year as described in section 2.1.

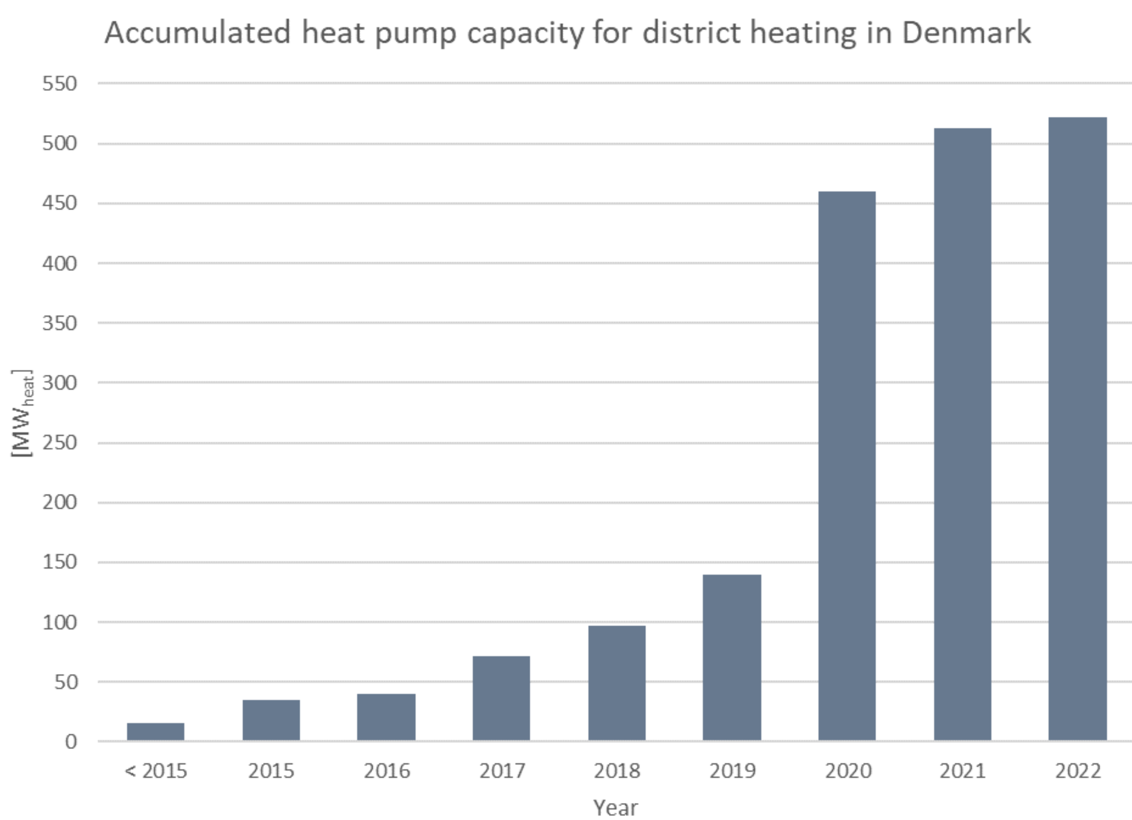

Figure 1. Accumulated heat pump capacity (heating) for district heating in Denmark.

1.2 Heat source trends

Both in terms of thermal capacity and number of systems, more than half of the installed heat pump systems are air-source heat pumps as seen in Figure 2.

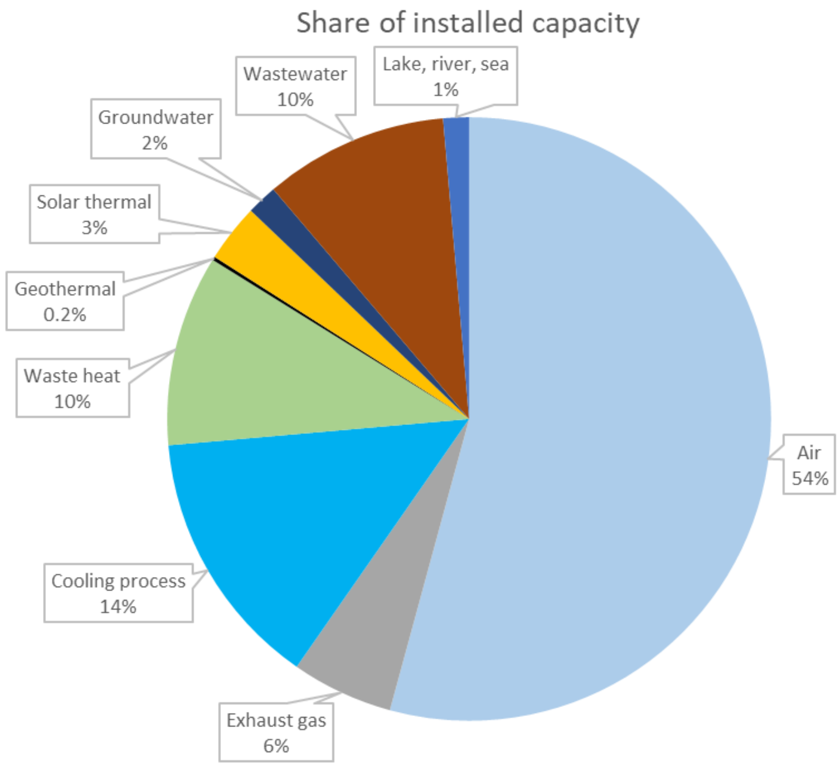

Figure 2. Share of installed heat pump (heating) capacity for district heating.

The difference between the category “cooling process” and “waste heat” is that the cooling process implies an active demand for cooling whereas waste heat would if unused alternatively simply be discarded to the environment without any (or almost any) energy required to do so. One example of a cooling processes in this respect is district cooling supply where the condenser side of the heat pump is used for district heating and the evaporator side is supplying district cooling. Another example is data centres.

A different way to indicate the market share of heat pumps in district heating is by the number of heat pump systems installed as seen in Figure 3. It is seen that in general the ratio levels are somewhat similar to the installed heat pump capacity in Figure 2. However, the typically relatively small exhaust air heat pumps cover a larger share when it comes to the number of installed heat pump systems.

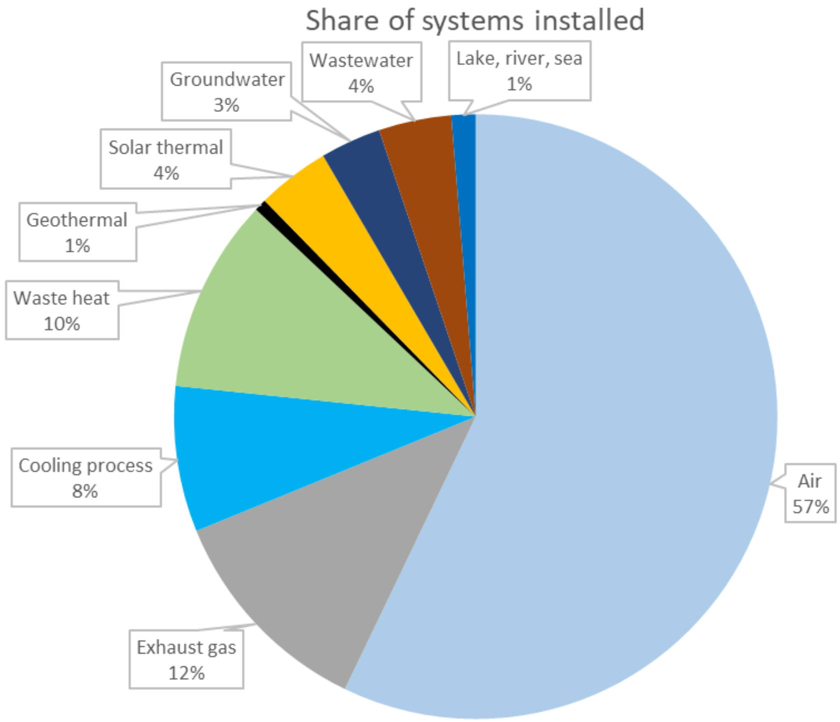

Figure 3. Share of heat pump units by (main) heat source.

1.3 Heat pump capacities

To compare the sizes of systems, the average and maximum size of the heat pumps are illustrated in Figure 4. The largest number of air-source heat pumps on average have a nominal capacity of 3.2 MW (heat output). Waste heat systems are on average at 3.3 MW, cooling processes at 6.1 MW, exhaust gas at 1.6 MW, and wastewater heat pumps at 8.6 MW. In many cases small towns have been leading the way for the use of heat pumps for district heating. However, there are also cities taking part in the development representing a potential for larger scale heat pumps in the future. Currently there are a number of systems planned at city scale e.g. a 50 MW sea water heat pump in Esbjerg. The availability of various heat source options is often higher in a big city compared to a small town and the connection to the network using a transmission line represents a relatively small share of the overall heat pump system costs. Compared to Figure 3, a more diverse heat source distribution is expected in the coming years.

The heat pump size does not follow a certain capacity-to-population ratio. By investing in several heat pumps instead of one big system – possibly using different heat sources – the utility can reduce its risks by being less dependent on a specific technology and the supply of that specific heat source (e.g. weather conditions for air or amount of wastewater).

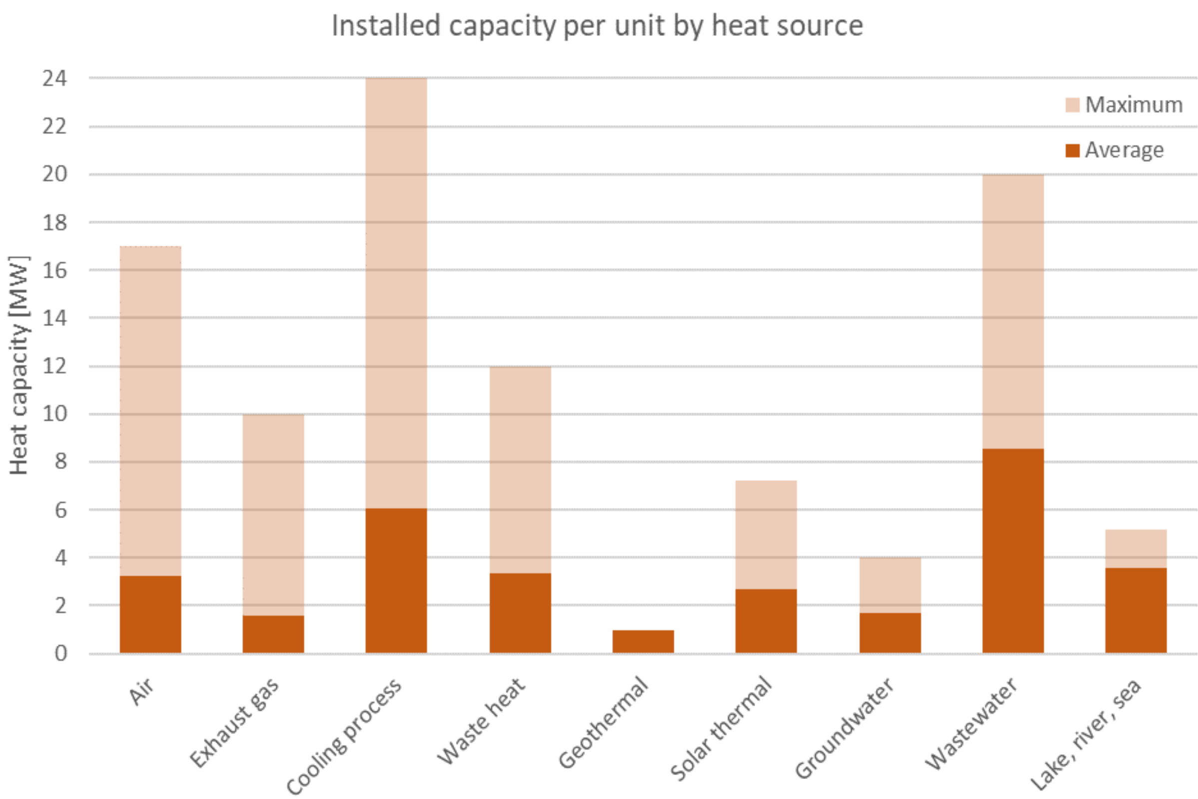

Figure 4. Average and maximum heat capacity per heat pump unit by (main) heat source.

2 Policies and incentives

2.1 Overview of measures promoting large scale heat pumps

Denmark is one of the countries with the highest share of wind power compared to the electricity demand. The electrification of a range of demand categories (residential heating, industry, transport etc.) is politically a priority as a means to replace fossil fuel use with renewable energy in order to reach the national target to become carbon neutral by the year 2045. District heating presents an opportunity to convert entire towns and cities by changing the centralised heat supply without the need for individual households to invest or engage in a new heating unit. Financial support for investments in large scale heat pumps have been granted in several ways over the past few years.

The figure below shows two key support categories implemented in Denmark to promote the use of heat pumps in district heating.

Knowledge support	Financial support
2015-2018: The Danish Energy Agency's own traveling experts team visits the DH plants to discuss opportunities and providing advice on heat pump options for free. Experienced from cases are gathered and shared.	2017-2018: Investment support to promote and showcase heat pump for DH as a viable option.
2019-2023: Smaller DH plants can apply for free consultancy services to investigate how to lower prices. Public funding ensured professional advice from a consortium of experienced companies.	2017-2020: The installation of HP in DH created energy savings credits which could be sold on an associated credit stock market thus representing up to 20% of the HP investment cost.
The Danish Energy Agency supports the participation in several heat pump research projects through the "Energy Technology Development and Demonstration Programme (EUDP)" (continuous).	2018-2023: Substantial reduction of electricity taxes (several times) – initially targeting only electric heating solutions, lately in general.
The Danish District Heating Association facilitates the sharing of practical experiences by organising knowledge sharing groups (networks). Since 2020 one group has been dedicated to heat pumps.	2020-2023: Investment support for DH plants replacing fossil fuels. Funding prioritized in order of most CO_2 displaced per DKK. Possible grant: 15-30% (2021/2022) provided that 50%/25% (2021/2022) of DH supply is fossil fuel-based.

Figure 5. Knowledge and financial support mechanisms for large scale heat pumps in Denmark.

In terms of the energy savings credits mentioned in Figure 5, district heating was part of a cross-sectoral political agreement on energy savings between the government and the grid and distribution companies for electricity, natural gas, district heating and oil[1]. The agreement meant that all sectors were obliged to realise a certain amount of savings each year. Realised savings created credits which could be sold on a dedicated stock market by those who created more than needed to those who did not themselves achieve their required savings. Heat pumps in district heating would create credits according to the production during one year of operation minus the associated energy demand.

Key stakeholder organisations were interested to enter such an agreement since they preferred to have their say in the wording of such an agreement rather than being forced by law to comply with restrictions developed without their inputs.

The setup was attractive enough for the supply of credits at some point to result in credit prices close to zero. This credit market uncertainty did not discourage investments in heat pumps and the end of the agreement resulted in a rush to commission heat pumps before the deadline at the end of 2020.

There were also other indirect incentives such as the taxation of fossil fuel alternatives. Similarly, the extension of the district heating coverage is politically regarded as an important measure to replace fossil fuels with sustainable heating. Public funding to support the conversion from natural gas to district heating has been granted. This increases the demand thus also extending the market potential for large scale heat pumps.

2.2 The incentive dilemma

The political decision to promote heat pumps by lowering electricity taxes/tariffs reveals an "incentive dilemma" where lowering electricity taxes to improve the feasibility of heat pumps also reduces the incentive to improve the performance of heat pumps (COP) (relatively) thereby indirectly somehow favouring less efficient solutions. On the other hand, and the use of heat pumps replacing fossil fuels is an effective way to reduce GHG emissions in general. Another parameter in the equation is *when* the electricity is used, which affects the electricity's carbon footprint. With a growing share of variable RES, the energy system requires an intelligent interaction with the electricity grid rather than non-flexible electricity consumption. Larger variation in tariffs across the day and seasons – on top of the variable spot prices – can be used to divert electricity use away from peak load

[1] The original 2012 agreement text (English) can be downloaded at energy.ec.europa.eu/document/download/a994940a-bd8e-4b26-b7a4-0f5d303b5f11_en?filename=article7_en_denmark_annex-a.pdf and the 2016 update (in Danish) at ens.dk/sites/ens.dk/files/Energibesparelser/bilag_5_-_energispareaftale_2016.pdf.

hours. Such diversification of tariffs has recently been applied to an increased extent over the day, week, and seasons.

In terms of the political “incentive dilemma” between lowering operation costs and incentivising efficient operation, a stepwise process can be derived:

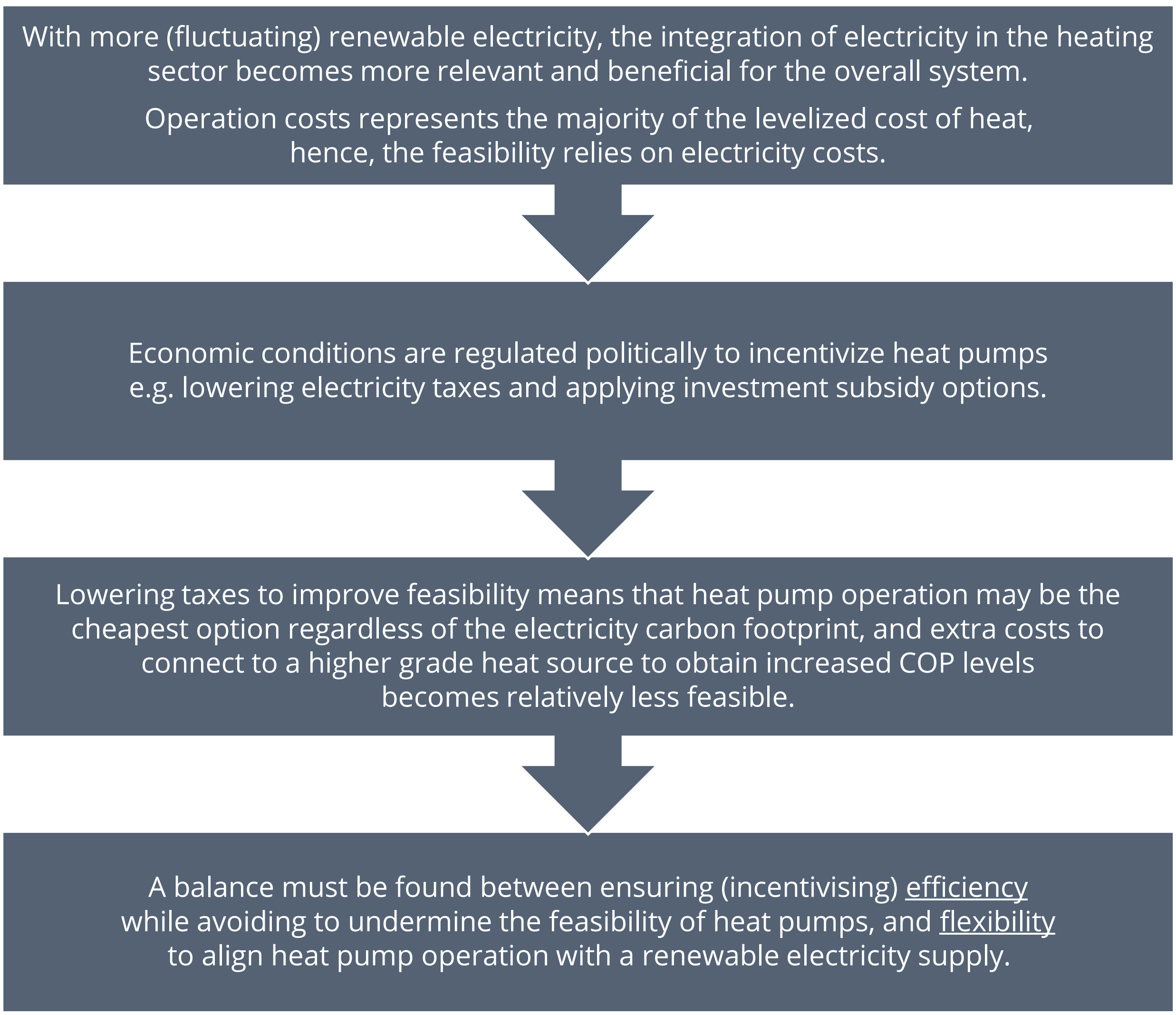

Figure 6. The promotion of heat pumps reveals an “incentive dilemma” between lowering operation costs and incentivising efficient operation.

3 Renewable energy fuels for district heating

Some alternative options for producing heat throughout the year are boilers or CHPs. The options to ensure sustainability and alignment with national and international climate targetsinvolve the use of synthetic fuels (e.g. green hydrogen or a product based on it) and biomass/biogas. The use of these – including the option to use biogas and green hydrogen as a direct replacement for fossil methane (natural gas) – comes with significant limitations and other drawbacks.

3.1 Biomass

A substantial share of the current renewable energy supply in Denmark consists of biomass. Though certification schemes are put in place to avoid deforestation e.g. in Brazilian rain forests, and there is a focus on the use of waste wood when it comes to wood pellets/chips, the role of biomass as a means to a renewable energy transition is not simply replicable in all countries – mainly due to the scarcity and future demand of biomass in other hard-to-abate sectors such as heavy transport and industry. As indicated in the International Renewable Energy Agency (IRENA) publication "Bioenergy for the Transition: Ensuring Sustainability and Overcoming Barriers", different key stakeholder organisations estimate the biomass supply by 2050 to be between 40 and 250 EJ per year with IRENA itself stating around 150 EJ."2 With 8-10 billion people globally 100-150 EJ corresponds roughly to around 15 GJ/person annually. To put things in perspective, this (only) corresponds to the heating value contained in approx. two straw bales of 500 kg. This illustrates how the use of biomass is not expected to be suited as widely used baseload option for the future of district heating.

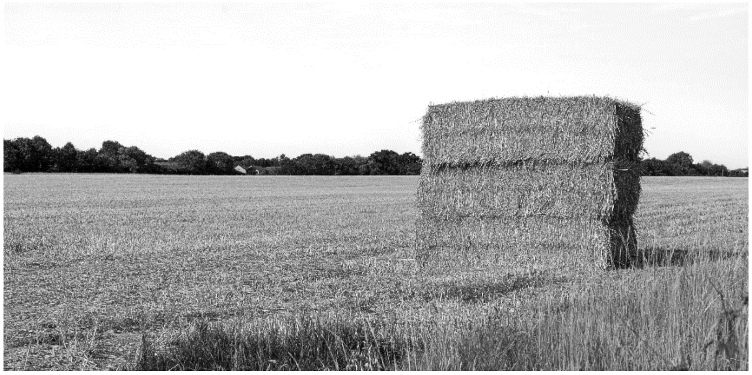

Figure 7. If the biomass resources are to be shared evenly, there will only be enough for a couple of straw bales similar to the ones in the picture per person each year.

[2] IRENA: 153 EJ of biomass supply by 2050. IEA: Likely 130-240 EJ. IPBES/IPCC: 50-90 EJ. The Energy Transition Commission: 40-120 EJ. www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Aug/IRENA_Bioenergy_for_the_transition_2022.pdf?rev=875a997481f04168b17499f1e5dc1473.

3.2 Hydrogen for heating

Hydrogen boilers are highly inefficient compared to heat pumps and even in a 100% RE-based energy system where the hydrogen is considered green, it would require a substantial amount of extra RE capacity to generate the extra energy required to supply hydrogen boilers compared to heat pumps. Even if it is obtainable in practice, it would result in additional costs, additional efforts and a missed opportunity to displace fossil fuels elsewhere with the hydrogen wasted in inefficient boilers where the final energy demand is warm water/space heating. Hydrogen can play a role in stabilizing the energy system in periods of the so-called "dunkelfaute" (cold night-time periods with no wind) but should not be used for baseload heating. It should be mentioned that hydrogen may not be used in tis pure form, but in green fuels such as upgraded biomethane, methanol etc. Figure 8 below illustrates an example of scale between using wind power to generate hydrogen for heating or to power heat pumps. Though the exact numbers may not be representative everywhere, the figure indicates the obvious disadvantage of relying on a system using only hydrogen for heating.

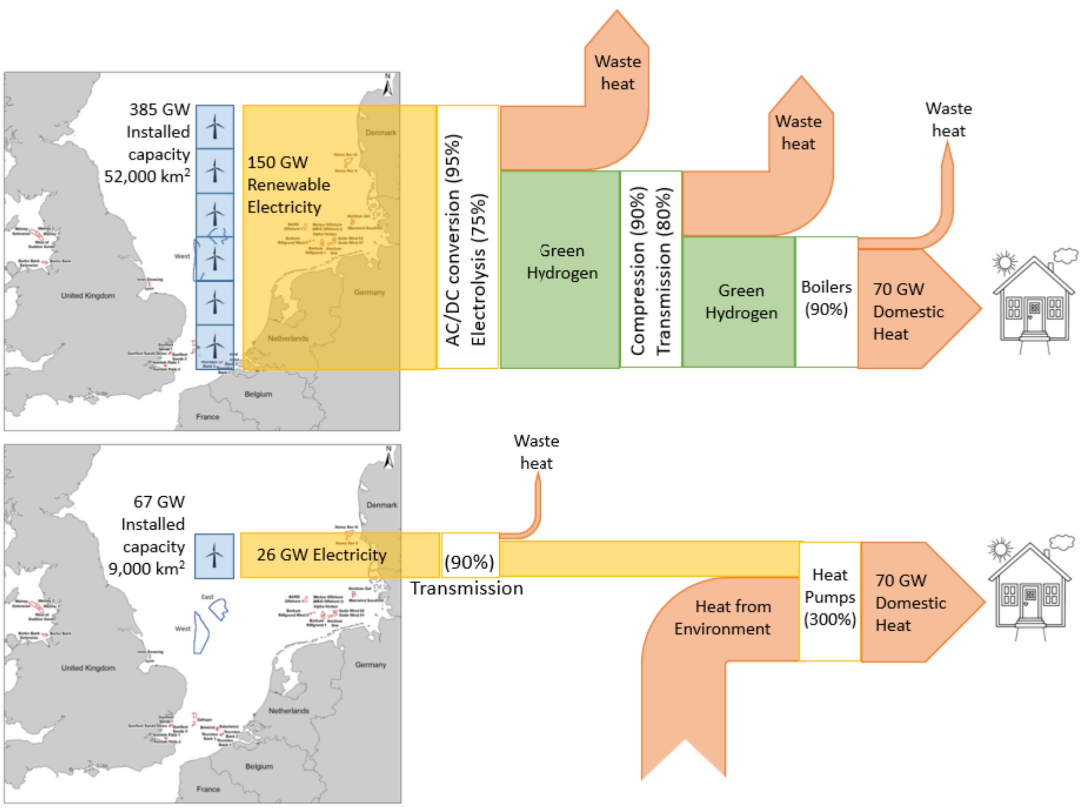

Figure 8. Comparison between hydrogen and heat pumps for heating from the "Briefing on the Energy" Bill by Hydrogen Science Coalition 28/8 2022, https://t.co/ib6LoQEdNW.