# Results of the quantitative assessment of selected policy packages for Helsingør
(Deliverable 4.1)

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# Results of the quantitative assessment of selected policy packages for Helsingør

# (Deliverable 4.1)

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## The progRESsHEAT project

The progRESsHEAT project aims at assisting policy makers at the local, regional, national and EU-level in developing integrated, effective and efficient policy strategies to achieve a rapid and widespread penetration of renewable and efficient heating and cooling systems. Together with 6 local authorities in 6 target countries across Europe (AT, DE, CZ, DK, PT, RO), heating and cooling strategies will be developed by a detailed analysis of (1) heating and cooling demands and future developments, (2) long-term potentials of renewable energies and waste heat in the regions, (3) barriers & drivers and (4) a model-based assessment of policy intervention in scenarios up to 2050. progRESsHEAT will assist national policy makers to implement the right policies based on a model-based quantitative impact assessment of local, regional and national policies up to 2050.

Policy makers and other stakeholders will be strongly involved in the process, learn from experiences in other regions and gain a deeper understanding of the impact of policy instruments and their specific design. They are involved in the project through policy group meetings, workshops, interviews and webinars targeted to the fields of assistance in policy development, capacity building and dissemination.

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### Legal Notice

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**Project consortium:**

| | |
|---|---|
| Energy Economics Group | Energy Economics Group, Institute of Energy Systems and Electrical Drives, Technische Universität Wien |
| Fraunhofer ISI | Fraunhofer Institute for System and Innovation Research ISI |
| DTU | Technical University Denmark |
| IREES Institute for Resource Efficiency and Energy Strategies | Institute for Resource Efficiency and Energy Strategies |
| energycities WHERE ACTION & VISION MEET | Energy Cities |
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| GATE 21 | Gate 21 |
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# Contents





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# 1. Introduction and method

The objective of this report is to provide a quantitative analysis and assessment of policies for renewable individual heating and district heating for Helsingør municipality for the time horizon until 2030 and 2050. Similar reports are also available for the other local cases covered in the progRESsHEAT project, i.e. Ansfelden, Brasov, Herten, Litomerice and Matosinhos. The project also provides results of the policy assessment on the national level, which are summarised in the reports "Results of the quantitative assessment of selected policy packages at the national level"[1].

The local policy assessment is based on the quantitative model results and methodology documented in the report "Assessment of local feasible renewable energy-based heating/cooling utilisation for Helsingør" (Ben Amer-Allam, 2016) and accompanied by the policy assistance carried out in workshops and policy group meetings. The results in the present report are not directly comparable to the aforementioned report, because some of the economic and technical assumptions are different. For example, for 2050 the perspective in this report is private-economic, where all taxes and VAT are included. Some results concerning shares of district heating and heat savings also differ, e.g. due to changes in interest rates and heat pump COP (coefficient of performance) values that were implemented. All the modelling results were obtained using energyPRO and the Least Cost Tool, where different heating options and heat savings could be simultaneously compared to cost-optimal solutions - for methodology see the report "Documentation of the modelling framework in the project progRESsHEAT" (Petrovic, 2016).

The methodological overview for this report is depicted in Figure 1. It comprises the identification of a reference scenario for each local case. Different desirable alternative scenarios were discussed with the stakeholders and implemented with the modelling framework described in the report "Assessment of local feasible renewable energy-based heating/cooling utilisation for Helsingør" (Ben Amer-Allam, 2016). Within the modelling framework the need for support to reach the desired alternative scenario was calculated.

This report includes the documentation of the different policies assessed for the local case of Helsingør and the identified need for support.

[1] Available at: http://www.progressheat.eu/Reports-publications-69.html



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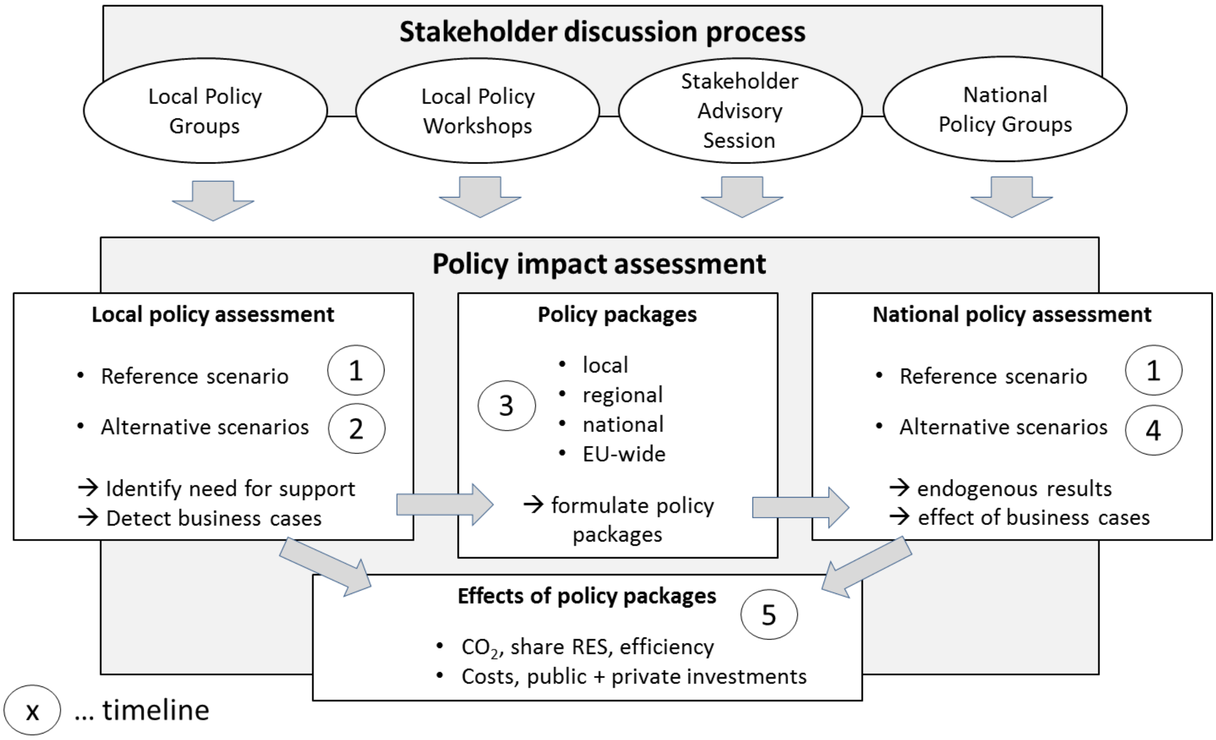


**Figure 1 Methodological overview of the policy impact assessment**

## 1.1 Indicators for policy assessment

Several indicators are needed for the assessment of the different policies and scenarios. The calculation method for the following indicators is described in detail in Appendix A:

1) Total useful energy demand for heat
2) Share of district heating
3) Total and specific $CO_2$ emissions for heat
4) Total and average private-economic costs of heat supply and heat savings
5) Share of renewables
6) Difference in total private-economic costs for the different policies

## 1.2 Main assumptions

The policies are implemented and compared one at a time, to be able to clearly understand their impact. Due to the volatility of taxes and subsidies and their dependence on political will, the assumption that taxes and subsidies will remain the same in 2030 and 2050 is a crucial factor for deriving the most feasible scenarios. In 2030 and 2050, the discount rate used for investments in district heating is 0.99%, for investments in large buildings: 2.18% and for the remaining ones: 4.46%.

District heating in Helsingør consist of two sites: Forsyning Helsingør and Norfors, connected with a transmission line. Helsingør municipality has been divided into four types of areas: DH areas, Next-to-DH areas, Individual areas and Scattered buildings (buildings in low heat density areas) - where, technically, district heating can be implemented in all of the area types except for the last one.



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Although the majority of buildings in DH areas are supplied by district heating, some are not connected to the network, requiring investments in connecting pipes and heat exchangers. Next-to-DH areas share a border with existing DH areas, but are not supplied by district heating. Connecting the buildings located in Next-to-DH areas require investments in distribution and connecting pipes and heat exchangers. Individual areas are not supplied by district heating and do not share a border with existing district heating areas, thus require investments in transmission, distribution and connecting pipes and heat exchangers.

The calculated heat saving potentials in Invert/EE-Lab model are not restricted but it is assumed that until 2050 the total building stock is renovated. To limit the renovations until 2030, renovation rates per building category and construction period were calculated endogenously within the Invert scenarios (see Appendix B).

## 1.3 Current situation in Helsingør

As of 2014, district heating covered 33% of heat demand in Helsingør. This share is below the national average of 50%, so there is potential for increasing it. However, Helsingør has a rather small population density, thus considering the population density as a proxy for heat density indicates that reaching high shares of district heating may not be as cost optimal in Helsingør as in big cities like e.g. Copenhagen. In 2014, 8% of district heating supply came from renewables - but more can be expected in the near future, when Forsyning Helsingør switches to biomass. Also $CO_2$ emissions are expected to drop thanks to fuel switching. Nonetheless, it is still worthwhile to compare these options to alternatives, in relation to costs and possible policies.

## 1.4 Policies assessed for Helsingør in 2030 and 2050

In this report we do not assess any policy implementation costs (such as administration and monitoring), but the effect of implementing each specific scenario and policy on the total (and average) cost of heat supply and heat savings, as well as on the difference between the total costs, when a specific policy is present and when it is not. Not all policies are favourable to increasing the share of renewables or district heating implementation - some simply reflect the energy policies currently discussed in Denmark. While the policies we analyse are assessed on a municipal level, the decision power for most of them lies primarily at the level of national government. The compared policies are discussed in sections 1.4.1 - 1.4.5 below.

### 1.4.1 Prohibition of oil and natural gas in individual heating supply

This policy instrument is a legislation banning individual heating based on fossil fuels (in the case of Helsingør, fuel oil and natural gas). Such a policy is in line with the Energy Agreement between Danish political parties from 2012 (Regering, 2012). This policy could be implemented by the national government.

### 1.4.2 Tax on particulate matter (PM) emissions of biomass-fired individual boilers and CHPs

While most fuels used for energy generation are heavily taxed in Denmark, all biomass is exempted from tax, despite its particle matter (PM) emissions. A lack of such tax may promote the choice of



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biomass, which is clearly visible, when comparing the modelling results from a simple socio-economic and private-economic perspective (see Ben Amer-Allam, 2016). The Danish Tax Ministry (Skatteministeriet, 2016) agrees that the particle matter (PM) emissions are a significant externality. The present analysis tries to address this externality both for residential installations and large biomass-fired CHPs. This policy could be implemented by the national government.

The subject of particle emissions is very complex, because the emissions from biomass combustion depend on the fuel type, its humidity, type of operation (batch/manual or continuous/automatic), type of incinerator and filters installed (Wierzbicka et al., 2005). According to (Nussbaumer, 2010) PM emissions for wood combustion in larger plants range between 5 - 300 mg/MJ, depending on the type of post-combustion flue gas cleaning technology (filters etc.). In wood stoves, it ranges from 20 to above 1000 mg/MJ. Moreover, the PM type is different whether the boiler is operated manually or automatically - in the latter case, it mainly consist of salts, contrarily to harmful organic particles from incomplete combustion.

Devising a policy addressing all different types of biomass boilers, their age and location, combustion temperatures, quality of biomass used etc. would require an extensive data collection and significant administrative expenses, that is why in this report, we apply an average value calculated by the Danish Tax Ministry, which is relevant for Danish conditions. The damage values from PM emissions oscillate between 20 EUR/GJ fuel for most populated areas and highly polluting boilers and 3.4 EUR/GJ for least polluting boilers. The weighted average is then 6.66 EUR/GJ, which we charge on individual boilers. Large CHPs are charged with 50% of the suggested tax, that is 3.33 EUR/GJ, because they emit less PM than individual boilers, however this value can be even lower in the newest plants (such as the biomass CHP planned in Helsingør).

### 1.4.3 Tax reduction for large heat pumps and individual heat pumps

While from the simple socio-economic perspective large heat pumps are competitive with biomass-fired CHPs, this is not the case if all the taxes are considered. In this study we follow the approach used in a scenario analyzed in the report "Energiforsyning 2030" (Grøn Energi and Ea Energianalyse, 2016), where the PSO (Public Service Obligation) tax and 50% of the electricity tax is removed. For individual heat pumps, we remove PSO tax and assume a tax reduction for electricity consumption over 4000 kWh (an already existing policy, also included in the reference scenario). This policy could be implemented by the national government.

### 1.4.4 Liberalization of the heat supply sector

In 2016, the Danish government proposed new a strategy for utilities (Regeringen, 2016). Regarding the district heating sector, the future ownership of district heating companies in Denmark is the main change discussed. Today, the majority of these companies is either partly or fully owned by municipalities (e.g. Forsyning Helsingør is 100% owned by Helsingør municipality) or cooperatives. Their possible privatisation may mean that the possibility for preferential municipal loans (Kommunekreditlån) will disappear, non-profit operation ("hvile-i-sig-selv") will be replaced with a profit-based operation and the new buildings in district heating areas will not be required to connect to the district heating network or the existing buildings to remain within it. In the present report, we analyse three separate policies to assess the effect they could have on the heating system in



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Helsingør municipality. These policies could be implemented partly by the national government and partly by the local municipality.

1) **Higher discount rate for district heating companies**

Such a policy would mean that the preferential municipal loans would not be given to district heating companies and could be implemented by the loan-giving institution (Kommunekredit) itself or government. To analyse the impact of these changes, instead of 0.99% discount rate for investments in district heating plants and grid, we use 2.18%, the same as in the case of heat savings and heat installations in large buildings (e.g. public offices).

2) **Allowed disconnection in district heating areas**

In Denmark, a local municipality can require a building located in designated district heating areas to be connected to the district heating, to avoid double supply (e.g. with natural gas). The possible privatisation will mean an exemption from this rule and the effect of this action is analysed with this policy. It could be implemented by the municipality.

3) **Profit-based district heating operation**

This policy shows the situation when the district heating companies are allowed to generate profit. This policy could be implemented by the government. In this report, it is modelled as allowing 10% district heating price increase above the cost-based price, which we deem complying with the government's plan to implement ceilings for the district heating price, with a possibility for yearly reduction and an efficiency requirement (Altinget, 2017) (Regering, 2016).

### 1.4.5 Restricting individual biomass boilers in district heating areas

This policy excludes a possibility for existing or new individual biomass boilers, reflecting the increased air pollution in densely populated areas and practical aspects of handling biomass in areas where more convenient options such as district heating are available. The policy could be implemented by the municipality.

## 2. Results in 2030

This section describes the results of the different policies described in Section 1.4 on the indicators described in Section 1.1 of this report for the following 2030 scenarios:

1) BIO2030 (Biomass) - reference scenario: District heating based on a biomass CHP and a biomass boiler, and individual supply with various shares of biomass boilers, natural gas boilers and heat pumps

2) HP2030 (Heat Pumps) - District heating based on heat pumps and thermal storage and individual supply with various shares of biomass boilers, natural gas boilers and heat pumps

The names of the scenarios relate to the technology used for district heating generation in Forsyning Helsingør, so only the competition with other supply options determines what the fuel mix for the



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individual supply will be in each scenario. In both scenarios, about 32 GWh of heat yearly is supplied from the neighbouring Norfors, generated from waste and natural gas.

## 2.1 Energy demand for heat for implemented scenarios in 2030

The largest potential for heat savings of around 50% of their heating demand (sum of space heating and domestic hot water demand) lays in the buildings built before 1950; however, it varies between 19 and 61% depending on the use of buildings. The buildings built after 1979 are built according to better standards of energy efficiency and the assumed heat saving potentials are smaller in this group – they vary between 9 and 51%, while the potential of the whole group is 31% of their heating demand. Large heat saving potentials are available in Small Multifamily and Large Multifamily buildings, and Summer Houses. The potentials vary between construction periods with the average values of 52%, 43% and 45% of their heat demand in average, respectively. Heat saving potentials in Small Multifamily and Large Multifamily buildings are more significant for the analysis as they are responsible for 31% of the heating demand in the municipality, while summer houses are responsible for only 2%. 47% and 39% of the heating demand is located in DH and Next-to-DH areas, respectively. Accordingly, these areas also have the highest heat saving potentials.

There are a couple of additional considerations which are not taken into account in the present analysis. First, this is an energy-economic analysis, i.e. if an annuitized cost of heat savings are lower than the costs of supply, then the savings are assumed to be implemented. However, people are often not behaving in a cost-optimal manner. In order to make the residents aware of benefits from heat saving measures, significant information campaigns are needed. This is one area in which municipality can make an impact. Second, private comfort is disturbed during renovations; this is a barrier which is not included in the present analysis. Third, we have assumed relatively cheap long-term financing of heat savings which are usually based on equity. In some cases this financing option won't be available. Further, rebound effects, which are often seen in reality are not considered in the present analysis. The rebound effect is reflected as a smaller decrease of heating demand than expected due to increase of internal temperature. Finally, Helsingør has a number of buildings protected by law which are very expensive or impossible to energy renovate. In the present analysis, these buildings are seen as ordinary buildings. Therefore, the realisable potential for heat savings is probably smaller than what is described in the present report.

Table 1 shows the results of the different policies on final energy demand for heating for each scenario. In all scenarios, the reductions of heating demands are around 50%, 35% and 20%, for buildings built before 1950, between 1950 and 1979 and after 1979, respectively. The average heating demand in the municipality is reduced around 40% in all scenarios. The reduction of heating demand occurs almost uniformly across different areas – around 40% for buildings in DH and Individual areas, 36% for buildings in Next-to-DH areas and 42% for Scattered buildings. Compared to the current situation, the total heat demand for each future scenario and each policy is reduced. The heat demand reduction results from the implemented heat savings until 2030 and is largest if the tax on PM (particulate matter) emissions is implemented, accounting for 40.4%. However, it is only about 0.6% lower than the case of scenarios with biomass restriction policy and 1.5% lower than the remaining scenarios. The fact that a PM policy and a biomass restriction policy affect the share of



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heat savings the most is due to the high share of individual biomass boilers in all the scenarios and the close competition between biomass boilers and heat savings.

**Table 1 Total heat demand [MWh] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 558,590 | 341,481 | 341,481 |
| Prohibition of oil and gas in individual supply | | 341,481 | 341,481 |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 332,955 | 332,955 |
| Tax reduction for large and individual HPs | | 341,481 | 341,481 |
| Higher discount rate for DH | | 341,481 | 341,481 |
| Allowed disconnection in DH areas | | 341,481 | 341,481 |
| Profit-based DH operation | | 341,481 | 341,481 |
| Ind. biomass restricted in DH areas | | 336,347 | 336,347 |

Figure 2 shows the shares of the different supply technologies in each scenario and each policy. A significant fuel shift takes places between 2014 and 2030, where substantial reductions in individual natural gas consumption are implemented. The PM tax policy enables significant heat pump investments in both BIO and HP scenario, but also leads to higher natural gas consumption. The policies connected with sectoral liberalization show an increase in individual biomass boilers, especially in the case when disconnection from district heating is allowed. This is however under the assumption that it will be possible in practice to shift from district heating to individual biomass boilers, which may be difficult due to e.g. issues with instalment of boilers and chimneys, handling of the required biomass storage etc. If in "BIO disconnect" scenario installation of biomass boilers would be forbidden in all buildings except in Small Multifamily and Large Multifamily buildings, district heating supplied to consumers would be increased by 15 GWh, i.e. the share of heating



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demand supplied by district heating would increase from 14% to 19%. Furthermore, the shift to biomass would be risky, as taxing of biomass consumption is regularly discussed. In reality few disconnections from district heating are seen, but the result illustrates that the DH price in Helsingør - which is currently high compared to the rest of Denmark - may get challenged by competing individual heating options.

The HP scenario is highly influenced by the PM tax, disconnection and restriction on individual biomass boilers. For example, allowing disconnection from district heating in the HP scenario could in theory result in all customers disconnecting, thus there would be no DH supply, only individual biomass and individual natural gas.

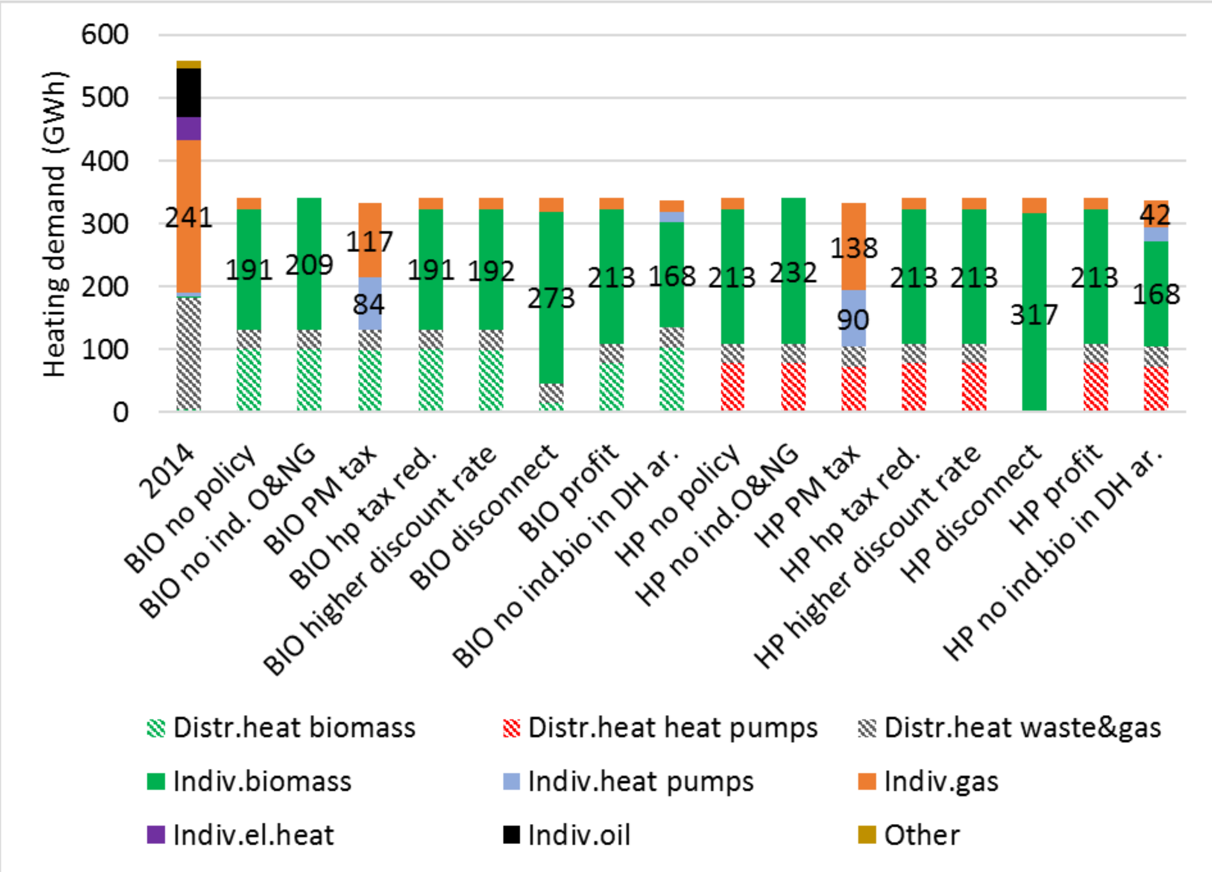


**Figure 2 Total heat demand [GWh] per heat supply type in the different scenarios for different policies in 2030**

## 2.2 District heating share for implemented scenarios in 2030

Table 2 and Figure 3 show the results of the different policies on the share of district heating for each scenario.

**Table 2 Share of DH of total heat demand [%] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 33% | 39% | 32% |
| Prohibition of oil and gas in individual supply | | 39% | 32% |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 40% | 32% |
| Tax reduction for large and individual HPs | | 39% | 32% |
| Higher discount rate for DH | | 38% | 32% |
| Allowed disconnection in DH areas | | 14% | 0% |
| Profit-based DH operation | | 32% | 32% |
| Ind. biomass restricted in DH areas | | 40% | 31% |

In most of the cases, the policies do not significantly influence the share of district heating in relation to the reference (no policy). However, allowing disconnection from district heating will theoretically reduce the share of district heating significantly, leading to only 14% DH share in the BIO scenario and no district heating customers in the HP scenario subject to the assumptions that a shift from district heating to individual biomass boilers will in practice be possible.

The modelling results presented in the present report represent a form of economic simplification in which the choice of heat supply/heat savings is made solely on the annuitized costs of heat supply/heat savings. There are several factors which are not taken into account in the present analysis which would make such a drastic switch very difficult:

- Building specific technical and legal restrictions may apply
- Heating expenses often represent small part of the budgets. Comfort may play a more important role in decision making.
- Investments in new heat savings/heat supply sometimes have too long pay-back times.



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- Free money is reserved for other purposes, e.g. a modern kitchen, etc.
- Lack of information/knowledge about heat supply/heat savings

On the other hand, district heating in Helsingør is one of the most expensive in Denmark and therefore it is expected that it may have difficulties in competing with individual heat supply options and heat savings based purely on costs.

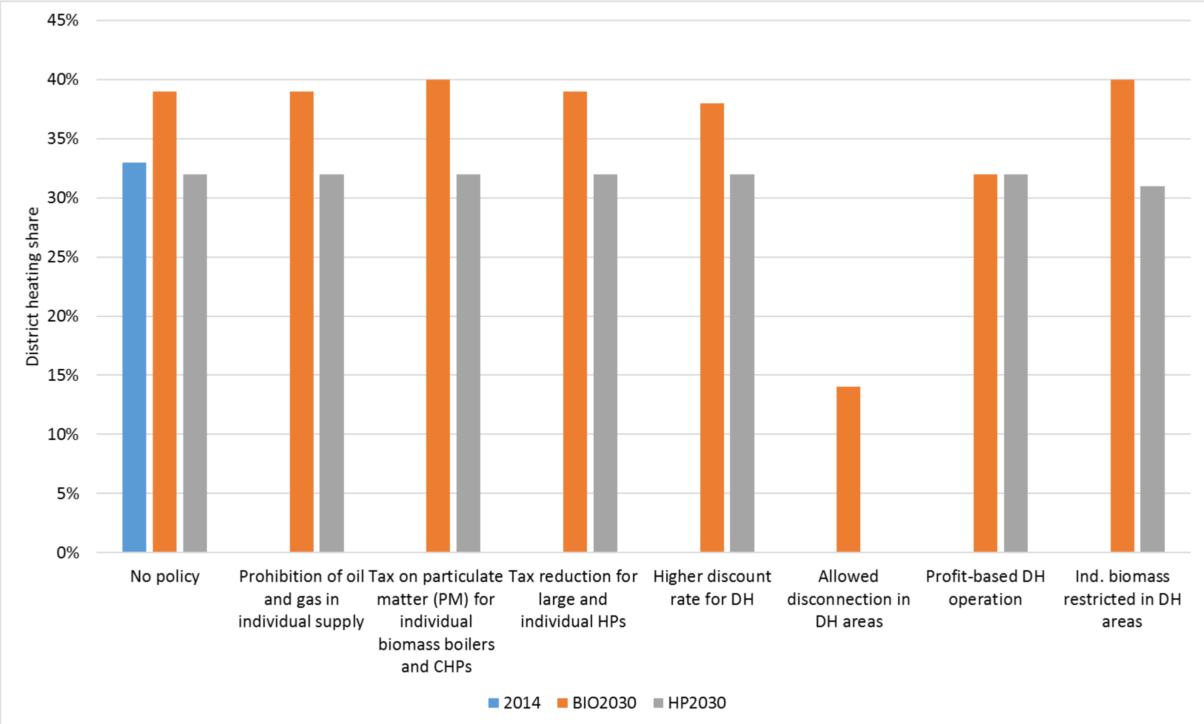


**Figure 3 Share of DH for the different policies in the different scenarios in 2030**

## 2.3 Total and specific $CO_2$ emissions for heat for implemented scenarios in 2030

Table 3 and Figure 4 show the results of the different policies on total heat related $CO_2$ emissions for each scenario. Compared to the current situation, the $CO_2$ emissions in the future will decrease remarkably by between 65% and 96%, due to Forsyning Helsingør switching to biomass or to large heat pumps. Some $CO_2$ emissions from district heating will remain in all scenarios as the supply from Norfors based on municipal waste and natural gas is assumed constant. In most cases, the BIO scenarios result in lower $CO_2$ emissions than the HP scenario, independently of the implemented policies, which is partly due to the projection that electricity will not be entirely fossil fuel free in 2030 (see also Appendix A). The lowest $CO_2$ emissions in the BIO scenario can be achieved, when fossil fuels in the individual supply are forbidden. The lowest emissions in the HP scenario occur, when disconnection from district heating is allowed - in this case, the district heating supply produced from (partly non-renewable) waste and natural gas in Norfors is replaced with individual biomass boilers, which are assumed to be $CO_2$-neutral.



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Introducing a tax on PM can actually cause significantly higher $CO_2$ emissions than the no policy option, because it results in more natural gas boilers installed. For HP and electric heating, the CO2 intensities of the Danish power sector according to the EU reference scenario (European Commission, 2016) is used for 2030, 0.09 tCO2/MWh is assumed and for 2050, 0 tCO2/MWh is assumed, due to the Danish government's policy of energy system becoming independent of fossil fuels by then.

For district heating the specific CO2 emission is calculated for each scenario depending on the produced heat.

CO2 emissions from CHP are allocated according to IEA Method [Fuel for heat = eff_th/eff_total].

**Table 3 Total heat related $CO_2$-emissions [$t_{CO2}$] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 115,516 | 9,540 | 13,267 |
| Prohibition of oil and gas in individual supply | | 5,845 | 9,342 |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 32,423 | 40,145 |
| Tax reduction for large and individual HPs | | 9,540 | 13,267 |
| Higher discount rate for DH | | 9,540 | 13,267 |
| Allowed disconnection in DH areas | | 10,342 | 5,078 |
| Profit-based DH operation | | 9,770 | 13,267 |
| Ind. biomass restricted in DH areas | | 10,088 | 18,412 |



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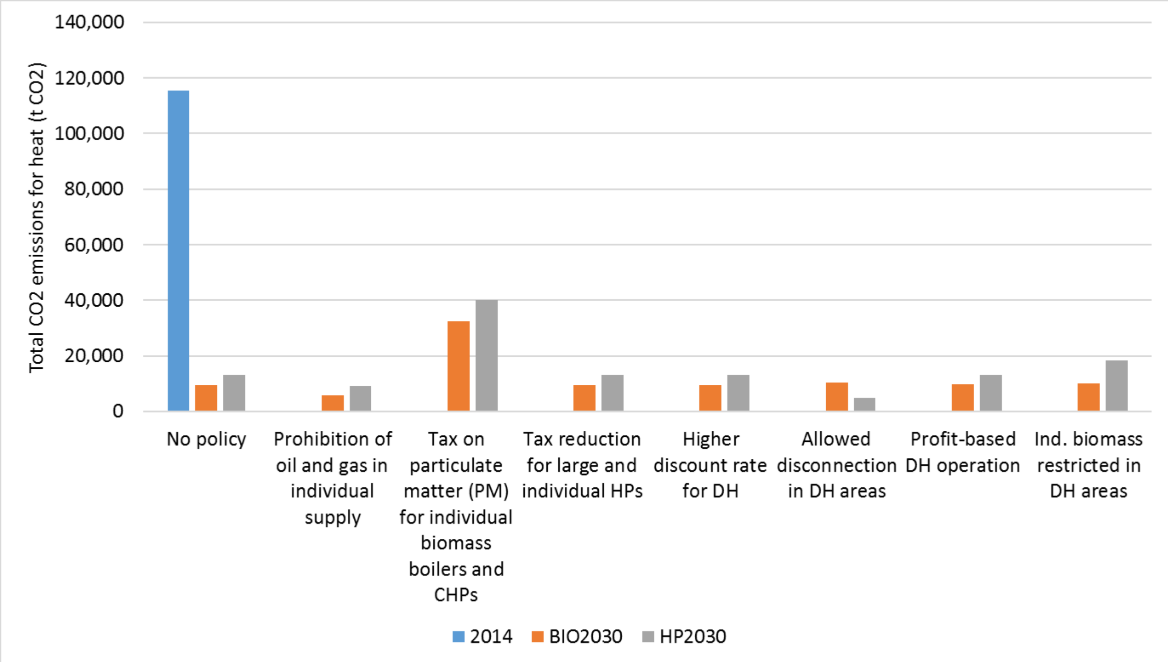


**Figure 4 Total $CO_2$ emissions for the different policies in the different scenarios in 2030**

Table 4 and Figure 5 show the results of the different policies on heat related specific $CO_2$ emissions for each scenario. While in general, the specific $CO_2$ emissions for the BIO scenario are lower than the HP scenario, the lowest specific $CO_2$ emissions occur in the case of implementing a policy of allowed disconnection from district heating in the HP scenario. Since heat savings are similar in the different scenarios, the specific $CO_2$ emissions show a similar pattern as the total $CO_2$ emissions discussed above.



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**Table 4 Specific $CO_2$-emissions for heat [$t_{CO2}$/MWh] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 0.21 | 0.03 | 0.04 |
| Prohibition of oil and gas in individual supply | | 0.02 | 0.03 |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 0.10 | 0.12 |
| Tax reduction for large and individual HPs | | 0.03 | 0.04 |
| Higher discount rate for DH | | 0.03 | 0.04 |
| Allowed disconnection in DH areas | | 0.03 | 0.01 |
| Profit-based DH operation | | 0.03 | 0.04 |
| Ind. biomass restricted in DH areas | | 0.03 | 0.05 |



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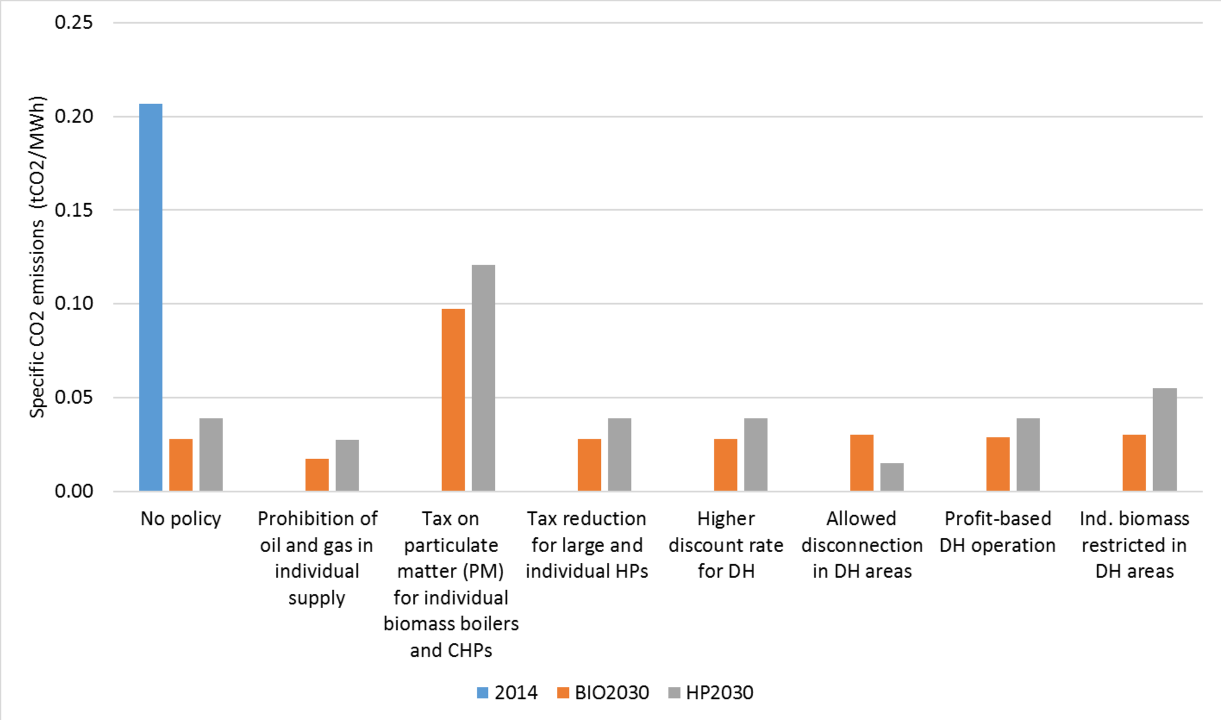


**Figure 5 Specific $CO_2$ emissions [t/MWh] for the different policies in the different scenarios in 2030**

## 2.4 Total and average costs for heat savings and heat supply for implemented scenarios in 2030

Table 5 and Figure 6 show the results of the different policies on total private-economic costs for heat for each scenario. For details on how costs are calculated, see Appendix A. In all the cases, heating costs decrease substantially in the future compared to now and they are on average 14% lower in the policies implemented for the BIO scenario than in those for the HP scenario. In both scenarios, the lowest total costs are achieved if the policy allowing for disconnection from district heating is implemented, indicating that the cost for district heating will in some cases be higher than heat savings or individual solutions. The analysis shows the broad perspective but local analyses would be required as e.g. implementation of individual heat supply could be limited by practical matters such as available space for storage of biomass, implementation of chimneys etc.



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**Table 5 Total costs for heat and savings [kEUR/year] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 66,919 | 38,074 | 45,849 |
| Prohibition of oil and gas in individual supply | | 38,291 | 46,069 |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 41,597 | 48,411 |
| Tax reduction for large and individual HPs | | 38,074 | 42,827 |
| Higher discount rate for DH | | 38,359 | 45,849 |
| Allowed disconnection in DH areas | | 36,235 | 36,391 |
| Profit-based DH operation | | 39,369 | 47,247 |
| Ind. biomass restricted in DH areas | | 38,216 | 45,964 |



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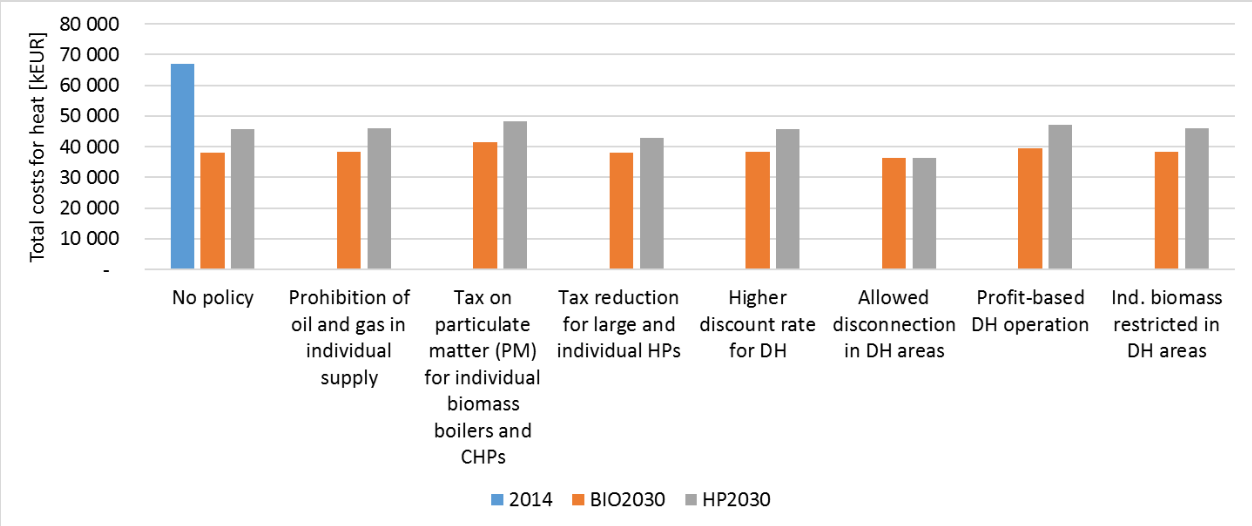


**Figure 6 Total cost for heat supply and heat savings [kEUR/year] for the different policies in the different scenarios in 2030**

Table 6 shows the results of the different policies on average costs for heat supply and heat savings for each scenario. Implementing a tax on PM will result in higher average costs of heat in BIO and HP scenarios. This is caused mainly by biomass boilers not being selected if this policy is applied, due to higher cost than in the No policy scenario. The model selects more natural gas boilers and heat pumps instead.



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**Table 6 Average costs for heat plus savings [EUR/MWh] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 119.8 | 68.2 | 82.1 |
| Prohibition of oil and gas in individual supply | | 68.5 | 82.5 |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 74.5 | 86.7 |
| Tax reduction for large and individual HPs | | 68.2 | 76.7 |
| Higher discount rate for DH | | 68.7 | 82.1 |
| Allowed disconnection in DH areas | | 64.9 | 65.1 |
| Profit-based DH operation | | 70.5 | 84.6 |
| Ind. biomass restricted in DH areas | | 68.4 | 82.3 |

## 2.5 Share of renewables (RES) for implemented scenarios in 2030

Table 7 and **Figure 7** show the results of the different policies on the share of renewables for heat for each scenario. The largest share of renewables in the heat supply are found, when oil and gas are prohibited in the individual supply in the scenario BIO2030 and when disconnection from district heating is allowed in the scenario HP2030, due to switching to individual biomass boilers. The difference between this policy and the No policy option is also caused by the assumption that part of district heating supply is imported from Norfors area, where waste and natural gas are used. For the no policy option and all the other options, the share of renewables oscillates between 77-89%, but for PM tax policy, the share is only between 44-54% percent for both scenarios, because of the many natural gas boilers implemented and heat pumps using electricity, which is assumed partly non-renewable in 2030 (see Appendix A for details).



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**Table 7 RES share of heat [%] in the different scenarios for different policies in 2030**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 8% | 89% | 85% |
| Prohibition of oil and gas in individual supply | | 94% | 91% |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 54% | 44% |
| Tax reduction for large and individual HPs | | 89% | 85% |
| Higher discount rate for DH | | 89% | 85% |
| Allowed disconnection in DH areas | | 88% | 93% |
| Profit-based DH operation | | 89% | 85% |
| Ind. biomass restricted in DH areas | | 88% | 77% |



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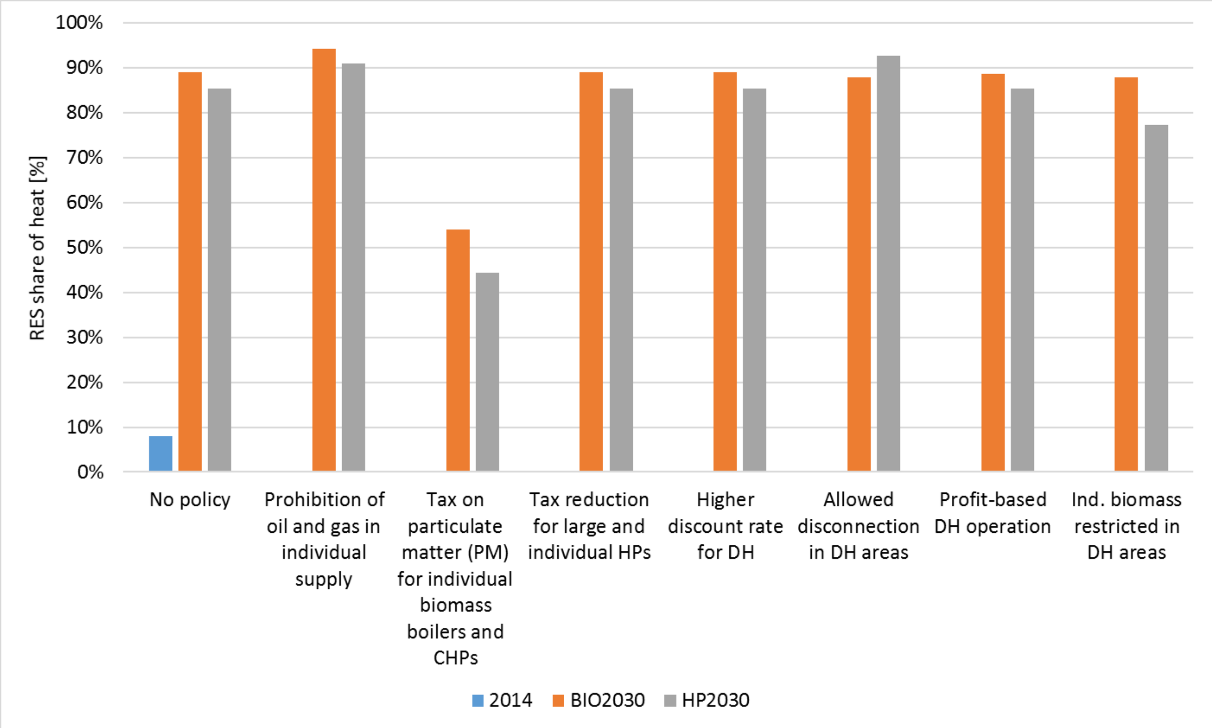


**Figure 7 Share of renewables for the different policies in the different scenarios in 2030**



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## 2.6 Difference in total system costs for the different policies for implemented scenarios in 2030

Table 8 and **Figure 8** compare the total system costs for the different policies and the different scenarios with the No policy scenarios.

**Table 8 Difference in total system costs [kEUR/year] for the different policies and implemented scenarios compared to no policy**

| Policy | 2014 | BIO2030 | HP2030 |
|---|---|---|---|
| No policy | 43,644 | - | - |
| Prohibition of oil and gas in individual supply | | 217 | 221 |
| Tax on particulate matter (PM) for individual biomass boilers and CHPs | | 3 523 | 2 562 |
| Tax reduction for large and individual HPs | | - | -3 022 |
| Higher discount rate for DH | | 285 | - |
| Allowed disconnection in DH areas | | -1 839 | -9 457 |
| Profit-based DH operation | | 1 295 | 1 399 |
| Ind. biomass restricted in DH areas | | 142 | 115 |

The cost of the PM tax policy on the heating supply exceeds the No policy cost the most. Other policies, which are more expensive than No policy are: prohibition of fossil fuels in individual heating, higher discount rate for district heating (in case of the BIO scenario) and the profit-based DH operation. Tax reduction for large and individual heat pumps, allowed disconnection from district heating and biomass restriction cost less than the No policy scenarios.



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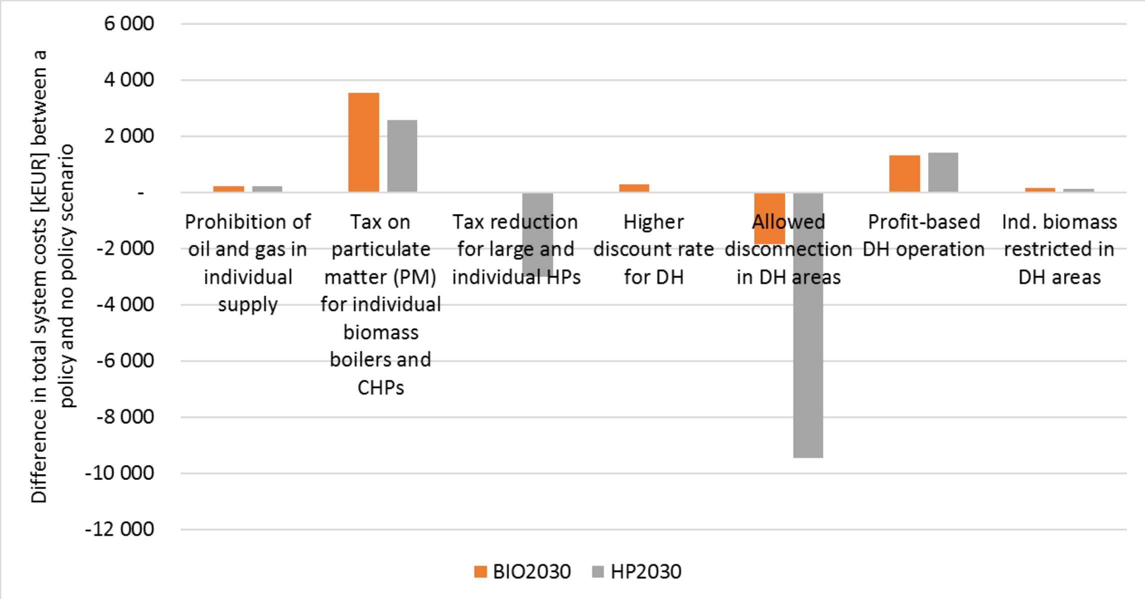


**Figure 8 Difference in total system costs [kEUR/year] for the different policies and implemented scenarios compared to no policy**

# 3. Results in 2050

This section describes the results of the different policies described in Section 1.4 on the indicators described in Section 1.1 in this report for the following 2050 scenarios:

1) BIO2050 (Biomass) - Reference Scenario: District heating based on a biomass CHP and a biomass boiler, and individual supply with various shares of biomass boilers, natural gas boilers and heat pumps
2) Combi2050 (Combination) - District heating based on heat pumps, thermal storage, solar heating and heat-only biomass boilers, as well as individual supply with various shares of biomass boilers, natural gas boilers and heat pumps

The names of the scenarios relate to the technology used for district heating generation in Forsyning Helsingør, so only the competition with other supply options determines what the fuel mix for the individual supply will be in each scenario. In both scenarios, about 33 GWh of district heat generated from waste and natural gas is supplied yearly from the neighbouring Norfors.

## 3.1 Energy demand for heat for implemented scenarios in 2050

**Figure 9** shows the shares of the different supply technologies in each scenario and each policy. Compared to the current situation the total heat demand for each future scenario and each policy is reduced, but not more than in 2030, when all the feasible heat savings are already assumed implemented. The PM tax policy and a tax reduction for heat pumps enables significant heat pump investments in both BIO and Combi scenario, but also increases the supply from individual natural gas boilers. As in 2030, allowing disconnection from district heating results in an increase in individual biomass boilers under the assumption that this is possible in practice.



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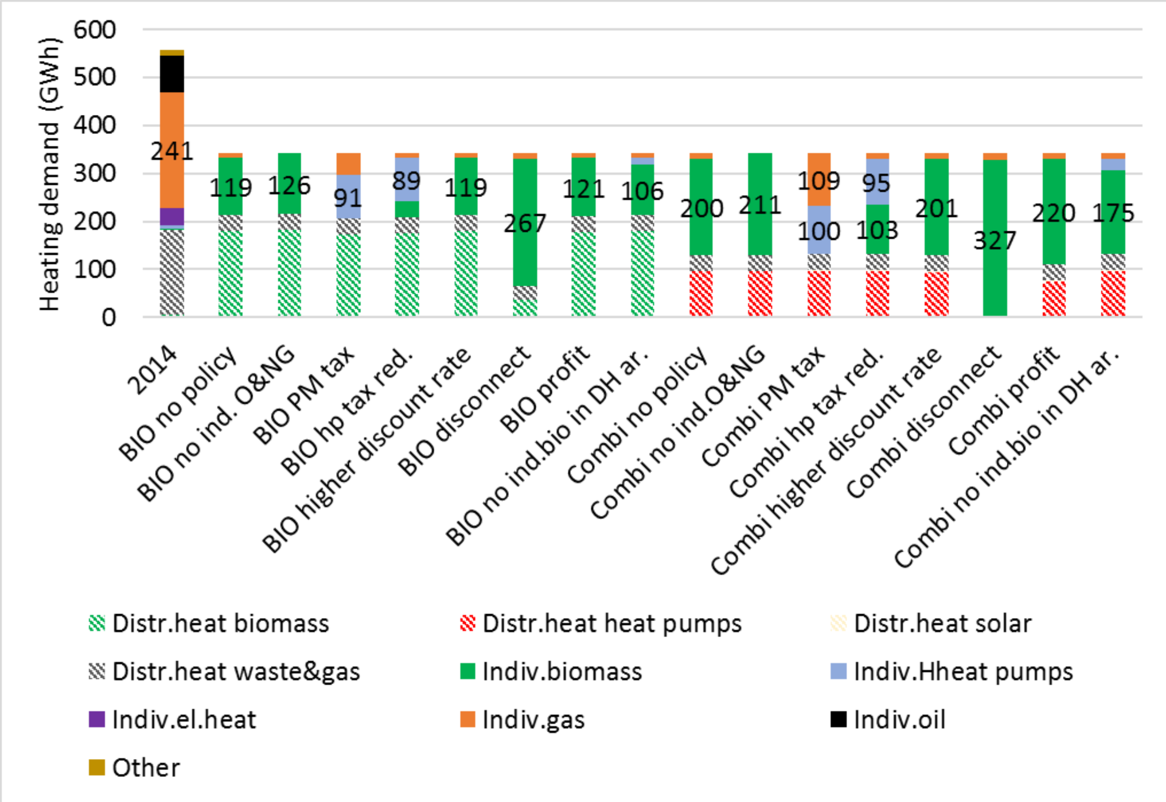


**Figure 9 Comparison of heat demand and technologies for different policies in 2050**

## 3.2 District heating share for implemented scenarios in 2050

**Figure 10** shows the results of the different policies on the share of district heating for each scenario. In the case of BIO scenario, the share of district heating is significantly higher for all policies in 2050 than in 2014 and in 2030 (see Figure 3 for comparison). For the Combi scenario, this share is around 40%, which corresponds with 2030 results in terms of share, but is higher in terms of absolute values (see Figure 9 above). These results are very sensitive to the district heating prices calculated with energyPRO - for the two scenarios without policies the prices vary on average only by about 3%. In most of the cases, the policies do not significantly influence the share of district heating relative to the reference (No policy). However, allowing disconnection from district heating will significantly reduce the share of district heating as in 2030, leading to only 19% DH share in the BIO scenario and no district heating customers in the Combi scenario. As in the results for 2030, the results for 2050 disregard possible practical issues with instalment of individual biomass boilers.



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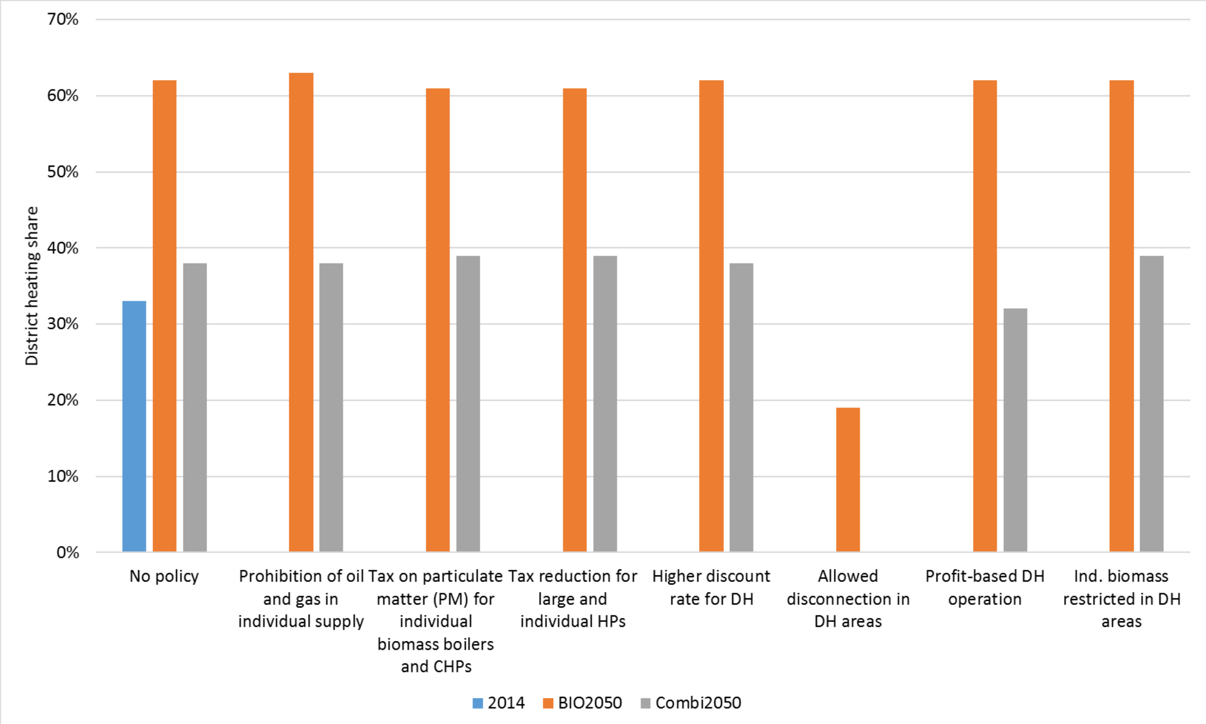


**Figure 10 Share of DH for the different policies in the different scenarios in 2050**

## 3.3 Total and specific $CO_2$ emissions for heat for implemented scenarios in 2050

**Figure 11** shows the results of the different policies on total $CO_2$ emissions for heat for each scenario. Compared to the current situation, the $CO_2$ emissions in the future will decrease up to 97%, due to Forsyning Helsingør switching to biomass (BIO2050) or large heat pumps and solar district heating (Combi). As in 2030, the lowest emissions in the BIO scenario can be achieved, when fossil fuels in the individual supply are forbidden. The lowest emissions in the HP scenario occur, when disconnection from district heating is allowed as in 2030. In this case, the district heating supply produced from (partly non-renewable) waste and natural gas in Norfors is replaced with individual biomass boilers, which are assumed to be $CO_2$-neutral. Introducing a tax on PM can actually cause higher $CO_2$ emissions than the No policy option, because it results in more natural gas boilers installed as was also seen in 2030.



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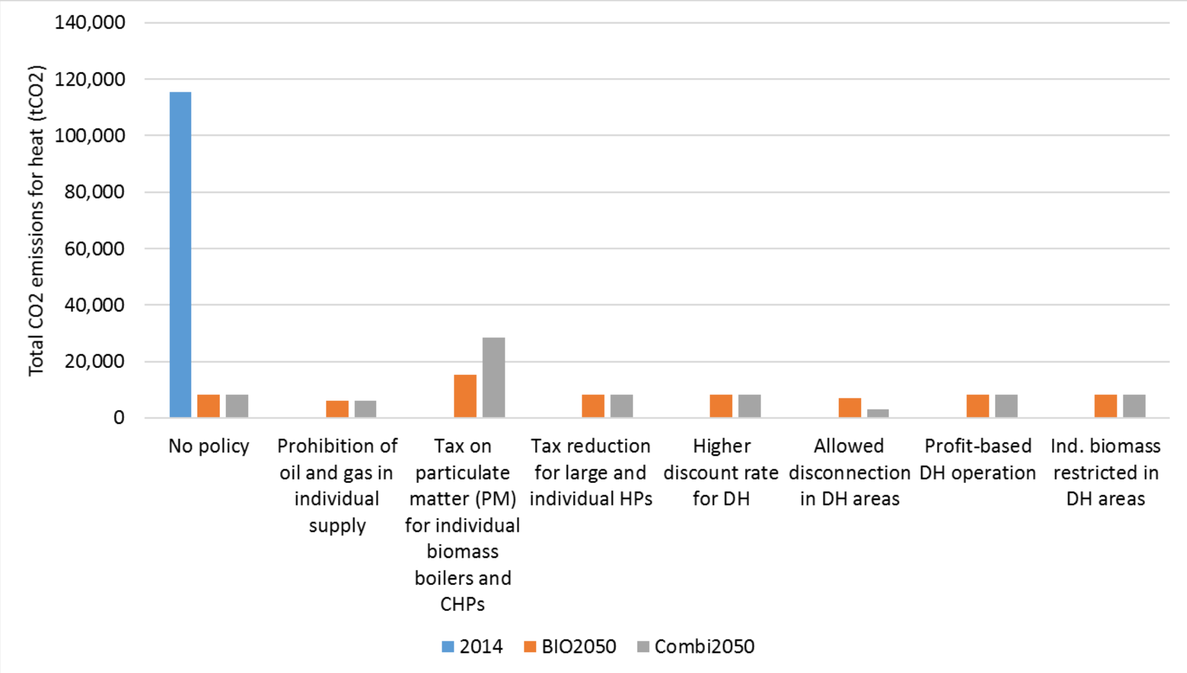


**Figure 11 CO2 emissions for the different policies in the different scenarios in 2050**

**Figure 12** shows the specific $CO_2$-emissions for heat [tCO2/MWh] in the different scenarios for different policies. The specific $CO_2$ emissions show a similar pattern as the total $CO_2$ emissions. Except for the policies of PM tax and DH disconnection, the results are almost identical for both BIO2050 and Combi2050 scenarios. The lowest specific $CO_2$ emissions occur in the case of implementing a policy of allowed disconnection from district heating in the Combi scenario subject to the assumptions discussed above.



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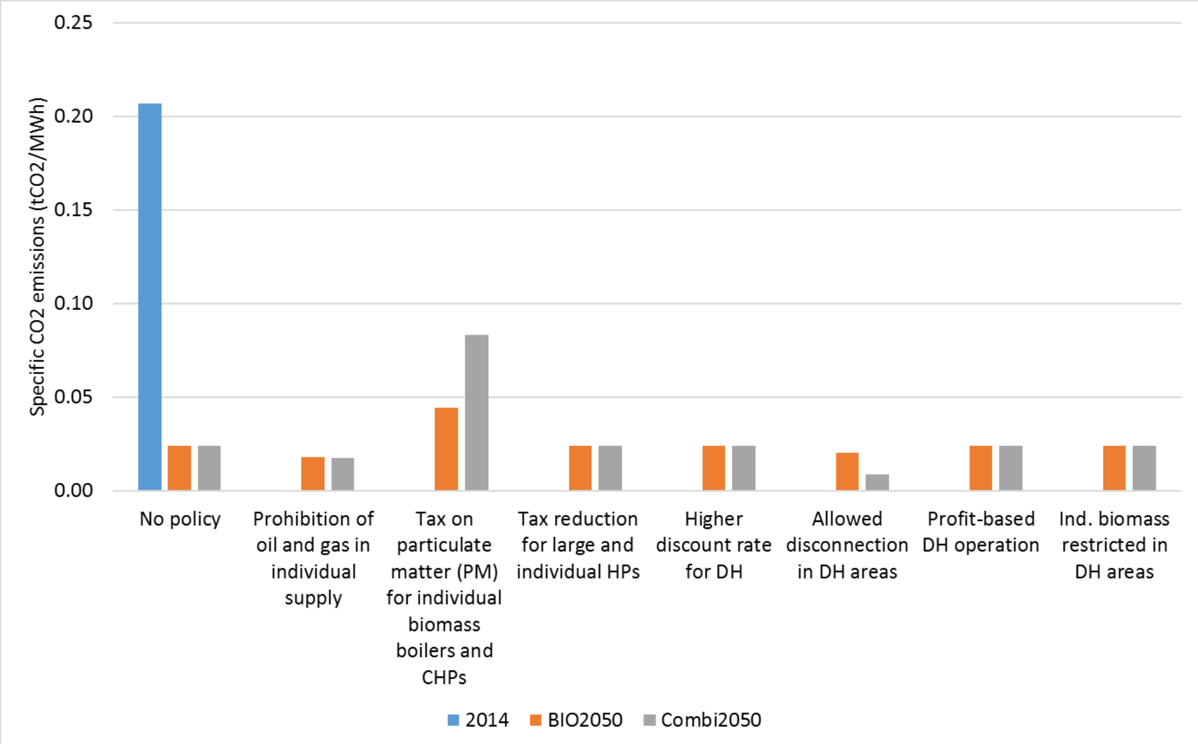


**Figure 12 Specific CO2 emissions [t/WMh] for the different policies in the different scenarios in 2050**

## 3.4 Total and average costs for heat supply and heat savings for implemented scenarios in 2050

**Figure 13** shows the results of the different policies on total costs for heat for each scenario. For details on how costs are calculated, see Appendix A. In all the cases, heating costs decrease in 2050 compared to now and are slightly lower for the BIO scenario, but are quite similar, independently of the policy implemented.

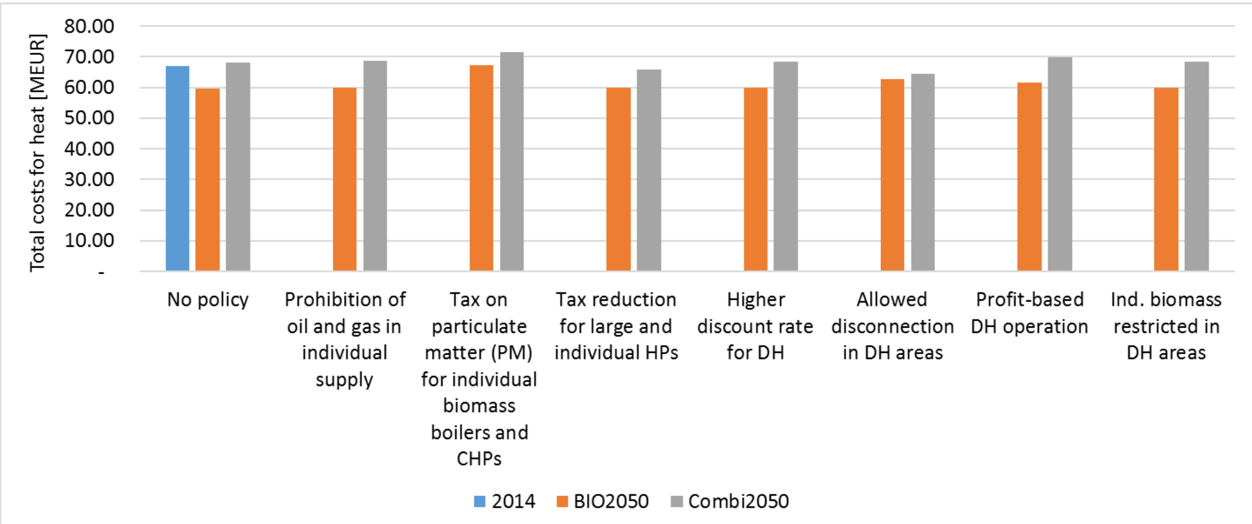


**Figure 13 Total cost for heat [MEUR/year] for the different policies in the different scenarios in 2050**



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Figure 14 shows the results of the different policies on average costs of heat including heat savings for each scenario. While in 2030, the average costs are significantly lower than in 2014, this is not the case in 2050. The reasons for this are higher assumed fuel and electricity costs in 2050 than in 2030.

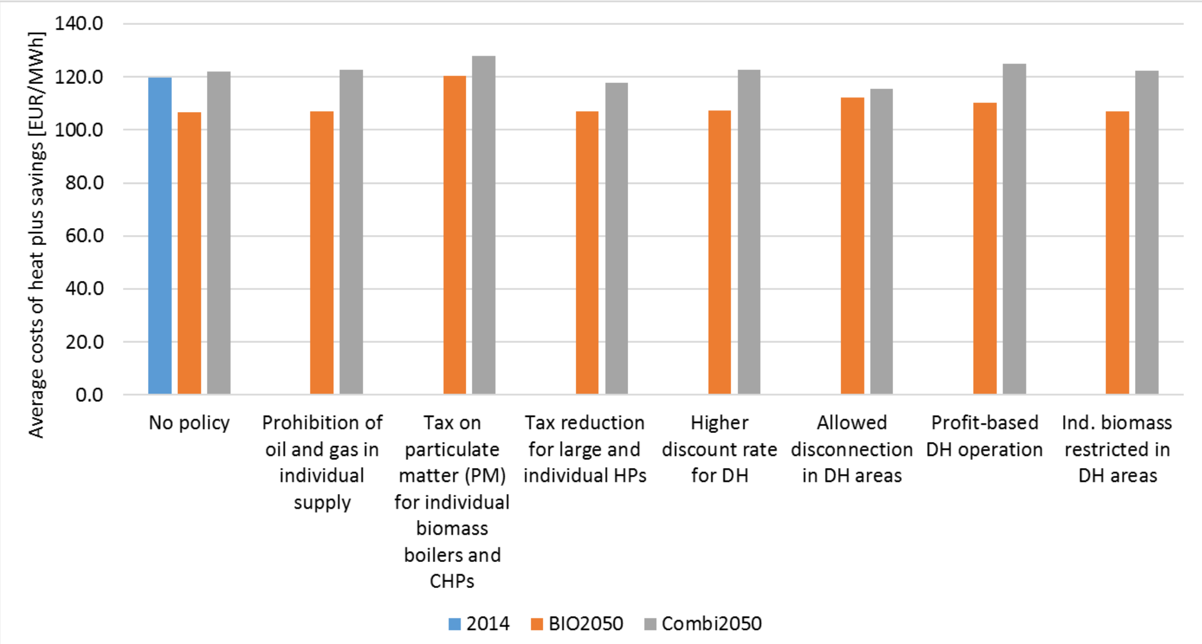


**Figure 14 Average costs for heat plus savings [EUR/MWh] in the different scenarios for different policies in 2030**

## 3.5 Share of renewables (RES) for implemented scenarios in 2050

Figure 15 shows the results of the different policies on the share of renewables for heat for each scenario. The largest share of renewables in the heat supply occurs, when oil and gas are prohibited in the individual supply in the scenario BIO2030 and when disconnection from district heating is allowed in the scenario Combi2030, due to switching to individual biomass boilers. The difference between this policy and the No policy option is also caused by the assumption that part of district heating supply is imported from Norfors area, where waste and natural gas are used. For the No policy option and all the other options, the share of renewables oscillates around 90%, but for PM tax policy, the share is only between 62-81% percent for both scenarios, because of many individual natural gas boilers implemented.



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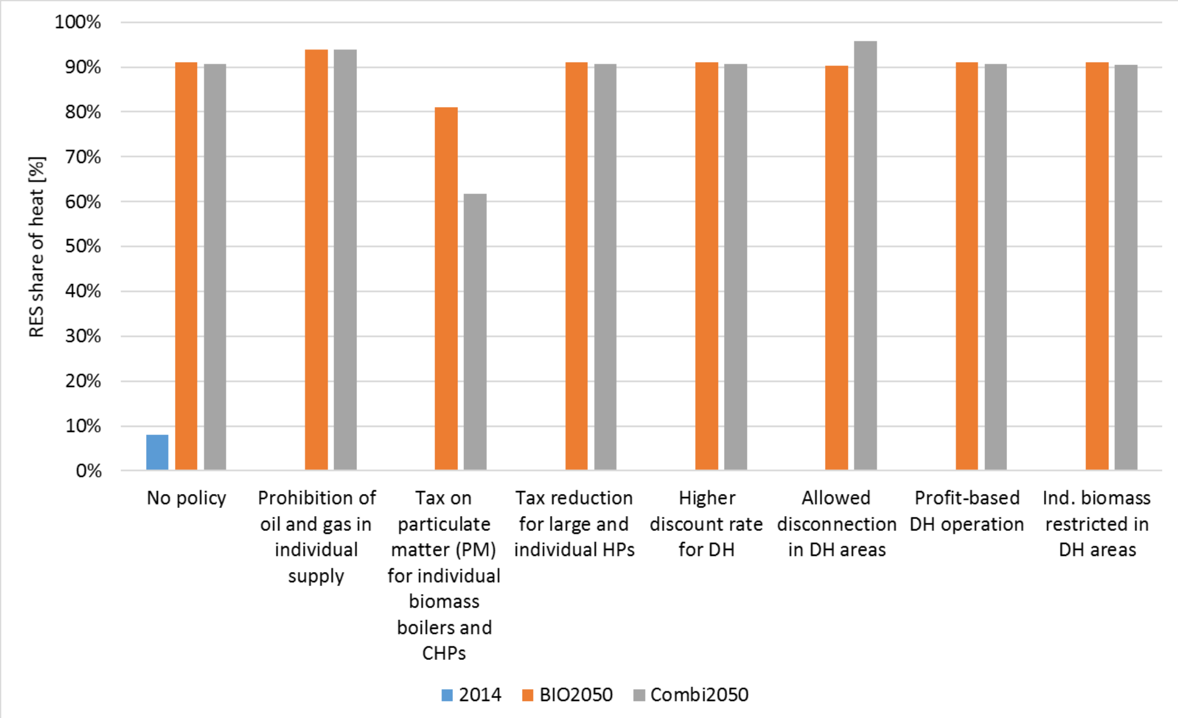


**Figure 15 Share of renewables for the different policies in the different scenarios in 2050**

## 3.6 Difference in total system costs for the different policies for implemented scenarios in 2050

Figure 16 compares the total system costs for the different policies and the different scenarios with the No policy scenarios. The cost of the PM tax policy on the heating supply exceeds the No policy cost the most. Most of the policies are more expensive than No policy, but for the Combi scenario, the tax reduction and allowed disconnection are less expensive.



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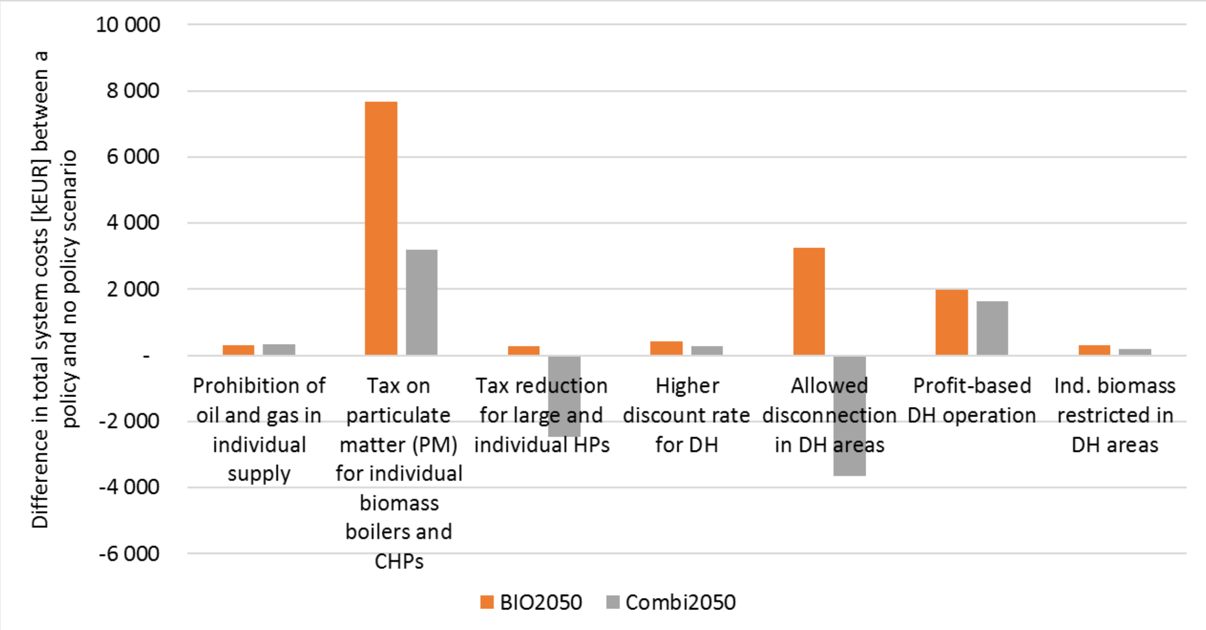


**Figure 16 Difference in total system costs for the different policies for implemented scenarios in 2050**

## 4. Conclusions and policy recommendations

This report aims to provide a quantitative analysis and assessment of policies for renewable heating and district heating for Helsingør municipality for the time horizon until 2030 and 2050. The analysis shows that substantial $CO_2$ emission reductions are achievable through substantial heat savings and through decarbonisation of district heating and individual heat supply through use of mainly biomass or heat pump alternatives. With the existing tax regime, biomass use is favoured.

In 2030, two scenarios were analysed: BIO2030 and HP2030. In 2050, two scenarios were analysed as well: BIO2050 and Combi2050. For each scenario, seven different policies were devised: 1) prohibition of fossil fuels in the individual heat supply, 2) particulate matter (PM) tax on biomass used in individual biomass boilers and CHPs, 3) tax reduction for large and individual heat pumps, 4) higher discount rate for district heating, 5) allowed disconnection from district heating, 6) profit-based operation for district heating companies and 7) restricting individual biomass boilers in district heating areas. These policies were assessed using the following criteria: total useful energy demand for heat, share of district heating, total and specific $CO_2$ emissions for heat, total and average costs of heat supply and heat savings, share of renewables and difference in total system costs for the different policies.

In 2030, about 40% of heat savings are feasible in Helsingør based on the analyses, with the effect of the assessed policies on the share of heat savings being marginal. For 2050, no further heat savings are achieved, as it is assumed that the entire heat saving potential is achieved until 2030. The results take costs of heat savings and competing heat supply options into account. The choice between individual heat supply, district heating supply and heat savings is made solely on the annuitized costs of heat savings and heat supply. The effects of consumers often not acting in a cost-optimal manner,



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lack of cheap financing or rebound effects are not taken into account. In order to achieve the savings in real life, substantial information efforts and reduction of practical barriers may however be required. A strong recommendation from the analyses is therefore for Helsingør municipality to promote heat savings through information campaigns targeting the "lowest hanging fruits" i.e. buildings with high energy demands such as older buildings and/or emitting high shares of CO2 such as buildings supplied with heat from individual oil boilers.

The highest district heating share in the BIO2030 scenario (40%) can be achieved, when a PM tax is implemented or biomass boilers restricted in district heating areas. In the HP2030 scenario, up to 32% of district heating share is feasible - the share would only be lower, if a disconnection from DH is allowed. The highest district heating share in the BIO2050 scenario (63%) can be achieved, when individual oil and natural gas boilers are forbidden. In the Combi2050 scenario, up to 39% of district heating share can occur.

The lowest $CO_2$ emissions in the BIO2030 scenario and the BIO2050 scenarios (6 kt) are achieved, when fossil fuels are prohibited in the individual supply. For HP2030, the lowest $CO_2$ emission levels (5 kt) occur, when disconnection from DH is allowed as emissions from Norfors would be avoided. The same is the case for the Combi2050 scenario achieving CO2 emissions of only 3 kt. These conclusions also hold for the specific $CO_2$ emissions.

The lowest total, as well as average costs in the BIO2030 and HP 2030 scenarios (64.9 and 65.1 EUR/MWh, respectively) occur, when it is possible to disconnect from DH, subject to assumptions on the possibility to shift to individual biomass boilers. Due to fuel and electricity price increases and no further possibility for heat savings, the resulting heating costs in 2050 are for each policy very similar to the costs in 2014. The lowest total, as well as average costs in the BIO2050 scenario occur, when no policy is implemented, while for the Combi2050 scenario - when it is possible to disconnect from DH, again subject to assumptions on the possibility to shift to individual biomass boilers.

Similarly, the highest renewables share for the BIO2030 and HP2030 scenario occur if disconnection is allowed, due to heat supplied primarily with individual biomass boilers. A crucial assumption is that biomass is assumed a $CO_2$-neutral resource and that in all the cases around 24% of district heating supply is imported from Norfors, which is assumed to continue to be produced using municipal waste (partly non-renewable) and natural gas. The highest renewables share for the BIO2050 scenario occur if fossil fuels are forbidden in the heat supply, while for the Combi2050 - when disconnection from partly fossil fuelled district heating is allowed.

Due to the competition between heat savings, individual heating and district heating, changing policies may have undesired environmental consequences. If we disregard the space requirement and cost of biomass storage and chimney maintenance, in all the scenarios except for the PM tax policy, individual biomass boilers will be the dominating heat source in 2030, which would have implications on the local air quality. Introducing a tax on PM may on the other hand cause higher $CO_2$ emissions, because it results in more natural gas boilers installed e.g. than in the No policy scenario. Nonetheless, if we assume biomass boilers will not be installed in district heating areas, it will cause an increase mostly in individual heat pumps and DH supply.



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Use of biomass proves to be economically feasible with the assumed costs, prices and taxes. Four factors do however need to be mentioned regarding this: 1) It is uncertain that the extensive conversion from district heating to individual biomass boilers will be feasible when practical issues are taken into account, 2) externalities from local particle emissions are only taken into account in one scenario, where individual biomass boilers are replaced completely, 3) the price of sustainably grown biomass is highly uncertain towards 2050, where the global biomass demand is expected to increase drastically and 4) the current taxing of biomass and electricity is continuously debated with a certain likelihood of electricity taxes decreasing and biomass taxes increasing. For the abovementioned reasons it may be connected with less risk to choose the heat pump path for the future, rather than the biomass. Future electricity prices are of course also highly uncertain, but combined with heat storages, heat pumps have the possibility of optimising the operation to occur on hours with low prices.

Decreasing district heating costs in Helsingør should be given a high priority - and the step towards switching to biomass is a good solution, enabling a higher share of district heating. However, the results in this report depend on the assumption that future taxation will be identical to the existing. Future changes may e.g. improve the profitability of large-scale heat pumps, which do not use scarce biomass resources. Moreover, the technical improvements of solar thermal plants and thermal storages in the future may also mean, that their costs and efficiencies will drop, improving the business case for HP2030 and Combi2050 scenarios.

Helsingør municipality already has ambitious climate goals and all the scenarios will allow to achieve a substantial reduction in $CO_2$ emissions in the heat sector, with the part supplied from Norfors assumed to continue on waste and natural gas, as the only contributor to the $CO_2$ emissions from district heating and remaining from individual gas boilers. While the disconnection from district heating has some environmental advantages, if Norfors replaces is natural gas units with a renewable source of energy and begins using more renewable fuels in the waste mix, the emissions will drop.

While the policies we analyse are assessed on a municipal level, the decision power for most of them lies primarily at the level of national government.

Summing up, the main recommended actions for Helsingør municipality are:

- Promote heat savings in buildings - particularly in buildings from before 1950 and in multifamily houses
- Promote shift from individual fossil heat supply - especially oil boilers
- Discourage implementation of individual biomass boilers in densely populated areas due to particle emissions
- Ensure cheap, $CO_2$ neutral DH from Forsyning Helsingør
- Advocate shift to fossil free district heating from Norfors - if continued import

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# Appendix A Calculation of indicators

Table A1 explains the indicators used. The following symbols are used:

| | |
|---|---|
| $i$ | Index for building class |
| $j$ | Index for supply technology |
| $d_{T\_ued}$ | Total useful energy demand for space heating and domestic hot water |
| $A_i$ | Floor area (per building class) |
| $HWB_i$ | Specific heating demand (per building class) |
| $CO_2$ | Total amount of $CO_2$ |
| $f_j^{CO2}$ | Specific $CO_2$-emission factor (per supply technology) |
| $f_{T\_CO2}$ | Average $CO_2$-emission factor for heat |
| $\eta_j$ | Efficiency (per supply technology) |
| $d_j$ | Useful energy demand (supplied per technology) |
| $C_T$ | Total system costs of heat supply and heat savings |
| $\Delta C_T$ | Difference in total system costs between different policies |
| $C_A$ | Average cost of heat (after implementation of heat savings) |
| $LCOH_{ij}$ | Levelized cost of heat per building class and supply technology |
| $LCOHS_{ij}$ | Levelized cost of heat savings per building class and supply technology |
| $\Delta d$ | Difference in useful energy demand for SH&DHW before and after renovation |
| $f_{T\_RES}$ | Total share of useful energy demand supplied by renewable technologies |
| $f_{T\_DH}$ | Total share of useful energy demand supplied by DH |
| $f_j^{RES}$ | Renewable factor (per supply technology) |

**Table A1 Indicators used for the policy assessment**

| Indicator | Unit | Description |
|---|---|---|
| Total useful energy demand for heat (space heating and domestic hot water) | MWh | Total useful energy demand for space heating and domestic hot water within the municipality<br>$d_{T\_ued} = \sum_i A_i * HWB_i$ |
| Share of district heating (DH) | % | Share of heat demand supplied by district heating of total heat demand<br>$f_{T\_DH} = \frac{d_{DH}}{d_{T\_ued}}$ |
| Total $CO_2$ emissions for heat | $t_{CO2}$ | Total $CO_2$ emissions for heat supply with district heat and with individual technologies within the municipality<br>$CO_2 = \sum_j f_j^{CO2} * \eta_j * d_j$<br><br>For HP and electric heating the $CO_2$ intensities of the Danish power sector according to the EU reference scenario (European Commission, 2016) is used for 2030=0.09 t of $CO_2$/MWh; for 2050 0 is assumed, due to the Danish government's policy of energy system becoming independent of fossil fuels by then.<br><br>For district heating the specific $CO_2$ emission is calculated for each scenario depending on the produced heat. |



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| | | |
|---|---|---|
| | | $CO_2$ emissions from CHP are allocated according to IEA Method [Fuel for heat = eff_th/eff_total] |
| Average specific $CO_2$ emissions for heat | $t_{CO2}$/ MWh | Average specific $CO_2$ emissions for all heating technologies after implementation of respective savings $f_{T\_CO2} = \frac{CO2}{d_{T\_ued}}$ |
| Share of renewables | % | Share of renewable energy in total useful heat demand: $f_{T\_RES} = \sum_j f_j^{RES} * d_j$ <br>• For renewable share of electricity the share of net power generation from RES according to the EU reference scenario (European Commission, 2016) is used for 2030=71.4%; for 2050=100% due to the Danish government's policy of energy system becoming independent of fossil fuels by then <br>• For renewable share of heat pumps the ambient heat plus the renewable share of power is used <br>• The renewable share of district heating is individually calculated for each scenario <br>• The renewable share of waste in Denmark is assumed at 40%. |
| Total costs of heat supply and heat savings | EUR | Total private economic system costs of heat supply and implemented renovation options. $C_T = \sum_{i\,j} (LCOH_{ij} * d_{ij} + LCOHS_{ij} * \Delta d_{ij})$ <br><br>Calculated by the levelized costs of heat per technology (including annualized investments, operation costs and taxes) multiplied with the heat supplied by the respective technology plus implemented savings multiplied by the costs of the respective saving. |
| Average levelized cost of heat supply and heat savings | EUR/ MWh | Average cost of heat for all supply options and implementation of renovation options. Calculated by dividing the total costs of heat supply and heat savings by the total heat demand before implementing the heat savings. $C_A = \frac{C_T}{d_{T\_ued}}$ |
| Difference in total system costs for the different policies for implemented scenarios in 2030 and 2050 | EUR | Costs for each policy and scenario compared to no policy. $\Delta C_T = \Delta C_T^{\text{no\_policy}} - \Delta C_T^{\text{policy\_x}}$ <br>The difference in costs to implement the respective policy has to be interpreted individually |



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# Appendix B Renovation rates calculated with the Invert/EE-Lab model for Helsingør

| Building Category | construction period | total floor area 2014 | remaining floor area 2030 | total floor area renovated until 2030 | Share of floor area renovated (renovation rate) |
|---|---|---|---|---|---|
| | | [tsd m²] | [tsd m²] | [tsd m²] | [%] |
| SFH | very old | 602.9 | 334.7 | 126.54 | 37.8% |
| SFH | old | 1059.1 | 1001.4 | 551.74 | 55.1% |
| SFH | normal | 528.4 | 526.2 | 121.5 | 23.1% |
| MFH | very old | 367.1 | 200.1 | 80.7 | 40.3% |
| MFH | old | 564.3 | 528.7 | 385.24 | 72.9% |
| MFH | normal | 131.3 | 130.4 | 28.62 | 22.0% |
| PubOffi | very old | 77.8 | 71.0 | 48.16 | 67.9% |
| PubOffi | old | 23.6 | 23.1 | 4.4 | 19.1% |
| PubOffi | normal | 33.6 | 33.1 | 5.2 | 15.7% |
| PrivOffi | very old | 3.9 | 3.6 | 1.12 | 31.1% |
| PrivOffi | old | 6.8 | 6.7 | 1.27 | 19.0% |
| PrivOffi | normal | 8.1 | 8.0 | 1.13 | 14.2% |
| WhoRet | very old | 180.9 | 163.6 | 44.31 | 27.1% |
| WhoRet | old | 80.3 | 78.7 | 68.89 | 87.5% |
| WhoRet | normal | 118.9 | 117.7 | 34.16 | 29.0% |
| HotRest | very old | 48.7 | 45.0 | 23.49 | 52.2% |
| HotRest | old | 13.0 | 12.6 | 11 | 87.4% |
| HotRest | normal | 23.1 | 22.7 | 7.57 | 33.3% |
| Health | very old | 6.7 | 6.1 | 1.88 | 31.1% |
| Health | old | 10.1 | 9.8 | 8.14 | 83.0% |
| Health | normal | 10.1 | 9.9 | 1.03 | 10.4% |
| Educ | very old | 78.8 | 71.1 | 22.25 | 31.3% |
| Educ | old | 94.4 | 91.7 | 73.42 | 80.1% |
| Educ | normal | 92.1 | 90.6 | 28.32 | 31.3% |
| Others | very old | 288.2 | 262.4 | 67.4 | 25.7% |
| Others | old | 134.5 | 132.5 | 93.89 | 70.9% |
| Others | normal | 175.5 | 174.2 | 46.82 | 26.9% |
| All non-residential buildings | very old | 685.1 | 622.7 | 208.6 | 33.5% |
| All non-residential buildings | old | 362.7 | 355.1 | 261.0 | 73.5% |
| All non-residential buildings | normal | 461.4 | 456.2 | 124.2 | 27.2% |



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