NIRAS

Analysis of Balanced District Heating

Viborg District Heating

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Contents

1 Introduction

What are the advantages and disadvantages of utilising heat pumps to take advantage of local surplus heat? This is the question that this report aims to answer by reviewing the opportunities and costs of a modern approach to the future of district heating in the city of Viborg.

The motivation behind the publication of this report is the imminent expiration of a support scheme known as ‘Grundbeløbet’ (or the ‘basic amount’). This is an annual grant supporting the operation of the existing Combined Heat and Power (CHP) plant, that will expire at the end of 2018. This will lead to a substantial rise in heating prices, unless alternatives are found. In addition, the remaining district heating plants in Viborg are based on natural gas, which have high fuel, and hence, heating costs.

These issues make clear the need to explore new technologies and examine different scenarios in order to provide a cheap and environmentally sound district heating supply in the near future.

It is hoped that this report will encourage debate between consumers and local politicians about opportunities in urban planning and organization, and in relation to action-plans to reduce CO2 emissions.

The report has been prepared by NIRAS in cooperation with Viborg District Heating and PlanEnergi. It is an update of a similar report from Spring 2017. The report has been updated in terms of fuels prices, taxes, and new developments in alternative technologies.

Thanks to Viborg District Heating for providing inspiration, facts and data for the report, and thanks also to PlanEnergi for their investigations into heat pump technologies.

2 Summary

The ‘Grundbeløbet’ grant, which expires at the end of 2018, has supported historical investments in natural-gas-powered CHP plants since the electricity market was liberalized and electricity prices fell. This report sets out a series of scenarios for a cheap and environmentally sound district heating supply in Viborg. The scenarios combine a number of technologies and solutions into different models, several of which employ surplus heat from Apple's data centre at Foulum in the eastern part of Viborg Municipality. Other models investigate alternatives to the expected surplus heat from Apple, as there are still uncertainties as to when, in what quantity, and for how long, Apple's heat will be available for use in Viborg's district heating system.

The report reviews a number of common prerequisites for district heating production and distribution in Viborg. This includes fuel prices - both electricity and natural gas - as well as taxes, investments and plant efficiencies. The report then presents a sensitivity analysis, in order to assess which assumptions influence the different scenarios - including electricity price, customer demand, and efficiency - and hence how robust the different scenarios are in terms of the various assumptions.

The next section outlines the practical implementation of selected scenarios, as well as the technologies behind balanced district heating. The sections 'Value Chain' and 'Organization' deal with some of the framework conditions that apply to Viborg District Heating - including organizational structure and staffing.

The average project prices of the scenarios over the 25-year lifetime of the plants, and the resulting socio-economic gains, are then presented. Issues related to the scenarios’ dependence and interaction with Apple's data centre, are analysed and summarized.

The report has also examined the price implications for different scenarios of when Apple's maximum surplus heat becomes available. For the three cheapest scenarios with balanced district heating, the consequence of the expiration of the energy suppliers’ Energy Savings Directorate at the end of 2020 is also considered. This would negate the value of energy savings of the investment in the heat pumps. The consequence of a change to the current political agreement on reduced electricity tax, with a permanent further easing of electricity heating tax, is also examined.

Based on the results of these analyses, the recommended scenario is that of a balanced district heating system in Viborg city, with zoned network temperature divisions; partially lowered temperatures in the city center, and even lower temperatures in the surrounding areas. The

recommended source for this system is urban air-to-water heat pumps.

The strengths of this scenario are; greater security of supply, lower heat-loss in the grid, the lowest consumer price of the analysed scenarios, the best socio-economic solution, the lowest CO2 emissions, and the optimal utilization of urban surplus heat through the use of urban heat pumps .

Alternative scenarios have been weakened by the uncertainty as to when a 25-year binding production agreement with Apple can be expected, when an Apple heat pump plant is expected to be at 100 percent operation, and at what maximum output. Last, and not least, is uncertainty about the progress of the required technological developments, and thus the permanent heat dissipation in the data centre.

The heat demand in the period until a heat pump plant at Apple becomes fully operational, must be covered by natural gas-based district heating, which will mean very high project prices and hence higher consumer costs.

However, this include major investments in a production plant far away from Viborg city.

Conversely, an outdoor-air based heat pump will have a poorer efficiency than a plant based on surplus heat, which makes it more sensitive to increases in electricity prices.

3 Scenarios

Viborg District Heating supplies more than 16,000 households and companies in the city of Viborg and Hald Ege town, with district heating. Viborg District Heating is a distribution company, which means that it purchases hot water from suppliers and delivers it to consumers via 185 km of mains pipeline and 145 km of distribution pipeline at the cheapest possible price. Today, the hot water is sourced from Energi Viborg CHP, which uses natural gas as an energy source.

However, efforts are being made to find new, supplementary energy sources - including surplus heat - that can benefit consumers in the form of cheap and sustainable heating. In order to explore and elucidate the advantages and disadvantages of different solutions and technologies for the of future the district heating supply in Viborg, this report sets out a series of scenarios that deal with economy, environment, security of supply, and so on.

Many solutions in combination

One of the scenarios investigated is that of building a heat pump plant at Apple's upcoming data centre at Foulum, in the eastern part of Viborg Municipality. The heat pump plant would enable the use of surplus heat from the data centre to supply Viborg City with district heating. Variations within this scenario have been investigated, based around current, projected, and balanced temperature sets. A further variation on this scenario involves combining the heat pump plant at Apple's data centre with similar heat pump systems at peak-load stations in Viborg.

A visualisation of the planned Apple data centre in Foulum.

Another main scenario involves establishing an air-to-water heat pump plant in Viborg, as a supplement to some of the above combinations.

Unlike conventional heat pump systems, that are dependent upon surplus heat or the return temperature of the district heating supply, air-to-water heat pumps can be independently cooled using outdoor air. Large-scale air-to-water heat pump solutions are new scenarios, the relevance of which have increased with the fall in the electricity price forecast since last year.

The intakes to the air-to-water heat pump system at Ringkøbing district heating plant.

A third main scenario focuses on investing in solar heaters and pit heat storage, instead of Apple's heat pump plant. This scenario is new, and requires investment in a large plant. Although such a plant can produce 45 percent of the heating needs (with the help of pit heat storage), there is still a need for maximum capacity at other plants - especially in the winter period where the sun is weakest, the storage capacity is exhausted, and the heat demand is greatest.

Further explanations and figures for the distribution of heat production and storage capacity throughout the year can be found within the full report.

In order to calculate and assess the pros and cons of the different scenarios, a number of fundamental variables are considered, such as fluctuating energy prices. These variables have an influence upon the various technical solutions and combinations of technologies, and therefore the final heat prices that consumers will pay. This is examined in the following section.

Dronninglund district heating plant, with solar array, and pit heat storage.

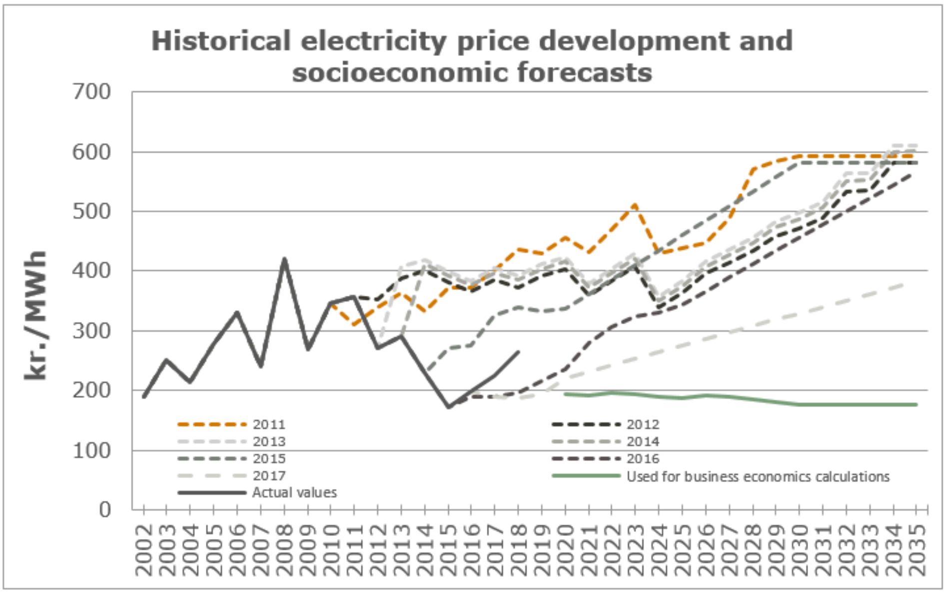
4 Presuppositions

This new version of the previous report (NIRAS, 2017) includes an update of the assumptions upon which calculations are based. Those of particular note include; current electricity and natural gas prices, the latest estimates of expected price developments and taxes, plus investment costs and system efficiencies for the various scenarios.

Fuel Prices

Of particular significance is the trend in electricity prices, which differ significantly from last year. The illustration below charts the historical electricity prices as well as the annual economic forecasts of electricity price developments. The new figures, adjusted to include the 2017 prices, now indicate that an expected increase in electricity prices over the next 20 years should be adjusted down. In the previous report, the expectation was a price increase from 175 Danish kroner per MWh to almost 600 kroner. Now a smaller increase is expected; from 200 kroner per MWh to almost 400 kroner over the next 20 years.

Electricity price fluctuations and predictions.



It's not easy to predict the trend in electricity prices. The figure shows how forecasts since 2011 have repeatedly estimated that prices would rise in the future - but this has not come to pass. The black line is the actual development, while the dotted lines are the forecasts.

The above figure uses actual electricity prices to determine the electricity price forecast as far as is possible. For the operating and consumer cost calculations, the Nasdaq Stock Exchange's electricity prices for long-term contracts for the period 2018-2026 were used. In the period 2027-

2035, Dansk Energi's forward electricity price scenario (published March 2018) was used. Only after then has the forecast been based upon the Danish Energy Authority's socio-economic electricity price scenario. For actual figures, refer to the full report.

For further details about the sensitivities and assumptions, see the full report.

The downward adjustment of electricity prices means that the air-to-water heat pump scenario has been included in the report as a new, interesting alternative.

In addition, the natural-gas price is updated with 2018 prices and the Danish Energy Agency's latest socio-economic forecast for gas price developments, published August 2017. From this it appears that the natural gas price has risen slightly since the previous report. Changes in the natural-gas price are so small that they are irrelevant to the report's results compared with last year.

Energy-savings agreement ends in 2020.

Taxes

The taxes that are relevant to the various scenarios for Viborg's future district heating supply have been updated. Focus has been placed on the taxes on electric heating which, by political consensus, will be partially reduced in 2018 and 2020, but slightly increased again in 2021.

In addition, it should be noted that the government's latest energy policy proposal includes a permanent tax reduction after 2021. The sensitivity of electricity prices to this effect is highlighted in the report.

A further downgrade of the electricity price by a permanent tax reduction after 2021 will mean that all heat pump scenario projections become even cheaper, with the greatest effect for the air-to-water heat pump. Compared to heat pumps on surplus heat, air-to-water heat pumps have a lower efficiency and higher power consumption, and are therefore influenced to a greater degree by reduced electricity prices.

Scenarios include an optimized mix between the different production methods, maximizing the effects of production output, technologies, and their phase-in. Also considered are investment costs, system efficiency, and operating and maintenance costs.

Investments

This section outlines the total investments and expected energy savings for each scenario. The energy savings are a result of both the reduced heat loss in the supply pipelines, which is achieved by a reduction in the temperature set, and the reduced fuel consumption, which results from the shift from low-efficiency natural gas boilers to large, high-efficiency electric heat pumps.

Excluding Viborg's current district heating supply, the lowest investment scenario is that of the air-to-water heat pumps placed in Viborg. Apple's heat pump solution costs close to double, and the solution with heat pumps in Viborg combined with solar heating costs close to 4 times as much as the cheapest.

Investments in the different scenarios

Scenario	Price before energy savings. Mil. kr.	Value of energy savings. Mil. kr.	Total investment Mil. kr.
Viborg's current district heating supply (natural gas co-generation)	29	0	29
Heat pump at Apple (current temperature set)	345	-71	274
Heat pump at Apple (pre-set temperature set)	377	-74	303
Heat-pump at Apple and peak-load boilers in Viborg (balanced temperature set)	432	-75	357
Air-to-water heat pump (pre-set temperature set)	271	-64	207
Air-to-water heat pump and peak-load boilers in Viborg (balanced temperature set)	276	-63	213
Half-sized heat pump plant at Viborg and heat pump at Apple	403	-71	332
Half-sized heat pump plant in Viborg and 45 % solar heating + pit heat storage	815	-35	780

It should be mentioned here that energy companies' Energy-savings Directive is expected to be closed by the end of 2020, and scenarios implemented after this date cannot be subsidized.

Other assumptions
- see the journal report.

Efficiencies

System efficiencies have been calculated for the different scenarios. The scenarios with heat pump systems that use surplus heat or the returned heat in the district heating network have the highest efficiency levels.

Scenarios with air-to-water heat pumps have lower system efficiencies. In both cases, however, the efficiency levels are significantly higher than for existing natural gas boilers. Of course, the different scenarios exhibit varying sensitivities with regard to, for example, electricity prices.

5 Implementation

in addition to the establishment of the central production facilities, the two scenarios that use balanced temperature sets; 'Apple's heat pump and peak-load boilers in Viborg' as well as 'Air-to-water heat pump and peak-load boilers in Viborg', can implement the following measures in Viborg city:

1. Division of the district heating distribution net into zones with temperature sets of 60/35 and 55/30

2. Local heat pump plants at the four peak-load boiler locations

3. Local mini-heat pump plants (or alternative facilities) for the control of Legionella bacteria at major single consumers (90 properties in Viborg city).

4. Within housing blocks, a modification of the connection between the transmission network and the central heating plant from indirect (with the heat-exchange station) to direct, with operation at the associated temperature sets.

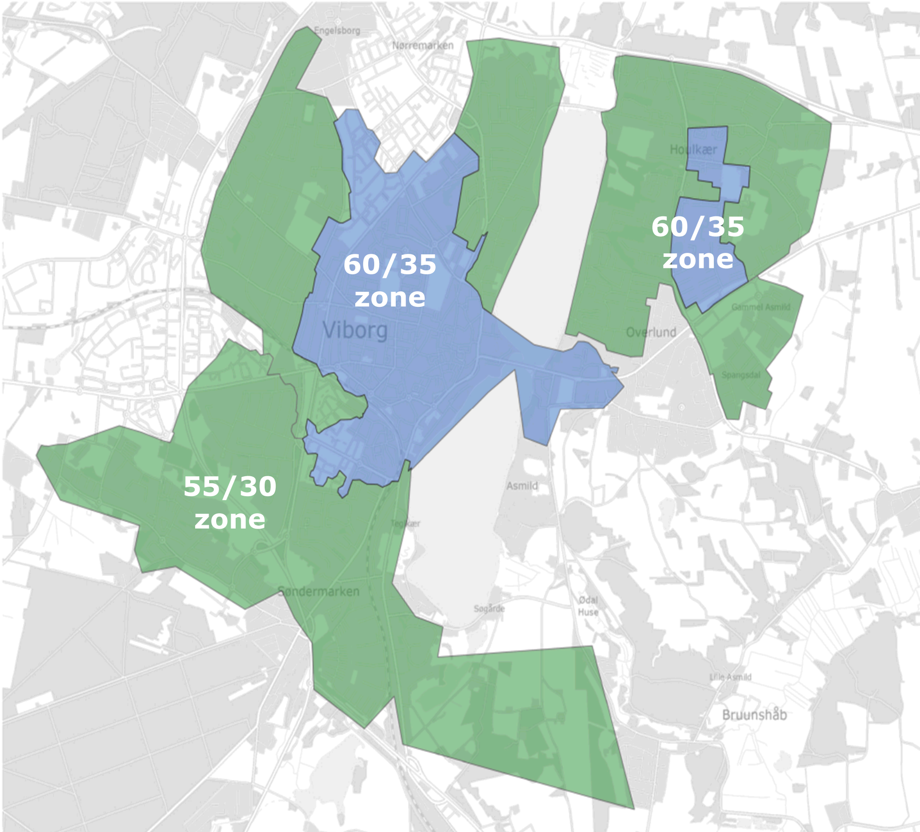
5. The necessary changes to the urban transmission network.

6. The necessary changes to the distribution network, pumps and flow meters, in a single subzone.

7. Replacement of end-user installations for managing the balanced district heating temperature set. A lease agreement will be made in order to minimize consumer investment.

8. Improved advice on energy use, focusing on the return temperature from individual consumers.

Zoning of Viborg's district heating network



The figure above illustrates the zone divisions.

6 Installations and Technologies

The temperatures in the district heating network are fundamental to heat losses in the transmission network, distribution network, heat exchangers, and consumer installations. The higher the temperatures, both out-flow and return, the greater the heat loss. By reducing the temperatures, heat loss can be reduced. This reduces the heat production requirements, and saves fuel. In addition, the efficiency of heat pumps for heat production is significantly increased at lower temperature sets. So, the lower the temperatures, the cheaper the heating costs.

Scenarios using balanced temperature sets presuppose that the temperature of district heating water is lowered from the present 60-65 degrees to 55 degrees in most places. It is also assumed that decentralized heat pumps at the existing peak-load plants at Hamlen, Gyldenrisvej, Farvervej and Industrivej raise the district heating to the required temperatures, based on a baseline temperature in the main transmission line of 50 degrees.

In addition, smaller heat pump plants or other means of water treatment should be installed at larger consumers – e.g. housing blocks.

New consumer installations

Overall, 2/3 of the 9,000 households (about 6,000 households) must change their household technical installations – the so-called 'fjernvarmevekslere' ('household heat exchangers') - to a new and updated version that can handle the lower temperatures whilst ensuring an efficient utilization of district heating water. The replacement will take place over a number of years, and the system will be such that consumers can rent the equipment from Viborg District Heating rather than purchasing it outright.

Centrally-heated Housing Blocks

In addition to individual consumer installations, there exists several housing blocks, owned by local housing associations. These are currently supplied via a transmission network powered by a CHP plant run by Energi Viborg, which also supplies Viborg District Heating. This means that these centrally heated housing blocks are dimensioned for higher incoming district heating temperatures than are necessary for the city as a whole. It is therefore recommended that the centrally heated housing blocks be supplied directly from Viborg District Heating's local district heating distribution network, which can provide the necessary heat from the distribution network without necessarily having to raise the rest of the city to the same high temperature.

Viborg District Heating has, over the years, been working extensively with the distribution network temperatures. Between 2002 and 2017 they achieved a reduction in out-flow temperature from 75-85 degrees to 63-70 degrees. The limiting factor in making a further reduction to 55-60 degrees is the issue of the centrally heated housing blocks.

Lower Return Temperature

It has been possible to lower the return temperature from 47-54 degrees in 2002 to 38-43 degrees in 2017. To make a further reduction to around 30 degrees return temperature, the current consumer installations required particular attention. Replacing 2/3 of the old household heat exchangers to new heat exchangers will ensure that the return temperature is significantly lowered. Also needed are increased efforts in advising customers on energy use, to ensure that the required return temperatures can be achieved.

New user installations

7 Value Chain

Earlier reports on the future energy supply in Viborg have focused on either production or distribution, corresponding to the two-part organizational structure that has been in Viborg since 1996, when Energi Viborg CHP took over heat production from Viborg District Heating in the wake of the establishment of the CHP plant.

This report has looked at the entire value chain from fuel to consumer, as illustrated in the figure below, and highlights where new technology means that it is no longer appropriate for the division of production and distribution, as has been the case for the last 20 year

Combined organisation

The entire value chain incl. air-to-water heat pump in Viborg and peak load centers

55 MW of air-to-water heat pumps are installed as they provide a cheaper project price than, for example, 45 MW. This is due to, among other things, a lower natural gas consumption at 55 MW compared to 45 MW.

Urban heat pump systems are put to work. This proves to be the solution with the cheapest project price, partly because of the advantages of easy connection to future urban surplus heat, etc.

Only a few necessary changes are made to the existing urban transmission network.

The natural gas boilers at the peak load centers are maintained, but only for production at the absolute peak load, which, with the scenarios fully developed, is actually only a few hours a year.

The city is divided into zones. This is done in part to raise the temperatures only as desired in the different zones, and partly to minimize transmission losses.

The housing-block central-heating plants will be closed down and direct supply will be established. This is partly to minimize heat loss in the building blocks' heat exchangers, partly to minimize transmission losses and partly to achieve overall optimization to enable a lower temperature set in the city as a whole.

With the use of localized boilers, water temperatures of large users is raised in the green zones. This is to eliminate the risk of Legionella bacteria, whilst allowing the implementation of a lower temperature set.

A priority is placed on efforts to replace consumer installations using a rental model. This is mainly to ensure a low return temperature is achieved when the in-flow temperature is lowered.

There are obvious benefits to an organization of a merger of production and distribution. Firstly, it ensures investments are more cost effective. Secondly, there are some management conditions that change by going from a production-driven system as before, to a consumer-controlled system, as in the case of balanced district heating. Furthermore, there are significant rationalization gains in terms of the fixed capacity costs of a merger.

The savings on aggregation (scenario: "Apple's heat pump with projected temperature set" compared with the scenario with balanced district heating including heat pumps at the peak-load centers, etc.) is 8 million Danish kroner per year equivalent to 200 million kroner over 25 years.

The distribution of fixed operating costs is assumed to be made to Energi Viborg CHP, and can be reduced after the decommissioning of, for instance, the CHP plant. It should also be noted that heat pumps need significantly fewer personnel than are required at the CHP plant.

Operating budget before and after merger

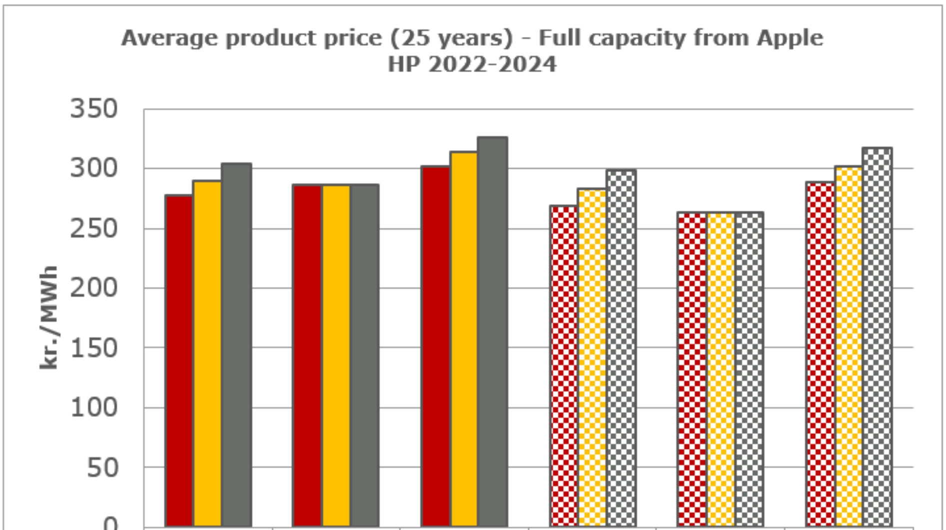
Operating budget	Prior to merger - CHP plant [mil. kr./yr]	After merger – combined contribution [mil. kr./yr]
Management/leadership	4,0	1,9
Operation and op. staff	8,0	3,7
Administration	3,0	1,4
Total	15	7

Where total staff is expected to be reduced from 25 employees (Energi Viborg CHP + Viborg District Heating) to 19 in the overall organization.

8 Economic results – heat prices

The results of the above-mentioned analyses are shown in the figure below, indicating average project prices with full capacity (55 MW) from the Apple heat pump plant in and with full capacity in 2022, 2023 and 2024.

Project prices with approved electrical heating tax and with permanently reduced electrical heating tax



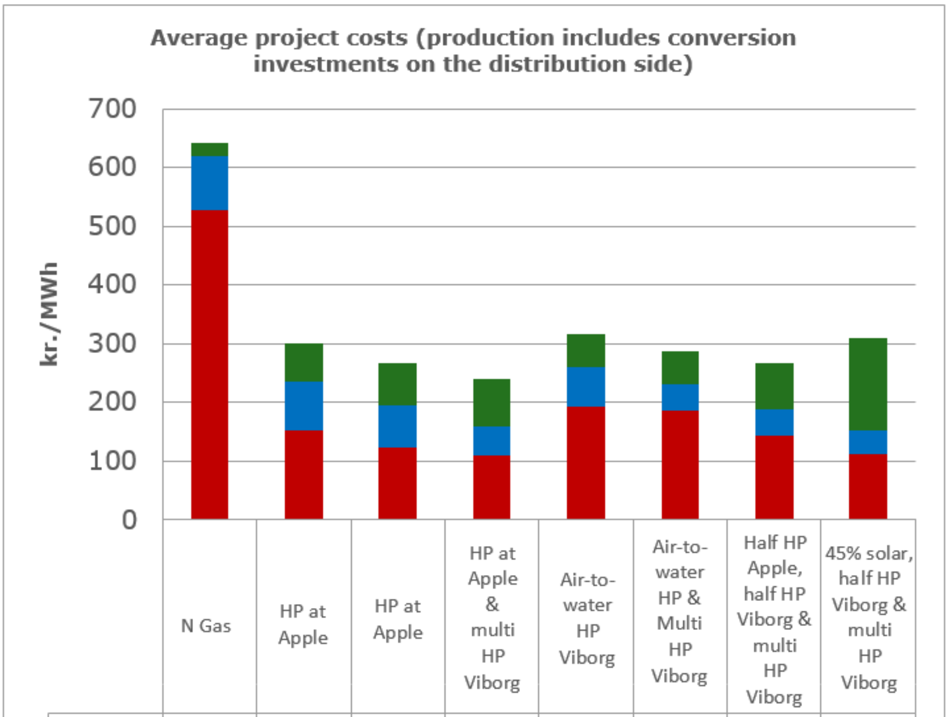
	HP Apple & multi HP Viborg Approved electricity taxes	Air-to-water HP & multi HP Viborg Approved electricity taxes	Half HP Apple, half HP Viborg & multi HP Viborg Approved electricity taxes	HP Apple & multi HP Viborg Permanently reduced electricity taxes	Air-to-water HP & multi HP Viborg Permanently reduced electricity taxes	Half HP Apple, half HP Viborg & multi HP Viborg Permanently reduced electricity taxes
2022	277	286	302	269	264	289
2023	290	286	313	283	264	302
2024	304	286	326	298	264	317

The above figure illustrates that the scenario of 'Air-to-Water heat pump with Viborg peak-load boilers (balanced temperature set)' will be a competitive solution if the Apple heat pump plant has full capacity (55 MW) after 2023, and if considering the approved electricity taxes. A similar calculation - but with a permanent reduction of the electricity heating tax after 2021, as proposed by the government in their April 2018 energy policy initiative, or correspondingly reduced electricity prices in the market as forecast, means that 'Air-to-water heat pump and peak-load stations in Viborg (balanced temperature set)' is competitive even if Apple's heat pump plant is in full operation in 2022.

Aside from the above projections, all analyses in this report are made on the assumption that all scenarios can be in full operation by 2020. This was done to determine the energy efficiency of the different scenarios over the 25-year technical lifetime of the installations. In the figure below are the financial results for the different scenarios displayed as the average project price of district heating over the entire lifetime of the plant.

The figure below also shows that the cheapest three scenarios are the 'Apple heat pumps (projected temperature set)', 'Apple heat pump and Viborg peak-load centres (balanced temperature set)', and 'Air-to-water heat pump and peak-load centres in Viborg (balanced temperature set)'. It should be mentioned that, depending on when Apple's heat pump plant is at full capacity, the last scenario - with 'Air-to-water combined with the peak-load centres in Viborg' - becomes relatively cheaper compared to the Apple solution, as this is not dependent of an agreement with Apple.

This assumes that all facilities are established and commissioned by 2020, which is unrealistic for the scenarios that contain heat pump systems at Apple.

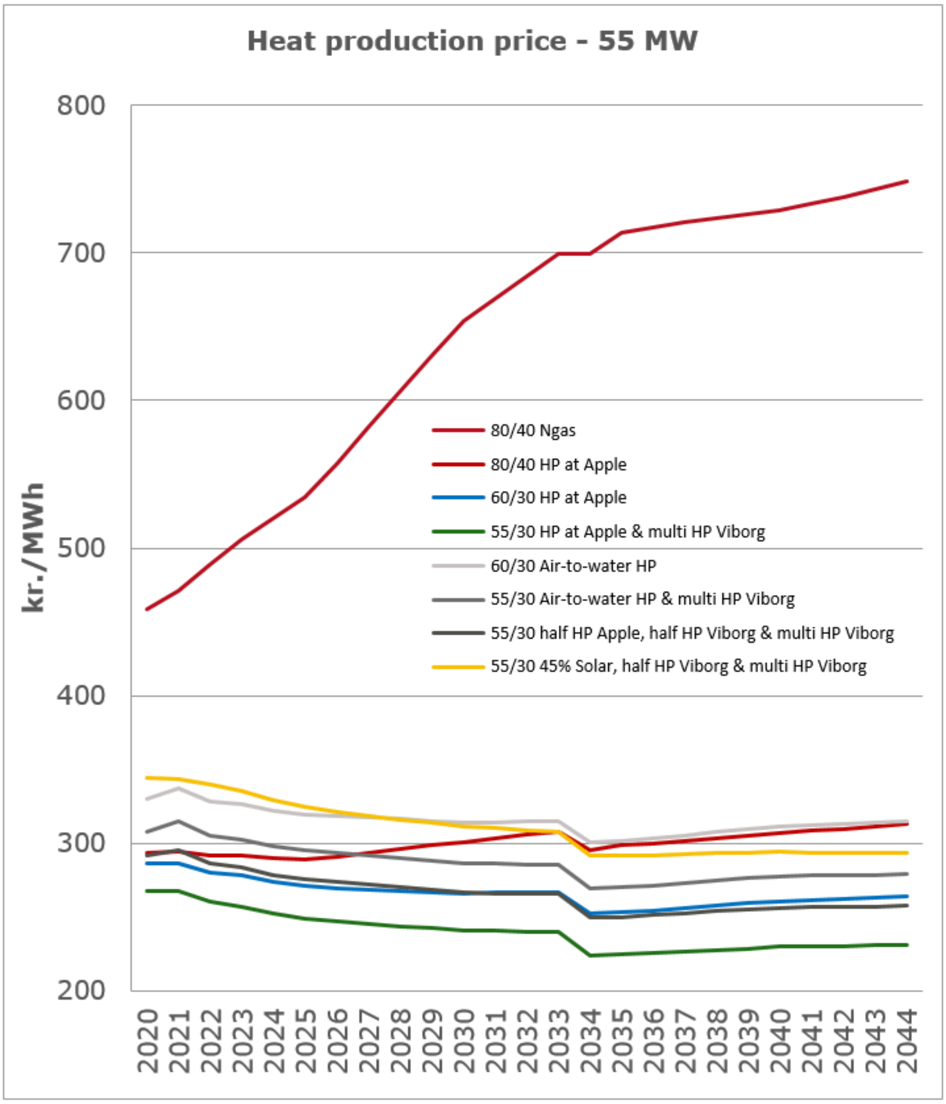


	N Gas	HP at Apple	HP at Apple	HP at Apple & multi HP Viborg	Air-to-water HP Viborg	Air-to-water HP & Multi HP Viborg	Half HP Apple, half HP Viborg & multi HP Viborg	45% solar, half HP Viborg & multi HP Viborg
Depr.	23	65	71	82	55	56	77	158
O&M	93	82	73	50	68	44	46	41
Fuel	526	153	122	108	192	186	143	111
Total	642	300	266	240	315	286	266	310

Price forecasts are provided in the figure below. It is clearly illustrated that the cost of Viborg District Heating's current solution is set to rise dramatically, due mainly to the forecasted increase in natural-gas prices.

The scenario that applies to a 'heat pump at Apple (current temperature set)' also increases slightly in price. This is due to the continued need to raise the temperature to the current temperature set using natural gas boilers. The scenario of a 'half-size heat pump plant in Viborg and 45 percent solar heat + pit heat storage' has a slight fall in prices, which is due to the fact that the "fuel" in the case of solar heating is free, while there is still the need for additional production and full capacity for other fuels. Other scenarios have a steady price development.

Forecast for project price developments



However, as mentioned above, these price developments should be revised as soon as the sources, in particular Apple's excess heat, become available. Therefore they cannot be regarded as pricing examples that can be chosen from immediately.

9 Socio-economics and Environment

Below we look at the results of the socio-economic calculations for the cheapest scenarios and compare them with Viborg District Heating's current solution for a period of 20 years. The socio-economic surplus for the three cheapest scenarios are almost the same, ranging from DKK 2.9 to 3.1 billion, although the scenario 'Air-to-water heat pump and peak-load centres in Viborg (balanced temperature set)' is the lowest of the three.

However, the two other scenarios that are based upon the construction of a heat pump plant at Apple, will need natural gas production to cover the heat demand until such a facility is fully operational. This means that the socio-economic benefits will be inferior to the scenario with 'Air-to-water heat pump and peak-load stations in Viborg (balanced temperature set)'.

A similar result is found in regards to CO_2 emissions, if the scenarios are established at the same time. They provide largely the same climate-savings, compared with the reference figure of approx. 1.1 million tonnes of CO_2 over 20 years. However, if the Apple heat pump plant is first established in 2022 or later, the CO_2 emissions from the Apple-based heat pump scenarios will be significantly higher than that of the 'Air-to-water heat pump and Viborg peak-load centres (balanced temperature set)' scenario, which can be established quickly and independently of an agreement with Apple. This is mostly due to the fact that heat will continue to be produced from natural gas, with a large CO_2 emission, until a plant at Apple is fully operational.

10 Consumer Perspective

When considering the consumer perspective, particular focus is placed upon the practical implications for the consumer, security of supply, environmental conditions, and the consumer cost.

Changes for individual consumers are minimal, and consist only of replacing the consumer installation with a newer and more modern household heat exchanger that can handle the lower temperatures, and is more energy efficient. The new household heat exchanger is the same size as the old one. Viborg District Heating offers a rental programme, so consumers do not have to invest in equipment, and the rental cost is matched by the cheaper heating cost over the 20 year rental period. Particular attention is placed on the return temperature and heat utilization of the individual consumers, which contributes to reducing the overall temperature set in the pipeline, reducing heat losses and lowering prices.

The supply security, in terms of available thermal capacity from the individual production units, is unchanged. Even when the CHP is shut down and if the central heat pump plant should be out of service, there is sufficient capacity at the other peak-load stations, including local heat pumps, for supplying consumers in a peak-load situation (a cold Winter day).

In addition, consideration is given to the supply source of production facilities. Current heat production is based solely on natural gas. The heat pump solutions are partly supplied by the natural gas boilers at the peak-load stations, and partly by the electricity consumption of the heat pumps run from either excess heat or outdoor air. Whilst there may be uncertainties associated with the supply security of surplus heat, systems utilizing outdoor air have a secure source. The greatest supply security, in respect to production facility supply, is thus achieved by the scenario 'Air-to-Water heat pump and peak-load stations in Viborg (balanced temperature set)'.

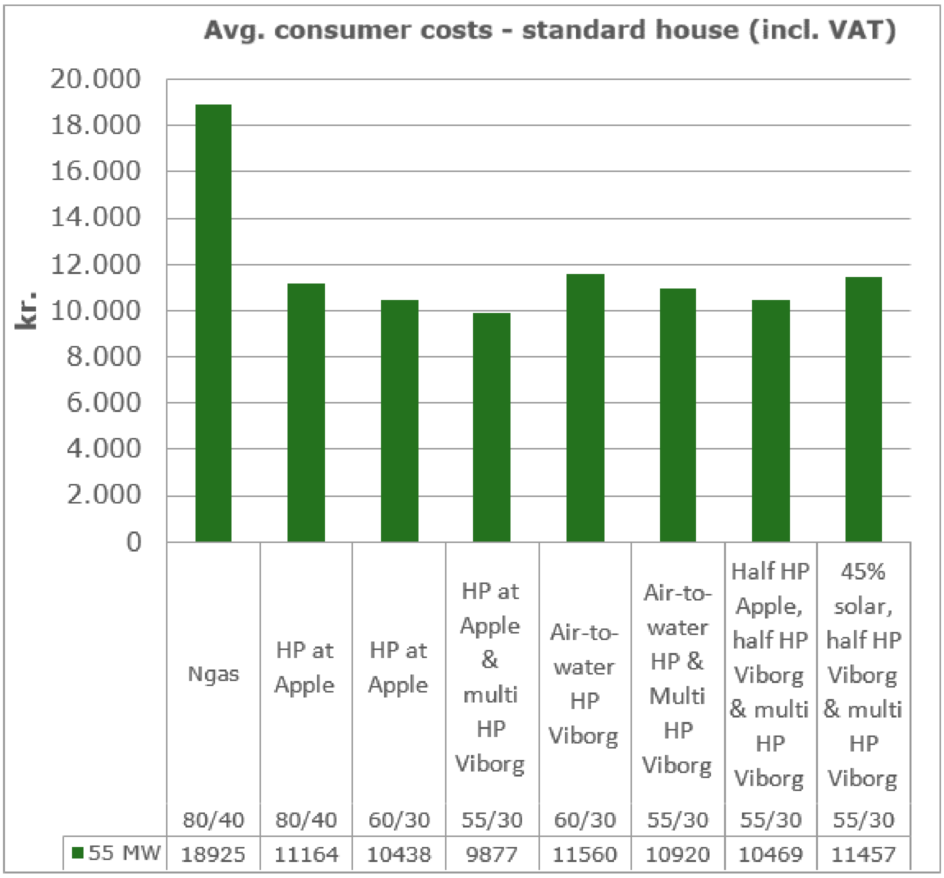
No electrical backup is available for existing installations or in the scenarios considered. That means that if parts, or all of the city lost power, district heating production will also stop. Electricity is required for pumps, control systems, and production plants, including heat pumps. There is no security of electrical supply in any of the scenarios, just as is the case today.

In environmentally terms, a shift from low-efficiency natural gas boiler plants, to electrically-powered, high-efficiency heat pumps, generates the largest reduction in CO2 emissions. The longer it takes for Apple's heat pump plant to become fully operational, the longer the time that the natural gas boilers will be operational, which results in significant CO2 emissions compared with the 'Air-to-Water heat pump and Viborg peak-load stations (balanced temperature set)', which can be established quickly and independently of excess heat from Apple.

The final point regarding the consumer perspective, is economy. The average consumer price with regard to project efficiency (assuming an increase overall efficiency in the distribution network to 90 per cent), administrative costs, fixed costs and meter rental, is shown in the figure below. This is based upon a standard house of 130 m^2, and with a consumption of 18.1 MWh / year.

It is clear from the figure that the scenarios 'Apple's heat pump (projected temperature set)' and 'Apple's heat pump and Viborg peak-load centers (balanced temperature set)' are the cheapest solutions based on consumer costs. They are also the 2 solutions with the biggest savings for the consumer compared with the current plant and temperature set. Consideration is also given to when Apple's plant is expected to be fully operational. If this is first after 2022, the scenario 'Air-to-Water heat pump and peak-load centers in Viborg (balanced temperature set)' is the cheapest solution.

Consumer costs for a standard house



For comparison, all installations are assumed to be established and in full operation by 2020, which is unrealistic for scenarios with heat pump plants at Apple.

11 Conclusion

The strengths of a balanced temperature set include an improved supply security, which is a result of the increased capacity supplied by the peak-load stations with heat pumps. In addition, low heat losses in the pipeline network are a result of the fact that the temperature set has been reduced significantly from their present values. In addition, when the solution is based on surplus heat or outside air as an energy source, the balanced temperature set also contributes to the lowest consumer price and the best socio-economic solution, as natural gas consumption is reduced to a minimum. In addition, the scenario gives the lowest CO2 emissions, as emissions from natural gas combustion are minimized, as well as optimizing the potential utilization of urban excess heat using the urban heat pump systems.

The weaknesses of the scenario involving the ‘Apple heat pump and Viborg peak-load centres (balanced temperature set)’ are the uncertainty as to when a 25-year, binding production agreement with Apple can be expected. There is also uncertainty as to when a major Apple heat pump plant can be expected to be 100 percent operational. In addition, there are large investments in a production plant located 10 km from Viborg. These issues are highlighted in the sensitivity analysis and risk assessment.

The surplus heat from Apple's data centre cannot realistically become available until 2022, or later. Therefore, the solution with Apple's surplus heat becomes a more expensive solution than that of utilizing heat energy from the outside air of an air-to-water heat pump plant in Viborg.

In the scenarios presented here, that of the 'Air-to-water heat pump and peak-load stations in Viborg (balanced temperature set)', with a capital investment of 212 million Danish kroner, can be implemented faster and significantly cheaper than an Apple solution that will cost at least 274 mill. kroner; not least because of the significant investment in a transmission line out to Foulum. Also, the average project price and customer cost will be cheaper for this scenario, compared to the scenario of ‘Apple's heat pump and Viborg peak-load (balanced temperature set)’, with the expectation that Apple's heat pump plant will not be operational until 2022 or later. This is despite the fact that the overall system efficiency of the scenario without the Apple solution is lower than that with the Apple solution.

In both cases, the urban overcapacity of heat pumps at the peak-load centres could be used partly for security of supply, and partly for the utilization of urban surplus heat.

12 Recommendations

The recommended scenario is that of 'Air-to-water heat pump and peak power stations in Viborg'. Additional recommendations are as follows:

- Balanced district heating (with the city's supply network divided into two zones)
- Heat pump installations at peak load centers (with cooling by return district heating supply and/or outdoor air)
- Urban production (for maximum security of supply)
- One overall organization (merging of production and distribution)
- Decommissioning of the CHP (when new production is established)

13 Further Reading

Below is a guide to the full technical report, which is divided into the following sections:

- Chapter 1. A short résumé of the report's conclusions
- Chapter 2. Describes the structure of the report
- Chapter 3. The presuppositions of the report
- Chapter 4. A description of the reference scenario, and the various selected scenarios
- Chapter 5. Investments
- Chapter 6. A description of the operating conditions
- Chapter 7. Organisation and management
- Chapter 8. Company economy
- Chapter 9. The customer perspective
- Chapter 10. Sensitivity analysis for selected parameters
- Chapter 11. The socio-economic circumstances
- Chapter 12. Conclusions and recommendations
- Chapter 13. Appendix