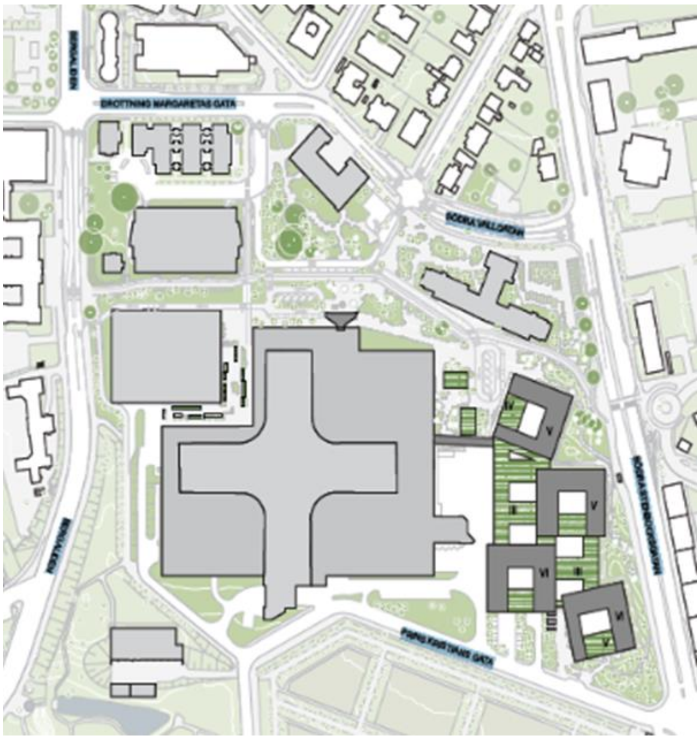
ENERGY IMPROVEMENT CIRCLE TOOL



A Demand-Response tool for identifying and quantifying smart energy solutions for reduced cost and climate footprint.

Region Skåne (PP7) and Öresundskraft (PP8) AREA 21, WP4

Henrik Gadd, Öresundskraft

Table of content

1 Abstract

The energy sector is in a change from fossil to renewable energy supply. In traditional energy systems the energy supply adepts to the demand, and the focus of energy efficiency matters has been on saving energy. Future energy system, based on renewable and reused energy, must focus more on saving electricity as well as heat power. As a result, the system border of energy production, distribution and thereby also the optimisation must include the energy end-users, i.e. the customers. The Energy Improvement Circle Tool is a method developed to support electricity and heat power optimisation from both an economical and a greenhouse gas emission point of view. A case study has been performed on Helsingborg hospital area, displaying that the total annually saving potential is €18 700 and 160 tonnes of CO_2 emissions.

2 Introduction

In traditional energy systems the energy supply adepts to the demand. If the energy use is increased, the production units will increase the supply. But, this way of supplying energy has an inbuilt inefficiency. Energy producers must always have available free capacity that can be used the upcoming hours, this since the energy demand for the future cannot be 100% predicted. The classic way to solve this problem is to build energy storages, but the development of ICT tools has during the latest decades enabled a possibility to involve the energy users in the energy optimisation. This is often referred to as Demand-Response solutions.

Energy efficiency matters should, as earlier mentioned, not only focus on saving energy, but also to save power. Energy produced in powerplants which addresses peak demands for both electricity and heat are often not only expensive but also produced with fossil fuels, I e there are both economic and environmental reasons to decrease peaks in energy supply. Many renewable and recycled energy sources are characterised by low energy cost but at the same time a high cost for power. For example, this can be wind-, solar-, hydro power and waste incineration, which all have very low or even negative marginal cost and it is almost only the fixed costs, i e power, which is expensive.

When saving energy, it is mainly a matter of an investment in insulation and energy efficient equipment that result in less energy use. When saving power is a matter of when to use energy or not. Power saving does not necessary involve energy saving, it can simply be to just move the energy use in time. However, this is a lot more complex since it then must involve not only your own energy use but also the energy generation. The Energy Improvement Circle Tool (EICT) is a developed method to analyse the potential savings for heat- and electricity peak power on an EID-level. The method is applied at the Helsingborg Hospital Area and is visualised in Power BI, a Microsoft standard software, but the method is not dependent in any specific visualisation software. To take act, it is necessary to identify were energy is used during the hour or hours that is expensive/cause large greenhouse emissions. The EICT method support to drill down these analyses from an EID-level down to a single equipment depending on what measurements that is available. The method is described by using a case study where the object of the study is Helsingborg Hospital Area; the EID of PP7 (Region Skåne) and PP8(Öresundskraft) in the AREA 21 project.

3 General idea of the EICT-method

The data on EID level energy use is used together with day-ahead data regarding energy cost and CO_2 eq (carbon dioxide equivalents) emissions on an hourly basis. The general idea is to reduce energy use at times when price and/or CO_2-eq emissions are higher than a certain limit. When the hour for over-limit cost/emission is identified, depending on what metering that is available, a possibility to drill down to see the energy use in each building, a part of building or even down to individual equipment will be available.

By introducing a limit for a maximum price and/or maximum CO_2eq-emission and set up an alarm that is trigged when the price/emission will reach a certain level next day, it is possible to reduce the cost and/or CO_2eq-emission of the EID area of interest.

3.1 Difference electricity - district heating

There is a major difference in electricity supply/use and heat ditto. Electric equipment is generally either switched on or off. There are exceptions as for example with frequency controlled electrical motors that is common in pumps and fans. District heating is mainly used for space heating and domestic hot water, where space heating is dominating the heat demand. Because of the thermal inertia of buildings, space heat does not need to meet the heat demand each specific moment. It is, within reasonable limits, possible to increase or decrease heat supply compared to the reference point without affecting the thermal comfort within the building. However, for domestic hot water and ventilation, heat must meet the demand momentarily to maintain indoor comfort.

3.2 Marginal vs average energy use

In the evaluation of cost and emission the marginal cost/emission is used. Marginal cost and emission are the cost and the emission of the last supplied kWh I e normally the most expensive production unit. In energy supply systems there are normally several different plants with different sources of energy, and thereby there will be different costs and emissions linked to the options. Figure 1 below illustrates the electricity pricing depending on what energy source that is used to produce the electricity, compared to the electricity demand. If the electricity demand decrease, not all powerplants that will decrease the supply. It is the power plant with the highest production cost that will adapt to a lower demand. The same reasoning can be applied on CO_2 emissions. Depending on the demand a certain hour, the CO_2 emission depend on what power plant that will decrease the production. In other words, how much cost that can be saved and emissions reduced depend not only on how much energy that is saved, but also when it is saved.

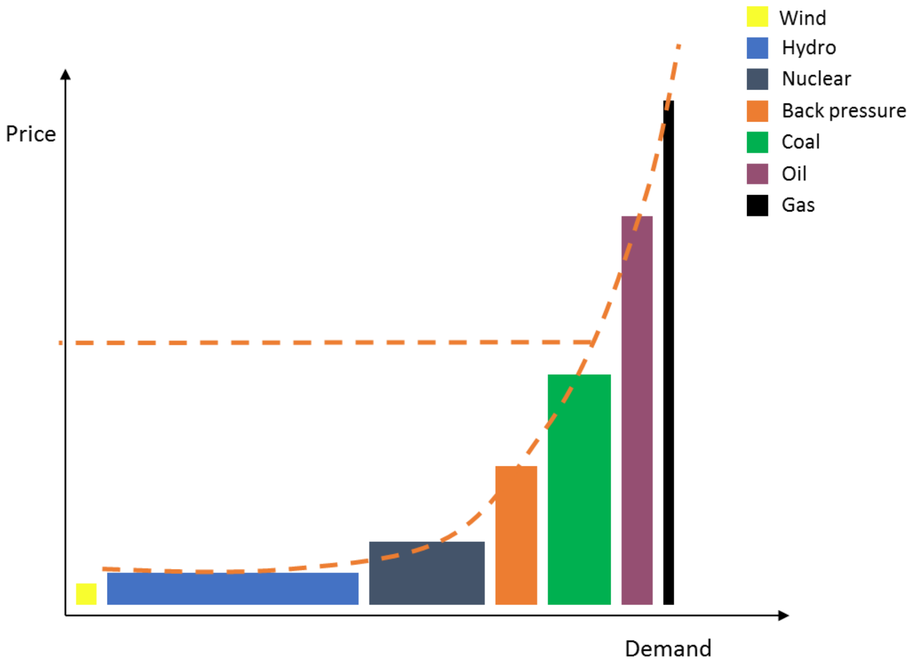


Figure 1. *Illustration of electricity pricing.*

For district heating the same reasoning is applicable even if the market is totally different. The price is fixed and not dependent in demand even if it is common with seasonal differences in the price, a kWh has the same cost independently of the hourly demand. One component that is common in Swedish district heating industry is to have a heat power component in the tariff. This is set by a cost in €/kW for the highest hourly or daily average heat power used during a period. For CO_2 emissions on the other hand, it is a lot easier. In a district heating system, there are a limited number of production units and the emission for each unit is known. The merit order, which is the order in which the different plans operate, is also well known. As a result, it is easy to predict the marginal CO_2 emissions and thereby receive information of when to decrease the heat demand to decrease CO_2 emissions the most.

Hence, by using the marginal price and CO_2 emission in optimisation, the hours with most impact on cost and/or emission will be saved.

3.3 Working steps in Energy Improvement Circle Tool

The work with the Energy Improvement Circle Tool can be divided in 5 steps:

1. Analyse the potential power saving and CO_2 reduction.

2. Identify possible electricity equipment possible to switch off on demand.

3. Identify buildings that can reduce the heat demand.

4. Set up API: s for price and CO_2-emissions on electricity forecast data and decide alarm levels.

5. Set up an agreement with the district heating supplier for demand side management.

The Power-BI model built for Helsingborg Hospital Area is described further down in this document, supporting step 1, 2 and partly step 3. For step 4, there are API: s which are already available, however, local administration needs to be developed to handle alarms. Step 5 must be solved by local negotiations between heat supplier and heat user.

1.Analyse the potential power saving and CO_2 reduction.

The first step is to identify the potential of measures to reduce power or emissions to conclude if the benefits exceeds the efforts. The analysis must be performed with historical data with the same resolution as the emission and price data, e g historical hourly data for heat and electricity must be available. This step actually consists of 4 different parts; Analysis of potential cost saving for electricity, Analysis for potential cost saving for district heating, analysis of potential CO_2eq emission reduction for electricity and Analysis of potential CO_2eq emission reduction for district heating.

2.Identify possible electricity equipment possible to switch off on demand.

Identify electric equipment that is OK to turn off part of times, but also to identify electric equipment where the use can be moved in time. The basic idea is to either decrease or to move electricity use in time at times when the cost or the emissions are high. To be able to do that, an inventory of the electricity use must be performed to identify electricity or heat that not necessarily needs to be in operation during certain hours. This also include a system of switching on and off equipment or control of regulators in the heating system. In Helsingborg Hospital Area, electric equipment is today in coupling terms split, depending of importance in the electric supply in interruptible and uninterruptible loads. This could be expanded to also include “disconnectable” loads.

To perform this step for large and complex buildings, is vital to have available submetering in the buildings. This to be able to identify where to start to identify electricity use, both from a volume point of view but also to be able to see at what times electricity is used.

3. Identify buildings that can reduce the heat demand.

Most buildings can reduce the heat demand during a limited period of time. For smaller buildings it is hours, but for lager buildings the heat demand can be reduced more than a day without decreased comfort thanks to the thermal inertia in the buildings. This is valid for building heated by radiators or floor heating, in other words water suppled heating systems. Ventilation and domestic hot water do not have an inbuilt thermal inertia, so to reduce the heat demand to ventilation and domestic hot water it is necessary to reduce the use comparable to how to reduce electricity use.

4. Set up API: s for price and CO_2-emission on electricity forecast data and decide alarm levels.

API: s for day ahead hourly prices are available from Noordpool and the CO_2eq emission are available on electricityMap. With the results from step 1-3, limits for acceptable price and CO_2eq emission levels can be set. How to handle alarms when the price and/or emission exceed s set limit must be solved in each case or installation. In some cases, it might be totally automated where equipment is automatically is turned off, while as in other cases it might require a total manual acknowledgement before action or a mixture of automated and manual methods.

5. Set up an agreement with the district heating supplier for demand side management.

The district heating business is local and consequently the prerequisites of the operation of district heating system are dependent of local conditions. So far, it has normally been the district heating companies that have taken the initiative to be able to reduce heat demand peaks because of bottlenecks in the production or distributions. There are two main occasions that could trig a demand for decreased heat demand; Very low outdoor temperature or failure in a larger production unit. Prediction of low outdoor temperatures are available from meteorological institutes, but major failures in production plants are not predictable. To obtain the most benefit of heat load reduction, the district heating operator needs to be in control of the system. This kind of solution, often referred to as demand side management, has been available from commercial operators the latest 10 years. To implement the technologies, an agreement between the local district heating company and customer needs to be set.

4 Method applied on Helsingborg hospital area

To illustrate how to work with the Energy Improvement Circle Tool in practice, it has been applied to Helsingborg Hospital Area based on historical data from the year 2018. This following part of the report also includes a description of Helsingborg Hospital Area.

4.1 Helsingborg Hospital Area

Helsingborg Hospital Area consist of 6 lager and 2 smaller buildings. The main building, *By02*, is dominating the energy use in the EID. One of the larger buildings is a carpark (see Figure 1 *Parkeringshus*) which does not use any heat and only small amount of electricity. The *Teknikbyggnad* and *By 23* are under construction and not yet in operation.

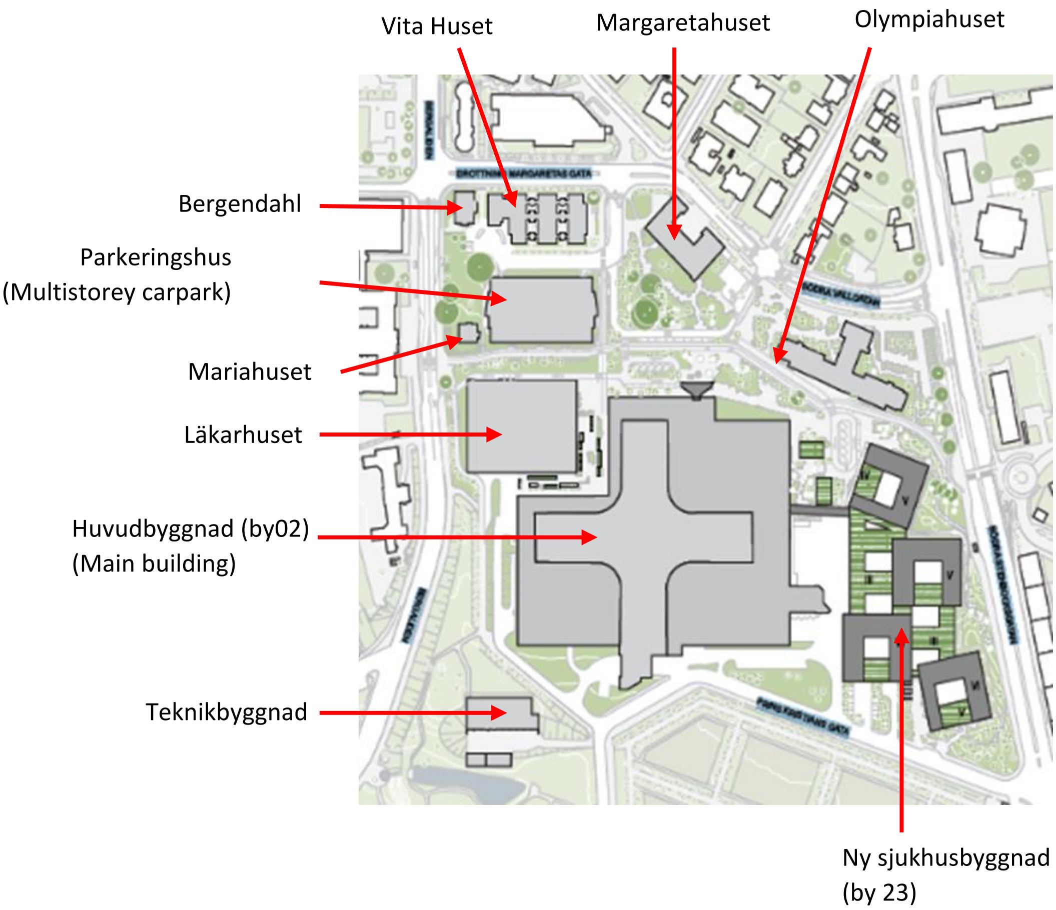


Figure 2. *Figure 1 Map of Helsingborg Hospital with named buildings.*

The energy use for each building in Helsingborg Hospital Area, Electricity and heat, can be found in Table 1 below. Notable is that approximately 90% of the energy, electricity and district heating, is used in the main building, By02.

Table 1. Heated area, use of electricity and heat energy for the buildings in Helsingborg hospital area 2018 in MWh

Building	**Heated area**	**Annual electricity use**	**Annual heat use**
Main building By02	105 142	14 861	15 200
Margaretahuset	3 757	127	240
Olympiahuset	7 036	23	795
Läkarhuset	14 383	676	432
Vita huset	4 410	379	386
Bergendahl	720	78	92
Mariahuset	399	87	Supplied from Vita huset
SUM	**135 847**	**16 231**	**17 145**

4.2 Limitations

The energy study includes electricity use and district heating use. There is also district cooling connected to the main building, but it is not representative and the method that is presented in this report for district heating can be applied for district cooling. The evaluation is performed for year 2018. For the sub metering in the east wing of the main building, there are only metering values available from mid-October and the quality of the metering are sometimes unsatisfactory. However, they are considered to be sufficient to be working as a showcase. For the evaluation, there are only values on an EID-level for the electricity respective on a building level for the district heating. This data is anyway all considered as high quality data.

4.3 Data

Öresundskraft measure the supplied electricity and heat. Electricity is measured in one point for the whole EID and district heating is measured in each of the 6 buildings in Table 1. Region Skåne has installed submetering in the EID, and in connection with the refurbishment more sub-metering will be installed. All data sources used are described in Appendix 1.

4.3.1 *Electricity*

Öresundskraft is measuring the electricity use for the entire Helsingborg Hospital Area in one point, with a total supply of 16 GWh 2018. For each building, there are submetering which are measuring electricity for each one of the different buildings. The main building, By02 with 110 000 m^2 of floor area, is presently going through a total refurbishment. For the time being, one wing (the east wing) is more or less finished. As part of the refurbishment 10-15 meters/wing in each floor are installed, these meters have been in operation from October 2018. Hence, there are only two months of values in the model and only from 2 different floors. All electric meters supply hourly measurements.

Price for electricity, both historical and next coming day, are available at Nordpool free of charge. API: s for prices, historical and day-ahead, are also available for free.

Emission values are available from electricityMap. The supplied data is in carbon dioxide equivalents, (CO_2eq) I e all types of emissions are converted to carbon dioxide emissions based on their respective greenhouse effect. Two data sets have been used: marginal emission in Sweden and import to Sweden. Data of emission forecasts from electricityMap are available via API: s but are not for free. In this work historical data for emission rates of margin and imported electricity has been used. For imported emission, only the average emissions are available, not as preferable the marginal emissions.

4.3.2 *District heating*

In total, there are six district heating meters in Helsingborg Hospital Area with a total heat supply of 17 GWh in 2018. Each heat meter measure heat, flow, as well as supply- and return temperature on the primary side hourly in six buildings; *Mainbuilding (By02), Olympiahuset, Margaretahuset, Läkarhuset, Vitahuset* and *Bergendal. Mariahuset* is supplied with heat from *Vita huset* and the carpark does not have any district heating supply.

Öresundskraft is measuring the heat supply for each of the six building in HHA. The refurbishment of By02 includes installation heat meters for submetering, but at the time for the AREA21-project they were not yet in operation.

Emission data for district heating comes from the heat production department on Öresundskraft. There are three main heat production supplies: Industrial excess heat from chemical industry in Helsingborg, waste to energy combined heat and power (WTE CHP) and biomass CHP. There is also a heat pump that use heat from sewage water and a Fossil heat only boiler (HOB).

The district heating network is also interconnected with 4 other cities: Landskrona Lund, Eslöv and Lomma all located south of Helsingborg.

5 Description of the Power BI-model of Helsingborg hospital area

The Power BI model is an illustration of how to evaluate the benefit from economic and environmental point of view with the method Energy improvement circle tool. The model is built in Power BI, a Microsoft software, to illustrate the method. The PowerBI model has got four views: 1. *Electricity overview* and 2. *District heating overview* that as it sounds gives an overview of electricity and district heating use, but also a possibility to drill down in detail. On time scale down to hour and in energy volume scale down to whatever sub-metering is available. 3. *Electricity evaluation* and 4*. District heating evaluation* where an evaluation of possible benefits both from an economic and CO_2eq reduction point of view is performed.

5.1 Electricity overview

The purpose of this view is to get an overview of the electricity use in the EID. To be able to work with energy power peak reduction, it is vital to understand how and more specific when peaks occur. The same thing is valid for price and CO_2-emissions. In this view it is also possible to drill down to each building and, if meters are available, drill down to parts of a building or whatever resolution that is available. In this view, it is also possible to zoom in a specific period in the time scale regarding electricity use, price and CO_2eq emission.

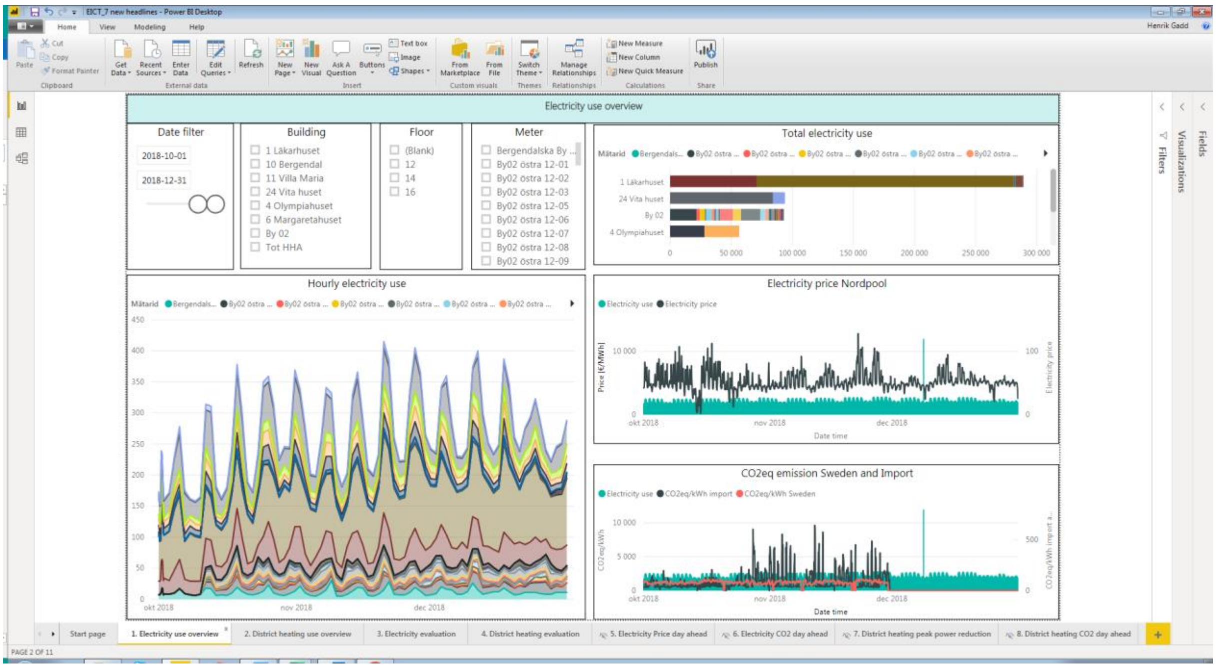


Figure 3. *Electricity overview used in PowerBI-modell of Helsingborg hospital area.*

Visualisations in the view:

-Top left: General filters: Year, Month, Building, Floor and sub meter.

-Top right: Total amount of electricity use on EID-level divided by building and submetering.

-Middle right: Time series diagram for electricity price and electricity use.

- Bottom left: Time series diagram for electricity use.

-Bottom right: CO_2eq-emission for electricity. Swedish marginal production and average import to Sweden as well as electricity use.

The electricity overview supports to give an overview of both electricity- use and production and thereby get a better understanding of the system functions, as well as how to act in order to decrease cost/emission.

5.2 District heating overview

The District heating use overview, Figure 4, has the same purpose as electricity overview for electricity. This to get an overview and understanding of the heat use in general, and the heat power use in particular. As for electricity, it is possible to start the analysis on an EID-level and then drill down to a building level and to look at specific periods of time.

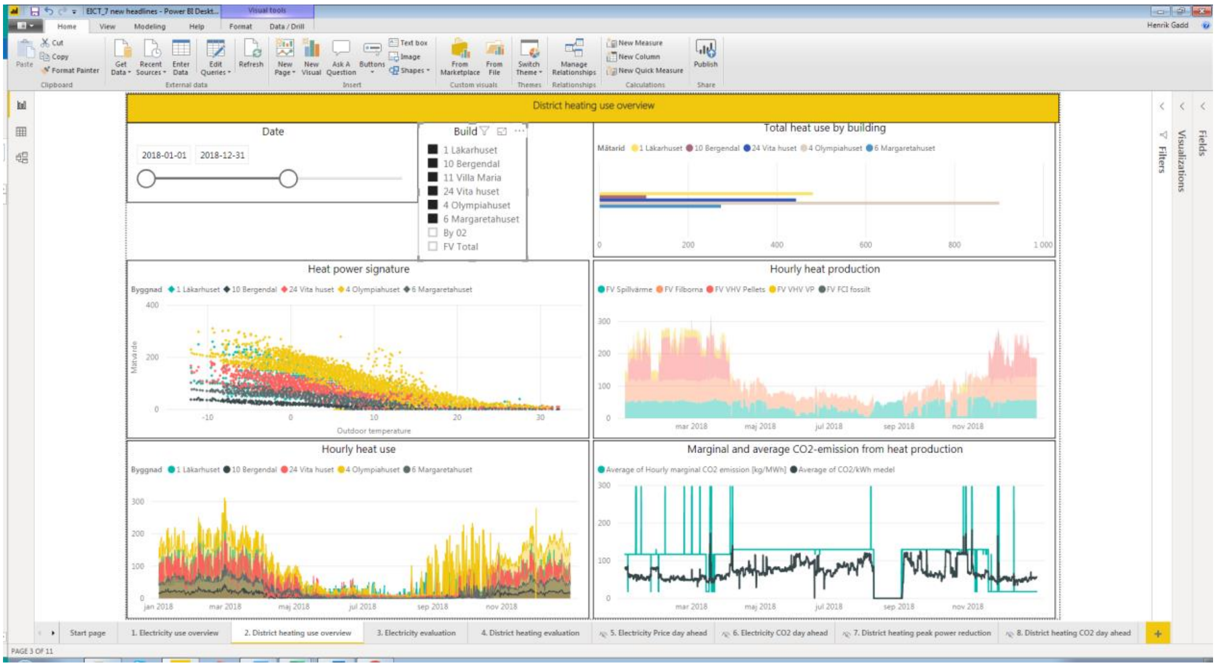


Figure 4. *District heating overview used in PowerBI-modell of Helsingborg hospital area.*

Visualisations in the view:

-Top left: General filters: Year, Month, Building.

-Top right: Total amount of use of district heating on EID-level divided by building.

-Middle left: Heat power signature for district heating use.

-Middle right: Time series diagram for heat production divided by heat supply unit in merit order from bottom to top.

- Bottom left: Time series diagram for district heating use.

-Bottom right: CO_2-emission for district heating. Average and marginal.

The district heating overview supports to give an overview of both district heating- use and production, and thereby also to get a better understanding of the system functions and how to act in order to decrease cost/emission.

5.3 Electricity evaluation

Before working with peak reduction for electricity, an evaluation of potential economic savings and reduction of CO2-emissons need to be performed. The electricity overview supports to perform this evaluation. By setting limits for electricity price and for CO_2 emission rates, the hours exceeding that limit is displayed for price and CO_2eq emission.

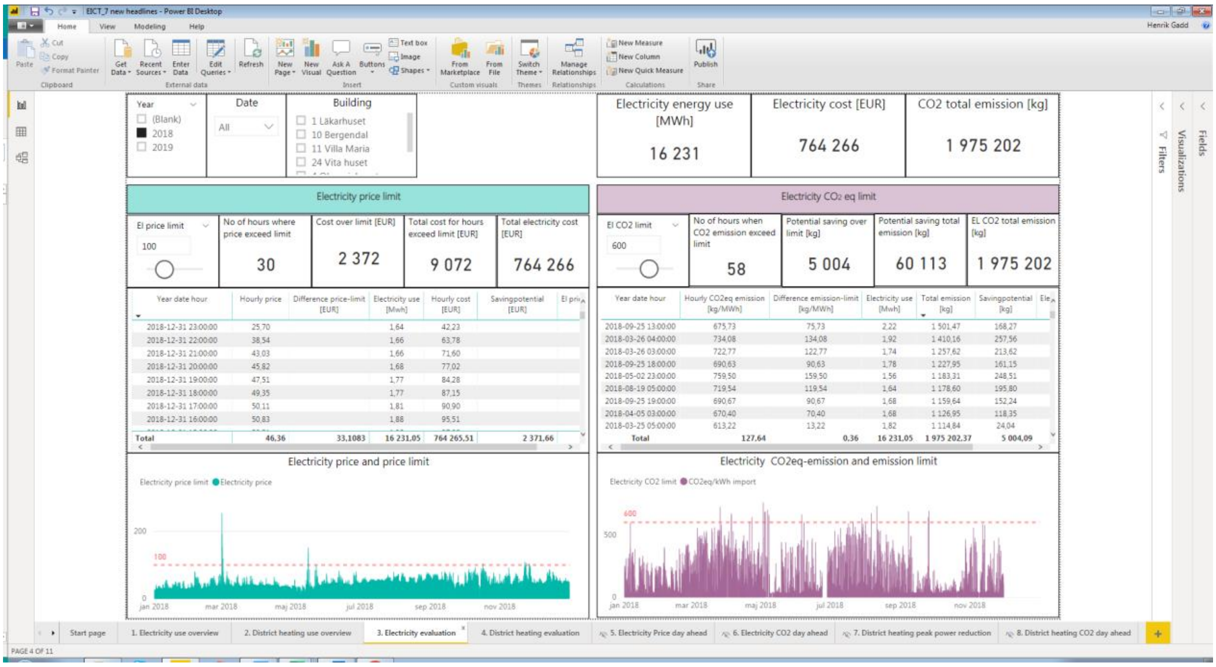


Figure 5. *Electricity evaluation of cost and CO_2eq emissions used in in PowerBI-modell of Helsingborg hospital area.*

Visualisations in the view:

-Top left: General filters: Year, Month and Building.

-Top right: Total amount of used electricity, cost and emission for that energy on EID-level.

- Bottom left: Selectable cost limit, Number of hours exceeding limit, Cost for energy over limit, Total cost for hours exceeding limit, Total cost within filter settings except limit.

-Bottom right: For CO_2eq-emission: selectable emission limit, Number of hours exceeding limit, _Emission for energy over limit, Total emission for hours exceeding limit, Total emission within filter settings except limit.

In this view, it is possible to change the limit value to see what really is the consequence of changed behaviour in € respective in kg of emissions as well as how many hours that require action, or the other way around, to see how many hours of action which have to be taken to achieve a certain amount of savings of money and/or CO_2 emission. Buy looking at those hours in the "Electricity overview", it is then possible to see where the electricity is used those specific hours and thereby to get information of where to look for equipment that can be switched off during these hours.

5.4 District heating evaluation

For CO_2eq emission evaluation in this view, it is much the same as for electricity. By setting a limit, a list with hours when the limit is exceeded is displayed. By looking in the "District heating overview", it is possible to identify where and how much heat is used during the listed hours. For peak load reduction (I e cost) it is not possible to set a limit. Peaks is normally reversed proportional to outdoor temperature; a variable that is out of our control. Instead, the actual peak load is compared with a 3-day average. The difference between the actual and the 3-day average for the analysed time frame is considered as a saving potential.

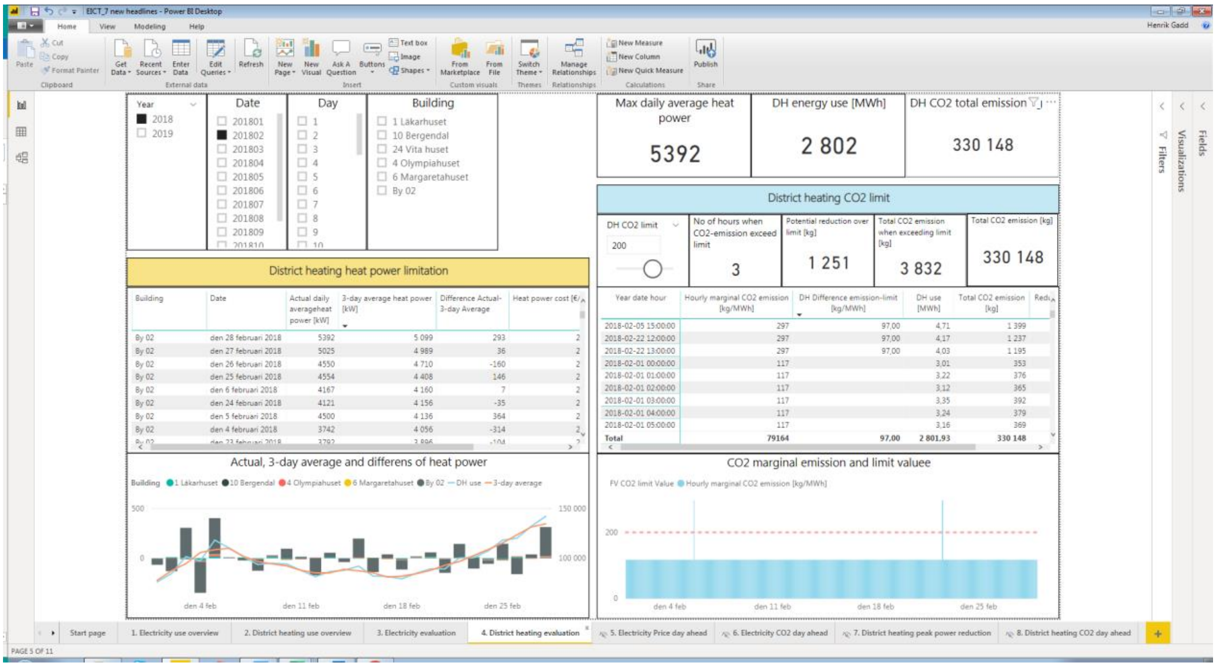


Figure 6. *District heating evaluation of peak load cost and CO_2 emissions in PowerBI-modell of Helsingborg hospital area.*

Visualisations in the view:

-Top left: General filters: Year, Month, Day and Building.

-Top right: Total amount of used district heating, cost and emission for that energy on EID-level.

Middle left: Table of hourly peak heat power, 3-day average heat power, cost for heat power all divided on building.

Middle right: For CO_2-emission: selectable emission limit, number of hours exceeding limit, emission for energy over limit, total emission for hours exceeding limit, total emission within filter settings except limit.

- Bottom left: Actual heat power and 3-day average heat power as lines. Difference in heat power between actual and 3-day average as bars.

-Bottom right: `Time series of marginal CO_2 emission for district heating production.

As for *Electricity evaluation,* it is possible to change the limit value to see what really is the consequence of changed behaviour in kg of emission and how many hours that require action, or the other way around, to see how many hours of action that have to be taken to achieve a certain amount of savings of money and/or CO2 emission.

6 Energy improvement circle tool applied at Helsingborg Hospital Area

Energy improvement tool is a method to decrease cost and/or CO_2 emissions by supporting the reduction of electricity- and heat power peaks. To show how the method work and to be able to evaluate Helsingborg Hospital Area, a model has been built in Power BI, a standard Microsoft software. The Energy Improvement Circle Tool is developed by Öresundskraft, but in close cooperation with Region Skåne. Region Skåne and Öresundskraft have during the AREA21-project had monthly whole-day workshops and the EICT has been a reoccurring paragraph in the agenda. Attending at the meetings has been the energy strategists, and technical management engineers of Region Skåne working with maintenance and energy efficiency matters in Helsingborg Hospital Area. Hence, the development has been an iterative process with monthly reconciliation. The input from the workshops has continuously been implemented in the tool development.

In the case study of Helsingborg hospital area, the potential savings of cost is €10 000 (1,3%), and €8 700 (6,6%) for electricity as well as district heating. This does only refer to the heat power fee and not to the entire heat cost. The CO_2 reduction potential for electricity is 100 tonnes (5%) CO_2 eq and for district heating 60 tonnes (3%) CO_2 eq. in other words, the total saving potential is €18 700 and 160 tonnes of CO_2 eq emission in Helsingborg hospital area. This is based on existing energy supply. For details see below.

6.1 Electricity analysis in Helsingborg hospital area

6.1.1 *Electricity cost*

The cost of electricity in this report is based on the market price in Nordpool and not actual prices agreed between Region Skåne and their electricity retailer. Figure 7 below show, depending on price limit settings, the relation between saving potential and number of hours that exceed the limit. As an example: The market price exceeded 80 €/MWh 156 times (orange line) and the total cost of the electricity over the limit of €80 was €5 624. I e (actual price-80) * electricity use.

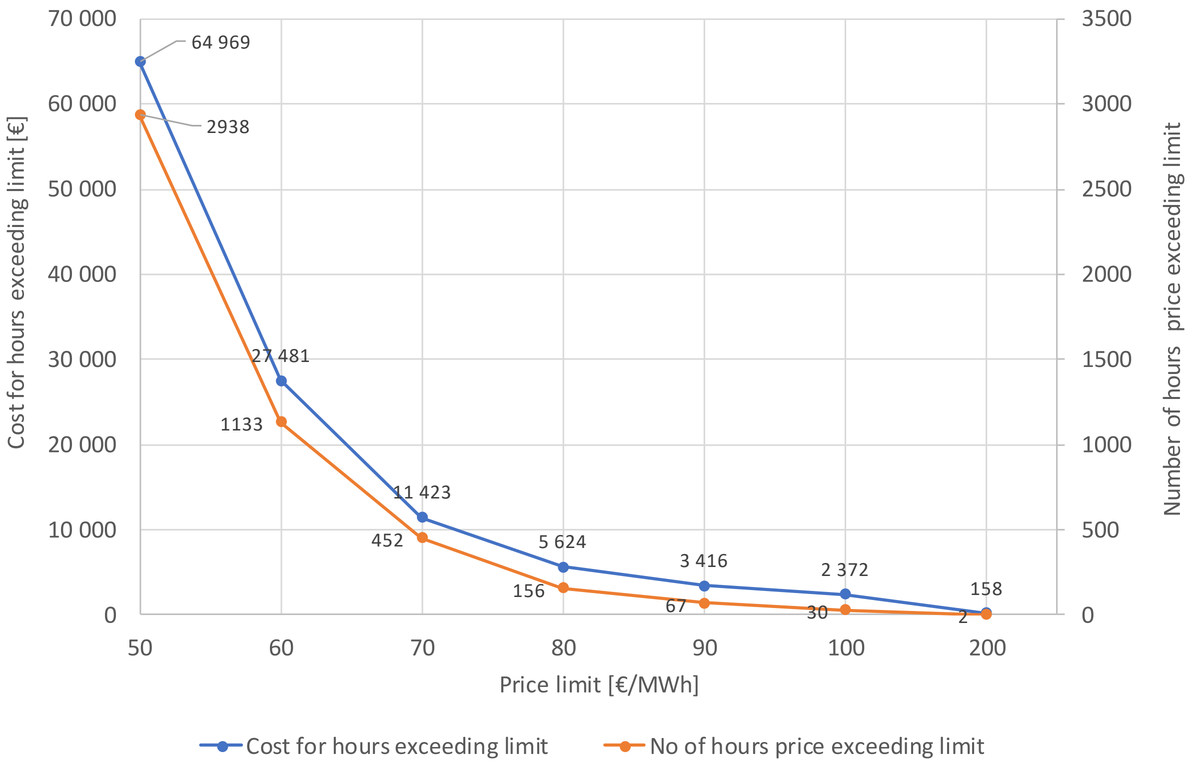


Figure 7. *Cost of electricity and corresponding number of hours exceeding price limit.*

It should be reasonable to take action at least once a day, which according to Figure 7 above indicates a potential saving of at least € 10 000 annually. This is based on that the electricity load will be moved to times when electricity price is below limit, I e no electricity saving in kilowatt hours is assumed.

6.1.2 *Electricity CO2eq emission*

There is no information available of what really is the marginal production of electricity. In electricityMap's, emissions for national marginal production and imported averages are available. The emissions for electricity that is used here is an imported average of CO_2equivalents. Figure 8 below shows in the same way as above, but for CO2-emission instead of cost, the relation between potential emission decrease and number of hours that exceed the limit. As example: The emission exceeded 500 kg/MWh 175 times (orange line) and the emission decrease of the electricity over the limit was 22 220 kg or 22 tons.

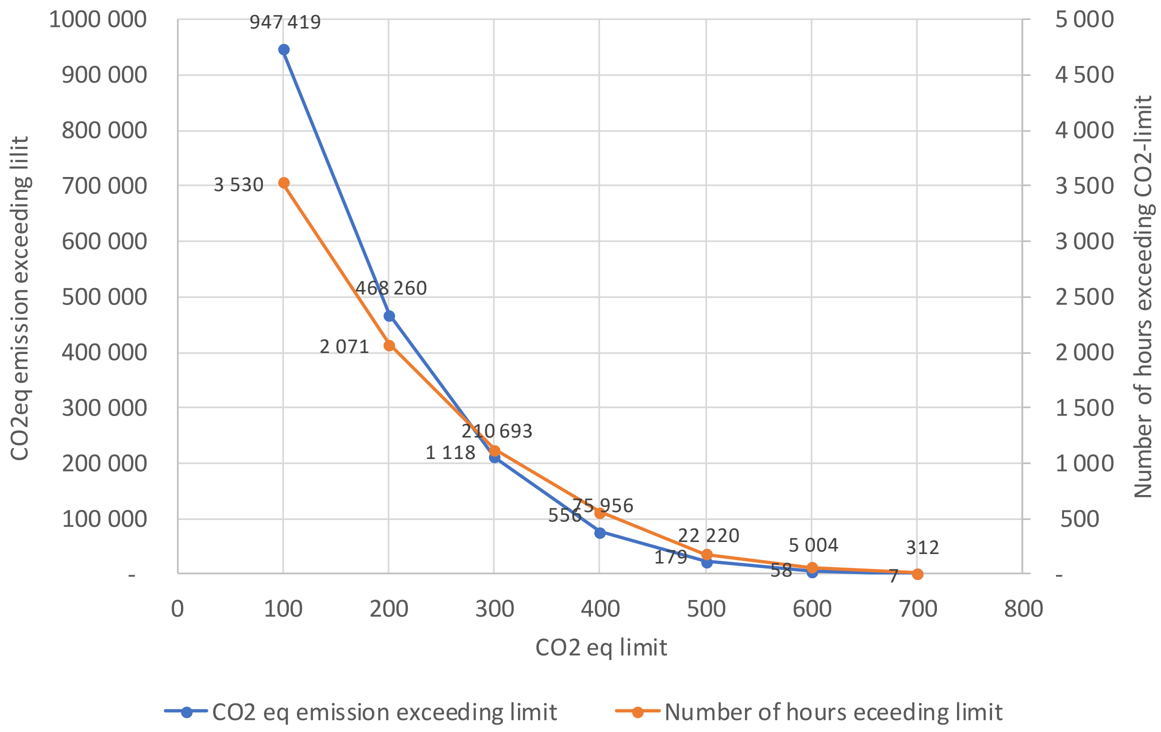


Figure 8. *CO2 eq emission and corresponding number of hours exceeding CO2 eq emission limit*

With the same argumentation as for electricity cost, that it should be reasonable to take action once a day, the potential CO_2 emission savings are about 100 tonnes annually.

6.2 District heating analysis in Helsingborg hospital area

6.2.1 *DH cost*

Space heating is a slow process and it is possible to use large buildings with large thermal inertia as heat storages. The principle is to supply more heat to the building the day before the demand and after a temperature peak, to thereby reduce the peak in between. The signal for peak load is a prognosis on the outdoor temperature. In the case Helsingborg Hospital Area, the benefit is decreased heat power tariff that is calculated on the highest daily heat power the latest 12 month. To reduce the peak, a simulation to supply the building with the a 3-day average instead of actual demand is performed.

This is illustrated in Figure 9 below, where the orange line is the actual use and the purple is the 3-day average. The bars are peak load savings, in other words the difference between actual and 3-day average.

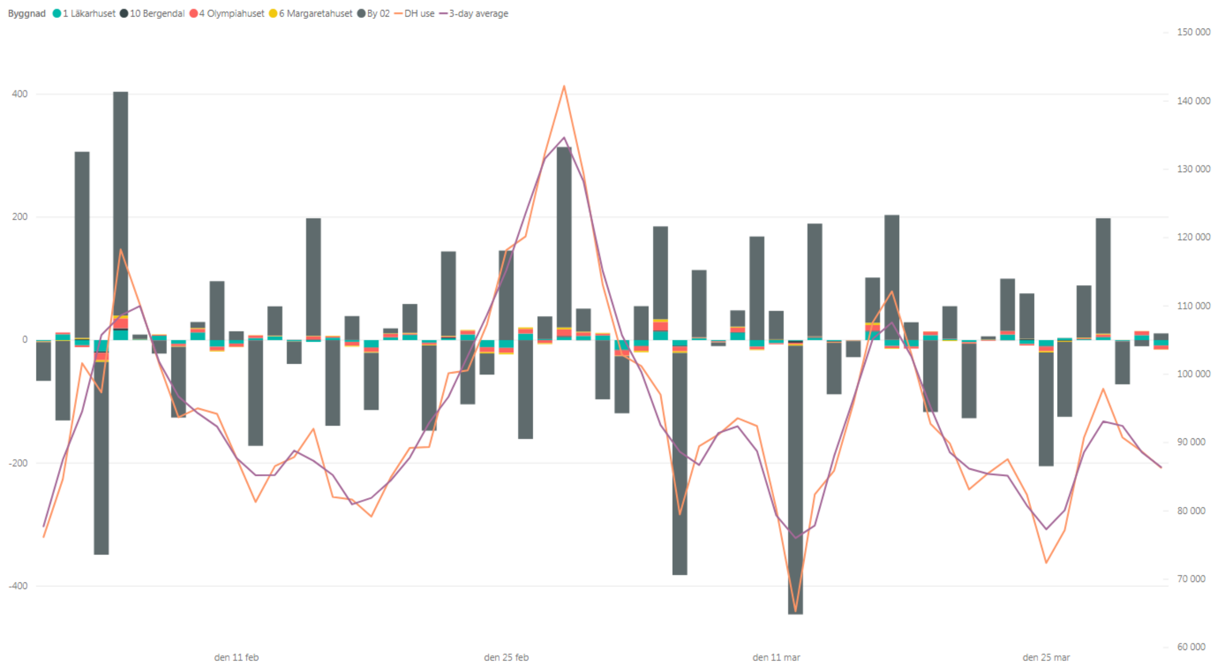


Figure 9. *The lines describe the Actual district heating use and 3-day average. The bars are the difference of the two lines and thereby potential saving. The time period is November.*

The benefit from the peak shaving above is about € 8 000 for Helsingborg Hospital Area. The four highest heat power values were between 26-28th of February and 1st of March. It was four days in a row. Which were the tree coldest days in Helsingborg (between minus 8,7 to minus 6.2 as daily average) during 2018, 26th was the 5:th coldest day. (minus 4.8 as daily average). [1]

The evaluation is based on the existing tariff system for district heating in Öresundskraft. In fact, it is not necessarily low outdoor temperature that causes the start of expensive fossil fuel boilers. It can also be because of faults in other production units. In that sense, the existing tariff reflect average costs and not marginal costs.

6.2.2 *District heating CO2eq emission*

The marginal emission of CO_2 from district heating will, in contrast to electricity production, be in obvious steps. This is depending on that there are few production units with shifting emission levels. Figure 10 below show, depending on CO_2 limit setting, the relation between potential decreased emission and number of hours that the CO_2 emission exceed the limit.

[1] The actual saving potential is less. In the main building there is limited possibility to use the main building in peak power reduction for heat. The heating is mainly based on air heating and therefor difficult to reduce without affecting the comfort.This technical is not representative and the potential is based on a corresponding building with regular heating system.

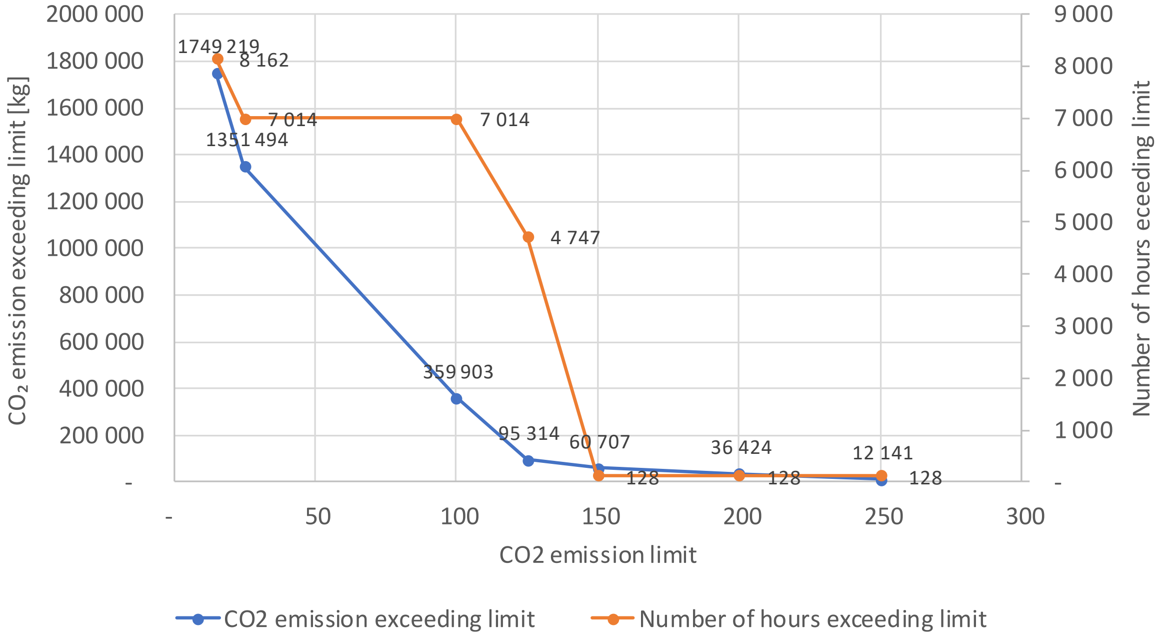


Figure 10. *CO2eq emission and corresponding number of hours exceeding CO2 eq emission limit.*

The graph in Figure 10 might look a little bit strange, but the reason is, as described above, that there are only a few heat sources and thereby the marginal production will have distinct steps. All hours with emissions over 120 kg/MWh origin from the fossil heat only boiler. As a result, what can be seen is that it has been in operation 128 hours during 2018. The potential saving is 60 tonnes of CO_2 eq emissions.

7 Discussion

There is an ongoing transformation of the energy system from fossil to renewable energy supply. Renewable energy sources like wind and solar will create more volatile prices, and there have already occurred negative prices on electricity a few times. Storage is one way to handle this problem, and a large electrification of the transport sector could be part of the solution as they could be used not only as energy storage for the vehicle itself but also as a storage service. Another is to use technology with a flexible way of using electricity to match the production, to move electricity demands from times with low production and high demand to times with high productions and low demand. An obvious advantage by this method is that it doesn't require investment or material use in batteries.

The Swedish district heating market is saturated, where the amount of sold heat has not increased in a decade. The new buildings that is connected compensate for energy efficiency measures in existing buildings but doesn't increase the sales. Historically, is was not a problem if a CHP or boiler were oversized, it would not last since the demand increased over the years. The base energy source for district heating is waste, biomass and industrial excess heat. All residuals from different processes have a low cost, but every saved MW of new built production save €100 000 in investment cost. I e as for electricity, heat power is cost driving, not energy.

With a more volatile electricity price, and when the cost for district heating move from fuel to the actual investment in heat power, there should be a shift in focus from saving energy to saving electricity and heat power. A method like Energy Improvement Circle Tool support this transition to improve the system of energy efficiency and thereby maintain competitiveness.

Price vs climate

An obvious risk is if the incentives of saving money and saving the planet is contradictory. I e an important issue to analyse is to how price and emission correlate to each other, and if there is a difference between heating and electricity.

Correlation between price and CO2 emission district heating

Figure 11 below show the relation between production cost and CO_2 emission for different heating units. There is an obvious correlation between cost and CO_2 emissions.

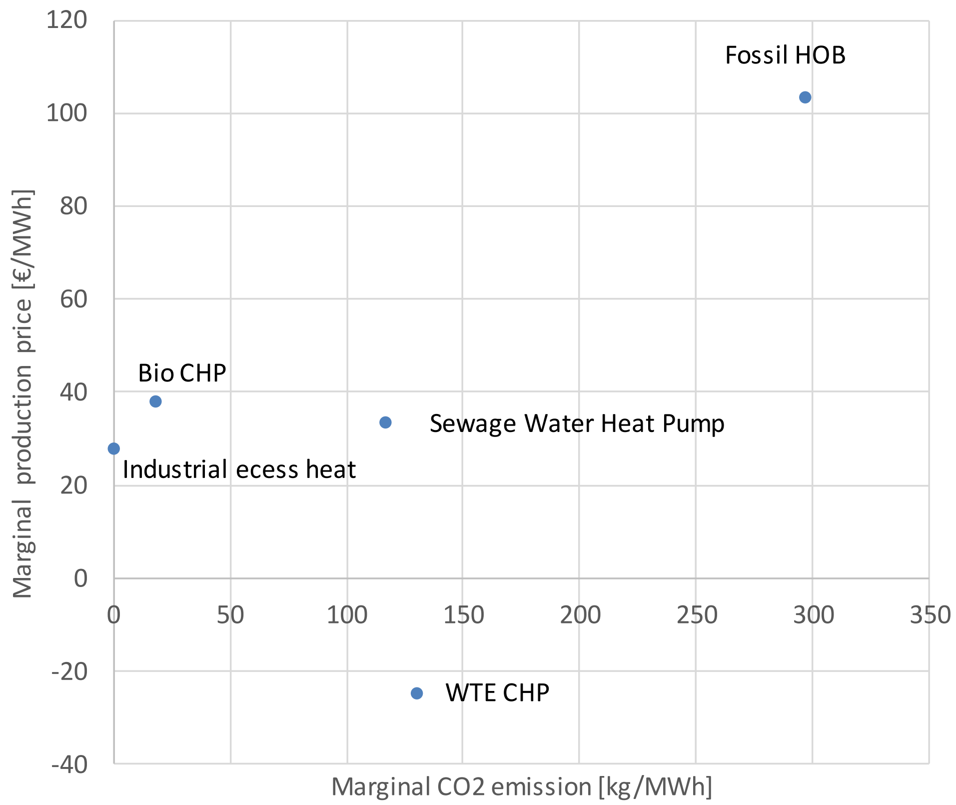


Figure 11. *CO_2 emission and production cost for Helsingborg district heating system in 2018.*

The Fossil heat only boiler is the most expensive and most emitting unit, and thereby not contradictive in the choice between cost and emission reduction. The main contradiction is for the waste to energy combined heat and power unit, WTE CHP, where the CO_2 emissions are higher than the Bio CHP but the cost is lower. The CO_2 emissions from the WTE CHP origin from plastics in the waste, and the stumbling block in Sweden is if this should be allocated to the waste collective or to the energy collective. For now, it is allocated to the energy collective and thereby cause relative high CO_2 emissions for heating. The reason for the high cost of emitting CO_2 is the Swedish carbon dioxide tax that was introduced 1990 and is today about €100 per ton.

Correlation between price and CO_2 emission electricity

In Figure 12 below, the correlation between price and CO_2 emissions for electricity is illustrated. The blue points are imported electricity and the orange points are marginal CO_2eq emission in Sweden.

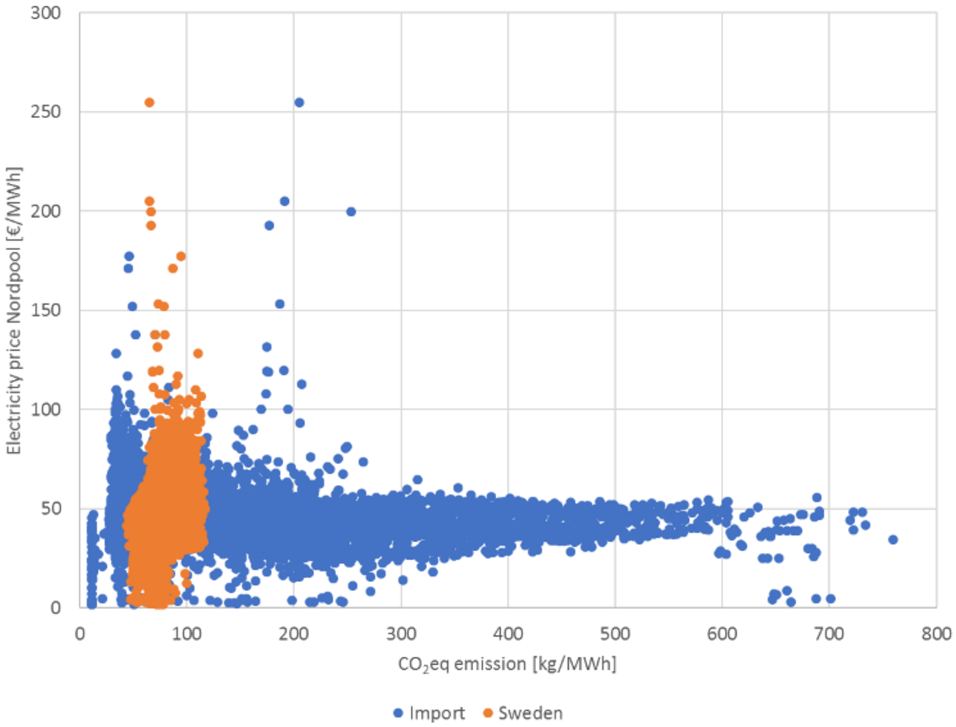


Figure 12. *Marginal CO2 emission (Domestic production and imported) and market price for electricity in Sweden in 2018.*

It is obvious that there is no correlation between price and CO_2 emissions. I e eliminating high CO_2 hours doesn't interfere with economic matters. On the other hand, it does not support it either.

According to the case study in Helsingborg Hospital Area, it is by changing the energy use behaviour during one to two hours a day that a potential to save 1-5 % of cost or decrease of CO_2 emissions occur. To know what is possible, a deeper analysis must be performed to identify how and where the change of energy use can be performed and keep the production of health care intact.

In the future, with more intermittent energy supply, there are reasons to believe that the energy market prices will be more volatile which will result in an increased benefit from electricity and heat power reduction at high load hours. Here this described method can be one tool in the toolbox to support the work in meeting the new energy system. Working with power reduction and not only energy use reduction is an important step to a sustainable energy use.

Appendix 1. Description of data sources

Table 2. Data sources used in Energy Improvement Circle Tool

	1. Electricity use overview	2. District Heating use overview	3. Electricity evaluation	4. District heating evaluation	Data origin
General data					
Date/time	x	x	x	x	Calendar date
Building/building part identity	x	x	x	x	Region Skåne
Hourly outdoor temperature		x			SMHI (Swedish meteorological and hydrological institute)
Electricity data					
Hour electricity use HHA level	x		x		Öresundskraft metering system
Hourly electricity use building level	x		x		Granlund(RS building data management system)
Hourly electricity use floor level	x				Granlund(RS building data management system)
Hourly electricity market price	x		x		Nordpool
Hourly CO2-emission for electricity domestic and import	x		x		ElectricityMap
Electricity meter identity	x				Granlund(RS building data management system)
District heating data					
Hourly district heating use building level		x		x	Öresundskraft metering system
District heating meter identity		x		x	Öresundskraft metering system
Heat power cost				x	Öresundskraft production department
Hourly district heating CO2 emission marginal and average		x		x	Öresundskraft production department
Hourly heat production		x			Öresundskraft production department
3-day average heat power use				x	Calculated