Final report

1.1 Project details

Project title	EUDP 2016 Super Supermarkets
Project identification (program abbrev. and file)	EUDP J.nr. 64016-0106
Name of the programme which has funded the project	Energiteknologisk Udviklings- og Demonstrations Program (EUDP). System integration
Project managing company/institution (name and address)	CLEAN, Sundsmarkvej 20, 1., 6400 Sønderborg, Denmark Lotte Gramkow
Project partners	CLEAN; CVR: 29727538 Danfoss; CVR: 20165715 COOP; CVR: 27907768 Dansk Fjernvarme Forening; CVR: 55831017 Dansk Fjernvarmes Projektselskab A.M.B.A.; CVR: 14766707 Teknologisk Institut; CVR No. 56976116 Ivar Lykke Kristensen Rådgiv. Ing. A/S; CVR: 57359315 AK-Centralen A/S; CVR: 27611877 OK A.M.B.A; CVR: 39170418 Royal Institute of Technology – KTH; Vat: SE202100305401 Kerteminde Forsyning A/S; CVR: 32079253 *(changed from Bramming Fjernvarme A.M.B.A.; CVR: 63446319)* Fjernvarme Fyn A/S; CVR: 30174968 *(changed from Mølholm Fjernvarme Andelsselskabet; CVR: 44424010)* Bjerringbro Varmeværk; CVR: 17256319 *(Later changed name to Gudenådalens Energiselskab and/or Bjerringbro Varmeværk A.m.b.A.)*
CVR (central business register)	29727538
Date for submission	29th of January 2020

1.2 Short description of project objective and results

English version:

The main purpose of the Super Supermarkets project was to evaluate, demonstrate and implement the full potential of district heating production and system services that are available, but not yet utilized in Danish supermarkets.

The Super Supermarkets project has had the goal to optimize and standardize the technology of heat recovery and to expand with two additional levels of energy system integration:

1. Optimize and standardize the recycling of surplus heat from supermarket cooling systems to;
    a.) Internal use of the heat for heating purposes in the supermarket,
    b.) supply of heat to the district heating system.
2. Expand with two additional levels of energy integration - sector switching;
    a.) The first level is to use unused compressor power in the supermarket refrigerator by means of heat pumps for direct district heating production, and

b.) The second level is to use the possibilities of flexible electricity consumption in the supermarkets cooling systems.

Furthermore, two calculation models have been produced in the project, and finally, a so-called COOKBOOK has been produced.

Danish version:
Hovedformålet med Super Supermarkets-projektet var at vurdere, demonstrere og implementere det fulde potentiale af den fjernvarme produktion og de systemtjenester, der er tilgængelige, men endnu ikke udnyttet i de danske supermarkeder.
Super Supermarkets-projektet mål var at optimere og standardisere teknologien til varmegenvinding og udvidelse med yderligere to niveauer af energisystemintegration:

1. Optimere og standardisere genanvendelse af overskydende varme fra supermarkedskøleanlæg til;
    a.) Intern brug af varmen til opvarmningsformål i supermarkedet,
    b.) tilførsel af varme til fjernvarmenettet.
2. Udvide med to yderligere niveauer af energiintegration - skifte af sektorer;
    a.) Det første niveau er at anvende ubrugt kompressoreffekt i supermarkedets egne kølemontre ved hjælp af varmepumpen til direkte fjernvarme produktion, og
    b.) Det andet niveau er at udnytte mulighederne for fleksibelt elforbrug i supermarkedets kølesystemer.

Yderligere er der, i projektet, blevet produceret to beregningsmodeller, og til sidst er der produceret en såkaldt KOGEBOG (COOKBOOK).

1.3 Executive summary

HVAC is fundamental to sustain the UN SDG's on health, food and energy

The Super Supermarket project engages and influences directly and indirectly, and is 'hitting' several of the UN's SDG goals

The ambitious political goals regarding energy- and climate changes towards 2030 with a 70% reduction of CO2 emissions for Denmark, compared to 1990 emission will require all technical and economical feasible contribution to be activated. From the energy sector it is possible to reduce CO2 emission using three major elements.

1. Energy efficiency – less energy consumption for the same task e.g. when an 80-Watt filament light bulb is replaced by an 8-Watt LED bulb and the same light is achieved.

2. Energy generation from sustainable energy sources with low or no emission of greenhouse gasses (CO2 and CO2 equivalents).

3. Sector coupling, where surplus of energy in one process will be recycled in another process – energy will solve more tasks.

Denmark is among the few countries, where district heating has a penetration larger than 65% of the buildings. The large and distributed district heating system is ready for absorption of heat from multiple sources and might also be used for thermal storage, helping integration of volatile energy generation. Geothermal heat, heat from datacentres, and other industries are at a much higher volume compared with chillers at the supermarket. Supermarkets have the advantage of delivering heat in the local distribution system with the right temperature. With a substantial need for sustainable fuel free energy there is not room for excluding any relevant energy sources.

The value chain is, as follows, in relation to recycling of surplus heat from chillers in supermarkets.

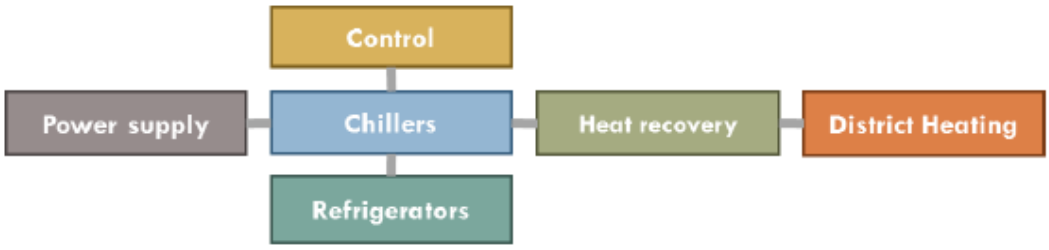


Figure 1: The figure 1 shows the chain components for recycling of surplus heat from chillers in supermarkets to the district heating system.

In the project technical, financial, practical, and regulatory aspects has been evaluated regarding the recycling of heat from supermarkets chillers for district heating purposes. In this cookbook relevant information is being distributed for enhancing innovative investments and projects in supermarkets, district heating companies, consulting engineers, and suppliers.

In a supermarket, a large part of the store's energy intake is for cooling and freezing. This is done by removing ambient heat to ensure the durability of the goods. There are great opportunities in collecting and recycling this heat. It is heat that has already been paid for in the form of electricity.

<u>The Super Supermarkets project addresses several national and international strategies:</u>

- Better use of recycled heat from the industrial and retail/ service sector
- Implementation of substantial heat pump capacity in the district heating networks
- Smart grid implementation. To make high energy consumers more flexible to adapt to more fluctuating power production (Wind)
- Exploring and utilizing heat sources in cities for district heat production
- EU Strategy on Heating and Cooling (16. Feb. 2016): "Heating and cooling and the electricity system can support each other in the effort to decarbonize. It is essential to recognize the links between them and exploit synergies."

The main purpose of the Super Supermarkets project was to evaluate, demonstrate and implement the full potential of district heating production and system services that are available but not yet utilized in Danish supermarkets.

Basic heat recovery - also called 'utilization of surplus heat' - has been carried out in around 150 supermarkets in Denmark. The Super Supermarkets project will optimize and standardize this technology, expanding with two additional levels of energy system integration.

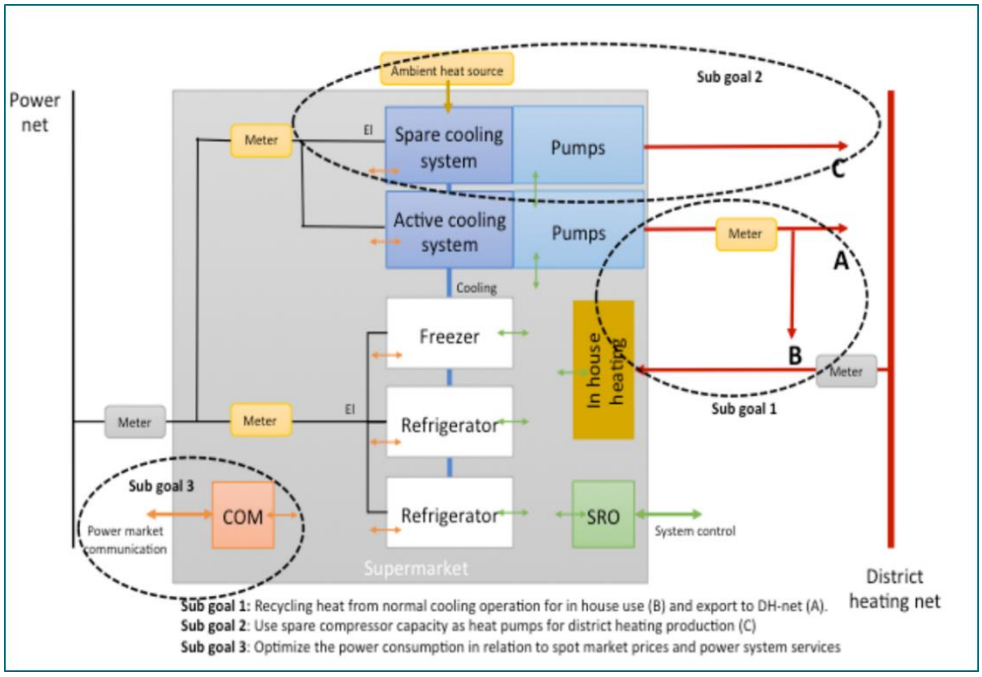


Figure 2: The figure 2 gives an overall view of possible solutions and sub-goals (models) for the recycling of surplus heat.

The main focus and activities have been to assess, demonstrate and implement the full potential of utilizing surplus heat from supermarkets, but there have also been several sub-goals from the project:

MODEL 1 (illustrated with B above): Simple solution in which the heat from the refrigerator is reused to the store's own need for space heating and hot water. There is no delivery to the district heating network. By contrast, the district heating network can supplement the store's heating needs in the winter. In order to document electricity consumption and heat recovery to authorities, several meters must be installed in the system.

MODEL 2 (illustrated with A above): There is district heating supply to the supermarket to cover heating needs. There is still supply of heat from the refrigerator to the district heating system, but only the part of the heat production that cannot be used to meet the supermarkets own heating needs. Typically, the supermarket will then need to buy district heating in the winter and sell heat to the district heating system in the summer.

MODEL 3 (illustrated with C above): The chiller has extra compressor capacity that can act as a type of heat pump and supply extra heat to the district heating system during the periods of the year, when the cooling demand is not so convenient in the winter period.

MODEL 4 (illustrated with sub goal 3 above): Optimizing the overall management of electricity consumption and heat sales; e.g. utilize hours with lower electricity prices in the spot market Nord Pool Spot, or through a market player to sell the opportunity for up or down regulation of electricity consumption and thus participate in the balance market. Ultimately, the refrigeration system can also participate in the system service market. All of this requires more advanced controls, as well as collaboration with electricity traders and/ or other market players, in the effort to decarbonize.

As some of the above-mentioned tasks are based on well-proven technology, the 'only' step before commercialization was a well-organized and thorough demonstration of the new couplings and well-substantiated calculations on the feasibility and the impact of implementing the technology. Every single supermarket project was, on the energy level, quite small, but aggregated, and on chain level considerable. Therefore, has a main focus in this project been to develop "plug and play" solutions which could be implemented easily. Hence, solutions being technology wise reliable, and where both the heating- and the cooling side could operate in an optimal way.

The barriers:

Unfortunately, as the project also addresses, some barriers are still experienced. Barriers such as;

- lack of strategy for the green transition, which also has an impact on recycling of surplus heat from supermarkets,
- out-of-date rules for investments in technical solutions for heat recycling,

- uncertainty about future conditions, including delayed conversion of inappropriate taxes and fees,
- being a heat producer is not a core activity of a supermarket (administrative hassle), as well as doubts about ownership. COOP has both so-called A and B stores, with different owner models,
- incorporating the heat activity into the supermarket's primary activities,
- the geographical location of the supermarket in relation to the district heating system,
- uncertainty about supermarket consolidation and market positioning

The potential is great, when these barriers are cleared. The Super Supermarkets project and the COOKBOOK have addressed the barriers.

The potential

The project partners expect that there, in Denmark alone, is the potential to have more than 1,000 supermarkets supplied with the necessary equipment for recycling the surplus heat. This is an estimate for the next 3-5 years after the end of the project - and on condition that the barriers are eased or completely removed. Currently, many supermarkets are getting new modern efficient refrigeration systems. It is obvious that the additional investments in the technical equipment for the supply of heat for reuse in the district heating system are made simultaneously. Alternatively, the supermarket will continue to cool the heat to the surrounding areas without any benefit, rather than becoming a supplier of heat for recycling in the district heating system.

The Super Supermarkets project has CLEAN as project manager (CLEAN). The other project participants are: AK-Centralen, COOP A.m.b.a., Danfoss A / S, Dansk Fjernvarme Forening, Dansk Fjernvarmes Projektselskab A.m.b.a., Ivar Lykke Kristensen A / S, OK A.m.b.a, TI, and KTH - Royal Institute of Technology Stockholm. There has been participation of COOP supermarkets in Otterup, Bjerringbro, and Kerteminde. In addition, three district heating companies, Fjernvarme Fyn A/S, Gudenådalens Energiselskab, and Kerteminde Forsyning A/S has participated in the project.

1.4 Project objectives

In a supermarket, a large part of the store's energy intake is for cooling and freezing. This is done by removing ambient heat to ensure the durability of the goods. There are great opportunities in collecting and recycling this heat. It is heat that has already been paid for in the form of electricity.

The main purpose of the Super Supermarkets project was to evaluate, demonstrate and implement the full potential of district heating production and system services that are available but not yet utilized in Danish supermarkets.

Basic heat recovery - also called 'utilization of surplus heat' - has been carried out in around 150 supermarkets in Denmark. The Super Supermarkets project will optimize and standardize this technology, expanding with two additional levels of energy system integration.

The main purpose of the project:

The main purpose of the Super Supermarkets project was;

1. To optimize and standardize the recycling of surplus heat from supermarkets' cooling systems to;
    a. Internal use of the heat for heating purposes in the supermarket,
    b. supply of heat to the district heating system.
2. As well as expand with two additional levels of energy integration - sector switching;

a. The first level is to use unused compressor power in the supermarket's cooling machines by means of heat pump for direct district heating production,

b. The second level is to use the possibilities of flexible electricity consumption in the supermarket cooling systems, in large groups to report capacity into the market for balancing, for example. regulatory power market, or system services.

Heat recovery has been established for approx. 150 supermarkets, of which less than 100 have delivery to the district heating. The typical supermarket has a compressor capacity of 150 to 240 kW – where 50 to 100 kW of this capacity might be used for optimizing purposes during the winter season. There are approx. 2.700 supermarkets in Denmark, with in total approx. 400 MW thermal capacity. A typical plant can supply 200-230 MWh of heat for reuse in the supermarket or for delivery to the district heating. In the project it was estimated that all supermarkets could participate with heat recovery, and that 75% of supermarkets could participate with flexible consumption.

In connection to the approx. 2.700 supermarkets a total of up to 250 MW electric capacity for Demand Response is available. This could be used as an "additional heat pump capacity" in the district heating networks. Therefore, the partners in the project also investigated the possibilities for optimizing and standardising the technology and the possibilities to expand it with two extra levels of energy system integration – sector coupling. First level was to utilize the auxiliary compressor capacity in the supermarkets. The second level was to aggregate supermarket cooling and heat production systems and activate them as an electricity grid service to help level out the fluctuations of wind power. In the balancing market there is, in Denmark, a lower limit of 5 MW. An aggregator or balance responsible can use a sum of supermarkets in the power market as an aggregated capacity.

The project has gathered key findings and analysis from former and ongoing research projects in the area of optimizing cooling systems in supermarkets, demand side flexibility on the energy consumption in supermarkets and heat pump implementation in the district heating networks. The project partners have been - or are - involved in all relevant research projects in this field, and thereby they all have access to recent new findings.

Combining this with the key actor in retrofitting supermarkets for heat recovery to district heating and the largest supermarkets owner in Denmark, opens up for both development of new integrated energy systems and big scale roll out of the technology.

<u>The activities and objectives in the Super Supermarkets project were based on four main stages:</u>

1. Pre-studies and various technical survey definitions

2. Demonstrations in existing supermarkets and in three new supermarkets, incl. evaluation of the demonstration results. The involved supermarkets and their respective district heating companies are:

    a. SuperBrugsen Kerteminde and Kerteminde Forsyning

    b. SuperBrugsen Bjerringbro and Gudenådalens Energiselskab

    c. SuperBrugsen Otterup and Fjernvarme Fyn

3. The production of a COOKBOOK, i.e. guidelines and intensive targeted communication to all interest groups to assure a nationwide roll out and long term follow up on results.

4. Two individual calculation models

The four-step approach above was important in getting the project disseminated to the key interest groups.

As the annual reports to the EUDP secretariat show, that the project has been very challenged in terms of data collection and data processing. This applies to both data on the cooling and heating side, as well as energy data. The data collection and data processing were in the project's first work package and resulted therefore in continuous changes in the schedule. These amendment requests have been regularly submitted to the EUDP Secretariat. Despite this, the important experiences gained during the project has been conveyed in articles and described in the COOKBOOK (for more information about the COOKBOOK please

see chapter 1.4 – "The COOKBOOK" and chapter 1.7 "Project conclusion and perspective"). Experience relates to the status of existing solutions, both regarding the technical design of the plants and the operation of the plants. Experience has been supplemented by analyses, which illuminate that the technical parameters are crucial for assessing the suitability of the supermarket for heat recovery and for designing the heat recovery for satisfactory operating economy, which is also contingent on dynamic set points that take into account the load of the plant. Many analyses also form the basis of the two very useful and user-friendly calculation models.

The risks

Following risks, has, in connection to the annual project report for July 2019, been described:

1. The data quality from the supermarkets is not of proper quality.
2. The remodelling is not carried out 100% regarding to the possibility of optimal operation on refrigeration systems and especially on the heating system.
3. The deliveries to, among other things, the COOKBOOK would be difficult to obtain.

Furthermore, the consequences as follows for the three above mention risk were described:

1. This may mean, that data analysis cannot be concluded within the project period and that a postponement may be necessary.
2. There is a lot of focus on the project, but if the rebuilding offers are too high, we can risk that COOP will not correct errors and deficiencies on the existing installations. In other words, we know the need on paper, which can be included in the COOKBOOK, but that the technical conversion in supermarkets is not necessarily 'Best case' examples and that the services realized therefore do not meet the objective.
3. In the extreme consequence, there may be sections in the COOKBOOK that are not fully described.

Finally, we described how we planned to deal with the identified risks:

1. In the future, the data will come from AK-Centralen, COOP, and from Danfoss. This, both the data concerning the cooling and heat system, and the energy meters. We expect the quality of data to be sufficiently high for data processing, to be provided. TI is, with input from KTH, responsible for this part.
2. There is ongoing dialogue on this with COOP through TI and ILK respectively.
3. The work package leader, The Danish District Heating Association, and CLEAN, are continuously working on getting input into the respective sections in the cookbook.

In particular, the first work package in the project was challenged by major delays, which resulted in the schedule not being followed. The data collection was thus very delayed, and in addition to this, the data received was of fluctuating quality for a long period. Therefore, it was necessary to correct this data collection. Specifically, this collection of data and its processing were only really solved as AK-Centralen together with Coop had a completely new system set up. Furthermore, Danfoss was challenged with their data, which was also important to access in connection with the analyses. The challenges of data collection and processing of this data meant that two out of three supermarkets were replaced during the project period.

The project has met challenges in getting the required data collection from the supermarkets and has therefore been delayed, which has also led to delays regarding the milestones in the project:

- M1; Final decision on technology for demo cases: This Milestone was achieved but with many delays. However, in the summer of 2019 all the technical solutions were in place for the three demo cases.
- M2; Tender specification late out: Milestone achieved despite delay. The contractual basis for the executives is in place.

- M3; Rebuild demo cases in normal operation: The milestone was postponed and therefore the remodelling of the last of the supermarkets was completed by the end of November 2019.

- M4; Final reporting and project closure: This milestone has not been changed and the project was completed as first assumed at the end of November 2019.

Commercial milestones:

- CM1; Final investment decision by COOP: The milestone was achieved despite delays, and Coop made a decision on the scale of investment.

- CM2; Project milestone with guidelines, templates and case stories was available for all stake-holders (The COOKBOOK): This milestone was moved due to several delays mentioned earlier. However, 26 of November 2019, an inspiring and well-concluded conference on the project was held, with approximately 40 participants. The conference was held at the Danish District Heating in Kolding. At the conference there was, among other things, a presentation of the COOKBOOK, as well as, of the two calculation models.

- CM3; All major stakeholders were informed of results and guidelines for roll out (Ref. CM2).

It was expected that the Super Supermarkets project would ensure around 1.000 retrofitted supermarkets in Denmark in a period of 3-5 years after the project end. Of course, depending on the regulative barriers and the conclusions of these. The annual heat generation for the district heating system was 200 MWh from each supermarket.

Furthermore, a Danish roll out will open for export of the technology solutions to the rest of Europe, North America and later also China according to the sales department at Danfoss. Partners in the project group have strong incentives to pursue the export potentials.

To reach this ambitious goal the Super Supermarkets project gathered a strong project group from day one. The project group has world-class knowledge of cooling and district heating systems, and the main business actors on supermarkets, cooling system, and district heating companies were represented throughout the project.

Unfortunately, some barriers are still being experienced, which are also addressed in the project. These include;

- lack of strategy for the green transition, which also has an impact on recycling surplus heat from supermarkets;

- out-of-date rules for investments in technical solutions for recycling of surplus heat,

- uncertainty about future conditions, including delayed conversion of inappropriate taxes and fees,

- being a heat producer is not a core activity for a supermarket (administrative difficulty), as well as doubts about ownership. COOP has both A and B stores, with different owner models,

- integration of the heating activity into the supermarket's primary activities; ▪ the geographical location of the supermarket in relation to the district heating system;

- uncertainty about supermarket consolidation and market positioning. The potentials are great when these barriers are cleared. Project Super Supermarkets and the cookbook have addressed these barriers.

Plants are already operative. Specific experiences from the establishment of these plants had emphasized the need of having the barriers removed and the processes from design to operation standardized.

The Potentials

The potential was much greater when processes become standardized. The total number of supermarkets in Denmark was approx. 2,684, all of which have cooling machines and thus the potential to become a heat supplier for i.e. district heating system. A plant will typically be able to supply around 200 MWh of heat a year.

In addition to this Danish potential, there are great potentials for exports of know-how, system and technology export to markets in Europe and the rest of the world, including both to North America and China. The projects group partners have strong incentives to pursue the potential in the export markets.

In other words, there are many good reasons for a much greater future utilization of the surplus heat from various sources. It could be either for internal reuse of surplus heat for space heating purposes or for external recycling where the surplus heat from the 'source' can be sold to a district heating company or other local buyer, e.g. another nearby business, or neighbouring stores in a centre. However, as mentioned in the COOKBOOK this kind of recycling was subject to taxes.

When looking at the climate issues, the energy supply, and the economy it makes no sense not to use the potentials. Hence, it is common sense to recycle the surplus heat, whether it comes from a supermarket or from other sources. Thus, presumed it is a well-thought out business case which, for each investment, turns out financially positive.

Parter	Case 1	Case 2	Case 3
Supermarked	SuperBrugsen, Kerteminde	SuperBrugsen, Bjerringbro	SuperBrugsen, Otterup
Fjernvarmeselskab	Kerteminde Forsyning	Gudenådalens Energiselskab	Fjernvarme Fyn
Anlægs-projektering	Danfoss	COOP	COOP/ILK

Table 1: Supermarkets and district heating companies in the project

The principles for recycling surplus heat

In a supermarket there is a need for cooling and freezing, to preserve the products in an adequate way. For many years, separate open refrigeration furniture, which either kept the items cooled at +5° C or frozen at -18 ° C was used. The new solutions include added cabinets with a door to limit the loss of cold to the store. Furthermore, there is often a central refrigerator in the back room today. The new cooling machine can also have CO2 as a propellant (not for emissions) and can thus be very efficient. The heat from the new cooling machines is supplied as 70 ºC of hot water, which can be reused immediately in the district heating system.

<u>The key elements are shown in the illustration below:</u>

Electric power supply for the chillers. From the chillers, cooling is delivered to the refrigeration counters in the shop. The heat from the chillers must go through the heat recovery unit to delivery to the district heating system. It all needs a control system right control and operating optimization.

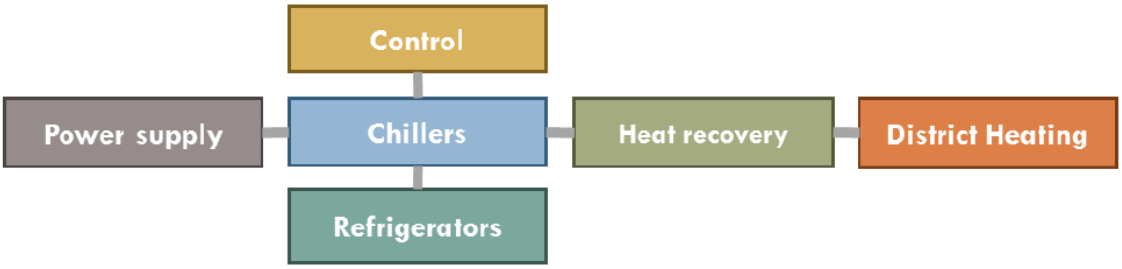


Figure 3: Elements of solutions of recycling of heat from the supermarket's refrigeration equipment for district heating purposes

The main focus and main activities are shown here once again but including a graphical illustration to each model. To assess, demonstrate and implement the full potential of utilizing surplus heat from supermarkets, there are several sub-goals from the project.

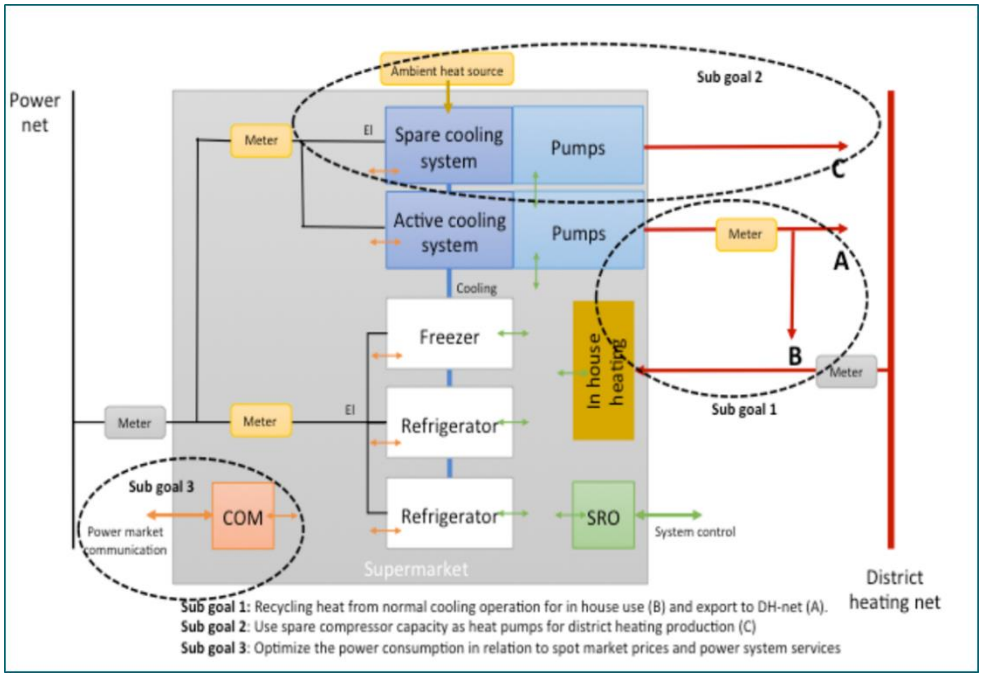


Figure 4: The figure 4 gives an overall view of possible solutions and sub-goals (models) for the recycling of surplus heat.

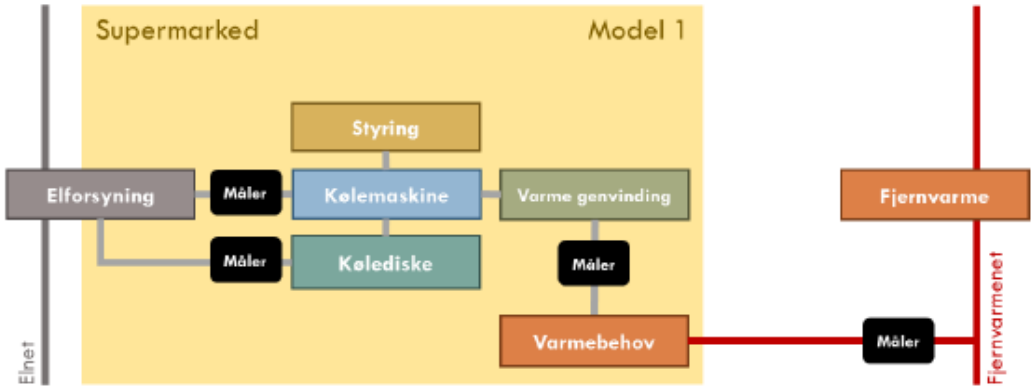


Figure 5: Illustration of model 1

MODEL 1: Simple solution in which the heat from the refrigerator is reused to the store's own need for space heating and hot water. There is no delivery to the district heating network. By contrast, the district heating network can supplement the store's heating needs in the winter. In order to document electricity consumption and heat recovery to authorities, several meters must be installed in the system.

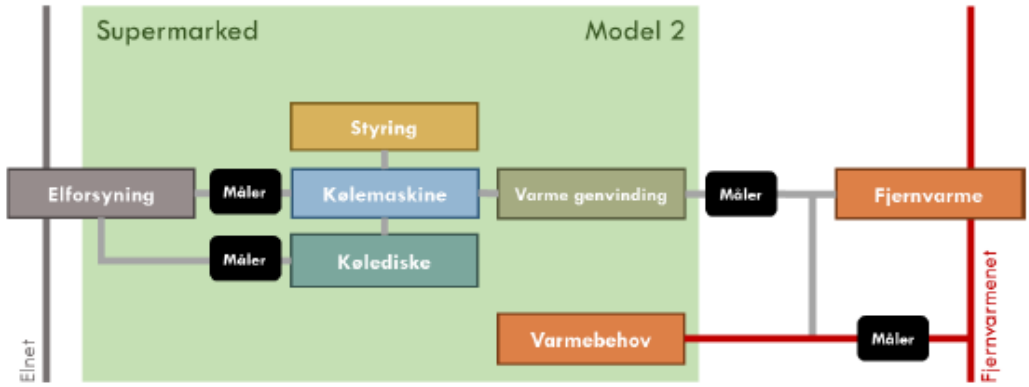


Figure 6: Illustration of model 2

MODEL 2: There is district heating supply to the supermarket to cover heating needs. There is still supply of heat from the refrigerator to the district heating system, but only the part of the heat production that cannot be used to meet the supermarkets own heating needs. Typically, the supermarket will then need to buy district heating in the winter and sell heat to the district heating system in the summer.

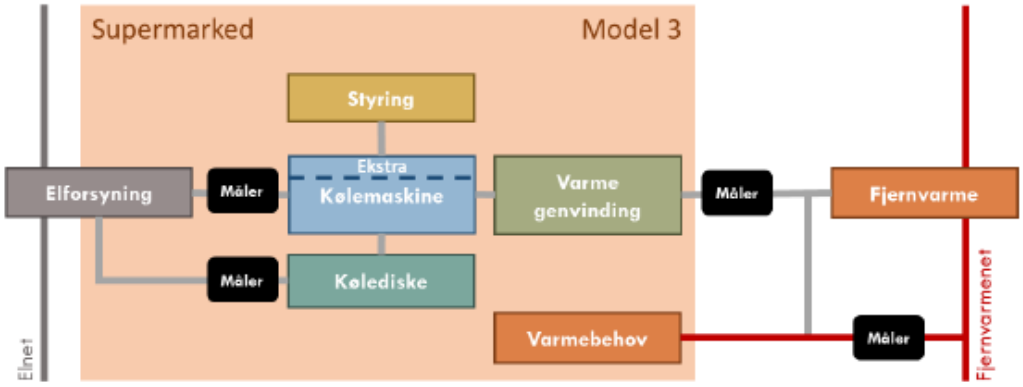


Figure 7: Illustration of model 3

MODEL 3: The chiller has extra compressor capacity that can act as a type of heat pump and supply extra heat to the district heating system during the periods of the year, when the cooling demand is not so great in the winter.

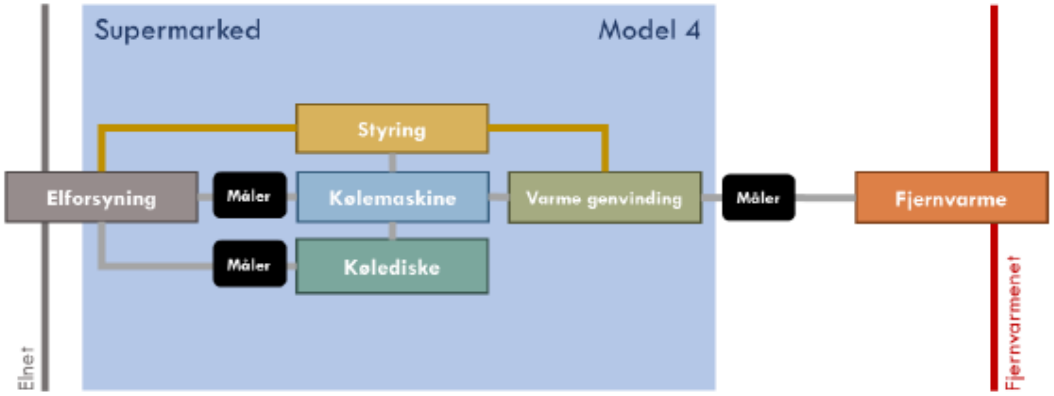


Figure 8: Illustration of model 4

MODEL 4: Optimizing the overall management of electricity consumption and heat sales; e.g. to utilize hours with lower electricity prices in the spot market Nord Pool Spot, or through a market player to sell the opportunity for up or down regulation of electricity consumption and thus participate in the balance market. Ultimately, the refrigeration system can also participate in the system services market. All of this requires more advanced controls, as well as collaboration with electricity traders and / or other market players in the effort to decarbonize.

This is the smart grid part of the project. Supermarket cooling systems are characterized by high power consumption and quite a long response time. In addition, there is a high additional standby capacity; therefore, suitable for flexible operation; also called Demand Response (DR). The project has investigated whether it is possible to sell system services, which has already been investigated on related systems, but not proven as a commercial concept in supermarkets.

In the set-up system, electricity consumption is logged to the cooling machine. Furthermore, there is a monitoring of the spot price of electricity, so that the capacity of the cooling machine can be utilized at the times when the electricity price in the spot market is lowest.

Focus areas in the project

There were several focus areas in the project;

- collecting, processing and analysing data from supermarkets,
- describe legislation, taxes and fees,
- identification of when the optimal conditions occur and what options are available for standardized solutions: The COOKBOOK will provide information about cheaper solutions,
- general dependence on the set of temperatures on the district heating (back and forth), as well as the amount of heat that is desired in relation to the immediate cooling load. The Coefficient of Performance, or efficiency, will typically be between 3 and 5, but may be lower,
- identification of when it is best to allow the cooling system to utilize extra capacity during the winter period for extra operation in hours with low electricity prices (high wind power),
- examine operating economies and what the price will be for generating heat sold to the district heating network,
- Investigate the most favourable conditions. Depends on several conditions, including what the district heating is accounted for in the local grid. Payback time will vary from place to place,
- business models, including analysis of tax scenarios: Already at the existing heat recovery plants, we can see that different operating strategies are used to manage the heat recovery due to different tax strategies,
- calculate the supermarkets' recycling potential with PackCalc. Pack Calculation Pro is a simulation tool for calculating and comparing the annual energy consumption for refrigeration systems and heat pumps.

Feasibility Studies

Eight supermarkets, in collaboration with their respective district heating plants, were invited to obtain a feasibility estimate so that they would subsequently have an economic basis for deciding whether to continue to optimize and rebuild their own CO2 plants. The feasibility calculations should serve, as an accelerator to promote the utilization of recycled heat and to establish heat recycling plants from the supermarket's own refrigeration system for recycling in the district heating system and of course internally in the supermarket. This, in combination with experiences for the three supermarkets participating in the project.

The purpose of the feasibility calculations was to give potential stakeholders the opportunity to get an 'estimate' of the possibilities of using the surplus heat locally from a specific supermarket in the immediate area. Thus, the overall intention was that many more people had the opportunity to know the potentials calculated with the developed calculation model developed in the project. Furthermore, if more plants are set up in the supermarkets, this will also lead to an increase in the number of heat pumps in the Danish district heating networks. In addition, it will improve the efficiency of supermarket refrigeration systems, and the feasibility calculations will help increase the demand side.

The calculation model is based on experience from the three installations in the supermarkets respectively. Bjerringbro, Otterup and Kerteminde. The overall purpose of using the calculation model is precisely - as the main purpose of the project - to ensure that good solutions come out for both the cold and the heat side.

The results of the eight feasibility estimates are available on www.supersupermarkets.dk for inspiration for other supermarkets and district heating networks.

Purpose of the feasibility calculation models

In the Super Supermarkets project, two calculation models have been developed for estimating the potential for heat recovery for each supermarket.

Calculation model #1 from CLEAN and TI

The purpose of the model is to make it easy for supermarkets across the country to get an estimate of the economy of heat recovery in their particular supermarket. The calculation model is not detailed enough for an actual investment basis, but can, on the other hand, form the basis for a decision to start a design work.

The profitability of heat recovery depends on some general framework conditions but to a great extent also on many local conditions such as the supermarket cooling system, current store heating system, district heating network supply temperatures and production units etc. It makes it difficult to see even for an experienced supermarket owner or district heating master whether is economical basis for heat recovery.

The developed model considers all these general and local conditions and can therefore provide an overview.

In general, there are the following input factors for the model calculation:

- Supermarket refrigeration system and load
- Supermarket heating system and heating needs
- District heating coupling and temperature levels
- Investments in heat recovery and district heating coupling
- Prices of existing heat source and sales to district heating
- Tax model and rates

Concepts for heat recovery

The calculation model covers three concepts of heat recovery.

Concept #1:

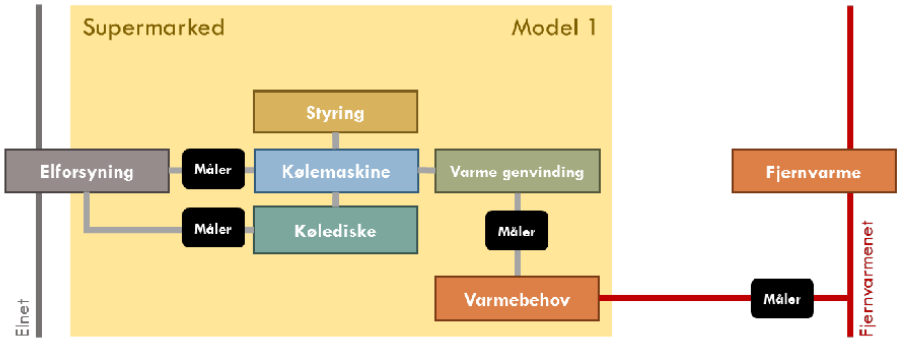


Figure 9: Illustration of Concept 1

In Concept 1 the supermarket produces enough heat to cover its own heat demand. There can be a coupling to the district heating net to level out some peaks in production or demand, but the nett sale/buy of heat is zero. The cooling circuit will often have to be operated with raised compressor pressure to deliver the needed quantity of heat.

Figure 10 shows EES calculations of the relationship between efficiency (COP_HR) of heat production and the quantity of heat produced. These efficiencies are used in the calculation model.

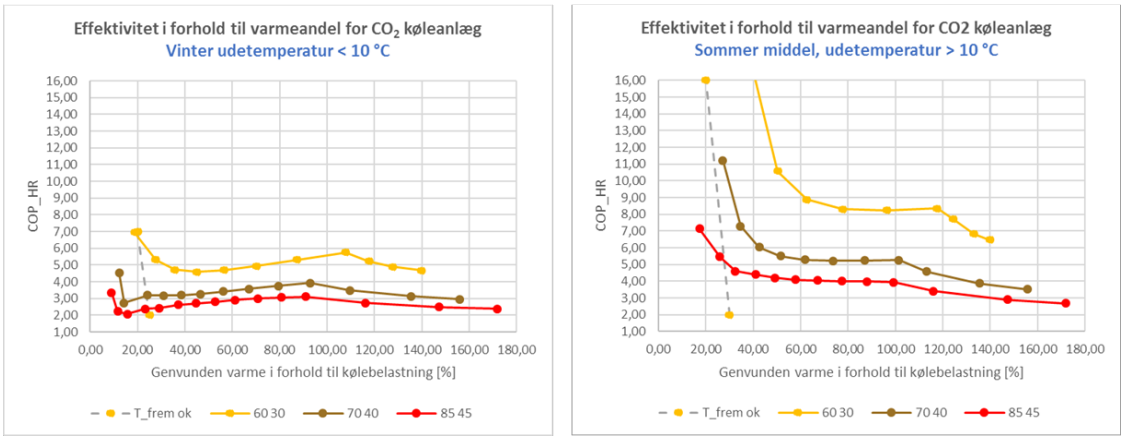


Figure 10: Relationship between efficiency of heat production COP_HR and heat output respectively. Winter and summer cases; core computation-forced operation.

Concept #2:

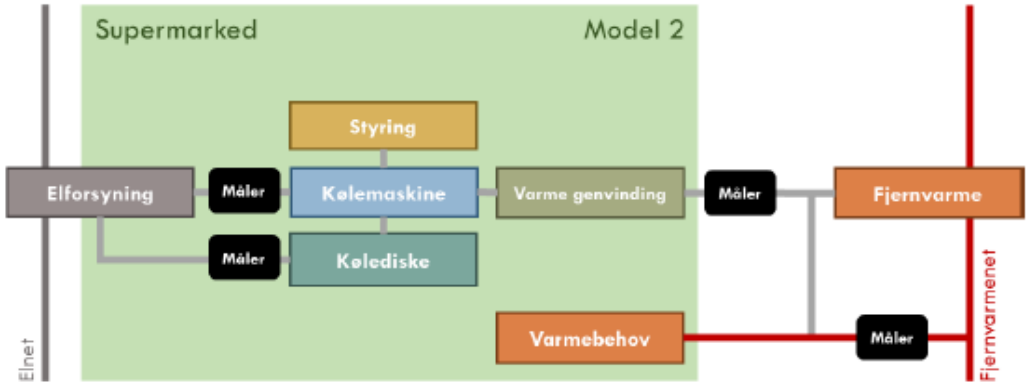


Figure 11: Illustration of Concept 2

In Concept 2, the supermarket is a nett producer of heat. It covers its own demand and sells heat to the district heating network. The extra heat is produced by raising the compressor pressure in the cooling circuit.

In concept 2, the quantity of produced heat is determined by the marginal COP of heat production. Figure 11 shows how the efficiency decline rapidly at a given heat production. This is the maximum heat production in Concept 2.

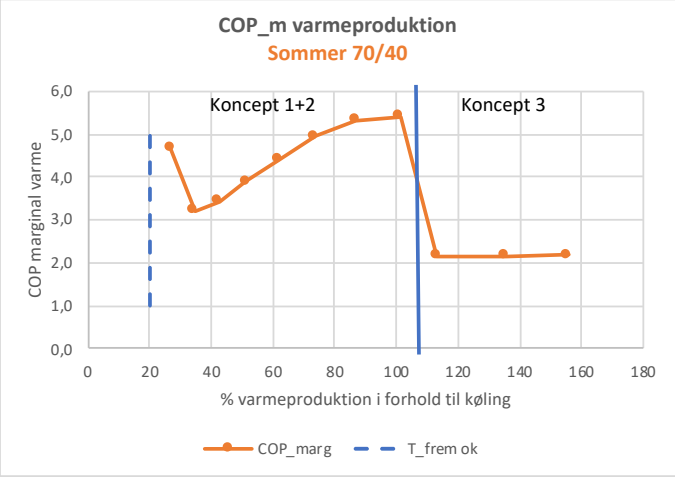


Figure 11: Concept 2: The supermarket sells heat up to the "crack"

Concept #3:

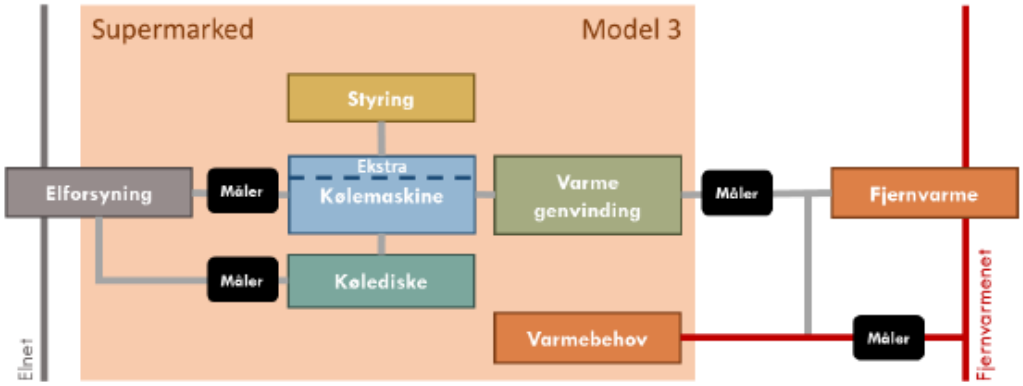


Figure 12: Illustration of Concept 3

In Concept 3 the extra compressor capacity in the cooling circuit is utilised for extra heat production compared to Concept 2. It is no more recovered heat, but actual heat production using the extra compressor capacity as heat pumps. The heat source is ambient air.

Figure 13 shows the efficiency of heat production when the cooling circuit is operated for maximum heat production (after the "crack").

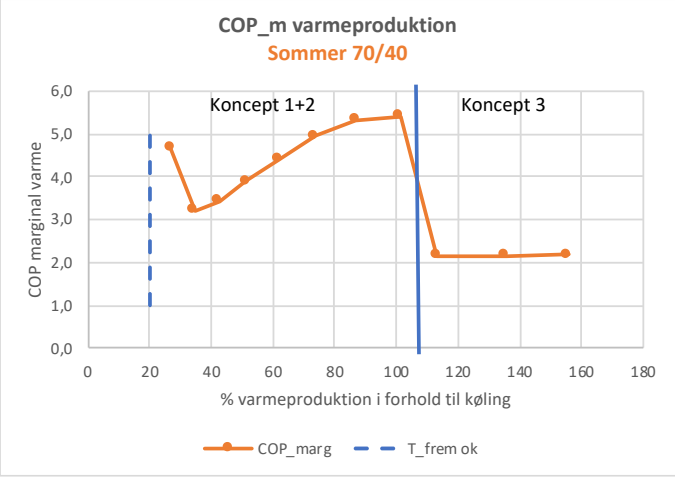


Figure 13: Concept 3: The supermarket sells heat after the "crack"

The calculation model will be available to all interested parties on the Super Supermarkets website: www.supersupermarkets.dk during the period 2020-2022 and can then be obtained by contacting CLEAN.

Calculation model #2 - Heat Recovery to District Heating Calculation tool- from KTH:

In this project, the potential of recovering heat from CO2 trans critical-booster systems in supermarkets and selling it to the district heating network (DHN) has been assessed. It must be said that a supermarket should always prioritize the space heating of the building. Then, if extra-heating capacity is available, heat could be sold to the DHN.

Field measurements of one supermarket have been utilized to build a case study. However, every installation is unique, and it is not possible to draw general conclusions only from one particular case. For this reason, at the KTH (Royal Institute of Technology, Stockholm) we have built a calculation tool which will enable researchers and technical personnel of supermarkets to evaluate the potential of selling heat to the district heating network. Table 2 gives information about the four scenarios simulated by the tool.

Floating Condensing mode	This scenario refers to a control strategy which satisfies only the cooling loads keeping the discharge pressure and gas cooler outlet as low as possible. The Space heating demand is completely satisfied by district heating. In summer waste heat is sold to the district heating network.
Space Heating Only	In this scenario, the control strategy optimizes discharge pressure and gas cooler outlet to satisfy the heating demand of the building. In case that the refrigeration system cannot satisfy the space heating demand, the heat is bought from the district heating network. In summer, the system is controlled in floating condensing mode and waste heat is sold to the district heating network.
Selling heat to the district heating	In this scenario, the pressure is controlled to the maximum allowed (set by the user) and the gas cooler can be set on bypass to recover as much heat as possible. In summer, the system is controlled in floating condensing mode and waste heat is sold to the district heating network.
Fixed settings (optional)	This optional scenario has been added to test some fixed conditions (either subcritical or trans critical). The inputs required are a fixed value for the discharge pressure and a fixed value for the gas cooler outlet-temperature.

Table 2: Scenarios Simulated in the Calculation Tool

The main aim of the tool is to help understanding if a certain supermarket can supply heat to the district heating network, in winter. This means that the tool calculates, for a given value of the outdoor temperature, the cost at which the supermarket can produce extra-heat and the amount of available capacity.

First of all, the user needs to choose between "Daily Calculations" and "Annual Simulations". The daily evaluation is meant to be used by the technical personnel of a supermarket. In this case, the output will give an estimation of the heat production cost for that day and available extra-heating capacity.

Additionally, the tool compares the expected daily energy expenditure for the scenarios mentioned in Table 1. The necessary inputs are the heating and cooling loads as well as the key parameters of the refrigeration systems. For example, some of these are maximum allowed pressure, evaporation temperatures, supply and return temperatures for the heating system and so forth. Advanced inputs such as approach temperatures in the heat exchangers, are set by default and they are based on rule-of-thumb and field measurements analysis. Anyway, the tool gives to the user the possibility to modify these advanced settings.

The annual simulation is adapted for more experienced users such as professionals or researchers. Cooling and heating loads need to be given as a function of the outdoor temperature. The data regarding the district heating network (e.g. prices and supply temperature) can be given as a function of the outdoor temperature or as fixed values. The calculation tool utilizes the BIN hours method to evaluate annual energy expenditure. This is given in the output together with the plots of the key parameters as functions of the outdoor temperature. The key parameters not only include heat production cost and available extra-heating capacity but also control parameters such as discharge pressure and gas cooler outlet-temperature.

The energy expenditures (daily or annual) takes into account both heat bought from district heating and electricity. Therefore, the economic parameters such as electricity price and heat price are necessary. Finally, since the Danish taxation on heat pumps is changing, the tool gives the possibility to the user to utilize a tax based on electricity or on heat. In case the selected taxation is based on heat, the user should input the value that needs to be multiplied for the amount of heat recovered.

In general, the tool has been designed to be as flexible as possible and to suggest values in case the users lack some of the input. The hope is to highlight the high energy-savings potential of heat recovery in CO2 refrigeration systems.

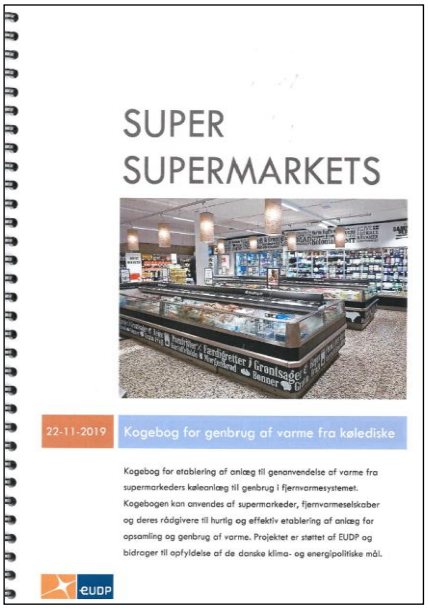
The COOKBOOK

During the project period a so-called COOKBOOK has been produced. The COOKBOOK contains a set of guidelines, technical data, and addresses supermarkets, district heating companies and their advisers and introduced then to an effective establishment of facilities for the collection and recycling of heat.

To assure a nationwide roll out and long term follow up on results both the COOKBOOK and an intensive targeted communication to all interest groups has been conducted.

The most important results from the Super Supermarkets project are gathered in the mentioned COOKBOOK, which includes:

1. Recommendations
2. Potentials
3. Analyses
4. Feasibility studies
5. Review of the electricity market
6. Calculation models
7. The technical solutions
8. Demonstrations
9. Permits and agreements (including agreements between partners and decision-making paths)
10. Economics and investment
11. Framework conditions; including taxes, law proposals, and administration of these
12. As well as information about the partners in the project and what each one contributed
13. Finally, a number of appendices



The cookbook produced in the project can help to spread the technology, not only in Denmark but also abroad. A review of the cookbook is shown in this report. The Cookbooks definition is: "Real or thought book where you can quickly and easily get an overview of the basics within a specific area". And the cookbook was one of the central deliveries from the project. The cookbook can be used by supermarkets, district heating companies, and their advisors to quickly and efficiently establish plants for the collection and recycling of heat.

1.5 Project results and dissemination of results

As described earlier were the main activities and objectives in the Super Supermarkets project based on four main stages:

1. Pre-studies and various technical survey definitions
2. Demonstration in existing supermarkets and in the three new supermarkets, incl. evaluation of demonstration results. The involved supermarkets and their respective district heating companies are:
    a. SuperBrugsen Kerteminde and Kerteminde Forsyning
    b. SuperBrugsen Bjerringbro and Gudenådalens Energiselskab
    c. SuperBrugsen Otterup and Fjernvarme Fyn
3. The production of a Cookbook, i.e. guidelines and intensive targeted communication to all interest groups to assure a nationwide roll out and long term follow up on results.
4. Two individual calculation models

The various results contained in work packages 1, 2 and 3 all formed the basis for the development of two very useful calculation models. In addition, the collection of data and the processing of this data from the invaded supermarkets were also very important in relation to being able to set up the two calculation models.

Below is a more detailed review of the two calculation models prepared - as mentioned earlier - by CLEAN and Ti and by KTH respectively.

To the questions: "Did the project succeed in realizing its objectives"? and the question "Did the project answer the problem stated in the project proposal which the funding has been based on?" As well as the question "Did the project produce results not expected?

In the project group we are very pleased with the success of the entire project. From day one, many have mentioned the project, and were expectant of the results. As we have described earlier in the annual reports, it has not been uncommon for many to have discussed the project regularly in assemblies. In general, the results are very promising. Here, special attention is paid to the use of the two calculation models, and not least the very useful cookbook.

In the project group, there is also agreement that the results of the entire project fully live up to the project application, although - as previously mentioned - unfortunately there have also been many delays in the project.

The project did not, as such, produce results that were not expected, but the project group has been extremely challenged on the given framework conditions, which has meant that COOP, Danfoss and Danish District Heating, in particular, have been in the press continuously to change these, to the benefit of the good potential opportunities that lie in using surplus heat also from supermarkets. So, all else being equal, the framework conditions have probably been the biggest challenge of the project and have led to several delays.

Best practise

Feasibility studies have been carried out as part of the project. In these studies, it was investigated whether it is technically and economically feasible for a supermarket to rebuild and optimize its own facilities, so that each supermarket and the respective heating plant could have a basis for deciding on weather or not to invest in equipment for recycling surplus heat and, of course, at the same time looking at the potential of operating the supermarket in question more flexible in relation to their electricity

consumption. In September 2014, an analysis from Aalborg University estimated that enough heat can be obtained from refrigeration equipment in the Danish supermarkets to heat 13,000 standard houses!

Typically, each supermarket will have compressor capacity of thermal 150 to 240 kW. From the larger plants, there will be an opportunity for annual heat supply of around 200-220 MWh. A standard house uses 18.1 MWh of heat a year. A supermarket can supply heat to 10-13 standard houses. With a potential of 2,500 supermarkets, heat will eventually be delivered to 25-30,000 standard houses. However, it is hardly realistic within a short number of years. It is estimated that there 3-5 years after this COOKBOOK is on the market, and the framework conditions are adjusted, will be about 1,000 supermarkets with heat supply. The analysis from Aalborg University with 13,000 standard houses is therefore not entirely beside the point.

It is still very difficult to say anything about the results of the project and if these have increased turnover, exports or employment. However, the project group has no doubt that the utilization of surplus heat from supermarkets can potentially be utilized internally in virtually all Danish supermarkets, and in a large proportion of supermarkets that are placed on the district heating network. But as mentioned earlier, and as stated in the cookbook, we are still very challenged on the Danish framework conditions. More about the framework conditions later in this report.

Dissemination:

The project has been disseminated at many occasions, including several events. A list of the dissemination is shown below:

On the Super Supermarkets website (http://supersupermarkets.dk/forside/genbrugsvarme/artikler) there are various links to research-related articles as well as press releases related to the project.

Research related articles:

- Operation Costs for Heat Recovery from Supermarkets to District Heating Grids. Christian Heerup, Danish Technological Institute, 2019
- Heat recovery from CO2 refrigeration system in supermarkets to district heating network – Lugas Raka Adrianto, Pierre-Alexandre Grandjean & Samer Sawalha, 2018
- State-of-the-art integrated CO2 refrigeration system for supermarkets: A comparative analysis – International Journal of Refrigeration, November, 2017
- Integration of the hidden refrigeration capacity as heat pump in smart energy systems – Torben Funder Kristensen, Lars Finn Sloth Larsen & Jan Eric Thorsen, 2016
- Supermarket refrigeration as an important smart grid appliance, Torben Funder-Kristensen, T. Green & P. Bjerg, 2015

Press Releases:

- CLEAN efterlyser otte supermarkeder og fjernvarmeværker – Energy Supply 4. november 2019
- Super Supermarkets – Udnyt overskudsvarmen fra supermarkedernes køle – og frostanlæg – Forsyninger i Danmark Varme, udgave 4, 21. juni 2019.
- Danfoss får grønt lys til stort projekt på Nordals – Jydskevestkysten, 6. februar 2019
- Danske supermarkeder skal levere til fjernvarmen – Energy Supply 10. oktober 2018
- Nye afgifter skal fremme dynamisk energiforbrug – Ingeniøren, 18. aug. 2017
- Coop sætter skarpt lys på energiforbruget – iEnergi, 6. november 2017

In addition, the website also contains a series of presentations related to recycling heat in supermarkets prepared by partners in the project.

Presentations from the closing conference November 26, 2019

- Velkomst – Jens Christian Nielsen, Dansk Fjernvarme
- Overblik over projektet – Super Supermarkets – Lotte Gramkow, CLEAN
- Overskudsvarme set med et supermarkets øjne – Peter Svendsen, COOP

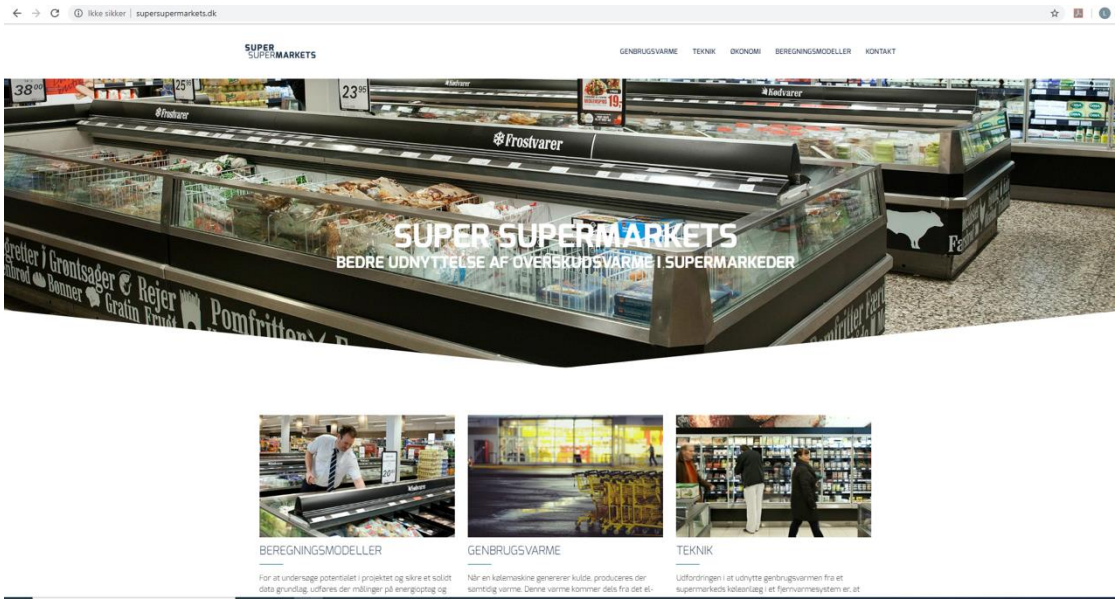
- Kogebogen – en gennemgang af optimal projektering af et anlæg – Kim Behnke, Dansk Fjernvarme
- Sådan bliver vi bedre! 2 eksempler med optimerings potentiale – Christian Heerup, TI
- Hvordan kan data samles op og bruges på en intelligent måde til at drifte anlæg? – Rasmus Gøttsch, AK-Centralen A/S
- Hvilke informationer skal projekterende være OBS på, når der projekteres anlæg fremadrettet? – Per Hougaard, Dansk Fjernvarmes Projektselskab
- Præsentation af ny dansk beregningsmodel for CO2 anlæg – Frank Iversen, CLEAN
- Flere løsninger i spil… Store potentialer rundt om i verden – Torben Funder-Kristensen, Danfoss A/S

Other presentations:

- De gode tekniske løsninger Overskudsvarme… (og kulde) – Torben Funder kristensen, Danfoss
- Super Supermarkets Benefitting from excess heat – Christian Heerup, Teknologisk Institut
- Præsentation om Super Supermarkets – Energidagen i Aalborg – Lotte Gramkow, CLEAN, 2019
- Super Supermarkets – Fjernvarmeproduktion fra køleanlæg i supermarkeder – Torben Funder Kristensen, Danfoss, 2019
- "Det 'komplicerede' afgiftssystem, som det ser ud i dag –og måske i morgen" – Claus Meineche, CLEAN
- The hidden refrigeration capacity in supermarkets – Lotte Gramkow, CLEAN, 2017
- Supermarkederne i nye energiperspektiver – Torben Funder Kristensen, Danfoss, 2016
- Supermarkets as an important smart grid application – Torben Funder Kristensen, Danfoss, 2015

Furthermore, a very important dissemination canal has of course been the actual COOKBOOK.

And not to mention information disseminated on the homepage; please see http://supersupermarkets.dk/



1.6 Utilization of project results

As we have heard in some of the above chapters, the potentials are great, when the described barriers are cleared, and the Super Supermarkets project has addressed the barriers and the potentials.

From the project partners, it is expected that in Denmark alone there is the potential to have more than 1,000 supermarkets supplied with the necessary equipment for recycling the excess heat. This is an

estimate for the next 3-5 years after the end of the project - and on condition that the barriers are relaxed or completely removed. Just these years, many supermarkets are getting new modern efficient refrigeration systems. It is obvious that the additional investments in the technical equipment for the supply of heat for reuse in the district heating system are made simultaneously. Alternatively, the supermarket will continue to cool the heat to the surrounding areas without any benefit, rather than becoming a supplier of heat for recycling in the district heating system.

Combining this with the key actor in retrofitting supermarkets for heat recovery to district heating and the largest supermarkets owner in Denmark, opens the road for both development of new integrated energy systems and big scale roll out of the technology.

The activities in the Super Supermarkets project were based on four main stages:

1. Pre-studies and various technical survey definitions
2. Demonstration in existing supermarkets and in the three new supermarkets, incl. evaluation of demonstration results. The involved supermarkets and their respective district heating companies are:
   - SuperBrugsen Kerteminde and Kerteminde Forsyning
   - SuperBrugsen Bjerringbro and Gudenådalens Energiselskab
   - SuperBrugsen Otterup and Fjernvarme Fyn
3. The production of a Cookbook, i.e. guidelines and intensive targeted communication to all interest groups to secure a nationwide roll out and long term follow up on results.
4. Two individual calculation models

The four-step approach above is important in getting the project disseminated to key interest groups. It is expected that the Super Supermarkets project will ensure some 1.000 retrofitted supermarkets in Denmark in a period of 3-5 years after the project ends. Of course, depending on the regulative barriers and the conclusions of these. The annual heat generation for the district heating system is 200 MWh from each supermarket.
Furthermore, a Danish roll out will open for export of the technology solutions to the rest of Europe, North America and later also China according to Danfoss sales department. Partners in the project group have strong incentives to pursue the export potentials.

It is expected that the project team will all utilize the results obtained in the project in various ways. Among other things, we hope that the framework conditions will be improved so that more attention can also be paid to the utilization of surplus heat, in the future. Promoting attention will be in the form of several installations such as, for example, Coop, Danfoss, Danish district heating, ILK and Ti are directly involved, as well as a greater dissemination of knowledge in the area, which several from the project group are already actively working on. Thus, the project results will also be used commercially

Initially, calculation models for this purpose for estimating the potential for heat recovery from supermarkets did not exist. As mentioned above, two calculation models have been developed. The calculation models are not detailed enough for an actual investment basis, but can, on the other hand easily, form the basis for a decision to start a design work.

Further the project team developed a so-called COOKBOOK. In this cookbook relevant information's are being distributed for enhancing innovative investments and projects in supermarkets, district heating companies, consulting engineers and suppliers. The Cookbook can be used by supermarkets, district heating companies and their advisers for the rapid and effective establishment of facilities for the collection and recycling of heat, and intensive targeted communication to all interest groups to secure a nationwide – and European wide roll out and long term follow up on results.

For further information, please see the project homepage at: http://supersupermarkets.dk

The main results of the Super Supermarkets project relevant to the cookbook are as follows:

- The potential to deliver fuel-free heat from supermarkets to the district heating system is present.
- The two parties, the supermarket and the district heating plant, would like to enter into agreements.
- Administrative rules are essential legends for appropriate solutions.
- The economy is challenged when tax rules require special taxes on heat that are otherwise diverted.
- Supermarkets' facilities can also be used as balancing of the electricity system by aggregation.

- Supermarkets can supply peak loads to the district heating system, just in winter.
- Reuse and supply of heat contribute to the energy climate policy goals.

The COOKBOOK produced in the project can help to spread the technology, not only in Denmark but also abroad. A review of the cookbook is shown in this report. The COOKBOOKs definition is: "Real or thought book where you can quickly and easily get an overview of the basics within a specific area". And the cookbook was one of the central deliveries from the project. The cookbook can be used by supermarkets, district heating companies, and their advisors to quickly and efficiently establish plants for the collection and recycling of heat.

From the Super Supermarkets project, there are several recommendations for advisors, supermarket chains and district heating companies, when establishing cooperation and investing in plants, which makes it possible to reuse the heat from the cooling machines for other heating purposes.

Supermarket

1. Calculate the potential of the store's (CO2) refrigeration plant, especially for new investments and modernizations.
2. Cooling and heating systems must be optimized for lower energy consumption, which makes a great financial contribution.
3. Reuse of the heat for own room heating and domestic water, and less heat purchase.
4. Agreement with the district heating company on a possible "net scheme" or direct supply of heat.
5. Investigate the possibility with electricity traders on optimization in the electricity market of electricity consumption.
6. Documentation of operating conditions through measurements and records.

District heating company

1. Visit supermarkets in the supply area to start a dialogue on heat recycling.
2. Check connection conditions. Is the supermarket already a district heating customer?
3. Preparation of an expected annual delivery profile. Is a "net scheme" an option?
4. Calculation of the price it is possible to pay for delivered recycled heating for district heating.
5. Design of connection plants, and determination of ownership limit.
6. Contract with the supermarket for the supply of heat.
7. Continuous evaluation and dialogue on optimization of heat supply e.g. time-shifted operation.

The authorities

1. Decrease limit for recycling plants of 250 - 500 kW heating power.
2. Small installations below the trifle limit must not be managed according to the Heat Supply Act.
3. Installations below the trifle limit shall not pay surplus heat tax.
4. Supermarket and district heating company must be able to agree on owner boundaries according to local conditions.
5. Investments in the extra heat recovery equipment must be possible to pay interest.

It goes without saying that the project team has not only prepared a very elaborate cookbook and created two comprehensive calculation models without these also having to be used commercially in the future. The market potential is very large. Not only in Denmark, but also in Europe, and yes, in the rest of the world. Cooling systems are located everywhere, and with the technical solutions that exist today, including the plug-and-play solutions, it is obvious to the entire project group that the distribution is spread - both of the results and of the specific outputs that have been in the project.
There have been no patents in the project, which was not expected either.

It is important to emphasize that agreements on the supply of heat from supermarket recycling to the district heating network are often a modest amount. The quantity often corresponds to the annual consumption of 15-20 standard houses (250-360 MWh). Therefore, the heat from the supermarkets comes as a supplement. However, it is the climate-friendly choice and local fuel-free heat.
Solutions and well-functioning agreements already exist. Often, the supermarket and district heating company agree on agreements based on local conditions. Unfortunately, the authorities' approach is to perceive these small heat deliveries as being actual heat production with the resulting administrative requirements and tax payment. Broad dissemination therefore requires political and administrative goodwill.

The potential for supply of heat, flexible electricity consumption and other energy services from cooling in supermarkets has several dimensions.

1. Simple heat delivery from refrigeration systems to district heating or other room heating.
2. Use of unused cooling capacity in winter for extra heat delivery.
3. Participation with flexible electricity consumption from the cooling machines opens the possibility of optimizing electricity consumption in the spot market for electricity trading, also called Demand Response.
4. Participation with MW capacity in the balance market and delivery of system services to the power system requires aggregation and cooperation with the balance manager.

Facts about heat supply
A standard house uses 18.1 MWh of heat a year for room heating and domestic water. A typical supermarket has refrigeration equipment that with heat recovery can deliver power of 150-240 kW of heat. On an annual basis, 200-220 MWh of heat can be supplied, or the equivalent of 10-13 standard houses' annual heating needs. It's about. 2,700 supermarkets with refrigerators and the possibility of heat recovery. Within 3-5 years, and with the right framework conditions, heat will be available from around 1,000 supermarkets. The potential for heat supply is up to 230 GWh or 13,000 standard houses within 5 years.

This potential applies to Denmark, and when viewed in a neighbouring country such as Germany, it can be increased proportionally in relation to the population. If the scale is further scaled up to the rest of Europe or the world, the picture is the same.

The number of supermarkets in Denmark is approx. 2700. As a starting point, the partner group believes that all stores can carry out internal heat recovery. In addition, it is estimated that around 75% of the supermarkets are expected to be able to participate in the utilization of flexible electricity consumption (DR).
Between 1,000 supermarkets are expected to be able to supply energy to district heating over the next 3-5 years, depending on where it is technically and economically relevant, around 230 GWh.

The 2,684 supermarkets in Denmark have an installed thermal capacity of heat pumps / cooling systems of approx. 400 MW. In average annual operations, only 30% of capacity is used. The capacity used is low when the ambient temperature is low, which means that, on average, up to 250 MW, and even more during the heating season, thermal cooling / heat pump capacity is present - which is unused.
The cooling capacity of the thermal 400 MW can supply 390 MW of district heating. This extra capacity has the potential of decentralized district heating production when the spot price of electricity is low - with significantly lower investment costs than when installing new heat pumps. The potential for collaboration between the local supermarket and the local district heating companies is significant, as there are around 400 Danish district heating companies located throughout the country.

Utilization of recycled heat from cooling systems is not new, but the technology must be optimized, and standardization must be implemented in a majority of Danish supermarkets.
Heat recovery for district heating has been carried out in a small number of supermarkets, but the area is growing. The project will help ensure a faster rollout with a well-described technology. A Danish rollout of the technologies will also open the export of technological solutions to the rest of the world.

So, from being companies that simply emit heat to the already paid environment, supermarkets are turning into efficient recyclable heat collectors that can be used for district heating.
The potential abroad to also reuse heat from supermarkets' cooling systems for district heating is, of course, present in the areas where the district heating network is available.

Denmark is with 65% among the handful of countries where district heating has a distribution of more than 60% for properties. However, heat from supermarkets can also be reused in smaller plants. These may be storeys near the supermarket and with water-based heating systems. It may be in shopping centres where other stores, traders or businesses with heat requirements can obtain a solution with recycling of heat from the supermarket.

1.7 Project conclusion and perspective

The conclusion of the Super Supermarkets project is that it has been a successful project, understood that the project has delivered what was stated in the application to the EUDP back in 2016. In fact, the project has produced two complete calculation models, which allows users to choose which model of the two they feel they can best work with.

The ambitious political goals about energy- and climate changes towards 2030 with a 70% reduction of CO2 emissions for Denmark, compared to 1990 emission will require all technical and economical feasible contribution to be activated. From the energy sector it is possible to reduce CO2 emission using three major elements.

1. Energy efficiency – less energy consumption for the same task
2. Energy generation from sustainable energy sources with low or no emission of greenhouse gasses (CO2 and CO2 equivalents)
3. Sector coupling, where surplus of energy in one process will be recycled in another pro-cess – energy will solve more tasks

The Super Supermarkets project has focused on all three contributions. Supermarkets are replacing their refrigeration equipment with new efficient machines with lower energy consumption. Electricity consumption is increasingly coming from renewable electricity generation. The cooling machines have heat as a by-product that can be recycled and reused in the district heating system. Therefore, the project fully meets the energy requirements in Denmark.

In the relatively large cookbook, the following are dealt with:

14. Recommendations
15. Potentials
16. Analyses
17. Feasibility studies
18. Review of the electricity market
19. Calculation models
20. The technical solutions
21. Demonstrations
22. Permits and agreements (including agreements between partners and decision-making paths)
23. Economics and investment
24. Framework conditions; including taxes, law proposals, and administration of these
25. As well as information about the partners in the project and what each one contributed
26. Finally, a number of appendices

The project groups are convinced that we will look much more at the utilization of surplus heat in the future. It is an ambitious goal that has been set, and this means that every opportunity must be at stake to reach the goal. It is important once again to point out that the technical solutions are present, so it is really more about getting the framework conditions to go hand-in-hand with these, so that in the future we will be able to see utilization of excess heat from large seen all supermarkets for either internal use, and the next step for utilization in a local district heating network.

Already, it will give good remembrance that the Danish know-how in this area is being disseminated to our neighbouring countries and generally to Europe, which the project team will work on together in the future.

All materials will be on www.supermarkets.dk for 3 years.

Thanks to the EUDP:
The project team would like to say a big thank you to the EUDP - Energy Technology Development and Demonstration Program - which has supported the project with DKK 2,881,072 (total expenditure DKK 4,908,075).

Annex

Relevant links

We have included the following in the annex section:

Annex 1	The Cookbook called "Kogebog for genbrug af varme fra kølediske"
Annex 2	Information input to Calculation model #1 from CLEAN and TI
Annex 3	Information input to Calculation model #2 - Heat Recovery to District Heating Calculation tool- from KTH
Annex 4	De 8 stk. beregningsmodeller og cases