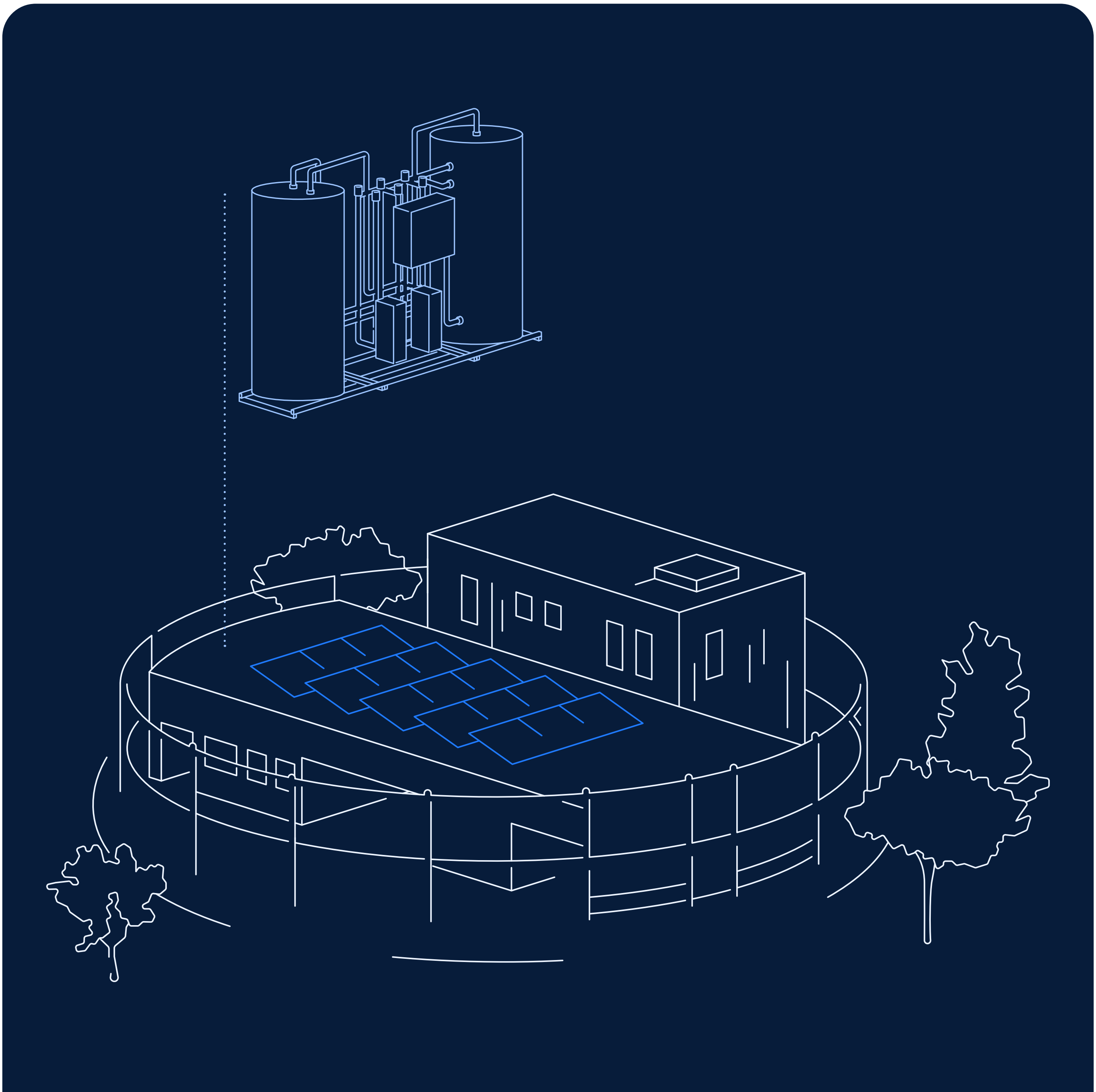
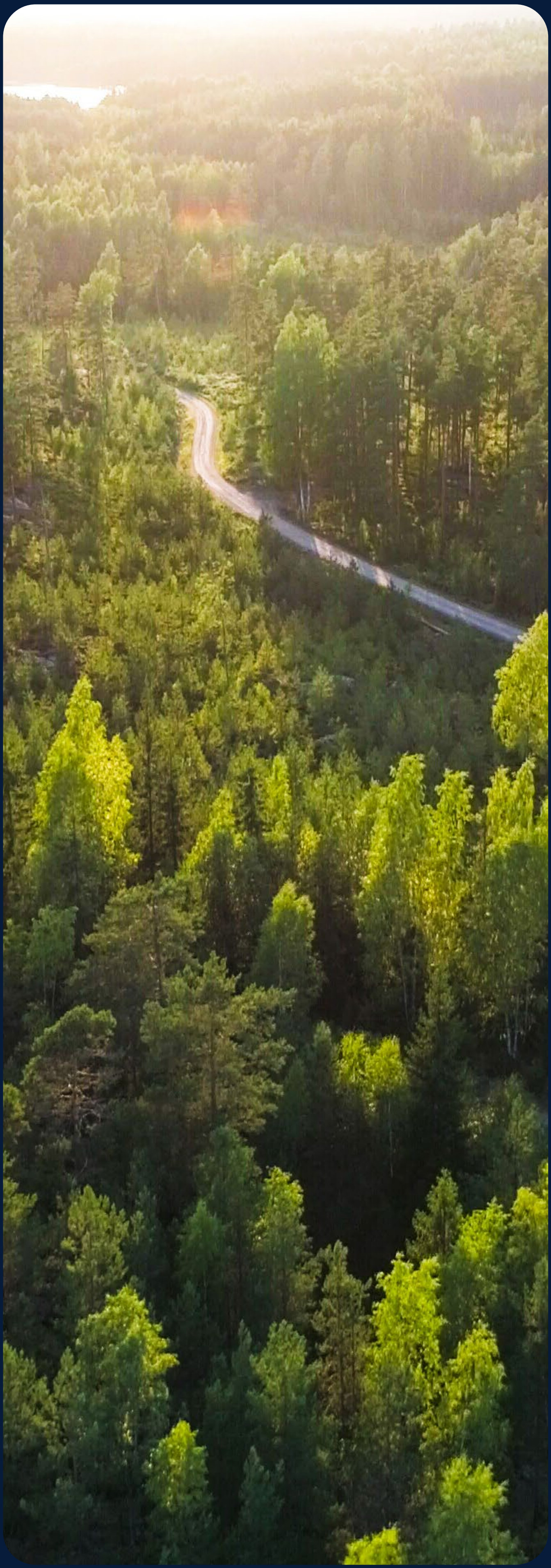
Avoided Emissions
Smart Store case study

Unlocking CO_2 emission savings in modern supermarkets



Executive Summary



Based on the wide Danfoss product portfolio and extensive application know-how, the Danfoss Smart Store in Nordborg, Denmark, demonstrates real-life achievements of integrating systems for refrigeration, heating, air-conditioning, and ventilation in an otherwise normal food retail store. It also showcases the benefits of using low-carbon electricity, and refrigerants with low Global Warming Potential (GWP).

The Danfoss Smart Store features a CO_2-based refrigeration system. Compared to a CO_2-based reference store of similar size and type in Denmark, this case study shows emission savings of 39 %. This equals Avoided Emissions of 90.7 tonCO_2e over the 15-year lifetime of the refrigeration system. Compared to an HFC-based reference store, the emissions savings are 68 % which equals Avoided Emissions of 302.8 tonCO_2e.

The main operational contributions to the **Avoided Emissions come from heat recovery and from the use of the store's 100 kW photovoltaic panel array**. During the case study period of 2024 the Danfoss Smart Store has been fully self-sufficient with heat and has additionally been able to provide 21.5 MWh of electricity and 23 MWh of heat to the grid making it available to local consumers. For the HFC-based reference store the main contribution is the high GWP of the refrigerant itself.

The Danfoss Smart Store in Nordborg is built in connection with an Application Development Center, which enables Danfoss engineers to test solutions and further optimize system integration and performance. Even now the benefits of the Danfoss Smart Store concept are clear, but the future potential is substantial, and the journey has just begun.

Avoided emissions

Avoided emissions refer to emissions savings achieved by customers by using a product or solution compared to a reference scenario. Avoided emissions represent the difference between the two scenarios where:

+ A reference scenario is considered without the implementation of a specific product or solution utilizing emissions reduction technology

+ The new scenario follows the implementation of such a product or solution by the customer

Avoided emissions occur outside of our products' value chain, thereby they do not contribute to our own CO_2 emission accounting. However, our customers can realize benefits through the implementation of our products and solutions. These benefits are captured through direct installation in their facilities, resulting in operational emission savings, or through the integration of our products into their own offerings. The latter thus directly contributes to the reduction of our customers' Scope 3 emissions.

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Avoided GHG emissions, Danfoss Smart Store, verification
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Verified case:
Potentially avoided emissions from using a Danfoss Smart Store. A Danfoss Smart Store is a supermarket concept for optimizing refrigeration, heating and energy supply for a typical supermarket. Emissions from a Smart Store are compared with two reference scenarios that represent the market average in Denmark.

Conclusion:
The calculations of avoided GHG emissions for the Danfoss Smart Store case were in general found to not be overestimated and the relevant requirements of the WBCSD guidelines are fulfilled to the extent this is currently possible given the availability of information related to the reference scenarios. This case is not for one specific product, but rather at a system level, which implies a relatively high degree of complexity and accompanying uncertainties.

The observed potential inconsistencies w.r.t. upstream and downstream emissions are of limited significance, but if better data becomes available, then the conclusion of the avoided emissions calculations should be reassessed accordingly.

In line with the purpose, the results, and thus the scale of avoided emissions, cannot be transferred to other systems and does not represent savings that can be achieved in any other specific cases other than the one described.

Date of verification:
19.12.2025

Table of Contents

01 Introduction

1.1 Danfoss Smart Store is our take on how a supermarket should work

Figure 1: Danfoss Smart Store layout with store and ADC

On 29th June, 2023 the Danfoss Smart Store opened to the public for the first time. A seemingly normal supermarket with customers doing their normal grocery shopping, and display cabinet and freezer doors being opened hundreds of times a day. Refrigeration, air conditioning, ventilation, and heating systems running around the clock year after year. It is all of that, but also so much more.

Although the Danfoss Smart Store is both DGNB Silver and LEED Gold certified, the building itself is quite standard. It uses standard materials and normal building practices just like any other new Danish stores of this type and size. This means that it can be used directly as a template for this type and size of supermarket. Apart from the large panoramic windows inside the store providing the shoppers with a direct view into the beating heart of the compressor room, the store looks like, feels like, and is like any other grocery store thus showcasing that the technology and know-how to get more out of our limited resources is already here.

Looking a bit closer, it becomes clear that the store is also something special. On the roof a 100 kW array of photovoltaic panels is providing a very significant amount of low-carbon electricity to be used by the store and also enabling the store to sell electricity back to the grid in periods with abundant solar power.

When cooling the foodstuff, heat is released from the back of the display cabinets and freezers as well as through the refrigeration line. The Danfoss Smart Store is equipped with heat recovery technology to collect the energy, store it, and use it for comfort heating or for selling to the local district heating network.

Excess heat is generally one of the largest untapped sources of energy. At European level the amount of 2860 tWh almost equals that of the total need for heating and hot water in the residential and service sectors[1]. Danfoss provides skills, technologies, and solutions that can help tap into this vast resource and make it available to users. The Smart Store demonstrates how, by keeping food fresh at the same time as contributing to warming homes.

A ground loop is also available as heating source if additional heat is needed on very cold days.

What also makes the Danfoss Smart Store in Nordborg unique (Figure 1) is the integration between a supermarket and an Application Development Center (ADC). The ADC has two main purposes:

01

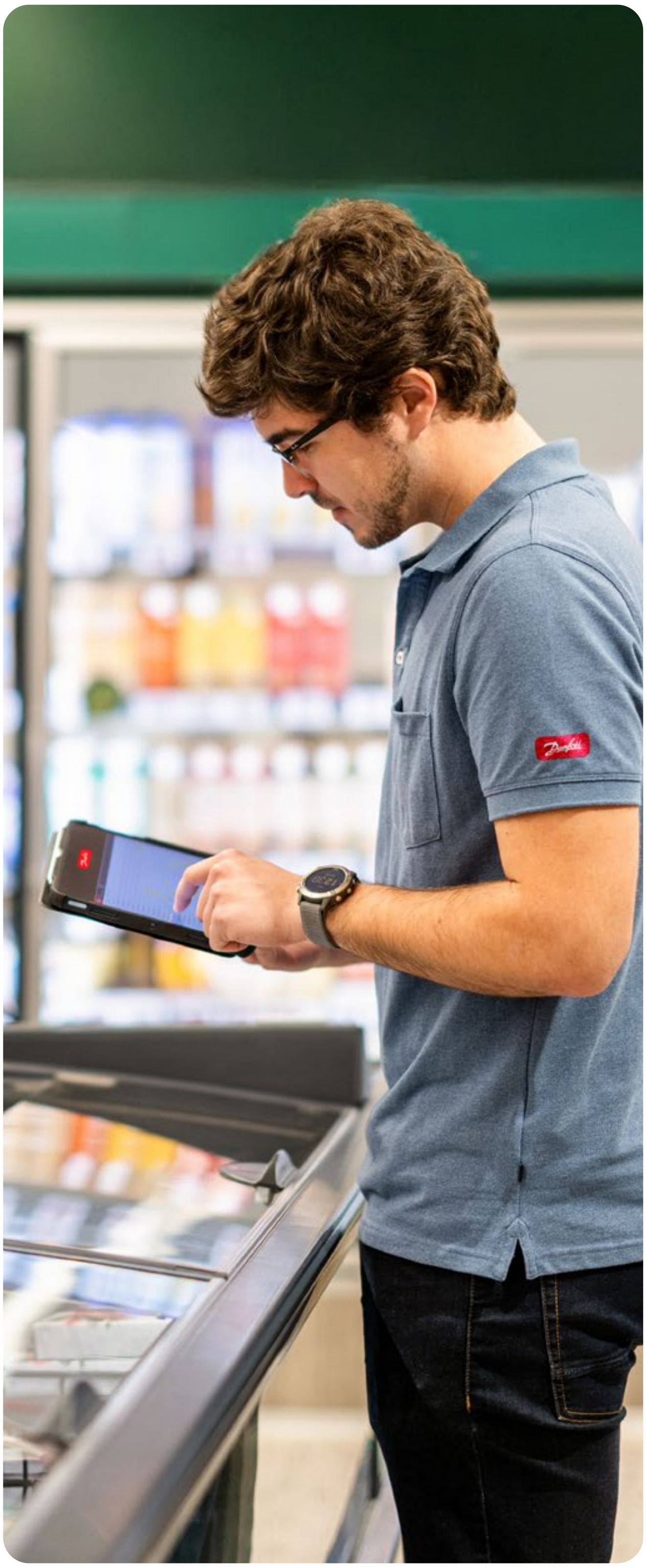
Provide

the necessary refrigeration, heating, air conditioning, and ventilation for running the store (this is the focus of this case study)

02

Function

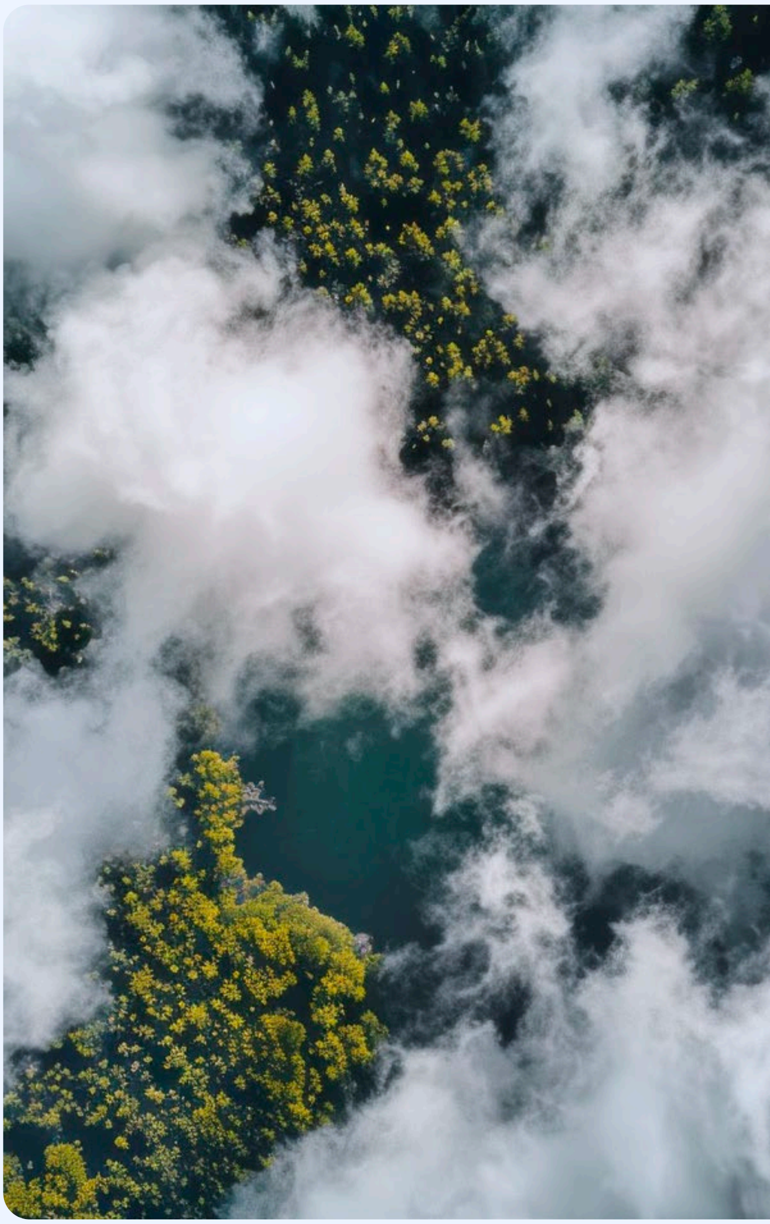
as a real-world testing facility based on the wide portfolio of Danfoss components. This enables customers and Danfoss engineers to develop new technologies and optimize solutions to enhance energy and operational efficiency in food retail



The store's refrigeration system is designed for CO_2. Besides being a natural refrigerant and one that is commonly used for energy efficient systems also in warmer climate zones CO_2 poses the benefit of having a very low Global Warming Potential (GWP) compared to traditional HFCs.

02 Scoping, reference solution and eligibility

2.1 Scoping and reference of case study



Danfoss is a component supplier providing a wide range of products for refrigeration systems, air conditioning, heating, ventilation and other applications. As such the scope of an avoided emissions claim would be specifically on component level and in a typical application. However, with the Danfoss Smart Store this has been elevated to a wider boundary[17] demonstrating how system integration and application of multiple solutions within the same store can provide a host of decarbonization opportunities. Even though this case study does mention the impact of specific solutions provided by Danfoss such as the use of the Heat Recovery Unit the goal of the study is not to establish the ability to claim avoided emissions for all the individual components used in the store. The intention is rather to demonstrate the current performance and future potential of the store as a whole and to highlight overall factors influencing the avoided emissions.

The results are therefore specifically for the Danfoss Smart Store in Nordborg, Denmark, compared to the reference scenario and must as such be scaled to other locations, store types and sizes, climate conditions and other location specific context if the concept is applied elsewhere. Such specific and individual scaling is outside the scope of this case study, but the study does provide general considerations assessing some of the potential as inspiration for what to investigate further in other use cases.

The main purpose of this study is to investigate the impact of utilizing a Smart Store configuration when building a standard new store of similar type and size or secondarily of installing a new refrigeration system when upgrading a store with old worn-out equipment. As illustrated in Figure 2 when applying the World Business Council for Sustainable Development (WBCSD) process[17] this means that the reference solution should be the "average solution for the same kind of improvement or the continued use of existing solution".

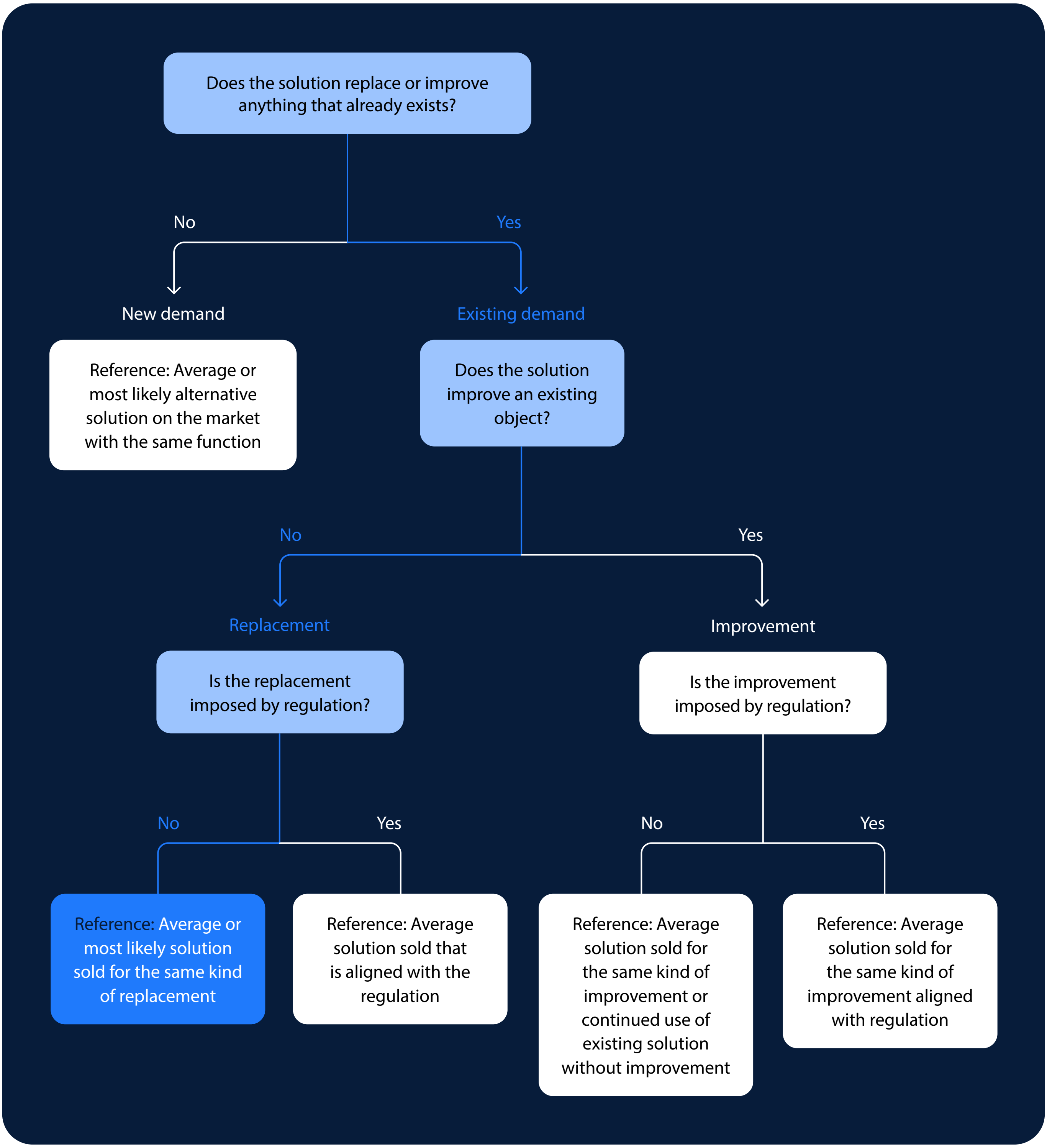


Figure 2: Identifying reference solutions[17]

Currently a reference new store of this type and size in Denmark would be using CO_2 as refrigerant and a standardized refrigeration pack optimized for CO_2[2,9,16].

When refurbishing an existing HFC based store there are two options: either switching to a CO_2 system or replacing the old worn-out HFC based system with a new HFC based system. Initiatives such as Europe's F-gas regulation and the Montreal Protocol Kigali amendment are driving the transition towards refrigerants with lower GWP so a second reference scenario is therefore specified to use HFC as refrigerant (e.g. R404A) and a new, standardized refrigeration pack optimized for HFC.

The expected lifetime of such refrigeration systems is 15 years[9,16]. A typical store is refurbished every 7-8 years and a refrigeration system is expected to last two such cycles before decommissioned[9,16]. A summary comparing the Danfoss Smart Store with these two scenarios can be seen in Table 1.

Danfoss Smart Store System configuration	Reference CO_2 based store System configuration	Reference HFC based store System configuration
Standard size for this type of supermarket in Denmark	Same size and store type as Danfoss Smart Store	Same size and store type as Danfoss Smart Store
Location: Denmark	Location: Denmark	Location: Denmark
CO_2 as refrigerant	CO_2 as refrigerant	HFC as refrigerant (e.g. R404A)
Standard refrigeration pack optimized for CO_2	Standard refrigeration pack optimized for CO_2	Standard refrigeration pack optimized for HFC
System lifetime: 15 years	System lifetime: 15 years	System lifetime: 15 years
Advanced refrigeration pack		
Heat Recovery Unit (HRU)		
Ground loop		
Photovoltaic panels		
Ability to transfer energy to power grid and district heating grid		

Table 1: Scope and reference scenarios

2.2
Eligibility and Danfoss' Commitment in Climate

In July 2025, the World Business Council for Sustainable Development (WBCSD) published its latest version of "Guidance on Avoided Emissions: Helping Business Drive Innovations and Scale Solutions Towards Net Zero"[17], to support solution providers willing to make credible claims on the environmental performance of their products. Danfoss welcomes this important contribution to ensuring robust environmental claims, providing decision-makers with tools and information to select the most impactful solutions supporting a global sustainability transition. This avoided emissions case study uses the WBCSD approach.

The first gate within the WBCSD methodology is company related "Climate action credibility". At Danfoss this is addressed through our strategic initiatives to become the preferred partner in helping customers decarbonize, and a strong foundation has been built for achieving the targets.

In January 2020, Danfoss took a significant step toward contributing to the goals of the Paris Agreement by committing to set science-based targets. The emission reduction targets were validated and approved by the Science Based Targets initiative in May 2022 and updated in February 2026. Danfoss is committed to reduce 90% of absolute scope 1 and 2 GHG emissions by 2035 from a 2024 base year and reduce scope 3 GHG emissions 66.33% per EUR value added within the same timeframe.

Gates two and three of the WBCSD methodology are solution related. Gate two, "Latest climate science alignment", is addressed by applying the general Danfoss sustainability approach of "Reduce" the energy need, "Reuse" energy to its full extend, and "Resource" to renewable energy sources. Danfoss applies this approach across own operations, targeting carbon neutrality of all sites by 2030. For the Danfoss Smart Store this is implemented through technologies such as integrated systems, electrification, heat recovery, and CO_2 as low carbon refrigerant.

The third WBCSD gate is "Contribution legitimacy". As recommended by the WBCSD, avoided emissions potential within this study are estimated using a conservative and full lifecycle based approach on the system considered.

03
Methodology and Assumption

3.1
The Danfoss Smart Store refrigeration system is also used for developing new solutions

As described in section 2, "Scoping, reference solution and eligibility", a typical store with a new CO_2 based refrigeration system is normally equipped with a standardized refrigeration pack optimized for the type, size and climate zone of the store[2,9,16]. The specific Danfoss Smart Store in Nordborg has a dual purpose of an ADC providing application design facilities as well as being a normal supermarket. This will not be a general feature if applying the Smart Store concept elsewhere, but it is important to keep in mind in order to understand the assumptions of this study and why this means that the power consumption estimates are considered conservative. Due to the ADC integration the store features two different refrigeration packs:

Standard pack

The configuration of this pack is identical to general market packs optimized for this type and size of CO_2 based stores and it is therefore expected to currently be the most energy efficient of the two packs. If a Smart Store was to be built by others then it would also be equipped with a standard pack. In the data collection period, the standard pack has mainly been used as backup to the advanced pack.

Standard refrigeration pack

→ Advanced refrigeration pack

Advanced pack

Apart from being able to provide the necessary cooling capacity for the store, the advanced pack has the main purpose of testing Danfoss components and solutions for a wide range of different use conditions and store sizes, some of which are significantly bigger than the Danfoss Smart Store. To do so, the advanced pack is somewhat over-dimensioned compared to the typical needs of a relatively small store like the Danfoss Smart Store and is therefore expected to have a different and most likely higher energy consumption than when running with a standard pack such as in the reference store. Due to the limited time the Danfoss Smart Store has been in operation, the data needed for assessing such impacts in either direction is not yet available.

The measured energy consumption in this study covers the calendar year of 2024 for the operation of the advanced pack. With an energy consumption of the advanced pack expected to be somewhat higher than that of a standard pack this means that the avoided emissions are expected to be conservative compared to the optimized standard pack. The period from store opening in mid-2023 to end 2023 is not included as it is assessed to be influenced by run-in of the systems hence not being representative for the actual normal operation.

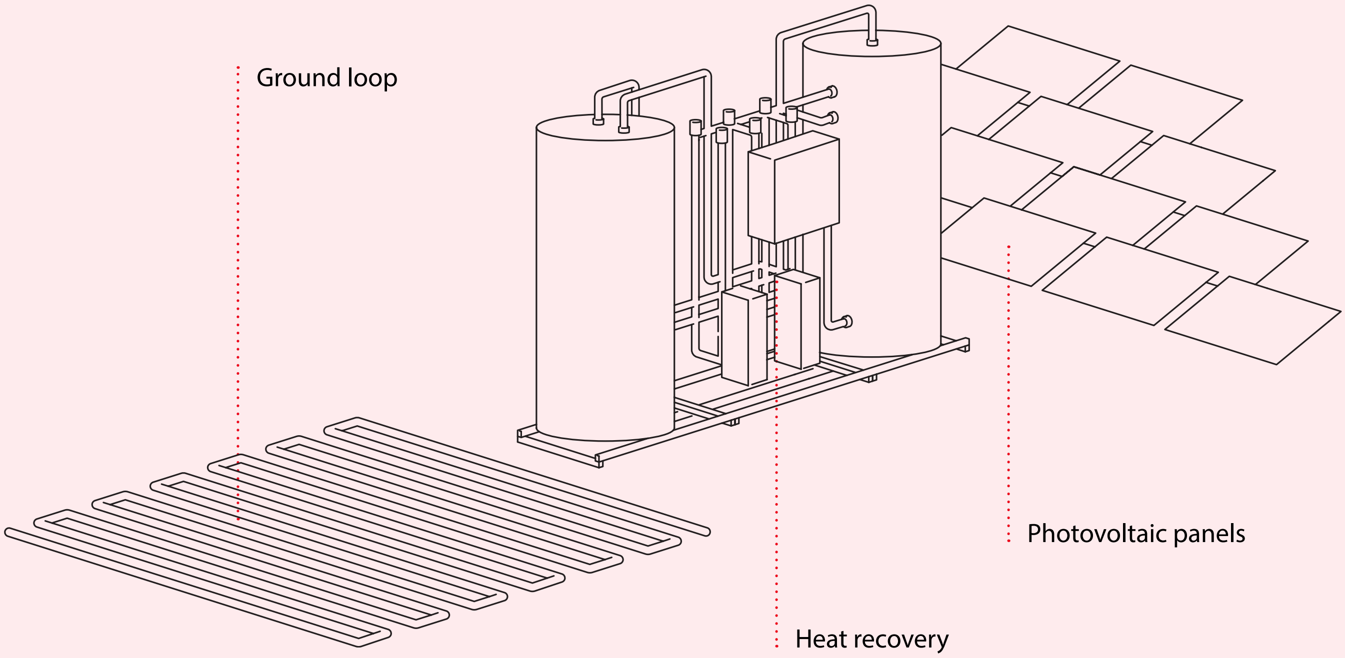
3.2
General configuration and location-based limitations

In Table 1 it was shown that the Danfoss Smart Store is equipped with a number of subsystems, which today are not generally available in other stores. Due to the nature of some of these subsystems there will be locations where it will either not be possible to install them or where there will be limitations as to achieving the full benefit from them.

→ A ground loop requires availability of outdoor spaces with no bedrock so for a store in closely populated urban areas or in countries dominated by bedrock this might not be possible. If geological conditions do allow for installing a ground loop, then it is expected to be able to deliver similar performance as in the Danfoss Smart Store[2]. The reason for this is that it is connected into the refrigeration loop of the store. This will be operating at similar temperatures no matter the local conditions meaning that the temperature difference between ground loop and system will also be sufficient to support the conservatively estimated COP of 2 used for the Smart Store calculation[2].

→ The heat recovery unit (HRU) is less dependent on the physical surroundings, but lack of availability of connections to district heating grids or other uses for the residual heat would limit the impact of the HRU.

→ Also, the photovoltaic panels are generally applicable with performance more influenced by overall climate conditions rather than the technical confines of the store and immediate surroundings. For the photovoltaic panels it is also worth noting that there may be either local or regional push towards increasing the use for stores or other commercial buildings. This will of course improve electricity carbon footprint over time hence influence the avoided emissions and should therefore be taken into account.



3.3
Embodied carbon

As mentioned in the introduction the building itself is quite standard for this type and size of supermarkets in Denmark[2, 9]. This means that the embodied carbon of the building itself will equal out. If the store was to be built elsewhere there may very well be different traditions or requirements regarding materials or insulation, which would influence the absolute emissions of a store. However, as avoided emissions are comparative by nature then as long as the building is built according to local standard, the embodied carbon of the building itself will equal out no matter the location.

From an operational point of view a Smart Store not running in parallel with an ADC would apply a standard refrigeration pack[2,9]. The standard pack of the Danfoss Smart Store has the same configuration as one in a new CO_2 based store[2] meaning that the embodied carbon for the refrigeration packs also equals out of the avoided emissions calculation.

CO_2 based systems operate at higher pressures but with lower volumes than HFC based systems. This means that equipment for CO_2 is generally smaller but with higher wall thickness than HFC systems. Due to this, a CO_2 system and an HFC system for the same size of store may be assumed to use the same amount of material hence the embodied carbon of the two types are assumed to be identical[2]. This is considered a conservative approach also as HFC is and older technology than CO_2 and as older HFC based systems tend to be less standardized than new CO_2 based ones[2,16] hence using more material mainly for piping.

The Danfoss Smart Store does feature photovoltaic panels and a Heat Recovery Unit (HRU), which a reference store would not, so the materials used for those must be taken into account.

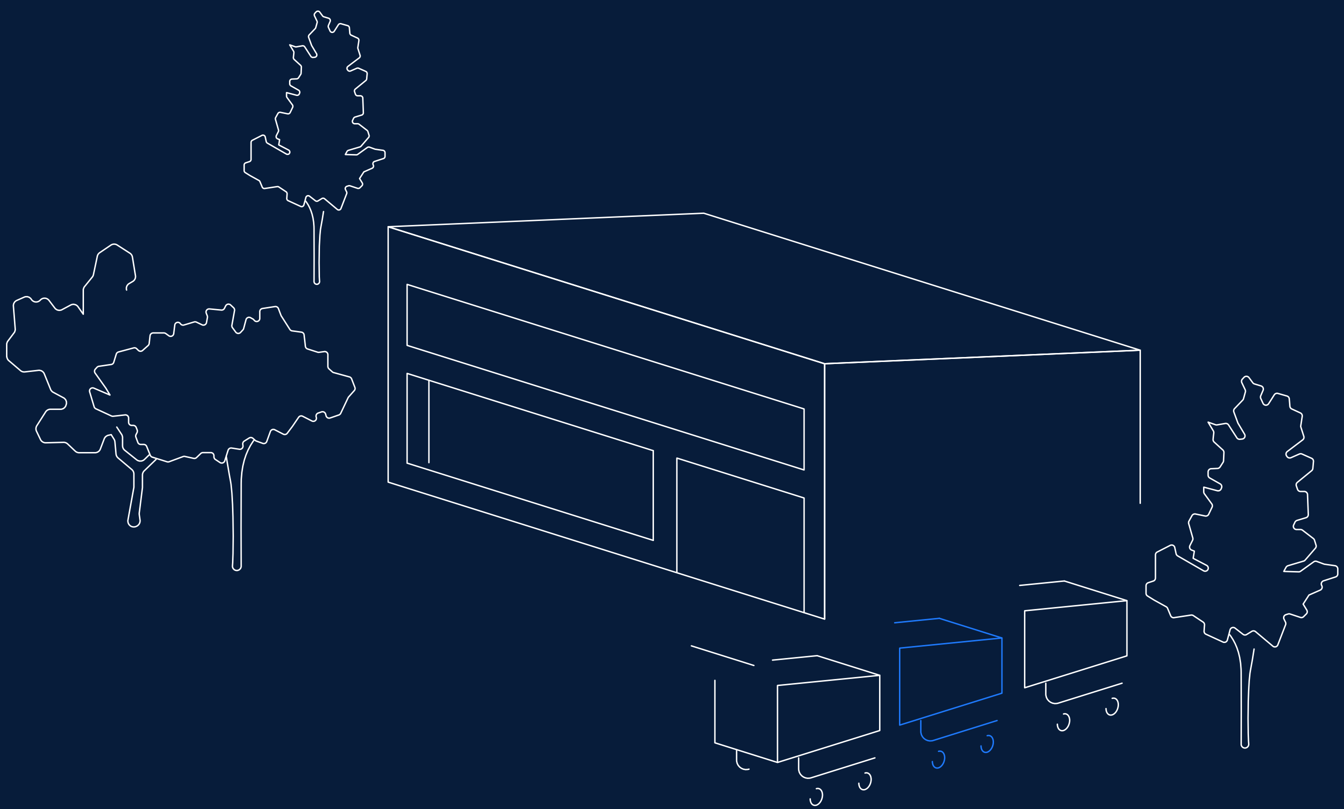
The two-tanks Danfoss HRU (Figure 3) used in the Smart Store has a net weight of 500 kg[15] and consists mainly of sheet steel. A reference store in this location would also be connected to district heating but using a smaller heating station compared to the HRU in the Smart Store. Based on the rated heating effect for the store and depending on configuration, a proxy Danfoss solution would have a net weight of approximately 100 to 150 kg also consisting mainly of steel sheet. This means a conservative contribution from the HRU of additional 400 kg of sheet steel. The emissions are calculated using the Danfoss LCA model used to create all Danfoss EPD and applying the emission factor for European sheet steel[6]. The embodied carbon of the photovoltaic panels is included in the emission factor per kWh of Danish PV electricity used for the calculation. This is also pulled from the Danfoss LCA model[6].

Figure 3: Danfoss two-tanks Heat Recovery Unit

3.4
Refrigerants and leak rates

The amount of refrigerant charge in the reference store is set to 100 kg of CO_2[7]. Due to the setup with the two interchangeable refrigeration packs, the Danfoss Smart Store has a charge of 140 kg of CO_2. Stores using HFC are set to have a charge of 60 kg of R404A[7]. The annual refrigerant leak for CO_2 systems is 10-15%[7]. In order to make a conservative calculation and in light of the larger charge in the Danfoss Smart Store it is decided to set the CO_2 charge leak to 15%. HFC systems is expected to have an annual charge leak of 5%[8,14]. As will later be shown in chapter 4, "Results", the annual leak rate matters very much over the full lifespan of the HFC system. In 2005 IPCC (the Intergovernmental Panel on Climate Change) published "Special Report: Safeguarding the Ozone Layer and the Global Climate System"[13] indicating average leak rates from supermarkets across Europe and North America of as much as 18%[13]. Even though that report is no longer new it does provide indications that the leak rate of 5% used in this case study is quite conservative.

In order to reduce refrigerant losses when systems are decommissioned, the refrigerant is recovered and returned to refrigerant supplier for cleansing and re-use. An assessment report from the EU commission staff indicates recovery rates of 82% (disposal emissions of 18%) for central refrigeration systems[18]. However, internal Danfoss experience indicates that a recovery rate of as much as 90% would be feasible even taking into consideration that the decommissioning takes place in the field.[10] In order to ensure conservative results, it is decided to use this stricter level for this case study. A sensitivity study calculating emissions at 85%, 90% and 95% recovery rates shows a change of +/- 4% on the total avoided emissions for HFC based systems. The sensitivity study also shows that due to the low GWP, the changes for CO_2 based stores are so small that they would be very difficult to detect in field conditions.



3.5
Energy consumption of the stores

The reference stores use separate systems for refrigeration and heating. In the Danfoss Smart Store these systems are integrated in order to utilize the excess heat for comfort heating and for providing energy to the district heating grid.

The Smart Store's ground loop is connected into the same refrigeration string as the display cabinets hence using the refrigeration pack as power source. This means that the heat extracted by the ground loop goes through the HRU along with the excess heat from the refrigeration system.

Regarding electricity, the main consumption of any of the stores in this study is for refrigeration. This is specifically measured in the Danfoss Smart Store, which also features energy meters for comfort cooling, for ventilation, for lighting, and one for self-contained cooling, check-out counters and administration. If no data is available for the reference store on specific points (e.g. lighting), then it is assumed that the consumption is the same as that of the Danfoss Smart Store.

As the main refrigeration system applied in the Danfoss Smart Store during the period of this case study is the advanced pack, which is not optimized for this size and type of store, it is expected that the energy consumption is somewhat higher than if running a standard pack. This means that the consumption may be considered conservative.

A new CO_2-based store with modern controls and well-commissioned is set to have an average annual consumption of 120 MWh for refrigeration,[11] which is 10-15% less energy than an older store based on HFC[11]. To ensure a conservative approach not overestimating the consumption for an HFC based store compared to CO_2 a 10% saving has been used for the calculations.

In the Danfoss Smart Store a significant part of the electricity is generated by the 100 kW photovoltaic panels installed on the roof. As Smart Stores built by others would not include the ADC, the amount included in this case study is specifically for the store itself and not for running the ADC. For the reference stores electricity is bought from the grid.

Consumption data used in this case study covers one specific year (2024). This means that long term year over year variance caused by fluctuations in weather and climate is not fully reflected. If the general assumption of future increasing temperatures and humidity holds true then the need for heating and thereby the possible benefits of heat recovery is expected to decrease but the need for refrigeration to increase. As will later be shown in section 4, "Results", the energy consumption for refrigeration is much higher than that for heating meaning that it is most likely that using data for only one year may be considered slightly conservative.

In contrast to the embodied carbon as previously described, the building itself, and especially the materials and insulation degree, could be expected to have significant influence on the avoided emissions from energy consumption. One should therefore be cautious transferring energy and emission savings directly to other types of buildings or other locations without considering localized information regarding typical energy consumption and split between refrigeration, heating and ventilation of similar types and sizes of stores.

3.6
Emission factors

The Danfoss headquarters in Nordborg, where the Danfoss Smart Store is located, have been carbon neutral since 2022. This is partially done by use of Power Purchase Agreements (PPA) and carbon neutral heating, and it means that the Danfoss Smart Store's energy consumption is - by definition - carbon neutral. However, in this study it has been decided to disregard this as the use of a Smart Store setup is most likely to happen in locations where such carbon neutral energy is not available. If taking the carbon neutral energy into account, the Danfoss Smart Store would have an even better footprint than reflected in this study.

For electricity and heating the calculations are based on average projected IEA location-based grid mix emission factors for the expected lifespan of the refrigeration system*. The store opened in 2023, which is therefore used as base year. With a 15 years lifespan the average projected emission factor for Denmark in 2023 through 2037 is 0.06 kgCO_2e/kWh[12]. This projected emission factor is for electricity alone but is applied for both electricity and heat in this calculation. Historically speaking the emission factor for combined electricity and heat has been lower which would mean overestimating the benefit of the Danfoss Smart Store. However, the IEA emission factor for electricity has decreased significantly faster from 1990 to now than that for combined electricity and heat[12]. This means that the 2022 difference was only 0.008 kgCO_2e/kWh and that the 2023 estimated value for Denmark is actually lower for electricity alone than for combined electricity and heat. If the 2023 estimated value holds true then using the electricity only emission factor is in fact the conservative approach**.

There may be differences between local energy providers, but this study uses the IEA Denmark total emission factor in order to make a fair comparison no matter where in the country the reference store would be located. The projected emission factor used for the geographical considerations in chapter 5 for Germany is 0,250 kgCO_2 e/kWh[12] and the projected global emission factor used is 0.452 kgCO_2e/kWh[12].

*Calculated for each year based on IEA and World Energy Outlook data.
**Sensitivity study on the calculations indicates low sensitivity to differences between estimated and actual emission factor and that the estimates are conservative as long as the electricity only factor is lower than the combined one.

The photovoltaic panels at the Danfoss Smart Store provided the store with 99 MWh of electricity for the duration of this study. The emission factor for Danish PV electricity of 0,0333 kgCO_2e/kWh used for the calculation includes the embodied carbon of the panels[6]. It should be noted that the grid emission factor tends to be lower in periods with high solar intake. If surplus electricity from the PV panels is sold to grid during such periods, then the avoided emissions from the panels would be somewhat overstated. However, as just mentioned, solar energy does have a carbon footprint of as much as approximately half of that for the average projected Danish grid. Furthermore, periods with high solar intake would also mean higher heat influx and thus higher need for refrigeration meaning that there may be a timing shift between the two factors which is currently not well described. Combining these considerations it is therefore decided to use average projected grid emission factor for the electricity sold to grid just like for the electricity bought from grid.

When using the HRU or the ground loop to produce heat, extra electricity is used. The emission factor for the produced heat is calculated based on ratios between the electricity consumed and the heat produced. The HRU has used 1 kWh per day[9] throughout 2024 and the ground loop is assessed to have used 2500 kWh[9] for the three months of operation during 2024[#].

Regarding refrigerants, the HFC based reference store is assumed to be running on R404A which has a GWP of 3922 kgCO_2e[8].

[#]As ground loop is powered by increasing the compressor load, consumption cannot be measured directly but has been assessed by comparing the consumptions of adjacent months.

04
Results

4.1
Danfoss Smart Store demonstrates significant avoided emissions

In 2024 the Danfoss Smart Store used 4% less electricity than calculated for the CO_2 based reference store even including limited periods with product testing during which energy consumption is expected to be higher than normal (chapter 3.1). That being said, however, as shown in Figure 4 and 5, page 24, the emissions from the Danfoss Smart Store are as much as 39% lower than those of the CO_2 based reference store and 68% lower than for the HFC based reference store. This equals avoided emissions of 90.7 $tonCO_2e$ and 302.5 $tonCO_2e$ respectively over the 15 year expected lifetime of the refrigeration system.

→ In Table 2, page 26 the main results of the avoided emissions calculations are shown. Some of the electricity-related avoided emissions come from the higher electricity consumptions of the refrigeration systems and especially the HFC based one, but the biggest contribution comes from the PV panels which are expected to save the Danfoss Smart Store 39.7 $tonCO_2e$ over the system lifetime. If the PV panels were to be installed in one of the reference stores, then this saving would most likely be somewhat smaller due to the higher energy consumption of their systems, but it would probably still be on a comparable level.

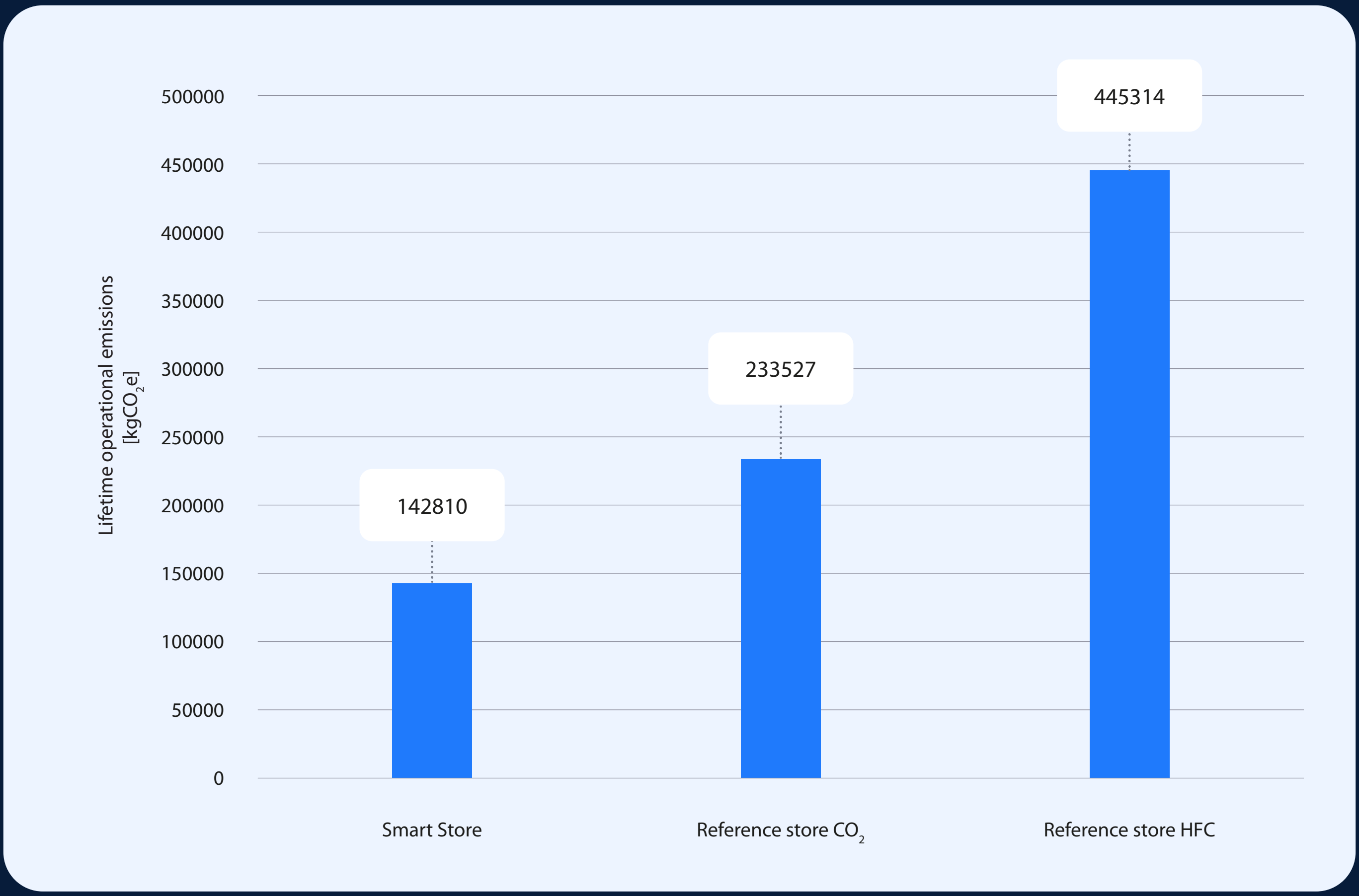


Figure 4: Lifetime operational emissions of the store types

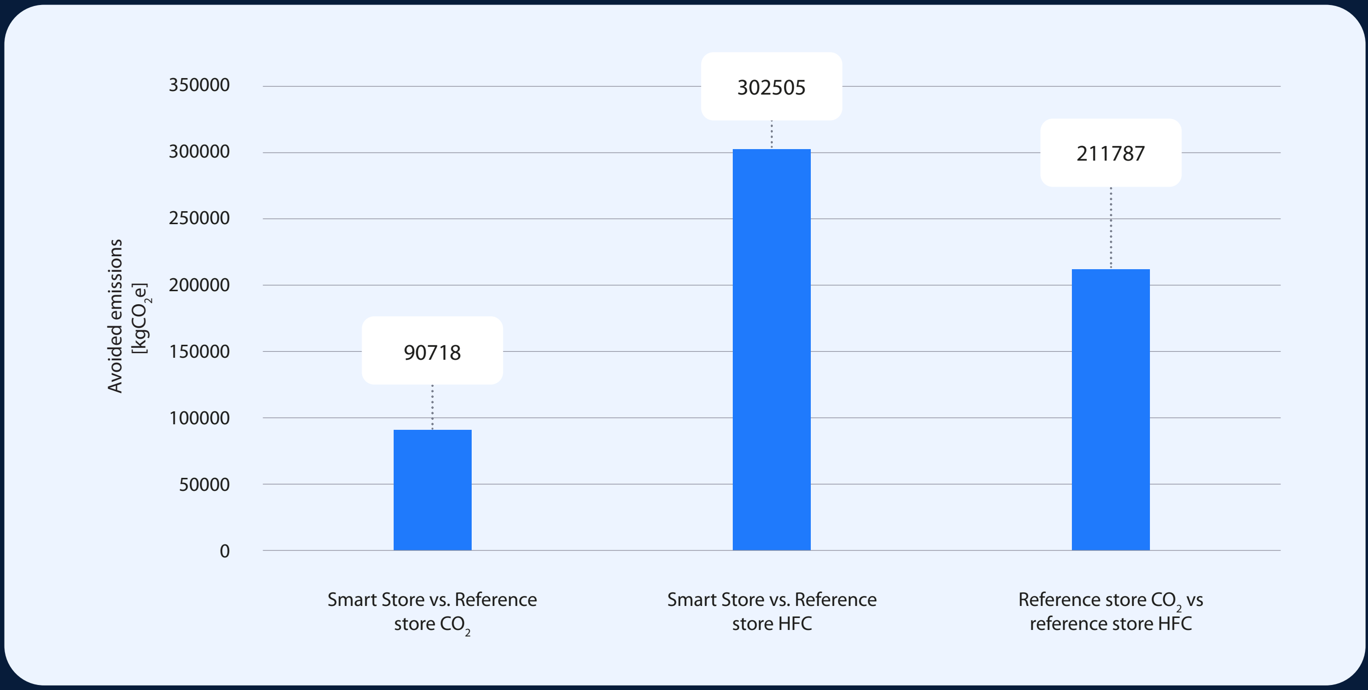


Figure 5: Avoided emissions of the Danfoss Smart Store

→ The heating-related avoided emissions are mainly due to the use of heat recovery and to a smaller extent due to the ground loop which has been in operation for limited periods throughout the year. By this the store has been fully self-sufficient with heat during 2024. It has even provided 23 MWh to the local district heating network which is enough to supply two family houses with heat and hot water for three quarters of a year[3,4,5].

→ The HRU itself is calculated to save the Danfoss Smart Store 40 tonCO_2e. What is interesting is the fact that the HRU actually contributes equally to the PV panels even if the electricity consumption of the store is more than 7 times as high as the heating consumption. The reasons are that the store has been a net contributor of heat and that the heat has been produced using only a very small amount of electricity compared to the recovered heat.

→ Materials used for equipment have a limited impact. Even relatively heavy equipment such as the HRU itself equals out by the carbon savings after less than 8 months in operation due to its very high ratio between recovered heat and electricity consumption. After that point the only negative carbon related impact of the HRU is the energy consumption for the pump which is negligible.

- Looking specifically at the HFC based reference store the main contribution comes from leaking refrigerants which at 199.7 tonCO_2e constitutes of almost 45% of its lifetime emissions and 40% more than the total operational emissions of the Danfoss Smart Store. This is underpinning that transition from HFC to low GWP refrigerants is essential for decarbonization and without comparison the one single factor in this case study with the highest impact. What is also interesting about this particular topic is that the CO_2-based reference store would provide the same benefits as the Danfoss Smart Store as they share this core technology.

- No meaningful rebound effects have been identified during this case study either from a material consumption nor energy consumption point of view. It has therefore been decided not to investigate this topic further within this case study.

	Danfoss Smart Store vs. reference CO_2 based store [tonCO_2e]	Danfoss Smart Store vs. reference HFC based store [tonCO_2e]
Lifetime Avoided Emissions	90.7	302.5
AE from heating	42.3	42.3
– of which is from HRU	40.0	40.0
AE from electricity	48.6	60.6
– of which is from PV panels	39.7	39.7
AE from refrigerants	-0.09	199.7

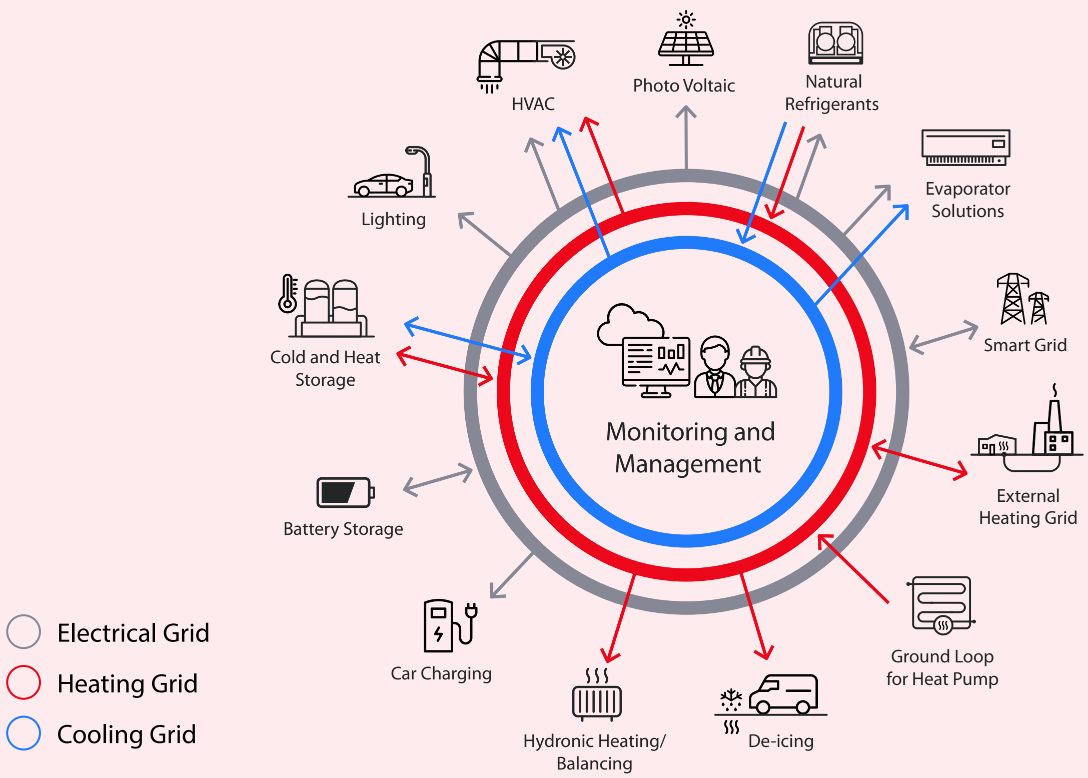
Table 2: Overview of Avoided Emissions

05
Potential for further performance gains using the Smart Store configuration

5.1
Considerations if building a Smart Store in other locations

The grid emission factors for electricity and heat determine the operational carbon impact of the Smart Store technologies. When comparing the calculated results for the Danfoss Smart Store and the CO_2 based reference store this study indicates a growth in avoided emission of as much as 236 ton CO_2e for every 100 gram increase in grid emission by use of the Smart Store concept. This means that if the smart store configuration was to be used under identical ambient conditions e.g. in Germany where electricity has a higher CO_2 intensity, the expected avoided emissions using average projected German grid[12] would be more than 5 times as high as in Denmark.

This is of course a very simplified consideration. As also addressed in chapter 3 there will be many factors such as local building codes and traditions, local use of low carbon energy sources, local development in weather and climate and maybe most importantly the actual development in the grid emission factors, which will all have significant impact on the results. To translate the results of this study for a store elsewhere it is essential to map such local factors.



5.2
Future Potential and Opportunities

The advanced pack installed in the Danfoss Smart Store (chapter 3.1) is over-dimensioned compared to the cooling needs of the modestly sized store. This means that there is untapped potential in the technologies, which is expected to come to fruition when applied in larger stores and more demanding environments.

Running the Danfoss Smart Store has revealed that even under less demanding conditions such as in Denmark with mild coastal climate and a relatively low carbon energy supply does the Smart Store show its value. As mentioned earlier, the avoided emissions are directly linked to energy grid emission factors so the benefits of using the Smart Store technologies in locations with more extensive use of fossil fuels will be even more pronounced.

In this study the HRU has a recovery rate of 128 kWh heat per kWh electricity for its operation. This could be expected to grow with the need for refrigeration in warmer climates, but this energy is only of value if there is use for the heat elsewhere and if the necessary infrastructure is in place. Also, the photovoltaic panels could be expected to have a bigger impact in more sunny regions, which would have a positive impact on the avoided emissions of the Smart Store.

The integration of an Application Development Center and store within the same building and full access to combining heating, ventilation, air conditioning, and refrigeration installations offers a range of opportunities to improve performance even more in the future. Not just on main components but also by optimizing day-to-day operations. Not just in controlled lab conditions but also in the seeming chaos of ever-changing weather and climate and fluctuating grid emissions with increasing wind and solar power in the mix.

This could be on specific topics such as how to combine rail heat and air handling controls to save energy without condensation on display cabinet doors. It could also be on more general ones such as how to balance energy consumption and energy availability for optimized cost and carbon footprint. This could be done by e.g. deliberately turning sub-systems on and off consuming energy when it is abundant and reducing consumption during peak loads on the grid. As described in section 3.6, "Emission Factors", there is a potential regarding timing of solar intake, use of electricity and the selling of electricity to grid that could be worthwhile investigating further. The Danfoss Smart Store has just started its journey and even though the benefits are already clear the future opportunities seem plentiful.

06 Conclusion

By using the combination of heat recovery and the ability to sell heat to the grid, the Danfoss Smart Store has been self-sufficient with heat throughout 2024 and has even been able to provide 23 MWh of heat to the district energy grid to be used by local households. The photovoltaic panels provided the store with 99 MWh of electricity which enabled selling 21.5 MWh of electricity back to the grid in periods when the output was higher than the need for electricity. This study also indicates that the biggest decarbonization lever is transitioning to low GWP refrigerants.

The operational avoided emissions of the Danfoss Smart Store compared to a CO_2 based reference store in Denmark are

90.7 tonCO_2e which equals a reduction of

39%

The operational avoided emissions of the Danfoss Smart Store compared to an HFC based reference store in Denmark are

302.5 tonCO_2e which equals a reduction of

68%

07
References

1. Danfoss Impact Paper: "The World's Largest Untapped Energy Source Excess Heat"; 2023
2. Hans Ole Matthiesen; Senior Director, Global ADC; Applications, Systems and Technology; Danfoss Climate Solutions; 2024
3. Fjernvarmepriser | Forsyningstilsynet; 2024
4. Standardhuset er forældet: Så lidt varme bruger en gennemsnitlig husholdning med fjernvarme | Danskfjernvarme; 2024
5. Dansk Fjernvarme; analysenotat-standardhus-2024.pdf
6. Sphera LCA calculation software suite including databases; 2024
7. Mads Schandorf Cort Jensen; Anneo DK; 2024
8. Expert paper: "Reducing the global warming impact of supermarket refrigeration systems"; Public and Industry Affairs; Danfoss Climate Solutions; 2024
9. Ejnar Luckmann; Technical Manager; Danfoss Smart Store ADC Nordborg. (Retired in 2025).
10. Frederic Molle; Senior Manager; Commercial Compressors labs France; Danfoss Climate Solutions; 2025
11. Rasmus Gøtch; CEO; AK-Centralen; 2024
12. IEA emission factors 2023
13. "Safeguarding the Ozone Layer and the Global Climate System" p. 240, IPCC 2005
14. UNEP 2022 Report of the Refrigeration, Air Conditioning and Heat Pumps Technical Options Committee, 2022 Assessment p. 103
15. Danfoss Product store.
16. Preben Alfred Bertelsen; Global Solutions Engineer, FR; Danfoss Climate Solutions
17. WBCSD "Guidance on Avoided Emissions® Helping business drive innovations and scale solutions toward Net zero", July 2025
18. "Commission staff working document, Impact Assessment Report Accompanying the document Proposal for a Regulation of the European Parliament and of the Council on fluorinated greenhouse gases, amending Directive (EU) 2019/1937 and repealing Regulation (EU) No 517/2014".

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