COLD CHAIN INNOVATION HUB

Recommendation Report for the Philippines' Commercial Food Retail Sector

Research Report - December 2021

www.cci-hub.org

About the Cold Chain Innovation Hub

The Cold Chain Innovation Hub (CCI-Hub) is the official platform for the "Global Partnership for Improving the Food Cold Chain in the Philippines" project. It serves as the project's central ecosystem of technical resources, training, knowledge sharing and stakeholder collaboration.

The "Global Partnership for Improving the Food Cold Chain in the Philippines" project aims to identify, develop and stimulate the application of low-carbon, energy-efficient refrigeration technologies and business practices throughout the food cold chain to increase food safety and food security.

The project is being implemented by the United Nations Industrial Development Organization (UNIDO) together with the Department of Environment and Natural Resources of the Philippines (DENR). It is funded by US$2 million from the Global Environment Facility (GEF), with US$25 million in co-financing (in-kind, grants and loans).

The Philippines' Technical Education and Skills Development Authority (TESDA) serves as the official host of the physical CCI-Hub space at its Regional Training Center - National Capital Region in Metro Manila.

To receive all project updates, announcements, event notifications, research and more, sign up for the official project newsletter here.

To see our previous market research reports, click here.

Acknowledgments

We would like to say a special thank you to the management team and staff at Royal Duty Free Shops for their willingness to participate in this case study and their effort and transparency in supplying us with their data, feedback and support.

In addition, we would like to thank the management team and staff at Cold Front Technologies Asia for their cooperation and willingness to share their expertise for the benefit of the CCI-Hub project.

Introduction

The problem: Decoupling cold chain development from emissions

On April 15, 2021, the Philippines officially submitted its pledge to the United Nations to reduce its greenhouse gas emissions trajectory by 75% by 2030. And then on October 13, it announced that it would reduce the importation and use of HFC refrigerants by 80% by 2045.

At the same time, the Philippines aims to increase the demand for cold storage by 10-15% annually — or around 50,000 pallets per year — for the next few years.

In addition, small-scale cold chain infrastructure is urgently needed in rural areas to support agricultural, fishery and live stock farmers where, in some cases, post-harvest food loss reached as high as 75% during the worst periods of the COVID-19 pandemic.

On top of this, the Philippines suffers from some of the highest costs of electricity in Southeast Asia and continues to be battered by increasingly violent typhoons and other extreme weather events every year.

If the Philippines is to develop its food cold chain infrastructure while at the same time minimizing greenhouse gas emissions from energy use, refrigerant leaks and food loss, then it needs to decouple the growth of its food cold chain industry from growth in emissions.

This can be done by deploying energy efficient and environmentally sustainable cooling technologies in all food cold chain sectors — from post-harvest cold rooms to refrigerated trucks and cold storage distribution centers, supermarkets and grocery stores.

In addition, this deployment needs to happen as soon as possible. Not doing so risks ensuring an additional amount of committed emissions for the Philippines for the next decade or more from the unrestrained deployment of business-as-usual cold chain equipment.

The opportunity: HFC-free refrigeration and energy efficiency

Over the past decade, in the commercial food retail industry around the world (i.e. grocery and convenience stores, supermarkets and hypermarkets), HFC-free refrigeration systems are quickly emerging as the most environmentally sustainable and energy efficient alternative to traditional cold chain equipment.

These technologies use natural refrigerants and are being installed on a large scale by the world's leading commercial food retailers such as Whole Foods in the U.S., Lawson in Japan, METRO in Europe and Woolworths in Australia, among many others.

In this report, we examine a case study of the first natural refrigerant-based water loop refrigeration system installed in the commercial food retail sector in the Philippines. We provide background on the decision making process made by the management team, detail the installation process and analyze energy consumption data.

Based on this analysis, we provide practical considerations on installation, maintenance and safety as well as rough energy performance benchmarks and comparisons to global best practice figures.

We also provide our specific recommendations on how to progress towards decoupling cold chain growth from emissions in this sector of the Philippines food cold chain through the use of these technologies going forward.

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Executive summary

Key recommendations

Here are our key industry recommendations based on the research conducted for this report and on our case study analysis of Royal Duty Free Shops:

- **If you are a commercial food retail business operator:** Consider making your next purchase HFC-free refrigeration systems that are energy efficient. By doing this, you can reduce your business' risk and exposure to volatile environmental regulations and electricity prices.

- **If you are a financial institution:** Consider investing in projects that use HFC-free and energy efficient refrigeration systems. By doing this, you can expect to have a quick return on your investment and increase the environmental sustainability ratio of your portfolio.

- **If you are an HVAC&R technician or engineer:** Consider joining a class on installing, maintaining and operating the latest HFC-free and energy efficient refrigeration systems. By doing this, you can ensure that your skills are up-to-date in a quickly growing field with a high demand for skilled, trained and certified technicians.

Key facts and figures

Here are the key facts and figures that we have learned based on the research conducted for this report and on our case study analysis on Royal Duty Free Shops:

- **Energy use benchmark:** Royal Duty Free Shops' supermarket is achieving an estimated electrical energy intensity of around 216kWh per square meter of sales area per year

- **Reduced average energy use:** Royal Duty Free Shops' R290 water loop refrigeration system is consuming an average of 741.35kWh of electricity per day (18.5% less than the estimated 909.49kWh average daily energy consumption of its previous R404a plug-in equipment)

- **Reduced maintenance costs:** Royal Duty Free Shops' R290 water loop refrigeration system has reduced overall refrigeration system maintenance costs and the additional heat load on its air-conditioning system costs by eliminating indoor heat emission.

- **Reduced global warming potential:** Royal Duty Free Shops' refrigeration system uses a refrigerant that has a global warming potential value of 3 per kg (99.9% less than its previous system which used R404a, an HFC refrigerant which has a global warming potential value of 3,922)

Royal Duty Free Shops case study

In the following sections, we introduce Royal Duty Free Shops, the food retail and business that has installed the first R290 water loop refrigeration system in the Philippines.

We provide background on the project and detail the installation process. Through this, we aim to provide other retailers with practical considerations on installing and operating these types of systems at their own stores.

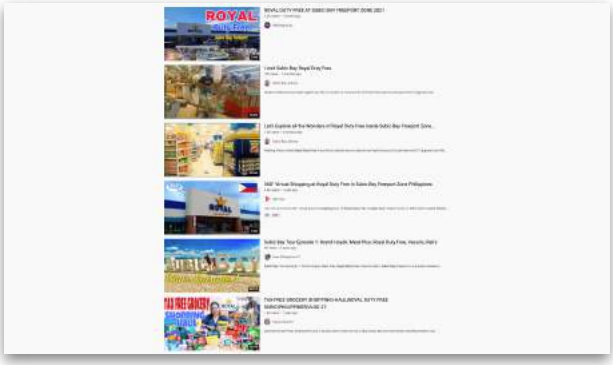
About Royal Duty Free Shops

Royal Duty Free Shops is a Philippine-based retail business. It was established in 1993 when it opened its first supermarket in Subic Bay in Zambales province.

Subic Bay is shorthand for the Subic Special Economic and Freeport Zone. The area served as the largest United States military naval base in Asia until 1991. Following the volcanic eruption of Mt. Pinatubo that year, the area was returned to the Philippine government and converted into commercial use. Royal Duty Free Shops' first supermarket was opened in the same building that served as the old United States navy commissary.

Royal Duty Free Shops flagship store in Subic Bay Freeport Zone, Zambales province, Philippines

Today, the Royal Duty Free Shops brand has gained a loyal following of customers who travel from within the Philippines, specifically to its Subic Bay flagship supermarket, to browse its unique offering of products. It sells a mix of imported and local goods, food, beverages and produce and has an annual sales revenue of around $57 million USD.



Multiple search results for “Royal Duty Free Shops Subic Bay” on Youtube

Aging equipment, frequent breakdowns and high maintenance costs

In 2019, Royal Duty Free Shops' flagship Subic Bay store had been operating for more than 26 years. The building itself was 50 years old. The refrigeration equipment ranged from 11 to 15 years old.

Royal Duty Free Shops' management team wanted to renovate and replace the refrigeration equipment in its chilled and frozen food sales area in order to solve two main issues:

- **Indoor heat emission:** All the old refrigeration equipment were stand-alone pieces of refrigeration equipment that emitted heat indoors within the sales area.
- **High maintenance costs:** The indoor heat emission caused frequent equipment breakdowns and unnecessary additional heat load on the store's air-conditioning system.

The solution had to fit the following criteria:

- **Eliminate unnecessary expenses:** The solution had to eliminate the indoor heat emission issue and thereby eliminate all unnecessary maintenance expenses.
- **Layout flexibility:** The solution had to be flexible to accommodate any changes to the layout of the store in case of any future expansion plans.
- **Zero store downtime:** The installation and commissioning of the equipment had to be done with zero store downtime because the project was scheduled to take place during the Christmas shopping season.
- **Environmental sustainability:** The equipment had to be environmentally sustainable because the businesses' primary customer base was increasingly of the younger generation who value this highly.

So in late 2019, Royal Duty Free Shops underwent a major renovation of the refrigerated sales section of its Subic Bay store. All of the store's HFC-based plug-in refrigerated display shelves, freezer cabinets and freezer chests were to be replaced with natural refrigerant-based equipment and a water loop system.

Equipment	Manufacturer	Quantity
Upright multi-deck chiller	Freor	8
Serve over chiller	Freor	7
Glass door freezer	Freor	1
Stand-alone freezer	AHT	25
Twin pump set	Grundfos	1
Outdoor dry cooler with three fans	Güntner	1

List of main pieces of equipment, manufacturers and quantities for the new R290 refrigeration system at Royal Duty Free Shops

The old equipment used a refrigerant called R404a. R404a is a synthetic refrigerant in the hydrofluorocarbon (HFC) category. The new equipment used a refrigerant called R290. R290 is propane that is applied as a refrigerant. R290 is a natural refrigerant because propane is a chemical compound that consists only of hydrogen and carbon.

A short overview of the environmental impact of synthetic versus natural refrigerants

In the 1980s and 1990s, HFCs began to replace by CFCs and HCFCs due to their ozone depletion potential.

Now, HFCs are being phased down under the Kigali Amendment due to their global warming potential.

They are being replaced by a new class of synthetic refrigerants called HFOs.

HFOs do not have ozone depletion or global warming potential. But there is growing concern over HFOs possible negative impacts on the environment (See "Zhai et al., 2014" in *Additional sources and citations* at the end of this report). Due to this, they are now also being subject to environmental regulation and scrutiny.

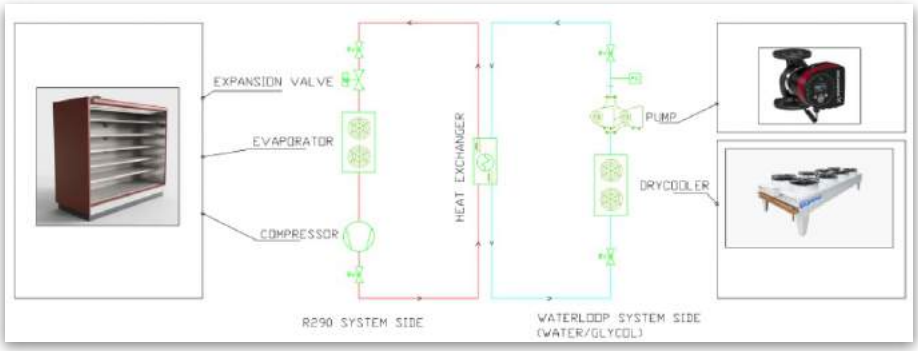
Refrigerants such as propane, carbon dioxide and ammonia are considered non-synthetic natural refrigerants. This is because they consist of chemical compounds that already exist in the environment.

Natural refrigerants have negligible ozone depletion and global warming potential. There is also no uncertainty on the impact of these refrigerants in the environment. Due to this, they are not expected to be subject to any environmental regulation or scrutiny.

The first R290 water loop refrigeration system in the Philippines

The R290 water loop refrigeration system consists of all stand-alone plug-in pieces of refrigeration equipment that use R290. The main difference with a water loop system is that the refrigerated shelves and cabinets that line the walls and are used in the meat and deli area are all connected by water loop piping.

The water loop piping system carries all of the exhaust heat that would have been emitted inside the store and rejects it outside via a water pump and dry cooler system located outside of the building.



Basic diagram for the R290 water loop system

In addition to the equipment connected by the water loop piping, all of the HFC-based stand-alone freezer chests would be replaced with R290 stand-alone freezer chests. These freezer chests would not be connected to the water loop piping system.

The installation process

Basic layout of the chilled and frozen goods section of the supermarket

Royal Duty Free Shops hired a local contractor named Cold Front Technologies Asia to handle the renovation project. The project began in August and ended in December of 2019.

The Cold Front Technologies Asia team divided the installation process into three major phases.

1. Preparation and planning
2. Installation, testing and commissioning of the water loop system
3. Dismantling, installation, testing and commissioning of new display shelves

Importance of employing properly trained and certified technicians

When installing, servicing and maintaining your refrigeration equipment, it is important to make sure that all technicians and engineers are properly trained and certified.

The Philippines' Technical Education and Skills Development Authority (TESDA) is the official government institution mandated to develop and implement a certification program for the commercial refrigeration sector.

TESDA is the only authority that issues nationally recognized certification and assessment programs.

Within commercial refrigeration, TESDA has issued its "Commercial Refrigeration Installation & Servicing NC III" training regulations document. This document describes in detail the scope of certification, the type of equipment covered, core competency and training standards as well as the assessment and certification process.

Once a technician has undergone training and completed the assessment and certification process, they will be issued a national certificate. This certificate includes

a unique certification number which can be verified through TESDA's online registry of certified workers database.

Example of National Certificate Issued by TESDA Including Certificate Number, Certificate Type and Recipient Name

One of the main differences between today's latest technologies and traditionally used equipment for commercial refrigeration is the higher flammability of the refrigerants used. That is why it is important to employ properly trained and certified technicians. The technologies in use today require the use of new equipment, tools and instruments as well as new approaches to installation, service and maintenance.

For example, ordinary vacuum pumps used with traditional refrigerants such as HFCs and HCFCs cannot be used with R290 or other flammable refrigerants. ATEX compliant vacuum pumps need to be used. Also, during installation and servicing, technicians must bring with them a fire extinguisher and a ventilator if the site is not properly ventilated.

These new approaches to installation, servicing and maintenance were not previously required with older technologies and equipment.

Preparation and planning

The first thing that the Cold Front Technologies Asia team did was have an approved construction plan. This included the piping layout for the water loop system and a new electrical plan for the new equipment. The team also conducted site visits and inspections since the store was already existing and in operation.

Since the Royal Duty Free Shops management team required that the store have zero downtime, the Cold Front team split the installation of all the equipment into separate batches of around 3-4 units. The Cold Front team would then position, install, test and commission each batch of equipment overnight while the store was closed.

The Cold Front team then also prepared a list of all piping materials and tools that would be needed.

Piping materials and tools

Once the Royal Duty Free Shops management team approved the construction plan, the Cold Front team immediately placed the order for all the materials and tools since extra time would be needed to wait for the items being shipped in from overseas.

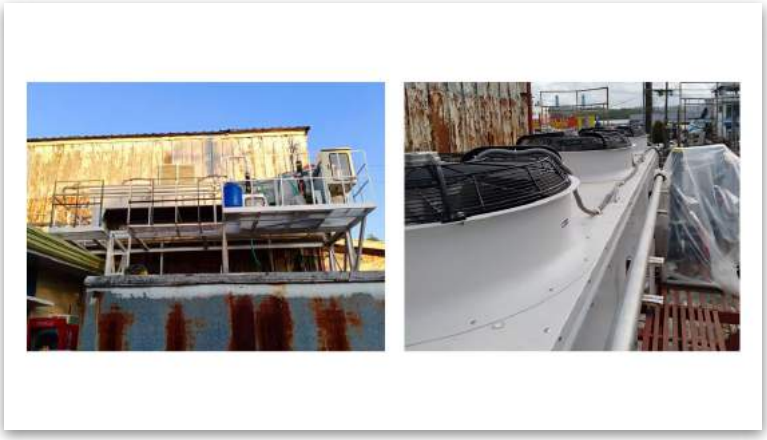
At this point, the Cold Front team moved into the next major phase of the project: the installation, testing and commissioning of the water loop system.

Installation, testing and commissioning of the water loop system

For this process, the first thing that the Cold Front team did was install the hangars, brackets and the stainless steel piping for the water loop system. The hangars and brackets were inside the store. The piping would later connect to the pump and dry cooler outside the store.

To install the pump and the dry cooler, the Cold Front team conducted air pressure and leak testing of the stainless steel pipes and connections.

Then the team charged the water loop system with a 50/50 water and glycol mixture. The system was then tested for a final time. The water loop system had to be fully operational before the



Installation of the pump and dry cooler outside the store

indoor refrigerated display shelves were installed and connected.
Once the water loop system was installed and tested and the refrigerated display shelves were fitted with the R290 compressors, the Cold Front team moved into the final phase of the project:

the dismantling of the old refrigerated display shelves and the installation, testing and commissioning of the new refrigerated display shelves.

Dismantling, installation, testing and commissioning of the new display shelves

Following the installation of the water loop system, the Cold Front team began the process of installing all the refrigerated display shelves inside the store.

The project coincided with the peak Christmas shopping season for Royal Duty Free Shops. Therefore, Cold Front team had to carry out the installation, testing and commissioning of the display shelves overnight.

This process was divided into five separate days where the separate batches of old display shelves would be dismantled and the new display shelves would be installed and commissioned at night, ready for operation by the store's opening the next morning.

The Cold Front team began work at 10pm and finished by 6am for every batch.

To illustrate, the first batch of refrigerated display shelves that the Cold Front team replaced were the three HFC-based beverage display shelves.

For this first batch, the team dismantled the three old pieces of HFC-based refrigerated display shelves for the beverage section. The team then aligned the R290 refrigerated display shelves using laser-based alignment tools. The equipment was then moved and positioned in to place.

Positioning the R290 water loop equipment

Then the team connected the ends of the three pieces of equipment, installed the drain lines and fastened each unit's connection to the water loop system.

Once all the mechanical connections were completed, the team connected the electrical power supply, commissioned the system and initiated the first temperature pull-down with the refrigerated beverages already placed on the shelves.

With the R290-based equipment, the time it took the equipment to reach the designed temperature from ambient temperature was one to two hours — **half the time it takes for HFC-based equipment**.

Once the desired temperature was reached, the team monitored the system to make sure it was operating properly.

This process was repeated for the rest of the R290-based refrigerated display shelves for the dairy, produce, cheese and deli sections.

Finally, the Cold Front team replaced all the old HFC-based stand-alone freezer chests with the 25 pieces of new R290 stand-alone freezer chests. These freezer chests were not connected to the water loop system.

Practical maintenance considerations for the R290 water loop system

R290 refrigeration systems and conventional refrigerant systems have similar maintenance standards. However, the Cold Front team suggests taking the following maintenance considerations into special account for R290-based refrigeration systems.

No oil changes needed: The R290 refrigerated display shelves and stand-alone freezer chests all use completely hermetic compressors that have a maximum of 150 grams of R290 refrigerant charge per refrigeration circuit. Therefore, there is no need for oil changes in the preventative maintenance schedule.

Monthly cleaning: It is important to conduct monthly cleaning of every refrigeration cabinet for sanitation purposes. This is true for both R290 refrigeration systems and conventional refrigeration systems.

Retourquing of electrical connections: It is important to retourque electrical connections to prevent any loose connections that may cause a fire. This is especially important for R290 refrigeration systems since R290 is flammable.

Flameless repair tools: It is important to use flameless tools when conducting repairs on the refrigeration system. This means using crimping tools and copper tubes rather than oxyacetylene welding.

Other important maintenance considerations include proper monitoring of the glycol in the system, cleaning of the wire strainers at the pump station once a year, and cleaning of the dry cooler fins once a quarter.

Data collection and analysis

Installing electrical sub-meters

On July 31, 2021, Royal Duty Free Shops completed the installation of 10 sub-meters to measure the kWh energy consumption of all the R290 refrigerated display shelves, stand-alone freezer chests and water loop system.

Electrical sub-meters installed at Royal Duty Free Shops

Each sub-meter was linked to either one or several pieces of equipment, as outlined below:

Sub-meters	Equipment group
Sub-meter 1	Serve over chillers 1 and 2 (meat, deli and cheese section)
Sub-meter 2	Serve over chiller 3 (meat, deli and cheese section)
Sub-meter 3	Serve over chiller 4 (meat, deli and cheese section)
Sub-meter 4	Stand-alone freezer chests 1 to 5
Sub-meter 5	Stand-alone freezer chests 6 to 10
Sub-meter 6	Stand-alone freezer chests 11 to 15
Sub-meter 7	Stand-alone freezer chests 16 to 20
Sub-meter 8	Stand-alone freezer chests 21 to 25
Sub-meter 9	Serve over chillers 5 to 7 (meat, deli and cheese section)
Sub-meter 10	Refrigerated display shelves 1 to 9 (dairy, produce, beverage and frozen goods section) plus water loop pump station and dry cooler

List of electrical sub-meters and associated equipment groups

Royal Duty Free Shops took daily readings of each sub-meter from August 1 to November 23 and recorded them manually on a worksheet.

shecco used raw data from August 1 to September 31 as a representative two-month data sample as the basis for the following analysis.

Sub-meters	Total kWh consumed (two months)
Sub-meter 1	2,061.10
Sub-meter 2	631.30
Sub-meter 3	810.10
Sub-meter 4	2,109.60
Sub-meter 5	3,085.90
Sub-meter 6	2,564.20
Sub-meter 7	3,183.40
Sub-meter 8	2,107.30
Sub-meter 9	2,459.20
Sub-meter 10	38,579.61
Total	57,591.71

Total kWh consumed for all sub-meters in August and September combined

Analyzing energy consumption data

By replacing its HFC-based refrigeration equipment with natural-refrigerant based equipment, Royal Duty Free Shops has achieved the following outcomes:

- Reduced energy consumption to an average of 741.35 kWh per day (versus an estimated 909.49 kWh per day from R404a equipment)
- Reduced its potential for on-site greenhouse gas emissions to a GWP value of 3 per kg of refrigerant (versus 3,922 per kg of refrigerant for R404a)
- Achieved an electrical energy intensity value of 216 kWh per m^2 per year (excluding lights, air-conditioning and ventilation systems, etc. More work needs to be done in this area but this figure is approaching industry best practice benchmarks from around the world)

The total amount of energy consumed by all of the equipment for the period from August to September was 57,591.71 kWh.

shecco extrapolated this figure out to a one year period to get an estimated total energy consumption figure of 345,550.28 kWh per year.

In addition, shecco analyzed energy consumption per sub-meter to obtain average energy consumption per equipment group per day.

Sub-meters	Average kWh consumed per day
Sub-meter 1	17.18
Sub-meter 2	10.52
Sub-meter 3	13.50
Sub-meter 4	7.03
Sub-meter 5	10.29
Sub-meter 6	8.55
Sub-meter 7	10.61
Sub-meter 8	7.02
Sub-meter 9	13.66
Sub-meter 10	642.99
Total	741.35

Average kWh consumed per equipment group from August to September 2021

The entire system consumed 741.35 kWh on average per day in the period from August to September.

Average energy consumption per day in line with expectations

In 2019, before the project was completed, Cold Front Technologies Asia presented its initial estimated average energy consumption figure for the entire R290 water loop system per day.

Cold Front estimated that the R290 water loop system would consume around 727.59 kWh per day.

The actual average energy consumption measured for the system per day from August to September is 741.35 kWh.

Average energy consumption around 18.5% less than previous system

In 2019, Cold Front Technologies Asia also presented estimated average daily energy consumption figures for an R404a plug-in system and an R404a remote system.

Cold Front Technologies Asia estimated an average daily energy consumption of 909.49 kWh for the R404a plug-in system and 1,158.35 kWh for the R404a remote system.

Refrigeration system	Average energy consumption per day in kWh	Percentage difference compared to R290 waterloop
R290 waterloop	741.35	N/A
R404a plug-in (estimated)	909.49	18.5%

Refrigeration system	Average energy consumption per day in kWh	Percentage difference compared to R290 waterloop
R404a remote (estimated)	1,158.35	36%

Average energy consumption per day comparison between R290 water loop and R404a plug-in and remote systems

Benchmarking electrical energy intensity

In order to conduct an initial comparison and analysis of the resulting energy consumption data, shecco used the electrical energy intensity benchmark used widely in the international commercial food retail industry.

Electrical energy intensity is defined as the total amount of electrical energy consumed in kWh per square meter of sales area per year (kWh/m^2/year).

Based on our analysis of the data from August to September, we found that the R290 water loop system would consume an estimated 345,550.28 kWh per year.

The supermarket has a total sales area of 1,600 m^2.

Therefore, the estimated electrical energy intensity of the supermarket is about 216 kWh per square meter of sales area per year.

This is very low compared to the average electrical energy intensity figures we found for similar sized supermarkets and stores in published studies from the U.S. and Europe over the past decade (See *Additional sources and citations* at the end of this report).

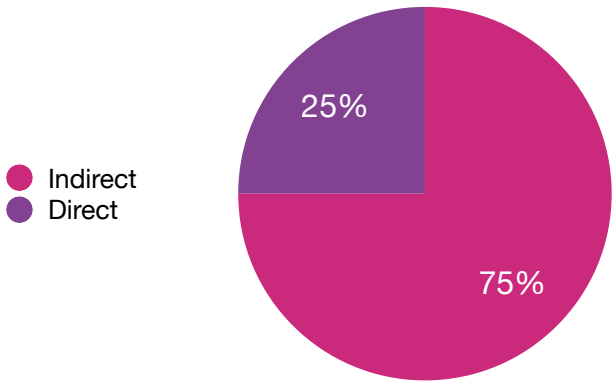
However, these studies take into account the energy used for other major store equipment such as lighting, air-conditioning and ventilation.

More work is needed to reach a more comparable estimated electrical energy intensity value for this Royal Duty Free Shops store.

Learn more

Carbon emissions from a supermarket's perspective

If you manage a commercial food retail business (supermarket, hypermarket, grocery or convenience store), it is helpful to look at your overall carbon emission footprint as a direct vs. indirect pie chart.



General emissions breakdown
for a supermarket

Indirect emissions

75% of your overall carbon emissions footprint is generally attributable to off-site or indirect emissions.

Indirect emissions result from the consumption of electricity produced by fossil fuel power plants off-site. This electricity is used to power your store's heating, ventilation, air-conditioning and refrigeration systems as well as lights and other ancillary devices such as bakery equipment or comfort room hand dryers for example

Close to 50% percent of the Philippines' current energy mix is supplied by coal and 25% by natural gas, according to the Philippines Department of Energy's 2015 Power Generation Mix data.

Indirect emissions can be mitigated through the use of on-site renewable energy generation such as roof-top solar panels. They can also be mitigated by using renewable energy power supply agreements.

Direct emissions

Around 25% of this pie chart is attributable to on-site or direct emissions.

The majority of direct emissions at a commercial food retail business result from refrigerant leakage from the store's refrigeration and air-conditioning systems during maintenance and disposal.

These systems leak at an average rate of 15-30% per year — often much higher — according to a 2015 report by the United Nations Environment Programme Technology and Economic Assessment Panel.

In addition, the Washington, D.C.-based non-governmental organization, Environmental Investigation Agency (EIA) found that HFC refrigerants were leaking at 57% of the stores involved

in a months-long investigation of grocery stores and supermarkets in the Washington, D.C. area in 2021. This included 60% of Walmart stores that were investigated, according to the report.

Therefore, we strongly recommend that you, as a commercial food retail business manager, consider making the investment to reduce your store's indirect and direct emissions through the use of HFC-free and energy refrigerant refrigeration equipment.

Other HFC-free and energy efficient equipment options

The following is adapted from "SuperSmart, Eco-friendly Supermarkets - an Overview, 2016". See Additional sources and citations at the end of this report.

The latest HFC-free and energy efficient refrigeration systems generally fall into three categories:

Stand-alone (a.k.a "self-contained" or "plug-in"): These systems are similar to domestic refrigerators. Stand-alone equipment is often a display case where the refrigeration system is integrated into the cabinet and the condenser heat is rejected to the sales area of the supermarket. The function of plug-in equipment is usually to display ice cream or cold beverages such as beer or soft drinks. HFC-free options include equipment using R290 (with or without a water loop system), R600a or occasionally R744 as refrigerants.

R290 island stand-alone cabinet from AHT

Condensing units: These systems are small-size refrigeration equipment with one or two compressors and a condenser installed outdoors or in a small machine room. Condensing units provide refrigeration to a small group of cabinets installed in convenience stores and small supermarkets. HFC-free options usually include equipment using R744 as a refrigerant.

Panasonic 20HP outdoor condensing unit

Centralized: Centralized systems consist of a central refrigeration unit located in a machine room. There are two types of centralized systems: direct and indirect systems. In a direct system, racks

of compressors in the machine room are connected to the evaporators in the display cases and to the condensers on the roof by long pipes containing the refrigerant.

In an indirect system, the central refrigeration unit cools a fluid that circulates between the evaporator in the machine room and the display cases in the sales area. This fluid is known by different names, such as secondary refrigerant, secondary fluid, secondary coolant, heat transfer fluid, or brine. Secondary fluid is typically a solution of water with salts or alcohols which decreases the freezing point of water well below zero.

HFC-free options often include systems using R744 or occasionally ammonia as refrigerants.

See below for a table summarizing the different types of refrigeration systems used in food retail and refrigerants, applications and capacities.

Type	Application	Capacity (kW)	Traditional refrigerants	HFC-free refrigerants	Emission	Global numbers (millions)
Stand-alone	Small stores, gas stations, offices and hotels	0.1-2	R22, R134a, R404A, R507A	R290, R600a, R744	Low	~50
Condensing unit	Medium-small stores, gas stations, offices and hotels	5-25	R22, R134a, R404A, R507a	R744	Medium	~30
Centralized	Supermarkets, hypermarkets	20-1000	R22, R134a, R404A, R507a	R744, R290, R717	High-medium	~0.5

Major refrigeration system types in commercial food retail businesses

Technology selection considerations

The following is adapted from "SuperSmart, Eco-friendly Supermarkets - an Overview, 2016". See Additional sources and citations at the end of this report.

Equipment and components selection is of high importance for proper operation of heating, ventilation, air conditioning and refrigeration systems. Implementing new technologies can save energy and prolong the service life of these systems.

The following recommendations are given as best practices in installation:

- Choose refrigeration systems with minimum possible quantity of refrigerant relative to cooling capacity (e.g. reduce length of piping and pipe bends)
- Optimize number of compressors on a rack, and minimize starts during lower load operation, if possible using inverter motors having in mind efficient operation during part load
- Ensure minimum head pressure at design and allow head pressure to float to the lowest level possible to ensure system stability
- Take care that condenser pipework design allows liquid refrigerant to drain back to the receiver under all operating conditions
- Specify independent isolation of split/larger condensers to compensate for refrigerant migration in all ambient conditions
- Design the plant for minimum vibration, ample ventilation and ease of access to maintenance
- Specify minimum use of non-hermetic components

- Opt for full pump-down capacity receivers
- Size the system capacity correctly, according to the estimated cooling requirement and outdoor conditions. Over sizing induces cost increase, larger components and refrigerant charge, together with increased amount of part load operation.

Equipment and components should further have clear indications and procedures about required regular maintenance and operation checks.The suggestions given above are valid also for HVAC systems. Having in mind that HVAC systems can differ a lot, depending on the building location, capacity, and type of system, proper equipment and components selection of HVAC systems is of high significance for proper supermarket operation.

Some examples of possible selection of components is reported below. Components are grouped according to their role in the refrigeration system:

- Refrigeration systems (sub-coolers, heat recovery systems, condenser technology, electronic expansion valve)
- Display cases (LED lighting, sliding lids, glass doors, anti-condensation glass doors and night blinds)
- Electronics (periodic frame heating, electronic expansion valves, remote service system, latest control software)
- Controls and monitoring system components (adaptive controls, continuously monitor and adjust system parameters such as superheat or evaporating/condensing pressures, speed controllers for evaporator/condenser fans, timers for display case lighting, on-demand defrost, night-time set back, remote service system, latest control software, wireless communication)

Additional sources and citations

"CCI-Hub Technical Training Workshop on Advanced Technologies for Commercial Food Retail, Online Webinar", October 7, 2020, Cold Front Technologies Asia, Cold Chain Innovation Hub [link]

"A 17-fold increase of trifluoroacetic acid in landscape waters of Beijing, China during the last decade", Zhai et al., 2014 [link]

"SuperSmart, Eco-friendly Supermarkets - an Overview, 2016", European Commission, Horizon 2020 Programme [link]

Recent Electrical Energy Intensity studies from the U.S. and Europe, Cold Chain Innovation Hub 2020 [link]