Fluorinated Gases (F-Gas) Overview and Opportunities

October 18, 2022

Call-in Details 1-202-991-0477 ID: 578 920 254#

Today’s Host

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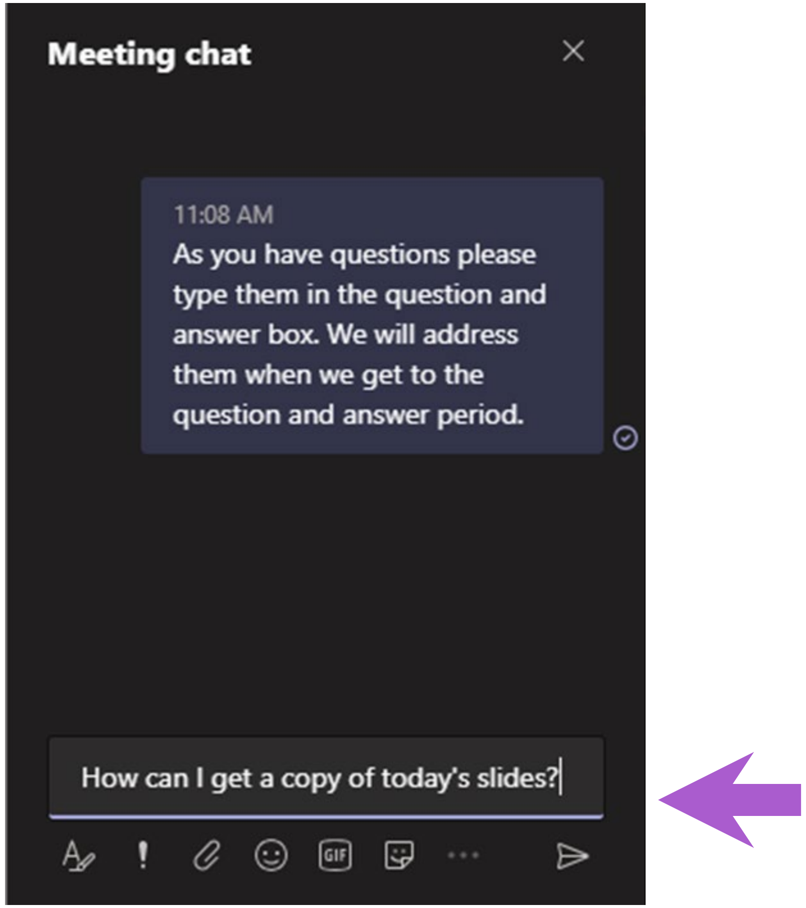
Kersey has worked in various sectors before coming to the U.S. Environmental Protection Agency (EPA) where he is the Program Manager for EPA’s GreenChill Advanced Refrigeration Partnership. Most recently, he worked for 3.5 years at the California Air Resources Board implementing an incentive program for cleaner agricultural equipment and ensuring that Cap-and-Trade incentive programs benefitted disadvantaged communities. Prior to that, he worked with state agencies to plan hydrogen fueling infrastructure for fuel cell electric vehicles. He holds a Bachelor of Science (BS) in Mechanical Engineering, a BS in Materials Science & Engineering, a Masters of Science (MS), and a PhD in Environmental Engineering, all from the University of California, Irvine.

Questions and Webinar Feedback

Question and Answer Session

- Participants are muted
- Questions will be moderated at the end
- To ask a question, enter your comment into the chat box



Feedback Form

- We value your input!
- The link to a feedback form will appear in the chat window

Webinar Materials

Recording and Slides

- Webinar is being recorded
- Materials will be posted on the GreenChill website under Events and Webinars: www.epa.gov/greenchill
- To receive notification when materials are posted email:

  EPA-GreenChill@abtassoc.com

Program Overview

www.epa.gov/greenchill

GreenChill is a voluntary partnership program that works collaboratively with the food retail industry to reduce refrigerant emission and decrease stores' impact on the ozone layer and climate system

GreenChill works to help food retailers:

- Lower refrigerant charge sizes and eliminate leaks
- Transition to environmentally friendlier refrigerants
- Adopt green refrigeration technologies and best environmental practices

Upcoming GreenChill Webinars

- We are planning the remainder of our 2022 and 2023 webinar series. Email GreenChill@epa.gov if you have any ideas for a webinar or would like to present.

- To be added to our webinar invitation list, email EPA-GreenChill@abtassoc.com

Celebrating 15 Years of GreenChill

2022 is the 15th anniversary of GreenChill!

- View GreenChill's 15th anniversary report: www.epa.gov/greenchill/greenchill-resources-and-reports
- Explore GreenChill's Partner accomplishment page: www.epa.gov/greenchill/partnership-accomplishments

Learn More

www.epa.gov/greenchill

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Today's Speaker…

Alan Saban

Alan Saban
WAVE Engineering Director
Email: alans@wave-refrigeration.com

Alan has worked in the refrigeration industry for 20 years. He is experienced in both independent consulting and contracting across a range of project sizes and solution types. Alan has worked for and been involved with notable projects in the United Kingdom (UK) with regards to F-gas reduction solutions. He brings real-world learnings from these projects into everyday decision making as well as long term business investment strategy.

Sam Cameron

Sam Cameron
Bachelor of Science (BSc)
Member of the Institute of Refrigeration Source (MInstR)
WAVE Engineering Manager
Email: samc@wave-refrigeration.com

Sam comes from a background of sustainability and entered the industry in the UK at a time of rapid change. He has independent consultancy experience in system design, theoretical modelling and metering of energy and performance as well as international tender and contract management. Sam has carried out independent feasibility and performance studies for a range of clients in the UK and Europe, each with their own requirements and challenges. He believes the holistic end goal should be carbon reduction of all emission scopes.

Christopher Parker

Christopher Parker
Masters of Engineering (Meng), Associate Member of the Institution of Mechanical Engineers (AMIMechE), Foundation Charted Manager (fCMgr), Chartered Manager of Engineering (MCMI), Associate Member of the Institute of Refrigeration (AMInstR)
WAVE Technical Consultant
Email: Chris@wave-refrigeration.com

Chris graduated from Liverpool John Moores University with a first-class MEng degree. During his career he has applied the knowledge developed from his studies at university to create detailed procedures and programmes. These have enabled users and clients to make informed decisions of which refrigeration systems can best meet their unique requirements. He has co-authored three international technical papers since the start of his career.

F-Gas Overview & Opportunities

A presentation of findings from technology implementation across the pond

By Alan Saban, Engineering Director

October 2022

wave
an employee owned company

Who are we?

co op

Sainsbury's

Chemours™

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Morrisons
Since 1899

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Bidfood
Inspired by you

Introduction

Refrigerant Regulations

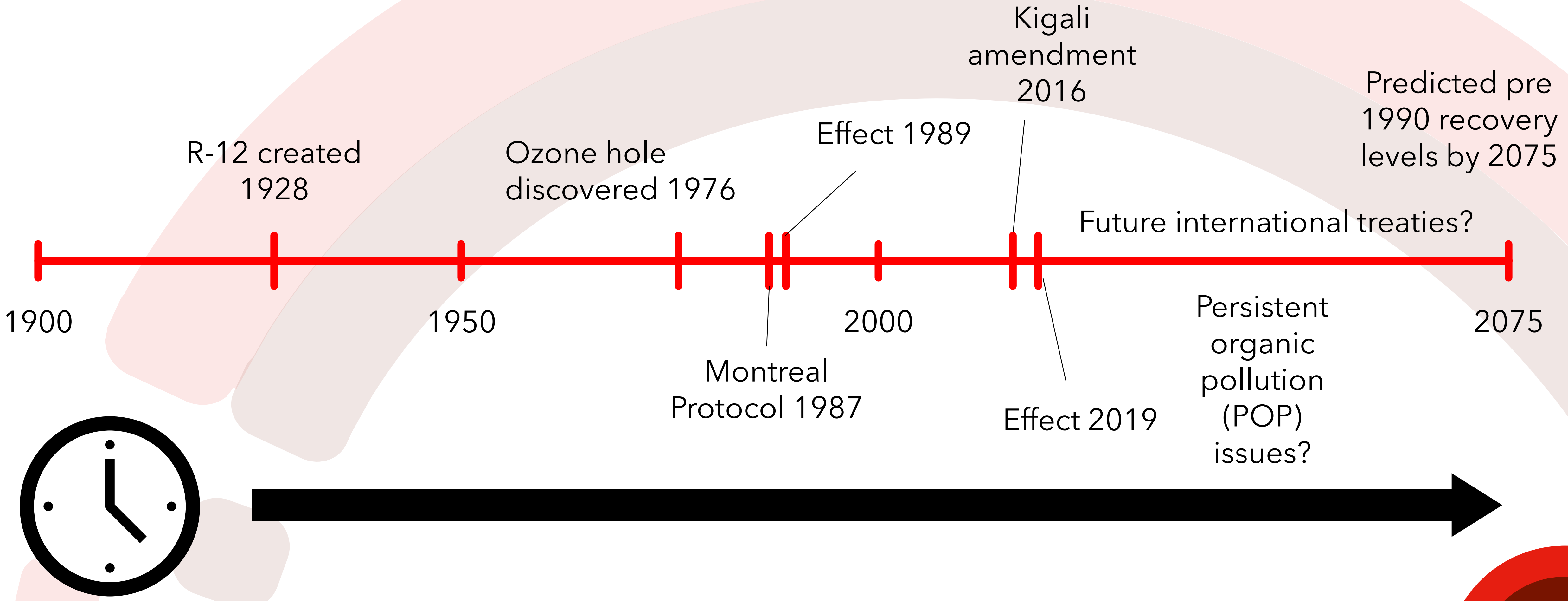
Retailers' Approach Based on Size

Importance of Proactive Maintenance

Integrated Heat Reclaim

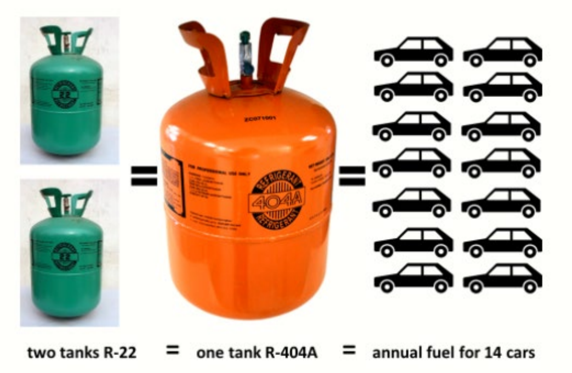
Refrigerant Regulations

Global Regulations



F-Gas Regulations - the UK and European Union (EU) approach

Refrigerant	GWP
HFC 507	3,985
HFC 404A	3,922
HFC 227ae	3,220
HFC 407C	1,774
HFC 134a	1,430
HFC 245fa	1,030
HFC 32	675
HFO 1234yf	4
Propane	3
CO_2	1
Ammonia	0



- What is the EU F-gas regulation?
- How has this affected retailers and their capital expenditure?
- Were retailers and manufacturers quick to respond?
- How does this fit into 'Net Zero' approaches?

Refrigerant Ban Based on Global Warming Potential (GWP)

Market Sector	Product Description	Scope of banned F-Gases	Start Date[1]
Refrigeration	Non-confined direct evaporation systems	All HFCs and PFCs	2007
	Domestic refrigerators and freezers[2]	HFCs with GWP > 150	2015
	Refrigerators and freezers for commercial use (hermetically sealed)[3]	HFCs with GWP > 2,500	2020
		HFCs with GWP > 150	2022
	All stationary refrigeration equipment[4]	HFCs with GWP > 2,500	2020
	Multipack central systems for commercial use with a cooling capacity above 40kW [5]	F-Gases with GWP > 150	2022
Air-conditioning	Moveable, hermetically sealed air-conditioning	HFCs with GWP > 150	2020
	Single split systems containing 3 kg or less	F-Gases with GWP >750	2025
Insulating foam[6]	One component foam aerosols	F-Gases with GWP > 150	2008
	Extruded Polystyrene foam (XPS)	HFCs with GWP > 150	2020
	Other foams (including polyurethane)	HFCs with GWP > 150	2023
Fire protection	Systems using PFCs	All PFCs	2007
	Systems using HFC 23	HFC 23	2016
Aerosols	Novelty aerosols[7] and signal horns	HFCs with GWP > 150	2009
	Technical aerosols[8]	HFCs with GWP > 150	2018
Other applications	Non-refillable containers for bulk product	All F-Gases	2007
	Windows for domestic use	All F-Gases	2007
	All other windows	All F-Gases	2008
	Footwear	All F-Gases	2006
	Tyres	All F-Gases	2007

What is GWP?

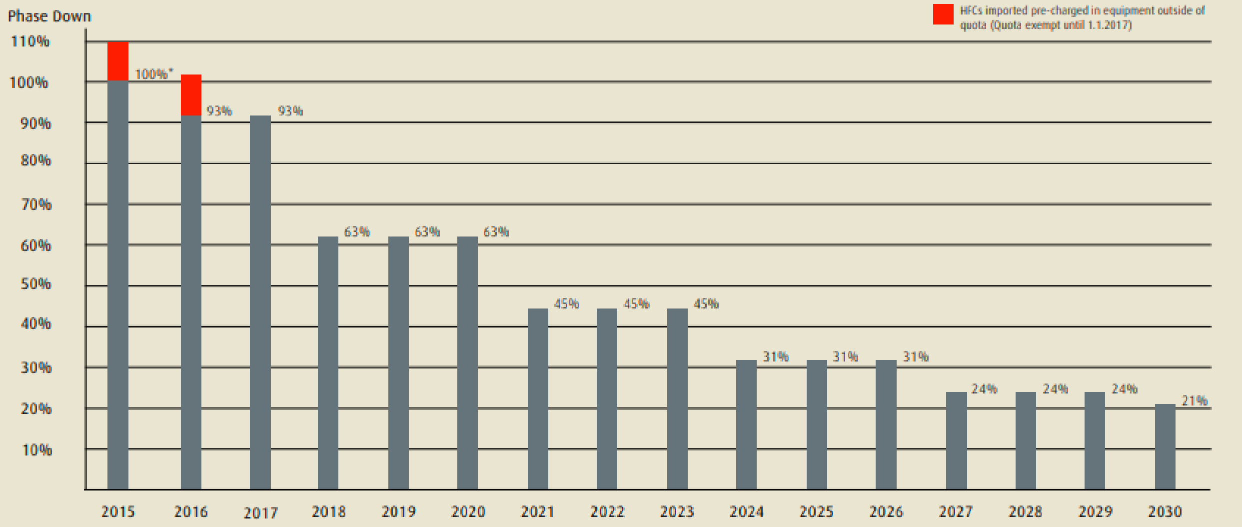
Requirement	2006 Regulation	2014 Regulation		
	kg threshold	tonnes CO_2 threshold	kg equivalent for HFC 404A	kg equivalent for HFC 134a
Thresholds for equipment size: mandatory leak tests, record keeping and service ban				
Annual leak test*	3 kg	5 tonnes CO_2	1.3 kg	3.5 kg
6 monthly leak test	30 kg	50 tonnes CO_2	12.7 kg	35 kg
Automatic leak detection	300 kg	500 tonnes CO_2	127 kg	350 kg
Record keeping*	3 kg	5 tonnes CO_2	1.3 kg	3.5 kg
Service ban	n/a	40 tonnes CO_2	10.2 kg	28 kg
Thresholds for reporting of bulk product				
Production, import, export	1,000 kg	100 tonnes CO_2	25 kg	70 kg
Destruction, feedstock	n/a	1,000 tonnes CO_2	250 kg	700 kg
Products	n/a	500 tonnes CO_2	125 kg	350 kg
Independent audit	n/a	10,000 tonnes CO_2	2 500 kg	7,000 kg

* The lowest thresholds for mandatory leak testing and record keeping are doubled for hermetically sealed equipment, from 5 tonnes CO_2 to 10 tonnes CO_2

CO_2: Carbon dioxide
HFC: Hydrofluorocarbons
PFC: Perfluorocarbon
kg: Kilogram
n/a: Not applicable

Phase Down Quota

Diagram 1: HFC phase down schedule (CO_2e basis, in %)



* 100% = Average of 2009-2012

Table 5: Annex V: Quantities

2009-2012 average	2015	2016-17	2018-20	2021-23	2024-26	2027-29	2030
Baseline (100 %)	100%	93%	63%	45%	31%	24%	21%

Table 6: Global warming potential of some HFC gases

Gas	R134a	R404A	R407A	R407C	R410A	R422D	R427A	R438A	R507	R744 (CO_2)
GWP	1430	3922	2107	1774	2088	2729	2138	2265	3985	1

Table 9: Article 4: Leak check frequency

F-gas system contents	Leak check frequency (No leak detection system installed)	Leak check frequency (Leak detection system installed)
500 tonnes CO_2e or more	*At least once every 3 months*	*At least once every 6 months*
50 to 499.99 tonnes CO_2e	*At least once every 6 months*	*At least once every 12 months*
5 to 49.99 tonnes CO_2e	*At least once every 12 months*	*At least once every 24 months*

What is the quota for the EU and how does it work?

Rules for maintenance of existing equipment

Rules for installing new equipment?

Rules for leak checking and keeping track of F-gas usage?

CO_2e: Carbon dioxide equivalent

Retailers' Approach Based on Size

Influence of Design Considerations

Relevant design considerations to different retailers.

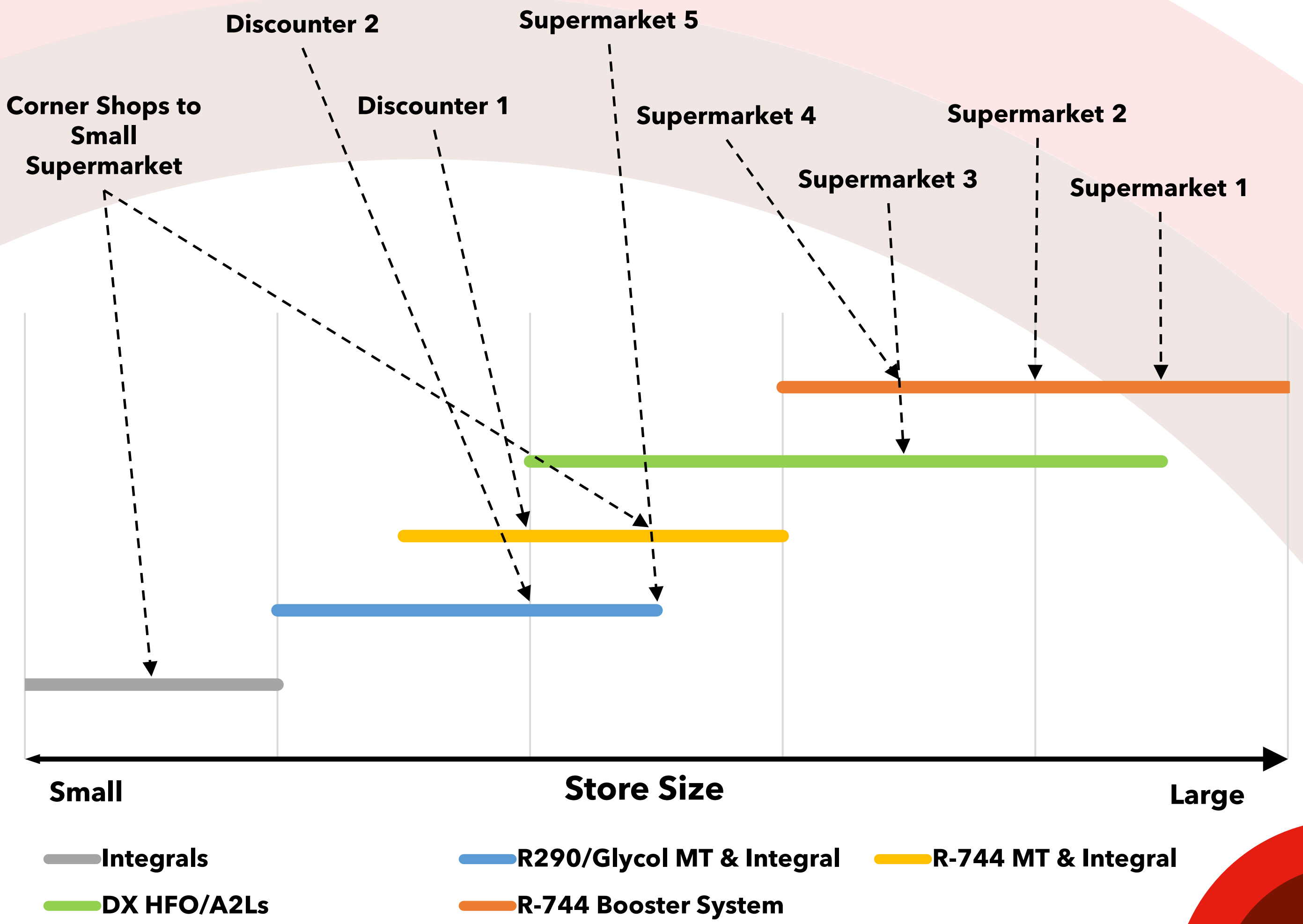
- Current Legislation
- Capital Cost
- Medium Temperature (MT)/Low Temperature (LT) Split
- Heat Reclaim
- Store Size/Load and External Space
- Risk Adversity
- Complexity for Install and Maintenance
- Longevity
- Emissions
- Energy Consumption

The following slides provide an introduction to the common refrigerant and system types used by retailers within the EU and UK.

Current Retailers' Approach

Retailer Description	Refrigeration Equipment Description
Corner Shops to Small Supermarkets	a) Range of store sizes from corner to small supermarket models. b) Convenience models represent the majority of the estate. c) Refrigeration systems vary in architecture depending on the building restrictions. d) R-744 (CO_2) centralised and R-290 integral cabinets are the preferred choice.
Discounter 1	a) Standard one store model size. b) R-744 (CO_2) centralised IT refrigeration with integrated heat reclaim. c) R-290 integral LT refrigeration cabinets. d) All cabinets feature doors.
Discounter 2	a) Standard one store model size. b) Adopting water-cooled integral refrigeration technology in IT applications c) Air-cooled in freezer display cases – using Hydrocarbons and R-744 (CO_2) refrigeration technologies. d) Installing doors.
Supermarket 5	a) Majority supermarket estate but does include convenience models. b) Adopting water-cooled hydrocarbon integrals throughout the store c) The heat from water (glycol) circuit is removed via a blend of dry coolers and chiller sets. d) Introduced and rolled out Wirth Research Eco-blade technology.
Supermarket 4	a) Majority supermarket estate but does include convenience models. b) Transition to R-744 (CO_2) refrigerant. c) Fridge doors or shelf-edge technology fitted to open front cabinets. d) Trim heat boxes installed on frozen display cabinets to reduce heat demand for glass doors.
Supermarket 3	a) Supermarket estate b) Adopting de-centralised low GWP refrigerants. c) Modular refrigeration systems
Supermarket 2	a) Majority supermarket estate but does include convenience models. b) Installed aerofoil technology across 1,400 stores and are transitioning to trans-critical R-744 (CO_2).
Supermarket 1	a) Majority supermarket estate but does include convenience models b) Are transitioning to trans-critical R-744 (CO_2).

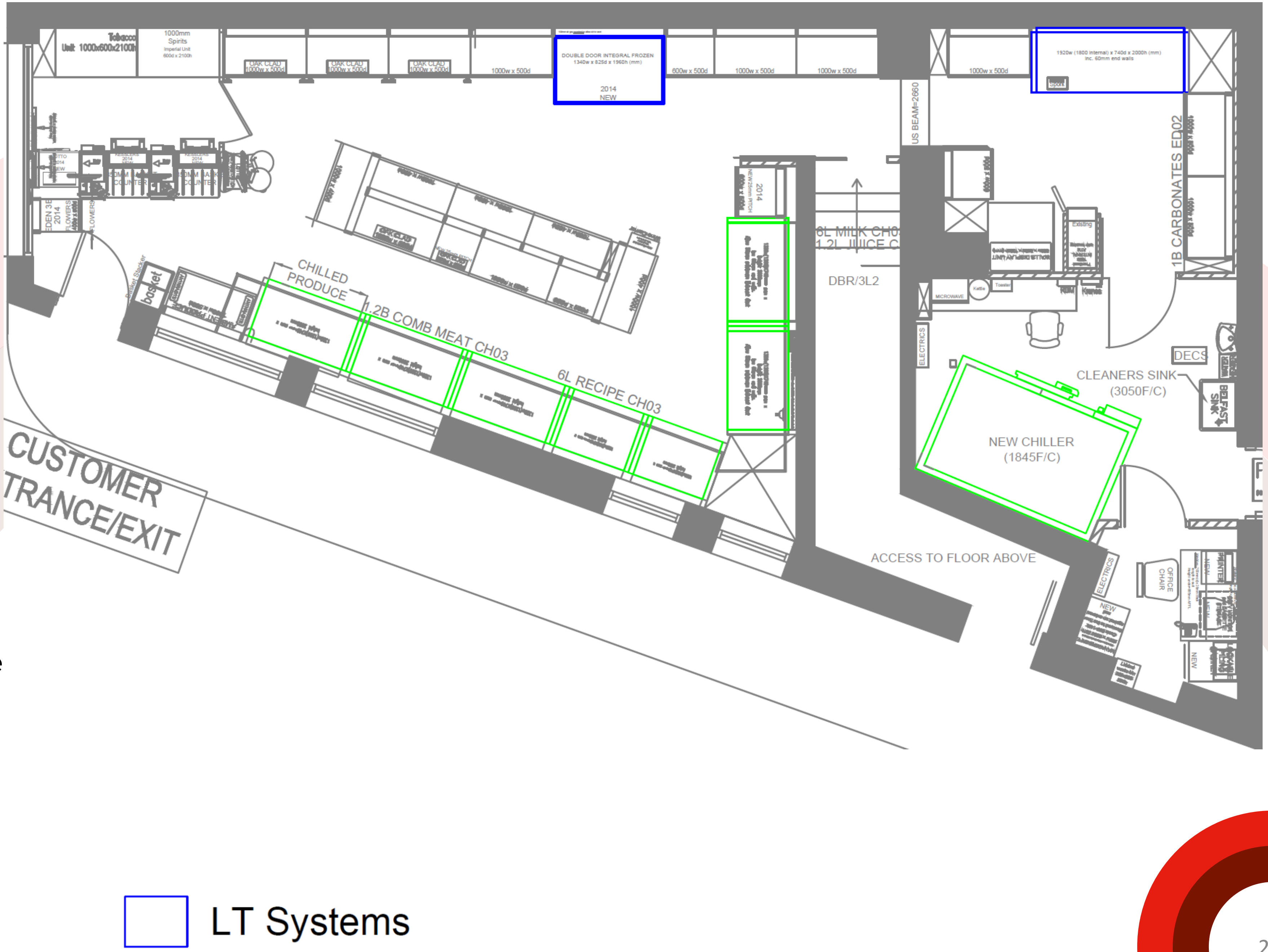
Typical System Types per Store Size in the UK



DX: Direct expansion; HFO: Hydrofluoroolefins

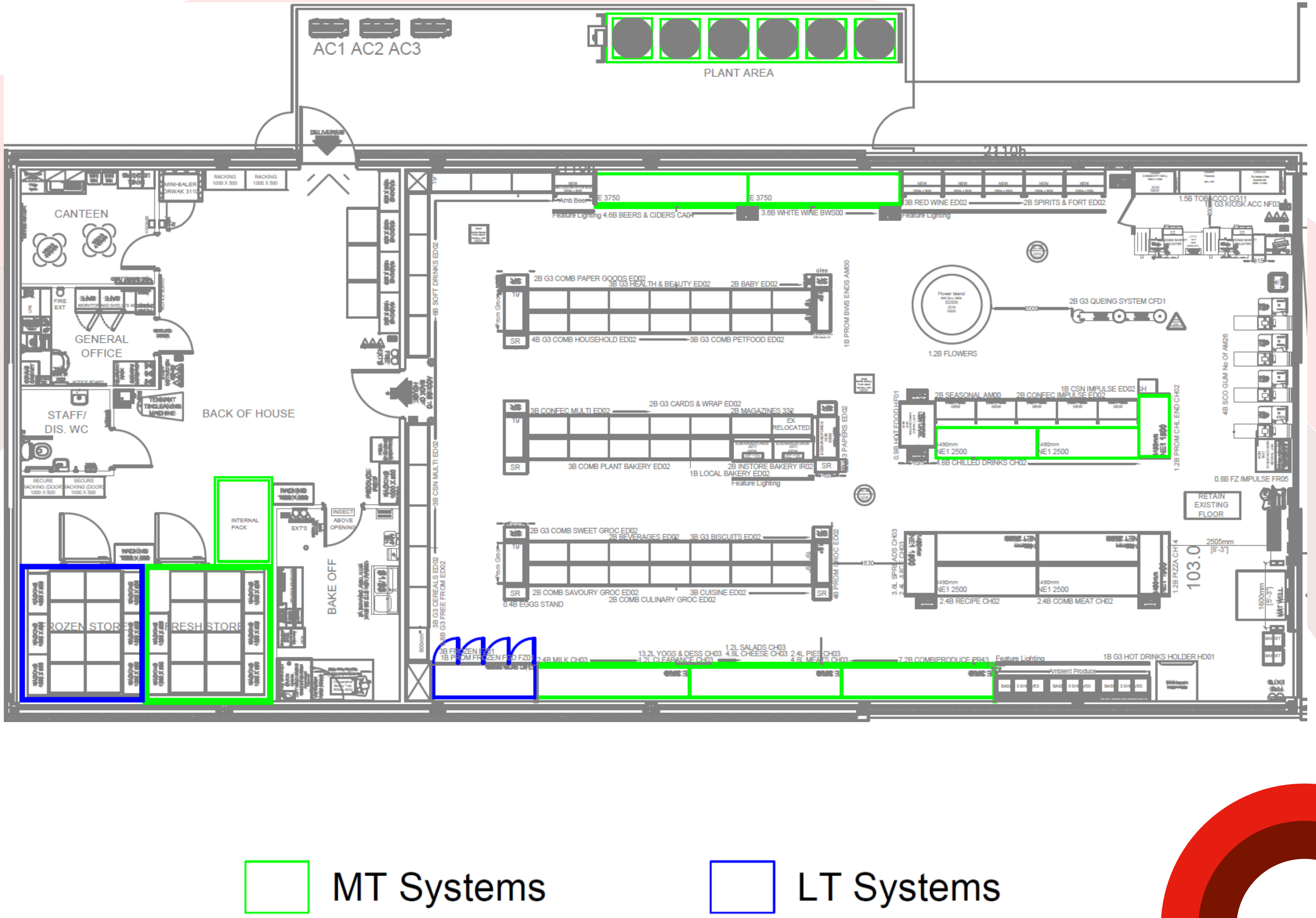
Corner Shop

- Generally use integrals due to ease and capital cost
- R-290 or R-600a are generally used to optimise efficiency for integrals
- Hydrocarbons (HCs) also have low GWP
    - R-290 (HC) GWP = 3
    - R-600a (HC) GWP = 3
- HCs cannot be used in large systems



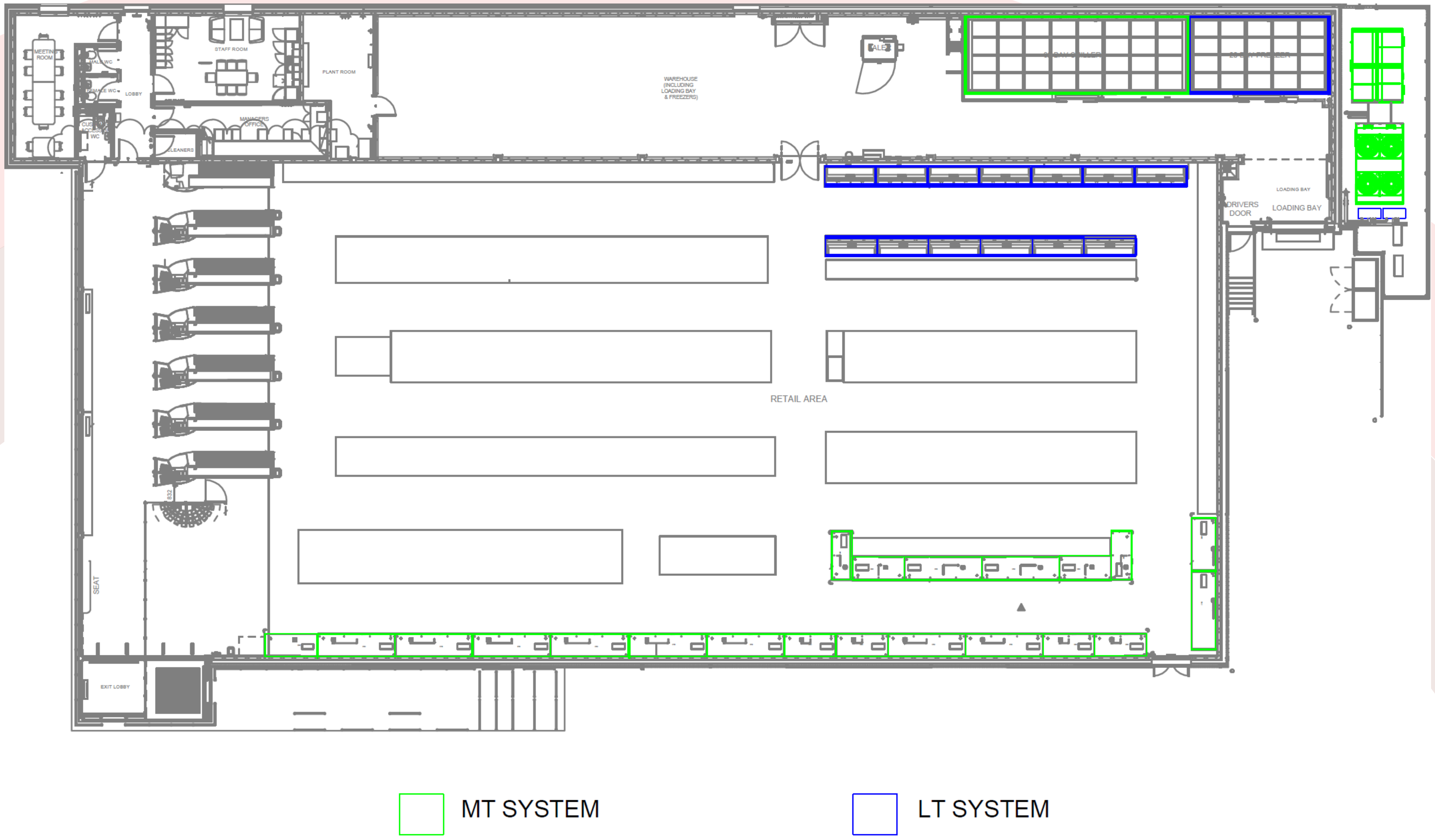
Convenience

- Start to see 'standard' layouts for stores
- More capital available and efficiency is considered
- Purely integrals not favoured as lower efficiency is exaggerated and longevity is considered
- Hydrocarbon (HC), Hydrofluoroolefin (HFO) and Natural refrigerants can be seen at this level
    - R-290 (HC) GWP = 3
    - R-454C (HFO) GWP = 148
    - R-744 (Natural) GWP = 1



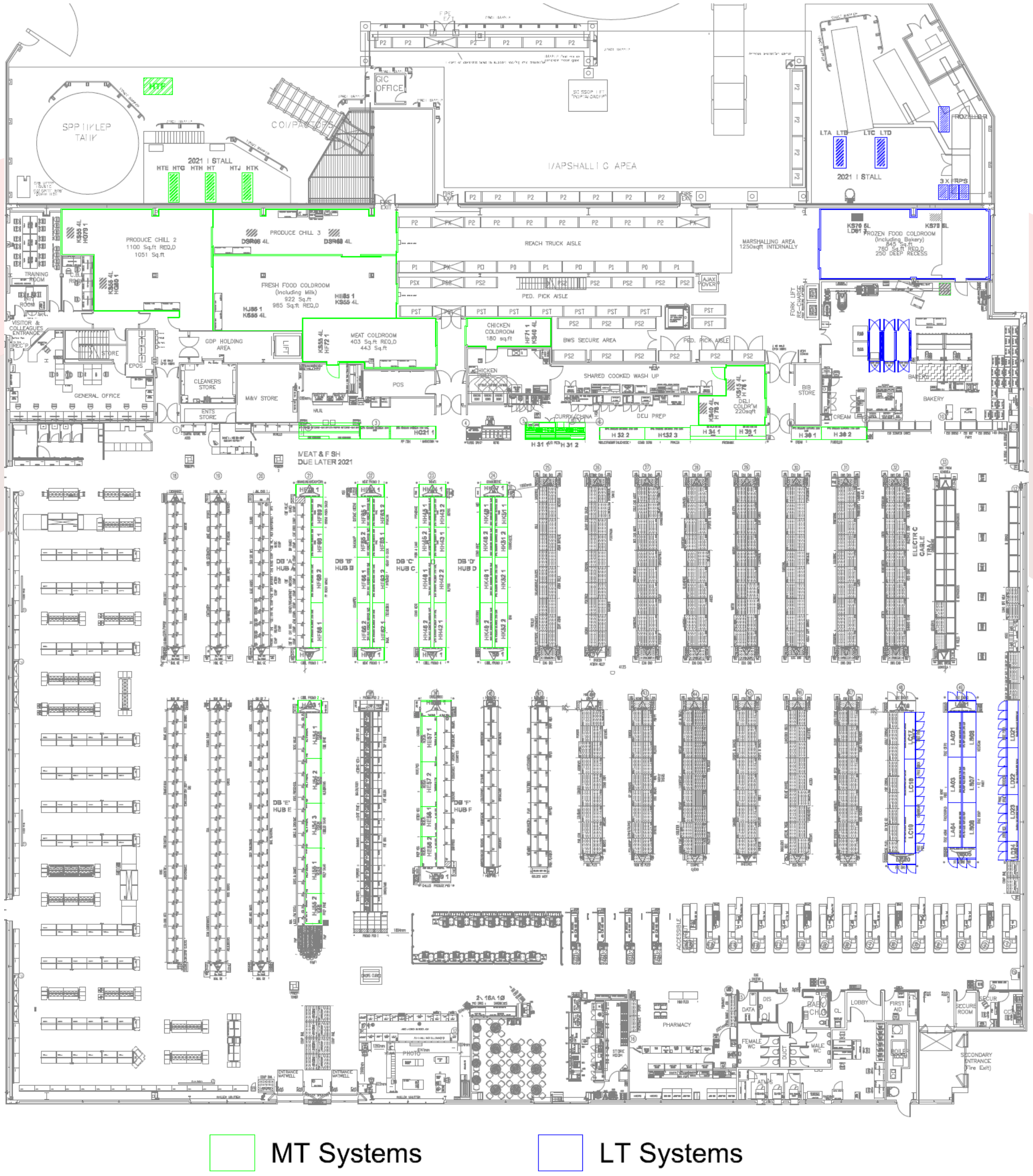
Discounter

- Larger than convenience stores, usually standard layouts
- Size lends itself to multiple solutions
- LT integral R-290 cabinets
- MT remote R-744 cabinets
- Secondary systems and HFOs also an option
  - R-290 (HC) GWP = 3
  - R-744 (Natural) GWP = 1
  - R-454C (HFO) GWP = 148
- Complex transcritical R-744 systems are sometimes utilised, but do not always make financial sense at this size



Supermarket

- Can range from slightly larger than a discounter up to superstore size
- Capital expenditure higher
- Transcritical booster CO_2 , centralised HFOs, secondary systems
- This example shows the way HFOs can be used on a larger level
  - R-454C (HFO) GWP = 148

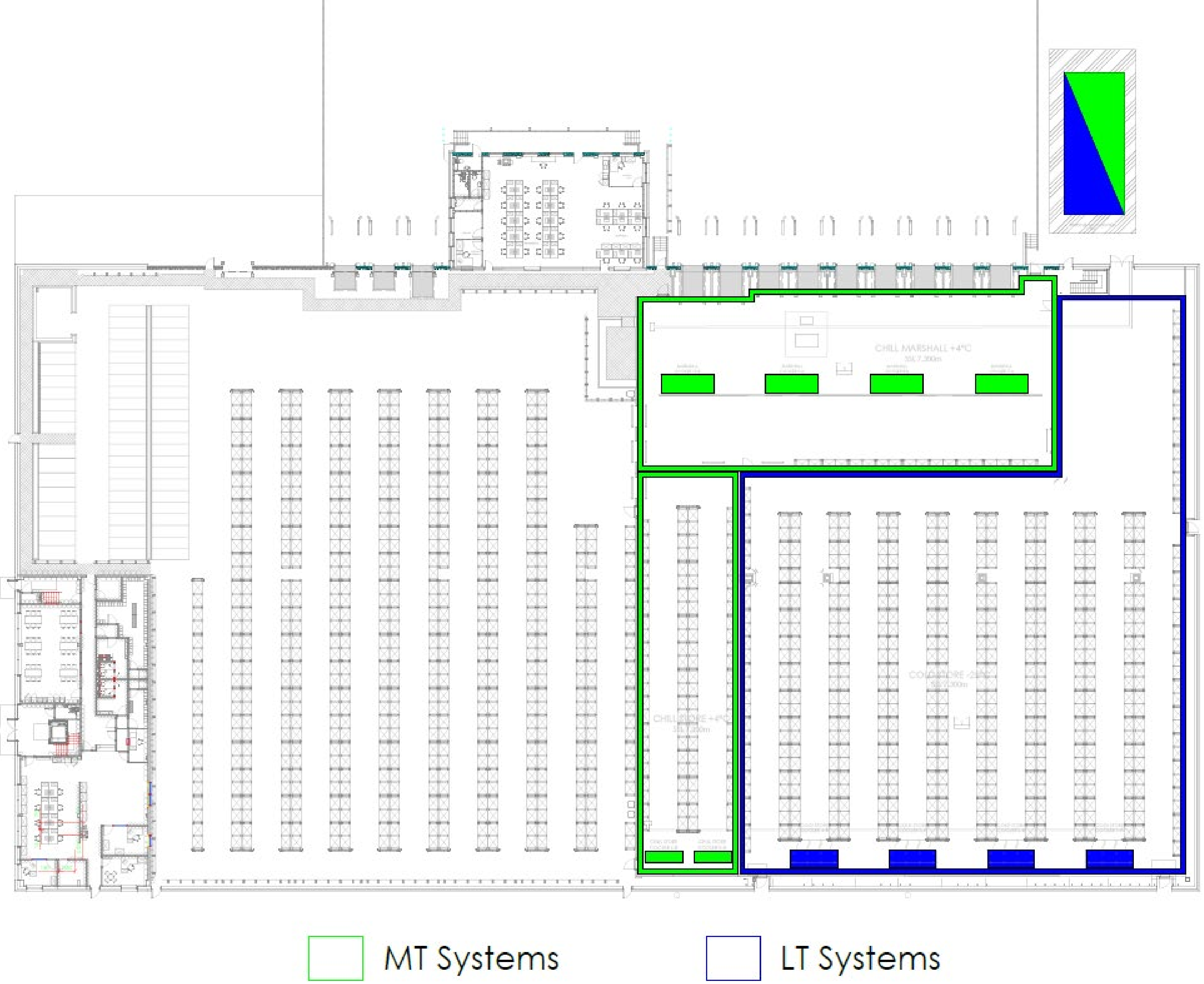


Supermarket (Continued)

- This example shows a store layout using transcritical R-744
  - R-744 (Natural) GWP = 1
- Truly centralised system
- Heat reclaim opportunities
- Complex systems

Refrigerated Distribu Centres (RDC)

- Example shows smaller RDC using CO_2
- Ammonia & CO_2
  - R-744 (Natural) GWP = 1
  - R-717 GWP = 0
- Ammonia
  - Expensive to install
  - Toxic and flammable
  - Significant maintenance schedules and risk assessment
  - Energy efficient
- CO_2
  - Less expensive install at smaller scale
  - Non-flammable, non-toxic
  - Less maintenance
  - Comparable efficiency at smaller scale

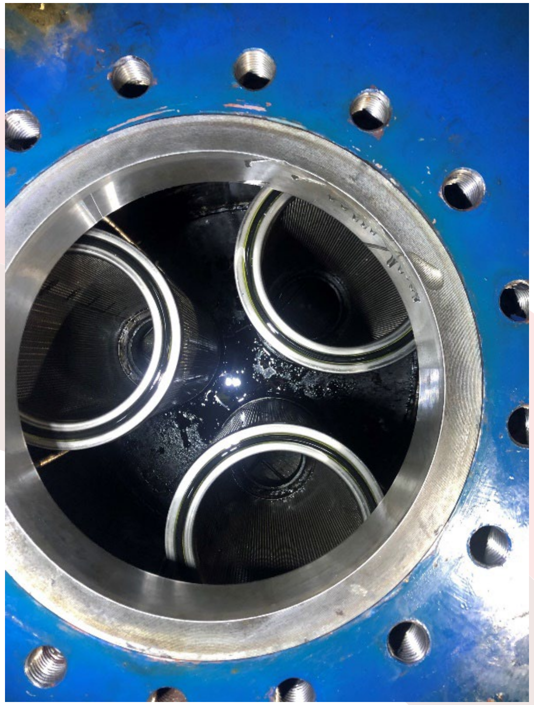


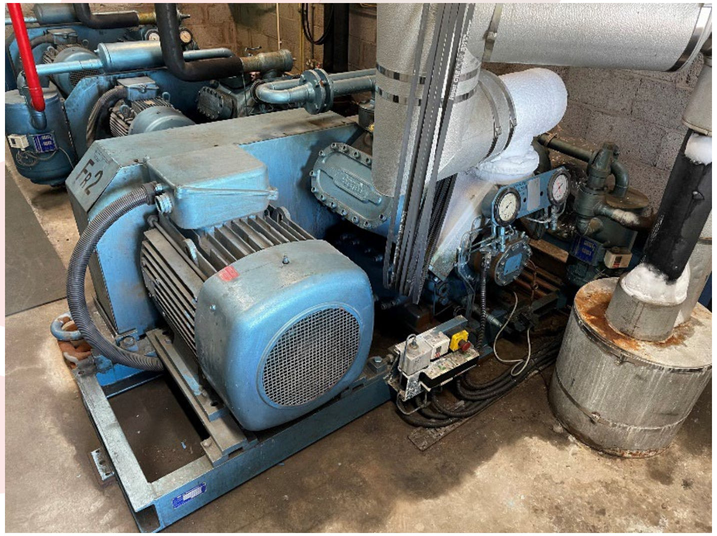
Proactive Maintenance

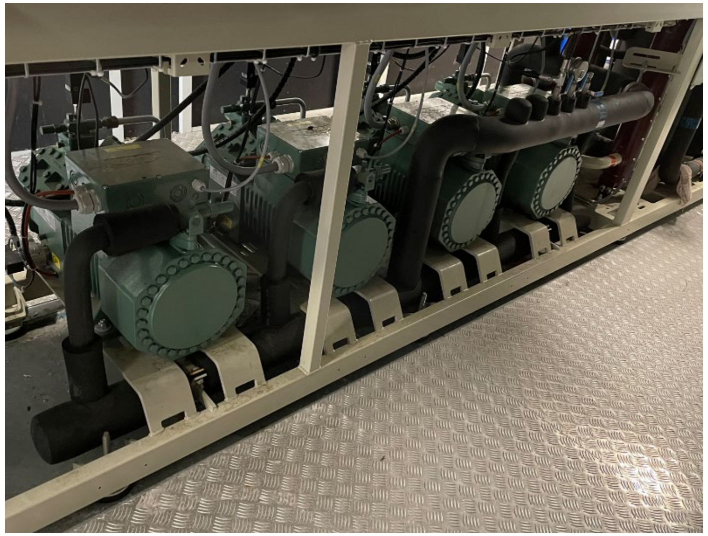
Importance of Proactive Maintenance

Refrigeration systems are complex, dynamic and subject to wear and tear.

- **Designed and Modelled**
- **Installed**
- **Maintained**



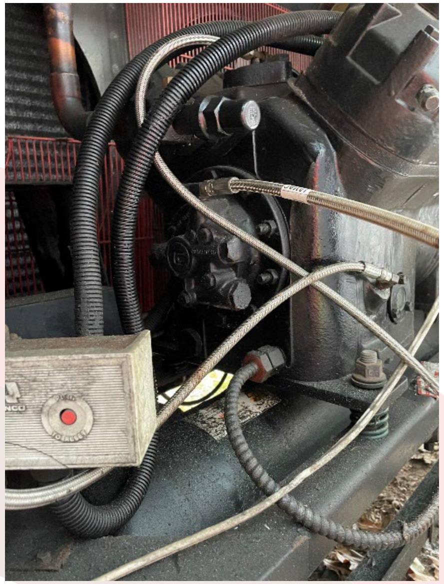


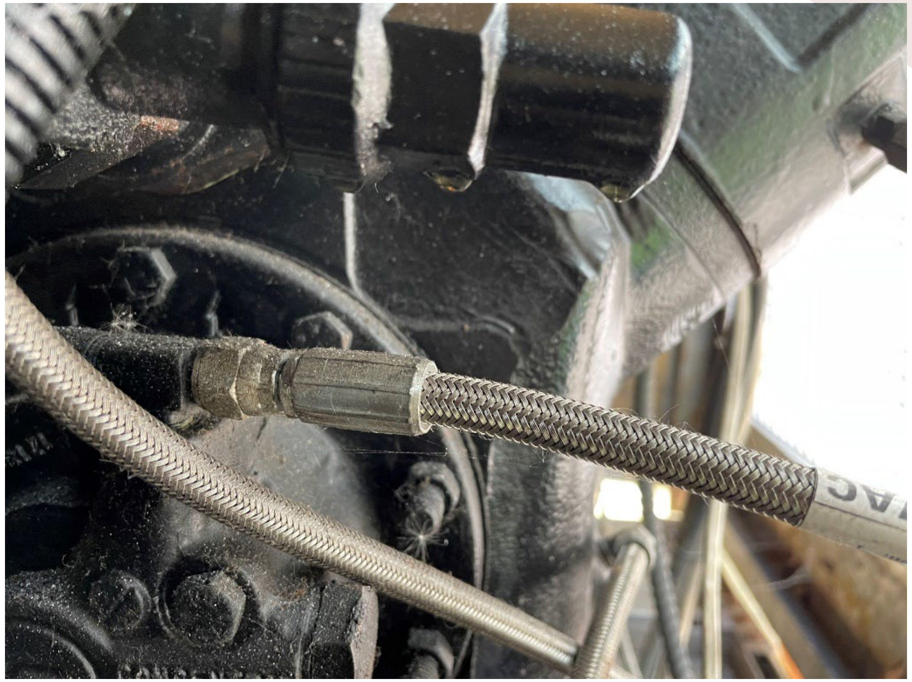


Leak Reduction

Leak Checking

- Visual
- Electronic Handheld Leak Detector
- Monitoring of Refrigerant Levels
- Frequency





Component Replacement

Replacement of components before failure should be targeted but the frequency will vary per system.

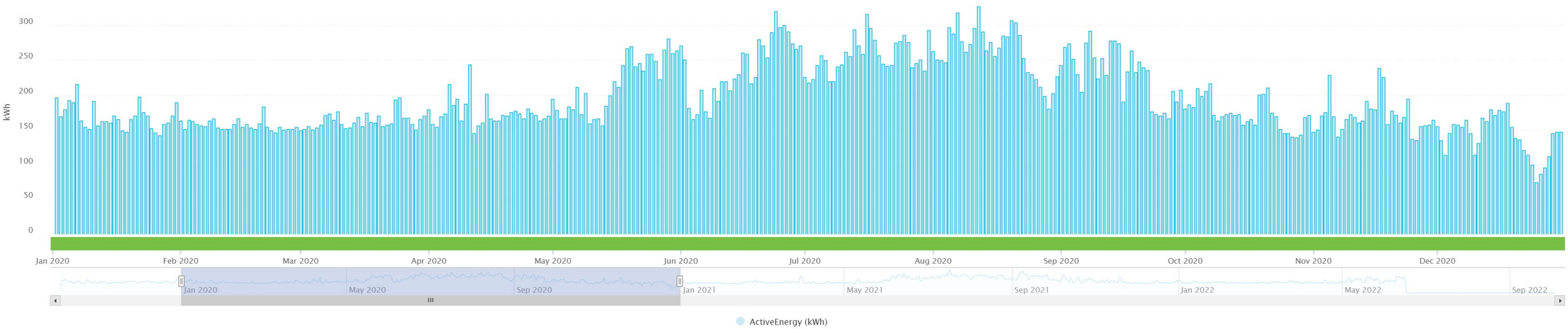
Most component manufacturers will offer a limited warranty on what they supply. Complicated assemblies should be supplied with recommended service requirements and/or an expected useful working life.

- Maintenance inspections
- Asset condition reports
- Cost of unplanned down time

Energy Consumption

Modelling - expectations

Metering - deviations



Remote Monitoring

Remotely Accessible

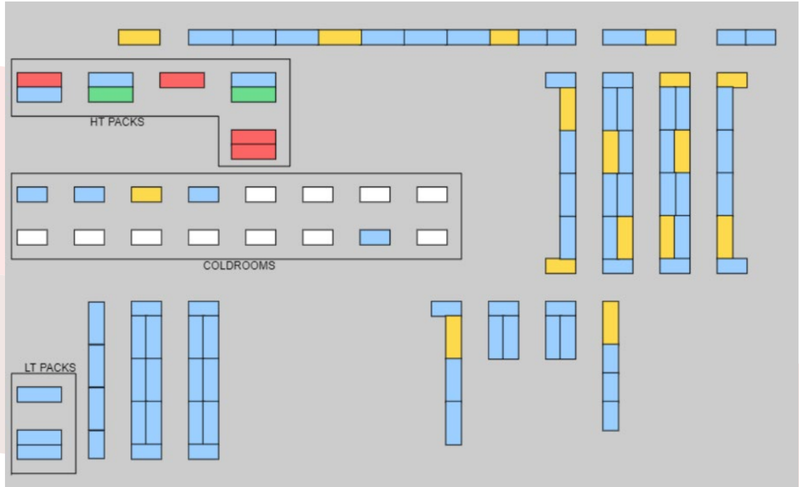
Real Time

Remote Triage

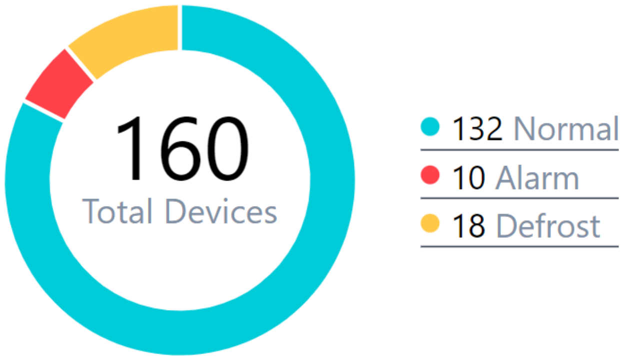
Trusted Users

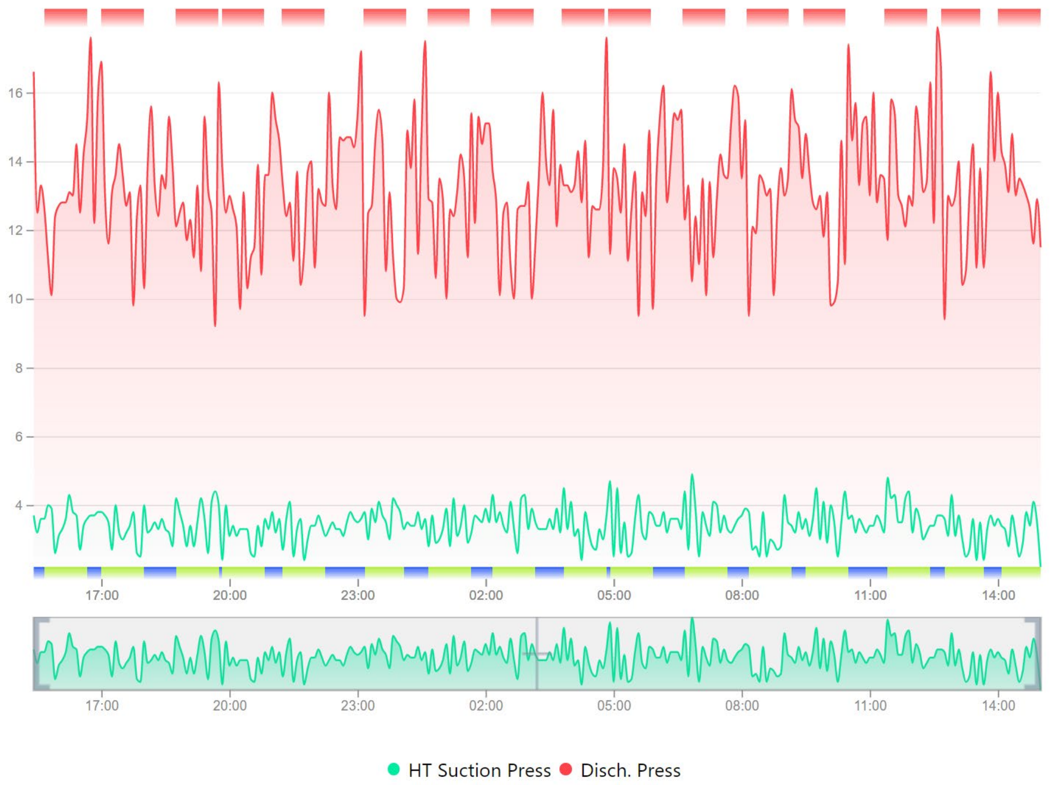
Estate Oversight

Optimisation



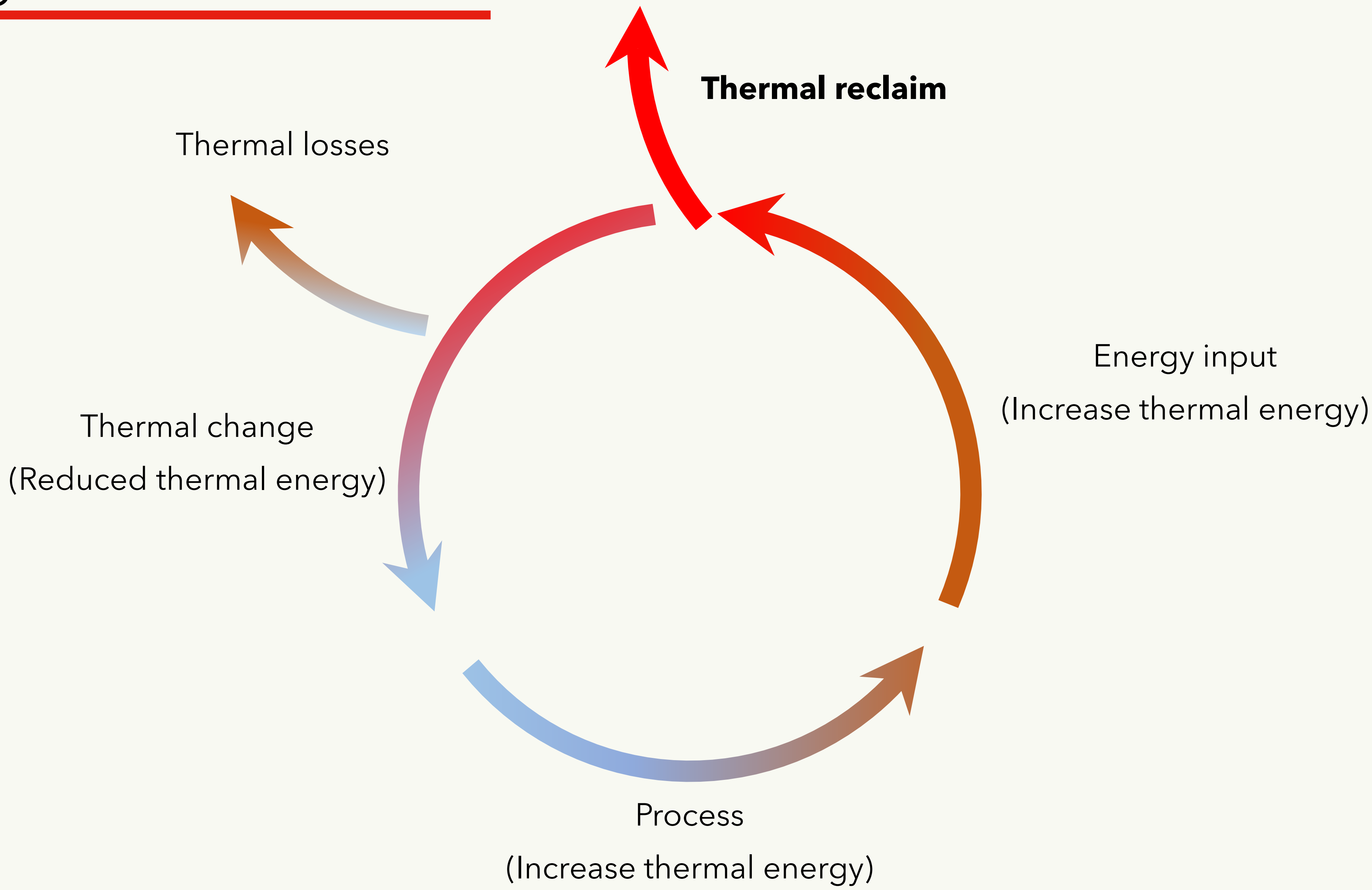
Device Status



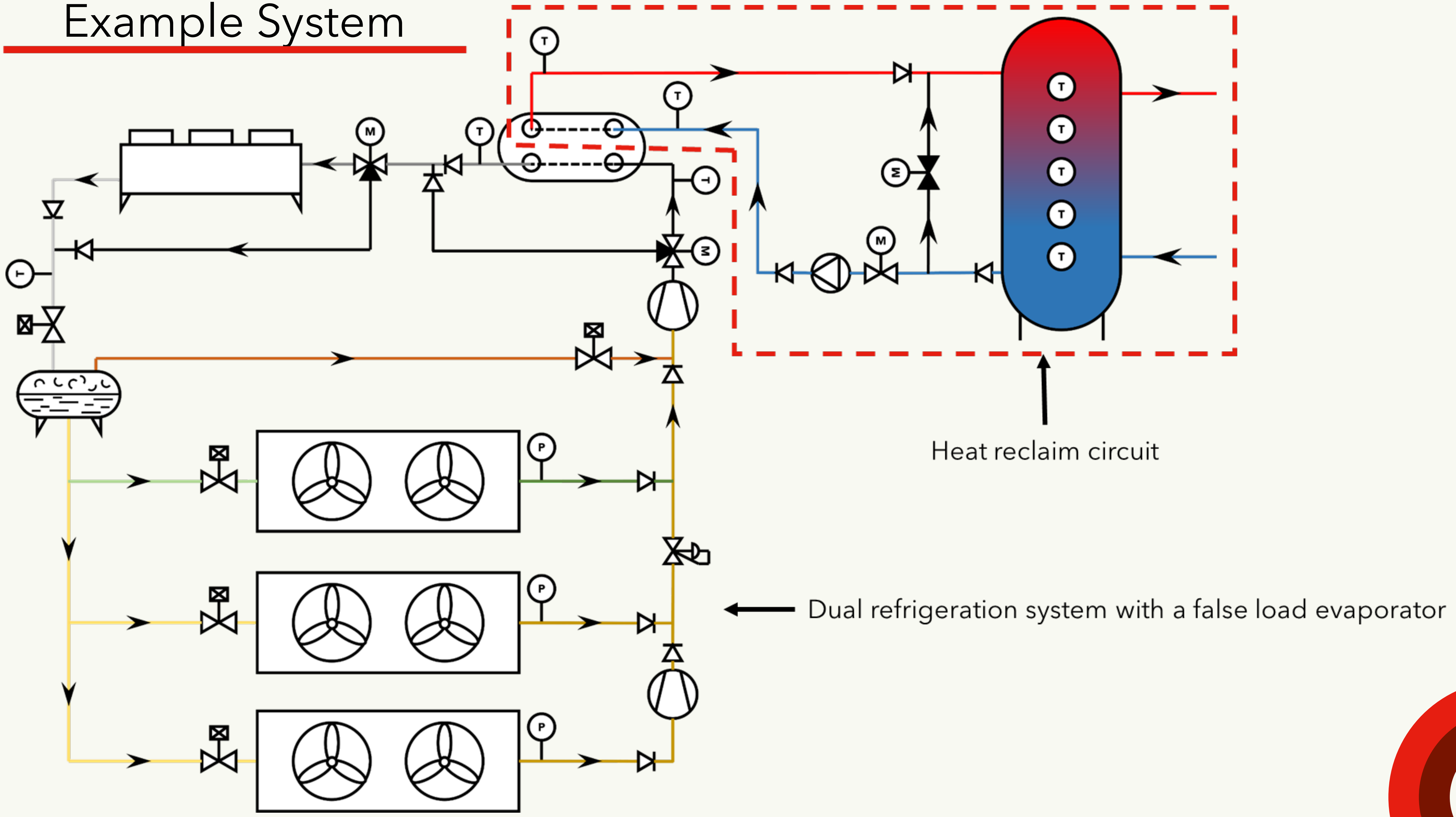


Integrated Heat Reclaim

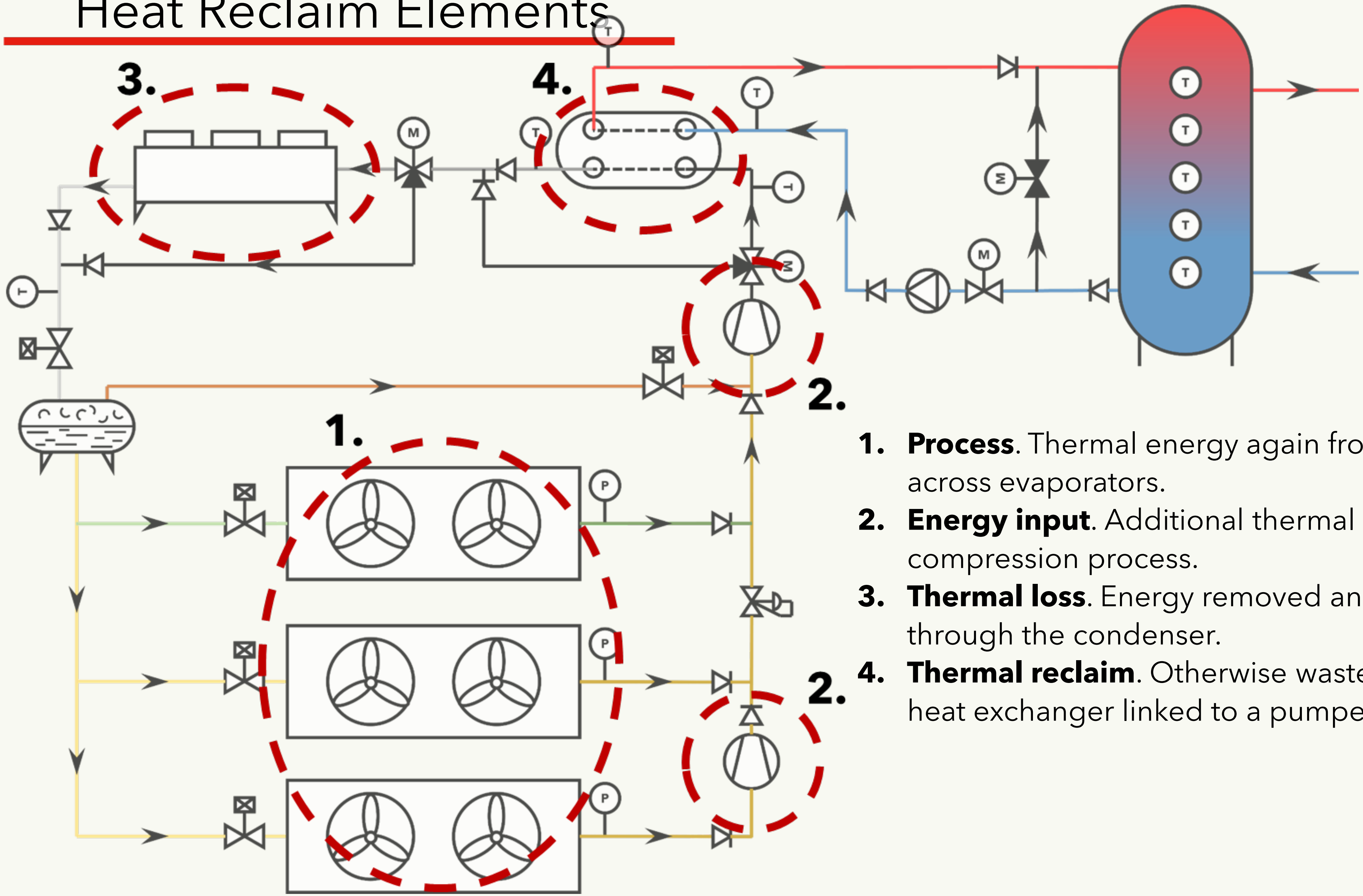
Integrated Heat Reclaim



Example System



Heat Reclaim Elements



1. **Process**. Thermal energy again from heat absorption across evaporators.
2. **Energy input**. Additional thermal energy gain from compression process.
3. **Thermal loss**. Energy removed and made unrecoverable through the condenser.
4. **Thermal reclaim**. Otherwise wasted heat is captured by a heat exchanger linked to a pumped water circuit.

Operational Cost

Example scenario:

A retailer with a dual R-744 refrigeration system:

- Intermediate temperature: 120 kilowatt (kW) (409 457 British Thermal Unit/Hour (BTU/h)
- Low temperature: 24 kW (81 891 BTU/h)
- Heat requirement: 145 kW(494 761 BTU/h)

At 15°C external ambient temperature:

a) Regular refrigeration operation with no heat reclaim = 29.30 kW & 4.91 COP
b) Regular refrigeration operation with heat reclaim = 34.39 kW & 8.40 COP

An increased energy input of **5.09 kW** enables **145 kW** of heat to be recovered.

A gas boiler of 80% efficiency would need 182 kW (621 010 BTU/h) natural gas input to produce the same heat.

Cost to produce 145 kW heat per hour
Heat reclaim = $4.65
Gas boiler = $5.64

Unit cost
Electricity = 13.53 ¢/ kilowatt-hour (kWh)
Natural gas = 11.27 $/square feet ($ft^3$)

Advantages & Disadvantages

Advantages	Disadvantages
✓ Increased magnitude of 'useable' energy in a refrigeration cycle	Increased system complexity cannot be avoided ✗
✓ Tangible decarbonisation of heating (carbon factor dependent)	Cultural change in heating supply must be overcome ✗
✓ Design can account for seasonal demand	Is not suitable for all buildings as additional assets must be installed ✗
✓ Reduces the use of other energy sources used for heating	Design must account for seasonal demand and operational change ✗

Contacts

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