



Energy Modelling of Supermarkets

Jaime Arias

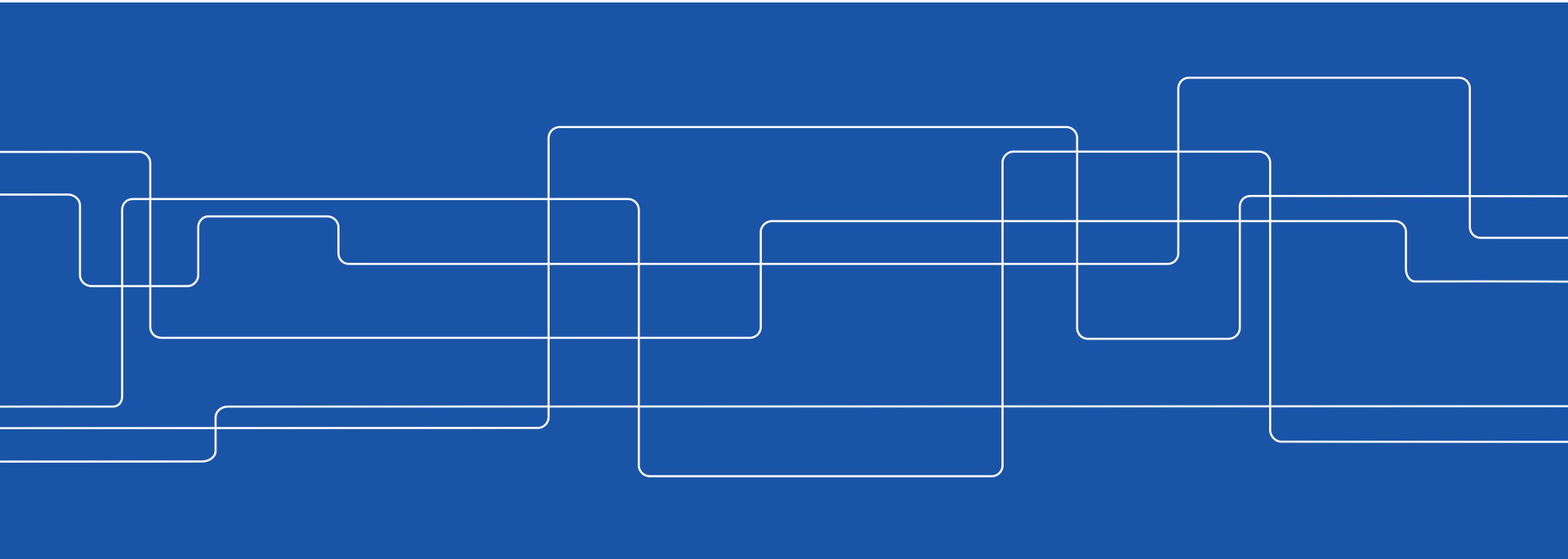
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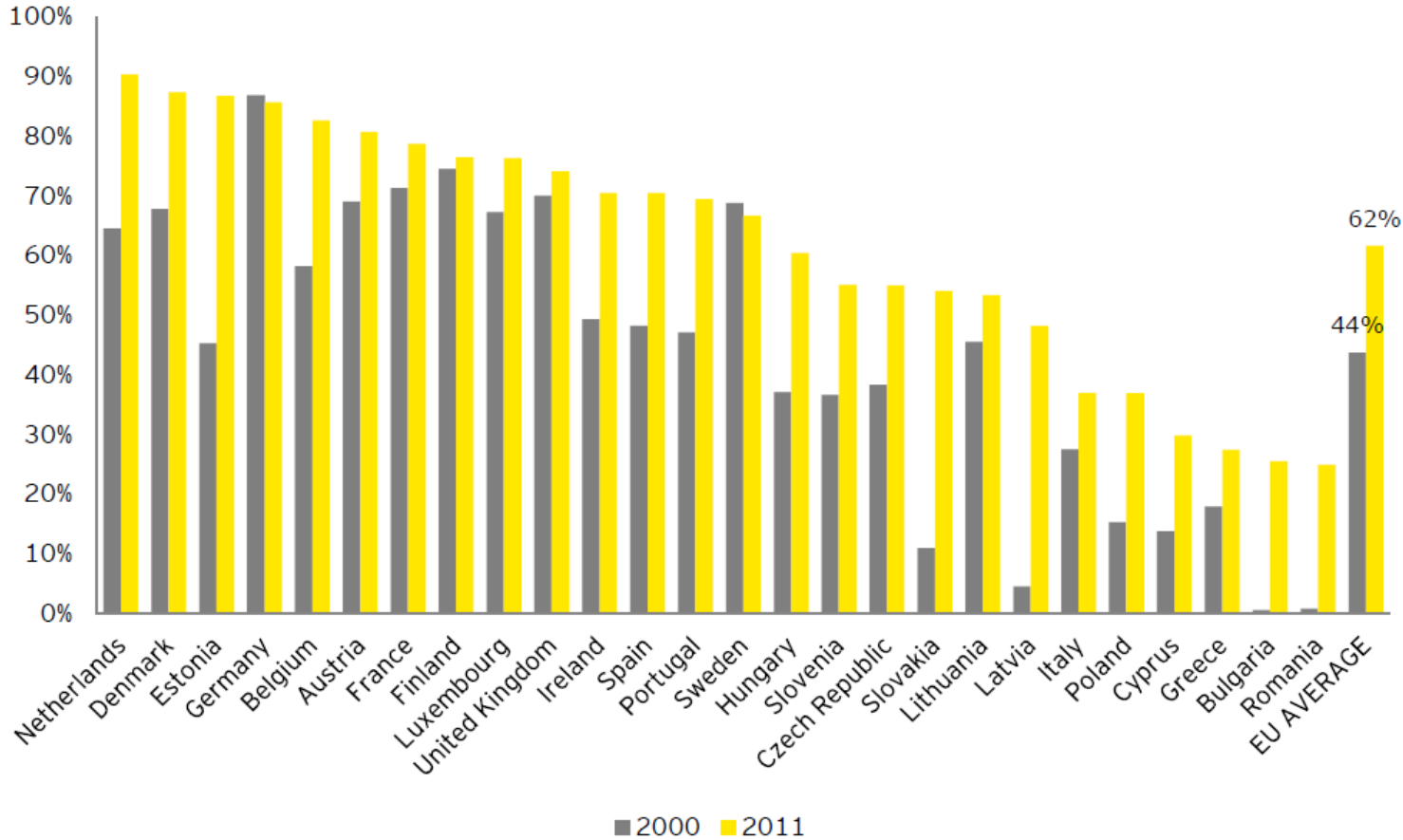
1.- Introduction.

Several parameters show the growth of supermarkets in Europe as the increasing number of hypermarkets, supermarkets and the increasing total food retail surface area

New Directives and regulations have been implemented in EU to improve efficiency in energy use and stimulate the use of renewable energy and to reduce emissions of greenhouse gases

1.- Introduction.

Increasing number of hypermarkets, supermarkets in Europe



**EU average:
44% (2000)
62% (2011)**



1.- Introduction.

The Energy Performance of Buildings Directive requires all new buildings to be nearly zero-energy by the end of 2020. All new public buildings must be nearly zero-energy by 2018.

But there is no clear and standardized definition and it is left to the member states to define nearly ZEBs according to their own country specific conditions



1.- Introduction.

The F-Gas Regulation strengthens the existing measures by:

- **Limiting the total amount of the most important F-gases that can be sold in the EU from 2015**
- **Banning the use of F-gases in many new types of equipment such as fridges in homes or supermarkets, air conditioning and foams and aerosols**
- **Preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.**



1.- Introduction.

The energy consumption of an average supermarket in Sweden is 350-450 kWh/m². In Canada the figure is 800 kWh/m², in USA around 600 kWh/m² and in the UK 800-1000 kWh/m².

Share of national energy use of electricity in Supermarkets

USA: 4% (Orphelin, 1997)

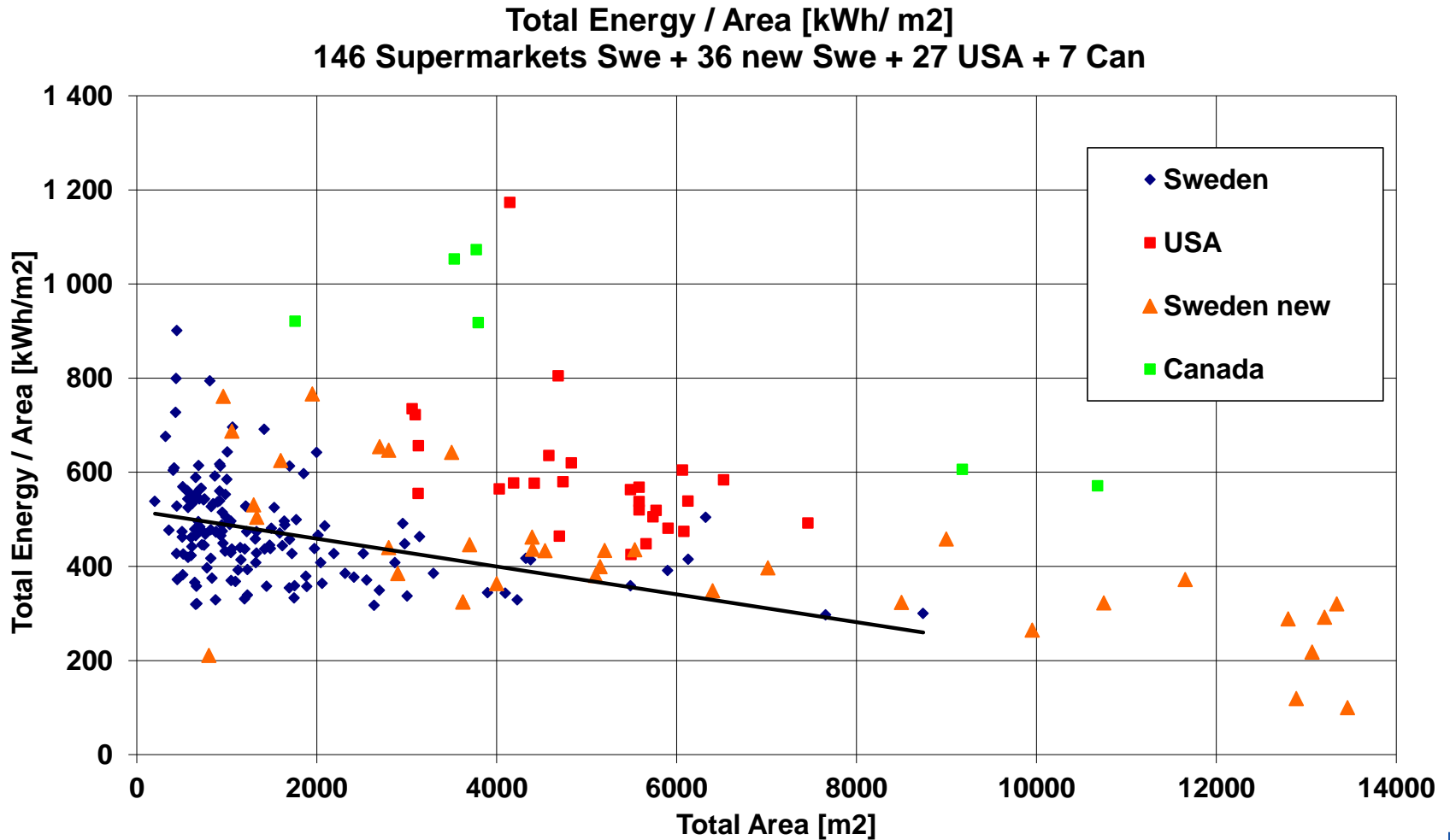
UK: 3% (Tassou, 2011)

France: 4% (Orphelin, 1997)

Denmark: 4% (Reinholdt and Madsen, 2010), and

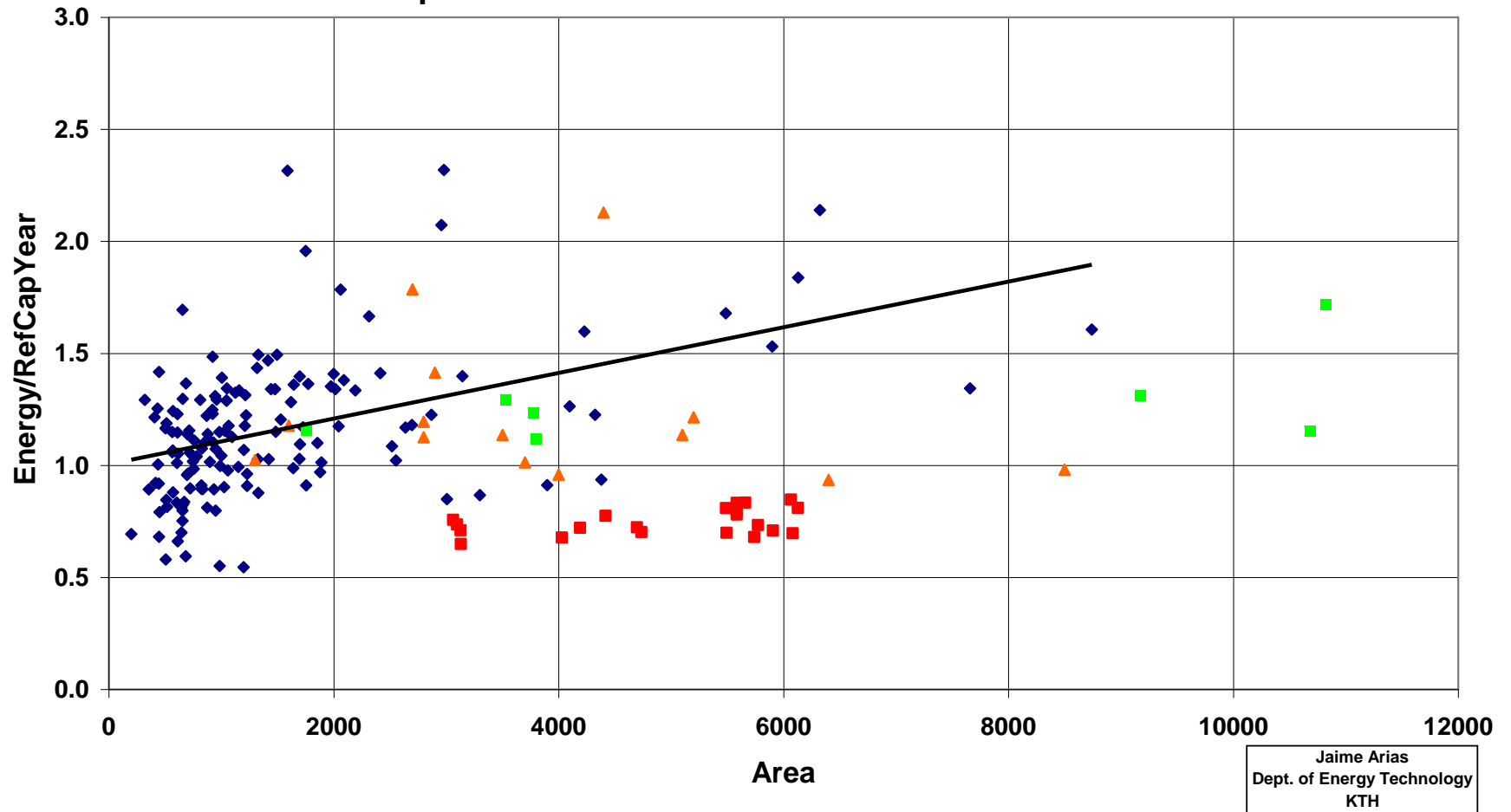
In Sweden approximately 3%

1.- Introduction.



1.- Introduction.

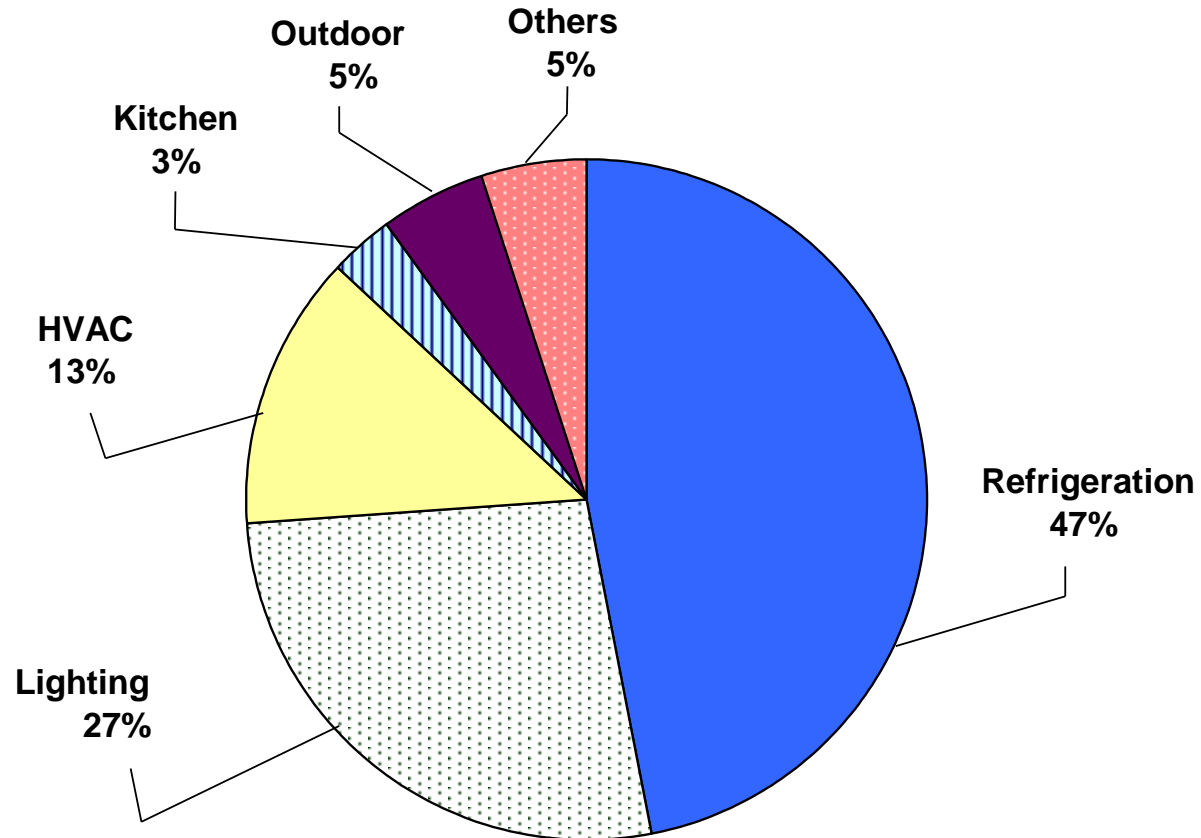
Total Energy / (Ref.Cap * 24*365) [kWh/KWhRefCap]
 146 Supermarkets Swe + 14 new Swe + 21 USA + 7 Can



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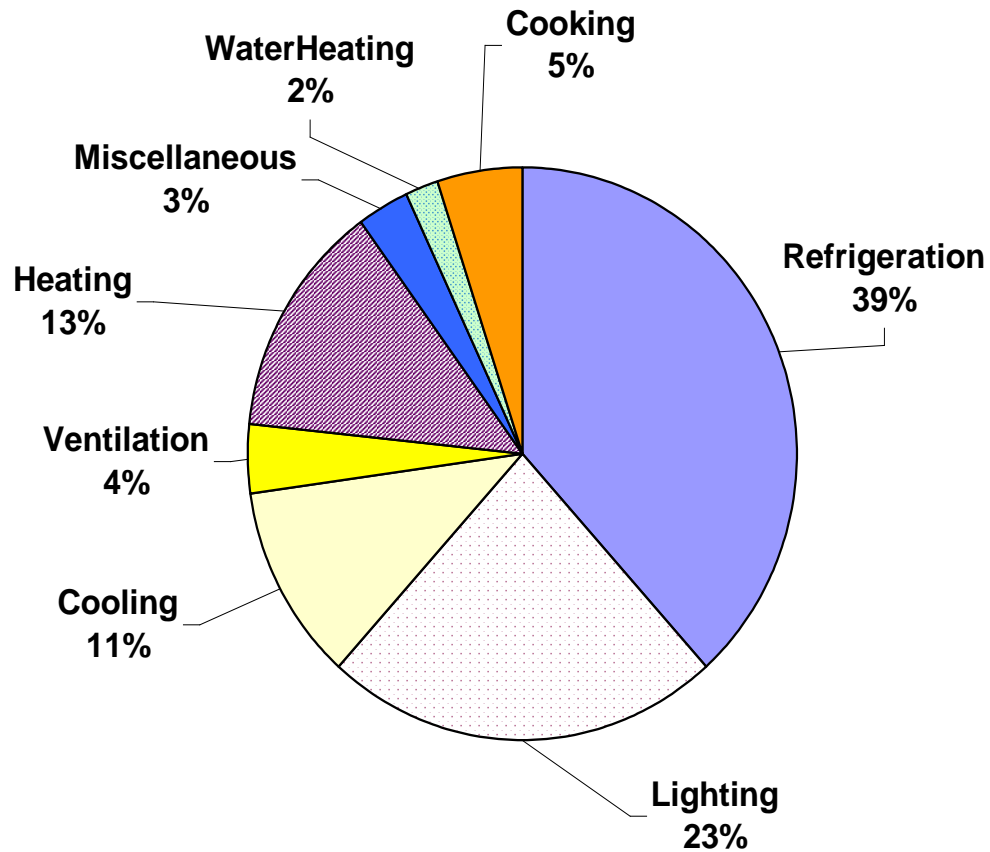
1.- Introduction.

Energy usage in a supermarket in Sweden



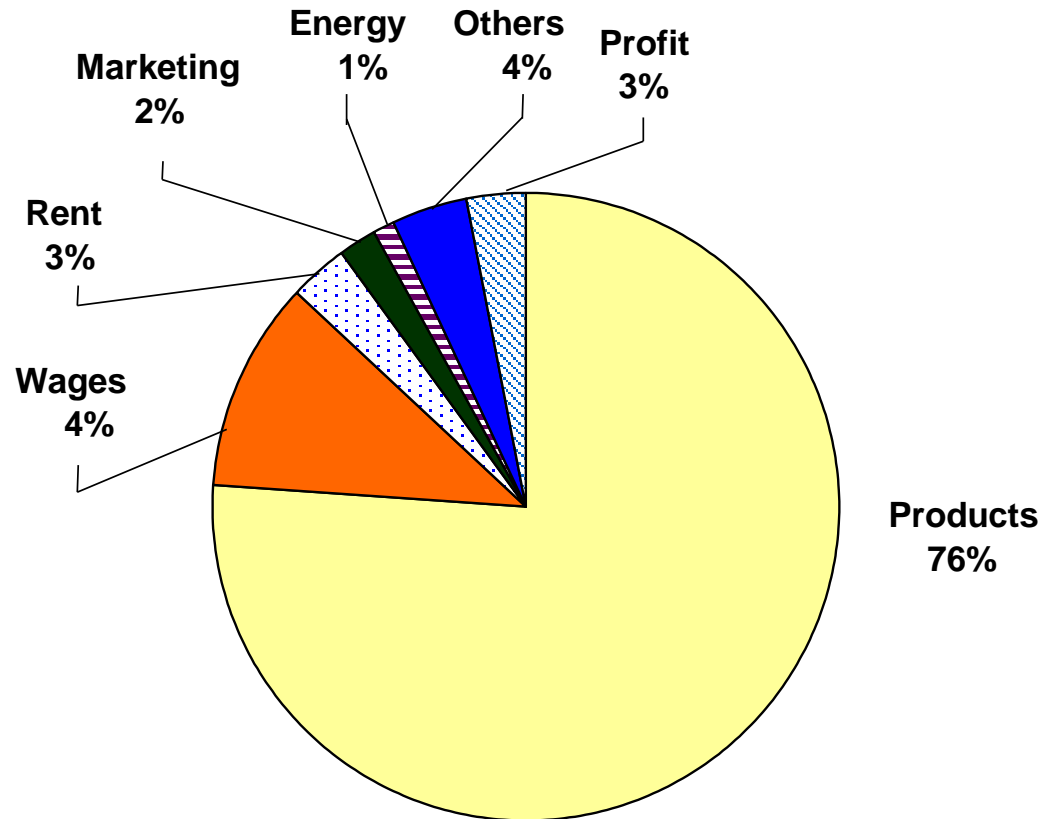
1.- Introduction.

Typical Electric Energy Usage in A Grocery Store in U.S.



1.- Introduction.

Cost structure and profit





2.- Building Energy Simulation.

Energy-saving technologies as heat recovery, floating condensing temperature, energy efficient lighting, energy efficient display cases have been implemented in several supermarkets.

New refrigeration system solutions using CO₂ as the refrigerant have been introduced in supermarkets to lower F-gas emissions.



2.- Building Energy Simulation.

The supermarket branch has more and less used the trial and error approach to implement and evaluate new ideas and concepts.

A systems model is necessary to be implemented in order to predict and evaluate the introduction of new concepts and ideas in supermarkets.



2.- Building Energy Simulation.

There are many models for evaluation of energy efficiency, renewable energy and sustainability of buildings.

In the Building Energy Software Tools Directory on the homepage of the U.S. Department of Energy, there is information about 67 Whole Building Energy Simulation.

The majority of those Whole Building Energy simulation tools are able to model Building and HVAC performance but not refrigeration system performance or the interaction between cabinets and the surrounding environment

3.- Project SuperSmart.



SUPERSMART

Expertise hub for a market uptake
of energy-efficient supermarkets by
awareness raising, knowledge transfer
and pre-preparation of an EU Ecolabel



Source: <http://www.supersmart-supermarket.info>



3.- Project SuperSmart.



SuperSmart was a EU funded Horizon 2020 Project

- Started: 1st of February 2016
- Project Partners:
 - SINTEF (coordinator)
 - Shecco
 - CNR
 - Umweltbundesamt
 - KTH
 - TUBS
 - CIRCE
 - Energija doo
 - IIR





3.- Project SuperSmart.



- 1. Identify market barriers**
- 2. Removing non-technical market barriers.**
- 3. Supporting the introduction of a new European Ecolabel for supermarkets**
- 4. Reduction of environmental impact of supermarkets**

3.- Project SuperSmart.

Mapping and
segmentation of
barriers &
description of
supermarket
sector

Report 1

Eco-friendly
supermarkets -
an overview

Report 2

How to build a
new eco-friendly
supermarket

Report 3

Computational
tools for
supermarket
planning

Report 5

Eco-friendly
operation and
maintenance of
supermarkets

Report 6

How to refurbish
a supermarket

Report 4

EU Ecolabel for
food retail stores

Report 7

Report 5: Computational tools for supermarket planning

List of Computational Tools:

CoolPack: is a “collection of simulation programs that can be used for designing, dimensioning, analysing and optimizing refrigeration systems”. (<https://www.ipu.dk/products/coolpack/>)

CoolTool: is a software for planning and calculation of refrigeration- and air conditioning systems developed by CoolTool Technology GmbH (<http://www.cooltool-software.com/>)

Pack Calculation Pro is a simulation tool which compare the annual energy consumption of refrigeration systems and heat pumps (<https://www.ipu.dk/products/pack-calculation-pro/>)



3.- Project SuperSmart.



Report 5: Computational tools for supermarket planning

List of Computational Tools:

EnergyPlus is “a whole building energy simulation program”. It is free and open source and financed by the U.S. DOE. There are several third party graphical user interfaces available.

(<https://energyplus.net/>)

TRNSYS (TRaNsient System Simulation program). It is commercial software which is widely used especially for building simulation. The supermarket system models have to be created by the user.

(<http://www.trnsys.com/>)

CyberMart is a tool for estimating the annual energy consumption of an entire supermarket. Developed by KTH



3.- New Project at KTH

“Building state of the art supermarket-put theory into practice”

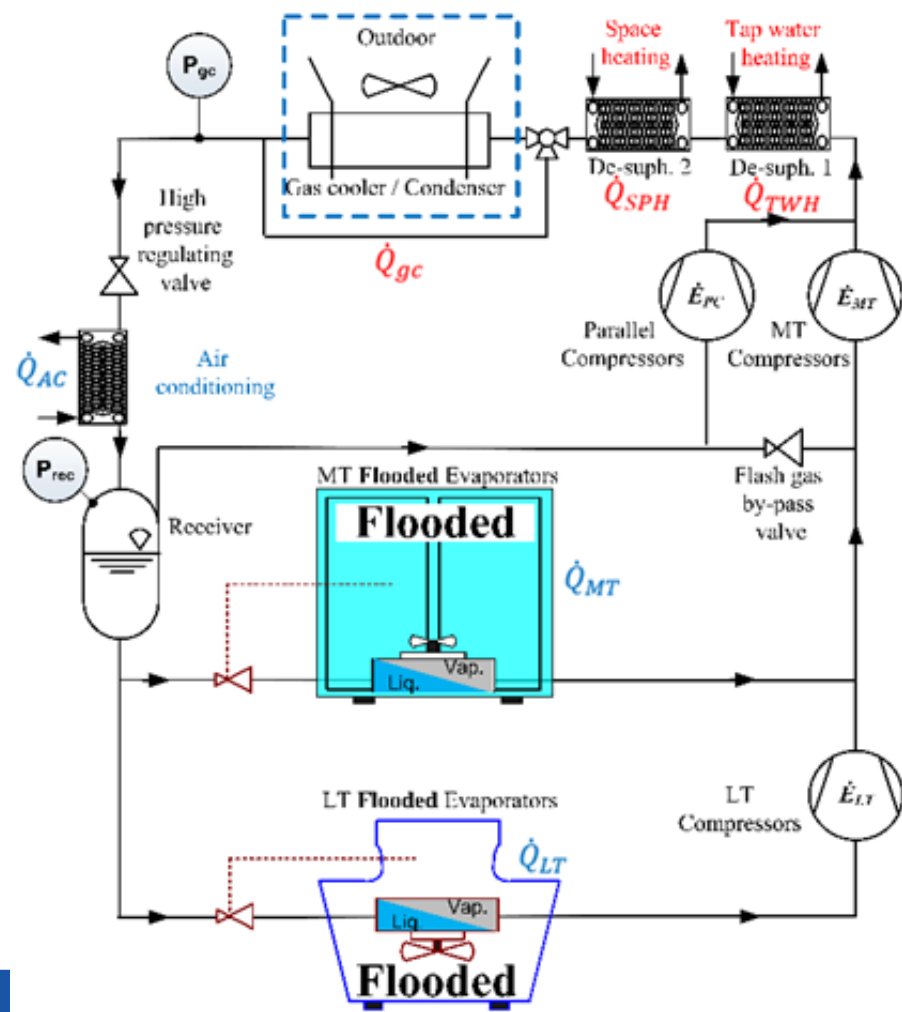
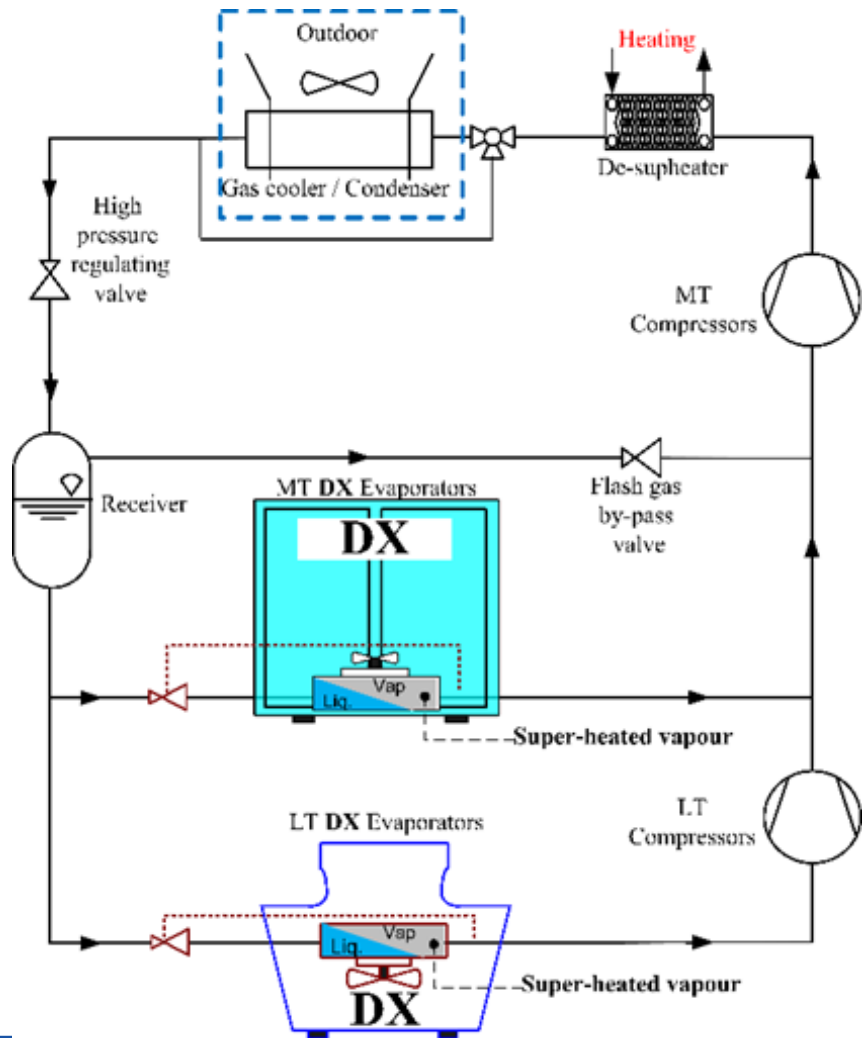
Project Leader: Samer Sawalha

PhD. Student: Sotirios Thanasoulas (soth@kth.se)

The proposed system offers:

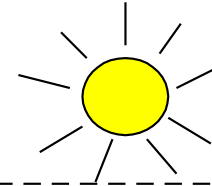
- **At least 15% annual energy savings compared to standard CO2 system.**
- **At least 25% annual energy savings compared to conventional systems**
- **The system is the most efficient and cost effective that can be installed in Sweden today.**

3.- New Project at KTH

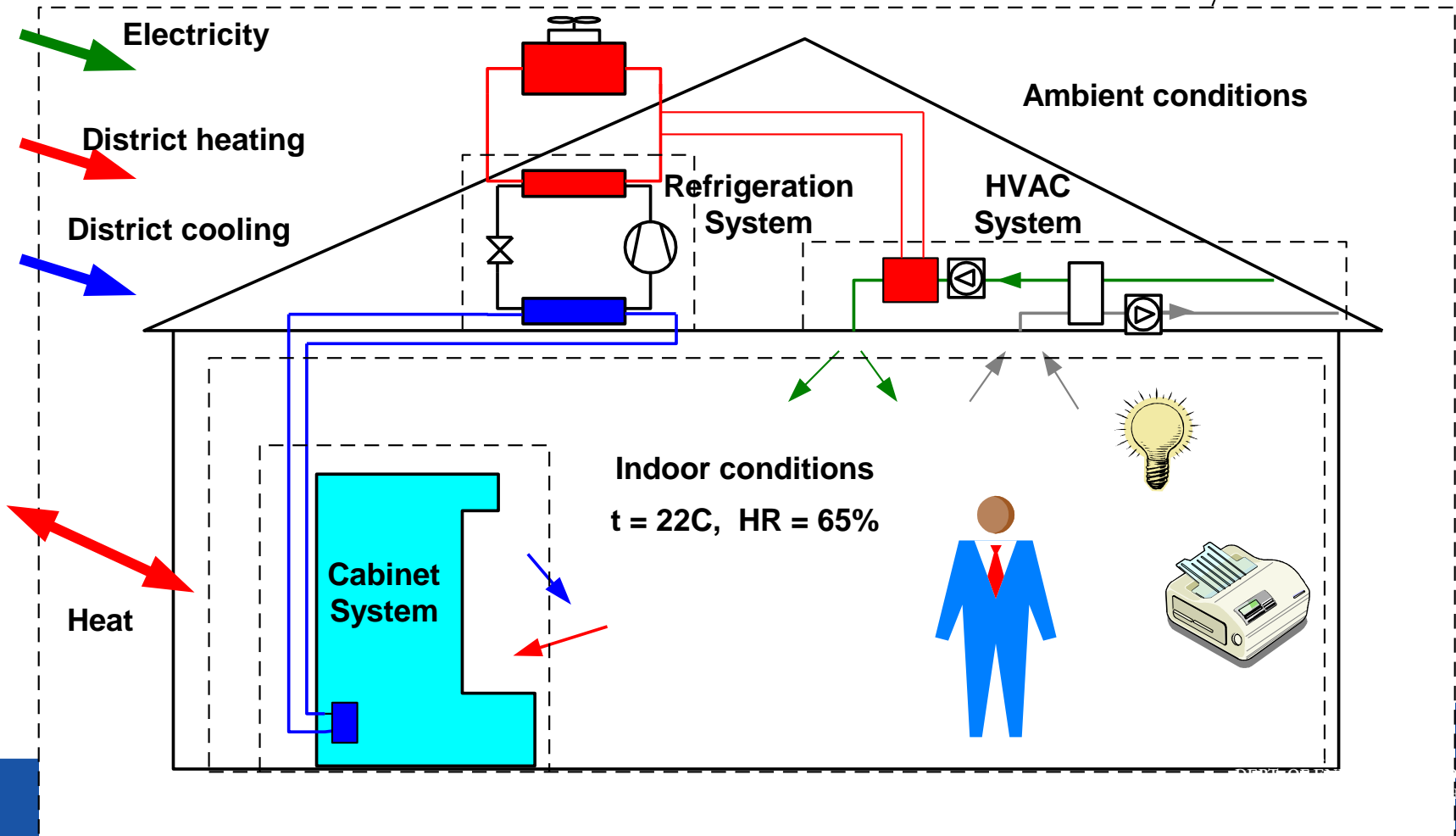


4.- Systems and Models for Supermarkets.

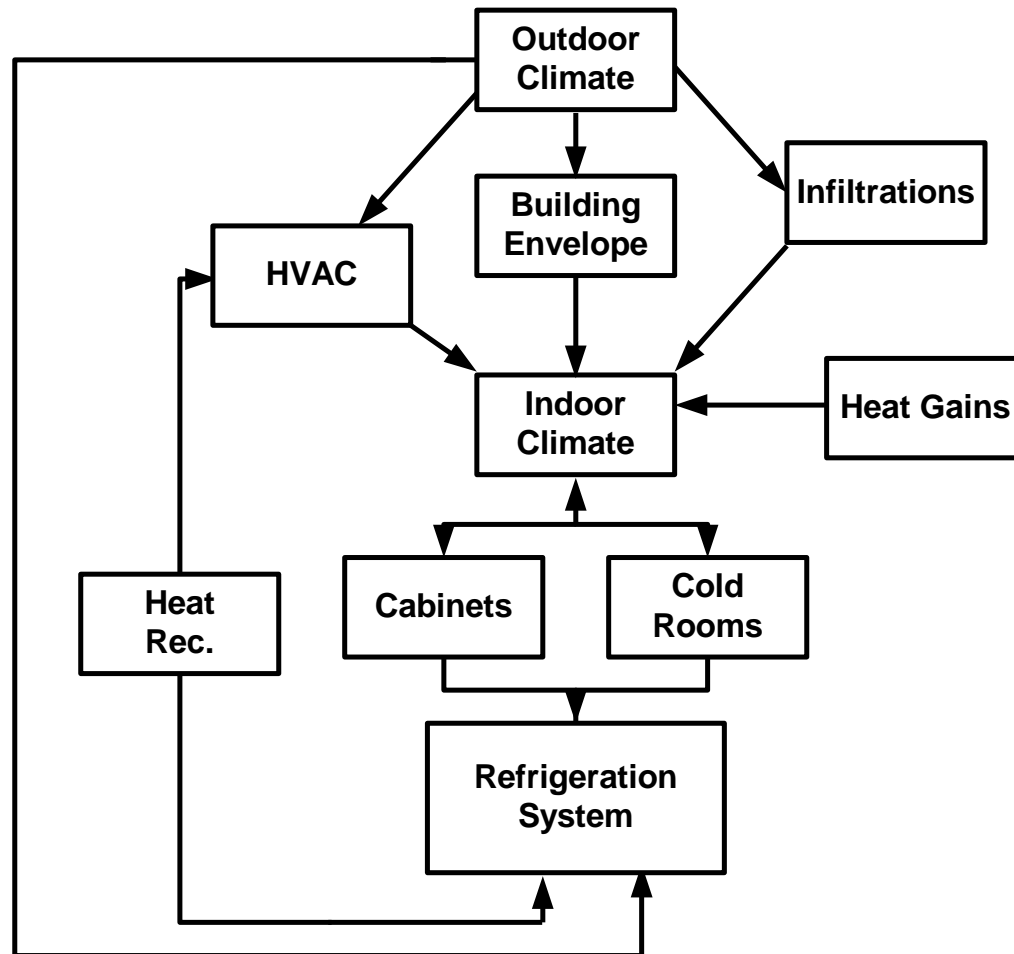
The Supermarket System



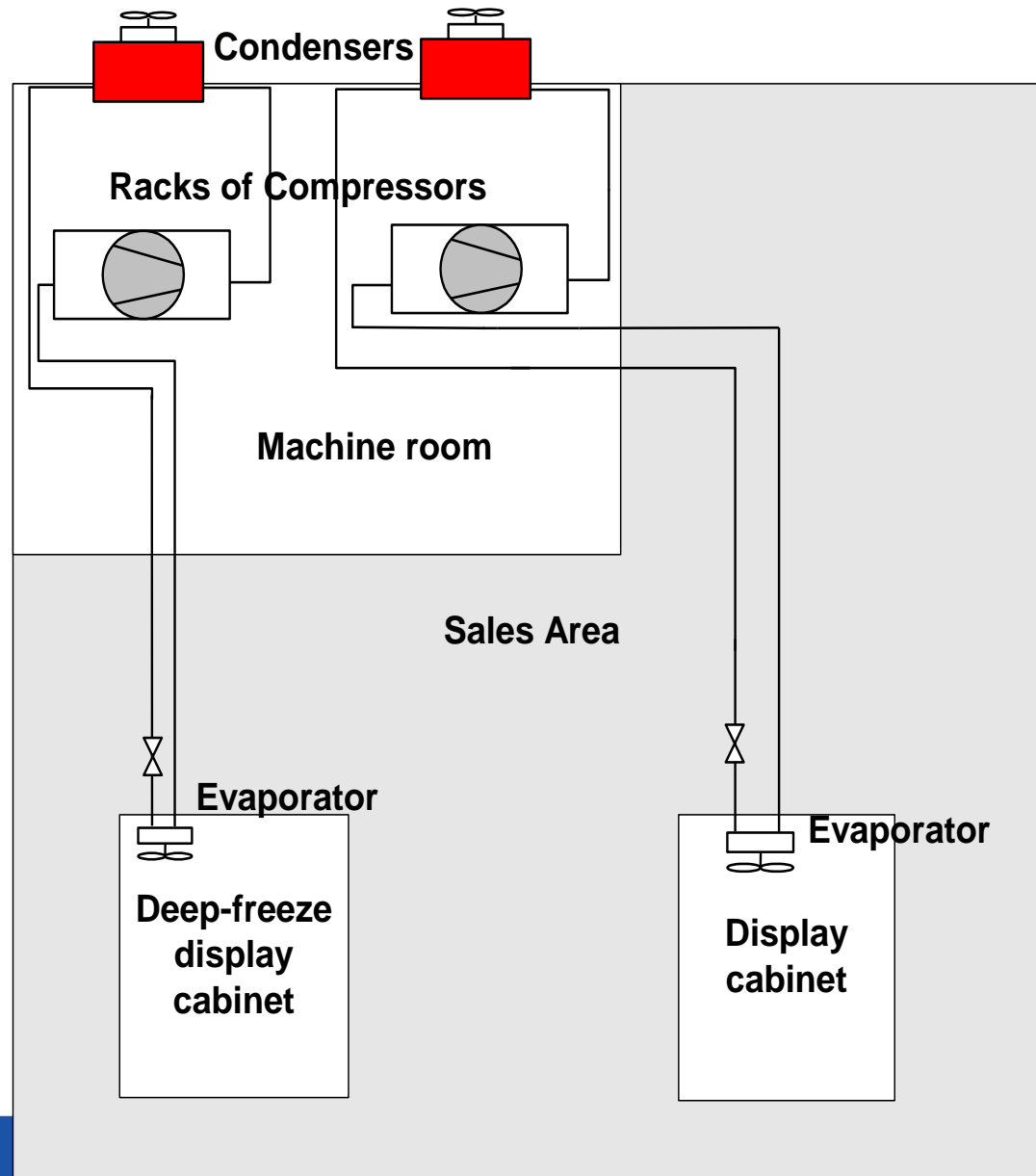
System Boundaries



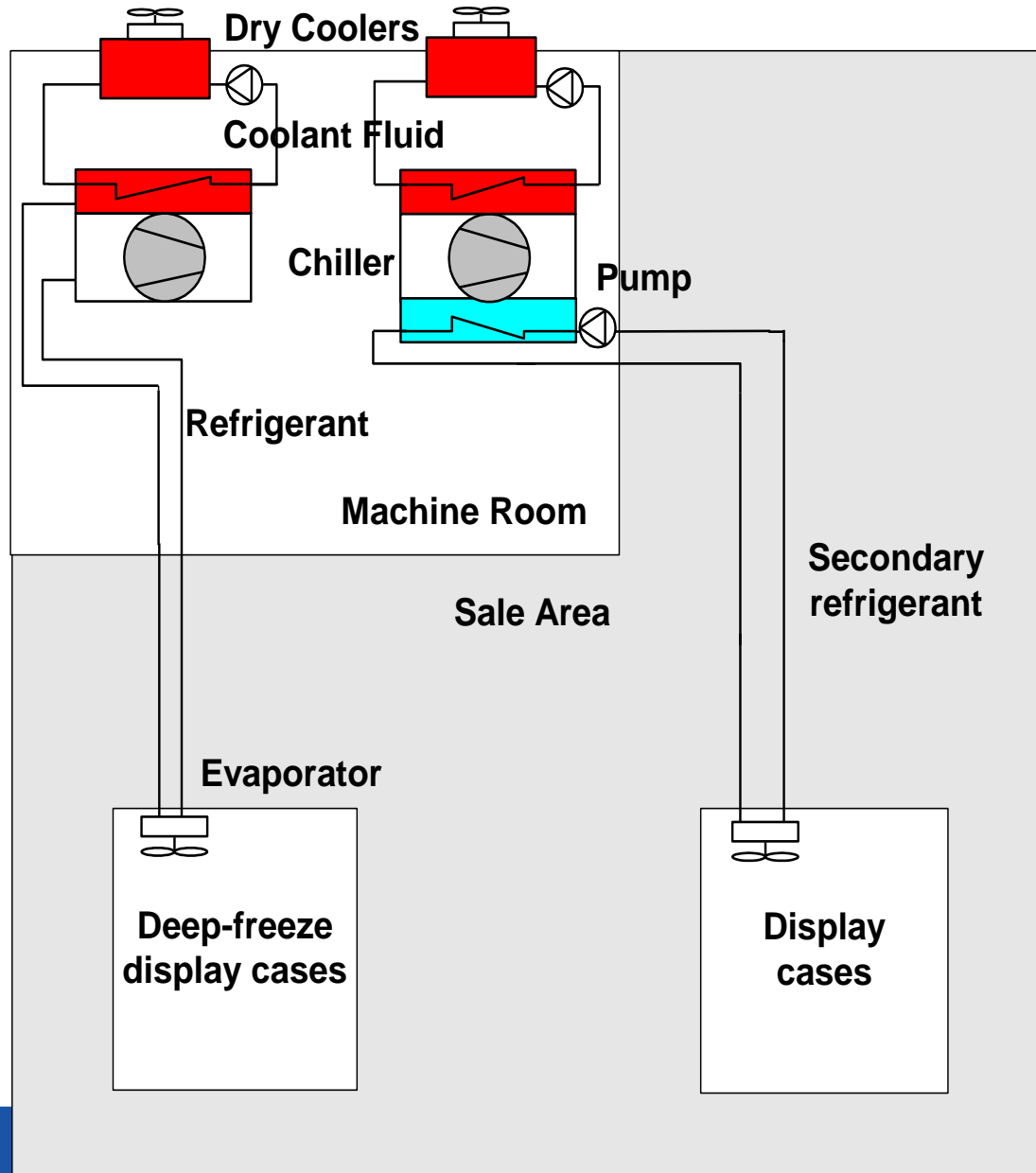
4.- Systems and Models for Supermarkets.

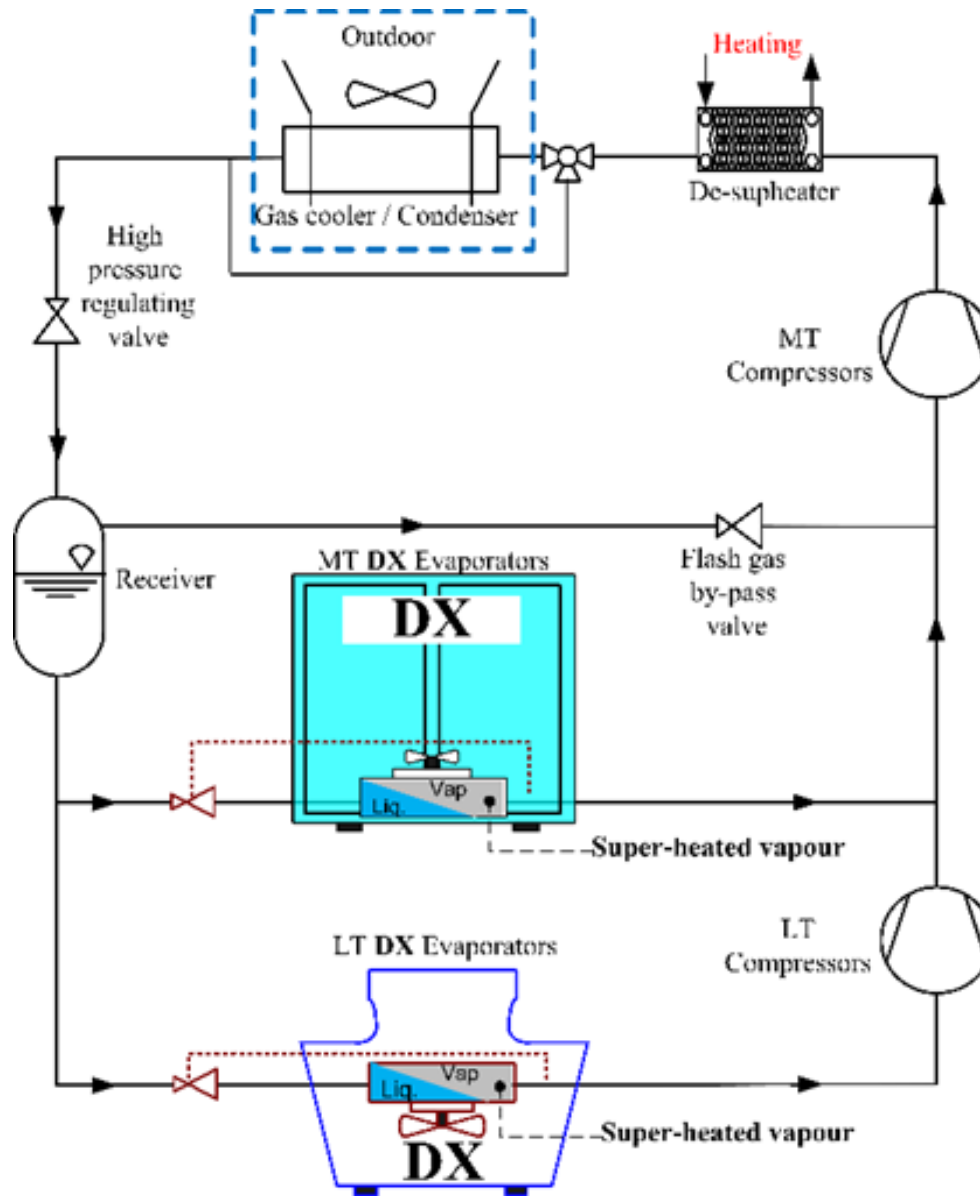


Direct system

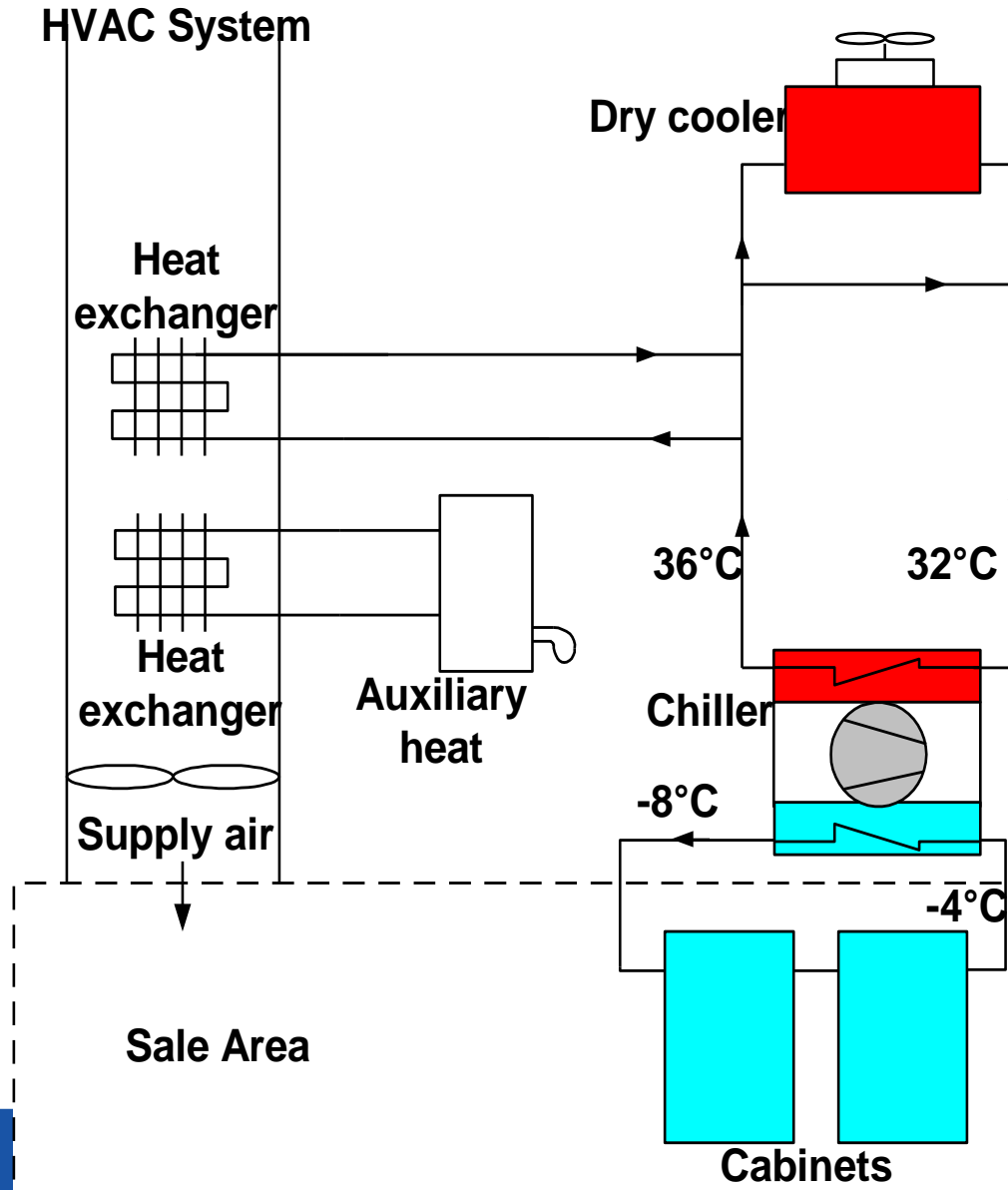


Partially Indirect System

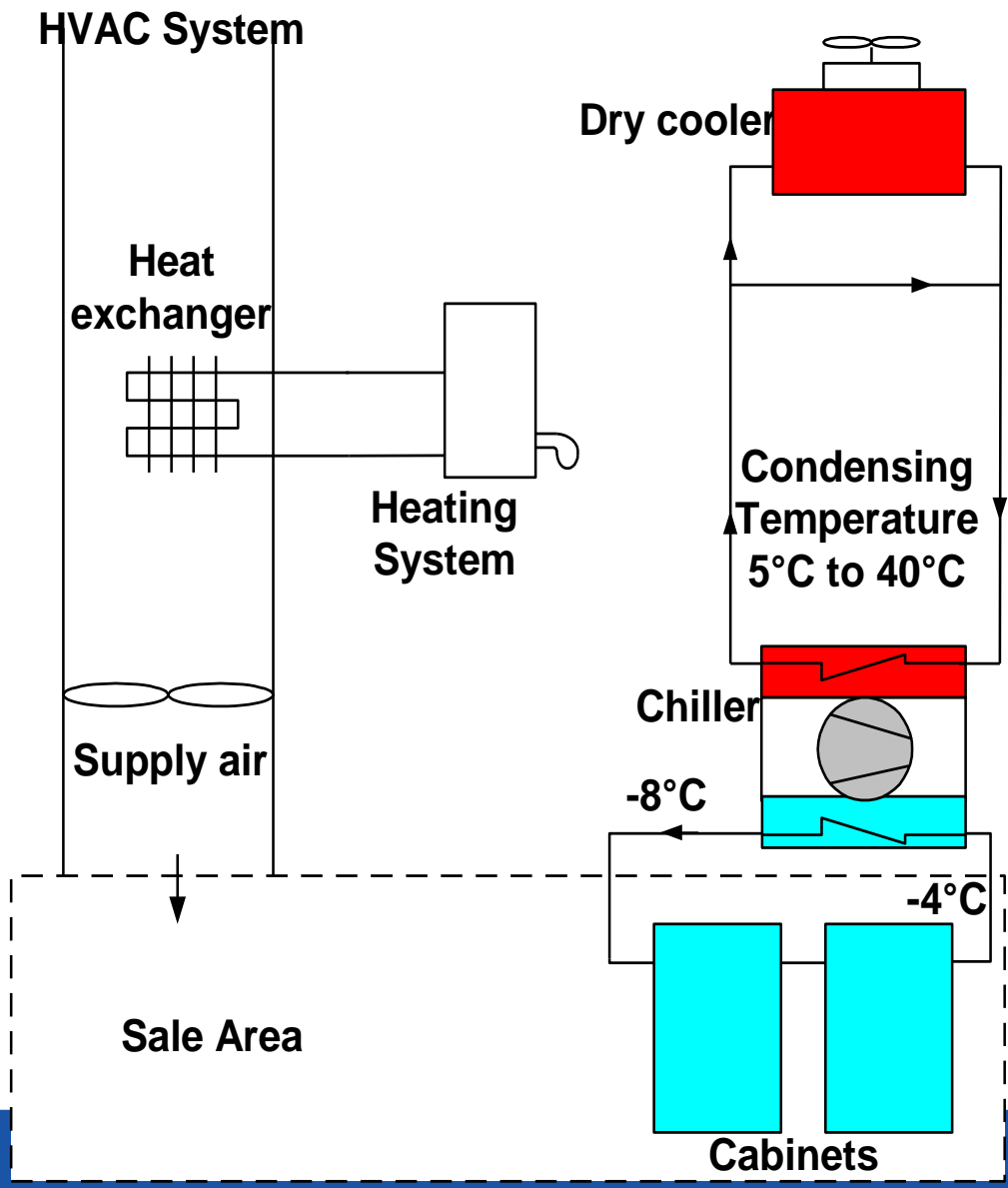


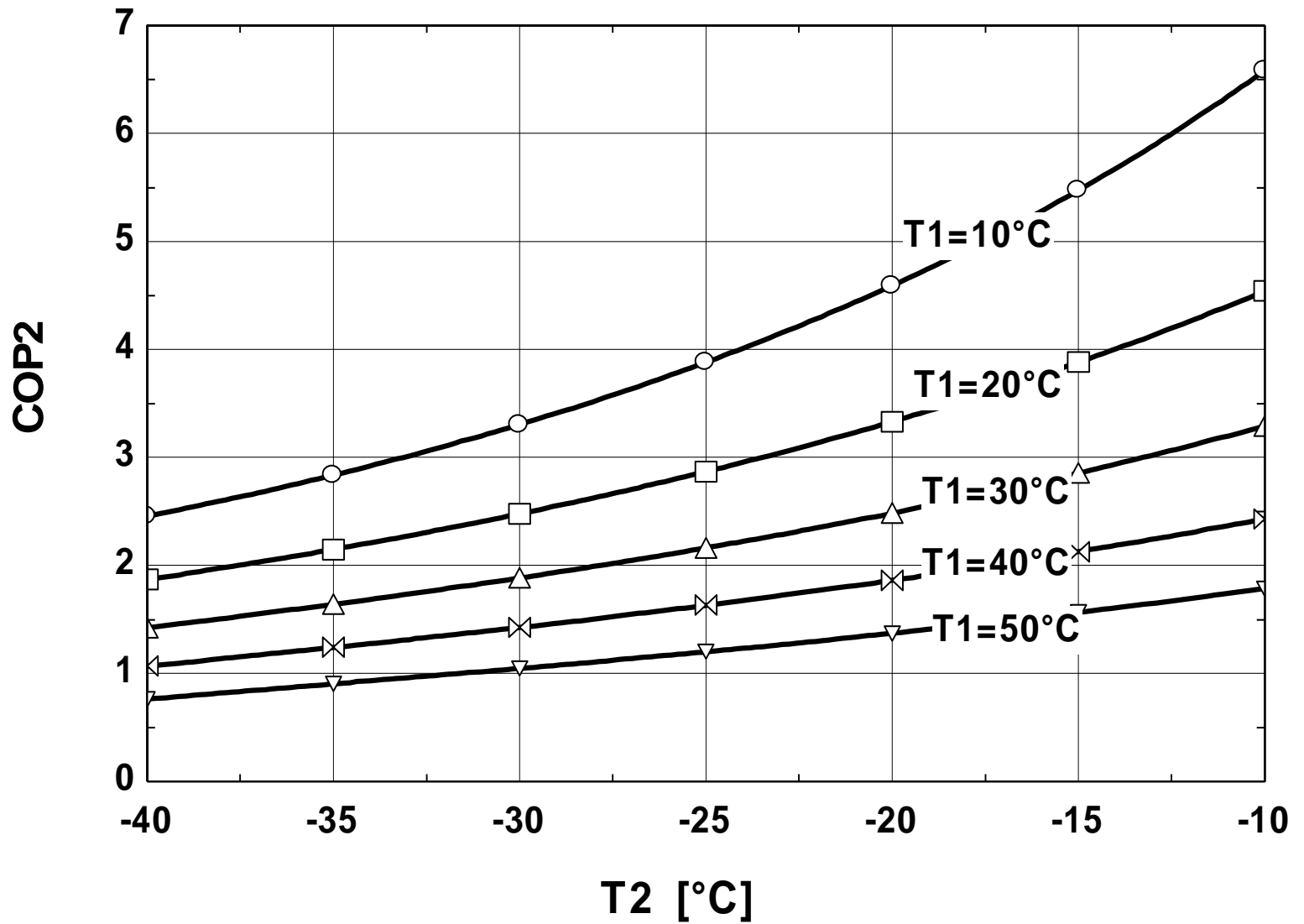


Heat recovery System 3

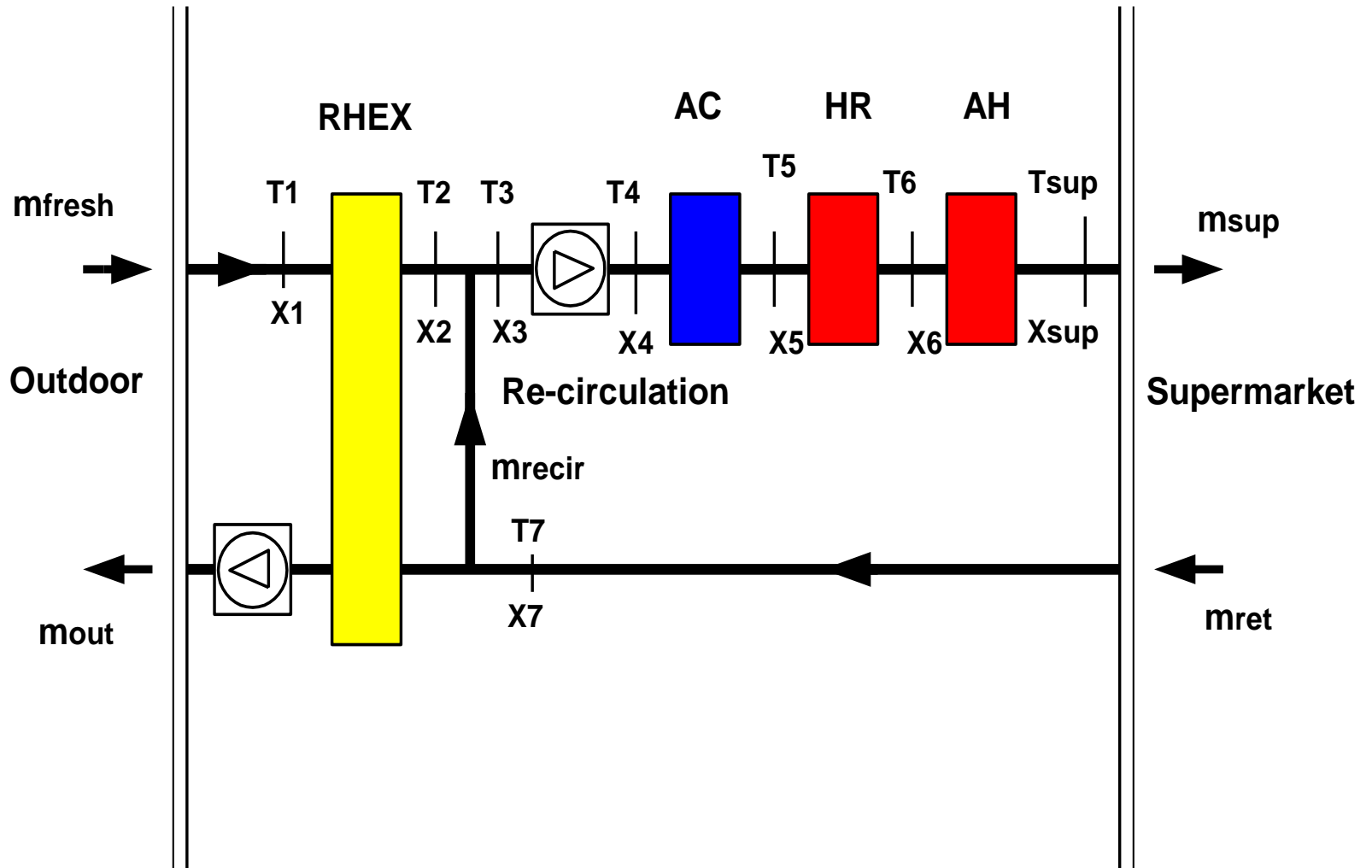


Floating Condensing System

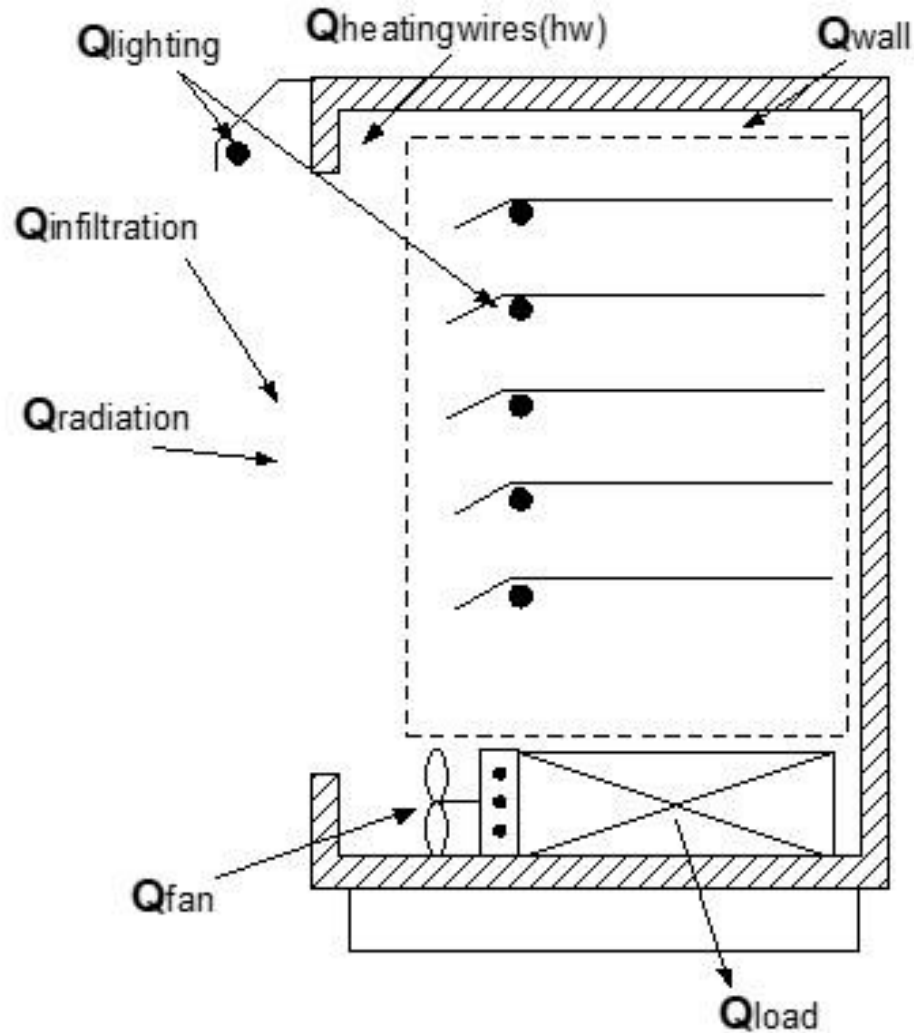




HVAC Model



4.- Systems and Models for Supermarkets.



$$Q_{wall} = 7 \%$$

$$Q_{infiltration} = 64 \%$$

$$Q_{radiation} = 11 \%$$

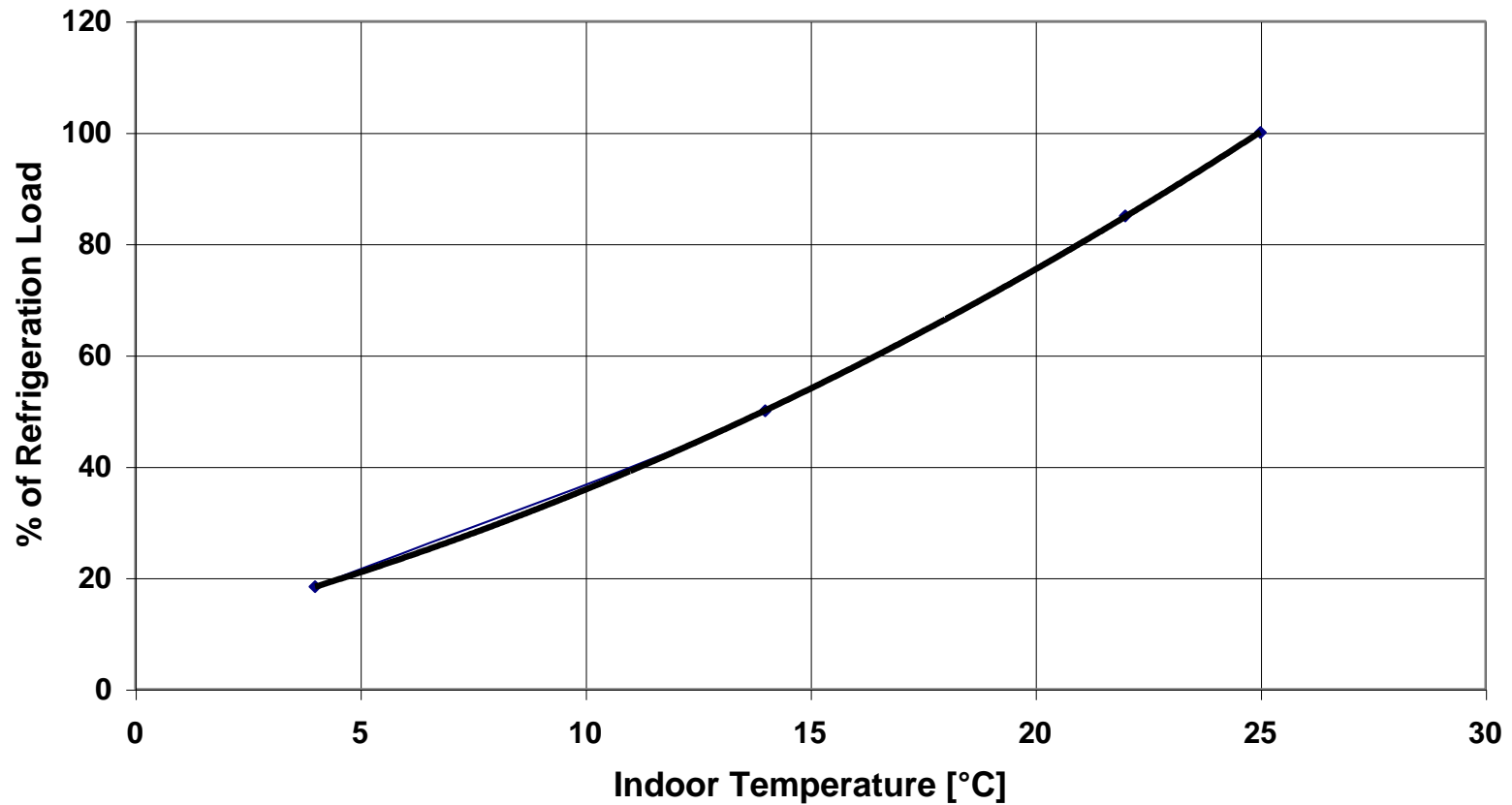
$$Q_{lighting} = 11 \%$$

$$Q_{fan} = 5 \%$$

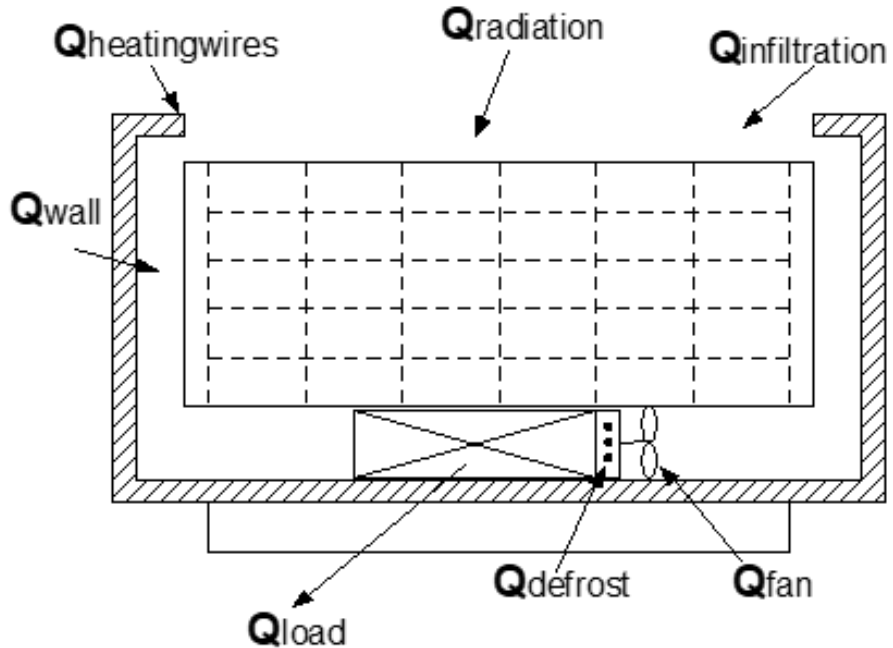
$$Q_{hw} = 2 \%$$

4.- Systems and Models for Supermarkets.

Cabinet



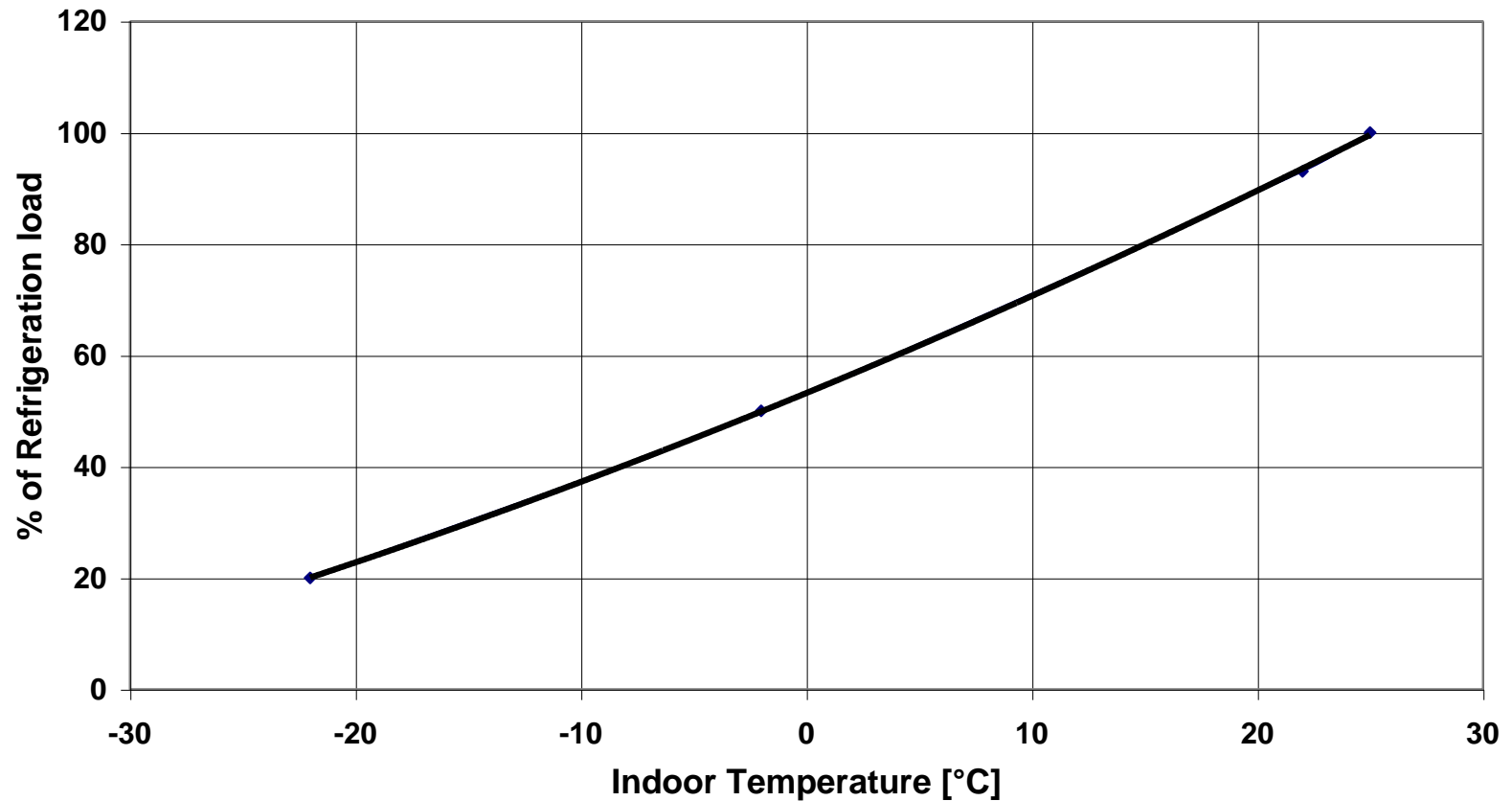
4.- Systems and Models for Supermarkets.



- $Q_{wall} = 11 \%$
- $Q_{infiltration} = 23 \%$
- $Q_{radiation} = 46 \%$
- $Q_{lighting} = 0 \%$
- $Q_{fan} = 8 \%$
- $Q_{hw} = 9 \%$
- $Q_{defrost} = 4 \%$

4.- Systems and Models for Supermarkets.

Deep-freeze Cabinet





5.- CyberMart

CyberMart



CyberMart

Computer model for energy calculation in supermarkets

Project

Supermarket COOP Konsum Sala

Reference









Jaime Arias



Building



Refrigeration System Design

-  **DEX** Direct System
-  **CINS** Completely Indirect System
-  **PINS** Partially Indirect System
-  **CCA** Cascade A
-  **CCB** Cascade B
-  **PSS** Parallel System with Subcooling
-  **DCO** District Cooling or other
-  **CO2** CO2 Transcritical





Supermarket Building

Main Program



Climatic Conditions



Building Envelope



Ventilation



Heat Sources



Opening Hours



Heating Air Conditioning



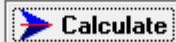
Energy Calculation



City

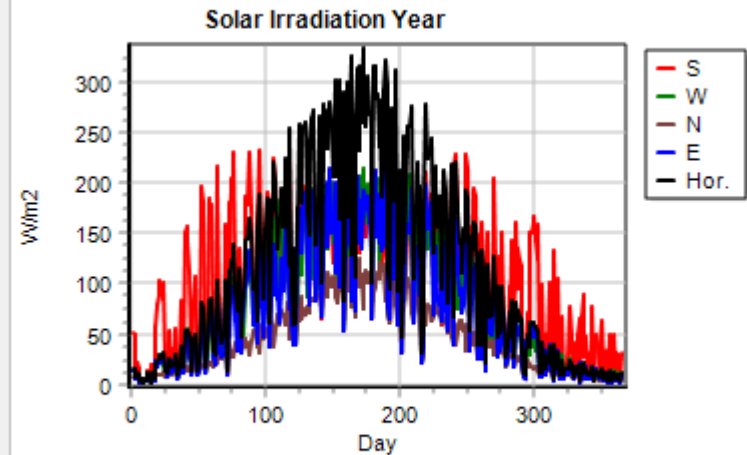
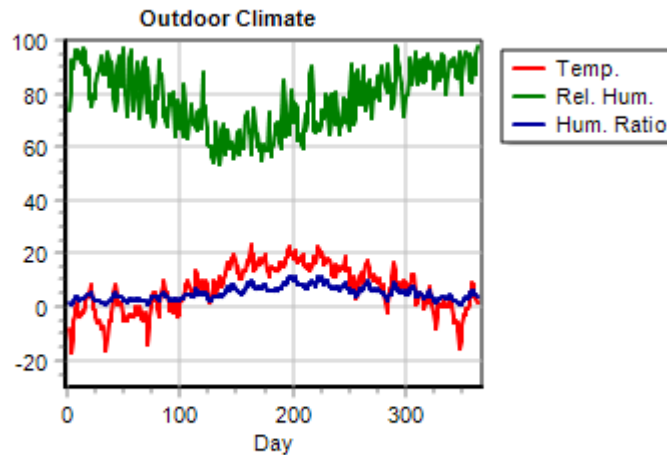
Stockholm.bd

Outdoor Climate



Climatic Conditions

Solar Irradiation





Supermarket Building

Main Program

Climatic Conditions

Building Envelope

Ventilation

Heat Sources

Opening Hours

Heating Air Conditioning

Energy Calculation

Heat Sources

Lighting Average

Open

W/m²

Close

W/m²

Equipments Average

Power

Open

W

Close

W

Water production

gr/h

gr/h

Service Water

Heating

Liter / day

Occupants

Weekly profile

Monday

%

Tuesday

%

Wednesday

%

Thursday

%

Friday

%

Saturday

%

Sunday

%

Maximum occupants per day

Daily profile

8.00h - 11.00h

%

11.00h - 14.00h

%

14.00h - 17.00h

%

17.00h - 19.00h

%

19.00h - 21.00h

%

21.00h - 8.00h

%

Plug in cabinets

Medium Temp.

Low Temp.

Heat disipated

W

Comp. Power

W

Heat disipated

W

Comp. Power

W



Supermarket Building

Main Program

Climatic Conditions

Building Envelope

Ventilation

Heat Sources

Opening Hours

Heating Air Conditioning

Energy Calculation

Heating and Air Conditioning

Heating

Heat Recovery Condensers

Floating Condensing

Air Conditioning

Heating

District Heating

Price

kr/kWh

Oil Boiler

Electric Boiler

Max. Heat Capacity

[kW]

Sala

Air Conditioning

Chiller

District Cooling

Max. Cooling Capacity

[kW]

Supermarket Temperature

Winter

Open

Close

Summer

Control

End Winter

Start Summer

Electricity

Price

[kr/kWh]

Heat Recovery Condenser Cooler Fluid

Temperature

After Condenser

Water

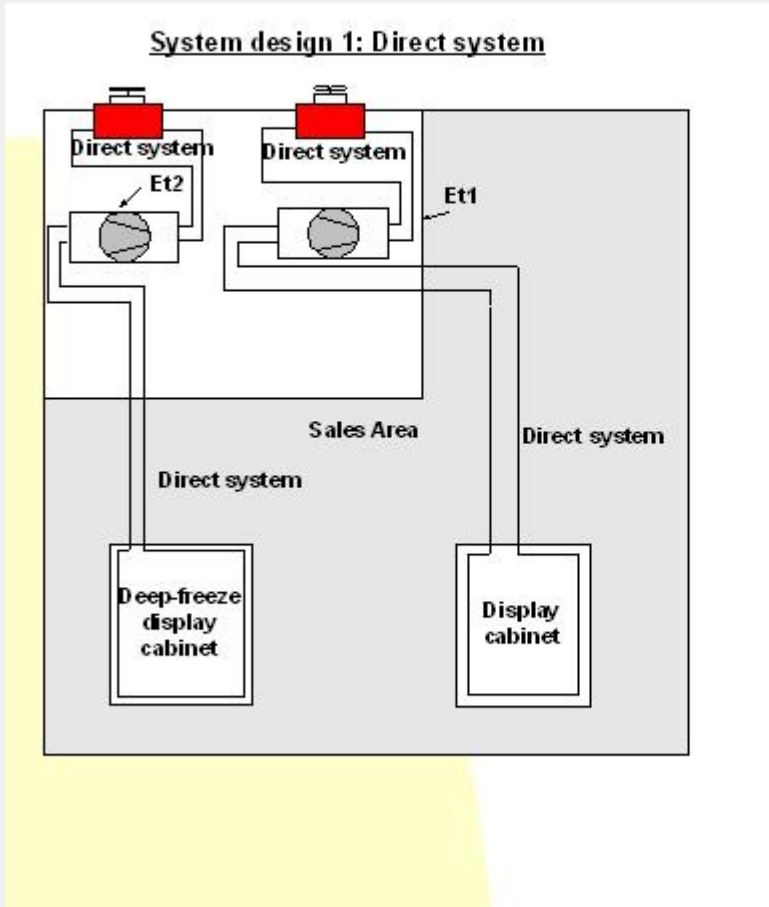
Temperature

In

Out

Direct System

System design 1: Direct system



Med. temp.

Refrigerant

Compressor

Number of rack

Night Cover Cabinets

Low temp.

Refrigerant

Compressor

Number of rack

Night Cover Cabinets



Input



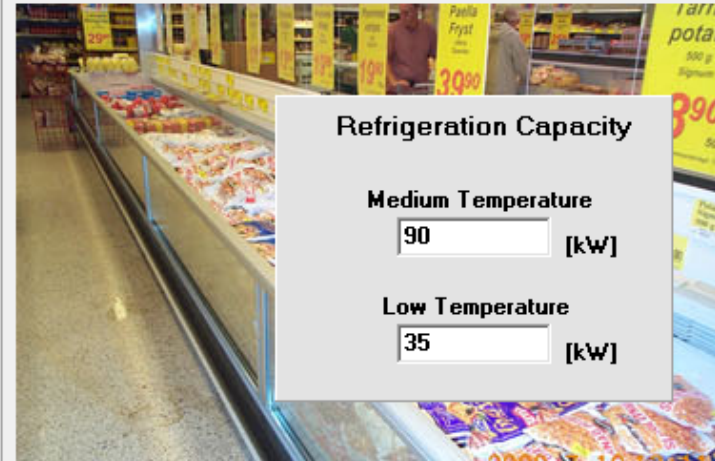
Give number of Cabinets and Cold Storages

System	Cabinet	Storage
Rack 1	7	2

Give number of Deep-freeze Cabinets and Deep-freeze Storages


DF.System	DF.Cabinet	DF.Storage
Rack 1	3	1

 Med.Temp.



Model	Lenght/Area	Capacity [W]
Electrolux - BA S - 3750	18.75	14250
Electrolux - BA S - 2500	5	3800
Electrolux - DA - 3750	3.75	1950

Calculation of Refrigeration Capacity

 Calculate

 Back

 Next

Cabinets with dorr Medium

Cabinets with dorr Low



Supermarket Energy Calculation

Pressure Drop

Back

New Refrigeration System Design

Back

Building

Back

Refrigeration System

Results

Save Hour

Results

Save Month

Results

Energy

Calculate

Temp

Year

Load

Year

Energy

Year

Cost

Year

Energy

Month

CO2

Day

Temp. and Load

Day

Day

31

DX

Comment

Winter

Rot. Hex. Heat

55522

Summer

Rot. Hex. Cooling

1217

Fan

116800

Heat

3732

Cooling

2275

Lighting

306300

Heat Recovery

222077

Total Cooling

3492

Equipment

53300

Plug-in Cabinets

0

Total Heat

281332

Refrigeration system

452700

Service Water

39632

Total Electricity

929500

Energy [KWh/year]

Comment

Winter

Rot. Hex. Heat

55522

Summer

Rot. Hex. Cooling

1217

Fan

116800

Heat

225809

Cooling

2275

Lighting

306300

Heat Recovery

0

Total Cooling

3492

Equipment

53300

Plug-in Cabinets

0

Total Heat

281332

Refrigeration system

336400

Service Water

39632

Total Electricity

813200

Supermarket Energy Calculation

Pressure Drop

← Back

New Refrigeration System Design

← Back

Building

← Back

Refrigeration System

→ Results

Save Hour

→ Results

Save Month

→ Results

Energy

→ Calculate

Temp

→ Year

Load

→ Year

Energy

→ Year

Cost

→ Year

Energy

→ Month

CO2

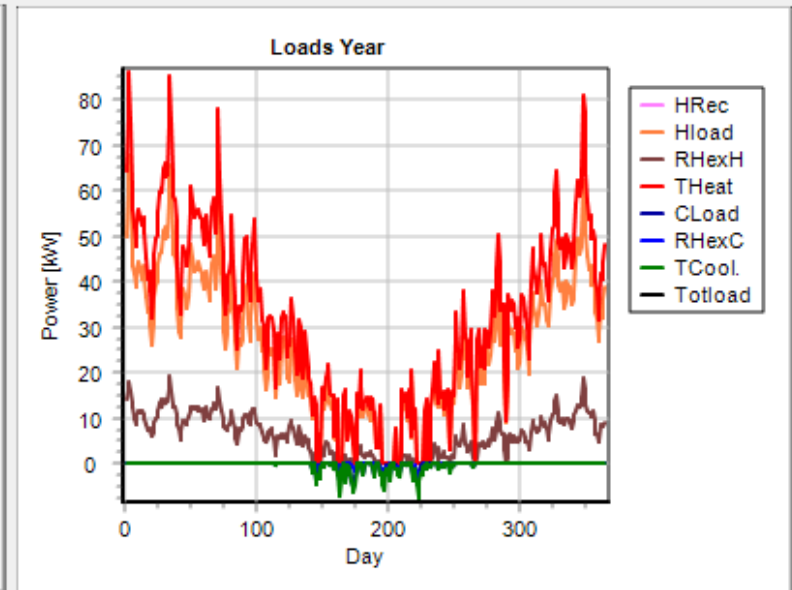
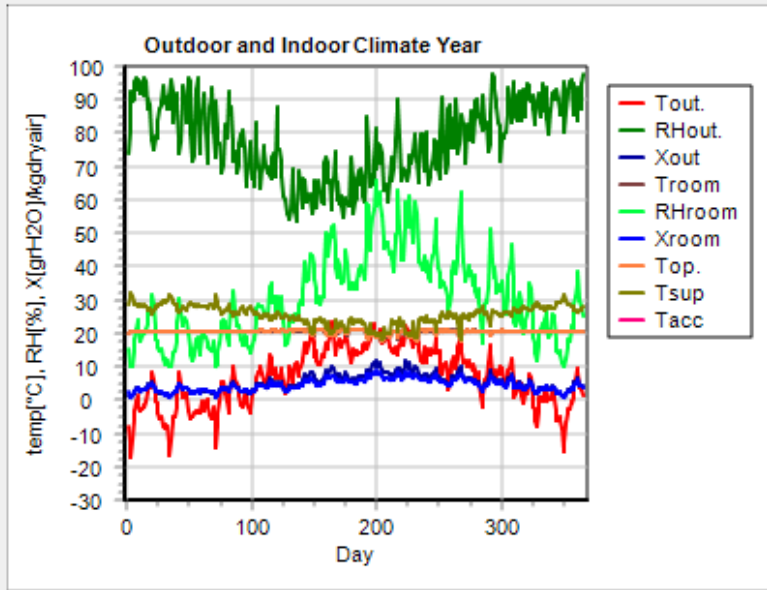
→ Day

Temp. and Load

→ Day

Day

31





5.- CyberMart

Lambohov Total Energy Usage

	Measurement	CyberMart	
January	54193	47290	12,7%
February	46811	42449	9,3%
Mars	50733	47102	7,2%
April	50317	47062	6,5%
May	54180	50950	6,0%
June	54761	52692	3,8%
July	58830	57220	2,7%
August	56983	55113	3,3%
September	52538	51358	2,2%
Total	479348	451235	5,9%



6.- Discussion and Conclusions

There is a great potential for improvement of energy systems in supermarkets.

A system model is necessary to predict and evaluate the introduction of new concepts and ideas in supermarkets.

A particular energy efficient solution for each supermarket is possible to achieve only when there is a balance between Energy Performance, Costs, and Environmental Impact



6.- Discussion and Conclusions.

The implementation of new energy saving technologies in supermarkets requires an extensive analyse of energy performances.

This analysis should be done during a long period to evaluate and compare the real energy performance with the theoretical values calculated.



Thank You!