Expertise hub for energy-efficient cooling & heating in European supermarkets
D2.2 Eco-friendly Supermarkets- an Overview
2. AGENDA

1. Introduction of objectives and scope
2. Supermarkets scope in Europe
3. Environmental impacts of supermarkets
4. Eco-friendly and conventional energy systems
5. Best practices and case studies
Objectives: to review:
- Supermarkets status in Europe
- Supermarkets Environmental Impacts & F-gas regulation
- Conventional and state-of-the-art systems for: Cooling and Heating (Focus: Refrigeration system)
- Best practices and case examples.

Scope:
- Cooling and heating systems in supermarkets.

grocery stores / supermarkets
when more than 50% of the annual turnover is generated by sale of groceries, mainly food
Several parameters show the growth of supermarkets in Europe:

- **Increasing** number of hypermarkets, supermarkets, discounters and convenience stores
- **Increasing** total food retail surface area
- **Increasing** share of modern food retail market in European food retail market

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

- Urbanization;
- Emerging middle class;
- Globalization;
- Increase of female labor;
- Liberalization of investment in East Europe;
ENVIRONMENTAL IMPACTS & F-GAS REGULATION

1 - High GWP refrigerants

2 - High specific energy consumption among commercial buildings

• Largest part due to refrigeration
• Contribution of lightning is decreasing (modern LED lights)
Present conventional supermarket refrigeration systems are not future long-term solutions:

- Ban refrigerants GWP>150 from 2022 (centralized refrigeration system >40 kW, Primary Cycle in Cascade configuration >1500)
- 79% Reduction of GWP related emission by 2030

Which options are available for supermarket stakeholders?

- **Business as usual** until 2020 and then usage of recycled gas until 2030;
  - Availability/cost of the gas and equipment
  - Future ban of service and maintenance
  - Stricter leak detection and refrigerant recovery processes

- **Convert/retrofit with new synthetic low-GWP refrigerants**;
  - Future environmental Regulation?
  - Cost of the refrigerant

- **Natural Refrigerant** business orientation.
  - Long term solution
  - Investment cost no longer higher than traditional HFC
Conventional and eco-friendly energy systems in supermarkets:

- **Refrigeration:**
  - Central system: CO2 transcritical booster system

- **Heating**
  - Heat recovery

- **Air Conditioning**
  - NH3 or HCs Chillers
  - Integrated CO2 system

- **Ventilation**

- **Dehumidification**
Functionality: provide storage of and display of perishable food prior to sale. Mainly two temperature levels:

- **Medium Temperature**: Food is chilled to 1/14 °C
- **Low Temperature**: Frozen food kept -12/-18 °C

Types of Refrigeration system:
- **Stand Alone (Plug-in)**
- **Condensing Unit**
- **Centralized**
  - **Direct/Indirect HFC system**
  - **CO2 Refrigeration system**
    - **CO2 Indirect system**
    - **CO2 Cascade system**
    - **CO2 Transcritical Booster system**
REFRIGERATION SYSTEMS

• **Plug in / Stand-alone**
  • Refrigeration system integrated into the cabinet;
  • Condenser heat is rejected to the sales area of the supermarket;
  • Use to display products like ice cream or cold beverages (beer, soft drinks)

• **Condensing units**
  • Small-size refrigeration equipment with a condenser installed on the roof or in a small machine room;
  • Connected to a small group of cabinets installed in small supermarket
• **Direct/ Indirect HFC systems**
  
  • HFC systems can be considered as conventional solutions
  • They *generally* consist of two completely separate MT and LT loops
  • Heat/cold can be transported by the refrigerant itself (direct system) or using a secondary fluid, generally a brine solution (indirect system)
• **CO2 indirect system**
  - CO2 as secondary fluid
  - Good heat transfer and fluid-dynamical properties
  - No corrosion

• **CO2 Cascade system**
  - CO2 used into MT/LT levels
  - High temperature Rejection is performed by an upper cycle using HFC, NH3 or Hydrocarbons
  - Limitation of the safety/environmental problems in the sales area
  - Efficiency decrease for the presence of the intermediate heat transfer
ECO-FRIENDLY REFRIGERATION SYSTEM

• CO2 Transcritical Booster system

One of latest developments towards using climate friendly refrigerants in European supermarkets.

- «Booster»: All the heat at low temperature level is «boosted» to the medium temperature level

- «Transcritical»: High pressure stage over the critical point
ECO-FRIENDLY REFRIGERATION SYSTEM

CO2 Transcritical Booster system in the word

Over 7,200 CO₂ transcritical stores worldwide

CO₂ SUPERMARKETS WORLDWIDE

The use of CO₂ transcritical systems is growing globally. The map shows that both eastward and westward, from the United States to Europe and South America, CO₂ transcritical systems are being adopted. The map highlights China, the United States, and South Africa as regions with high CO₂ transcritical system adoption. The key legend indicates the number of CO₂ transcritical systems in each region, ranging from 1-2 to over 1000+.
1st Trend: CO₂ Integrated Systems

- Refrigeration + Heat recovery + Air conditioning
- Heat recovery as standard in Central-Northern Europe
- “Air conditioning + Parallel compression”
**2nd Trend:** **State-of-the-Art** solutions to increase CO$_2$ system performance in **Warm and Cold** climates:

- **Parallel Compression**
- **Ejector**
- **Mechanical Sub-cooling**
- **Thermal Storage**
- **Evaporative Cooling**
- **Flooded Evaporators**
- …
Wide range of heating demands in a Supermarket:

<table>
<thead>
<tr>
<th>Demand</th>
<th>Distribution system</th>
<th>Delivery temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space heating</td>
<td>Water: Floor heating</td>
<td>30-45</td>
</tr>
<tr>
<td>Space heating</td>
<td>Water: Low temperature radiators</td>
<td>45-55</td>
</tr>
<tr>
<td>Space heating</td>
<td>Water: Conventional radiators</td>
<td>60-90</td>
</tr>
<tr>
<td>Space heating</td>
<td>Air: air handling units</td>
<td>30-50</td>
</tr>
<tr>
<td>Tap water heating</td>
<td>Water</td>
<td>55-65</td>
</tr>
<tr>
<td>Ground freeze protection/snow melting</td>
<td>Water/secondary fluids</td>
<td>10-20</td>
</tr>
</tbody>
</table>

**Conventional systems:**
- Boiler/condensing boiler
- Electric heater
- District heating

**More eco-friendly options:**
- **Refrigeration heat recovery**
- Heat pumps: ground source, air source, water source
- Solar thermal panels (Tap water heating)
- Ventilation exhaust air heat recovery by heat recovery wheel
- Co-generation/tri-generation of electricity, heating and cooling
REFRIGERATION HEAT RECOVERY

Heat Recovery options

A

De-superheater

B

Heat rejection to ambient-Floating condensing

C

To HVAC system

D

To HVAC system

No Heat Recovery
A ventilation system distributes and provides outdoor air to the customers and personnel of the supermarket:

- Maintain quality of the products
- Guarantee air quality for people
- Unique mix of thermal zone (not isolated and interacting)

How to make ventilation more **Eco-friendly**?

- Demand control ventilation based on CO₂ PPM (parts per million) level
- Minimum air intake and maximum reuse of exhaust air in winter
- Air curtain at the entrance
- Exhaust air thermal/heat recovery wheel
Air Conditioning (AC) cools and controls the temperature level in supermarkets:
- R134a, R410A and R407C are currently used for stationary AC;

EU F-gas Regulation!

Which are the new trends?

- Using other low-GWP HFC / HFO in chillers
- Using Ammonia or Hydrocarbons in chillers
- AC Integration in CO2 booster refrigeration system
Disadvantages of high humidity in supermarket:

- Frost formation on the evaporator coils, less efficient heat transfer process
- Higher de-frost demand
- More formation of condensate/ice on the cabinets’ glass lids
- More formation of condensate or ice on products

Dehumidification solutions:

- Water condensation by cooling (A);
- Dessicant wheel (B);
BEST PRACTICES AND CASE EXAMPLES

Examples from Europe and World

- Sweden
- Germany
- Norway
- UK
- Switzerland
- Spain
- Italy
- U.S.
- Romania
- Japan
ICA Kvantum Täby (Sweden)

**Opening Year:** 2013

**Eco-friendly characteristics:**
- First ejector-based system in Sweden
- One liquid ejector
- Glass doors on cabinets and freezers
- Real-time energy measurements monitoring
- 4 K higher MT evaporation temperature by using ejector
BEST PRACTICES AND CASE EXAMPLES

**Migros Ibach (Switzerland)**

**Opening Year:** 2014 (refurbished)

**Eco-friendly characteristics:**
- CO2 refrigeration system using multi-ejector technology
- Parallel compression
- Partially flooded evaporators
- Tap water heating and facility heating
- Subcooling by ground water in summer
Migros Ibach (Switzerland)

With Five vapour and liquid ejectors:

• MT evaporation temperature could be raised from -8 °C to -2 °C

• LT evaporation temperature increases from -33 °C to -25 °C
REMA 1000 Kroppanmarka (Norway)

Opening Year: 2013 (refurbished)

Eco-friendly characteristics:

- Energy Saving Prize in Trondheim in 2014.
- CO2 as the refrigerant, heat recovery at multiple temperature levels
- Doors/lids in all refrigerated cabinets
- Aerogel facades, and demand controlled lighting based on amount of daylight available
- Energy wells for storage of heat and cold, four 170 m deep boreholes (energy wells) ...
Tegut supermarket, Marburg-Cappel (Germany)

Opening Year: 2014

Eco-friendly characteristics:

- The first supermarket to receive the German ecolabel Blue Angel, in 2015
- Integrated CO2 refrigeration + heating system
- Photovoltaic (PV) panels on the roof, 90 kW capacity
- Glass doors, LED lighting and EC fans in the cabinets
- LED lighting
- Energy management system according to DIN EN ISO 50001
Walgreens store, Evanston (USA)

Opening Year: 2013

Eco-friendly characteristics:

Sustainable construction:
- Automatic shade control
- Highly insulating walls, roof and windows prevent heat/cold loss.
- Window glass with light redirecting film technology (80% of the direct solar radiation is redirect to the ceiling)

Continue...
Walgreens store, Evanston (USA)

**Refrigeration**
- CO₂ refrigeration system with heat recovery for the ventilation air heating and DHW pre-heating
- AC + parallel compression + sub-cooling using a ground thermal storage (energy wells)
- Seasonal storage with energy wells

**Indoor air quality**
- Control of natural ventilation with motorized aperture in the roof
- Ventilation system control based on CO₂ levels in retails space with single-zone air handling units for local temperature control.

**Lighting**
- LED technology installation with an automatic light control system with daylight sensing zone
- Energized control of power and lighting systems based on time of day schedule for reducing the parasitic loads for HVAC

**Renewable energy sources:**
- 256 kW solar PV installation on the roof
- Two 2 kW wind turbines
- Power measurement and visualization
This project has received funding from the European Union’s Horizon 2020 research and innovation programme