Eco-friendly operation and maintenance of supermarkets

Report 6

SUPERSMART

Public report

for the project:

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

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EXECUTIVE SUMMARY

The objective of this deliverable is to provide the stakeholders in the supermarket sector a best practice guide on service and maintenance of supermarket equipment. The report identifies training needs and the standard that should be aimed to achieve reliable operation with regard to safety and efficiency of the equipment.

The report describes equipment and component selection as well as installations. The entire installation process is critical in ensuring the long-term safety and energy efficiency of the equipment as well as operation according to the technical specifications.

Operation of the supermarket is another topic covered in the report. A perfectly built supermarket which is not operated correctly or in which each subsystem is managed without interaction with the remaining system will have unnecessary high energy consumption. Key points concerning the operation are introduced, including operator responsibilities, training, operation practices, and energy benchmarking. A monitoring/control system that unites and coordinates the functions of all components in the refrigeration and heating, ventilation and air conditioning (HVAC) systems is essential for optimized energy use. State-of-the-art operation systems have this property and hence enable minimum (or significantly reduced) energy consumption. Saving maintenance costs and reducing supermarket staff working hours is another great benefit gained when implementing a functional monitoring system with fast response.

In recent years we have witnessed an enormous progress in digital technology, including computers, software, networks, etc. Fortunately, this progress is reflected in the development of monitoring/control systems for refrigeration and HVAC as well. The report includes information on energy management systems that are used in the supermarket sector in Europe, including installation, commissioning and operation of the system as well as the generated data. Examples of companies delivering monitoring systems are also given.

Furthermore, a case study is presented, showing how an advanced monitoring system influences the operation of convenience stores. This example shows that great energy savings as well as increased lifetime of major system equipment can be achieved with such a monitoring system.

Special focus is paid on service and maintenance required to keep the supermarket building and its energy systems working on peak performance, maintaining the designed capacities. The focus is on the refrigeration components, refrigeration system being responsible for the largest share of energy consumption in an average supermarket. Further described are the maintenance of HVAC systems (boilers, chillers, air handling unit, air terminals, etc.), lighting, and the building envelope as a whole. Finally, a checklist with description of each system component and the maintenance actions that should be taken at regular time intervals is included to support supermarket staff in their daily work.

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1 INTRODUCTION

Efficient solutions for supermarket heating, cooling and refrigeration - such as integrated systems or the use of natural refrigerant-based equipment - are already available in the European market. However, their use is not yet widespread due to remaining non-technological barriers, including lack of knowledge and awareness, social, organizational and political barriers.

The European project SuperSmart aims at removing these barriers and additionally supports the introduction of the EU Ecolabel for food retail stores. The EU Ecolabel can encourage supermarket stakeholders to implement environmentally friendly and energy efficient technologies and thus reduce the environmental impact of food retail stores.

Within the project several activities are carried out to remove the barriers: campaigns to raise the general awareness and spread the information about energy efficient and eco-friendly supermarkets, as well as training activities within the following specific topics:

1. Eco-friendly supermarkets – an overview
2. How to build a new eco-friendly supermarket
3. How to refurbish a supermarket
4. Computational tools for supermarket planning
5. Eco friendly operation and maintenance of supermarkets
6. EU Ecolabel for food retail stores

For each of the topics a set of training material is developed, which will be used in the training activities. The different kinds of training activities are:

- Conference related activities
- Dedicated training sessions
- Self-learning online activities

Dedicated training sessions are free-of-charge for the different stakeholders in the supermarket sector. This means that highly-qualified experts from the project consortium will carry out a training session on a specific topic at the premises of the stakeholder. If you are interested in receiving such a training regarding any of the above mentioned topics, please contact the project partner via the project website: www.supersmart-supermarket.info.

The present report forms a part of the training material for the topic *Eco-friendly Operation and Maintenance of Supermarkets*. It can be used for self-studying and is freely available. There will be conferences where this topic is included as a training activity. Information on conferences where members of the SuperSmart-team will be present as well as the planned training activities can be found on the project website.

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1.1 Introduction to eco-friendly operation and maintenance of supermarkets

1.1.1 Background for the topic

The key factors for achieving a system operating at its peak efficiency are proper operation, sufficient frequency of system check-up and maintenance as well as the expertise and experience of servicing staff. Energy savings and regulatory compliance are dependent on careful and thorough operation and maintenance of refrigeration systems and other energy consuming products in supermarkets. Improper operation and maintenance of refrigeration units and other appliances/installations in supermarkets can deteriorate the energy performance of the equipment.

All refrigeration systems are vulnerable to environmental and operational factors such as seasonal temperature fluctuations, vibration, dirt, and incorrect use of the refrigeration system. These factors can lead to drifting the refrigeration system outside its originally set working range. Good operation and maintenance will keep the system working at its optimum.

1.1.2 Significance of each stakeholder in supermarket operation and maintenance

1.1.2.1 Supermarket chain or single supermarket owner

Every end user must understand the importance of regular maintenance during lifetime of the equipment. They should allow maintenance staff sufficient time and access freedom to inspect the systems, and to provide planned preventive maintenance and repair if necessary.

End users have a significant role to play in the operational efficiency of their refrigeration systems. Providing employees training possibilities to expand their skills and knowledge can be vital in ensuring that equipment is operated correctly and that problems are identified at an early stage.

1.1.2.2 Supermarket responsible staff

Another key person in the organization is the technical staff responsible for the refrigeration system and other energy consuming equipment. Operators who need to have significant knowledge of system operation and performance shall:

- Identify possible refrigerant leakage from the refrigeration system.
- Analyze monitored information and interpret them.
- Identify possible problems and instruct contractors to carry out relevant work.
- Be informed and comply with regulations related to refrigerants and food safety regarding storage temperatures.
- Train and educate employees about energy efficiency measures.

1.1.2.3 HVAC&R service and maintenance provider

Service personnel must possess system and product knowledge in order to approach the equipment and establish proper maintenance routines. They should also be able to keep continuously updated on current and future technologies through their own professional development. The personnel should have suitable working tools and perform required training for safe service operation and proper equipment maintenance. At the end of the performed work, they should advise the end users if there are issues or possible weak spots that may affect the performance of the system.

1.1.2.4 Engineering society/studio

Maintenance is effective and less time/cost consuming when it is addressed in the right way from the beginning, i.e. from the planning and design of the building. In addition, when a certain upgrade is planned, proper maintenance conditions and easy access for the service personnel must be secured. They must point out the necessity for proper operation and regular maintenance when offering services to the supermarket sector.

1.1.2.5 Public bodies

Legislation should protect the technicians and encourage all personnel engaged in equipment maintenance to obtain proper level of certification which will give them knowledge and good working practice. With the help and support from different NGOs (e.g. associations of supermarket installers/maintenance companies) the level of maintenance can be raised on a higher professional level.

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During the survey on non-technological barriers in the SuperSmart project[Minetto 2016] stakeholders were asked about the frequency of inspections and maintenance in their supermarket sites or in those of their partners or customers. Figure 1 reports the collected results: from a total of 127 respondents, 22% claimed monthly inspection,15% inspection on demand and 13%annually inspection.11% stated that a periodicity different from the proposed one is applied: they majorly stayed on trimestral cadence or on what is required by the EU F-gas Regulation, depending on total charge and type of refrigerant. Those who responded not to be aware of inspection periodicity mainly belong to refrigeration systems or components manufacturers or suppliers; therefore they are not directly involved in inspections.

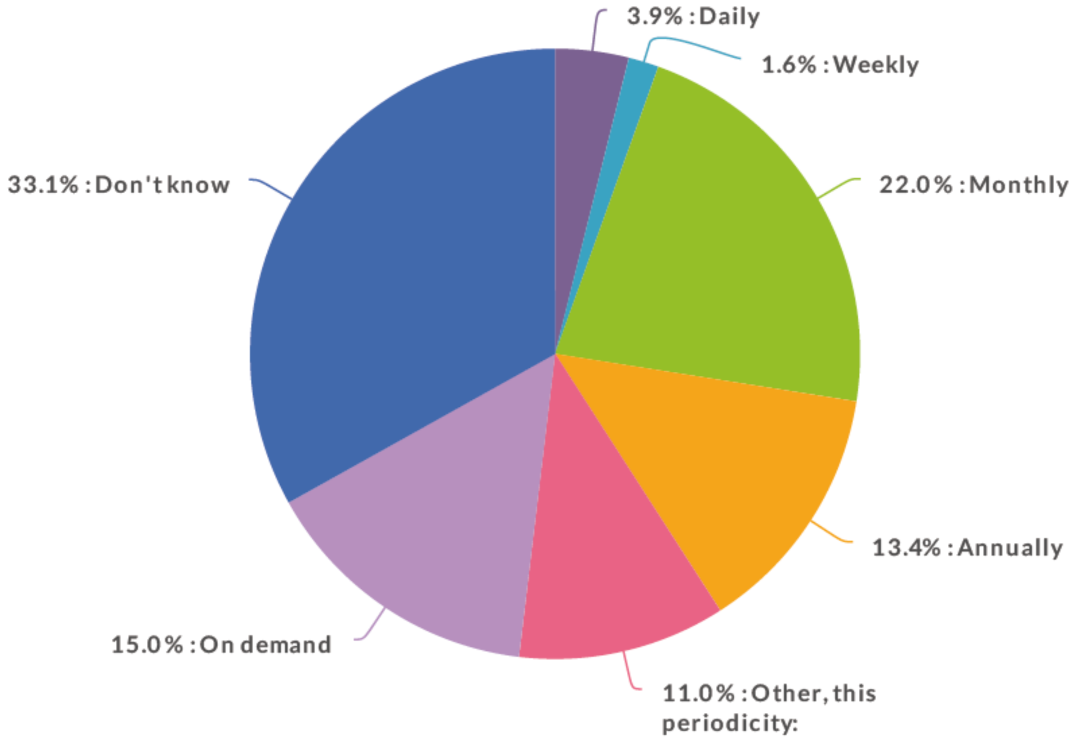

Figure 1 Frequency of inspections of HVAC&R systems in food retail stores [Minetto 2016]

As far as the penetration of data monitoring systems is concerned, Figure 2 reports results from 127 respondents on the above mentioned survey. Advanced monitoring, which is likely to include innovative management of collected data for fault detection and energy consumption evaluation, is widely practiced in North, Central West and South West Europe.

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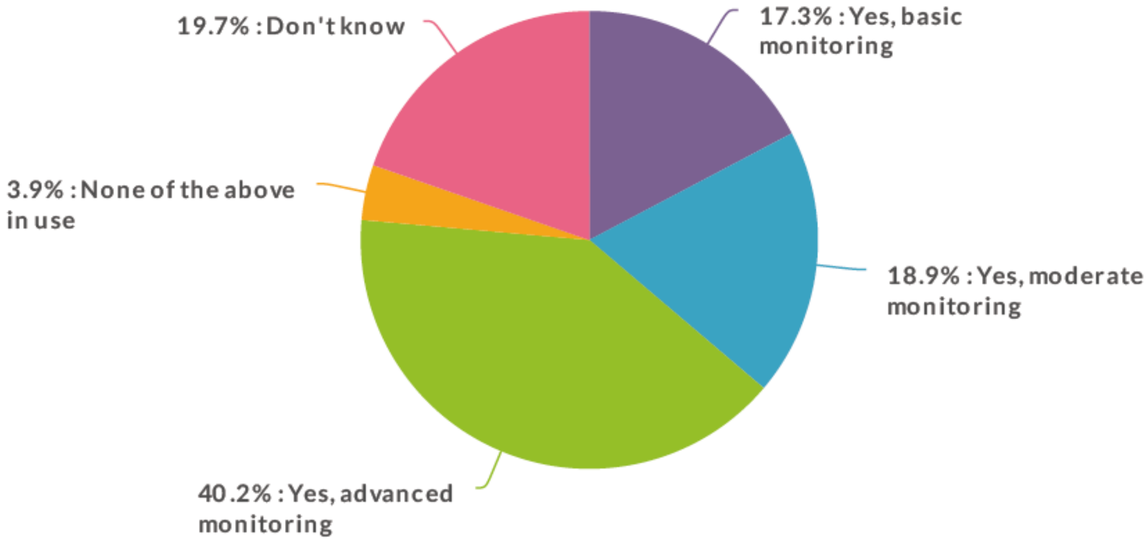

Figure 2 Penetration of data monitoring systems in the food retail sector[Minetto 2016]

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2 TECHNOLOGICAL REQUIREMENTS

2.1 Equipment and components

Equipment and component selection is of high importance for proper operation of heating, ventilation, air conditioning and refrigeration (HVAC&R) systems. Implementing new technologies can save energy and prolong the service life of the HVAC&R systems.

New equipment must be tested and certified by the manufacturer and leak tested in accordance with standard EN-378: 2008 (Refrigeration systems and heat pumps).

The following recommendations are given as best practices in installation [Carbon Trust-BPG 2010]:

- 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.
- 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 are 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).

2.2 System installations

The installation consists of many activities from the site selection to finally ensuring that appropriate manuals are in place. The entire installation process is critical in ensuring the long-term safety of the equipment, for example, by guaranteeing that the safety features included within the design are correctly setup within the plant.

Any complete installation including the refrigeration system should be checked against appropriate drawings and operational specifications, before the system is put into service. Particular attention must be paid to the safety features when using flammable and/or toxic refrigerants. Improper installation procedures can lead to faulty equipment operation and/or complete overhaul of the refrigeration system.

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2.2.1 Important considerations when installing major system components

- Heat exchangers must be protected against possible mechanical damage.
- Heat exchangers containing water must be protected against freezing.
- Access must be provided for leak testing of compressors, evaporators, condensers and associated components.
- Where there is a risk of refrigerant leakage into water or other heat sink fluid, means of drawing off and sampling that fluid must be provided.
- Lower temperature air coolers and drip trays should be completely defrosted during every defrost cycle. Drip tray should be installed with proper slope enabling water drainage.
- Defrost controls should be designed and adjusted to minimize any unnecessary defrost operations, to avoid thermal stresses.
- Anti-vibration mountings should be applied on all compressors.
- Equipment shall be positioned to minimise pipework runs and allow easy access for maintenance and testing.

Best installations of HVAC&R systems are those made according to design specifications and guidelines. The installation team and installation supervisors will have responsibility for proper system operation and zero leakage. Sufficient time should be considered for pressure testing and checking of the installations.

2.2.2 Installation examples and tips

- The installer must identify the position of joints on the outside of insulation using fluorescent cable ties.
- Flared joints shall be avoided.
- The number of joints used shall be minimised.
  Valves or other line components should not be installed in ceiling voids, etc. where asbestos is present or which are inaccessible.

When joining different metal types such as copper and steel, an appropriate silver solder rod and flux compound should be used. All threaded mechanical joints should be sealed using a reliable sealant compound (for example shut off valve caps, flared connections, rota lock connections). This will certainly reduce the risk of leakage from these areas over the lifetime of the system. During the brazing of copper joints, moisture-free nitrogen should be purged through the system at a positive pressure. This should be done that the outlet open end of the pipe run restricts the flow of nitrogen, but still allows the free flow of nitrogen through the pipework generating the positive pressure. This can be achieved by not completely sealing the end. This will minimise the risk of carbonisation within the pipework which will assist in good brazing-rod penetration and adhesion.

Installation drawings provided by the design team should include reference to all relevant standards. Brazed joints should be identified on layout drawings which must be updated to reflect the actual location. The expected system refrigerant gas charge should be indicated by applying refrigerant labels to all refrigeration plans. All installations should comply with national codes and standards.

Essential for good installation is that all people included in the process are familiar with the system operation and have relevant knowledge and experience on installing HVAC&R equipment. Implementing new technologies, in particular new refrigerants, without technical background or supervision and experience will lead to operation failures and incorrect equipment operation. Even the latest and most advanced equipment will not have normal operation parameters and the expected efficiency if it is incorrectly or poorly installed, leading to unsatisfactory overall system performance.

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3 OPERATION OF SUPERMARKETS

A perfectly built supermarket which is not correctly operated or in which each subsystem is managed without interactions with the rest of the system may have an unnecessarily high energy consumption during its operation phase. Operation of a supermarket includes topics such as operational schedules of HVAC&R systems, setting different working scenarios, setting different temperature set points, scheduling equipment start-up and shutdown, defining emergency procedures, etc.

The main focus in this chapter is on control and operation for best performance supermarket equipment and systems. Proper operation leads to reaching the required capacity in an efficient way. Supermarkets can thus drastically reduce the energy and service expenses by ensuring optimum operation of their cooling and freezing equipment. In addition, proper operation will also reduce the risk of operational interruptions leading to shorter equipment lifetime, destroyed food and reduced comfort level for the customers.

3.1 Operator responsibilities

The operator must have sufficient knowledge about the building systems and to be involved in decision making related to operations in the supermarket building. This person needs to develop an efficient operation plan including all major interactions in the installed systems. Proper operation should also address simple problems that are very often ignored and can lead to rising energy costs or even equipment damage over a period of time. In table 3.1,a short description of operator responsibilities is given.

Table 3.1 Operator responsibilities

Operator responsibilities	Description
Maintenance plan	Ensuring the frequency and quality of maintenance work, and the updating of refrigerant log books including any details concerning refrigerant charge, additions according to the F-gas Regulation, etc.
Monitoring system	Using data from monitoring system and investigating the data trends. This analysis can help in identifying any potential problems in the system on time.
Temperature sensors	Regular recalibration of temperature and humidity sensors of the cabinets. Over time the temperature sensors can be off by several degrees. Inaccurate or damaged humidity sensors lead to unnecessary operation of electrical heaters or air coolers in the cabinets.
HVAC&R system integration	Considering cost-effective ways to operate and integrate the HVAC&R system.

3.2 Training regarding efficient operation

Training of store managers and non-technical staff on proper operation is very important. This could be concluded also from the survey on non-technological barriers[Minetto 2016], where the importance of training of the food retail chain owners was classified as crucial all over Europe. The significance of energy costs vs. investment costs and how operation influences the efficiency of a store should be emphasized in training. Training should also educate staff about the negative environmental impact of increasing energy consumption caused by poor operation and poor maintenance procedures. It is also important to understand the irreversible damage on the environment from releasing high GWP refrigerants into the atmosphere and their effect in accelerating climate change.

All employees must be trained to understand how their daily actions have impact on the operation of the store. For example filling display cabinets with products should be done in a way not to block supply/return grilles. Overstocking can cause poor air circulation leading to additional refrigeration load and poor distribution of cold air. This kind of awareness training and introduction of working procedures to relevant staff should be done regularly, several times in a year, especially in places where staff is changing frequently.

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3.3 Operation practices

3.3.1 Refrigeration systems

Refrigeration accounts for about35-50% of total electrical energy use in the average supermarket[Karampour 2016].Energy efficient operation of the refrigeration system is hence crucial. The following operation activities will lead to better refrigeration performance:

- Maintain minimum recommended refrigeration temperature for products. The most commonly setpoint temperatures to be maintained inside display cases are between -22 °C ÷ -18 °C for frozen and +4 °C ÷ +6 °C for chilled products.
- Optimal refrigeration efficiency is achieved with indoor air relative humidity levels between 40-55%[Supermarket BP 2012].
- Turn off plug-in refrigeration units when not in use. Generally, the number of plug-in units should be minimized and most/all of the refrigeration should be performed by a central refrigeration system.
- Continuously monitor and if needed adjust system parameters such as condenser pressure, evaporator pressure or superheat.
- Use floating pressure control in order to allow lower condensing temperatures in colder weather.
- Optimise the compressor loading if multiple compressors are installed in order to perfectly match the load with less energy consumption.
- Set up timers and dimmers on display case lighting.
- Set up defrost cycle on-demand.
- Close display case curtains in the store during off-hours.
- Cold storage and cabinet doors should be kept closed as much as possible.
- Investigate possibility for heat recovery of the rejected heat from the condenser side of refrigeration units.

3.3.2 HVAC systems

Approximately one quarter of all energy used in one supermarket building goes to HVAC [US DOE 2012].Operation activities regarding the HVAC system impact both customer comfort and building efficiency. Some well-known operation practices can improve the energy performance:

- Maintain appropriate indoor temperature settings in winter and summer according to national standards for this type of building.
- If a building management system is used, continuously check, and if necessary, adjust the temperature set points.
- Use night setback temperature mode of operation.
- Monitor and control the supply of fresh air flow.
- Install heat recovery solution for heat recovery from exhaust air to incoming air.
- Introduce air handling units designed for supermarket applications (for more details, see[Kauko 2016]).
- Set programmable thermostats to maximize comfort and efficiency.
- Adjust automatic timers for on-off control of the ventilation unit and set the start time as late as possible having in mind optimal customer comfort level.
- In summer period operate the ventilation system during the night to reduce the air conditioning load during the day.
- Use safety lock on thermostats in order to prevent unauthorized temperature adjustments.
- Minimize heating and cooling in less occupied areas or when building is not in use.
- Set local extract ventilation where needed depending on occupancy or activity, such as in rest rooms and kitchen.

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3.3.3 Lighting

Lighting corresponds to approximately 20% of the supermarket energy demand, hence an energy efficient lighting is crucial for an eco-friendly supermarket[Karampour 2016]. Lighting energy use should be optimized through operational control coupled e.g. to the operating hours of the store. For example night time and outdoor lighting should be minimized as much as safety and local regulations allow. The following measures can reduce energy consumption for lighting:

- Implement automated lighting controls and task lighting where possible.
- Install timers in parking spaces.
- Use lighting control based on the amount of daylight available.
- Use motion sensors on less frequent areas.
- Make sure to turn off lights that are not being used.
- Improve labelling of lighting switches for easier use.

Some examples on efficient lighting has been presented in deliverable report D2.3: How to build a new energy efficient supermarket[Kauko 2016].

3.4 Energy benchmarking

Supermarket operators should focus on improving the energy performance of their store through comparing their energy consumption to a certain benchmark of the supermarket organization they belong to or to more global benchmarking systems. Examples on calculation tools that also can be used for energy benchmarking has been presented in deliverable report D2.5: Computational tools for supermarket planning[Fidorra 2016].

It is important to have energy indicators that are clearly defined and can be easily measured. This requires certain measuring equipment such as power meters located on energy consuming equipment. Once set up, the information received from the measuring equipment can be sorted and shared within the organization management for different analyses.

Having this information available on day-to-day bases can be a powerful tool in the hands of the operator in order to assess and take certain actions in improving the energy performance of equipment and the entire system. It will influence also the service and maintenance plan and will better shape their focus of work in preventing potential equipment damage and improving the performance of the systems they work on. This not only helps in taking actions for improving the energy efficiency but also gives valuable information for supermarket operators and owners to better plan and focus their further investment in more efficient technologies.

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4 MONITORING

Monitoring is taking records of data from various points or processes, information from service and maintenance procedures, information from inspections, field results, external reports, etc. The gathered data are stored for safety and legislative fulfilments (for example hazard analysis and critical control-HACCP), and afterwards studied and compared in order to determine possible malfunctions, components failure or even low performance from key system components. Any activity in the supermarket can be monitored, including installation and operation of HVAC&R systems, lighting system, service and maintenance operation as well as tests and inspections. Having accurate and comparable data easily available can give a very clear picture about performance of the HVAC&R system.

4.1 Monitoring systems

A monitoring system can have different features from basic only monitoring data up to more advanced “intelligent” auto-adaptive control systems. There can be different levels of monitoring[Carel, 2016]:

- Basic monitoring system which features a hardware device and a purpose-developed software program used to monitor a series of parameters and significant values for the operation of the entire system as well as the operating status. In this case, the status of the system being monitored can only be checked: the software cannot be used to modify or set any of the values.
- Remote management system allows better possibilities for optimisation because of remote access to the monitoring system. From the remote control centre the user can set the system control parameters, such as the operating times, set points and alarm thresholds. This centralized management system can be installed at large distances, simplifying troubleshooting operations.
- Supervision is a more complex and evolved control system, which can also make decisions by itself when certain situations arise, to ensure correct operation, resolve problems and optimise energy consumption. These systems that are based on the supervision concept and may be defined as "intelligent", as they are programmed to manage a large number of combinations of data and variations.

4.1.1 Information integrated into monitoring systems

Information that is by default integrated into monitoring systems:

- List of equipment and components
- HVAC&R system schematics
- Working procedures required for particular equipment
- Temperatures (ambient, display cabinets, coldrooms, etc.)
- Humidity
- Refrigeration system parameters (working fluid temperatures, oil parameters, capacity used, refrigerant operating temperatures, operation mode, etc.)
- Refrigerant leak equipment status
- Comparison charts of different operation periods
- Preferable average values
- Different store operation data
- Maintenance schedule plans
- Service performed and its outcome
- Safety procedures
- Energy consumption
- Test and inspection intervals
- Alarms and alerts

Information that should additionally be integrated into a monitoring system may include information associated with personnel, equipment and system processes. For example:

- Personnel activity and specific roles
- Qualification of personnel doing specific jobs, education level, trainings, certificates, skill and experience
- Regular training activities
- How recommendations and problems were handled
- Not following processes and procedures, reasons and alternative actions

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4.1.2 Description of monitoring process

Monitoring/control system is a central point for receiving signals from ambient temperature sensors, humidity sensors, gas detectors, ventilation pressure sensors, gas vessel or pipe pressure sensors, manual emergency buttons, etc. The monitoring/control system sends the activation signals to visual and audible alarms, controls the operation of pumps and other components or whole systems, activates shut-off valves, etc., as necessary based on the input signals. The monitoring system together with the HVAC&R systems should be provided with an uninterruptible power supply (UPS)that will maintain operation for a minimum period of time (e.g. one hour) in the case of a power cut.

Monitoring/control systems optimize refrigeration system efficiency and improve reliability while minimizing maintenance requirements. Control system options include, but are not limited to, the following[GIZ 2014]:

- Machinery equipment failure detection and diagnostics;
- Communicating with and/or controlling lighting and HVAC&R systems;
- Communicating with other control elements;
- Facilitating remote monitoring and control through the energy management system (EMS) and energy information system (EIS);
- Integrating control signal access to HVAC and refrigeration systems.

4.1.3 Operation of monitoring systems

Proper operation of refrigeration monitoring systems requires more than a good design and installation of the hardware and software. It requires also training of personnel to ensure that operators and other users know how to use the monitoring system, how to read it and operate upon system results and alarms and how to make full functionality if a control function must be temporarily adjusted, bypassed or turned off.

System energy and temperature data should be regularly reviewed to ensure that energy consumption is consistent and within expected and designed values and tracks to historical values for equivalent ambient conditions. Irregularities in performance may reveal malfunctions/leakage at an early stage. Monitoring system data should be checked to be sure that the refrigeration system is running with designed parameters for the type of refrigerant used. If the operating parameters are outside operating limits, this should be alarmed to the maintenance/service staff. The lowest possible condensing pressures and highest evaporating pressures should be maintained to achieve desired performance, product temperatures and energy efficiency. Long-term system performance should be monitored and cross-checked against commissioning data. Any data outside the operating limits needs to be alarmed to the maintenance/service team.

An important step in achieving energy savings and maintaining them is the targeted use of specific information from the monitoring system, and ensuring the energy performance is a key performance indicator (KPI) for the maintaining/service contractor. Visualizing the monitored data in the form of graphics, tables and charts is an invaluable aid to the technical staff.

4.1.4 Installation and commissioning of monitoring systems

Installation and commissioning of monitoring equipment is demanding and requires at least one week, depending on the size of the supermarket. The refrigeration load is complex and changes constantly over a 24-hour period depending on indoor/outdoor temperatures, humidity, day of the week, season, etc. It is hence important to develop a scenario in order to be able to notice the deviations in the parameters if any problems occur during the start-up phase. During a period of several weeks, the system should be monitored and data collected in order to have a clearer picture of the system performance, to control if leakage or system malfunction occur, or even to perform energy performance comparison.

4.1.5 Generated data from monitoring systems

Monitoring system installers must ensure that data sharing capability exists between the building management system (BMS), refrigeration controls and other monitoring systems. One system must however not be able to change the settings of the other.

Monitoring provides the necessary information on reviews to be carried out on components, refrigeration and HVAC systems and helps to identify how to improve guidelines and thus, performance. Next step

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after reviewing the monitoring system results can be creating audits, either by personnel within the organisation or by third parties from outside the organisation. Auditing may be used to check the suitability or accuracy of the monitoring process, test within a different environment. It helps to inform about the reliability and effectiveness of the monitoring and safety systems. It is useful to combine the results from monitoring, measuring performance with information from the audits to help improve the approach for the operation and maintenance management and safety management[Supermarket BP 2012].

Monitoring systems should generate reports which can be easily read and shared among the technical staff for further analysis. Internet based monitoring system is a favourable choice, accessible for the supermarket technical department at any time 24/7 without need of visiting the store itself. This option allows considerable flexibility outside store operating hours. It enables alarming the service and maintenance company fast to dispatch the service team on site next day. Easy accessibility of the monitoring system enables more precise and faster comparisons between individual stores, therefore more precise analyses and actions planning.

Creating alarm thresholds is important in determining the importance of the problem and consequently solving the issue faster if there is a need for technical company to solve the problem or if it can be checked and solved by supermarket staff. All parties concerned (for example end user, service contractor, and manufacturer) should be able to access relevant data concerning the operation of the refrigeration system in a timely manner to assist with identifying improvements or diagnosis of problems. These data should be remotely accessible.

Monitoring data, service checks and maintenance records should be kept in a recognised format that is easily accessible (for example a spreadsheet, table, and charts).Key monitoring parameters should all be available through one access point. Remote and local access to monitoring parameters should be available, and service and maintenance staff must be familiar with their location.

Monitoring systems can have two components[GIZ 2014]:

- Active monitoring; before things go wrong – checking whether the setting points are met and within the approach previously indicated in the guidelines.
- Reactive monitoring; after things go wrong – following and correction after operation mistakes and therefore optimizing of procedures and guidelines based on the occurred failure.

Gathered information from both active and reactive monitoring should be used to identify situations that create system failures or safety risks, and to do something about them. Prioritizing is very important and focus should be given where risks are greatest. Special attention is needed at serious events and those with potential for serious breakdowns. Both require an understanding of the problems that occur and the real causes of the events. In the case of reactive monitoring, investigate and record what happened, and find out why. Forward the information to personnel with authority to take appropriate actions. Follow-up may include change of suppliers, maintenance and service companies, improving test methods, or even organisational and policy changes.

To summarize, it is important to ensure that:

- The organisation is following the objectives and guidelines for safety aspects.
- There are accurate records of all faults, problems, errors, and so on that may lead to system breakdowns, incidents or even injuries.
- The investigations are revealing the real causes of the problems.

The research leading to these results has received funding from the
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4.2 Energy management systems

Energy management systems (EMS) are computerized centralized systems that enable the supermarket operator to program various functions from a central point in the building and provide early detection of operational problems. EMS can be combined together with the supermarket monitoring system in monitoring system data and optimizing functions. Some systems feature scheduling and monitoring functions that control temperatures and equipment in different zones, lighting system and monitor energy consumption.

There are several possibilities of EMS:

- Monitoring and energy management of each store
- Comparison of energy consumption between stores
- Monitoring and control of parameters for billing of electricity

In Figure 3,a snapshot from the user interface is shown from EMS installed in a supermarket in Barcelona, Spain with an 830 m² floor area. Here, energy consumption in kWh per energy system is given. Also easy comparison is made between each energy consuming sector.

Figure 3 Voltage and current status, kWh/day consumption[Circutor 2016]

In this EMS, an alarm occurs if there is more than 10% voltage drop or phase imbalance. Also, if daily power consumption is not within the proposed objectives, action is required and alert triggers. There are several options how monitoring energy consumption can help finding weak spots. With the EMS systems, detailed analyzes can be performed and it provides a great overview of each system (refrigeration, HVAC, lights, etc.) consumption within the supermarket. Therefore, significant savings on the energy bills can be achieved.

4.3 Examples of different monitoring systems

In this chapter, examples of monitoring systems from different suppliers are shown. The main focus is on the refrigeration system monitoring systems.

4.3.1 Danfoss smart store control system

Enterprise service by Danfoss is a cloud-based service offering 24x365 monitoring [Danfoss 2016]. It is a platform that collects various types of data of every store and offers a great overview of store operation. This system offers complete infrastructure, software, components, data storage, and back-up solution. In Figure 4, the control product overview is shown, including user interface, sensors, valves, controllers, etc. Refrigeration systems, HVAC, lighting and other equipment can all be controlled together from the same platform. Various types of information and data can be collected and stored, and further analyses of typical store operation or typical faults can be performed.

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Figure 4 Controls product overview from Danfoss [Danfoss2016]

The platform includes the following features:

- Alarm Management
- Compressor Status
- Leak Detection
- Refrigerant Levels
- HACCP Reporting
- Global Set point Control
- Password Lockdown
- Energy Information Systems
- Continuous Commissioning Process
- Demand Response
- Remote Assist
- Executive Reporting

One of the options in the monitoring system by Danfoss is compressor status operation monitoring. Monitoring compressor operating hours and comparing it with compressor start up enables:

- Identifying operational inefficiencies.
- Monitoring the running condition of a specific compressor pack, showing reasons of compressor failure (i.e. number of starts per hour). Therefore, correct sizing and capacity control of compressors in the pack can be managed.
- Managing start conditions in order to avoid excessive and expensive in-rush current effect.

Global set point control enables control of set points in several stores simultaneously. It also enables returning to previous set point values and making schedules for different set points at different periods.

In Figure 5, HACCP reporting is presented, including a list from different temperature readings from refrigerated spaces for each hour of the day.

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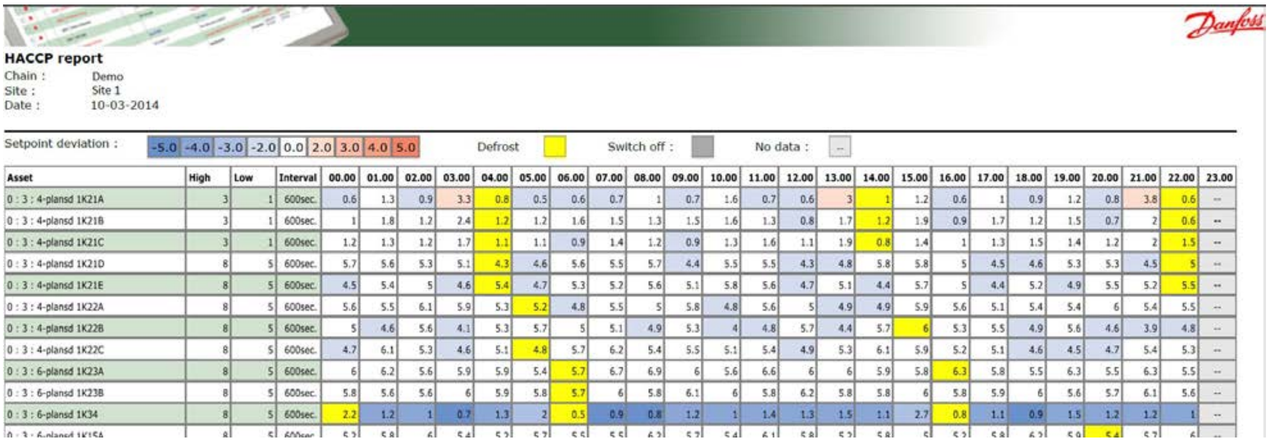


HACCP report
Chain : Demo
Site : Site 1
Date : 10-03-2014

Setpoint deviation : -5.0 -4.0 -3.0 -2.0 0.0 2.0 3.0 4.0 5.0 Defrost Switch off : No data : --

Asset	High	Low	Interval	00.00	01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
0 : 3 : 4-plansd 1K21A	3	1	600sec.	0.6	1.3	0.9	3.3	0.8	0.5	0.6	0.7	1	0.7	1.6	0.7	0.6	3	1	1.2	0.6	1	0.9	1.2	0.8	3.8	0.6	--
0 : 3 : 4-plansd 1K21B	3	1	600sec.	1	1.8	1.2	2.4	1.2	1.2	1.6	1.5	1.3	1.5	1.6	1.3	0.8	1.7	1.2	1.9	0.9	1.7	1.2	1.5	0.7	2	0.6	--
0 : 3 : 4-plansd 1K21C	3	1	600sec.	1.2	1.3	1.2	1.7	1.1	1.1	0.9	1.4	1.2	0.9	1.3	1.6	1.1	1.9	0.8	1.4	1	1.3	1.5	1.4	1.2	2	1.5	--
0 : 3 : 4-plansd 1K21D	8	5	600sec.	5.7	5.6	5.3	5.1	4.3	4.6	5.6	5.5	5.7	4.4	5.5	5.5	4.3	4.8	5.8	5.8	5	4.5	4.6	5.3	5.3	4.5	5	--
0 : 3 : 4-plansd 1K21E	8	5	600sec.	4.5	5.4	5	4.6	5.4	4.7	5.3	5.2	5.6	5.1	5.8	5.6	4.7	5.1	4.4	5.7	5	4.4	5.2	4.9	5.5	5.2	5.5	--
0 : 3 : 4-plansd 1K22A	8	5	600sec.	5.6	5.5	6.1	5.9	5.3	5.2	4.8	5.5	5	5.8	4.8	5.6	5	4.9	4.9	5.9	5.6	5.1	5.4	5.4	6	5.4	5.5	--
0 : 3 : 4-plansd 1K22B	8	5	600sec.	5	4.6	5.6	4.1	5.3	5.7	5	5.1	4.9	5.3	4	4.8	5.7	4.4	5.7	6	5.3	5.5	4.9	5.6	4.6	3.9	4.8	--
0 : 3 : 4-plansd 1K22C	8	5	600sec.	4.7	6.1	5.3	4.6	5.1	4.8	5.7	6.2	5.4	5.5	5.1	5.4	4.9	5.3	6.1	5.9	5.2	5.1	4.6	4.5	4.7	5.4	5.3	--
0 : 3 : 6-plansd 1K23A	8	5	600sec.	6	6.2	5.6	5.9	5.9	5.4	5.7	6.7	6.9	6	5.6	6.6	6	6	5.9	5.8	6.3	5.8	5.5	6.3	5.5	6.3	5.5	--
0 : 3 : 6-plansd 1K23B	8	5	600sec.	5.8	5.6	5.6	6	5.9	5.8	5.7	6	5.8	6.1	6	5.8	6.2	5.8	5.8	6	5.8	5.9	6	5.6	5.7	6.1	5.6	--
0 : 3 : 6-plansd 1K34	8	5	600sec.	2.2	1.2	1	0.7	1.3	2	0.5	0.9	0.8	1.2	1	1.4	1.3	1.5	1.1	2.7	0.8	1.1	0.9	1.5	1.2	1.2	1	--

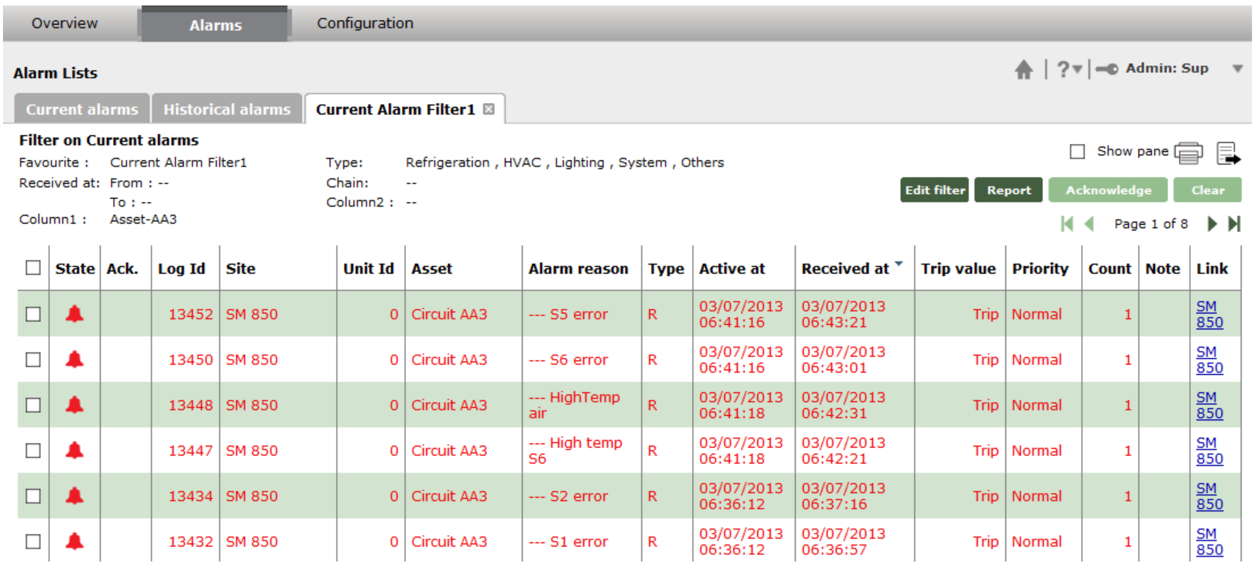
Figure 5 HACCP reporting with temperature deviations [Danfoss2016]

The monitoring system by Danfoss includes also an EIS which utilizes existing energy data to baseline and benchmark the retail stores energy use. Comparison can be made between different stores and different systems. This service provides insight into current usage against historical data to identify areas where you can gain the biggest efficiency improvements and cost reductions.

Keeping up on store operations can be time consuming. The system therefore includes executive reports, providing a monthly consolidated view of the performance of the stores. This resource can be very valuable to identify items that need attention; from leak detection, refrigerant levels, and repeat alarms to energy consumption.

One possible option in the system by Danfoss is an enterprise management solution for the food retail industry. This is a multi-user, multi-site server PC application which provides alarm management and automatic data collection, together with reporting features. This online web interface can give the supermarket operator an understanding of how the facilities are operating based on alarms, log data, and reports. This includes details of current alarms and action status, data points from different stores within the same chain, collection of data over a longer period of time, HACCP reports, energy reports, and temperature performance reports.

Figure 6 shows an example of an alarm list in the Danfoss smart store control system. Alarm lists can be filtered, based on e.g. specific period of day or occurrence of alarms. Different alarm lists can be shown (HVAC, Refrigeration, lighting, etc.). Alarm reports can be generated, for different alarms from different sites. Suspension of alarms is also a possible option.



Overview | Alarms | Configuration

Alarm Lists

Admin: Sup

Current alarms | Historical alarms | Current Alarm Filter1

Filter on Current alarms
Favourite : Current Alarm Filter1
Received at: From : --
To : --
Column1 : Asset-AA3
Type: Refrigeration , HVAC , Lighting , System , Others
Chain: --
Column2 : --

Show pane

Edit filter | Report | Acknowledge | Clear

Page 1 of 8

State	Ack.	Log Id	Site	Unit Id	Asset	Alarm reason	Type	Active at	Received at	Trip value	Priority	Count	Note	Link
		13452	SM 850	0	Circuit AA3	--- S5 error	R	03/07/2013 06:41:16	03/07/2013 06:43:21	Trip	Normal	1		SM 850
		13450	SM 850	0	Circuit AA3	--- S6 error	R	03/07/2013 06:41:16	03/07/2013 06:43:01	Trip	Normal	1		SM 850
		13448	SM 850	0	Circuit AA3	--- HighTemp air	R	03/07/2013 06:41:18	03/07/2013 06:42:31	Trip	Normal	1		SM 850
		13447	SM 850	0	Circuit AA3	--- High temp S6	R	03/07/2013 06:41:18	03/07/2013 06:42:21	Trip	Normal	1		SM 850
		13434	SM 850	0	Circuit AA3	--- S2 error	R	03/07/2013 06:36:12	03/07/2013 06:37:16	Trip	Normal	1		SM 850
		13432	SM 850	0	Circuit AA3	--- S1 error	R	03/07/2013 06:36:12	03/07/2013 06:36:57	Trip	Normal	1		SM 850

Figure 6 Example of AK-EM800 alarm list[Danfoss2016]

One of the most important energy saving functions of this system manager is the adaptive suction pressure function which enables to automatically optimize the suction pressure so that it will be adapted

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to the systems actual load. During optimization, data is collected that tells the system which refrigeration appliances are most heavily loaded. This function enables substantial energy savings directly whilst also saving on compressor wear as well as providing an analysis tool for refrigeration appliances. The individual controllers handle the temperature control in the refrigeration appliances. The load and operating conditions of each compressor are continuously collected via the data communication system. The collected data is computed and the most heavily loaded refrigeration points are identified. The suction pressure can be adapted accordingly, whilst ensuring that the air temperature at the refrigeration appliance is maintained.

It is the controller that collects data from the refrigeration appliances and after that transmits any offset to the compressor pack control so that suction pressure reference is changed to suit the needs of the "most heavily loaded" refrigeration point. It is always the temperature at the appliance that takes top priority and in fact the suction pressure can float down if necessary.

4.3.2 Carel monitoring system

The monitoring system by Carel offers high efficient control and monitoring for different sizes of supermarkets and many features. System optimisation covers the main areas of energy consumption, such as refrigeration, HVAC, and lighting, with the aim of reducing running costs as well as simplifying the life of the people responsible for making strategic decisions across thousands of stores. The data acquired locally can be made available via a remote supervisory system to monitor individual stores, optimise energy performance, and maximise savings for the end customer. Figure 7 shows an overview of Carel retail monitoring and control systems.

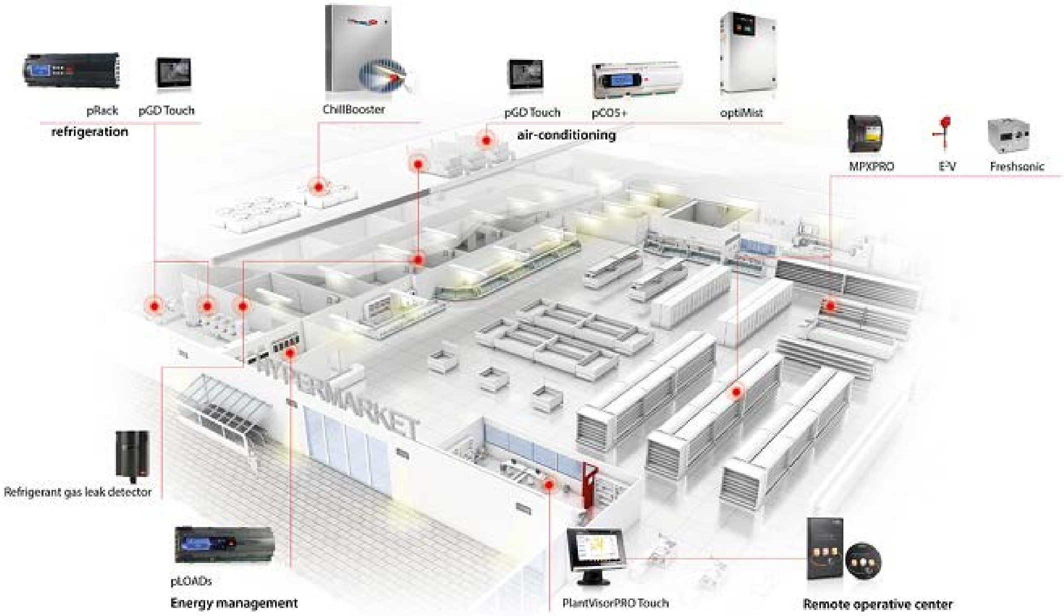

Figure 7 Carel retail monitoring and control system overview[Carel 2016]

In the system by Carel, there are three different levels provided for supermarket end user for monitoring and remote management [Carel 2016]:

- Local monitoring system with data analyse functions, energy saving function(floating suction pressure control), dew point management, control of various parameters, and possibility to integrate with larger enterprise system for centralized data processing.
- Advanced enterprise monitoring system with an interface that can analyse and compare data by the local supervisors on each system for centralized site management. There is also the possibility for energy benchmarking between systems for energy saving and an alarm benchmark to optimise system maintenance.
- Remote monitoring system that offers remote control with adjustments updated in real time. The platform uses GSM wireless channel or Ethernet, and it can be accessed remotely through devices PC or tablet. The system enables analyses of selectable data from thousands of systems and has functions for reading and writing of variables in real time.

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The more advanced system allows complete control and monitoring of the site and the various sub-systems in more complex superstores, efficiently managing alarms and supervision. It ensures intelligent and semiautomatic programming functions, graphical and touch screen user interfaces, and self-adapting energy saving algorithms.

4.3.3 Eliwell integrated monitoring solutions

Remote control and supervision systems can integrate multiple components of the plant and functions including refrigeration control, HACCP recordings, energy consumption monitoring, and lighting and air conditioning control[Eliwell 2016].Control of compressor racks enables floating condensation control and inverter compressor control and contributes to a considerable reduction in energy consumption. Remote chilled cabinet controllers can improve the performance and offer high flexibility through algorithms and overall cabinet components control. HVAC and lighting are also integrated in the system control, with scheduling based on actual use of facilities and programming by days of the week and seasons. Cold room controller controls all static or ventilated cold room functions from a single point. Data acquisition and alarm signalling through wireless connectivity and I/O modules enable data collection.

One of the system advantages is floating condensation pressure based on environmental conditions. It enables to dynamically manage condensation pressure in order to maintain the best temperature differential between the condenser and external air, adapting itself to daily and seasonal changes. Power consumption reduction during low ambient temperature conditions allows considerable energy savings of up to 25% compared to fixed set point systems[Eliwell 2016]. Figure 8 shows floating set point modulation as a function of external air temperature and compared with fixed set point temperature.

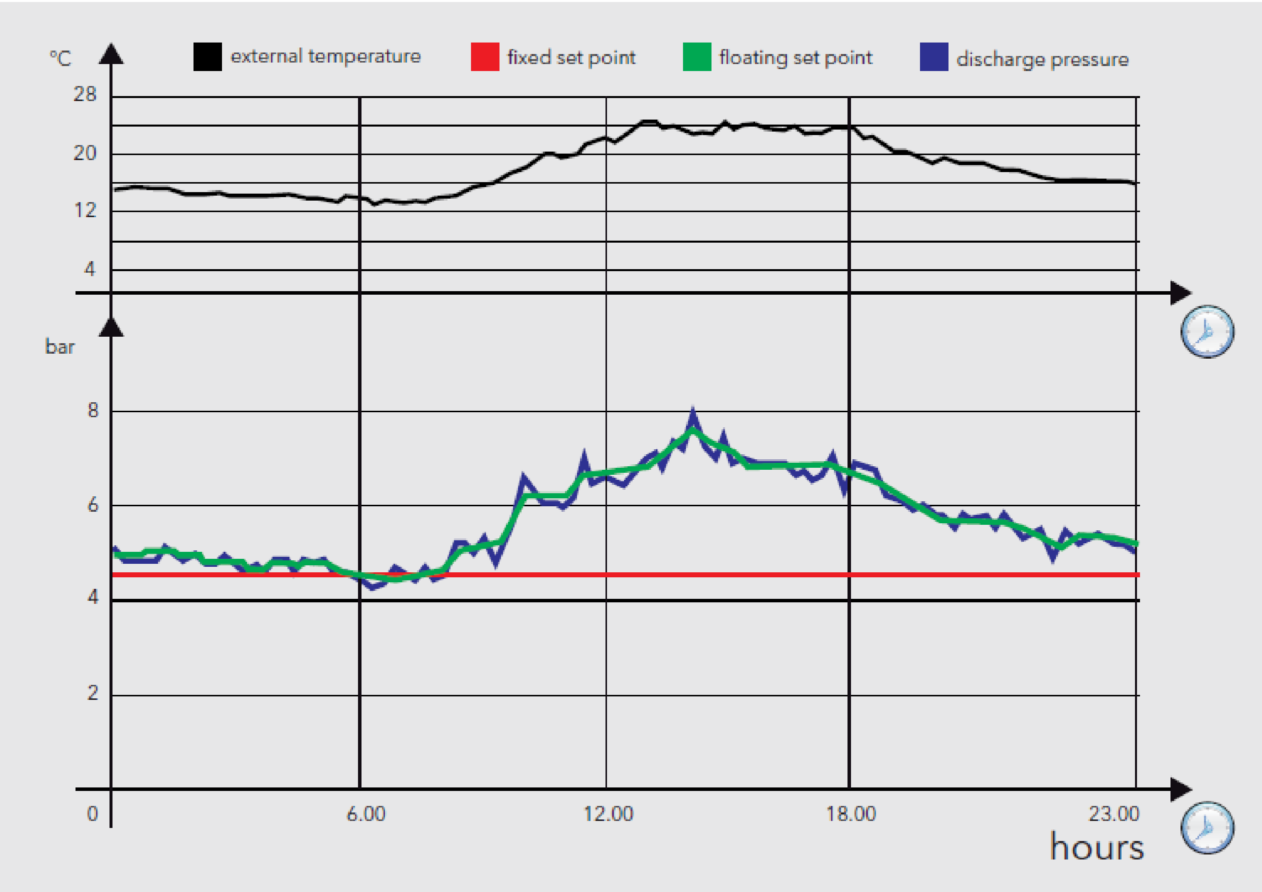

Figure 8 Eliwell 24 hours floating set point modulation[Eliwell 2016]

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4.3.4 Green&Cool control system

The Green&Cool control system unit is equipped with a PLC-based control system combined with a touch screen that can display a user-friendly flow diagram. There is also the option of connecting the equipment to the Internet to allow monitoring and control of the equipment via a web browser. This system has user management where different levels of authorization are given, and, accordingly, it gives access to different pages. The different user levels give access to changing set points, resetting alarms, overview of the specific system/equipment parameters, notifying technical staff, and viewing trend graphs. Figure 9 shows the main menu screen which displays the hub of the system and contains links to all other pages, such as Trends/Events menu, Settings menu, and Alarm list menu. Start-up and shutdown of the refrigeration system is determined by the set operating mode. The three modes available are: AUTO, ON, and OFF, and each mode is selected via buttons in the menu bar.

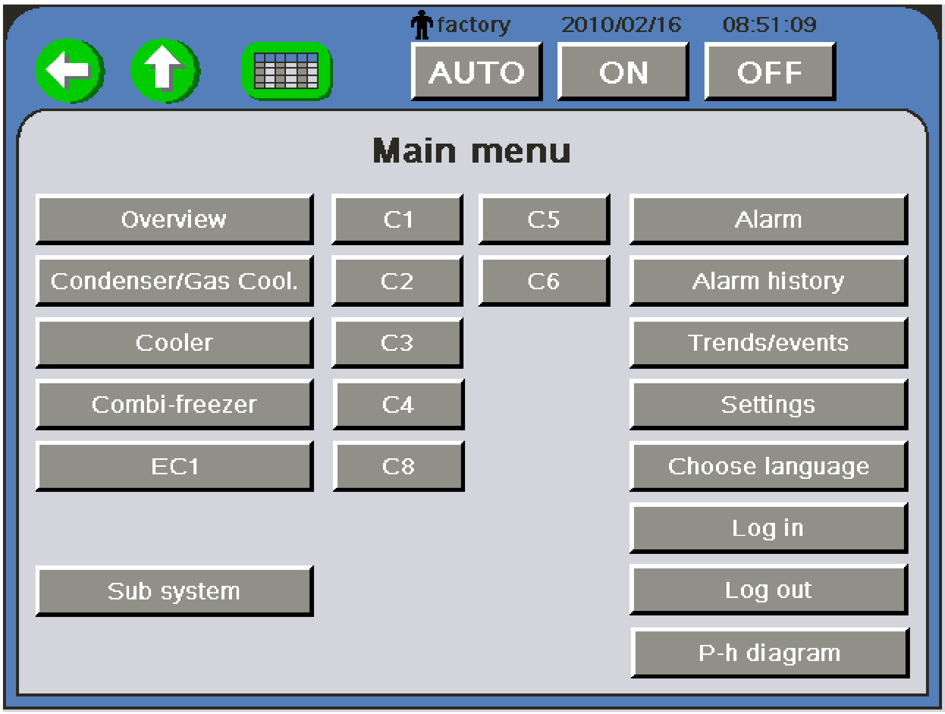

Figure 9 Main menu with links to all system pages[Green&Cool 2015]

There are further four zones, controlling the compressor operation in start-up and stop phases:

- Green Zone – Neutral zone
  If the process value is in the Green zone, no compressor will start or stop.
- Yellow Zone – Start zone
  When the pressure rises, the yellow zone will be reached. When entering this zone, the start delay will start counting down from its set point. When it reaches zero, one compressor will start. After start of a compressor, all timers are set to their set point and the regulation starts all over again.
- Red Zone – Upper start zone
  This zone has the same principle as the yellow zone. This delay should be set lower than the delay in the yellow zone. The yellow zone timer is also counting down if the process is in the red zone. The timer that first reaches zero will start a compressor.
- White zone – Stop zone
  This zone has the same principle as the yellow zone but instead of starting a compressor, it will stop compressors. As the other zones this also has a timer. When the timer reaches zero, a compressor will stop.

Figure 10 shows the overview screen for the system by Green&Cool. The screen is divided into four touch-sensitive zones, and by pressing on these, you will be able to access the detail page. All pages in the system can be reached via navigation through the pages or via the main menu.

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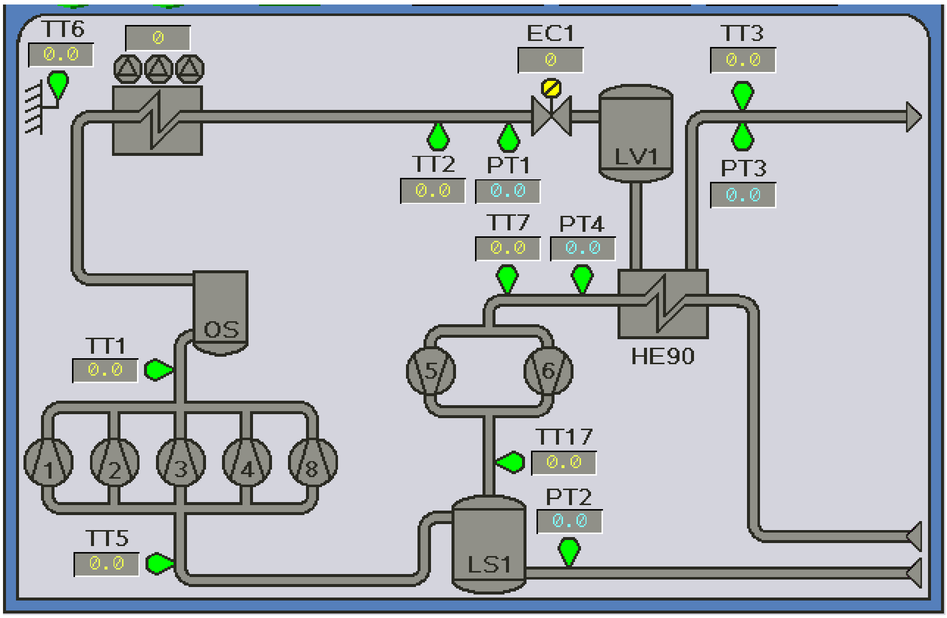

Figure 10 Overview screen in the monitoring system by Green&Cool[Green&Cool 2015]

One of the system options is trends menu which can help the operator checking different operation parameters throughout a 24-hour period or even days. Relevant operation parameters include temperature fluctuations according to different loads or periods of day, pressures, oil temperature/levels, compressor loads, climate conditions, etc.

Different alarm levels can be seen on different points in the system. There is also the possibility to change the importance of the alarms and the level of action is required accordingly. For example, each compressor has its own oil fill valve that controls the oil flow to the compressor. The valve is controlled by the oil pressure (PT11). If the pressure drops under allowed limit (Low alarm limit) for a certain time (Delay Low pressure), the valve is opened to fill oil into the compressor. It is open for a minimum time (Min open time) and closes when the oil pressure is above a certain level (Low alarm limit + Difference). If the valve is open longer than “Max open time”, an alarm is generated to show the operator that there is a problem in the oil system. No action is taken, this is just a warning. The valve cannot open if the oil temperature (TT11) is too low or high or if the oil return temperature (TT4) is too low. The alarm history page consists of the last 100 alarms that can be read. The oldest are overwritten with the new alarms.

4.3.5 Huurre control system

The control system by Huurre facilitates monitoring the temperature of cold rooms and refrigeration equipment. The equipment is connected to the automation of the refrigeration system. It reads the data from the system and stores it on a controlled server, where the data is verified and stored. The temperatures and other process information are available online. Also this monitoring service can provide temperature monitoring, remote control, and energy consumption analysis. After monitoring data and temperatures of the plant, appropriate measures can be taken, speeding up the maintenance or service procedures. With this service, monthly reports can be generated, and the supermarket staff can monitor the refrigeration equipment by themselves.

Figure 11 shows the first screen in Huurre monitoring system, which is the layout of the plant. Green coloured units are refrigerators, while blue units are freezers. The point in the unit is the device controller. By clicking the point, the user is taken directly to the main control panel, where all set points are changed. The device control reports the device status: green colour indicates OK, red colour indicates alarm status; cold snowflake indicates that the device calls for cold; water droplets indicate defrosting. Temperature figures show the device temperature. With a click on the temperature, the device temperature curve is shown.

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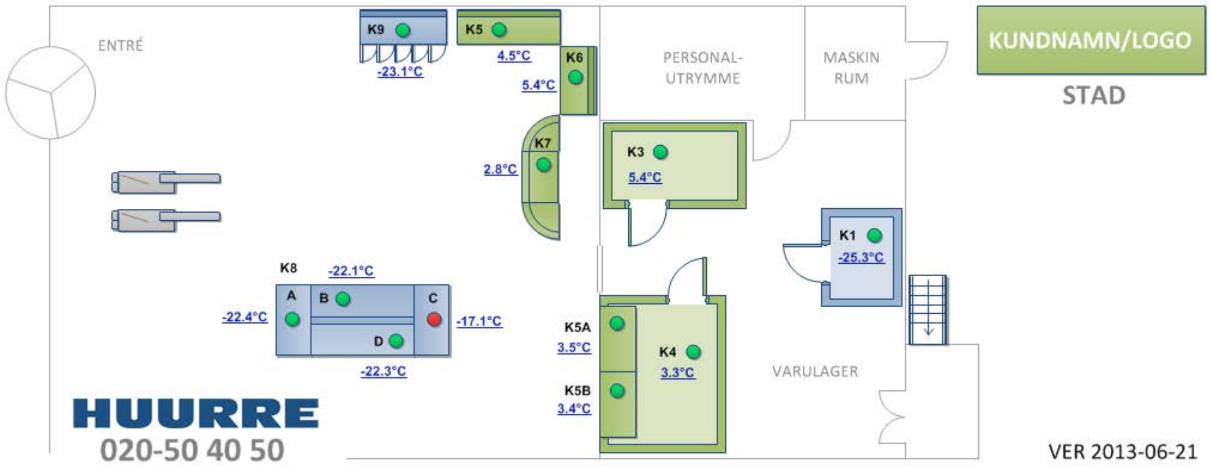

Figure 11 Typical plant layout in the control system by Huurre[Huurre 2013]

Figure 12 shows the machinery room layout, including main refrigeration system components, operating temperatures, valve status, etc.

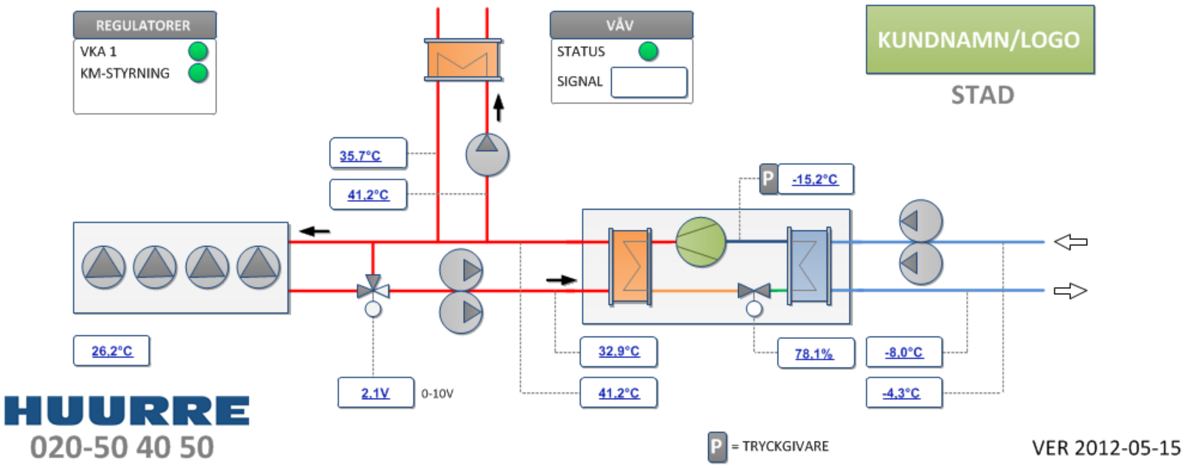

Figure 12 Machinery room layout in the control system by Huurre[Huurre 2013]

All data from the refrigeration system is collected at the server, where also the energy consumption is analyzed, the refrigeration system can be optimized and controlled, and detailed reports can be made. The Remote Monitoring and Control Service identifies problems before they develop, which allows timely response and avoids unnecessary maintenance visits and costs. The remote diagnostics and control optimise the regulation values of the refrigeration process according to environmental factors, and monitor that the temperatures of the refrigeration equipment are controlled. The optimisation is based on the energy analysis and enables significant savings in the power consumption of the refrigeration system.

4.3.6 Iwmac control system

Figure 13 shows the overview image of the supermarket plant in the Iwmac control system. This overview shows all the coolers and refrigeration units in the facility with measurement values and status indicators. Pressing the temperature or symbols plot the values for each device over a certain period of time. The system by Iwmac includes a wide range of graphics and trending reports which are a great tool for faster acknowledgement of the problems in the installation. HACCP reports can be generated for historical temperatures to check if there are big temperature deviations over time. With the alarm menu, every incident can be monitored and get very fast respond. User, service or advanced menu can be selected depending on the access level the operator has.

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Iwmac system also offers the possibility to control and monitor the plant via central monitoring station and directly alarming the supermarket staff of system problems or breakdowns. This option is useful for smaller stores and reduces the required number of staff. Several stores can be monitored at the same time and on several devices, such that supermarket personnel can monitor the store data from everywhere at any time. Significant energy savings can be achieved with monitoring and afterwards optimizing plant temperatures.

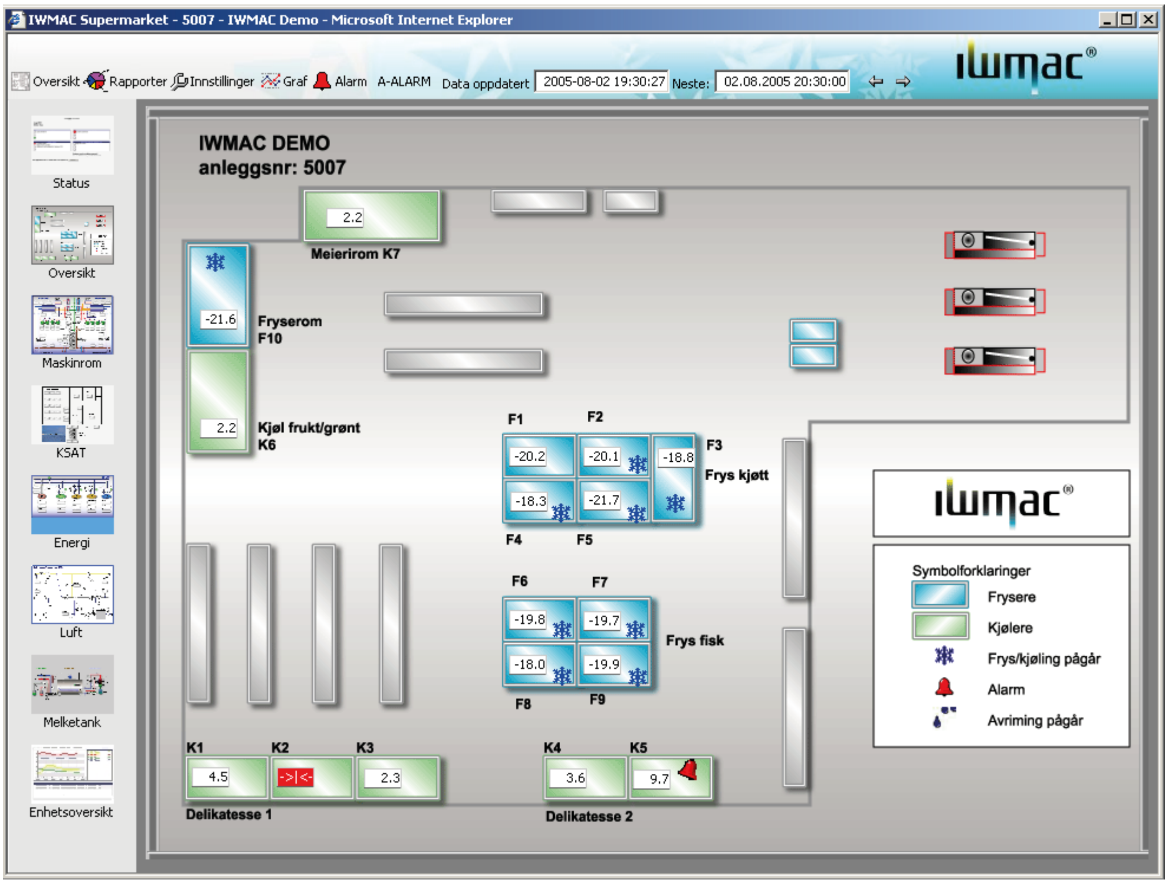

Figure 13 Supermarket layout [Iwmac 2015]

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4.3.7 Summary

Table 4.1 summarizes the monitoring systems discussed in this section, including general system descriptions.

Table 4.1 Overview of monitoring systems

Company	System Overview
Danfoss	• Units and programs for monitoring of temperature and pressure in refrigeration appliances, cold storage rooms, and refrigeration plant, including gateways and communication modules • System manager units for management of complex control systems with alarm monitoring • Data logging of decentralized refrigeration systems
Carel	• Local and remote monitoring systems (floating suction pressure control, dew point management, data analysis) • Energy management systems (energy benchmark between systems)
Eliwell	• Data recording • Alarms management • Graphical visualization of the installation
Green&Cool	• Remote monitoring and control systems • Monitoring and control of the equipment via a web browser
Huurre	• Temperature monitoring • Remote control and energy consumption analysis • Verifying and storage data option online
Iwmac	• Web-based monitoring system with alarm handling and automatic analysis • HACCP reports can be generated for historical temperatures analyses

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5 BEST PRACTICES AND CASE EXAMPLES

Convenience store in Ukraine

Opening year	2015
Location, country	Ukraine
Size [m²]	
Type	Convenience store
Energy efficiency measures implemented	• Implementing adaptive controls with Adap Kool controllers. • Adding frequency converters to the compressors.
Reduction in energy demand and CO_2 emissions (when applicable)	Energy savings of 34% in fall/winter, 25% during summer with adaptive technology. Installing frequency converters increased the energy savings for further 10%. Increased life time of compressors due to less start/stops. Evaporation temperature raised from -12°C to -5°C. Average compressor run capacity dropped from 53% to 29%.
Total investment and payback[1] (when applicable)	Payback time of adaptive technology 2-3 years.
Financing solution (when applicable)	
Link for more information	http://food-retail.danfoss.com/technicalarticles/rc/the-power-of-adaptive-solutions-field-tests-in-ukraine/?ref=17179926127

The research leading to these results has received funding from the
European Union/EASME H2020 Programme under Grant Agreement No 696076.

Intermarche Supermarket in Portugal	
 	
Opening year	2011
Location, country	Minde, Portugal
Size [m^2]	900
Type	Supermarket
Energy efficiency measures implemented	• Eliwell Invensys Controls system integrator. • TelevisNet, EWCM 9900and other controllers. • System integration of supermarket refrigeration and HVAC, ventilation, lighting, and heat recycling for radiant floor heating.
Reduction in energy demand and CO_2 emissions[1] (when applicable)	The supermarket has cut energy consumption by 23%and reduced carbon dioxide emissions by 142 tonnes in the year.
Total investment and payback (when applicable)	
Financing solution (when applicable)	
Link for more information	http://www.eliwell.it/uploadedFiles/Eliwell/End_User_Application/Case_Studies/Case_Studies_Minde_EN_210x297.pdf

The research leading to these results has received funding from the
European Union/EASME H2020 Programme under Grant Agreement No 696076.

6 SERVICE AND MAINTENANCE

Service and maintenance are required to keep the building and its energy consuming systems working on peak performance with respect to designed capacities and energy consumption. Maintenance typically refers to routines, that is, periodic physical activities conducted to prevent the failure or decline of building equipment and assemblies. Service usually means activity that solves breakdowns and failure of equipment. Proper implementation of both service and maintenance is the most cost-effective approach to ensure reliability and energy efficient operation of the systems. This will lead to significantly enhanced performance with small initial investments. The benefits include:

- Whole-building energy savings of 5–20%[US DOE 2012];
- Minimal comfort complaints;
- Equipment that operates adequately until the end of its planned useful life, or beyond;
- Design levels of indoor environmental quality;
- Safe working conditions for building operating staff.

6.1 System components covered by maintenance

Supermarkets are a mix of different systems constantly operating with different loads. Having a template on how, when and which system should be checked and maintained is a useful tool for every operation and maintenance staff.

6.1.1 Refrigeration

6.1.1.1 Refrigeration equipment

Visual inspection and testing with appropriate test equipment should be carried out according to refrigeration principles, procedures, and safety requirements. Maintenance staff should be aware of the environmental impact of refrigeration systems concerning refrigerants and should understand their legal responsibilities under F-gas Regulation and Ozone Depleting Substances Regulation.[Peixoto 2010]

Refrigerant charge should be checked regularly, as over- and undercharged systems have a significantly reduced efficiency. The load on the compressor will increase, causing it to run for longer periods of time; suction and head pressures decrease, and ultimately there is an inability to maintain required temperatures within refrigerated cabinets. Regular inspections should identify possible leaks and should be repaired immediately. Under the F-gas Regulation it is obligatory to have log books for any refrigerant additions and removals, dates for leak tests, and actions that have been taken with time interval according to system refrigerant charge. For systems that have over 300kg of charge, automatic leak detection equipment should be mounted.

Refrigerant leaks are caused by material failure. In Table 6.1, a list of possible causes for refrigerant leaks is given.

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Table 6.1 Possible causes for refrigerant leaks[GTZ Proklima 2008]

Possible cause	Description
Vibration	Vibration can lead to material failure, misalignment of seals, loosening of bolts to flange connections, etc.
Damage due to frictional wear	There are many cases of frictional wear causing material failure, and they vary from poorly-fixed pipework to malfunctioning shaft seals.
Not proper material used	There are certain cases where not suitable material is used, and that will eventually lead to leaks. Different examples exist, such as using flexible connection hoses, which are known to have a potential risk for leaking, or using materials that cannot withstand the high pressure of the system or pressure/temperature difference changes that are occurring in the system.
Poor quality control	Important factor during the production process itself is the quality control of both material components and assembly process having in mind the excessive temperature/pressure difference that the material needs to comply with.
Poor connections	There are different types of joints, brazed, flared or even valves with no caps, and all of these points are potential places where refrigerant can leak out of the system.
Corrosion	Corrosion can be caused by different chemicals in different weather conditions that will eventually decay the used material.
Accidental damage	Accidents should be prevented right from the transport and during installation, operation, and service. Packaging should prevent mechanical damage during transport and the system should be designed, installed, and located in a way to prevent external mechanical damages as much as possible.

On-site technicians should have access to user manual, refrigerant charge of the unit, P&ID controls, and electrical wiring schemes. This will help them to better understand and to perform quality work on the refrigeration plant.

Prior to any service action inside the refrigeration circuit, precautions should be taken to avoid the presence of any type of contaminants or moisture in the system. Moisture can cause several operating problems in refrigeration systems, such as formation of solid ice within the expansion device, causing a blockage. In addition to possible freezing, another serious problem is corrosion that can occur within the system due to the presence of moisture. It is important to remember that moisture can easily get into a system but it is difficult to get out. [Peixoto 2010]

To eliminate moisture problems it is necessary to take precautions, such as changing the filter drier frequently. The most effective way to eliminate moisture from a system is through the use of a high vacuum pump to create a vacuum deep enough to evaporate and remove the moisture. The recommended level of evacuation is of 1 mbar absolute (100 Pa). This level of vacuum must be maintained for 10 minutes without the help of a vacuum pump.

Also gases in the system which do not liquefy in the condenser are contaminants and reduce the cooling capacity and system efficiency. The quantity of non-condensable gas that is harmful depends on the design and size of the refrigeration system and nature of the refrigerant. Their presence contributes to higher discharge pressures, resulting in higher discharge temperatures.

6.1.1.2 Display cabinets

Very important for energy saving is proper door operation and sealing of display cabinets, since these items are exposed to very frequent use. Special care should be focused on function and cleanness of door gaskets, and they should be replaced if damaged. Damaged or dirty door gaskets result in air leakage leading to energy loss and increasing the refrigeration load. Also inspection of cabinet fans is important to ensure meeting the expected fan lifetime and proper operation of the cabinet. Bearings should be inspected and lubricated according to manufacturer recommendations. Also proper cabinet loading (no products on return grid) and proper cabinet location (especially for open cabinets), i.e. no interaction of the air curtain with the HVAC air discharge, is important. Check of proper evaporator superheat and defrost is also crucial.

6.1.1.3 Heat Exchangers

Dirty condenser and evaporator coils reduce air flow and hence cooling capabilities. Layers of dirt on evaporators and condensers prevent heat convection, leading to lower heat transfer efficiency and higher energy consumption. Dirty refrigerated display cases are not only unhygienic and inefficient, but also cause operating faults. They should be both inspected regularly and cleaned if necessary. One way

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for cleaning the coils is a power washer, specially approved for copper/aluminium coils, that supplies chemical cleaning solution into a high-pressure water flow. Another way is using spray-on cleaning solutions that are intended to be used with a brush and a hose. This may not be a good solution especially in heavy clogged coils since the outer surface of the heat exchanger can be seen brightened and shiny but the heat exchange surface itself still can be heavily blocked.

6.1.2 Heating, Ventilation and Air Conditioning (HVAC)

The preventive maintenance gives supermarkets staff an opportunity to evaluate HVAC systems regularly, identifying potential problems, and intervene before major fault occurs. It also gives a step ahead in planning of necessary replacement of parts and organizing the parts inventory.

6.1.2.1 Boiler/burner heating source

If the HVAC system includes a boiler, it should be checked for fuel leaks regularly, especially in the case of a gas boiler. Special attention should be paid to flame sensor and fuel line for any possible clogging or reduced fuel flow. Burners are a sensitive part of the boiler system since much of the efficiency of the whole combustion process depends on it, and should be inspected for build-up of different residues and insure cleanliness and proper flame control. From the size and colour of the flame, trained technicians can recognize if there is too much or too little fuel flow, lack of primary air, presence of dirty particles, etc. During heating season the proper burner operation should be inspected frequently and detailed inspection should be done prior to start of the season in order to achieve peak efficiency during operation.

6.1.2.2 Chiller/heat pump for cooling/heating

The same maintenance procedure that counts for refrigeration unit applies to chiller/heat pump. Weak spots that can be identified regarding leaks should be checked regularly. This applies mostly to parts of the unit that are exposed to extensive vibration, inadequate supports, and poor quality joints. Proper vibration isolation should be done on time to prevent such problems. The condenser/evaporator coils should be kept clean and maintenance cleaning routine established during whole life time of the equipment. If the condenser is water-cooled, non-obstructed and stable water flow is needed. The water filter/strainer mounted on the condenser/evaporator inlet should be checked and cleaned at least once a year.

6.1.2.3 Air handling unit - AHU

AHU unit provides ventilation and supplies fresh air to the supermarket. Airflow capacity should be tested to confirm that it meets the requirements for the conditioned space. Since lower air flow means decreased energy use, proper balance should be found not influencing indoor air quality. Air filters used in the AHU should be cleaned weekly and replaced if they are damaged since they can lead to clogging of AHU coils and supply of polluted air. Filters are helping in maintaining indoor air quality and are also protecting the other components in the AHU sections from accumulation of dirt. The easiest way of determining if the air filter is dirty is to measure the air pressure drop across the filter section. Fan motors operation and belt tensions should be tested in order to supply required air flow rates. Air flow regulation is done by motor actuator operated dampers or by an economizer when outdoor conditions permit. These moving parts are exposed to outdoor conditions the whole year and should be inspected, cleaned, and lubricated regularly such that the components do not get stuck in one position. It is important during maintenance to get proper damper response position regarding the used set point. This will confirm that overloading of cooling/heating coil will not happen and full potential of free cooling is used.

6.1.2.4 Air ducts and grilles

Air leaks should be prevented since it leads to reducing the HVAC efficiency. Air grilles should have non obstructive air intake/outlet for proper air flow operation. It is important to have access panels in the ducting for proper maintenance to take place. The insulation of air ducts should be inspected at least once per year in order to be sure that there is no insulation damage and heat loss is prevented.

6.1.2.5 Indoor units (water terminals, DX units)

To have efficient energy transfer from the cooling/heating source to the indoor air, the HVAC system should have well maintained indoor terminals that operate by their design. Dirt on the indoor coils reduces the heat transfer area and decreases the indoor terminal performance. This can be prevented by having clean air filters. Measurements of the air temperature difference at inlet/outlet of the indoor unit should be performed before and after cleaning the filters, and compared with previous data to verify if the coil needs cleaning. The measurements from air temperature inlet/outlet and water pressure drop

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across the terminal should be included in a maintenance report. Fans of the indoor units should also be inspected for proper air flow operation.

6.1.3 Lighting

The lighting systems loose efficiency over time. The effect is inevitable since light sources naturally degrade over the years. Especially if lighting is extensively used, as in supermarket applications, the level of degradation is expected to be faster. The lighting efficiency can also be reduced due to dirt accumulation on the lenses, bulbs or reflectors. This can be avoided by regular maintenance. Having scheduled cleaning can keep the lighting output at maximum performance and extend its life. When replacing fixtures, more efficient equivalents such asT5 lamps and high-frequency electronic control gear should be considered. The use of LED lighting should be considered whenever possible. Good efficiency in the lighting system is also dependent on the control system. Inspection should be performed on lighting controls to ensure that lights are off when spaces are unoccupied and when enough daylight is available.

6.1.4 Building envelope

In the maintenance programme, the building itself should be checked at least once a year for maintaining the thermal performance. The inspection should notify possible weak spots, confirmed with thermal camera to check if insulation is damaged. Improve the insulation by adding new insulation with better thermal performance in roof spaces, suspended floors, and cavity walls when possible.

Also for doors and windows, loss in energy performance is expected due to wear of seals over time. Signs such as doors not closing properly, spots with water marks, and air draft noticed by staff are indications of inefficient building envelope. Doors left open cause loss of heat or cool. If there is a door closer, it should be checked if it is working properly. Attention should be placed on rationalising occupied space and isolating empty zones for heating, ventilation, and air conditioning.

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7 GOLDEN RULES AND CHECKLISTS

The following checklist for system components is very useful for supermarket operators to identify and pursue certain actions to reduce the supermarket's energy use.

Table 7.1 Checklist for system component maintenance[Supermarket BP 2012]

Description	Daily	Weekly	Monthly	Yearly
Refrigeration - Maintenance				
Cabinets and cold rooms operation (superheat control, cold air distribution, defrost, etc.)			x	
Check for abnormal noise, vibration or low performance of compressors/motors.	x			
Inspect refrigeration coils and establish regularly cleaning routine.		x		
Check and replace worn and/or leaky door seals.	x			
Control proper operation and time efficiency of defrost system management and moisture sensors to ensure optimal performance.		x		
Clean fans and inspect for wear and tear of fan belts.				x
Clean and disinfect condensate drain pans.			x	
If local controls are present, check if non-authorized temperature adjustment is locked.		x		
If refrigerant detectors are placed, inspect regular operation according to manufacturer instruction.		x		
Control the work performance of maintenance contractor if existing.			x	
Heating, Ventilation and Air Conditioning (HVAC) - Maintenance				
Clean/replace the air filters on fan coils (water terminals), DX indoor units, and AHU's.		x		
Secure non obstructive air flow to and from FCU or DX units.			x	
Check work condition on air curtains in entry areas.			x	
Inspect insulation on all piping and ductwork of the HVAC system.				x
Inspect ductwork connections and seal if there is air leakage.				x
Check for abnormal noise, vibration or low performance of compressors/motors.		x		
Inspect condenser coils and establish regularly cleaning routine.			x	
Clean and disinfect condensate drain pans.				x
Check if the control adjustment is locked on HVAC temperatures for non-authorized usage.			x	
Control proper combustion process if boiler/burner is used for heating.		x		
If fossil fuels are used in burner, test operation of carbon monoxide (CO) detectors.			x	
If water heaters are used, proper operation of electrical heater and set point control should be checked.			x	

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Description	Daily	Weekly	Monthly	Yearly
Control the work performance of maintenance contract contractor if existing.			x	
Lighting - Maintenance				
Clean lamps to achieve maximum illumination.			x	
Check for broken lamps and replace with energy efficient lighting.		x		
Test task lamping and motion sensor if present for proper timing operation.			x	
Building Envelope - Maintenance				
Make visual inspection on the building insulation.				x
Check window seals and possible window cracks.				x
Clean windows and roof-lights to maximise daylight where possible.		x		
Inspect for possible draft areas in the building.			x	

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8 CONCLUSIONS

The aims and objectives of this deliverable are to provide the stakeholders in the organisations of the supermarket sector a best practice guide on service and maintenance, identifying training needs, and the standard they should aim for to achieve for reliable operation, with regard to safety and efficiency of the equipment.

Appropriate and rational solutions should be selected during early stage of supermarket design, in such a way that selected refrigeration and HVAC systems will satisfy all requirements of its exploitation at any time during the day and year. Equipment and components selection is described in this material and the importance of it. Installations are also described in another chapter as important element in future energy saving and proper plant operation. The entire installation process is critical in ensuring the long-term safety of the equipment and also proper equipment operation according to the technical specifications.

Operation of the supermarket is another topic which is covered. Operation of one supermarket can cover topics such as operational schedules of HVAC&R systems, setting different working scenarios, setting different temperature setpoints, scheduling equipment start-up and shutdown, defining emergency procedures, etc. Several key points are introduced, for example operator responsibilities, training, operation practices, and energy benchmarking.

Monitoring/control system that unites and coordinates functions of all components of the HVAC&R systems is essential for energy savings. Detailed monitoring system description, information for systems that are used in the supermarket sector in Europe, operation of monitoring system, installation and commissioning, generated data, and energy management systems are presented in the report. Examples of monitoring systems provided by different companies, including their possibilities and practical use, are also provided.

Case examples are shown in chapter 5 Best practices and case examples with implementation of modern advanced monitoring systems in existing supermarkets are described. Great energy savings as well as increased lifetime of major system equipment have been achieved.

In this training material special focus is made on service and maintenance which are required to keep the building and its energy consuming systems to work on peak performance related to designed capacities and energy consumption. Focus is on the refrigeration system as it is the largest energy consumer in average supermarkets. Further described are maintenance of HVAC systems (boilers, chillers, AHU, air terminals, etc.), lighting, and building envelope as a whole. A checklist with description of every system component, which action should be taken, and at which time interval is also given.

Best practice operation of refrigeration systems and other energy consumers in supermarkets ensures that equipment is operating as efficiently as possible, that any maintenance issues are addressed in a timely fashion, and that there is a minimum level of conflict with other energy consuming systems in the building. This report addresses the importance of regular and proper maintenance procedures and provides guidelines on how to perform them. The report hence serves as a checklist and manual to support supermarket staff in their daily work.

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