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# INTRODUCTION

The overall aim of the ICE-E project was to reduce energy consumption and greenhouse gas emissions from the European food cold storage sector through application of energy efficient equipment choices in line with European policy.

In Europe there are 60-70 million cubic meters of cold storage for food. In 2002 the IIR estimated that cold stores use between 30 and 50 $kWhm^{-3}$ $year^{-1}$. Surveys carried out by partners in ICE-E have shown that energy consumption can dramatically exceed this figure, often by at least double. These surveys have also demonstrated that energy savings of 30-70% are achievable by optimising usage of the stores, repairing current equipment and by retrofitting of energy efficient equipment. However, cold store operators are often reluctant to install new equipment without sufficient information on savings that can be achieved. The main aim of ICE-E was therefore to overcome these reservations to the uptake of new technologies within the cold storage sector. Through a combination of knowledge based information packages, mathematical models and education programmes the team worked with cold store operators to help them make informed decisions on equipment and to select and identify cost efficient paybacks to their businesses. In addition the team developed a benchmark/labelling system for cold store operators so that they could compare performance against others users within the sector.

In additional to technical barriers to the uptake of new technology there are also non technical barriers preventing uptake of new technologies. Proven technologies are often not taken up due to wider social, political, economic and organisational contextual issues. To overcome these issues the team worked to create change and awareness of the issues and a sense of agency to initiate relevant change.

# BACKGROUND

The cold chain is believed to be responsible for approximately 2.5% of global greenhouse gas (GHG) emissions through direct and indirect (energy consumption) effects. Studies have shown that leakage of refrigerants may be higher than 17% in industrial plant (Clodic and Palandre 2004). Refrigeration energy consumed in the food chain has not been accurately quantified due to a lack of measured energy consumption and process throughput data in most sectors (Swain, 2006). Overall figures would indicate that excluding domestic refrigeration, approximately 50% of the energy is associated with retail and commercial refrigeration and 50% with chilling, freezing and storage (Market Transformation Programme).

Cold storage rooms consume considerable amounts of energy. Within cold storage facilities 60-70% of the electrical energy used is for refrigeration. Therefore cold store users have considerable incentive to reduce energy consumption. In Europe there are 60-70 million cubic meters of cold storage for food. In 2002 the IIR estimated that cold stores used between 30 and 50 kWh/m3/year (Duiven and Binard, 2002). Previous surveys carried out on a small number of cold stores have shown that energy consumption can dramatically exceed this figure, often by at least double (Evans and Gigiel, 2007, 2010). These surveys also demonstrated that energy savings of 30-40% were achievable by optimising usage of the stores, repairing current equipment and by retrofitting of energy efficient equipment. However, cold store operators are often reluctant to install new equipment without sufficient information on savings that could be achieved.

There are few published surveys comparing the performance of more than a few cold stores. The most comprehensive recent survey was carried out in New Zealand by Werner et al (2006) which compared performance of 34 cold stores. This demonstrated that there was a large variation in energy consumed by cold stores and that savings of between 15 and 26% could be achieved by applying best practice technologies.

The performance of European cold stores has never been compared in detail and there is little information to compare their performance with other stores Worldwide. With government targets to reduce energy and reduce emissions of greenhouse gasses the need to benchmark and understand potential energy and GHG reductions is of great interested to end users. To enable end users to improve the performance of their cold stores the ICE-E project was developed with 8 partners from across Europe. The initial aim of the project was to collect data to benchmark the performance of cold stores in Europe.

# THE ICE-E PROJECT

The ICE-E project was structures around interconnected technical work packages:

**Benchmarking**

Information to benchmark current cold storage facilities was obtained by developing a benchmarking survey. The benchmarks developed was tested/validated against best practice and generated targets to enable the industry to meet its future environmental obligations. Participants in the benchmarking survey could volunteer for a detailed energy audit. Twenty-five cold stores were selected for detailed energy and refrigerant use audits to identify where precise savings could be made. These audits were carried out in the UK, Italy, Denmark and Bulgaria. From these audits the project team identified areas where the most energy could be saved and areas of common problems. Audited cold stores were encouraged to take up new technologies and equipment and were re-audited at the end of the project to determine take up and energy savings.

**Non technical barriers**

It was know from previous work that non technical barriers to uptake of technology can have as great an impact on improving performance of cold stores as the technical issues. The project therefore also worked to understand how low carbon potential could be unlocked through the wider social, political, economic and organisational context. End users involved in the audits were also invited to be involved in the technical barriers work. The impact of their involvement was assesses.


*Benchmarking, auditing, non technical barriers*

**Information generation**

Using the information from the cold store audits case studies and information packs were developed to assist cold store operators make informed choices when improving equipment or selecting new equipment. Advice was provided on the financial aspects of using new technologies.


*Case studies, information packs, e-learning modules, financial advice, dissemination and publicity*

Web based tools were developed that could be used by cold store operators and technicians to identify energy savings. Two simulation tools will be developed; the first a simple model for use by end users and the second a more detailed model to be used by technicians and more experienced refrigeration users. Both models identified the energy saving potential of new equipment and technologies. The models were translated into all partner languages and were downloadable from the project web site. They will remain available as freeware after the project completion.

Training materials were also developed for cold store technicians. Five e-learning modules were created.. These educational tools were tested and a sustainable means to maintain these outputs developed.

**Dissemination and publicity**

Work from all initiatives was disseminated though a variety of means (web site, newsletter, database, leaflets, posters, scientific publications, articles, presentations at conferences and trade events and at local workshops and seminars). Specific training and dissemination events were set up to disseminate information to end users and technicians.

# ICE-E SURVEY

## Development of survey tool

The survey was developed using a NET web application. Development was carried out in Microsoft Visual Studio using c# (c sharp) which used .NET Framework 4.0. The data was saved in a Microsoft SQL database.

The survey was initially tested on a selected number of cold store operators to ensure the questions were appropriate and relevant. Improvements were then made based on their comments. A picture of the final survey entry page is shown in Figure 1.

The survey allowed participants to initially register their details and then to enter data on as many refrigeration systems as they wished. It was set up to collect information per single refrigeration system that might supply one of several cold stores. The survey was designed to be simple to complete with the aim that is should take a cold store operator less than 20 minutes to complete the survey. The final survey document consisted of 5 pages collecting basic information, information on the refrigeration system, the food stored, the facility and the refrigeration equipment at the facility.

During the initial registration process, cold store operators could ensure that data was anonymous and could also register to participate in a detailed energy audit of their facilities. The detailed audits were selected to cover different locations, sizes, types and uses The data from these audits were used in later studies, verification of the mathematical models and in the ‘case studies’ to show where improvements could be achieved.


Figure 1. Survey entry page.

## Data collected

The survey parameters collected are shown in Table 1. In all cases the users were asked to rate the accuracy of the data they submitted. The collected data was retained on a server where users could return to update information or add further data.

## Benchmark analysis

Once users had input data they could then compare the performance of their store through an automatic benchmark analysis. This enabled them to compare the energy used by their cold store system with systems of a similar size and product throughput (Figure 2). In addition users could compare the set point temperatures, food type and room function and refrigerant type with others in the survey. In all comparisons the user had the ability to define the range over which comparisons were carried out.

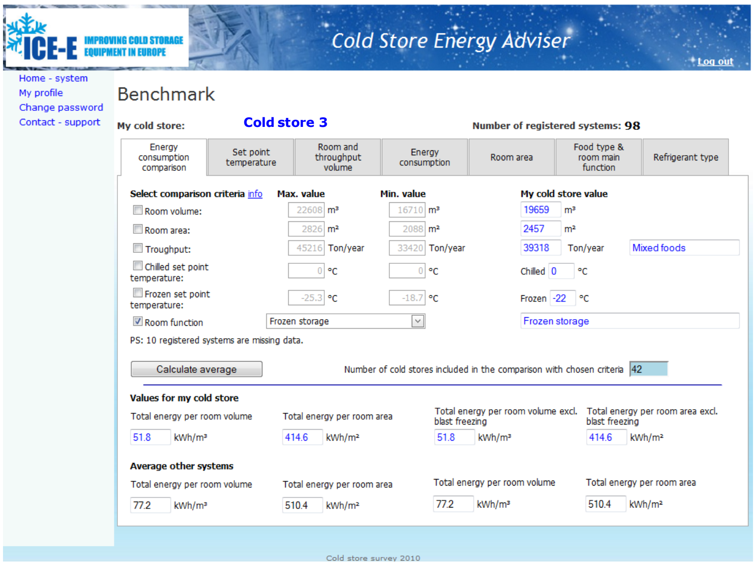


Figure 2. Information from benchmark for energy consumption.

Table 1. Information collected in survey.

| Survey page heading | Units |
|---|---|
| **Basic information:** | |
| Total electricity usage for the system in 2009? | kWh |
| Does the electricity energy figure of the system submitted | |
| include? | Yes/No/Don't know |
| 1. Compressor | Yes/No/Don't know |
| 2. Lights | Yes/No/Don't know |
| 3. Fans | Yes/No/Don't know |
| 4. Pumps | Yes/No/Don't know |
| 5. Fork/lift charging | Yes/No/Don't know |
| 6. Blast freezing | Yes/No/Don't know |
| 7. Floor heating | kWh |
| If figure supplied includes blast freezing what is energy use | |
| EXCLUDING blast freezing? | $m^3$ |
| What is the total volume of the room(s) supplied by the system? | Ton |
| What was the throughput in 2009? | Chilled/frozen/mixed storage/blast freezing/loading |
| What is the main function of the room(s)? | Mixed foods/Meat/Fish/Fruit/Vegetables/Dairy/Cereal products |
| What is stored in the room(s)? | °C |
| What is the chilled set point temperature of room(s)? | °C |
| What is the frozen set point temperature of room(s)? | Yes/No/Don't know |
| Do you plans to invest in energy saving equipment? | |
| **Refrigeration system:** | |
| Primary refrigerant | Don't know/R22/$CO_2$/Ammonia/Other |
| Refrigerant quantity/charge | kg |
| Amount of refrigerant added to primary system in 2009 | kg |
| Secondary refrigerant | Don't know/R22/$CO_2$/Ammonia/Other |
| Refrigerant quantity/charge | kg |
| Amount of refrigerant added to primary system in 2009 | kg |
| **Food stored:** | |
| Average intake temperature for chilled products | °C |
| Average intake temperature for frozen products | °C (for mixed system fill both) |
| Does the room have controlled atmosphere? | Yes/No/Don't know |
| Does the room have humidity control? | Yes/No/Don't know |
| How is the food stored in the area? | Don't know/Pallets/Bins/Dolavs or containers/Placed on shelves |
| How much food can be stored in the storage area | Kg |
| How many pallets/containers can be stored in the storage area | Number |
| What is the number of pallets/containers INTAKE in 2009 | Number |
| What is the number of pallets/containers RELEASE in 2009 | Number |
| What is the average size and weight of one pallet/container | Width/Height/Depth all in m /kg |
| **Facility:** | |
| How many separate rooms does the system supply? | Number |
| What is the total floor area supplied by the system? | $m^2$ |
| How much of the floor area is used for: | |
| • Chilled storage | $m^2$ |
| • Frozen storage | $m^2$ |
| • Blast freezing storage | $m^2$ |
| How many doors (total) are there on the room(s)? | Number |
| How many times on average will each door be opened per day? | Number |
| Do the doors have any protection? | Don't know/No protection/Strip curtain/Air curtain or Air |
| | lock/Automatic doors |
| Is product automatically or manually loading into the room? | Don't know/Manual (hand or fork lift)/Automatic (robot crane) |
| Where are the room (s) positioned? | Don't know/Inside a building/Outside |
| What is the age of insulation? | Don't know/<5 years/ 5 to 10 years/ 10 to 20 years/>20 years |
| What is the thickness of the: | |
| • Wall insulation | mm |
| • Ceiling insulation | mm |
| • Thickness of the floor | mm |
| **Refrigeration equipment:** | |
| Type of refrigeration cycle? | Don't know/Single stage/Multi stage/Cascade/Absorption cycle/Air |
| | cycle |
| Type of refrigeration system? | Don't know/Dry evaporator with thermostatic valve/Flooded- |
| | pumped/Flooded-natural circulation |
| Type of compressors? | Don't know/Reciprocating/Screw or Scroll/Rolling piston/Centrifugal |
| | Yes/No/Don't know |
| Do you have economized compressors? | Don't know/VSD/Unloading/Other |
| What is the compressor control system? | Don't know/Suction pressure/Room air temperature/Other |
| How are compressors controlled? | Don't know/Air cooled/Evaporative/Water cooled/Cooling |
| Type of condensers? | tower/Other |
| | Don't know/Hot gas/Electric/Passive/Other |
| Defrost type? | Yes/No/Don't know |
| Do you use any heat from the refrigeration plant? | Water heating/Floor heating/Other heating |
| • If yes, what for | Year |
| What is the year of installation of the system? | |

## Express survey tool

In response to some end users requesting a simpler and more rapid means to benchmark their stores an ‘Express Survey’ was developed. This required only 5 minutes to complete.

## Development of survey tool

The tool was part of the ICE-E web site and written in HyperText Markup Language (HTML) using a web form to collect the data. As in the detailed survey all data collected was anonymous.

## Data collected

The data collection form is shown in Figure 3. A limited data set was collected (set temperature, area and volume of the store, food throughput and energy usage per year) which reflected what were considered to be the most important factors affecting energy use in cold stores.

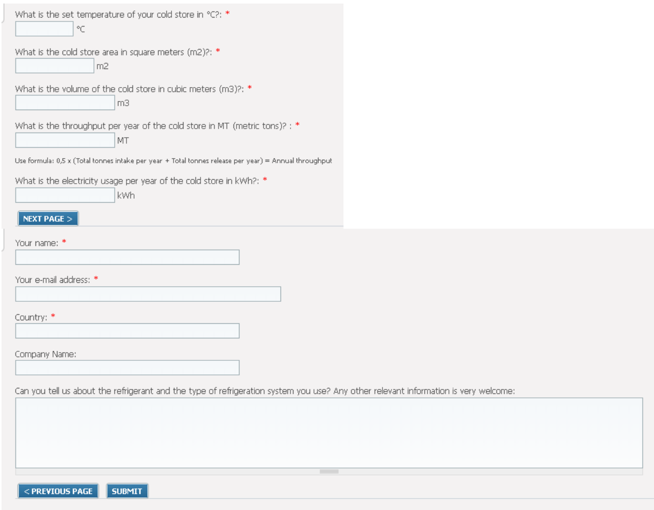


Figure 3. Data collected as part of the Express survey.

## Benchmark analysis

Once data was submitted the information was input manually into the main benchmark survey and information sent directly to the cold store operator.

# BENCHMARKING

## Data collected

Data from 329 cold stores was collected. One data point was the mean of 331 cold stores in the UK (i.e. the total data collection encompassed 659 stores). This point was excluded from the analysis as data was not available on the data variance. Therefore the data point could not be included at an equal weighting to the other data sets and so was used for purely comparative purposes in the analysis. After removal of data that was considered unreliable (i.e. data that was obviously wrong, inputs not completed etc) this left 295 data sets.

Not all data sets had complete data as many users had not replied to every question asked. However, the core data set had the 5 main attributes collected (temperature of the store, area and volume of the store, food throughput and energy usage per year).

The data collected covered 21 different countries (Belgium, Bulgaria, China, Czech Republic, Denmark, France, Germany, Greece, Ireland, Italy, Mexico, Netherlands, New Zealand, Portugal, Romania, Serbia, Spain, Sweden, Switzerland, United Kingdom, USA). Seventy percent of the 294 data sets originated from EU countries. The division of data between each country is shown in Figure 4.

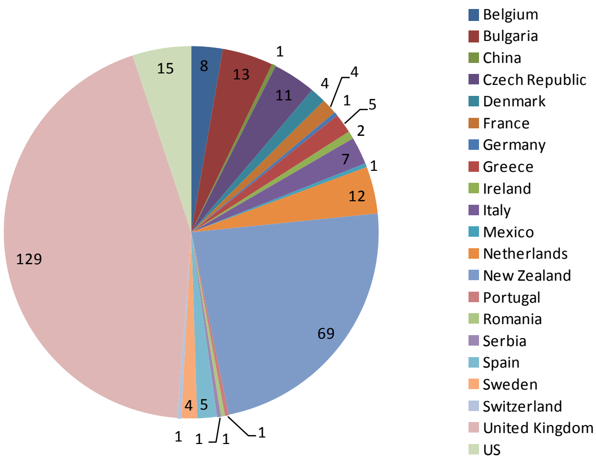


Figure 4. Data sets collected per country.

## Cold store type

Cold store function was divided into chilled, frozen or mixed stores (those with both chilled and frozen rooms operating from a common refrigeration system). Analysis of variance (ANOVA) showed a highly significant difference ($P<0.05$) between the specific energy consumption (SEC) of all store types (Figure 5). Differences between chilled and frozen and chilled and mixed were greater ($P<0.01$) than between frozen and mixed stores ($P<0.05$).

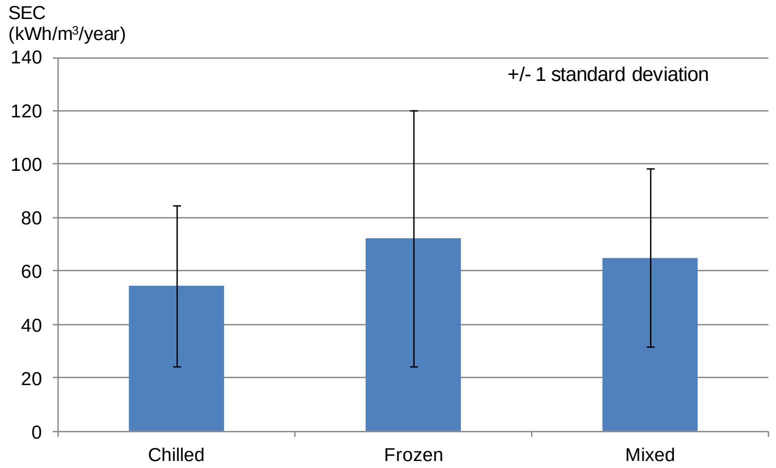


Figure 5. Data sets collected per country.

## Country

Large variations in SEC were shown between countries. Significant differences were found between chilled and frozen stores but not mixed stores in the countries within the survey. Figure 6 shows average SEC for chilled, frozen and mixed stores in each country where data was collected and the standard deviations around the means.  This showed large variability in the SEC between countries and within countries. Due to the limited number of data sets for some countries it would not have been possible to analyse data from each country separately. All further analysis was carried out on data divided into chilled, frozen and mixed stores.

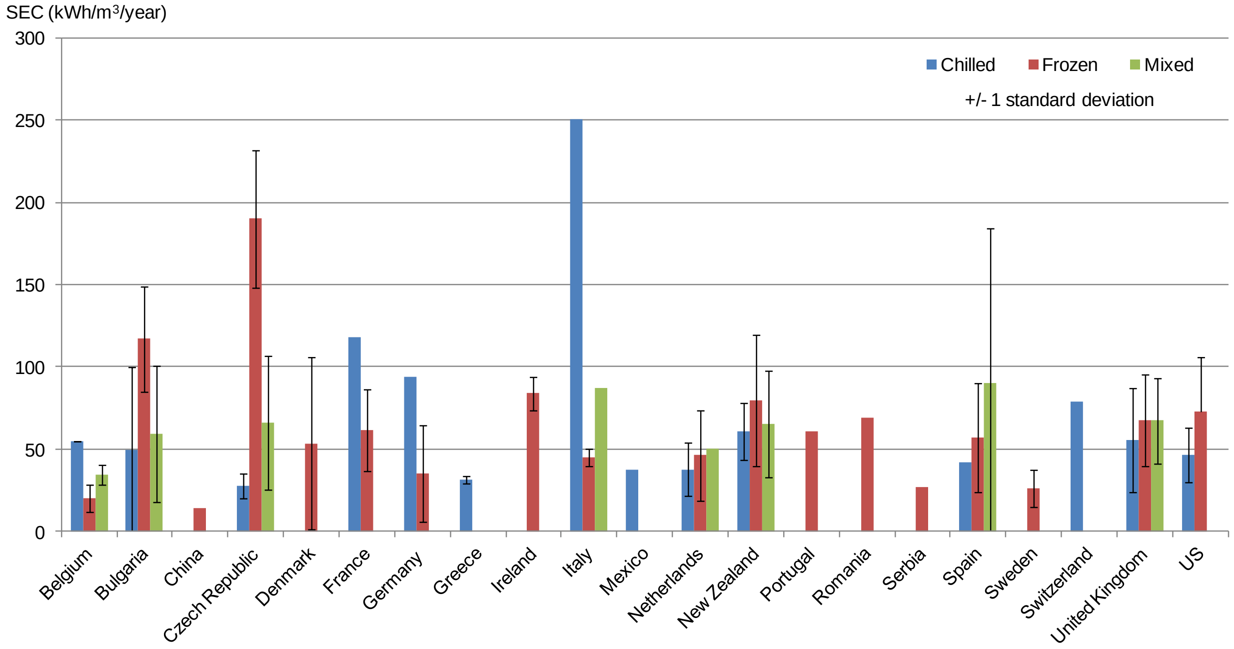


Figure 6. Average SEC per country and standard deviation around means where replicate data was available (where no s.d. is plotted, this is because there is only one data point).

## Relationship between energy use and store size

The relationship between store energy consumption (in kWh/year) and the information collected was investigated using multiple regression. As part of this analysis the data was found to be near to a normal distribution.

## Chilled stores

Regression demonstrated that 93% of the variation in annual energy consumption was related to store volume (Figure 7). Multiple regression demonstrated that food type and food throughput had some impact on annual energy but that these factors only increased the $R^2$ value to 95% and therefore their impact was very low. All other factors collected had no influence on annual energy consumption.

Applying non linear relationships to the data did not improve the regression R2 value. This indicates that SEC is independent of store volume.

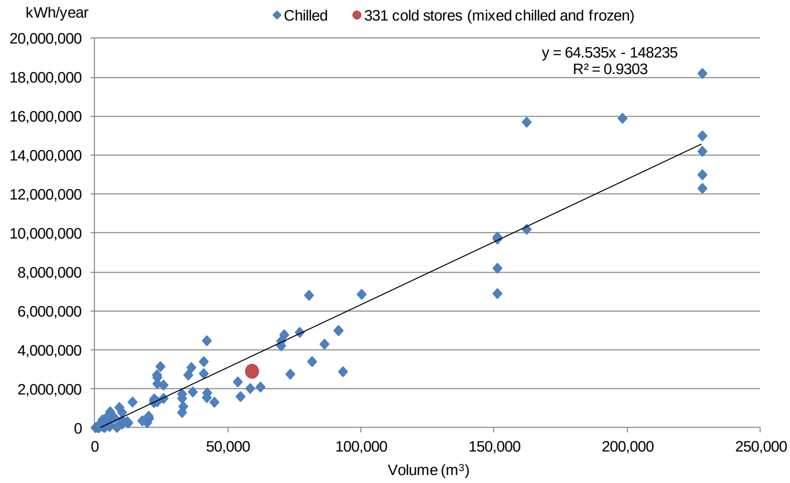


Figure 7. Relationship between store volume and total energy use per year (kWh/year) for chilled stores.

## Frozen stores

Store volume accounted for 56% of the variability in annual energy consumption of frozen stores when a linear regression was applied. Applying a non linear power function to the data improved the regression $R^2$ value to 66% (Figure 8). This would indicate that for frozen stores that SEC reduced as the store size increased.

None of the factors recorded that had anything above a very minimal impact on annual energy consumption. Therefore approximately 34% of the variability in annual energy consumption was related to a factor that was not collected in the survey.

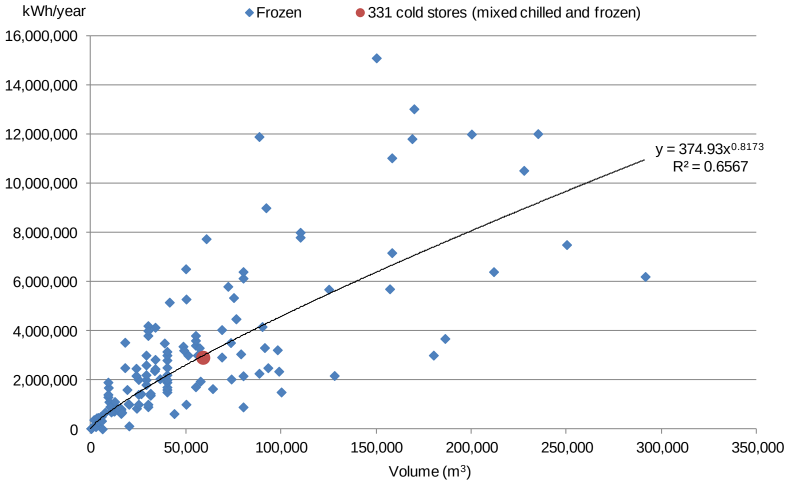


Figure 8. Relationship between store volume and total energy use per year (kWh/year) for frozen stores (non linear regression).

## Mixed stores

A number of factors had an impact on mixed store annual energy consumption. As a linear regression store volume accounted for 67% of the variability, however if a power function was applied this increased to 76%. (Figure 9). In addition throughput, thickness of the store insulation (wall, ceiling and floor) and insulation age also appeared to have a minor impact on annual energy consumption. However, for these data sets the number of replicates was low and so their impact needs further investigation.

Mixed stores appeared to have a similar volume relationship with annual energy consumption as frozen stores and therefore the store SEC reduced for larger stores.

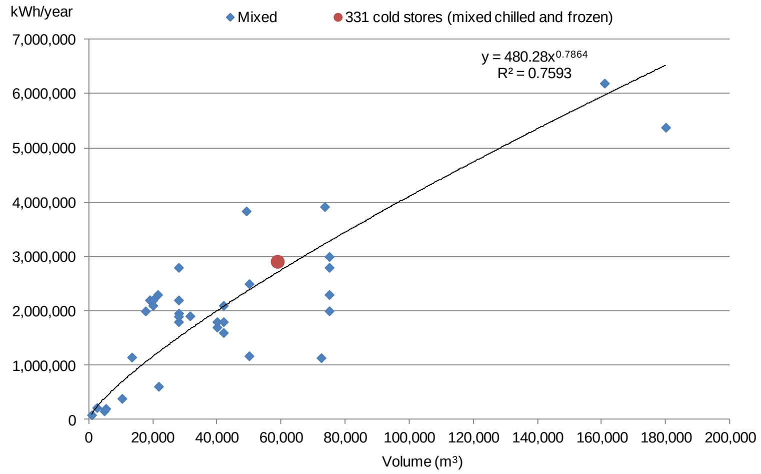


Figure 9. Relationship between store volume and total energy use per year (kWh/year) for mixed stores (non linear regression).

## All stores

A comparison of the best fit regressions for chilled, frozen and mixed stores is shown in Figure 10. It is interesting to note that mixed and frozen stores had a relatively similar relationship between volume and annual energy (although statistically the regressions lines were significantly different at P<0.01). At volumes below 22,000 $m^3$ chilled store used less energy than frozen or mixed stores but at volumes above 22,000 $m^3$ chilled stores used more energy than frozen or mixed stores. This was mainly due to a cluster of smaller chilled stores that had low energy consumption.

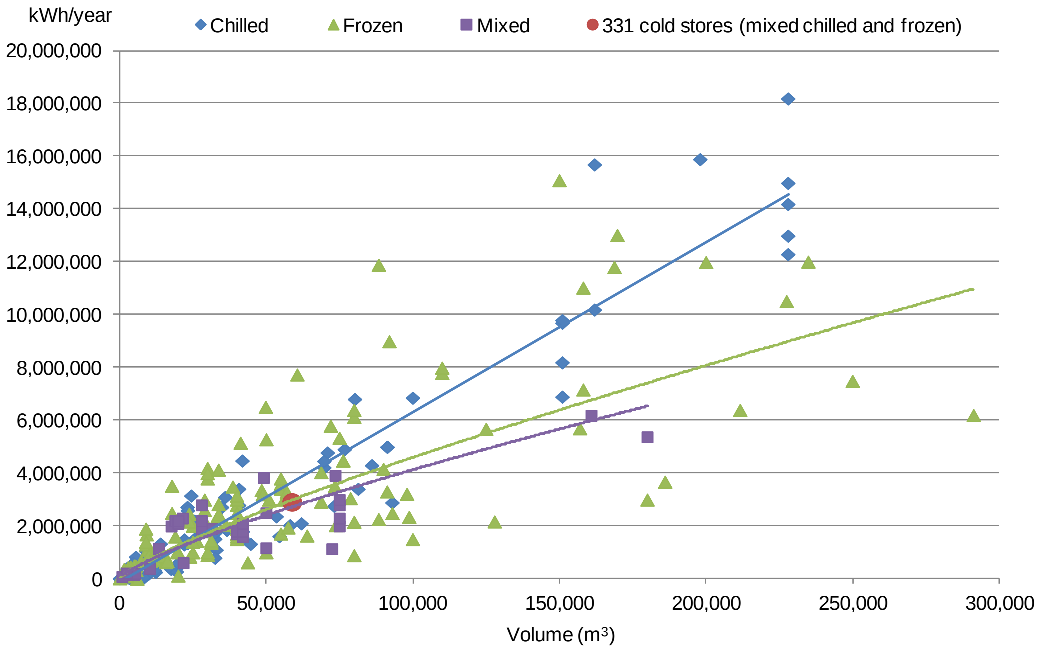


Figure 10. Comparison between store volume and energy use per year (kWh/year) for all stores.

The SEC for the cold stores examined varied considerable. The distribution of the SEC values for chilled, frozen and mixed cold stores are shown in Figure 11.

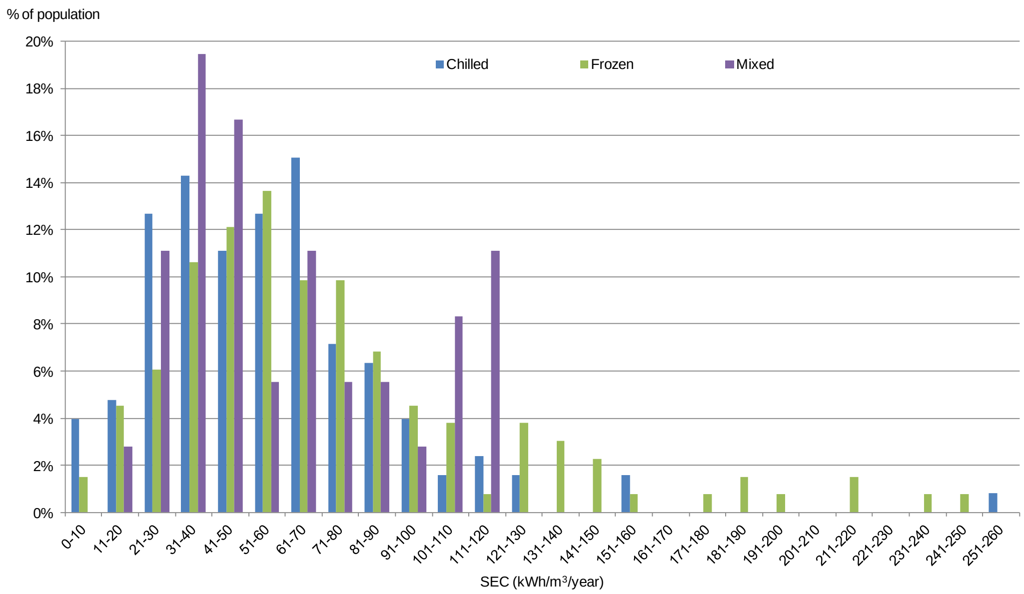


Figure 11. Distribution of SEC values.

## Conclusions

The data collected in showed that there was large variability in the energy used by cold stores. The SEC varied between 4 and 250 kWh/m$^3$/year for chillers, between 6 and 240 kWh/m$^3$/year for freezers and between 23 and 157 kWh/m$^3$/year for mixed stores. Duiven and Binard (2002) estimated that cold stores should use between 30 and 50 kWh/m$^3$/year. The data collected in this survey demonstrated that 47% of chilled stores, 35% of frozen stores and 50% f mixed stores had an SEC of less than 50 kWh/m$^3$/year. This demonstrates that there is considerable potential to reduce energy consumption in cold stores.

Large differences were found between cold stores in different countries but the reasons for this were not able to be extracted due to lack of replicate data.

Differences were found between chilled, frozen and mixed usage cold stores. The major influence on annual energy consumption in all store types was the volume of the store. For chilled stores volume accounted for 93% of the variation in annual energy consumption. In frozen and mixed stores, volume accounted for 66-76% of the variation in annual energy consumption but this was a non linear relationship. In frozen and mixed stores other factors had minimal impact on variation in annual energy consumption. This may have been due to lack of replicate data for some factors recorded. There also appears, especially with frozen and mixed stores, a factor or factors affecting annual energy consumption that were not collected in the survey. The survey was not able to assess heat loads from chamber freezing or processing in chamber (although this information was requested it was rarely provided). Therefore the variations in energy consumption may be explained by the additional heat loads in some chambers. This requires further investigation.

The performance of all stores (chilled, frozen and mixed) was statistically different. However, there was more relationship between the performance of frozen and mixed stores than there was between chilled and frozen or chilled and mixed stores. The energy used by chilled stores was less than frozen or mixed stores at volumes below 22,000 $m^3$ but was higher above this value. This might indicate that large frozen stores tend to be long term stores with less usage and that larger chilled stores have high usage (e.g. large regional distribution centres). This again requires further investigation.

It would be expected that larger stores would be more efficient and have a lower SEC than smaller stores. The indications were that this was only the case for frozen and mixed stores. For chilled stores the relationship between volume and store size was linear. This indicates that chilled and frozen/mixed stores are affected by transmission heat loads in different ways. It is possible that transmission is more dominant in stores with lower temperatures and so the impact of surface to volume ratio (which is less in a larger store) is greater than in chilled stores. It might also be expected that usage of chilled stores may be greater than that of frozen stores (more movement of food, more door openings etc) and that this may be a more dominant factor affecting energy than transmission. However, there was no relationship between annual energy consumption and food throughout in chilled stores and so this does not appear to be the answer.

The analysis demonstrated a surprising lack of relationships between the factors recorded (apart from volume) and annual energy consumption. There was for example no relationship for any store types with temperature of the store even though the range in temperatures recorded were relatively wide ranging (13°C for chilled and 5°C for frozen) and there was an extensive data set. In other instances the lack of any relationship may have been due to the restricted data sets available.

The data collected provides an indication of the factors that most affect the energy used by cold stores. This provides a useful framework to develop labelling of cold stores and the factors that should be considered when creating a benchmarking or labelling scheme.

# LABELLING OF COLD STORES

## Introduction

One the deliverables in the ICE-E project was to develop an energy labelling system to be used by cold stores in Europe. It was intended that the label should create maximum transparency for persons and institutions not related to the cold store industry. It should offer anyone inside and outside the industry the opportunity to easily understand and compare the energy efficiency of cold stores.

Such an energy label would be a helpful tool for increasing awareness of energy efficiency of cold stores and encourage those with a poor score to investigate the reasons behind that, consider improvements and to implement more energy efficient systems if (financially) feasible.

## Design of the energy label

A suitable design for the label is already available on the market and is already being used in many sectors, in many countries, for many years. Both consumers and professionals have familiarized themselves with this type of labelling which can be found in the automotive industry, domestic refrigerators, etc.


Figure 12. Typical energy label.

The main characteristics of this energy labelling model are:

- Categories marked from A to G
- A is the best (most energy efficient)
- The colour for a very positive score is dark green
- Red denotes a poor score ('traffic light' type system)

The ICE-E project group selected this design in order to present a very user-friendly label. A new and different design might meet with some resistance from potential users. A design that is known and obviously accepted will increase the success rate of the energy label and by that, the success rate of the ICE-E project and the sustainability of the label.

## Defining the 7 categories on the label

In order to make comparisons possible it was decided to define a label based on energy consumed in kWh per year per $m^3$. This metric is common in the cold storage industry and is easy to communicate and expresses exactly how much energy a cold store uses.

To define the label the models developed within the project were used. The simple model was used to predict energy used by a 'standard' chilled or frozen cold store (i.e. a class 'D' store). This was defined from the audits carried out in WP2 and was defined as a typical chilled or frozen cold store with average energy efficiency and not especially advanced energy saving features. The annual energy consumed by such stores was calculated for stores of between 1,000 and 250,000 $m^3$. As ambient conditions affect store energy consumption the location of the stores was varied according to their position in Europe. Conditions for Northern, Central and Southern Europe were calculated from the model. Conditions used are show in Table 2.

Table 2. Ambient conditions used for European locations.

| | Average annual temperature (°C) | Average annual RH (%) | City |
|---|---|---|---|
| Northern Europe | 10.0 | 77 | Stockholm |
| Central Europe | 14.8 | 77 | London |
| Southern Europe | 22.3 | 63 | Athens |

The resulting predicted energy consumed by the typical chilled and frozen stores in the 3 European locations was fitted to a polynomial trend line (value for 'D' rated stores) and compared to data collected from the ICE-E survey. This encompassed at the time of the label development data from 216 stores and one data set that covered 331 cold stores.

Using the survey data as a guide the A, B, C, E, F and G thresholds were plotted as show in Figure 13.

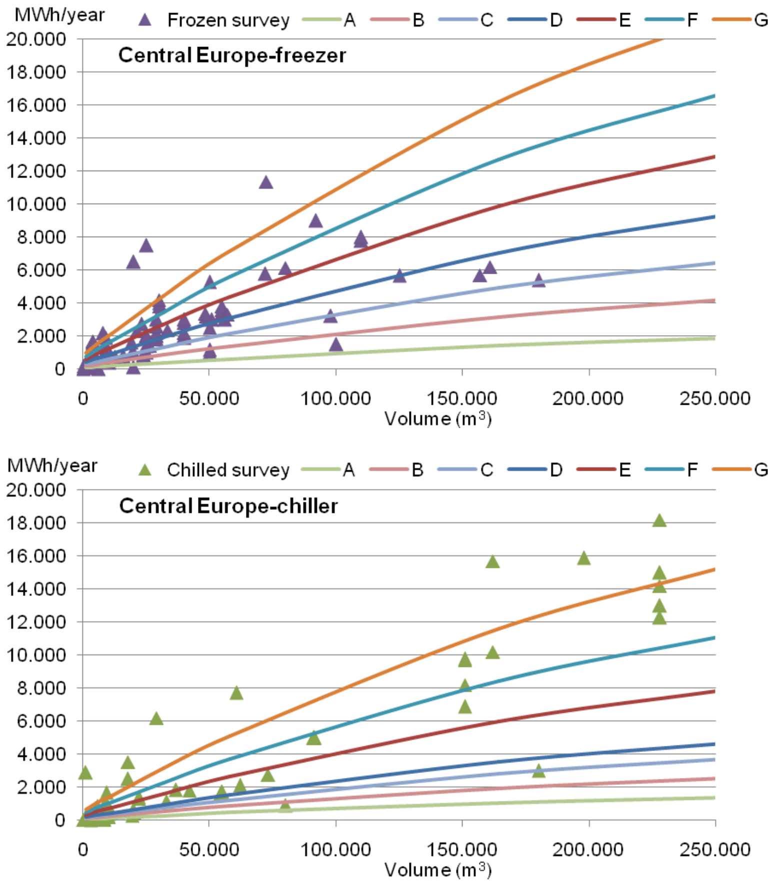


Figure 13. Thresholds for chilled and frozen stores in Central and Europe.

When compared to the survey data this labelling system showed that 18% of stores would be ‘A’ rated and 19% ‘G’ rated (Figure 14).

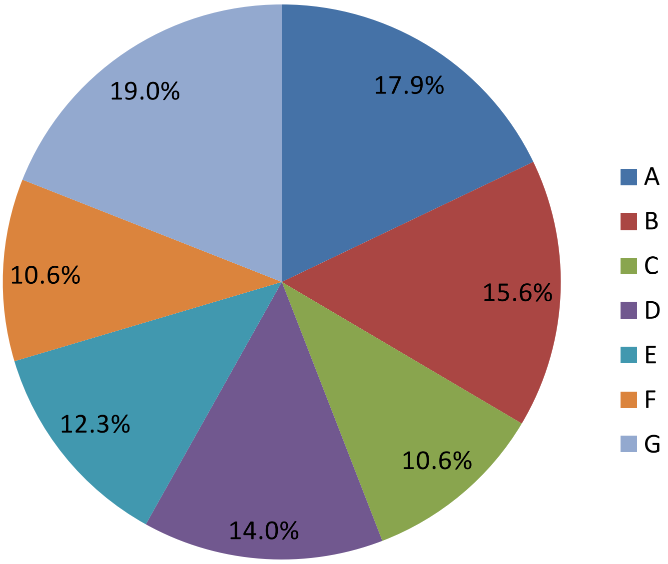


Figure 14. Performance of cold store in ICE-E survey using labelling methodology developed.

## Acceptance by the market of an energy label

Cold stores all vary and so it is likely that a more bespoke model will be required to cover all these variations. For example this might include:

- Different temperature zones and storage temperatures.
- Ways in which products are handled and stored.
- Throughput and number of inventory turns.
- Occupation rate during the year.
- Blast freezing and quantity of product blast frozen.
- In chamber cooling/freezing (product load).
- Detailed location in Europe and the ambient conditions.
- Average intake volume.
- Intake temperatures of products.
- Age of building and consequences for insulation quality.
- Number of doors and door openings.

- Total capacity of cold storage area/room.
- Position in the cold supply chain (before or after manufacturing/processing).
- Supply of other services that take energy e.g. re-packing, order picking, etc.
- Equipment in the cold room e.g. conveyor belts

It is possible that the performance of the stores could have been modelled and the above factors included. However, this would create a complex list of variables and the label would lack clarity. Further work is required to determine the most important parameters so that a streamlined but detailed label can be created.

This was corroborated from feedback from opinion leaders in the cold store industry and members of the steering committee who were not comfortable with the labelling system as described above because too many variables had not been included in the study.

It is obvious that an energy label for cold stores will only be accepted and used by the industry and its customers if it is perceived as reliable from the perspective of the operators. The conclusion of the ICE-E partners is that introducing the label requires further development to include a greater number of variables and that further work is required to increase consumer acceptance.

## Conclusion

An energy label was developed using models and data collected within the ICE-E project. The label provided an indicative benchmark for cold stores in various parts of Europe and can be considered a preparatory benchmarking mechanism. It however, needs further development to include the complexity of different cold room usage functions to enable the label to fairly reflect energy use for different cold store types. This requires further work to develop the label but also to present the information to the cold storage industry and to gain their support and acceptance.

# ENERGY AUDITS

Twenty-eight detailed audits were carried out by the ICE-E partners. Nine audits were carried out in the UK, 9 in Italy, 5 in Denmark, 4 in Bulgaria and 1 in Belgium (Figure 15).

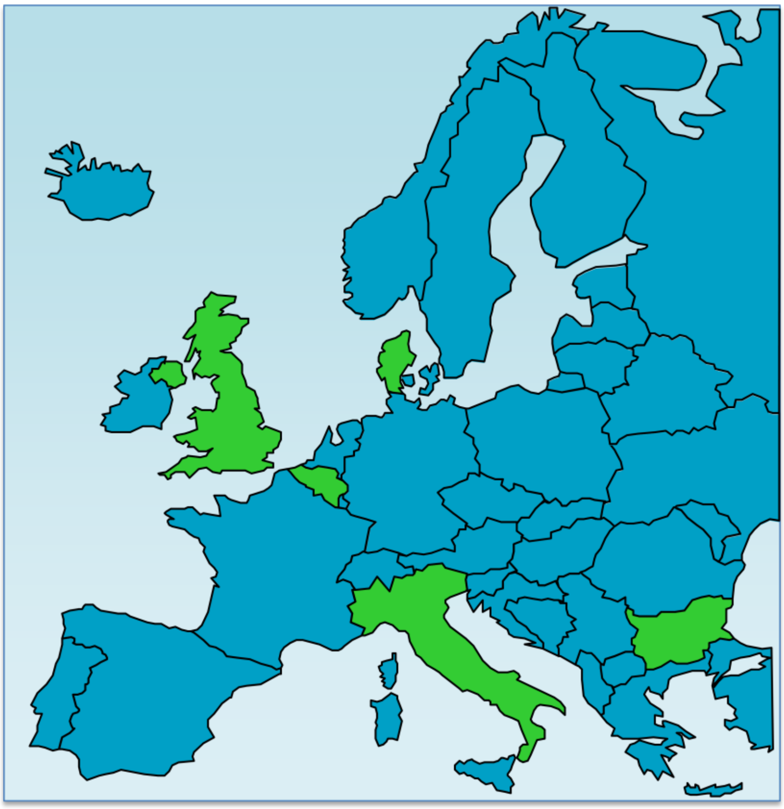

Figure 15. Location of ICE-E audits.

## Audit procedure

The cold store facilities were examined in detail in order to determine the potential for energy saving.

The methodology used in the audits was divided into

- Estimating the heat load including electrical load
- Investigating the electrical consumption
- Analysing the refrigeration system
- Identifying and quantifying potential savings

## Issues identified in the audits

The following issues impacting the energy consumption were identified

### Infiltration/door protection

Significant infiltration of warm and moist air was found in 10 audits including all the low temperature stores. Investigation into energy saving can be done by the owner /operator without special skills.

## Lighting

An issue in 9 audits. The heat load from lighting can quite easily be investigated by the owner /operator without special skills. The saving potential is both direct and indirect (the COP of the refrigeration system).

### Insulation

An issue in 8 audits. Insulation can both be too thin, too low quality and damaged/old. A detailed analysis including infra-red measurements is a job for a consultant.

### Reduce condensing pressure

An issue in 11 audits. The daily/automatic checking of the condensing pressure compared to the temperature of the ambient (or cooling water etc.) can be done by the owner / operator. But the actual work of reducing the pressure is a job for a refrigeration specialist. The ICE-E Complex model is an effective tool for analyzing the impact but as a rule of thumb 1°C too high condensing temperature equals 2-3% extra power consumption.

### Control of condenser fans

This was only registered as an issue in 1 audit, but quite simple controllers are available optimizing the condenser fan speed and condensing pressure. Reducing speed of pumps and fans has an enormous impact on the energy consumption. The analysis is a job for a refrigeration specialist or consultant experienced in refrigeration.

**Subcooling**

An issue in 3 audits. This is especially a problem for DX systems: loosing the sub cooling of the liquid refrigerant supplied to the expansion valves can cause too little liquid supply. The analysis is a job for a refrigeration specialist or consultant experienced into refrigeration.

**Defrost control**

An issue in 10 audits. Correct timing and length of defrost has a direct impact on both the heat dissipated into the cold store and the performance of the air cooler/evaporator. Daily checking of the status can be done by the owner/operator but it is recommended to consult a refrigeration specialist before starting to optimizing the defrost process. At air temperatures above 0°C the use of the air flow through evaporator instead of electrical or hot gas defrost should be considered (of-cycle or passive defrosting).

**Room temp settings**

An issue in 10 audits. Too low set point for the cold store air temperature wastes energy and it can raise the weight loss of the stored products due to drying out.  As a rule of thumb 1°C too low cold store air temperature equals 2-3% extra power consumption. The daily checking of the status and adjustment can be done by the owner/operator.

**Superheat control**

An issue in 4 audits. Too high superheat out of the evaporator on DX systems indicates poor expansion valve control, loss of refrigerant or lack of sub cooling. As a rule of thumb 1°C too low evaporation temperature equals 2-3% extra power consumption. The analysis and solving of the problem is a job for a refrigeration specialist.

**Control of evaporator fans**

An issue in 10 audits. Reducing the speed of pumps and fans has an enormous impact on the energy consumption and running evaporator fans at lower speed instead of on/off regulation can provide quite high saving if the off-time is significant (low duty factor). But also cascading of multiple fans or pulsing fans so only the required fan capacity is running can save power as well as controlling the optimum condensing pressure. The analysis of duty factor can quite easily be investigated by the owner /operator without special skills.

**EC fans**

An issue in 3 audits. EC fans are more efficient than ordinary fan shaded pole motors and should be considered when changing fan motors. EC motors have built-in variable speed drive so a control signal is needed in order to get the full benefit of the investment in EC fans. The analysis of the benefit of using EC fans is a job for a consultant.

**Control of compressors**

An issue in 11 audits. Optimal operation of the refrigeration compressors can have a high impact on the power consumption. Especially fixed speed screw compressors have very bad part load efficiency and should be operating at 100% load as much as possible. In case of a mix of screws and reciprocating compressors it is highly recommended to do the part load operation on the reciprocating compressors. The detailed analysis is a job for a refrigeration specialist or consultant experienced into refrigeration.

**Other refrigeration system issues**

This was an issue in 4 audits and covers a lot of other possible issues and problems. The daily check of running condition etc. can reveal problems but the detailed analysis is a job for a refrigeration specialist or consultant experienced into refrigeration.

**Other controls**

This was an issue in 4 audits and covers other possible issues and problems. The daily check of running condition etc. can reveal problems but the detailed analysis is a job for a refrigeration specialist or consultant experienced into refrigeration.

**Expansion device**

An issue in 4 audits. The size and function of the expansion valve in DX systems has an enormous impact on the performance of the evaporator and the evaporations temperature. The daily check of running condition etc. can reveal problems but the detailed analysis is a job for a refrigeration specialist.

**System design**

An issue in 12 audits. A change of systems design (e.g. the inter connection of different compressors or piping) will some time make savings possible. The detailed analysis is a job for a refrigeration specialist or consultant experienced into refrigeration.

**Battery charging**

An issue in 2 audits. When charging batteries for forklifts etc. quite some heat is dissipated into the surrounding air. Therefore charging shall not be done in refrigerated areas as it is a source of heat load.

**Service/maintenance/monitoring**

An issue in 3 audits. Daily monitoring of the running condition of the refrigeration system is highly recommended. Scheduled service and maintenance is also recommended in order to have a safe and stable refrigeration system. The daily monitoring should be done by the owner/operator in order to have updates knowledge of the system performance. Most of the service and maintenance on the refrigeration system have to be done by refrigeration specialist.

**Product temperature**

This was only an issue in 2 audits but the heat load from products not having the right temperature when loaded to the store or different temperatures in different stores/rooms impacting the product temperature is wasted energy. The ICE-E simple calculation tool is efficient in order to analysis the impact from product temperature. The analysis and daily monitoring should be done by the owner/operator.

### Restoring of control settings

An issue in 6 audits. Often the set points for the room temperature and/or settings for the refrigeration system “slip” and are changed due to some event (e.g. a blocked door) but never changed back. The daily monitoring do by the owner/operator is capable of catching this “slipping” which also can be caused by some malfunctioning component in the system.

## Conclusions from audits

The saving potential found was up to 72% of the power consumption related to the operation of the cold store.

Based on the audits some general conclusions could be drawn:

- In total 130 options were identified which could be grouped is 20 different issue-groups (Figure 16).
- No one issue dominated in terms of the energy that could be saved (Figure 17).

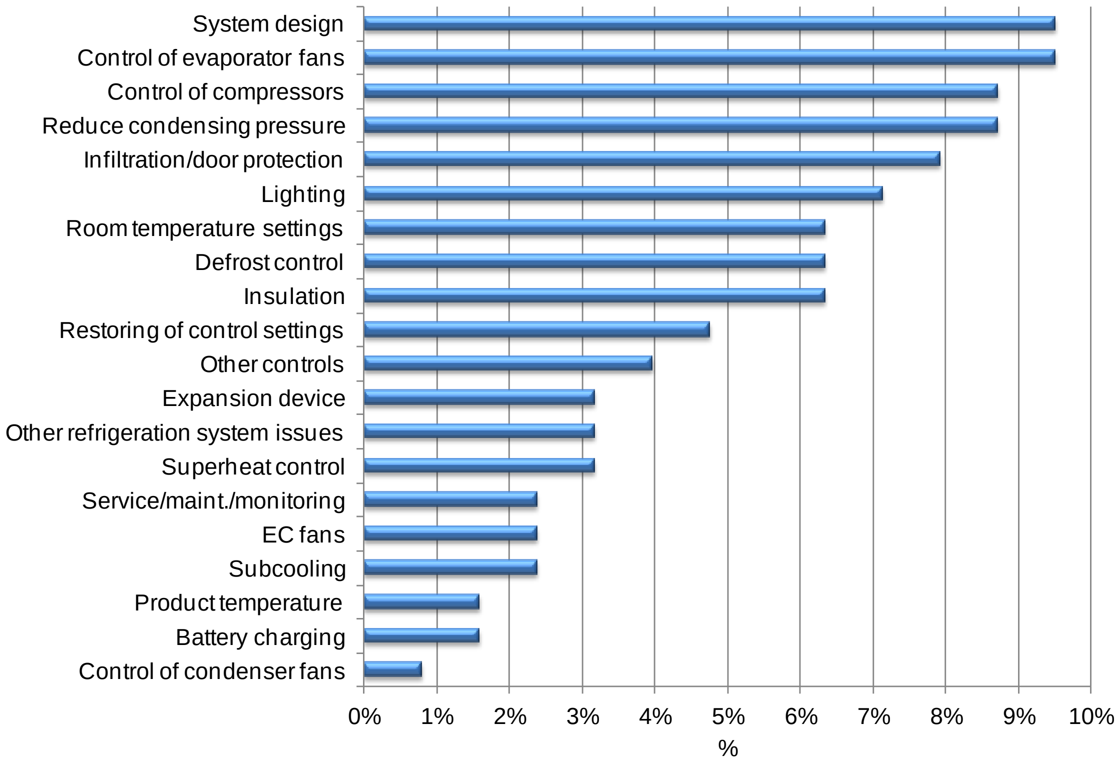


Figure 16. Issues identified in the audits.

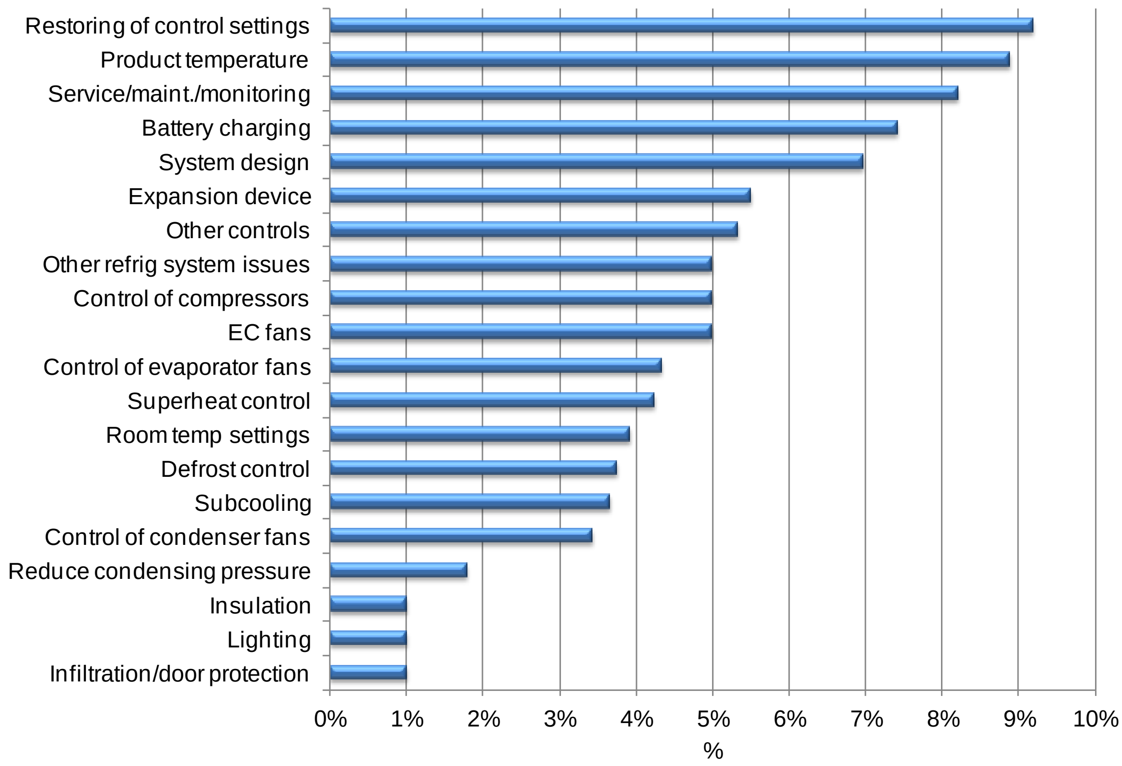


Figure 17. Average energy saving potential of each of the issue identified.

In terms of the issues identified:

- 36 could be handled by the owner / operator not having specialized technical knowledge.
- 66 needed assistance by a refrigeration specialist.
- 28 need assistance by a consultant specialized in refrigeration technology and/or cold storage (Figure 18).

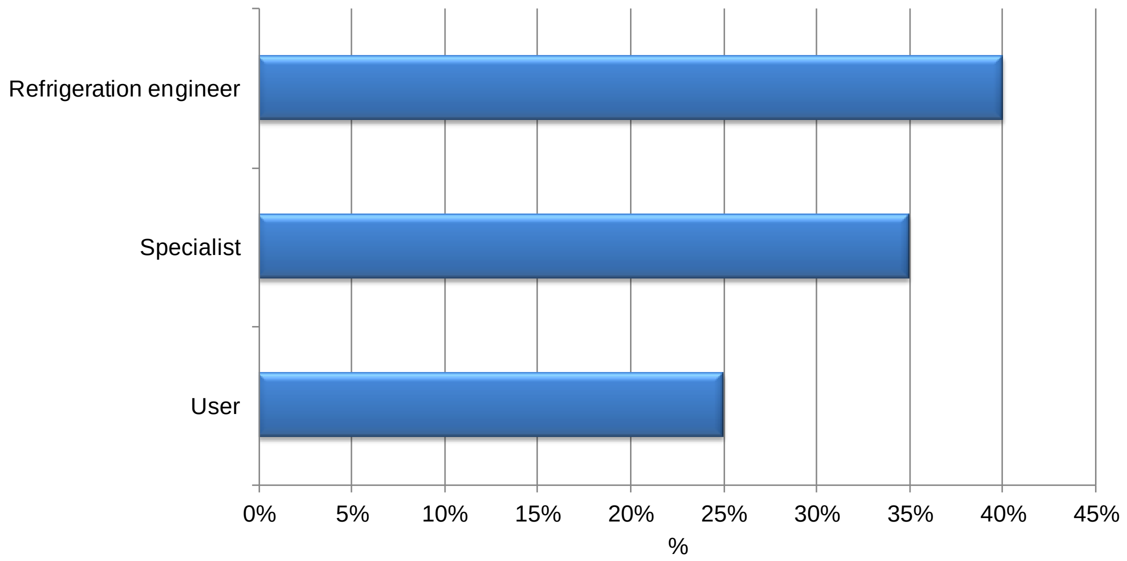


Figure 18. Level of expertise required to solve energy related isues identified i audits.

## Feedback after completion of the audits

After completing the audits feedback from the companies involved was sought. The majority of the companies involved in audits became involved after filling out the benchmarking survey. In Southern Europe the personal relationship between auditor and company was an important factor in companies deciding to take up an audit.

The reason companies decide to participate in an audit were a mixture of: saving energy, reducing costs and a wish to protect the environment. Often operators valued an independent opinion as they did not always trust the independence of companies or contractors. The reputation and independence of the ICE-E team was a clear factor in motivating companies to be involved in an audit.

Feedback on the audits was positive. All of the audited companies stated that they appreciated the audit. In all audits energy savings were identified. In all cases there were some very obvious methods to save energy (e.g. keeping doors closed, air extract from cold rooms, holes in doors) but the operators did not do anything about them (even though they knew they were an issue).

Due to timescales it was not possible to fully cost the return in investment on all suggestions. Often company internal systems and policy prevented rapid implementation of the suggested options. This was more apparent in larger companies. In smaller companies, often the owner was involved in the audit process and was able to make rapid decisions on implementing the audit suggestions. For example in one audit investing €,4000 was found to save 148,000 kWh/year and this was implemented almost immediately.

The cold store's refrigeration contractor was generally heavily involved in the operation of the cold store. However, in 25% of the audits no contractor was regularly involved in the store's operation. Generally the expertise of the contractor was good but often they lacked the motivation to reduce energy. Most contractors were paid a fee to keep the cold store operational. They therefore were not motivated to reduce energy, only to make sure the store was maintained at the desired conditions for the least cost to themselves. If asked to examine store performance most contractors also only seemed to advise cold store operators on the operation of the refrigeration plant and did not look at the heat loads on the plant or try and reduce them. This seems to be a real failing and resulted in quite large savings being missed.

The results of the audit, the analysis and investment calculations almost universally met the expectations of the audited companies. Most companies were so positive about the audit that they would be willing to pay for a similar audit.

Some barriers to implementing technology were identified. Often owners or cold store managers were positive about change. However, some resistance was apparent from the operators of the cold store (fork lift truck drivers, maintenance operatives, packers/pickers) who did were not necessarily motivated to save energy.

Unlike energy audits of buildings, audits of cold store facilities and their refrigeration plants are not yet sufficiently popular in Europe. Hence, the ICE-E activities highlighted this important instrument for improving the energy efficiency and environmental friendliness of the sector.

# INFORMATION PACKS AND CASE STUDIES


## Information packs

Twenty-one information packs were developed by the project partners:

1. Refrigerant cycles
2. Operation and choice of compressors
3. Heat exchangers
4. Throttling valves
5. Pipe work and system layout
6. Pumps
7. Refrigerants
8. Insulation and structure
9. Heat reclaim/recovery
10. Thermal storage
11. Renewable energy (solar, wind)
12. Free cooling
13. Operation of doors and door protection
14. Inverters
15. Loading of the store
16. Minimising load
17. Temperature control
18. Control systems (defrosts, lighting, fans)
19. Targeting and monitoring
20. Lighting
21. Maintenance

Figure 19 shows a typical information pack.

All information packs are available for download from the ICE-E web site and are available in:

- English
- Italian
- Danish
- Dutch
- Bulgarian
- Czech

ICE-E INFORMATION PACK

Cold store lighting

**In some cold stores lighting can be a significant heat load**

**There are many methods to reduce the energy usage of lights**

## Introduction

The purpose of lights within a cold store is to illuminate the area so that personnel can see what they are doing whilst they work in the store. Lighting can also have a psychological effect on the occupants within the cold store.

## Lux

It is highly unlikely that a cold store will have any natural light (e.g. through windows) and therefore lighting will need to come from artificial light sources (lamps). The level of illuminance, known as lux (units are in lx) is a measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface. Therefore a high lux will appear brighter than a lower lux. To give an example of two extreme levels of brightness, direct sunlight has a lux of up to about 100 000, whereas a moonless clear night sky is about 0.002 lx. More meaningful lux levels are a family living room (50 lx) and office lights (up to 300 lx).

The correct level of lux is dependent on the task being carried out. For example if the cold store has hazards for example, fork lift trucks or a slippery store, a higher lux level would be required, as the personnel will be safer if they can see the hazards more easily. Lower lux can also produce eye strain and tiredness when carrying out certain tasks, e.g. reading.

The downside of high lux in a cold store is two-fold, firstly in the electrical energy to power the lights and secondly in the heat energy dissipated into the cold store. Using more efficient lights allows a high lux for a small electrical energy and heat dissipation.

***Illuminance:** Measure of the intensity, as perceived by the human eye, of light that hits or passes through a surface (measured in lux)*

***Luminous efficiency:** The efficiency of the light to produce lux at low power is called its luminous efficacy (lm/W)*

## Luminous efficacy

The efficiency of the light to produce lux at low power is called its luminous efficacy (lm/W). It is the ratio of luminous flux, also known as lumens (units are in lm) to power (W). Lumens is a measure of the total quantity of light from a light source.

To achieve a high lux in a large room (or cold store) will require more lumens from the lights because the light is spread over a larger area. The difference between the lux and the lumen is that the lux takes into account the area the lumen is spread over. Another way to look at it is the closer you are to the light source, the brighter it appears.

Therefore the luminous efficacy shows the quantity of light produced per Watt of energy input. The higher the efficacy, the less power to produce the same lumens.

As an example incandescent lamps produce about 10-18 lm/W, linear fluorescent lamps including ballasts (50 to 100 lm/W) and gas discharge lamps (80 to 100 lm/W). However, accurate figures should be given by the manufacturer of the lamp. There are many different figures for the efficacy of LED lights, as they are a rapidly changing technology with constantly improving efficacies (30 to 100 lm/W).

## Colour Quality

Another aspect which needs to be considered is the quality of colour from the lamp. Different technology lamps tend to produce different colours.

Metal halides lamps tend to produce a crisp white light. Sodium and mercury lamps are limited in their colour quality.

LEDs are not inherently white light sources. They have been used for a long time as very efficient coloured lights, but only recently as white light sources.

One measure of the quality of the light is the correlated colour temperature (CCT) which describes the colour appearance of the light. It is the temperature in K of a blackbody radiator that would emit the same colour of light. As the temperature increases the colour shift from red to orange to yellow to white and, finally, to blue white.

Incandescent and fluorescent lamps have a CCT of around 2700 to 3000 K, often known as warm colours. The more efficient LEDs have a CCT of more than 5000 K, which gives a very blue light, often known as cool colours.

## Temperature

Another aspect which needs to be taken into account is the temperature of the environment where the lamps operate. The manufacturer's figures are likely to be given at ambient temperatures which are acceptable for most applications. However, many lamps do not perform the same at the low temperatures within cold stores.

Fluorescent lamps are very sensitive to temperature. Peak efficiency is around 25 to 35°C. However, at -20°C light output can be reduced by 90% and some lamps will not even start. If using fluorescent lamps, it is important to use lamps which are designed to work at the cold store temperature.

The opposite is true of LED lights, whose efficiency increases with a reduction in temperature. This makes LEDs a natural choice for cold store applications.

***The efficiency of LED lights increases at lower temperatures***

## Life

Another important consideration is the lifetime of the lamp and how they fail. Fluorescent lamps do not generally fail, but instead gradually reduce their light intensity. The fluorescent lamp is general considered to have a longer life than an incandescent lamp, however, their life can be seriously reduced by constant turning on and off. Incandescent lights are considered to have a life of about 1000 to 2000 hours, linear fluorescent 20 000 to 30 000 hours and LEDs 35 000 to 50 000 hours.

## Switching

An obvious way to save energy with lighting is to switch off the lights when not required. This can be done using sensors. Fluorescent lights have a limited life when switched more than about 8 times per day and also can take some time reaching their optimum light output. LED lights can be switched rapidly with no warm up time required.

## Starters

Fluorescent lamps require a ballast to provide the correct starting voltage and control the running current. Older T12 fluorescent lamps use magnetic ballasts, whereas newer T8 lamps use electronic ballasts. Electronic ballasts run at higher frequency reducing flicker, and increasing light output and efficacy. There are two methods of lamp starting, rapid and instant start. Rapid start systems use cathode heating to increase the life by allowing more on-off cycles. The Instant start systems are more energy efficient as they do not heat the cathodes.

The fluorescent lamp and ballast need to be considered together. It is possible to increase the lumens of a lamp by using a different ballast factor (BF). For example a lamp rated at 3000 lm with a ballast with a BF of 0.7 will only have 70% (2100 lm), with a corresponding reduction in energy usage. A higher BF of 1.2 will give an output of 120% (3600 lm). Fluorescent lamps can be dimmed as low as 1% of their output by using dimming ballasts.

## Power supplies

LED lights operate with a direct current (DC) at about 12V, therefore require a transformer to convert the mains (230 V AC) voltage to 12 V DC. Some lamps have this built in and some require a transformer.

## Power factors

The power factor (PF) describes the efficiency that an electrical appliance uses the current it draws in an alternating current (AC) circuit. An incandescent light has a PF of 1.0 and therefore is totally efficient in this respect. Fluorescent lamps will have lower PFs, perhaps down to 0.9. LED lamps may have PFs as low as 0.5. The consequence of lower PFs is higher current for the same power. This causes greater losses in the transmission lines, which is why the electricity generating companies often charge a surplus when PFs fall below a certain amount.



For more information, please contact: Alan Foster (alan.foster@lsbu.ac.uk)

WWW.ICE-E.EU

Figure 19. Typical information pack.

## Case studies

Fifteen case studies originating from the cold store audits were developed by the partners. These covered common issues that were found in the audits.

1. Superheat
2. Room setting
3. Defrost control
4. Door protection
5. Refrigerants
6. Heat recovery
7. Insulation
8. Condenser selection
9. Evaporator selection
10. Compressor selection
11. Life cycle analysis
12. Lighting
13. Secondary (glycol) cooling
14. Re-commissioning of condensers
15. Loading and operation of cold rooms

Figure 19 shows a typical case study.

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ICE-E IMPROVING COLD STORAGE EQUIPMENT IN EUROPE

CASE STUDY

Lighting

**Many cold stores are equipped with fluorescent tubes**

**At low temperatures these can often be switched to much more efficient LED lighting even using the original fixtures.**

LED lighting offers high energy efficiency and longer lifetime, but the investment costs are higher than conventional fluorescent lightening.

### Experiencing the potential

At a cold store site in Denmark, an audit was carried out to examine the potential of changing from fluorescent lighting to LED lighting.

One of the cold stores (running at -20°C) at the site was equipped with fluorescent tubes. Each of the 400 tubes consumed 115 W electrical power plus 20 % in ballast and capacitor corresponding to a total direct energy consumption per year on 200,000 kWh. In addition, since this energy was delivered to the cold store as a heat load, it also had to be removed by the refrigeration system having a COP (coefficient of performance) of 1.9. This means, the refrigeration system used an extra 105,000 kWh/year to remove the heat load from the lighting. In other words the total energy consumption for lighting was 305,000 kWh per year.

### Changing to LED lighting

For this case the original fixtures could be used for the new LED based tubes, only needing to remove the ballasts and capacitors which were necessary for the original fluorescent tubes to function. As the electrical consumption of the new LED tubes was 18 W each, the total energy consumption for lighting was reduced to 40,000 kWh per year including the reduced load on the refrigeration system, with an overall energy saving on 265,000 kWh per year.

In addition there was a consensus among the staff working in the cold store that the light quality was better.

### Investment costs

Even though cost of a tube based on LED is more than ten times the cost of a fluorescent tube giving the same light it is highly compensated by the longer life time of 50,000 h for the LED tubes compared to 10,000 h for the fluorescent tubes: Over a period of 50,000 h the investment in LED is only 3 times the investment in fluorescent tubes (excluding the cost of installation).

### Savings and simple return of investment

The installation of LED tube reduced the total power consumption for lighting in the cold store 65% including the savings on the refrigeration system.

Even though the higher investment cost it was returned less than 1.5 year due to the reduction the electrical consumption.

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CASE STUDY

### Different energy savings at different temperatures

When considering changing to LED lighting in a cold store, it is important to note, that fluorescent tubes light output reduces with temperature. As explained in the ICE-E info Pack "Cold Store Lighting" the luminous efficacy at -20°C can be as low as 25 % of the luminous efficacy at 20°C with the same fluorescent tube. LED lighting on the other hand has increased light output with reduced temperature, because the internal electrical resistance is reduced in low temperatures. In addition, at low temperatures the COP of the cooling system is lower, which means that the energy consumption to remove heat from the lightening is greater.

For more information, please contact: Lars Reinholdt (lre@teknologisk.dk)

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Figure 20. Typical case study.

# FINANCIAL ASPECTS

Financial aspects of investment in upgraded and new technology were examined and examples generated from the ICE-E audits to show cold store operator how they can justify investments.

Several methods to calculate the feasibility of an investment were demonstrated:

## Break-even analysis (BE)

A break even analysis is made to find out from what point on, a new investment opportunity does not cost money any more. The break-even point is the point where there are no losses and no gains.

For example: We plan a new investment in machinery. The cost of this investment is € 100,000, the break-even point will be where our future cash-flows will also be € 100,000.

The problem with this method is that this does not consider the time-value of money or in other words, this method assumes that € 1 in hand today is the same as € 1 in hand tomorrow.

Why would you use this method anyway?

It gives a good indication. If future cash-flows from an investment are lower than the investment itself it seems, from financial point of view not a good investment to make.

If future cash-flows are higher than the investment value. It is useful to make more detailed financial analyses on it. Therefore we refer to the methods of the Net present value and the internal rate of return hereafter spoken off.

## Net present value (NPV)

When starting to explain this method, you have to start by telling that a euro received tomorrow is not the same as a euro in hand today.

Therefore the method of NPV starts by calculating the value of the future cash-flows from an investment we make today as of today.

This can be expressed by the next formula:

$$\text{NPV}= \sum_{t=1}^{n} \frac{S}{(1+k)^t} - I$$

Where: S = the expected net cash receipt at the end of year t

I = the initial investment

k = the discount rate or the required minimal annual rate of return on new investment

n= the project duration in years

### The internal rate of return (IRR)

The internal rate of return is another time discounted measure of investment worth. The IRR is defined as that rate of discount which equates the present value of the stream of net receipts with the initial investment outlay.

This can be expressed by the next formula:

$$\text{IRR} = \sum_{t=1}^{n} \frac{S}{(1+R)^t} - I = 0$$

Where: R gives the annual rate which makes the net present value zero.

I = the initial investment

n = the project duration in years

S = the annual savings

Or in other words the IRR is a combination of the break even analysis and the net present value.

It searches for the expected rate of return on a new investment where there are no losses and no gains, based on an expected rate of annual return.

## Return on investment (ROI)

The accounting rate of return (ARR), also called the average rate of return or return on investment (ROI) is defined as the average accounting income to the investment.

The average accounting income for this purpose may be simply income after tax or income before interest and tax (EBIT) or the after-tax income that would be generated by the project if it did not result in more interest expenses.

Why take the after tax income? This income is the income that provides benefits to the owners.

Formula for ROI:

ARR = ROI = EBIT x (1 – tax rate) / start value of investment

To make an investment decision the accounting rate of return is compared to a standard, such as the existing ARR of a company or the companies targeted ARR.

For example:

We have an investment of £ 3,000 in Belgian cold store. This investment will last for 2 years. After two years he investment will be worth £ 0. The annual savings of this investment are £ 4,309 per year. Tax rate in Belgium is 39%.

So the ROI of this investment is:

ROI = (4,309 x (1 – 0.39))/3000 = 87,61% which is a rather high ROI.

There is a lot of comment on this method as it is just a number and it does not take the time value of money into consideration. Most of the times it is also more useful to consider the ROI on your total assets and not only on one part of the assets.

## Total cost of ownership (TCO)

This is a financial estimate whose purpose is to help enterprise managers determine direct and indirect costs of a product or system.

It is a management accounting concept that can be used in full cost accounting or even ecological economics where it includes social costs. For manufacturing, as TCO is typically compared with doing business overseas, it goes beyond the initial manufacturing cycle time and cost to make parts.

TCO includes a variety of cost of doing business items, for example, ship and re-ship, opportunity costs, while it also considers incentives developed for an alternative approach. Incentives and other variables include tax credits, common language, expatiated delivery, customer oriented supplier visits.

## Case studies from the ICE-E project

### Case 1: Increasing roof insulation

The first case is a case from a Danish cold store. They could save money by increasing roof insulation with 280 mm polystyrene on the high bays.

The insulation on the high bay roof (+/- 3,200 $m^2$) is increased by 280 mm polystyrene, and is fitted with 20 mm TF-plates. The frames for the fire hatches are raised by a height corresponding to the thickness of the extra insulation.

With the increased insulation, the heat load through the high bay roof can be reduced by an average of 16.6 kW.

The total investment is estimated at DKK 1,380,000. The savings potential is DKK 42,075 per year for 20 to 30 years.

This is not a good investment to make. This investment will not bring enough savings over time to have it paid back.

Also the simple break-even method shows this: Investment = 1,380,000 DKK, Savings = 42,075 DKK for 30 years or 30 x 42,075 – 1,380,000 = - 117,750. Even if we assume the time value of money to be zero this would not generate enough cash-flows to become break even.

**Case 2: Pressurizing the coolant water tank**

This is also a case from a Danish cold store. They could save money by putting more pressure on the coolant water tank. The original coolant water tank is replaced by a pressure tested tank of 2,500 litre. This is placed under pressure of 1 bar corresponding to 10 metres of head. Thus, the initial head is reduced to 3 metres, and thereby the power consumption for the coolant water pump will be reduced by approx. 6.7 kW. The new tank costs 20,000 DKK excl. assembly, let's assume 60,000 DKK assembly included.

The total investment is estimated at DKK 60,000. The savings potential is DKK 32,120 per year for 20 to 30 years.

This is a good investment to make. Even if the shareholders expect more the 50% IRR this is still a good investment to make and an IRR of more than 50% is extremely high.

**Case 3: Controlling of fan operation on the evaporators in the dispatch area and the unloading bay with frequency converters**

Also the 3rd case is from a Danish cold store and involved controlling of fan operation on the evaporators in the dispatch area and the unloading bay with frequency converters.

If 14 frequency converters at 2.2 kW each were fitted in the plant room the gross price from ABB is 6,489 DKK / Pcs. A reduction of approximately 40 % is expected thus the total investment in frequency converters is 54.500 DKK. In addition, there are further added costs of setting up an electrical distribution board of 50,000 DKK.

Total investment is DKK 104,500 and the savings per year are DKK 41,452 for 15 years. Even if shareholders expect an annual return of 39.4% it stills seems a good investment to make.

**Case 4: Total energy savings of a yoghurt plant in Great Britain**

This case study evaluates the total savings possible in a cold store in Great Britain. The audit team proposed several changes in order to get more savings in the future.

These changes can be summarized as all refrigeration system and heat load energy savings. Total costs of this investment are estimated at £300,000 but they would last for at least 15 years. The potential savings per year are estimated at kWh 2,301,348. We assume a cost of £0.1 per kWh and we assume that the price of electricity will go up by 3% per year.

So we could save £230,135 per year per year and with prices going up 3% a year (assumption) this will be £237,038 per year in year 2, £244,150 in year 3 etc.

The calculations were made assuming that shareholders expect an annual return of at least 15% per year. As we could already expect this investment has, because of the large savings, a positive NPV. Even if management expects an IRR of nearly 80% it is still worth going for.

# COLD STORE TOOLS

Currently few cold store operators have the tools to be able to identify the most appropriate energy savings options. Most energy saving options are only selected and then installed after a case has been made for a relatively short payback period. This often requires a greater level of knowledge than most cold store operators have available. Therefore it is often difficult for cold store operators to obtain a clear and unbiased view on whether energy saving options are worthwhile in terms of carbon and financial savings.

The ICE-E project developed two user friendly tools that can be used by cold store operators and technicians to identify energy and refrigerant savings. The aim of the models are to provide cold store operators with a means to simply identify whether a technology is appropriate for their cold store and whether it is likely to achieve suitable benefits. The models are Microsoft Excel spreadsheets and are available at the ICE-E website http://www.khlim-inet.be/drupalice/models. Both models are available in English, Italian, Dutch, Czech, Bulgarian and Danish languages.

## Simple model

The user inputs data about their cold store into a spreadsheet (Figure 21). The inputs include:

- Information about each wall (including ceiling and floor) of the cold store, e.g. face area, whether it is in the sun, outside ambient or internal and the type and thickness of the insulation.
- The size of the door, its opening schedule, whether it is protected (e.g. by strip or curtains), amount of traffic through the door and the outside conditions.
- The refrigeration system, refrigerant, type of condenser, condenser ambient, efficiency of compressor and number of stages.
- Heat loads inside the store, forklifts, lights, personnel, product, defrosts, evaporator and condenser fans.

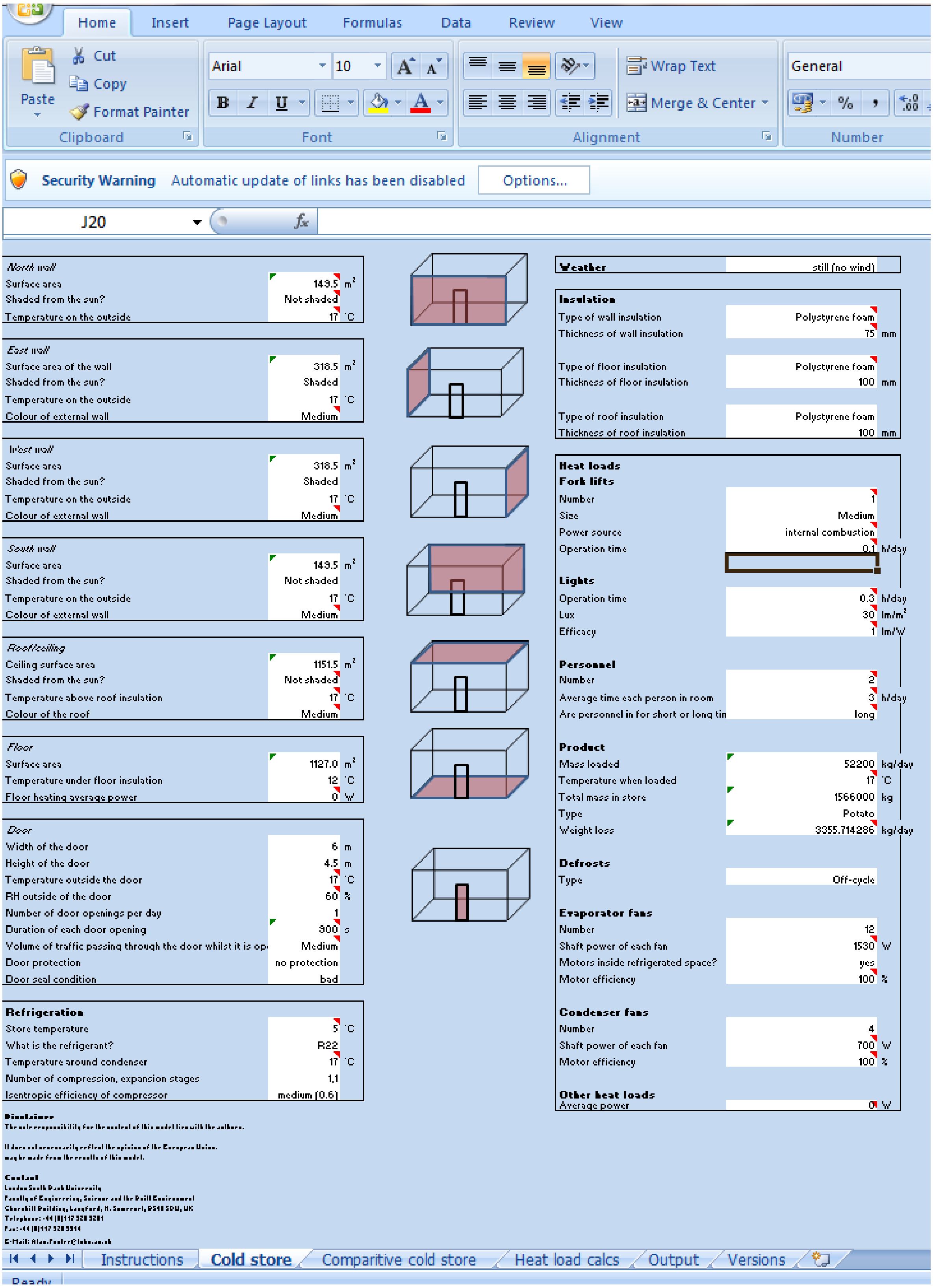



Figure 21. Input worksheet for model.

From this data a steady state heat load is calculated for the cold store. An electrical energy is calculated from the heat load by calculating a COP.  he COP is calculated using the formula given in Cleland (1992) (eq 1).

$E_{comp} = [Q(T_c\text{-}T_e)] / [(273+T_e)(1-\alpha x)^n \mu_c]$ (eq 1)

Where;

Q = Total heat load on cold store (W)

$T_c$ = condensing temperature (°C)

$T_e$ = evaporating temperature (°C)

$\alpha$ = the refrigeration coefficient

x = fractional vaporisation

n = stage coefficient

$\mu_c$ = Isentropic efficiency of compressor

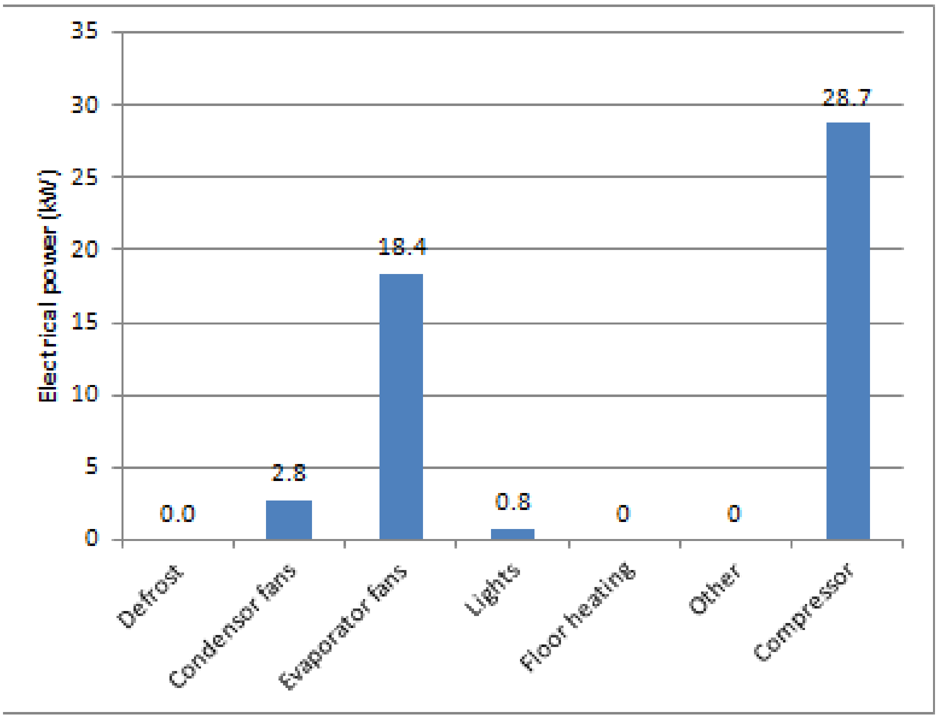
This electrical energy is added to the other electrical energy's from fans etc.

The total calculated heat load is presented along with a pie chart showing the individual heat loads from transmission, infiltration (door opening), defrost, lights, fork lift trucks, personnel, product, evaporator fans and other heat loads.

The total electrical energy is presented along with a bar chart showing the individual electrical loads from the defrost, condenser and evaporator fans, lights, floor heating and compressor (Figure 22).

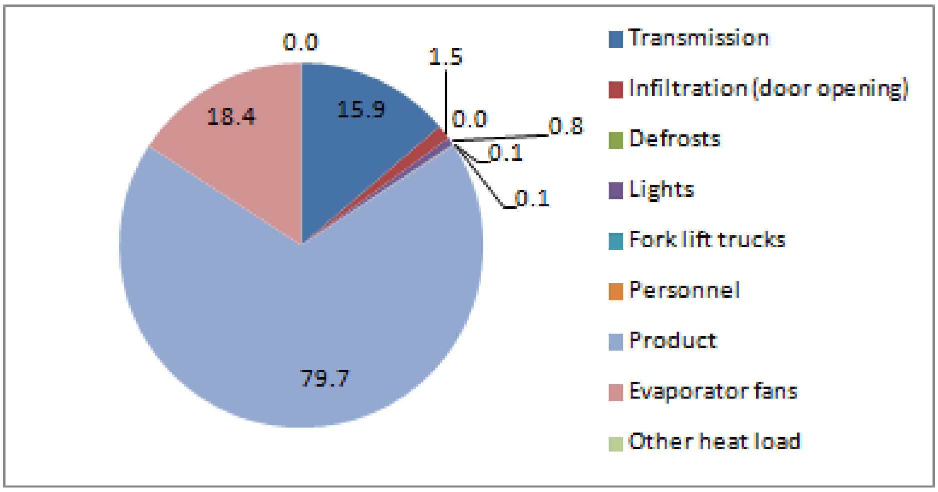
The output sheet recommends potential ways to improve energy. Another worksheet allows the cold store to be improved, for example by the fitment of more energy efficient lights or fans. The output sheet displays a comparison of both cold store energy's showing the energy saving of the improved store.

**Electrical consumption** Total 50.6 kW




Your largest electrical load is from
Compressor 28.7 kW
Try changing to a more efficient compressor

**Heat loads (kW)** Total 116.4 kW




Your maximum heat load is from
Product 79.7 kW
Try reducing temperature of loaded product to room temeprature

Figure 22. Output data from simple model.

## Complex model

The complex model is based upon the simple model but has some enhancements.

The model calculates hourly energy consumption based on hourly weather data imported from the U.S. Department of Energy, Energy Plus Energy Simulation Software, weather data (http://apps1.eere.energy.gov/buildings/energyplus/cfm/weather_data.cfm). The transient weather data used in the model is the dry bulb temperature, relative humidity (RH), ground temperature, wind speed and solar radiation. The position of the sun in the sky is used to calculate the radiant gain on each surface throughout the day.

The calculations are made at each hour of the day for each month by using Visual Basic macros accessed by a 'Calculate' button.

The daily heat load for the 12 months of the year is show as a bar graph (Figure 23). The hourly heat load during the day for the months of the year is shown as a line graph. The same output is given on another sheet, however, the heat load is replaced by the electrical consumption.

If the simplistic refrigeration model (eqn 1) is not adequate, the hourly heat loads can be exported via another macro accessed by an 'Export' macro. These heat loads can be imported into Pack Calculation (IPU Technology Development, Denmark). Pack Calculation is an application for comparing the yearly energy consumption of refrigeration plants. Among other features, transcritical CO2 systems can be compared with traditional systems. (http://www.ipu.dk/English/IPU-Manufacturing/Refrigeration-and-energy-technology/Downloads/PackCalculation.aspx).

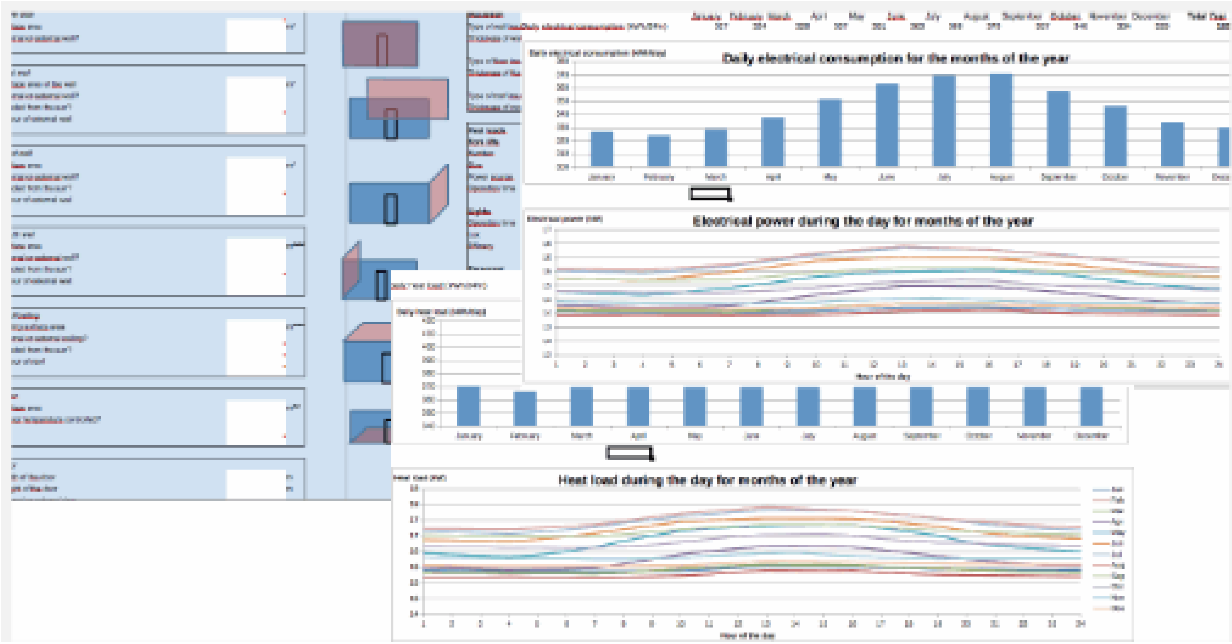



Figure 23. Input and output data from complex model.

# E-LEARNING


Five e-learning modules were created.

1. Introduction to:
    a. Refrigerated Storage.
    b. Refrigeration.

    *Describes how a refrigeration system works using two modules. The first concentrates on thermodynamics and the second on hardware.*

2. Environmental and legal aspects of carbon reduction.

    *Informs about the use of alternative and more sustainable refrigeration technologies in the context of the fight against climate change, global warming and ozone depletion.*

3. Service and maintenance to reduce carbon.

    *Understanding how to reduce costs and improve reliability of the refrigeration system, reducing the environmental impact of the system.*

4. Energy improvements through plant design and retrofitting.

    *Improving energy efficiency in medium to large scale refrigeration systems for cold stores.*

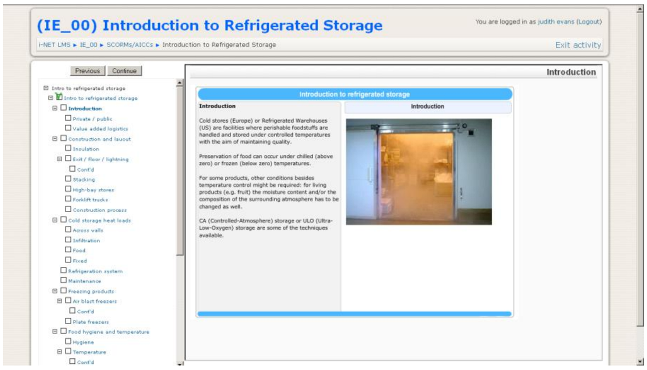
5. Auditing and energy improvements.

    *The main aspects to an energy audit and simple examples.*

Each module contains a general introduction, the goals of the module, the theory, practical examples and exercises. Every module is illustrated by film, Flash animations and photographs (Figure 24).

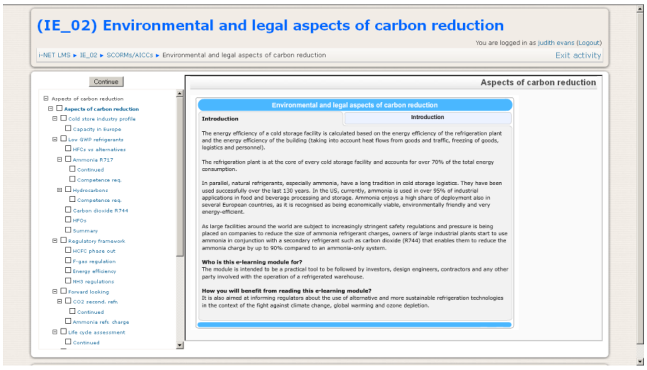
A web based portal (Moodle) was set up to host the modules. Users could request access to the site via the ICE-E web site.

A business plan was created to enable the modules to be supported and used after the end of the ICE-E project.

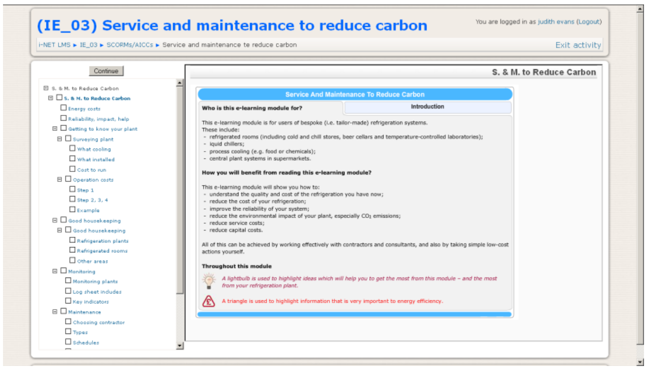



Module 1a

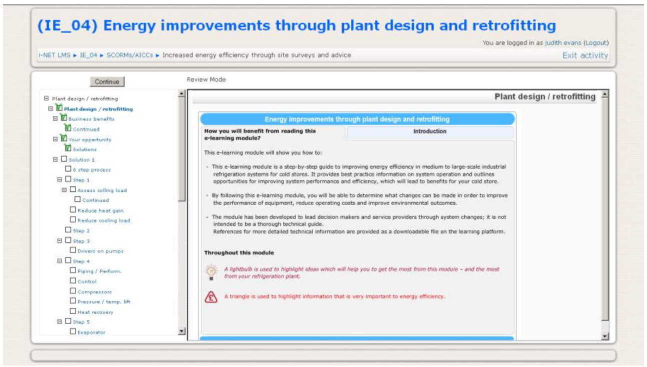

Module 1b



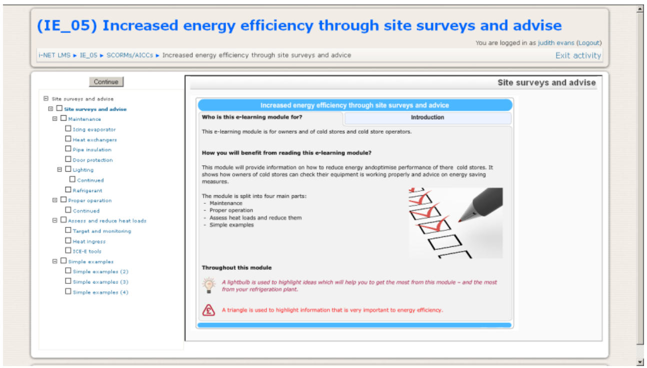

Module 2



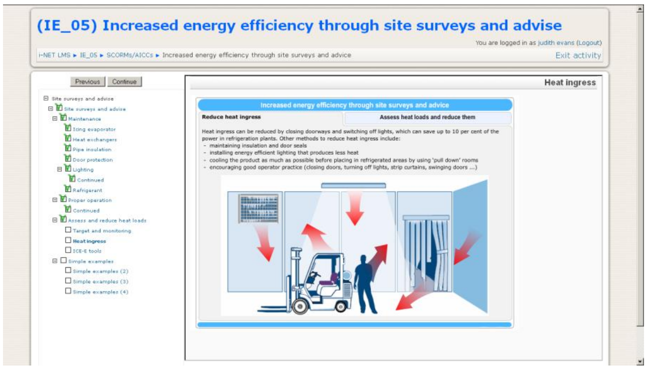

Module 3




Module 4




Module 5




Module 5

Figure 24. Examples from each e-learnimg module.

# NON TECHNICAL BARRIERS

## Introduction

The premise of the non technical barriers work was that in addition to technical barriers to the uptake of new energy efficient, low carbon technologies there are also *non* technical barriers preventing their uptake. This is often due to wider social, political, economic and organisational contextual issues, including such things as:

- human skills and motivations
- cultures and organisations
- professional and social conduct
- how we see and define the issues
- how we mobilise information, energy and resources
- institutional structures
- power, politics and vested interests

Previous research investigations (Reason et al, 2010) undertaken by the University of Bath concluded that:

- The barriers to low carbon change are not primarily technological but the technological, economic and human factors are systemically interlinked and may be 'locked in'. Attempting to change one factor alone may be of limited impact. It may even be damaging if it causes the whole system to lock in to a suboptimal path, but addressing several of these at the same time can result in a 'virtuous cycle of change.'
- There are fleeting windows of opportunity for technological transformation and individuals can only act when an opportunity arises in their actual environment.
- Significant human factors in enabling change include awareness of the issues, membership of an ongoing and committed community of practice, and a sense of concerted agency that we can initiate relevant change.

## Complementarities theory

Any project/movement to create change toward low carbon takes place in a context that offers constraints and enablers. Contextual issues are those that lie outside the direct scope of the project or activity in question but which have a significant effect (typically a constraining effect) on its likelihood.

In 2000 American author Ken Wilber's integral theory identified different aspects of reality according to whether they were internal or external, individual or collective.

David Ballard (Reason et al, 2010) developed this idea to create a comprehensive way of mapping contextual issues along two dimensions individual-collective and subjective-objective. Subjective – soft issues; objective – hard issues (Table 3).

*Complementarities theory* shows how change is created when 'doing more of one thing increases the returns of doing more of another' or 'investing in one variable makes more profitable investing in another, setting off a potentially virtuous circle (Pettigrew et al, 2004)…' Similarly the Limits to Growth analysis shows interacting layers of limits creating vicious cycle (Meadows et al, 2004).

| | |
|---|---|
| **Quadrant 1.** *Person*<br>**Individual subjective factors**<br><br>(Personal values, worldview, emotions, assumptions, etc) | **Quadrant 2.** *Job*<br>**Individual objective factors**<br><br>(Influence of one's role, skills, knowledge, relationship set, etc) |
| **Quadrant 3.** *Organisation*<br>**Collective subjective factors**<br><br>(Group cultures, shared mindsets, shared norms, etc) | **Quadrant 4.** *Sector*<br>**Collective objective factors**<br><br>(Political, economic, social, technological, legal, environmental) |

Table 3: Contexts for change – Complementarities Matrix

Change is facilitated when an individual's sense of themselves as being ready to take action (Quadrant 1) and having relevant knowledge, skills and capacities (Quadrant 2) occurs alongside cultural impetus towards change (Quadrant 3) and an opportunity in the outside world (Quadrant 4)

Complementarities theory suggests that at certain times, when all these contextual factors come together they create a window of opportunity when individuals and groups are likely to be able to act effectively for change. This methodology was applied in the ICE-E project to examine non technical barriers in cold stores.

The response to an opportunity for change in the world (quadrant 4) for example at the end of an investment cycle when industrial plant must be replaced and/or at times of major policy revision or the arrival of a new technology will depend partly on how it is perceived by individuals within an organisation (as an opportunity or a threat) and on their sense of agency and are able to grasp the opportunity (quadrant 1), partly on their skills and knowledge including being able to engage others (quadrant 2) and partly on the capacity of the organisational culture to support originality and risk taking.( quadrant 3)

The most highly motivated individuals, even if they have a good idea, will be frustrated if their social context is fragmented and unsupportive (quadrant 3) and if the opportunities in the real world are occluded or nonexistent.

This demonstrates the interplay between the 'hard' objective world of technology and the 'soft' world of individuals and human relationships.

Timeliness is key – the need to seize, create or adapt opportunities in the external environment and interpret them within the organisation. These windows of opportunity may be brief and so there is a need to build capacity in waiting so that opportunities can be responded to when they arise – this is agency at both an individual and collective level.

## Non technical barriers work within ICE-E

During the ICE-E project ten non-technical audits were conducted with cold store operators. The ten cold stores worked with were spread across five countries as follows:

- Belgium - x1 large public facility
- Bulgaria - x1 private, x1 public
- Denmark - x1 private, x1 public
- Italy - x2 private
- United Kingdom – x2 private, x1 co-operative

In each case the cold store operators and, where possible, a selection of their staff were interviewed on site over time in order to discuss and determine the non-technical issues and conditions, which were either forming a barrier to energy efficiency practices or conversely, were actively helping to promote good energy efficiency practice within the cold stores.

From the information gathered, opportunities for positive change were identified and ideas and suggestions were fed back to the cold store operators.

The key findings from all ten stores were amalgamated to produce a ‘non-technical checklist for energy efficiency in cold stores’, which complements the results and outcomes from the technical strands of the project, and will help inform, motivate and enable cold store operators to attend to non-technical issues and create positive change for more energy efficient working.

The following is an amalgamated thematic analysis of the non-technical issues impacting energy efficiency, incorporating the prime barriers and enablers that were identified across all ten cold stores.

| | |
|---|---|
| ***Person***<br>**Awareness** held at a personal level of energy efficiency issues both at home and at work.<br>**Attitude** that energy efficiency is important, and not only because it saves money. Product quality and safety and energy efficiency are linked.<br>**Agency** - individuals feel willing and able to make suggestions and to have a positive influence on energy efficiency.<br>**Action** for energy efficiency is incentivised and normalised; part of the company's DNA. | ***Job***<br>**Communication** - energy efficiency relates to each role through simple connections to job specifications. Incorporated into induction training, on the job training, specialist training and into maintenance contracts.<br>**Targets** – energy efficiency KPIs created for all posts. Results measured, monitored and rewarded. Bonus schemes based on energy/ tonne of throughput or productivity or similar and designed to overcome any cultural barriers.<br>**Change agents** and energy efficiency champions are nurtured and supported. |
| ***Company***<br>**Enabling culture** encourages workers to innovate, instigate bigger energy efficiency wins, optimise equipment and share information top down and bottom up.<br>**Energy policy** for efficiency and green energy generation drives delivery of cost reduction and energy security benefits.<br>**Standards** – Company is benchmarked for energy efficiency and adopts energy management standards incorporating continual improvement and measuring and monitoring methodologies.<br>**Energy efficiency credentials** are shared with customers and other stakeholders and used to retain and grow customer base and maintain competitive edge.<br>**Investment** – realistic payback terms adopted and innovative approaches developed for funding of energy efficiency projects. | ***Sector***<br>**Best practice** shared within sector (including clients) and economies of scale realised through joint working. Sector wide partnerships facilitate joint energy efficiency and renewable energy investment and project opportunities.<br>**Influence** of sector agenda through development of relationships with key sector associations and stakeholders including refrigeration equipment manufacturers and installers.<br>**Opportunities** offered by emerging local, regional or national Government schemes anticipated, cultivated and taken up. |

The thematic analysis reveals the key non-technical issues that have been identified from interactions with our sample of ten companies, and which, when working together, create the potential for a virtuous circle of high performance in energy efficiency.

These issues can be further distilled into a checklist which, used with accompanying graded questions can help cold store operators to:

- understand and benchmark non-technical energy efficiency practices in their own stores and
- apply measures and techniques to improve the context for energy related activities and move towards a virtuous circle of energy efficiency high performance.

The checklist and graded questions form part of the training pack for cold store operators.

| Energy Efficiency Checklist | |
|---|---|
| **Key issue** | **Graded questions** |
| **Awareness** | What level of awareness does your staff have of energy efficiency?<br>Do you communicate energy efficiency through all job specifications?<br>What training for energy efficiency takes place? |
| **Agency** | Does your company support energy efficiency innovation?<br>Does your company cultivate change agents and energy efficiency champions?<br>What systems do you have in place to monitor and be ready for taking action on emerging energy efficiency opportunities? |
| **Authority** | What is your energy policy?<br>Have you benchmarked your company for energy efficiency?<br>What energy management standards if any do you have in place?<br>What is your investment policy for energy efficiency? |
| **Alliance** | What joint working projects are you involved with? With which stakeholders?<br>How are you influencing others in the sector?<br>Are you sharing best practice with others? Who? |
| **Action** | What targets do you set?<br>How do you measure and monitor results?<br>How do you incentivise action? |

# KEY LESSONS

1. Considerable energy saving are achievable in European cold stores. Savings of up to 72% were found in the energy audits.
2. End users rarely have access to audits that cover all aspects of energy use in cold stores as auditors tend to concentrate on specific areas such as the refrigerant plant, lighting, insulation etc.
3. The advice given to cold store end users is often not ideal and is not always conducive to saving energy.
4. Cold store operators have difficulties obtaining truly independent advice.
5. The areas where energy could be saved varied between cold stores. Usually 3-10 issues per cold store were highlighted. No one issue stood out as having a greater impact than any other.
6. Issues identified in the audits did not vary especially between the 5 countries where audits were carried out.
7. Approximately a quarter of the issues highlighted in the audits could be solved by cold store operators without specialized training.
8. Approximately a third of the issues highlighted in the audits would require a specialist to be able to suggest improvements.
9. The level of involvement in saving energy varied considerably. Generally smaller (often owner operated) stores were especially keen to learn how to save energy.
10. The most successful and vibrant dissemination areas were those involving cold store operator groups. In particular those involving SMEs or organisations that had a strong environmental culture were especially open to the information available from the ICE-E project.
11. Technical and non technical issues need to be considered together to enable energy savings to be achieved.

# DISSEMINATION


Information generated within ICE-E was widely disseminated. The following lists the project outputs and forms a reference for further information.

## Articles

| | |
|---|---|
| Aug-10 | LSBU web page: http://www.lsbu.ac.uk/news-php/news.php?newsid=570 |
| Sep-10 | Food Manufacture magazine. http://www.foodmanufacture.co.uk/Supply-Chain/Better-cold-stores-from-new-EU-project |
| Nov-10 | RAC magazine (LSBU) |
| Aug-11 | Presentation at Frisbee workshop, IRC, Prague |
| Apr-12 | Bulgarian Food Industry magazine |
| Jun-12 | Food Science and Technology Magazine |
| Jun-11 | News article in Frozen Food Europe magazine |
| Jun-11 | Letter to national cold store associations |
| Nov-11 | Hard copy mailing to several hundred European cold stores (CEC) |
| Apr-12 | Article/news in bulletin BFFF |
| Sep-12 | Interview published in Zerosottozero (a specialistic journal for technicians in refrigeration in Italy |

## Newsletters

| | |
|---|---|
| Feb-11 | Ammonia21.com |
| Jun-11 | RD&T newsletter |
| Jul-11 | Newsletter 1 |
| Oct-11 | Newsletter 2 |
| Oct-11 | CCE newsletter |
| Jan-12 | Bulgarian Logistics magazine |
| Aug-12 | CCE newsletter |
| Oct-10 | ECSLA newsletter e-Cold Facts |
| May-11 | CEC newsletter to European cold stores |
| Jun-11 | CEC newsletter to Dutch cold stores (in Dutch) |
| Jul-11 | ECSLA newsletter e-Cold Facts |
| Nov-11 | ECSLA newsletter e-Cold Facts |
| Dec-11 | CEC newsletter |
| May-12 | ECSLA newsletter e-Cold Facts |
| Jul-12 | CCE newsletter |
| Jul-12 | FSDF website/newsletter |
| Ap-12 | The European project ICE-E saves energy and money. New Engineering Avant-garde, Sofia, 2012, No.2, pp. 12-13 |
| Sept-12 | ammonia21.com, launch of complex model |

## Presentations

| | |
|---|---|
| Aug-10 | Presentation to GEA |
| Sep-10 | Presentation to Trinord (fresh pasta producer) |
| Nov-10 | Presentation to DDO (Danish Board of freezing houses) |
| Nov-10 | Presentation to Frigosystem |
| Jan-11 | Presentation to Assofrigoristi executive committee |
| Feb-11 | Belgium association BVBVK (15 attendees) |
| Jun-12 | Food Industry (Heel wat besparingspotentieel in koel- en vriesruimtes) |
| Mar-12 | UoP presentation at MC Mostra Convegno expoconfort in Milan |
| Ap-12 | ICE-E presented in Russia, web article: http://www.khlim-inet.be/media/ice-e/news/ICE-E%20in%20Russia%2020120422-24.pdf |

## Scientific publications

| | |
|---|---|
| Aug-11 | Paper at IRC, Prague |

## Seminars

| | |
|---|---|
| Feb-11 | Presentation to ECSLA (European Cold Storage and Logistics Association) |
| Feb-11 | Presentation to Refrigeration Technical Committee AiCarr (Italian Association for Air Conditioning, Heating and Refrigeration) |
| Mar-11 | EMR (East Malling Research) (LSBU) |
| Apr-11 | Presentation to AREA (Air Conditioning and Refrigeration European Association)and ATF (Associazione Tecnici del Freddo) |
| Jun-11 | Presentation to Assofrigoristi |
| Jul-11 | Presentation to Assologistica |
| Aug-11 | Work shop at IRC, Prague |
| Aug-11 | FSDF event |
| Oct-11 | Cold chain event, Paris |
| Nov-11 | Sofia workshop/seminar |
| Jan-12 | Holbech training group |
| Feb-12 | Wisbech training group |
| Feb-12 | ECSLA Rotterdam |
| Ap-12 | ICE-E dissemination event at NEEFood 2012 and the 19th Annual General Conference of IAR, St. Petersburg, Russia, 22-24 April 2012 |

## Future events

| | |
|---|---|
| Nov-12 | Energy savings in the industry. DTI workshop. |
| Mar-12 | Initiatives to reduce energy in cold stores. IOR paper. |
| Ap-13 | IIR Cold Chain Conference, Paris. ICE-E workshop |
| Ap-13 | IIR Cold Chain Conference, Paris. Paper: Cold store energy performance |
| Ap-13 | IIR Cold Chain Conference, Paris. Paper: Improving the energy performance of cold stores |
| Ap-13 | IIR Cold Chain Conference, Paris. Paper: Freely available cold store energy models. |

# ICE-E PROJECT PARTNERS

## LSBU (London South Bank University) (UK)

LSBU is one of the largest universities in the UK committing to quality research and teaching. The Centre of Air-conditioning and Refrigeration Research has a 25-year track record in refrigeration and air-conditioning research, developing themes in refrigeration modelling, control, green refrigerants and food chain cooling, where it has an international reputation. The Centre's works in the areas of food refrigeration, heat powered cycles and sustainable cooling. The Centre aim is to increase global productivity and quality of life, both for the UK and the world community, in the field of cooling.

## Danish Teknologisk Institut (Denmark)

Danish Technological Institute occupies a crucial position at the point where research, business, and the community converge. The Institute's mission is to promote growth by improving interaction and encourage synergy between these areas.

The Institute employs experts in hundreds of different fields at 34 centres organised under the auspices of the 5 organisational units that define the main parameters for their work: Building Technology, Industry and Energy, Business Development, Materials and Productivity and Logistics

The Institute adopts an interdisciplinary approach to innovation and to the task of improving the ability of small and medium-sized companies to exploit new technologies and management tools.

## TUS (Bulgaria)

The Technical University of Sofia (TUS) is the largest and the most important academic institution in Bulgaria for higher engineering education. TUS consists of 14 main Faculties (including 3 Faculties for English, German and French language education in engineering) and 3 outsourced Faculties in the cities of Plovdiv and Sliven. TUS is experienced and has an impressive record of successful research projects supported within the EU's Framework Programmes. Based on the number of retained projects, TUS has been ranked among the nation's top two universities and top three scientific institutions. There are about 13000 students from 48 countries around the globe. The academic and research staff exceed 1200 specialists. Refrigeration-related activities are conducted in the TUS Directorate for Scientific Research (called NIS) and more specifically in the Refrigeration Science and Technology Research Group (Refrigeration Division), which belongs to the Faculty of Energy Engineering.

## University of Padova (Italy)

The University of Padova (Università degli Studi di Padova) was founded in 1222 and comprises 13 Faculties (Medicine, Engineering, Law, etc.); at present about 65,000 students in several subjects with more than 2200 teachers are attending the University of Padova. Within this, the Department di Fisica Tecnica of the Engineering Faculty gets together 16 permanent staff teachers and research workers and several post-doctoral research positions and PhD students. The research activities of the Department are devoted to thermodynamics, heat transfer, refrigeration technology (vapour compression experimental circuits and cycle simulation, development of prototypes for refrigerating units, heat exchangers design optimisation), heat pumps, air conditioning, thermodynamic properties of refrigerants, applied acoustics.

### VUPP (Czech Republic)

The Food Research Institute Prague (FRIP) was founded in 1958 as a multidisciplinary food industry research institution focused on foods properties in general and on new developments in food processing, new products and technologies in particular. It is now the complex institution with high level of competency in conducting basic and applied research projects in the fields of food chemistry, biochemistry, microbiology, food processing technologies, food engineering and human nutrition. Their workers participated in many national and several international (mainly European) joint research projects.

### Carbon Data Resources Ltd (UK)

Carbon Data Resources Ltd work in the area of 'action research'. Our interest and concern is with approaches to action research which integrate action and reflection, so that the knowledge gained in the inquiry is directly relevant to the issues being studied; and in which there is increased collaboration between all those involved in the inquiry project. Our work aims at helping the individual practitioner develop skills of reflective practice and to help organisational members develop communities of inquiry, as well as contribute to wider understanding of the place of inquiry in the development of professional practice.

### KHLim, vzw Katholieke Hogeschool Limburg (Belgium)

The KHLim (Catholic university college, Diepenbeek, Belgium) is an education and research institution located in Diepenbeek, Belgium with both bachelor and master courses in engineering. The KHLim is associated with the Catholic University of Leuven (KULeuven) and 11 other university colleges. Through close collaboration with the KULeuven and companies, the university colleges form the bridge from fundamental research to applied research for local and international companies. The KHLim research policy is therefore focussed on applied research, driven through the need of the market. The KHLim's mission is to develop innovative technology for companies, and to transfer new technology to the market. iRefrigeration, the research group of the KHLim, has a certified lab for the certification of technicians who works on cooling installations. iRefrigeration offers training to students and employees. Therefore iRefrigeration developed blended learning modules.

### Cold Chain Experts (Netherlands)

ColdChainExperts is a cooperation between more than 20 specialists. Most of them are independently operating consultants, engineers, scientists or specialists. The alliance was established in the spring of 2004. The group specialises in cold storage of food and provide a range of services associated with cold storage design, optimisation and energy efficiency.

Dr van Sambeeck, the director, also represents the European Director of The International Association of Refrigerated Warehouses (IARW). IARW's goals and activities have broadened considerably over the years. Today, in addition to collecting information and encouraging the exchange of ideas, the association aggressively promotes more efficient distribution services, aids members in adopting new technology, advises members of legislation and regulations affecting the food industry, assists members in complying with U.S. and international regulations, and participates in alliances with industry and international organisations having a common interest in the safe and efficient flow of food products around the world. All active members of IARW are also members and beneficiaries of the work of The World Food Logistics Organisation.

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# REFERENCES

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