Needs and Expectations of European Consumers and Industry regarding Refrigeration

The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement No. 245288.
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1 Introduction

1.1 FRISBEE PROJECT

The European FRISBEE (Food Refrigeration Innovations for Safety, consumers’ Benefit, Environmental impact and Energy optimisation along the cold chain in Europe) project is dedicated to Refrigeration Innovation on the Food Cold Chain. This 4-year (2010–2014) EU 7th Framework Programme funded project, includes 26 partners from 12 EU members, associated and candidate countries.

Food safety and quality, energy consumption and environmental impact are of major importance when it comes to the food cold chain. The FRISBEE team (http://www.frisbee-project.eu/) provided food manufacturers and the industrial sector with new tools, concepts and solutions to improve refrigeration technologies and innovating technologies in the European food cold chain.

The FRISBEE project results aim to improve current refrigeration technologies throughout the European food cold chain by providing new tools, concepts and solutions for enhanced efficiency. Among tasks within the project, new innovative mathematical modelling tools have been developed to combine food quality and safety together with energy, environmental and economic aspects; and to predict and control food quality and safety in the cold chain.

The FRISBEE team developed a comprehensive European cold chain database, identified refrigeration needs and current technologies in the food industry; and investigated consumer needs and expectations with respect to the food cold chain. Also, it developed new and emerging refrigeration technologies providing energy efficient and sustainable alternatives to existing technologies.

1.2 FRISBEE PARTNERS

The project includes 26 partners from 12 EU member, associated and candidate countries. Within the partner consortium, there are companies, non-governmental organizations or representatives of other companies (mainly SME Small and Medium Enterprises), and research based partners. The international expertise and synergy of the 26 FRISBEE partners enables the work to be exploited on a European level. Therefore, it is expected that the European food industry, related cold chain actors and consumers will all benefit from the FRISBEE project.

The FRISBEE partners are listed below:

| Agencia Estatal Consejo Superior de Investigaciones Científicas (Spain) | Marfo (Netherlands) |
| Arcelik A.S. (Turkey) | NanoBioMatters S.L. (Spain) |
| ACTIA - Association de Coordination Technique pour l’industrie Agroalimentaire (France) | National Technical University of Athens (Greece) |
| Bonduelle S.A. (France) | TNO - Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek (Netherlands) |
| Camfridge LTD (United Kingdom) | Psutec S.C.R.L. (Belgium) |
| IRSTEA (France) | Saint Trofee (Netherlands) |
| CNRS - Centre National de la Recherche Scientifique (France) | SINTEF Energiforskning A.S. (Norway) |
| Costan SPA (Italy) | SPES - Societa di Progettazione Elettronica e software S.C.R.L. |
| Cristopia Energy Systems (France) | Spread European Safety GEIE (Italy) |
| Fatland Jaeren A.S. (Norway) | Federalimentare (Italy) |
| IIR - International Institute of Refrigeration (France) | Szent István Egyetem (Hungary) |
| ITP Multilingual Communication (Belgium) | Vlaams Centrum Voor Bewaring Van Tuinbouwproducten (Belgium) |
| Katholieke Universiteit Leuven (Belgium) | Vysoká Škola Chemicko-Technologická v Praze (Czech Republic) |
| London South Bank University (United Kingdom) | |
1.3 OVERALL PROJECT STRATEGY AND ACHIEVEMENTS

The first objective was to develop a comprehensive European cold chain database in order to investigate consumer needs and expectations with respect to the food cold chain as well as to identify the refrigeration needs and available current technologies in the food industry.

Several achievements have been obtained: sociological studies on consumer attitudes in regards to the food cold chain; a review of the needs and attitudes of European consumers and industry with respect to refrigeration; an open modular knowledge database of the above gathered cold chain data for statistical analysis, continuously updated throughout the project; a review of the state of the art of refrigeration technology in Europe and the rest of the world by literature and patent search; measured data of food temperature, change of quality and safety attributes, consumer well-being and acceptance, energy efficiency and environmental impact in representative cold chains across Europe.

The second objective was the development of quality, energy consumption environmental impact of refrigeration technologies. Thus, softwares were built: for heat and mass transfer during refrigeration processes; for energy consumption of refrigeration technologies; for quality and microbial load evolution of selected reference food products in cold chains (apple, spinach, pork, salmon, ice cream); for optimization of cold chains and refrigeration technologies.

A controlled equipment for cold chain simulation and a wireless temperature sensor for cold chain monitoring were developed. At that stage, the project started to focus on five representative high volume food products covering a range of product properties and refrigeration technologies: apple, spinach, pork, salmon, and ice cream. These products are considered as representative.

The third objective was to improve existing refrigeration technologies and to develop emerging technologies. In order to reduce the energy consumption of existing refrigeration technologies; thermal energy storage systems permitting the desynchronisation between the cold production and the thermal energy (use of intermittent sources of energy such as solar or wind energy) were designed. Refrigeration control systems based on combined energy criteria and food quality criteria were also established.

Large scale pilot equipment of emerging food refrigeration technologies were built, including a system for superchilling and supercooling of pork; magnetic refrigeration system for domestic refrigeration; air cycle equipment for fast freezing, storage and transport systems; smart packaging using vacuum insulated panels and micro –an nano encapsulated phase change materials (PCM); nanoparticles enhanced refrigeration system. Cold chains of pork, salmon, apples, spinach and ice cream were optimized in terms of energy consumption, food quality and safety, consumer acceptance, cost using advanced temperature control, phase charge materials, nanoparticle refrigeration and air cycle systems. Particular actions were taken such as ice growth and ice fraction sensors for precise control of superchilling of beef and salmon, reduction of quality loss and energy consumption of apples in controlled atmosphere storage and cold storage warehouse for ice cream with a thermal energy storage device for close temperature control. A close temperature controlled retail display cabinet was equipped with a PCM and thermal energy storage devices (TESD) supplying ice slurry suitable for superchilled or supercooled products. A novel energy efficient PCM domestic refrigerator was proposed.

1.4 REVIEW OF NEEDS AND ATTITUDES OF EUROPEAN CONSUMERS AND INDUSTRY REGARDING THE FOOD COLD CHAIN

Data were collected and pilot equipment were built. Articles were published in international peer-review journals. Seminars and workshops were organized during international conferences. Researches still have to be investigated; however, as a first conclusion of these works and a first step to new works, it is necessary to summarize consumer and industry needs and expectations in an interactive way. Conclusions of the surveys and platforms will now be successively presented for consumers and industries which will be described in the text book accompanied of recommendations.
2 Consumer needs and expectations study

This chapter summarises consumer needs and expectation studies performed with respect to food safety and quality, energy efficiency, sustainability and social issues related to the European refrigerated food sector.

2.1 SURVEY OUTCOMES

Quantitative and qualitative surveys were done in France, Germany, Spain, United Kingdom and a quantitative survey in Romania. The report is available from http://www.frisbee-project.eu/deliverables/185-report-of-consumer-surveys.html.

2.1.1 Shopping frequencies

The opinions expressed can vary slightly from one country to another. As a matter of fact, we have to face practices that seem to be very similar today, not to say very standardized, in the studied population.

Ways of obtaining food, places where it can be found, travel time from these places, are very similar in the countries studied.

Most of the consumers find their food on points of sales (POS) located less than two kilometres from their home, and for a large majority, these POS are located less than 10 km from their home. Similar graphs are provided for meat, fish and dairy products in this report.
2.1.2 Supply places

Markets places also change sometimes according to products:

Supply place for meat in the four countries

Supply place for fruits and vegetables in the four countries

2.1.3 Food transport

Food transport times are mostly under 20 minutes (76.2% of the cases) and are under 30 minutes in 91.4% of the cases.

Food transport times in the four countries

People purchase their food while accessing it either by car (the majority of cases), or on foot for urban dwellers. The kind of place where one lives (city or countryside) correlates strongly with the means of transport giving access its food.

How people go shopping in the four countries
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Practices are relatively similar including practices of women and children. Behaviours do not seem particularly dangerous for consumers’ health. However, there is a real need for information, as shown in the following figures:

2.1.4 Public general knowledge

The coolest area of the fridge is a “strategic” zone, however, approximately 40% of consumers don’t know its location. Most interesting is that this proportion is almost the same in the four countries involved in the quantitative study.

Do you know where is the coldest area of your fridge is?

2.2 RECOMMENDATION TO CONSUMERS

Food can be contaminated by harmful bacteria and viruses at any stage that involves contact with food products. The consumer is the final element of the cold chain. Food that has been perfectly safe at the point of purchase needs to be handled carefully to avoid contamination at home. Pathogen bacteria can multiply enough to cause very serious illness when perishable foods are at a temperature higher than 4°C for too long. Most harmful bacteria growth at those temperatures and the more susceptible to be contaminated are elderly people, children or an ill person.

A number of measures can be taken to avoid risks when shopping, during the transport and at home. Remember to always follow manufacturers recommended instructions:

2.2.1 Shopping

Guidelines to plan and organize shopping:

1. Start your shopping with non-perishable products first, and the refrigerated and frozen products last, just prior to checkout.
2. Already use the insulated bag to store the refrigerated and frozen products when in the shop and in the car.
3. Always check the expiration date before buying.
4. Separate meat, poultry and seafood from other items in the grocery cart, at the check-out counter and in the grocery bags.
5. Avoid products in loose vacuum packs (e.g., bacon). The packaging should always be tight and with no air pocket.
6. All refrigerated products bought at the shop should be put in the refrigerator at home.
7. All perishable foods like meat, poultry and seafood must be refrigerated as soon as possible.

2.2.2 Dates

Best if used by / best if used before

Manufacturers recommend consuming the food by this date for best flavour and quality. This is NOT a safety date. The products are not at their best quality after this date, but can still be used safely for a short period of time thereafter.

Expiration date / use by date

The last date recommended by the manufacturer for peak quality. This means that the product should not be consumed after that date. Do not purchase any food not used by that date.

Shelf-life

It is the length of time that a product may be stored without becoming unfit for use or consumption.
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#### 2.2.3 Transport

- Don’t do other errands on the way home from the grocery store. The temperature in a parked car in the summertime can exceed 60°C within a few minutes.
- Place food in the air conditioned part of the car and not the trunk.
- If the travel time is longer than an hour, put your perishable products in an ice chest or insulated bag. This is especially recommended to do so when the outside temperature is high.
- When you get home, immediately transfer chilled and frozen foods into the fridge or freezer.

#### 2.2.4 Fridge

Take food that needs refrigeration home quickly and place it in the refrigerator or freezer promptly.

**Safe Refrigerator Temperatures: 0°C and 4°C**

This is a safe temperature for transporting and storing perishable foods because refrigeration slows bacterial growth.

**Safe Freezer Temperature: -18°C**

Foods kept at this temperature will have an extended storage time. Freezing stops, but does not kill, harmful bacteria.

**In the fridge**

- Check your temperature with a food appliance thermometer to make sure temperatures in your fridge and freezer are within recommended guidelines. Keep refrigerator between 0° and 4°C and freezer at or below – 18°C. If it is too warm, it can decrease foods’ shelf life and increase the growth of unhealthy bacteria.

- Store first, wash later. In most cases, it is better to wash produce just before eating. If washed prior to storing in the refrigerator, the moisture can accelerate spoilage. (Unlike most produce, lettuce and other leafy vegetables should be washed and drained before storing in a sealed plastic bag with paper towels to absorb excess moisture.)

- Check on the product packaging the temperature at which it needs to be stored. If below or equal to 4°C, place the product in the coolest part of the fridge.

- Do not put hot food in the refrigerator, as it will cause the temperature to rise in the fridge.

- Be sure stored foods are well wrapped.

- Remove external packaging before storing the product in the fridge. For example the carton packaging for the yoghurt.

**In the freezer**

- When home freezing, freeze only fresh, good quality food - freezing will not kill pathogens

- Freeze small amounts of food at a time

- Frozen foods should be stored in moisture-proof, gas-impermeable plastic or freezer wrap. Make sure to label and date frozen foods.

To ensure food stored in the refrigerator, freezer, or pantry is consumed within the expiration dates, practice FIFO (First-In-First-Out). When stocking food storage areas, place recently purchased items behind the existing food items.

#### 2.2.5 When the power goes out

When the power goes out in the home, minimize opening the refrigerator and freezer. Refrigerators and freezers are insulated, aiding in keeping foods cold.

If the frozen food has completely thawed but is cold, it must be cooked within a 24-hour period. However, quality may be diminished. If in doubt about when the food actually thawed in the freezer, discard the thawed food.
2.2.6 **Hygiene**

**Food safety when cooking**

Never thaw frozen food on the bench - it can be thawed in the fridge overnight, or in the microwave (using the defrost or lowest power setting)

**Hand hygiene**

Wash and dry your hands:

- Before and after preparing food
- After handling raw meat and chicken (before you handle any other foods, or before you touch your face, mouth or eyes)
- After going to the toilet, helping a child go to the toilet, or changing a baby’s nappy
- After blowing or touching your nose, sneezing into your hand, or touching your hair or your mouth while preparing food
- After handling rubbish.

2.3 **CONSUMERS PLATFORM**

The consumer platform develop by ITP is meant to provide general information on the cold chain and targets all consumers. The content of the consumer platform have been translated into 5 languages (French, Italian, Spanish, Slovenian and Turkish). It will also be soon translated into 2 extra languages (German and Dutch). The Consumer platform will be available in all these languages beginning of 2014. The consumer platform is located on the current website and is accessible through a new item in the homepage: [http://www.frisbee-project.eu/consumer.html](http://www.frisbee-project.eu/consumer.html)
The platform is divided into several modules which are detailed below.

2.3.1 Quiz

Two quizzes have been created to test your knowledge on the cold chain and the frozen products: the refrigeration and cold chain and the healthy habits in using frozen food webpages.

The 10 questions (refrigeration and cold chain) and 5 questions (healthy habits in using frozen food) consumer quiz relates to day-to-day information and refrigeration history. The consumer answers the different questions (multiple choice answers) and submits the answer he/she considers to be the correct one. A pop-message informs the consumer whether his/her answer is correct and provides a brief explanation of the correct answer.
At the end of the quiz, the consumer sees his/her score and he/she is invited to visit the FRISBEE website for more information on refrigeration and on the FRISBEE project.

2.3.2 Fridge

This animation is dedicated to the fridge which has become a very important food storage space in most families. It provides information on how to efficiently arrange food in your refrigerator, the importance of the different temperature areas in the refrigerator as well as more generic food safety tips.

2.3.3 Sociological study

The sociological study was conducted by the CNRS and results obtained can be uploaded in PDF format from this webpage.
2.3.4 Comic Strip

The non-animated comic strip, created by IRSTEA, illustrates graphically the cold chain to young children. This comic can be uploaded from the comic strip webpage in PDF format.

2.3.5 Virtual Supermarket

This module provides the link to the WEb3D Knowledge Hot Spots developed within the AgrifoodResults project. The information on FRISBEE project can be found in the FROZEN FOOD section of this virtual supermarket.

2.3.6 Consumer articles

This module displays articles meant for the consumers. The 2 available articles are on the food selection criteria and the food waste. The 2 articles are based on the results of the sociological survey conducted by the CNRS.

2.3.7 Interesting links

This module directs the consumer to external links related to the cold chain. An additional link leads to a 3D movie about the production process of frozen vegetables, made Bonduelle, one of the FRISBEE partners.

2.3.8 Cold chain animation

An animation on the food cold chain has been created and is meant to provide information for the consumers. The focus is on providing information related to the shop, transport to home and consumer’s home.
3 Industry needs and expectations study

End-user studies in the food refrigeration industry were carried out in order to obtain an overview of needs and expectations regarding food safety and quality, energy efficiency, sustainability and social issues related to the European refrigerated foods sector. The work consisted of a web based survey (http://www.surveymonkey.com/s/52XTZGJ) accompanied by in depth consultation with end-users.

3.1 SURVEY OUTCOMES

137 end-users worldwide participated in the survey. The end-users were mostly companies installing and maintaining refrigeration plants in particular facilities. The majority were from France, Italy and Spain (72%) with the remainder from Belgium, the Netherlands, Norway, Slovenia, Turkey, the UK and USA.

The majority of respondents process vegetables, dairy or ready meals.

Some respondents processed more than one food product and therefore total can exceed 100%
The above studies identify a number of issues broadly based on the following:

### 3.1.1 Costs

Generally, plant operating costs are often not taken into account. However, initial cost is a priority for end users. This is an issue with contractors who want to provide excellent equipment but are continually stretched on costs and cannot invest in new technologies or ideas.

Relatively old, there are few plans to replace/refurbish most cooling plants. Required paybacks are generally less than 3 years and life cycle costs are typically ignored.

### 3.1.2 Energy

Energy usage for cooling plants is generally less than 100,000 MWh/year with one third of them without energy monitoring. Therefore, end-users cannot monitor energy consumed. Most companies used a large proportion of their energy for refrigeration.

### 3.1.3 Refrigerants

Refrigerant leakage in plants is very high. Even though end-users are concerned about refrigerants being banned, they still use R22, and a small number (4%) still use CFC. The majority of end-users have plants operating on R717, R22, R134a or R404A.

In most companies, their refrigeration knowledge is classified as 'medium', but they doubtful and have mixed opinions on installing new technologies.

### 3.1.4 Food wastage

Food wastage appeared high with an average of 1,108 tonnes/year.

### 3.1.5 Training

End-users want greater and unbiased information to facilitate plant selection. In addition, there is a lack of emphasis on training and quality. End-users use cheap contractors who give poor quality advice and workmanship, creating a greater need for industry and end-user knowledge.

### 3.1.6 New technologies

End-users were very familiar with new technologies; however, they all have concerns about the environment and carbon emissions. Also, they are constrained by financial issues that prevent them from making changes. New developments and research are under-valued and the food industry is risk adverse.

### 3.1.7 Legislation

Focus of components and not systems from policy makers that mislead end-users.

### 3.1.8 Potential of novel technologies

The industry survey highlighted that end-users were very familiar with new technologies. However, they all have concerns about the environment and carbon emissions. The table below lists the different new technologies in terms of energy consumption, environmental impact and temperature control. Application to products investigated within FRISBEE and a brief description of these new technologies are described in the following report: [http://www.frisbee-project.eu/deliverables/59-analysis-of-potential.html](http://www.frisbee-project.eu/deliverables/59-analysis-of-potential.html)
<table>
<thead>
<tr>
<th>Technology</th>
<th>Time to commercial application (estimated)</th>
<th>Potential to save direct emissions</th>
<th>Potential to save indirect emissions</th>
<th>Potential to improve food quality</th>
<th>Potential to improve food temperature control</th>
<th>Likely initial cost against ‘conventional’ technologies</th>
<th>Ease of use and installation against ‘conventional’ technologies</th>
<th>Maintenance cost against ‘conventional’ technologies</th>
<th>Will future legislation potentially affect uptake of technology?</th>
<th>Most likely application</th>
<th>Most likely capacity range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acoustic refrigeration</td>
<td>5-10</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>Yes</td>
<td>Freezing-cooling</td>
<td>0.1 kW → 1-10 kW → 10 kW</td>
</tr>
<tr>
<td>Air cycle refrigeration</td>
<td>5-10</td>
<td>High</td>
<td>Certain conditions</td>
<td>High</td>
<td>Medium</td>
<td>Higher</td>
<td>Medium</td>
<td>Less</td>
<td>Yes</td>
<td>Freezing-AC</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Ammonia (sealed hermetic) compressors</td>
<td>2-3</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Similar</td>
<td>Yes</td>
<td>Freezing-cooling-AC</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Antifreeze proteins</td>
<td>&gt;10</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>No</td>
<td>Freezing</td>
<td>All</td>
</tr>
<tr>
<td>Barocaloric refrigeration</td>
<td>&gt;10</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>No</td>
<td>Freezing</td>
<td>All</td>
</tr>
<tr>
<td>Dehydrofreezing</td>
<td>3-5</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>No</td>
<td>Freezing</td>
<td>All</td>
</tr>
<tr>
<td>Ejector or jet pump</td>
<td>0</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Less</td>
<td>Yes</td>
<td>Cooling</td>
<td>All</td>
</tr>
<tr>
<td>Electrocaloric</td>
<td>5-10</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>Yes</td>
<td>Cooling</td>
<td>0-1</td>
</tr>
<tr>
<td>Eutectic packaging</td>
<td>2-5</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>High</td>
<td>Higher</td>
<td>Simple</td>
<td>Higher</td>
<td>No</td>
<td>Freezing-cooling</td>
<td>All</td>
</tr>
<tr>
<td>Heat pipes and spot cooling</td>
<td>0</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Higher</td>
<td>Simple</td>
<td>Higher</td>
<td>No</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td>HFOs (Hydrofluorolefins)</td>
<td>2-5</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>Yes</td>
<td>Cooling/AC</td>
<td>All</td>
</tr>
<tr>
<td>Hydraulic refrigeration</td>
<td>0-5</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>Yes</td>
<td>Cooling/AC</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Hydrofluidisation</td>
<td>0-5</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>No</td>
<td>Freezing-cooling</td>
<td>All</td>
</tr>
<tr>
<td>Ice nucleation proteins</td>
<td>&gt;10</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>No</td>
<td>Cooling</td>
<td>All</td>
</tr>
<tr>
<td>Magnetic field freezing/CAS (Cell Alive System)</td>
<td>0-5</td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Higher</td>
<td>No</td>
<td>Freezing</td>
<td>&lt;10</td>
</tr>
<tr>
<td>Magnetic refrigeration</td>
<td>3-5</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Simple</td>
<td>Less</td>
<td>Yes</td>
<td>Cooling</td>
</tr>
<tr>
<td>Nanoparticles</td>
<td>2-5</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>No</td>
<td>Freezing-cooling/AC</td>
<td>All</td>
</tr>
<tr>
<td>New foods</td>
<td>&gt;10</td>
<td>High</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Higher</td>
<td>Greater</td>
<td>Less</td>
<td>Yes</td>
<td>Freezing-chilling</td>
<td>All</td>
</tr>
<tr>
<td>Technology</td>
<td>Time to commercial application (estimated)</td>
<td>Potential to save direct emissions</td>
<td>Potential to save indirect emissions</td>
<td>Potential to improve food quality</td>
<td>Potential to improve food temperature control</td>
<td>Likely initial cost against ‘conventional’ technologies</td>
<td>Ease of use and installation against ‘conventional’ technologies</td>
<td>Maintenance cost against ‘conventional’ technologies</td>
<td>Will future legislation potentially affect uptake of technology?</td>
<td>Most likely application</td>
<td>Most likely capacity range</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>-------------------------------------------</td>
<td>-----------------------------------</td>
<td>-------------------------------------</td>
<td>----------------------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-----------------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
</tr>
<tr>
<td>Novel building fabric</td>
<td>3-5</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>No</td>
<td>No</td>
<td>Simple</td>
<td>0-1, 1-10 kW</td>
</tr>
<tr>
<td>Optical cooling</td>
<td>&gt;10</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Not known</td>
<td>Not known</td>
<td>No</td>
<td>Yes</td>
<td>Cooling</td>
<td>0-1 kW</td>
</tr>
<tr>
<td>Perfusion</td>
<td>5</td>
<td>Low</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Yes</td>
<td>Yes</td>
<td>Cooling</td>
<td>&gt;10 kW</td>
</tr>
<tr>
<td>Pressure shift freezing</td>
<td>5-10</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>No</td>
<td>Freezing</td>
<td>&gt;10 kW</td>
<td></td>
</tr>
<tr>
<td>Pulsed electrical thermal de-icers</td>
<td>5-10</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Higher</td>
<td>Greater</td>
<td>Not known</td>
<td>No</td>
<td>Freezing</td>
<td>&gt;10 kW</td>
<td></td>
</tr>
<tr>
<td>Secondary systems (novel)</td>
<td>1-5</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Greater</td>
<td>Yes</td>
<td>Yes</td>
<td>Cooling-AC</td>
<td>0-1 kW</td>
</tr>
<tr>
<td>Solar</td>
<td>5-10</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Greater</td>
<td>Yes</td>
<td>Yes</td>
<td>Cooling-AC</td>
<td>0-1, 1-10 kW</td>
</tr>
<tr>
<td>Stirling cycle variations</td>
<td>0-5</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Lower</td>
<td>Simple</td>
<td>Not known</td>
<td>Yes</td>
<td>Yes</td>
<td>Freezing-cooling</td>
<td>0-1 kW</td>
</tr>
<tr>
<td>Supercooling</td>
<td>3-6</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>Low</td>
<td>Lower</td>
<td>Simple</td>
<td>No</td>
<td>No</td>
<td>Cooling</td>
<td>All</td>
</tr>
<tr>
<td>Thermionic refrigeration</td>
<td>5-10</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>Yes</td>
<td>Yes</td>
<td>Cooling</td>
<td>0-1 kW</td>
</tr>
<tr>
<td>Thermoelectric generation</td>
<td>5-10</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>Less</td>
<td>Yes</td>
<td>Yes</td>
<td>Cooling</td>
<td>0-1 kW</td>
</tr>
<tr>
<td>Ultrasound assisted freezing</td>
<td>&gt;10</td>
<td>Low</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
<td>Higher</td>
<td>Greater</td>
<td>No</td>
<td>No</td>
<td>Freezing</td>
<td>&lt;10 kW</td>
</tr>
<tr>
<td>Vortex tube cooling</td>
<td>0-5</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>Yes</td>
<td>Yes</td>
<td>Cooling</td>
<td>0-1 kW</td>
</tr>
<tr>
<td>Water in vapour compression</td>
<td>0</td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
<td>Higher</td>
<td>Simple</td>
<td>Not known</td>
<td>Yes</td>
<td>Yes</td>
<td>AC</td>
<td>&gt;10 kW</td>
</tr>
</tbody>
</table>
3.2 DEVELOPMENT OF A VIRTUAL EUROPEAN FOOD REFRIGERATION TECHNOLOGIES PLATFORM

One of the objectives of the FRISBEE project is to design and implement a Virtual European food refrigeration technologies platform. The purpose of the platform is to host all tools, models and software in a virtual food refrigeration platform. The industrial section of the Virtual Platform (VP) is currently being developed and is at the proof-of-concept stage. This platform will allow end-users to compare and evaluate their refrigeration technologies against benchmarked data and to identify how to reduce energy whilst maintaining food quality and safety.

Registered users can access to a cloud storage and computing tool. This platform is intended for researchers and industrial people, who wanted to elaborate, share and acquire data. They'll have a universally accessible tool to work with, from anywhere and at anytime. Moreover, they can have access to a library of functions and graphs for scientific calculus or statistics.

The FRISBEE VP platform is shown below and it is accessible from:

Web address: http://frisbeevp.spcs-services.it/

Visitor Username: frisbeedemo

Visitor Password: frisbeedemo

This visitor access allows limited but enough functionalities to grasp the potentialities of the tool.

After authentication user accesses the initial page where 4 classes of actions can be chosen from a menu containing the following items: COLDBASE, DATASET, COMPUTING and RENDERING. Each of the classes constitutes a context of actions and resources that can finely be assigned, limited or forbidden to users or class of users. The set of the available actions, resources and context parameters compose the domain of an operator that maps Web requests from the user with the resulting actions.

VP has the capability to enrol partners that provide their computing power and their tools in a cluster. User can access, if provided with access rights, to the computation supplied by third parties. The COMPUTING tab on the VP page lets us enter the set of features that can be used to make complex computations or elaborations on the datasets. These computations can require a high load on system resources. This can grow even worse when a lot of users are on a computing queue as in a batch system. Actually it constitutes an important core feature of the VP.
A particularity of the VP is that an interface has been developed to simplify the utilization of the QEEAT tool through the Dataset option as shown below:

In particular as a demonstration of distributed computing capabilities the QEEAT tool has been integrated in a distributed way. The QEEAT tool has been modified to be separated in three parts: the input, the core computation and the output. The input and the output will still reside on the VP as Web pages, while the core computation will be run from a remote machine.

The adaptation process of a stand-alone software is described pictorially in the figure.
This way QEEAT Input GUI goes Web. Inputs are transferred and computed remotely by KUL’s dedicated machine. Also, using the RENDERING features on the results obtained from the COMPUTING part and obtained graphics equivalent and very similar to the original ones in QEEAT tool. This is shown below: