Assessment of the applicability of current EC correction factors and tolerance levels for domestic refrigerating appliances

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Intertek

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List of abbreviations

AC	Annual (energy) Consumption
AE	Annual Energy (consumption)
AV	Adjusted (net) volume
BI	Built-in
Defra	Department for Environment, Food and Rural Affairs
CECED	Conseil Européen de la Construction d'Appareils Domestiques (European Committee of Domestic Equipment Manufacturers)
CF	Correction Factor
CH	Chill (compartment)
COP	Coefficient of Performance
GB	Great Britain
GEA	Group for Efficient Appliances
EC	European Commission
EEI	Energy Efficiency Index
ErP	Energy Related Product
EU	European Union
EuP	Energy-using Product
FF	Frost-free
ICRT	International Research and Testing
IEC	International Electrotechnical Commission
ISO	International Organisation of Standardisation
MEPS	Minimum Energy Performance Standards
NMO	National Measurement Office
MTP	Market Transformation Programme
LLCC	Least Lifecycle Cost
UK	United Kingdom
SAE	Standard Annual Energy (Consumption)
SC	Standard (annual energy) Consumption
UEC	Unit Energy Consumption
UKHES	UK Household Energy Survey
V_{eq}	Equivalent Volume
WRAP	Waste and Resources Action Programme

1 Executive Summary

The objective of this research is to bring together existing published information. market and test data in order to review the appropriateness of refrigeration correction factors, the level of verification tolerances permitted under the ecodesign and energy labelling Directives, and the issue of appropriate volume measurements, with a view to drafting recommendations for future policy changes.

The project has been commissioned by Defra in the UK but aims to reflect a European perspective, where information is available. The project has also been overseen by a Steering Group made up of organisations across Europe including the Danish Technological Institute Centre for Refrigeration & Heat Pump Technology, the Swedish Energy Agency, the Federal Ministry of Economics and Technology - Consumer goods industries - in Germany, the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) in Italy and the NL Agency, as well as representatives from the European appliance manufacturers body CECED. The conclusions of the study represent the independent view point of the consultants

Background

In order to reduce overall energy consumption, the aim of the energy labelling policy for domestic appliances is twofold;

- to inform consumers of the relative energy efficiencies of appliances when making purchasing decisions,
- to encourage manufacturers to provide more efficient appliances.

Energy efficiency for refrigerating appliances is expressed as an Energy Efficiency Index (EEI) and determined by comparing the actual energy consumed by a given sized appliance with a standard energy consumption value which is calculated from the volume and operating temperature of the appliance (equivalent volume). Coefficients (M and N) are applied for the calculation of the standard consumption. A simplified representation of the calculations involved is given below:

EEI* = *Actual energy consumption* / *Standard energy consumption

***Standard energy consumption* = *Equivalent volume* x *M* + *N* (+ *chill factor*)**

Equivalent volume* = *Volume* x *Thermodynamic factor* x *applicable Correction Factors

Correction factors should be used to normalise differences that occur due to testing procedures or evaluations that would not allow appropriate comparisons or misrepresent the comparative energy use. The current factors consider the main characteristics and functionality of refrigerating appliances. The frost-free factor has been included since the setting up of energy labelling; the other three were introduced in revisions to the label which came into force in 2004.

The correction factors currently applicable are:

- CC; Climate class - for appliances designed to work in the warmest climatic conditions (tropical and subtropical classed appliances),

- FF; Frost-free - for appliances that automatically defrost the freezer compartment,
- BI; Built-in - for built-in appliances with particular width restrictions (<58cm),
- CH; Chill compartment - for appliances with chill compartments greater than 15litres.

This report will assess whether correction factors are still appropriate by looking at the market to see whether the energy bonus from a correction factor has distorted the supply of different types of appliance, and considering the energy use by different technologies and designs that make appliances eligible to use correction factors.

The energy efficiency communicated to consumers needs to be accurate, relevant and comparable in order that it can influence the end-user's choice in favour of those products which consume less energy and other essential resources. For this reason, the determination of the energy efficiency index should only use correction factors where the result still provides appropriate comparisons across the range of appliances that potential purchasers are considering. Consumers are not always aware of the aspects that contribute to the efficiency, and should not need to be, but should be confident that they are comparing like with like and are given appropriate choices of appliances to suit their needs.

Correction factors give an energy bonus to appliances eligible to use them compared to similar appliances; they are able to use more energy to achieve an energy efficiency class than if the correction factor was not there.

Climate class correction factor

There are two levels of correction factor depending upon the maximum ambient temperature an appliance is designed to operate in. The highest factor (for climate class T) provides an energy bonus of between 6% and 10%, i.e. this is the difference in the energy consumption to achieve the same energy efficiency index with and without the correction factor.

Climate class is not an obvious characteristic and consumers may be comparing similar appliances, some with and some without the correction factor, without their knowledge. The information is therefore not comparable and consumers may not be choosing the most appropriate and efficient appliance for their circumstances.

Appliances can be efficient for all ambient conditions if appropriate technology and components are utilised. Removal of the correction factors will encourage the incorporation and development of more efficient technologies.

Around 80% of appliances available in Europe have a maximum climate class of ST or T and many of these are multi-climate class such as SN to T. This evidence suggest that the majority of appliances are using the correction factor even though in many regions the appliances do not need to operate in ambient temperatures at which such appliances are sold to cope with.

The recommendation is the removal of the climate class correction factors.

Frost-free correction factor

The frost-free correction factor provides an energy bonus of around 8%; this is similar to the amount of energy used for the automatic defrosting functioning of a frost-free appliance. The factor therefore compensates for the extra energy used during standard testing compared to a similar static appliance that is operating optimally during testing. This comparison does not however, consider the extra energy that may be used by static appliances during real use due to frost build up. This information is not available.

Although this is one of the correction factors that does compensate for energy use during standard testing compared to an appliance providing a similar service but without the automatic defrost, it is possible to produce frost-free appliances that are as efficient as static appliances under standard test conditions. It is therefore felt that now is an appropriate time to reduce the level of the correction factor as this will encourage more efficient technologies and improve the efficiency of appliances with this increasingly popular feature.

The report recommendation is a reduction in the level of the frost-free correction factor.

Built-in correction factor

The built-in correction factor is applied to a subset of appliances in the built-in market, namely those that are less than 58cm wide.

Currently it gives an energy bonus to a type of appliance that is inefficient due to its design. Not only does the correction factor hide the inefficiency by improving its energy efficiency index, but also leads to inconsistent consumer information when comparing built-in appliances of different widths.

The recommendation is the removal of this correction factor.

Chill compartment factor

The chill compartment factor is a constant value (50kWh) that is applied to the standard energy consumption of appliances with a chill compartment greater than 15 litres in volume.

Chill compartments are a relatively new feature and found on around 5% of refrigerating appliances available in Europe as a whole and in around 3% of fridge-freezers sold in Great Britain. This feature offers enhanced storage conditions for highly perishable foods and is increasing in availability but it is an added feature which increases the energy consumption of an appliance compared to one without. This additional energy consumption should be reflected in the energy efficiency index allowing consumers to appropriately compare appliances with and without such a feature. Additionally, the size of the chill compartment factor was based upon a volume of chill compartment which is not necessarily representative.

The recommendation is the removal of the chill compartment factor.

Impact assessment

An impact assessment to consider the energy reductions achievable if all correction factors were all removed and energy performance improved (to compensate for the loss of correction factors) shows a significant reduction in energy consumption of around 4.6TWh for the whole of Europe in 2030, based on current market pictures for appliances using correction factors.

The analysis is illustrative and not intended to advocate the removal of the factors principally as an energy saving option but does show the comparative effects of the different correction factors. For the UK the frost-free factor would theoretically have the greatest effect due to the popularity of this type of appliance. In relation to energy consumption in 2030, the removal of the frost-free factor would result in nearly 50% of the energy reduction compared to other factors.

Verification tolerances

The latest domestic refrigeration energy label and ecodesign Regulations set out a verification procedure for market surveillance purposes which states verification tolerances of 3% for volume measurements and 10% for energy consumption.

The performance of appliances compared to their declared energy value is important in ensuring that the information given to consumers is robust and an appliance performs as expected based on this information.

Verification tolerances allow compliance organisations to carry out market surveillance to ensure declared information is accurate within given parameters.

The conclusion is based on results of a ring test organised by the European manufacturers association in collaboration with various test laboratories to consider the current variation between test measurements, along with data for a European-wide test project.

The current tolerance is tighter than in previous Regulations as a result of manufacturers taking more responsibility and account of appliance production variability. The tolerance should only be accounting for differences between testing laboratories and should not be used by manufacturers to deliberately make lower energy claims than appropriate, as has been reported by the UK market surveillance authority and also seen in the analysis of test results from across Europe and in the UK.

The current level of tolerance and two stage testing regime is still considered to be appropriate.

Volume measurements

The compartment volume measurement is critical when calculating the Energy Efficiency Index; a larger declared volume gives a better (lower) Energy Efficiency Index.

There is inconsistency across the industry in the approach to volume measurement and set up of appliances in relation to the use of freezer drawers for energy consumption tests and efficiency calculations. Some manufacturers remove all or just some of the freezer drawers during testing whilst others have these elements in place, despite the test standard stating that appliances should be “set up as in service in accordance with manufacturer's instructions”. This inconsistency has been clearly illustrated by a pan-European test project where the load plans from manufacturers showed differences in their approach.

The variety of approaches leads to inconsistencies in the data behind the energy efficiency calculation and consumers are ignorant of the fact that they may not be comparing like with like when using the energy label information. The difference in volume with and without drawers can mean a difference of one energy label class. It also goes against the principle of a test standard specifying a methodology for all parties to use.

This issue has been discussed by standards organisations for many years but there is a possibility that a new proposed IEC standard may specify an alternative approach that avoids the interpretations contributing to the current inconsistencies.

Overall recommendations

The recommendations from this research are:

- Climate class correction factor - Remove
- Built-in correction factor - Remove
- Chill compartment factor - Remove
- Frost-free correction factor - Reduce
- Verification tolerances - Retain current levels and approach
- Volume Measurements - Clarify test standard

2 Report summary

2.1 Introduction

Energy labelling for refrigerating appliances became mandatory with the implementation of the 1994 energy label Directive. The aim of this policy measure was twofold; to inform consumers of the relative energy efficiencies of appliances when making purchasing decisions and to encourage manufacturers to provide more efficient appliances, both with the outcome of reducing overall energy consumption attributed to this appliance sector.

With revisions to the energy labelling Regulations and the introduction of minimum energy performance standards Regulations the calculation of the energy efficiency index (EEI) used to classify the energy performance of appliances, has also changed slightly. The energy efficiency of an appliance is expressed by comparing the actual energy consumed by a given sized appliance with a standard energy consumption value determined from the volume and operating temperature of the appliance (equivalent volume). Coefficients (M and N) are applied to the calculation of the standard consumption. The equations given below are a simplified way of representing how the calculation of the EEI is built up from the characteristics of the appliance. The thermodynamic factor used in the equivalent volume calculation is dependent upon the operating temperature of the compartment being assessed.

EEI* = *Actual energy consumption* / *Standard energy consumption

Standard energy consumption* = *Equivalent volume* x *M* + *N

Equivalent volume* = *Volume* x *Thermodynamic factor* x *applicable Correction Factors

Correction factors give an energy bonus to appliances eligible to use them compared to similar appliances; they are able to use more energy to achieve an energy efficiency class than if the correction factor was not there. The magnitude of this bonus depends upon the type of refrigerating appliance and the storage compartment volume. All the correction factors applied to the calculation of the equivalent volume, except the ST climate class, apply a 1.2 factor. For ST appliances a factor of 1.1 is applied to the calculation of the equivalent volume. The 1.2 factor equates to around a 5% energy bonus, i.e. the appliance is able to use 5% more energy to achieve a particular EEI than if the correction factor was not used. When actual appliances on the market are used to evaluate the removal of the correction factor the magnitude of the bonus is anywhere between 2.2% for the ST factor on fridges to around 8% to 9% for a 1.2 factor applied to fridge-freezers and fridges. The differences arise because of the contribution of the operating temperature of a compartment and also the volume in the EEI calculation. The correction factors generally give a slightly greater bonus to larger appliances.

2.2 Correction factors use

Correction factors are used to normalise differences that occur due to testing procedures or evaluations that would not allow appropriate comparisons or misrepresent the comparative energy use. They give an energy bonus to the appliance by increasing the value of the standard consumption (by increasing the equivalent volume). The larger the standard consumption compared to the actual consumption, the lower the EEI (greater efficiency). The correction factors currently applicable are:

- Climate class; for appliances designed to work in the warmest climatic conditions (tropical and subtropical classed appliances),
- Frost-free; for frost-free appliances,
- Built-in; for built-in appliances with particular width restrictions
- Chill compartment; for appliances with chill compartments.

It is these correction factors that are the focus of this report. The key considerations are:

- the proportion of the market that each correction factor is applicable to,
- whether there has been any market distortion due to the advantages in the use of a correction factor,
- the functional benefits offered by appliances with characteristics that lend themselves to correction factors,
- comparing the technological justifications for the correction factors,
- assessing whether the correction factors are still appropriate, and are set at the correct level.

Additionally, an impact assessment has been used to consider the effects on the market if the correction factors were removed, by calculating the improvements in performance that would be necessary to maintain current levels of efficiency without the correction factors.

As prescribed in the EU energy label framework Directive, the information communicated to consumers needs to be accurate, relevant and comparable in order that it can influence the end-user's choice in favour of those products which consume less energy and other essential resources. For this reason, the determination of the energy efficiency index should only use correction factors where the result still provides appropriate comparisons across the range of appliances potential purchasers are considering. Consumers are not aware of the aspects that contribute to the efficiency, and should not need to be, but should be confident that they are comparing like with like and are given appropriate choices of appliances to suit their needs.

Of the four correction factors reviewed, the frost-free factor could be considered to be the only one that actually *corrects* for anomalies between the energy used during the tests, compared to a similar appliance without this characteristic. All the other factors are a compensation for a design characteristic that costs more in energy use terms unless additional modifications are made by the manufacturer that could increase the cost of the appliance. For this reason the recommendations from this research are:

- the removal of the climate class, built-in, and chill compartments correction factors,
- consideration of a reduction in the frost-free correction factor.

2.3 Climate class correction factor

The climate class factor is the only one that might be considered to have resulted in an increase in the prevalence of appliance eligible to use the correction factor. Around 80% of appliances available in Europe have a maximum climate class of ST or T and many of these are multi-climate class such as SN to T. Historical market data suggests that the availability of appliances of these classes was already growing prior to the introduction of the correction factor in 2004, and there are also other factors that could have contributed to the increased availability of these, and also multiple climate class appliances; in a widening consumer market, with greater competitive pressures, some manufacturers have rationalised the diversity of the appliances produced. Providing multiple climate class appliances allows them to have efficient production lines that can service consumers across the whole of Europe, and the wider global market. Having said that, it is expected that if the correction factor is there and it offers a marketing edge in terms of efficiency class then manufacturers are going to use it if it is possible without accruing too much cost to manufacturing. ST and T class appliances still have to be able to provide appropriate storage temperatures in lower ambient temperatures specified for Normal (N) class appliances so the increase in maximum climate class ST and T appliances is not replacing the availability of appliances suitable for N class conditions.

The climate class correction factor is used by a proportion of the refrigeration appliance market that is probably not acknowledged as being any different by a consumer purchasing an appliance. The climate class is not a characteristic that is readily promoted to consumers, many of whom would probably not know what the classifications mean. When presented with a range of appliances, some using the factor and some not, the consumer, who may not need to take advantage of a T or ST appliance characteristic, is not comparing like with like when looking at the energy efficiency index.

This correction factor is applied to appliances that are designed to cope with hotter ambient temperatures. The factor is designed to compensate for the fact that to offer this functionality the design of the appliance means that it may not be able to operate as efficiently at the energy label test temperature. A technical assessment of the components used for different class appliances and a review of the efficiency performances of different climate class appliances suggests that if appropriate components are utilised then the climate class classifications are not necessary. Only a minority of consumers, around 10%, perceive their room with the refrigerator to have a maximum temperature of hotter than 36°C yet around 80% of appliances available in Europe are ST and T class appliances.

2.4 Frost-free correction factor

Frost-free appliances are generally increasing in popularity and this is assumed to be due to the convenience that this feature offers to consumers. Around 60% of fridge-freezers sold in Great Britain in 2010 were frost-free. Across Europe nearly 30% of cold appliance models available are frost-free.

The frost-free factor is the only correction factor with some justification on the basis that, when compared to a static appliance that essentially provides the same service to the consumer, the frost-free appliance uses more energy during testing. The level of the correction factor compensates for the extra energy used and this closely matches the extra energy used by the defrost cycle of a frost-free appliance. However, this corrects for the extra energy used in standard test conditions, the energy in actual use is not considered compared to the extra energy used by a frosted up static appliance. There is very little information on the effect that ice accumulation has on a static appliance in terms of extra energy use. One laboratory assessment suggested increased consumption of around 22% for a frosted evaporator, but this does not necessarily represent the situation in consumer homes. More data is needed to fully evaluate the extra energy used by frost-free appliances to perform the defrost cycle compared to the extra energy used by frosted up static appliances in consumer use.

Given that market data indicates that there are appliances, both frost-free and static, that have similar energy consumption for a given volume of storage, it can be concluded that technology is available to produce frost-free appliances that are as efficient as static appliances even without the correction factor. A theoretical analysis of the technologies used for frost-free supports this and it is therefore thought that a reduction in the level of the frost-free correction factor would be appropriate to encourage optimum design and technology implementation.

2.5 Built-in correction factor

Built-in appliances which are eligible for the correction factor because they have a width of less than 58cm are a small minority of the market in the UK. European market data does not specify appliance width so it is difficult to conclude on the prevalence of appliances eligible to use this correction factor. There is nothing in the testing of these appliances that is different to any other built-in appliances so no correction in the calculation of energy efficiency is necessary.

The width restrictions of built-in refrigerating appliances means that any improvements in efficiency achieved by improved insulation is detrimental on the storage volume for the consumer, unless vacuum insulated panels are used and these are still considered too expensive to be economically viable. The fundamental flaw in the use of this correction factor is that is disguises the deficiencies of a particular design that restricts the storage capacity of an appliance. A consumer comparing the efficiency of a 56cm wide appliance in a showroom next to a 59cm wide appliance is not comparing energy efficiency ratings calculated in the same way, the former can use about 5% more energy but achieve the same energy efficiency index. A consumer may conclude that the smaller appliance is okay because according to its EEI it appears as efficient as a slightly wider one, but this is not the case, the correction factor just makes it look as efficient.

Freestanding appliances with widths of less than 58cm are not eligible to use the factor even though there are more freestanding appliances of this width available in the UK than built-in appliances of this width range.

The built-in factor is specific to a very small sector of the built-in market and on appliances that are amongst the smallest appliances offered to consumers. It is not thought that the factor is encouraging a growth in this area. Built-in appliances on the whole are becoming more popular due to kitchen fashions, but any connection with the correction factor for built-in is thought to be insignificant.

2.6 Chill compartment factor

Chill compartments are a feature that offers enhancement to the storage facilities of fridges but they are not essential for normal storage of fresh food requiring refrigeration. They are designed to prolong the storage time and quality of food and are particularly suitable to highly perishable foods, but this is a feature that comes at a price and is still not commonly found on the market.

The chill compartment factor is a bonus given to appliances that have a design feature which uses more energy. Like a frozen food compartment incorporated into a fridge, they present an additional energy demand that should be communicated to the consumer. The chill compartment correction factor should be removed on the basis that an appliance using more energy, because it provides different storage facilities, is going to be less efficient and this level of efficiency should be accurately portrayed on the energy label.

As it stands, the energy bonus is not necessarily representative of the extra energy used by all appliances with a chill compartment. The 50kWh factor applies to compartments able to maintain chill temperatures between -2 and +3°C that are over 15 litres in volume. It is irrespective of the size of the compartment once it is over this minimum level and was prescribed based on an assessment of the extra energy of appliances with chill compartments around 40 litres. This size is not necessarily representative of the range of chill compartments available today and means that appliances with chill compartments closer to the 15 litres minimum that use the factor are receiving potentially a disproportionate advantage.

2.7 Correction factors impact assessment

An analysis has been carried out which models the energy reduction that would result if correction factors were removed from the calculation of the energy efficiency index. If the correction factors were removed it has been assumed that manufacturers would reduce the energy consumption, through design measures, which would ensure appliances retain the energy efficiency index (EEI) achieved using the correction factors, or at least meet the minimum energy requirements set by ecodesign Regulations. The analysis is for illustrative purposes and not intended to demonstrate a method of achieving energy savings, as there are alternative options for achieving this, for example regulatory policies such as minimum standards and other ecodesign requirements.

Market data has been used to evaluate the level of improvement that would be necessary in this situation and also assess the proportion of the market that would be affected by the removal of the factors.

A projection for the resultant reduction in energy use has been calculated for the four types of refrigerating appliances for the UK analysis, based on similar modelling undertaken for Defra by the Market Transformation Programme. For a European perspective a simpler modelling has been used reflecting that undertaken for the EuP preparatory study (in 2007) which considered all refrigerators together and all freezers.

The energy reductions in 2030 for the UK, for all refrigerating appliances with all the correction factors removed, is around 290GWh/year. For the EU (including UK) this reduction is around 4,560GWh/year. These represent noticeable financial benefits to consumers and also noticeable reduction in carbon emissions. For comparison, the prediction for the effect of the current ecodesign and energy labelling Regulations was for a combined energy saving of 6TWh in 2020.

Increasing the efficiency of the products which have had the correction factors removed, to reach the same efficiency levels as when the corrections factors are present, may increase the cost of these appliances to consumers. A simple costs-per-appliance improvement approach, based on the EuP preparatory study has been used, with a small annual reduction over time. This analysis suggests that any increase in consumer costs are more than outweighed by the financial benefits to consumers and society.

2.8 Verification tolerances

The issue of verification tolerances has been considered as part of this review of the energy labelling Regulation as the performance of appliances compared to declared values is important in ensuring that the information given to consumers is robust and an appliance performs as expected based on this information. It is inappropriate if a consumer purchases an appliance with a lower energy consumption compared to another if the former uses more energy in use due to poorer quality control or inappropriate claims by the manufacturer. The verification tolerances for all appliances are now specified in any revised energy label and/or ecodesign regulations. As way of an example, the latest draft[1] for domestic tumble driers has a reduced energy measurement tolerance at 6% compared to 10% in the previous draft.

[1] Commission delegated regulation (EU) No.../.. of 1.03.2012 supplementing Direction 2010/30/EU for the European Parliament and of the Council with regard to energy labelling of household tumble driers. Circulated to Defra March 2012

The latest domestic refrigeration energy label and ecodesign Directives set out a verification procedure for market surveillance purposes which states verification tolerances of 3% for volume measurements and 10% for energy consumption. It is a two stage process, allowing three further samples to be evaluated if the first sample is outside the tolerance level. This approach and level of tolerance is still considered to be appropriate.

The tolerance for energy consumption has been reduced from 15%, for the first sample, in previous labelling Regulations due to the assumption that manufacturers are able to, and going to, consider appliance variability when declaring energy consumption values. The 10% tolerance is therefore to account for any variability between testing organisations. A two stage verification process is necessary to take account of any rogue samples.

On the basis of the CECED 2009 ring test the difference in energy consumption results between laboratories is in the range of 8% to 16% compared to the mean value of the results, depending upon the appliance. There is however an issue associated with the difference in recorded consumption of the appliance at the start and end of the tests. This may be due to the lack of repeatability of the performance of the appliance samples or issues associated with the transportation of the appliances, although the differences are greater with some samples than others. The results do illustrate that there is a lack of repeatability and this could be due to deficiencies in the test method which should be investigated further.

From a review of the results from the ATLETE project and UK market surveillance activities it seems likely that some manufacturers have used some of the 15% tolerance when setting the energy label claimed value. The above tests were carried out when the Regulation still stipulated 15% for the first sample. Manufacturers may have assumed that any tests were going to give accurate results and that their production methods were able to produce consistent appliances. They have therefore declared energy consumption values that were lower than those they expected to achieve when products were tested and were confident that the results would fall within the tolerance value allowed for a single sample. The range of results suggests that manufacturers are declaring a value lower than that which they expect to achieve under standard conditions. If manufacturers were not using the tolerance then the range of results would distribute more evenly around a zero point with an equal distribution curve when plotted.

The results of the ATLETE project gave an average of 10% difference between declared and measured values for all the appliances tested (excluding 2 obvious outliers), but with a standard deviation of around 17%. Nearly 40% of the samples had measured values with a difference from the claimed value of more than 15%.

UK market surveillance tests gave an average difference from the claim of 5.4%, all in excess, but some of the samples tested were selected on the basis that they might fail. The UK surveillance body, the NMO, has reported that manufacturers are deliberately declaring that their products have better energy use characteristics than can be demonstrated by independent testing or internal production control. Continues policing is necessary to eliminate any abuse of the tolerances in declaring energy label information.

2.9 Volume measurements

Another issue associated with appropriate comparative testing and energy efficiency calculation is the measurement of volume for freezer compartments. Currently there are a variety of practices when it comes to the set up of a freezer in relation to drawer arrangement.

Removal of the drawers from a freezer compartment during testing will allow for a larger volume measurement and also possibly affect the energy consumption during standard tests. The difference in the volume measurement compared to the value measured with the drawers in place will have a significant effect on the energy efficiency index calculation, ultimately giving a better EEI than if the drawers are left in. The difference in volume measurement between an appliance with the drawers in place and with all, or all but the bottom drawer removed, (a configuration often adopted by manufacturers) may be between 2% and 15% depending upon the appliance. This difference can mean the difference of one letter when the energy efficiency index is calculated

For testing purposes, appliances should be set up as 'in service', with all fittings supplied in place, in other words with an arrangements of fittings that are expected to be used by consumers. The user instructions provided with refrigerating appliances rarely suggest the removal of freezer drawers or shelves. Where a suggestion is made this is interpreted as being for exceptional use when large items such as a large joint of meat needs to be accommodated.

Conversely, when manufacturers provide instructions for standard testing of an appliance (not in the user handbook) a loading plan may frequently be provided showing drawers removed. The ATLETE project illustrated the inconsistency that occurs whereby some manufacturers provide load plans or instructions with some or all drawers removed, whilst others provided load plans that retained the drawers.

Adding to the variability of the interpretation of the standard is the fact that it is not a case of all the drawers in or all of them out, quite often the instruction is to remove all but the bottom drawer. It is difficult to understand how manufacturers can claim that this practice follows the requirements of the standard. The reason for this is assumed to be that the lower drawer is next to the compressor housing and will shield the load from any heat transferred from the compressor.

A larger volume recorded, when an appliance is measured without drawers, will result in a larger equivalent volume. This larger equivalent volume results in a larger standard consumption (SC). As the energy efficiency index is the actual energy consumption divided by the SC the result is a better energy efficiency rating.

There is no significant set of tests that compares the energy consumption used by appliances with and without the drawers. Depending upon the configuration of the drawers; all or just some of the drawers removed can result in an increase or decrease in the energy consumption. An increase may be due to the easier ingress of heat to the test load, and a decrease may be due to more effective air flow, but either way it is likely to depend upon the appliance design. Any increase in consumption due to the removal of drawers is expected to be negated by the larger volume measured and used in the energy efficiency index calculation.

3 Introduction and objectives

3.1 Background

The information presented in this report aims to bring together existing published information along with evaluated market and test data to create an evidence based discussion regarding the appropriateness of the correction factors, the level of verification tolerances stated in the ecodesign and energy label Directives, and the issue of appropriate volume measurements.

The project has been commissioned by Defra in the UK but aims to reflect a European perspective, where information is available. The project has also been overseen by a Steering Group made up of organisations across Europe including the Danish Technological Institute
Centre for Refrigeration & Heat Pump Technology, the Swedish Energy Agency, the Federal Ministry of Economics and Technology - Consumer goods industries - in Germany, the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) in Italy and the NL Agency, as well as representatives from the European appliance manufacturers body CECED. The conclusions of the study represent the independent view point of the consultants.

Since the publication of the first Directive[2] for energy labelling of refrigeration appliances in 1994, followed by the Minimum Energy Performance Standards (MEPS) regulation in1996[3] and extension of the labelling to A++ in 2003[4], the policies for refrigerated appliances have evolved to specify current requirements for ecodesign and energy labelling. During the revision and improvement processes the introduction of correction factors has attempted to normalise the comparative efficiencies of appliances with different characteristics. As raised by Defra during the consultation process for the, then proposed, ecodesign regulation, there was some concern that these correction factors unfairly benefit some types of appliances and potentially inhibit the reduction of energy consumption. Through changes in product design and market penetrations the use of correction factors may have distorted the range of products available to consumers and additionally the information provided to consumers is not necessarily transparent.

Additionally, there have been concerns that verification tolerances initially introduced to take account of both the uncertainty in the test laboratories measurement and the expected variability in model performance, have been used to benefit manufacturers' appliance performance claims and limit the effectiveness of compliance checking. During the revision of the energy labelling and the setting of ecodesign requirements, the improvements in production line quality control are understood to have contributed to a reduction in the size of the tolerances and ensure more accurate declarations, which ultimately are used to model total energy consumption and steer future policy activities.

[2] Commission Directive 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations

[3] Commission Directive 96/57/EC efficiency requirements for household electric refrigerators, freezers and their combinations

[4] Commission Directive 2003/66/EC amending Directive 94/2/EC implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations

In order to have an accurate and transparent energy performance measurement there needs to be consistency in the testing regimes. The area of volume measurement has presented some debate regarding the removal of drawers during volume and energy measurements. The ecodesign regulation has attempted to draw further attention to this issue in requiring manufacturers to provide advice in instruction books, but this area still needs some investigation to consider appropriate and best practice.

The European Commission (EC) is obliged to review the regulations within five years of implementation, i.e. by 2014. It is therefore timely for the issue of correction factors and other issues highlighted in this report to be considered. The findings of this research will then be available for consideration with sufficient time for any mandates to be instructed to standards organisations, and further reviews and consultations prior to the EC formal review.

3.2 Project scope

The overall objectives for this research were to:

- see if the use of correction factors is still justified and if they are whether they are still at an appropriate level in current legislation,
- see if the use of verification tolerances is still justified, and if they are whether they are still at an appropriate level in current legislation.

In the process the research was required to assess:

- whether the current calculation method of the energy efficiency index allows a fair comparison of products with different configurations;
- whether it also allows consumers to correctly discriminate between appliances on the basis of energy efficiency.

The research also aimed to consider whether some improvements may be made to optimise the energy savings potential of household refrigerating appliances and transparency of information.

This project considers the correction factors currently applicable when calculating the energy efficiency of domestic refrigeration appliances as well as verification tolerance and volume measurement issues, and also attempts to quantify any distorting effect of correction factors on UK and EU-wide CO_2 and energy consumption.

This report is laid out to consider each of these areas under the task headings below and also the general effect of correction factors for the calculation of energy efficiency compared to real use consumption.

Task 1. Climate class correction factor
Task 2. Frost-free correction factor
Task 3. Built-in correction factor
Task 4. Chill compartment factor
Task 5. Real use consumption and correction factor benefits
Task 6. Review of correction factors cost benefit impact analysis
Task 7. Verification tolerances
Task 8. Volume measurements

The summary and discussion sections towards the end of each section address the questions presented in the original project specification for this research.

3.3 Energy labelling and correction factors

There are features and technologies on some products within an appliance category that either affects the performance of an appliance during standard testing compared to in-use and/or offer benefits to consumers. These differences may not be initially apparent to a consumer choosing or comparing appliances.

It is expected that when presented with a range of appliances consumers would assume that the energy label provides a simple comparative tool. The coloured efficiency arrows and letters are recognisable and simple. Research suggests that consumers are more likely to use these indicators over a comparison of the actual energy consumption given on the label. The annual energy consumption (kWh/year) provides the benchmark but the energy efficiency represented by the letter may include one or more correction factors, depending on to the characteristics of the appliance.

As energy labelling is designed to help consumers to make informed decisions that will reduce energy consumption, only those functions where energy saving is not demonstrated by standard testing should be considered when portraying efficiency information to consumers. Some current correction factors are used to improve the reported energy efficiency of appliances that have design aspects that result in an appliance using more energy than a similar appliance without such a characteristic or feature (eg. the chill compartment and built-in factor).

Correction factors should only be justified if they are used in association with a characteristic that results in more energy consumed during the test but not necessarily in real use and are present on appliances in a subsector of a refrigerating appliance category. An example of a subsector is a fridge-freezer which is frost-free and sold alongside static fridge-freezers.

In some countries the use of correction factors (or similar adjustments) is avoided by having a large range of different categories of appliance. Different calculation methods can then be applied to each of these, sometimes numerous, categories. In Europe the smaller range of appliance categories seems appropriate to represent the types of appliance that consumers are going to be comparing in the broadest sense, eg. a fridge-freezer or a larder fridge. If a consumer is going to purchase a fridge-freezer they should be able to compare across the range of all fridge-freezers that are available to them, for example, with and without frost-free technology or a chill compartment, and make direct comparisons between the efficiency of all the appliances within the category regardless of functional characteristics. In the retail environment appliances are unlikely to be segregated according to characteristics or functional difference such with or without a chill compartment, so these differences may not be apparent to consumers.

The energy label communicates energy consumption in terms of an annual energy consumption which is declared using a standard test method, and the energy efficiency class as a letter aligned to a coloured arrow. There is some argument that consumers are able to use the annual energy consumption in kWh to compare appliances and this value has had no normalisation or adjustment. However, the energy efficiency class is a simpler communication tool for consumers. Correction factors used to give energy bonuses in the calculation of the efficiency index potentially obscure any comparative benchmarking if a consumer is comparing across a range of appliances, within a category, which includes various subsets of appliances each with different characteristics that may or may not make them eligible to use a correction factor.

4 Conclusions and interpretation

The latest energy label Directive 2010/30/EU[5], which replaced the original energy label framework Directive 92/75/EEC, states that:

"*the provision of accurate, relevant and comparable information on the specific energy consumption of energy-related products should influence the end-user's choice in favour of those products which consume or indirectly result in consuming less energy and other essential resources during use, thus prompting manufacturers to take steps to reduce the consumption of energy and other essential resources of the products which they manufacture.*"

On this basis the calculation of the energy efficiency index, itself used to indicate a level of efficiency performance to consumers via the class letter, should be as consistent and comparable between different types of products offering the same service to the consumer. There are multiple circumstances where correction factors can be useful including normalising any differences that occur due to testing procedures or evaluations that would not allow appropriate comparisons (due to design or functional differences) or misrepresent the comparative energy use.

Of the four correction factors applicable to the calculation of the energy efficiency index for refrigerating appliances, only the climate class and frost-free factors could be considered to compensate for differences in expected energy use in real use compared to the standard energy test, or differences between types of appliances that are only apparent during use. The climate class factor applied to ST and T climate class appliances is intended to consider any performance differences of compressors suitable for different climate conditions. The frost-free correction factor attempts to compensate for the additional energy used for the defrost operation during standard testing and makes frost-free appliances difficult to compare with similar static appliances at the point of purchase.

The built-in and chill compartment factors provide bonuses for appliances due to design aspects that are detrimental to the appliances' energy efficiency performance both in standard tests and in real use. Even though the design and functions may be seen as beneficial and convenient for consumers, the correction factors hide the additional energy due to such design aspects.

The following conclusions have been made regarding the use of correction factors and are discussed further in the following sections:

- Climate class correction factor - remove
- Frost-free correction factor - reduce
- Built-in correction factor - remove
- Chill compartment factor - remove

5 DIRECTIVE 2010/30/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.

Climate class correction factor

This factor was introduced to compensate for the fact that to enable an appliance to work at higher ambient temperatures than those of the standard test the components used means that it may not be able to operate as efficiently during the energy label test as in warmer consumer conditions. From a technical perspective, this correction factor could be removed on the basis that appliances can be produced that are efficient for all climate conditions if appropriate technology and components are utilised. Additionally, from a market position the proliferation of multi-climate class appliances means that energy efficiency claims are being made using a correction factor bonus on appliances that are not necessarily destined for the climate conditions pertaining to the use of the factor.

Whilst it is acknowledged that the energy consumption test at an ambient temperature of 25°C does not necessarily represent all typical use, it provides a suitable benchmark for comparisons between appliances. The actual consumption in consumer houses may differ from that claimed on the label, due to installation and habits, but consumers need a simple comparative message that the energy class gives. The information on the appropriate ambient temperatures for an appliance is not a key consideration for consumers and not apparent when looking at an array of products on sale. For this reason the use of the correction factor is not necessarily relevant or acknowledgeable for consumers choosing between similar appliances. It is possible to look at two appliances offering the same characteristics but with different climate class classifications that have different energy efficiency classes due to the use of the climate class correction factor.

Frost-free correction factor

Of all the correction factors, the frost-free correction factor is probably the most defendable. The bonus it gives compensates for the difference in performance during the standard test compared to the performance of static appliances during consumer use. Whilst the correction factor appears to be in line with the extra energy required for the frost-free defrosting operation during standard testing, it is not known how this compares with the extra energy used by static appliances when they are frosted up.

There is some evidence of frost-free appliances that do not use much more energy than their static counterparts and, for this reason, it is felt that a reduction in the correction factor should be considered to stimulate more efficiency improvements for a sector of the market that is expected to increase in size.

Built-in correction factor

The correction factor cannot be justified due to the different construction comparisons between freestanding and built-in appliances as they are considered to be different types of appliance and therefore not comparable. Consumers are unlikely to be comparing a built-in appliance alongside a freestanding one. Additionally, the factor is only applicable to the smaller width built-in appliances. The correction factor benefits narrow built-in appliances on the basis that any additional efficiency gains by thicker insulation has a detrimental effect on the storage volume; it increase the equivalent volume and therefore the standard energy consumption of an appliance. So the EEI is essentially determined by comparing the actual energy consumption of the small appliances with a standard appliance (represented by the SC) that is larger.

The correction factor currently supports a particular sector of the market that demonstrates poor comparable efficiency or practical benefits to consumers. Consumers opting to compromise on storage volume by having a built-in appliance should be able to see the corresponding compromise in the efficiency of the appliance.

Chill compartment factor

The chill compartment correction factor should be removed on the basis that an appliance using more energy, because it provides different storage facilities, is going to be less efficient and this level of efficiency should be accurately portrayed on the energy label.

Chill compartments offer enhanced storage conditions within a fridge, but they are not essential for normal storage of fresh food requiring refrigeration. Like a frozen food compartment incorporated into a fridge, they present an additional energy demand that should be communicated to the consumer.

Impact assessment

An analysis was undertaken to consider the energy reduction that may come about if correction factors were removed. This is based on the assumption that improvements would be made to reduce energy consumption so that individual appliances would maintain the same EEI if the correction factor is taken out of the equation. The analysis is for illustrative purposes and not intended to demonstrate a method of achieving energy savings, as there are alternative options for achieving this, for example regulatory policies such as minimum standards and other ecodesign requirements.

The analysis considered the energy bonus that a correction factor offers and the proportion of appliances currently available that are eligible to use the correction factor. As well as providing predicted energy reductions the analysis illustrates the significance of the individual correction factors in the market.

For the UK the energy reduction in 2030 after the removal of all correction factors would be just under 300GWh/year. For Europe the energy reduction would be around 4.6TWh in 2030 which is not insignificant when the prediction for the effect of the current ecodesign and energy labelling Regulations was for a combined energy saving of 6TWh in 2020.

Verification tolerances

The two stage approach to testing for verification purposes allows for any rogue samples that may have been inadvertently selected for testing.

- It is agreed that this process is still appropriate.

The most recent tolerance level of 10% set for verification of energy performance is an improvement on previous Regulations and reflects improvements and/or the responsibility undertaken by manufacturers to consider, and account for, any variability of the appliances from their production lines.

The expected variability between claimed and measured values revealed through market surveillance procedures should therefore only be attributed to the lack of reproducibility between test laboratories.

- An evaluation of industry and laboratory measurements confirms that the current tolerance level is still appropriate.

Recent market surveillance and pan-European testing reviewed for this research were undertaken under the Regulation allowing a 15% difference between claimed and measured values. The results support the suspicions that manufacturers have been using the tolerances to their advantage when declaring energy consumption values. It is essential that enforcement authorities maintain close vigilance on such practices and work with manufacturers to improve the accuracy of the data used for declarations.

Associated with the issue of verification and tolerances, there needs to be further consideration and attention to the reproducibility of the test methods used for energy label declarations. This is needed to service the fundamental requirement that the data on the energy label should be accurate and comparable.

Volume measurements

There is a distinct variation between the way manufacturers test appliances in relation to the inclusion or removal of freezer drawers. This affects the volume measurement, critical to the calculation of the energy efficiency index and also the energy consumption. Regardless of the fact that the removal of the drawers does not represent the way in which an appliances is used, the different practices by different manufacturers means that the information on the label is not determined in a comparable way.

A consistent interpretation of the standard, ideally testing the appliance with freezer drawers in place needs to be emphasised with manufacturers. This is necessary to prevent the undermining of the principles of using harmonised test standards and ensure consumers are given consistent comparable information.

Correction factors - general approach

The fundamental methodology for calculating the energy efficiency index of refrigerated appliances was devised for the introduction of the energy label in 1994. Since then there have been some additions and changes to factors and coefficients used in the calculation. In the process of reviewing the correction factors it has been acknowledged that the effect of correction factors in increasing the equivalent volume benefits appliances as the compartment volumes increase. Whilst correction factors are intended to provide more appropriate comparisons between appliances and correct for undesired effects in the methodology for calculating the EEI, they are also having a distorting effect dependent upon the volume of the appliance.

In comparison to the basic use of correction factors, this issue is not thought to be of huge significance as it is assumed that consumers will be comparing appliances of similar size. One means of addressing this element could be to use an offset factor in addition to the correction factor.

5 Methods and approach

This project aims to compile the evidence surrounding the use of the correction factors for domestic refrigerating appliances. It is intended that the report compiles information and evidence from the market, surveillance exercises, published literature and technical analysis to allow a balanced discussion and consideration of the appropriateness and levels of correction factors.

For each correction factor the information covers the key issues detailed in the project scope. Generally this is:

- looking at the market to consider trends in appliances with the particular characteristic
- comparing appliances with and without a given characteristic to identify differences in energy use
- assessing whether market shares have been distorted by the use of correction factors.

For verification tolerances a review of appliance design and performance will consider whether the current expectations in allowable tolerances are appropriate. There are two main considerations when looking at tolerances, those of the manufacturing variations between appliances of the same specification coming from the same production line and also the variation in test results obtained by different test establishments. The verification tolerances given in the ErP and energy labelling directives are intended to address the latter, but in this report both will be considered and reviewed.

Notes:
This report uses x.y notation, whereas some EC reports use x,y notation for the decimal point.
Where stated, the data from GfK[6] includes market data collected and analysed to cover retail sales for Great Britain (GB) only, as this is the only geographical coverage of the data set available from the UK Market Transformation Programme.

5.1 The Energy Efficiency Index

The methods used for calculating the energy efficiency index (EEI) can be found in Annex A. This includes the efficiency classes attributed according to the different energy labelling Directives and minimum standards for ecodesign requirements.

5.2 Resources

The project aims to bring together existing information and evidence with limited new appliance assessments undertaken. There are three main types of data used for this research as briefly considered below:

Market Data
Market data from the market research organisation GfK have been used to consider appliance availability and characteristics related to correction factors. The most readily

[6] GfK are a global market research organisation (www.gfk.com)

available information is from the UK and this has been supplemented by information from the CECED database provided via the EuP preparatory studies and more recent data direct from CECED and directly, as well as projects such as ATLETE[7].

Technical Data
The research team has used its experience of the mechanics of refrigeration appliances and appreciation of the test standards and associated issues. Knowledge from carrying out testing for manufacturers, market surveillance organisations and other government bodies has been drawn upon, including test parameters such as energy consumption, storage volume and storage temperatures.

Academic and Policy Research
Previously published research materials relating to the issues covered by this project have been evaluated. Key sources referred to include the Save Cold II study, the EuP Preparatory Studies for Ecodesign Requirements Lot 13, as well as numerous other research papers available in this area of work.

5.3 Impact assessment modelling

For each issue covered in this project, an assessment of the impacts on the UK and EU wide CO_2 emissions and energy consumption has been carried out using a stock-sales model. This draws much of the basic evidence such as number of households and ownership, to consider stock, from information in previous studies such at the EuP preparatory study for Europe and MTP modelling for the UK. Information on the effects of the correction factors has been worked into different scenarios to provide comparative outputs to show marginal changes that occur if correction factors are removed from the Regulations. Details of the methodology can be found in Annex G.

[7] The ATLETE project was implemented by CECED (European Committee of Domestic Equipment Manufacturers) and the European Commission in 2009 with the aim of improving market surveillance in EU member states and furthering energy efficiency as a selling point. www.atlete.eu

6 Refrigeration energy class calculations and correction factors

Since the publication of the Commission Directive 94/2/EC, implementing Council Directive 92/75/EEC, which defines energy labelling requirements for household electric refrigerators, freezers and their combinations[8] in 1994, the regulation has evolved to the current requirements for ecodesign and energy labelling. During the revision and improvement processes, the introduction of correction factors has attempted to normalise the comparative efficiencies of appliances with different characteristics.

The methods used for calculating the energy efficiency index (EEI) including the use of correction factors, categories of appliances and coefficient (M and N) values can be found in Annex A.

Appliances are attributed an energy efficiency class (letter) according to an energy efficiency index (EEI). This EEI is a comparison of the Annual Energy Consumption (AC)* of an appliance with a Standard Annual Energy Consumption (SC)*, the latter being a function of the volume and characteristics of the appliance.

* Annual Energy Consumption is abbreviated to AC in some Regulations and AE in others, similarly Standard Annual Energy Consumption is written as SC or SAE

The factors used in the calculations given below, and considered in this report, are:

FF Frost-free
CC Climate class
BI Built-in
CH Chill compartment

The general equation for the standard energy consumption given in kWh/y is as follows:

$$SAE_c = V_{eq} \times M + N + CH \qquad \text{Equation 1}$$

M and N are co-efficient values which vary depending upon the type of compartment and appliance.

The SAE uses the equivalent volume calculation:

Equation 2

$$V_{eq} = \left[\sum_{c=1}^{c=n} V_c \times \frac{25 - T_c}{20} \times FF_c \right] \times CC \times BI$$

V_c = storage compartment volume
T_c = the nominal temperature of the compartment(s)

[8] COMMISSION DIRECTIVE 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations

The use of correction factors presents an advantage to larger appliances. As the volume of the appliance increases, the effect on the equivalent volume calculation of the correction factors on the standard annual energy consumption also increases. The effect is less apparent for smaller appliances. Figure 1 below show the impact on the standard annual energy consumption with a correction factor of 1.2 (the most common values used) for five categories[9] of appliance.

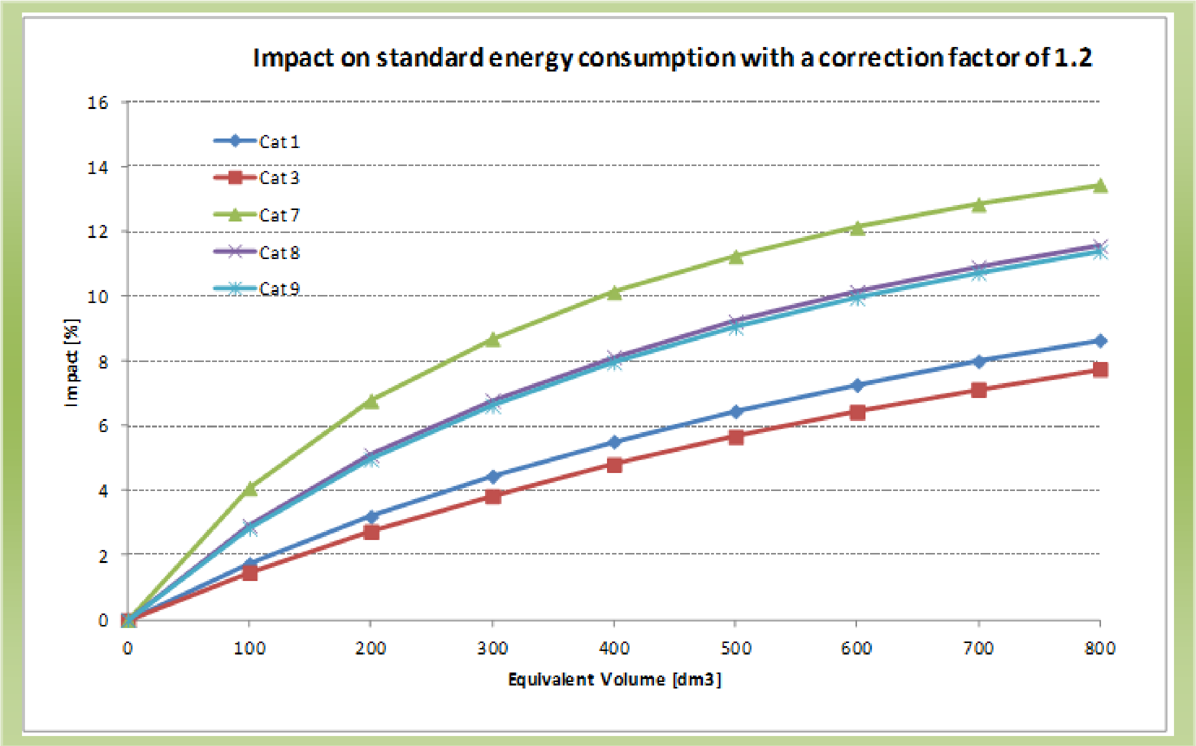

Figure 1: Impact on the standard energy consumption of a 1.2 correction factor. (Source: CECED 2011)

Additionally, Figure 2 shows a worked example of the effect on the standard annual energy consumption for a fridge-freezer applying a 1.2 factor compared to a similar appliance without the factor. This example assumes equally sized fridge and freezer compartments (with no other correction factors or allowances).

[9] Category 1: larder refrigerator; Category 3: refrigerator with no star compartment; Category 7: fridge-freezer, Category 8: upright freezer; Category 9: chest freezer

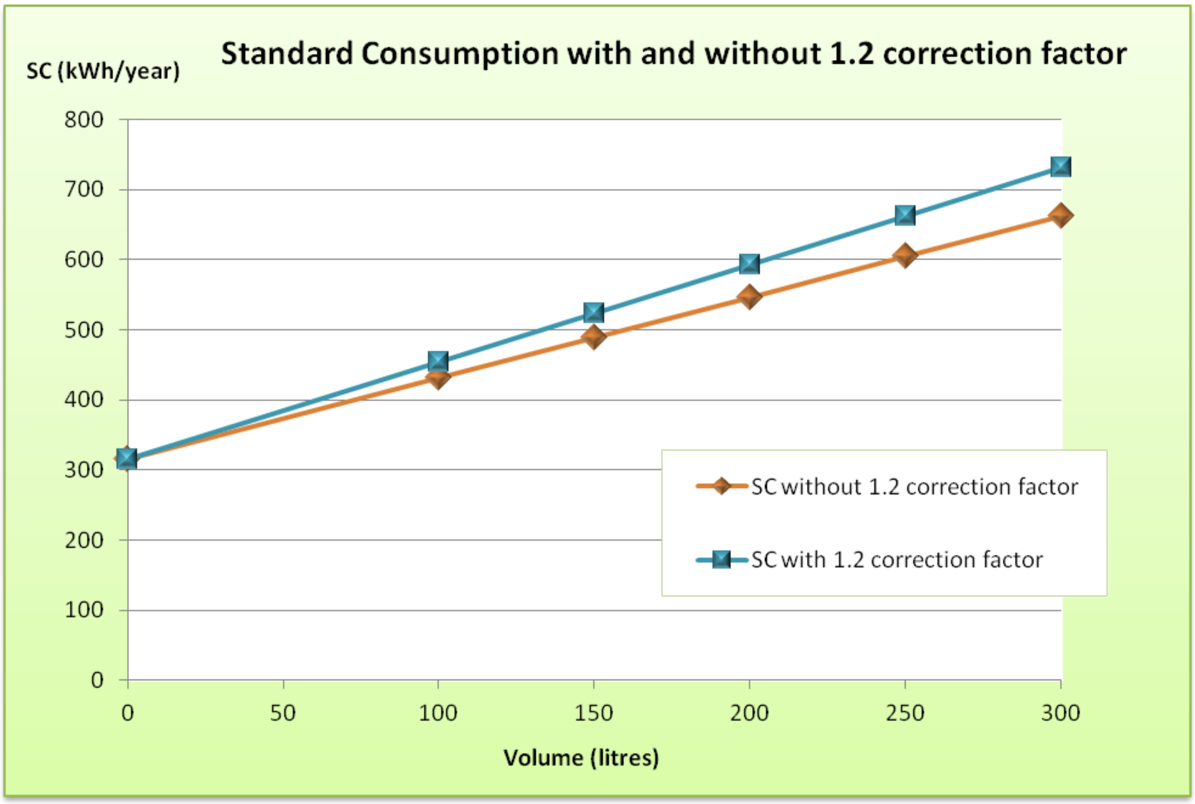

Figure 2: Standard energy consumption against volume for a fridge-freezer with and without a 1.2 correction factor applied.

The EEI calculation divides the energy consumption of the actual appliance by the standard energy consumption so the larger the standard consumption the smaller (more efficient) the EEI will be.

If the spirit of the energy efficiency calculation and use of correction factors is to provide more appropriate comparisons between appliances and correct for undesired effects in the methodology for calculating indexes, the information above illustrates an inconsistency in the effect of a correction factor across appliance volumes.

This issue is further commented on within the specific correction factor sections in this report.

7 Task 1: Climate class correction factor

7.1 Introduction

Domestic refrigeration appliances are designated a climate class by the manufacturer which identifies the climate conditions, i.e. the ambient temperature, in which an appliance is able to maintain appropriate food storage temperatures effectively. There are four different single climate classes for different ambient temperature conditions as given in Table 1 below. A range of climate classes to signify a broader spectrum of ambient temperatures is sometimes stated, ie. an appliance can be classified as an SN - T.

The refrigerating appliance supplier is obliged to include the climate class in the product fiche in accordance with Annex III of the latest energy labelling regulation (*Regulation No 1060/2010 of 28 September 2010).* It is often also given on the rating plate on the appliance.

Table 1: Climate Class Definitions and Correction Factor

Class	Symbol	Ambient Temperatures °C	Correction factor
Extended temperate	SN	+ 10 to +32	none
Normal	N	+16 to +32	none
Subtropical*	ST	+16 to + 38	1.1
Tropical*	T	+16 to +43	1.2

* the lower limit of these climate classes was reduced from 18°C to 16°C by EN ISO 15502:2005

The intention of the climate class designation is to identify appliances that are designed to cope with the different ambient temperatures across the European region. These designations were in place well before energy labelling and the energy efficiency index calculations were introduced. Appliances produced for hotter climates require design characteristics such as higher capacity compressors to cope with greater demands in maintaining appropriate food storage temperatures. In colder regions of Europe, SN appliances have been recommended to cope with cooler kitchen or utility room conditions.

The climate class correction factors are applied when calculating the equivalent volume for determining the energy efficiency index (EEI). The larger the equivalent volume, and consequently the standard consumption, the better the efficiency rating. The allowances are a factor of 1.1 [10] for ST and 1.2 for T class appliances. These factors were initially available when the energy label Directive was revised in 2003 to define A+ and A++ efficiencies, but only applied to these higher efficiency appliances to encourage appropriate technology improvements. The correction factors aimed to compensate the cost of improvements such as better and/or thicker insulation and heat exchangers to produce an appliance which will operate effectively in warmer climate areas. Under the latest regulations the factor is applied to the calculation for all appliances, regardless of the efficiency class, although due to the specific ecodesign requirements from 1st July 2012 only appliances with efficiencies of A+ or better will be permitted on the market.

[10] This report uses x.y notation, whereas some EC reports use x,y notation for the decimal point

The following paragraph appeared in the European Commission working document[11] circulated prior to the draft implementing documents for the setting of ecodesign criteria.

" The same correction factors are kept in this measure due to the fact that the high energy-efficiency levels of today (the market entry level for compressor-type refrigerating appliances will be EEI<55 one year after the enforcement of this IM) any SN or N class product can only be redesigned as an ST or T class product by the use of measures which increase its cost beyond the life-cycle optimum i.e. beyond the LLCC. The same will happen for a ST or T class product to maintain the same climate class at the decreasing of the EEI needed to comply with the new energy labelling rating."

Appliances claiming a greater range of climate classes are now common. This means that the correction factor for ST and T class may be applied to appliances sold and used in colder climates. Refrigeration appliances in colder regions may be over engineered compared to the basic requirements to fulfil their intended purpose due to the use of oversized compressors and other relevant components.

The correction factor improves the energy efficiency index of ST and T climate class appliances by giving an energy bonus to the SC. The additional energy used in testing is not represented in the EEI because of the use of correction factor.

Conversely, without the correction factors, appliances designed to operate in warmer climates but which cannot perform efficiently during the standard tests, may not be as attractive to consumers because of their poorer energy label class. If they purchase a more efficient appliance not engineered for warmer conditions then its performance may not be as effective possibly resulting in food spoilage or increased energy consumption due to the consumer needing to use a thermostat setting that gives cooler storage, when used in warmer ambient temperature conditions.

7.1.1 Historical perspective

The GEA study[12] used to inform the Commission did not investigate climate class and it was therefore assumed, in the run up to the energy labelling Directive, that the climate class made little difference to the energy efficiency rating using EN153.

In preparation for the 1996 MEPS Directive[13] a limited technical theoretical review was conducted. This concluded that there *was* a need to apply correction bonuses to subtropical and tropical class appliances. However, according to the Cold II report *"this analysis was seemingly based on a misunderstanding of the EN153 test procedure[14], and as a consequence its results are invalid".* It was believed that the energy was measured according to ISO 15502 where T class appliances are measured at an ambient temperature of 32°C. However, they are actually measured according to EN 153 and measured at an ambient temperature of 25°C (same as all other climate classes). This does not however, explain why ST classes have a correction factor.

[11] WORKING DOCUMENT ON A POSSIBLE COMMISSION DIRECTIVE IMPLEMENTING COUNCIL DIRECTIVE 92/75/EC WITH REGARD TO HOUSEHOLD REFRIGERATING APPLIANCES Explanatory Notes. Circulated to members of the Regulatory Committee (Defra in the UK) November 2008

[12] GEA (1993) *Study on energy efficiency standards for domestic refrigeration appliances*, Group for Efficient Appliances, for DG-XVII of the commission of the European Communities, March.

[13] Commission Directive 96/57/EC on the energy efficiency requirements of household electric refrigerators, freezers and combinations thereof. 3 September 1996

[14] Analysis was based on ISO test which was assumed to be the same as EN153, but was not because the ISO test uses a higher ambient for the energy test. (COLD II report, page 53)

According to the Cold II study[15] an analysis of the cold appliance efficiency data from 1996 by climate class showed that subtropical and tropical appliances had a sales weighted average energy efficiency of between around 7 and 8% better than the EU average appliance EEI of 90.7%. This suggests that there was no need to give preferential treatment to subtropical or tropical class appliances. The reason for higher efficiency (EEI) may be due to other improvements (thicker insulation, larger evaporator and condenser) made to the cabinet to allow it to maintain the appropriate temperature(s) at the higher operating ambient temperatures. These changes will reduce the energy consumption at the standard test ambient temperature.

The analysis in the Cold II report calculated that a typical N class upright freezer would require 5% more energy if converted to an ST or T class appliance by adding a high-capacity compressor, one of the design change options. It was considered that the relative calculated differences between the N, ST and T class for upright freezers could be applied across all types of refrigerating appliances. In general, appliances that are designed to operate in higher ambient temperatures and classed as ST or T class will use other design options such as better insulation, larger-capacity heat exchangers in addition to a high-capacity compressor. This is a necessity to attain the climate class classifications performance regardless of policy measures such as labelling, but obviously has the consequence of achieving good energy efficiency when tested at an ambient temperature of 25°C for energy label class declarations. The Cold II report thus suggests that it is not surprising that on average ST and T class appliances are more efficient than SN and N class appliances.

After considering the costs and benefits of different design improvements in terms of lifecycle costs and economic costs to consumers the Cold II report suggests that an adjusted-volume correction factor of up to 1.1 for ST and T class appliances may be justified at very high efficiency levels, but there is no justification for a climate class correction factor for lower efficiency levels. This adjusted-volume correction factor of 1.1 corresponds to an absolute energy correction factor of ~ 5%.

Despite the considerations summarised above, the Cold II report recommendation was that no correction factors should be given to ST and T class products for energy labelling or MEPS. If it was decided that a bonus for ST and T class appliances is necessary then the correction factor should be a maximum of 1.1 on the adjusted volume and should only apply to appliances with an EEI of 49% of better. If applied to all levels of efficiency there was concern expressed that a large percentage of appliances would be reclassified as up to ST and T class appliances without any further design improvements. They would then be able to benefit from the correction factor.

In response to the Cold II findings and recommendations, CECED requested the inclusion of climate class correction factors for both future labelling and MEPS policies. Whilst acknowledging that the correction factors for MEPS in the 1996 regulation lacks a technical basis they proposed 1.1 and 1.2 correction factors for ST and T class appliances respectively to be applied to the adjusted volumes for all categories.

7.2 Technical requirements for different ambient temperature conditions

The Cold II report states that ST and T class appliances will apply a combination of design changes compared to equivalent SN and N class appliances:

[15] European Commission, December 2000. Cold II The revision of energy labelling and minimum energy efficiency standards for domestic refrigeration appliances. Contractor ADEME, Coordinator PW Consulting (UK).

- thicker or better insulation
- higher-capacity heat exchangers (evaporator and condenser)
- larger capacity compressor.

The first two options are among the most cost effective options for improving efficiency, however, adding a larger compressor (third option) without also increasing the size of the evaporator and condenser can reduce the efficiency of the refrigerator when running at the energy test conditions of 25°C ambient temperature. This is because the refrigerant evaporation temperature will be lower. So expert opinion is that it is likely other components would be resized accordingly as well.

The reason an increased sized compressor is required for a higher climate class is due to the effect of an increased ambient temperature on the heat load and condensing temperature of the appliance, both of which are increased when an appliance is used in a warm ambient temperature (i.e. the condenser is trying to dissipate heat when surrounded by warmer air than in cooler climates). The increased condensing temperature reduces the ability to remove the increased heat load, compounding the effect.

7.2.1 Compressor comparisons

To investigate the differences between the efficiencies of compressors, the heat load at different climate classes was simulated for an upright freezer (blue line in Figure 3).

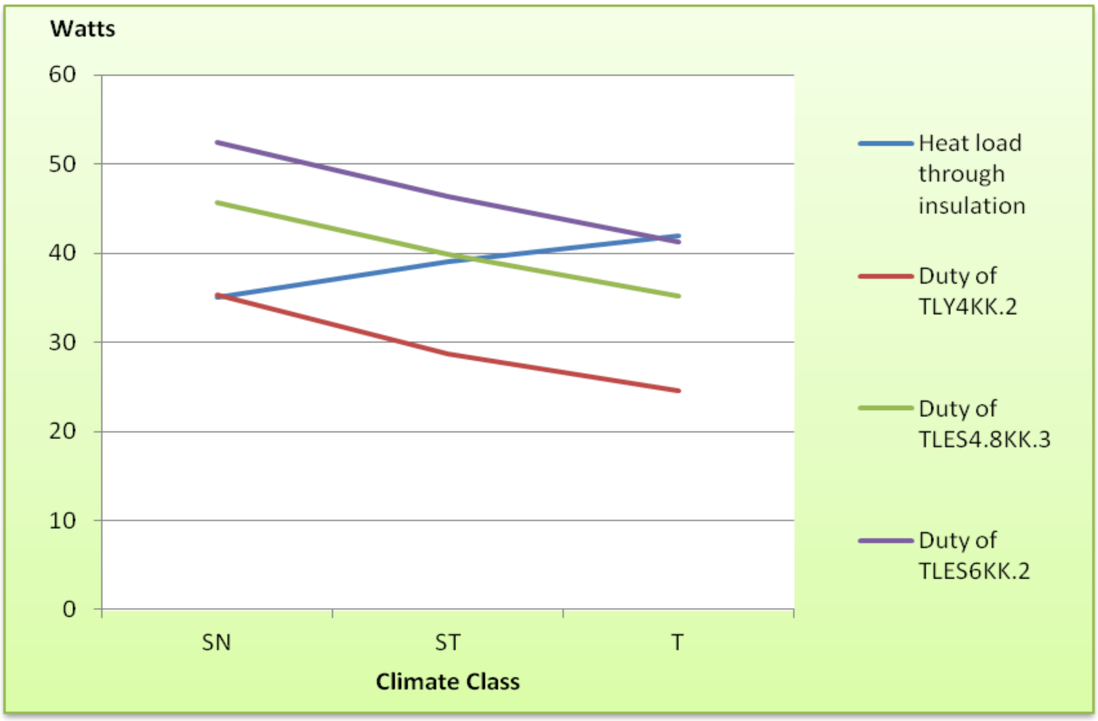

Figure 3: Compressor selection for a fridge-freezer (Source: Danfoss).

Software from a compressor manufacturer, Danfoss, was used to match a selected compressor with a heat load. At SN conditions (10°C to 32°C) the TLY4KK.2 Danfoss compressor was selected. As the conditions were changed to climate class ST (16°C to 38°C), the duty of this compressor was lower than the required heat load (red line is below blue line). Therefore a TLES4.8KK.3 compressor is chosen. As conditions are raised again to climate class T (16°C to 43°C) a TLES6KK.2 compressor is required (purple line). The power needed to cope with higher ambient temperatures therefore goes up with change to a more capable compressor.

For energy efficiency purposes the energy will be measured at 25°C ambient. If the evaporator and condenser are *not* appropriately increased in line with the compressor, the larger compressor (TLES6KK.2) will reduce the evaporating temperature to below what it would be if the small compressor (TLY4KK.2) was fitted. To see the effect of the reduction in evaporating temperature on the coefficient of performance (COP) of the appliance the Danfoss software was used again. The results are shown in Figure 4.

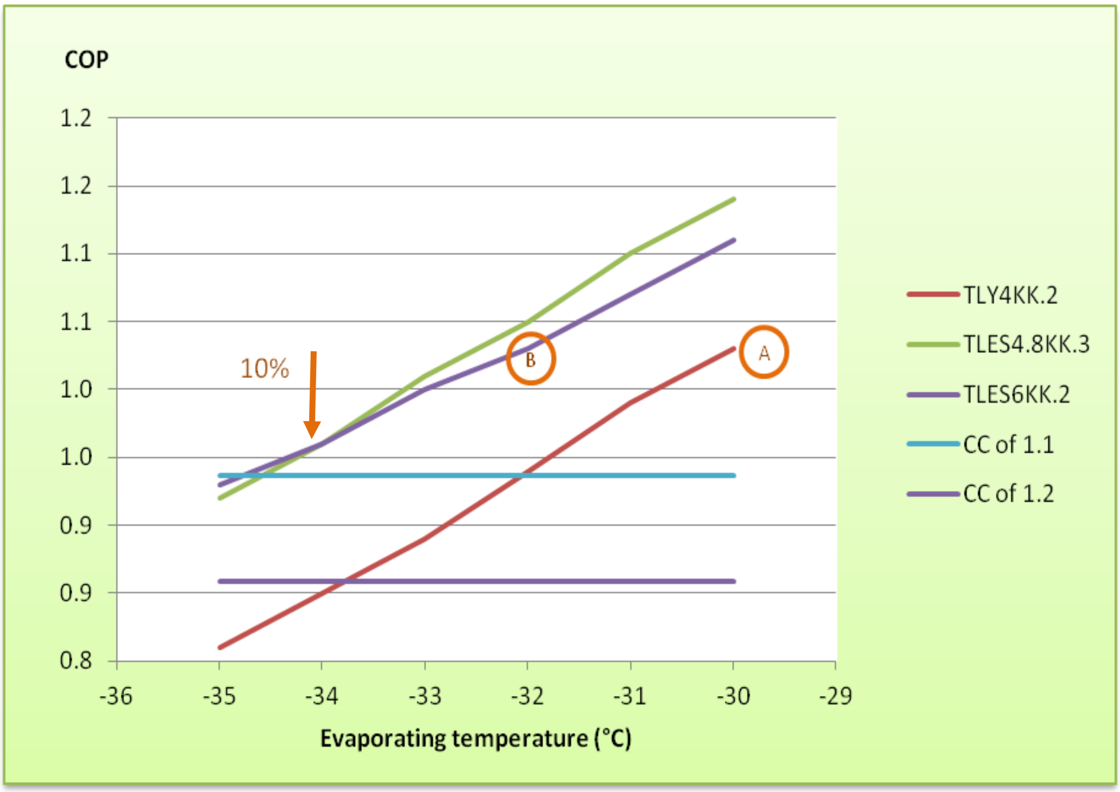

Figure 4: Impact of compressor selection on COP (without adjustment of other components)

At an evaporating temperature[16] of -30°C the smaller compressor has a lower COP (or efficiency) than the larger compressors (marker A in Figure 4). This means that if the evaporator and condenser were appropriately re-sized the larger compressor appliances would be more efficient. However, if the condenser and evaporator are *not* re-sized, the consequence is that the evaporating temperature will drop. The larger compressor COP is equal to the smaller compressor COP once the evaporating temperature has reduced by about 2°C (marker B). Once the larger compressor evaporating temperature has dropped by about 4°C the COP is 10% less than the original COP of the smaller compressor. This equates to removing the benefit of the ST climate class correction factor of 1.1. It was not possible to extend the graph beyond -35°C (extent of Danfoss data). However, if the graph was extrapolated, we would expect the benefit of the T climate class correction factor of 1.2 to be removed by about -36°C evaporating temperature.

16 The evaporating temperature is the temperature at which the refrigerant is evaporating inside the evaporator. At lower ambient temperatures there is less heat load on the appliance and the evaporating temperature is lower.

This is a theoretical evaluation and assumes that not all the components are optimised. If all the components where optimised then the correction factor would not be necessary.

When running in cooler conditions the evaporating temperature will drop even lower and the cabinet will off-cycle even more. This would decrease the efficiency of the appliance with a compressor selected for higher ambient temperatures, compared to an appliance optimised to run at cooler conditions further still. With the energy test still carried out at 25°C, the effect is only in real use conditions, not test conditions.

A similar analysis was conducted in the Cold II report which appears to take into account the running time ratio and cycle time. This showed that increasing the compressor size for an N class upright freezer to a T class raised energy consumption by 5%. This seems to be in line with the above theoretical calculations.

7.2.2 Compressor losses

A factor not considered in the above analysis is the effect of off-cycle losses. When a compressor reaches the thermostat set point temperature and turns off, there is an equalisation in the refrigeration system pressure which leads to efficiency losses. Refrigerant gas can migrate across the capillary and then condenses in the evaporator which adds a heat load to the cabinet cavity. Therefore there is a relationship between the time the compressor is off and the number of off compressor cycles. Generally, the more a compressor turns off the more the heat load on the cabinet. This could be the case if an appliance designed to operate in high ambient temperatures is used in cooler (N class climate) conditions.

The use of a liquid line solenoid that is interlocked with the compressor can prevent this occurring; however, these are not used on domestic appliances because they are expensive and not all compressors are capable of operating at the low starting back pressure which a liquid line solenoid valve creates. Increasing the size of the compressor and evaporator and condenser to operate at a higher climate class will lead to the compressor turning off more often as it is able to maintain temperature with less operation, increasing overall energy consumption. Tests carried out by RD&T[17] showed that a liquid line solenoid valve can halve energy consumption in some cases, proving that off-cycle losses can be very significant.

It is possible to avoid off-cycle losses by using an inverter driven compressor. An inverter driven compressor will reduce in speed rather than switch off, therefore minimising and potentially removing off-cycle losses. However, an inverter driven compressor is less efficient than a normal compressor when running. This is because the inverter uses energy and also a compressor is less efficient when not running at full speed. Whether an inverter driven compressor is more efficient will depend on a number of factors, e.g. number of off-cycles, size of refrigeration components, characteristics of compressor etc. However, it does illustrate that there may be alterative technologies that could compensate for the benefits of the correction factor if they were removed.

7.3 Energy consumption at different ambient temperatures

7.3.1 European appliance energy consumption comparisons

The test reports from the ATLETE project have been analysed to compare the energy consumption of appliances tested for storage temperatures at different ambient temperatures according to their climate class classification with the consumption for the

[17] Refrigeration Development and Testing Ltd. One of the contractors for this research.

energy test at 25°C. The set up of appliances for the storage temperature tests is slightly different to the energy test; the fridge is required to have a slightly lower overall average temperature. Twenty-five of the 85 samples tested were freezers so unaffected by this aspect.

Not all appliances had the energy consumption recorded during the storage temperature test. The storage temperature test is not a requirement for compliance testing for energy labelling or ecodesign Regulations as part of market surveillance activities. Table 2 shows the number of appliances with energy consumption recorded for the different ambient temperatures and Table 3 shows the amount of energy used for the storage temperature tests compared to the energy test at 25°C.

Although this data set from the ATLETE provides a broad comparison of products across Europe, the analysis of energy consumption at different ambient temperatures compared to the energy consumption test has the limitation that the test set up is not directly comparable. The internal fridge temperature requirements for the storage temperature test is an overall mean of 4°C[18] compared to a mean of 5°C for the energy consumption test. Additionally, there is no limit of the cooling in the freezer compartment other than the warmest measurement is to be colder than -18°C. The energy consumption recorded for storage temperatures at different ambient temperatures may therefore be greater than if all compartment temperatures were optimised more specifically.

It is not possible to see the effect of an N class appliance operating at 38°C or 43°C as none of the appliances were tested outside the temperatures appropriate for their climate class.

Figure 5 shows the average amount of energy use for the ATLETE samples recorded at the different ambient temperatures during the storage temperature tests compared to the energy consumed for the energy test. The energy consumption for the storage temperature tests at 10°C and 16°C is lower than the energy consumption test at 25°C, e.g. using 52% of the energy used at 25°C.

Table 2: Number of samples with energy consumption recorded during storage temperature tests

Number of appliances tested	N	N-ST	SN	SN-ST	ST	SN-T
at 10°C ambient temperature			9	6		13
at 16°C ambient temperature	41	2		1	1	
at 32°C ambient temperature	41		8			
at 38°C ambient temperature		2		6	1	
at 43°C ambient temperature						13

(Source: ATLETE test reports)

Table 3: Average amount of energy used for storage temperature test compared to 25°C energy test

Average amount of energy used compared to 25°C energy test	N	N-ST	SN	SN-ST	ST	SN-T	Average of all tested
10°C storage temperature test			52%	55%		40%	47.2%
16°C storage temperature test	35%	39%		41%	31%		35.4%
32°C storage temperature test	175%		166%				174.5%
38°C storage temperature test		210%		230%	218%		224.0%
43°C storage temperature test						298%	297.7%

(Source: ATLETE test reports)

[18] Storage test requirements according to EN ISO 15502 Table 2: Fresh food compartment: The mean of any one thermocouple must lie between 0 and 8°C inclusive. Overall mean must be no warmer than 4°C.

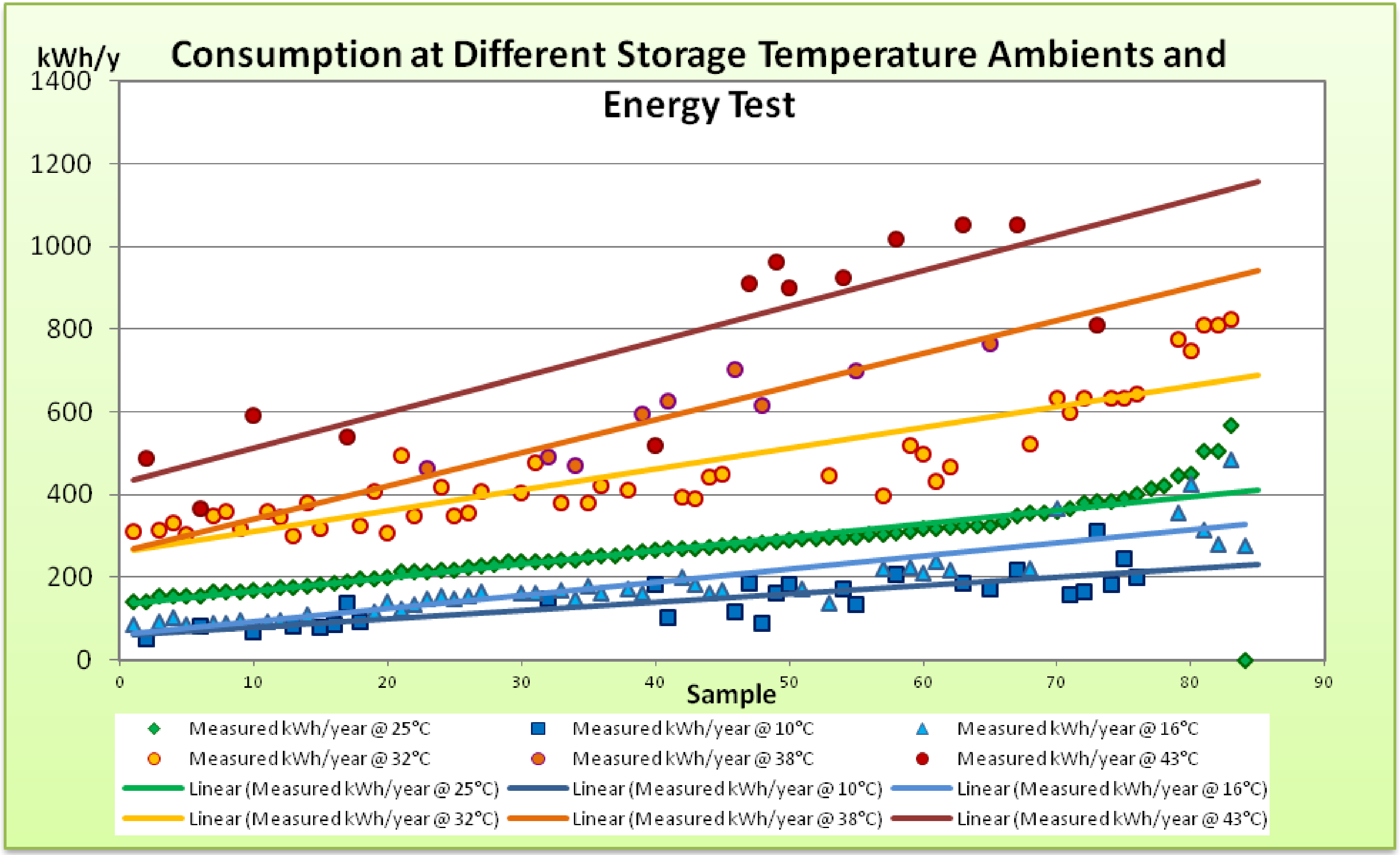

Figure 5: Energy consumption (kWh/y) at 25°C energy test and storage temperature test ambients (Source analysis of ATLETE data)

7.4 Climate class energy consumption comparison - GB

Figure 6 plots the power consumption against volume for all the upright freezers available in GB in 2010 where climate class could be determined (57 appliances in total). The consumption is based on the claimed kWh per year given on the energy label. It indicates a range of efficiencies across the different climate class classifications when tested at 25 °C ambient test temperature and that similar consumption is found for all climate class appliances. Table 4 provides details of the energy classes for the appliance included in Figure 6.

Table 4: Frequency of efficiencies for appliances plotted in Figure 6

Climate class	A++	A+	A	B
SN/N	0	2	16	4
ST	0	1	12	4
T	1	8	9	0

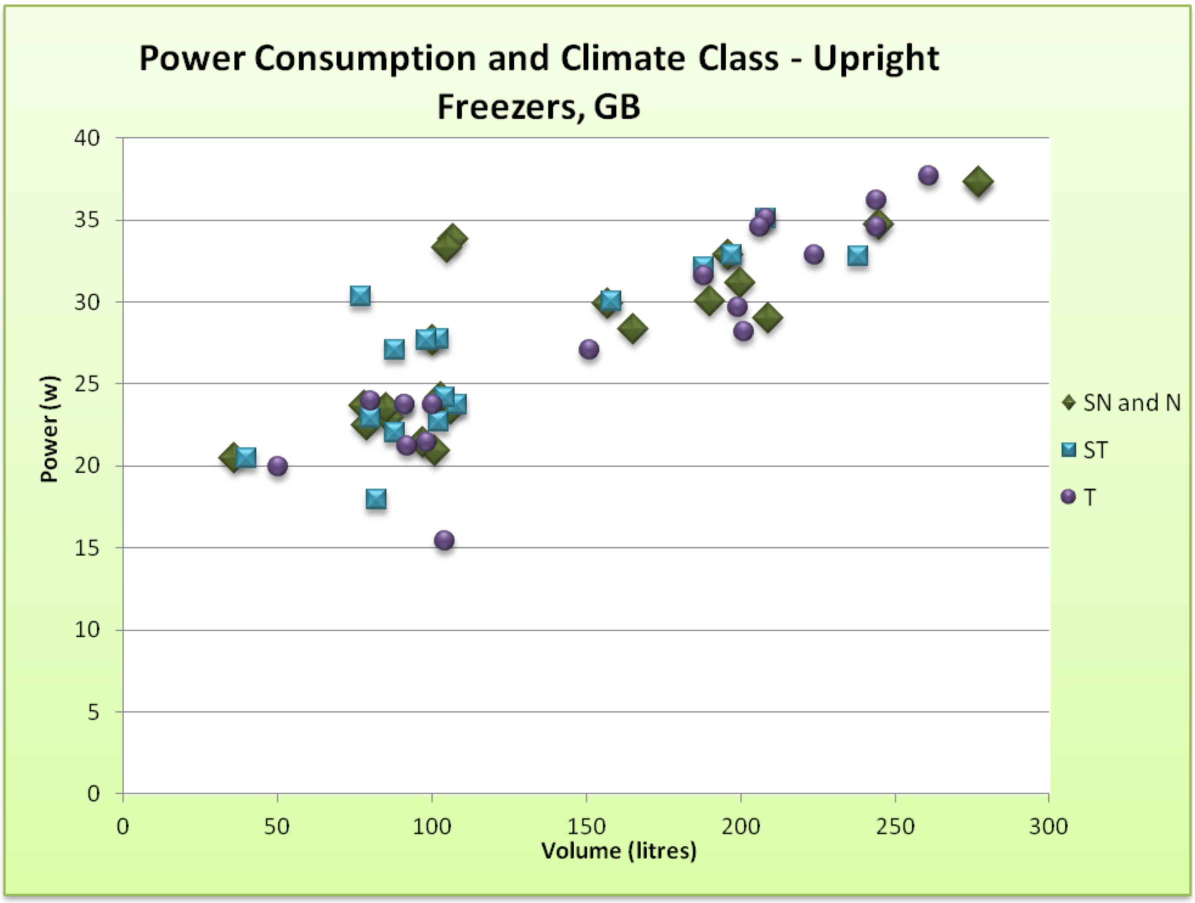

Figure 6: Power consumption (at 25°C ambient) of upright freezers available in GB according the maximum climate class classification (Source: analysis of GfK and market data)

7.5 Ambient temperatures across Europe

Many studies have discussed the influence that the ambient temperature has on the energy consumption and efficiency of refrigeration appliances. Of interest in this research are the ambient temperatures across Europe in order to consider the use of the climate class classifications.

The EuP preparatory study[19] carried out a consumer survey across 10 European countries and asked owners what the minimum and maximum temperatures are in the room where the refrigerator is located. The results can be seen in Figure 7 and the main observations are given below.

- Average maximum temperature is 24.2°C.
- Maximum of between 20 and 23°C in around 30% of household.
- In Germany; more than 65% of households reached a maximum of 23°C, plus 24% less than 31°C (so for 89% of households, the maximum is between 23 and 31°C).
- 10.8% of Spanish and 6% of Italian households have ambient room temperatures over 36°C.

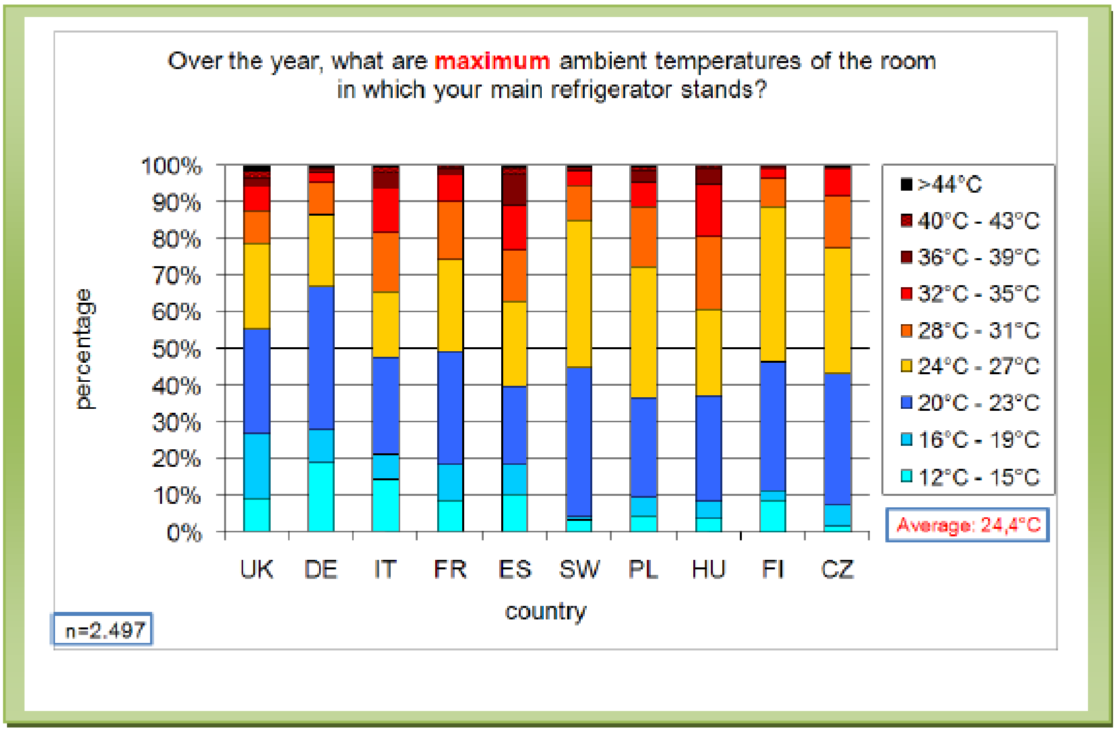

Figure 7: Maximum ambient temperature of room where refrigerator is located (source: EuP preparatory study Task 3)

The study also collected information on the minimum room temperatures where the refrigerated appliance is located, see Figure 8.

- Average minimum ambient temperature is 14.6°C.
- Room temperatures of between 16 and 19°C in around 44% of households.
- Between 40% and 50% of households have ambient temperatures under 11°C in the United Kingdom and Spain.
- 20% of households in each of UK, Germany, Italy and Spain have a minimum temperature below 7°C.

[19] EuP preparatory study Task 3 3.3.2 page 281

The general perception that conditions might be warm in Southern countries and cold in Northern is not necessarily reflected in the ambient temperatures within the home.

- Spain, Italy and Hungary have households with highest and lowest room temperatures.
- Cold northern countries such as Finland and Sweden have higher minimum room ambient temperatures than other countries.

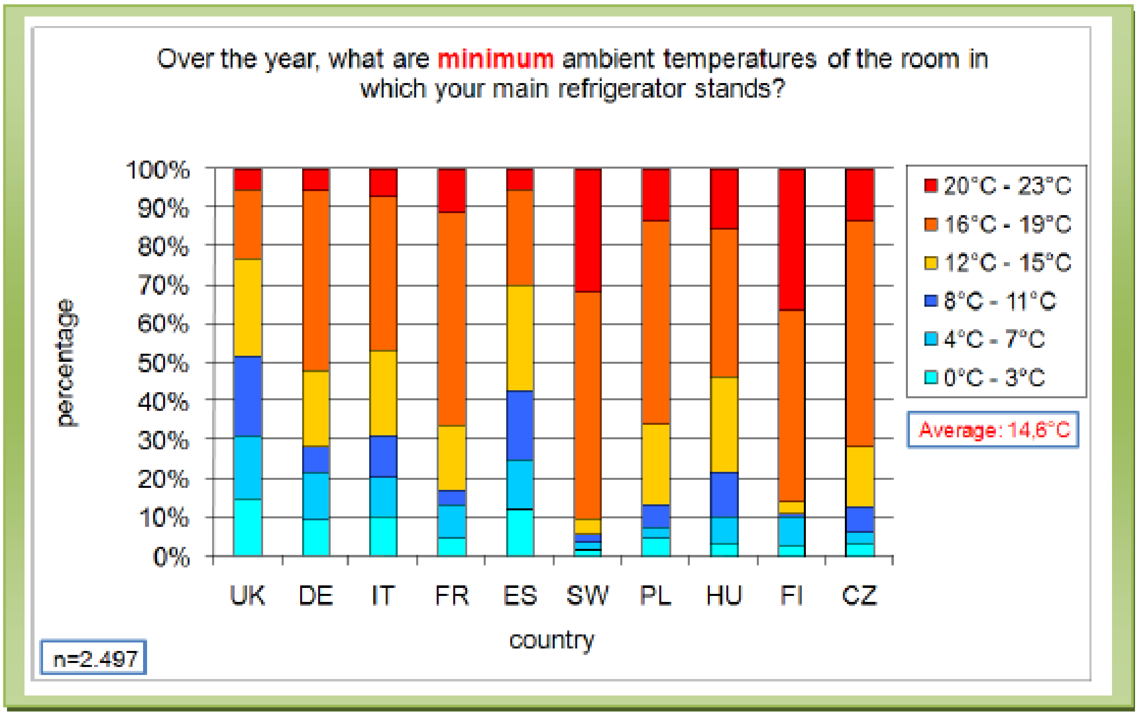

Figure 8: Minimum ambient temperature of room where refrigerator is located (source: EuP preparatory study Task 3)

When the data on the maximum and minimum ambient temperatures is considered there are regional differences in the extremes of temperatures that refrigerators have to work in. In countries such as Spain, UK and Italy the differences can be over 28°C in around 5 to 7% of households. The smallest temperature differences are seen in Swedish, Finnish, German, French and Czech households, where about 80% of the rooms reach a temperature difference of 8°C maximum.

The analysis of the data provided in the EuP study suggests that the main refrigerator is either kept in a heated room such as a kitchen which has relatively constant temperatures throughout the year, or placed somewhere unheated where the surrounding temperature fluctuates according to the outside ambient such as in a garage, cellar or balcony.

Consumers were also asked about the ambient temperature where the freezer is located. The results are illustrated in Figure 9 and Figure 10.

- Average maximum room temperature is 23.6°C.
- 13% of Spanish households have a maximum room temperature of over 36°C.
- 25% of freezers are in rooms which reach a maximum temperature of only 15°C in Germany.
- In over 50% of households the maximum room temperature is between 20 and 27°C
- The minimum temperature reaches below 11°C down to 0°C where the freezer operates in nearly 39% of cases.
- Some countries, such as the UK and Spain, have over 50% of rooms with freezers reaching a minimum temperature below 11°C.

- Northern countries such as Sweden and Finland have almost 80% of household with the ambient above 12°C and 30% are between 20 and 23°C.

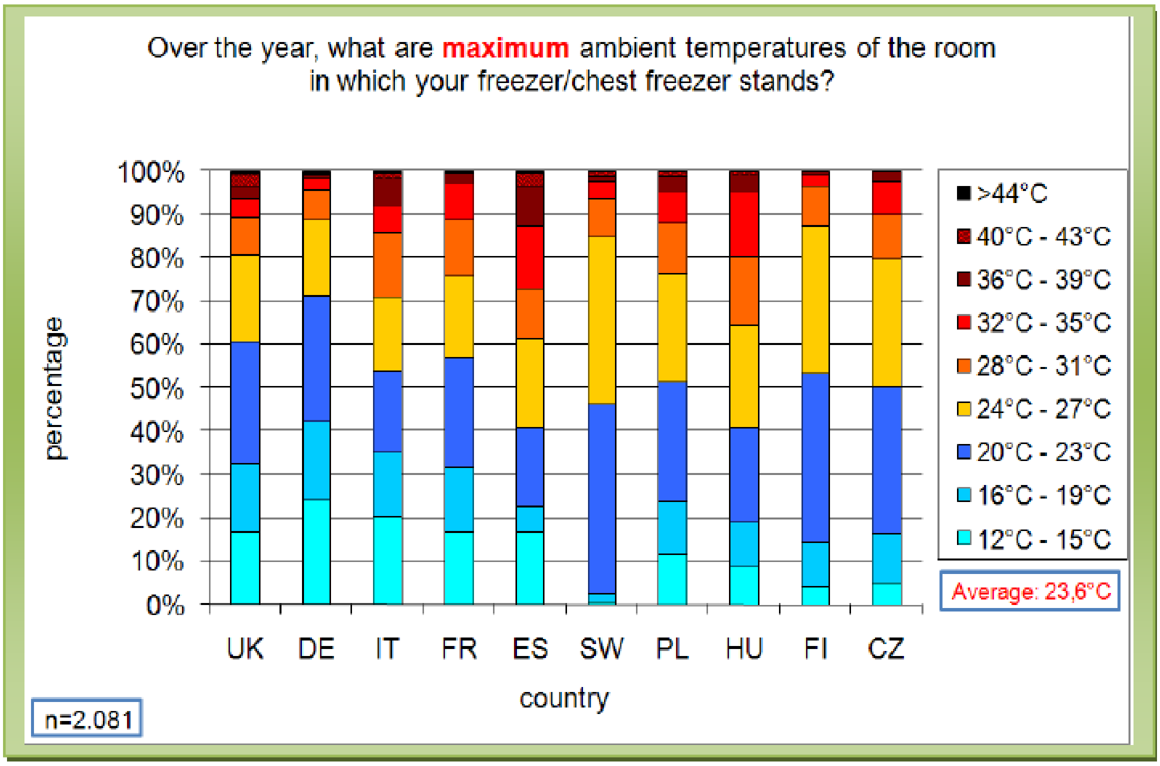

Figure 9: Maximum ambient temperature of room where freezer is located (source: EuP preparatory study Task 3)

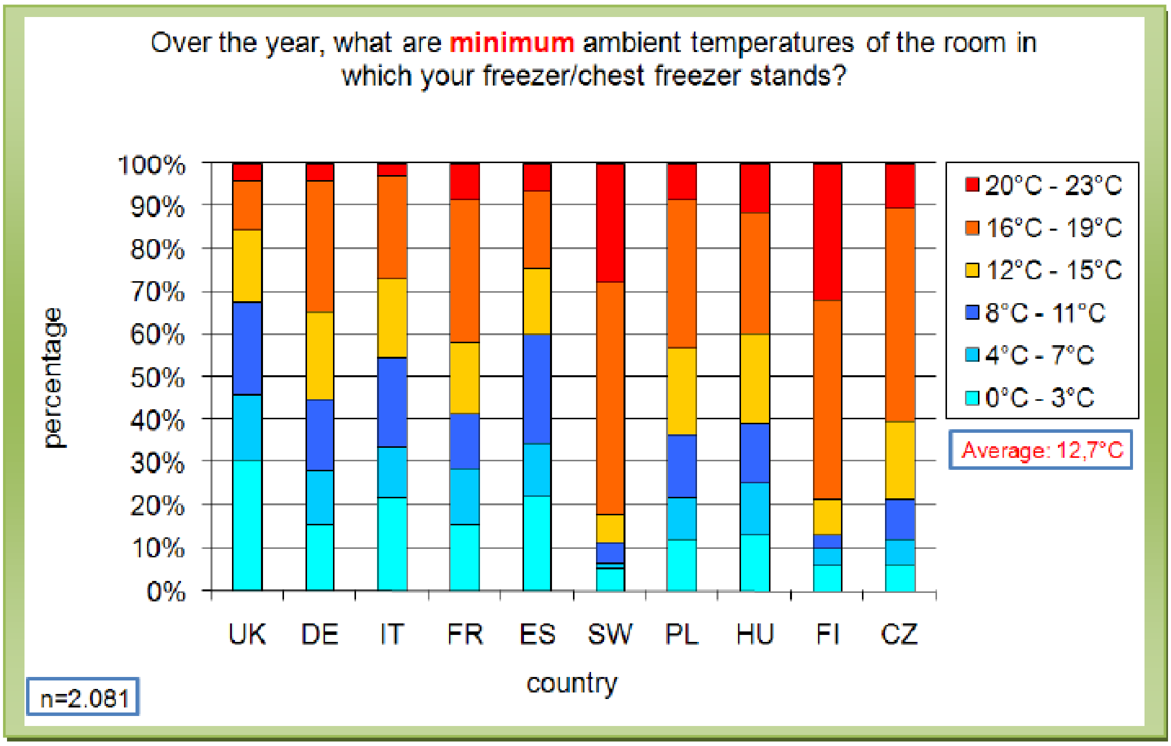

Figure 10: Minimum ambient temperature of room where freezer is located (source: EuP preparatory study Task 3)

It would appear from the EuP study data that more households have conditions where an SN appliance is more appropriate than an ST or T class appliance. However, the information used for this analysis is consumer's perceived temperature and therefore not as reliable as if the room temperatures had been measured. There may be a degree of over estimation by consumers for both maximum and minimum temperatures, additionally the data does not reflect possible extremes in temperature.

7.6 Performance of tropical and sub-tropical appliances

This section reviews product testing data available to assess if products making use of tropical and sub-tropical climate class classifications can meet the appropriate storage temperature requirements.

7.6.1 ATLETE project results

The results from the pan-European compliance testing project found that overall 90% of appliances were compliant for the storage temperature test i.e. maintained appropriate temperatures when tested at the range of ambient temperatures corresponding to climate class classifications.

The ATLETE project[20] selected models for testing on the basis that half of the models chosen were among 'EU top-sellers' according the market share of the relevant manufacturers/importers. The other half of the models was selected randomly within the remaining producers active on the EU27 market, so only those with a market share lower than 0.5% or operating only nationally/regionally were targeted. So it was a semi-random selection which was not targeted at identifying models likely to fail but gave a picture of the EU market

Of the 82 appliances tested 44 were fridge-freezers, four were refrigerators with low temperature compartments and eight were upright freezers. Seventy appliances completed the full sets of test and of the refrigerators with low temperature compartments and fridge-freezers 85% were compliant in respect to storage temperatures, but 100% of the upright freezers were compliant. The project report[21] provides an evaluation of the results but does not provide detailed model information although this is available in the individual model result sheets.

Details of the seven appliances that failed on the storage temperatures are given in Table 5 below. In some of the cases the first sample tested passed the storage temperature test but subsequent samples (tested because they had not performed adequately against other assessment criteria) failed.

There is no consistent pattern in the climate classes of appliance that failed. In six of the samples the freezers were too warm. Most of the failures were testing appliances suitable for lower ambient temperatures; N and SN class. In the case of two appliances tested the initial samples were N class, but subsequent samples were classified as ST.

In total 24 refrigerating appliances with climate classes including ST and T were tested in the ATLETE project. Of these there were only 4 failures and 2 of these examples were for

[20] http://www.atlete.eu/

[21] ATLETE Project Work Package 6: Evaluation, Outcome of the pan-Eu compliance of refrigerators and freezers, Draft Report July 2011. http://www.atlete.eu/index.php?option=com_docman&Itemid=111

samples during the second stage of the testing which were ST compared to the original appliance classification of N class.

Table 5: Appliances failing the storage temperature test - ATLETE

Brand	Model number	Climate class	Ambient temperature of test	Reason for failure
Zanussi	ZRT318W	SN.N.ST	10°C	First sample passed All 3 subsequent samples failed owing to freezer too warm at 10°C ambient
Fagor	FC37LA	N.ST	16°C & 38°C	Fridge too cold at 16°C and 38°C ambients
Daewoo	ERF-387 MH	N (1st sample) ST (subsequent 3 samples)	32°C 38°C	First sample, freezer too warm at 32°C ambient All 3 subsequent samples, freezer too warm at 38°C ambient
Daewoo	ERF-362 MA	N (1st sample) ST (subsequent 3 samples)	32°C & 16°C	First sample passed Of subsequent samples; one failed 32°C ambient only, other two failed at 16°C and 32°C ambients; freezer too warm.
Frigidaire	FRC150FFS	N	32°C	First sample passed One of the subsequent 3 samples failed at 32°C ambient; freezer too warm
Lec	TF5586	SN	32°C	First sample passed One of the subsequent 3 samples failed at 32°C ambient; freezer too warm
Baumatic	BR27	N	16°C	First sample passed One of the subsequent 3 samples failed at 16°C ambient; freezer too warm

(Source: Evaluation of individual test reports for appliances tested under the ATLETE programme)

7.6.2 Multi-climate class performance test

In accordance with the project specification a fridge-freezer was selected to test the storage temperatures according to its climate class classification.

Sample selection

The GfK market data for sales of fridge-freezers in Great Britain for 2010 was analysed to identify the top selling branded appliances. Of the top 11 (with sales greater than 10 000 units), only four were shortlisted as they had multi-climate class classifications. Of these two were considered more appropriate due to being introduced to the market in the past three years. Following further market research and consultation with the project steering group, it was concluded that the Bosch KGH33X was the most suitable and the most recent version of this model, the KGH33X10, has climate classification of SN through to T.

Test programme

The test sample was evaluated using the following criteria:

- Storage volume

Storage volume was measured according to EN ISO 15502 Clause 7.

- Energy consumption

The test sample installed in test room with three thermocouples in the fresh food compartment (fridge) in accordance with EN ISO 15502 Figure 14 and test packages in the frozen food storage compartment (freezer) in accordance with EN ISO 15502 Clause 13. (See Annex B for details).

The energy consumption test was carried out at 25°C ambient temperature in accordance with EN 153:2006 Clause 8. Two test runs were carried out; one at temperatures slightly warmer than the compartment characteristic temperatures and one at temperatures slightly colder than the compartment characteristic temperatures. An interpolation of the energy results give the energy consumption at an average temperature of 5°C in the fridge and maximum temperature of -18°C in the freezer.

- Storage temperatures

For the storage test, thermostatic controls were re-set to give an average temperature of 4°C in the fridge in accordance with EN ISO 15502 Table 2 and then the ambient changed 43°C as required by the claimed climate class.

- Freezing capacity test

The project specification suggested carrying out a freezing capacity test according to the ISO method, i.e. at an ambient of 32°C for a T class appliance. This is not an essential test for energy label declaration, although a freezing test according the EN153 (tested at 25°C) is a requirement for product information. The sample appliance underwent freezing tests at both 25°C and 32°C ambient temperatures.

Test results summary and discussion

A copy of the laboratory test report can be found in Annex C.

- Storage volume

The measured volumes were very close to the claimed volume with all drawers in situ.

- Energy consumption

The test sample used less energy than claimed, the yearly energy consumption result being nearly 12% lower than stated on the energy label. Calculating the energy index used the measured energy consumption and the measured volumes gave an energy index of 38.7, giving an energy class of A+ which agrees with the energy label.

- Storage temperatures

The test sample was able to maintain appropriate internal temperatures at 25°C ambient and 43°C ambient with little or no adjustment of the thermostat. It is reasonable to assume that it can also maintain appropriate internal temperatures at a range of ambient temperatures in-between those tested.

- Freezing capacity test

When tested at the rated freezing capacity of 8 kg, the test sample failed the freezing test at 25°C ambient temperature; the fridge was colder than zero (-1.2°C) for more than 15 hours during the freezing of the light load.

Similarly when tested at 32°C ambient temperature, the sample also failed the freezing test as the fridge was colder than zero (-0.7°C) for more than 15 hours during the freezing of the light load. Although a minimum fridge temperature of -0.7°C may not be considered to be much colder than zero, the fridge was cold for a significant period and therefore the failure cannot be considered to be borderline.

The sample is able to cool down the rated freezing capacity within 24 hours as required but it is not able to adequately control the fridge temperature during this process. The test house expert feels that the freezer actually appeared to have too much cooling power which pulled down the fridge temperature for a number of hours as well as the freezer temperature. Adjusting the light load to more than 8kg (to take advantage of the excessive cooling power) might have had the effect of increasing the freezing time to longer than 24 hours.

7.7 Market Picture and trends for climate class

7.7.1 Trends in climate class classifications

The EuP preparatory study[22] evaluated the types of refrigeration appliances offered across Europe and the trends and changes in climate class classifications over the years 1995 to 2005. Figure 11 to Figure 14 show the maximum climate class classification for the four main appliance types. This is for the appliances available and is not sales weighted. The information comes from the CECED database for this period, during which it should be noted that the European market enlarged from 15 to 25 countries. This increase in inhabitants partly explained for an increase in the models available. The change in market structure may have been influenced by this or the change in demographics and more segmented markets, but another development over the years has been a focus on the demand for just 4 out of the 10 categories of appliance offered. These types of appliance are category 1 (larder fridge), category 7 (fridge-freezer), category 8 (upright freezer) and category 9 (chest freezer). With this concentration of types of appliances there has been a slight change in the average volumes, but more significantly, there has been a substantial move towards more appliances with a maximum climate class declared as sub-tropical and, to a lesser extent, tropical. The EuP preparatory study suggests that this cannot be wholly attributed to changes in the geographical picture of Europe or global warming.

The pattern of change has seen appliances change from being categorised with one climate class to becoming multi-climate class. By 2005 each appliance had an average of 2.5 climate classes with SN, N and ST being most commonly used. Fridges (category 1), in terms of the maximum climate class there has been a move from 70% of appliances offering SN and N climate classes in 1995 to just over 70% being ST or T by 2005. The pattern is the same with the other main categories of appliance, upright freezers and fridge-freezers. For chest freezers the market transformation was not as rapid and started from a near saturation of N class in 1995, but by 2005 nearly 70% of chest freezers are ST and T.

[22] EuP preparatory study, Task 2 section 2.3.2

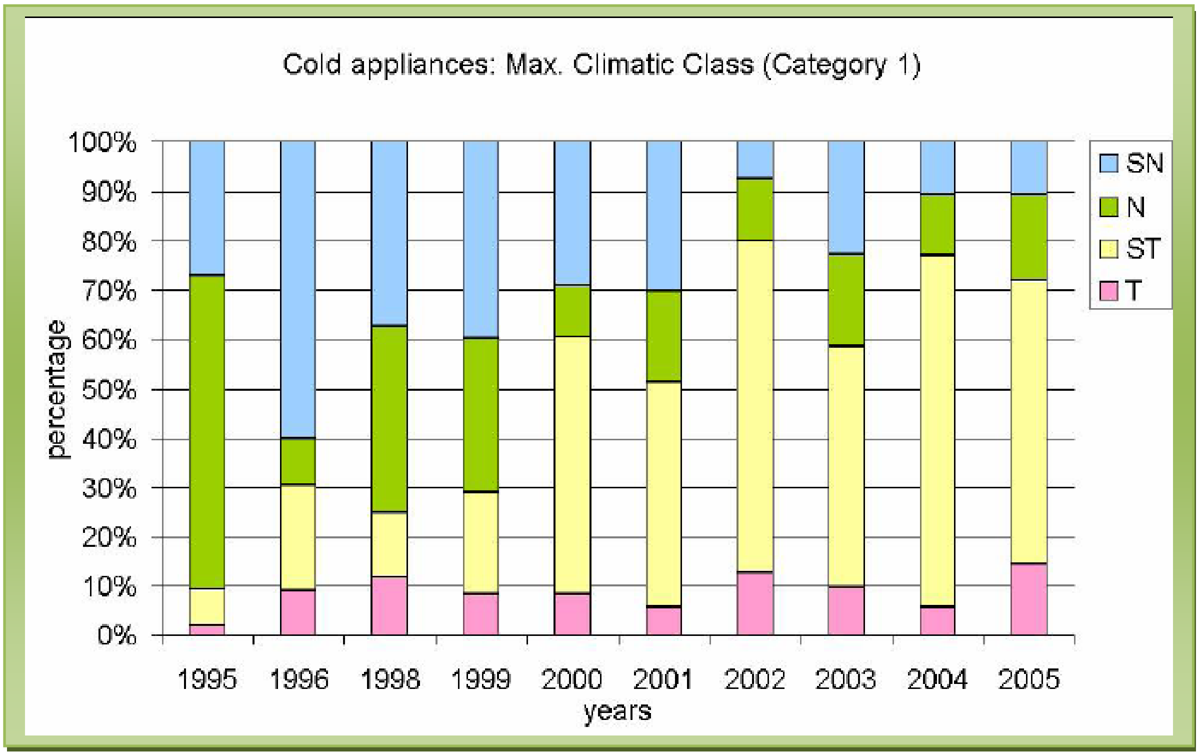

Figure 11: Maximum climate class; Larder fridge (Source: EuP Preparatory Study Task 2)

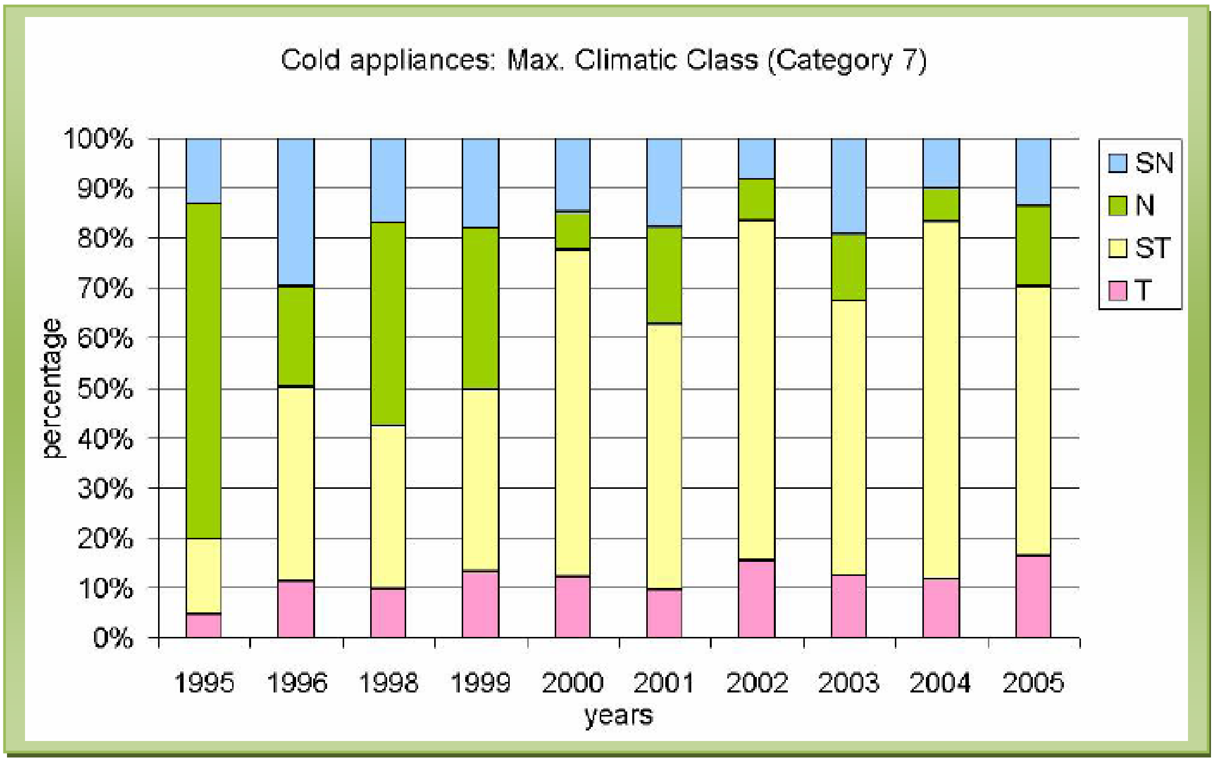

Figure 12: Maximum climate class; Fridge-freezer (Source: EuP Preparatory Study Task 2)

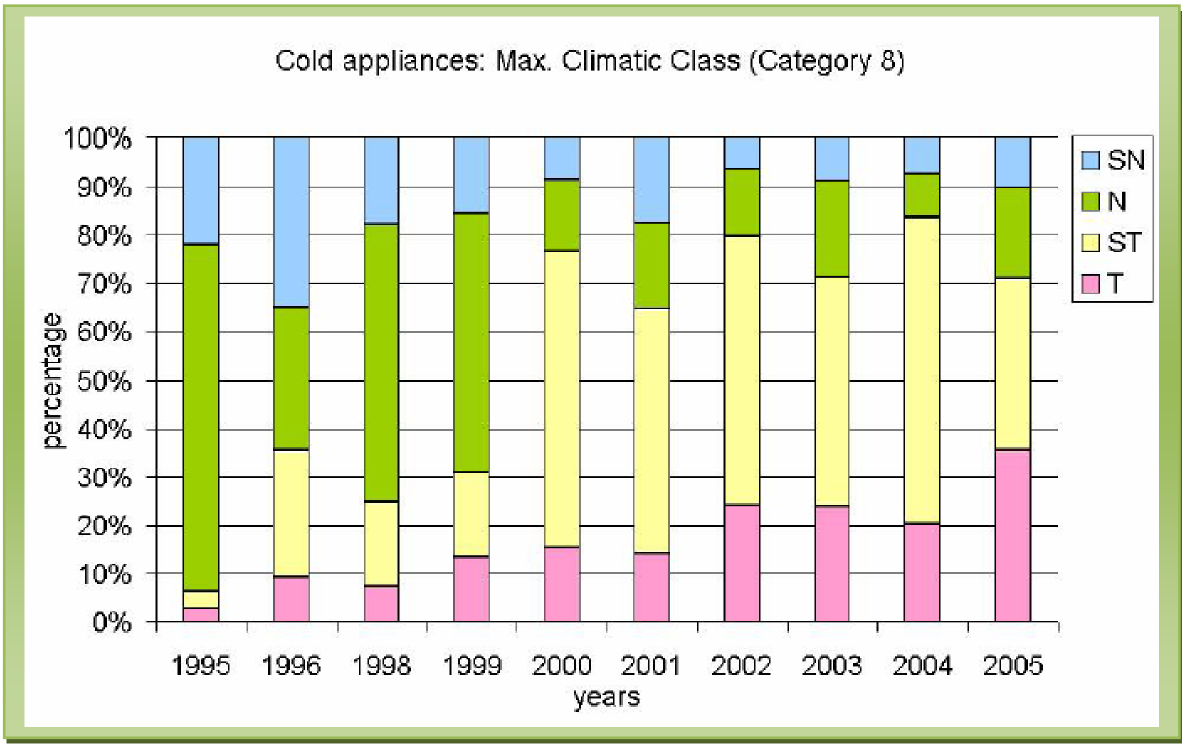

Figure 13: Maximum climate class; Upright freezer (Source: EuP Preparatory Study Task 2)

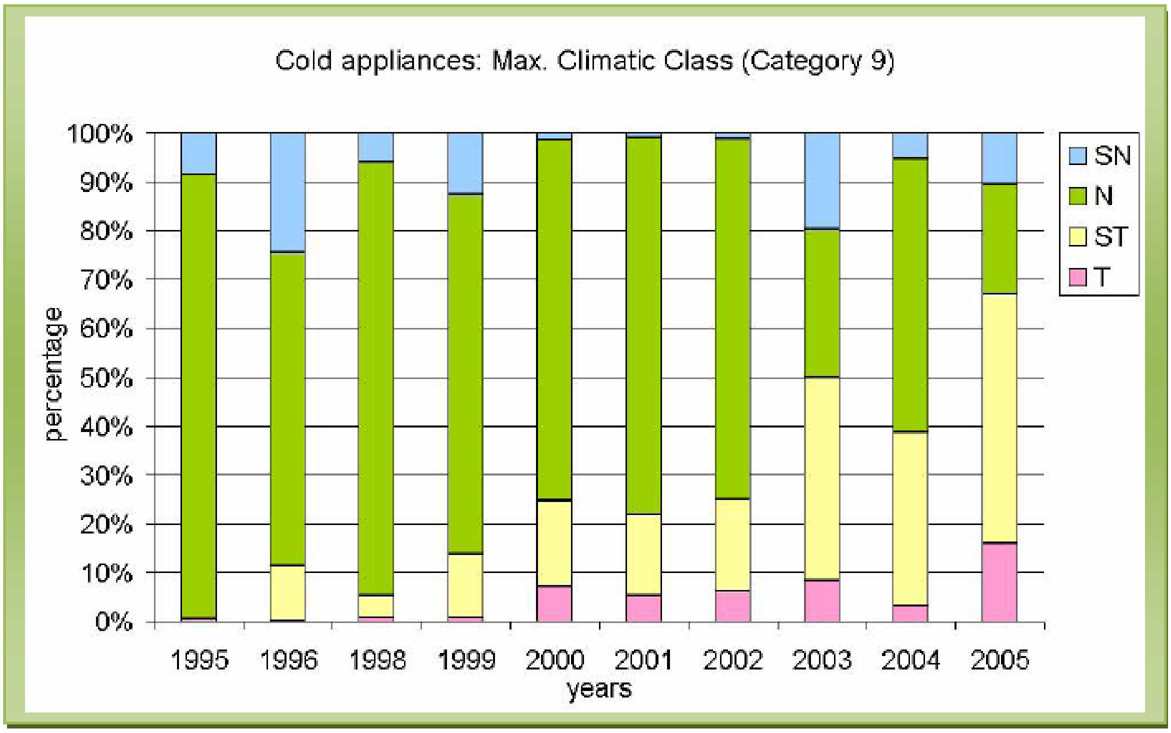

Figure 14: Maximum climate class; Chest freezer (Source: EuP Preparatory Study Task 2)

The EuP preparatory study does not provide any suggestion for the reason behind this change in market in terms of the range of climate classes offered. Information more recently provided by a major appliance manufacturer suggests two factors;

- Manufacturers need to produce pan-European appliances that can be offered in any of the Member States and possibly more widely due to the absence of trade barriers.
- Economic pressures to reduce costs have also lead to a rationalisation of product variations, again resulting in appliances that can be marketed as widely as possible; it is not economically justifiable to produce appliances specific to particular climatic regions.

7.7.2 Current market picture for climate class

A review of the products tested by consumer magazines illustrates the availability of multi-climate class appliances across Europe. Figure 15 shows the climate class ranges of the appliances most recently published by Stiftung Warentest[23] (German consumer test magazine). The sample of appliances reviewed were selected on the basis of manufacturer market share, best selling models and a selection that gives all the main brand coverage for the German market. Figure 16 shows the climate classes for appliances tested in 2011 by a range of consumer organisations that are members of ICRT [24] and often carry out sets of tests together; samples were selected on the same basis as for Germany in terms of market share and popularity. Figure 17 considers the information provided by the European consumer organisation in terms of maximum climate class classifications.

The UK consumer magazine Which? gives minimal information about climate class. What is provided as a footnote to a comparison table does not appear to have been updated in terms of the operating temperature range for ST and T climate ranges starting at 16°C, or the most likely climate classes available. An example text from a recent product review report;
"Every fridge freezer has a 'climate class', which tells you the range of room temperatures with which it can cope. The two you're most likely to come across in the UK are N class and SN class. Both work effectively in room temperatures up to 32°C. N models shouldn't be used in rooms that become colder than 16°C. SN models shouldn't be used at room temperatures below 10°C. Other classes that you might come across are ST and T. ST models work best at between 18°C and 38°C, and T models between 18°C and 43°C."

[23] *www.test.de*

[24] ICRT; International Consumer Research and Testing. http://www.international-testing.org/index.html

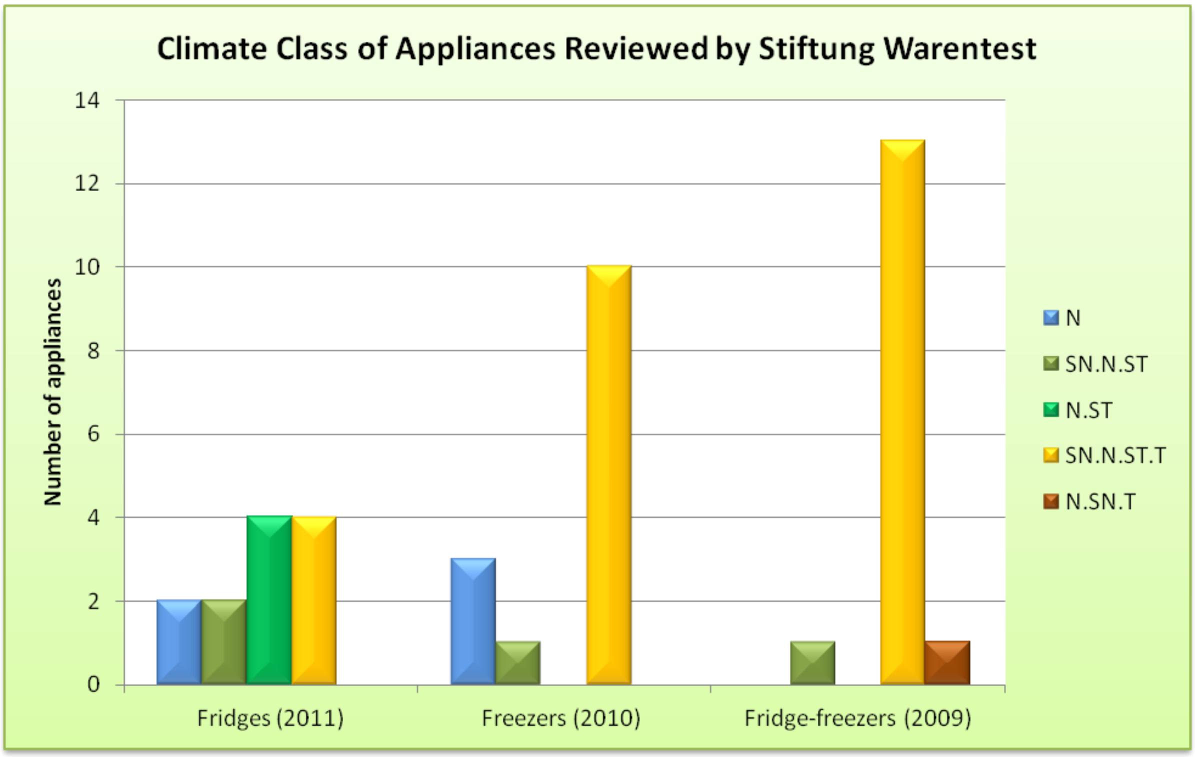

Figure 15: Climate class classifications for appliances tested and reviewed in Test magazine. (Source: Stiftung Warentest)

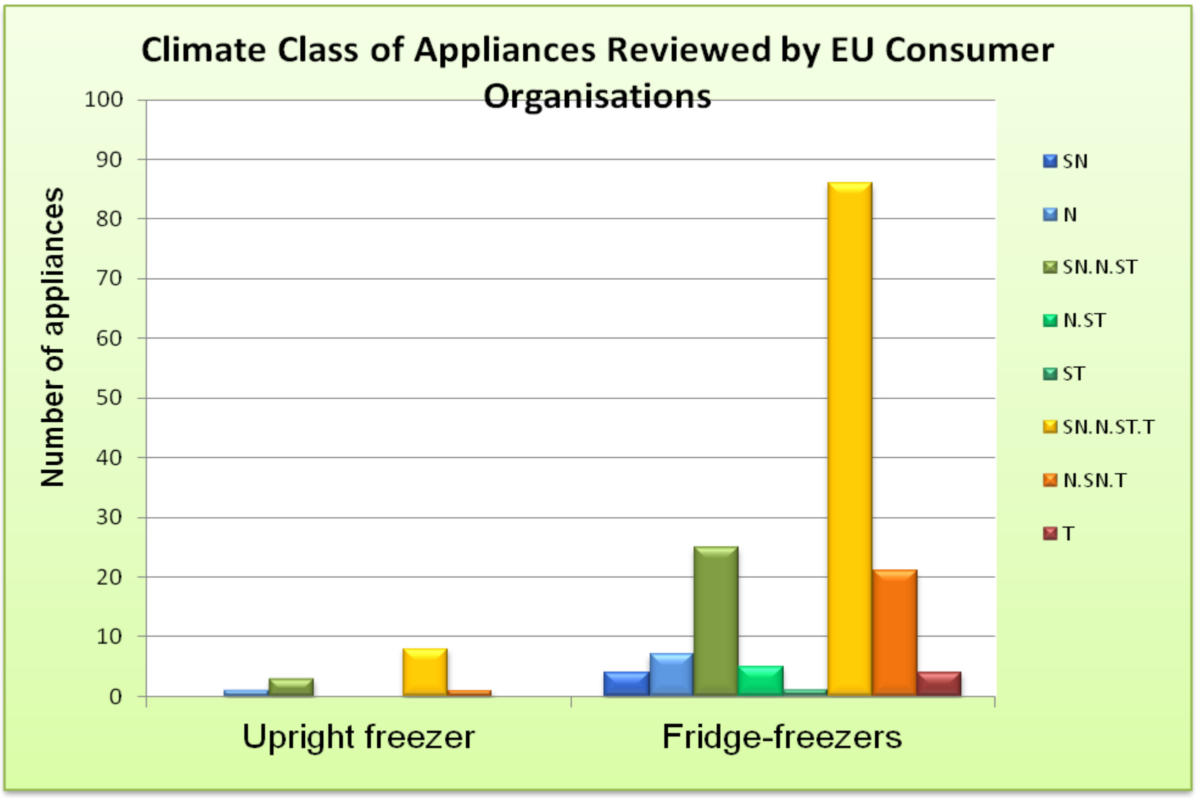

Figure 16: Climate class classifications for appliances tested and reviewed by European consumer organisations (Source: ICRT members - Consumentenbond, Netherlands: Altroconsumo, Italy: DECO-Proteste, Portugal: OCU, Spain: Taenk Forbrugerraedet, Denmark: Kuluttajavirasto, Finland: Rad & Ron, Sweden: Test Achats, SC, Belgium: Which?, UK)

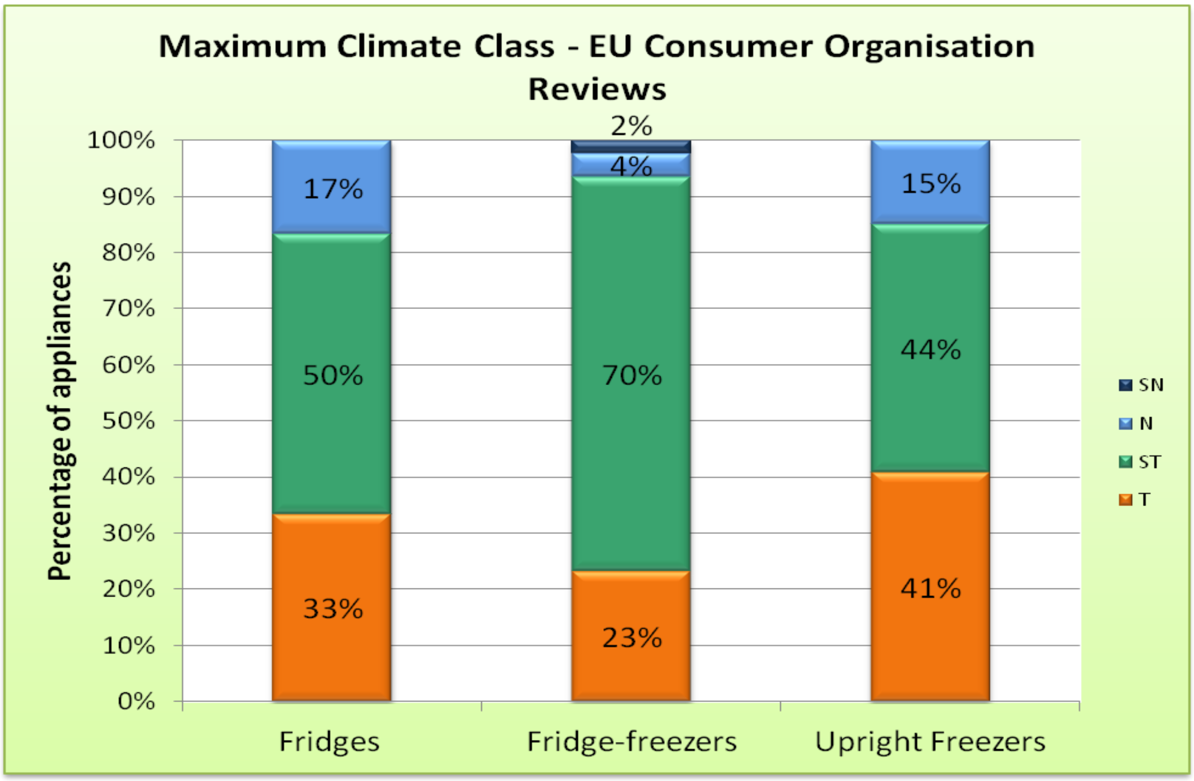

Figure 17: Maximum climate class classifications for appliances reviewed by European consumer organisations (Source: Consumentenbond, Netherlands: Altroconsumo, Italy: DECO-Proteste, Portugal: OCU, Spain: Taenk Forbrugerraedet, Denmark: Kuluttajavirasto, Finland: Rad & Ron, Sweden: Test Achats, SC, Belgium: Stiftung Warentest, Germany: Which?, UK)

The range of climate class appliances available across Europe has been considered from two other sources of information. Figure 18 shows the percentage of appliances by maximum climate class from the sample of appliances tested by the ATLETE project and also the appliance information recorded in the CECED database. Although the types of appliance in the ATLETE sample is very similar to the market share of different categories of appliance in the CECED database, the ATLETE sample has more appliances with a maximum climate class of N than the CECED data. The CECED data allows a comparison with the trends in climate classes from CECED given in Figure 11 to Figure 14, but does not necessarily represent the spread of climate class appliances actually purchased.

The ATLETE appliances were selected to give half of the sample consisting of the top-sellers according to the market share of the manufacturers and importers in Europe. The other half were from suppliers with a market share of less than 0.5% or those only operating locally/regionally. This set of samples therefore, potentially, represents purchasing habits more realistically than the CECED data.

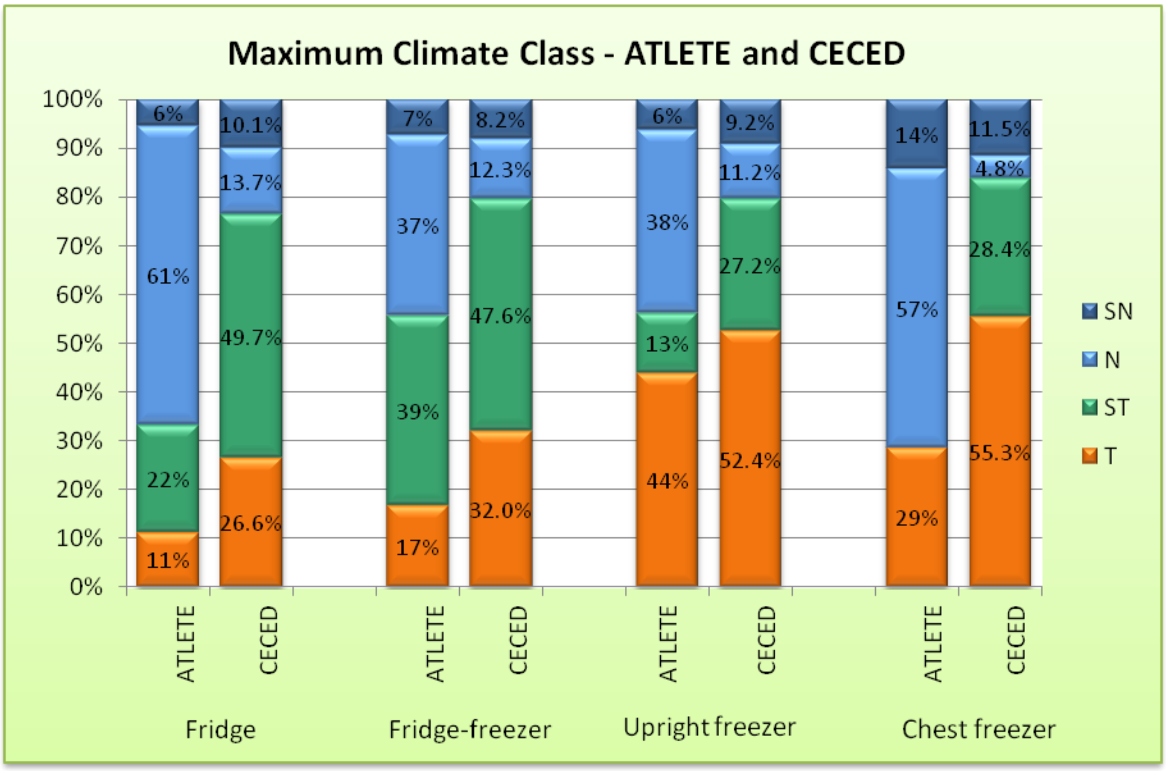

Figure 18: Maximum climate classifications for appliances ATLETE project and CECED database (Source: ATLETE individual test reports - 2011, CECED database - 2009)

Figure 19 shows the climate class classifications of the appliances available and sold in Great Britain in 2010 (it is not sales weighted so comparative with EU data). This information is predominantly branded appliances where the climate class could be obtained from manufacturer's data so excludes appliances sold under trade (retailer exclusive) brand names. Consequently the data set covers between 50% and 60% of available fridge-freezers, refrigerators and upright freezers, and 35% of chest freezers on sale. For fridge-freezers 37% of the appliances available are multi-climate class (SN to T).

When sales weighted analysis is undertaken for just those appliances where climate class is known, appliances with the maximum climate class of ST or T account for 35% of sales of fridge-freezer, 48% of upright freezers, 26% of chest freezers and 49% of fridges. Looking at the GB data from a sales weighted perspective shows sales patterns represented more closely by the ATLETE appliance sample than the CECED database information. The average number of climate classes for the different categories are between 2.1 and 2.6 depending upon the appliance type. These are similar to the average of 2.5 given for the European 2005 data in the EuP preparatory study.

Maximum climate class classification of appliances is considered in Figure 20 using GB market data. These allow a comparison of the types of appliances available in the UK in a similar way to the European data presented from the CECED database and is not sales weighted.

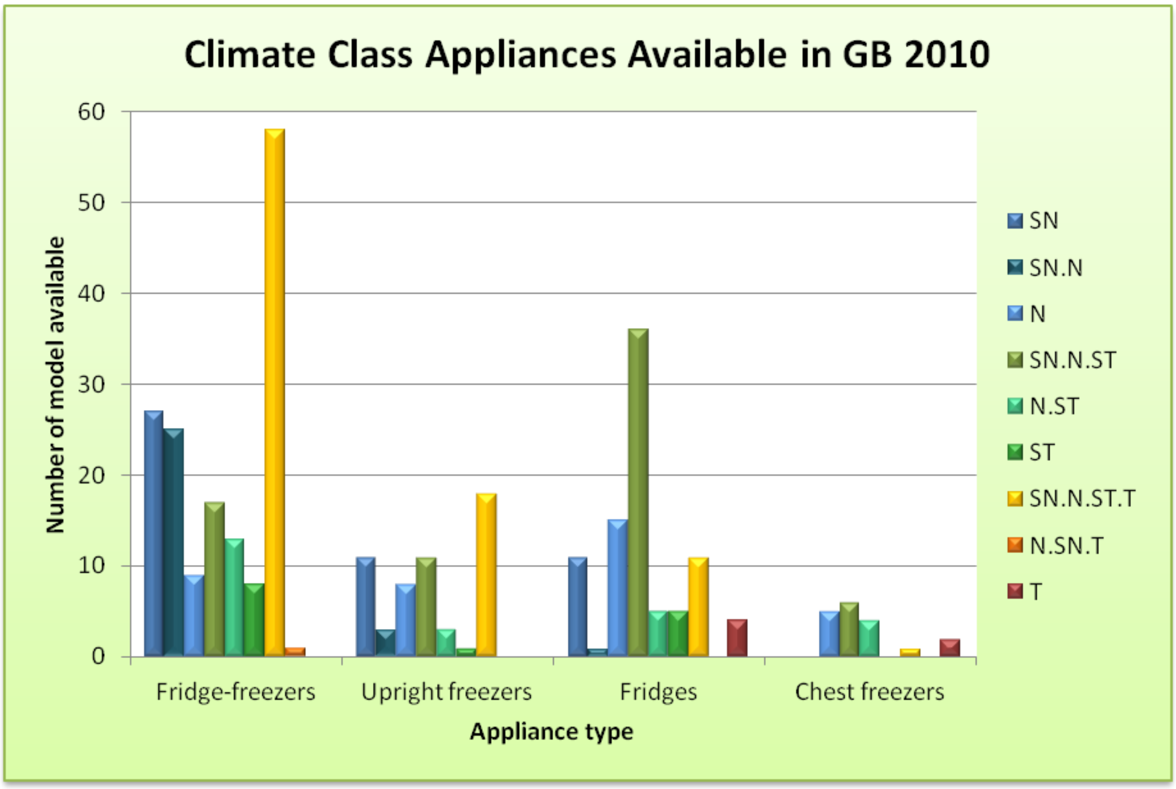

Figure 19: Number of cold appliances available in Great Britain in 2010 (Source: GfK and market research)

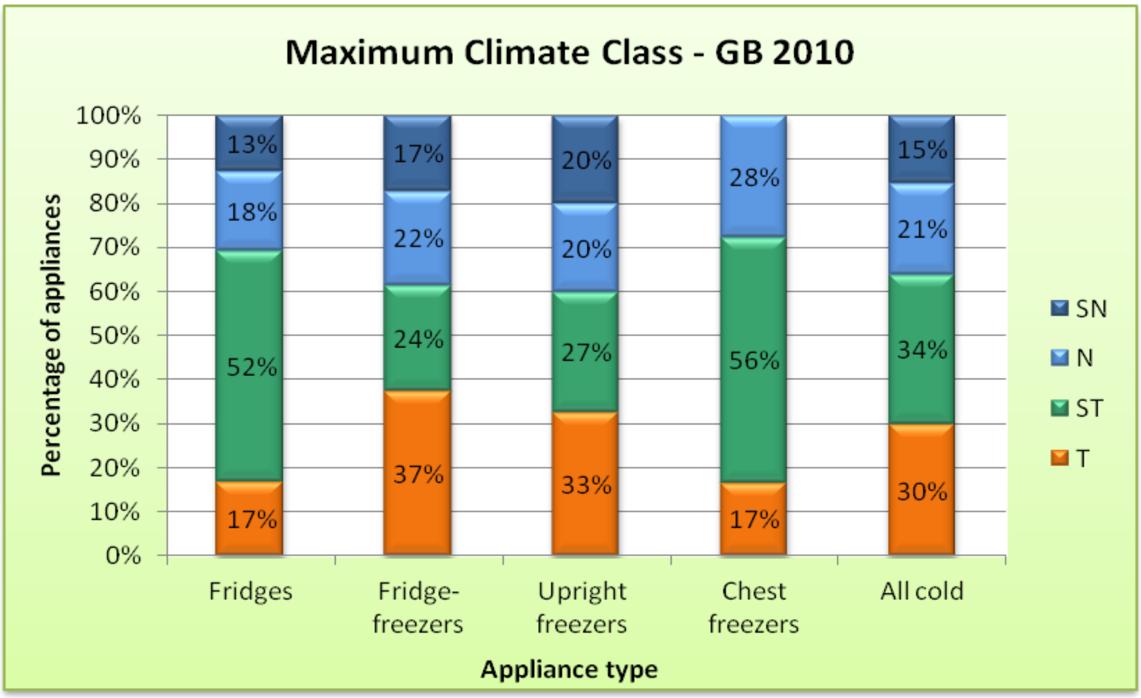

Figure 20: Maximum climate class classifications for appliances available in GB 2010 (Source: Analysis of Gfk and market data)

7.8 Market distortion

A review of the changing use of different climate classes is recorded in the EuP preparatory study which suggests a trend to warmer climate class appliances. This is most noticeable in the data from the year 2000 onwards when there appeared to be a move to the supply of more appliances with a maximum class of ST. The increase appears to have continued although the trend in the CECED data is not smooth. The increase in the maximum class of ST appears to be taking the share from maximum N class appliances. Generally, chest freezers have lagged behind other refrigerating appliances in this trend.

There is no conclusive evidence as to the reason for the change in the nature of appliances supplied, but the increase in ST and T class appliances appears to coincide with the introduction of the correction factors for the higher efficiency appliances from 2003. Comparing the 2009 and 2005 CECED database information shows a further increase in the availability of ST and T maximum climate class appliances, notably for chest freezers which now has over 80% of appliances on the database made up of maximum ST and T class appliances whereas in 2005 it was below 70% and in 2003 prior to the revision of the Regulation, introducing the correction factor, it was around 50%. Of all the refrigerating appliances, chest freezers are thought to be those most likely to be situated outside the normal kitchen environment and subject to low ambient temperatures. In the GB sales data these are the only type of appliance without SN only classifications. All SN chest freezers are multi-climate class and eligible to use the ST or T correction factor.

Expert opinion is that the correction factor is probably having some distorting effect on the market. Now that the market has become more saturated with higher efficiency appliances and the production has probably overcome the initial technology cost of product improvements it is the opinion of expert that the correct factor will be being used as an incentive to produce appliances that are classified as coping with warmer ambient temperatures. It is not assumed that multi-class appliances would not be as readily available without the correction factor, due to the pan-European marketing needs of manufacturers, but the presence of the correction factor advantage in the energy efficiency index seems less appropriate for appliances claiming to cover a range of climate classes compared to those specifically designed for warmer climates.

The average number of climate classes for appliances recently sold in GB would appear to be similar to the 2.5 quoted for Europe as a whole in the EuP preparatory study, but looking at the frequency of multi-class appliances from European consumer tests and GB sales data a significant number stand out as being multi-class from SN to T.

7.9 Summary and discussion

- Estimation of the share of product sold as tropical (T) and sub-tropical (ST) climate classes, and the prevalence of multiple climate class appliances.

Market data provides a general picture of the availability of appliances which are multi-climate class and the maximum climate classifications. Percentages of sales by climate class for the whole of Europe is not available, but the range of appliances recorded on the CECED database indicates that around 80% of refrigerating appliances manufactured have a maximum climate class classification of ST or T. According to market data from GB the percentage of appliances with maximum ST and T class classifications is between around 60 and 70% depending upon the appliance type. Many of these appliances are multi-climate class, with the average climate class ranging from 2.1 for chest freezer s and 2.6 for fridge-freezers sold in the UK.

When considering the availability and sales of different climate classes it is important to consider the consumers position and knowledge on this matter. Climate class has a very insignificant profile for consumers when choosing an appliance. The EuP preparatory study did not include it as one of the purchasing considerations in its survey with manufacturers and consumers and experience in researching this area has demonstrated that it is not easy to find climate class information. Its absence on the energy label means that even if consumers were aware of any benefits in use and the adjustments made for the energy efficiency index, they would not be able to easily identify the necessary information.

- Assessment of whether ST and T class appliances can meet the temperature requirements for their climate class classification.

The review of the test data from the ATLETE project and the limited testing commissioned as part of this research suggests that in the majority of cases appliances that are climate class ST and T are able to perform adequately at a range of ambient temperatures.

- Assessment of the energy benefits for consumers of the use of ST and T appliances.

In order to cope with higher ambient temperatures than those used for standard tests and temperatures expected to be encountered by ST and T class appliances, more efficient compressors are used. Hot ambient conditions present more challenges for refrigerating appliances and if the components are not optimised for this environment then energy consumption will increase and energy efficiency is reduced. The use of multi-climate class classifications results in a potential compromise. It may not be as easy to optimise all the components for a multi-class product as it is for a product to be used in a smaller ambient temperature range. Potentially, the use of multi-climate class classifications results in less efficient appliances when they are operated at higher temperatures than appliances specifically designed for hot conditions only.

In considering the appropriateness of the provision of different climate class appliances according to consumers' requirements, and thus the benefits that a wider range of climate classes offers consumers, it has been observed that in many households across Europe the minimum operating ambient temperature may be significant. The average minimum temperature of the room with a refrigerator is 14.6°C according to the research for the EuP preparatory study, and 12.7°C for the freezer. Around 70% of households in Spain and UK suggested that the minimum temperature where they operate a refrigerator is less than 16°C. The frequency of temperatures below 16°C is greater for freezers in all countries.

Whilst the efficiency and performance of an appliance at lower temperatures may not be so critical in terms of food storage and energy consumption, there is the possibility of consumers purchasing inappropriate appliances if climate class is not considered.

- Assess whether the market share of appliances eligible for the correction factor has distorted the market.

The provision of appliances with ST and T climate class classifications has increased. However, there is no clear indication why this is the case, except manufacturers claim it is easier to make appliances suitable for all environments than it is to make lots of products tailored to individual climate locations. Expert opinion is that it is unlikely to be due to consumer demand as this characteristic is generally not considered to be high in consumers purchasing preferences. Catering for a wider European consumer market, economising production and manufacturing efficiency may be seen as one influence, but it cannot be ignored that, in a competitive market, the benefit offered by the correction factor in reflecting a better efficiency index could help in determining the types of appliance produced. One interpretation could be that manufacturers take the simplest option of producing appliances suitable for all climate class ranges, which also allows them to use the correction factor and portray good energy efficiency regardless of where it is to be used. Energy efficiency is a focus for consumers purchasing an appliance and any measures to present a highly regarded appliance is expected to be a focus for manufacturers.

7.10 Conclusion

From a technical perspective it is the opinion of experts that the correction factor could be removed on the basis that appliances can be produced that will be efficient for operating in all climate conditions if the technology and components are optimised. Removing the correction factors would encourage the development and introduction of the best technologies. Conversely, without the correction factors, appliances designed to operate in warmer climates but which cannot perform efficiently during the standard tests, may not be as attractive to consumers because of their poorer energy label class.

Anecdotal evidence suggests that the climate class must be the least prominent characteristic to consumers purchasing an appliance that is considered in the energy efficiency calculation. If consumers are not aware of this performance aspect of appliances they are not able to fully consider the efficiency information provided on the label. It seems inappropriate that the correction factor used in determining the energy efficiency index is applied to the majority of appliances regardless of the location of their use. According to the EuP preparatory study only around 10% of European households have their refrigerating appliances in locations where the maximum ambient temperature would result in the need for an ST or T class appliance. Information regarding climate class and what this means needs to be better communicated to consumers, for example as a characteristic provided on the energy label. It is a requirement of the current Regulations that the climate class information should be provided on the fiche and product literature as well as when consumers are unable to see a product. However, an increase in its prominence and further explanations to consumers would be beneficial, regardless of the use or otherwise of the correction factor, to ensure consumers are using the most appropriate technology for their circumstances.

The energy label can only provide indicative information in relation to energy consumption. The energy test at 25°C may not be representative of many appliances in use, but it should offer a fair comparison. Consumers do not necessarily consider the actual kWh/y data but are more easily informed by the colour coded efficiency letter. It is essential that this information is therefore as transparent and consistent as possible.

The simplification of the energy label layout does not help in the possible provision of more detail or explanation of the data given. However, if the operation of appliances for different European regions is considered important then perhaps a label that links the energy efficiency with the climate class of an appliance should be considered and which provides efficiency ratings for the appliance tested at up to two additional different ambient temperatures, depending upon the classification. The air conditioners energy label[25] provides energy efficiency for the heating function for different climatic regions represented on a European map. Some kind of similar approach could be taken, but not necessarily using the same map as the key element is the temperature in people's homes. The requirement of a revised label layout would be to show consumers that a multiclass appliance could use more energy than necessary if not used at the higher range of its classification, and highlight the availability of different climate class appliances.

[25] COMMISSION DELEGATED REGULATION (EU) No 626/2011 of 4 May 2011 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of air conditioners

At the time of this research the market is in a transition stage, the GB market data recorded a mixture of energy efficiencies with some appliances being eligible to use the climate class correction factors (namely A+ or better). Considering the same market data but assuming all efficiencies are able to use the correction factor, and in this scenario the market is the same in terms of the types of climate class classification offered, then in GB 35% of fridge-freezers sold could be using the correction factor, along with almost 50% of upright freezers and fridges and 26% of chest freezers.

The justification by the European Commission for the use of climate class correction factors when the energy label was extended to A++ in 2004 was to compensate for the cost of using a range of design options to ensure appliances can operate efficiently at all climate classes and encourage technology development. This was not the conclusion of the Cold II study in 2000 which recommended that no correction factor should be attributed to ST or T class appliances. Using the EC justification, the correction factor is a benefit to the manufacturer in helping them maintain marketable priced appliances. This suggests that without the correction factor the ST and T class appliances which are able to meet minimum energy efficiency requirements might be too expensive.

This benefit to the manufacturers by making it more economical to product a certain type of appliance undermines the purpose of the energy label if the correction factors are used to make appliances look more efficient.

8 Task 2: Frost-free correction factor

8.1 Introduction

For frost-free appliances (sometimes described as 'no frost', 'forced air' or 'dynamic'), a 1.2 factor can be applied to frozen food compartments for the calculation of the energy efficiency index. The factor effectively increases the volume of the storage compartment in the calculation of the 'equivalent volume' used to determine the standard annual energy consumption for the calculation of the energy efficiency index (EEI). The larger the standard consumption (SC) compared to the actual energy consumption the better (lower) the efficiency rating.

The Energy Label Directive (94/2/EC January 1994[26]) states that the factor *“allows for the possible bias of the measurement method, which does not allow for the lack of ice build up on ‘no frost’ appliances. In practical use ice build up will somewhat increase the consumption of ‘conventional’ appliances”.* The 1.2 factor was intended to allow fairer comparisons between frost-free (dynamic) appliances and conventional (static) appliances, taking account of the fact that during testing, the frost-free appliance will use energy for the defrost cycle whereas a conventional appliance would not even frost up during the test period. The Cold II[27] study suggested that under test conditions frost-free appliances used 3.5% to 15% more energy depending upon the system.

The following extract is from the European Commission working document[28] circulated prior to draft implementing documents for the setting of ecodesign criteria.

“The no frost correction factor (FF): a 1,2 factor is set only for the frozen-food compartments or cabinets. The specific analysis developed during a previous SAVE study of 2000 showed that depending on the no-frost technology used, under the EN 153 test conditions no-frost appliances would be expected to use between 3,5% and 15% more energy than equivalent natural-convection appliances. For partial no-frost appliances with a ‘no-frost’ refrigerator compartment and a natural-convection frozen-food compartment, the increment in energy consumption would be expected to be very small and not sufficient to justify the correction factor; conversely, if a combination appliance has a no-frost frozen-food compartment and a natural-convection fresh-food compartment, a correction factor of 1,2 times the equivalent volume of the freezer compartment appears to be justified.”

8.2 The frost-free allowance and volume

As introduced in chapter 6 the effect of the correction factors applied to the equivalent volume is not consistent across all volumes of appliance.

[26] COMMISSION DIRECTIVE 94/2/EC of 21 January 1994 implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations

[27] European Commission, December 2000. Cold II The revision of energy labelling and minimum energy efficiency standards for domestic refrigeration appliances. Contractor ADEME, Coordinator PW Consulting (UK).

[28] WORKING DOCUMENT ON A POSSIBLE COMMISSION DIRECTIVE IMPLEMENTING COUNCIL DIRECTIVE 2005/32/EC WITH REGARD TO HOUSEHOLD REFRIGERATING APPLIANCES Explanatory Notes. Circulated to members of the Regulatory Committee (Defra in the UK) November 2008.

It seems reasonable that a larger appliance consumes more energy and that as an appliance increases in size it has a larger evaporator that requires a larger defrost heater and a larger fan to distribute air within the appliance. It is also reasonable that the heater and fan has a minimum size and therefore, if used appropriately, the frost-free factor should have an offset.

If actual volume is plotted against standard energy consumption (SC) the frost-free and static appliances the effect of the correction factor can be illustrated. The frost-free appliance is allowed to use relatively more energy than the static appliance as shown in Figure 21 and Figure 22. The comparison starts from a typical smallest volume appliance found in the UK (GfK 2010); around 80 litres for the fridge-freezer and around 30 litres for the upright freezer, both static. The smallest frost-free formats are around twice the size of the smallest static appliances. The figures illustrate, for example, that a 150 litre frost-free fridge-freezer can consume 5.2% more energy and a 300 litre fridge-freezer can consume 7.5% more energy than a non frost-free fridge-freezer (everything else being equal). The same trend is apparent for a fully frost-free freezer with a 150 litre frost-free freezer consuming 7.1% more energy and a 300 litre appliance consuming 10.5% more energy than a non frost-free freezer appliance (everything else being equal). As larger appliances generally should be more efficient this does not seem appropriate.

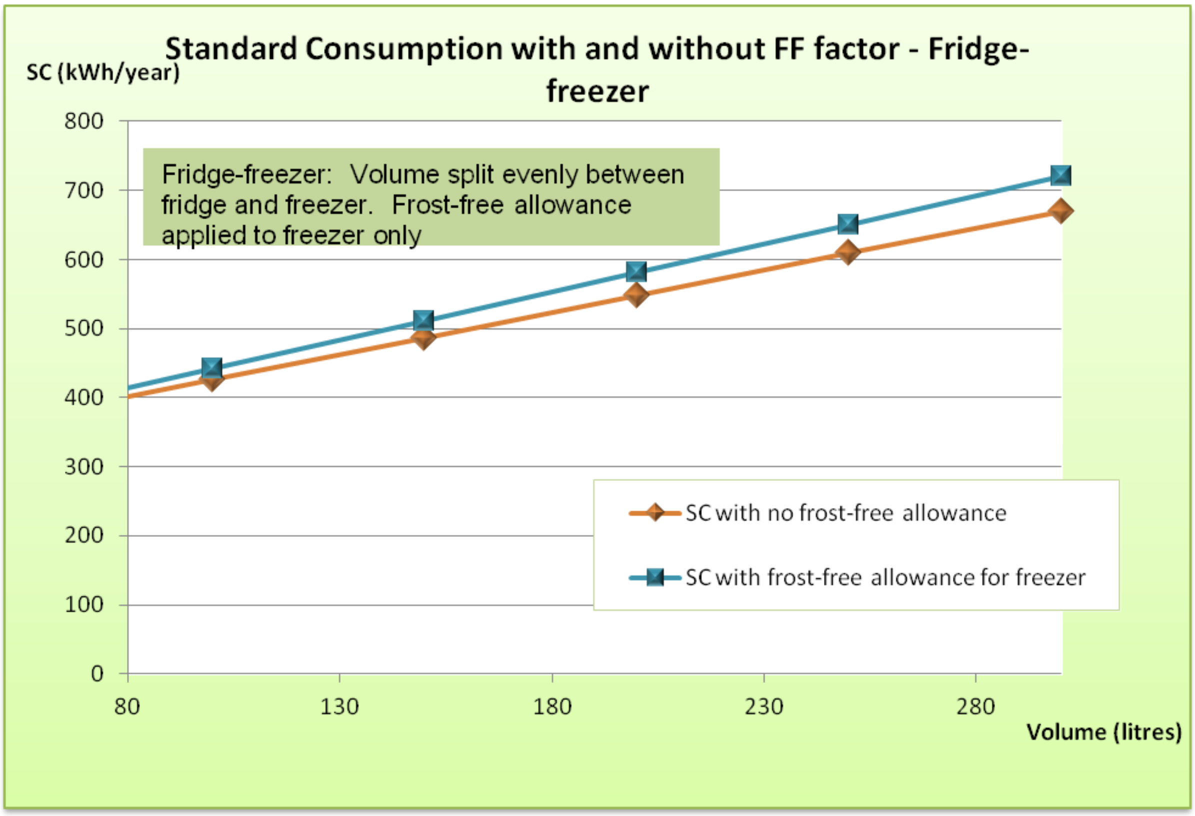

Figure 21: Standard energy consumption (SC) against actual volume with and without frost-free factor: fridge-freezer.

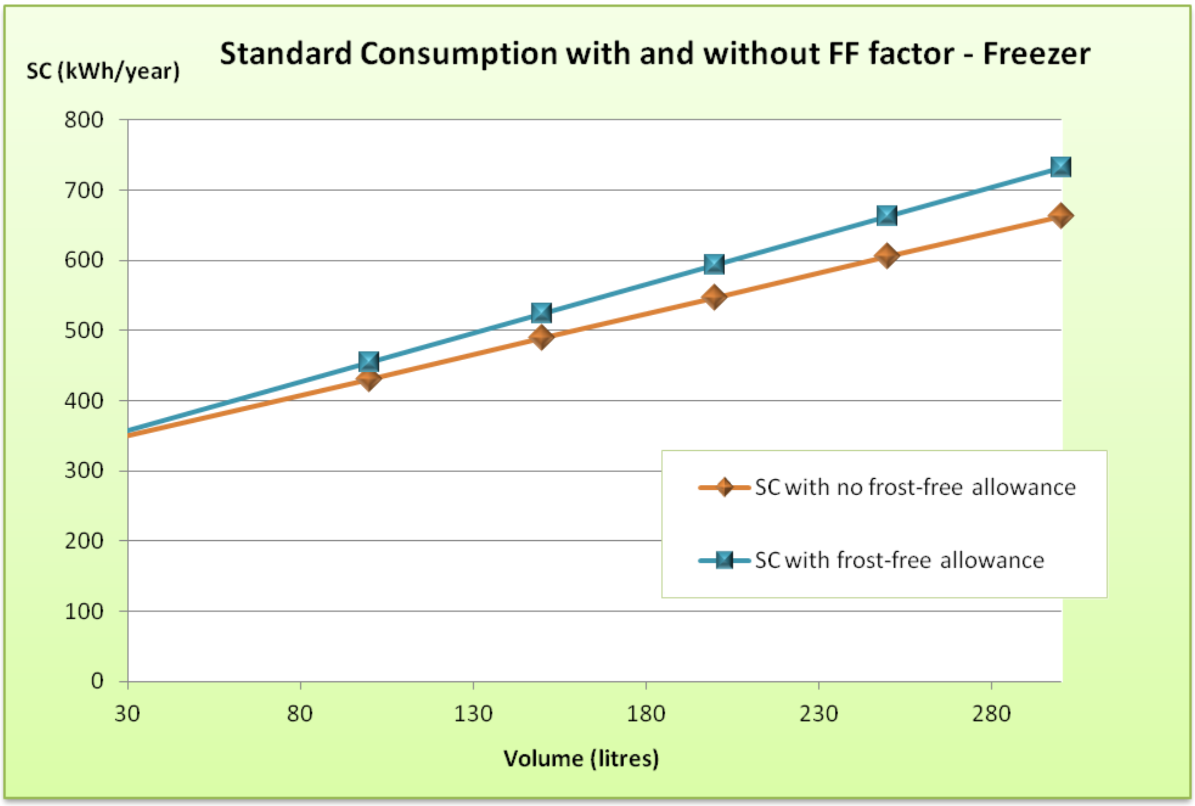

Figure 22: Standard energy consumption (SC) against actual volume with and without frost-free factor: freezer

The current SC equation therefore allows larger frost-free appliances to have an advantage. If the correction factor for frost-free is to be used it would be more appropriate, even if SC and volume are considered to be directly related, to allow frost-free appliances to have the same additional percentage allowable energy when compared to non frost-free models. This could only be achieved by revising the SC equation so that the FF factor was included in the offset (i.e. N_a + CH) as well as the AV part of the SC calculation:

Equation 3

$$SC_a = M_a \; x \; \sum_{Compartments}(V_c \; x \; \frac{(25-Tc)}{20} \; x \; FF \; x \; CC \; x \; BI) + N_a + \; CH + FF$$

If this were to be implemented the FF factor would need to change to provide similar SC values to the current SC equation. Figure 23 shows the SC equation before and after adjustment to create a consistent frost-free allowance across appliance volumes for the fridge-freezer and freezer examples. To generate approximately the same allowance a FF factor of 1.045 was applied to Equation 3.

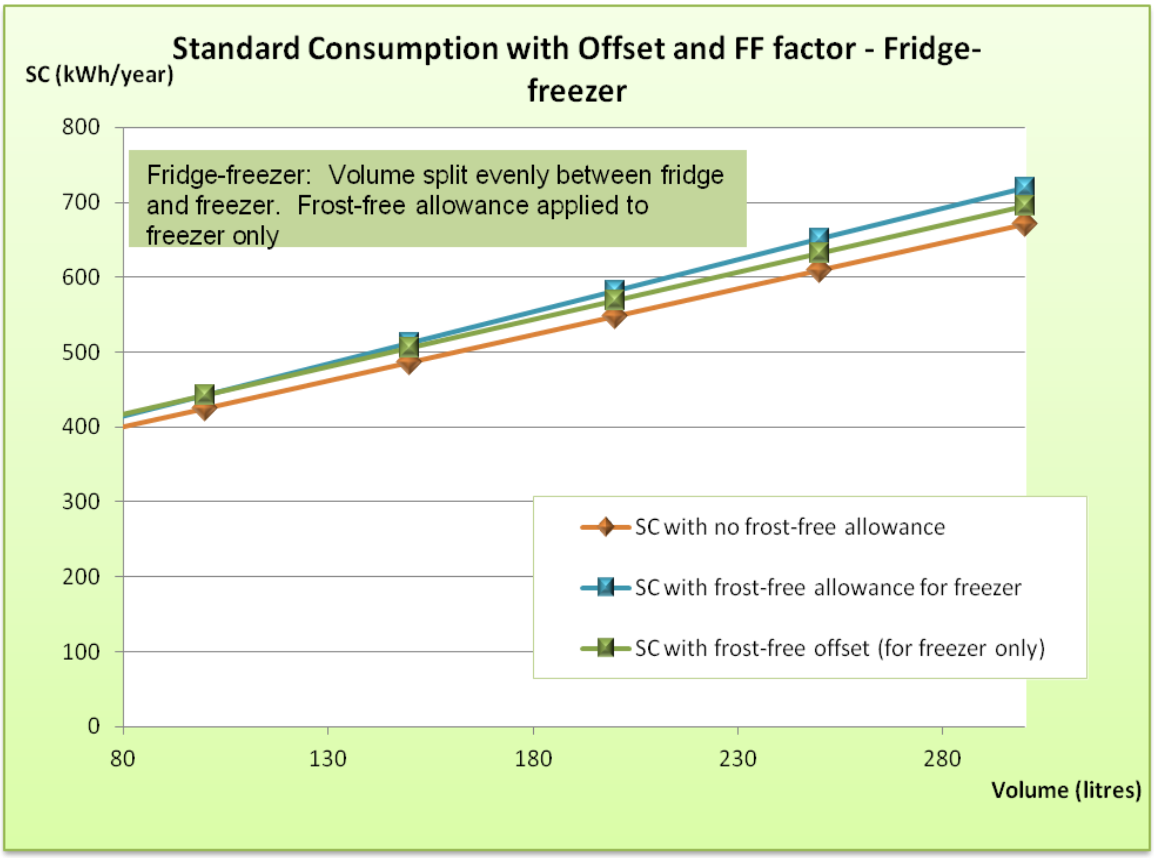

Figure 23: SC against actual volume with and without correction factor and showing adjusted FF offset: fridge-freezer.

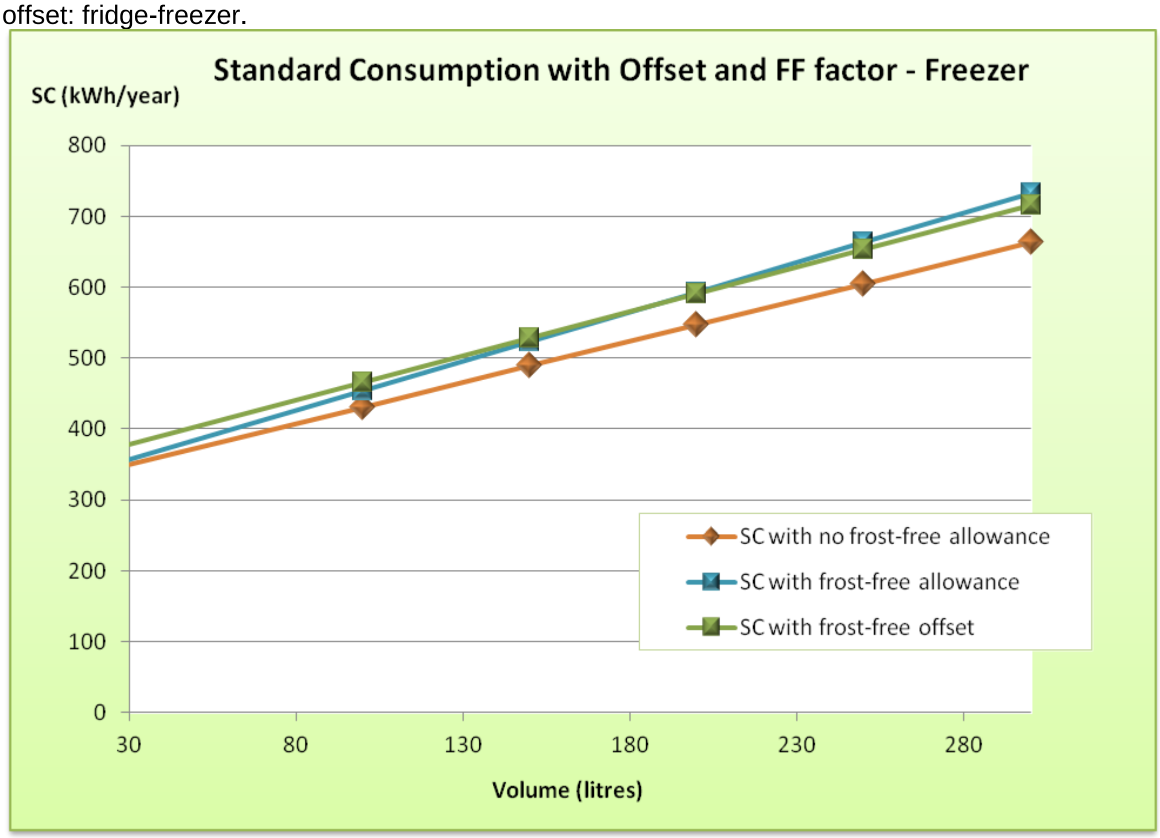

Figure 24: SC against actual volume with and without correction factor and showing adjusted FF offset: freezer.

8.3 Theoretical calculation of frost-free allowance

The effect of the frost-free allowance was analysed using a simplistic calculation to compare frost-free and non frost-free fridge-freezers and freezers. The assumption was made that the only difference between a frost-free and non frost free appliance was that the frost-free cabinet had an added heater and fan. In reality this is not fully the case as is outlined above. The assumptions made in the calculation are listed in Table 6.

It was assumed that the non frost-free (static) and frost-free appliances were identical apart from the additional energy used in the frost-free fridge-freezer supplied by the heater and fan. The direct energy used by these components was calculated and the additional heat that the components created that had to be extracted by the refrigeration system was calculated based on the COP of the refrigeration system. Calculations were made based on the number of times the freezer defrost cycle activates (to simulate the effect of defrost on demand type controllers), for example, defrosts every 8 hours (three defrosts a day), 12 hours (two defrosts a day), 24 hours (one defrost a day), 48 hours (0.5 defrosts a day).

Table 6: Assumptions made when assessing frost-free allowance value.

Factor	Static	Frost-free
Size	300 litres fridge- freezer (evenly divided between fridge and freezer)	300 litres fridge- freezer (evenly divided between fridge and freezer)
Frost-free factor	Not applied	Applied to the freezer
Temperature	-18°C freezer, 5°C fridge	-18°C freezer, 5°C fridge
Power consumed	30 W (based on steady state mathematical model of domestic fridge)	30 W plus energy consumed by fan and heater
COP of refrigeration system	1.1 (based on COLD II, 2000, data), input into mathematical model	1.1 (based on COLD II, 2000, data)
Defrost heater	n/a	150 W (70% of energy provided to cabinet based on data from Bansal et al, 2010)
Defrost timer	n/a	15 minutes (based on RD&T data)
Fan power	n/a	1.5 W (based on COLD II, 2000, data)

The base non frost-free cabinet consumed 262.8 kWh/year based on an average power of 30 W. The SC for the same cabinet was 765.4 kWh/year giving an energy efficiency index (annual energy consumption/SC)) of 34.3%. To be equally comparable the frost-free cabinet should have an equal energy index when the frost-free factor is included. The actual frost-free factor that would give exactly comparable results to a non frost-free cabinet for the varied defrosts timings is presented in the FF factor column in Table 7. Table 8 provides results of a further calculation to assess the effect of reverse cycle defrosting where the energy of the frost-free appliance was reduced by 8% in line with the work by Yang et al (2010).

Table 7: Frost-free factor required to make the EEI of a non frost-free and a frost-free 300 litre fridge-freezer exactly comparable.

Defrosts per day	Total energy of frost-free fridge-freezer (kWh/year)	FF factor
3	354.2	1.80
2	332.2	1.61
1	310.0	1.41
0.5	299.0	1.31
0.2	292.3	1.26
0.1	290.1	1.24

Table 8: Frost-free factor required to make the EEI of a non frost-free and a frost-free 300 litre fridge-freezer exactly comparable when reverse cycle defrost was applied.

Defrosts per day	Total energy of frost-free fridge-freezer (kWh/year)	FF factor
3	326.0	1.55
2	305.6	1.37
1	285.2	1.20
0.5	275.0	1.11
0.2	268.9	1.05
0.1	266.9	1.03

The results from these simplistic calculations agree well with those carried out in the COLD II (2000) report where calculations were made to determine whether the value for the frost-free factor was valid. The results from the COLD II (2000) report showed that correction factors could range from 1.02 to 1.3 depending on the technology and test standard applied. The results in Table 7 demonstrate that if a demand defrost system is applied the correction factor for frost-free is unlikely to be this low and is most likely to be between 1.2 and 1.3. If reverse cycle defrost was also applied the correction factors could be as low as 1.1 (see Table 8).

Assuming that the aim of the energy labelling scheme is to encourage the market towards energy efficient appliances then applying energy efficient fans, defrost on demand and reverse cycle defrosting are all methods to minimise energy consumption. Theoretically if all three technologies were applied the correction factor for frost-free could be as low as 1.03.

8.4 Effect of the correction factor - market examples

The frost-free correction factor increases the equivalent volume used in the calculation of the standard energy consumption. It is only applied to the frozen food compartment. To consider the effect this has on actual appliances a selection of top selling upright freezers sold in the UK in 2010 have been analysed. The difference between the equivalent volumes calculated with and without the 1.2 correction factor is 16.7%. When the standard consumption is considered the differences with and without a 1.2 correction factor ranges from between 4% and 9%. If the correction factor is removed, this is the level of improvement in the energy consumption that would be necessary to retain the EEI achieved with the correction factor. For the 6 examples used the average improvement necessary if the correction factor of 1.2 was removed would be 7%. The comparison using a range of fridge-freezers gives a slightly different result, but this is because the fridge consumption and volume contribution is different for each appliances. As the factor is only applied to the freezer compartment, an analysis of using only freezers is more effective.

Section 8.6.1 considered the amount of energy used by a frost-free appliances during the defrost cycle. The consumption data for two upright freezers used for the analysis of defrost energy was used to review the effect of the correction factor. If the correction factor is set at an appropriate level then the effect of the correction factor should be similar to that amount of energy used for the defrosting element of the appliances' consumption. On average the difference in the energy consumption with the energy consumption necessary to achieve the same EEI without the 1.2 correction factor was 6.01%. The difference between the energy consumption and the energy consumption with the defrost energy use removed was 6.23%. This comparison is using only two freezers. This same analysis has been carried out on an additional 6 freezers with a range of volumes and efficiencies ranging from A to A++. The difference is 6.9% between in energy consumption with and without the correction factor and 5.4% between the total energy consumption and the energy consumption with the defrost energy used removed (using an average of 11.9% of total energy consumption being consumed due to the defrost operation).

This analysis of the effect of the frost-free correction factor compared to the energy used for defrosting in a frost-free appliance illustrates that it is possible to make a comparison. It suggests that the correction factor may be at an appropriate level to reflect the extra energy used by frost-free appliances, but substantial evidence would be needed to qualify these findings for a wider market.

This analysis is also confined to considering the level of the correction factor but does not consider the comparison in the energy used by a frost-free appliance compared to a static appliance, which is dealt with elsewhere in this chapter (section 8.6).

8.5 Comparison of frost-free and static appliances

It is not possible to examine two identical appliances from the market place, one with and one without the frost-free defrost function since frost-free and static appliances cool in quite different ways. The no-frost function is not just an “add-on” it requires a different design and components. Most notably the freezer volume is decreased and volume has a significant effect of the EEI calculation. However, from a review of the market it has been possible to find appliances that appear to be the same in all other features and dimensions except for the frost-free characteristics affecting the freezer volume, these are given in Table 9. In Great Britain (GB) the first and third best selling fridge-freezers in 2010 were Hotpoint appliances which appear to be essentially the same, they have the same overall dimensions, features and fridge capacity, but one is frost-free. The manufacturer has confirmed that the two appliances are essentially the same, including the compressors, except for the frost-free equipment and a user interface. The frost-free model has a reduced freezer volume by 5 litres and increased declared energy consumption of 10 kWh per year compared to the static version. Similarly, another very popular fridge-freezer in GB, a Beko model has a near identical cousin in the range with the only significant difference being that the frost-free appliance has a freezer volume 14 litres less, but in this example both appliances claim to use the same amount of energy per year. Another pair of Beko appliances, one frost-free, has a 12 litre difference in the freezer volume and the frost-free version only uses 1 kWh per year more than the static version. There is also a Beko tall upright freezer example where the frost-free version has a net storage volume of 18 litres less than the static version and uses 8 kWh per year more.

These examples provide useful comparisons, but may conversely illustrate the fact that it is not possible to make a direct comparison of appliances with and without frost-free characteristics because of volume differences.

Table 9: Comparison of static and frost-free similar appliances

Appliance	Defrost	Fridge Volume	Freezer Volume	% difference in freezer volume	kWh/y	% difference kWh/y
Hotpoint fridge-freezer	Static	150	85		307	
Hotpoint fridge-freezer	Frost-free	150	80	6.3%	317	3.3%
Beko fridge-freezer	Static	175	100		335	
Beko fridge-freezer	Frost-free	175	94	6%	335	0.0%
Beko fridge-freezer	Static	134	75		292	
Beko fridge-freezer	Frost-free	134	63	16%	293	0.34%
Beko upright freezer	Static	_	175		254	
Beko upright freezer	Frost-free	_	157	10.3%	262	3.1%

Information provided by CECED illustrates further examples of similar appliances on the market. Two examples of frost-free upright freezers and two fridge-freezers are considered which have similar static versions with the same external dimensions. The frost-free versions consume between 5.8 and 9.9% more energy as well as having slightly reduced freezer compartment volumes. It is suggested that for all the example appliances to achieve the same (A+) energy class the manufacturers have used compressors for the frost-free appliances that are 5 to 19% more efficient. (Further detail on this comparison from CECED can be found in Annex D)

It is reasonable that the whole system needs to be more efficient because the heat used in the defrosting phase must be removed along with the heat for post-cooling and normal cooling.

8.6 Energy demand related to freezer frosting

Two main issues need to be considered when comparing differences in characteristics that effect the energy consumption in test and actual use for frost-free appliances and static appliances. These issues contribute to the consideration of differences in testing that could be accounted for by a correction factor. Put simply these are the extra energy used by a frost-free appliance to maintain an ice-free compartment and any extra energy used by a static appliance in use due to a frosted-up interior and any associated energy used to manually defrost the appliance.

8.6.1 Frost-free appliances

Under laboratory conditions when frost-free appliances are tested for energy consumption it is possible to analyse the test data to identify the amount of energy used for a defrost cycle. Information has been gathered from market surveillance testing of a range of appliances in the UK.

The information is taken from energy consumption tests at 25°C for 8 appliances. The sample includes side-by-side (4) and upright fridge-freezers (2) and upright freezers (2), all were energy class A+ or better, and all climate class types are included.

On average the appliances used 1.03 kWh per 24 hours including the defrost cycle (kWh averaged over a 3 day test period). The defrost cycle used 0.095 kWh on average. As a percentage of energy use the defrost cycle accounted for 9.6% of the energy use on average. The frost-free cycle consumption ranged from 3.9% to 13.7% of the total energy consumption per 24 hours. The lowest value came from the smallest upright fridge-freezer which only had a frost-free freezer compartment.

The limitation of this analysis is that the range of appliances evaluated is only small and does not necessarily represent the typical market. The side-by-side appliances were larger than the upright fridge-freezers, but did not necessarily use a significantly greater or lesser amount of energy for the defrost cycle (the average of the side-by-side only fridge-freezers was 9.3% of the energy is used for defrosting).

Although a small sample, this analysis supports the information given in the Cold II report that frost-free appliances use between 3.5% and 15% more energy than equivalent static appliances. Given that the Cold II report was looking at appliances around 10 years ago, current appliances appear to be operating in a similar manner in terms of the energy used for defrosting.

The analysis above considered appliances in the test environment and the critical difference affecting the icing up and defrosting of an appliance is that under test conditions the door is not opened so there is little transfer of moist air into the cabinet. An appliance initiating a defrost cycle once in three days under test conditions might be expected to defrost more frequently, for example once every two days in actual use.

8.6.2 Static appliances

In order to fully assess whether the frost-free function is likely to result in a reduced energy demand in real use, it would be useful to know how much energy is needed by a static appliance compared to a frost-free appliance in actual use. A direct comparison is not available, little information has been found that assesses how much extra energy is used by a frosted up static appliance in use and the energy used to defrost such an appliance (including the energy used to restore a defrosted appliance to normal operating temperatures).

In order to give this comparison some assumptions have been generated to consider the amount of energy used for defrosting static appliances. The energy used by the frosted up static appliance also needs to be considered.

An anecdotal survey for this research was undertaken with UK and Italian consumers to determine how frequently freezer compartments are defrosted and also the methods used.

Consumers may use a combination of methods to defrost a freezer compartment ranging from leaving the ice to defrost naturally to speeding up the process with the application of heat. This heat is usually introduced in the form of containers of hot (boiled) water, although this practice is less common within the Italian sample than in the UK survey results. Hair dryers were also used and in a few cases steam cleaners and fan heaters were used.

There are three main elements to consider for evaluating the energy associated with having a static appliance when comparing with the defrosting feature offered on frost-free appliances:

1. the extra energy used by a static appliance which has accumulated frost and ice.
2. the energy used to defrost the appliances, i.e. any added heat to thaw the ice.
3. the energy used to re-cool the appliance and any food removed from the freezer during defrosting that may have warmed.

- Extra energy used by a frosted static appliance

There is little recorded information on this aspect of appliance performance. This research has not been able to find any robust evidence that suggests the difference in the consumption for an ice-free and frosted up static appliance in use. A paper by Bansal[29] considered the effect of ice on a refrigerator evaporator. The appliance used around 22% more energy than when the compressor was clear of ice, but this laboratory simulation may not be typical of actual consumer use. There have been other theoretical and experimental considerations of the effect of frosting on evaporator performance. Work[30] by Arcelik and Istanbul Technical University concluded that the frosting of the evaporator had an effect on the air flow but did not provide any information on any changes in energy consumption. The experimentation was limited to one modified appliance and considered the effect of different increased levels of humidity on the evaporator. The results are not directly transferable to typical refrigeration appliance use.

Intertek undertook some energy data logging of four appliances before and after defrosting, but the sample was small and may not representative and the outcome was inconclusive. Some appliances appear to operate more efficiently when moderately frosted up whereas others use a lot more energy. The expert assumption would be that a frosted appliance uses more energy due to the ice covering the evaporator creating a longer evaporator time constant which affects the operation of the refrigerating system and usually giving a longer compressor duty cycle which means fewer compressor “switch-ons”. More research is needed in this area to provide more substantial data on the effect of frosting on static appliances, in order to appropriately quantify the extra energy use and compare it with the energy used by frost-free appliances for defrosting automatically.

- Energy used to defrost a frosted static appliance

The most common methods of defrosting a freezer are to either switch off the appliance and let the ice thaw naturally, or introduce heat to speed up the melting process. Allowing natural defrosting obviously involves no additional energy input. The most common method for provided heat to thaw the ice is placing containers of hot water into the appliance. An assumption can be made that a kettle worth of boiling water uses 0.2 kWh. Using 6 kettles worth per defrost equates to 1.2 kWh.

- Energy used to re-cool any food

Reviewing the amount of energy used to cool a test load from -5°C to -15°C it is suggested that it takes around 1 kWh for a typical 150 litre freezer. This is based on an analysis of the performance of 4 fridge-freezers and 4 freezers during data logging prior to standard tests. The introduced load had a starting average temperature of around -3.5°C.

The consumption due to defrosting also depends upon the frequency of defrosting. From the survey it was found that the most common frequencies were once and twice a year.

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[29] Bansal, P., Fothergill, D. and Fernandes, R. (2010). Thermal analysis of the defrost cycle in a domestic freezer. International Journal of Refrigeration 33 (2010) 589 – 599.

[30] Aynur, T. N.; Inan, C.; Karatas, H.; Egrican, N.; and Lale, C., "Real Time Upright Freezer Evaporator Performance Under Frosted Conditions" (2002). *International Refrigeration and Air Conditioning Conference.* Paper 610.
http://docs.lib.purdue.edu/iracc/610

8.7 Energy efficiency comparisons

Figure 25 provides a comparison between a selection of appliances, static and frost-free. This uses the claimed energy consumption data from a range of appliances recorded in households from the UK Household Energy Survey[31] and appliances tested at RD&T, to show power consumption against volume. Where the information is known (in 13 out of 20 static appliances and 25 out of 28 frost-free appliances) the majority are energy label class A. Two appliances that are not A class are indicated by their efficiency letter in the figure. There may be other appliances that are not efficiency rated A, but this information is not available in the dataset used. In a test situation there is statistically no significant difference between the power consumed by frost-free and non frost free appliances (P>0.05). Experts concluded that this may indicate that frost-free appliances are already competitive with static appliances. It is unlikely to fully answer the question of whether static appliances ice up over time and become less efficient as generally it is unusual to keep a cabinet in a test facility for sufficient time to allow the evaporator to ice up (it also should be remembered that tests are carried out with the appliance door closed and so unless the door seal is poor there is little opportunity for moist air to enter the cabinet and water to freeze on the evaporator).

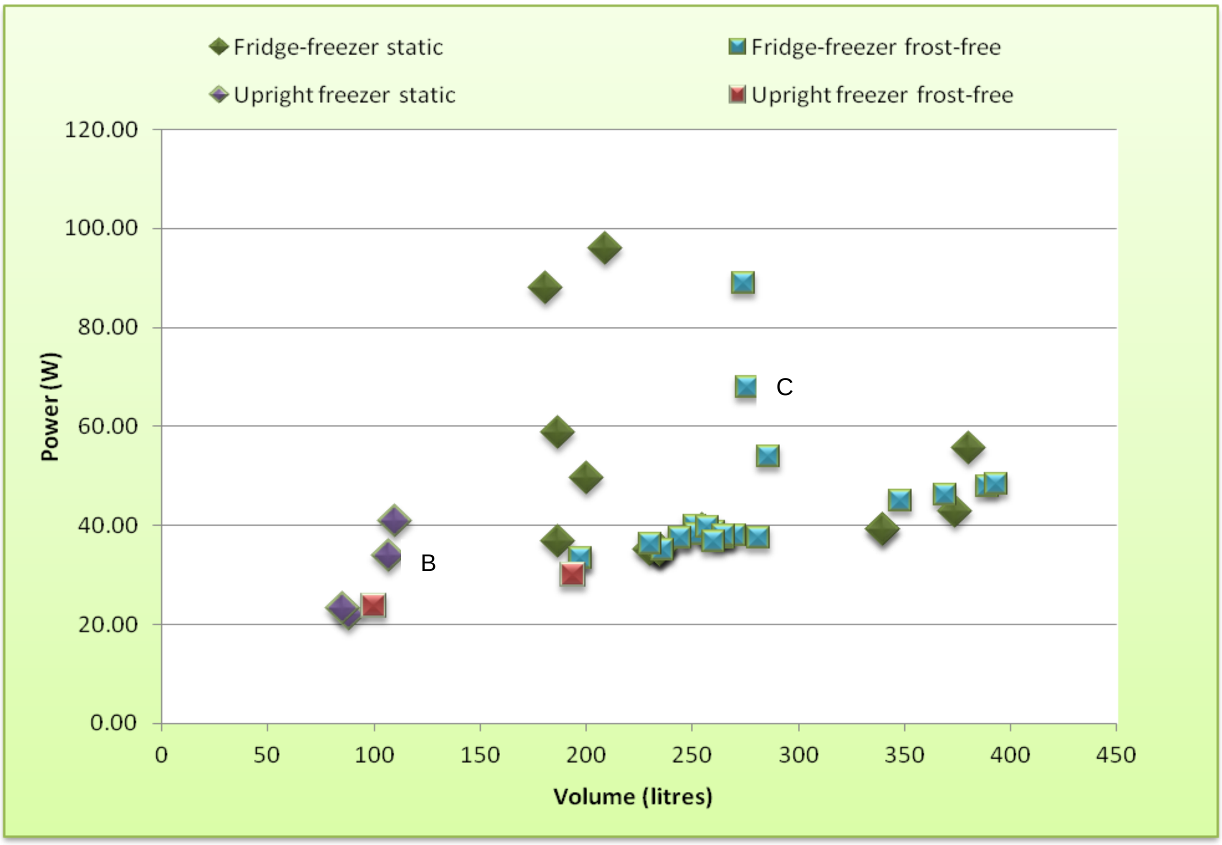


Figure 25 Power consumption of frost-free and non frost-free appliances in test conditions (Source: UK Household Survey and RD&T test data).

[31] The UK Household Energy Survey has been carried out recording the energy consumption of appliances in a sample of households during 2010 and 2011. The final results are yet to be published

8.8 Technical comparison of frost-free and static appliance

In the current ISO and EN 153 test standard a frost-free or no frost system is defined as 'a system in which cooling is provided by forced air circulation and the evaporator(s) is (are) defrosted by an automatic defrost system'.

Commission Directive 2003/66/EC allows manufacturers of frost-free appliances to claim a correction factor of 1.2 for frost-free (no-frost) frozen food compartments. The factor is applied in the following equation to determine the equivalent volume used for the calculation of the standard energy consumption (see Annex A for more detail on the energy efficiency calculation and appliance categories referred to below).

Only certain appliances are able to claim the frost-free allowance. These fall within categories 7, 8, 9 and 10 (fridge-freezers, upright freezers, chest freezers and multi-door or other appliances respectively). Of these, domestic chest freezers are almost never frost-free because ice build up is at a lower rate and the technical complexities of making the appliance frost-free are relatively high (and costly). The COLD II (2000)[32] report states that the fact that the frost-free correction factor cannot be claimed for categories of appliances 1 to 6 has resulted in the almost complete eradication of frost-free units on the market in these categories Market data[33] for 2005 suggests that although there are no frost-free appliances available for categories 2 to 6, there are still a small number of category 1 appliances available that are frost-free (7%). These are likely to be using a passive auto-defrost; regulating the compressor cycle to allow ice to defrost off the evaporator, rather than the fan operated system used on category 7 and 8 appliances.

Frost-free systems require additional energy for their automatic defrost operation. The energy is used by a heater to defrost the evaporator and a fan to distribute air around the appliance storage cabinet. Both the heater and the fan are a direct energy and heat load that has to be removed by the refrigeration system. Therefore depending on how efficiently the refrigeration system removes the heat (coefficient of performance, COP) the overall effect may be up to double the direct energy usage (assuming a COP at worst of 1). The heat from the fans and heater has to be removed and with a COP of 1 this is equal to the energy used by the fans and heater. However, it is not possible to have a refrigerator system with a COP of 1 as the system needs to remove its own heat and the heat ingress into the cabinet from the ambient temperature, as well as the heat from the defrosting system. In addition forcing air around the appliance cavity may increase heat loss through seals and gaskets and more space may be required for air to be distributed inside the appliance. Frost-free appliances also tend to have lower evaporating temperatures than static appliances. This is due to the static appliances generally having evaporators within the storage area (usually within the shelves) and this provides direct cooling to food and a larger evaporator surface area compared to frost-free appliances. Although the impact on energy of a frost-free system would initially appear negative there are some potential benefits such as reducing thermal stratification in the storage cavity which may reduce energy usage.

Frost-free appliances have an electric radiant type heater or a heater integrated into the evaporator that is used to melt ice built up on the evaporator. The temperature of the heater may reach 560°C within 5 minutes of operation (Bansal *et a*l, 2010)[34]. This is controlled by a timer and thermostat. Such appliances usually have a fan that is used to distribute air during

[32] COLD II (2000). The revision of energy labelling and minimum energy efficiency standards for domestic refrigeration appliances.

[33] Data provided by Milena Pressutto, ENEA (CECED technical database used in EuP preparatory studies 2007)

[34] Bansal, P., Fothergill, D. and Fernandes, R. (2010). Thermal analysis of the defrost cycle in a domestic freezer. International Journal of Refrigeration 33 (2010) 589 – 599.

the period outside of the defrost period. The COLD II (2000) report states that the power to operate the defrost heaters varies considerably but that heaters are always operated at full power. In the work reported by Bansal et al (2010) the defrost heater in the appliance examined was 450 W in a 308 litre freezer. In work carried out by RD&T the defrost heaters in three fridge-freezers varied between 142 and 199 W (259-320 litres net volume of fridge and freezer combined). The large difference in defrost heater power between the Bansal *et al* (2010) and RD&T data may be accounted for by the variation in location. All the RD&T tests were on European cabinets whereas the Bansal cabinet was from Australia/New Zealand where humidity is higher and therefore larger defrost heaters tend to be fitted (this is also the same for the USA where humidity can be high in southern states). Tests on cabinets from the USA and Japan in the COLD II (2000) reported defrost powers of between 137 and 158 W for the USA cabinets and between 70 and 158 W for the Japanese cabinets.

Frost-free appliances originally tended to have defrosts that were either activated on a time basis or on a compressor run/cycles basis. In some cases defrosts might be every 8 hours for 20 minutes irrespective of whether the evaporator required defrosting (Figure 26). More recently adaptive or smart defrosting systems that predict when a defrost is required have come onto the market. These use electronics to determine evaporator frosting and only operate a defrost if necessary. Theoretically adaptive defrosts should save energy compared to a timed defrost mechanism. In EN 153 the test period is a normalised period of 24 hours. The test period must begin at the start of an operating cycle and comprise a whole number of operating cycles (defined as the period from initiation of a defrost cycle to initiation of the next defrost cycle) unless the whole operating cycle has not been completed within 72 hours. In some adaptive defrost systems the defrost may only operate every 3 days and so when normalised this equates to 0.33 of a defrost per day. Compared to a system with defrosts every 8 hours this would equate using a crude energy saving calculation (assuming defrosts are of equal length and power input is also equal) to the adaptive system using 1/12th the energy of the ‘traditional’ timed defrost system.

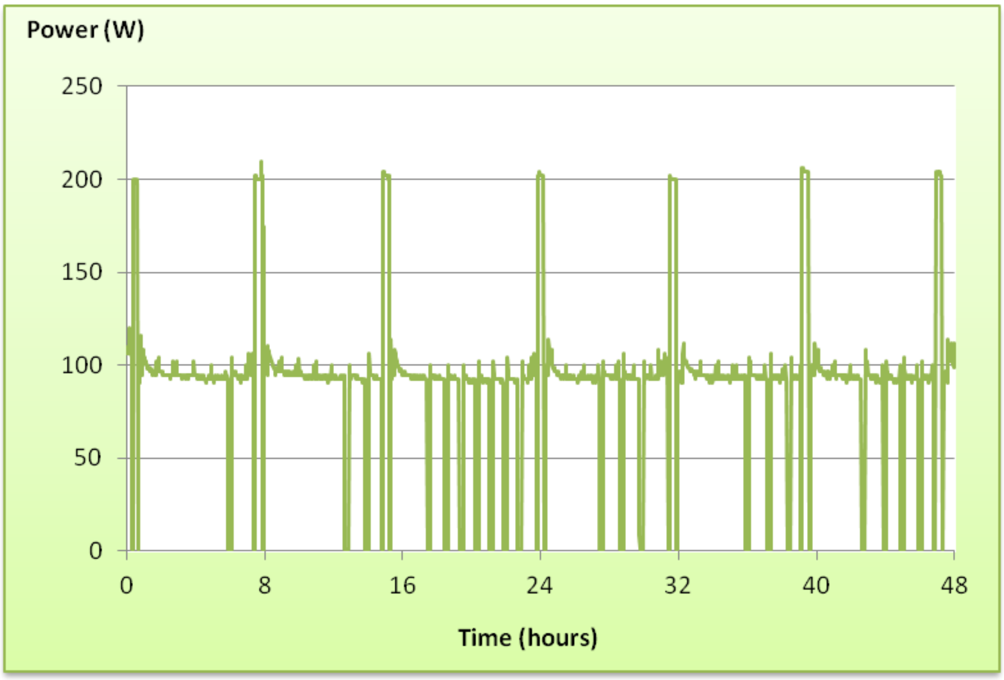


Figure 26: Illustration of the power consumption for an appliance defrosting on a timed basis (W) (Source: RD&T test data logging).

Fans used as part of the frost-free system tend to be between 5.5 and 11 W for USA appliances and as low as 1-2 W for Japanese appliances (COLD II, 2000). The Japanese appliances used DC fans that are widely available in Europe. The COLD II (2000) report states that DC fans provide 'no significant cost increase over conventional low-efficiency shaded-pole fans whereas for the 4 W AC fans the cost is estimated by AHAM to be US$9'.

The COLD II report (2000) states that the energy labelling and MEPS (Minimum Energy Performance Standards) Directives do not supply any technical analysis to support the 1.2 correction factor for frost-free appliances. An analysis of 4 fridge-freezers from the USA and two Japanese appliances was carried out as part of the COLD II project. It was found that the Japanese units consumed less energy than the cabinets from the USA. The reason for this was suggested to be due to lower heater power and better defrost controllers in the Japanese cabinets that prevented evaporators being 'over defrosted'.

8.8.1 Frost-free operation and efficiency

The analysis of the frost-free factor presented is based on a technological analysis of the appliance efficiency and is not an economic analysis based on cost of components.
There is evidence from literature (Bansal et al, 2010) that appliances with ice build up on the evaporator are less efficient than those with an active defrost. Bansal *et a*l (2010) presented figures of 532 kWh/year for a frosted evaporator against 412 kWh/year for an appliance with defrosts. This seems logical if the appliance thermostat is placed in the cabinet, rather than attached to the evaporator. In this case the evaporator will become gradually encased in ice and after the initial frost build up the heat transfer to the evaporator will be greatly restricted and the thermostat will ensure that the appliance operates for greater periods of time to achieve the set point temperature.

Although defrosting the evaporator would appear to be necessary and a means to reduce energy consumption, it needs to be remembered that the defrost process adds heat to the cabinet. This then needs to be removed and results in a longer compressor on cycle immediately after the defrost. Bansal *et al* (2010) estimated in trials with 'normal' operation (i.e. no added water to cause the evaporator to ice up) that the cycle immediately after a defrost was 66.4 minutes compared to a cycle under normal freezer operation of 11.8 minutes. In addition frost-free cabinets have a fan which is also a heat load on the cabinet but also helps to distribute air and increase heat transfer from the evaporator.

The efficiency of the defrost operation using a heater element is relatively low. Bansal *et a*l (2010) calculated using a model and measured data that 'only 28% of the total heat is applied to melting the ice on the evaporator and 10% to heating the melted water to 30°C exiting the drain'. The remaining non useful energy was used as follows: 11% absorbed by the evaporator, 43% absorbed by various freezer components and 8% unaccounted for. It should be noted that minimal energy went into heating up the freezer air. The overall efficiency of the defrost heater for an upright freezer was calculated to be 30.3%. A calculation was carried out in trials carried out by Lawrence and Evans (2008)[35] on a large supermarket freezer cabinet with an electric defrost heater (not embedded in the evaporator block). In the trials the defrost overhead (i.e. the energy not used usefully) was found to be 85% of the energy used in the defrost.

The conclusion from the available trials is that radiant defrost heaters are not the most efficient means to defrost an evaporator. They are however, cheap and relatively simple to install and operate. Bansal *et al* (2010) presented several options available to increase the efficiency of defrosting freezers:

[35] Lawrence, M. and Evans J.A. (2008). Reducing the number of defrosts safely. International Journal of Refrigeration 31 (2008) 107 – 112.

1. Embedding a heater that operates at a lower temperature into the evaporator. This would reduce the radiant heat from the heater and would allow direct contact with the evaporator, thereby increasing efficiency.
2. Using a reverse cycle defrost system. This type of system was investigated by Yang et al (2010)[36]. They found that compared to a conventional heater element defrost cycle a reverse cycle defrost saved 8% of the total energy used by a freezer.

A reverse cycle defrost system uses additional valves which during the defrost cycle restricts the refrigerant circulating through the condenser. The de-superheated refrigerant is passed through the evaporator and then sent via a heat exchanger to ensure the refrigerant is evaporated before it returns to the compressor (further detail is given in Annex E).

8.9 Market picture and trends in frost-free

8.9.1 Consumer opinions

The frost-free feature is a characteristic that manufacturers promote to consumers as part of the marketing package. The EuP preparatory study[37] considered both the importance of this to consumers and manufacturers through reviewing sales documentation and also surveys.

A review of advertising and brochures produced by manufacturers for consumers, the functionality aspect of no or low frost is mentioned by almost all the major manufacturers, pointing out the ease of use benefit of such a feature.

The EuP preparatory study carried out surveys with nine manufacturers to assess which aspects of product design they felt were most important to consumers today and also how important they would be in the future.
Each design attribute was rated on a scale of 1 to 10, with 10 being most important.

- For refrigerators, common across all manufacturers was the importance of 'lower energy consumption' to consumers today and in the future.
- Easy or no defrosting was ranked 6th after lower energy consumption, bigger capacity, lower price, greater storage flexibility and improved cooling adapted for food, with a rating of 6.7 out of 10 for consumers today.
- In terms of consumer priorities in the future, easy or no defrosting was ranked 4th with a rating of around 7.3, but only marginally behind the aspects of adaptive cooling and larger capacity.
- A similar pattern is presented when prioritising design aspects for freezers although easy or no defrosting was ranked 4th and 2nd as a priority for consumers now and in five years time with ratings of 6.7 and 7.2 respectively.

A survey, with a similar approach to that for manufacturers, asked consumers to rate the importance of different design aspects, again on a scale of 1 to 10.

- Ease of defrosting was rated with a score of 8.3 for refrigerators and was ranked 3rd in the list of priority attributes after lower energy consumption and lower running costs.

[36] Yang, C.T.; Mei, V.C.; Chang, W.R. and Lin, J.Y. (2010). A new reverse cycle defrost design concept for refrigerators. ASHRAE Transactions, Vol. 116, Part 1, 242-245.

[37] ISIS. 2007. Preparatory Studies for Eco-design Requirements of EuPs Lot 13: Domestic Refrigerators & Freezers Tasks 2: Economic and Market Analysis. Final Draft. (section 2.3.5)

- For freezers, easy or no defrosting was joint first in terms of importance to consumers purchasing an appliance today, with a priority rating of 8.4 alongside lower energy consumption.
- In four of the ten countries (including the UK) where consumers completed the questionnaire, the easy or no defrost feature was rated with a higher priority than lower energy consumption or running costs for freezers.

The EuP study also carried out a review of consumer test magazines, which are assumed to reflect consumers' priorities and preferences, showed that ease of defrosting did appear in calculations for rating different refrigerators. In some countries it was attributed around 5% of the total score, in others it was assumed to be included in the general ease of use evaluation. In its evaluation the EuP preparatory study rated ease of defrosting as a priority level 2 design aspect, compared to priority level 1 aspects such as volume, performance and price. The frequency of this aspect appearing in appliance reviews by all consumer organisations was on 61% of occasions. For freezers it was also rated with a priority level 2 and a score of 64%.

From this information it can be seen that frost-free is consistently a design feature recognised by consumers and manufacturers as important in the purchasing decision. Experts feel that this is a feature that is expected to increase in importance for consumers.

In a recent survey by the UK consumer organisation using 10,000 Which? members[38], 95% stated that a frost-free function is the most useful feature of a fridge freezer.

8.9.2 Prevalence and popularity

The market for frost-free appliances has been steadily increasing. In Great Britain the number of frost-free fridge-freezers sold has doubled in size since the year 2000.

Figure 27 provides a picture of the increase in the popularity of frost-free appliances in Great Britain over recent years. The increase in frost-free fridge-freezers up to around 2009 also reflects an increase in the sales of side-by-side appliances which are almost exclusively frost-free. In recent years the sales of side-by-side appliances has slowed and been the hardest hit by a general reduction in sales in the refrigeration sector. The suggestion is that people are buying replacement freestanding appliances that fit their kitchen rather than refitting the kitchen to accommodate a larger high specification appliance such as a side-by-side. This factor sits alongside a general decline in replacement cycles, drops in house moves and a general weakening of the economy.[39]

[38] http://www.which.co.uk/home-and-garden/kitchen/reviews/fridges/page/faqs/#ixzz1lnDMXFKl

[39] ERT Cooling Supplement May 2009 http://www.ertonline.co.uk/electrical-online-supplement.html

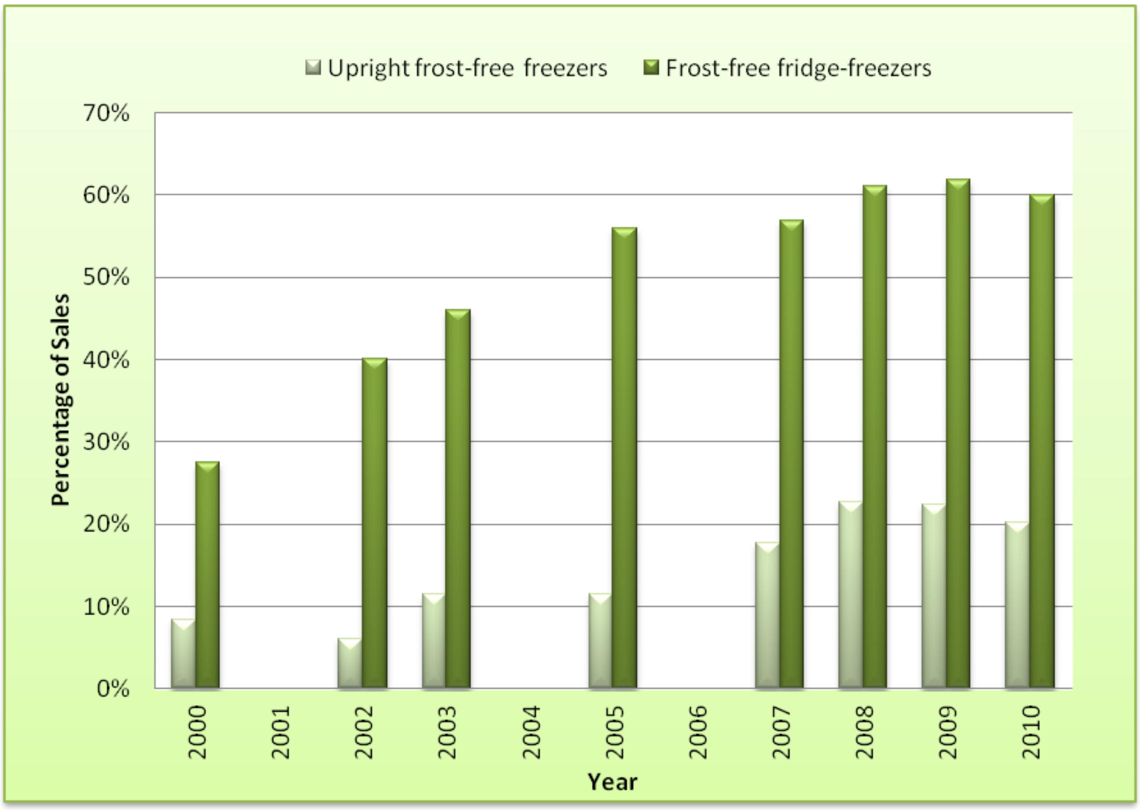


Figure 27: Percentage sales of frost-free appliances in Great Britain (Source: analysis of GfK annual market data purchased by MTP).

In terms of the number of appliance available in GB (not sales weighted) frost-free models for all categories account of 33% of models. This value is used to give a comparison with the CECED European data which is not sales weighted. For fridge-freezers 52% of the models available in GB are frost-free and 34% of upright freezers available in GB are frost-fee.

Table 10 below provides market information about the number of appliances available with frost-free characteristics across Europe. The information was provided by CECED for the EuP preparatory study from its technical data base (2005 data) and is not sales weighted.

Table 10: Frost-free appliances available in Europe, CECED technical data base 2005[40]

Appliance category	Number of appliances in data base	% no frost
1 (refrigerator)	2204	7 %
7 (fridge-freezer)	9535	17%
8 (upright freezer)	2441	13%
9 (chest freezer)	879	8%
10 (multi use / other)	232	43%
Total (categories 1-10)	15643	14 %
7 & 10	9767	17%

More recently available data showing the availability of frost-free appliances over recent years is represented in Figure 28 below. Again this is not sales weighted.

[40] ISIS. 2007. Preparatory Studies for Eco-design Requirements of EuPs Lot 13: Domestic Refrigerators & Freezers Tasks 3-5: Final Report. Draft Version.

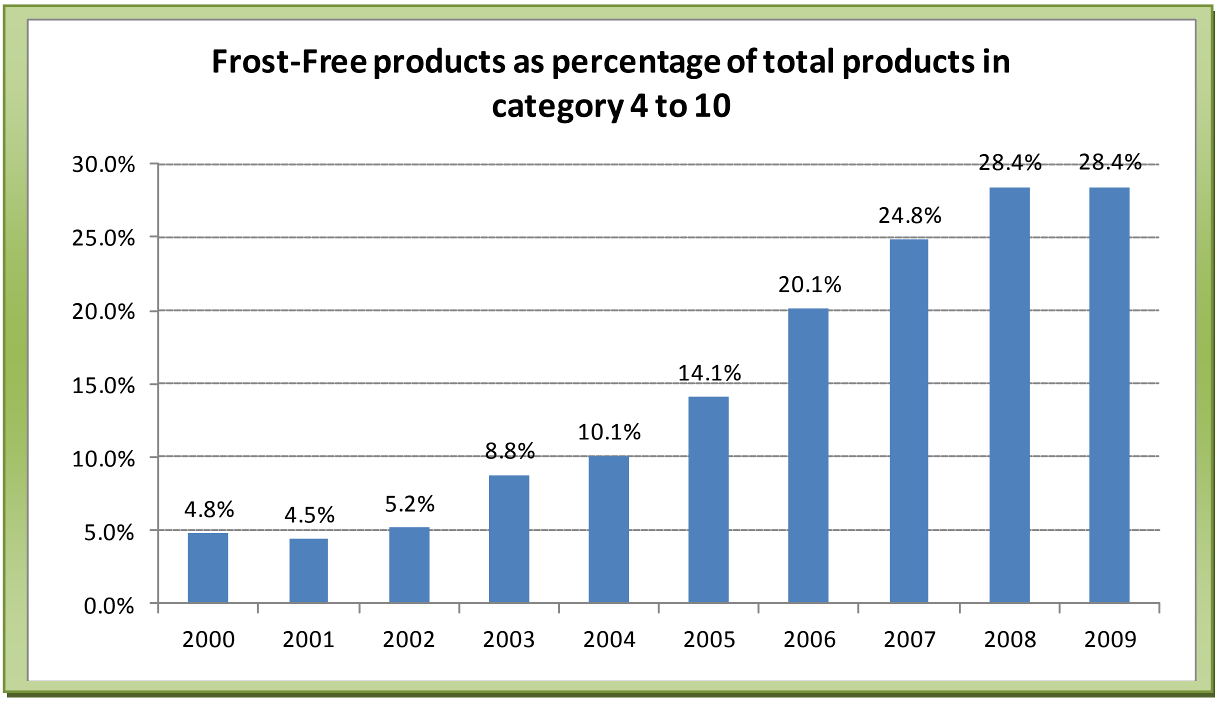


Figure 28: Percentage of frost-free appliances available in Europe. (Source: CECED)

8.10 Market distortion

The market evidence, showing an increase in the sales and availability of frost-free appliances, would suggest that the increase in the popularity of frost-free appliances could be attributed to consumers responding positively to manufacturers providing this feature on new appliances. It is difficult to gauge whether without the correction factor, which allows manufacturers to present frost-free appliances with the same energy efficiency ratings alongside static appliances, frost-free appliances would still be as attractive to consumers. The assumption could be made that even if a less efficient frost-free appliance is offered alongside an efficient static appliance, consumers may still be prepared to opt for the convenience feature, or pay the additional cost that may be charged for a frost-free appliance achieving the same efficiency, without the correction factor, as a static appliance. Consumer choice is based upon a package of purchasing considerations including price, efficiency and features. Frost-free appliances suit a particular sector of the market and their increased prevalence is assumed to be due to consumer demand and not due to any market distortion resulting from the correction factor.

From a global perspective the northern European market with such a significant share of static appliances is not the norm, automatic defrost appliances are far more common place in markets on other continents.

8.11 Summary and discussion

- Review of similar appliances with and without frost-free functionality, and resulting differences in energy consumption.

Due to differences in the components and design of frost-free and static appliances, it is not possible to make a direct perfect comparison between the different types of appliance. However, there are a handful of appliances that are essentially the same cabinet but with different internal arrangements and components to allow for frost-free functioning. The most obvious difference between two similar appliances, one with and one without frost-free, is the reduced freezer volume. When the small selection of similar appliances is evaluated, there is a difference in energy consumption of between 0% and 10%.

An alternative way of considering the extra energy due to the automatic defrosting feature of frost-free appliances is to look at the amount of energy this particular part of their operation uses. The analysis of eight A+ refrigerating appliances revealed that each defrost used around 0.095kWh. Depending upon the appliance it accounted for between 3.9% and 13.7% of the total appliance energy consumption, on average 9.6%. This is similar to the findings in the Cold II (2000) report.

- Assessment of whether a frost-free function is likely to result in a 20% reduction in energy demand in real use.

The benefit from the frost-free correction factor equates to allowing a frost-free appliance to use around 6% more energy than without the correction factor, to achieve the same energy efficiency index. This equates roughly to the amount of energy used by the defrost operation of the appliance. In test conditions, static appliances are seen to be at an advantage as the testing does not consider any possible reduction in efficiency due to frosting up in use. The frost-free factor attempts to compensate for this; however there is little comparative evidence to quantify any extra energy used due to frosting on static appliances.

When comparing appliances in the market it is considered that the frost-free correction factor could be reduced on the basis that there are frost-free appliances that offer better or similar efficiency to static appliances. A reduction in the correction factor would help to incentivise further improvements in efficiency. A reduction in energy consumption in the sector would be welcome as the market penetration of frost-free appliances increases.

- Assess whether the market share of appliances eligible for the correction factor has distorted the market.

There has been an increase in the availability and sales of frost-free refrigerating appliances. In some EU countries an easy or no defrost feature is considered to be as important, or more important, than energy efficiency for some consumers. Given this evidence it could be considered that the increased market share of frost-free appliances is likely to be due to consumer demand rather than any distortion in the market due to the correction factor. However, the purchasing decision is made using a combination of criteria and a mixture of price, features and the energy efficiency letter will all contribute to the final decision.

There is no evidence to suggest what consumers would opt for if the correction factor was not used for frost-free appliances. The consequence might be manufacturers producing a more expensive frost-free appliance in order to provide a product with comparable efficiency to a static appliance. The consumer would then need to weigh up the extra cost of the frost-free appliance. Alternatively, if a frost-free appliance with a poorer efficiency than a static, due to not using the correction factor is on the market, the consumer may still opt for the frost-free on the grounds of convenience.

8.12 Conclusion

The frost-free correction factor should be reduced in order to stimulate the introduction of the most efficient technologies. Market data has shown that it is possible to make frost-free appliances that are as efficient as static appliances when comparing energy consumption claims. This would suggest that the more efficient technologies are available and the correction factor should be reduced, if not removed. Without any significant incentive manufacturers are unlikely to embrace more efficient technologies and design.

Additionally, if the increase in sales of frost-free appliances continues at the rate seen in the last ten years then the market is moving to a significant majority of sales being frost-free and it could be argued that it is not appropriate to have the correction factor for a type of appliance which is becoming the norm.

There is a technical justification for a correction factor on the basis that during the standard energy test most frost-free appliances currently use more energy than similar static versions. Limited analysis in this report suggests that the benefit of the correction factor for the energy consumption necessary for a particular energy efficiency index is similar to the amount of energy used by a frost-free appliance to carry out the automatic defrost. The unknown element in this consideration is the comparison of energy consumption of the two types of appliance is actual use in consumer's homes.

There could be an argument that without the frost-free correction factor manufacturers would need to improve the efficiency of an appliance to maintain its efficiency classification in the market or meet minimum standards. The cost of this would most likely be passed on to the consumer. If consumers are sensitive to the additional price of a frost-free appliance they may opt for a static appliance. Frost-free appliances already generally cost more than static appliances but the general trend showing an increase in sales illustrates that consumers are willing to pay for such a feature.

There is a need for robust information on the performance of frosted up static appliances before the possible scenario of a move back to static appliances is considered. It is generally expected that the market will find a way of continuing to make frost-free appliances competitive and attractive to consumers with or without the correction factor.

9 Task 3: Built-in correction factor

9.1 Introduction

This correction factor was introduced into the calculation for the standard annual energy consumption for the consideration of A+ and A++ energy classes as presented in the 2004 amendment to the energy label directive[41]. It only applies to built-in appliances under 58 cm in width which are designed "for installation within a kitchen cavity with a need of furniture finishing". It is not intended to compensate for any differences between built-in and freestanding appliances, only design constraints due to the limited width of some built-in appliances.

For built-in appliances less than 58cm wide the 1.2 factor is applied in the calculation of the equivalent volume in the same manner as the frost-free and climate class correction factors. It is roughly equivalent to a 10% bonus on the energy consumption. The correction factor is awarded on the basis that, because of installation restrictions, i.e. appliances are designed to fit specific kitchen spaces and cabinets, it is not possible to increase the insulation thickness without substantial detrimental effects on the function of the appliance, i.e. the internal storage volume available.

The following extract is from the European Commission working document[42] circulated prior to draft implementing documents for the setting of ecodesign criteria.

“The built in correction factor (BI): a 1,2 correction factor is set for real built-in products (built-under are excluded) of no more than 58 cm. The rationale is that the external dimensions of built-in appliances are particularly constrained as they have to be incorporated into standard fitted-kitchen designs, which use in general a fixed unit depth and width of 60 cm. In practice this means the appliance should be 55cm deep and 55cm wide if there is to be enough space to add the finishing panels. Constraining the width and depth means that it is only possible to increase the insulation thickness by raising the height if the internal volume is to remain constant (but this modifies the product dimensions) or to use vacuum insulation panels but the energy-engineering analysis for free standing products developed in the preparatory study has indicated that they are not yet cost-effective for the consumer.”

In the current ISO and EN 153 test standard a built-in appliance is defined as an appliance intended only for building-in or for placing under a counter or under a worktop, or between cabinets (under-counter types).

According to the COLD II report, the reason for the adjusted volume correction factor is to compensate for the technical limitations some refrigerators have in attaining higher efficiency levels due to space constraints. The external dimensions of built-in appliances are particularly constrained as they have to fit within a fixed unit depth and width of 60 cm. In practice this leads to an appliance which is 55 cm wide and deep to allow for the finishing

[41] COMMISSION DIRECTIVE 2003/66/EC of 3 July 2003 amending Directive 94/2/EC implementing Council Directive 92/75/EEC with regard to energy labelling of household electric refrigerators, freezers and their combinations

[42] WORKING DOCUMENT ON A POSSIBLE COMMISSION DIRECTIVE IMPLEMENTING COUNCIL DIRECTIVE 2005/32/EC WITH REGARD TO HOUSEHOLD REFRIGERATING APPLIANCES Explanatory Notes. Circulated to members of the Regulatory Committee (Defra in the UK) November 2008.

panel. To keep a fixed volume and insulation thickness compared to a 'conventional' non-built in appliance requires raising the height of the appliance. Built-in appliances can only grow upwards as far as the limitations of standard built-in arrangements allow; this may be the worktop height or taller units. The size of built-in appliances is considered later in this section. If it is not possible to raise the height of the appliance, vacuum insulated panels can be used to reduce the insulation thickness, but they are currently too expensive.

As with the other correction factors considered in this report, the built-in correction factor (in terms of energy) is not consistent across all appliance volumes. If the effect of the correction factor for built-in is calculated for a range of fridge-freezer volumes a 150 litre built-in appliance using the factor can use 7.5% more energy than one without. For a 300 litre appliance the allowance is 11% (Figure 29). This does not seem technically correct as the major heat load on an appliance is through the insulation (ASHRAE 1998) and as the size of an appliance increases the surface to volume ratio decreases, reducing the specific heat load through the insulation. Therefore a larger appliance should have a lower correction factor than a smaller appliance if comparisons are to be appropriate.

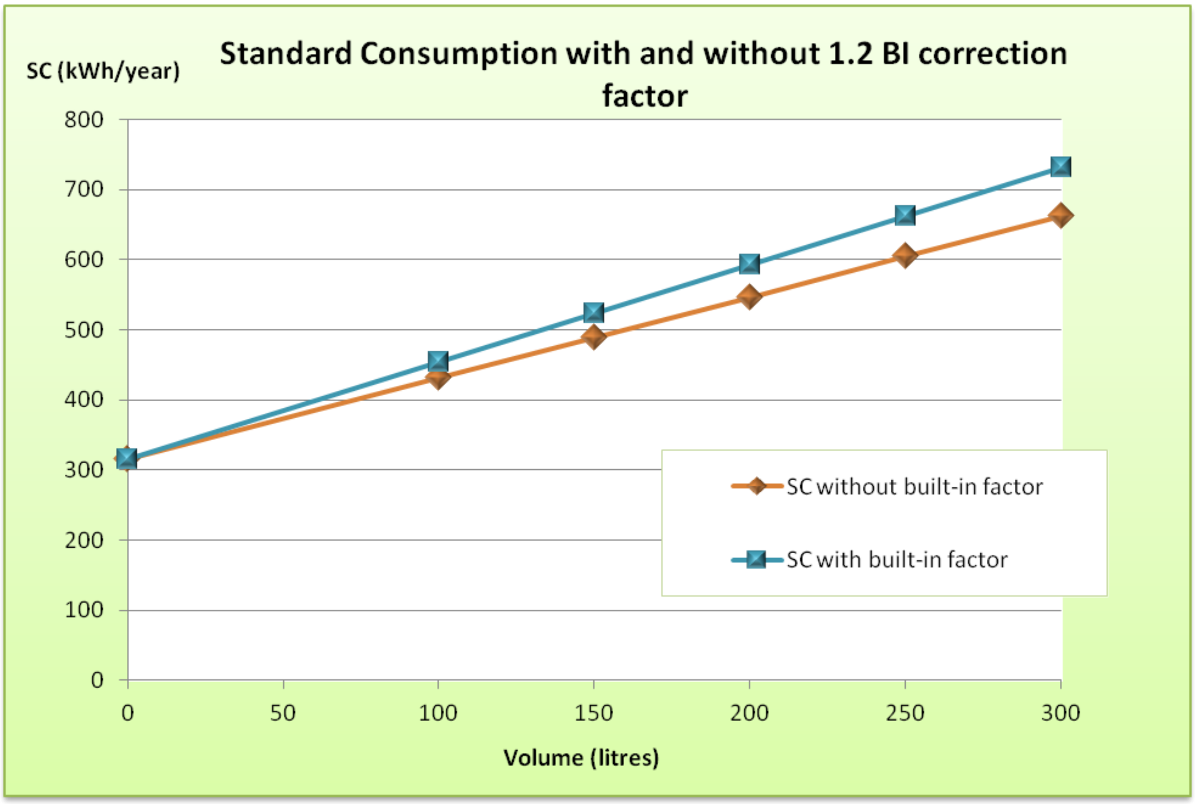


Figure 29: Effect on standard energy consumption (SC) of built-in factor for varied volumes of fridge-freezer

9.2 Appliance width comparison

The built-in correction factor is only available to a subset of built-in appliances, namely those that are less than 58cm wide. The extent of this subset is considered by looking at the sizes of appliances available on the market.

The analysis of the GB market and sales of built-in appliances has concentrated on those that are A to A++ energy label class, because from July 2010 new appliances with these classes were able to use the BI correction factor. When the whole market is considered only

3.1% of fridges 2.5% of fridge-freezers and 2.2% of upright freezers sold in GB fit the width criterion for the BI correction factor.

Ninety-nine percent of built-in fridge-freezers, energy classes A to A+++, sold in Great Britain in 2010 were below 58 cm wide and able to claim the built-in factor. However, 61% of freestanding A to A+++ fridge-freezers were also below 58 cm wide. If reduced width is the reason for this factor maybe freestanding appliances with limited width should also be entitled to claim this factor.

An analysis of the sales of A to A+++ appliances in Great Britain in 2010 shows that built-in upright freezers accounted for 8% of sales, of these 22% percent were below 58cm wide, whereas 77% of freestanding freezers are below 58 cm wide. For fridges the figures are 36% of built-in below 58 cm wide and 93% for freestanding. An interesting observation from the data is that freestanding units are rarely between 55 and 58 cm wide, they are much more likely to be less than 55 cm or over 58 cm. This is probably due to building the appliances to fit into a 55 *or* 60 cm gap, whereas the built-in appliances need to fit within a 56 to 57 cm gap. Additionally, when considering the issue of limitations of space for built-in appliances the GB market data reports that the majority of fridges that are less than 58 cm are either of a height around 122 cm or 177 cm suggesting that consumers opt for taller fridges for building in than when opting for freestanding appliances, maybe to overcome the limitations of storage volumes for built-in under counter appliances.

The availability of different widths of the three main refrigeration appliances for built-in and freestanding appliances can be seen in
Figure 30 to Figure 32. This covers appliances of all energy classes. Even though the correction factor only applies to higher efficiencies, once the MEPS are introduced from 2012 only permitting A+ or better then the market picture is expected to still follow this pattern.

For Europe as the whole it has not been possible to carry out the same review. The market data from the CECED database records all the appliances available but only identifies built-in appliances in total and does not provide any information about only those eligible to use the correction factor. However, it has been suggested by an industry expert that in German speaking countries the majority of built-in appliances are less than 58cm wide, generally 56 to 57cm wide due to limitations of the kitchen furniture industry standards.

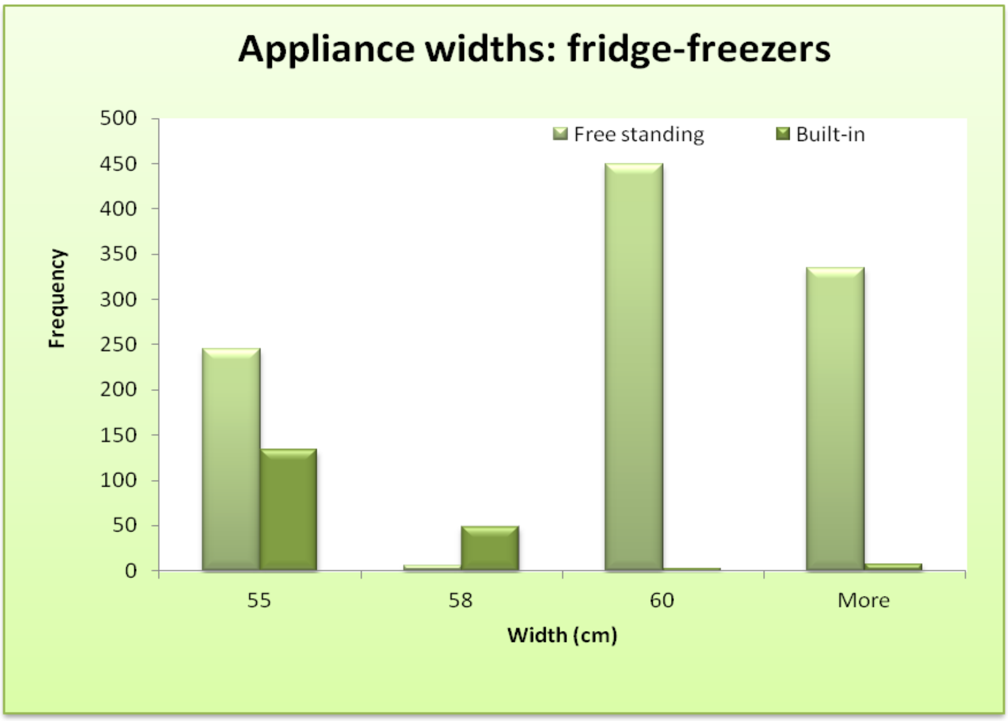


Figure 30: Width of built-in and free standing fridge-freezers, all sales (Source: Analysis of GfK 2010 market data).

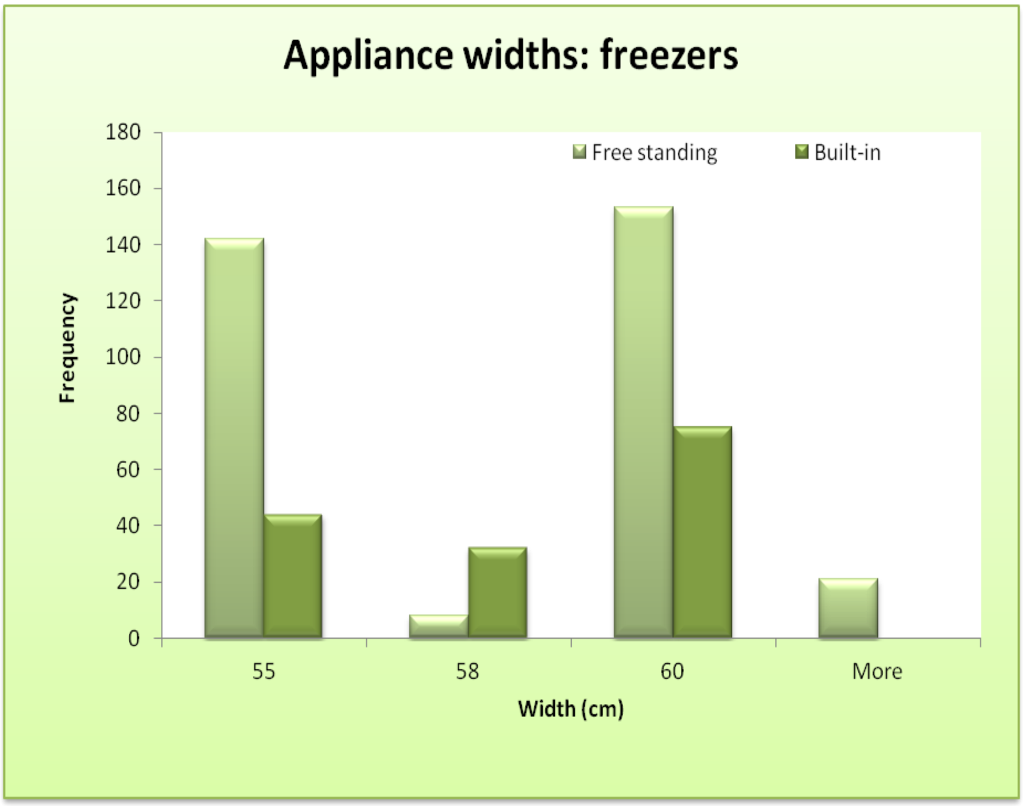


Figure 31: Width of built-in and free standing upright freezers, all sales (Source: Analysis of GfK 2010 market data).

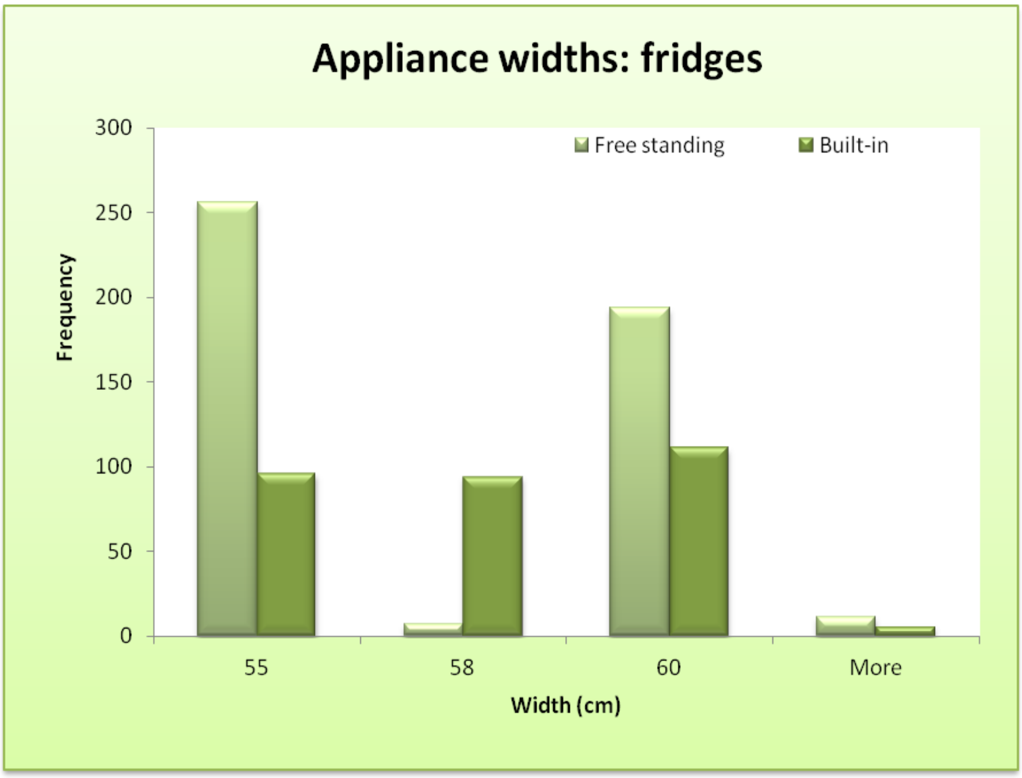


Figure 32: Width of built-in and free standing refrigerators, all sales (Source: Analysis of GfK 2010 market data).

9.3 Energy consumption and built-in design

The built-in correction factor compensates for the limitations imposed on narrow built-in appliances which constrain the improvements, such as increased wall insulation, without detrimental effect on the storage volume. The correction factor does not normalise for any differences in the energy consumption that this subset of built-in appliances display compared to wider built-in or freestanding appliances, during standard testing or use.

It is not possible to give a direct comparative analysis between built-in and freestanding appliances because the two types differ in their construction and storage volumes due to their intended installation. Additionally, it is not expected that consumers would be comparing freestanding and built-in appliances and the issue in relation to this correction factor is the benefit given to a subset of the built-in market rather than a comparison with built-in and freestanding appliances.

There are potentially differences in energy use from the building-in of appliances due to different ventilation conditions compared to freestanding appliances, although this is not the consideration of the correction factor.

9.4 Market picture and trends

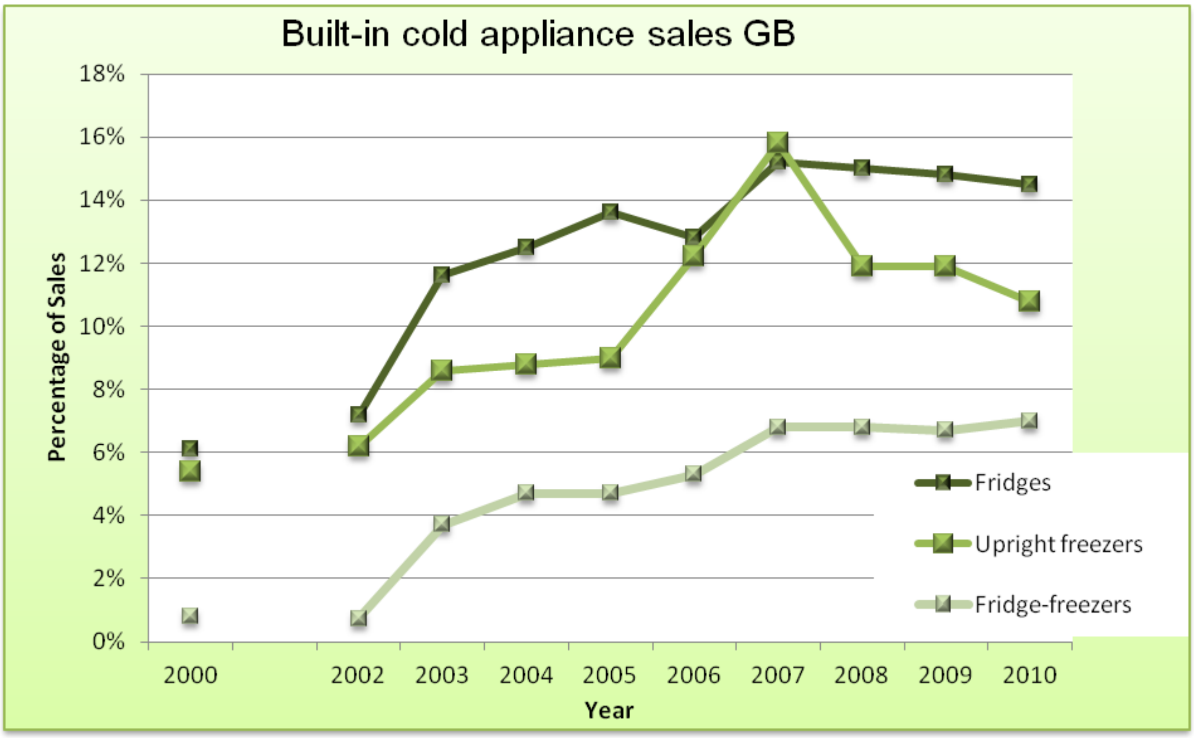
9.4.1 Purchasing trends - UK

In the UK, during the period from 1998 to around 2008 the built-in market for kitchen appliances grew overall and in particular for refrigerated appliances. There were three main reasons for this:

- The number of new homes built

- An increase in kitchen replacement in existing homes
- The replacement of existing built-in appliances.

Figure 33 below shows the increase in sales of built-in refrigerated appliances in Great Britain over the past 10 years. This data collected is predominately from major appliance retail outlets and does not include appliances installed by specialist kitchen fitters.



* 2000 data only branded products

Figure 33: Percentage sales of built-in appliances in Great Britain. (Source: analysis of GfK annual market data purchased by MTP).

The replacement of kitchens in existing homes is likely to have been the most influential on the share of the market of built-in refrigerated products. In the period around 2006 to 2008 some 3% of homes (approx 780K assuming 26 million homes) had a new or expanded kitchen each year and during this period kitchens were the most popular area for home extensions[43]. Not all of these would have had built-in refrigerating appliances installed, and many were likely to choose free-standing appliances for a variety of reasons.

In contrast during this time approximately 160 thousand new homes were built each year. It is not known how many of these had a built-in cold appliance, but it was more likely to be found at the upper end of the market. Starter homes and flats, etc were more likely to be supplied with a minimum of an oven and hob, allowing the buyer to choose their own free-standing products separately.

At that time sales of cold appliances were in the order of over 3 million items per year. According to Mintel[44], sales of cold appliances in 2008 were a total of 3,075K products (770 freezers, 875 fridges, 1430 fridge-freezers), this does not include the proportion of new build installed products. As the trend for built-in kitchens and appliances is relatively new, the proportion of sales that are replacement of existing built-in products is relatively low.

[43] Mintel Kitchens Market Intelligence report August 2009.

[44] Mintel White Goods Market Intelligence report April 2010

New Homes and built-in appliances market

The provision of new homes with built-in kitchens/appliances fuels the proportion of market that is built-in. Typically, larger builders offer cheap 'contract' appliances from cheapest suppliers. PJH Group[45] is a major supplier to larger builders.

Smaller builders and contractors may use a supplier such as Howdens to source products. Howdens has 'own brand' built-in appliances called Lamona and a few products from Bosch. Howdens boast they supply 500,000 appliances per year across all types.

Existing homes with new kitchens

The main suppliers for new kitchens are:

- Top of the range manufacturer – i.e. Miele – only offers own products
- Independent kitchen installer – i.e. Bells in Northampton – offers a range of products, can be at a range of price points, (similar businesses could also use intermediate supplier such as PJH)
- Builders merchants eg. Howdens
- Chain store kitchen departments eg. Magnet, IKEA, John Lewis, - ranges can be limited to a few or own brands, or extensive
- DIY sheds eg. Homebase, Wickes, B&Q – offers a range of products but may only supply a few brands and focus on cheaper end (eg B&Q).

Existing built-in replacement market

These are purchased through various cold appliance retailers:

- Department stores, multiple retailers, online only, independents, kitchen specialists etc.

9.4.2 Availability of built-in appliances in Europe

For Europe, Figure 34 shows the percentage of appliances available that are built-in. This data from the CECED database uses the recorded number of appliances on offer in Europe but is not sales weighted. It also includes all built-in appliances not just those that are eligible for the correction factor. However, it has been suggested that built-in appliances with a width of less than 58cm are more prevalent in the rest of Europe than in the UK[46]. The data includes two years only so it is not possible to consider the trends in availability, but the figure does not suggest a significant shift toward the supply of built-in appliances. It is important to remember that this data does not reflect the purchasing habits of consumers in terms of the number of built-in appliances bought. No comparative data has been found on the total number purchased.

[45] http://www.pjhgroup.com/about

[46] Friedrich Arnold BSH

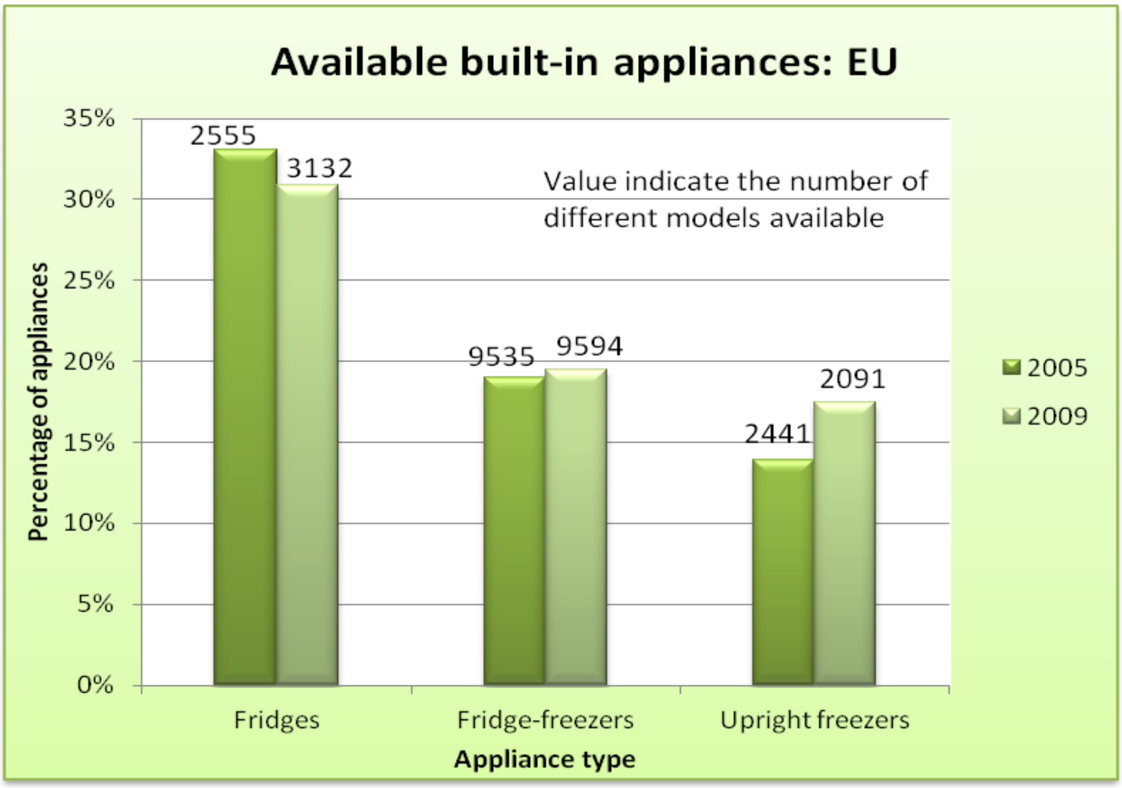


Figure 34: Availability of built-in appliances for Europe (Source: CECED database)

9.5 Consumer choice and built-in refrigerators

Buying a built-in product means that the owner is not making a 'feature' of their appliances, some freestanding appliances are bought precisely because they can be a feature due to the colour or finish and/or styling or other functions which are available on the front of the product. Most major appliance manufacturers provide separate product brochures for their freestanding and built-in ranges. From this it can be interpreted that it is recognised that there are specific customers for each of these two sectors of the market.

The decisions consumers make when choosing new cold appliances depend on when that decision is made i.e. new house, new kitchen or replacement. The following are some of the main aspects to consider:

- Size – how much cooling and freezing do they want or have room for?
- Style – built-in or not – do they want to hide the appliances or see them, do they want a feature in the kitchen i.e. side-by-side?
- Features – through door dispensers for ice and/or water.
- Price – cost can be an important factor in product choice.
- Energy efficiency – claimed as an important aspect in decision making by Mintel survey 2006[47], but not the most important for many people.

The factors and characteristics that are most important in the buying process depend upon when the appliance is needed. The following lists consumer's priorities depending upon circumstances[48]:

[47] Mintel Fridges and Freezers Market Intelligence April 2007 fig 48.

[48] Mintel Fridges and Freezers Market Intelligence April 2007 fig 48.

- Moving home – the most important is looking in shops and then ordering via Internet (price), looking at functions i.e. icemaker, energy efficiency
- Setting up home – price, looking in shops/buying on internet (price), functions, matching décor, appearance
- Kitchen upgrade – appearance, functions, matches décor, extra capacity in other room
- Replacement – functions, separate in other room, matches décor, price, separate appliance (not fridge-freezer)
- Upgrading to more efficient – functions, shops then order via internet, separates, energy efficient

While several categories of consumers mentioned energy efficiency as important, it is not a major deciding factor when buying a new appliance. Appearance was the most important aspect.

9.6 Market distortion

It seems unlikely that the decision to buy a built-in appliance would rest on whether or not the energy efficiency class of a product or products matched the freestanding equivalents. On this basis the use of the correction factor to compensate built-in appliances in general for any design constraints is not relevant.

The decision to buy a built-in appliance over a freestanding one would be based on the desire the consumer has for a fully-fitted kitchen opposed to having a kitchen and/or living space with white goods on display. They may prefer having the built-in kitchen cabinet rather than any feature on the front of the appliance, such as ice or water, and also prefer built-in to any ‘designer’ style appliance such as coloured, mirrored, metal finish etc. There may be cases where consumers have to make a replacement purchasing decision based upon what was in the kitchen before, particularly for built-in tall units. For under counter units it is less of an issue as consumers can use the same space as a freestanding appliance.

Any difference in energy efficiency class between a freestanding and built-in equivalent could be disregarded by consumers because the perceived additional cost of running a less efficient appliance is insignificant when considering the total buying and annual running costs of the appliance and the amount of money being spent on the kitchen refurbishment.

Built-in appliances are often more expensive to buy than freestanding equivalents. The additional cost includes the panel to fit to the front. Consumers who choose built-in appliances may therefore not be as price sensitive at the point of purchase as people who have freestanding appliances. By choosing to buy a built-in refrigerated appliance consumers are taking the conscious decision to pay more for a service which could be delivered at a much lower cost throughout the lifespan of the product if they had chosen a freestanding appliance. The relative annual energy consumption and the cost of that energy is therefore of minimal importance to people who decide to buy built-in appliances.

So in terms of market distortion it is considered to be unlikely that the correction factor has contributed to any distortion in the popularity and supply of built-in appliances. In addition to the discussion on this point above, the factor is only applicable to such a small percentage of available appliances, particularly in the UK, that any distortion would still only be within the confines of a small percentage of the overall refrigerating appliance market.

9.7 Summary and discussion

- Information about similar products with and without the built-in feature.

Built-in and freestanding appliances are significantly different in their construction and storage volumes offered. This is predominantly due to the space restrictions placed upon built-in appliances to fit standard kitchen cabinets.

In terms of purchasing comparisons by consumers, the two types of product are a different proposition. Expert opinion is that it is unlikely that a consumer will be comparing a built-in appliance against a freestanding appliance because they are expected to have preselected the type of appliance to be installed.

- Assess whether the market share of appliances eligible for the correction factor has distorted the market.

The sector of the market eligible to use the built-in correction factor is small and the market share is unlikely to have been affected by the factor. The GB sales data suggests that only around 2 to 3% of appliances sold meet the requirements to qualify for the factor. Whilst there appears to have been an increased interest in built-in appliances this is assumed to be due to popularity and fashions in built-in kitchens and not any benefit offered by the correction factor. In contrast to the other correction factors that relate to characteristics that are seen to offer additional practical benefits for consumers the built-in correction factor is applied to what could be considered a negative aspect of the appliance design; the limitation on storage volume as a result of the build in feature.

9.8 Conclusion

The built-in correction factor is applied to a sub-set of built-in appliances, namely those that are less than 58cm wide, and for this reason should be removed.

The correction factor is not used to consider the different construction comparisons between freestanding and built-in appliances as may be the initial expectation. Consumers are unlikely to be comparing a built-in appliance alongside a freestanding one due to the different design and appearance aspect offered by each type.

Whilst it is acknowledged that the building-in and width restrictions affect the construction and technologies that can be incorporated, the use of the factor for just some built-in appliances and not others presents an inconsistency in the information provided to consumers in the form of the energy efficiency class.

An alternative approach may be to have a different product category for built-in appliances separate to freestanding. However, this would not address the issue if a correction factor is still desired for narrow built-in appliances; it would still be giving preferential treatment to a subset of the category and not present a comparable efficiency for consumers considering different width appliances.

As it stands, the built-in correction factor increases equivalent volume and therefore the standard energy consumption of an appliance. So the EEI is essentially determined by comparing the actual energy consumption of the small appliances with a standard appliance (represented by the SC) that is larger.

The correction factor cannot be defended on the grounds of supporting a particular sector of the market, or technology, because its efficiency or practical benefits are poor.

If a fundamentally inefficient design, or product specification, is being offered then this should be reflected in the information provided to consumers via the energy label.

Consumers opting to compromise on storage volume by having a built-in appliance should see the true efficiency of the appliance. There should be no justification for supporting an inefficient product by distorting the energy efficiency calculation to make the appliance look better than it actually is, compared to other slightly wider built-in appliances.

The sector of the market currently eligible to use the factor is small in the UK in particular, and as such there is also little point in having a correction factor for such a small sector. If it is decided that a correction factor should be retained, any further review should consider additional specifications to tighten the use of the factor, particularly the height of the appliance as well as the width. If it is considered that the reduced width and height limits the usable volume offered to consumers, then this should be reflected in the use of any factor. The built-in appliances offered in the UK are often not under counter, particularly fridge-freezers and separate fridges.

10 Task 4: Chill compartment factor

10.1 Introduction

The current ecodesign regulation defines a chill compartment as *"a compartment intended specifically for the storage of highly perishable foodstuffs"*. It should maintain storage temperatures between -2 and +3 °C.

In order to be eligible for the chill compartment allowance the compartment must be at least 15 litres. The factor is an additional 50 kWh/year is added to the calculation of the standard annual energy consumption which is the value that the appliance performance is compared with to give the energy efficiency index.

This factor was introduced into the calculation for the standard annual energy consumption for the consideration of A+ and A++ energy classes as presented in the 2004 amendment to the energy label Directive. It is now applicable to all appliances (which due to the recent ecodesign requirement have to be efficiency class A or better).

The following extract is from the European Commission working document[49] circulated prior to draft implementing documents for the setting of ecodesign criteria.

"An allowance of 50 kWh/year in the standard annual energy consumption is given for the presence of a chill compartment of at least 15 litre volume, since this compartment allows a longer preservation of highly perishable food."

No reference is made to the origins of this allowance or the justification for its size and application. According to CECED[50] the size and application of the chill compartment allowance was the result of research amongst a group of manufacturers. This research concluded that chill compartments are normally made up of three drawers and appliances with such compartments of this size require around an additional 50 kWh per year to provide this facility.

10.2 Chill compartment technical requirements

Due to the temperature profile needed for a chill compartment, in the same way as frost-free functions, chill compartments generally need fans and space for the components to provide this feature. However, the majority of appliances with chill compartments are already using frost-free systems with fans and electronic controls already integral to the fridge and freezer cooling system and diverting cold air to the appropriate drawer designated as a chill compartment.

The requirements of a compartment to be classified as a chill compartment are specified as maintaining storage temperatures between -2°C and +3°C. Anecdotal evidence from Intertek[51] suggests that appliances with compartments fitting these criteria according to the

[49] WORKING DOCUMENT ON A POSSIBLE COMMISSION DIRECTIVE IMPLEMENTING COUNCIL DIRECTIVE 2005/32/EC WITH REGARD TO HOUSEHOLD REFRIGERATING APPLIANCES Explanatory Notes. Circulated to members of the Regulatory Committee (Defra in the UK) November 2008.

[50] Communication with Friedrich Arnold 8/11/2011.

[51] Personal correspondence; Simon Leach

manufacturer are often unable to maintain these conditions, sometimes even giving storage temperatures warmer than other areas of the fridge during energy label testing.

10.3 Chill compartment feature

Chill compartments provide additional enhanced storage conditions intended to prolong the quality of particular foods. Some experts feel that although it is an attractive additional feature for some consumers, chill compartments offer what is not an essential function; a fridge compartment itself should be adequate for the storage of fresh food.

Some manufacturers point out the benefits of chill compartments to consumers in their marketing information, i.e. that it will store fresh meat, fish, ready cooked and chilled food at around 0°C for safer and longer[52]. In an era where there are concerns about food wastage then prolonging the time food can be stored before eating could be seen as advantageous. It may be of particular benefit to some consumers who wish to store highly perishable food purchased from markets that are not packaged with use-by dates.

In the UK, WRAP[53] has been reviewing how correct storage could reduce food wastage. Recommendations in a recent report[54] were aimed at encouraging consumers to improve the use of their fridge by ensuring that it operates at temperatures between 0°C and 5°C facilitated by improved food product labelling and clearer thermostatic controls, amongst other things. This recommendation does not go beyond current fridge temperature recommendations. In fact it found many consumers' fridges were not cold enough which suggests that consumers are not aware of, and/or are not checking fridge temperatures for appropriate storage. The report did not acknowledge or consider the use of chill compartments. There is no evidence that consumers using chill compartments extend the storage of foods beyond the recommendation on food packaging ('use by' and 'best before' dates). Another WRAP report[55] suggested that 255,000 tonnes of food is thrown away before it has reached 'use by' or 'best before' dates.

There is potentially a whole additional discussion area, which is not within the remit of this research, which could assess the environmental advantages of less food wastage in terms of food costs, production, packaging and transportation that could be weighed against the benefits of the chill compartment allowance given to refrigeration appliances. It is not possible to conclude on the importance of chill compartments to consumers as there are different opinions about consumer habits in terms of purchasing habits and frequency, recognition of use-by and best-before dates and whether the benefits that chill compartments present are really appreciated by consumers.

The following sections consider the level and application of the chill compartment factor. This includes evidence used for the introduction of the factor; however, it has been difficult to compare this evidence with current appliances incorporating chill compartments due to a lack of information about volumes of chill compartments. This detail is not recorded in the available sales data or provided in manufacturer's brochures or marketing information. The chill volume is incorporated into the fridge volume total.

[52] Beko Refrigeration Brochure October 2010

[53] WRAP (Waste & Resources Action Programme) works in England, Scotland, Wales and Northern Ireland to help businesses and individuals reap the benefits of reducing waste, develop sustainable products and use resources in an efficient way. www.wrap.org.uk

[54] Reducing food waste through the chill chain, Part 1: Insights around the domestic refrigerator WRAP. August 2010.

[55] Household Food and Drink Waste in the UK, WRAP, 2009

10.3.1 Application of the chill compartment factor

Above the 15 litre minimum size, the 50 kWh allowance is irrespective of the capacity of the chill compartment. The 50 kWh allowance is added to the standard energy consumption. Figure 35 below shows the values making up the energy efficiency index for a fridge with a chill compartment. This example was taken from an appliance recorded in the Gfk market data for 2010, but the volume of the chill compartment is unknown so a value of 18 litres has been used for illustrative purposes.

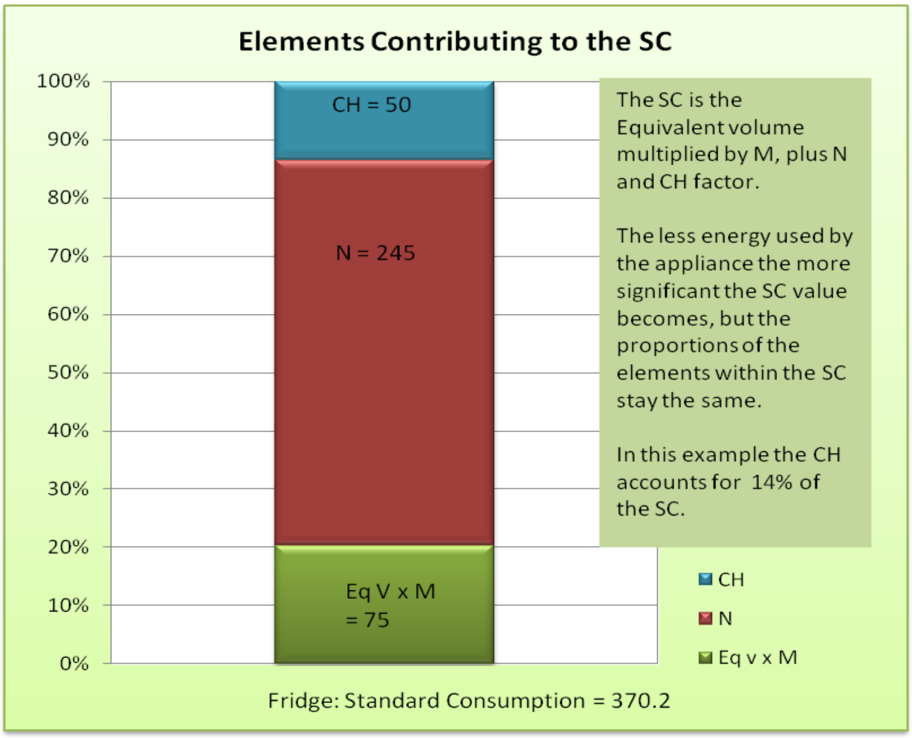


Figure 35: Contributing elements to the SC

Figure 36 additionally illustrates the proportions for the same appliance if improvements in the energy consumption are made to achieve better energy classes. Although, as the efficiency of an appliance improves, the standard consumption is bigger compared to the actual consumption, the proportion that the chill factor contributes is the same.

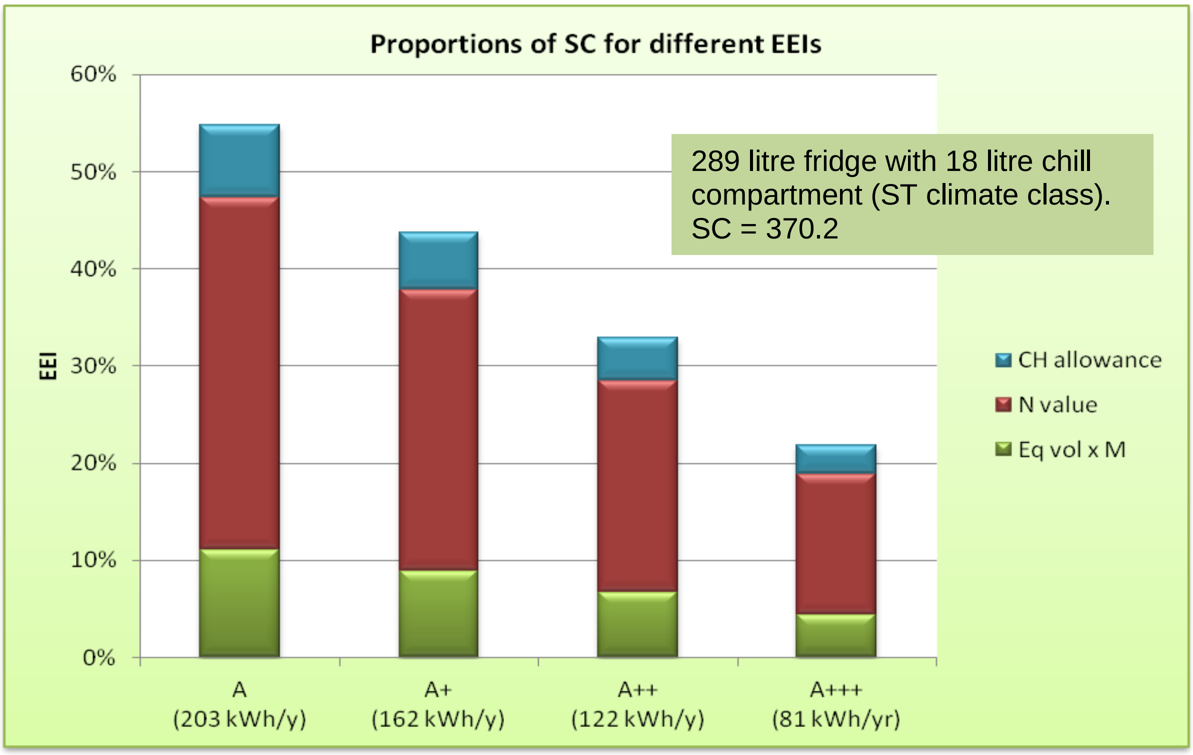


Figure 36: Proportions of contributing factors to the SC for different efficiencies

10.3.2 Level of the chill compartment factor

It is understood from industry sources that the level of the allowance is probably related to the fact that most chill compartments were of a more moderate size at the time the factor was introduced[56]. A range of major appliance manufacturers appliances were reviewed to consider the size of chill compartments and consumption of similar appliances without chill compartments. The exclusion of compartments below 15 litres was introduced to prohibit the misuse of this bonus for unrealistically small compartments. The original industry request was a bonus of 60kWh/y to the reference line and was based on the assumption that chill compartments would also get the frost-free correction factor. In the final implementation of the labelling directive update the 60kWh/y has been reduced to 50kWh/y and the frost-free correction factor was eliminated for all non-frozen food compartments.

Table 11 below shows some of the appliances used for the analysis to consider the application of the chill compartment allowance, provided by CECED. The appliances in each pair have the same external dimensions and technologies, but one has a chill compartment.

Table 11: Comparison of refrigerators with and without chill compartments (Source: CECED)

				Net volumes in [dm3]					Standard Energy consumption			Energy efficiency index		
Brand	Type of Compartment	Modell		Chill	Fresh Food	Freezer	Energy Cons [kWh/y]	Adjusted Volume	w.o. chill factor	with chill factor	Diff. [%]	w.o. chill factor	with chill factor	Diff. [%]
Liebherr	Only refrig.	Kle2360		0	225	0	160	225.0	297.4	297.4		53.8	53.8	
Liebherr	Refrig. with chill	KIB 2340		40	140	0	222	190.0	289.3	339.3	**17.3**	76.7	65.4	**-14.7**
		Difference					38.8%	-15.6%	-2.7%	14.1%		42.7%	21.6%	
BSH	Only refrig.	KIR 2640		0	218	0	157	218.0	295.8	295.8		53.1	53.1	
BSH	Refrig. with chill	KIF 2640		45	135	0	219	191.3	289.6	339.6	**17.3**	75.6	64.5	**-14.7**
		Difference					39.5%	-12.3%	-2.1%	14.8%		42.5%	21.5%	

[56] Information from CECED December 2011

These examples demonstrate the proposition to a consumer considering two appliances that appear identical from an external point of view, but which offer different features, particularly the provision of a chill compartment. In the examples in Table 11, the impact of having a chill compartment increases the energy consumption by almost 40% and increases the energy efficiency index by around 43% when compared to a similar appliance without a chill compartment. The total net volume is also reduced; the adjusted volume is reduced by around 12 and 15%. Without a chill compartment factor there is a difference between the two types of appliance in the standard energy consumption of around 2 %. The chill compartment allowance applied to the relevant appliance increases the standard energy consumption by around 17%. For the energy efficiency index the factor reduces the difference between the appliances with a chill compartment to those without from around 43% to around 22%.

CECED suggest that the main reason for using a chill compartment factor is to compensate for the fact that it would otherwise be difficult to adjust for this 42 % increase with efficiency improvements through design without excessive costs.

CECED also suggested that attempts for including the chill factor as a compensation factor to the adjusted volume failed due to the fact that the standard energy consumption is only marginally affected by the volume for the category 3 products such as those illustrated above. For this reason a constant value was suggested. There has been no further deep technical analysis.

Although the details above provide a useful comparison and perspective for the level of the chill compartment factor it does not deal with the issue that a fridge with a chill compartment is a different purchasing proposition for the consumer. It is not a fridge, but a fridge with a cooler compartment, in the same way that a larder fridge and a fridge with a one star compartment are different appliances, and it will consequently use more energy. On the basis of the discussion above it could be considered that fridges with a no star compartment should have some kind of allowance. There seems little justification for the use of a correction factor to make two different types of appliance appear to have the same efficiency.

The anomaly that the chill compartment factor is independent of product size is illustrated by a tall built-in fridge available in the UK that provides a large chill compartment capacity. The top two-thirds of the storage compartment is a conventional fridge layout, but the lower third consists of three chill drawers (the total appliance capacity is nearly 300 litres). The appliance has A+ energy efficiency, but without the use of the chill allowance the EEI would result in an A appliance unless the manufacturer used other design methods to improve the efficiency.

10.4 Market analysis - chill compartment availability

The availability of fridge-freezers with chill compartments in Great Britain can be seen in Figure 37. Prior to 2008 the presence of this characteristic was not recorded in the market data sourced for this research so it is not possible to give a historical perspective on the trends in the provision of this characteristic. (European perspective is provided in Figure 38.)

For fridge-freezers, this characteristic is more commonly found in side-by-side type appliances than in upright fridge-freezers. According to the GfK data the majority of upright fridge-freezers with a chill compartment are also frost-free appliances. In 2010, 85% of upright fridge-freezers with chill compartments were also frost-free appliances. Compared with side-by-side models where 99.9% of those sold with chill compartments are also frost-free. Chill compartments also tend to be found on appliances with higher efficiencies. For upright fridge-freezers 52% of those sold with chill compartments were energy class A+ or better, although this is not the case for side-by-side appliances where only 19% of those with chill compartments were of the higher efficiency classes.

Fridges are also sold with chill compartments but to a lesser degree. In 2010 in Great Britain, only 0.32% of fridges sold had a chill compartment. The majority of these (62%) were category 1 appliances (fridges without freezer compartments), additionally those sold with chill compartments tended to be A+ or better efficiency class (75%).

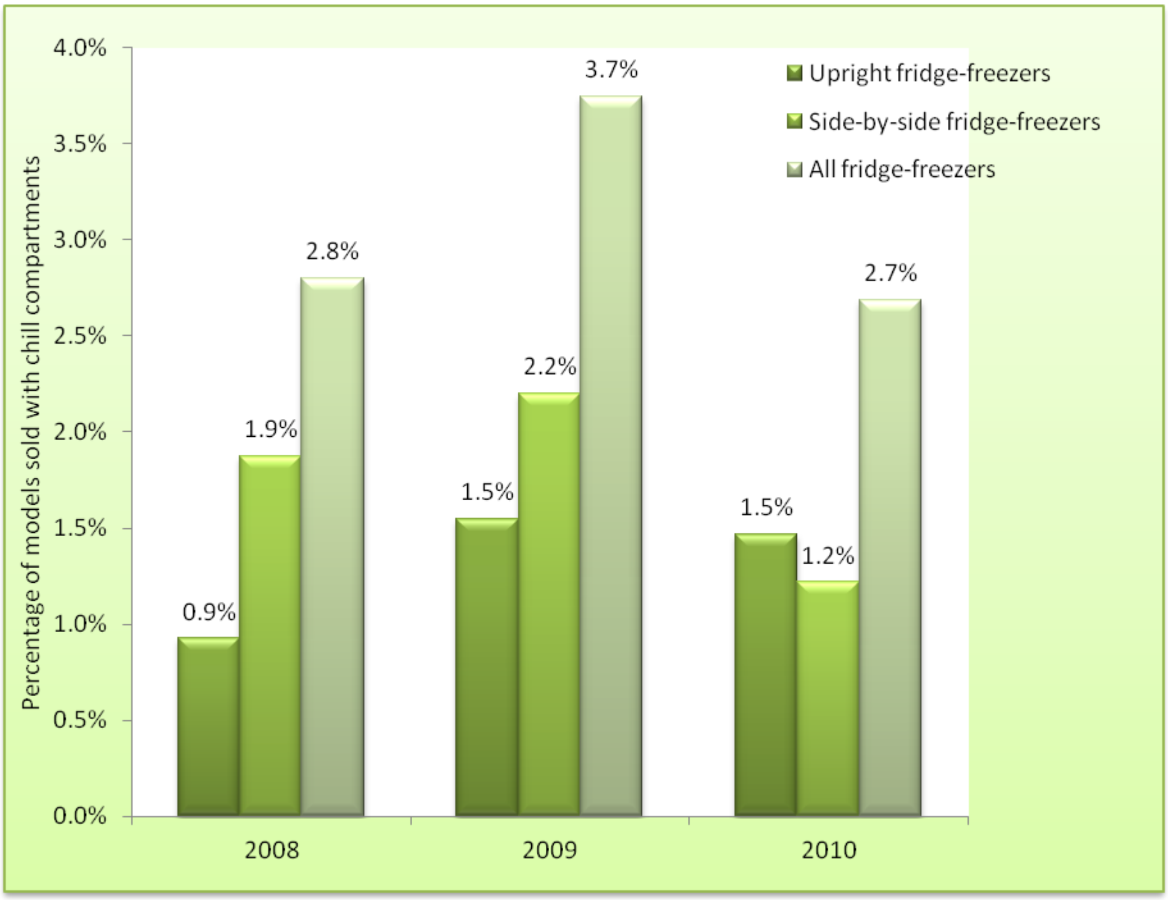


Figure 37: Percentage of new fridge-freezers sold with chill compartments - Great Britain (Source: analysis of GfK annual market data purchased by MTP).

The market data used for this analysis does not record the size of the chill compartment so it is not possible to suggest what percentage of these are eligible to use the chill compartment factor in the calculation of the energy efficiency index, or if they are a similar volume to the 40 litres used for calculating the level of the factor. Further research into the typical volumes of chill compartments has been hampered by the fact that, although manufacturers indicate the presence of a chill compartment in appliance brochures, the volume is rarely provided separate to the total fridge volume. Anecdotal evidence suggests that the most commonly seen chill compartment volumes range from a 15 to 30 litre single drawer (loaded with 3 or 4 half-kilogram test packages in accordance with EN ISO 15502 Clause 13.3.1 when under test).

The growth in the availability of appliances with chill compartments is more obvious from a Europe-wide perspective. Figure 38 show the prevalence of refrigerators available with chill compartments over recent years. In contrast to the data for GB, the information from the CECED database documenting the types of appliances available in Europe, suggests that chill compartments and frost-free do not always appear together. Only 28% of fridge-freezers (categories 7 &10) available in Europe in 2009 were also frost-free. They do however, tend to appear on the more efficient appliances (84% were A+ or better), but this could be due to the increased popularity of this feature and newer appliances that are also the more efficient incorporating chill compartments.

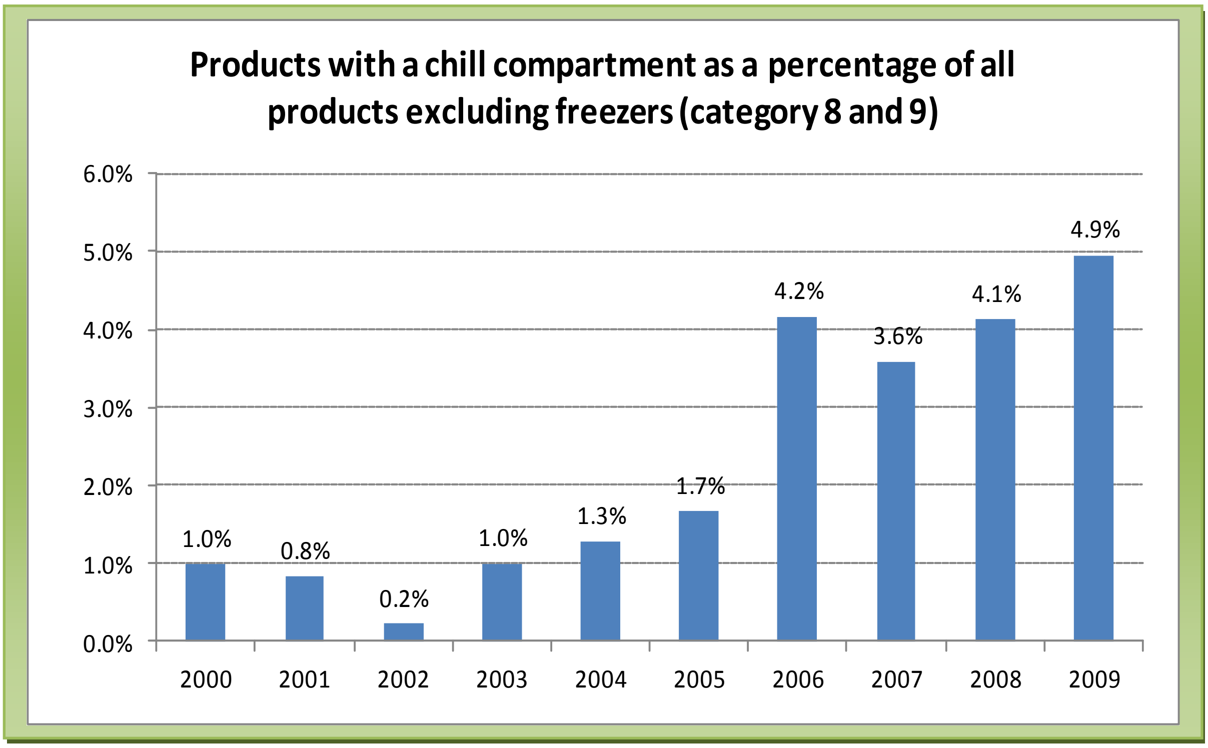


Figure 38: Percentage of refrigerators available in Europe with chill compartments, not sales weighted. (Source: CECED)

It has been suggested that in some countries the market penetration is probably growing faster due to consumers realising the potential advantages offered by chill compartments in terms of food preservation and different habits such as increased buying intervals.

The EuP preparatory study Task 2 research in 2007 surveyed consumers opinions on the importance of “improved cooling performance adapted to food (several cooling areas)” for new appliances. Chill compartments are assumed to fit into this definition. For consumers it was ranked in 7th place out of 11 characteristics that consumers rated in order of importance when purchasing a new appliance, with a rating of 7.2 out of 10. This is above characteristics such as greater convenience offered such as water and ice dispensers and hygienic surfaces, capacity and network connectivity. This suggests that it is not high in consumers' assessment of features, but probably beneficial if it is offered along with other consumer preferences. There were regional variations, with the UK and Sweden rating this characteristic with a score of 6.5 or below, but Germany, Italy, Spain and Hungary giving a score of 7.7 or 7.8.

10.5 Market distortion

The market information presented in this report does not support a suggestion that the chill compartment allowance may have distorted the market by encouraging the inclusion of this feature in new appliances. In Great Britain, it is rarely seen in fridges (categories 1 to 6) and in the largest sector of the market, upright fridge-freezers, appliances with a chill compartment only account for less than 2% of sales. In the EU as a whole, chill compartments are found on around 5% of available appliances, but this may be less if sales weighted data were considered due to the fact that such added features are expected to be available on premium brands and more expensive than average appliances. Expert opinion is that the interest in chill compartments is more likely to be a response to consumer's interest in food safety than manufacturers making use of the correction factor. Consumers are generally attracted to additional features when purchasing appliances and these provide a potential for manufacturers and retailers to encourage consumer to trade up to more premium priced appliances.

10.6 Summary and discussion

- Review of market data to consider the prevalence of chill compartments and any similar appliances with and without this feature.

Chill compartments are still relatively rare with only around 3% of fridge-freezers and less than 0.5% of fridges in GB sold with them. The European data suggests that around 5% of all refrigerators available have a chill compartment, but this is not necessarily reflected in the actual sales.

It has only been possible to find limited information on similar appliances with and without chill compartments. Appliances with chill compartments will generally be less efficient than those without because of the extra cooling required to maintain the chilled area between -2°C and 3°C. In the UK they are generally frost-free appliances and use the forced air to direct cold air to the chill compartment, however, this is not always the case across the rest of Europe.

- Assess whether the market share of appliances eligible for the correction factor has distorted the market.

With little historical sales data it is difficult to review any possible market distortion due to the chill compartment correction factor. The availability of chill compartments in the EU appears to have increased notably from 2006. This may have been a reaction to the introduction of the correction factor with the 2004 labelling extension to A+ and A++, but may also be as a result of increased interest in this feature. A combination of both has probably facilitated the increase in the availability of chill compartments.

As with all the added characteristics that are currently eligible for correction factors, the incorporation of a chill compartment involves more expensive design differences compared to a standard appliance, but the availability of the correction factor assists in presenting an efficient appliance more easily than without a correction factor.

10.7 Conclusion

The chill compartment correction factor should be removed on the basis that the provision of a colder storage area in the fridge results in additional energy consumption which should be reflected in the energy efficiency information given to consumers.

Whilst chill compartments offer a feature that is attractive to some consumers, they are a feature that consumers are expected to have to pay for. Chill compartments offer enhanced storage conditions within a fridge but they are not essential for normal storage of fresh food requiring refrigeration and as such are an extra. If an appliance is going to use more energy because it offers colder storage conditions, this poorer efficiency should be taken into account and represented in the efficiency information given to consumers. Consumers in a retail environment are likely to be reviewing a range of appliances, some that may have chill compartments. Presenting appliances with chill compartments in a different product category, one suggested option to avoid correction factors and having different calculations for different categories, would not resolve the problem as it is thought unlikely that consumers will refine their selection to just those appliances with or without chill compartments initially, so the efficiency information still needs to be comparative across similar products.

An analysis appears to have been carried out by the European Commission using data from manufacturers prior to the introduction of the correction factor assessing the additional energy consumption that appliances with chill compartments use. This appears to have considered chill compartments with a volume around 40 litres whereas they are thought to now more typically be around 18 litres. If the factor was based upon larger chill compartments than those that actually appear in appliances, then using that factor gives an unwarranted advantage.

If it is to remain, the chill compartment factor should be reviewed in respect to the volumes of chill compartments currently available and possible proportioned according to the volume. However, fundamentally there seems little justification for giving appliances with a chill compartment an energy bonus which is ultimately misleading the consumer.

11 Task 5: Real use consumption and correction factor benefits

11.1 Introduction

In order to consider the whether the use of correction factors reflects real use it is necessary to try and evaluate the differences between appliances energy consumption in real use compared to standard tests and manufacturers declarations.

Although the effect of the correction factors is not reflected in the declared annual energy consumption given on the energy label only, it is useful to look at real use and the differences compared to annual energy claims.

11.2 Standard testing and consumer Use

Standard energy testing (EN 153) requires appliances to be stabilised in a test room with an ambient of 25°C. Fridge compartments are empty or practically empty; with three small thermocouples for recording the internal temperatures. Freezer compartments are loaded with test packages and M packs. The temperatures that the appliance compartments are expected to achieve are similar to those expected for an appliance in actual use.

There are a few key parameters in the standard testing of an appliance that are different in actual use by the consumer. The ambient test temperature is warmer than the average user environment and there is no door opening during the test. However, the warmer test ambient temperature is assumed to compensate for the lack of door opening. The lack of door opening creates another possible difference between standard testing and in use performance. Particularly the effect of frosting up of freezers which in the case of static appliance could lead to different energy consumption and in the case of frost-free appliances does not create the frost formation that triggers a defrost cycle.

Whilst estimations can be made for the frequency of defrost cycles in actual use compared to standard testing, there is little evidence to consider the extent and effect of frosting up on static appliances. This is further discussed in Chapter 7 which considers the frost-free correction factor.

The EuP preparatory study[57] considered the aspects of real use that affect energy consumption compared to standard testing. Comparisons were made between a real-life base case fridge-freezer and a standard base case fridge-freezer. Once adjustments were made for different ambient temperatures, and other consumer intervention such as door opening and the introduction of food as well as the thermostat setting, the standard base case used around 3.5% less kWh per year than the real-life base case.

[57] ISIS. 2007. Preparatory Studies for Eco-design Requirements of EuPs Lot 13: Domestic Refrigerators & Freezers Tasks 3-5: Final Report. Draft Version. (section 3.3.3)

11.3 Real life data

The UK Household Energy Survey (UKHES) energy monitoring survey recorded electricity consumption in 251 English households between May 2010 and July 2011. Where possible, all cold appliances were monitored. The electricians who installed the data logging equipment also recorded the brand and model details of the appliances. Intertek identified a small number of appliances where all the details of the correction factors that might be claimed for the appliance could be found either in GfK sales data or from the manufacturer's information. There were 17 fridge-freezers from three different manufacturers. The majority were frost-free and over two-thirds were SN climate class. The data has been analysed to correct for the seasonality effect for households measured for one month.

Table 12 shows the claimed and measured data for these products. The average proportion of the energy label claim used was 87%. With the claimed values adjusted to expected consumption at 20°C the average proportion used was 106%.

Table 12: Claimed and measured data from UKHES

Household code	Energy label annual consumption (kWh/y)	Measured annual consumption Seasonality effect applied (kWh/y)	Proportion of energy label claim actually used (%)	Claimed energy adjusted to 20°C (kWh/y)	Proportion of adjusted claim actually used (%)
103012	293	194	66%	240	81%
103032	420	483	115%	344	140%
201190	340	285	84%	279	102%
201222	343	253	74%	281	90%
202246	332	334	101%	272	123%
202275	343	345	101%	281	123%
202278	395	330	84%	324	102%
202305	329	282	86%	270	105%
202352	340	182	54%	279	65%
202434	334	320	96%	274	117%
203139	340	265	78%	279	95%
203198	340	288	85%	279	103%
203258	329	350	106%	270	130%
203335	308	249	81%	253	99%
203340	293	227	78%	240	95%
203356	423	438	103%	347	126%
203386	343	289	84%	281	103%

In use energy consumption is most strongly influenced by the ambient temperature where the appliance is located, and also by the internal temperatures that are achieved inside the appliance. Other factors such as the introduction of 'warm' food and door opening have a lower, less significant impact on the energy consumption in general[58]. However, there may be circumstances where an individual's user habits can have an influence on energy that

[58] Geppert, Jasmin 2011 *Modelling of domestic refrigerators' energy consumption under real life conditions in Europe*. Bonn University. Dissertation for Dr.-Ing. see http://hss.ulb.uni-bonn.de/2011/2587/2587.pdf accessed 26 January 2012.

exceeds the differences caused by ambient temperatures so caution should be taken when reviewing a small data set.

UK kitchen temperatures are most likely to be within the range 13°C to 19°C, with some seasonal variation for very cold and very warm days. Table 2-4 of Geppert (2011) summarises research into the amount of energy variation found when ambient temperature is changed. A figure in the order of 18% less energy is expected to be used if the ambient temperature is reduced from 25°C to 20°C.

As the UKHES data has been corrected for seasonal variations, it can be considered representative of in-use results. The ambient temperatures in the households were measured, but the thermometers were not in all cases placed in the kitchens adjacent to the refrigerated appliances. It would be necessary correlate the temperature data against each appliance to more closely consider the claimed and measured values.

Data from the UKHES survey supports the theory that the energy label data should at best only be used as an indicator of relative energy consumption for consumers at point-of-sale. It is not necessarily a true indicator of levels of energy consumption likely to be achieved in any particular home due to the variation in ambient temperature and the internal temperature selected by the consumer, and door opening effects. The influence of the energy label letter rating is likely to be more persuasive to consumers at point-of-sale than the declared annual consumption in kWh. A study in 2008 in six EU countries[59] suggested:
"Most consumers are not aware of all the details on the energy label (e.g. limited familiarity with measures such as kWh/hours (sic)) but there is a strong general recognition and intuitive understanding of the alphabetical colour-coded scale (A-G) in all markets."[60]

If this is the case then the energy classes should be a comparative as possible across all types of appliance. Consumers may be choosing appliances with the higher classes (all other factors such as price, brand, and design features being equal) even though there are other appliances with similar energy consumptions not using correction factors.

11.4 Summary and discussion

- Analysis of whether the use of correction factors reflects real energy savings in actual consumer use.

Of the four correction factors applicable to the calculation of the energy efficiency index for refrigerating appliances, only the climate class and frost-free factors could be considered to compensate for differences in expected energy use in real use compared to the standard energy test. The climate class factor applied to ST and T climate class appliances is intended to consider the different performance of compressors suitable for appropriate operations in different climate conditions compared to the 25°C ambient temperatures used for the energy test. The frost-free correction factor attempts to compensate for the energy used for the defrost operation during standard testing and makes frost-free appliances difficult to compare with similar static appliances.

The built-in and chill compartment factors provide bonuses for appliances due to design aspects that are detrimental to the appliances energy efficiency performance both in

[59] UK, France, Netherlands, Italy, Poland, Sweden.

[60] Ipsos Marketing 2008 *EU Energy Labelling Global Research Report* http://efficient-products.defra.gov.uk/spm/download/document/id/979 accessed 26 January 2012

standard tests and real use, even though they may be seen as favourable and convenient for consumers.

It is very difficult to compare real use consumption with standard test energy claims due to the various ways that consumers set up and use their appliances. A review of 17 fridge-freezers with characteristics making eligible for correction factors in UK homes suggests that the average proportion of the energy consumption claimed by the manufacturer in actual use is 87%. If the standard test energy declaration is reduced to account of cooler kitchens in real homes than the energy label test method, the proportion of the energy claim used is 106%.

The effect of the correction factors is not reflected in the declared annual energy consumption which appears on the energy label. The correction factors have the effect of making appliances look more efficient when the energy efficiency index is calculated and letter classification awarded.

The frost-free correction factor is the most appropriate factor to compare with actual use. However, the sample from the UKHES is not large enough to significantly compare the energy consumption of a range of frost-free with a range of static fridge-freezers.

11.5 Conclusion

The energy label data should at best only be used as an indicator of relative energy consumption for consumers at point-of-sale. It is not a true indicator of levels of energy consumption likely to be achieved in any particular home due to the variation in ambient temperature and the internal temperatures selected by the consumer, and this may vary depending upon different European regions. The influence of the energy label letter rating is likely to be more persuasive to consumers at point-of-sale than the declared annual consumption in kWh.

For this reason the efficiency rating on the label should be as comparable as possible between appliances and represent consumer use were possible.

12 Task 6: Removal of correction factors cost/benefit impact assessment

This section considers the reduction in energy consumption and carbon emissions that would result if the correction factors were removed and appliance efficiency improved to maintain the current level of overall efficiency in the UK and EU market place. It is for illustrative purposes and is not intended to justify a removal of correction factors and also indicates the correction factors that have the greatest influence in the market.

In order to consider the effect that the correction factor makes on the energy consumption needed to attain a particular energy efficiency index, the market data on appliances sold in GB in 2010 has been analysed. This analysis considers the correction factor that is used in the energy efficiency index (EEI) and then recalculates the EEI if the correction factor is removed. In order to regain the EEI without the correction factor the adjustment needed to the energy consumption (kWh/y) is calculated, i.e. the lower energy consumption needed to achieve the same energy efficiency letter without a correction factor. Table 13 shows a simplified example of the analysis.

Table 13: Example of the analysis used to consider the effect if a 1.2 correction factor (CF) is removed: upright freezer

Claimed kWh/y	SC with CF	SC without CF	EEI with CF	EEI without CF	% difference between the EEI with and without CF	New kWh needed to achieve original EEI (without use of CF)
186	446.33	422.44	42.35	44.74	5.35%	179

The analysis considered the difference between the EEI with and without the correction factor and uses the sales data to give a sales weighted adjustment that would be necessary to maintain the current efficiencies on the market without the correction factor.

This value, along with the percentage of appliances eligible to use the correction factor, is used in the modelling for the impact assessment.

The detailed methodology and assumptions used for the cost benefit analysis can be found in Annex G.

This analysis is based upon the assumption that in order to maintain the same levels of efficiency manufacturers would improve the performance of appliances, if the correction factors were not used for the calculation of the EEI. However, it should be acknowledged that this may not be the option taken in reality due to various reasons such as the technology available and associated increased cost. Without correction factors there might be a call to reassess the energy efficiency boundaries used for energy labelling and minimum standards. This aside, the analysis illustrates the energy bonus provided by correction factors and those that have the most significance in the market.

12.1 UK data - inputs

For the UK analysis existing Defra MTP models were used as the basis of the analysis. The version used for the EuP analysis (done in 2009) has been used. The ex-ante policy scenario in the EUP have been used as a good surrogate for the current reference scenario.

The data inputs each of the four domestic refrigerator types (refrigerator, chest freezer, upright freezer, fridge-freezer) are listed in Table 14. For each correction factors this includes:

- the % of models (ideally sales-weighted) that make use of each of the factors;
- the impact on average annual new energy consumption if they were to be removed (either in % or kWh terms);
- the costs (to consumer) of improving the product to reach the efficiency requirements for (re)reaching any MEPS level (the Low impact case).

Table 14: Main input data for UK impact analysis

Product	Correction factor	Proportion sales (%)	Energy impact (%)	Combined impact (%)
Fridge-freezer	Climate class ST	15%	4.43%	0.7%
	Climate class T	20%	9.44%	1.9%
	Frost-free	59.20%	5.00%	3.0%
	Built-in	2.54%	8.92%	0.6%
	Chill compartment	2.80%	6.42%	0.2%
Upright freezer	Climate class ST	37.90%	2.93%	1.1%
	Climate class T	11.30%	7.55%	0.9%
	Frost-free	20.20%	6.58%	1.3%
	Built-in	2.29%	7.11%	0.1%
	Chill compartment	-	-	-
Chest freezer	Climate class ST	21.60%	4.62%	1.0%
	Climate class T	7.60%	6.03%	0.5%
	Frost-free	0.39%	11.25%	0.0%
	Built-in	-	-	-
	Chill compartment	-	-	-
Refrigerator	Climate class ST	44.80%	1.97%	0.9%
	Climate class T	3.10%	6.26%	0.2%
	Frost-free	-	-	-
	Built-in	3.10%	4.56%	0.1%
	Chill compartment	0.32%	10.95%	0.0%

Source: Based on analysis of GfK 2010 data

Note – the impact energy impact could be analysed in several ways. The lowest impact would be the case were the product which had their effect of the factor removed would need to (re)meet MEPS levels. A higher impact would be for the case where products which had the impact of the factor removed would (re)reach the same efficiency level as when the factor was included. For the current analysis the higher impact is be examined. This is more likely to be the case since the MEPS performance levels are being ratcheted up.

The combined impact (%) column in Table 14 shows the overall impact on the average new consumption if the factor is removed (the simple product of the energy impact on products which use the factor, multiplied by the proportion of sales which use the particular factor).

These data have been considered to be fixed over time, i.e. the same factors have been used from 2014 through to 2030.

Using these figures it is possible to generate different future ‘scenarios’. The analysis is based on generating different average new consumption of the four products (see Annex G, Equation 7).

If appliances have to be made more efficient to (re)reach the same efficiency level as when the ‘correction’ factor was in place, there is usually assumed to be a cost. This is not a trivial task, with multiple approaches possible and little data. For the current analysis, will propose to take a conservative approach, and use the information presented in the EUP research study.

The EUP study assumed that an increase in cost to move from the basecase product to the LLCC product: a simple calculation has been used to provide a figure for the average cost per kWh reduction, and is shown in Table 15. These consumer costs are based on an industry mark-up of 2.5.

Table 15:. Marginal consumer cost for reduction in consumption (Euro/kWh)

Product	Marginal cost (Euro/kWh)
Chest freezer	1.13
Upright freezer	1.39
Refrigerator-freezer	1.36

Source: based on ISIS 2007, Tables 7.2.3 and 7.3.1

In the impact modelling, these costs have been assumed to apply from 2014 onwards. A simple 10% per annum decrease has been included in the analysis (to reflect costs falling over time for the improved efficiency, and falling margins/mark-ups for established products). This may be revised in the next iteration.

12.2 UK analysis - outputs

Using the data presented in the previous section, the energy consumption for the different ‘scenario’s can be estimated. These are the summed estimates for all four products.

Table 16: UK energy consumption under different ‘scenarios’ (GWh/year)

	2010	2015	2020	2025	2030
Ref (EUP scenario)	14,480	12,209	10,030	8,418	7,509
Climate class ST	14,480	12,201	10,004	8,376	7,455
Climate class T	14,480	12,197	9,987	8,350	7,422
Frost-free	14,480	12,190	9,966	8,316	7,379
Built-in	14,480	12,207	10,024	8,409	7,496
Chill compartment	14,480	12,208	10,027	8,412	7,501

It can be seen that the reference (Ref-EUP) scenario already shows significant and continued falling energy consumption due to previous policies, and especially the recently agreed EuP implementing measures.

The energy reductions associated with the removals of each correction factor can be estimated by using the reference (Ref-EUP) scenario as the baseline. The energy reductions compared to this baseline are shown graphically in
Figure 39.

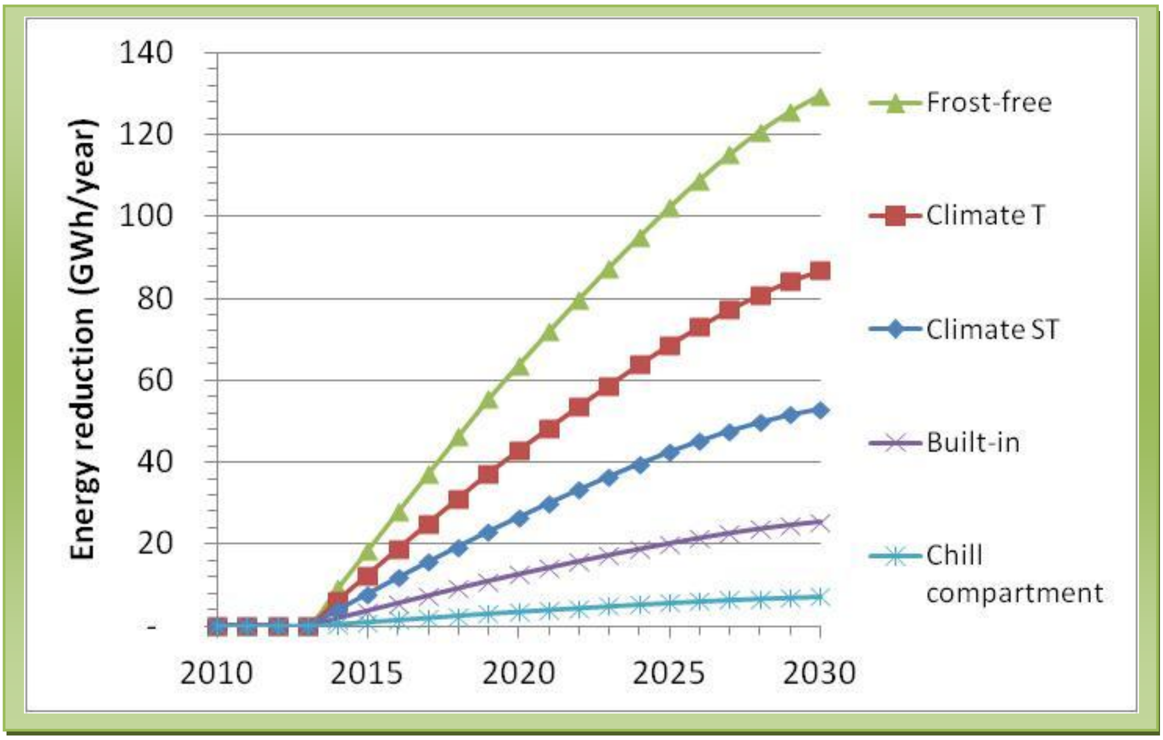


Figure 39: UK energy reductions by removing correction factors

Based on the input figures in Table 14 and the MTP stock model, the ranking of the impact on UK energy consumption of the different correction factors can be seen.

Table 17: Energy reduction by product by correction factor in 2030 (GWh/year)

Factor	Chest freezer	Fridge-freezer	Refrigerator	Upright freezer
Climate class ST	4.74	25.43	9.49	13.45
Climate class T	2.18	72.24	2.09	10.33
Frost-free	0.21	113.17	-	16.10
Built-in	-	8.67	1.52	1.97
Chill compartment	-	6.88	0.38	-

There is a detailed methodology for undertaking impact assessments in the UK (DECC, 2011)[61]. This approach includes an examination of all the likely costs and benefits. This

[61] DECC (2011) *Valuation of energy use and greenhouse gas emissions for appraisal and evaluation*. HM Treasury and DECC. October 2011.

covers the inclusion of carbon (traded and non-traded values) and air quality benefits. The values used in this assessment are listed in Annex G.
The expected carbon reductions are shown in Table 18 along with a cost-effectiveness indicator, which shows that such a measure is very cost-effective (negative in this case).

Table 18: Cumulative carbon emission reduction by 2030, and cost effectiveness indicator

Factor	CO2 traded (ktCO2)	CO2 Non-traded (ktCO2)	CEI-traded (£/tCO2)
Climate class ST	184.0	-26.2	-174.6
Climate class T	297.2	-42.3	-188.4
Frost-free	442.3	-63.0	-136.8
Built-in	87.5	-6.0	-210.7
Chill compartment	24.9	-3.5	-210.2

Note: In the UK the Heat Replacement Effect means there will be a slight increase in domestic heating, hence the increase in non-traded emissions.

The total financial benefit to the UK based on the above analysis is summarised in Table 19, where the financial values have been discounted with 2011 as the base year.

Table 19: Net financial benefits to 2030 (Discounted, £M,)

Factor	Present Value (£M, 2011)
Climate class ST	35.5
Climate class T	57.4
Frost-free	85.4
Built-in	8.1
Chill compartment	4.8

The above analysis shows that there are clear benefits to removing these factors.

A detailed examination of the costs is not complete. At present a simple and conservative cost analysis has been included. The net present value of the costs (increased purchase costs for consumers and increased heating due to the HRE effect) are presented in Table 20.

Table 20: Financial costs to 2030 (Present value)

Factor	Discounted Costs (£M, 2011)
Climate class ST	8.4
Climate class T	9.5
Frost-free	37.0
Built-in	0.4
Chill compartment	0.3

Note: these costs cover increased appliance costs and additional heating from HRE effect.

Even with these conservative costs estimates, the changes are cost-effective for the UK, as shown by the cost-effectiveness indicator earlier, and also the net present value (benefits less costs) shown in Table 21.

Table 21: Net benefit to 2030 (Present value, £M, 2001)

Factor	NPV (£M, 2011)
Climate class ST	27.1
Climate class T	47.9
Frost-free	48.4
Built-in	7.7
Chill compartment	4.5

12.3 EU data - inputs

For the EU analysis, the model has been differently constructed though the input data for correction factors is similar to the UK. The EU model is based on all 27 Member States, including the UK.

The underlying stock model data has been based on EUP preparatory study research[62] (ISIS, 2008). As such, there are different refrigerator type classifications: whereas there are four types modelled in the UK, for the EU they are separated into two types (since this is the level of analysis in the EUP study):

- Refrigerator (includes both fridge-freezer and refrigerators);
- Freezer (includes both chest and upright freezers).

For the impact of removing correction factors, the same approach as used for the UK analysis has been followed. The proportion of sales for the use of these correction factors was based on a model-weighted analysis of CECED database of products.

Without access to the product models and their feature data it is difficult to estimate the impact of removing each correction factor. In this instant it was assumed that the impact would be the same as the UK models (which is not unreasonable). However, since there are different classifications (two product groups in the EU, rather than four in the UK), the product-weighted averages have been used. That is for the energy impact in the EU for 'Fridge-freezer and refrigerators' the product-weighted (based on CECED database) average of the UK energy impact values have been used. The product-weighting in the European CECED database is:

- Refrigerator: fridge-freezer (79%) and refrigerator (21%);
- Freezer: chest freezer (31%) and upright freezer (69%).

[62] ISIS (2008) *LOT 13: Domestic Refrigerators & Freezers: tasks 6-7.* Final report, draft version. Preparatory Studies for Eco-design (Tender TREN/D1/40-2005).

Table 22: Main input data for EU analysis

Product	Correction factor	Proportion sales (%)	Energy impact (%)	Combined impact (%)
Refrigerator	Climate class ST	30.8%	3.9%	1.2%
	Climate class T	48.0%	8.7%	4.2%
	Frost-free	25.7%	3.9%	1.0%
	Built-in	28.3%	8.0%	2.3%
	Chill compartment	4.9%	7.4%	0.4%
Freezer	Climate class ST	53.3%	3.5%	1.8%
	Climate class T	27.6%	7.1%	2.0%
	Frost-free	21.1%	8.0%	1.7%
	Built-in	14.6%	4.9%	0.7%
	Chill compartment	-	-	0.0%

(Sources: Proportion of sales based on CECED analysis of database. Proportion of chill compartments sales, CECED pers comm. Energy impact assumed the same as UK, though product-weighted.)

The largest difference between the EU factors and the UK ones is in the use of built-in, which is significantly higher in the EU. This is due to fact that all built-in appliances have to be assumed to use the correction factor because the CECED database reported all built-in appliances and does not identify any subset of those eligible to use the correction factor. Another large difference is the use of Climate class ST and T, which are more prevalent in EU (as opposed to the UK alone).

As with UK data, these impact data are assumed to be fixed from 2014 through to 2030. The EU model has been setup to mimic the EUP model, and the 'Realistic' scenario has been used as the baseline for the analysis (may need to revise this assumption, so that it better matches the actual implementing measure).

12.4 EU analysis - outputs

Using the simple stock model approach, the reductions in energy if the correction factors are removed is shown for each scenario in Figure 40, and results shown by correction factor in Table 23 and Table 24.

The total energy reduction achievable could be around 4.6TWh in 2030. This is not insubstantial when compared to the 6TWh by 2020[63] suggested as the annual electricity saving due to the combined effects of the provisions set out in the latest ecodesign and energy labelling Regulations.

63 COMMISSION DELEGATED REGULATION (EU) No 1060/2010 of 28 September 2010 supplementing Directive 2010/30/EU of the European Parliament and of the Council with regard to energy labelling of household refrigerating appliances.

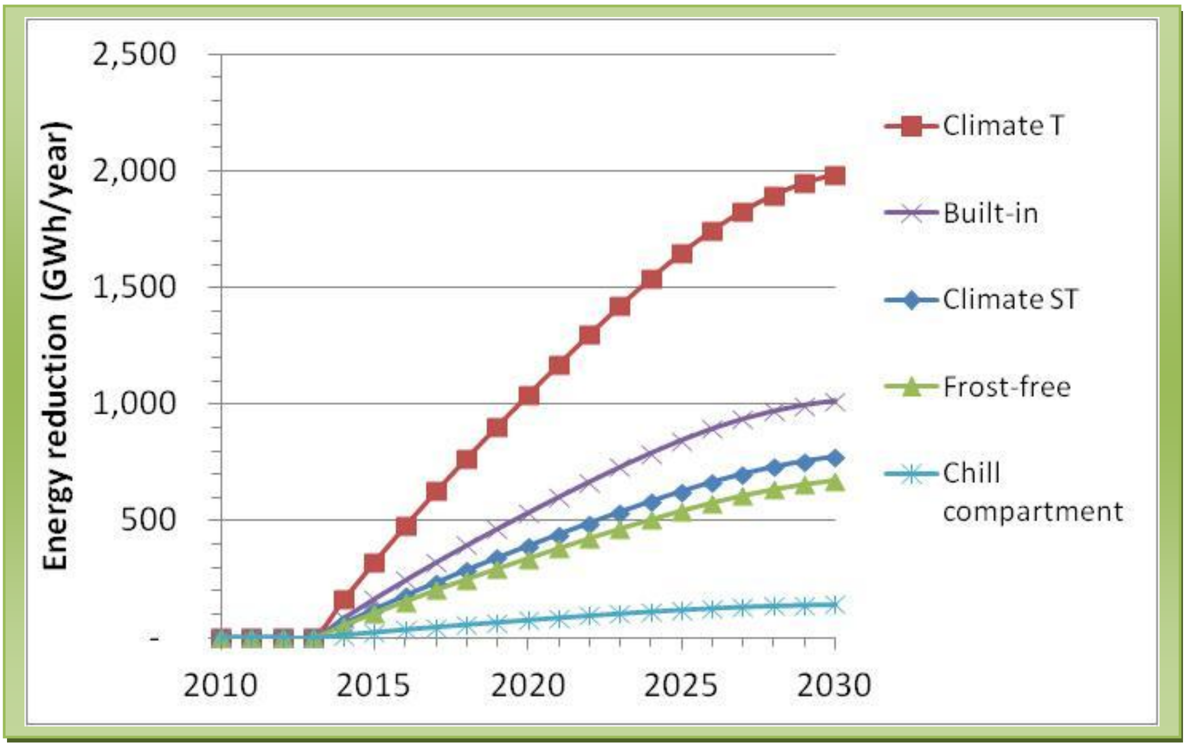


Figure 40: EU energy reductions by removing correction factors (all refrigerating appliances)

There will be some difference between the stock model generated for this analysis and the one used in the EUP research lot, and the likely impact of the implanting measure. However, the ranking of the options and relative importance of each correction factor will be the same regardless.

Table 23: Energy reductions by product by correction factor in 2030 (GWh/year)

Factor	Refrigerators	Freezers
Climate class ST	478	295
Climate class T	1,671	313
Frost-free	402	271
Built-in	899	115
Chill compartment	143	-

Using the same carbon emission factors as the UK, the reduction in carbon emissions can also be estimated as shown in Table 24.

Table 24: Carbon emission impact by 2030 (ktCO2)

Factor	CO2 traded (ktCO2)
Climate class ST	2,710
Climate class T	7,121
Frost-free	2,354
Built-in	3,656
Chill compartment	523

13 Task 7: Verification tolerances

13.1 Introduction

The latest domestic refrigeration energy label and ecodesign Directives set out a verification procedure for market surveillance purposes which states verification tolerances of 3% for volume measurements and 10% for energy consumption. These are the two main parameters affecting the energy efficiency index. The EN153:2006 test standard states tolerances allowing 15% for energy consumption of the first sample tested and a mean of 10% of three subsequent samples.

In order to assess the appropriateness of, and any possible evidence for, changing the market surveillance tolerances, research and consultations have been undertaken to try to determine the origins of tolerance values and what factors are taken into account in setting them. This has proved to be a complex and contentious issue with different technical experts taking different positions.

The general consensus would appear to be that the original 15% tolerance for energy labelling aimed to allow for both:

- variations between samples of the same appliance - appliance production variability
- variability of a measured value expected if the same appliance is tested in different laboratories - laboratory variation.

It is difficult to quantify the variability involved, but ideally the manufacturer should know the variation in the performance of appliances from its production line and laboratories should be able to provide an uncertainty assessment for their own measurements. The work of Standards committees and 'ring tests' where a sample appliance is tested in a range of test laboratories, help to provide information on laboratory variability.

There also appears to be consensus (through discussions with steering group members) on the following aspects:

- that the verification tolerance has been reduced to 10% in the latest domestic cold appliance Directives because manufacturers are able to better control and/or take better account of their production variability when making claims.
- that the purpose of testing three samples after the result from a first sample being outside a level of tolerance is to consider any rogue samples.
- that the tolerance currently (i.e. in the new labelling scheme and ecodesign Regulations) encompasses only laboratory variability.

13.2 Measurement issues

For measurements to be good and reliable, they need to be

a) *repeatable* – the same test sample, in the same laboratory, under the same test conditions, must give the same result from one day to the next day to the next and so on and,
b) *reproducible*, i.e. the same test sample should give the same result when measured in different laboratories under the same test conditions.

It has been shown that *some* test samples can vary day-on-day by 3% or more and the current test standard requires repeatability to be at least as good as 3%.

The development of appropriate repeatable and reproducible test methods are essential to enable accurate and defendable appliance measurements.

It is production line variation plus any lack of reproducibility when testing the same sample at different laboratories which will limit any tolerance.
- production line variation should be minimal as manufacturers should be able to measure, control and consider this themselves, and is the assumption taken for the current Regulations.
- any lack of accuracy in laboratory testing is a separate issue which can be covered by a laboratory's own uncertainty declaration in accordance with IEC 17025. (All accredited test laboratories must comply with IEC 17025).

It is important to understand the terms often used in the context of testing and tolerances as it may help to avoid confusion during the discussions of these issues.

- Error

An error is the known difference between the “true value” and the measured value. The measured value is sometimes known as the “measurand”. An error should be a precise magnitude in a particular direction. Certain instruments may have a correction applied where you add or subtract a certain (known) amount to the reading. This is an error correction. For many other instruments, the error correction is already applied internally and you just take the read-out as it is.

In the past, the term “error” has been used when trying to estimate the accuracy of a result when what they are really looking at is an uncertainty contributor (see below). Also, error does not mean “mistake”. If a mistake has been made e.g. wrong reading or applying the test method incorrectly or not setting up correctly, then this is an invalid reading and should not be included in any analysis.

- Uncertainty

It should be appreciated that, you never know precisely where the true result lies and therefore an error correction cannot always or accurately be applied.

No result or reading is perfect or can be absolutely perfect but should be good enough for the purpose, e.g. using instrumentation as required by a test standard can be sufficient to achieve an appropriate uncertainty. The expectation is that the true result lays within a measured value ± an uncertainty estimation. In industry, it is the norm to predict this within a 95% confidence or probability level, ie a laboratory should know the level of imperfection of their result. Uncertainty is a cloud or fuzziness that cannot be avoided and is actually useful to examine "uncertainty contributors" and their impact on any final result. This can help refine the test method or demand better instrumentation or if this is not possible, stipulated limits to discrimination between performance levels.

One way is to consider the contributors to the uncertainty in what is technically known as an uncertainty “budget”. While the magnitude of the uncertainty can be estimated, the direction of that magnitude cannot, so the result should be expressed for example, Lifespan = 12 ± 2 years.

Briefly, the uncertainty in a measured result can broadly arise from the following contributors:

a) limitations of instrumentation
b) limitation of test method
c) non-repeatability of measured variable

For the uncertainty budget, each of the above has to be unpacked and justified in detail. For c) it should be appreciated that the measured variable can be affected by the appliance which may not give exactly the same energy day-on-day even though test conditions and other parameters have not changed.

13.3 Australian approach to tolerances

The Australian refrigeration test standard has a testing tolerance of 7.5%. There is a two stage verification process with one and then three samples tested as necessary. AS/NZ 4474.2:2009, Paragraph 2.10 "Energy label validity and checking testing" states that the 7.5% is not to be applied as a tolerance on the original test measurements which are used to support an application for registration. The 7.5% is only an allowance for possible variation in test results for test samples due to production variability, sampling error and all measurement uncertainties in or between laboratories which is applied when assessing a check test result.

The tolerance for refrigeration appliances has been reduced from 10% following a review of the verification guidelines in 2004. This tolerance was developed to account for inherent product variability, inter-laboratory variability (reproducibility) and intra-laboratory variability (repeatability) (some of which will be attributable to testing apparatus),

13.4 CECED 2009 ring test

Whether a test measurement is reproducible has been examined by a “ring test” or a “round robin” test. During the ring test the same test sample is tested in a number of different laboratories under the same test conditions. Such ring tests occurred in 1999 and in 2009.

The 2009 CECED ring test involved 10 laboratories from across Europe. The ring test was managed and financed by CECED in order to;

- evaluate the Laboratory to Laboratory results variation for each model,
- evaluate the variability of the measurement method in 10 laboratories,
- estimate the effect of the aging process on the energy consumption,
- confirm the testing ability of each laboratory.

No specific communication has been issued to the EC or an EC representative.

Appliances from four major manufacturers were circulated between the laboratories for energy consumption and volume measurements according to EN153. The appliances were also measured by the manufacturer at the beginning and end of the ring test. Two samples of each appliance were supplied, one sample tested by a group of five laboratories. The tables given in Figure 41 show the results provided by CECED after the ring test was completed. The results are ordered from highest to lowest consumption, not in the order of testing. The average results and other analysis combines the results of the two samples of each appliance even though there is some slight sample variability identifiable by the initial energy consumption tests.

Labs	Energy consumption (kWh/year)	Difference to average (kWh/year)	Difference to average (%)	manufacturer laboratory initial test (kWh/year)	manufacturer laboratory final test (kWh/year)	ELECTROLUX RRA34391 W
A	142,4	-3,7	-2,53	134,3	155,5	82400062
B	144,5	-1,6	-1,1			
C	144,8	-1,3	-0,89			
D	148,6	2,5	1,71			
E	150,5	4,4	3,01			
V	[215,4]	--	--	131,8	151,1	82400093
W	138,7	-6,1	-4,21			
X	141,3	-3,5	-2,42			
Y	148,2	3,4	2,35			
Z	151,1	6,3	4,35			
Average	145,5	Standard dev. (%)				4,01

Labs	Energy consumption (kWh/year)	Difference to average (kWh/year)	Difference to average (%)	manufacturer laboratory initial test (kWh/year)	manufacturer laboratory final test (kWh/year)	BSH KGN 39P
D	316	-10,6	-3,25	318,6	337,3	8711 00212
E	324,95	-1,65	-0,51			
A	328,5	1,9	0,58			
C	333	6,4	1,96			
B	341,4	14,8	4,53			
Y	298,2	-28,4	-8,7	323,8	338,4	8712 00211
X	317,9	-8,7	-2,66			
Z	323,8	-2,8	-0,86			
W	325,9	-0,7	-0,21			
V	354,1	27,5	8,42			
Average	326,6	Standard dev. (%)				4,39

Table 1: Differences between the measured annual energy consumption in each Laboratory and the average consumption of the 10 Laboratories for the refrigerator ELECTROLUX RRA34391W and for the No-frost refrigerator-freezer BSH KGN 39P1.
The measurement of the energy consumption for the ELECTROLUX refrigerator in laboratory V, which was made with the fan on, has not been considered in the analysis.

Labs	Energy consumption (kWh/year)	Difference to average (kWh/year)	Difference to average (%)	manufacturer laboratory initial test (kWh/year)	manufacturer laboratory final test (kWh/year)	LIEBHERR ICBS 3156
B	260,8	-15,3	-5,54	287,4	294,6	25.447.722.1
A	266,5	-9,6	-3,48			
E	272,4	-3,7	-1,34			
C	295,3	19,2	6,95			
D	299,3	23,2	8,4			
X	240,9	-35,2	-12,75	290,2	302,3	25.447.711.5
Y	258,8	-17,3	-6,27			
W	266,5	-9,6	-3,48			
V	288,4	12,3	4,45			
Z	312,1	36	13,04			
Average	276,1	Standard dev. (%)				7,94

Labs	Energy consumption (kWh/year)	Difference to average (kWh/year)	Difference to average (%)	manufacturer laboratory initial test (kWh/year)	manufacturer laboratory final test (kWh/year)	WHIRLPOOL AFG 8150/CV225S
D	244,6	-15,1	-5,81	257,0	258,8	50 0746 017616
C	258,2	-1,5	-0,58			
A	266,5	6,8	2,62			
B	273,9	14,2	5,47			
E	278,75	19,05	7,34			
Y	240,9	-18,8	-7,24	256,2	258,4	50 0746 017617
X	253,3	-6,4	-2,46			
Z	258,8	-0,9	-0,35			
W	259,5	-0,2	-0,08			
V	262,8	3,1	1,19			
Average	259,7	Standard dev. (%)				4,53

Table 2: Differences between the measured annual energy consumption in each Laboratory and the average consumption of the 10 Laboratories for the built-in refrigerator-freezer LIEBHERR ICBS 3156 and the upright freezer WHIRLPOOL AFG 8150/CV225S

Figure 41: Results for the 2009 ring test provided by CECED

The results have been reanalysed and treated as for two mini-ring tests for each appliance sample. These can be found in Annex F.

No conclusion from this ring test have been provided by CECED, but the results from the reanalysis, including the values measured by the manufacturers, show a variation from the mean of a range between 8% and 26% depending upon the appliance tested. Analysis without the manufacturer's measurements has a minimum difference from the mean of 5.5%. However, it has not been possible to account for differences between the appliance tests in the manufacturers' laboratories at the start and end of the tests. The results measured before and after differed by between less than 1% and 16%. This may be due to the lack of repeatability of the appliance as the differences are more significant with one appliance. The amount of transportation and possible aging of the appliance may also have some bearing on the differences in the energy measured by the manufacturers at the start and end of the ring test, but no evidence is available.

The data illustrates that the energy consumption result is not repeatable and commentators offer two main reasons: some consider M packs (the test packages with thermocouples embedded for data logging) do not give correct temperature data and the freezer loaded with tylose (test packages – blocks of gel representing food), can show variance in the energy consumed even when loaded to exactly the same plan. These two factors are being addressed in the next issue of the IEC test standard but this may not become European law for some time and is not within the scope of this study. However, the fact that US and Australian commentators consider the European 10% tolerance too wide partly stems from their confidence in energy testing with almost empty freezers.

13.5 Variation between claimed and measured performance data

This project has examined in detail the published results from ATLETE and the results made available by Defra and the NMO. All of the ATLETE tests were undertaken in laboratories that had undergone rigorous checks before the project selected them and Intertek was used by Defra and NMO.

- The UK government, through the Defra Market Transformation Programme (MTP) has funded a programme of testing products that carry the EU energy label (2005 – 2011).
- The National Measurement Office (NMO), the UK Market Surveillance Authority for the EU energy label, has also tested a number of products.
- In 2011 the results of ATLETE, a large EC funded project that tested cold appliances, were made publicly available.

The aim of the ATLETE project was to assess the EU market for cold appliances and products were selected to be representative of both EU market leading manufacturers and smaller, more local brands. The products selected by the MTP and NMO were targeted at particular sections of the market or because there was intelligence that they might be non-compliant. The results have been analysed separately to allow comparison between the different groups.

Under the EU energy label regulations that were in force up until December 2011, a single tested sample was deemed to be compliant if the energy consumption results fell within 15% of the declared value. It should be noted that the tolerance did not appear in the EU legislation, but was described in the applicable test standard, EN 153. The results of the historic testing projects should not be assessed under the 2011 regulations because the regulations were not in force at the time of the testing projects.

Under the 2011 EU energy label and ecodesign regulations the energy consumption tolerance has been reduced to 10% for a single sample and only appears in Annex V, where the verification procedure for market surveillance is described.

From the results of both the ATLETE and UK tests it seems likely that some of the manufacturers have used some of the 15% tolerance when setting the energy label claimed value. The manufacturers may have assumed that any tests were going to give accurate results and that their production methods were able to produce consistent appliances. They have therefore declared energy consumption values that were lower than those they expected to achieve when products were tested and were confident that the results would fall within the tolerance value allowed for a single sample. It is not possible to identify within the sample particular manufacturers or models that have done this, the data indicates that there is a significant trend within this market.

13.5.1 ATLETE Data

The ATLETE project[64] selected models for testing on the basis that half of the models chosen were among 'EU top-sellers' according to the market share of the relevant manufacturers/importers. The other half of the models was selected randomly within the remaining producers active on the EU27 market, so only those with a market share lower than 0.5% or operating only nationally/regionally were targeted. So it was a semi-random selection which was not targeted at identifying models likely to fail because the aim of the project was to show how trustworthy the energy label scheme was and give a picture of the EU market.

A total of 82 models were put forward for testing. The project originally selected 80 but when additional samples of 'failed' products were supplied they were different to the original models and the new models were added to the test list. The project aimed to test one sample of each model and if it 'failed' one or more of the tests, then three further samples were tested.

It should be remember that at the time of testing and ATLETE project reporting that the measurement tolerance was 15% for the first sample.

Stage 1 testing

- Twenty five (33%) of the 74 single sample models tested in Stage 1 that produced valid results had an energy consumption that was 15% in excess or below the claimed value.
- Three models tested in Stage 1 did not produce valid kWh/year data for various reasons, (codes 23, 44 and 74)

Stage 2 testing

- Twelve of the models failing Stage 1, for whatever reason, did not have three additional samples available for Stage 2 testing of 3 samples.
- Not all models selected for Stage 2 testing failed average kWh/year within 15% of tolerance during stage 1 testing, some failed on other tests included in the ATLETE project.
- Twenty codes had three or more samples tested in Stage 2.

A total of 132 items produced valid energy test data. Two products, codes 61 and 71 were over 100% in excess of the declared value.

64 http://www.atlete.eu/

Table 25 shows the average percentage difference between declared and measured kWh/year and standard deviations for ATLETE test data. Values for the limits of a 95% confidence interval were calculated for each of the average difference values.

Table 25: Analysis of ATLETE energy consumption data

Analysis	Number of items	Average % difference	Lower boundary of 95% confidence interval	Upper boundary of 95% confidence interval	Standard Deviation	Percentage: larger or smaller than 15% difference
All tested items (Figure 42)	132	13.02	7.83	18.22	30.45	60% < 15% 40% > 15%
All without codes 61 & 71 (Figure 43)	130	10.07	7.15	12.98	16.94	61% < 15% 39% > 15%
Stage 1 only all codes	74	13.38	4.91	21.85	37.16	66% < 15% 34% > 15%
Stage 1 only without codes 61 & 71 (Figure 44)	72	8.05	4.61	11.49	14.88	68% < 15% 32% > 15%
Stage 2 only (Figure 45)	58	12.57	7.68	17.46	19.02	52% < 15% 48% > 15%

The various analyses in Table 25 can be seen in bell curves in Figure 42 to Figure 45.

In all examples the bell curve distribution graphs show that the results were likely to be in excess of the declared value. This suggests that either none of the laboratories involved could accurately measure the energy consumption or the manufacturers were using part of the tolerance when selecting the energy consumption value to declare on the energy label, and declaring a value lower than that which they expected to achieve under test conditions.

Stage 1 without codes 61 and 71 (Figure 44) has the lowest average and smallest Standard Deviation. It is most likely to reflect a true picture of the market as a whole. The two models excluded are so far from the required level as to introduce a skewing effect to any analysis. Two thirds (68%) of the market is likely to fall within plus or minus 1 Standard Deviation of the mean, so in this case that is between -7% and + 23% of the declared value.

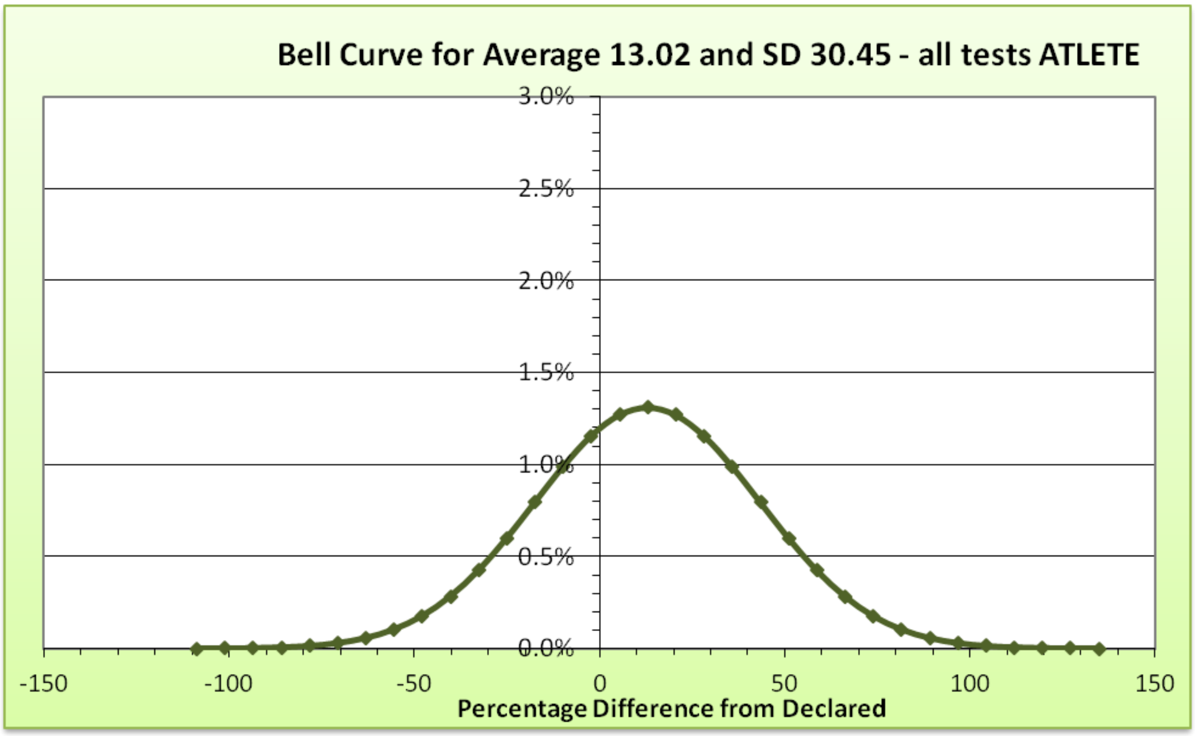


Figure 42: Energy consumption bell curve distribution for average 13.02 and SD 30.45: all 132 appliances (Source: analysis of ATLETE results)

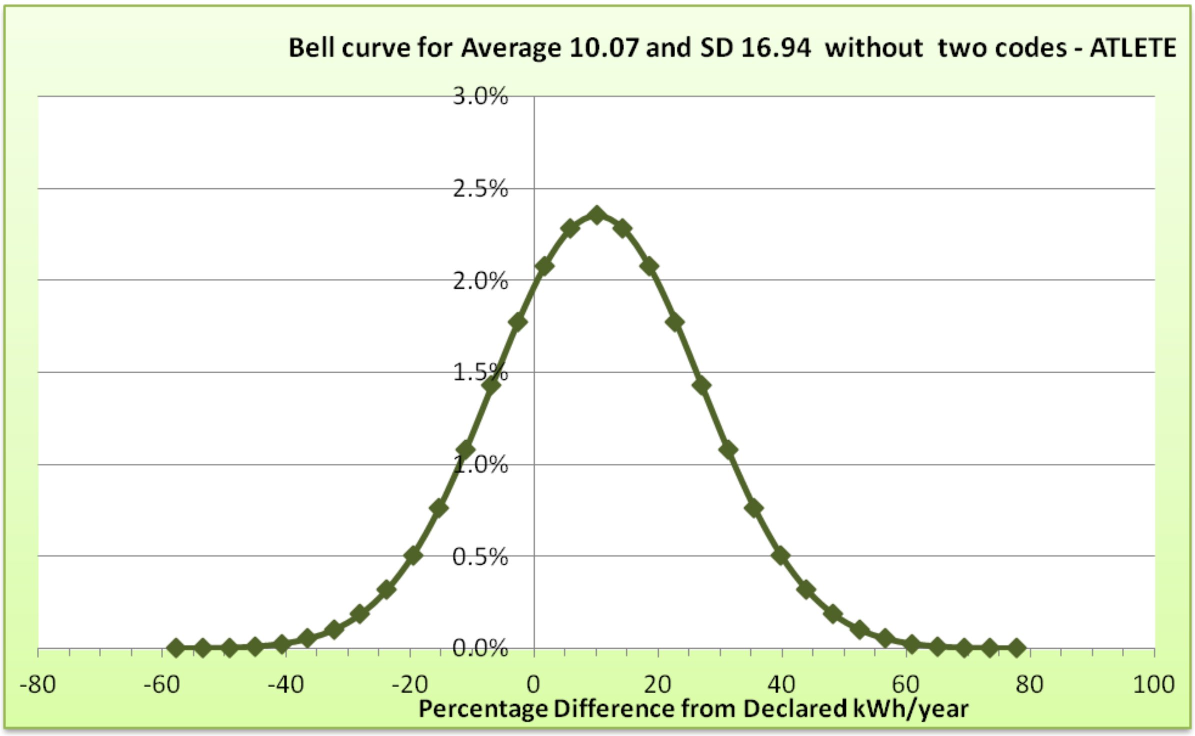


Figure 43: Energy consumption bell curve distribution for average 10.07 and SD 16.94; all appliances excluding codes 61 & 71, 130 items. (Source: analysis of ATLETE results)

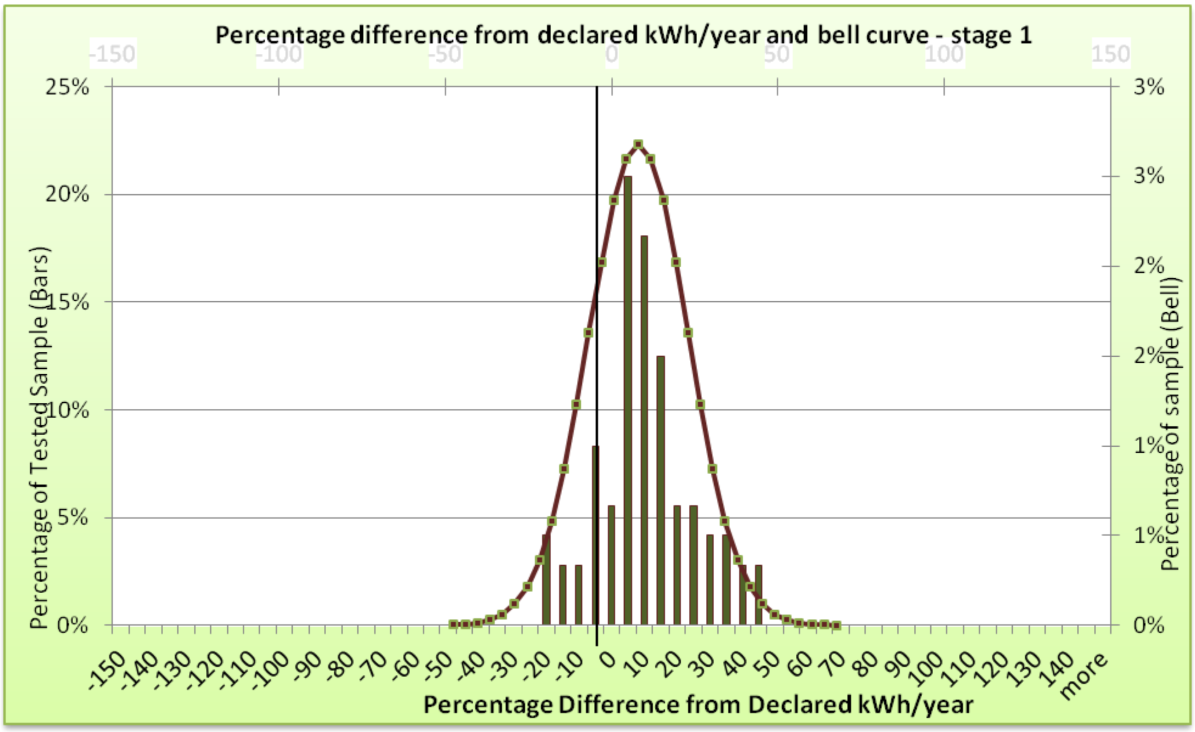


Figure 44: Distribution of percentage difference from declared kWh/year and bell curve distribution for Average 8.05 and SD 14.88: Stage 1, 72 appliances tested (excluding codes 61 & 71)

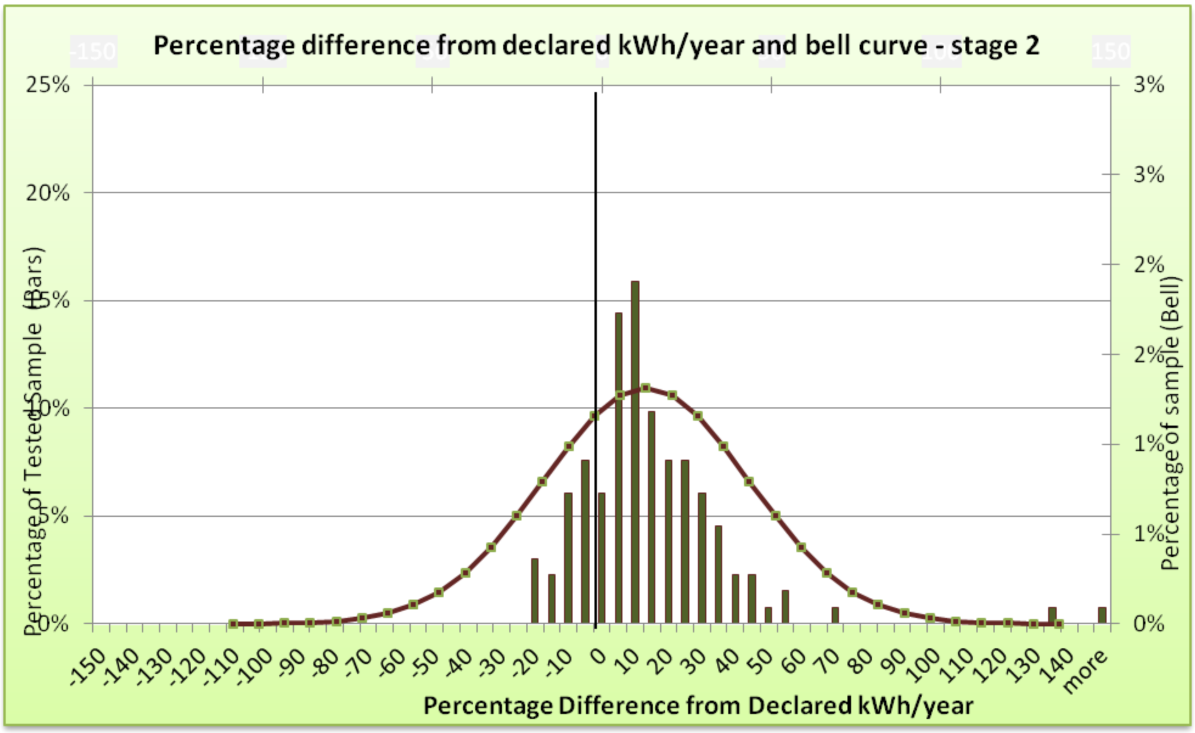


Figure 45: Distribution of percentage difference from declared kWh/year and bell curve distribution for average 12.57 and SD 19.02: Stage 2, 58 appliances tested

13.5.2 Defra MTP and NMO data

Data on percentage differences from claimed kWh/year energy consumption tests was taken from various tests carried out by Intertek for two government agencies[65].

Table 26 shows the number of models taken from each organisation. Models that did not produce a valid energy test result were not included in this analysis.

Table 26: Number of models from each organisation by year

Year	MTP	NMO	Total
2005	19		19
2006	6		6
2010		11	11
Total	25	11	36
Selection criteria	2005: A rated fridge-freezers receiving Energy Efficiency Commitment support in major retailers and some fridges and freezers that were not. 2006: selected for TSOs on the basis that they were likely to fail one or more aspects of the energy label tests.	NMO models were selected for a number of reasons, although some models were chosen because they were likely to be non-compliant on the basis of cost or other intelligence.	

Three models produced test results over 75% in excess of the claimed value and these are disregarded from further analysis. The average difference found for the remaining 32 models was 5.39% in excess of the claimed value, and the Standard Deviation was 13.08. Two thirds (68%) of the market is likely to fall within plus or minus 1 Standard Deviation of the mean, so in this case that is between -8% and + 18% of the declared value.

The bell curve for this data suggests that either the manufacturers were using part of the tolerance when selecting the energy consumption value to declare on the energy label, and declaring a value lower than that which they expected to achieve under test conditions, or there is an issue with the laboratory testing. If manufacturer were not using the tolerance then the curve of the graph should be distributed about the zero line, not around a point on the positive side. It has to be assumed that the accredited laboratories were capable of testing correctly, and that the observed distribution is as a result of actions on the part of the manufacturers to declare optimistic energy consumptions.

Figure 46 shows all data and a bell curve distribution without outliers over 75% in excess of claimed.

65 NMO 2010 Refrigerators & Freezers – Eco-design & Energy Labelling Compliance Project http://www.bis.gov.uk/assets/bispartners/nmo/docs/elf/news/news-2009/refridgerators%20and%20freezer%20report%20anonymised.pdf

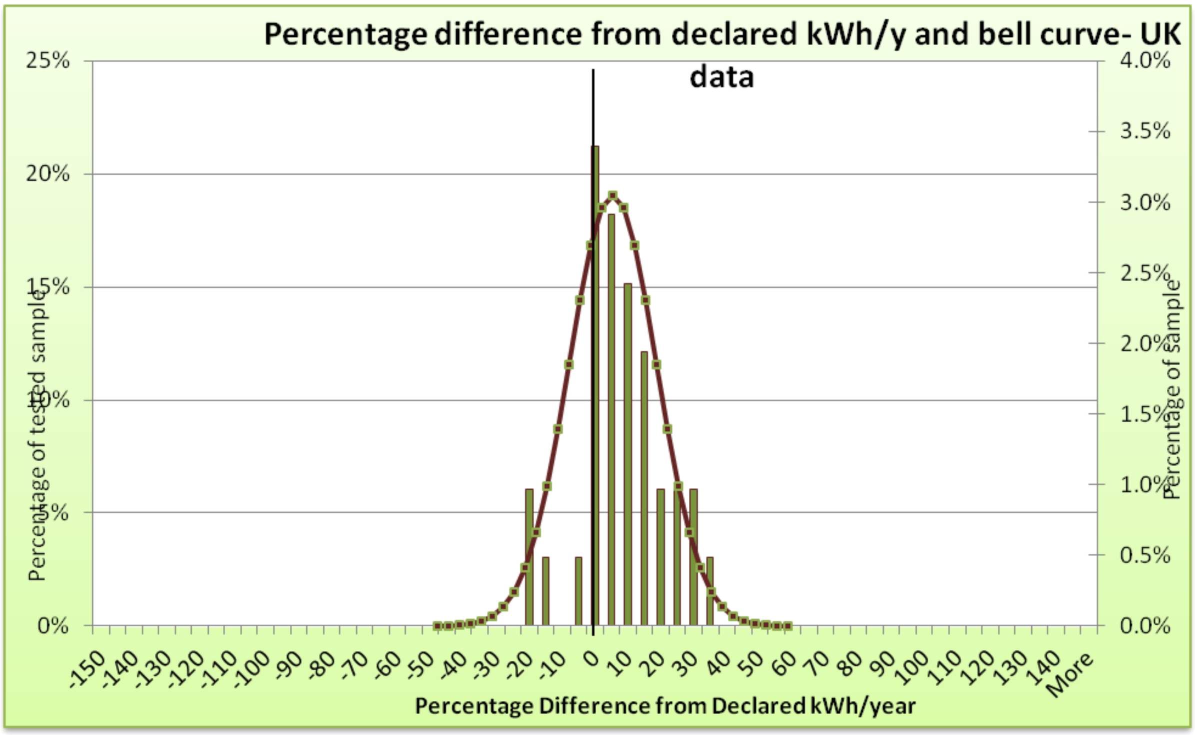


Figure 46: UK Percentage of tested samples and bell curve of distribution for average 5.39 and STDev 13.08 (Source: analysis of NMO and MTP surveillance test data)

13.6 Consultation with National Measurement Office (UK)

The National Measurement Office (NMO) carries out market surveillance in the UK. Its mission is to provide policy support to Ministers on measurement issues and a measurement infrastructure which enables innovation, promotes trade and facilitates fair competition and the protection of consumers, health and the environment. Within its remit is compliance testing for energy labeling regulations for domestic appliances.

The NMO has evidence that manufacturers use the verification tolerance to increase the value of appliance efficiency and volume declarations. This is therefore an abuse of the legislation which has verification tolerances for compliance authorities to use, not for manufacturers to take advantage of.

Following any surveillance activities, the NMO takes the approach of working with a manufacturer to determine the cause of any difference between a claimed and measured result. This may take many forms from reviewing the basis for the manufacturers claim, to reviewing its internal verification and quality systems. For this reason it is not so important what the verification tolerance is derived from; the manufacturing variability or a measurement uncertainty. The NMO does not take a simplified pass-fail approach based upon a 10% tolerance allowance. It uses the tolerances as a tool to work from, and considers how a manufacturer applies a test result and whether this is appropriate and up to date. Each case is considered on its own merit and circumstances, and the surveillance activities of the NMO aim to ensure that a claim is justifiable, consistently accurate and any measured deviation from a claim is minimised.

The NMO would like manufacturers to take greater responsibility to review and change their declarations on a regular basis. If a claim has been based on the first design and production run, then regular tests should be undertaken to check that the production line appliances still meet this value, and labels should be changed accordingly, especially if components such as compressors change over time.

The following information is extracted from an internal report produced by the NMO in 2011 to summarise the engagement the NMO has had with the marketplace and to set out problems encountered with energy label declarations related to the use of Market Surveillance Authority tolerances.

"Manufacturers of domestic appliances are deliberately declaring that their products have better energy use characteristics than can be demonstrated by independent testing or internal production control.

This misleads consumers, reduces the environmental impact of more energy efficient technology and distorts the market place to disadvantage companies making accurate statements and investing in new energy efficient technology.

The values used on labels are carefully controlled and standardised in EU legislation so that a consumer can make a fair comparison between competing products. As this information can directly influence consumer choice, the labels must be accurate in order for the consumer to receive the product that they are expecting; but also so that there is a fair level market between the different brands and manufacturers of these products."

The report recommendations included the following points:

Data based enforcement projects should be considered comparing a manufacturers test results with their declarations in order to reduce cost to taxpayer through testing programmes.

- Increased involvement of trade associations within the structure for communication with industry to try to promote a consistent approach.
- Consultation should be carried out with other EU nations on the issue of the use of tolerances to check for a general consensus in the approach that tolerances should not be used to improve the declaration for a product.
- Consider the deliberate use of tolerances when deciding upon the appropriate level of enforcement action against a company. If tolerances have been exploited more, then more robust action.
- Manufacturers to receive a clear message. “Declare on the label only those values that are supported by testing and production data”.

13.7 Summary and discussion

The latest domestic refrigeration energy label and ecodesign Directives set out a verification procedure for market surveillance purposes which states verification tolerances of 3% for volume measurements and 10% for energy consumption. The tolerance for energy consumption has been reduced from 15%, for the first sample, in previous labelling Regulations due to assumption that manufacturers are able to consider appliance variability when declaring energy consumption values. The 10% tolerance is therefore to account for any variability between testing organisations. A two stage verification process is necessary to take account of any rogue samples.

On the basis of the CECED 2009 ring test the difference in energy consumption results between laboratories is in the range of 8% to 16% compared to the mean value of the results, depending upon the appliance. However, it has not been possible to account for differences between the appliance tests in the manufacturers' laboratories at the start and end of the tests. This may be due to the lack of repeatability of the performance of the appliance samples or issues associated with the transportation of the appliances, although the differences are greater with some samples than others. The results illustrate that there is a lack of reproducibility and this could be due to deficiencies in the test method or laboratories' application of the test method.

From a review of the results from the ATLETE project and UK market surveillance tests it seems likely that some manufacturers have used some of the 15% tolerance when setting the energy label claimed value. The tests were carried out when the Regulation still stipulated 15% for the first sample. The manufacturers may have assumed that any tests were going to give accurate results and that their production methods were able to produce consistent appliances. They have therefore declared energy consumption values that were lower than those they expected to achieve when products were tested and were confident that the results would fall within the tolerance value allowed for a single sample. The range of results suggests that manufacturers are declaring a value lower than that which they expect to achieve under standard conditions. If manufacturers were not using the tolerance then the range of results would distribute more evenly around a zero point with an equal distribution curve when plotted.

The results of the ATLETE project gave an average of 10% difference between declared and measured values for all the appliances tested (excluding 2 obvious outliers), but with a standard deviation of around 17%. Nearly 40% of the samples had measured values with a difference from the claimed value of more than 15%.

UK market surveillance tests gave an average difference from the claim of 5.4%, but some of the samples tested were selected on the basis that they might fail. The NMO has reported that manufacturers are deliberately declaring that their products have better energy use characteristics than can be demonstrated by independent testing or internal production control.

13.8 Conclusion

Analysis from a laboratory ring test results suggest that there is still a notable difference in measurements due to laboratory variability and possible sample repeatability. It is understand from opinions of those contributing to this research, that manufacturers are now going to more closely take account of their appliance production line and repeatability, in which case the 10% tolerance level would appear to be appropriate. It is assumed that the data from the 2009 CECED ring test contributed to this current level. It is also felt that the 2 stage verification procedure is appropriate.

There are examples of tighter tolerances such as those used in Australia. However, Australia's requirements for energy labelling are different to those in Europe, requiring appliances to be registered and the submission of technical documents to the authorities prior to an appliance being placed on the market. The test methods for energy consumption are also slightly different.

There would appear to be a need for further scrutiny as to the reproducibility of the current test method as this may have a bearing on the variability between laboratory testing. Until this issue is address there is little justification for tightening the tolerances.

Additionally, market surveillance activities have identified practices that undermine the purpose of the verification tolerances. Continued policing of the Regulation is essential to eliminate abuse of the tolerances.

14 Task 8: Volume measurements

14.1 Introduction

The test standard for cold appliances states that appliances should be "set up as in service and in accordance with the manufacturer's instructions" "all internal fittings supplied shall be in position" and "a compartment shall be tested in the condition as delivered". Generally it would be expected that appliances are provided with all drawers and shelves in place, in particular for frozen food compartments. However, experience of testing establishments and consultations for market surveillance exercises has shown that manufacturers do not always test energy consumption or measure volume with all freezer compartment drawers in place. Many appliances are provided with freezer shelves to give an apparent consumer option to use without drawers, although no clear evidence has been found in instruction books regarding recommended drawers or shelf arrangements. For testing purposes, laboratories are presented with loading plans with and without drawers from different manufacturers. This presents a lack of consistency in testing, gives the appliance a larger volume measurement and a consequential improved energy index if the drawers are removed.

The current generic ecodesign requirements which came into force in July 2010 states that *"information shall be provided in the instruction booklet provided by the manufacturers concerning - the combination of drawers, baskets and shelves that result in the most efficient use of energy for the appliance".*

This may help to formalise the drawer arrangements that manufacturers recommend and use for their own energy declarations, but may present an appliance in a format that is not appropriate for storage of real food in the consumer's home. If the intention is that the energy usage declared on the energy label is meant to represent typical use then using alternative arrangements does not necessarily do this, and, if different manufacturers are adopting different practices, appliances are not necessarily comparative in the retail environment.

By removing the drawers and/or shelves the volume measurement is larger and thus the energy efficiency, calculated from a relationship of energy consumption and volume, will be better than if a smaller volume is used from a measurement with drawers in place. Additionally, the removal of drawers may affect the energy performance of an appliance compared with drawers, due to the effect on cold air circulation within the compartment.

14.2 Typical drawer and shelf formats

The issue of volumes and the arrangement of drawers and shelves predominantly affect freezer compartments, because these compartments are normally supplied with pull-out drawers or a combination of drawers and shelves with pull down fronts. Fridges generally have mostly open shelves for the majority of the storage space. Frost-free appliances may have just drawers or sometimes drawers and shelves and the cooling effect is provided by fans circulating the cold air around the compartment. These arrangements facilitate the removal of drawers and/or shelves. For static appliances the cooling is often provided by evaporators incorporated into the shelves between drawers. Although drawers may be removed shelves are an integral part of the appliance as they form part of the cooling circuit.

Anecdotal evidence suggests that the practise of removing drawers in load plans is relatively recent and one expert opinion is that this allows manufacturers to obtain an improved energy efficiency rating without having to use other means such as adding the verification tolerance to an energy measurement. As an independent test laboratory, Intertek has had several examples of manufacturer obtaining an energy result and then suggesting that they can declare this value minus the verification tolerance (e.g. 10%) to get a better efficiency rating. Increasing the volume is an alternative (or additional) way of improving the declared efficiency.

14.3 Removal of drawers during standard testing

14.3.1 Test standard

Under general test conditions, ISO 15502 Clause 8.6.4 (operating requirements for refrigerating appliances – general conditions for the use of baskets, containers, shelves and trays) states: *“All shelves, but only those baskets, containers and trays which have been considered in place when determining the storage volume shall be in position”.* Clause 7 (determination of linear dimensions, volumes and areas) refers to the measurement of shelf area and volume; it is not specific about the issue of drawers in or out, but does describe areas that are excluded from the measurements. Under the list of volumes that should be deducted from the gross volume is (point f) *“the volume of rendered unusable by the use of removable parts (e.g. baskets, shelves) necessary for obtaining satisfactory thermal and mechanical characteristic”*. This point does suggest also referring the Clause 8.6.4 (mentioned above).

Two other parts of the standard also consider the set up of the appliance:

ISO 15502 Clause 13.3 covers the storage plans used for storage temperatures tests. It states *“The refrigerating appliance shall be set up as in service in accordance with the manufacturer’s instructions. All internal fittings supplied with the refrigerating appliance, including ice-trays, shall be put in position, except that the ice trays shall be removed in the case of a food freezer compartment or cabinet, or frozen food storage compartment or cabinet, having no specific compartment to accommodate such trays.”*

ISO 15502 Table 5 states *“A compartment shall be tested in the condition as delivered”.* It may be debatable what is meant by “condition” but the inference is to test the sample as it arrives. It is hoped that it unlikely that manufacturers would sell an appliance without shelves and/or drawers.

As Clause 8 is the General Test Conditions these are taken to be the dominant requirements.

The definitions and measurements of different volumes have been extensively debated by standards making organisations over the years. The net volume used for the energy efficiency calculation attempts to represent a real use volume as opposed to the gross volume which is the overall cabinet 'cooled volume'. However, the difficulty still appears to be in the interpretation of 'real use'. The IEC is currently attempting to develop a global test standard and is moving towards a simpler volume definition which is closer to the gross volume (a total cooled volume). This method is also closer to the measurement method already used by some countries outside the EU. This may have the disadvantage that the volume provided may not be representative of how a consumer uses the storage volume, but aims to provide a consistent approach that will allow benchmarking between appliances.

14.3.2 Effect on measurements - with and without drawers

On the basis that the measurements should be undertaken in the configuration in which the appliance is sold for use, in the majority of cases it is expected that this will be with the drawers in place since the test standard states “all internal fittings supplied including ice trays shall be put in position”.
Although the standard may appear to be clear in the test set up requirements, evidence from test laboratories suggests that there is a need for a more clearly defined configuration, ideally one that reflects how consumers use the appliances.

Manufacturers’ load plans quite often have all except the lowest drawer removed. It is assumed that this is to facilitate a larger volume claim and to protect test packages from heat ingressing from the compressor near the bottom of the freezer cabinet. This illustrates the duplicity of their position. If there is a need for a clearer statement in the test standard, it should state “Appliance to be tested as supplied (to the consumer)”. If a manufacturer wishes a particular model to be tested without drawers, then the model would be expected to be sold without drawers.

There is anecdotal evidence that keeping drawers in place allows for better cold air circulation and better efficiency because channels for air flow back to front are ensured. A consumer loading freezer shelves (ie. no drawers) could easily block the flow of cold air essential for correct functioning of the appliance. Generally appliances should be tested in a way that is representative of consumer use, and such that the testing is standardised. Laboratory experts feel that the interpretation of the standard by some manufacturers creates an inconsistent approach with some drawers in, some drawers out, and undermines the principle of having a standard providing one methodology for all to use. Although there are other elements of the test standard that do not follow the principle of testing as in use, such as the unloaded fridge, they do not include removing strategic parts of the appliance.

To illustrate anomalies in test practice a review of a set of 11 A+ appliances tested by Intertek in May 2011 has been undertaken. Load plans from 4 appliances set up the appliances for testing with all the freezer drawers removed, 2 were frost-free and 2 were static appliances. Five appliances had loading plans with the freezer drawers removed except the bottom most one, also a combination of frost-free and static appliances. Two appliances had a testing arrangement with all the freezer drawers left in; a frost-free and a static appliance.

It is assumed that the volumes claimed by the manufacturers are with the configurations given for the loading plans used when testing for energy consumption. The volumes were measured by the laboratory in a format that it is assumed consumers will adopt, with the drawers in place. In the 9 examples where all or some of the drawers were removed the re-measured volumes were smaller, as expected, by anything between 2% and 16% for 8 of the samples. For one appliance the measured volume was 45% less because of discrepancies in the claimed measurement. Details of the measurement differences can be seen in Table 27.

Table 27: Examples of differences between freezer volumes measured with and without drawers (Source: Intertek test data)

Code	Manufacturers loading plan configuration	Claimed freezer volume	Measured freezer volume (drawers in)	% difference measured and claimed volume
G1	All drawers out	106*	58	45%
J1	All drawers out	180	176	2%
K1	All drawers out	188	169	10%
P1	All drawers out	70	65	7%
A1	Lowest drawer left in	85	76	11%
F1	Lowest drawer left in	175	162	7%
M1	Lowest drawer left in	179	173	3%
N1	Lowest drawer left in	82	69	16%
S1	Lowest drawer left in	193	184	5%

*Top tray is less than 52mm high and should not be included in storage volume. The manufacturer has included this.

The storage volume is a critical component in the calculation of the energy efficiency index. A claimed larger measured volume gives a larger equivalent volume which gives a smaller EEI. All the appliances evaluated had EEI less than 42, achieving an A+ rating (under the previous Regulation) using the claimed volumes measured without drawers in place. When the volumes measured with drawers in place were used for the efficiency rating, 7 of the 9 appliances had EEI greater than 42 so would have been class A (under the previous Regulation).

Removing the drawers also has an effect on the energy consumption. This theoretically could increase or decrease the consumption. Of the 9 appliances reviewed that had some deviation from having all the drawers in place, 5 had all the drawers removed except the bottom most one. The reason for this is assumed to be that this lower drawer is next to the compressor housing and shield the load from any heat ingress from the compressor.

An example of the effect on energy consumption of removing the drawers is illustrated by limited unpublished research work undertaken by Intertek testing an under counter upright freezer (gross volume 120 litres) and a tall upright freezer (gross volume 251 litres) with and without drawers. The interpolated energy consumption increased by 9.6% and 16.9% respectively for the two freezers.

14.4 Analysis of instruction books

In order to consider the advice given to consumers regarding the use of freezer drawers and shelves an analysis of the GfK market data was used to identify appliances introduced after July 2010. This is the date that the generic ecodesign requirements came into force requiring manufacturers to provide information about the use of drawers and shelves to achieve the most efficient use of energy. Between July 2010 and December 2011 20,456 fridge-freezers were sold in Great Britain. Of these only 9.5% of the sales were from 8 branded models. Only instruction books for half of these models were found accessible and evaluated. Only one appliance mentions the installation of the freezer drawers and this does not appear to be in relation to efficient operation but to do with general setting up of the appliance, although even this message appears to have been lost in translation: *"Install removed all shelves and compartments during transport in the correct positions".*

Further anecdotal research was carried out in early 2012 reviewing the instruction books of freezers and fridge-freezers available in John Lewis. Of the 13 fridge-freezers and 5 under counter freezers checked only two appliances mentioned the removal of drawers and shelves in order to fit large joints of meat or poultry into the freezer. One appliance stated that the bottom drawer must stay in place. Conversely, one under counter freezer stated that *"food should be stored in the baskets"*.

In none of the instructions was information given regarding the arrangement of shelves or drawers to achieve efficient use of energy. Some instructions give energy saving information, but this is more in relation to such things as allowing adequate ventilation and not opening the door too much.

14.5 Information from ATLETE

The evaluation work package provides detailed reasons for failure following correspondence with the appliance manufacturer. The report also considers clarification in test methods or data used for declarations.

In the case of a fridge-freezer failing the energy consumption test it was discovered that any slight deviation in the positioning of the test packages has a big effect on the inner air circulation. The test laboratory was using the factory's loading plan. The outcome was to implement a more stringent loading plan by keeping the bottom freezer basket in place during testing which results in lower energy consumption. This measure also affects the claimed capacity of the freezer which would be reduced. This case illustrates a situation where the load plan provided by the supplier presumably specified the removal of the drawers and the consequence of this was a larger volume measurement and also a different energy consumption than if operated with drawers in place.

There is another example that highlights the necessity for clarification on how the appliances are tested regarding freezer arrangements. A failed appliance was retested with a new load plan provided by the manufacturer that included eutectic (cold plates). In the ATLETE report recommendation for improving the harmonised standard, specific mention is made of eutectic accumulators:

- The use of "cold plates" (eutectic accumulators) should be ruled and the impact on the load plan and the appliance volume measurement described. The use of eutectic plates can be acceptable but only in accordance with the already established conditions for the volume measurement:
    - The appliance storage volume should exclude the space needed for the plates
    - The load plan should show the positions of the plates that cannot be placed directly over the stacks [of test packages].

However, it should be noted that the recommendation given in the second bullet above is not appropriate as the this is not permitted by the test standard as it contradicts Clause 13.3.2.8 which states compartments shall be loaded with as many test packages as possible and it contradicts the first bullet point to an extent. Fully loading with packs within the standard rules is an over-riding principle of freezer testing. Intertek expert opinion is that that cold plates should only be placed where there are dedicated places for them where test packs cannot be placed, although this is not stated in the standard.

The recommendations also suggested that
- storage volume measurement is critical, at least for some manufacturers and product configurations. The need for further clarification should be evaluated by the standardization experts.

There were also issues relating to the claimed and measured volume measurement during the ATLETE project. The following illustrates the conflicts that can arise between laboratories and manufacturers[66]:

"It can be assumed that for the 12 models having failed the volume measurement there is little scope to re-measure the same volume for 3 additional units in Step 2, therefore 11 out of these 12 models fail the verification. For the 12th model (EC8) the outcome of the volume measurement is apparently controversial, since the laboratory and the supplier have a different opinion about the use of the drawers in the volume measurement."

14.6 Summary and discussion

- Analysis of test data to consider impact of removing drawers on the volume during product testing.

Removal of the drawers from a freezer compartment during testing will allow for a larger volume measurement and also possibly affect the energy consumption during standard tests. The difference in the volume measurement compared to the value measured with the drawers in place will have a significant effect on the energy efficiency index calculation, ultimately giving a better EEI than if the drawers are left in. In a sample of appliances evaluated the difference in volume measurement between an appliance with the drawers in place and with all or all but the bottom drawer removed (a configuration often adopted by manufacturers) was between 2% and 15% depending upon the appliance. In 7 out of 9 cases the energy efficiency index calculated with the drawers in place resulted in the appliance being categorised in a letter class lower than that claimed according to the manufacturers preferred configuration during testing.

- Analysis of typical instructions supplied by manufacturers and evaluation of the share of products where drawer removal is prescribed and evaluation for the reason.

Limited research in the UK suggests that the user instructions provided with refrigerating appliances rarely suggest the removal of freezer drawers or shelves. Where a suggestion is made this is interpreted as being for exceptional use when large items such as a large joint of meat needs to be accommodated.

Conversely, when manufacturers provide instructions for standard testing of an appliance a loading plan may frequently be provided showing drawers removed. The ATLETE project illustrated the inconsistency that occurs whereby some manufacturers provide load plans or instructions with some or all drawers removed, with others providing load plans that retained the drawers.

Adding to the variability of the interpretation of the standard is the fact that it is not a case of all the drawers in or all of them out, quite often the instruction is to remove all but the bottom drawer. It is difficult to understand how manufacturers can claim that this practice follows the requirements of the standard. The reason for this is assumed to be that the lower drawer is next to the compressor housing and will shield the load from any heat transferred from the compressor. This has nothing to do with whether the lower drawer is recognised any more as a fitting compared to the other drawers.

[66] ATLETE Project Work Package 6, page 59.

- Assessment of the likely impact of removing drawers on the volume measurement and energy consumption.

A larger volume recorded when an appliance is measured without drawers will result in a larger equivalent volume. This larger equivalent volume results in a larger standard consumption (SC). As the energy efficiency index is the actual energy consumption divided by the SC the result is a better (lower) energy efficiency rating.

There is no significant set of test results that compares the energy consumption used by appliances with and without the drawers. Depending upon the configuration of the drawers; all or just some of the drawers removed can result in an increase or decrease in the energy consumption. An increase may be due to the easier ingress of heat to the test load, and a decrease may be due to more effective air flow, but either way it is likely to depend upon the appliance design. A test of two freezers, with all the drawers removed, resulted in an increased energy consumption of around 10% and 17%.

14.7 Conclusion

Appliances should be set up for testing 'as delivered', with all internal fitting provided in position according to manufacturer's instructions. Manufacturers are using their own interpretations to take advantage of measuring the volume of an appliance and carrying out the energy test with all or some of the drawers removed. Not only does this undermine the principle of an industry test standard to ensure consistent methodologies used by all, but also leads to an inconsistency in the way that the appliances are measured and the resultant calculation of an appliance’s energy efficiency index. Consumers are being misled as to the useable volume of an appliance and also the energy use and EEI when considering appliances when tested without drawers. The different approaches also mean that the information on all appliances is not necessarily comparative if different volume measurements and appliance set ups are used.

There needs to be a clear description of the configuration of drawers and shelves in freezer compartments that is the same for energy consumption and volume measurements. The proposed new IEC standard may be one way forward.

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Annex A: Energy Efficiency Index calculations

Section A Energy Labelling Requirements

Section A1 Commission Directive 94/2/EC 21st January 1994 (A to G)

Came into force: 1995 Entry into force 20 days after publication. Provisions applicable by 1 January 1995.

The energy efficiency class of an appliance is determined in accordance with Table 1 where:
Energy efficiency index = annual energy consumption / standard annual energy consumption (expressed as a percentage)

Standard annual energy consumption = M x adjusted net volume + N
(expressed in kWh/year)

Adjusted net volume = net volume of fresh food compartment + Ω x net volume of frozen food compartment (expressed in litres)

Table 1

Energy efficiency index I	Energy efficiency class
I < 55	A
55 ≤ I < 75	B
75 ≤ I < 90	C
90 ≤ I < 100	D
100 ≤ I < 110	E
110 ≤ I < 125	F
125 ≤ I	G

Table 2

Category of appliance	Ω	M	N
1. Larder fridge	-	0.233	245
2. Refrigerator/chiller	0.75 (1)	0.233	245
3. Refrigerator no star	1.25	0.233	245
4. Refrigerator *	1.55	0.643	191
5. Refrigerator **	1.85	0.450	245
6. Refrigerator ***	2.15	0.657	235
7. Fridge/freezer *(***)	(3)	0.777	303
8. Upright freezer	2.15 (2)	0.472	286
9. Chest freezer	2.15 (2)	0.446	181
10. Multi-door or other appliances	(3)	(4)	(4)

Notes to Table 2
(1) For refrigerator/chiller the adjusted volume = net volume of fresh food compartment + Ω x net volume of chiller (10°C) compartment (expressed in litres)
(NB although written as 'chiller' in the Directive this compartment is not a chiller as now defined ie. compartment with temperatures between -2 and +3 °C)

(2) For "no frost" appliances the index is increased by a provisional factor of 1.2, giving a value of 2.58. (This allows for the possible bias of the measurement method, which does not allow for the lack of ice build-up in "no frost" appliances. In practice, ice build-up will somewhat increase the consumption of "conventional" appliances)

(3) Adjusted net volume (AV) shall be calculated by the formula:

$$AV = \sum \frac{(25 - T_c)}{20} \times V_c \times F_c$$

all compartments

where T_c is design temperature (in °C) of each compartment, V_c is the net volume (in litres) of each compartment

and F_c is a factor which equals 1.2 for " no frost" compartments and 1 for other compartments

(4) For these appliances the values of M and N shall be determined by the temperature and star rating of the compartment with the lowest temperature, in accordance with Table 3:

Table 3

Temperature of coldest compartment	Equivalent category	M	N
> - 6°C	1 Larder fridge; 2 no-star refrigerator; 3 refrigerator/chiller	0.233	245
≤ - 6°C*	4 Refrigerator(*)	0.643	191
≤ - 12°C**	5 Refrigerator (**)	0.450	245
≤ - 18°C***	6 Refrigerator (***)	0.657	235
≤ - 18°C*(***) with freezing capacity	7 Fridge/freezer *(***)	0.777	303

Section A2 Commission Directive 2003/66/EC 3rd July 2003 (A+/A++)

Came into force: 1st July 2004 Entry into force 20 days after publication. Provisions applicable by 1 July 2004.

An appliance shall be classified as A+ or A++ where the energy efficiency index alpha (I_α) is within the ranges specified in Tale 1.

Table 1

Energy efficiency index α (I_α)	Energy efficiency class
30 < I_α	A++
42 > I_α ≥ 30	A+
I_α ≥ 42	A to G (see above)

The energy efficiency index alpha shall be calculated using the formula:

$$I_\alpha = \frac{AC}{SC_\alpha} \times 100$$

where
AC means the annual energy consumption of the appliance
SC_α means the standard energy consumption α of the appliance

SC_α is calculated as:

$$M_{\alpha} X \sum_{Compartments} \left(Vc \times \frac{(25-Tc)}{20} \times FF \times CC \times BI \right) + N_{\alpha} + CH$$

where Vc means the net volume (in litres) of the compartment;
Tc is the design temperature (in °C) of the compartment;
the values of M_{α} and N_{α} are given in Table 2; and
the values of FF, CC, BI and CH are given in Table 3.

Table 2

Type of appliance	Temperature of coldest compartment	M_{α}	N_{α}
1. Larder fridge	> - 6°C	0.233	245
2. Refrigerator/chiller	> - 6°C	0.233	245
3. Refrigerator no star	> - 6°C	0.233	245
4. Refrigerator *	≤ - 6°C*	0.643	191
5. Refrigerator **	≤ - 12°C**	0.450	245
6. Refrigerator ***	≤ - 18°C***/*(***)	0.777	303
7. Fridge/freezer *(***)	≤ - 18°C***/*(***)	0.777	303
8. Upright freezer	≤ - 18°C*(***)	0.539	315
9. Chest freezer	≤ - 18°C*(***)	0.472	286
10. Multi-door or other appliances		(1)	(1)

(1) For these appliances, the temperature and star rating of the compartment with the lowest temperature will determine the valued of M and N. Appliances with -18°C *(***) compartments shall be considered as fridge freezers *(***).

Table 3

Correction factor	Value	Conditions
FF (frost-free)	1.2	For " frost free" (ventilated) frozen food compartments
	1	Otherwise
CC (climate class)	1.2	For " tropical" appliances
	1.1	For "subtropical" appliances
	1	Otherwise
BI (built-in)	1.2	For built-in appliances [1] of under 58cm in width
	1	Otherwise
CH (chill compartment)	50kWh/y	For appliances with a chill compartment of at least 15 litres
	0	Otherwise

[1] An appliance is "built-in" only if it is designed exclusively for installation within a kitchen cavity with a need of furniture finishing, and tested as such.

If an appliance is not A+ or A++, it shall be classified in accordance with the calculations given in Part 2 of the directive, which repeats section A1 above (Commission directive 94/2/EC)

Section A3 Commission Directive 2010/30/EU 19 May 2010 (supplemented by Commission Delegated Regulation No. 1060/2010 28 September 2010) **(A to A+++)**

Applies from : 30th November 2011

The Energy Efficiency Index (EEI) is calculated and rounded to the first decimal place.

EEI = Annual energy consumption (AE_c) / Standard annual energy consumption (SAE_c) x 100

The annual energy consumption is calculated in kWh/year and rounded to two decimal places

$AE_c = E_{24h} \times 365$

where E_{24h} is the energy consumption of the household refrigerating appliance in kWh/24h and rounded to three decimal places

The standard annual energy consumption is calculated in kWh/year and rounded to two decimal places

$SAE_c = V_{eq} \times M + N + CH$

where V_{eq} is the equivalent volume of the appliance
CH is equal to 50kWh/year for household refrigerating appliances with a chill compartment with a storage volume of at least 15 litres.
The M and N values are given below;

Category	M	N
1 (refrigerator)	0.233	245
2 (refrigerator-cellar, cellar and wine storage)	0.233	245
3 (refrigerator-chiller and refrigerator no star)	0.233	245
4 (refrigerator 1 star)	0.643	191
5 (refrigerator 2 star)	0.450	245
6 (refrigerator 3 star)	0.777	303
7 (fridge-freezer 4 star)	0.777	303
8 (upright freezer)	0.539	315
9 (chest freezer)	0.472	286
10 (multi-door or other)	(*)	(*)

(*) for category 10 appliances (multi-use and other refrigeration appliances) the M and N values depend on the temperatures and star rating of the compartment with the lowest storage temperature capable of being set by the end-user and maintained continuously according to the manufacturer's instructions. When only an 'other compartment' is present the M and N values for category 1 are used. Appliances with three-star compartments or food-freezer compartments are considered to be refrigerator-freezers.

Calculation of the Equivalent Volume (V_{eq})

$$Veq = \left[\sum_{c=1}^{c=n} Vc \times \frac{(25 - Tc)}{20} \times FFc\right] \times CC \times BI$$

where;
n is the number of compartments
V_c is the storage volume of the compartment(s)

T_c is the nominal temperature of the compartment(s)
(25- Tc) / 20 is the thermodynamic factor (see table below)
$FF_{c,}$ CC and BI are volume correction factors (see below)

The thermodynamic correction factor is the temperature difference between the nominal temperature of a compartment T_c and the ambient temperature under standard test conditions at +25°C, expressed as a ratio of the same difference for a fresh-food compartment at +5°C.

Thermodynamic factors for refrigeration appliance compartments

Compartment	Nominal temperature	$(25-T_c)/20$
Other compartment	Design temperature	$(25-T_c)/20$
Cellar compartment/Wine storage compartment	+12°C	0.65
Fresh-food storage compartment	+5°C	1.00
Chill compartment	0°C	1.25
Ice-making compartment and 0-star compartment	0°C	1.25
One-star compartment	- 6°C	1.55
Two-star compartment	- 12°C	1.85
Three-star compartment	- 18°C	2.15
Food freezer compartment (four-star compartment)	- 18°C	2.15

Notes:
(i) for multi-use compartments, the thermodynamic factor is determined by the nominal temperature of the coldest compartment type capable of being set by the end-user and maintained continuously according to the manufacturer's instructions;
(ii) for any two-star section (within a freezer) the thermodynamic factor is determined as T_c = -12°C
(iii) for other compartments the thermodynamic factor is determined by the coldest design temperature capable of being set by the end-user and maintained continuously according to the manufacturer's instructions.

Value of correction factors

Correction factor	Value	Conditions
FF (frost-free)	1.2	For " frost free" (ventilated) frozen food compartments
	1	Otherwise
CC (climate class)	1.2	For " tropical" appliances
	1.1	For "subtropical" appliances
	1	Otherwise
BI (built-in)	1.2	For built-in appliances under 58cm in width
	1	Otherwise
	0	Otherwise

Notes;
(i) FF is the volume correction factor for frost-free compartments;
(ii) CC is the volume correction factor for a given climate class. If a refrigerating appliance is classified in more than one climate class, the climate class with the highest correction factor is used for the calculation of the equivalent volume;
(iii) BI is the volume correction factor for built-in appliances.
Energy Efficiency Classes

From 20th December 2011 until 30th June 2014

Energy efficiency index	Energy efficiency class
EEI < 22	A+++
22 ≤ EEI < 33	A++
33 ≤ EEI < 44	A+
44 ≤ EEI < 55	A
55 ≤ EEI < 75	B
75 ≤ EEI < 95	C
95 ≤ EEI <110	D
110 ≤ EEI < 125	E
125 ≤ EEI < 150	F
EEI ≥ 150	G

(B and worse eliminated by MEPS in 2010 see section B)

From 1st July 2014

Energy efficiency index	Energy efficiency class
EEI < 22	A+++
22 ≤ EEI < 33	A++
33 ≤ EEI < **42**	A+
42 ≤ EEI < 55	A
55 ≤ EEI < 75	B
75 ≤ EEI < 95	C
95 ≤ EEI <110	D
110 ≤ EEI < 125	E
125 ≤ EEI < 150	F
EEI ≥ 150	G

(A and worse eliminated by MEPS in 2014 see section B)

Section B Ecodesign (minimum energy performance) Requirements

Section B1 Commission Directive 96/57/EC

Came into force: 3 September 1996 Entry into force 20 days after publication, Provisions applied from 3 September 1999.

Method for calculating the maximum allowable electricity consumption of an appliance: Because appliances contain different compartments maintained at different temperatures (which will significantly influence electricity consumption), the maximum allowable electricity consumption is defined in practice as a function of the adjusted volume, which is the weighed sum of the volumes of the different compartments.

Adjusted volume:
$V_{adj} = \sum V_c \times W_c \times F_c \times C_c$

Where Wc = $(25 - T_c)/20$

where T_c is the design temperature of each compartment (in °C);
where V_c is the net volume of a given type of compartments in the appliance and F_c is a factor which equals 1.2 for no-frost compartments and 1 for other compartments;
Cc = 1 for refrigeration appliances belonging to the normal (N) and subnormal (SN) climate class;
Cc = Xc for refrigeration appliances belonging to the sub-tropical (ST) climate class;

Cc = Yc for refrigeration appliance belonging to the tropical (T) climate class

Table of weighting co-efficients Xc and Yc

	Xc	Yc
Cellar compartment	1.25	1.35
Fresh food compartment	1.20	1.30
0°C compartment	1.15	1.25
1-star (*) compartment	1.12	1.20
2-star (**) compartment	1.08	1.15
3 (***) and 4 (****) star compartments	1.05	1.10

Both the adjusted volume and net volume are expressed in litres.

Type of appliance	Emax (kWh/24hr)
1. Larder fridge	(0.207 x Vadj + 218)/365
2. Refrigerator/chiller	(0.207 x Vadj + 218)/365
3. Refrigerator no star	(0.207 x Vadj + 218)/365
4. Refrigerator *	(0.557 x Vadj + 166)/365
5. Refrigerator **	(0.402 x Vadj + 219)/365
6. Refrigerator ***	(0.573 x Vadj + 206)/365
7. Fridge/freezer *(***)	(0.697 x Vadj + 272)/365
8. Upright freezer	(0.434 x Vadj + 262)/365
9. Chest freezer	(0.480 x Vadj + 195)/365

For refrigerators/freezers with more than two doors, or other appliances not covered above, the maximum allowable energy consumption (Emax) shall be determined by the temperature and the star rating of the compartment with the lowest temperature:

Temperature of coldest compartment	category	Emax (kWh/24hours)
> - 6°C	1 / 2 / 3	(0.207 x Vadj + 218)/365
≤ - 6°C*	4	(0.557 x Vadj + 166)/365
≤ - 12°C**	5	(0.402 x Vadj + 219)/365
≤ - 18°C***	6	(0.573 x Vadj + 206)/365
≤ - 18°C*(***)	7	(0.697 x Vadj + 272)/365

Section B2 Commission Directive 2005/32/EC ecodesign requirements as implemented by Commission Regulation EC 643/2009

The ecodesign requirements for compression-type appliances specify minimum efficiency performance limits defined using the Energy Efficiency Index.

Application date	Energy Efficiency Index (EEI)
1 July 2010	EEI < 55
1 July 2012	EEI < 44
1 July 2014	EEI < 42

The Energy Efficiency Index is calculated in the same way as given in Section A3 above, using the same M and N values and correction factors.

Annex B: Key sources of information

ATLETE

www.atlete.eu

The purpose of the ATLETE Project is to increase European-wide implementation and control of energy labelling and eco-design implementing measures for appliances. The developed methodology, once validated, will be applicable with very minor adaptations for any Energy-using Products (EuP). It carried out a programme of testing which was completed in Spring 2011. The objective of the project was to demonstrate that market surveillance testing is possible and cost-effective. The test results have been published by the ATLETE Project with test results for the 80 appliances tested from 40 manufacturers. The results allow an indicative review of such surveillance activities.
The test programme included storage volume, energy consumption, storage temperatures, freezing capacity and temperature rise parameters. Some of these have not traditionally been checked when energy label market surveillance was undertaken, although it was required for the technical fiche, i.e. the information sheet.

For the purpose of this correction factor research, the results provide an indication of the performance of a cross section of appliances from across Europe.

EuP Preparatory study

www.ecocold-domestic.org

Lot 13 of the Preparatory Studies for Eco-design Requirements of EuPs considered domestic refrigerators and freezers. The project was managed by the main contractor ISIS. The study was divided in two working phases or study Parts and seven Tasks or Chapters:

Part I: Present Situation that envisages the following five Tasks:
Task 1 General Situation
Task 2 Economic and Market Analysis
Task 3 Consumer Behaviour
Task 4 Product System Analysis
Task 5 Definition of base case

Part II : Improvement Potential, with the following two Tasks:
Task 6 Technical Analysis
Task 7 Scenario, Policy, Impact and Sensitivity analysis.

The final project reports were published in 2009. They provide a European perspective on some of the issues raised in the correction factors research, including market information and trends, consumer behaviour and also evidence used in the stock/sales modelling using for the impact assessments in this project.

Annex C: Fridge-freezer climate class storage temperature testing - Test report

REPORT

Client: Louise Evans
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DATE: February 2012

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A66770 Issue 1

Test Sample for Correction Factors Project Code CF1

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APPENDIX I	Copy of Energy Label
APPENDIX II	Load Plan for Energy & Storage Tests
APPENDIX III	Load Plan for Freezing Tests
APPENDIX IV	Outline of Test Procedure

INTRODUCTION

This report outlines the results of tests carried out on one sample of a Bosch KGH33X10GB/02 fridge-freezer. This appliance was tested in conjunction with the A66770 Correction factors project.

Tests carried out were:

- storage volume measurements
- energy consumption
- storage temperature test at 25℃ ambient
- storage temperature test at 43℃ ambient
- freezing test at 25℃ ambient (in accordance with EN 153)
- freezing test at 32℃ ambient (in accordance with EN ISO 15502)

Tests were carried out in accordance with:

- EN 153: 2006 Methods of measuring the energy consumption of electric mains operated household refrigerators, frozen food storage cabinets, food freezers and their combinations, together with associated characteristics.
- EN ISO 15502: 2005 / Cor 1: 2007 Household refrigerating appliances – Characteristics and test methods

All tests were carried out at Intertek from November 2011 to February 2012.

The tests have been carried out in accordance with the relevant standard, and as such, the results are only applicable to the sample tested and the conditions of the test. Sample variability and changes in test conditions could influence some results, and the result(s) as stated may not be representative of the mean result if a number of different samples were tested under a variety of test conditions.

1.0 Initial Inspection

The test sample was inspected on arrival at Intertek for any damage and brand information was recorded for reference. The results of this inspection can be found in Table 1 below.

A scanned copy of the energy label supplied with the sample is shown in Appendix I.

Table 1: Brand details

Initial Inspection	
Laboratory code	CF1
Condition on arrival	Good
Appliance type	Frost-free fridge freezer
Brand details	
Manufacturer / distributor	Bosch
Model	KGH33X10GB/02
Type / product no.	KIKGN33AV
Serial number(s)	FD9102 100176
Climate class as per rating plate	SN - T
Energy Label Info (from label supplied with appliance)	
Energy label group	A+
Star rating	4
Energy consumption stated on label (kWh)	279
Fresh food storage volume	186
Chill food storage volume	NA
Frozen food storage volume	66
Method of defrosting (automatic or manual)	Automatic

NA = Not applicable

2.0 Storage Volume

The storage volumes of the sample was measured in accordance with EN ISO 15502: 2005 Clause 7.

The rated storage volume, measured storage volume and difference in results are shown in Table 2 below.

Table 2: Storage volume

Storage volumes (litre)	Stated	Measured	Difference
Laboratory code	CF1		-
Fresh food storage volume	186	185	-0.5%
Chill food storage volume	NA	NA	
Food freezer storage volume	68	67	-1.5%
2 Star volume	NA	NA	

NA = Not applicable

3.0 Performance

3.1 Energy Consumption Tests

Energy consumption tests were carried out on the appliances in accordance with EN 153: 2006.

The results of this test are shown in Table 3, Figure 1 and Figure 2 on the following pages.

The energy index calculation is shown in Table 4 on page 8.

The load plan used for the energy consumption test and for the storage test is shown in Appendix II. M-packages were placed in the positions expected to give the warmest temperatures in accordance with EN ISO 15502 Clause 13.3.2.7. This load plan was devised by the laboratory. No loading information was requested from the manufacturer.

Table 3: Energy consumption test

Energy Consumption Test	Warm Run	Cold Run
Laboratory code	CF1	
Ambient temperature (℃)	25.0	25.0
Fridge thermostat setting	2	2½
Freezer thermostat setting	-16	-18
Chiller setting	NA	NA
Fresh food storage compartment (℃)		
Mean tm	5.8	4.3
t1	4.9	3.3
t2	6.2	4.6
t3	6.5	5
Max	8.2	6.9
Min	1.3	0.4
Chill compartment (℃)		
Mean	NA	NA
Max	NA	NA
Min	NA	NA
Frozen food compartment (℃)		
Defrost peak temperature	-16.5	-18.8
Warmest stable temperature	-17.7	-20.2
2 star section warmest temperature	NA	NA
Duty cycle and energy consumption		
On time (minute)	19.2	22.7
Off time (minute)	31.7	30.4
Percentage running time	38.1	43.2
Energy consumption at 230 V (kWh/24h)	0.655	0.715
Overall Energy consumption (kWh/24h)	0.67	
Energy consumption per year (kWh)	246.23	
Comments	None	

NA = Not applicable

Figure 1: Energy consumption test (Warm Run)

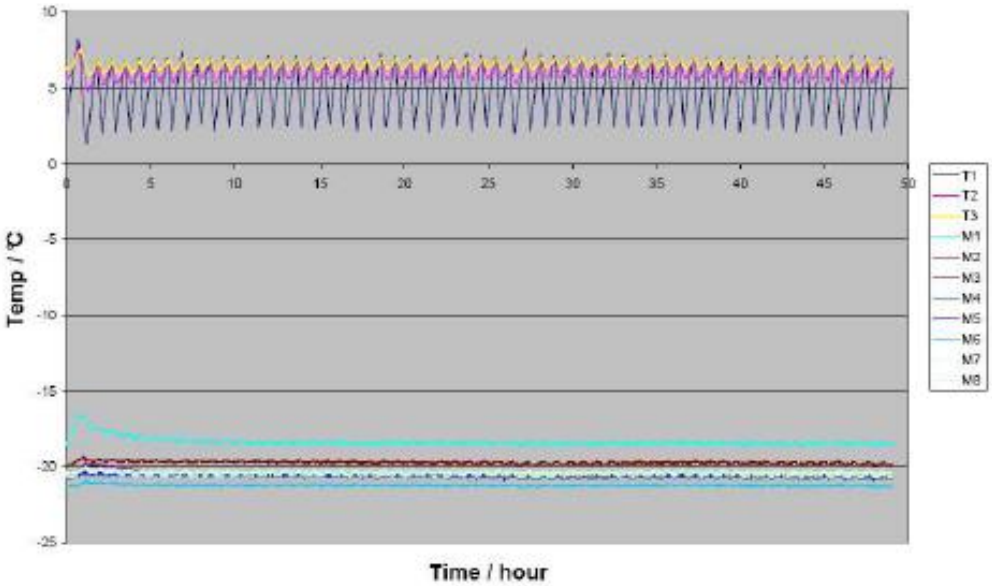


Figure 2: Energy consumption test (Cold Run)

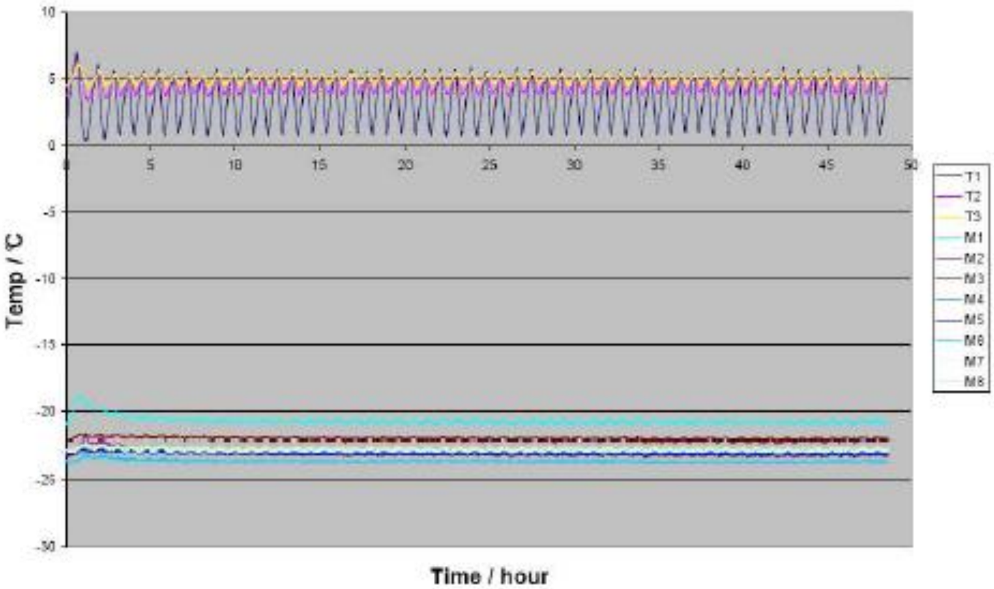


Table 4: Energy index calculation

Energy Index Calculation	
Laboratory code	CF1
Category of appliance	4 star
Forced air?	Yes
Climate class for A+ calculation	T
Built-in and under 58 cm wide?	No
Fridge volume (litre)	185
Chiller volume (litre)	NA
2 Star volume (litre)	NA
4 star volume (litre)	67
Energy consumption per year (kWh)	246.23
Coefficients and constant	
Omega	2.15
M(a)	0.777
N(a)	303
Correction factors	
FCA_freezer	1.20
FCA_2 star	1.20
CC_Climate class	1.20
BI_Built-in	1.00
Ratio factors	
Standard energy consumption (per year)	636.7
Adjusted net volume	429.4
Energy index & Energy class	
Energy Efficiency Index (%)	38.7
Energy label (A+ or A++)	A+
Comments	None

NA = Not applicable

3.2 Storage Temperature Tests

Storage temperature tests were carried out at 25℃ ambient and 43℃ ambient in accordance with EN ISO 15502: 2005 Clause 13.

The results of this test are shown in Table 5, Figure 3, Table 6 and Figure 4 on the following pages.

Table 5: Storage test at 25℃ ambient

Storage test at 25℃ ambient	
Intertek code	CF1
Ambient temperature (℃)	25.0
Fridge thermostat setting	3¾
Freezer thermostat setting	-16
Chiller thermostat setting	NA
Fresh food storage compartment (℃)	
Mean tm	3.9
t1	2.8
t2	4.2
t3	4.7
Max	6.2
Min	-2.0
Frozen food compartment (℃)	
Defrost peak temperature	-16.3
Warmest stable temperature	-17.8
2 star section warmest temperature	NA
Duty cycle and energy consumption	
On time (minute)	19.4
Off time (minute)	28.7
Percentage running time (%)	40.7
Energy consumption at 230 V (kWh/24h)	0.698

Figure 3: Storage test at 25℃ ambient

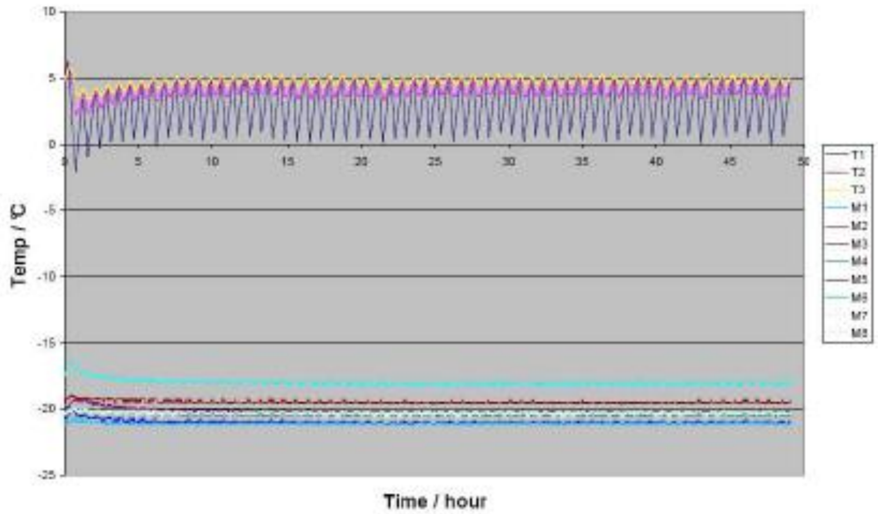
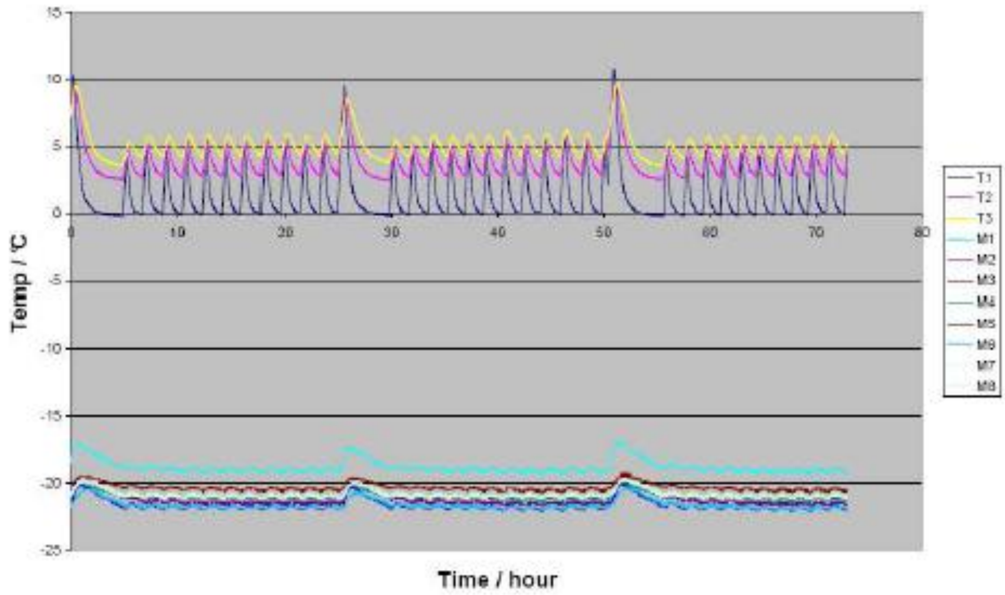


Table 6: Storage test at 43℃ ambient

Storage test at 43℃ ambient	
Laboratory code	CF1
Ambient temperature (℃)	43.2
Fridge thermostat setting	3 ¾
Freezer thermostat setting	-16
Chiller thermostat setting	NA
Fresh food storage compartment (℃)	
Mean tm	3.5
t1	1.4
t2	3.9
t3	5.1
Max	10.7
Min	-0.2
Frozen food compartment (℃)	
Defrost peak temperature	-16.9
Warmest stable temperature	-18.8
2 star section warmest temperature	NA
Duty cycle and energy consumption	
On time (minute)	101.7
Off time (minute)	13.6
Percentage running time (%)	88.5
Energy consumption at 230 V (kWh/24h)	1.618
Comments	None

NA = Not applicable

Figure 4: Storage test at 43℃ ambient



3.3 Freezing Capacity Tests

Freezing capacity tests were carried out at 25℃ am bient in accordance with EN 153 and at 32℃ ambient in accordance with EN ISO 15502: 2005 Clause 17.

The results of this test are shown in Table 7, Figure 5, Table 8 and Figure 6 on the following pages.

Table 7: Freezing capacity at 25℃ ambient

Freezing test at 25℃ ambient	
Laboratory code	CF1
Ambient temperature (℃)	25.0
Initial Conditions	
Pre-freeze time (h)	6.0
Light load (kg)	8.0
Heavy load (kg)	26.5
Results - Fresh food compartment (℃)	
Maximum Mean Temp (℃)	4.2
Maximum Temperature (℃)	4.9
Minimum Temperature (℃)	-1.2
Results - Light load (hour)	
Time for LL mean to reach -18℃	19.8
Time for last TC to reach -18℃	20.3
Results - Heavy load (℃)	
Max temp at Start (℃)	-19.6
Max temp during test (℃)	-18.9
Comments	Failed - fridge too cold

Figure 5: Freezing capacity at 25℃ ambient

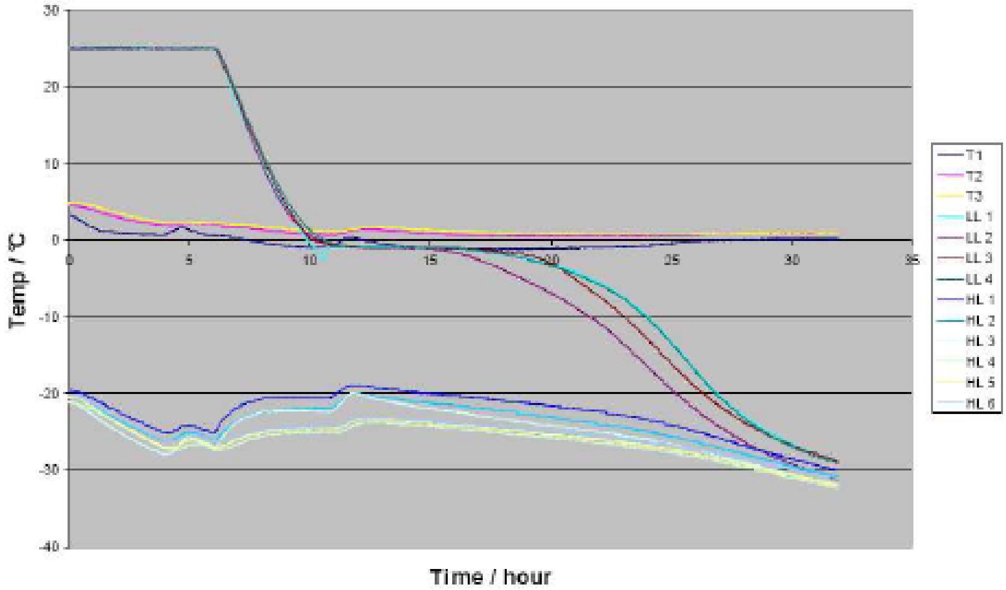
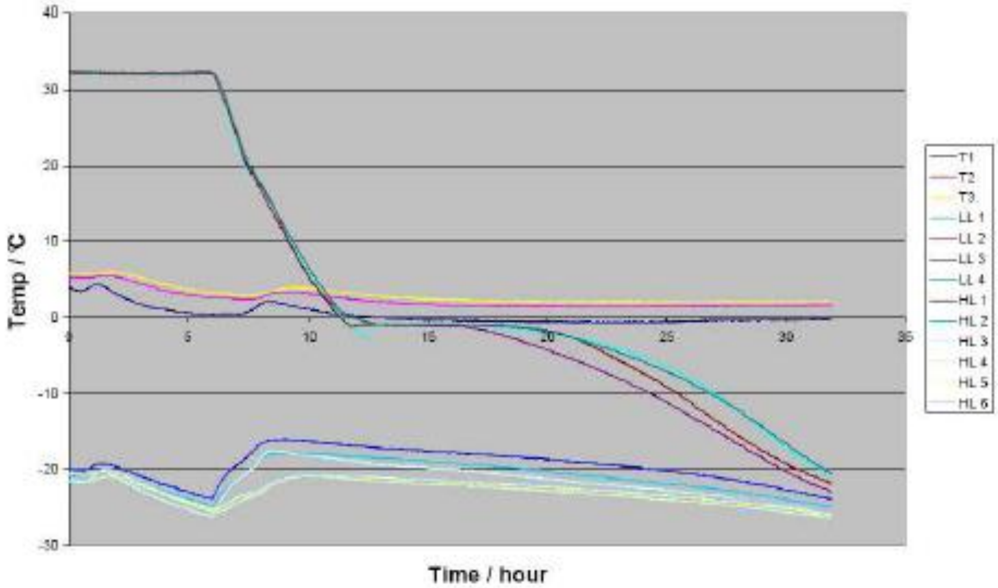


Table 8: Freezing capacity at 32℃ ambient

Freezing test at 32℃ ambient	
Laboratory code	CF1
Ambient Temperature (℃)	32.3
Initial Conditions	
Pre-freeze Time (h)	6.0
Light load (kg)	8.0
Heavy load (kg)	26.5
Results - Fresh food compartment (℃)	
Maximum Mean Temp (℃)	5.2
Maximum Temperature (℃)	6.0
Minimum Temperature (℃)	-0.7
Results - Light load (hour)	
Time for LL mean to reach -18℃ (h)	23.9
Time for last TC to reach -18℃ (h)	24.7
Results - Heavy load (℃)	
Max temp at Start (℃)	-23.8
Max temp during test (℃)	-15.9
Comments	Failed - fridge too cold

Figure 6: Freezing capacity at 32℃ ambient



4.0 Summary of Results

See Table 9 for a summary of all results (continued on page 15).

Rated storage volume
Commission delegated regulation (EU) No 1060/2010 Annex VII Table 1 states:
"The measured value shall not be less than the rated value by more than 3% or 1 litre, whichever is the greater value."

Energy consumption
Commission delegated regulation (EU) No 1060/2010 Annex VII Table 1 states:
"The measured value shall not be greater than the rated value by more than 10%."

Table 9 below summarises all results for this test sample.

Results summary			
Intertek code	CF1		
Appliance type	Frost-free fridge freezer		
Manufacturer / distributor	Bosch		
Model	KGH33X10GB/02		
Climate class as per rating plate	SN - T		
Category of appliance	4 star		
Energy & volume	**Stated**	**Measured**	**Difference**
Energy consumption per year (kWh)	279	246.23	-11.7%
Energy efficiency Index (%)	-	38.67	-
Energy label (A+ or A++)	A+	A+	-
Fresh food storage volume (litre)	186	185	-0.5%
Food freezer storage volume (litre)	68	67	-1.5%
Storage test at 25℃ ambient			
Fridge mean temperature (℃)	3.9		Passed
Freezer maximum stable temperature (℃)	-17.8		Passed
Energy consumption at 230 V (kWh/24h)	0.698		
Comments	None		
Storage test at 43℃ ambient			
Fridge mean temperature (℃)	3.5		Passed
Freezer maximum stable temperature (℃)	-18.8		Passed
Energy consumption at 230 V (kWh/24h)	1.618		
Comments	Internal temps can sometimes be colder at higher ambients owing to appliance working harder.		

Table 9: Summary of all results continued.

Results summary (continued)		
Freezing test at 25℃ ambient		
Fridge maximum mean temp (℃)	4.2	Passed
Fridge maximum temperature (℃)	4.9	Passed
Fridge minimum temperature (℃)	-1.2	Failed
Time for LL mean to reach -18℃ (h)	19.8	Passed
Time for last TC to reach -18℃ (h)	20.3	
Max freezer temp at start (℃)	-19.6	
Max freezer temp during test (℃)	-18.9	Passed
Comments	Fridge temp should remain between 0 and 10℃	
Freezing test at 32℃ ambient		
Fridge maximum mean temp (℃)	5.2	Passed
Fridge maximum temperature (℃)	6.0	Passed
Fridge minimum temperature (℃)	-0.7	Failed
Time for LL mean to reach -18℃ (h)	23.9	Passed
Time for last TC to reach -18℃ (h)	24.7	
Max freezer temp at start (℃)	-23.8	
Max freezer temp during test (℃)	-15.9	Passed
Comments	Fridge temp should remain between 0 and 10℃	

5.0 Discussion

There were no issues regarding the volume. The measured volumes were very close to the claimed volumes with all drawers in situ. For this reason, the load plan devised at Intertek had all test packages inside drawers. (It is common for manufacturer's own load plans to have some or all freezer drawers removed.)

This test sample used less energy than claimed, the yearly energy consumption result being nearly 12% lower than stated on the energy label.

Calculating the energy index using measured energy consumption and measured volumes gave an energy index of 38.7 giving an energy class of A+ which agrees with the energy label.

This test sample is able to maintain appropriate internal temperatures at 25℃ ambient and 43℃ ambient with little or no adjustment of the thermostat. It is reasonable to assume that it can also maintain appropriate internal temperatures at a range of ambients in-between 25℃ and 43℃.

When tested at the rated freezing capacity of 8 kg, this test sample failed the freezing test at 25℃ ambient. The fridge was colder than zero (-1.2℃) for more than 15 hours during the freezing of the light load.

Similarly when tested at 32℃ ambient, this test sample also failed the freezing test as the fridge was colder than zero (-0.7℃) for more than 15 hours during the freezing of the light load. Although a minimum fridge temperature of -0.7℃ may not be consider to be much colder than zero, it is colder for a significant period and therefore the failure cannot be considered to be borderline.

The freezer actually had too much cooling power which pulled down the fridge temperature for a number of hours as well as the freezer temperature. Adjusting the light load to more than 8 kg might have had the effect of increasing the freezing time to longer than 24 hours.

This test sample is able to cool down the rated freezing capacity within 24 hours as required. It is not able to adequately control the fridge temperature during this process. Fridge temperatures becoming colder than zero for a significant period may damage delicate foods with high water content.

6.0 Condition of Tested Goods

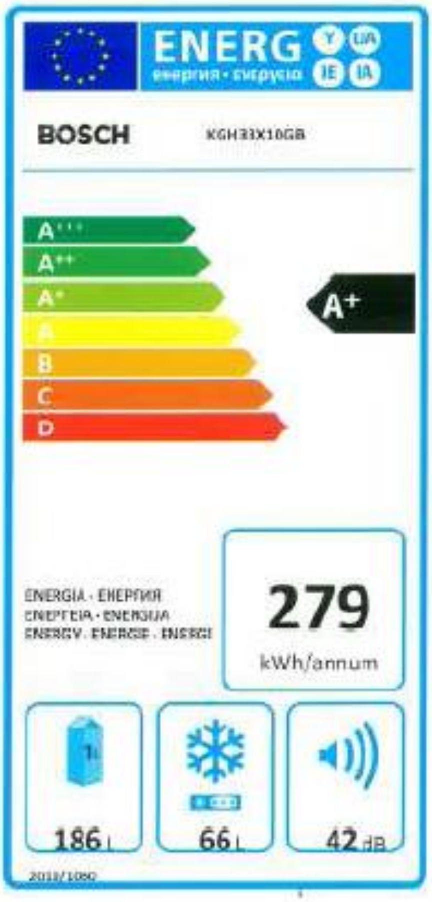
Table 10 below details any deterioration, damage or defects on the test sample after testing.

Condition of tested sample	
Laboratory code	CF1
Condition	A
Comment	None

A	In working condition
B	Minor damage
C	Major damage / defect
D	Suitable for disposal only
E	As new - not tested

APPENDIX I

COPY OF ENERGY LABEL


ENERG
енергия · ενεργεια
Y IJA IE IA
BOSCH
KGH33X10GB
A+++
A++
A+
A
B
C
D
A+
ENERGIA · ЕНЕРГИЯ
279
kWh/annum
186 L
66 L
42 dB

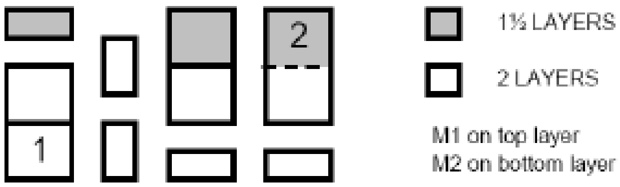
APPENDIX II

LOAD PLAN FOR ENERGY & STORAGE TESTS

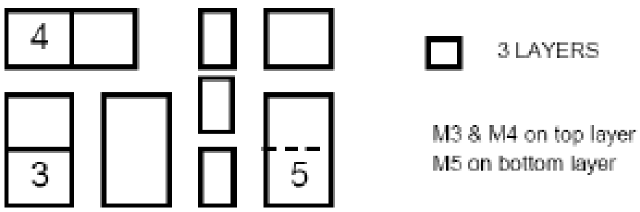
A66770 Code CF1 Load plan for energy consumption and storage tests

M denotes measurement package or "M Pack" as numbered below.

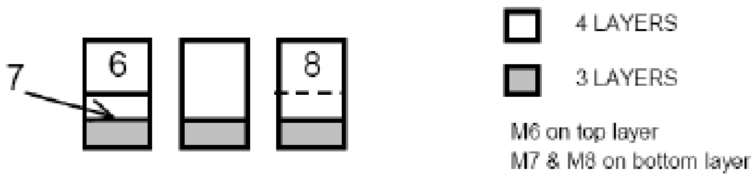
TOP DRAWER



MIDDLE DRAWER



BOTTOM DRAWER



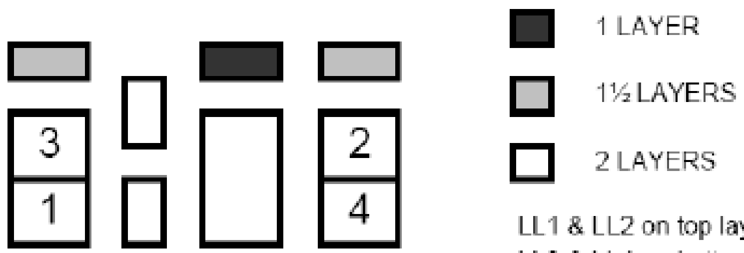
APPENDIX III

LOAD PLAN FOR FREEZING TESTS

A66770 Code CF1 Load plan for freezing tests

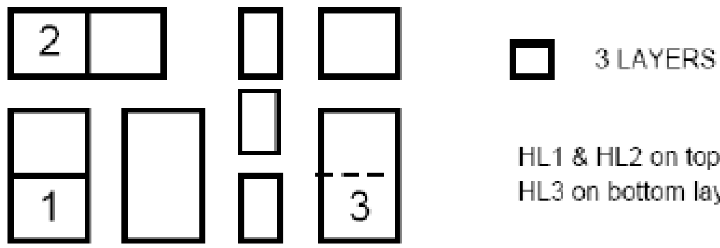
M denotes measurement package or "M Pack" as numbered below.

TOP DRAWER (LIGHT LOAD)



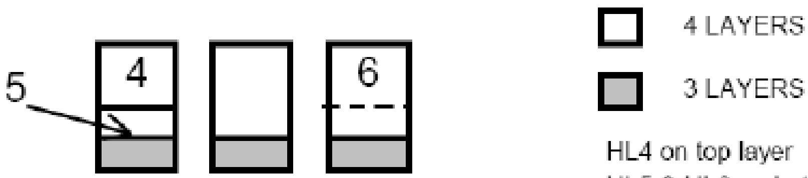
LL1 & LL2 on top layer
LL3 & LL4 on bottom layer

MIDDLE DRAWER (HEAVY LOAD)



HL1 & HL2 on top layer
HL3 on bottom layer

BOTTOM DRAWER (HEAVY LOAD)



HL4 on top layer
HL5 & HL6 on bottom layer

APPENDIX IV

OUTLINE OF TEST PROCEDURE

Outline of Test Procedure

An appliance is installed in a test bay and loaded with thermocouples and test packages in accordance with the test standard and the manufacturer's instructions. Fridge thermocouples are in set positions at the top, middle and bottom where the bottom position is above all salad drawers. The freezer is completely filled with test packages in accordance the test standard; there should be as many as possible while still maintaining 15 mm between stacks or towers of packages for example. Some of these test packages will be measurement or "M Packs" which consists of 0.5 kg of the standard test material with a thermocouple inserted into the centre. The position of these M packs is not prescribed. They should be placed where the warmest places might be expected for example at the top (since cold air drifts downwards), near the door seal and at the bottom near the compressor housing, since there might be some heat ingress from the compressor unit at the bottom.

The appliance is switched on with the thermostat(s) and other control devices set to achieve the characteristic temperatures for each compartment. It is rare or impossible to achieve exact characteristic temperatures (eg. a mean of +5℃ for the fridge and a maximum of -18℃ for a 3 / 4 star freezer) so norma lly a "warm run" and a "cold run" are carried out at adjusted thermostat settings. The warm run is slightly warmer than the characteristic temperatures and the cold run is slightly colder within in limits prescribed by the standard.

The energy consumptions from these two runs are then interpolated to give the energy consumption at the precise characteristic temperature(s).

A storage temperature test may also be carried out normally at the extremes of the climate class range. eg. a T class appliance would be tested at +16℃ and +43℃ ambients. Adjusting the thermostat is permitted if it is necessary to maintain correct internal temperatures.

A freezing test may be carried out if the appliance has a 4 star freezer. The rated freezing load should be declared on the rating plate and instructions for best freezing practice should be stated in the user manual. eg. there may be an instruction for optimum pre-freeze time to pull down freezer temperature before inserting the "light" load to be frozen. The rated light load should freeze within 24 hours without unduly affecting internal temperatures of the compartments including the freezer compartment.

Annex D: Frost-free and static appliance comparisons

The following table provides more detail on the comparisons provided by CECED during the course of the research for this report.

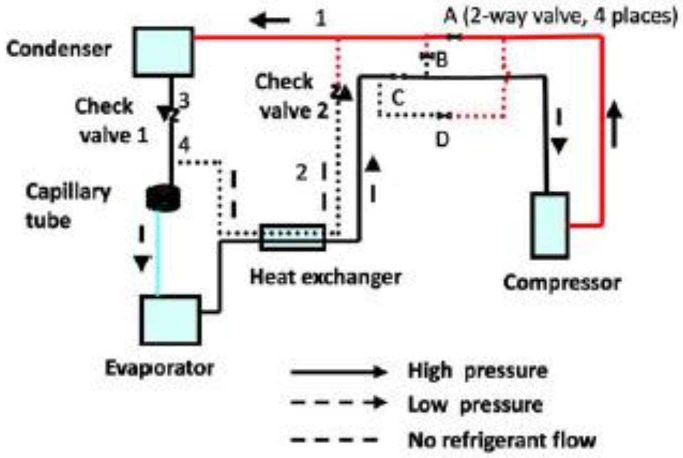
Brand	Type of Compartment	Model	Climate Class	Net volume Fresh Food [dm3]	Net volume Freezer [dm3]	Energy Cons [kWh/y]	Adjusted Volume	Standard energy cons. [kWh/y]	Energy efficiency index
BSH	UF, static	GSV30V23	SN-T	0	223	275	575.3	625.1	44.0
BSH	UF, NF	GSN28V23	SN-T	0	217	298	671.8	677.1	44.0
		Difference				8.4%	16.8%	8.3%	0.0%
		Compressor efficiency difference				5.0%			
		Total difference				13.4%			
Whirlpool	UF, static	WVE1610A+	SN-T	0	202	259	521.2	595.9	43.5
Whirlpool	UF, NF	WVE1650A+NF	SN-T	0	195	281	603.7	640.4	43.9
		Difference				8.5%	15.8%	7.5%	1.0%
		Compressor efficiency difference				19.3%	(at compressor rating point)		
		Total difference				27.8%			
Whirlpool	BM, BI, static	ART762/A+	SN-T	201	65	284	490.7	684.3	41.5
Whirlpool	BM, BI, NF	ART863/A+/NF	SN-T	201	63	312	523.5	709.8	44.0
		Difference				9.9%	6.7%	3.7%	5.9%
		Compressor efficiency difference				10.4%			
		Total difference				20.3%			
Whirlpool	BM, static	WBE3411A+	N-ST	226	116	310	522.9	709.3	43.7
Whirlpool	BM, NF	WBE3321A+NF	N-T	226	97	328	571.5	747.1	43.9
		Difference				5.8%	9.3%	5.3%	0.5%
		Compressor efficiency difference				10.5%			
		Total difference				16.3%			
	BM=Bottom Mount Freezer								
	UF=Upright Freezer								
	BI=Built-in								
	NF=No-Frost (frost-free)								

Annex E: Reverse cycle defrost system

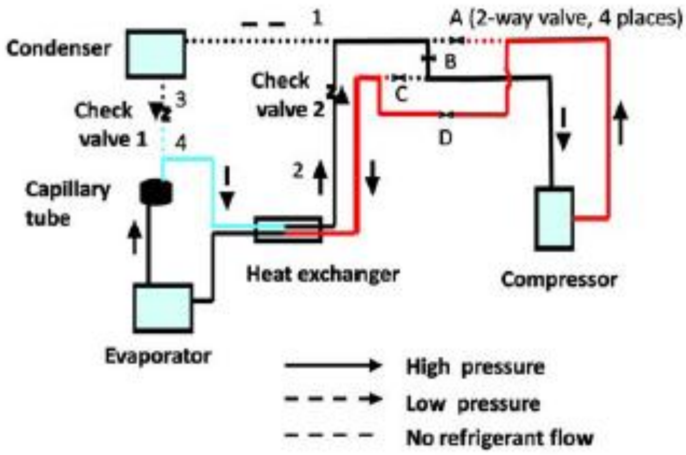
The diagrams below show normal and defrost operation for this novel defrosting system. The main aim of the system is to allow reverse cycle defrosting without condensing refrigerant in the condenser which may result in condensation on the surface of the appliance (skin condenser) or the rear of the cabinet (air cooled condenser).

In normal operation the system operates in a similar manner to almost all domestic refrigerators (capillary expansion to evaporator, suction-liquid heat exchange between the refrigerant suction gas and liquid, compression and condensation).

The system includes additional 2-way valves marked at A, B, C and D on the diagrams.
In normal operation valves A and C are open and valves B and D are closed.
In defrost mode valves A and C are closed and valves B and D are opened which excludes the condenser from the refrigerant circuit. Hot superheated refrigerant is passed from the compressor to the evaporator, on the way passing through the heat exchanger where it is de- superheated. It defrosts the evaporator and is then heated in the heat exchanger to ensure that refrigerant has evaporated to return to the compressor as a gas.



Novel defrosting refrigeration cycle—normal operation (2-way valves A, C open, B, D close).



Novel defrosting refrigeration cycle—defrost operation (2-way valves A, C close, B, D open).

Annex F: CECED 2009 ring test results

Electrolux RRA34391W Larder fridge (serial no. 82400062)				Electrolux RRA34391W Larder fridge (serial no. 82400093)			
	Difference to mean				Difference to mean		
Laboratory	kWh/y	kWh/y	%	Laboratory	kWh/y	kWh/y	%
Manufacturer before	134.3	-11.9	-8.1%	Manufacturer before	131.8	-13.0	-9.0%
A	142.4	-3.8	-2.6%	V	215.4	NC	NC
B	144.5	-1.7	-1.1%	W	138.7	-6.1	-4.2%
C	144.8	-1.4	-0.9%	X	141.3	-3.5	-2.4%
D	148.6	2.4	1.7%	Y	148.2	3.4	2.3%
E	150.5	4.3	3.0%	Z	151.1	6.3	4.3%
Manufacturer after	155.5	9.3	6.4%	Manufacturer after	151.1	6.3	4.3%
	Mean	St Dev	St Dev %		Mean	St Dev	St Dev %
Labs A to E	146.2	3.3	2.3%	Labs V to Z	144.8	32.0	4.0%
Labs A to E + Manuf.	145.8	6.7	4.6%	Labs V to Z + Manuf.	143.7	7.8	5.4%
		Range	Range %			Range	Range %
Labs A to E		8.1	5.5%	Labs V to Z		12.4	8.6%
Labs A to E + Manuf.		21.2	14.5%	Labs V to Z + Manuf.		19.3	13.3%

BSH KGN 39P frost-free fridge-freezer (serial no. 8711 00212)				BSH KGN 39P frost-free fridge-freezer (serial no. 8712 00211)			
	Difference to mean				Difference to mean		
Laboratory	kWh/y	kWh/y	%	Laboratory	kWh/y	kWh/y	%
Manufacturer before	318.6	-10.1	-3.1%	Manufacturer before	323.8	-0.2	-0.1%
D	316.0	-12.7	-3.9%	Y	298.2	-25.8	-8.0%
E	325.0	-3.7	-1.1%	X	317.9	-6.1	-1.9%
A	328.0	-0.7	-0.2%	Z	323.8	-0.2	-0.1%
B	333.0	4.3	1.3%	W	325.9	1.9	0.6%
C	341.4	12.7	3.9%	V	354.1	30.1	9.3%
Manufacturer after	337.3	8.6	2.6%	Manufacturer after	338.4	14.4	4.5%
	Mean	St Dev	St Dev %		Mean	St Dev	St Dev %
Labs A to E	328.7	9.4	2.9%	Labs V to Z	324.0	20.1	6.2%
Labs A to E + Manuf.	328.5	9.4	2.9%	Labs V to Z + Manuf.	326.0	17.3	5.3%
		Range	Range %			Range	Range %
Labs A to E		25.4	7.7%	Labs V to Z		55.9	17.3%
Labs A to E + Manuf.		25.4	7.7%	Labs V to Z + Manuf.		55.9	17.3%

Liebherr RICBS 3156 built-in fridge-freezer (serial no. 25.447.722.1)				Liebherr RICBS 3156 built-in fridge-freezer (serial no. 25.447.711.5)			
	Difference to mean				Difference to mean		
Laboratory	kWh/y	kWh/y	%	Laboratory	kWh/y	kWh/y	%
Manufacturer before	287.4	8.5	3.1%	Manufacturer before	290.2	16.9	6.2%
B	260.8	-18.1	-6.5%	X	240.9	-32.4	-11.9%
A	266.5	-12.4	-4.4%	Y	258.8	-14.5	-5.3%
E	272.4	-6.5	-2.3%	W	266.5	-6.8	-2.5%
C	295.3	16.4	5.9%	V	288.4	15.1	5.5%
D	299.3	20.4	7.3%	Z	312.1	38.8	14.2%
Manufacturer after	294.6	15.7	5.6%	Manufacturer after	302.3	29.0	10.6%
	Mean	St Dev	St Dev %		Mean	St Dev	St Dev %
Labs A to E	278.9	17.4	6.2%	Labs V to Z	273.3	27.6	10.1%
Labs A to E + Manuf.	282.3	15.5	5.6%	Labs V to Z + Manuf.	279.9	25.4	9.3%
		Range	Range %			Range	Range %
Labs A to E		38.5	13.8%	Labs V to Z		71.2	26.0%
Labs A to E + Manuf.		38.5	13.8%	Labs V to Z + Manuf.		71.2	26.0%

Whirlpool OL AFG 8150/CV22 upright freezer (serial no. 50 0746 017616)				Whirlpool OL AFG 8150/CV22 upright freezer (serial no. 50 0746 017617)			
	Difference to mean				Difference to mean		
Laboratory	kWh/y	kWh/y	%	Laboratory	kWh/y	kWh/y	%
Manufacturer before	257.0	-7.4	-2.8%	Manufacturer before	256.2	1.1	0.4%
D	244.6	-19.8	-7.5%	Y	240.9	-14.2	-5.6%
C	258.2	-6.2	-2.3%	X	253.3	-1.8	-0.7%
A	266.5	2.1	0.8%	Z	258.8	3.7	1.5%
B	273.9	9.5	3.6%	W	259.5	4.4	1.7%
E	278.8	14.4	5.4%	V	262.8	7.7	3.0%
Manufacturer after	258.8	-5.6	-2.1%	Manufacturer after	258.4	3.3	1.3%
	Mean	St Dev	St Dev %		Mean	St Dev	St Dev %
Labs A - E	264.4	13.5	5.1%	Labs A - E	255.1	8.6	3.4%
Labs A to E + Manuf.	262.5	11.5	4.3%	Labs V to Z + Manuf.	255.7	7.2	2.8%
		Range	Range %			Range	Range %
Labs A - E		34.2	12.9%	Labs A - E		21.9	8.6%
Labs A to E + Manuf.		34.2	12.9%	Labs V to Z + Manuf.		21.9	8.6%

Annex G: Impact assessment modelling

For each correction factor considered in this project an assessment of the impacts on the UK and EU wide CO_2 emissions and energy consumption if the correction factor was removed has been carried out using a stock- sales model. This draws much of the basic evidence such as number of households and ownership, to consider stock, from information in previous studies such as the EuP preparatory study.

End-use modelling approach (UK)

A sales-stock model allows for the time-related energy effects of new products entering and old ones leaving the national stock of appliances, and importantly enables an ex-ante appraisal of the likely impact of technical and policy options on national energy consumption.

This can be extended to undertake cost-benefit assessments of such options. This type of end-use model is described mathematically by the following equations (Lane, 2000)[67].

.

$$\mathrm{Energy}(\mathrm{k}) = \sum_{k=1960}^{2030} \sum_{j=1960}^{k} (\mathrm{Sales}(\mathrm{j})\ \mathrm{x}\ \mathrm{Remain}(\mathrm{j},\mathrm{k})\mathrm{x}\ \mathrm{UEC}(\mathrm{k})\mathrm{x}\ \mathrm{Use}(\mathrm{k}))$$

Equation 4

where:

- *Energy*(k) is the estimated energy consumption (kWh/year) of all appliances in year k. This can be divided by 1,000,000 to provide the energy estimates in units of GWh/year;
- *Sales*(j) is the number of appliances sold in year j;
- *Remain*(j,k) is the proportion of the appliances sold in year j and still remaining in the stock in year k;
- *UEC*(j) is the average unit energy consumption (UEC) consumption of the refrigerators under test conditions (EN 153) (kWh/year);
- *Use*(k) is a usage factor (set to 1). It could also be used as a simple scaling factor to adjust test values to real life conditions.

If the ownership levels are known, then the stock of appliance is simply the product of ownership and household numbers:

$$\mathrm{Stock}(\mathrm{k}) = \mathrm{Household}(\mathrm{k})\ \mathrm{x}\ \mathrm{Ownership}(\mathrm{k})$$

Equation 5

where:

- *Households*(k) is the number of households, eg, UK;
- *Ownership* (k) is the household ownership (as a proportion) for the country.

[67] Lane, K (2000) *CADENCE - Appendix O, Modelling Approach*. Environmental Change Institute, University of Oxford, UK.

Mathematically speaking, ownership levels, annual sales and the lifetime of an appliance are inter-related variables; so that it is possible to estimate the third if any two are known. For instance, a new purchase is either going to be a first-time purchase (increasing ownership levels) or to replace an existing machine that has broken down (at the end of its useful life). Thus, any unknown sales volume data could be estimated from ownership data if the average appliance lifespan is known (or assumed). The average lifespan is sometimes available from life cycle analyses, though it can be estimated numerically if sufficient sales and ownership data are available. Through rationalising known sales and ownership data it is also possible to provide a (least squares) estimate for the average lifespan over the whole observation period. Where there are sufficient data, this approach is preferable since it provides a better estimate of the useful appliance lifetime.
Estimating sales from the ‘known’ stock of appliance can be represented as follows:

$$\text{Estimatd. Sales}(k) = Stock(k) - \sum_{k=1960}^{2030} \sum_{j=1960}^{k-1} \left(\text{Estimated.Sales}(j) \text{ x Remain}(j,k)\right)$$

Equation 6

The function $\text{Remain}(j,k)$, which is the same function as in Equation 6, describes the proportion of the appliances sold in year j and still remaining in the stock in year k. In the current project it is derived by assuming that the lifespan profile of each appliance type follows a normal distribution (modelled by two parameters: the mean and the variance). The average lifespan, or half-life, is defined as the time taken for 50% of each appliance type sold in a given year to leave the stock of appliances.

A schematic of the model input-output structure is shown in the following figure.

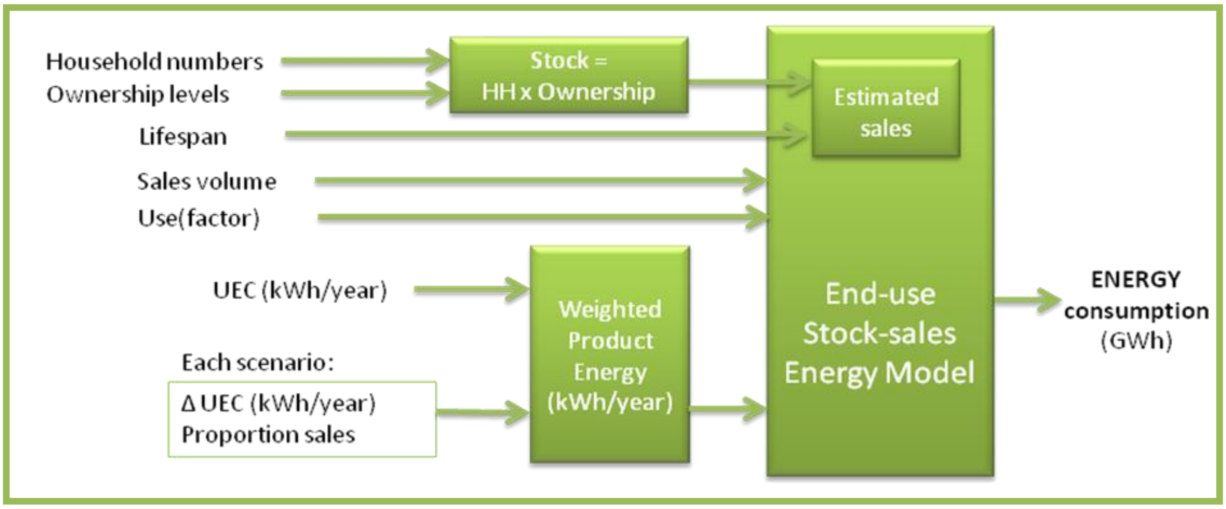


Figure 47: Schematic of end-use model.

Running 'scenarios'

Once the stock model has been constructed, a reference scenario will be available which reflects the best estimate of energy consumption into the future. This reference scenario is what is expected to happen with no further policy interventions.

These scenarios will be driven by making changes to the average efficiency/consumption of refrigerators/freezers sold, ie perturbations or changes to the input variable *UEC*(k), shown as Δ *UEC(k)*. The change to UEC will also be dependent on the proportion of sales which make use of the correction factor. For each year (k) where the factor is expected to have an impact, the following 'adjustment' is made to generate a new input series for the stock model.

$$\text{UEC. Scenario}(k) = \text{UEC.Reference}(k) \text{ x } \left(1 + \Delta \text{ UEC}(k)\right) \text{ x } (1 - \text{Proportion. Sales}(k))$$

Equation 7

So for example if a correction factor reduces consumption by 10% and 10% of products make use of the factor, then the UEC will be adjusted by 1%. This revised UEC value is then run through the stock model. An example schematic of the outcome of such an approach is shown in the figure below.

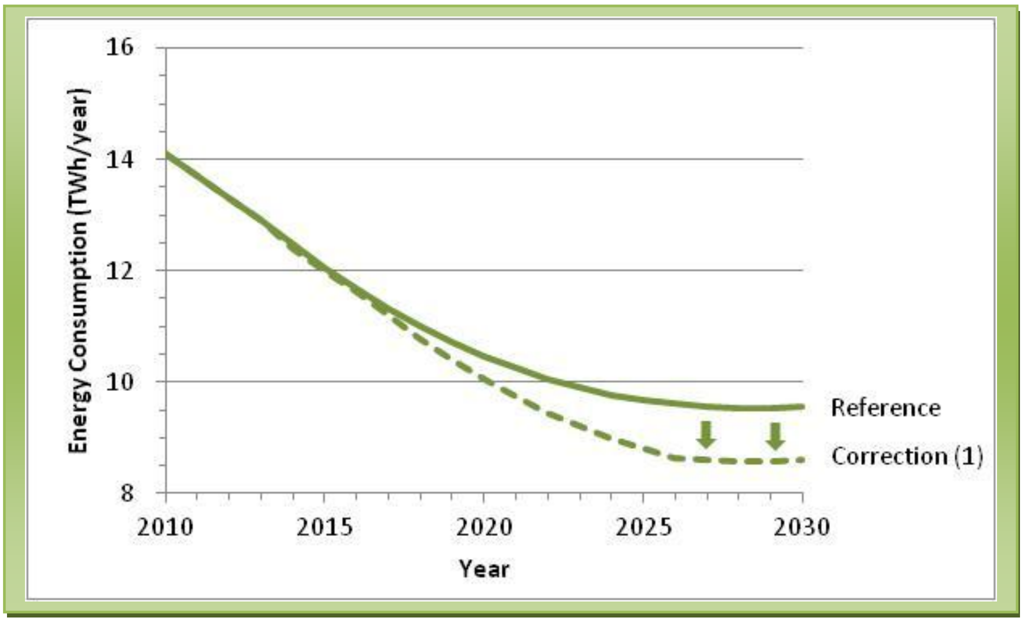


Figure 48: Example of scenario results (UK).

Using the above approach, the changes should be relatively straightforward to implement and will be dependent on the data available to describe the impact of changing factors currently used in labelling and MEPS policy measures.

Running 'scenarios' for EU

For the EU analysis we do not have access to the detailed EU model (for the 25 Member States) used in the EUP analysis; only the values reported in their reporting (specifically EUP research lot 13, ISIS 2008), such as estimated GWh/year outputs and some of the assumptions. To overcome this, there are at least two possible approaches: the first is to build an aggregated EU model which mimics the EUP as best as possible, or build an

‘anomaly’ model that estimates the likely energy change in EU consumption (then compare to EUP estimates as required). Both would provide similar outcomes (certainly within any bounds of confidence intervals).
To develop a detailed stock model for all of Europe would be a very time consuming task. In this case it is proposed that we will develop a model that estimates the changes to the output based on changes to the inputs: the inputs will be generated as below (for each factor).

$$\Delta\ UEC.Scenario(k) = (\Delta UEC(k))\ x\ (Proportion.Sales(k))$$

Equation 8

This new series will then be put through a dummy stock model to estimate the likely changes to energy consumption on an EU-wide scale. This change in energy can be used in the subsequent cost-benefit analysis.

Impact assessment factors used (2011)

The values used for the UK analysis are based on guidance and factors provided by DECC (2011).

For the CBA analysis use has been made of various economic and environmental conversion factors to convert the energy consumption values to carbon emissions and financial impacts. For the UK analysis, the guidance provided by DECC (2011) has been followed.

For the EU results simpler results may be shown, since there are no standard guidance notes for these (and importantly some of the conversion factors will be different).

CECED database: use of ‘factors’

The following tables show the prevalence of different correction factors for models in the CECED database (2009).

The tables are by refrigeration category (1 to 10), with the number of models in the CECED database in 2009. The average consumption (kWh/year) and average volume (litres) is provided, both as a simple average, and as a models-weighted average (MW).

Category	No-frost	Models	%	AVG kWh/year	AVG Vol
1	136	2003	6.79%	151.36	319.26
2	0	8	0.00%	0.00	0.00
3	1	98	1.02%	146.00	187.00
4	0	12	0.00%	0.00	0.00
5	0	32	0.00%	0.00	0.00
6	0	12	0.00%	0.00	0.00
7	2409	7726	31.18%	366.98	354.75
8	511	1726	29.61%	287.15	202.30
9	16	774	2.07%	265.81	242.50
10	97	392	24.74%	310.34	335.52
ALL	3170	12783	24.80%	254.61	273.56
MW				342.54	327.45

Category	Built in	Models	%	AVG kWh/year	AVG Vol
1	908	2003	45.33%	143.06	188.81
2	0	8	0.00%	0.00	0.00
3	48	98	48.98%	158.97	169.21
4	3	12	25.00%	206.77	203.67
5	1	32	3.13%	215.00	88.00
6	7	12	58.33%	222.14	120.86
7	1868	7726	24.18%	267.18	228.01
8	365	1726	21.15%	231.02	106.96
9	0	774	0.00%	0.00	0.00
10	76	392	19.39%	216.98	232.54
ALL	3276	12783	25.63%	207.64	167.26
MW				225.83	202.61

Category	Chill cmprt	Models	%	AVG kWh/year	AVG Vol
1	41	2003	2.05%	145.23	254.68
2	0	8	0.00%	0.00	0.00
3	34	98	34.69%	142.82	208.91
4	0	12	0.00%	0.00	0.00
5	0	32	0.00%	0.00	0.00
6	0	12	0.00%	0.00	0.00
7	219	7726	2.83%	311.02	308.62
8	0	1726	0.00%	0.00	0.00
9	0	774	0.00%	0.00	0.00
10	214	392	54.59%	266.03	298.26
ALL	508	12783	3.97%	216.27	267.62
MW				267.43	293.23

Category	Class N	Models	%	AVG kWh/year	AVG Vol
1	228	2003	11.38%	161.09	172.87
2	3	8	37.50%	171.00	338.00
3	20	98	20.41%	165.69	101.25
4	8	12	66.67%	146.38	105.50
5	26	32	81.25%	174.91	108.00
6	11	12	91.67%	229.55	123.64
7	995	7726	12.88%	281.69	242.94
8	194	1726	11.24%	266.17	137.97
9	37	774	4.78%	262.57	213.43
10	0	392	0.00%	262.57	213.43
ALL	1522	12783	11.91%	212.16	175.70
MW				256.53	212.78

Category	Class ST	Models	%	AVG kWh/year	AVG Vol
1	995	2003	49.68%	148.70	233.87
2	5	8	62.50%	149.40	154.20
3	67	98	68.37%	153.12	157.10
4	3	12	25.00%	218.33	230.00
5	5	32	15.63%	178.24	115.40
6	1	12	8.33%	273.00	235.00
7	3683	7726	47.67%	291.97	270.81
8	470	1726	27.23%	257.99	164.95
9	220	774	28.42%	295.39	260.65
10	178	392	45.41%	276.34	285.62
ALL	5627	12783	44.02%	224.25	210.76
MW				261.51	253.88

Category	Class T	Models	%	AVG kWh/year	AVG Vol
1	569	2003	28.41%	139.18	281.15
2	0	8	0.00%	0.00	0.00
3	6	98	6.12%	115.33	163.00
4	0	12	0.00%	0.00	0.00
5	0	32	0.00%	0.00	0.00
6	0	12	0.00%	0.00	0.00
7	2381	7726	30.82%	322.62	340.96
8	904	1726	52.38%	250.64	181.00
9	428	774	55.30%	254.55	261.29
10	214	392	54.59%	275.30	290.09
ALL	4502	12783	35.22%	226.27	252.92
MW				275.98	291.05