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Impact of the new IEC 62552-1,2,3:2015 global standard to cold appliance energy consumption rating (second study)

Prepared for and in co-operation with
CECED
Working Group Cold

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1 INTRODUCTION

1.1 Document revision history

Date	*Author*	*Version*	*Remark / document change*
6/4/2015	Martien Janssen	D1	First Draft
13/4/2015	Martien Janssen	V1	Modifications based on CECED Phone Conference 13/4/2015 • Technical analysis for Category 7, type I appliances moved to appendix D. • Explanation of different treatment defrost in the new global standard in appendix C • Small editorial changes
29/5/2015	Martien Janssen	V2	Confidentiality removed

Note that this report is a follow up of an earlier study performed in 2013 which has been concluded with report 13202/CE39/V3.

1.2 General

IEC SC59M/MT2 has completed a new, globally to be used, performance test standard for cold appliances. This standard replaces the current ISO15502 / IEC62552:2007 standard and is referred to as IEC62552-1,-2,-3:2015 (containing 3 parts). This new global standard should not be confused with the EN62552:2013 standard at European level. This is actually an update of the older EN153/ISO15502 standard and addresses a number of smaller issues, while the new standard at global level includes significant changes compared to the present standard. The process of converting the new global IEC standard to a European version is ongoing within CENELEC.

This study intends to evaluate the impact of this new standard on the energy consumption rating of cold appliances. To facilitate this, manufacturers organised within CECED have tested a series of cold appliances and have submitted their test results to Re/genT. All test results include energy consumption at the current standard in place (referred to as EN62552:2013 in this study) as well as tests according the new global standard (referred to as IEC 62552-1:2015, IEC 62552-2:2015 and IEC 62552-3:2015).

There are numerous changes between the new global standard and the current one, but the most dominant changes which impact the energy consumption are listed in the following table:

Item	*EN62552*	*New Global Standard (IEC-62552-1,-2,-3:2015)*
Ambient Temperature [°C]	25	16 and 32 °C. The annual energy consumption is to be calculated from $E_{total} = f\{E_{daily\text{-}16°C}, E_{daily\text{-}32°C}\}$ [1] where *f* is a function to be regionally defined. In this report the following relation is suggested: $E_{total} = F*365* E_{daily\text{-}16°C} + (1-$

[1] IEC62552-3:2015, clause 5.8.4

		*F)*365** $E_{daily-32°C}$, where *F* is a linear interpolation factor[2]. *F* = 0 gives the 32°C results and *F* = 1 the 16°C results.
Fresh Food Target Temperature [°C]	5	4
Frozen Food Target Temperature (3 and 4 star compartments) [°C]	-18 warmest package	-18 average temperature of 5 or more distributed temperature sensors (no packages)

Table 1: Main changes in the new global standard

For a more detailed discussion regarding the new global standard and its advantages, reference is made to Re/genT note 12320 / CE10 / V2 “Domestic cold appliances, global test standard revision”.

From the list above, it can be seen that, at equal ambient temperatures, fridges will consume more as the reference temperature has dropped from 5 to 4°C. Freezers will consume less as the -18°C average temperature inside the compartment is easier to achieve than the -18°C in the warmest package in the current standard. It can be expected that the combination appliances of fresh food and frozen food compartments will perform somewhere in between these two cases.

The new global standard has introduced two ambient test temperatures rather than one for a number of good reasons. Some facts which can be mentioned:

a) Relatively high energy consumption at low ambient temperature (e.g. because of the use of heaters) will now also be included in the final rating value.
b) Products with perfect compartment temperature control benefit from the new standard compared to products with less perfect control, having temperatures below target value when the ambient temperature deviates from 25°C.
c) It is much more difficult to introduce circumvention measures (which are also prohibited in the new global standard).

A final energy consumption declaration is based on taking part of the 16°C ambient temperature test and part of the 32°C ambient test. The fraction to take from each test is not defined in the new global standard but is left to each global region to define. This allows taking into account specific climate conditions.

In chapter 2 the products evaluated are listed and some particular remarks are made. In chapter 3 a comparison is made between energy consumption and volume using the current and new standard. This chapter starts with a discussion on the ambient factor *F* as there can be different views towards this factor.

Finally in chapter 4 some conclusions are drawn and recommendations for regulations update are given.

[2] It is recognised that since the standard does not define the relation itself, different versions of the formula may be applied. Above suggested formulation is in line with Australian and Japanese studies where in the final proposals the numbers of days at each temperature are listed.

2 PRODUCTS BEING STUDIED

2.1 Introduction

In total data of 73 products have been submitted for evaluation. These have been split over different groups according the following table, which are not exactly aligned with the product categories as defined in energy labelling/eco-design regulations:

Group	Main characteristic	Number of products
Category 1, 2 and 3	Fridges with or without chill compartments	5
Category 7, single control (Type I)	Combination appliances such as top and bottom mounted freezers	25
Category 7, double control (Type II) + Category 10, static type	Combination appliances	9
Category 7, double control (Type II) + Category 10, Frost Free	Combination appliances	16
Category 8, static	Upright Freezers	5
Category 8, Frost Free	Upright Freezers	11
Category 9	Chest Freezers	2

Table 2: Groups used in the comparison analysis

Category 1, 2 and 3 are similarly behaving products as the main component generally is the fresh food compartment. These have been dealt here within one group.

Category 7 products comprise combination appliances with a fresh food and frozen food compartment (three or four star). The analysis of category 7 products has been split between type I and type II products (according EN62552:2013). The difference is that type I products only have a single control whereas type II products are categorized by a double control. The single control products typically have a problem to balance both compartment temperatures at all ambient temperatures. Often such products are controlled on the fresh food temperature and the freezer compartment temperature results from the specific design. According the current standard the freezer has to have a temperature below -18°C at the target temperature of the fresh food compartment (+5°C)[3]. Storage tests are performed at the lowest and highest ambient temperature declared in order to verify correct compartment temperatures. Resetting of thermostats is allowed to achieve correct temperatures. Nevertheless, most products do include some measure to avoid that the freezer gets too warm at low ambient temperatures[4]. Such measures include additional heat sources into the fresh food compartment, sometimes these need to be set by the user (winter switch) or sometimes these are automatically activated using an ambient temperature switch.

Further category 7 comprises both Frost Free and static cooled appliances. The Frost Free appliances have a forced air circulation system and an automatic removal of frost being formed on the evaporators. This is typically done by activating a heating device at

[3] In case the appliance is not able to achieve these temperatures, the temperature of the fresh food compartment should be lowered until the freezer is -18°C, with the limiting case that none of the individual sensors in the fresh food compartment may get below 0°C.

[4] Namely at low ambient temperatures there is less cooling capacity needed for the fresh food compartment which commands generally the refrigeration system. E.g. at 10°C ambient temperature there is very little demand and the refrigeration system would not be able to keep the freezer cold.

regular intervals to melt the frost after which the water is drained to the outside of the appliance where it evaporates. The impact of the new standard is different for Frost Free versus static appliances due to the treatment of the energy related to defrosting the evaporator (see appendix C). In general the impact of defrost energy is more severe in the new standard.

As Frost Free appliances in category 7 of type I (single control) are very rare, this subcategory is not discussed, so the final division is in three groups: type I, type II static and type II Frost Free. As a few category 10 products were included in the list of products these are treated together with the category 7 products (mostly they were in 10 due to the presence of a chill compartment).

The upright freezers category has also been split between Frost Free and static. The reason for this is again that the new standard treats defrosts in a different way and generally does not accept the long defrosts interval times typically used for this category of products ((see appendix C).

2.2 Product data

The next tables show more details of the products evaluated, sorted per group. Experimental details of all products are shown in appendix E.

Number	Energy efficiency index (EN62552)	Appliance category	Appliance placement (FS=Free standing, BI=Built-in)	Max climate class	Min climate class	Number of compartments	Number of controls	Number of compressors	Compressor type (FS=Fixed speed, VS=Variable spe	Other product characteristics	Type of compartment 1	Type of compartment 2	Type of compartment 3	Forced air compartment 1	Forced air compartment 2	Forced air compartment 3
Cat 1..3																
1	21	3	FS	T	SN	2	1	1	FS		Fridge	Chill		Yes	Yes	
2	29	1	FS	T	SN	1	1	1	FS		Fridge			No		
3	30	1	BI	T	SN	1	1	1	FS		Fridge			No		
4	41	1	FS	T	SN	1	1	1	FS	fridge	Fridge			No		
5	33	1	FS	T	SN	1	1	1	FS		Fridge			No		
Cat 7-I																
1	23	7	BI	T	SN	2	1	1	VS		Fridge	*(***)		No	No	
2	31	7	BI	ST	SN	2	1	1	FS		*(***)	Fridge		No	No	
3	33	7	FS	ST	SN	2	1	1	FS	fridge w. 4*- comp	Fridge	*(***)		No	No	
4	33	7	FS	T	SN	2	1	1	FS	heater in low ambient	Fridge	*(***)		No	No	
5	36	7	FS	ST	SN	2	1	1	FS	comb sta to-fre	Fridge	*(***)		No	No	
6	28	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
7	22	7	BI	ST	SN	2	1	1	VS		Fridge	*(***)		No	No	
8	31	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
9	33	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
10	31	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
11	43	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
12	41	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
13	43	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
14	47	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
15	32	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
16	21	7	BI	ST	SN	2	1	1	VS		Fridge	*(***)		No	No	
17	36	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
18	38	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
19	35	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
20	28	7	FS	T	SN	2	1	1	FS		Fridge	*(***)		No	No	
21	43	7	BI	ST	N	2	1	1	FS		Fridge	*(***)		No	No	
22	45	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
23	43	7	BI	ST	SN	2	1	1	FS		Fridge	*(***)		No	No	
24	44	7	BI	ST	N	2	1	1	FS		Fridge	*(***)		No	No	
25	37	7	FS	ST	N	2	1	1	FS		Fridge	*(***)		No	No	

Table 3: Overview of products in category 1-3 and category 7, type I (single control)

Number	Energy efficiency index (EN62552)	Appliance category	Appliance placement (FS=Free standing, BI=Built-in)	Max climate class	Min climate class	Number of compartments	Number of controls	Number of compressors	Compressor type (FS=Fixed speed, VS=Variable spee	Other product characteristics	Type of compartment 1	Type of compartment 2	Type of compartment 3	Forced air compartment 1	Forced air compartment 2	Forced air compartment 3
Cat 7-II-Static																
1	22	7	FS	T	SN	2	2	1	VS		Fridge	*(***)		No	No	
2	23	7	FS	T	SN	2	2	1	VS	comb sta bo-fre	Fridge	*(***)		No	No	
3	31	7	FS	T	SN	2	2	1	FS		Fridge	*(***)		No	No	
4	19	7	FS	T	SN	2	2	1	VS		Fridge	*(***)		No	No	
5	33	7	BI	ST	SN	2	2	1	FS		Fridge	*(***)		No	No	
6	33	7	BI	T	SN	2	2	1	FS		Fridge	*(***)		No	No	
7	35	10	BI	ST	SN	3	2	1	FS		Fridge	*(***)	Chill	No	No	No
8	33	10	BI	ST	SN	3	2	1	VS		Fridge	*(***)	Chill	No	No	No
9	32	10	BI	ST	SN	3	1	1	FS		Fridge	Chill	*(***)	No	No	No
Cat 7-II-NF																
1	32	7	FS	T	SN	2	2	1	VS	comb sta nf bo-fre	Fridge	*(***)		No	Yes	
2	40	7	FS	T	SN	2	2	1	FS	side by side	Fridge	*(***)	**	Yes	Yes	Yes
3	44	7	FS	T	SN	2	2	1	FS	comb sta nf to-fre	Fridge	*(***)		No	Yes	
4	32	10	FS	T	SN	2	1	1	FS		Fridge	Chill	*(***)	Yes	Yes	Yes
5	31	7	FS	T	SN	2	2	1	FS		Fridge	*(***)		Yes	Yes	
6	33	7	FS	T	SN	2	2	1	FS		Fridge	*(***)		Yes	Yes	
7	36	10	BI	ST	SN	3	3	1	FS		Fridge	*(***)	Chill	No	Yes	No
8	31	10	FS	T	SN	3	3	1	VS		Fridge	*(***)	Chill	Yes	Yes	Yes
9	30	10	FS	T	SN	3	3	1	FS		Fridge	*(***)	Chill	Yes	Yes	Yes
10	31	10	FS	T	SN	3	3	1	FS		Fridge	*(***)	Chill	Yes	Yes	Yes
11	31	10	FS	T	SN	3	3	1	FS		Fridge	*(***)	Chill	Yes	Yes	Yes
12	21	10	FS	T	SN	3	3	1	VS		Fridge	*(***)	Chill	Yes	Yes	Yes
13	37	7	FS	T	SN	2	2	1	FS		Fridge	*(***)		Yes	Yes	
14	32	7	FS	T	SN	2	2	1	FS		Fridge	*(***)		Yes	Yes	
15	32	10	FS	T	SN	3	2	1	VS		Fridge	Chill	*(***)	No	No	Yes
16	31	7	FS	T	SN	2	2	1	VS		Fridge	*(***)		No	Yes	

Table 4: Overview of products in category 7, type II (double or more control), static and frost free

Number	Energy efficiency index (EN62552)	Appliance category	Appliance placement (FS=Free standing, BI=Built-in)	Max climate class	Min climate class	Number of compartments	Number of controls	Number of compressors	Compressor type (FS=Fixed speed, VS=Variable spee	Other product characteristics	Type of compartment 1	Type of compartment 2	Type of compartment 3	Forced air compartment 1	Forced air compartment 2	Forced air compartment 3
Cat 8-Static																
1	38	8	BI	T	SN	1	1	1	FS		*(***)			No		
2	44	8	FS	T	N	1	1	1	FS		*(***)					
3	46	8	FS	T	SN	1	1	1	FS	upright freezer	*(***)			No		
4	32	8	FS	T	SN	1	1	1	FS		*(***)			No		
5	24	8	FS	T	SN	1	1	1	VS		*(***)			No		
Cat 8-NF																
1	21	8	FS	T	SN	1	1	1	VS		*(***)			Yes		
2	22	8	FS	T	SN	1	1	1	VS		*(***)			Yes		
3	29	8	FS	T	SN	1	1	1	FS		*(***)			Yes		
4	47	8	FS	T	SN	1	1	1	FS	upright nf fre	*(***)			Yes		
5	35	8	FS	T	SN	1	1	1	FS		*(***)			Yes		
6	22	8	FS	T	SN	1	1	1	VS		*(***)			Yes		
7	34	8	BI	T	SN	1	1	1	VS		*(***)			Yes		
8	19	8	BI	T	SN	1	1	1	VS		*(***)			Yes		
9	25	8	BI	T	SN	1	1	1	FS		*(***)			Yes		
10	22	8	FS	T	SN	1	1	1	VS		*(***)			Yes		
11	47	8	FS	T	SN	1	1	1	FS		*(***)			Yes		
Cat 9																
1	34	9	FS	T	SN	1	1	1	FS	chest freezer	*(***)			No		
2	43	9	FS	T	SN	1	1	1	FS		*(***)			No		

Table 5: Overview of products in category 8 (upright freezers, static and Frost Free) and category 9 (chest freezers

3 COMPARISON OF ENERGY CONSUMPTION AND VOLUME

3.1 Discussion regarding the factor *F*

The interpolation factor *F* between the 16 and 32°C test can be looked at in different ways:

a) A simple procedure is to take the average of the two tests (so *F* = 0.5). Mathematically such factor *F*=0.5 equates to an ambient temperature of 24°C (linear interpolation).

b) One can calculate the factor which would be needed to get an average ambient temperature of 25°C by linear interpolation. This gives a factor *F*=0.4375.

c) One can analyse the energy consumption trend between 16 and 32°C and find the factor which results in the same energy consumption as a test at 25°C would yield. As the trend is not linear between these two temperatures, this does result in a different factor than 0.4375.

With respect to point c) there are two possibilities. One could analyse the trend by comparing experimental data. This has been performed in detail within SC59M/MT2 albeit with a different purpose, namely to derive correction factors for ambient test temperatures deviating from the nominal value. However, the experimental analysis performed is also valid for the discussion in this report. In Appendix B the experimental analysis is included.

A second possibility is to use a theoretical evaluation. Namely there are two fundamental physical effects which cause a specific trend in energy consumption as a function of the ambient temperature:

a) The heat load of a compartment scales approximately linearly with the temperature difference between ambient and target compartment temperatures.
b) The efficiency of any refrigeration system follows fundamentally the efficiency of a Carnot cycle. The Carnot cycle shows that the efficiency of pumping heat from a low to a high temperature reduces non-linearly with increasing temperature lift (defined as the temperature difference of the hot minus the cold side).

This analysis is carried out in appendix A.

The result of both the theoretical and experimental model, lead to the conclusion that a factor F=0.5 (interpolation temperature 24°C) yields on average the same result as a real test at 25°C. Consequently a factor *F*=0.4375 (interpolation temperature 25°C) gives an over prediction of the energy consumption at 25°C of app. 5 % (average of all categories).

In the meantime, within CENELEC, the work on a revision of EN62552 has started and consensus has been reached to use a factor *F*=0.4375 (interpolation temperature 25°C). Main reasons are:

1. An interpolation temperature of 24°C seems to relax the energy consumption test compared to today (though technical arguments are included in this report, these are fairly complex to demonstrate)
2. Simplicity (not the factor will be used in the communication but the linear interpolation temperature being 25°C)
3. As reference lines need to change for all categories in a future eco-design / label update, the average increase in energy consumption can easily be incorporated.

In this report, further a factor *F*=0.4375 (*Tk* = 25°C) is used.

3.2 Comparison of energy consumption and volume

As a first analysis the data of the products are collected and split over the different groups. For each product the energy consumption obtained with the new standard was compared with the energy consumption according the current standard (EN62552:2013) as baseline. The results are shown in Figure 1. Observations are made for each of the specific categories in the next subchapters.

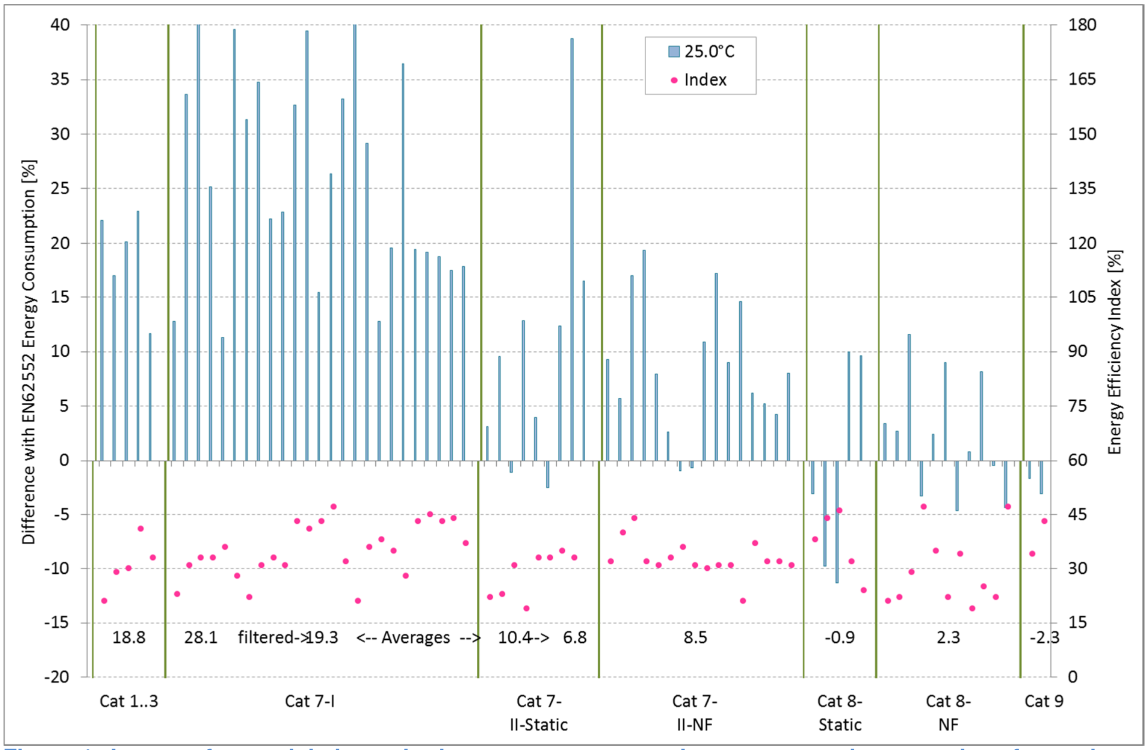

Figure 1: Impact of new global standard on energy consumption; average values are given for each group (for cat 7-I and Cat 7-II-static also averages after filtering are shown)

The red dots in the chart present the energy efficiency index of each product. As can be seen the products are well distributed between efficiency classes.

The measurement and definition of volume is also changed in the new global standard and have therefore been compared[5]. The results are shown in Figure 2 and are also discussed in the next subchapters. The volume increase of each compartment is given, so for products having three compartments, 3 columns are shown.

[5] Volume according the new global standard and storage volume according EN62552:2013.

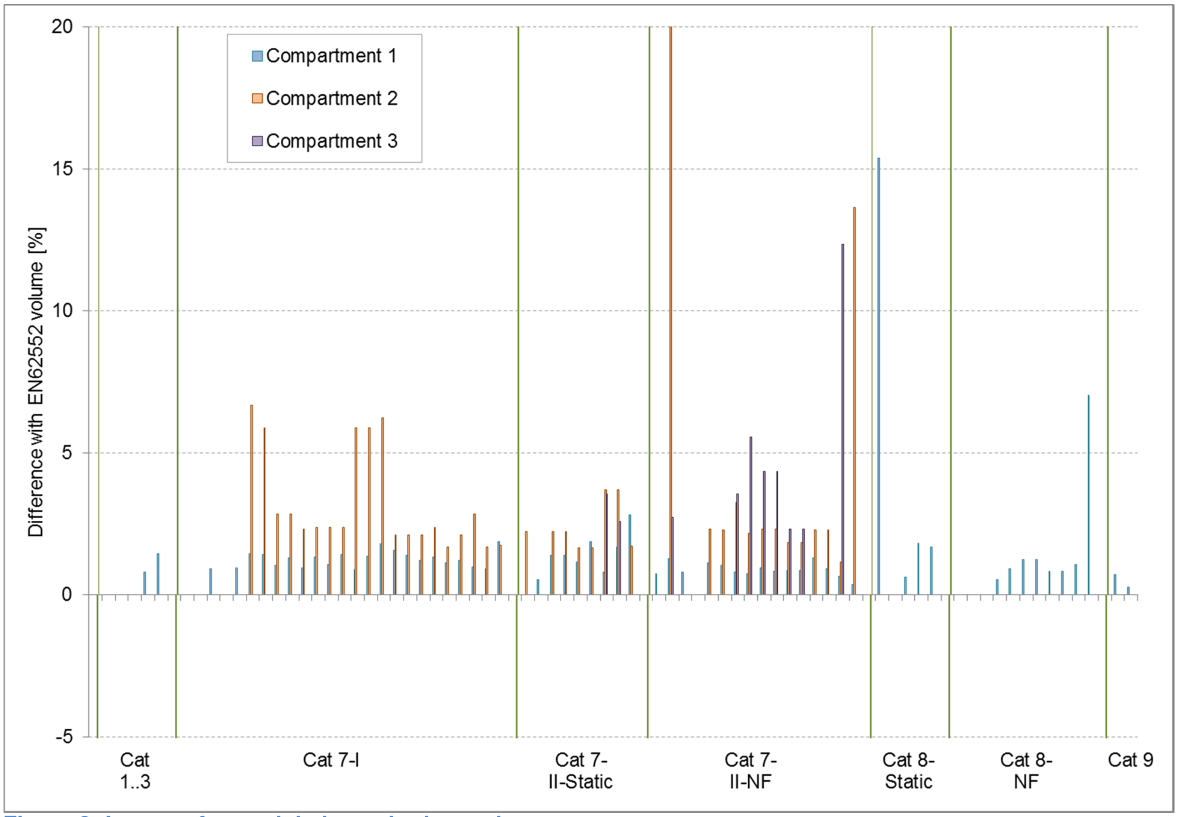

Figure 2: Impact of new global standard on volumes

3.2.1 Category 1

For the 5 fridges evaluated the average increase in consumption is (rounded) 19 % for *F*=0.4375[6]. This 19 % can be explained by the following effects:

- Reduction in fresh food target temperature from 5 to 4℃. On itself this is an increase in heat load of app. 5 % (at 25℃).
- Reduction in efficiency of the refrigeration system due to the lower compartment temperature.
- Effect that interpolation of 25℃ gives a higher consumption than an actual test at 25℃ (estimated at 7 % for fridges, see appendix A.)

On the volume the effect of the new global standard is very small or even absent.

3.2.2 Category 7, type I, static

Within this subcategory, 25 products where evaluated where the energy consumption increase shows a very wide spread, ranging from an increase as low as 12 % to as high as 75 %[7] with an average value of 28.1 %.

To better understand this large spread, a technical analysis has been performed which is included in appendix D. The conclusion of this analysis is that not all products are useful

[6] Which reduces to 12 % if *F*=0.5 would be used.
[7] The extreme case of 75 % (product 3) is for a fridge with a 4 star compartment inside which has an energy consumption at 16℃ app. equal to the consumption at 32℃ (659 versus 657 kWh/y) whereas the energy consumption at the current standard is 376 kWh/y. This is due to a heater being activated at 16℃

to estimate the impact of the global standard as these have been optimised against the current standard and will be optimised against the new standard once this is in place. In total 18 appliances were excluded due to these effects and 7 appliances remained where there is hardly any room for optimisation towards the new standard. The average energy consumption increase of these 7 products was 9 % (rounded).

As mentioned, to a certain extent manufacturers will be able to optimise the products towards the new standard, but within certain limitations. E.g. the appliance has to function correctly at the maximum and minimum ambient temperature (climate class) for which it is rated and which is verified by means of the storage temperature tests. These are carried out with load and here again the warmest package criterion applies[8]. Further a specification of a freezing capacity might need to be met. These issues limit the adaptations manufacturers can make towards evaporator sizes and the capacity of heaters.

The fact that manufacturers are able to improve these product is actually a strong positive aspect of the new standard as it increases the incentive to reduce additional heating power or add additional control elements (which will however increase product costs), which will finally reduce the energy consumption at consumers home.

The effect on volume is generally very small (max of 5 % for the frozen food compartments) as these products are typically equipped with smaller frozen food compartments (often without drawers) and the impact on the larger fresh food compartment is generally very small only.

3.2.3 Category 7, type II, static

For this type of product, 9 products have been evaluated. The average change in energy consumption is 10.4 %.

Also for these products a similar analysis can be made as for the type I products which is shown in Figure 3 (a similar picture is shown for type I products in appendix D). This shows the energy difference as function of the energy consumption ratio between 16°C and 32°C which should theoretically be around 40 % for optimally controlled appliances. For type II products, the results are indeed concentrated around 40 to 50 % of the energy consumption ratio which can be expected as the products are able to control temperatures at both ambient temperatures.

There is one exceptional case here, which is product 8 which had quite low freezer temperatures at both 16°C and 32°C ambient temperature, while the product was well controlled in the base line tests according the current standard. As it is expected that such product would be modified after the introduction of the new standard, it was further excluded. The average consumption increase of the remaining 8 products reduced to 7 % (rounded).

The increase in energy consumption is lower than for the refrigerators from category 1 to 3, which can be explained by the fact that the incremental energy for the fridge is compensated with a reduction for the freezer compartment. The final impact of the new global standard is of course dependent on the product design, which is shown here by the spread in results from -2 to +17 %.

[8] Suppose a product has climate class N-ST than a storage test at 16°C must be carried out with load, where the warmest temperature must be below -18°C. This means that adjusting the product so that the average of the freezer at 16°C is just -18°C is generally not feasible.

The effect on volume is again only small for this category, with maximum values of app. 3 %.

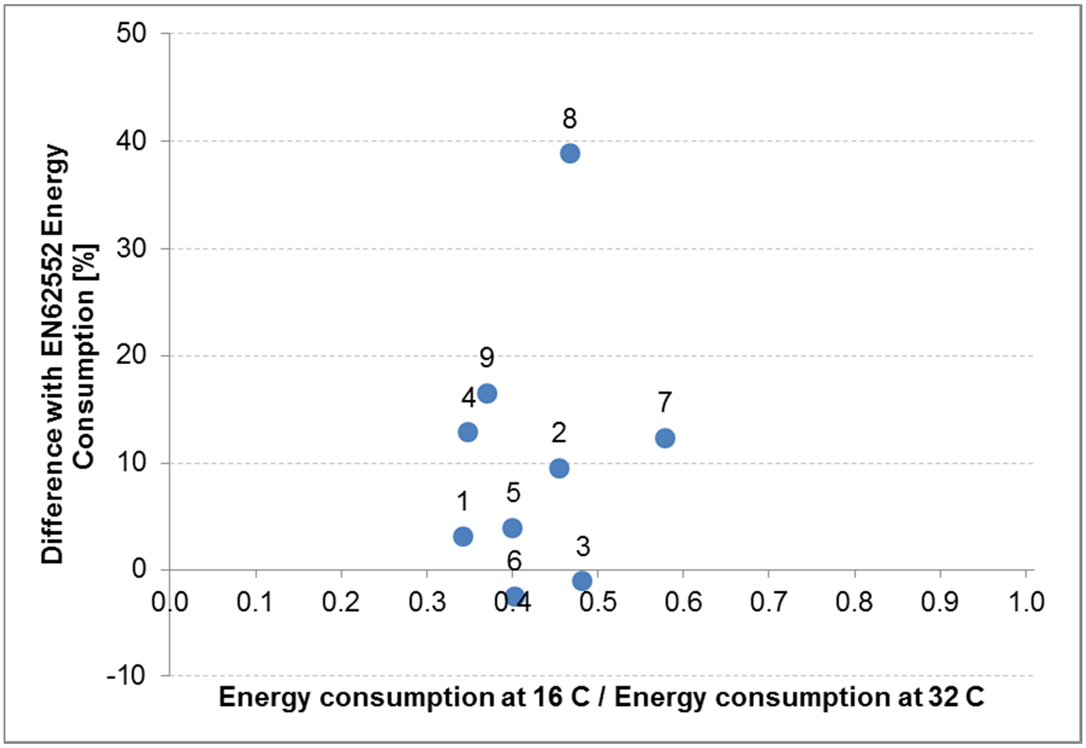

Figure 3: Energy consumption increase for category 7 type II-static appliances

3.2.4 Category 7, type II, Frost Free

For this subcategory, 16 products were evaluated having an average increase in consumption of (rounded) 9 %, which is higher than for the static products. This can be contributed to the higher impact of the defrost energy in the new standard (see appendix C). Namely the maximum defrost interval which can be used is more limited. According the current standard these products used time intervals of 48 or 72 hours while in the new standard this is shorter. Especially for very efficient products this has a large effect[9].

Again the products where analysed using the energy consumption ratio, which is shown in Figure 4. Here the products are again concentrated around 40 to 50 % of the energy consumption ratio which can be expected as the products are able to control temperatures at both ambient temperatures.

[9] Defrost energy is used to heat up the evaporator above zero and to melt the ice formed. The energy associated with this is relatively independent of the efficiency of the cold appliance itself, which means that the relative contribution of defrost increases for very low consuming cold appliances.

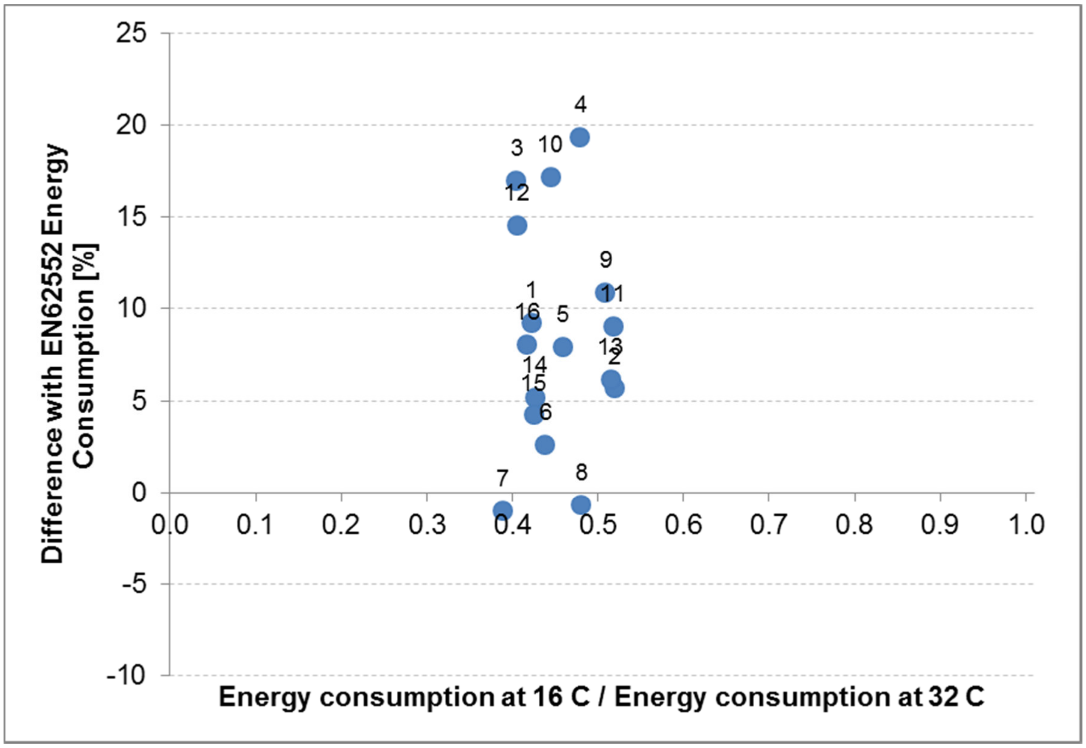

Figure 4: Energy consumption increase for category 7 type II-Frost Free appliances

The effect on volume is again only small for this category in general, where the relative differences represent mostly a few litres only. Exception is for the frozen food compartment of in total 3 appliances. Here the effect is significantly larger which is due to the fact that the measurement was done in the base-line tests with baskets in place, while in the new global standard these are not taken into account. In the current standard, mostly the volume is also declared without baskets unless testing without these is not feasible.

3.2.5 Category 8, static

Here 5 products were evaluated which had an average increase in energy consumption of (rounded) -1 % (so actually a reduction). This is the result of:

1. A higher average temperature in the freezer compartment in the new standard.
2. Effect that interpolation at 25℃ gives a higher consumption than an actual test at 25℃ (estimated at 3 to 5 % for freezers, see appendix A.)

The effect on volume differs per product. For product 1 a relatively high percentage is found (15 %), which can be contributed to the use of baskets in the current standard. The product is a relatively small (100 litre) freezer.

3.2.6 Category 8, Frost Free

The average effect on Frost Free upright freezers is (rounded) +2 % increase. Compared to the static versions, there is an additional negative impact due to the reduction in defrost interval. In the present standard these are tested with a defrost interval of 72 hours which reduced significantly for all products. As the defrost energy in relative sense becomes more important for low energy consuming products, the reduced defrost interval penalises the results further.

It can be expected that for the Frost Free appliances within this category the defrost algorithm will be adjusted by the manufacturer once the new standard is in place. This may slightly improve the results but, as the maximum defrost interval is more limited in the new standard, a penalty will remain compared to the current standard. This is on itself not a real problem. The current standard having intervals of 72 hours is also fairly unrealistic observing the normal use of such products. It does however support that maintaining a bonus for Frost Free frozen food compartments in the energy regulations, remains very relevant.

Again the impact on volume has been quite small for this category, as mostly the current declaration has also been performed without baskets.

3.2.7 Category 9

The data on chest freezers is limited to two products. These delivered on average a consumption reduction of (rounded) 2 %. Also here the advantage of the higher average compartment temperature is partly negated by the interpolation at 25°C which increases the consumption roughly by 3 to 5 %.

There is hardly any influence on volume for this type of product.

4 CONCLUSIONS

For this study a number of cold appliances have been experimentally evaluated with respect to the energy consumption under the current standard and with respect to the new global standard developed by IEC.

Energy consumption and volumes have been compared by making groups of products with different characteristics. This is necessary as due to the various changes, the impact of the new global standard is very different from one product to the other.

The new standard requires tests at 16°C and 32°C ambient and leaves open how the results should be interpolated. In this report, all results are interpolated at a temperature of 25°C (F=0.4375). It has been evaluated that, due to the curvature of energy consumption versus ambient temperature, this overestimates by approximately 5 % the energy consumption which would have been obtained from a real test at 25°C. If another interpolation temperature will be chosen, the results presented in this report need to be recalculated.

The following conclusions are derived from this study with respect to energy consumption.

1. For refrigerators (Category 1, 2 and 3) an average increase of 19 % has been found, for a large part due to the lower average fresh food compartment temperature in the new global standard.
2. For refrigerator-freezers (Category 7) with a single control (type I) a large spread in data has been found. Product adaptations to better match the new global standard are expected but will be limited. By filtering from the analysis those products which will likely be adapted, an average increase in consumption of 19 % has been found.
3. For static refrigerator-freezers with multiple controls (type II) an increase of 7 % was found. The new global standard advantages the frozen food compartment which results in this lower increase compared to the refrigerators group.
4. For frost-free refrigerator-freezers of type II an increase of 9 % was found. The difference with the previous group is the fact that the energy for defrost is more strongly taken into account in the new global standard.
5. For static upright freezers an average reduction of 1 % was found while for frost-free upright freezers an increase of 2 % was found. Again the difference can be contributed to different treatment of the energy needed for defrost.
6. For the chest freezers an average reduction of 2 % was noted.

With respect to volume it is concluded that in general the volumes increase as the definition of volume in the new standard is based on the volume being cooled. However, the increase in volume is generally fairly small, except for those cases where the storage volume is measured today taking baskets into account (which is only the case in a limited number of products).

It is of high importance that the new global standard will be considered in the next update of eco-design and energy labelling regulations. Several countries have already included the new global standard in their proposed regulation updates (e.g. China, Japan, Australia/New Zealand).

Obviously, due to the change in energy consumption when the new global standard is applied, a regulatory update should take converted energy consumption values into account, for which the data in this report is useful. CECED further proposes an update for categories and correction factors, which is presented in a separate note (see Re/genT note 15116 / CE12 / V6). In that note, also a data analysis is presented for each product category, taking into account the results from this study.

APPENDIX A THEORETICAL ANALYSIS OF ENERGY CONSUMPTION VERSUS AMBIENT TEMPERATURE

To evaluate the impact of the ambient temperature on the energy consumption of a domestic cold appliance it is possible to use a theoretical model based on the following physical fundamentals:

1. The heat flowing into a product is proportional to the temperature difference between ambient and inside of the product.
2. The efficiency of a refrigeration system reduces with increased temperature difference (lift) between the heat rejection side (the condenser) and the heat absorption side (the evaporator). As the refrigeration system is based on a reversed Rankine system it follows theoretically the efficiency as defined by Carnot.

Following these principles a mathematical, simplified, model of a cold appliance has been constructed.

The heat load of a product (multi compartment) is:

$$Q = \sum_{c=1}^{c=n} (UA)_c (T_a - T_c)$$

Where *UA* represents the appliance compartment conductance (W/K) and T_a and T_c the ambient and compartment temperature, respectively.

All calculations are carried out by using the 25°C ambient temperature case as reference or nominal case. Therefore the nominal heat load can be defined as follows:

$$Q^{nom} = \sum_{c=1}^{c=n} (UA)_c (25 - T_c)$$

This heat load needs to be adsorbed at the cold side heat exchanger (evaporator) and rejected (together with the compressor input) at the hot side (condenser). It is assumed that a certain temperature difference is needed between the compartment and the evaporator, respectively between the condenser and the ambient, to transfer this heat. It is assumed that these temperature differences remain constant over the ambient temperature. For standard compressors this may be more or less true as the increased heat load is compensated by increased running time percentages of the compressors. For variable capacity compressors, this is less correct as the temperature difference will change with the capacity. For the cold side the following formula is used:

$$T_{cold} = T_{ref} - \Delta T_{cold}^{nom}$$

The reference temperature T_{ref} should be chosen here as the coldest compartment present. The temperature difference ΔT_{cold} is taken as a nominal value at the 25 °C reference case, i.e. the temperature difference which occurs at 25°C ambient operation where $Q = Q^{nom}$.Typical values are used here for the different product categories.

For the hot side a similar relation is present here, where it should be noted that the hot side temperature also changes when the ambient temperature itself changes.

$$T_{hot} = T_a + \Delta T_{hot}^{nom}$$

For a reversed Rankine process, theoretically the maximum efficiency is defined by Carnot's relation. Based on the cold side efficiency the coefficient of performance (COP) is expressed as:

$$COP_{Carnot} = \frac{T_{cold} + 273.15}{T_{hot} - T_{cold}}$$

Where the temperatures must be given in °C. As no system reaches this maximum efficiency a Carnot efficiency ratio can be introduced in order to obtain the real system efficiency (COP):

$$COP = \eta_{Carnot} COP_{Carnot}$$

Once the heat load is known and the system efficiency, it is possible to calculate the power consumption (*P*) of the system by:

$$P = \frac{Q}{COP}$$

For convenience a reference can be made to the 25°C ambient case where the power consumption is:

$$P^{nom} = \frac{Q^{nom}}{COP^{nom}}$$

By dividing the power at any ambient temperature by the nominal power a non-dimensional power (or energy consumption) can be defined:

$$P^{*} = \frac{P}{P^{nom}}$$

This parameter has actually been charted in Figure 5, Figure 6 and Figure 7 as a function of the ambient temperature.

For the calculations the following values were used:

Parameter	Category 1	Category 8+9	Category 7
UA [W/K][10]	1	1	1
T_{ref} [°C]	4[11]	-18[12]	4 and -18
ΔT_{cold} [K]	15	10	8
ΔT_{hot} [K]	10	12	10
η_{Carnot}	0.6	0.6	0.6

Note that these values represent relatively well designed appliances with moderate temperature differences on the heat exchangers and a fairly high compressor efficiency.

[10] For the non-dimensional values which finally results, this value makes actually no difference.
[11] This calculation is made in view of the new global standard which defines 4°C as target for the fresh food compartment.
[12] This calculation is made in view of the new global standard which defines -18 °C for frozen food compartments.

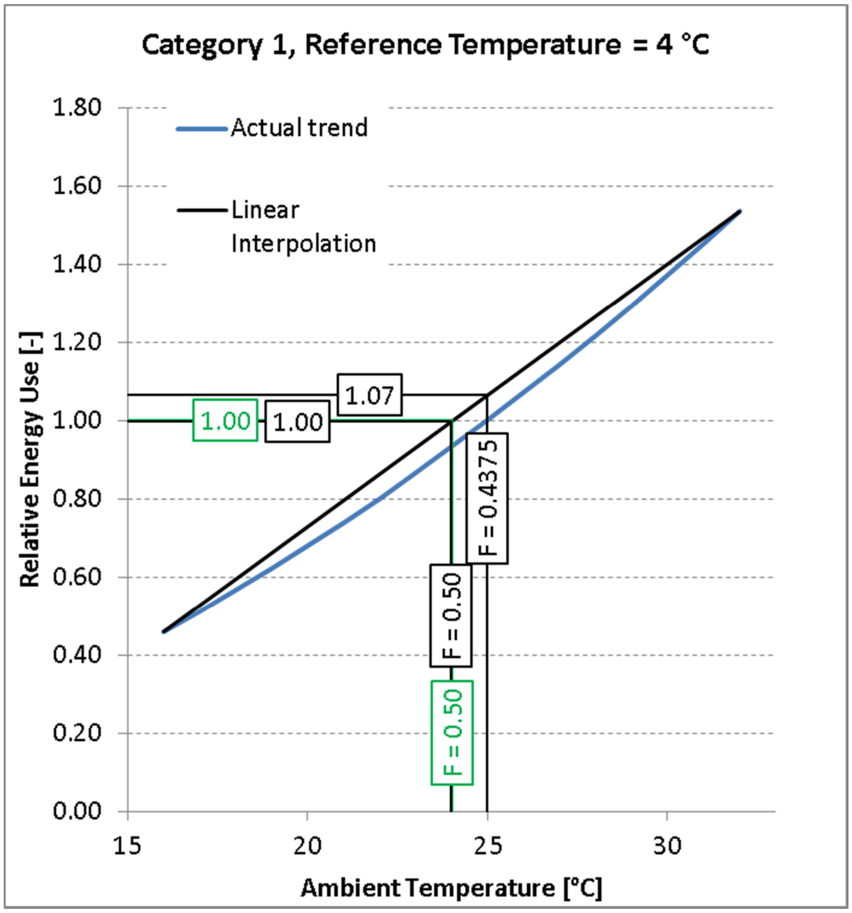

Figure 5: Effect of ambient temperature on energy consumption for fridges (relative to the consumption at 25°C which is set to 1.0).

As can be seen, for fridges one would need to use a factor *F*=0.5 to get equal energy consumption as a test of 25°C would reveal. If the linear relation would be applied (*F*=0.4375) the resulting energy consumption would be 7 % more.

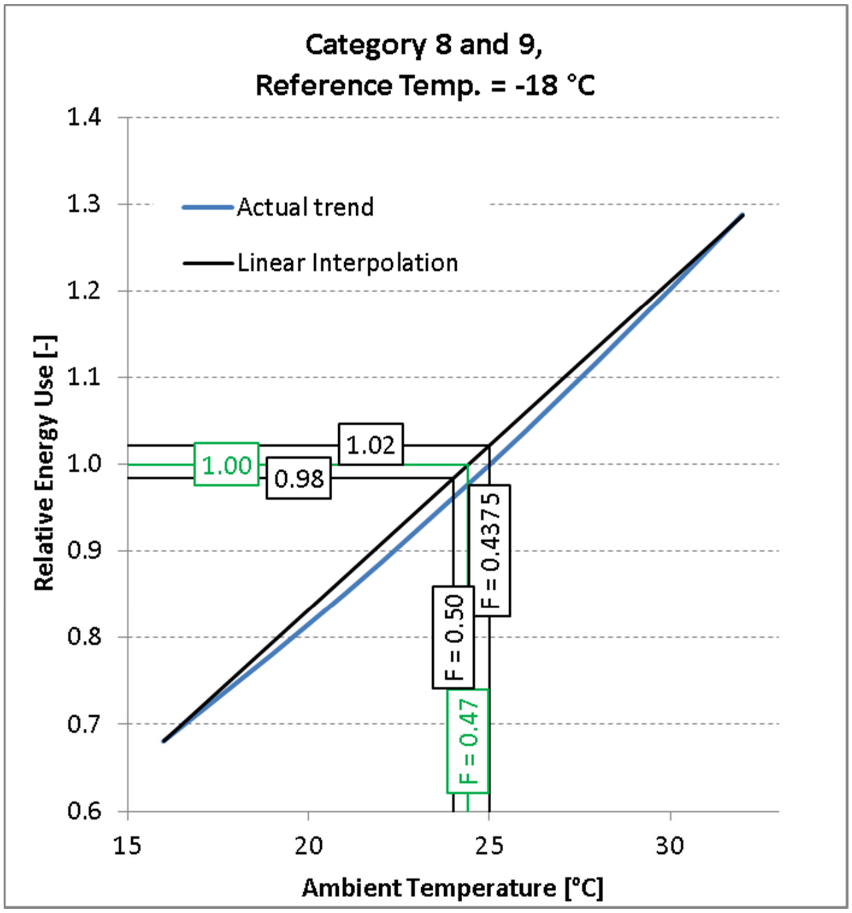

Figure 6: Effect of ambient temperature on energy consumption for upright and chest freezers (relative to the consumption at 25 °C which is set to 1.0).

For freezers the effect is significantly smaller and a factor *F*=0.47 would correspond with the 25 °C test condition. This difference with fridges is caused by the fact that the total temperature lift (from cold to hot side) changes less in relative sense for a freezer than for a fridge[13].

[13] E.g. if the ambient temperature increases 1 K this means for a fridge a relative increase of almost 5 % on the temperature difference between ambient (25°C) and target temperature (4°C). The same change results only in a relative increase of app. 2 % for a freezer (with target temperature of -18°C).

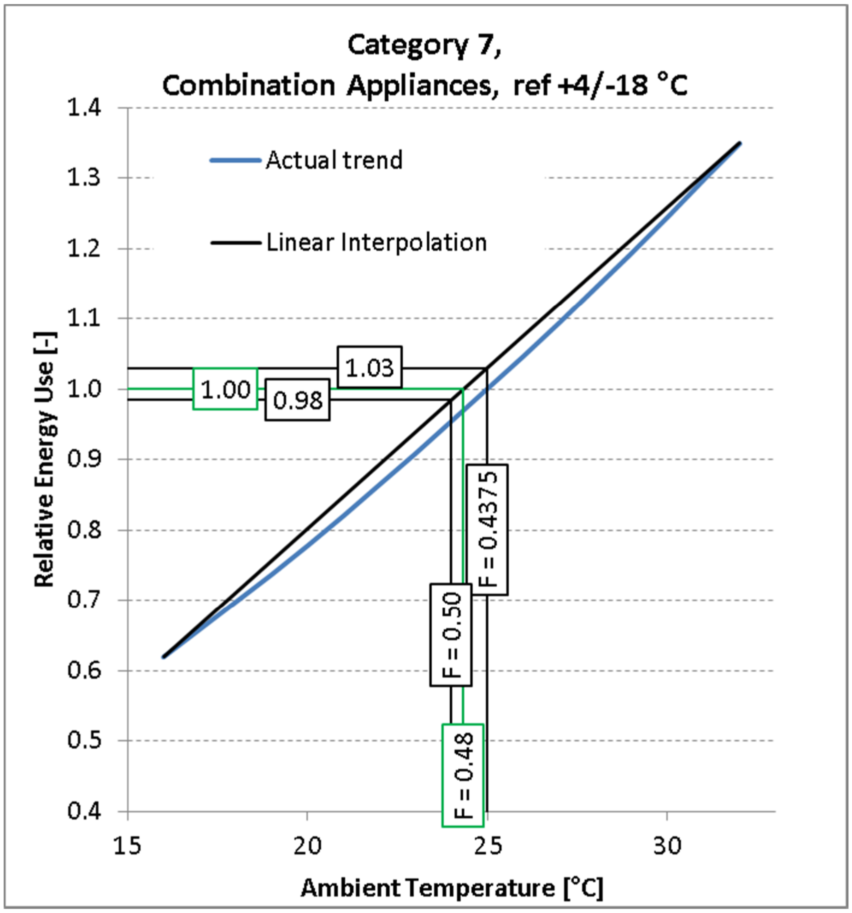

Figure 7: Effect of ambient temperature on energy consumption on combination appliances (relative to the consumption at 25 °C which is set to 1.0).).

For combination appliances a factor of *F*=0.48 is needed to get the same results as for the 25°C test. As can be expected this value is in between the factors found for the freezer and the fridge.

Concluding, the theoretical analysis justifies that a higher factor *F* is used than the linear one. Averaging all products, there is a basis for using a factor 0.5 for interpolating the energy consumption, despite the fact that this linearly equates to an ambient temperature of 24°C. This apparently seems to relax the test condition against a 25°C test, but it has been shown that this is not the case due to the non-linear fundamental trend in energy consumption as a function of ambient temperature.

To illustrate the validity of the theoretical model it has been compared with an experimental analysis (see appendix B). It is concluded that both models are well in line and support the remark that a factor *F* = 0.5 would yield similar results as a test performed at 25°C ambient.

Using a factor of 0.4375 (which correlates with an interpolation temperate of 25°C) would result in an average increase of 2 to 7 % depending on the category. Taking an average of both experimental analysis in appendix B and this theoretical model, a value of 5 % can be assumed.

APPENDIX B PRACTICAL ANALYSIS OF ENERGY CONSUMPTION VERSUS AMBIENT TEMPERATURE

For the evaluation of ambient correction factors a study was carried out within IEC59/MT (by L. Harrington) which was based on analysing the impact of the ambient temperature on the temperature consumption. This work was based on a large number of products from which consumption and temperature data was taken at various ambient temperatures. Data has been averaged from which trend lines were drawn. From these trend lines a correction factor formula was derived (see IEC 62552-3:20156). This formula can be seen as average trends for a large number of products where the trend differs depending on the compartment temperature and the type of appliance (1 or 2 compartments).

If this equation is used to calculate backwards the trend lines of energy consumption versus temperature (in relative sense to the consumption at 25°C), it is possible to draw similar graphs as presented in Figure 5, Figure 6 and Figure 7.

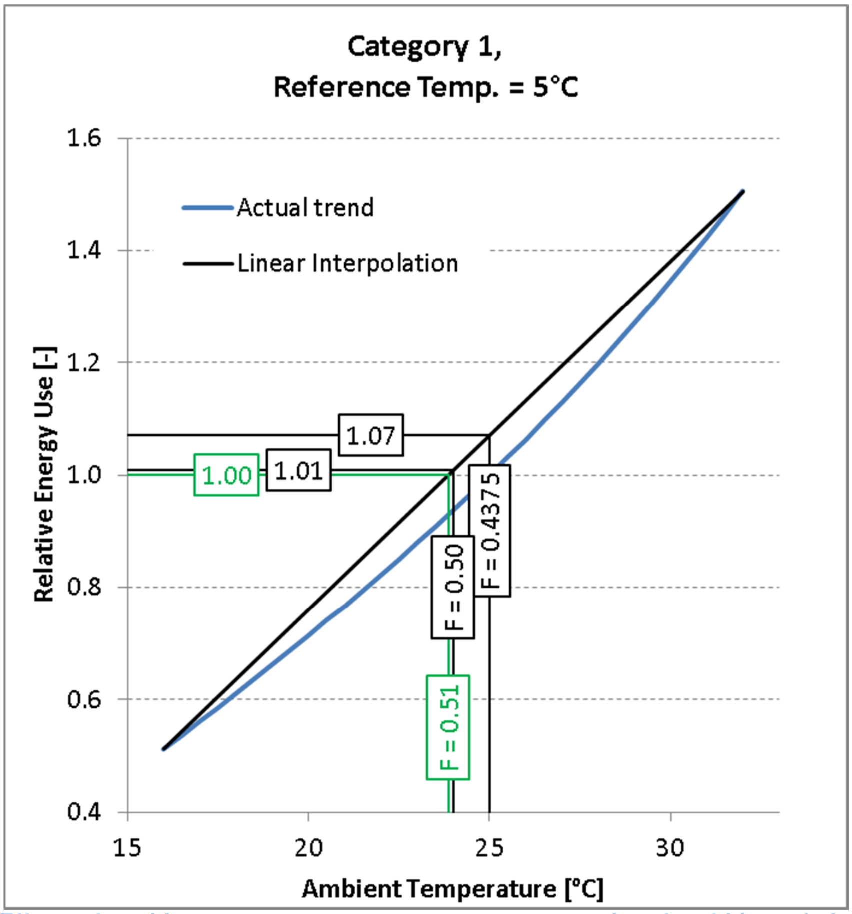

Figure 8: Effect of ambient temperature on energy consumption for fridges (relative to the consumption at 25 °C which is set to 1.0).

Compared to Figure 5 the curve is similar. The point where the interpolated consumption matches the 25°C ambient consumption is at *F*=0.51, whereas a value of 0.50 was found for the theoretical mode.

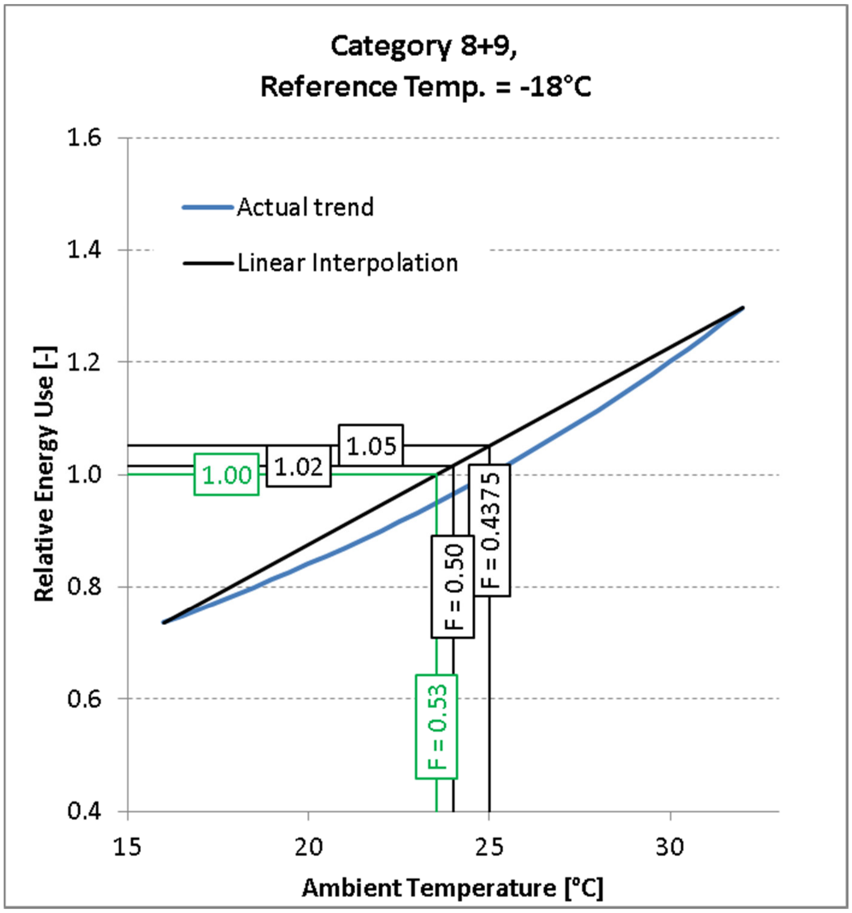

Figure 9: Effect of ambient temperature on energy consumption for freezers (relative to the consumption at 25 °C which is set to 1.0).

Also here a reasonable correlation with the theoretical model in Figure 6 is found. The point where the interpolated consumption matches the 25°C ambient consumption is at *F*=0.53, whereas a value of 0.47 was found for the theoretical mode showing that the curvature is stronger in the experimental data.

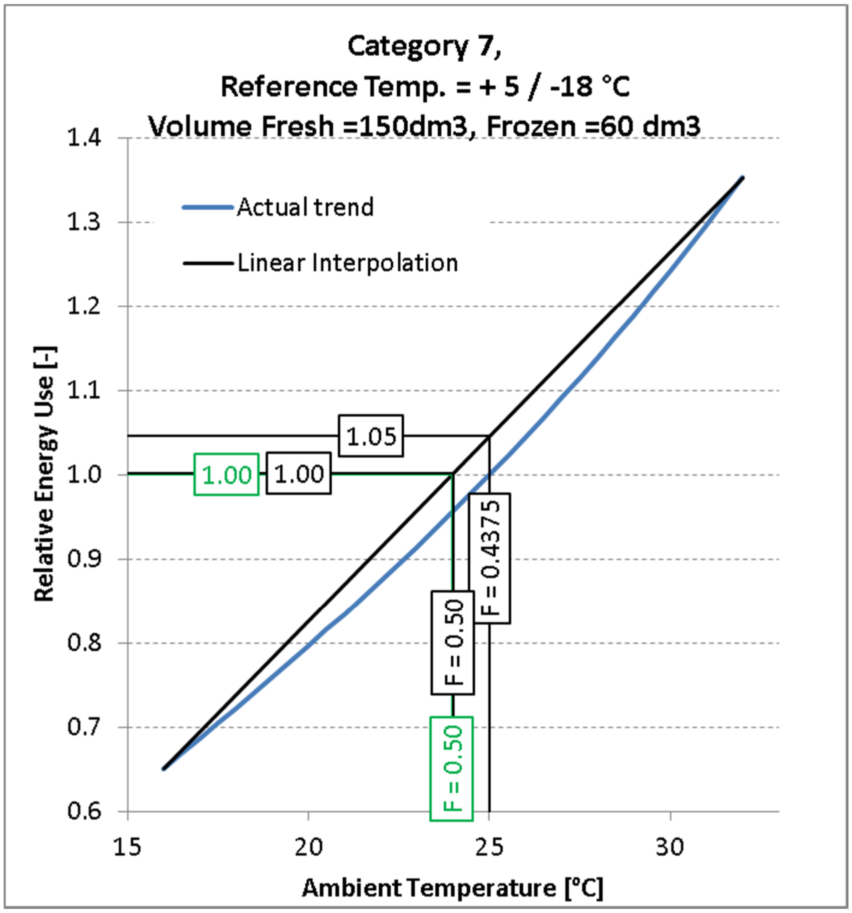

Figure 10: Effect of ambient temperature on energy consumption for combinations (relative to the consumption at 25 °C which is set to 1.0).

Compared to Figure 7 the curvature is again stronger. The predicted point where the interpolated energy consumption matches the 25°C ambient consumption is at *F*=0.5 versus 0.48 in the theoretical analysis.

APPENDIX C DEFROST INTERVAL

The measurement of defrost energy differs between the new global standard and EN62552:2013. The main differences are shown in the table below:

Aspect	*EN62552:2013*	*IE62552-3:2015*
Energy consumption	A test period must include at least one defrost and recovery period (which is called an operating cycle) and be longer than 24 h.	The test is split in two parts: a) a steady state part in which no defrost occurs b) a defrost and recovery part (including period prior to defrost) The two parts must be added together taking the defrost interval time into account.
Temperatures during defrost	During the test period it is allowed that temperatures increase above the compartment temperature for a limited duration (4 hours or 20 % of operating cycle) and for a maximum value of 3 K	Incremental temperatures during defrost must be calculated and are added to the temperatures during the steady state part (in a similar way as incremental energy is added).
Defrost interval time	For full frost-free (having air exchange between fresh food and frozen food) the maximum operating cycle length is 48 hours. For other frost free appliances the maximum length is 72 hours. The longer the defrost interval the smaller the impact of defrost energy.	Three possibilities: a) fixed time interval (as defined by the product hardware) b) fixed compressor run time (as defined by the product hardware) c) variable defrost For variable defrost the length of the defrost interval is not measured[14] but calculated based on two parameters which must be declared by the manufacturer (and which can be checked). These are the maximum and minimum defrost interval length at 32℃ ambient. Next a formula is used which gives a defrost interval time of 40 hour in the best case and 6 hours in the worst case. To obtain the 40 hours, the maximum defrost interval must be declared as 96 hours which may be difficult to achieve with full frost-free products. The defrost interval time at 16℃ is taken as the double value of the 32℃ case.

[14] In principle the defrost interval is not measurable as it depends on the history of the appliance (e.g. door openings, preceding temperature/humidity conditions etc.).

APPENDIX D ANALYSIS CATEGORY 7 TYPE I APPLIANCES

These product types showed a large spread in energy change when using the new global standard. To better understand this large spread, two type of analysis have been made.

The first one is based on the fact that for an optimal controlled system the energy consumption at 16℃ should be app. 40 % of the consumption at 32℃ for this category of appliance (see appendix A and B). Therefore it is interesting to plot the energy consumption increase versus this ratio of energy consumptions as shown in Figure 11.

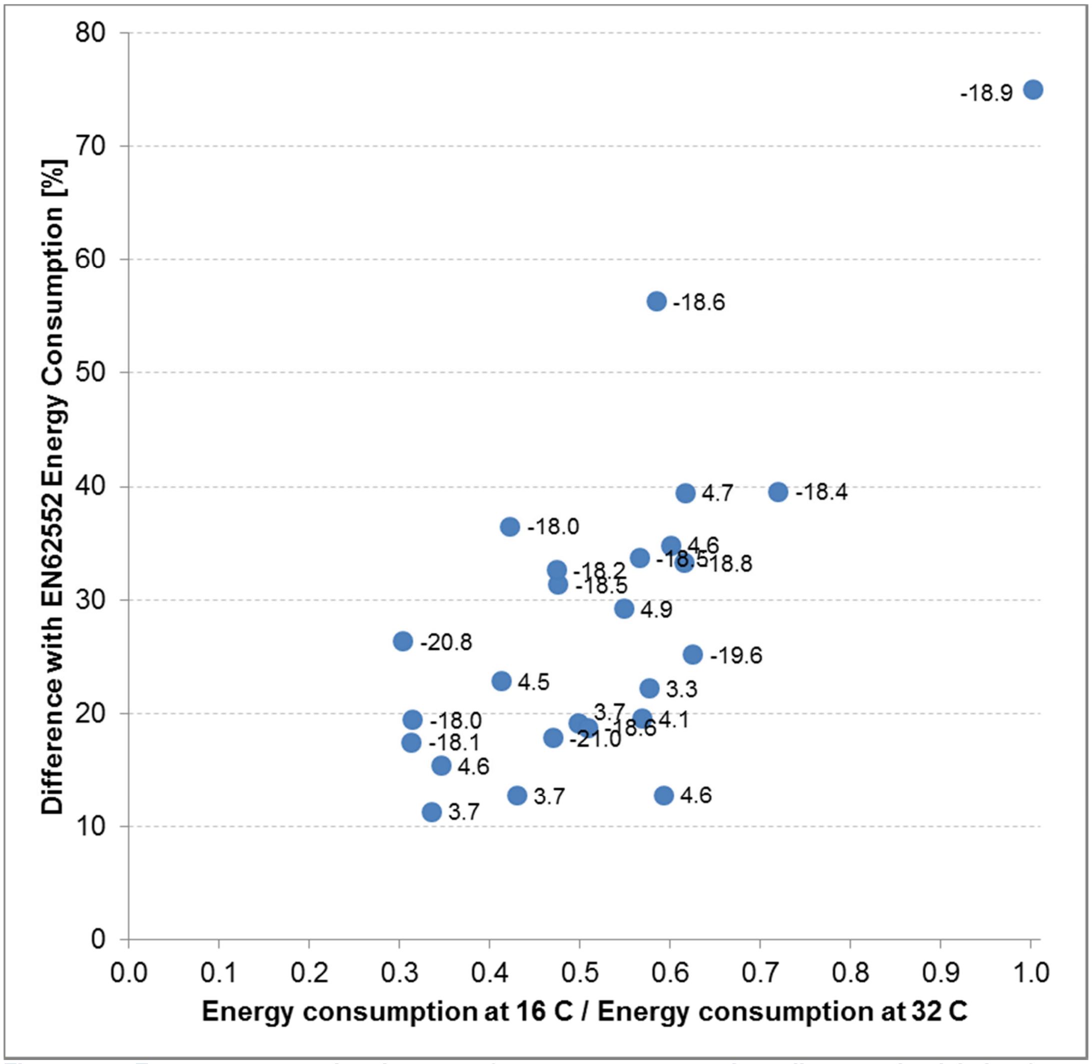

Figure 11: Energy consumption increase for category 7 type I appliances, the label refers to compartment temperatures in the base line test as explained in the text

Products having a ratio of around 0.6 and higher are most likely using some kind of heating device at 16℃ which increases the consumption. For each product also a label is shown in the diagram which represents data from the base line test (EN62552:2013) at 25 as follows:

- If the product is interpolated at 5℃, the label shows the interpolated frozen food compartment temperature (so always lower than -18℃).
- If the product is interpolated at a frozen food of -18℃, the label shows the interpolated fresh food temperature (so always lower than +5℃).

These temperatures at the base line test are relevant, as all products are assumed to have been optimised around the current test standard. If the fresh food compartment is below +5°C, this means that the product is actually running colder than needed and is therefore automatically closer to the new +4°C target in the new global standard. Hence the energy consumption increase becomes smaller. Products showing a low fresh food compartment temperature are indeed mostly present at the lower part of the chart.

Contrary, products with a low frozen food compartment temperature (which means that interpolation has taken place on the fresh food temperature), will become even colder in the new standard, so the energy consumption increase will be higher. Most of such products are indeed present in the upper part of the diagram.

A second analysis is made by plotting the tests at 16 and 32°C in a chart with the frozen food compartment temperature on the x-axis and the daily energy consumption as y-axis (this for all 25 products evaluated which have been split over 2 diagrams for visualisation). For all products the interpolation has taken place at 4°C fresh food temperature as the frozen food was always sufficiently cold[15]. This gives the diagrams shown in Figure 12. There are some conclusions which can be drawn from this figure:

1. In practically all cases the frozen food compartment is significantly colder than needed. This is not unexpected; all products have been designed for a -18°C warmest package while in the new global standard the average of the compartment is measured.
2. Theoretically a test at 16°C ambient should have about 40 % of the energy consumption of the test at 32°C and the frozen food compartment temperature should be higher than at 32°C. This means that a decreasing line is expected from the red to the blue dot. Many lines are quite different however, meaning that some other mechanism is influencing (e.g. heaters at 16°C, which drive up the consumption and make the frozen food compartment colder).
3. In several cases optimisation towards the new global standard is feasible, which means that not all measured energy consumption increases are representative for the actual effect which can be expected after implementation of the new standard.

In order to still get an impression of the impact of the standard the products were filtered:

1. All products where the frozen food at 16°C ambient has been below -20°C are excluded which filters out products where the balance temperature can be adjusted in the direction of warmer frozen food compartments.
2. All products where the ratio of energy consumption at 16 versus 32°C is larger than 60 % are excluded which likely filters out the use of heaters.

In total 7 products remained and their average increase was 19 % (rounded).

[15] With only one exception, the test at 16°C for appliance 14 was interpolated on the frozen food compartment of -18°C and in that particular case the fresh food was +3.5°C.

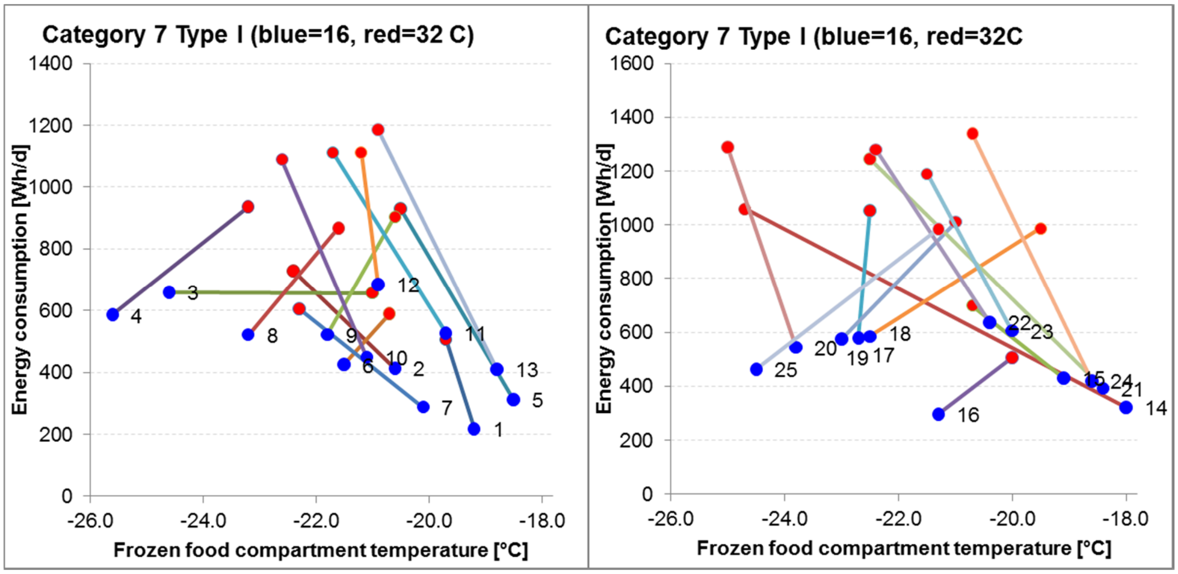

Figure 12: Energy consumption for cat 7 type I appliances using the new global standard, the red dots are at 32 °C and the blue dots at 16 °C ambient temperature. The numbers refer to the product.

APPENDIX E DETAILED TEST DATA

Please zoom this table to about 300 % to make the data readable

First factor 0.4375

Number	Data according present standard EN153/ISO15502	Energy consumption [Wh/d]	Compressor running time percentage [%]	Defrost interval length [h]	Temperature compartment 1 [°C]	Temperature compartment 2 [°C]	Temperature compartment 3 [°C]	Target temperature compartment 1 [°C]	Target temperature compartment 2 [°C]	Target temperature compartment 3 [°C]	Compressor running time percentage [%]	Volume compartment1 [dm3]	Volume compartment2 [dm3]	Volume compartment3 [dm3]	Adjusted volume [dm3]	Energy efficiency index [%]	Data according new global standard (IEC62552-1,-2	Target temperature compartment 1 [°C]	Target temperature compartment 2 [°C]	Target temperature compartment 3 [°C]	Volume compartment1 [dm3]	Volume compartment2 [dm3]	Volume compartment3 [dm3]	Volume difference compartment 1 [%]	Volume difference compartment 2 [%]	Volume difference compartment 3 [%]	Data according new global standard at 16 C ambien	Energy consumption [Wh/d]	Compressor running time percentage [%]	Defrost interval length [h]	Temperature compartment 1 [°C]	Temperature compartment 2 [°C]	Temperature compartment 3 [°C]	Data according new global standard at 32 C ambien	Energy consumption [Wh/d]	Compressor running time percentage [%]	Defrost interval length [h]	Temperature compartment 1 [°C]	Temperature compartment 2 [°C]	Temperature compartment 3 [°C]	Final energy consumption new standard [Wh/d]	Difference compared to current standard [%]
Cat 1..3																								0																		0
1		224.0	20.6	13.0	5.0	1.4		5.0	0.0			200.0	105.0		397.5	21.1		4.0	2.0		200.0	105.0		0.0	0.0			120.0	12.7	15.2	4.0	0.8			393.0	34.2	15.2	4.0	0.8		273.6	22.1
2		276.0	17.0		5.0			5.0				346.0			415.2	29.5		4.0			346.0			0.0				166.0	10.0		4.0				445.0	26.0		4.0			322.9	17.0
3		250.0	19.0		5.0			5.0				174.0			250.6	30.1		4.0			174.0			0.0				136.0	14.0		4.0				428.0	36.0		4.0			300.3	20.1
4		352.0			5.0			5.0				252.0			302.4	40.7		4.0			254.0			0.8				205.0			4.0				610.0			4.0			432.8	23.0
5		307.0			5.0			5.0				346.0			415.2	32.8		4.0			351.0			1.4				182.0			4.0				468.0			4.0			342.9	11.7
Cat 7-I																								0																		0
1		337.0	54.5		3.7	-18.0		5.0	-18.0			175.0	18.0		307.7	22.7		4.0	-18.0		175.0	18.0		0.0	0.0			218.0	23.8		4.0	-19.2			506.0	61.0		4.0	-19.7		380.0	12.8
2		442.0	33.0		5.0	-18.5		-18.0	5.0			16.0	180.0		283.0	30.9		-18.0	4.0		16.0	180.0		0.0	0.0			413.0	25.0		4.0	-20.6			729.0	57.0		4.0	-22.4		590.8	33.7
3		376.0			5.0	-18.9		5.0	-18.0			108.0	14.0		151.9	32.6		4.0	-18.0		109.0	14.0		0.9	0.0			659.0			4.0	-24.6			657.0			4.0	-21.0		657.9	75.0
4		626.0	34.7		5.0	-19.6		5.0	-18.0			215.0	94.0		500.5	33.0		4.0	-18.0		215.0	94.0		0.0	0.0			586.0	33.0		4.0	-25.6			937.0	53.3		4.0	-23.2		783.4	25.1
5		593.0	216.4		3.7	-18.0		5.0	-18.0			215.0	63.0		385.5	35.9		4.0	-18.0		217.0	63.0		0.9	0.0			312.0			4.0	-18.5			931.0			4.0	-20.5		660.2	11.3
6		371.0			5.0	-18.4		5.0	-18.0		33.0	139.0	15.0		226.1	28.3		4.0	-18.0		141.0	16.0		1.4	6.7			425.0			4.0	-21.5			590.0			4.0	-20.7		517.8	39.6
7		355.0			5.0	-18.5		5.0	-18.0		55.0	214.0	34.0		379.0	21.7		4.0	-18.0		217.0	36.0		1.4	5.9			288.0			4.0	-20.1			605.0			4.0	-22.3		466.3	31.4
8		531.0			4.6	-18.0		5.0	-18.0			194.0	70.0		413.4	31.0		4.0	-18.0		196.0	72.0		1.0	2.9			521.0	25.0		4.0	-23.2			867.0	44.0		4.0	-21.6		715.6	34.8
9		603.0			3.3	-18.0		5.0	-18.0			230.0	70.0		456.6	33.5		4.0	-18.0		233.0	72.0		1.3	2.9			522.0	24.0		4.0	-21.8			904.0	45.0		4.0	-20.6		736.9	22.2
10		659.0			4.5	-18.0		5.0	-18.0			315.0	86.0		599.9	31.3		4.0	-18.0		318.0	88.0		1.0	2.3			450.0	23.0		4.0	-21.1			1089.0	54.0		4.0	-22.6		809.4	22.8
11		645.0			5.0	-18.2		5.0	-18.0		32.0	152.0	42.0		319.8	42.7		4.0	-18.0		154.0	43.0		1.3	2.4			527.0	24.0		4.0	-19.7			1111.0	46.0		4.0	-21.7		855.5	32.6
12		663.0			4.7	-18.0		5.0	-18.0		34.0	187.0	42.0		366.0	41.2		4.0	-18.0		189.0	43.0		1.1	2.4			685.0	27.0		4.0	-20.9			1111.0	55.0		4.0	-21.2		924.6	39.5
13		733.0			4.6	-18.0		5.0	-18.0		31.0	214.0	42.0		401.7	43.5		4.0	-18.0		217.0	43.0		1.4	2.4			410.0	22.0		4.0	-18.8			1185.0	58.0		4.0	-20.9		845.9	15.4
14		583.0			5.0	-20.8		5.0	-18.0			114.0	17.0		198.7	46.5		4.0	-18.0		115.0	18.0		0.9	5.9			322.0			3.5	-18.0			1059.0			4.0	-24.7		736.6	26.3
15		437.0			5.0	-18.8		5.0	-18.0			147.0	17.0		242.3	32.5		4.0	-18.0		149.0	18.0		1.4	5.9			431.0			4.0	-19.1			700.0			4.0	-20.7		582.3	33.3
16		265.0			5.0	-18.6		5.0	-18.0			111.0	16.0		191.9	21.4		4.0	-18.0		113.0	17.0		1.8	6.3			296.0			4.0	-21.3			506.0			4.0	-20.0		414.1	56.3
17		655.0			4.9	-18.0		5.0	-18.0			194.0	94.0		475.3	35.6		4.0	-18.0		197.0	96.0		1.5	2.1			579.0			4.0	-22.7			1054.0			4.0	-22.5		846.2	29.2
18		719.0			4.6	-18.0		5.0	-18.0			215.0	94.0		500.5	37.9		4.0	-18.0		218.0	96.0		1.4	2.1			585.0			4.0	-22.5			987.0			4.0	-19.5		811.1	12.8
19		686.0			4.1	-18.0		5.0	-18.0			250.0	94.0		542.5	34.6		4.0	-18.0		253.0	96.0		1.2	2.1			575.0			4.0	-23.0			1011.0			4.0	-21.0		820.3	19.6
20		706.0			5.0	-18.0		5.0	-18.0			379.0	126.0		779.9	28.3		4.0	-18.0		384.0	129.0		1.3	2.4			545.0			4.0	-23.8			1289.0			4.0	-25.0		963.5	36.5
21		730.0			5.0	-18.0		5.0	-18.0		38.0	178.0	60.0		405.2	43.1		4.0	-18.0		180.0	61.0		1.1	1.7			392.0			4.0	-18.4			1245.0			4.0	-22.5		871.8	19.4
22		838.0			3.7	-18.0		5.0	-18.0		440.0	167.0	95.0		490.1	44.7		4.0	-18.0		169.0	97.0		1.2	2.1			637.0			4.0	-20.4			1280.0			4.0	-22.4		998.7	19.2
23		787.0			5.0	-18.6		5.0	-18.0		40.0	205.0	70.0		469.3	43.0		4.0	-18.0		207.0	72.0		1.0	2.9			606.0			4.0	-20.0			1190.0			4.0	-21.5		934.5	18.7
24		798.0			5.0	-18.1		5.0	-18.0		41.0	217.0	60.0		456.7	44.3		4.0	-18.0		219.0	61.0		0.9	1.7			420.0			4.0	-18.6			1340.0			4.0	-20.7		937.5	17.5
25		642.0	48.6		5.0	-21.0		5.0	-18.0		48.6	219.0	81.0		432.5	36.7		4.0	-18.0		223.1	82.4		1.9	1.7			463.0	38.5		4.0	-24.5			985.0	72.7		4.0	-21.3		756.6	17.9
Cat 7-II-Static																								0																		0
1		422.0	62.1		5.0	-18.0		5.0	-18.0			247.0	89.0		526.0	21.6		4.0	-18.0		247.0	91.0		0.0	2.2			209.0	31.6		4.0	-18.0			611.0	75.6		4.0	-18.0		435.1	3.1
2		410.0			5.0	-18.0		5.0	-18.0			191.0	91.0		464.0	22.6		4.0	-18.0		192.0	91.0		0.5	0.0			268.0			4.0	-18.0			590.0			4.0	-18.0		449.1	9.5
3		571.0			5.0	-18.0		5.0	-18.0		28.0	215.0	89.0		487.6	30.6		4.0	-18.0		218.0	91.0		1.4	2.2			352.0			4.0	-18.0			730.0			4.0	-18.0		564.6	-1.1
4		358.0			5.0	-18.0		5.0	-18.0		58.0	215.0	89.0		487.6	19.2		4.0	-18.0		218.0	91.0		1.4	2.2			197.0			4.0	-18.0			565.0			4.0	-18.0		404.0	12.8
5		555.0			4.9	-18.0		5.0	-18.0		42.0	172.0	61.0		400.2	33.0		4.0	-18.0		174.0	62.0		1.2	1.6			313.0			4.0	-18.0			782.0			4.0	-18.0		576.8	3.9
6		613.0			5.0	-18.0		5.0	-18.0		47.0	211.0	61.0		492.7	32.6		4.0	-18.0		215.0	62.0		1.9	1.6			326.0			4.0	-18.0			809.0			4.0	-18.0		597.7	-2.5
7		585.0			5.0	-18.0	2.0	5.0	-18.0	0.0	52.0	127.0	27.0	56.0	336.7	34.7		4.0	-18.0	2.0	128.0	28.0	58.0	0.8	3.7	3.6		466.0			4.0	-23.0	2.0		806.0			3.9	-22.9	-0.6	657.3	12.4
8		624.0			5.0	-18.0	2.2	5.0	-18.0	0.0	70.0	180.0	27.0	77.0	441.3	32.7		4.0	-18.0	2.0	183.0	28.0	79.0	1.7	3.7	2.6		528.0			4.0	-21.0	1.8		1129.0			4.0	-25.0	0.8	866.1	38.8
9		507.0			4.6	3.0	-19.6	5.0	0.0	-18.0		106.0	59.0	16.0	282.7	32.3		4.0	2.0	-18.0	109.0	60.0	16.0	2.8	1.7	0.0		302.0			3.4	2.0	-18.8		815.0			3.8	0.9	-18.0	590.6	16.5
Cat 7-II-NF																								0																		0
1		679.0		72.0	5.0	-18.0		5.0	-18.0			275.0	89.0		605.5	32.0		4.0	-18.0		277.0	89.0		0.7	0.0			419.0		80.0	4.0	-18.0			993.0		40.0	4.0	-18.0		741.9	9.3
2		1237.0	43.3	48.0				5.0	-18.0	-12.0		384.1	173.1	29.2	1074.6	39.7		4.0	-18.0	-12.0	389.0	210.0	30.0	1.3	21.3	2.7		860.0		24.0	4.0	-20.4			1655.0		24.0	4.0	-18.8		1307.2	5.7
3		817.0		72.0	5.0	-18.0		5.0	-18.0			250.0	60.0		485.8	43.8		4.0	-18.0		252.0	60.0		0.8	0.0			523.0		80.0	4.0	-18.0			1292.0		40.0	4.0	-18.0		955.6	17.0
4		693.0	36.8	54.0	5.0	1.5	-18.0	5.0	0.0	-18.0		223.0	23.0	86.0	568.4	31.8		4.0	2.0	-18.0	223.0	23.0	86.0	0.0	0.0	0.0		513.4	26.1	15.0	4.0	2.0	-18.0		1071.0	52.4	20.8	4.0	2.0	-18.0	827.0	19.3
5		642.0		48.0	5.0	-18.0		5.0	-18.0		38.0	268.0	86.0		587.9	30.8		4.0	-18.0		271.0	88.0		1.1	2.3			416.9		26.0	4.0	-18.0			908.0		48.0	4.0	-18.0		693.1	8.0
6		627.0		48.0	5.0	-18.0		5.0	-18.0			194.0	87.0		502.2	33.0		4.0	-18.0		196.0	89.0		1.0	2.3			374.0		28.0	4.0	-18.0			853.0		28.0	4.0	-18.0		643.4	2.6
7		711.0		72.0	5.0	-18.0	1.8	5.0	-18.0	0.0	69.0	128.0	61.0	56.0	469.1	36.2		4.0	-18.0	2.0	129.0	63.0	58.0	0.8	3.3	3.6		373.7		36.0	4.0	-20.5	-1.0		961.0		36.0	4.0	-20.1	-0.6	704.0	-1.0
8		738.0		48.0	5.0	-18.0	2.3	5.0	-18.0	0.0	70.0	267.0	92.0	36.0	659.2	31.1		4.0	-18.0	2.0	269.0	94.0	38.0	0.7	2.2	5.6		455.9		25.0	4.0	-18.0			949.0		49.0	4.0	-18.0		733.3	-0.6
9		647.0		48.0	5.0	-18.0	2.1	5.0	-18.0	0.0	35.0	211.0	86.0	23.0	554.0	30.1		4.0	-18.0	2.0	213.0	88.0	24.0	0.9	2.3	4.3		465.0		24.0	4.0	-19.2			914.0		40.0	4.0	-19.1		717.6	10.9
10		693.0		48.0	5.0	-18.0	2.0	5.0	-18.0	0.0		246.0	86.0	23.0	596.0	31.0		4.0	-18.0	2.0	248.0	88.0	24.0	0.8	2.3	4.3		477.0		28.0	4.0	-18.0			1073.0		28.0	4.0	-18.0		812.3	17.2
11		831.0		48.0	5.0	-18.0	2.5	5.0	-18.0	0.0		355.0	108.0	43.0	824.9	30.5		4.0	-18.0	2.0	358.0	110.0	44.0	0.8	1.9	2.3		595.0		28.0	4.0	-18.0			1148.0		28.0	4.0	-18.0		906.1	9.0
12		561.0		48.0	5.0	-18.0	2.7	5.0	-18.0	0.0		355.0	108.0	43.0	824.9	20.6		4.0	-18.0	2.0	358.0	110.0	44.0	0.8	1.9	2.3		352.0		28.0	4.0	-18.0			869.0		28.0	4.0	-18.0		642.8	14.6
13		743.0		48.0	5.0	-18.0		5.0	-18.0			233.0	87.0		549.0	37.2		4.0	-18.0		236.0	89.0		1.3	2.3			516.0		28.0	4.0	-18.0			1001.0		28.0	4.0	-18.0		788.8	6.2
14		631.0		48.0	5.0	-18.0		5.0	-18.0			216.0	87.0		528.6	32.3		4.0	-18.0		218.0	89.0		0.9	2.3			378.0		28.0	4.0	-18.0			886.0		28.0	4.0	-18.0		663.8	5.2
15		708.0		> 72	5.0	2.9	-18.0	5.0	0.0	-18.0		157.0	86.0	89.0	592.9	31.8		4.0	2.0	-18.0	158.0	87.0	100.0	0.6	1.2	###		419.0		80.0	4.0	2.0	-18.0		986.0		40.0	4.0	1.2	-18.0	737.9	4.2
16		654.0		> 72	5.0	-18.0		5.0	-18.0			276.0	88.0		603.6	30.9		4.0	-18.0		277.0	100.0		0.4	13.6			396.0		80.0	4.0	-18.0			948.2		40.0	4.0	-18.0		706.6	8.0
Cat 8-Static																								0																		0
1		481.0	38.4					-18.0				91.0			281.7	37.6		-18.0			105.0			15.4				320.0	21.0		-18.0				580.0	39.6		-18.0			466.3	-3.1
2		506.0	34.0					-18.0				78.0			201.2	43.6		-18.0			78.0			0.0				322.0	21.0		-18.0				561.0	34.0		-18.0			456.4	-9.8
3		668.0			-18.0			-18.0				158.0			407.6	45.6		-18.0			159.0			0.6				373.0			-18.0				763.0			-18.0			592.4	-11.3
4		540.0			-18.0						33.0	220.0			567.6	31.7		-18.0			224.0			1.8				402.0			-22.0				743.0			-20.7			593.8	10.0
5		424.0			-18.0						72.0	237.0			611.5	24.0		-18.0			241.0			1.7				282.0			-20.1				607.0			-19.8			464.8	9.6
Cat 8-NF																								0																		0
1		534.0	61.6	72.0	-18.0			-18.0				360.0			1114.6	21.3		-18.0			360.0			0.0				332.6	48.0	16.7	-18.0				723.0	68.4	25.3	-18.0			552.2	3.4
2		473.0	55.0	72.0	-18.0			-18.0				286.0			885.5	21.8		-18.0			286.0			0.0				305.6	35.0	16.7	-18.0				626.0	45.0	25.3	-18.0			485.8	2.7
3		719.0	40.0	72.0	-18.0			-18.0				360.0			1114.6	28.7		-18.0			360.0			0.0				562.6	28.0	16.7	-18.0				989.0	48.0	25.3	-18.0			802.5	11.6
4		815.0		72.0	-18.0			-18.0				188.0			582.0	47.3		-18.0			189.0			0.5				512.0		80.0	-18.0				1004.0		40.0	-18.0			788.8	-3.2
5		651.0		72.0	-18.0			-18.0			33.0	220.0			681.1	34.8		-18.0			222.0			0.9				492.7		36.0	-19.6				802.0		36.0	-19.6			666.7	2.4
6		510.0		72.0	-18.0			-18.0			66.0	323.0			1000.0	21.8		-18.0			327.0			1.2				343.7		36.0	-20.5				721.0		36.0	-19.2			555.9	9.0
7		587.0		72.0	-18.0			-18.0			44.0	160.0			594.4	33.7		-18.0			162.0			1.3				384.0		72.0	-18.0				696.0		72.0	-18.0			559.5	-4.7
8		534.0		72.0	-18.0			-18.0				360.0			1337.5	18.8		-18.0			363.0			0.8				301.0		30.0	-18.0				723.0		30.0	-18.0			538.4	0.8
9		719.0		72.0	-18.0			-18.0				360.0			1337.5	25.3		-18.0			363.0			0.8				511.0		30.0	-18.0				985.0		30.0	-18.0			777.6	8.2
10		473.0		72.0	-18.0			-18.0				286.0			885.5	21.8		-18.0			289.0			1.0				271.0		30.0	-18.0				626.0		30.0	-18.0			470.7	-0.5
11		795.0		> 72	-18.0			-18.0				185.0			572.8	46.5		-18.0			198.0			7.0				493.0		80.0	-18.0				968.0		40.0	-18.0			760.2	-4.4
Cat 9																								0																		0
1		580.0			-18.0			-18.0				284.0			732.7	33.5		-18.0			286.0			0.7				368.0			-18.0				728.0			-18.0			570.5	-1.6
2		893.0	47.3					-18.0				390.0			1006.2	42.8		-18.0			391.0			0.3				587.0	30.8		-18.0				1083.0	68.0		-18.0			866.0	-3.0