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Project	Ecodesign and labelling review Cold
Subject	Product categorisation and correction factors
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For	Prepared for and in co-operation with CECED, Working Group Cold

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1. Introduction

1.1. Document revision history

Release date	*Author*	*Version*	*Remark / document change*
30/1/2015	Martien Janssen	V1	First version for discussion during phone conference WG Cold on 27 Feb 2015
12/3/2015	Martien Janssen	V2	Update based on input received before and during the phone conference and as preparation to a WG Cold meeting held in Brussels on 25/26 March 2015
6/4/2015	Martien Janssen	V3	Update based on WG Cold meeting 25/26 March 2015
14/4/2015	Martien Janssen	V4	Update based on WG Cold phone conference on 13/4/2015.
22/04/2015	Martien Janssen	V5	Strengthening of the built-in definition
29/5/2015	Martien Janssen	V6	Updated references and confidentiality removed

1.2. Background

Currently a review process of the energy labelling and ecodesign regulations for cold appliances is ongoing. The consultancy company VHK, the Netherlands, has been instructed by the EU commission to perform an advisory study which should be completed by Oct/Nov 2015.

One of the aspects under review is the use of the correction factors within the current regulation. These correction factors have been criticised in an earlier study from Defra, UK[1] which has been commented upon by CECED[2]. One fundamental point of criticism of CECED to the Defra study has been that revising (or eliminating) correction factors and leaving categories, reference lines etc. unchanged is a too limited viewpoint. Current reference lines and categorisation cannot be seen as ideal, especially since they have been established more than 20 years ago and the products have changed very considerably, most notably in the energy used. The revision of the energy label offers an opportunity to make changes to the current system of categories, reference lines and correction factors, in order to better reflect the market today.

A revision of labels and limits must also be seen in the context of the implementation of the new global performance test standard for cold appliances, which addresses numerous issues in the existing current standard[3]. A simultaneous implementation of new labels/limits and this new standard is a key factor.

[1] *"Assessment of the applicability of current EC correction factors and tolerance levels for domestic refrigerating appliances", Draft Final Report (Version 1.8), Intertek*

[2] *Re/genT Note: 12432 / CE11 / V1 "CECED's comments to the Defra/Intertek study on correction factors and tolerances for cold appliances"*

[3] *Re/genT Note: 12320 / CE10 / V2 "Domestic cold appliances, global test standard revision"*

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The desire to review correction factors, reference lines and categories in an integral way has been communicated to the consulting company VHK during a meeting with CECED working group Cold on 27/1/2015. The present note is a final, public, version resulting from a series of discussions between CECED members. This has resulted in a final "wish lists" of changes or recommended areas for research which have been forwarded to VHK being responsible for the commission study.

In chapter 2 a table is presented with proposed categories and compensations for certain product features. The motivation behind this table is discussed in chapter 3. Chapter 4 presents a data analysis for each new category taking into account the elimination of correction factors on volume and the proposed compensations. It further takes into account the application of the new global standard for which the results of an impact study on 73 appliances is used (reference is made to Re/genT report 15127/CE40/V2, which is further referred to here as the "impact report").

The appendices address a number of other relevant issues. For reference, the actual situation with respect to categories, correction factors and formula's is included in Appendix 4.

Where appropriate, data analysis has been carried out using the CECED database of cold appliances of the year 2013, being the latest dataset available at the moment of this analysis.

2. Proposal for category changes

2.1. Introduction

Based on the various discussions and analysis a table of 9 new categories has been drawn on the next page.

Some general remarks:

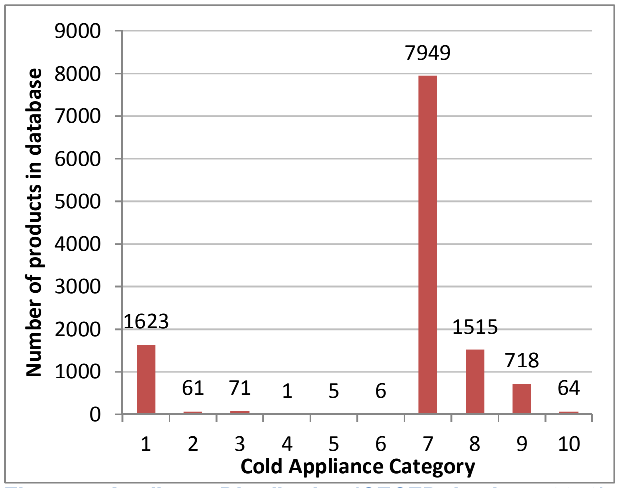

Figure 1: Appliance Distribution (CECED database 2013)

1. To date there are 10 categories, 3 correction factors on volume and one bonus (chill). Some categories have become very rare as shown in Figure 1. In this note, the number of categories has first been reduced by regrouping existing categories and then extended with new or changed categories.
2. To avoid confusion with existing categories, the new categories are identified by alphabetic letters rather than numbers. Capitals are presenting compartment types where lower case letters refer to properties such as upright or built-in.
3. The proposed modifications are aligned with IEC-62552-1,-2,-3:2015[4] and less to the current standard EN-62552:2013[5] and current label and limit regulations.
4. The proposed new categories aim to incorporate also products which did not fit well today in any of the existing categories.
5. No values for the *M* and *N* factors are included in the table, as in general all reference lines need to be redefined.
6. All correction factors on volume are eliminated. New factors, called "compensations" are defined and are based on energy consumption.

[4] The new global standard has been published in February 2015. It contains three parts. Here this new global standard is referred to as IEC-62552-1:2015, IEC-62552-2:2015 or IEC-62552-3:2015.

[5] The current test standard applicable for energy labelling and eco-design is EN-62552:2013. The only distinction between the current and future standard is the addition of the "-1", etc. which can be quite confusing, therefore the year of publication has been added.

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2.2. Proposed table

Category	Designation	*M*	*N*
	Stand alone		
R	At least one unfrozen compartment [1)] and optionally one or more other compartments from the types unfrozen, one-star or two-star	t.b.d.[6]	t.b.d.
RF	At least one unfrozen compartment and at least one freezer [2)] compartment	t.b.d.	t.b.d.
W	Wine storage appliance	t.b.d.	t.b.d.
Fu	Upright freezer [3)]	t.b.d.	t.b.d.
Fc	Chest freezer [3)]	t.b.d.	t.b.d.
	Built-in		
Rb	At least one unfrozen compartment [1)] and optionally one or more other compartments from the types unfrozen, one-star or two-star.	t.b.d.	t.b.d.
RFb	At least one unfrozen compartment and at least one freezer [2)] compartment	t.b.d.	t.b.d.
Wb	Wine storage appliance	t.b.d.	t.b.d.
Fub	Upright freezer[3)]	t.b.d.	t.b.d.
Compensations (all on reference line)			
FF	Frost-free compensation	FF_c (t.b.d)	
CH	Chill compartment compensation (for volumes > 15 dm3)	*C* (t.b.d.)	
MD	Multi-door compensation ($n_d \geq 3$ doors)	*D* (t.b.d)	
Formula's			
V_{eq}	Equivalent (or adjusted) volume $V_{eq} = \sum_{c=1}^{c=n} V_c \times \frac{T_k - T_c}{T_k - 4}$; T_k = interpolated ambient temperature		
SAE	Standard energy consumption $SAE_c = \left\{ \left[M + M_D \right] V_{eq} + N + M_{CH} V_{chill} + N_{CH} \right\} (1 + FF_c \times FF_{ratio})$		
Notes			
1)	According IEC62552-1:2015: any of the following compartment types: zero-star, chill, fresh food, cellar, wine storage or pantry		
2)	According IEC62552-1:2015: a freezer compartment can be a four star or a three star compartment		
3)	Two star compartments or sections inside the freezer are allowed		

Table 1: Proposed cold appliance categories

A discussion and motivation for this table is provided in the following chapter. The consequence of this definition on the distribution of categories is shown in Figure 2, definitely showing a better use of categories than today.

[6] *t.b.d. = to be determined.*

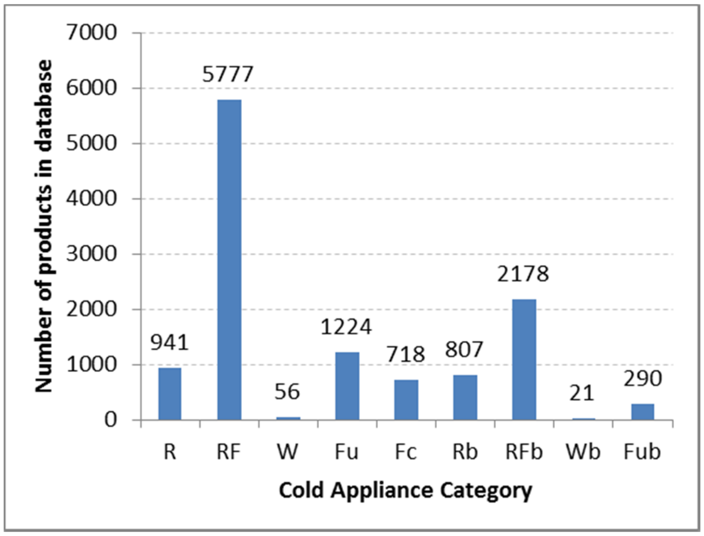

Figure 2: Appliance distribution after new categorisation (CECED Database 2013)

3. Motivation for new categories and compensations

3.1. Category *R* (Refrigerators)

Current categories 1, 2 and 3 are covered by the same reference line and can simply be added together into one new category. It basically deals with appliances having one or two **unfrozen compartments** according IEC62552-1:2015. In this way the newly defined pantries would be covered under the same reference line.

The current reference lines of category 1 to 5 as a function of equivalent volume are shown in Figure 3. (Cat 1, 2 and 3 have the same line, shown in green).

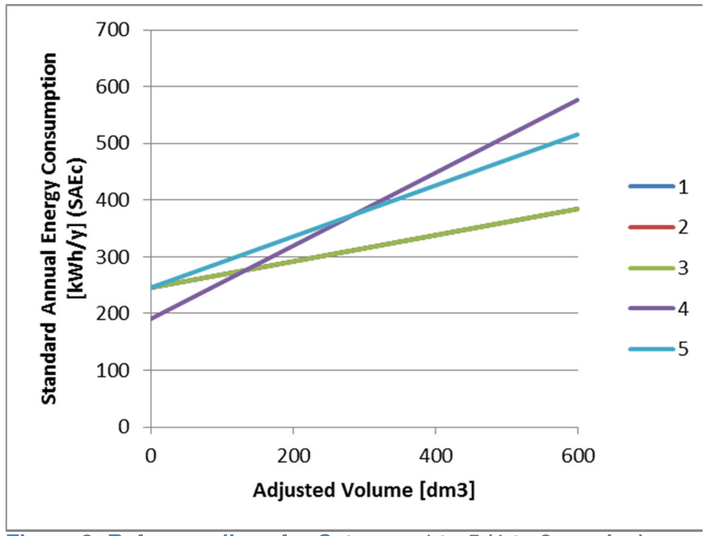

Figure 3: Reference lines for Category 1 to 5 (1 to 3 overlap)

Category 4 (one star) and 5 (two star) have some issues:

1. They have become extremely rare on the market. (e.g. the CECED database 2013 reports 1 product of category 4 and 5 products in category 5).
2. Making updates of reference lines or energy efficiency classes is practically impossible as no data is present.

Given the relatively small differences between the reference lines of cat 4 and 5 compared to 1, 2 and 3, these have all been added to category ***R*** (this by allowing also 1 star and 2 star compartments in the designation).

By defining category ***R*** to have at least one unfrozen compartment and one or **more** other compartments, it integrates all category 10 products which have multiple compartments and where none of them is a freezer compartment[7].

Concluding, by grouping category 1 to 5 and including a part of category 10 into one new category ***R***, the number of categories has reduced by 4.

[7] Category 10 products are typically products with 3 or more compartments. The reference line must be taken from the coldest product compartment. In most cases this means that the reference line of category 7 is used and in a few cases the reference lines of category 1, 2 or 3 (which are all the same). Products with 3 or more compartments and the coldest being a one star or two stars are probably non-existent. Therefore, by allowing more compartments in category ***R*** *(and also in category* ***RF*** *to be discussed later), the need for a category 10 is eliminated.*

3.2. Category *RF* (Refrigerator-Freezers)

To date two categories (6 and 7) deal with refrigerators having three or four star compartments. Originally category 6 products having a three-star compartment had a lower reference line than used for category 7. This practically eliminated category 6 from the market as a freezing capacity test was sufficient to let it enter category 7. Later category 6 has received the same coefficients as category 7, but the product remained rare (e.g. the CECED database 2013 had only 6 entries).

Combining 6 and 7 in one category is well feasible, especially if the definition of a freezer according IEC62552-1:2015 is used, where a freezer compartment can be a four star or a three star compartment. Note that this is different from the European definition in 1060/2010 as well as in EN62552:2013[8].

By defining category ***RF*** to have at least one unfrozen compartment and at least one freezer compartment it integrates all category 10 products which have multiple compartments and where one of them is a freezer compartment. This does not change any of these specific category 10 products, as these had to use the reference line of category 7 anyway.

3.3. Category *W* (Wine storage appliance)

Currently wine storage appliances are being dealt with in the labelling and ecodesign regulation and are treated as category 2 appliances. As no energy limit is in place yet, the additional energy use due to e.g. glass doors has not been a main issue so far. However, a separate category reflects much better the position of these products:

1. The level of energy efficiency class is very different to normal cold appliances (e.g. the highest efficiency wine storage appliances with glass-door are in class A whereas the best cold appliances are below A+++ target levels). This is also shown in Figure 4 where all products are up or above the threshold for category 2, while obviously all products in category 1, 2 and 3 are below. Retaining these products in the same category would seriously limit the redistribution of efficiency classes.
2. The use of a glass door should be taken into account, as visibility is an important feature of these products. This is especially relevant if a MEPS would be established.
3. The layout of the energy label could become the same for cold and for wine appliances once separate reference lines are in place.

GfK has reported a total market sales volume of 217,000 units for 8 EU countries in 2009[9]. Translated to all EU countries and to 2015, the number of units is expected to be significantly higher. Given the higher level of consumption compared to other cold appliances, the total energy consumption of the fleet is quite significant.

Figure 4 shows the distribution of wine storage appliances (both free standing and built-in) as found in the CECED database 2013. In total 77 products are present

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[8] This is a consequence of global standardisation. For other regions it was not acceptable that their freezers could not be called freezers any more, if these did not pass a freezing capacity test.

[9] GfK-RT (www.gfkrt.com) for the following 8 countries AT, BE, DE, ES, FR, GB, IT, NL

which should be sufficient for definition of new reference lines (a data analysis is presented in chapter 4.4).

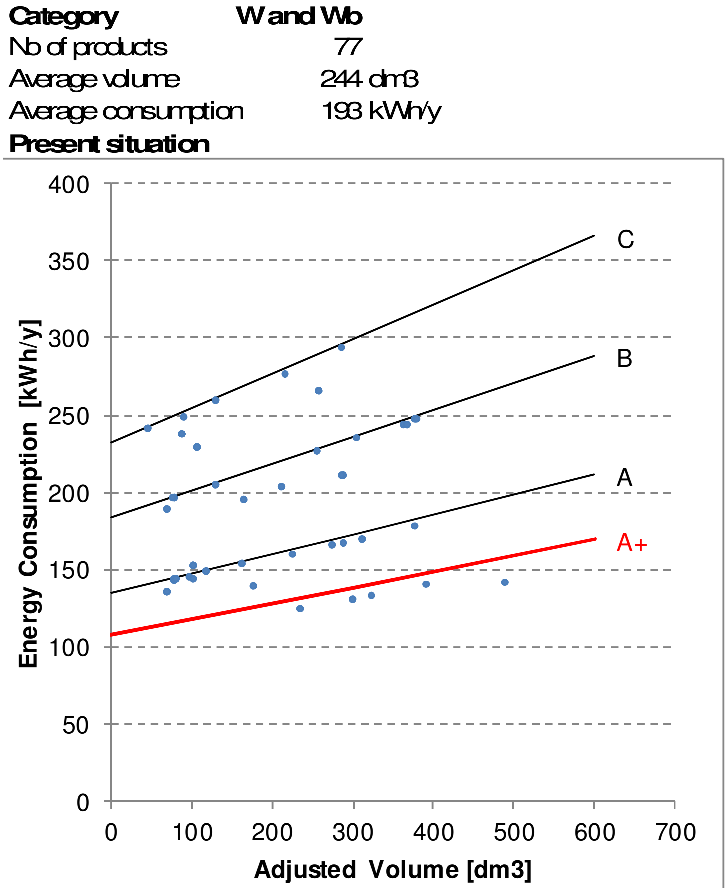

Figure 4: Wine storage appliances in CECED database 2013 (A+ is shown at index 44, relevant in 2013).

3.4. Category *Fu* (Freezers upright)

This category corresponds to the current category 8 covering vertical freezers. Just for consistency a renaming of this category is proposed. As today, 2 star sections inside freezer compartments are allowed in this category.

3.5. Category *Fc* (Freezers chest)

This category corresponds to the current category 9 covering chest freezers. Also here, just for consistency a renaming of this category is proposed. As the product type is quite distinct, it is proposed to keep it a separate category from the upright freezers.

3.6. Built-in products

Table 1 shows a number of separate categories for built-in products. To date products that are built-in and have a width of less than 58 cm receive a volume

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correction factor of 1.2. The following arguments are relevant for claiming special treatment of built-in products:

1. The number of built-in products is very significant, from the products in the database in total 29 % are built-in (see Figure 2). From these products 93 % have a width of 58 cm or smaller.
2. To be useable as a built appliance strict rules need to be obeyed. Generally the width must not exceed 58 cm, also the depth is not allowed to exceed 56.5 cm.
3. Kitchen manufacturers are very strict in keeping these limits and are not willing to open these limits.
4. Permitted outer dimensions are limited and so the insulation thickness of these appliances is less compared to free standing appliances having the same storage volume. In order to compensate this disadvantage and still achieve a certain and competitive energy efficiency, superior and advanced, but more expensive, cooling system technologies are necessary. This is an innovation driver for the entire cooling appliance industry.
5. The European cold appliances manufacturers have been leading since years and together with the kitchen manufacturer industry significant employment depends on this section.
6. Due to the limitations of the outer dimensions the average inner volume of built in appliances sold on the market is smaller than for free standing appliances (estimated to be app. 30 % less). In combination with more sophisticated cooling system technology, this actually leads to a reduction of the total energy consumption of cooling appliances in Europe (the average energy consumption of the build-in products is app. 25 % lower compared to the stand alone products).
7. Appendix 1 shows that the use of a volume correction factor has a different effect depending on the category of the product and depending on the equivalent volume. For built-in there is no technical justification for these differences. Treatment in separate categories allows differentiation between reference lines.
8. In general the consumer purchase decision for built-in or stand alone is not driven by the efficiency class, so treatment in the same category is not a necessity.
9. Built-in appliances are tested under more severe conditions than a free-standing product. A specific casing is used which allows air passages at the bottom and back side according the minimum specified built-in instructions. This means that the measured consumption is the worst case scenario and that any built-in appliance already consumes more during the test than it would do if tested as a stand-alone product.

The proposed table contains 4 built-in categories identified by a lower case ***b***. For chest freezers no built-in variant exists.

Currently the built-in correction factor is limited to products with a width of < 58 cm. There is no real technical argument for this differentiation. This limit has mainly been introduced to avoid misuse of the correction factor, in particular to avoid that large appliances are sold as built-in while at the same time these are suitable to be used as stand-alone. This risk can also be mitigated by a better definition of built-in. A suitable definition has been copied from the US energy standard but with some modifications to further strengthen the definition:

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Built-in appliance:
Any appliance that is designed, intended, tested[10] *and marketed exclusively*
(1) to be installed totally encased (top, bottom, sides and back)[11] *by cabinetry or panels that are attached during installation,*
(2) to be securely fastened to the sides, top or floor of the cabinetry[12] *and*
(3) to either be equipped with an integral factory-finished face or accept a custom front panel.

Note that this definition is more limiting than the definition in IEC62552-1:2015, so inclusion of the definition above in the regulation (or in the EN62552 update) is required to avoid any misuse of the built-in categories. Further, when a product is defined according the above definition and placed in a category "***b***'", then by definition the product must be tested as a built-in which means that its measured energy consumption will increase compared to a stand-alone measurement.

In fact, the placement of all built-in products in separate categories rather than as corrections, makes it easier to detect any incorrect usage, which is another argument for having separate categories rather than correction factors or compensations.

3.7. Frost free factor

There is general consensus that a frost free correction or bonus compared to static appliances is realistic (this is also concluded in the Defra study, albeit with a different value). The correction on volume of frozen food compartments with a factor of 1.2 does lead to some anomalies as discussed in appendix 1. This point has also been addressed in the Defra study, where it is concluded that it is technically more logic to use the correction factor also to the offset, which would make it effectively a correction of the reference line rather than on the volume. Such correction can be made as follows (see appendix 4 for the definition of the variables):

$$SAE_c = \left(V''_{eq} M + N\right) \times (1 + FF_c \times FF_{ratio})$$

Where FF_c is the newly to be defined frost-free compensation (e.g. if it is set to 0.1 the bonus for frost free is simply 10 % on energy consumption, irrespective of the volume of the product or the category.

The problem is that compensations shall only be made for frozen food compartments to stay in line with the current regulation. Therefore the compensation should not apply to the full extend for combi-products. This can be handled by introducing a frost free volume ratio as follows[13]:

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[10] *The word testing has been added to support the claim for the BI category and promote importance to this differentiation.*
[11] *The definition of encased has been added, requiring that the product should be covered at all surfaces except the door.*
[12] *Fastening has been defined as fastening to the cabinetry, so that e.g. only fixing on the back kitchen wall is not sufficient, as this would still allow some margin to declare a stand-alone product inside the category BI.*
[13] *Note that the equivalent volume formula is adjusted here for the new global standard (4 °C for the fresh food target temperature and T_k as the interpolation temperature). Correction factors have been removed from this formula.*

$$V_{c,eq} = V_c \times \frac{T_k - T_c}{T_k - 4} \text{ with } T_k = \text{interpolated ambient temperature}$$

$$V_{eq} = \sum_{c=1}^{c=n} V_{c,eq}$$

$$FF_{ratio} = \frac{\sum_{c=1}^{c=n} \left(V_{c,eq} \times \delta_c\right)}{V_{eq}} \quad \text{with } \delta_c = 1 \text{ if c is frozen food and frost free,} = 0 \text{ otherwise}$$

Using the same example with a frost-free compensation of 0.1, for combi appliances where only half the equivalent volume would be frozen frost-free (FF_{ratio}=0.5), the impact on the energy consumption would reduce to 5 %. Obviously the actual frost free compensation value needs further study, which is carried out in chapter 4.8.

3.8. Compensation for chill compartment

To date products with a chill compartment above 15 litre receive a bonus on the reference line of 50 kWh/y. At the current energy efficiency limit at index 42 this means that, for the worst appliances on the market, the bonus has already reduced to 21 kWh/y.

The main motivation for continuation of a special treatment for chill compartments is based on the following:

1. There are strict rules given in the performance standard regarding temperature stratification and fluctuation with challenging targets (the instantaneous temperature is evaluated and is limited to be within -2°C and +3°C).
2. In order to fulfill these requirements more sophisticated cooling systems are required with additional components (air circulation fan/ air guidance) which generally also reduce the volume.[14]
3. With these measures the customer can store perishable food longer which leads to less food spoilage, an aspect which is not considered in the performance standards.

As chill compartments generally form only a part of a product, separate treatment in new categories is difficult. It is therefore proposed to replace the current chill bonus with a chill compartment compensation which is further discussed in chapter 4.9.

3.9. Compensation for multiple doors

Products with a high amount of doors (larger than 2) offer a different service level compared to products having a similar amount of compartments but using internal separation. The following aspects can be mentioned:

1. The additional service is offered through extra doors giving access to compartments usually hidden inside. Also the use of extra drawers facilitates easier access.
2. A small amount of energy saving, not recognised in the test protocol, is due to the reduction of door openings with the multi-door concept.

[14] IEC62552-1,-2,-3:2015 will penalise the volume less than the existing standard for a chill compartment. Nevertheless, significant volume is still lost due to ducting and fans.

3. Opening a door does give less less disturbance of the other compartments compared to appliances with inner doors.
4. There are more heat leakage paths (e.g. gaskets), so generally the energy consumption increases.

In chapter 4.10 a possible value for the compensation is presented. Next figure shows the current distribution of these products.

Category	RF
No of products	96
Multidoor products (nd>=3)	

Present situation

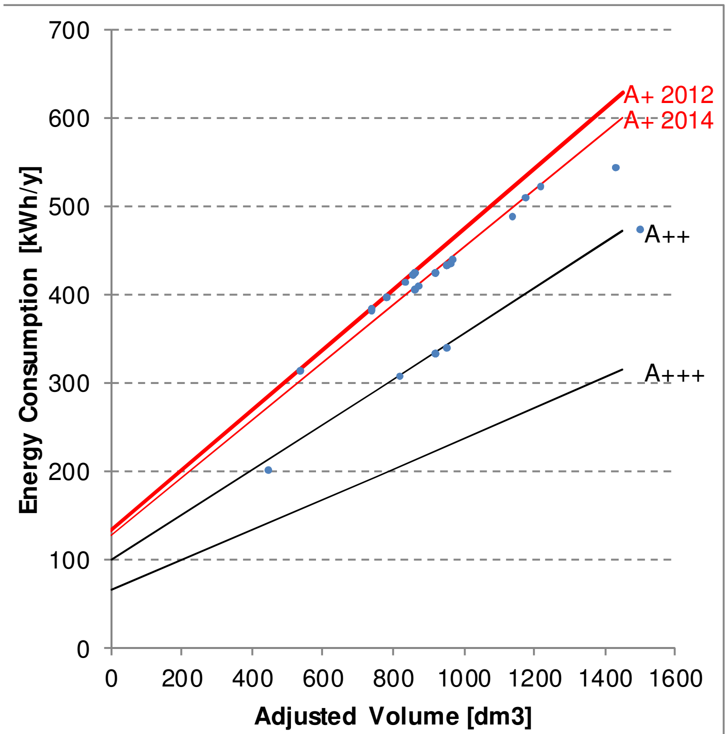

Figure 5: Multidoor appliances (in category *RF*), reference lines from Cat 7

3.10. Climate class correction factor

To date correction factors of 1.2 and 1.1 are applied for T and ST products, respectively, resulting in an effect on standard energy consumption from a few percent for small fridges up to 12 % for larger combi appliances (see appendix 1). Due to many different aspects including the correction factor itself, the market has shifted to ST and T products over Europe and the number of N products have become relatively small as shown in Figure 6. The discrimination between products on the basis of climate class has therefore become smaller and as the impact of the volume correction was already only small, this correction has not further been retained in the proposed new categories and compensations.

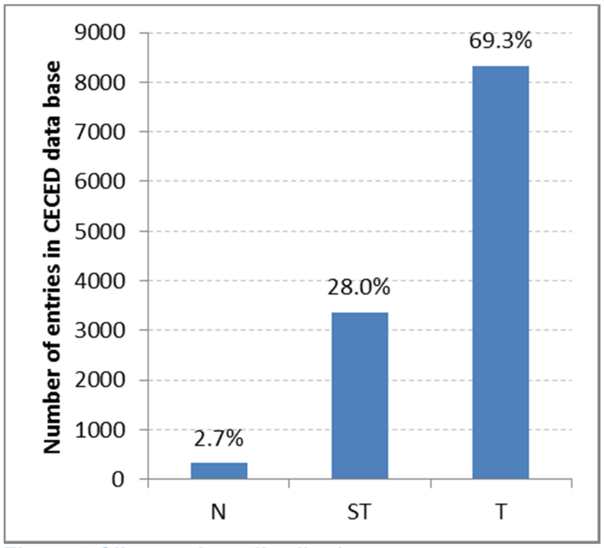

Figure 6 Climate class distribution

3.11. Wine storage compartments

To date products with multiple compartments and one of them being a wine storage compartment are not separately handled, the compartment is tested as a cellar compartment and the index calculation is performed accordingly. IEC62552-1,-2,-3 include additional requirements for such wine storage compartments. To recognize this in the labelling scheme, products with wine storage compartments (in addition to other compartments) could receive some kind of compensation. So far, this point has not been addressed yet. Also quantitative data on the amount of products is not available (the CECED data base does not yet distinguish between products with a wine storage compartments and cellar compartments).

3.12. Variable temperature compartments

Products having a compartment which can cover multiple temperature ranges and can therefore have multiple type classifications, today need to be tested and rated according the lowest possible target temperature. Actually this means that the declared energy consumption of the product does not well represent the actual situation as, for a given population of these products, the products may operate on average at higher compartment temperatures. Also for a single product, it may operate at a higher temperature when averaged over a year.

This issue has been addressed, but it has been decided to leave it as is. Reason for this is that it is difficult to prevent incorrect usage (i.e. many products can easily become variable temperature if all compartment types are considered, e.g. fresh-food and cellar compartment).

4. Data analysis

4.1. Introduction

The new definition of the categories, elimination of correction factors on volume and the introduction of the new global standard all have a unique effect on each product and will impact the energy efficiency index (or efficiency class). Therefore a revision of reference lines and MEPS (Minimum Efficiency Performance Standard) is required.

To quantify the impact of all changes, a data analysis is performed for each newly defined product category. As a basis the CECED database 2013 is used and charts are produced with the base case being the current labelling scheme. The following steps were performed in order to generate the base cases:

1. The data base was filtered for all products having an energy efficiency index > 44[15] in order to eliminate older database entries which were not compatible any more with the 2012 MEPS.
2. A few products where present in the database which had incorrect information regarding the label[16]. These were excluded from the analysis.
3. For products with a chill compartment the energy consumption plotted in the chart is a corrected energy consumption value by reducing the declared value with the chill compartment bonus (50 kWh/y) multiplied with the energy efficiency index of the product. This allows showing products with and without chill compartment in the same chart and using the same reference line or MEPS.
4. The MEPS lines (A+) of 2012 as well as of 2014 have been drawn in this chart, these MEPS lines refer to an index of 44%, respectively 42 %.

To quantify the effect of all changes, in general the following steps are made:

1. The energy consumption is increased with an average value for the given category derived from the impact study.
2. Adjusted volume correction factors (climate class, frost free and built-in) are all removed.
3. The energy consumption is reduced with the compensation factors[17].
4. The compartment volumes have not been changed. The conclusion of the impact report has been that the changes have been quite small.

4.2. Category *R*

To quantify the impact of all changes the following calculations are made for each product:

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[15] *Except for wine storage appliances, which have no MEPS.*

[16] *Their efficiency class could not be confirmed on the basis of the input data such as volumes and energy consumption.*

[17] *Compensations are proposed additions to the reference lines which means that for each product actually a different reference line is valid (as today for products with a chill compartment due to the chill bonus). E.g. if a compensation of 10 % is given, the energy efficiency index is obtained by dividing the declared energy consumption with the reference value multiplied with 1.1. In the charts the compensations are included as reductions on the energy consumption. This makes it possible to plot products with and without compensation in the same diagram and refer to the same reference line or MEPS. The end result on the energy efficiency index is obviously the same. Appendix 5 gives some calculation details.*

1. It is assumed that the energy consumption increases with 19 % due to the application of the new global standard (see impact report).
2. The adjusted volume will reduce due to the elimination of the climate class and the frost free correction factor (for frozen food compartments only).
3. For chill compartments a chill compensation is applied (see chapter 4.9).

The base case as well as the “converted” case is shown in Figure 7. For more details regarding the calculation process see appendix 5.

Category	**R**	Energy increase due to standard	19 %	
No of products	920	Elimination of climate class correction factor		
		Chill compensation M and N	0.25	15

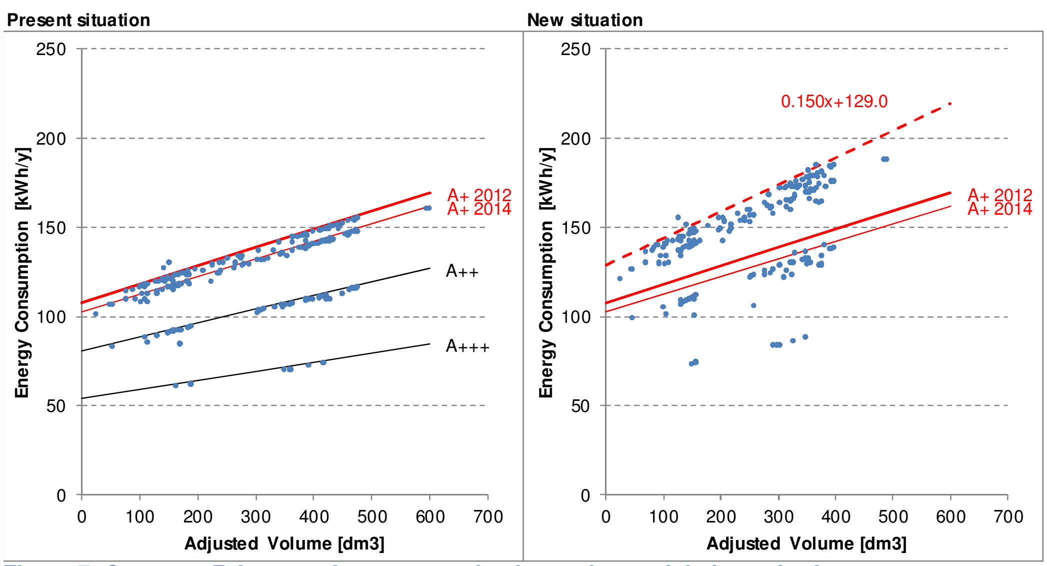


Figure 7: Category *R*, impact of new categorisation and new global standard

As can be seen most products will end up significantly above the A+ line (of 2012) as all data points shift in height due to the additional energy consumption related to the new global standard and most shift to the left due to the elimination of the climate class correction factor on volume. The red dashed line presents the position for the maximum energy consumption as a function of the adjusted volume and can be seen as a transformation of the 2012 limit to the new situation.

The current reference line for refrigerators has an anomaly as the inclination is very low. Appendix 2 includes an analysis which shows that the slope of this line is much smaller than for other products. This means that it is much more difficult to create high efficiency class refrigerators than smaller ones, which is a well-known effect. This is not possible to see in the distribution within the data base as apparently manufacturers have been able to accommodate more efficient technology in the large appliances. In any case, this anomaly could be considered during an update of the reference lines.

4.3. Category *RF* (Refrigerator-Freezers)

To quantify the impact of all changes the following calculations are made for each product (see for calculation details appendix 5):

1. The energy consumption increases with 19 % for type I appliances (single control) and 8 % for type II appliances (two or more controls), see the impact report for details. The impact report mentions 7 % for type II appliance static and 9 % for type II appliances frost-free. Here the calculation has been made with the average value of 8 %.
2. Elimination of the climate class and the frost free correction factor.
3. For multi-door appliances compensation is proposed, see chapter 4.10, however, this compensation has not yet been implemented at this stage of the analysis. The data will not change much due to the small amount of products involved.
4. For chill compartments a chill compensation is applied (see chapter 4.9).
5. For frost free appliances a frost free compensation of 10 % for the frozen food compartments is applied (see chapter 4.8). Note that the frost free compensation is proportional to the ratio of frozen food to total volume (both in terms of thermodynamic volumes).

The base case and “converted” result are shown in Figure 8.

Energy increase due to standard type I (%)	19	
Energy increase due to standard type II (%)	8	
Frost free compensation (%)	10	
Chill compensation M and N	0.25	15
Elimination of climate class correction factor		
Elimination of frost free correction factor		

Category	**RF**
No of products, Type I	3269
No of products, Type II	2220

Present situation **New situation**

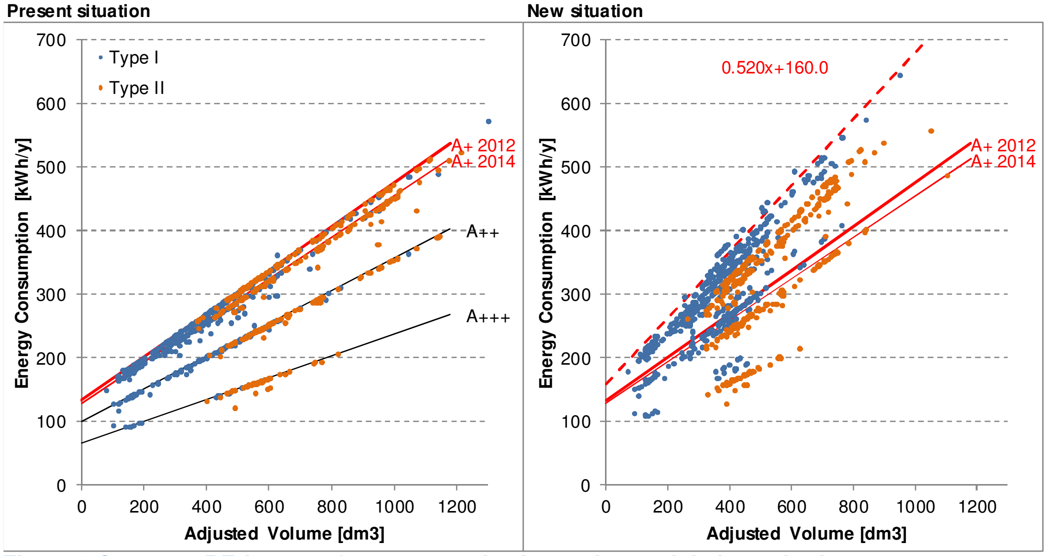


Figure 8 Category *RF*, impact of new categorisation and new global standard

As can be seen, similar to category ***R*** most products will end up significantly above the A+ line (of 2012) as all data points shift in height due to the additional energy consumption related to the new global standard and most shift to the left due to the elimination of the climate class and frost free correction factor on volume.

There is a significant difference between type I and type II appliances as is explained in the impact study. In principle this figure shows clearly how better controlled appliances (those of type II which can maintain compartment temperatures both at 16 and 32 °C) will perform better in the new situation while these are not distinguishable in the present situation.

With respect to reference lines there is also an anomaly between categories, which is described in appendix 3 and which may be considered when reviewing reference lines.

4.4. Category *W* (Wine storage appliance)

To quantify the impact of all changes the following calculations are made for each product:

1. The energy consumption increases with 13 %. This is not related to any change of target temperature (which stays at +12℃) but relates to the fact that interpolation at 25℃ instead of measuring at 25℃ introduces a large increase for these products. This is shown in Figure 9 derived from a theoretical analysis as included in the impact report.
2. Elimination of the climate class correction factor.

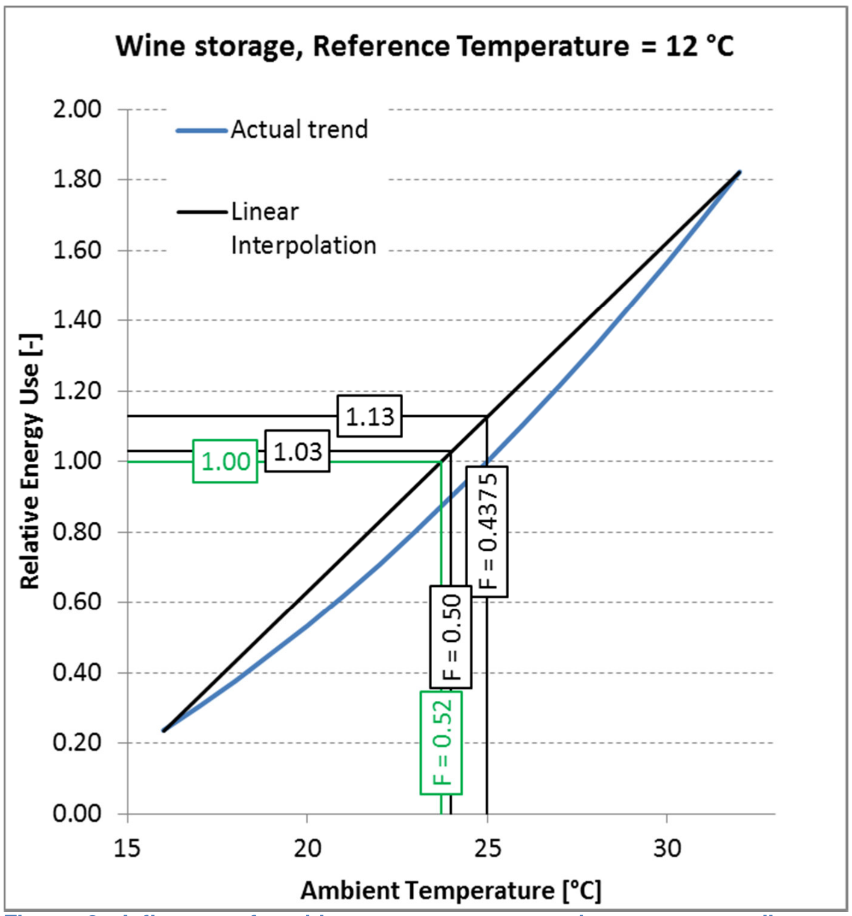


Figure 9: Influence of ambient temperature on wine storage appliances and interpolation methods

The base case and "converted" result are shown in Figure 10

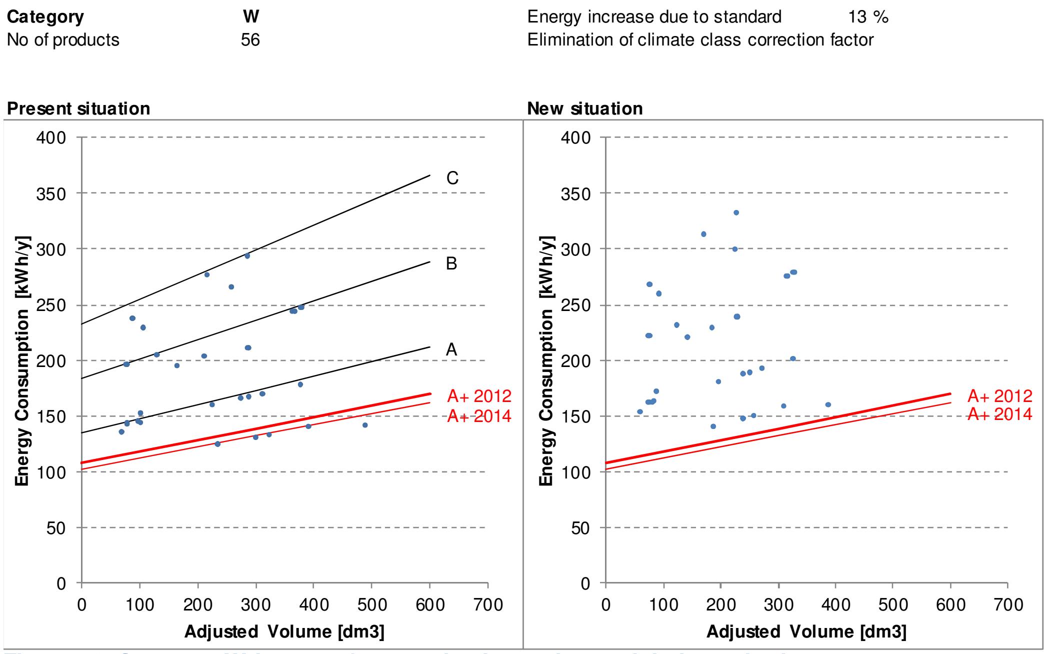


Figure 10: Category *W*, impact of categorisation and new global standard

For the wine storage appliances, to date no energy limit is present. For reference the A+ line of 2012 and 2014 for category 2 appliances is drawn. Due to the interpolation at 25℃ the energy consumption has increased and the removal of the climate class correction has shifted the points to the left.

The above analysis includes wine storage appliances with and without glass doors. It is estimated that from the products included here, 70 % contains a glass door.

4.5. Category *Fu* (Freezers upright)

To quantify the impact of all changes the following calculations are made for each product:

1. The energy consumption does reduce with 1 % for static freezers and increases with +2 % for no-frost products (see the impact report for details). As both figures are small and are on average almost zero, here no energy change has been taken into account.
2. Elimination of the climate class and the frost free correction factor.
3. For frost free appliances a frost free compensation of 10 % for the frozen food compartments is applied (see chapter 4.8).

	Energy increase due to standard [%]	0
Category **Fu**	Elimination of climate class correction factor	
No of products 1206	Elimination of frost free correction factor	
	Frost free compensation [%]	10

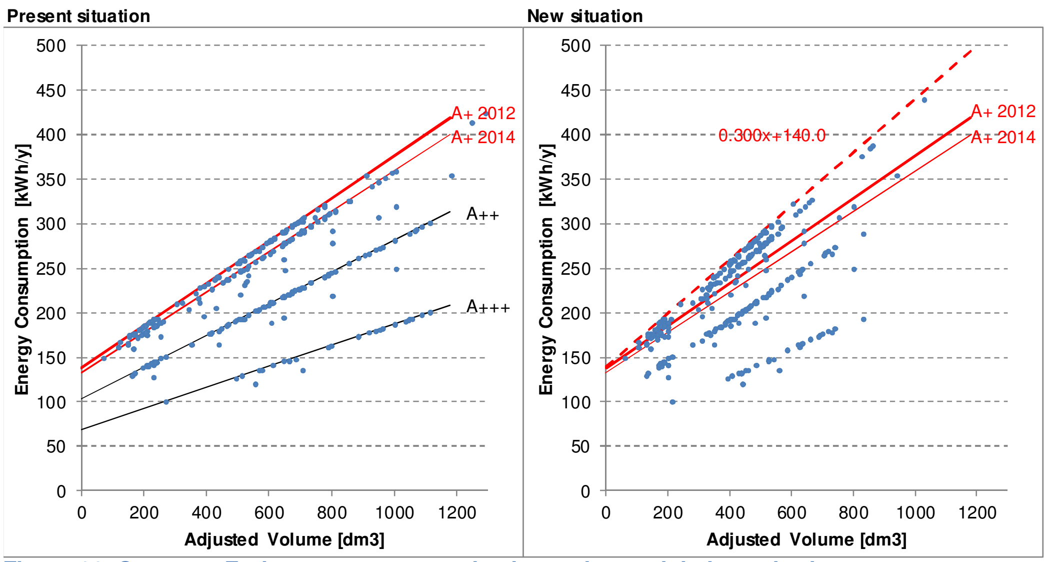


Figure 11: Category *Fu*, impact new categorisation and new global standard

In this case, a large number of products end up above the limit of 2012 due to the reduction in adjusted volume. To compensate for this a higher inclined limit would be needed (see the dashed red line).

4.6. Category *Fc* (Freezers chest)

To quantify the impact of all changes the following calculations are made for each product:

1. The energy consumption does reduce with 2 %, see the impact report.
2. Elimination of the climate class and the frost free correction factor.
3. For frost free appliances a frost free compensation of 10 % for the frozen food compartments is applied (see chapter 4.8). However, the number of frost free chest freezers is very limited (< 1 % in the CECED 2013 database).

		Energy increase due to standard [%]	-2
Category Fc		Elimination of climate class correction factor	
No of products	704	Elimination of frost free correction factor	
		Frost free compensation [%]	10

Present situation **New situation**

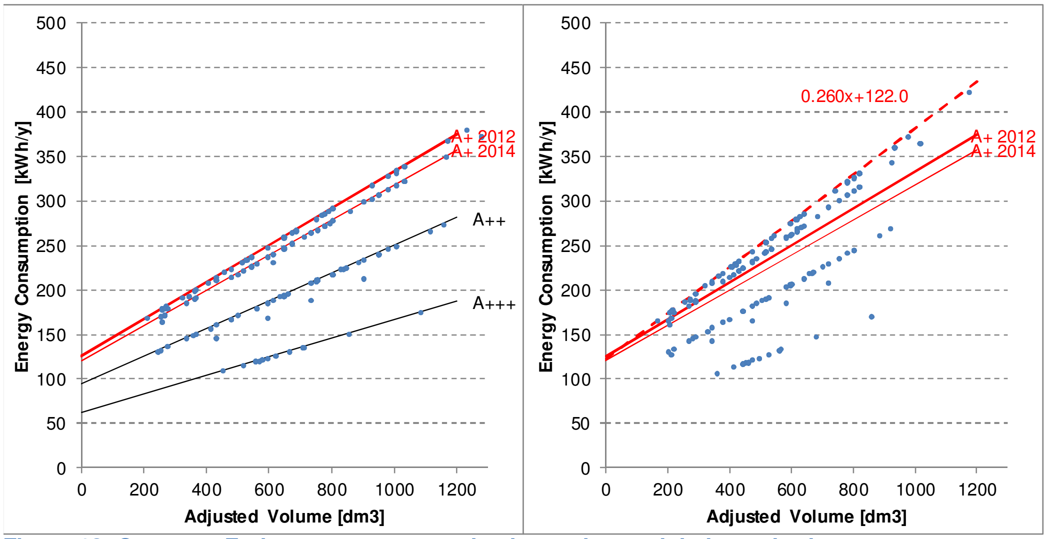


Figure 12: Category *Fc*, impact new categorisation and new global standard

As for the upright freezers, a large number of products end up above the limit of 2012 due to the reduction in adjusted volume. To compensate for this also here a higher inclined limit would be needed (see the dashed red line).

4.7. Built-in categories

A quantitative analysis can be carried out here as for category ***R***, ***RF*** and ***Fu***. This leads to similar charts and similar conclusions. The difference with the previous categories is that the built-in correction on volume has been taken away, so the reduction of adjusted volume is larger for these products compared to the stand-alone products.

For the category ***Rb*** the diagrams in Figure 13 result.

Category	**Rb**	Energy increase due to standard	19 %	
No of products	803	Elimination of climate class correction factor		
		Chill compensation M and N	0.25	15

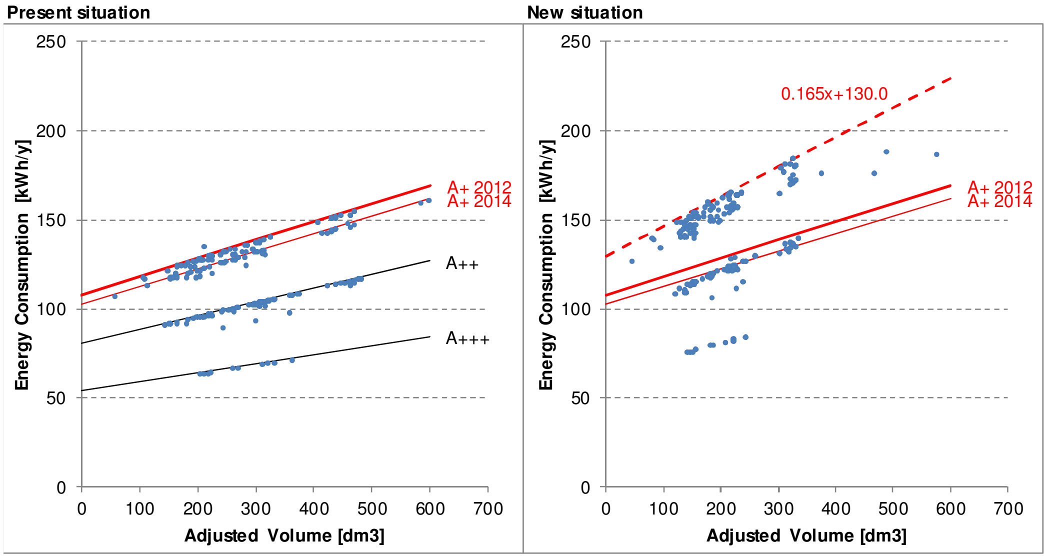


Figure 13: Category *Rb* (Refrigerator built-in), impact new categorisation and new global standard

Similary for category ***RFb*** the diagrams in Figure 14 result.

		Energy increase due to standard type I (%)	19	
		Energy increase due to standard type II (%)	8	
		Frost free compensation (%)	10	
Category	**RFb**	Chill compensation M and N	0.25	15
No of products, Type I	1832	Elimination of climate class correction factor		
No of products, Type II	310	Elimination of frost free correction factor		

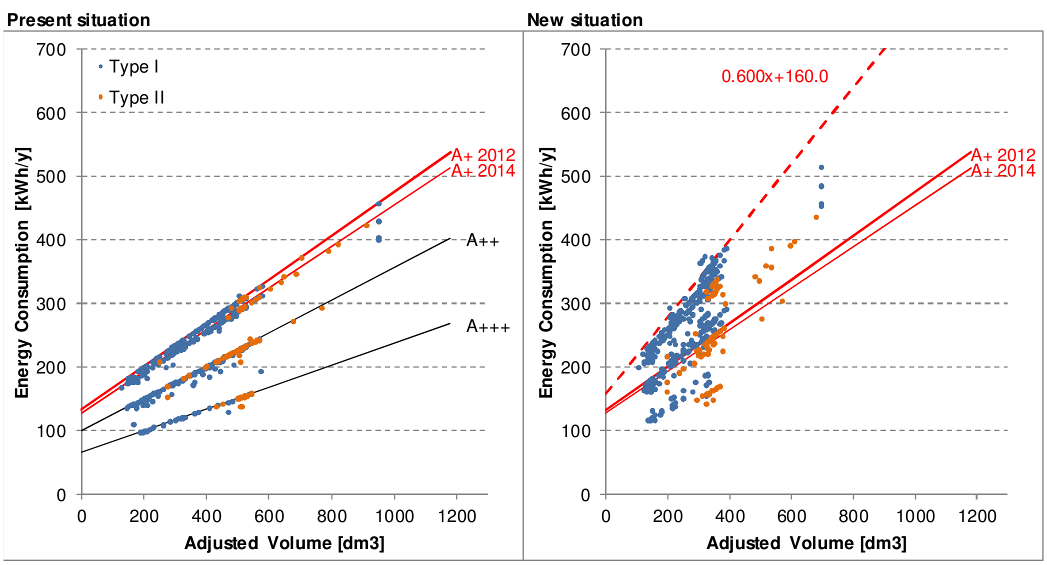


Figure 14: Category *RFb* (Refrigerator-Freezer built-in), impact new categorisation and new global standard

What is notable here, when comparing these diagrams to the category ***RF***, is the large concentration in the lower range of adjustment volumes. This is obviously due to the limitations for built-in appliances, but this does support the claim that built-in appliances are generally smaller which drives the acquisition to smaller appliances, hence reducing the overall energy consumption.

For wine storage appliances, built-in (***Wb***), Figure 15 can be drawn. The data is quite limited for properly analysing new reference lines, but from consistency stand point it is desired to keep also the wine storage appliance in a separate built-in category.

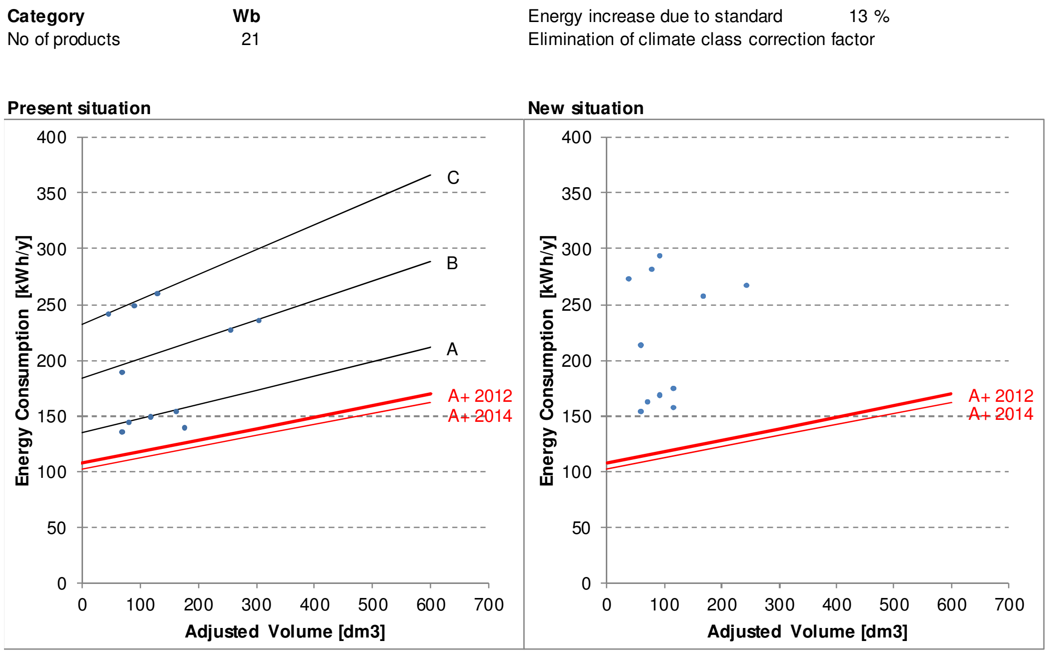


Figure 15: Category *Wb* (Wine storage, built-in), impact new categorisation and new global standard

Finally a figure can be drawn for upright freezers, of the built-in type (***Fub***).

		Energy increase due to standard [%]	0
Category	**Fub**	Elimination of climate class correction factor	
No of products	287	Elimination of frost free correction factor	
		Frost free compensation [%]	10

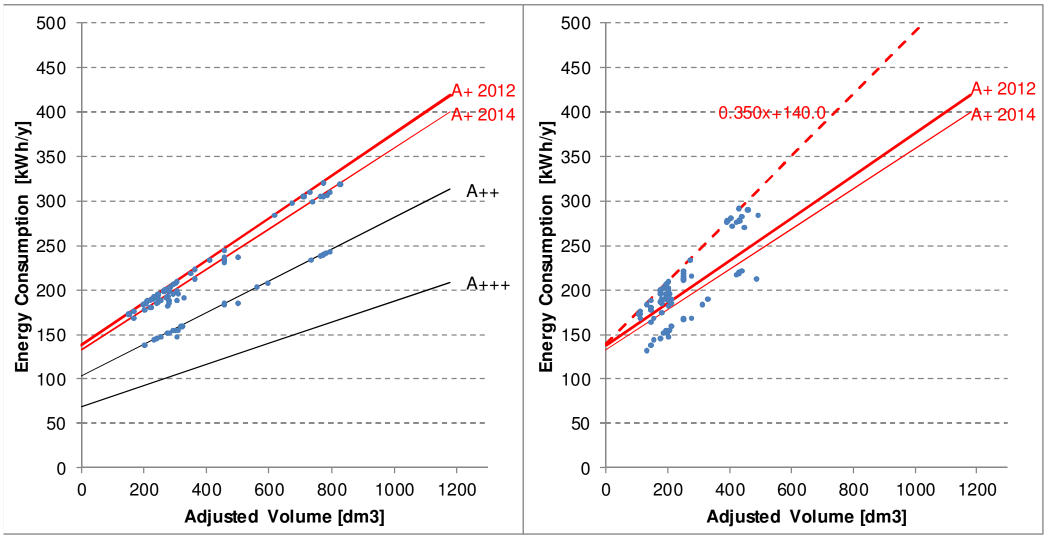


Figure 16: Category *Fub* (Upright freezers, built-in), impact new categorisation and new global standard

4.8. Frost free compensation

As mentioned in chapter 3.7 it is possible to convert the current frost free correction factor on volume to frost free compensation on the reference line. The consequence of this is that larger appliances get the same benefit than smaller ones while presently these products obtain a larger benefit for which there is no technical justification.

For a determination of the level of compensation there are two different methods possible:

1. A technical analysis, where a product with frost free technology is compared with a similar product using an equal technology level but in a static version. The incremental energy associated with the defrosting action[18] and with the operation of the fan[19] needs to be evaluated. This method is technically justifiable but requires detailed analysis falling outside the scope of this note. Further it is difficult to quantify equal level of technology for quite different appliances.
2. A statistical method, by comparing the data base for products without and with frost free technology. In theory this should show higher consumption for frost free appliances. However, as manufacturers have driven products to the target levels for MEPS and efficiency classes, the frost free effect has been completely mixed up with other parameters, making such extraction by statistical analysis impossible.

[18] Heating of evaporator, ice melting and recovery of the defrost phase
[19] This includes the electrical input to drive the fan as well as the additional compressor input power to remove the heat generated by the fan from the appliance.

In order to still get an idea for the compensation, a calculation has been made of the benefit of the current frost free correction factor. This can be obtained by calculating the ratio of the standard energy consumption with frost free factor taken into account and the same value without frost fee factor:

$$SAE_{ratio} = \frac{V_{eq}M + N + CH}{V''_{eq} \; M + N + CH}$$

Where V''_{eq} is the equivalent volume in case the frost free correction factor is excluded. If this is done for all frost free products in the data base the left diagram of Figure 17 can be constructed.

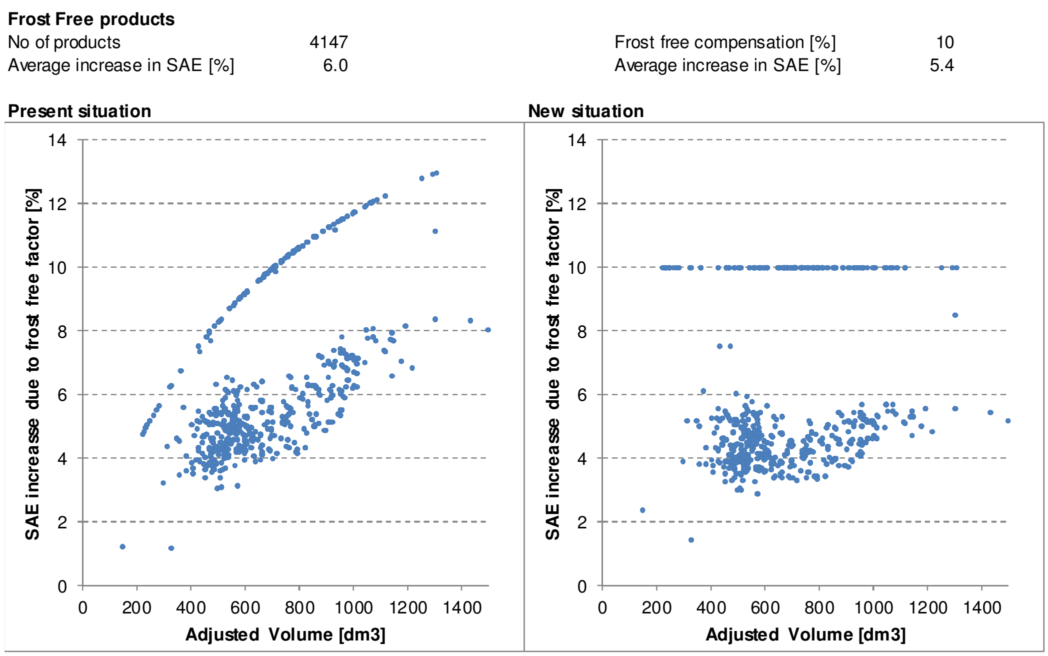


Figure 17: Frost free correction factor versus compensation

The left diagram shows two distinct groups, one group strictly following a curve which represents the single door products (in particular here the upright freezer). This is a curve identical to what is calculated in appendix 1 where the impact of a correction factor of 1.2 on the volume is shown. The second group shows a cloud of points which are all combination appliances. For these products, now included in category ***RF*** or ***RFb***, the frost free correction factor is only applicable to the frozen food compartments.

If one takes an average of the more than 4000 frost free products included in the data base, it has been calculated that the average contribution of the current frost free correction factor is 6 % on the standard annual energy consumption.

In the new situation using a compensation, the ratio formula actually simplifies:

$$SAE_{ratio} = \frac{\left(V''_{eq}M + N\right) \times (1 + FF_c \times FF_{ratio})}{\left(V''_{eq}M + N\right)} = (1 + FF_c \times FF_{ratio})$$

Note that the adjusted volume here does not contain any correction factors.

When this calculation is made for the frost free compensation of 10 % then the diagram to the right can be constructed. Obviously also here two groups can be distinguished (for single door a constant value of 10 % shows up and again a cloud of values for combination appliances). Also here an average effect can be calculated which amounts to 5.4 %. This means that a compensation for the frost free technology of 10 % on energy (weighted to compartment volume) delivers a net effect slightly smaller than the correction factor on volume today.

All analysis presented in this note are further carried out using a frost free compensation of 10 %. Is must be noted however, that the current correction factor is certainly not sufficient to compensate for the frost-free technology. The same holds for the newly defined compensation.

4.9. Compensation for chill compartment

The CECED database 2013 contains 1210 products with a chill compartment (9.3 % of the total). These are distributed according volume as shown in Figure 18. As can be seen the majority of chill compartments are below 35 dm3. Out of all products with a chill compartment, 85 % also contain a freezer compartment; the typical product is a combi having a fresh food compartment with internal chill compartment and a freezer at the bottom.

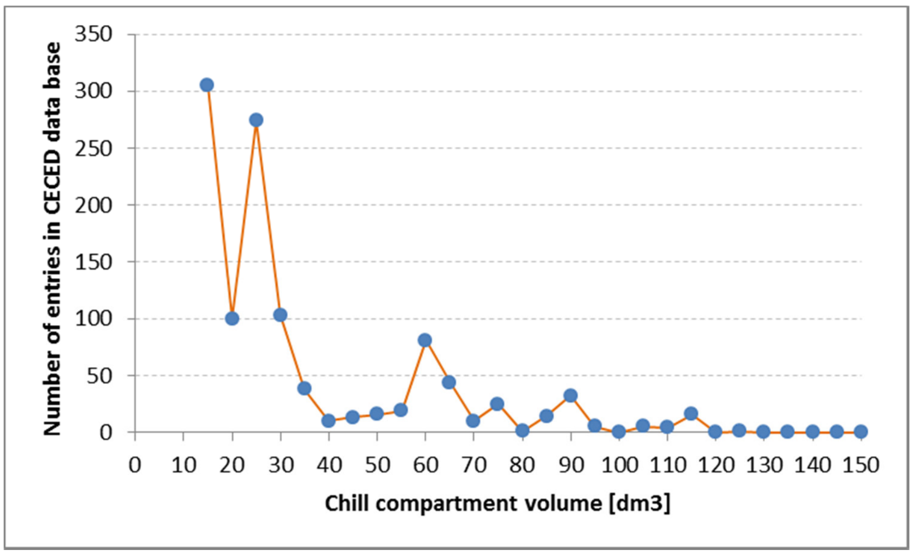


Figure 18: Chill compartment volume distribution (CECED database 2013)

To date products with a chill compartment above 15 litre receive a bonus on the reference line of 50 kWh/y. At the current energy efficiency limit at index 42 this means that, for the worst appliance, the bonus has already reduced to 21 kWh/y. There is some CECED data available (also used in the Defra study) of comparing products with and without chill compartment, but this data is from 2002 and limited to two products having efficiency indices above 55. The current bonus is in any case too low to compensate for the loss in volume and additional energy use of the chill compartment.

A proper technical analysis for the impact of introducing a chill compartment would be the best basis for a correct definition of chill compensation. This should be done on actual appliances with state of the art technology. However, such study is beyond the scope of this note.

Therefore another type of analysis is performed here using the CECED data base. If the effective chill bonus is plotted as a function of chill compartment volume, the left diagram in Figure 19 can be created. The effective bonus is defined as the actual bonus of 50 kWh/y multiplied with the energy efficiency index of the product. Obviously this shows a number of dots concentrated around the efficiency levels of the energy efficiency classes. On average, the effective bonus has been 18.4 kWh/y.

Products with chill compartment		Chill compensation M [kWh/(dm3*y)]	0.25
No of products	1116	Chill compensation N [kWh/y]	15
Average effective bonus [kWh/y]	18.4	Average effective bonus [kWh/y]	20.8

Present situation / **New situation**

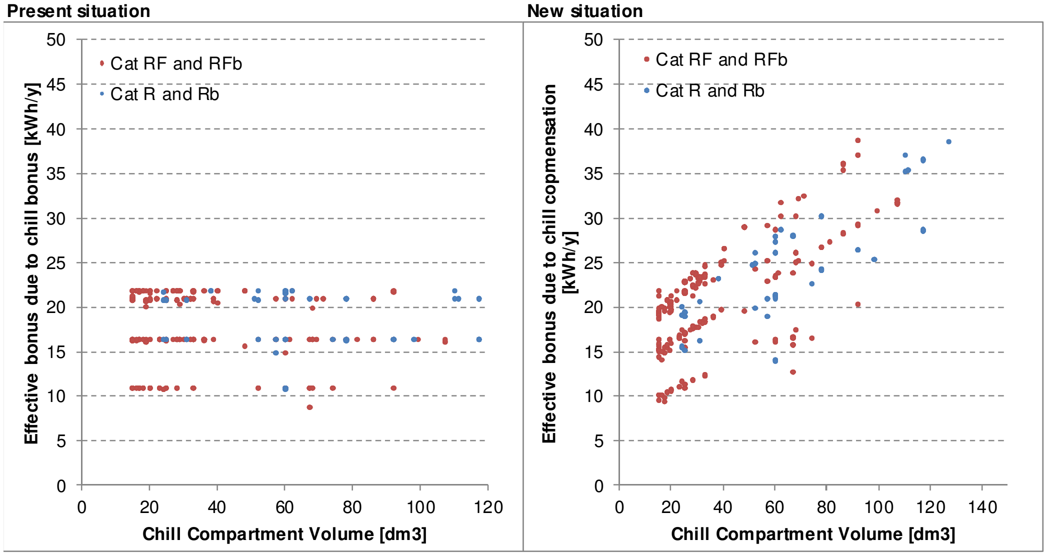


Figure 19: Chill bonus and chill compensation

The additional energy use for a chill compartment increases with increasing chill volume plus a more or less constant part (e.g. fans). This behaviour is not consistent with the current bonus. A possible measure to correct for this anomaly is to introduce a chill compensation which has a constant and a volume dependent part. This could be arranged by the following formula:

$$SAE = MV_{eq} + N + M_{CH}V_{chill} + N_{CH}$$

Where the chill compensation M_{CH} is then expressed in kWh per year per liter and N_{CH} in kWh/y.

As the *M* and *N* factor will likely be updated, the efficiency index in the new situation will change. To be able to calculate the effective bonus for the new situation, provisional *M* and *N* factors were derived for the categories ***R*** and ***RF*** as approximate averages of the data shown in Figure 7 and Figure 8. For category ***R*** the equation 0.12 * V_{eq}+116 was used and 0.42 * V_{eq} +126 for ***RF***. A more detailed explanation is given in appendix 5.

If these equations are used together with M_{CH} = 0.25 and N_{CH} = 15, the figure to the right is obtained, obviously resulting in an increasing effect for increasing volumes. The compensation for 15 litre compartments is slightly less than today. The average effective bonus is still close to the present value, which is caused by the large concentration of small chill compartments.

4.10.Compensation for multiple doors

The Australian/New Zealand standard (AUS/NZS4474.2-2009) includes a method to compensate for extra doors based on so called door allowances (this is applied to the MEPS only). This method uses the perimeter of each door of a product and compares it with the perimeter of an equivalent appliance without such extra doors. This requires altogether a fairly complicated calculation method (see page 17 to 21 of the aforementioned standard).

A more simple method would be to compensate simply on the number of doors (n_d). To make the compensation proportional to the product size, it can be made proportional to the adjusted volume[20] (M_D is defined in kWh/(y*Litre)):

$$SAE = [M + M_D]V_{eq} + N$$
$$M_D = 0.00 \quad n_d \leq 2$$
$$M_D = 0.03 \quad n_d = 3$$
$$M_D = 0.05 \quad n_d = 4$$
$$M_D = 0.06 \quad n_d \geq 5$$

Note that the compensation shall only apply to external doors (no through the doors) and for any product with 2 or less doors, the compensation should become zero. It can be assumed that multiple doors will only relate to category ***RF*** and ***RFb***.

Assuming that a new reference line would be built for the ***RF*** category (using again an average of the data in Figure 8: 0.42 * V_{eq} +126) an estimation of the impact of a door compensation can be made, shown in Figure 20.

[20] *Effectively it becomes a volume correction factor in this way, however, for this compensation this is a logical compensation while this is not the case for frost-free or built-in.*

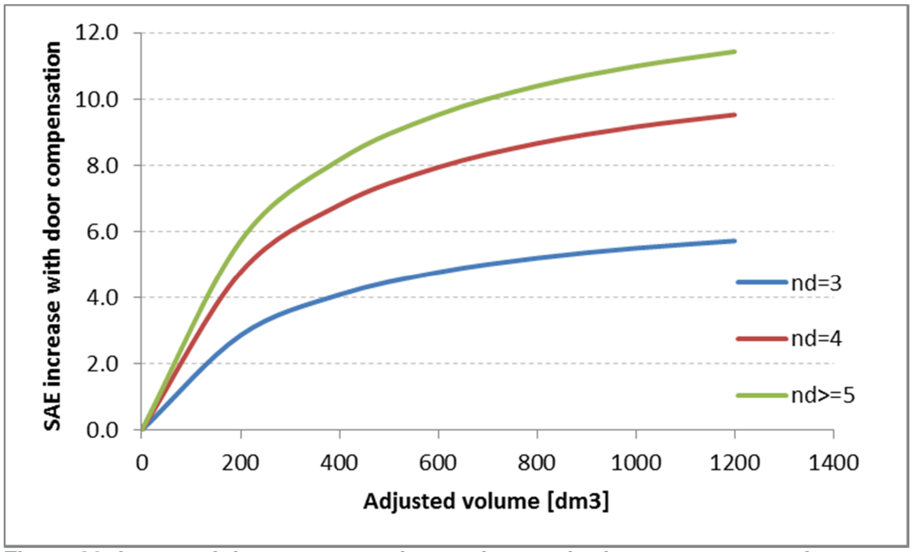
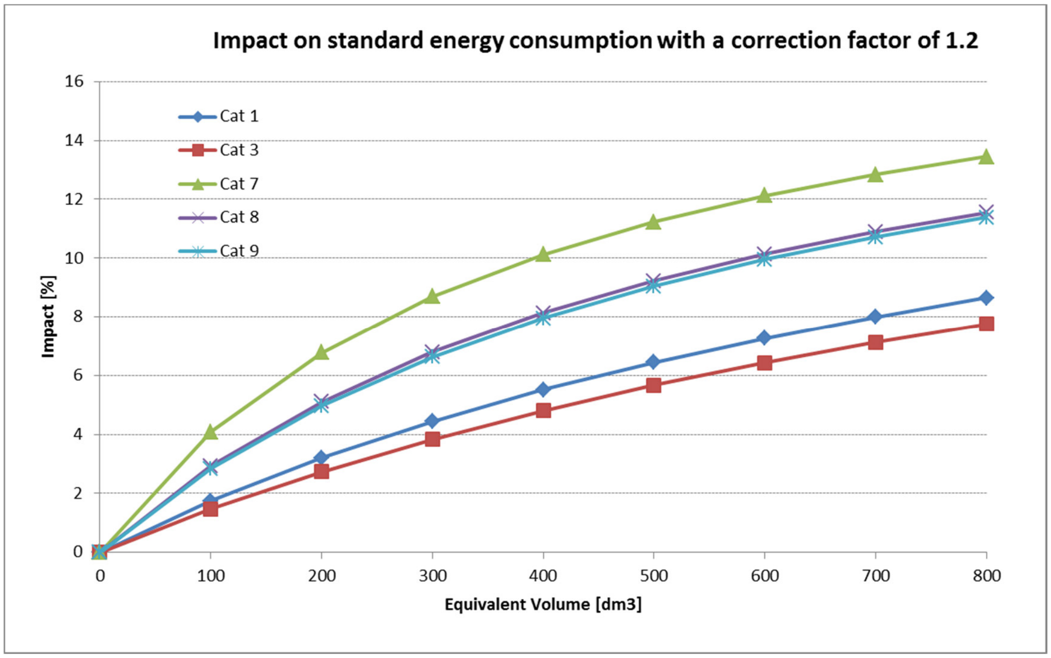


Figure 20: Impact of door compensation on the standard energy consumption

Appendix 1: Volume correction factors

Using a volume correction factor has a different effect depending on the category of product and depending on the equivalent volume as shown in the diagram below. It shows how much extra energy the product may consume if a correction factor of 1.2 is granted (e.g. for tropical or built-in).



The low impact on refrigerators (category 1 and 3) is due to the low inclination of the reference line curve (see also subchapter Appendix 2: Refrigerator standard energy reference line). As these products typically have lower equivalent volumes (up to app 300 litre), the actual compensation in praxis is somewhere between 2 and 4 %. Category 7, 8 and 9 have a higher benefit which is in praxis somewhere between 6 and 12 %.

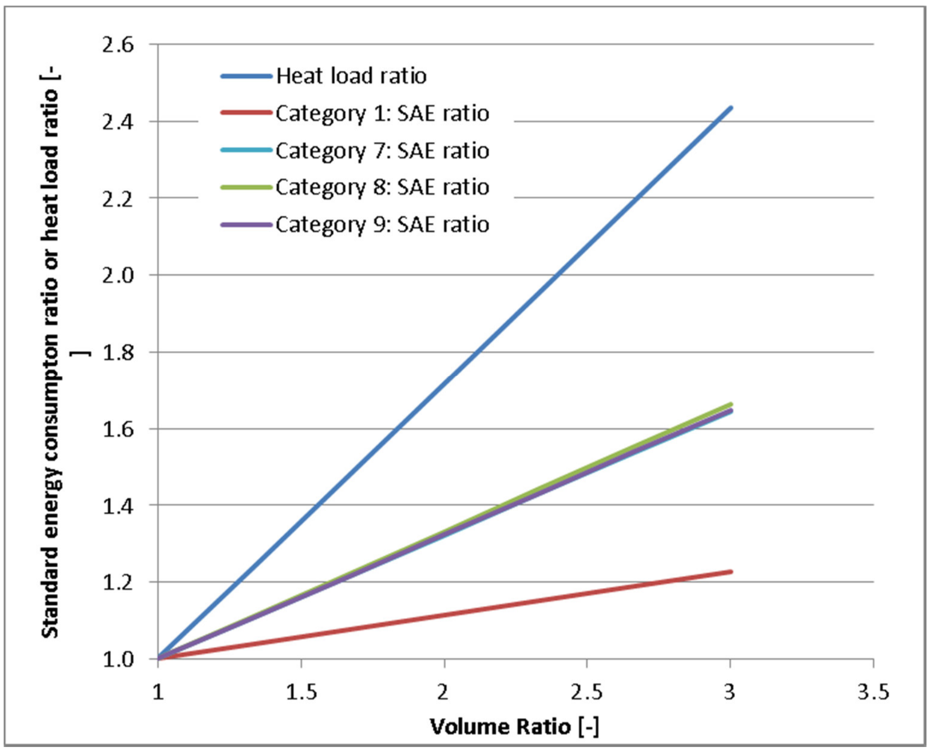
In principle there is often no reason why larger volume products should have a larger compensation. It is also difficult to argue why category 7, 8 and 9 should have a bigger correction than category 1.

Altogether it seems more logical to claim a constant correction factor on the reference lines for all products, e.g. a value anywhere from 4 to 10 %.

Appendix 2: Refrigerator standard energy reference line

The slope of the curves for category 1, 2 and 3 is very low (*M*=0.233). For other categories the slope is higher and is then even multiplied with equivalent volumes which have a correction for the temperature level. This means that per litre increment in volume cat 7, 8 and 9 products are allowed to increase much more in consumption than category 1. This effect is shown in the next figure which is derived from a small analysis where the reference case is a small fridge (or freezer or combi) of 135 litre from which the height is gradually increased. The volume then increases as well as the surface area. The surface area can be taken to be proportional to the heat load. By dividing the heat load with the reference heat load of the small product of 135 litre a heat load ratio is calculated. The figure shows that when the volume is doubled (volume ratio = 2) the heat load ratio is 1.72.

The standard energy consumption can also be calculated for each condition and compared to the reference case of 135 litre, in this way the SAE ratio is obtained.



Two facts are interesting:

a) In all cases the SAE ratio does not follow the heat load ratio, hence the larger products have to compensate a lot by increased efficiency compared to smaller products (e.g. at volume ratio 2, the heat load has increased 72 % and the SAE with 32 %, so the missing 40 % must be compensated with increased efficiency (or insulation) to reach the same efficiency class.

b) Category 1 products have a lot less compensation. At volume ratio 2 the SAE has only increased with 11 %, so more than 60 % must be compensated by other factors.

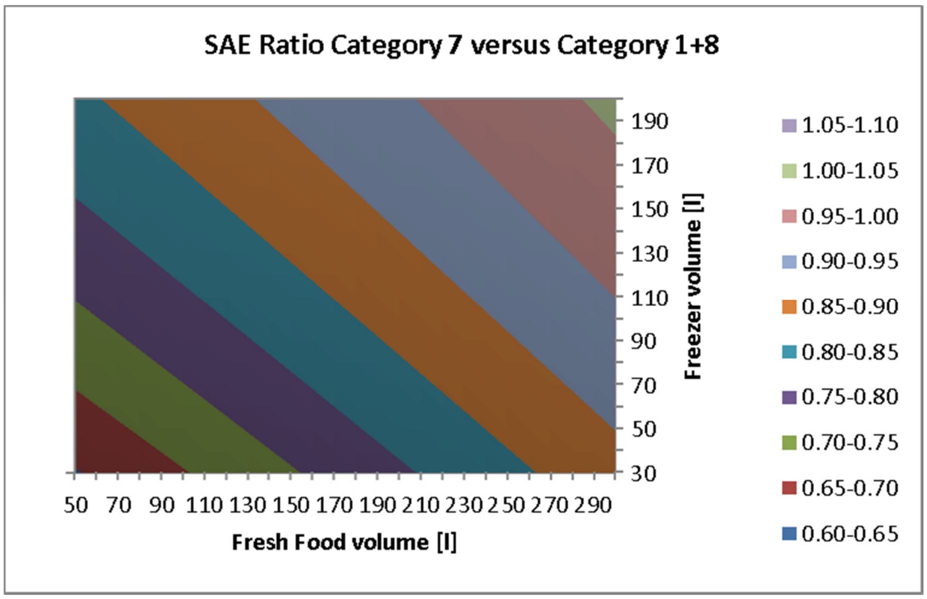
Of course, this effect is already well known as it is relatively easy to get low efficiency indexes for small refrigerators. The reason behind this is probably a too narrow data field when reference lines where established for the first label in 1995. There is no technical reason for this difference between categories, so a technically more realistic curve could be requested for category ***R***[21].

[21] *It is known that average efficiency curves should not follow a straight line but should follow a curve following more or less the increase in surface area when the volume is increased. However, straight reference lines have become the default in most energy efficiency schemes worldwide, so it is not suggested to modify this here.*

Appendix 3: Standard energy reference lines difference between categories

It is well known that for certain products it is easier to achieve the highest efficiency class (A+++) then for others. This mainly relates to the procedures used for determining average efficiencies for the first label in 1995. A statistic method would be to evaluate the fraction of A+++ in the most recent CECED database as a function of the category. Likely this is an exercise which will also be carried out by VHK. Based on this, reference lines could be shifted relative to each other.

A different way is to compare reference lines from category 1 and category 8 products with category 7 products. The comparison is made by dividing the standard energy consumption of a combi appliance of a given fresh food and freezer size and divide this through the standard energy consumption if it would have been two products (so adding the standard energy consumption of a category 1 with the same fresh food size and category 8 product with the same freezer size as the combi). No correction factors are assumed in this calculation.



An example, if you take a fridge of 200 litres and a freezer of 100 litres the SAE ratio is 0.86 which means that the combi product must consume 14 % less than the combined two products to get the same efficiency class. This is possibly realistic as the heat load is smaller for the combi (less external surface), though the efficiency of the refrigeration system may be slightly worse.

For a very small fridge of 90 litre fresh food and 30 litre freezer the SAE ratio is 0.68. This means that this product must consume 32 % less than the combination of a separate fridge of 90 litres and an upright freezer of 30 litres.

In any case this effect seems to discourage combi products compared to two separate products.

Appendix 4: Present categories and correction factors

Next picture gives a summarised view of the current categories, correction factors and formula's to calculate the energy efficiency index used to select the efficiency class.

Fridge & Freezers Energy Index

According EuP Regulation 643/2009

Published in Official Journal of European Union, 23/7/2009

According Energy Labelling Delegated Regulation 1060/2010

Published in Official Journal of European Union, 30/11/2010

Energy efficiency index

$$EEI = \frac{AE_c}{SAE_c} \times 100$$

AE_c = Annual Energy Cons. [kWh/y]

SAE_c = Standard Annual Energy Cons. [kWh/y]

$SAE_c = V_{eq}M + N + CH$

Equivalent Volume

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

V_c = Storage compartment volume

During measurements:

- Heaters must be on
- Through the door features on but not operated

Cat	Designation	M	N
1	Refrigerator with one or more fresh-food compartments	0.233	245
2	Refrigerator-cellar, Cellar and Wine storage appliances	0.233	245
3	Refrigerator-chiller and Refrigerator with a 0-star comp.	0.233	245
4	Refrigerator with a 1-star comp.	0.643	191
5	Refrigerator with a 2-star comp.	0.450	245
6	Refrigerator with a 3-star comp.	0.777	303
7	Refrigerator-freezer	0.777	303
8	Upright freezer	0.539	315
9	Chest freezer	0.472	286
10	Multi-use and other appliances	(1)	(1)

Note (1): M and N values are based on the temperature and the "star" classification of the coldest compartment.

Correction Factor	Value	Condition
FF Frost Free	1.2	For frost-free frozen food comp.
	1.0	Otherwise
CC Climate Class	1.2	For Tropical appliances
	1.1	For Subtropical appliances
	1.0	Otherwise
BI Built-in	1.2	For built in appliances < 58 cm width
	1.0	Otherwise
CH Chill	50	For appliances with a chill comp. > 15 liters
	0	Otherwise

Appendix 5: Calculation methods used in the data analysis

To use the CECED data base and convert data to the new categorisation and compensations a number of calculation steps need to be made, some of which are outlined in the next paragraphs (double quotes (") refer to the new situation).

Adjusted volume:

This uses the next formula which does not contain any correction factors any more.

$$V''_{eq} = \sum_{c=1}^{c=n} V_c \times \frac{T_k - T_c}{T_k - 4}$$

Note that an interpolated ambient temperature of Tk = 25℃ has been used. Further the target temperature of chill compartment is increased from 0 to 2℃, which reduces the equivalent volume of these compartments.

Category R:

For the present chart, the corrected energy consumption which is plotted is defined as:

$$CAE_c = AE_c - CH \times EEI$$

This allows plotting all energy consumptions, with and without chill, in one chart. This is based on the following reasoning:

$$EEI = \frac{AE_c}{SAE_c} = \frac{AE_c}{MV_{eq} + N + CH}$$

$$\Leftrightarrow AE_c - CH \times EEI = EEI \times (MV_{eq} + N)$$

In words: the corrected energy consumption can be plotted against the reference line without chill bonus.

For the new situation, the new energy consumption is calculated as follows:

$$AE''_c = AE_c \left(1 + \frac{IM_R}{100}\right)$$

Where IM_R is the impact of introducing the new global standard for category ***R*** which is estimated at 19 % in the impact report.

To plot this consumption in one chart, again a correction for the chill can be made, but now using the new chill compensation system.

$$CAE''_c = AE''_c - (M_{CH} V_{chill} + N_{CH}) EEI''$$

The problem in this correction is that the energy efficiency index in the new situation is needed which is not yet know as it depends on the new reference line.

To accommodate for this a temporary new reference line has been defined as follows:

$SAE''_c = M''V''_{eq} + N'' + (M_{CH}V_{chill} + N_{CH}) = 0.12 \times V''_{eq} + 116 + (M_{CH}V_{chill} + N_{CH})$ which is based on an average regression of the category ***R*** data.

Now the new energy efficiency index can be calculated with:

$$EEI'' = \frac{AE''_c}{SAE''_c}$$

An alternative to this procedure would have been to define chill compensation at the present level (e.g. 50 kWh/y and higher). However, this would result in impractical numbers which would need to be rescaled later.

Category RF:

The calculation method is very similar to the calculations done for category ***R***. The difference is in the impact factors (IM) which have been derived in the impact report and which depend on type I and type II.

Further the calculation of the corrected energy consumption used in the new situation chart, needs to include the frost free compensation as well. This is handled as follows:

$$CAE''_c = \frac{AE''_c - (M_{CH}V_{chill} + N_{CH})EEI''}{1 + FF_{ratio}FF_c}$$

Where the frost free parameters are defined in chapter 3.7. As for the category ***R*** also here a provisional reference line needs to be defined in order to calculate *EEI"*.

$$SAE''_c = 0.42 \times V''_{eq} + 126 + (M_{CH}V_{chill} + N_{CH})$$

This is based on an average regression of category ***RF***.

The corrected energy consumption needs also correction for the multi-door compensation but this has not been implemented yet.

Chill compartment:

The chill bonus is an increase on the reference line (SAE_c). The actual bonus received per product does depend on the efficiency level, so an effective bonus can be defined as:

$$CH_{eff} = EEI \times CH$$

For the new situation with a chill compensation, a similar effective bonus can be defined:

$$CH''_{eff} = EEI'' \times (M_{CH}V_{chill} + N_{CH})$$

This requires the energy efficiency index in the new situation which is unknown as it depends on updated *M* and *N* coefficients. For the analysis two reference lines are proposed which have already been presented above for category ***R*** and for category ***RF.***