Policy recommendations for household refrigerators and freezers

December 2013

Summary and key policy recommendations

The efficiency development of cold appliances of the last 20 years is a success story. Nevertheless, there are still large improvement potentials (e.g. vacuum space insulation, variable speed motors, LED lamps) and the current revision of the Energy Labelling and Ecodesign regulation can support developments towards refrigerators and freezers consuming even less energy. Key is the simplification of the EEI calculation formula so that the energy label brings real transparency regarding the energy efficiency of cold appliances and shows consumers which models have the lowest energy consumption.

- **New Label classes** are needed, restoring the Energy Label's incentive on manufacturers to develop even more efficient products. Topten favours an A-G Label, which is re-scaled regularly. Class A should be empty on a new Label, the target to be reached by innovation.

- **The EEI calculation formula must be made simpler and more transparent.** Realising the following principles will allow the Label to bring real transparency regarding energy efficiency and counteract current trends impeding higher energy savings:

  1. **The Energy Label and minimum efficiency requirements must be technology-neutral**. For cold appliances the current system of different reference lines for each category must be abandoned. A compartment of a certain volume and temperature must be treated equally, no matter which category it is part of. The 'adjusted volume' already accounts for different temperatures in the compartments, and **one reference line for all categories is sufficient**.

  2. **Energy efficiency must be defined considering only a product's primary function**. Extra features or functions receive **no bonuses or allowances**. For cold appliances, **the 'correction factors'** for a Frost Free function, for tropical/subtropical and built-in models and for a chill compartment **must be removed**. The correction factors hide the additional energy consumption of these extra features.

  3. The Energy Label and efficiency requirements should **challenge larger models more** than smaller ones: a curved or capped reference line would do the job.

  These changes would counteract the trends towards larger models and higher energy consumption through extra features, and would pose a stronger incentive to higher energy efficiency also for combi models by allowing consumers to compare their energy efficiency with refrigerators and freezers.

Introduction

Refrigeration is responsible for 14% of residential electricity consumption (JRC, 2009). Household refrigerators were the first appliance to be labelled and regulated, and their efficiency has increased by a factor two to three since the 1990'ies. There is still a large saving potential – from a technical point of view, but also because of their large contribution to household energy consumption.
The legislation defining the Energy Label and the Ecodesign requirements for cold appliances (and other products) is currently being revised. These policy recommendations by Topten show how the future Energy Label and Ecodesign requirements can contribute to achieving a future stock of cold appliances that consumes considerably less energy.

Best available and average technology

Energy Efficiency

Energy Efficiency has increased a lot since the introduction of the first Energy Label in 1994. Assuming that most refrigerators and freezers were in class D when the Label was introduced (Energy Efficiency Index EEI = 100%), the energy efficiency has been improved by more than a factor two (A+: EEI = 44%). Fig. 1 shows recent sales data from GfK: two thirds of the models that are sold in 23 EU Member States are in class A+, which actually is the minimum efficiency required for new models since July 2012, and 20% in A++.
The A+++ class was introduced in 2011 and reached only 4% of the sales in early 2013. The step from A++ (EEI = 33%) to A+++ (EEI=22%) requires an efficiency improvement of 33% and is relatively large. High efficiency A+++ refrigerators consume again about 50% less energy than A+ refrigerators.
Data from Topten shows that a large number of A+++ models is offered: in October 2013 60 refrigerator-freezers, 10 refrigerators and 41 freezers were listed on Topten.eu – a total of 111 A+++ models (excluding models of similar construction).

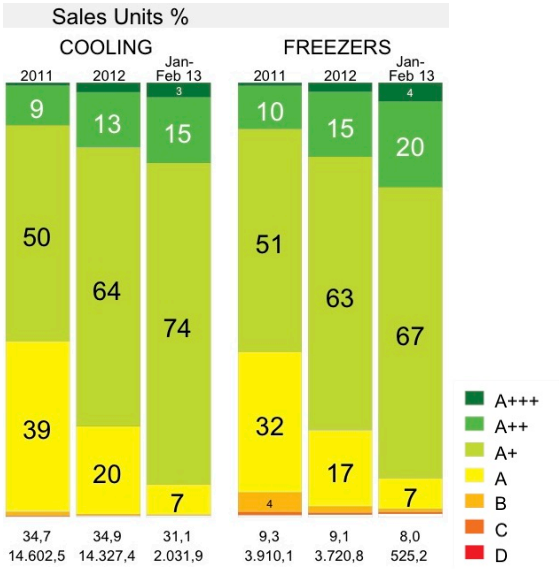


Fig. 1: Sales of refrigerators and freezers in 23 EU countries. Source: GfK.

Since July 2012 class A is being banned from the EU market, in July 2014 this step will be completed (EEI = 42). Only three classes remain on the EU market.
Clearly new classes are needed, challenging manufacturers to develop even more energy efficient products.

Absolute Energy Consumption
The absolute energy consumption of cold appliances has been reduced a lot in the last decades (IEA 4E, 2013). More recent data from CECED (Omnibus report, VHK, 2013) however shows that within the classes A++ and A+ the average energy consumption of the models on the market has increased by 11% and 8%, respectively, from 2010 to 2011. Some trends – which are supported by the Energy Label – are impeding more energy savings.

- Cold appliances are getting larger: according to CECED data from 2013 (in VHK, 2013), the net volume of cold appliances has increased from 233 l in 2001 to 268 l in 2012 (+15%). Especially for refrigerator-freezers the reference line is quite 'steep', allowing a comparatively large additional energy consumption per additional volume. The reference line should be degressive in order to ask for more efficiency improvements for large models.
- Extra features such as automatic defrosting or compressors fit for tropical conditions, increasing the energy consumption, are on the rise regarding market share. These features are rewarded by correction factors in the EEI calculation formula.
- Combined refrigerator-freezers are the most popular category and still gaining market share. This category is challenged less than for other categories by the reference lines of the EEI calculation formula. Refrigerator-freezers can have a higher energy consumption and still reach a better EEI than other categories.

EU policies and measurement standards

Requirements and Energy Label
The energy label for refrigerators and freezers was the first such label to be introduced in 1994, effective from 1995. In 1996 first energy efficiency requirements were announced and came into force in 1999, banning the majority of classes D, E and F from the market. By 2003 most products were in class A, and the Label was amended with classes A+ and A++. Based on the framework Directive on Ecodesign requirements for Energy-using products, new minimum efficiency requirements for refrigerators and freezers were introduced in 2009. Based on regulation No 643/2009, products less efficient than class A were banned from the EU market in 2010. Class A is banned from the market in two steps (Energy Efficiency Index < 44 since July 2012, EEI < 42 from July 2014), considering the measurement tolerances that have been tightened. Absorption refrigerators, which are much less efficient than compression-type refrigerators and mostly used in hotels, have less stringent minimum requirements (EEI < 125 (class F) since 2012, EEI < 110 (class E) from 2015). Wine storage appliances are excluded from the ecodesign requirements. Based on the revised framework Directive on Energy Labelling from 2010, also a new Labelling regulation (No 1060/2010) for refrigerators and freezers was adopted in 2010, introducing class A+++.

Now: revisions
Both Ecodesign and Labelling regulations will be revised in 2014. An interim report by VHK (2013) is preparing the revision (including six other product categories).
Also in 2014 the framework Directives are in revision, defining the aim, scope, approach, methodology, layout etc. of the Label and Ecodesign requirements. The revision of the cold regulations will consider the decisions of the framework revision.

Policies in other countries
Switzerland has banned A+ refrigerators and freezers since January 2013. For wine coolers Switzerland has also implemented minimum efficiency requirements: since January 2013 only class A wine coolers are allowed on the market (Swiss Energy regulation, October 2012).
According to IEA 4E, the minimum efficiency requirements benchmark is the Swiss A++ level for small appliances, but for large appliances the benchmark is what the USA applies in

2014. The reason is the steep reference line in the EU regulations especially for refrigerator-freezers, resulting in unambitious requirements for large appliances.

Complicated EEI calculation

The EU Energy Labelling scale and the minimum efficiency requirements of the regulations are based on the Energy Efficiency Index (EEI). The EEI is the annual energy consumption of a model relative to the consumption of a 'standard' model of the same category and with the same volume and temperature. The presence of different compartments and their temperature (the most important being 'fresh-food' 5°C, chill 0°C, * (one star) -6°C, ** -12°C, *** -18°C, **** (food freezer) -18°C) defines the appliance category. There are 10 different categories, of which four account for 98% of the market offer (CECED data in VHK, 2013):

- Category 1: Refrigerators (without freezer compartment)
- Category 7: Refrigerator-freezers (Combi models with fresh-food and freezer compartments)
- Category 8: Upright freezers
- Category 9: Chest freezers

For each of the ten categories a different gradient and intercept (Standard Energy Consumption at 0 litres) apply for calculating the standard energy consumption depending on the adjusted volume.
The volume is multiplied with the 'thermodynamic factor', which is the temperature difference of the compartment to an ambient temperature of 25°C, relative to the temperature difference of a fresh-food compartment (5°C). The coldest compartments, three- and four star compartments, are multiplied with a factor of 2.15 and thus are accounted for as more than twice their real volume ('adjusted volume'). All national and regional policies investigated by the Benchmarking report (IEA 4E, 2013) adjust the compartment volume to the different temperature.

Bonuses for features reducing efficiency hide extra energy consumption of up to 40%
Additionally in the EU there are bonuses granted for several functions ('correction factors'), which are multiplied with the volume of the compartments or the model to receive the 'adjusted' volume, based on which the standard energy consumption is calculated. Bonuses of up to 20% are granted for a No frost function (automatic, regular defrosting of the evaporator), for built-in appliances under 58cm width and for models that can work in tropical (up to 43°C) and subtropical (up to 38°C) conditions. The presence of a chill (0°C) compartment is rewarded with an extra 50 kWh/year bonus, even though the presence of such a compartment is already included in the adjusted volume.
The combination of several of these correction factors allows a model to reach a certain EEI with a nearly 40% higher energy consumption. In certain cases these bonuses can allow a refrigerator-freezer to jump to the next class.

The extra features that are rewarded with a bonus all contribute to higher energy consumption and have nothing to do with a cold appliance's primary function. A frost-free system heats up the evaporator in regular intervals to melt the ice, models that are able to keep a stable temperature even in 43°C need a larger compressor, built-in models may have thinner insulation because of restricted space. Instead of making the extra energy consumption of these features transparent to consumers, the Energy Label hides this and rewards these extra features. This rewarding system shows its effects on the market, and at least the No Frost and tropical cold appliances have increased their sales share.

- According to the Energy Efficiency status report from 2012 (Bertoldi 2012) the sales share of cold appliances with **No frost** function has increased from 16% to 25% between 2005 and 2010 in 10 West European countries. 47% of the 59 upright freezers and 2-door refrigerator-freezers on Topten.eu are equipped with a No Frost function (October

2013); 34% of the 29 2-door refrigerator-freezers and 60% of the upright freezers (refrigerators without freezer, chest freezers and 1-door refrigerator-freezers are never equipped with a No-Frost function).

- A survey which was conducted by the Preparatory study (2007) showed that the average ambient temperature in European kitchens is 19.5°C, with a maximum of 32°C in Spain, Italy and Hungary. The SN temperature range (10°C – 32°C) is sufficient also in the warmest places in Europe, most kitchens are clearly cooler than the 25°C the appliances are tested at today. Despite these results and without Europe having expanded into sub-tropical or even tropical regions since, the preparatory study also found that refrigerators and freezers ' *show a drastic increase of the market offer in terms of the 'maximum climatic class' towards the sub-tropic and partly the tropic climate class'.* Table 1 below shows with data from Topten.eu that nearly all A+++ models are designed to operate both in 'extended temperate' (10°C – 32°C) and **tropical** (16°C – 43°C) conditions. Only two of the models on Topten.eu cover one climate zone only. The trend observed in the preparatory study seems to have accelerated, at least in the high efficiency segment.

Table 1: Climate classes of Topten models

Climate classes; data from Topten.eu	No. Of models	N (16°-32°)	SN (10°-32°)	ST (16°-38°)	T (16°-43°)
Freestanding Refrigerator-Freezers and refrigerators	32	1	29	3	29
Chest Freezers	11		11		11
Upright Freezers	30		30	2	28

The correction factors counteract the Energy Label's aim to guide consumers to the most energy efficient models by rewarding and promoting inefficient extra features. A study from Inertek for Defra (2012) has investigated each of the correction factors in detail and recommends reducing the No Frost correction factor to 1.1 and removing the other three. Topten suggests removing all correction factors, because they impede the transparency the Energy Label is supposed to bring. The correction factors hide the additional energy consumption of extra features instead of making it visible to consumers through the EEI and energy class.

Refrigerators use only half the energy of combi appliances, but are rated as less efficient

Much larger than those hidden by the correction factors are the differences in energy consumption hidden by the different reference lines for categories. The reference lines are the correlations between the adjusted Volume (adjusted to different compartment temperatures) and the standard energy consumption, which are defined by the 'M' and 'N' values in the Ecodesign and Labelling regulations for cold appliances.
Refrigerator-Freezers have the 'steepest' correlation (M=0.777) – meaning that per additional liter this type can have the strongest increase in energy consumption. Refrigerators without freezer have the 'flattest' correlation (M=0.233), while upright (M=0.539) and chest freezers (0.472) are around 0.5 (Fig. 2). Also the N values (standard energy consumption of a model with 0 litres) are different.
These different reference lines have nothing to do with different compartment temperatures – this is already accounted for in the 'adjusted volume' (actual volume is multiplied with the 'thermodynamic factor').

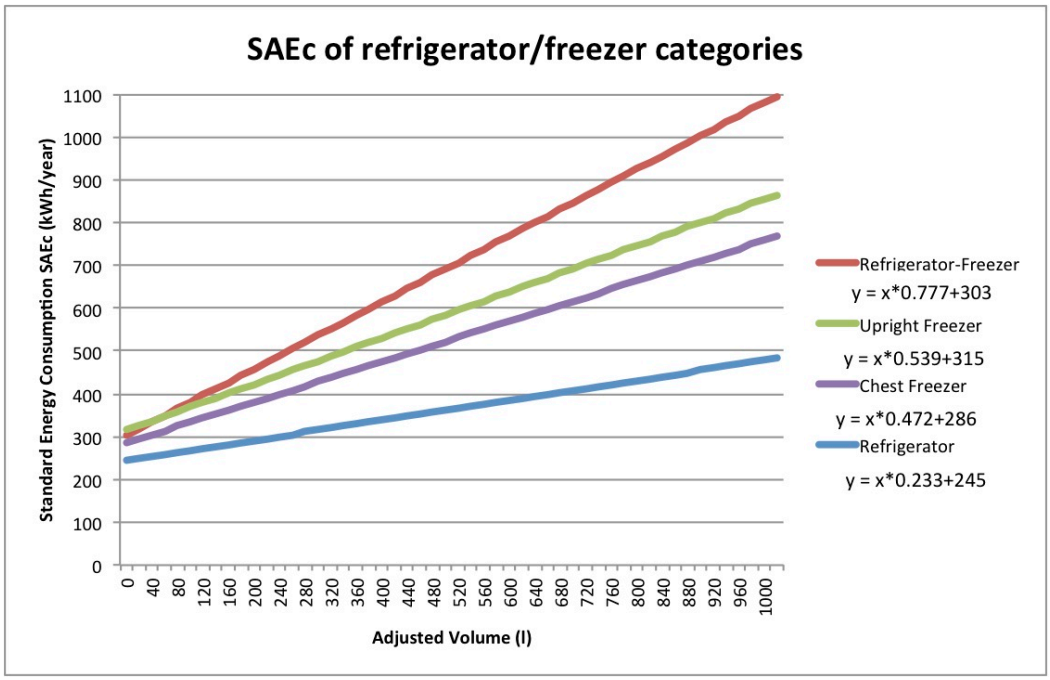


Fig. 2: Reference lines: the Standard energy consumption depends on the adjusted volume and the category

This means that a compartment of equal volume and temperature is treated differently, depending on the type of cold appliance it is part of. A compartment of 5°C and 300 litres can use 70% more energy if it is part of a refrigerator-freezer instead of a refrigerator, and still have the same EEI. A freezer compartment of 120 l that is part of a refrigerator-freezer can use 12% more energy than an upright and 24% more energy than a chest freezer – while getting the same EEI and the same energy class. A refrigerator-freezer of an adjusted volume of 600 litres can use twice as much energy as a refrigerator of the same adjusted volume and both have the same EEI.

Table 2 and figure 3 show the number of A+++ refrigerators and freezers that are on the European market in October 2013. There are 60 refrigerator-freezers in the best energy class A+++ but only 10 refrigerators - even though refrigerators on average use only half the energy of combi appliances. The situation is comparable but less extreme for upright and chest freezers: the less efficient type (upright) is 'rewarded' with a higher standard energy consumption for a given volume. Consequently, there are nearly three times as many A+++ upright freezers than chest freezers – despite their higher average energy consumption (Fig 3, table 2). Only in EU policy upright and chest freezers are not treated equally (IEA 4E, 2013). It is not understand-able, why different shapes of an identical appliance should be treated differently. The less demanding reference line for upright freezers hides their lower efficiency, while it would be the Energy Label's job to make exactly this visible.

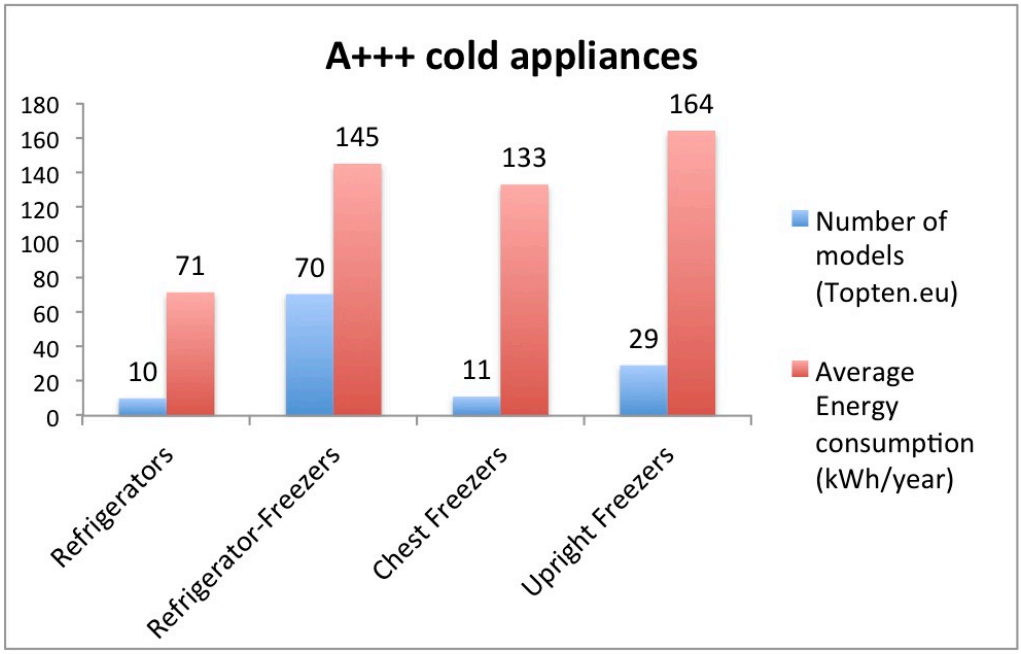
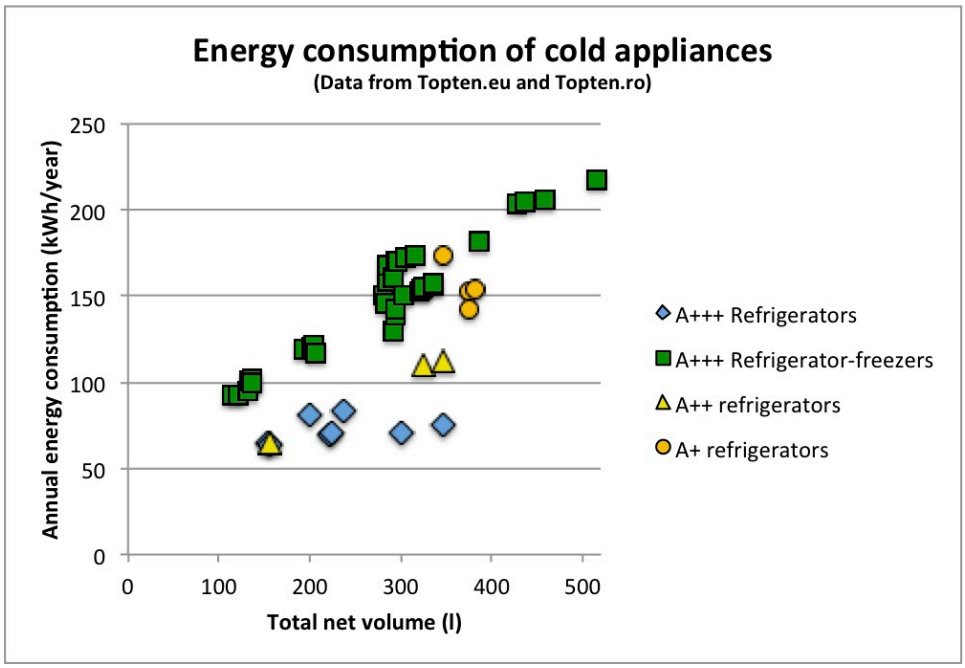


Fig. 3: Number of A+++ models and their average energy consumption (data from Topten.eu, October 2013)

Table 2: A+++ models on topten.eu (October 2013)

	Number of A+++ models	Annual Energy consumption (kWh/year)		
		Average	Min	Max
Refrigerators	10	71	64	83
Refrigerator-Freezers	60	145	93	217
Upright Freezers	30	164	101	201
Chest Freezers	11	133	117	175

Fig. 4 below shows the energy consumption of A+++ refrigerators and refrigerator-freezers in more detail, also with data from Topten (Topten.eu and Topten.ro, October 2013), according to the Energy Label. Combi models can consume twice (at same volume) or even three times (also looking at different volumes) as much energy as refrigerators – while having the same EEI and energy class. The green 'cloud' in the middle are differences caused by the No Frost – and Chill compartment – correction factors.
A+ refrigerators have a similar energy consumption as A+++ refrigerator-freezers. Thus, at the volume of around 350 – 370 litres, the difference between categories more or less equals the difference of two classes within one category. The Label Class is currently the information less important regarding energy consumption than the category. Instead, the Label should provide the main information regarding energy efficiency and consumption.



Fig, 4: Declared Energy Consumption of A+++ refrigerant-freezers and refrigerators (A+ and A++ refrigerators for comparison)

Instead of bringing transparency, the current Energy Label hides the higher energy consumption of refrigerator-freezers. To consumers it is not visible that this category can use twice or more as much energy as a refrigerator, even if they are in the same energy class. Consumers should however be able to make an informed decision. Therefore all categories, technologies, shapes etc. should be treated exactly equally, with only one reference line and identical labelling scales. One reference line is sufficient, because the different temperature of the compartments is already accounted for in the adjusted Volume.

Progressive reference lines would yield more energy savings
According to IEA 4E (2013), the use of linear performance requirements can lead to higher energy efficiency, but at the same time to higher energy consumption through increasing volume. The benchmark report also found that MEPS for large cold appliances are relatively weak in Europe compared to other regions. This can pose an incentive to market more large appliances. Indeed, data from CECED (Omnibus report, VHK, 2013) shows that the net volume of cold appliances has increased from 233 l in 2001 to 268 l in 2012 (+15%). CECED data in this report also shows that within the classes A++ and A+ the average energy consumption of the models on the market has increased by 11% and 8%, respectively, from 2010 to 2011. Increasing volume might be partly responsible for it.
In order to secure energy savings, minimum efficiency requirements and Label thresholds should be more demanding for larger products than for smaller ones. Also IEA 4E (2013) recommends to move away from linear functions as a basis for minimum efficiency requirements or Label thresholds. A curved or capped reference line would do the job.

Refrigerants

Ozone-depleting substances such as chlorinated hydrocarbons (CFCs and HCFCs) are being phased out in the EU under the Montreal Protocol and EU regulations. Fluorinated hydrocarbons (HFCs) have been used as replacement refrigerants. This type does not destroy the ozone layer, but has high Global Warming Potential (GWP). HFC-134a, the most common HFC that was applied in refrigeration systems, has a GWP of 1400 (100 years, IPCC). The use of the so-called F-gases is also restricted in the EU: the EU MAC Directive prohibits the use of F-gases with a GWP over 150 in new types of cars and vans introduced

from 2011 and in all new cars and vans produced from 2017. The F-gas regulation No 842/2006 aims at preventing leaks and at avoiding F-gases in applications where possible. The F-gas regulation is being revised and will be made more ambitious – a ban of F-gases from 2020 is considered (EIA, 2013).
According to the preparatory study (S. Faberi, 2007), HFCs were left in less than 10% of the models offered, the rest used natural refrigerants (HCs). In 2008, Greenpeace reported that around 90% of the household refrigerators and freezers used natural refrigerants (HCs), mostly isobutane (Greenpeace, 3/2008). The GWP of isobutane is indicated as <20.

Phase-out of climate-harming refrigerants
The Ecodesign regulation should ban the use of refrigerants with a GWP > 150. This GWP limit is in line with the categorisation in the MAC directive and the air conditioners Labelling and Ecodesign regulations. The Ecodesign regulation on household cold appliances could precede the planned phase-out of F-gases, complete the switch to natural refrigerants and prevent a comeback of substances speeding up global warming.

Declaration of refrigerants and their GWP
The name and GWP of the refrigerant should be included in the Fiche of the Energy Label. An icon on the Energy Label informing consumers whether the refrigerant has a high GWP or not, should be considered. Refrigerants with GWP below 40, such as R-600a/isobutane and R-290/propane, could be indicated as “climate-friendly”, others as „refrigerant with high global warming potential“.

Measurement standard

The new IEC 62552 test standard is on the way, allowing for a measurement that resembles more real-life conditions, including door openings, load rotations and measurements at different ambient temperatures. The new test standard will provide instructions for different sets of conditions and user interactions, so that it can be adapted to regional conditions and habits.
The new standard improves the chance to achieve an international harmonisation across many regions. Australia has announced that it will align with the new IEC test method and Japan is also likely to align shortly after publication. Also the US Department of Energy released a new test procedure in 2011 (finalized in 2012) that largely aligns with the requirements of the new IEC test method, and a number of Asian countries consider aligning with the new test standard (Harrington, 2013).
When Europe adapts the new standard, the test procedure should be kept as simple and inexpensive as possible – while still delivering accurate, reproducible and close-to-real-life results. Complicated and expensive measurements make the life of market surveillance authorities hard. To prove non-compliance of a model, usually four units have to be tested according to the standard. Market surveillance authorities in the EU Member States have limited budget, and more activities are needed in almost all Member States (ATLETE, 2011). Simple test standards can facilitate their life and allow for a broader range of products to be tested.

According to test results from RegenT (VHK, 2013) the new measurement standard will deliver higher energy consumption values for some models, especially for category 7 models.
Topten sees no need to adapt the Energy Label to the results according to the new standard – only if the resulting energy consumption values are lower and lead to many products being in the Label’s top classes. If most products result in having similar or higher energy consumption, no adaptation of the Label is needed for that. Technical progress will lead to more efficient products that ‘climb up the Label’s ladder’.

Technical improvement options

Despite the huge efficiency improvements that the industry has achieved in the past decades there are still large potentials in future improvements. More energy efficient motors (variable speed drives), LED lamps or better insulation are improvement options. Vacuum space insultion for example could yield more than 50% energy savings and at the same time allow for a larger volume because the normal thermal insulation material is not needed (Brüniger, et al., 2013).

Topten policy recommendations

EEI calculation for Energy Label and minimum efficiency requirements:

- **The EEI calculation formula must be made simpler and more transparent.** Realising the following principles will allow the Label to bring real transparency regarding energy efficiency and counteract current trends impeding higher energy savings:
  1. **The Energy Label and efficiency requirements must be technology-neutral**. For cold appliances the current system of different reference lines for each category must be abandoned. A compartment of a certain volume and temperature must be treated equally, no matter to which category it belongs. The 'adjusted volume' already accounts for different temperatures in the compartments, and **one reference line for all categories is sufficient**.
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  3. The Energy Label and efficiency requirements should **challenge larger models more** than smaller ones: a curved or capped reference line would do the job.

  These changes would counteract the trends towards larger models and higher energy consumption through extra features, and would pose a stronger incentive to higher energy efficiency also for combi models by allowing consumers to compare their energy efficiency with refrigerators and freezers.

Energy Label:

- **New Label classes** are needed, restoring the Energy Label's incentive on manufacturers to develop even more efficient products. Topten favours an A-G Label, which is re-scaled regularly. Class A should be empty on a new Label, the target to be reached by innovation.
- The name and **GWP of the refrigerant** should be included in the Label's Fiche, and an icon on the Label allow consumers to find models with low-GWP refrigerants should be considered.

Ecodesign:

- **New minimum efficiency requirements** should be announced. However, in order to lead to real energy savings, these need to be based on an EEI calculation formula that is not flawed (see above).
- Adopt **ecodesign requirements also for wine coolers:** this loophole should be closed with the current revision. Switzerland is going ahead with a minimum requirement asking for class A efficiency for all wine coolers. The EU should adopt the same reuquirement.

- **Phase out high-GWP refrigerants:** Refrigerants with a GWP > 150 should be banned from the market.
- If the energy consumption results according to the new standard are mostly higher, **no extra adaptation of the Label** to this is needed.

Measurement standard:

- The **new measurement standard** should be **kept simple** to make tests affordable for market surveillance authorities.

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