Appliances Guide
Get super-efficient appliances

bigEE

What users can save with energy-efficient refrigerators and freezers

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1. Introduction

About half of the typical energy consumption of today's refrigerators and freezers could be saved with the most energy-efficient appliances available today, and even higher savings will be possible with next generation technologies. These savings are very cost-effective as they exceed the additional costs of more efficient appliances.

Domestic refrigerators and freezers (known as 'cold appliances') are among the most widely used electrical appliances all round the world. They are used for storing and freezing food and increasing the lifespan of fresh food. As this is a basic need, many dwellings are equipped with cold appliances. In industrialised countries, the average household already owns more than one appliance and ownership is growing fast in developing countries.
This bigEE text presents the potential energy and cost savings from the most energy-efficient currently available appliances (Best Available Technology, BAT) and from designs that are technically feasible with what we know today but not yet commercialised (BNAT: Best Not (yet) Available Technology) for six common types of refrigerators and freezers, see chapter 2. Before, we present some basic facts about refrigerator and freezer functions and technology.

1.1 What are cold appliances?

Refrigerators and freezers, also known as "cold appliances", can be defined by two **product performance parameters**. The first parameter is the **volume** (expressed in litres) of the appliance, or of its compartments, when more than one is present. The volume is thereby expressed as net inside volume and by a so-called "equivalent volume", which is weighted by a factor in accordance with the different compartment temperature characteristics. The second parameter defines the product cooling/freezing performance or the **service** provided by the appliance, mainly as fresh food refrigeration or freezing, or frozen food conservation and is related to the minimum temperature to be reached inside the different compartments. This product performance is also quantified through the so-called "star system". Cold appliances are divided by service into the three categories refrigerator, freezer and refrigerator-freezer (combination in one appliance). The latter are often also referred to as *fridge-freezer*.
In principle, the same technology and kind of appliances are used worldwide though there are some differences regarding types of appliances, refrigerants, energy efficiency standards, or recycling procedures.

1.2 Main types of "cooling" technologies / technical background

Compressor type cold appliances are more efficient than absorption type appliances

In principle, all cold appliances work with the same physical effect: they use the evaporation of a liquid to absorb heat. The liquid used in a refrigerator or freezer is called *refrigerant*. It evaporates at an extremely low temperature, so it can create freezing temperatures inside the refrigerator.
Refrigeration appliances can further be differentiated between two main types according to the technology: **compression-type** and **absorption-type refrigeration** appliances[1]. In a compression-type appliance, refrigeration is effected by means of a motor-driven compressor, whereas for an absorption-type appliance, an absorption process using heat as energy source effects the refrigeration. This leads to about a factor three in **higher** energy efficiency for a compression-type appliance. Therefore, only compression-type appliances are described here.

Compression-type appliance

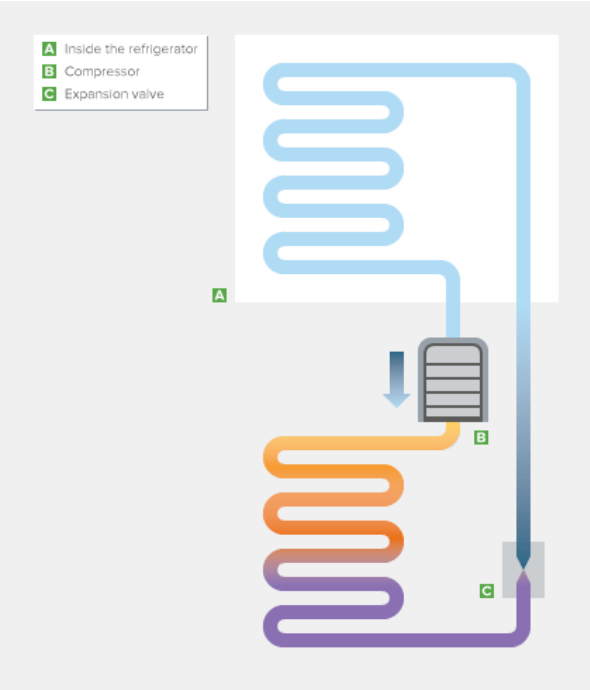

Figure 1: How a compression-type refrigerator works

The basic parts and mechanism of any compressor driven cold appliance are:

- **Compressor:** the electrically driven compressor compresses the gaseous refriger-ant. This raises the **refrigerants** pressure and temperature.
- **The heat exchanging pipes – serpentine or coiled set – outside the unit (condenser)** allow the refrigerant then to dissipate the heat of the pressurization; as it cools, the refrigerant condenses into liquid form;
- The refrigerant then flows through the **expansion valve**, which causes the refriger-ant to move from a high-pressure zone to a low-pressure zone so that it expands and evaporates.
- By evaporating, it cools down in the **heat exchanging pipes inside the unit (evaporator)** and absorbs heat, so the inside of the refrigerator or freezer is made cold.
- Then this cycle of heat transfer from inside to outside the unit is repeated.
- To retain the cold inside the cold appliance as best possible, the units have a **thermal door and cabinet insulation** and a good door gasket.

[1] The main type of refrigerator used in residential buildings is the compression-type and compared to this, the annual worldwide market for absorption refrigerators is very small and counts for only about 1.5 million units. Most of these appliances are used in recreation vehicles and boats (mainly gas appliances), and minibars for hotels and other professional applications whereas only less than 40,000 units are estimated for household use. Especially in developing countries, a niche market exists with kerosene vaccine coolers with absorption technology.

More technical background on refrigerators and freezers, and which technical options are available to save energy and reduce climate change impact, is provided in the bigEE text,Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'.

2. Energy and cost saving potential for six types of domestic cold appliances

Six types of cold appliances dominate the market and offer large cost-effective energy savings

The six types of "cold appliances" are in three **categories**:

- **Refrigerator**: intended for preservation of food, having at least one compartment suitable for the storage of fresh food (typical temperature range 2 to 6 °C);
- **Freezer**: having one or more compartments suitable for freezing foodstuff from ambient temperature down to a temperature of -18 °C and suitable for the storage of frozen food under three-star storage conditions (-18 °C).
- **Refrigerator-freezer**: having at least one compartment suitable for the storage of fresh food and at least one other suitable compartment for the freezing of fresh food and the storage of frozen food under three-star storage conditions (-18 °C);

Figure 2: Refrigerator, freezer, refrigerator-freezer

Appliances vary greatly in their configurations and the range of options.

The most common **types** of cold appliances worldwide are:

- Single-door refrigerator without freezer (chapter 2.1)
- Single-door refrigerator with freezer (chapter 2.2)
- Double-door fridge-freezer (chapter 2.3)
- Side-by-side fridge-freezer (chapter 2.4)
- Upright freezer (chapter 2.5)

- Chest freezer (chapter 2.6)

General information:

Units with restricted airflow circulation, such as built-in refrigerators, are usually less energy efficient than freestanding units, as the temperature of the surrounding environment of the unit is higher due to the restricted airflow.

Frost-free units or auto defrost units keep moisture out of the unit by using blower units and a heating coil beneath the unit, which heats the freezer compartment at regular intervals in order to melt any ice build up (Bhide 2010). Manual defrost models have tended to use less energy than frost free models (automatic defrost), but these must be defrosted periodically to remain energy efficient. The best frost-free models on the market are now as good as manual defrost models (energyrating.gov.au 2011).

2.1 Single-door refrigerator without freezer (freestanding and built-in)

Single-door refrigerators without freezer show large cost-effective energy savings compared to inefficient models on the market, especially in Western Europe and South Asia (India) as such refrigerators are popular in these regions.

Overview, Description of the appliance

Figure 3: Single-door refrigerator without freezer

This type of refrigerator is characterized by one or more compartments suitable for the storage of fresh food, which is/are accessible from one single door on the front.

Used mainly in these World regions:
Western Europe, South Asia (India)

Single-door refrigerators without freezer:
Comparing inefficient models and Best Available Technologies (BAT) on the worldwide market with future Best No yet Available Technologies (BNAT) potential

		Energy (kWh/year), in accordance with ISO standard**	Energy class	Energy saving potential vs. inefficient model	Energy cost savings versus inefficient model (EUR in 15 years at 12 EUR-Cent/kWh)
Small 156 litres (Volume in accordance with EU/ISO standard)	Inefficient model	91	EU Energy class: A		
	BAT level	64	EU Energy class: A+++	29 %	48
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	44	32 % better than required by EU Energy class A+++	52 %	85
Medium 224 litres (Volume in accordance with EU/ISO standard)	Inefficient model	163	EU Energy class: A		
	BAT level	71	EU Energy class: A+++	56 %	166
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	49	32 % better than required by EU Energy class A+++	70 %	206
Large 355 litres (Volume in accordance with EU/ISO standard)	Inefficient model	206	EU Energy class: A		
	BAT level	103	EU Energy class: A++	50 %	186
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	52	32 % better than required by EU Energy class A+++	75 %	278

Source: topten.eu (2012)[2] for Energy (kWh/year) of typical inefficient model and example of BAT model, own calculations of BNAT level, Energy saving potential and Energy cost savings

* EEI = Energy efficiency index

** Information on standards and test procedures for energy efficiency is provided in the bigEE text ‚Test procedures, measurements and standards for refrigerators and freezers'

The above-mentioned BAT/BNAT levels can be achieved by different design options (see the bigEE text ‚Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'). The supposed Energy efficiency index of 15 % (BNAT level) is based on our own estimate of what is technically feasible.

Additional information

India: The typical low-end direct-cool (not frost free version with natural convection) 160 litres model has been losing popularity drastically, while the market of frost-free units grows. A wide range of volumes is available in order to meet consumer prefer-ence and use. The volumes range from less than 150 litres to more than 300 litres (Bhide 2010).

[2] 2011 for "Small inefficient model" and "Large Model"

2.2 Single-door refrigerator with freezer (freestanding and built-in)

Single-door refrigerators with freezer show large cost-effective energy savings compared to inefficient models on the market, especially in West-ern Europe, South Asia (India) and Centrally planned Asia and China as such refrigerators are popular in these regions.

Overview, Description of the appliance

Figure 4: An energy-efficient single-door refrigerator with freezer

A refrigerator-freezer has at least one compartment suitable for the storage of fresh food and at least one other suitable for the freezing of fresh food and the storage of frozen food under three-star storage conditions (-18°C).

Used mainly in these World regions:
Western Europe, South Asia (India), Centrally planned Asia and China

The BAT/BNAT levels mentioned below can be achieved by different design options (see the bigEE text ‚Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'). The supposed Energy efficiency index of 15 % (BNAT level) is based on our own estimate of what is technically feasible.

Single-door refrigerator with freezer (freestanding and built-in):
Comparing inefficient models and Best Available Technologies (BAT) on the worldwide market with future Best No yet Available Technologies (BNAT) potential

		Energy (kWh/year), in accordance with ISO standard**	Energy class	Energy saving potential vs. inefficient model	Energy cost savings versus inefficient model (EUR in 15 years at 12 EUR-Cent/kWh)
Small 114 litres (Volume in accordance with EU/ISO standard)	Inefficient model	160	EU Energy class: A+		
	BAT level	71	EU Energy class: A+++	56 %	160
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	49	32 % better than required by EU Energy class A+++	70 %	201
Medium 193 litres (Volume in accordance with EU/ISO standard)	Inefficient model	231	EU Energy class: A+		
	BAT level	119	EU Energy class: A+++	48 %	201
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	82	32 % better than required by EU Energy class A+++	65 %	268
Large 224 litres (Volume in accordance with EU/ISO standard)	Inefficient model	268	EU Energy class: A+		
	BAT level	128	EU Energy class: A+++	52 %	252
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	88	32 % better than required by EU Energy class A+++	67 %	325

Source: topten.eu (2012) for Energy (kWh/year) of typical inefficient model and example of BAT model, own calculations of BNAT level, Energy saving potential and Energy cost savings

* EEI = Energy efficiency index

** Information on standards and test procedures for energy efficiency is provided in the bigEE text ‚Test procedures, measurements and standards for refrigerators and freezers'

2.3Double-door fridge-freezer (freestanding and built-in)

Double-door fridge-freezers show large cost-effective energy savings compared to inefficient models on the market, especially in Europe, North America, Centrally Planned Asia and China as such refrigerator-freezers are popular in these regions.

Overview, Description of the appliance

Figure 5: Double-door fridge-freezer

A double-door refrigerator-freezer has at least one compartment suitable for the storage of fresh food and at least one other suitable for the freezing of fresh food and the storage of frozen food under three-star storage conditions (-18°C). The two compartments are accessible independently from two doors on the front.
Top-freezer refrigerators: The freezer section is located at the top of the unit. They offer the most storage for their size and are usually more efficient than similar models of bottom freezer and side-by-side types. Bottom-Freezers: The freezers in these units are more conveniently placed at the bottom of the unit, however they are less energy efficient than similar top-freezer models (Bhide 2010).

Used mainly in these World regions:
Western Europe, North America, Central and Eastern Europe, Centrally planned Asia and China
Double-door fridge-freezer (freestanding and built-in):
Comparing inefficient models and Best Available Technologies (BAT) on the worldwide market with future Best No yet Available Technologies (BNAT) potential

		Energy (kWh/ year), in accord- ance with ISO stand- ard**	Energy class	Energy saving potential vs. ineffi- cient model	Energy cost savings versus inef- ficient mod- el (EUR in 15 years at 12 EUR-Cent/kWh)
Small[l] 172 litres (Volume in accord- ance with Chinese standard)	Inefficient model	237	Chinese National energy efficiency grade 2 (equivalent to EU Energy class A)		
	BAT level	91	55 % better than re- quired by the Chinese National energy efficiency grade 1 (equivalent to	62 %	262

			EU Energy class A+++)		
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	77	32 % better than required by EU Energy class A+++	68 %	288
Medium[2] 293 litres (Volume in accordance with EU/ISO standard)	Inefficient model	303	EU Energy class: A+		
	BAT level	139	EU Energy class: A+++	54 %	296
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	97	32 % better than required by EU Energy class A+++	68 %	371
Large[3] 583 litres (Volume in accordance with AHAM U.S. standard)	Inefficient model	510	No Energy Star (equivalent to EU Energy class A+)		
	BAT level	356	12,5 % better than required by Energy Star (equivalent to EU Energy class A++)	30 %	249
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	192	32 % better than required by EU Energy class A+++	62 %	514

Source: [1]top10.cn / [2]topten.eu / [3]toptenusa.org (2012) for Energy (kWh/year) of a typical inefficient model and example of a BAT model, own calculations of BNAT level, Energy saving potential and Energy cost savings

* EEI = Energy efficiency index

** Information on standards and test procedures for energy efficiency is provided in the bigEE text ‚Test procedures, measurements and standards for refrigerators and freezers'

The above-mentioned BAT/BNAT levels can be achieved by different design options (see the bigEE text ‚Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'). The supposed Energy efficiency index of 15 % (BNAT level) is based on our own estimate of what is technically feasible.

Additional information

The common size for refrigerators in the US is about 550 litres (Presutto et al. 2007) and traditionally, top-freezer appliances have been the most common type, although some of the other styles (e.g. side by side units) are also very popular (Refrigerator Market Profile 2009[3]).

In Australia, the most common type of refrigerator is the top and bottom laid-out model (Bhide 2010). The second most common model is the stand-alone freezer. Research has also shown that Australians prefer moderately sized refrigerators. When comparing their consumption with that of other countries in the world, it can be seen that most Australian fridge consumers tend to prefer commodities that are between 300-500 litres.

In Europe, the typical models are between 300-400 litres and the most popular purchase is a 300 litre model. There is an increase in use of combined refrigerator/freezer devices (Presutto et al. 2007). Most European refrigerators include a moist cold fridge section (which does require defrosting at irregular intervals) and a frost-free freezer section, to keep frozen food frost-free.

The most common type of refrigerator in China is the "Refrigerator/Freezer" (Class 5). Thereby, three major size categories constitute the bulk of Chinese refrigerator purchases: 170 litres, 220 litres, and

[3] http://www.energystar.gov/ia/partners/manuf_res/downloads/Refrigerator_Market_Profile_2009.pdf

270 litres. In 2007, the 170 litre refrigerators accounted for 15% of sales (down from nearly 100% for 170 litre and smaller refrigerators in the early 1990s), while 220 litre refrigerators accounted for the vast majority of sales, at 64% of the total. The remaining 21% included the 270 litre sizes and larger. Current trends suggest that the 170 litre size refrigerator will continue to decline in share, while that of the 270-litre size refrigerator will increase. Indeed, there is even a small but growing volume of purchases for refrigerators greater than 500 litres in capacity[4]. For the first time, the 2008 standard included refrigerators in this size category.
Refrigerator-freezers are more dominant in the Japanese market than in the EU one. No-frost models have the largest share amongst these and the models are usually between 300-400 litres (Presutto et al., 2007)

2.4 Side-by-side fridge-freezer

Side-by-side fridge-freezers show large cost-effective energy savings compared to inefficient models on the market, especially in North America, Centrally Planned Asia and China as such refrigerator-freezers are popular in these regions.

Overview, Description of the appliance

Figure 6: Side-by-side fridge-freezer

[4] http://www.osti.gov/bridge/servlets/purl/928311-qSUsOL/928311.PDF, 2008

A "Side-by-side fridge-freezer" describes a refrigerator-freezer with the freezer and fresh food compartments mounted next to each other (Toptenusa.org 2011).
Side-by-side fridge-freezers are less efficient than similar top-freezer and bottom-freezer units (Bhide 2010), therefore using more electricity and offering less usable space. According to toptenusa.org (2011), choosing a side-by-side unit "comes with an energy penalty in the range of 50-150 kWh per year (about 20% of total fridge energy consumption)". The cited 'Consumer Reports' approach to measure the usable space in a refrigerator shows dramatic results. According to that report, top freezer models average about 80% usable space, bottom freezers average 67%, and side-by-side units average 63%. That means a smaller top freezer model is able to store as much as the larger side-by-side or bottom-freezer option.

Used mainly in these World regions:
North America, Centrally planned Asia and China

Side-by-side fridge-freezer:
Comparing inefficient models and Best Available Technologies (BAT) on the worldwide market with future Best No yet Available Technologies (BNAT) potential

		Energy (kWh/year), in accordance with ISO standard**	Energy class	Energy saving potential vs. inefficient model	Energy cost savings versus inefficient model (EUR in 15 years at 12 EUR-Cent/kWh)
Medium[1] 524 litres (Volume in accordance with EU/ISO standard)	Inefficient model	522	EU Energy class: B		
	BAT level	315	EU Energy class: A++	40 %	373
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	158	32 % better than required by EU Energy class A+++	70 %	655
Large[2] 750 litres (Volume in accordance with AHAM U.S. standard)	Inefficient model	541	NO Energy Star (equivalent to EU Energy class A+)		
	BAT level	379	12,5 % better than required by Energy Star (equivalent to EU Energy class A++)	30 %	292
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	213	32 % better than required by EU Energy class A+++	61 %	590

Source: [1]topten.eu / [2]toptenusa.org (2012) for Energy (kWh/year) of a typical inefficient model and example of BAT model, own calculations of BNAT level, Energy saving potential and Energy cost savings
* EEI = Energy efficiency index
** Information on standards and test procedures for energy efficiency is provided in the bigEE text, Test procedures, measurements and standards for refrigerators and freezers'

The above-mentioned BAT/BNAT levels can be achieved by different design options (see the bigEE text ‚Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'). The supposed Energy efficiency index of 15 % (BNAT level) is based on our own estimate of what is technically feasible.

Additional information
China: The market share of side-by-side units in China is still very small but growing fast (Presutto et al., 2007).

2.5 Upright freezer (freestanding and built-in)

Upright freezers show large cost-effective energy savings compared to inefficient models on the market, especially in Western Europe and North America as such freezers are popular in these regions.

Overview, Description of the appliance

Food freezers have one or more compartments suitable for freezing foodstuffs from ambient temperature down to a temperature of -18°C and are also suitable for the storage of frozen food under three-star conditions. In the case of the upright type, the compartments are accessible from the front (cupboard-style). The front-mounted door and shelves allow for easy organization. On the other hand, vertical or upright freezers provide less usable storage volume than chest freezers and are less energy-efficient (Bhide 2010).

Used mainly in these World regions:
E.g. Western Europe, North America

Upright freezer (freestanding and built-in):
Comparing inefficient models and Best Available Technologies (BAT) on the worldwide market with future Best No yet Available Technologies (BNAT) potential

		Energy (kWh/year), in accordance with ISO standard**	**Energy class**	**Energy saving potential vs. inefficient model**	**Energy cost savings versus inefficient model (EUR in 15 years at 12 EUR-Cent/kWh)**
Small[1] 104 litres (Volume in accordance with EU/ISO standard)	Inefficient model	117	EU Energy class: A+		
	BAT level	101	EU Energy class: A++	14 %	29
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	69	32 % better than required by EU Energy class A+++	41 %	87

		Energy (kWh/year), in accordance with ISO standard**	Energy class	Energy saving potential vs. inefficient model	Energy cost savings versus inefficient model (EUR in 15 years at 12 EUR-Cent/kWh)
Medium[1] 255 litres (Volume in accordance with EU/ISO standard)	Inefficient model	287	EU Energy class: A+		
	BAT level	161	EU Energy class: A+++	44 %	226
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	111	32 % better than required by EU Energy class A+++	61 %	316
Large[2] 504 litres (Volume in accordance with AHAM U.S. standard)	Inefficient model	405	NO Energy Star (equivalent to EU Energy class A)		
	BAT level	355	Energy Star (equivalent to EU Energy class A+)	12 %	91
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	152	32 % better than required by EU Energy class A+++	62 %	454

Source: [1]topten.info / [2]toptenusa.org (2012) for Energy (kWh/year) of typical inefficient model and example of BAT model, own calculations of BNAT level, Energy saving potential and Energy cost savings

* EEI = Energy efficiency index

** Information on standards and test procedures for energy efficiency is provided in the bigEE text 'Test procedures, measurements and standards for refrigerators and freezers'

The above-mentioned BAT/BNAT levels can be achieved by different design options (see the bigEE text ‚Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'). The supposed Energy efficiency index of 15 % (BNAT level) is based on our own estimate of what is technically feasible.

2.6 Chest freezer

Chest freezers show large cost-effective energy savings compared to inefficient models on the market, especially in Western Europe and North America as such freezers are popular in these regions.

Overview, Description of the appliance

Figure 7: Chest freezer

Food freezers have one or more compartments suitable for freezing foodstuffs from ambient temperature down to a temperature of -18°C and are also suitable for the storage of frozen food under three-star conditions (Bhide 2010). In the case of the chest freezer type, the compartments are accessible from the top. Compared to upright freezers, chest freezers are usually more energy efficient, especially because less cold air escapes while the top-mounted door is open (energystar.gov).

Used mainly in these World regions:
Western Europe, North America

The BAT/BNAT levels mentioned in the table below can be achieved by different design options (see the bigEE text ‚Technical background and design options to raise cold appliance efficiency and to reduce their environmental impact'). The supposed Energy efficiency index of 15 % (BNAT level) is based on our own estimate of what is technically feasible.

Chest freezer:

Comparing inefficient models and Best Available Technologies (BAT) on the worldwide market with future Best No yet Available Technologies (BNAT) potential

		Energy (kWh/year), in accordance with ISO standard**	Energy class	Energy saving potential vs. inefficient model:	Energy cost savings versus inefficient model (EUR in 15 years at 12 EUR-Cent/kWh)
Small[1] 200 litres (Volume in accordance	Inefficient model	196	EU Energy class: A+		
	BAT level	117	EU Energy class: A+++	40 %	142

with EU/ISO standard)	BNAT level (Calculated in accordance with EU EEI* = 15 %)	80	32 % better than required by EU Energy class A+++	59 %	208
Medium[1] 331 litres (Volume in accordance with EU/ISO standard)	Inefficient model	324	EU Energy class: A		
	BAT level	152	EU Energy class: A+++	53 %	310
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	104	32 % better than required by EU Energy class A+++	68 %	397
Large[2] 615 litres (Volume in accordance with AHAM U.S. stand-ard)	Inefficient model	425	NO Energy Star (equivalent to EU Energy class A+)		
	BAT level	379	Energy Star (equivalent to EU Energy class A+)	11 %	82
	BNAT level (Calculated in accordance with EU EEI* = 15 %)	155	32 % better than required by EU Energy class A+++	63 %	485

Source: [1]topten.eu / [2]toptenusa.org (2012) for Energy (kWh/year) of typical inefficient model and example of BAT model, own calculations of BNAT level, Energy saving potential and Energy cost savings

* EEI = Energy efficiency index

** Information on standards and test procedures for energy efficiency is provided in the bigEE text ‚Test procedures, measurements and standards for refrigerators and freezers'

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