

Accelerated replacement of refrigerators and freezers – does it make sense?

Ina Rüdener, Carl-Otto Gensch

Öko-Institut e.V. - Institute for applied ecology

Abstract

The goal of this study was to assess the environmental and economic implications of the accelerated replacement of refrigerators and freezers of different age, used in private households. The evaluation was conducted in an individual households' perspective. The question "Does it make sense to further use an old refrigerator or freezer or is it better to buy a new one?" depends on the question, in what time the additional environmental impacts through the production of the new appliance and end-of-life-treatment of the old one are compensated through the lower electricity demand of the new one. The same question has to be answered on the cost side.

In the study at hand first a life cycle assessment and life cycle cost analysis of new cold appliances was conducted. Then the differences between appliances of different age were assessed. Finally the further use of appliances in stock (manufactured in 1980, 1985, 1990, 1995 and 2000) was compared with the acquisition and use of a new one of 2005 (including the recycling of the old appliance). Four appliance categories were investigated: refrigerators, fridge-freezers, upright and chest freezers. To evaluate, if and how much the results depend on the energy efficiency of the new appliance, next to the base case (with an A+-appliance) two sensitivity analyses with A- and A++-appliances were conducted.

Under environmental aspects the accelerated replacement of cold appliances in stock with new A+ and A++-appliances makes sense for refrigerators, fridge-freezers and upright freezers which are older than five to ten years.

Introduction

In Germany the market saturation rate of refrigerators in 2003 was 115 % and of freezers 74 % [1]. Both figures were quite stable in recent years, which indicates that the market is saturated and purchasing activities are dominated by replacement of existing appliances.

Next to the failure of the old appliance or changing needs of households another reason for the replacement of an existing appliance could be the presumably lower energy demand of a new one (even though the old one is still working). For an individual household the question "Does it make sense to further use an old refrigerator or freezer or is it better (in environmental and economic terms) to buy a new one?" depends on the question, in what time the additional environmental impacts through production of the new appliance and end-of-life-treatment of the old one are compensated through the lower electricity demand of the new one. The same question has to be answered on the cost side (acquisition costs versus lower running costs).

Considering the share of refrigerating and freezing at the total residential electricity consumption in Europe and the age distribution in stock a considerable saving potential in energy demand and the emission of greenhouse gases is foreseeable when older appliances are replaced.

Goal of the study

The goal of this study was to assess the environmental and economic implications of the accelerated replacement of refrigerators and freezers of different age, used in private households. The evaluation was conducted in an individual households' perspective.

This study was commissioned by the European Committee of Manufacturers of Domestic Equipment (CECED). The results were meant for internal and external communication purposes.

Methodological approach

To meet the goal of the study, the environmental impacts of the further use of existing cold appliances in stock of different age had to be compared to the acquisition and use of a new appliance in 2005.

To get an idea of the magnitude of the different life cycle stages, first a streamlined life cycle assessment (LCA) and life cycle cost analysis (LCC) of new cold appliances was conducted. The LCA was accomplished according to ISO 14040 ff., the LCC takes into account all costs, which occur for private households along the life cycle of the appliance.

Then, the differences between the cold appliances according to their age were assessed. Relevant differences mainly occur during the use phase (decreasing energy demand with later years of manufacture) and regarding the environmental impacts caused during the end-of-life treatment (due to different refrigerants and foaming agents used).

Finally the further use of cold appliances in stock (of different age) was compared to the acquisition and use of a new one. Two important assumptions regarding the allocation of certain impacts were made: firstly, the environmental impacts of the production and the costs of the acquisition of the old appliances are assumed to be already depreciated (i.e. no annual costs are considered). Secondly, the recycling of the old appliance is allocated to the alternative "acquisition of a new appliance". Both assumptions are not unambiguous, as for example the recycling will take place anyway sometime. However these decisions result in a realistic picture of the amount of the environmental impacts and costs, and at what point in time these occur, if one or the other alternative is chosen. Especially the end-of-life treatment of older appliances might result in an initial increase of the total emissions of greenhouse gases or ozone depleting substances as CFCs were used as cooling and foaming agents.

For each alternative the environmental impacts and the costs connected to the considered life cycle phases were calculated on an annual basis (per year). These annual values are then cumulated to give the total environmental impacts and costs after one, two, three ... up to some 20 years of use. Thus it can be determined after what time period the initial environmental impact through acquisition and recycling is compensated by the lower impacts during the use phase through the more efficient new appliance (= payback period). The same applies for the cost side. Usually these payback periods are not calculated by the households themselves.

Scope of the study and system modelling

Functional Unit

The functional unit of the system under consideration is defined as "use of a cold appliance of the below specified category, age, size and energy efficiency class in private households". For the streamlined LCA the use period is the life span of the product under consideration (14 years for refrigerators and fridge-freezers, 17 years for upright and chest freezers [2]). For the evaluation of the accelerated replacement the environmental impacts and costs are calculated on an annual basis for the years from 2005 to 2025 (21 years).

Regarded product categories and alternatives

Four categories of cold appliances were distinguished: refrigerators (155 litres), 2-Door fridge-freezer (200 + 90 litres), upright and chest freezers (190 litres). For the assessment of the accelerated replacement, for each category six alternatives were compared: The further use of old appliances of 1980, 1985, 1990, 1995 and 2000 and the acquisition and use of a new appliance in 2005. The latter alternative includes the recycling of the existing appliance.

System boundaries

For the environmental assessment three main life cycle phases of cold appliances were distinguished: *Production and Distribution*, *Use phase* and *End-of-Life treatment*.

To represent different sizes of appliances the production and distribution of a "small" and a "large" appliance was modelled. Included were the material supply, the manufacturing process itself and the distribution.

The use phase is mainly characterised by the electricity demand of the appliances. The electricity demand and the connected impacts were differentiated according to the four product categories (see above) and according to their year of manufacture (1980, 1985, 1990, 1995 and 2005). For the appliances in stock the energy demand was derived from fleet average figures and average energy efficiency indices for refrigerators and freezers [3, 4]. As electricity demand of the new appliances in all four categories the standard electricity consumption of an 'A+'-class appliance was assumed. Potential differences between the actual and the stated energy demand due to different user habits or ageing of materials were not considered. As sensitivity analysis the acquisition of 'A' (less efficient than in base case) and 'A++'-appliances (more efficient than in base case) was calculated.

The impacts through the end-of-life treatment (here: re-distribution and recycling) vary according to the age of the old appliance due to different used refrigerants and foaming agents [5]. Depending on their year of manufacture the appliances were assigned to four types, which differ with respect to type and amount of refrigerant and foaming agent used. Type I (before 1988) contains chlorofluorocarbons (CFCs) as refrigerant and foaming agent. From 1988 onwards the amount of CFCs used could be reduced (type II). Type III appliances (between 1993 and 1997) use the fluorinated hydrocarbon R134a as refrigerant and foaming agent. Type IV-appliances (from 1994 onwards) use isobutane as refrigerant and pentane as foaming agent.

The costs were calculated for private households. Considered cost types were acquisition costs and costs for electricity supply. Cost for repair or maintenance were not considered. The costs for the recycling were assumed to be included in the purchase price. For the next 21 years (2005 with 2025) the annual costs and the net present value (in 2005) were calculated. In the calculations regarding the accelerated replacement, future costs were discounted with a discounting rate of 5 % to give the net present value (NPV) in 2005.

Impact assessment

The following environmental indicators and impact categories were considered as relevant for the system under consideration: primary energy demand (indicator: cumulative energy demand, CED), global warming potential (GWP) and ozone depletion potential (ODP). Additionally the total environmental burden (determined by the method EcoGrade [6]) was calculated which includes the indicators GWP, photochemical ozone creation potential (POCP), eutrophication potential (EP) and acidification potential (AP).

Summary of assumptions

The following tables give an overview of the assumptions (size, volume, prices, electricity demand, electricity price and recycling type) regarding the four appliance categories and with respect to year of manufacture (where applicable).

Table 1 Specification of the size, volume and purchase prices of the regarded appliances

	Size of appliance	Fresh food volume	Frozen food volume	Purchase price (A, A+)	Purchase price (A+)	Average life span
refrigerator	"small"	155 litres		290,00 €	435,00 €	14 years
fridge-freezer	"large"	200 litres	90 litres	510,00 €	765,00 €	14 years
upright freezer	"large"	--	190 litres	350,00 €	525,00 €	17 years
chest freezer	"large"	--	190 litres	340,00 €	510,00 €	17 years

Purchase prices A, A+: Information received from Bosch/Siemens/Hausgeräte 2005 (Average prices for different cold appliance categories between February 2004 and January 2005); purchase prices A++: estimation (price A, A+ times 1,5), based on own market survey and data base of domestic appliances of Niedrig-Energie-Institut (NEI), 2004; Detmold 2004.

Table 2 Specification of the electricity demand and electricity price, and of the recycling type of the regarded appliances with respect to the year of manufacture

electricity demand (in kWh / appliance and year)	1980	1985	1990	1995	2000	2005 (A+)
refrigerator	360	330	300	250	210	118
fridge-freezer	760	610	600	480	430	254
upright freezer	700	570	530	500	470	224
chest freezer	530	410	380	350	310	201
electricity costs in 2005 (in €/ kWh)						
for all appliances (increase to 0,249 in 2020)						0,192
recycling type						
refrigerator	I	I	II	III	IV	IV
fridge-freezer	I	I	II	III	IV	IV
upright freezer	I	I	II	III	IV	IV
chest freezer	I	I	II	III	IV	IV

Limitations

When using and interpreting the results of the study, the following limitations have to be born in mind:

- Next to the type and age, the electricity demand of both the old and the new appliance depends on parameters like specific energy efficiency or volume (e.g. the size of refrigerators on the German market varies between some 50 and 400 litres!). In this study, for the appliances in stock only the average energy consumption is considered. For households with a more or less efficient appliance the result might differ from the results given in this report. Similarly only appliances with a certain volume are regarded.
- Potential differences between the actual and the stated energy demand due to different user habits, ambient conditions or ageing of materials are not considered.
- A proper recycling according to the WEEE directive is assumed without any deficits in its implementation.
- The recycling of the old appliance is fully allocated to the alternative “acquisition of a new appliance”. This assumption is questionable however this allocation problem cannot be solved in an ideal way.
- Due to a big variation in market prices (between but also within certain energy efficiency classes) an estimation of purchase prices for new appliances is difficult and bears the risk of being not representative for an individual purchasing decision.

Results

Life Cycle Assessment and Life Cycle Costing of new appliances

The results of the LCA and LCC show the environmental impacts and the costs over the whole life span of the regarded product categories (14 and 17 years respectively).

Regarding the environmental impacts the following figures (figure 1 and 2) show that the use phase is the most important life cycle phase. It contributes to the total impact category results between approximately 75 % (GWP) and 90 % (CED). From a cost point of view the purchase contribute to approximately 35 % to 45 % to the life cycle costs of the appliances (figure 3). This means the purchase is more relevant in financial terms than the production in environmental terms. The environmental impact (CED, GWP) of the recycling phase is negative, which means that the environmental benefits from the recycling of materials overweigh the impacts from re-distribution and the recycling process itself.s

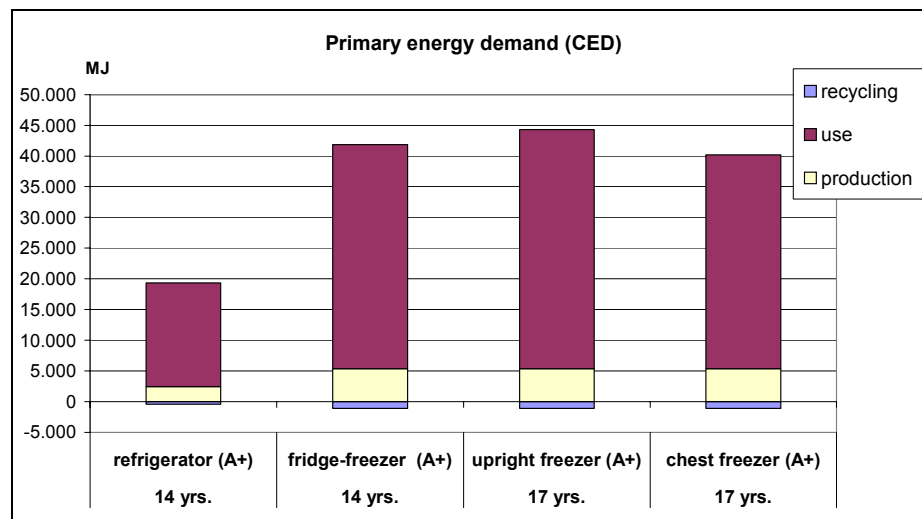


Figure 1 Primary energy demand (CED) of the production, use and recycling of cold appliances of the four regarded categories

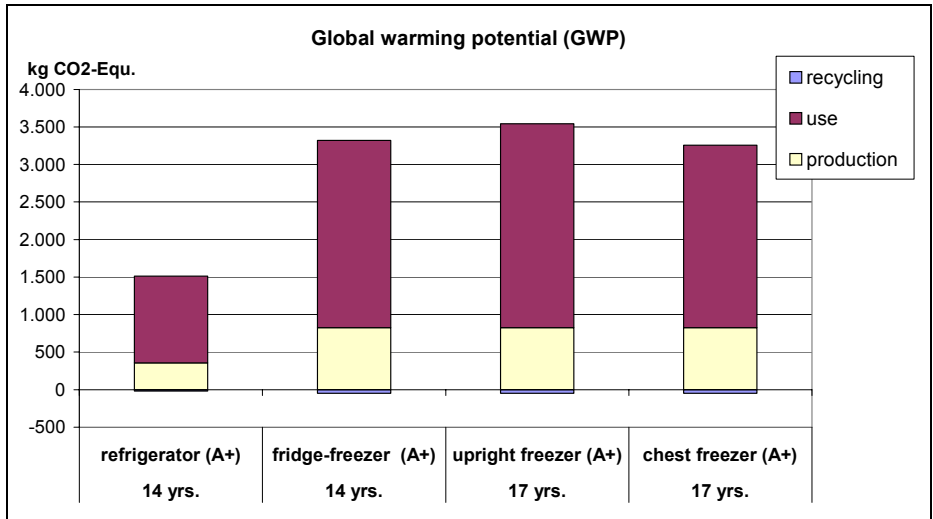


Figure 2 Global warming potential (GWP) of the production, use and recycling of cold appliances of the four regarded categories

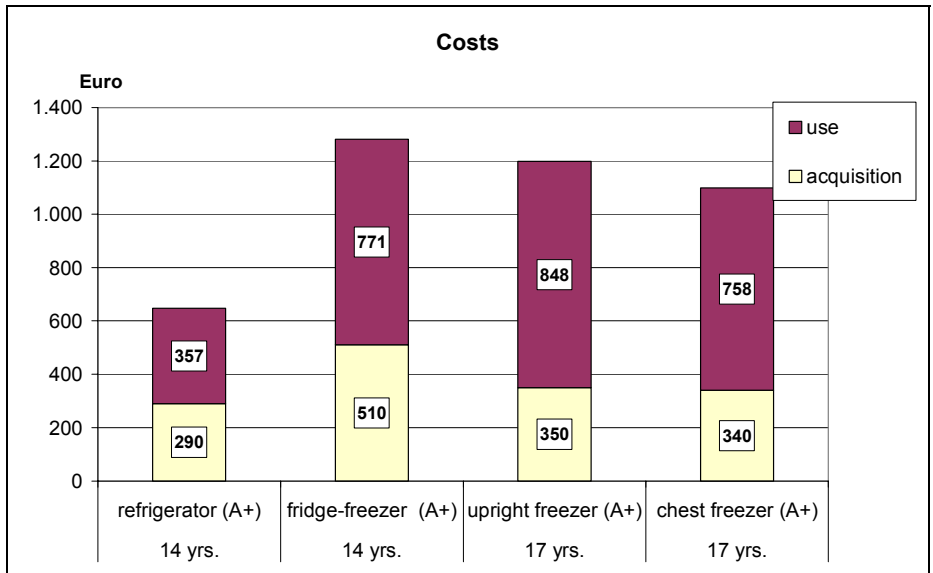


Figure 3 Costs of the purchase and use of cold appliances of the four regarded categories

Development of electricity demand in recent years

Figure 4 shows that in all categories the electricity consumption was decreasing with later years of manufacture. Especially in case of the upright freezer the electricity consumption of older appliances is much higher than that of a new 'A+'-class model.

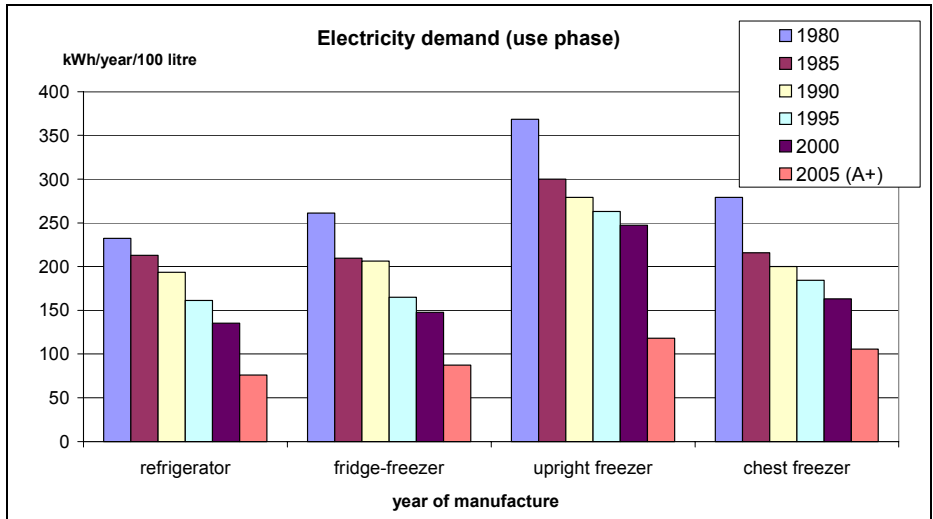


Figure 4 Electricity demand of cold appliances in the use phase

Environmental impacts through end-of-life treatment

The primary energy demand (CED) of the recycling does not vary according to the year of manufacture as it is independent from the used refrigerant and foaming agent.

Figure 5 shows that the GWP through recycling decreases significantly with later years of manufacture. Even though it is assumed that only 10 % of the amount of refrigerants and foaming agent is released into the atmosphere, the total GWP of the recycling of older appliances is quite high. A similar picture as the GWP gives the ODP (figure 6).

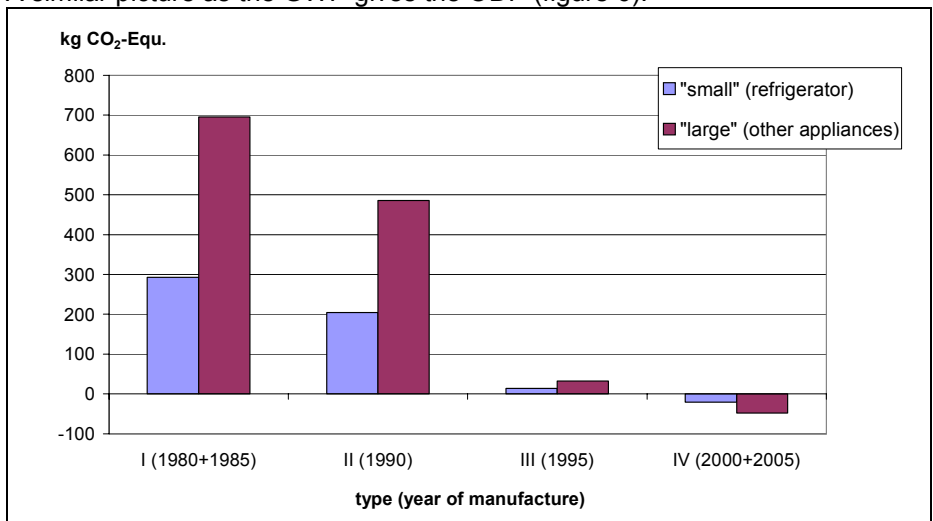


Figure 5 Global warming potential (GWP) of the recycling of "small" and "large" cold appliances of different age.

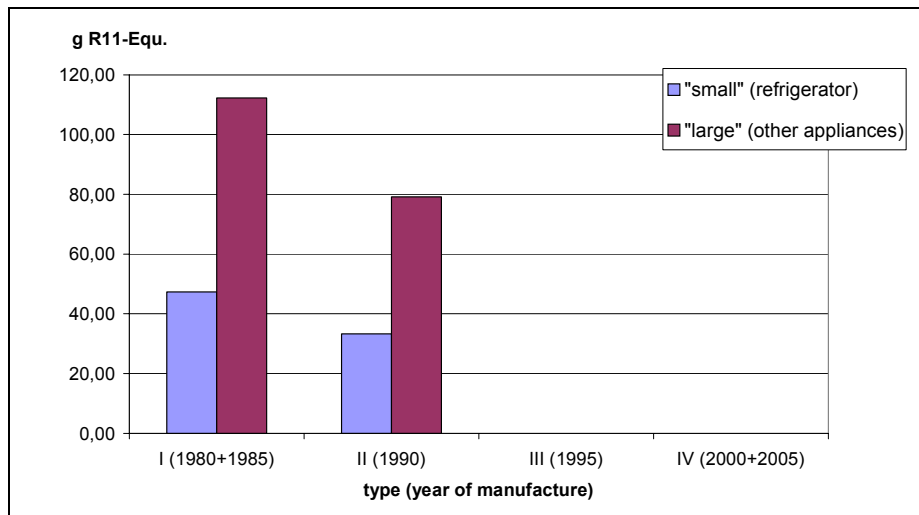


Figure 6 Ozone depletion potential (ODP) of the recycling of “small” and “large” cold appliances of different age.

Further use versus replacement of appliances in stock

For this step of the study a full range of results was produced:

- for the four cold appliance categories,
- for the four environmental indicators and the costs,
- for the three replacement variations (A+ in base case, A and A++ in sensitivity analyses).

The figures show for the year 2005:

- either acquisition and use of a new appliance + recycling of the old one (“2005”) or
- further use of the old appliance (“1980”, “1985”, “1990”, “1995”, “2000”)

According to annual electricity demand a smaller or bigger slope of cumulated impact / cost of the different curves results. At the intersection of the curves, the cumulated impacts of production and use of the new appliance and recycling of the old one (“2005”) is equal to the cumulated impacts of the mere use of the old appliance (“1980”, “1985”, “1990”, “1995”, “2000”).

Results of the base case

Cross-comparing the results between the refrigerators, fridge-freezers and upright freezers, the environmental payback periods are quite similar. In case of chest freezers the periods are higher than those of the other three categories. The following figures show some results considering fridge-freezers as example.

The payback period for the primary energy demand (CED) is very low for nearly all appliance categories (i.e. between less than one and five years), all appliances in stock to be replaced and all efficiency classes of the new appliance (see e.g. figure 7). The payback periods of the global warming potential (GWP) are higher than those regarding the CED (see e.g. figures 8 and 9). This increase mainly results from the release of refrigerants and foaming agents contained in older appliances. The results of the ozone depletion potential (ODP, not depicted) are not meaningful as these results only represent the very high impacts through recycling. There is no difference in ODP during the use phase. The methodological issue of allocation is strongly relevant here. Regarding the total environmental burden, the payback-periods are between those of the CED and the GWP (see figures 10 and 11).

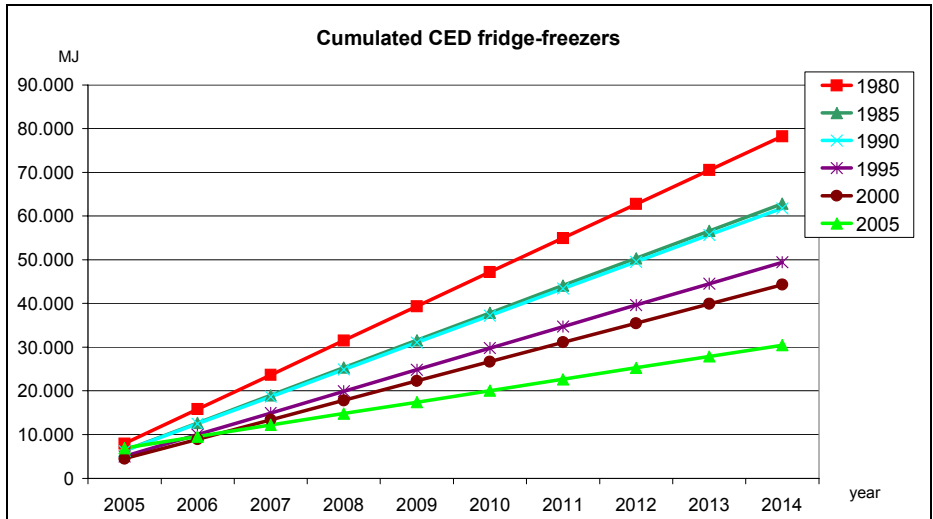


Figure 7 Cumulated primary energy demand (CED) of all regarded alternatives from 2005 until 2014, fridge-freezers (base case)

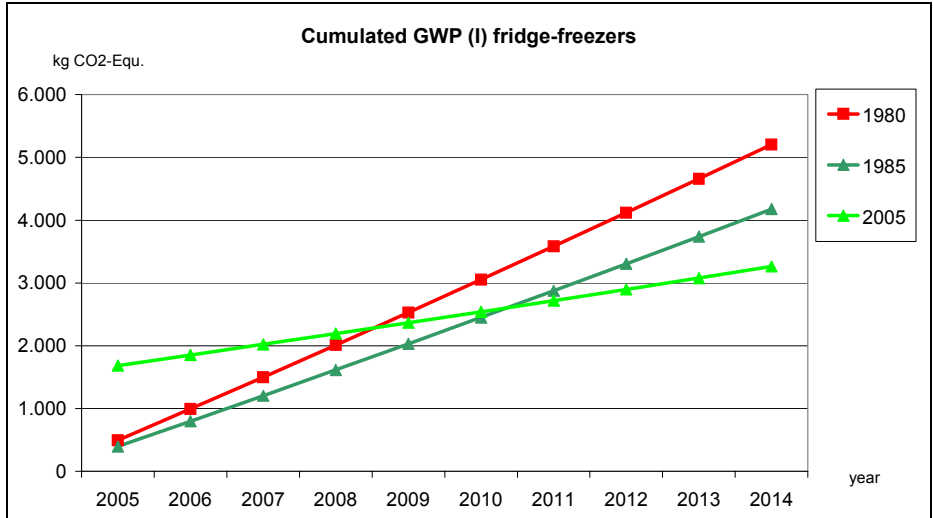


Figure 8 Cumulated global warming potential (GWP) of the regarded alternatives (2005 replaces 1980- or 1985-appliance) from 2005 until 2014, fridge-freezers (base case)

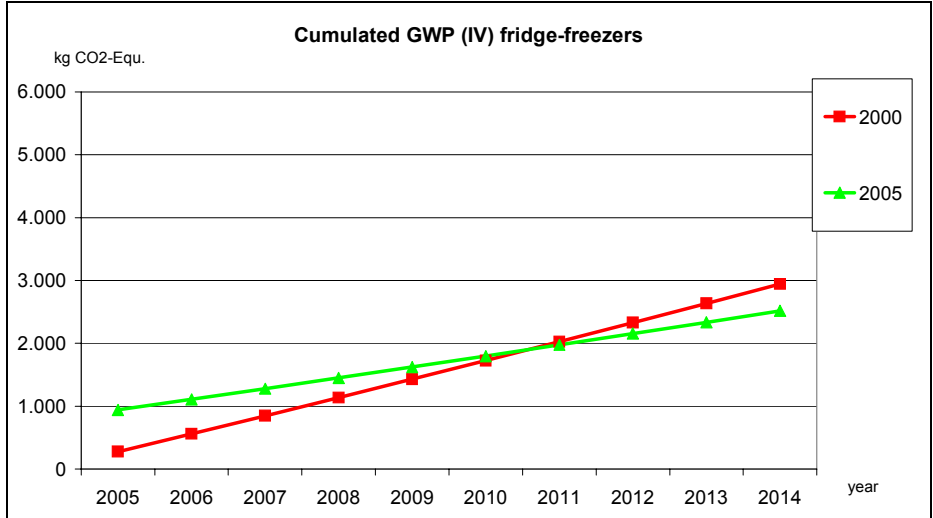


Figure 9 Cumulated global warming potential (GWP) of the regarded alternatives (2005 replaces 2000-appliance) from 2005 until 2014, fridge-freezers (base case)

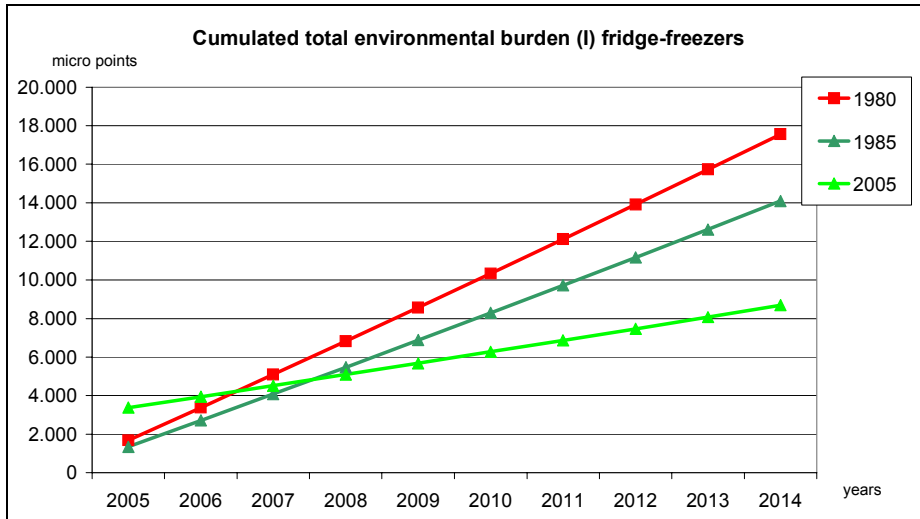


Figure 10 Cumulated total environmental burden of the regarded alternatives (2005 replaces 1980- or 1985-appliance) from 2005 until 2014, fridge-freezers (base case)

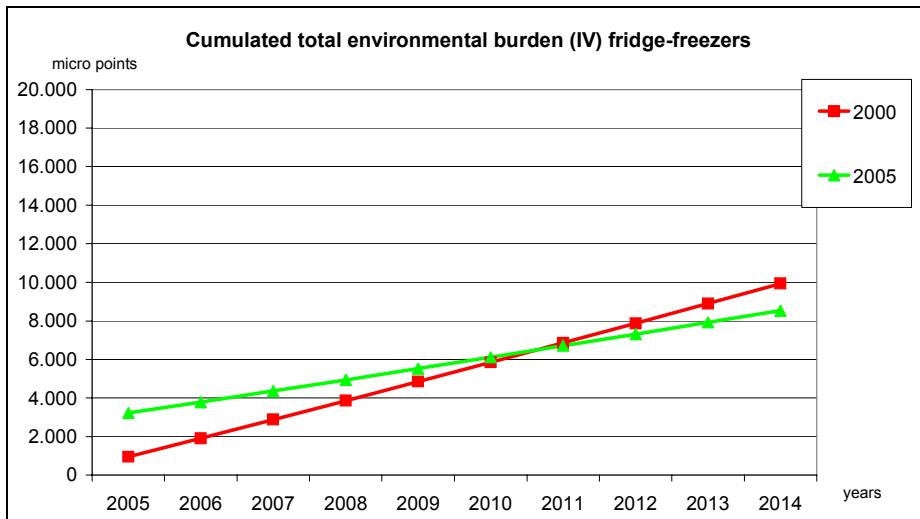


Figure 11 Cumulated total environmental burden of the regarded alternatives (2005 replaces 2000-appliance) from 2005 until 2014, fridge-freezers (base case)

The cost payback periods are higher than the environmental payback periods (see e.g. figure 12). However due to the variability of the purchase prices and the uncertainty of the dependency of the costs on energy efficiency class, the results of the costs are more uncertain than those of the environmental impacts.

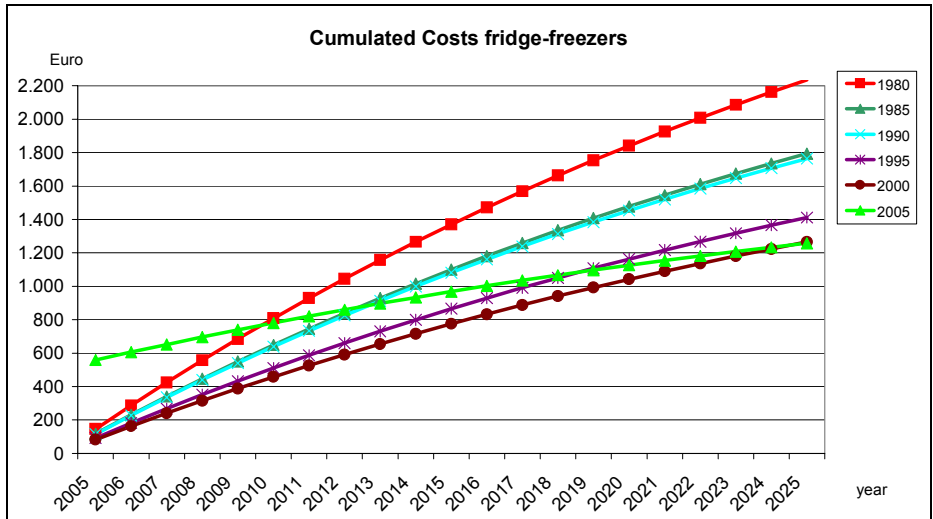


Figure 12 Cumulated life cycle costs of all regarded alternatives from 2005 until 2014, fridge-freezers (base case)

Results of the sensitivity analyses

Especially when comparing the payback periods of the primary energy demand (CED) and the global warming potential (GWP), it can be seen that the results quite strongly depend on the energy efficiency class of the new appliance. The better the energy efficiency class of the new appliance is, the shorter is the payback period (see e.g. figures 13 and 14).

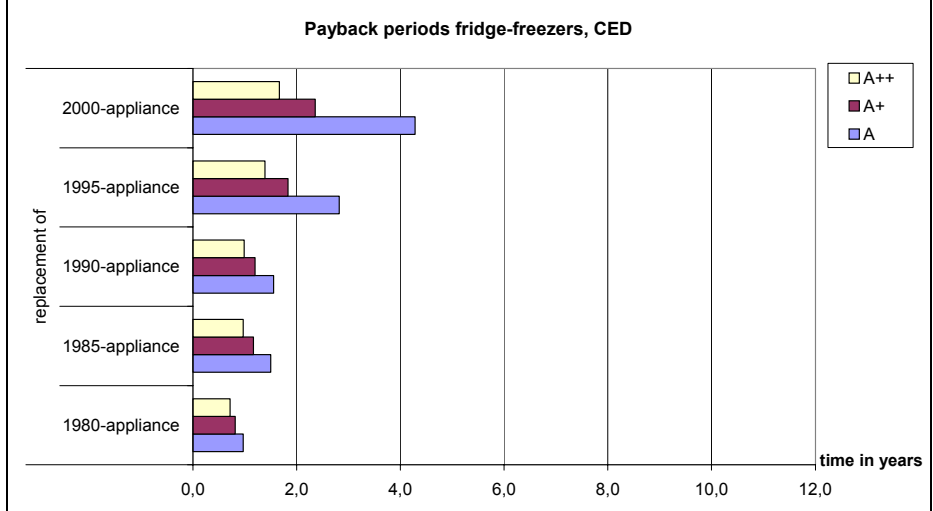


Figure 13 Payback periods of the primary energy demand (CED) with respect to the energy efficiency class of the new appliance, example fridge-freezers.

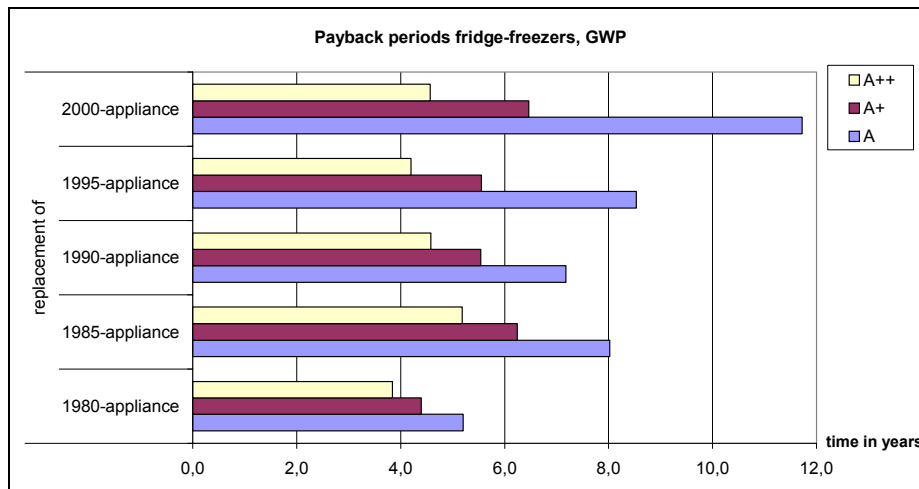


Figure 14 Payback periods of the global warming potential (GWP) with respect to the energy efficiency class of the new appliance, example fridge-freezers

Conclusions

The question if it is “worth” to further use an existing cold appliance or to substitute it and use a new model cannot be answered absolutely. The answer depends on the individual evaluation of the time span, which is acceptable for the payback period. If a payback period of up to 5 years is defined as acceptable, the replacement of cold appliances with a new one is justified in the cases shown in table 1 (regarding the total environmental burden).

Table 1 Year of manufacture of appliance with (environmental) payback periods of up to 5 years

	Refrigerators	Fridge-freezers	Upright freezers	Chest freezers
Energy efficiency class of new appliance				
A++	2000 and before	2000 and before	2000 and before	1980 and before
A+	1995 and before	1995 and before	2000 and before	1980 and before
A	1995 and before	1990 and before	1995 and before	1985 and before

Regarding the cost payback periods, only the replacement of upright freezers of 1980 with an ‘A’- or ‘A+’-model is justified. However this result has to be handled with care as the cost data is afflicted with a quite high degree of variability and uncertainty.

The results show, that an accelerated replacement of cold appliances in stock does make sense in most cases. However the following aspects should be considered:

- The energy efficiency of the new appliance should be as high as possible – at least an ‘A+’-labelling is recommended.
- The take back and proper recycling of the old appliance has to be ensured: on the one hand to prevent the further use in addition to the acquisition of the new appliance, on the other hand to prevent the incorporated refrigerants and foaming agents to be released into the atmosphere.

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