Energy

Preparatory Studies for Eco-design Requirements of EuPs

(Tender TREN/D1/40-2005)

LOT 13: Refrigerators & Freezers

Part I – PRESENT SITUATION

Task 3:
Economic and Market Analysis
Rev. 1.0

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The study Tasks

Refrigerators and freezers, also known as "cold appliances", have been the first and the most studied EuP in the European Union with the goal to reduce their energy consumption. In 1993, the study of the Group for Efficient Appliances (GEA, 1993) provided the technical basis for both the energy labelling and the energy efficiency requirements Directives, and later also partially for the eco-label awarding criteria. Its results and methodology were the starting point for the second study (ADEME, 2000, colloquially known as the COLD-II study) promoted by DG TREN in 1998 which took into consideration the methodological, technical, economical and market developments and proposed a new structure for a revised label and a new set of efficiency targets which then for various reasons were not fully accepted by Member States.

Contemporarily, the European Eco-label Board started to address this product group more from the environmental impact point of view with other studies, which resulted in the definition of a series of -labelling awarding criteria for refrigerators and freezers, the latest being established in 2004 and valid from May 1st 2004 until May 31st 2007.

In the meantime, a series of four monitoring studies were promoted by the SAVE Programme to evaluate the impact of the EU legislation on the market transformation of cold appliances and energy consumption (ADEME, 1998; ADEME, 2000; ADEME, 2001). More recently, the European Association of Household Appliance Manufacturers (CECED) issued in October 2002 a Voluntary Commitment on reducing energy consumption of household refrigerators, freezers and their combinations.

Since markets and technologies change continually, including in response to past policy settings, the present study proposal takes the results and methodology defined in the last decade of studies as the starting point to be updated and upgraded where necessary to evaluate the technical, economic and market developments of cold appliances and the new aspects of these products to be covered following the indications of the eco-design directive 2005/32/EC[1]. This is necessary in order to define the need of implementing measures and possible targets for voluntary or mandatory policies.

The study is divided in two working phases and seven Tasks or Chapters:

Part I: Present Situation, that envisages the following five Tasks:

- Task 1 - General Situation
- Task 2 - Economic and Market Analysis
- Task 3 - Consumer Behaviour
- Task 4 - Product System Analysis
- Task 5 - Definition of base case

Part II : Improvement Potential, with the following two Tasks:

- Task 6 - Technical Analysis
- Task 7 - Scenario, Policy, Impact and Sensitivity analysis.

Within the first part (Present Situation) the project team will set the study boundaries (Task 1), collect and organise the data for the economic, market (Task 2) and consumers behaviour analysis

[1] Directive 2005/32/EC of the European Parliament and of the Council of 6 July 2005 establishing a framework for the setting of ecodesign requirements for Energy-Using Products and amending Council Directive 92/42/EEC and Directives 96/57/EC and 2000/55/EC of the European Parliament and of the Council.

(Task 3), analyse the interaction of the studied appliances on the energy system to which the product belongs (Task 4) and set up the reference parameters, material, energy and costs inputs to define the starting base case (Task 5). All the data and information analysed within the first part of the study will serve as an input for the second part (Improvement Potential) during which the project team will carry out the technical and economic analysis to set up the optimal eco-design options of the analysed appliance (Task 6) and finally suggest the most suitable policies to achieve the recommended energy and ecological improvements (Task 7). A Glossary and References will be also included in the study.

This report refers to Task 3: Consumer behaviour and local infrastructure.

DESCRIPTION AND ABSTRACT OF TASK 3

The behaviour of the consumer with household appliances influences the environmental impact because of the usage of resources like water and/or energy and/or chemicals.

With the help of an extensive consumer survey (almost 2500 households interviewed from 10 European countries) the task to identify the "real life" consumer behaviour concerning the use/handling with household appliances, especially refrigerators and freezers, is fulfilled and differences from the standard test conditions to real life conditions affecting the environmental impact are identified, including their effect on the real life energy consumption.

In European households refrigerators are available in the local infrastructure for almost 100 % of the households and in even 21 % of the households in this report a secondary refrigerator is available. In average these refrigerators are 1,4 years older than the primary refrigerator. All refrigerators and freezers normally remain in the household for 10 years and more, keeping the status of efficiency of the machine remaining as they were at the production of the gadget. Improvements will therefore take more than 10 years to get fully effective in the market.

Another possible barrier for energy saving innovations for cold appliances is the necessity of food protection. The decrease of energy consumption can only go as far as food safety is ensured. There is common understanding that perishable food should be stored at temperatures below 5 °C in a refrigerator and at -18 °C in a freezer. Other important factors influencing the energy consumption in real life are identified especially by the temperature of the ambient where the refrigerator or freezer stands and the amount of new food loaded into the machines which needs to be cooled down. Recommendations to place the refrigerator and freezer at the lowest possible ambient temperature and not to place hot food into them are important ways to reduce the amount of energy used.

But refrigerators and freezers in consumer homes do not always seem to be set to follow this recommendation. Ambient temperatures go up to 40 °C for a considerable amount of households investigated and down to temperatures of 0 °C. While the higher ambient temperatures are covered by the climate classes as defined, ambient temperatures lower than 10 °C are not foreseen at all. But more than 20 % of the households investigated in 10 European countries report to have minimum ambient temperatures lower than 10 °C where the refrigerator stands. One consequence of this is that the right temperature in the refrigerator and freezer is no longer maintained and the quality of food stored may suffer significant losses. In refrigerators/freezers of category 7 many gadgets do have only one compressor which is used to provide cooling for both compartments. The consequence is, that at lower ambient temperatures these machines may either fail to keep the right storage temperatures or they activate additional heating devices to cause the compressor to provide

more cooling. This may cause considerable additional amounts of energy (up to 29 %) used as compared to a similar appliance with two compressor circles.

Consumer behaviour is also characterised by

- average temperature of the refrigerator is set at 5,0 °C at the correct level, but with relevant differences between countries
- average temperature of the freezer is at -16,7 °C again with differences between countries
- the capacity of the refrigerator compartment is used to a good extend by the consumers, but that of the freezer is used even more.

Summarising all of these findings about the consumer behaviour allows estimating the difference between the real life and standard base case energy consumption. Due to the lower ambient temperature in real life compared to the 25 °C used in the standard measurement will considerably reduce the energy taken by the gadgets. Part of this saving is balanced by cooling down food which is loaded and by cooling down the air which is exchanged when opening the door. So all in all the measured consumption following the standard is somehow taking care for this kind of real life behaviour. Not covered are the additional consumptions which may be used by cat. 7 refrigerators/freezers with just one compressor (and one thermostat) not operated within the temperature range of 20 to 30 °C. Here significant amounts of additional energy are used on which the consumer was not informed at the point of sale of the gadget.

3 Task 3: Consumer behaviour and local infrastructure

3.1 CONTENT AND BASIC RESULTS OF THE CONSUMER SURVEY

3.1.1 Data basis and objects of investigation of the survey

The behaviour of the consumer with household appliances influences the environmental impact because of the usage of resources like water and/or energy and/or chemicals.

The aim of the consumer survey within this study is to identify the "real life" consumer behaviour concerning the use/handling with household appliances and to identify differences from the standard test conditions affecting the environmental impact. With the aid of an external market research institute[2] 2 497 European households of 10 European countries were interviewed via an online questionnaire. Suitable households (participants) were chosen following pre-defined criteria. 250 households per country were interviewed (exception: Czech Republic with only 247 households) (Figure 3.1). All in all the countries selected nearly represent 75 % of the European population. The participants were asked about their behaviour with selected household appliances and about their opinion on this topic and energy saving issues in general. Demographic data were recorded additionally.

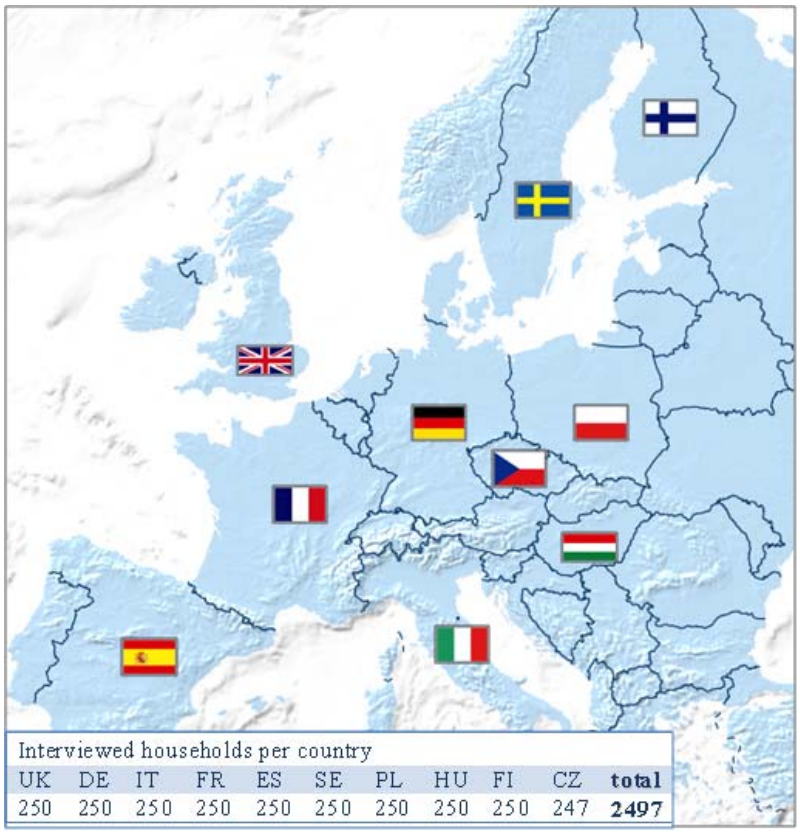


Figure 3.1: geographic coverage and sample size of the survey[3]

[2] ODC Services GmbH, 80636 Munich

[3] Figure created with Map Creator Version.1.0 (free edition)

Households for this survey were selected on the one hand to represent the relevant population in their country as well as possible and on the other hand to fit with the need of this study.

Within the scheduling of the survey following criteria and quotes were chosen:

- Indicator of citizenship: total
- Distribution of gender: not less than 50% female persons
- Selected age groups:
    - between 20 – 39 years
    - between 40 – 59 years
    - between 60 – 74 years
- Household size: 1, 2, 3, 4 and ≥4 persons

Also specific quotes about the existence of selected household appliances were set to be able to achieve a sufficient coverage of interested products and a better comparability of the results. So it was required that

- not less than 50 % of all questioned persons per country should possess a dishwasher,
- 100 % of all questioned persons per country should possess a washing machine,
- 100 % of all questioned persons per country should possess a refrigerator,
- not less than 70 % of all questioned persons per country should possess a freezer.

The quotation of gender and age-groups were made according to the aspect to reach persons which most likely are involved in housekeeping. Eurostat[4] data of the distribution of the population by age group and household size for each country were used to recalculate the population following this quotation (

[4]EUROSTAT: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=1996,45323734&_dad=portal&_schema=PORTAL&screen=welcomeref&open=/popul/popula/cens/cens_n2001/cens_nhou&language=de&product=EU_population_social_conditions&root=EU_population_social_conditions&scrollto=162

Table 3.1) maximum differences of ± 5 % resulted between the given quotes mentioned before and the real participation in the survey (

Table 3.1and Appendix 3.1- 1).

Table 3.1: population by household size and age group: comparison of results of own survey vs. Eurostatdata[5] e.g.UK

United Kingdom		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat [6]	1 person	4 %	5 %	5 %	*14 %*
	2 persons	10 %	13 %	12 %	*36 %*
	3 persons	10 %	9 %	2 %	*21 %*
	4 persons	10 %	8%	1 %	*19 %*
	more than 4 persons	6 %	4 %	0 %	*11 %*
	total	*41 %*	*39 %*	*20 %*	*100 %*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	3,9 %	7,1 %	4,2 %	15,1 %
	2 persons	11,6 %	12,2 %	10,6 %	34,4 %
	3 persons	11,6 %	10,9 %	1,6 %	24,1 %
	4 persons	8,0 %	8,7 %	1,0 %	17,7 %
	more than 4 persons	4,8 %	3,9 %	0,0 %	8,7 %
	total	*39,9 %*	*42,8 %*	*17,4 %*	*100,0 %*
		Age group			
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	0,1 %	-2,1 %	0,8 %	-1,1 %
	2 persons	-1,6 %	0,8 %	1,4 %	1,6 %
	3 persons	-1,6 %	-1,9 %	0,4 %	-3,1 %
	4 persons	2,0 %	-0,7 %	0,0 %	1,3 %
	more than 4 persons	1,2 %	0,1 %	0,0 %	2,3 %
	total	*1,1 %*	*-3,8 %*	*2,6 %*	*0,0 %*

3.1.2 Demography

Following the quotation by gender 56 % of all interviewed people are female and 44 % are male. The highest value with nearly 70 % of female persons can be found in our sample in United Kingdom and with over 60 % in Sweden (Figure 3.2). All in all the differences between the actual gender distributions in European countries and the results of this survey are between less than 1 % and 18 % (Table 3.2).

[5]Own calculation: Population by household size and age group based on EUROSTAT data.

[6]Own calculation: via crosstabs of EUROSTAT.data of population by household size and age group.

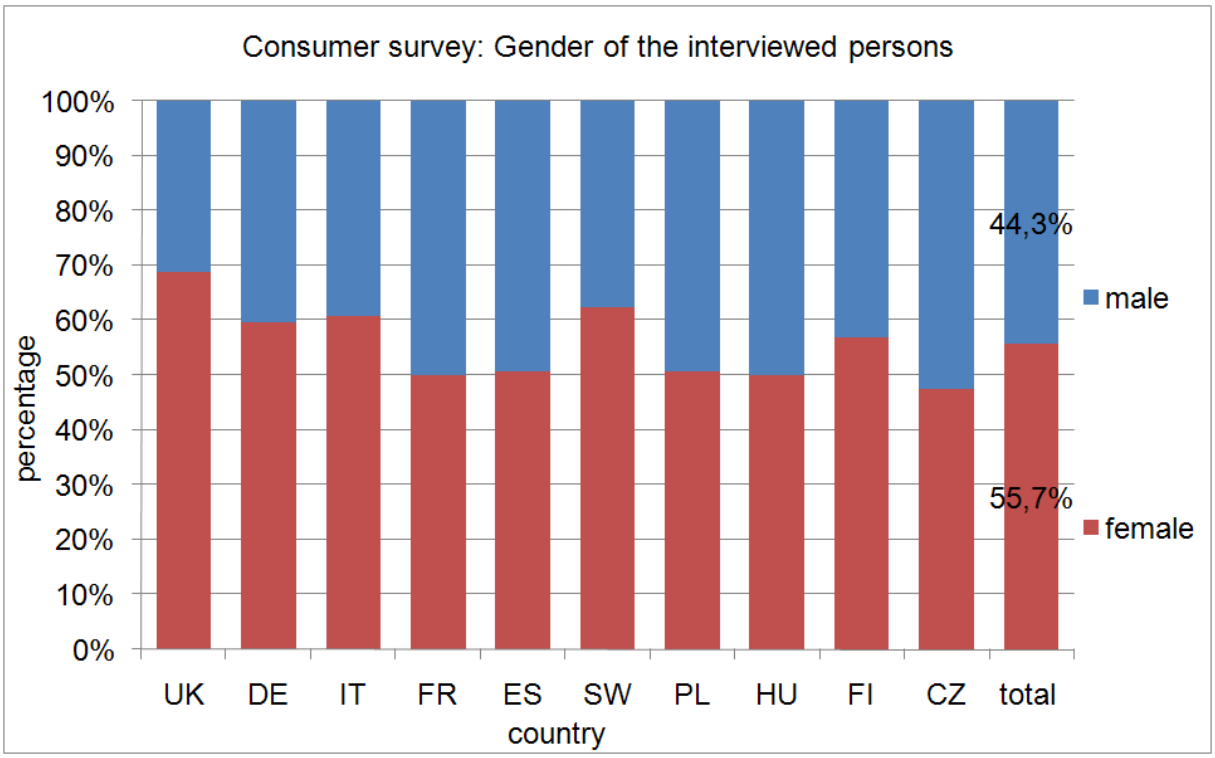


Figure 3.2: distribution: gender of the interviewed persons (per country)

Table 3.2: results consumer survey: share of female persons (per country)

		countries									
		UK	DE	IT	FR	ES	SW	PL	HU	FI	CZ
female	% of country	68,8 %	59,6 %	60,8 %	50,0 %	50,8 %	62,4 %	50,8 %	50,0 %	56,8 %	47,4 %

Because of the self-defined quotation of age groups only people between 20 and 74 years of age were interviewed. People with an age between 20 and 39 years as well as 40 and 59 years amount to nearly 40 % of all interviewees. Between all European countries there are no significant differences; here the values lay between 39 – 42 %. The highest share of young participants could be calculated for Italy (47,6 %), Spain (46 %) and Poland (44,8 %) (Figure 3.3). Of all interviewed persons 19 % are between 60 and 74 years old. The highest share of people of this age-group can be found in our sample in Sweden (22 %), Hungary (20,8 %) and Germany (19,6 %).

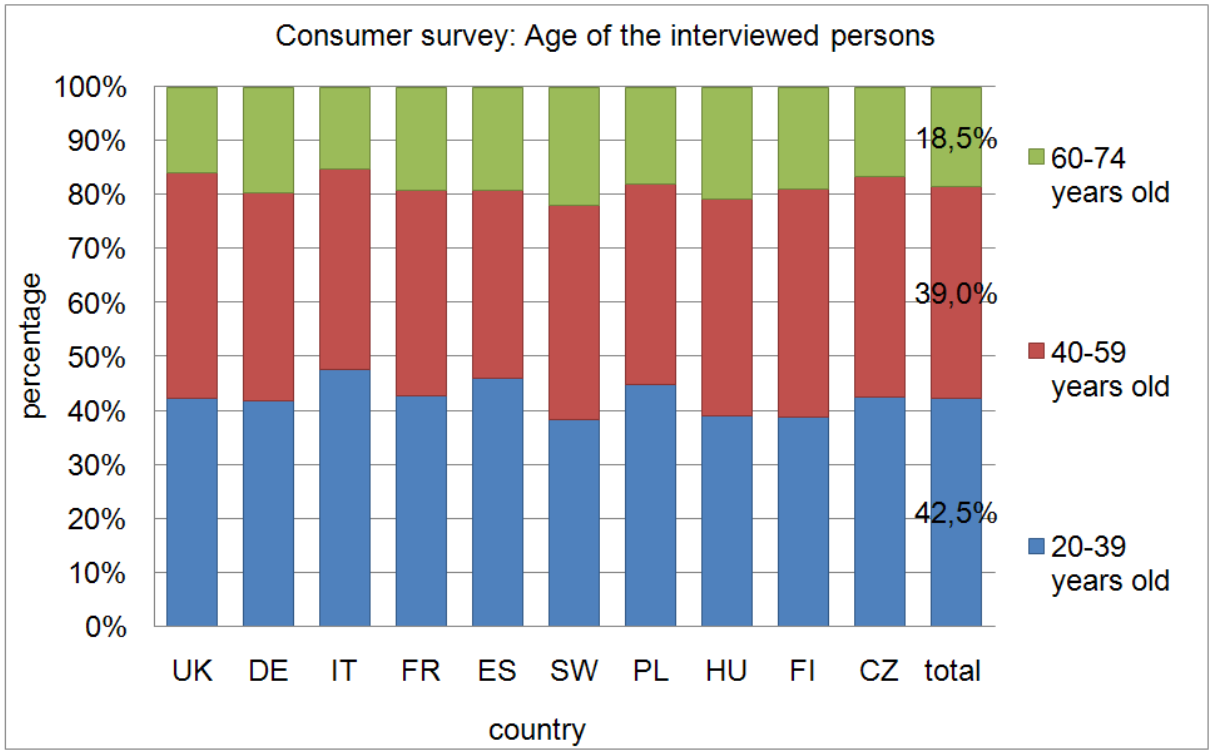


Figure 3.3: distribution: age of the interviewed persons (per country)

3.1.3 Living conditions

Within this survey people were also asked to describe their kind of habitation. When the consumers were asked about this point 52 % of all European households (n = 2.497) said that they *live in a city*. Nearly 80 % of all Polish interviewed persons live in a city (Figure 3.4). This is the highest share of all European countries. Also over 60 % of all Spanish participants are city dwellers. A fourth of all households live *in the suburbs of a city* (25 %). Mostly British (42 %) and Czech (39 %) interviewees live at this place. The other countries show percentages between 14 and 28. The remaining European households (23 %) answered that they *live in a rural area*, especially a high share of British participants (40 %). Furthermore German (33 %), French (29 %) and Hungarian (28 %) households follow.

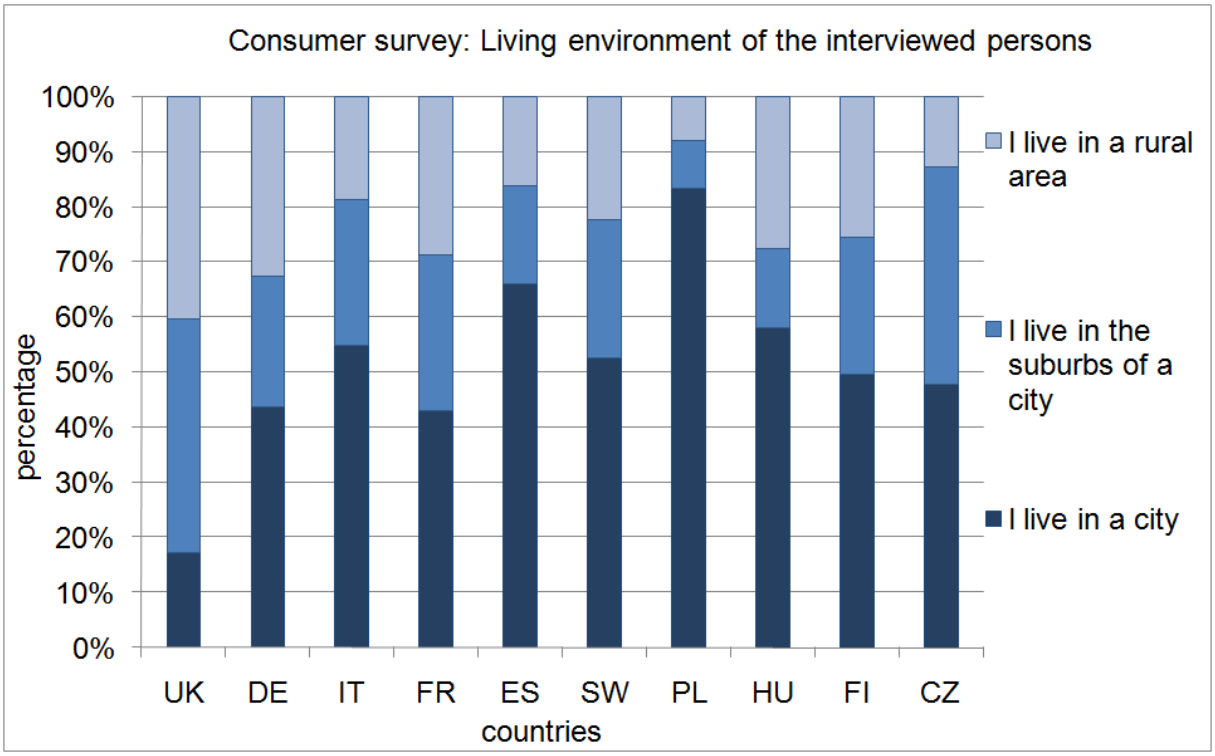


Figure 3.4: living environment of the interviewed persons (per country)

Nearly 60 % of all interviewed people live in a family household (Figure 3.5). This household type could be found mostly in our sample in Italy and Czech Republic with over 70 % and also in Poland and Hungary with over 66 % (Figure 3.6). Approximately 40 % of all family households consist of 3 or 4 persons and even 10 % over 4 persons (Figure 3.7).

Almost a fourth of all interviewed consumers (22 %) live in couple households, which are mostly represented by 2 -person households (18 %) (Figure 3.7). Especially in Finland and France this type of household could be determined with over 30 % (Figure 3.6).

Over 14 % of all participants live in a single-/one-person household. Particularly in Sweden 27,6 % and in Finland 18,4 % of all households are single-households.

With only 3,5 % the multi-person non family household was mentioned least frequently (Figure 3.5). With the exception of Italy, in all European countries the share in this type of household is marginal and shows values between 0,8 % and 5,2 % (Figure 3.6). Because of possible misunderstandings of the notation of the different types of households is it necessary to take a look at the number of persons in the households too.

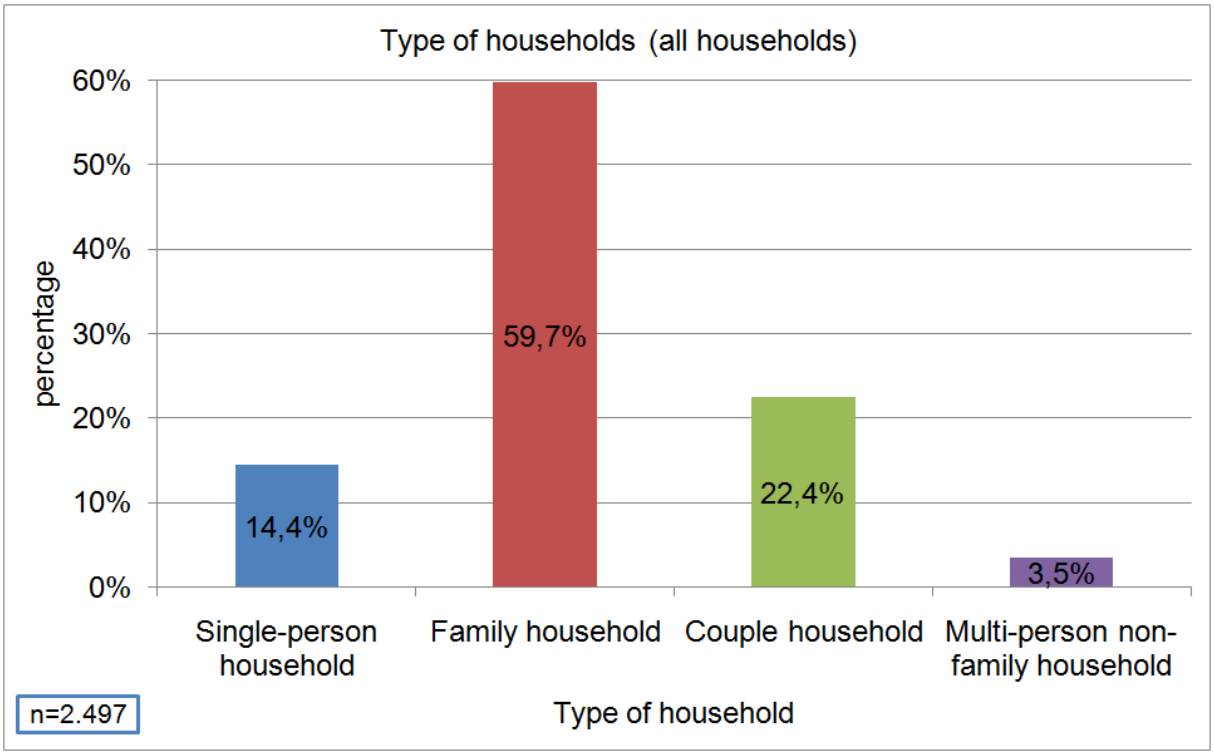
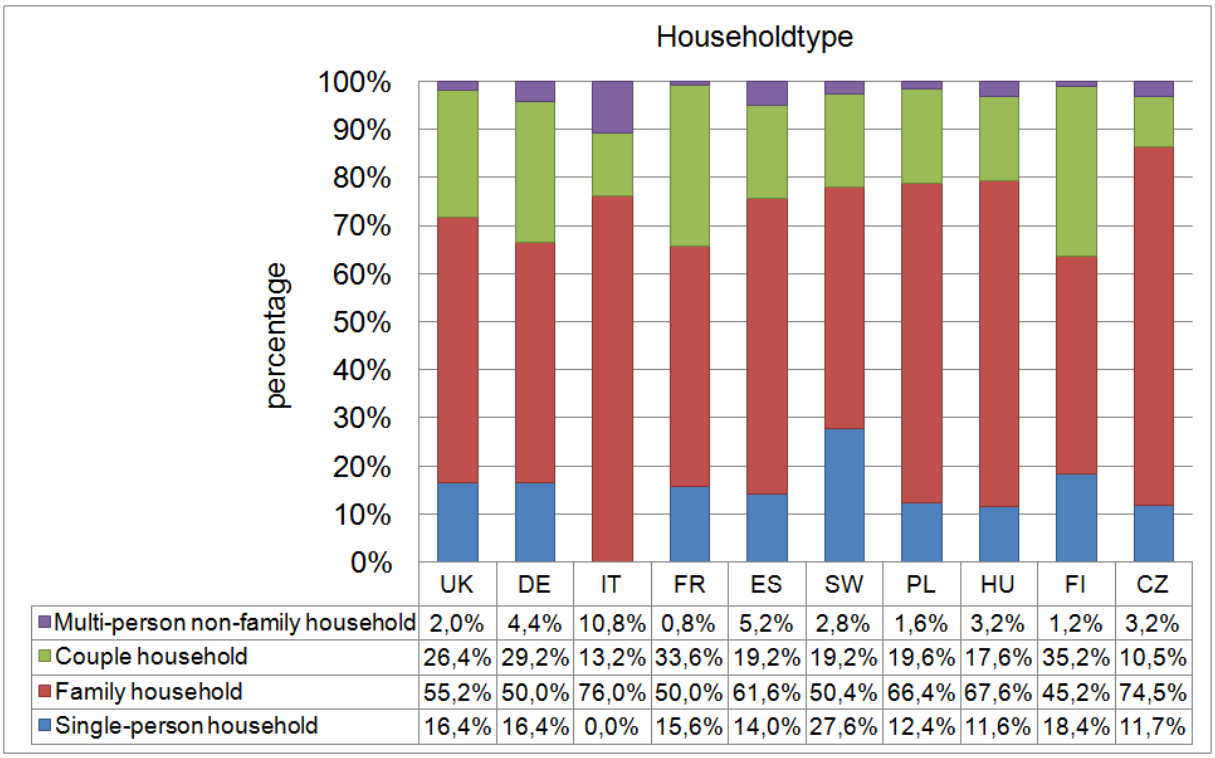
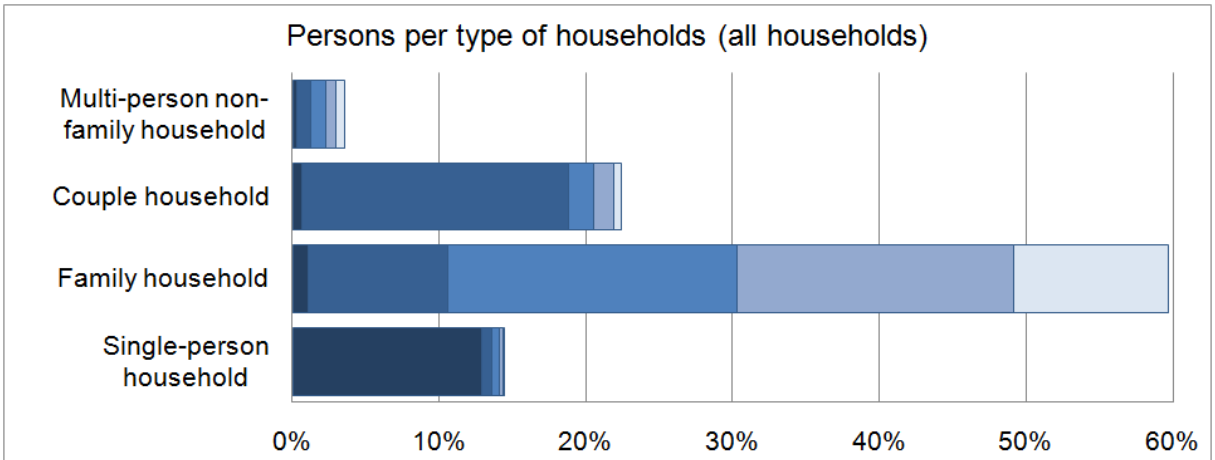


Figure 3.5: distribution: type of household (all households)



	UK	DE	IT	FR	ES	SW	PL	HU	FI	CZ
Multi-person non-family household	2,0%	4,4%	10,8%	0,8%	5,2%	2,8%	1,6%	3,2%	1,2%	3,2%
Couple household	26,4%	29,2%	13,2%	33,6%	19,2%	19,2%	19,6%	17,6%	35,2%	10,5%
Family household	55,2%	50,0%	76,0%	50,0%	61,6%	50,4%	66,4%	67,6%	45,2%	74,5%
Single-person household	16,4%	16,4%	0,0%	15,6%	14,0%	27,6%	12,4%	11,6%	18,4%	11,7%

Figure 3.6: distribution: type of household (per country)



	Single-person household	Family household	Couple household	Multi-person non-family household
1 person	12,9%	1,1%	0,6%	0,2%
2 persons	0,7%	9,5%	18,1%	1,0%
3 persons	0,5%	19,7%	1,7%	1,0%
4 persons	0,2%	18,8%	1,4%	0,7%
more than 4 persons	0,1%	10,6%	0,6%	0,6%

Figure 3.7: distribution: by type of household and person per household (all households)

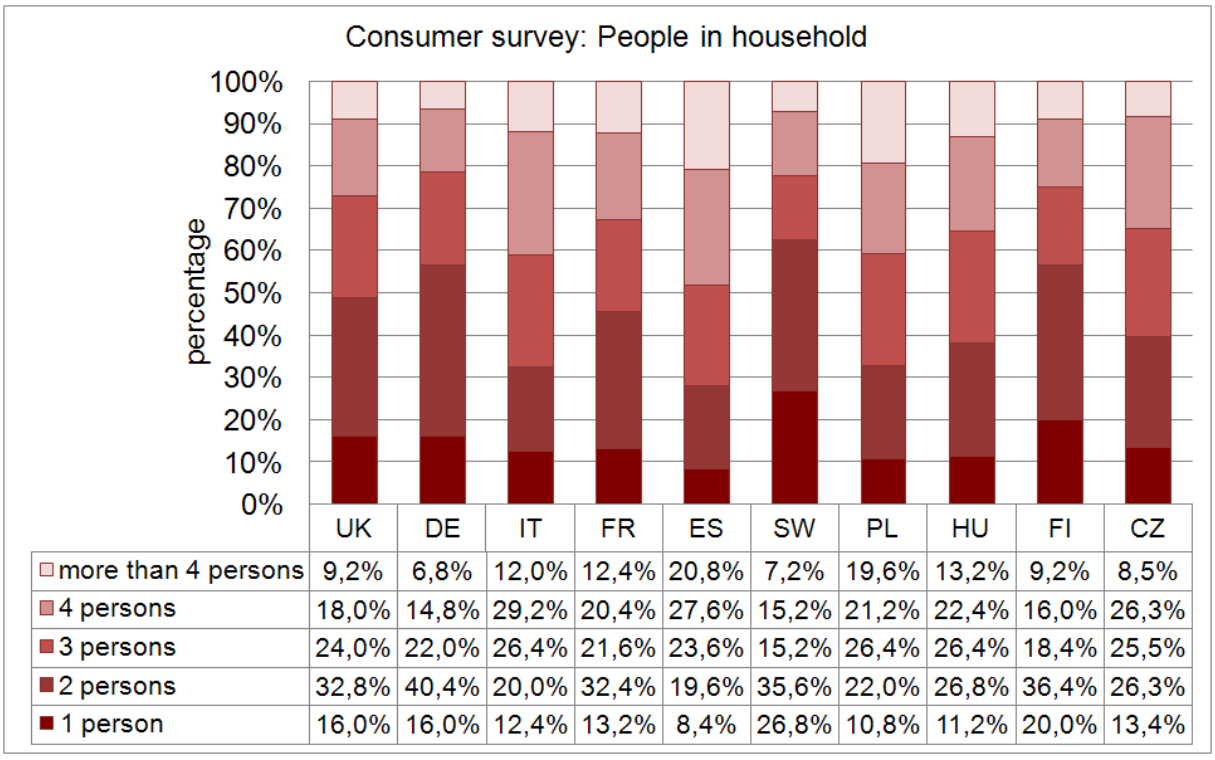
The detailed analysis of the answers to the question how many people are living in the household results an average of 2,9 people per household. In comparison with the average household size published by UNECE[7], for those countries investigated here, an average difference of -0,3 people per household could be calculated (Table 3.3). The highest number of people with more than 4 persons could be determined in nearly 20 % of the Spanish and Polish households in our survey (Figure 3.8). Also nearly 30 % of all Italian, Spanish, Czech and Polish interviewees stated that there are 4 persons in their households. Following the consumer survey analysis the most single households could be calculated with nearly 30 % for Sweden and with 20 % for Finnish households. For the other analysed European countries between 8 and 16 % of singles could be calculated (Figure 3.8 &

[7] The Statistical Yearbook of the Economic Commission for Europe 2003. Online: http://www.unece.org/stats/trends/ch2/2.1.xls

Appendix 3.1- 2).

Table 3.3: average household (countries of this survey) (source: UNECE (2004))

	EUROSTAT		Consumer survey		Δ Average household size (EUROSTAT – Consumer survey)
Countries	**Average household size**	**Year**	**Average household size**	**Year**	
Czech Republic	2,7	1998	2,9	2006	-0,2
Finland	2,1	2001	2,6		-0,5
France	2,4	2001	2,9		-0,5
Germany	2,2	2001	2,6		-0,4
Hungary	2,6	2001	3,0		-0,4
Italy	2,6	2001	3,1		-0,5
Poland	3,1	1995	3,2		-0,1
Spain	2,9	2001	3,3		-0,4
Sweden	2,9	2001	2,4		0,5
United Kingdom	2,3	2001	2,7		-0,4



	UK	DE	IT	FR	ES	SW	PL	HU	FI	CZ
more than 4 persons	9,2%	6,8%	12,0%	12,4%	20,8%	7,2%	19,6%	13,2%	9,2%	8,5%
4 persons	18,0%	14,8%	29,2%	20,4%	27,6%	15,2%	21,2%	22,4%	16,0%	26,3%
3 persons	24,0%	22,0%	26,4%	21,6%	23,6%	15,2%	26,4%	26,4%	18,4%	25,5%
2 persons	32,8%	40,4%	20,0%	32,4%	19,6%	35,6%	22,0%	26,8%	36,4%	26,3%
1 person	16,0%	16,0%	12,4%	13,2%	8,4%	26,8%	10,8%	11,2%	20,0%	13,4%

Figure 3.8: number of people in households (per country)

In nearly 38 % of all European households of our survey at least one person is younger than 18 years. Figure 3.9 shows that in 17 % of all households lives one and in nearly 14 % live two persons under this age, mostly in France (46 %), Hungary (44 %), Poland (42 %) and Italy (41 %). Households with the least share of people under 18 years could be found in Czech Republic (29,6 %), Sweden (33,6 %) and Spain (32,4 %) (Appendix 3.1- 3).

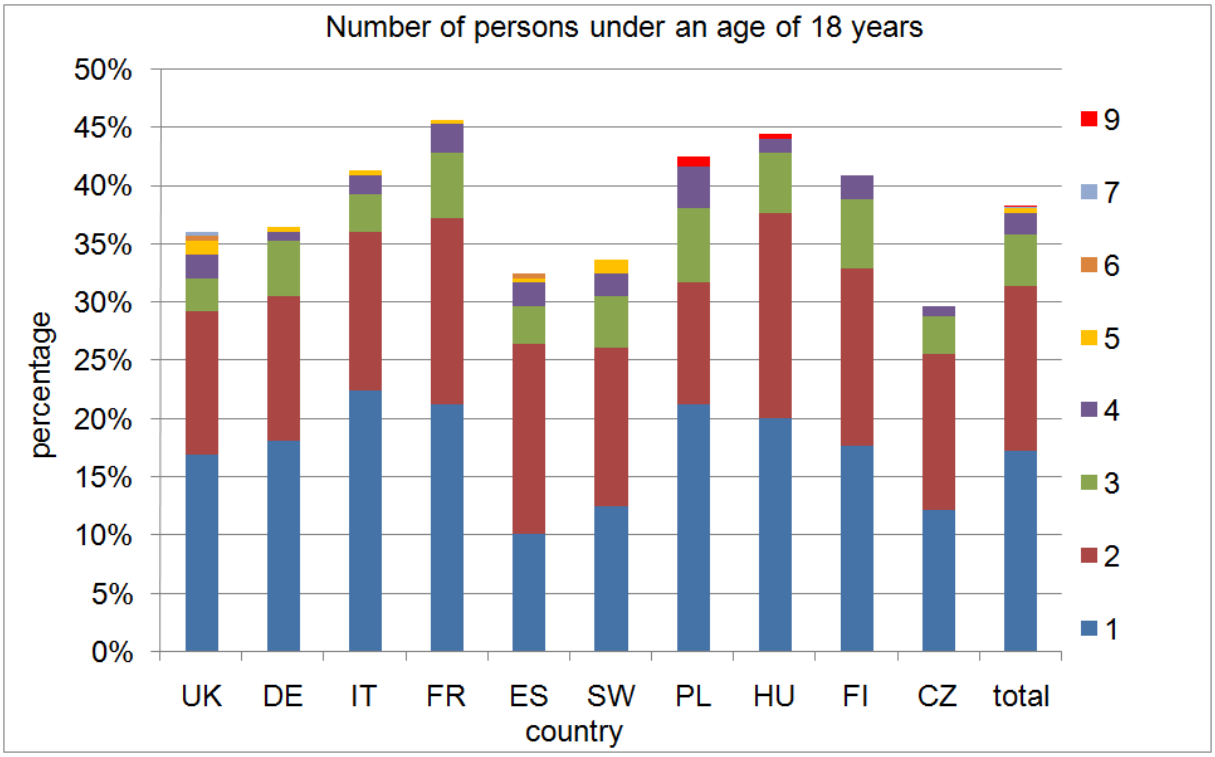


Figure 3.9: number of people under an age of 18 years (per country) living in household

Stock of household appliances

A total of 10 044 household appliances exist in all interviewed households (n = 2 497). Refrigerators and washing machines were reported with an ownership of 100 %, because of the predefined quota. 69 % (n = 1 722) of all households possess an automatic dishwasher and over 35 % (n = 893) a tumble dryer.

From the group of cold appliances approximately 75 % (n = 1 871) of all households own an upright freezer and nearly a fourth of all households own a chest freezer (22,6 %; n = 564). 14.2 % (n = 355) of all interviewees even mentioned to have both (Figure 3.10).

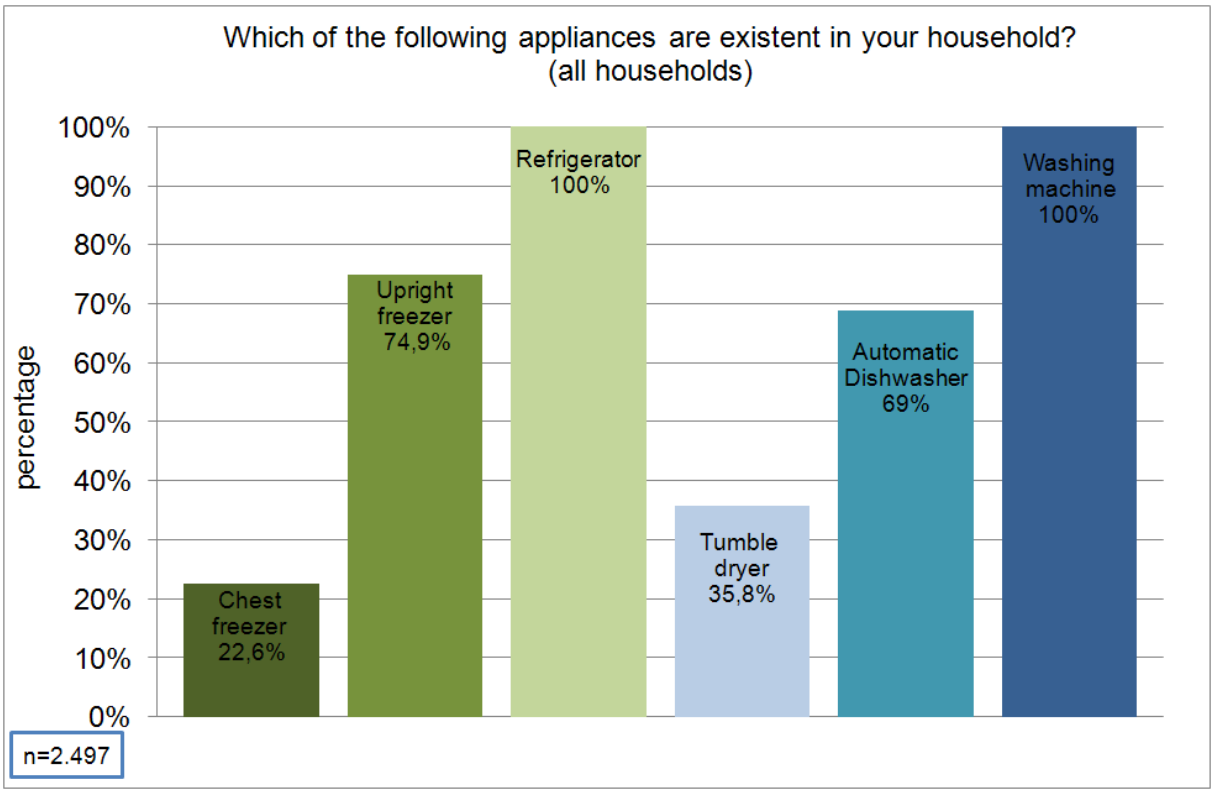


Figure 3.10: equipment of household appliances in % (all households)

Nearly all Swedish household possess an upright freezer (99,2 %) but only 4 % a chest freezer. For British households (91,2 %) a high share of freezers can be mentioned also. Additionally 33 % of all British participants mentioned that they have a chest freezer too. Only Finnish households show a higher share of chest freezers with nearly 40 %. Concerning the equipment with freezers values between 71 and 78 percentages for the other countries were calculated with the exception of Polish and French households. Here only approximately 57 % possess a freezer. The share of chest freezers is also very low in Polish households and in Czech households in comparison with the other countries with nearly 9 % respectively 11 %.

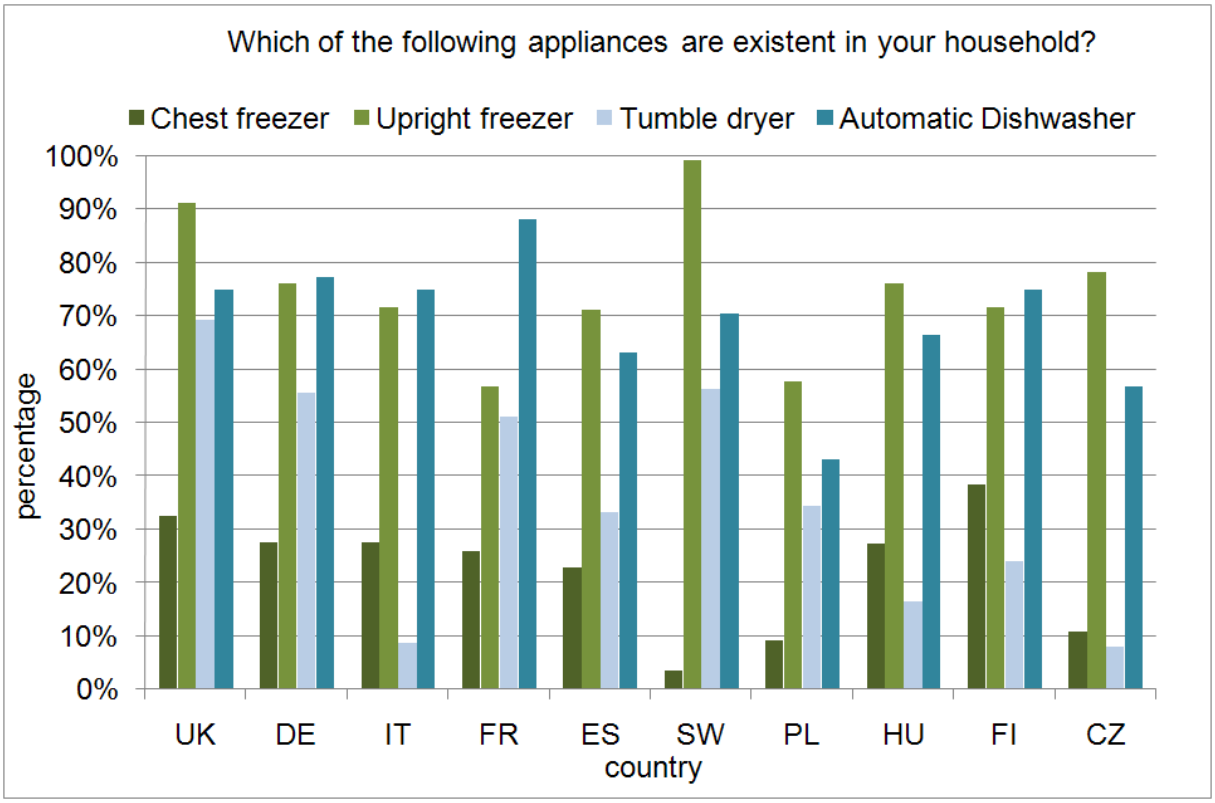


Figure 3.11: equipment of household appliances in % (per country)

One fourth of couple and family households have a chest freezer and over 70 % an upright freezer (Figure 3.12). One person households only show an equipment level of 10 % of chest freezers. The reason might be not enough space or that this appliance is unnecessary.

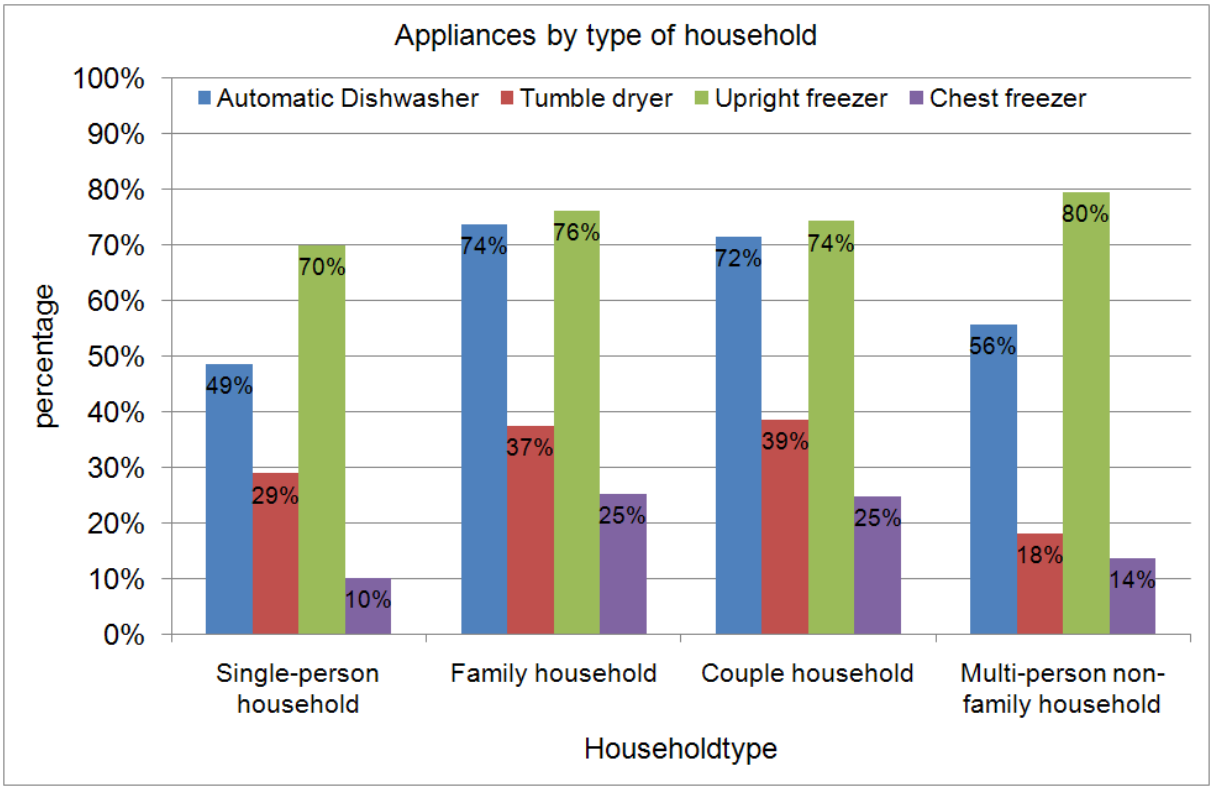


Figure 3.12: equipment of household appliances by type of household

3.1.4 *Consumer opinion about the topic "Household appliances"*

For a possible general estimation how consumers use their appliances or how they evaluate their influences on the environmental impact with their behaviour they were confronted with some general statements.

Nearly all interviewed consumers stated that appliances should *just do a perfect job* (Figure 3.13) so that the consumer does not need to worry about it (53,9 %) (Figure 3.14). Ecological aspects are very important for the consumers too. Most of the consumers know that their *behaviour plays a role for the environmental impact*. Consequently nearly 90 % of all interviewed persons mentioned that it's very important for them *to be able to protect the environment with their behaviour* (Figure 3.13) and they agree with the statement that *a correct use of their machines would save energy* (94,7 %) (Figure 3.14). So it is also a high priority for the interviewees that household *appliances show very good economical consumptions* (39,7 %) (Figure 3.13) and that they *work economically* too (38,3 %) (Figure 3.14). Aspects like design or the price seem to play a minor role for the consumers. Approximately 40 % of all consumers disagree and even 7,9 % strongly disagree with the statement that an *appliance should reflect their lifestyle or match the interior of their home* (Figure 3.13). Also nearly 30 % disagree that they primarily pay attention to an *attractive price of the appliances* (Figure 3.14).

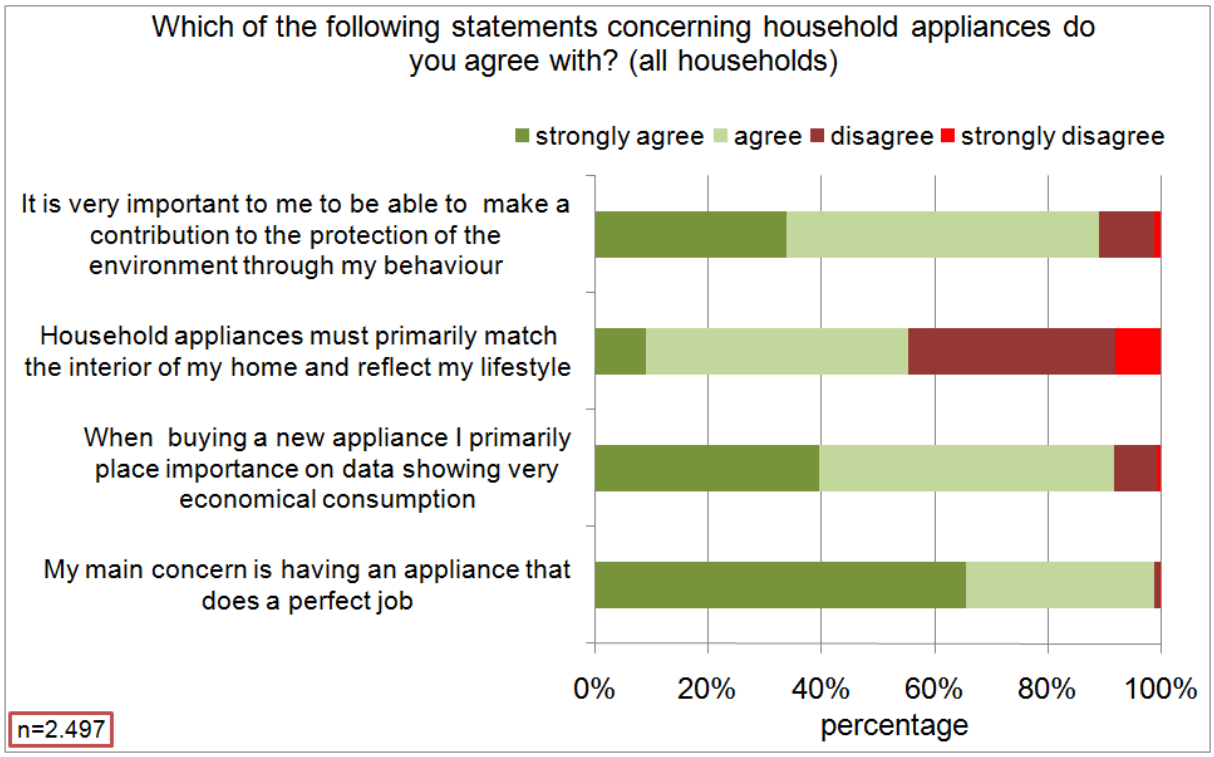


Figure 3.13: consumer statements – part I

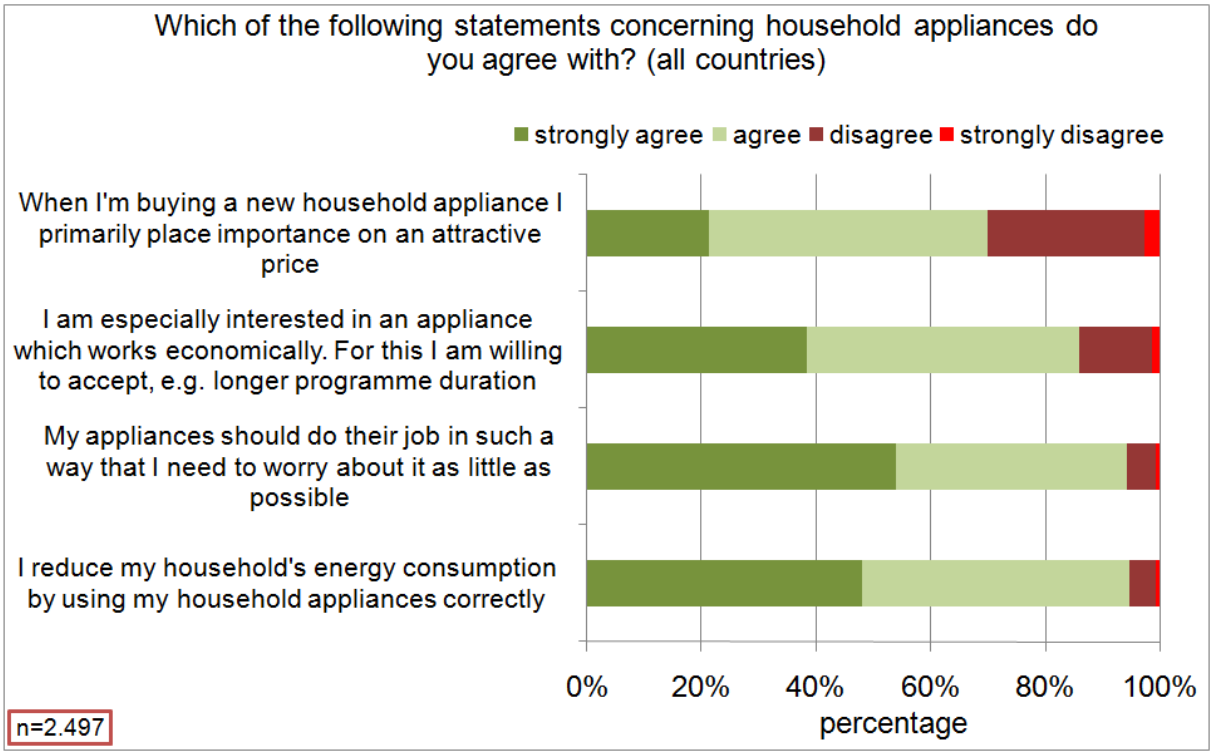


Figure 3.14: consumer statements – part II

The consumers were also asked which sources of information they would consult when they plan on buying a new appliance (multiple answers allowed). The main source of information for the consumer when buying a new appliance is his *own experience* (55,7 %) (Figure 3.15). The second main source of information is *internet sites of the manufacturers* (52,2 %). *Information on the energy label* is important for nearly 52 % of all interviewed consumers. Approximately equally quoted are *advices and experiences of friends* and *test reports from consumer organizations* (50,5 %; 50,8 %) (Figure 3.15). In comparison with the results of a study of a German magazine (STERN)[8] (Figure 3.16) concerning information when purchasing an electrical domestic appliance the importance of *information in trade* is quoted lower (Figure 3.16). These *advices from sales representatives in a shop* (46,4 %) are less relevant for the interviewees of our survey. But similar are the results for the importance level of "information *by manufacturers' brochures"*. Here in our study and the STERN study nearly 30 % of the consumers choose this source of information when they consider buying a new appliance (Figure 3.15; Figure 3.16).).

[8] STERN (2005): TrendProfil "Elektronische Haushaltsgeräte". Online: http://www.gujmedia.de/_content/20/50/205011/TP_0505_Elektr_HHG.pdf?PHPSESSID=3d884f1d5fee754e7b0e5320766a6ab2

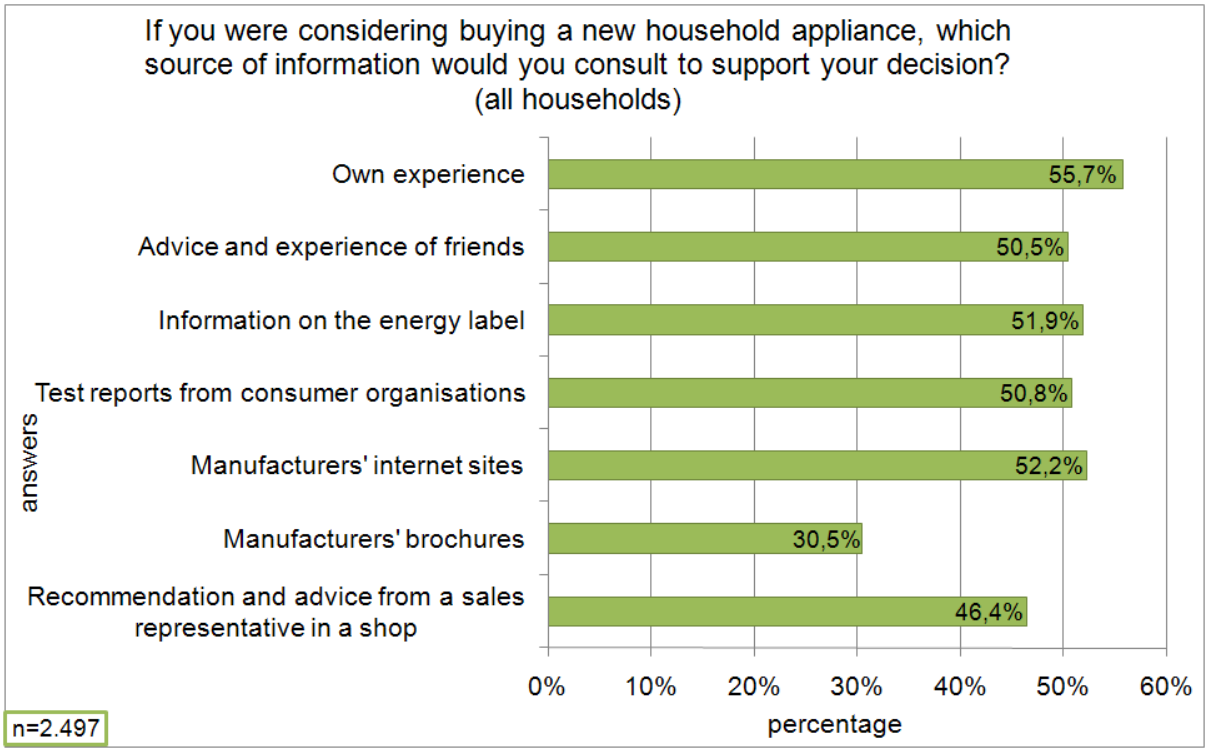


Figure 3.15: sources of information when purchasing a new appliance

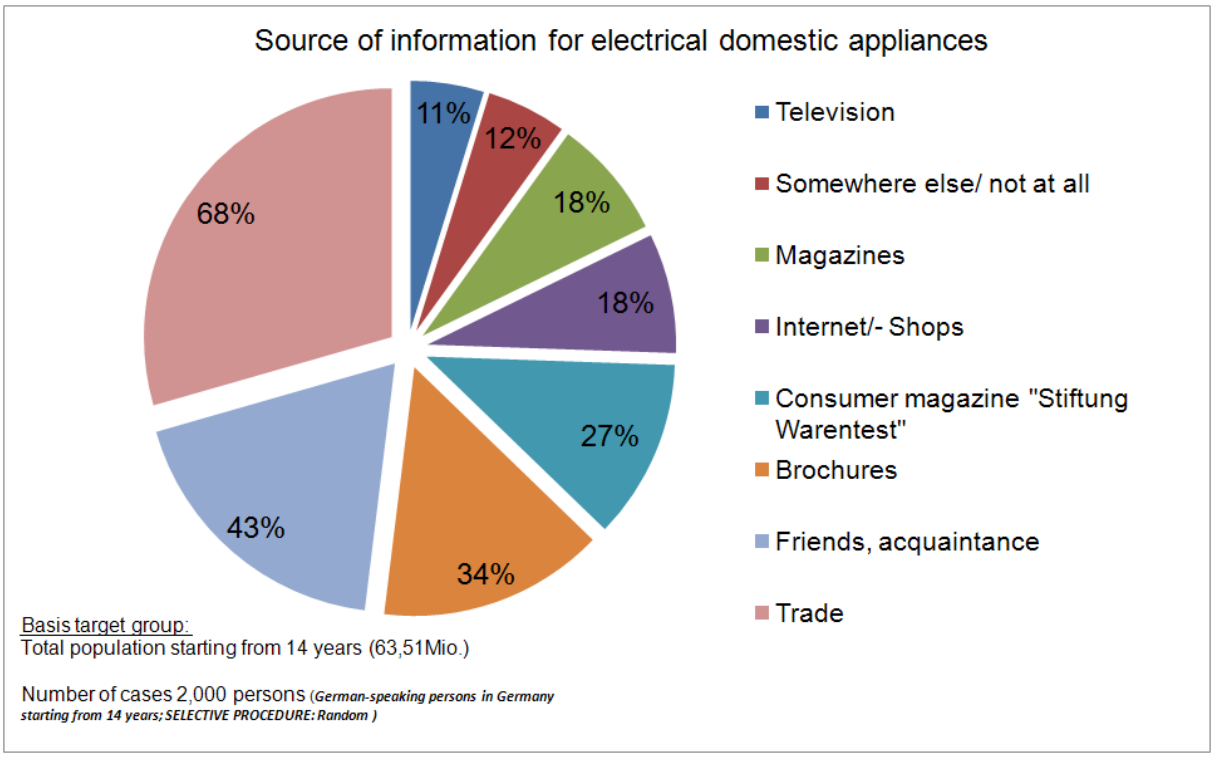


Figure 3.16: results study STERN: sources of information when purchasing an electrical domestic appliance (STERN (2005)[9]

[9] STERN (2005): TrendProfil "Elektronische Haushaltsgeräte". Online: http://www.gujmedia.de/_content/20/50/205011/TP_0505_Elektr_HHG.pdf?PHPSESSID=3d884f1d5fee754e7b0e5320766a6ab2

For approximately 52 % of all participants of this survey *information on the energy label* is important for their buying decision (Figure 3.15). Within this survey the consumers were asked in more detail what information on the energy label they would expect (list of options was provided). For over 80 % the *energy efficiency class* and information about the *water consumption* are rated as very important (Figure 3.17). More than about 50 and 60 % of all interviewees mentioned and chose points which are already listed on the energy label today, like e.g. *cleaning/washing performance* (58,1 %), *capacity* (57,5 %), *noise emission* (55,4 %) or *spin/drying performance* (50,5 %). A bit lower in the reply quota information on the *programme duration* (45,2 %) is requested.

Referring to the *energy consumption* the consumer expects more information on the consumption *per cycle per day* (56,4 %) than on the *annual consumption* (34,1 %). Other detailed information on all *programmes or features of the appliance* or on *programme and temperature used for the assessmen*t are only wished by approximately 28 % of the consumers. Financial aspects like *yearly* or *running cost (per cycle)* are also requested by only about 32 % to 34 %.

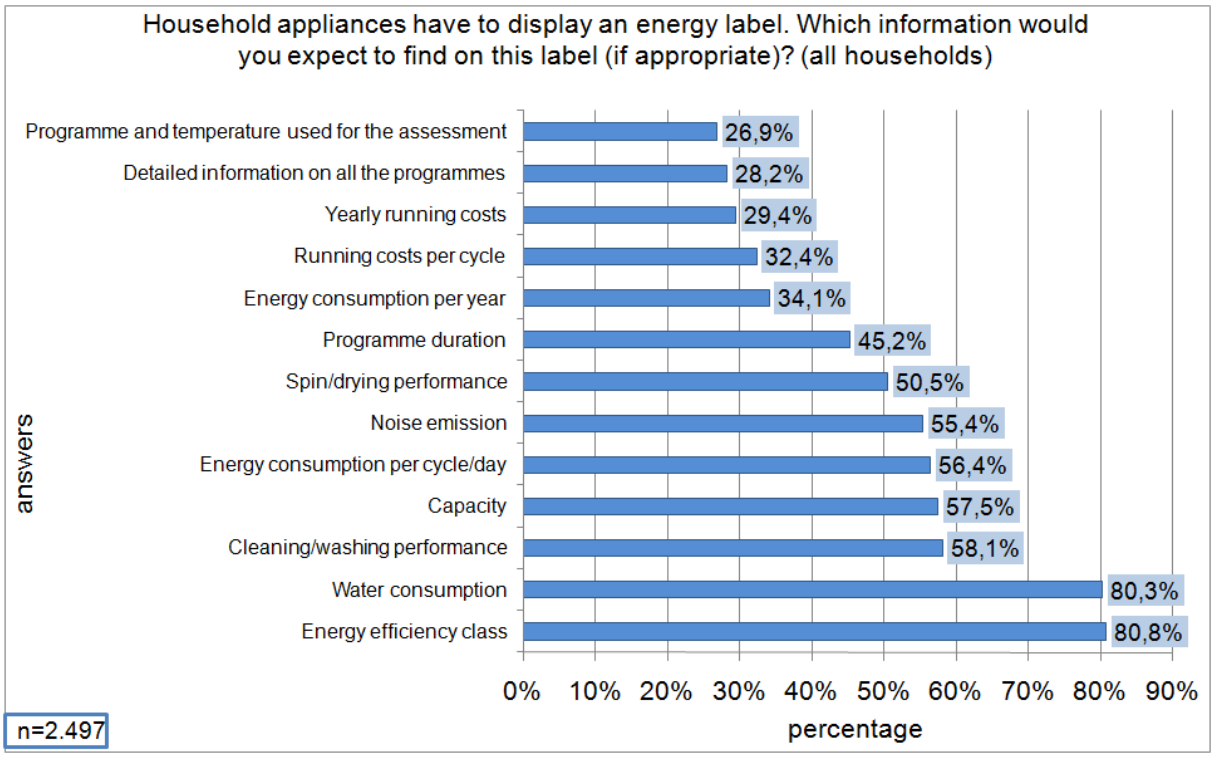


Figure 3.17: energy label – expected information

A very *low consumption of resources like water and/or energy* is the most important aspect for the consumers when they plan on buying a new appliance (83,9 %) (Figure 3.18). Also for over 70 % of all interviewed persons a *very good cleaning/washing performance* has a high priority. More than half of all participants of this study pay attention to a *low operating noise emission* of the appliance. Accordingly a lot of consumers not only look at the *purchase price of the machine* (38,2 %) but also for a very *good result on the energy label* (36 %). More than one fourth of the consumers attend to a *good dishes-/textile protection* too. The other criteria like *shorter programme duration*, *low detergent consumption* or a *large number of different programmes* are only mentioned by between 15 and 18,5 % of the consumers. The least values are reached by a *higher capacity* (10,2 %) and an *innovative aesthetic design* (7,2 %).

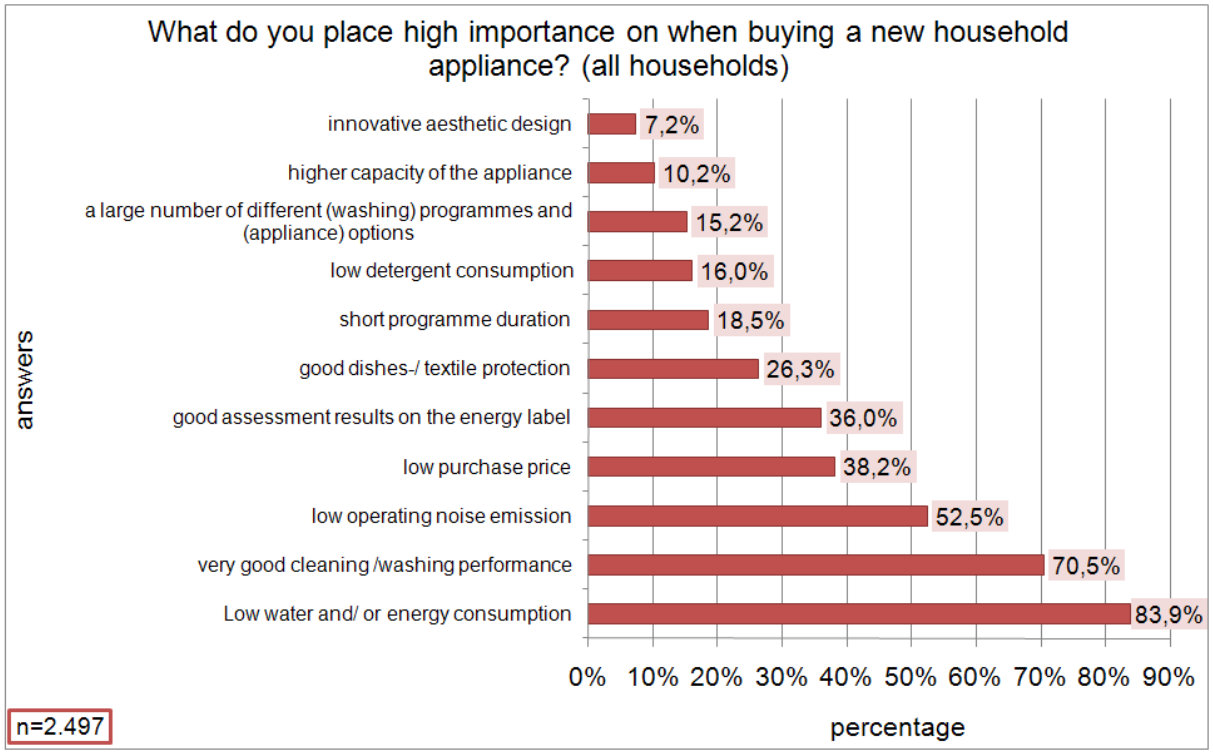


Figure 3.18 : criteria when purchasing a new appliance

3.2 IDENTIFICATION OF POSSIBLE BARRIERS TO ECO DESIGN INNOVATIONS

After development it takes some time for new energy efficient appliances to penetrate the market. It depends on how often consumers buy new refrigerators/ freezers, this in turn is depended on the life time of the appliance, on repairs and the second-hand market. Another possible barrier for energy saving innovations for cold appliances is the necessity of food protection. The decrease of energy consumption can only go as far as food safety is ensured.

First available data on these subjects is presented followed by results of the conducted survey of consumers of the EU.

3.2.1 Life time of the appliances

Consumers normally purchase an appliance and use it until it breaks before buying a new one. This implies that new refrigerator/ freezer models with innovative eco-designs only enter the households when an old appliance is replaced.

According to CECED[10] the life time of refrigerators is 14 years and 17 years for freezers.

A study conducted by S.A.F.E.[11] showed that 2 % of the participating households owned refrigerators manufactured between the years 1970 and 1979, 11 % owned appliances from the years 1980 to 1989, 37 % had refrigerators manufactured between 1990 and 1999, the remaining 50 % have appliances produced after 2000. The situation is similar for freezers. The same study showed that 2 % of the freezers owned were manufactured between 1970 and 1979, 15 % in the 1980s, 38 % were produced between 1990 and 1999 and 45 % after 2000.

MTP[12] estimated the life times of different old appliances by using the stock model and optimising estimated sales data with actual sales (Table 3.4).

Table 3.4: assumed life span of different cold appliances (source: MTP[12])

	Chest freezer	Upright freezer	Fridge	Fridge-freezer
Lifetime (years)	16.7	15.5	12.8	17.5

The consumer survey conducted for this study showed that more than 10 % of the main refrigerators in EU households are older than 10 years, with ages up to 25 years (Figure 3.19). Approximately 55 % of the appliances are less than 5 years old and therefore unlikely to be replaced in the near future.

[10] CECED (2006): White Paper: Energy efficiency a shortcut to Kyoto targets. The vision of European home appliance manufacturers, S.18 Online: http://www.ceced.org/IFEDE//easnet.dll/GetDoc?-APPL=1&DAT_IM=20429D&DWNLD=White Paper_Energy efficiency_Feb 2006_Final.pdf

[11] S.A.F.E. SCHWEIZERISCHE AGENTUR FÜR ENERGIEEFFIZIENZ/ SWISS AGENCY FOR EFFICIENT ENERGY USE (2005): www.energy box.ch – Auswertung der Nutzerdatenbank, Online: http://www.energieeffizienz.ch-/files/auswertung_energybox.pdf

[12] MTP MARKET TRANSFORMATION PROGRAMME (2006): BNC08: Assumptions underlying the energy projections for domestic cold appliances. Online: http://www.mtprog.com/ApprovedBriefingNotes/PDF-/MTP_BNC08_2006October31.pdf

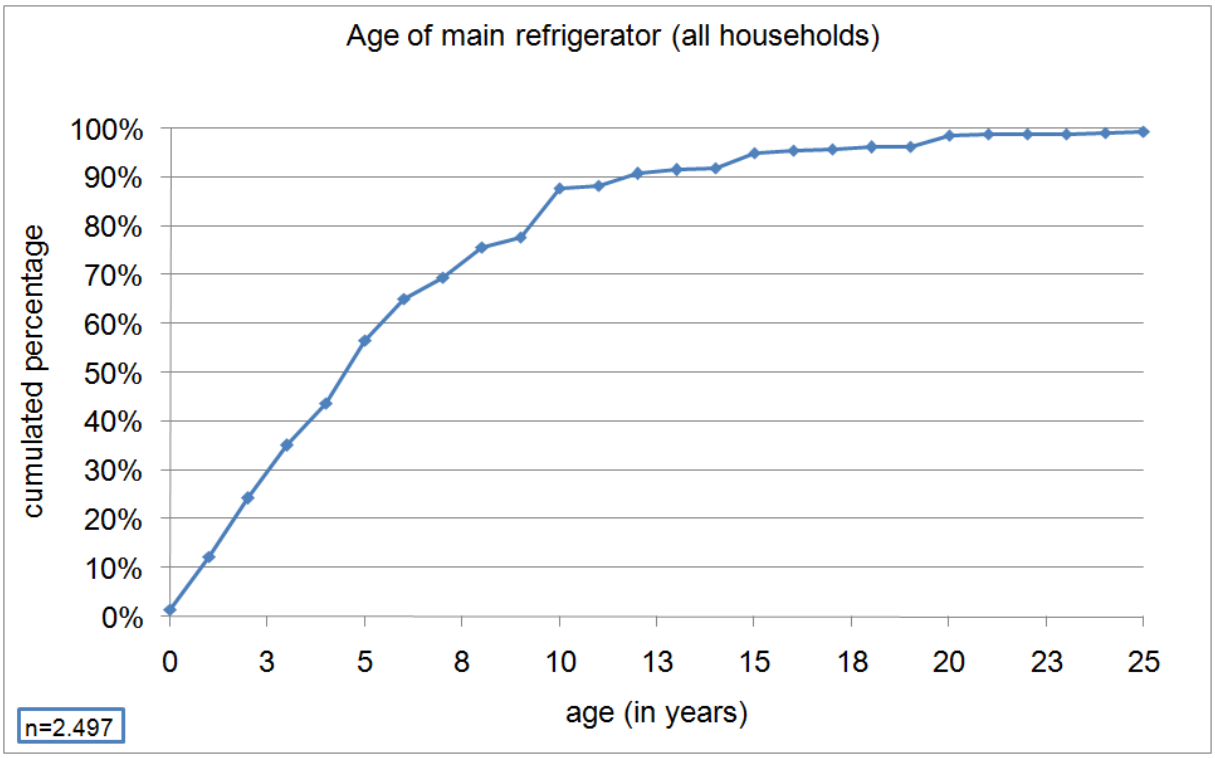


Figure 3.19: cumulated age of the main refrigerators of all questioned households

A separated look at the average refrigerator ages in the different countries shows that they are similar. 50 % of the appliances are less than 3,5 to approx. 5 years old. 10 % of the cold appliances are older than 9 to 15 years (Figure 3.20). The average ages of main refrigerators in the different countries only differ by 1,7 years, the youngest being found in the UK (5,1 years), the oldest in Sweden and Finland with 6,8 years and 6,7 years, respectively (Figure 3.21).

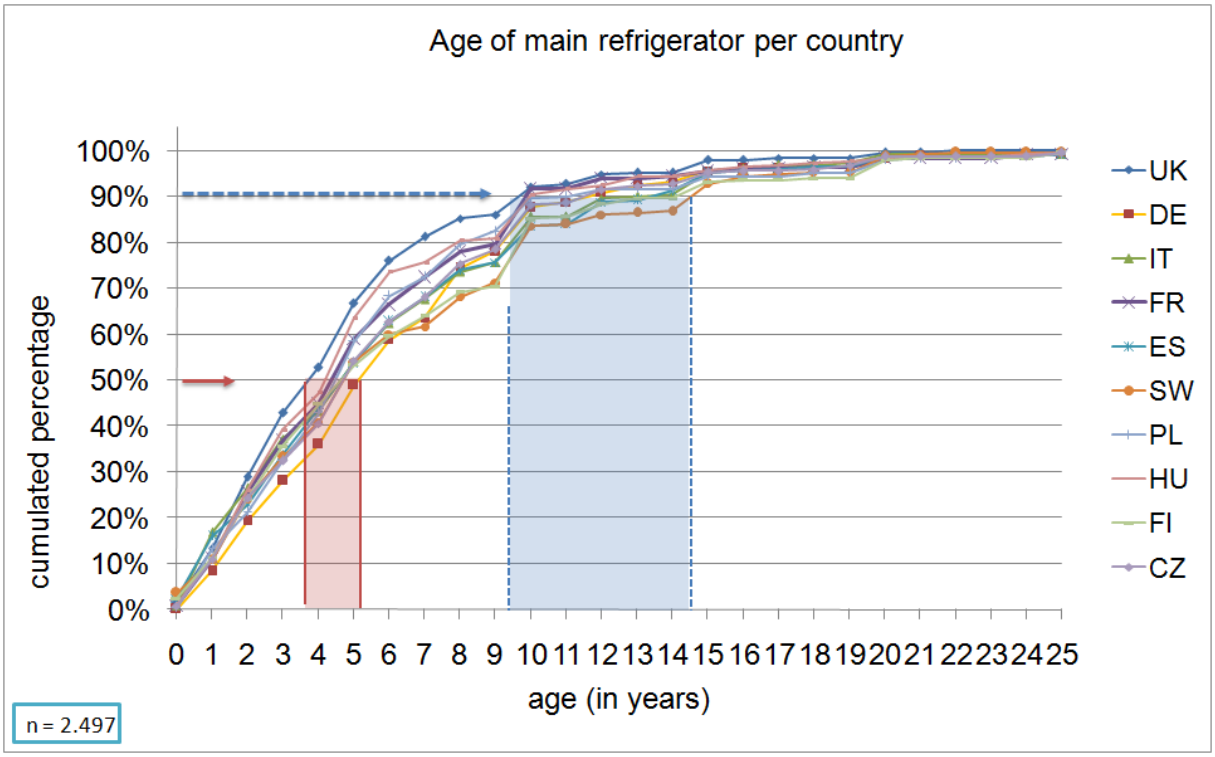


Figure 3.20: cumulated age of the main refrigerators of all questioned households per country

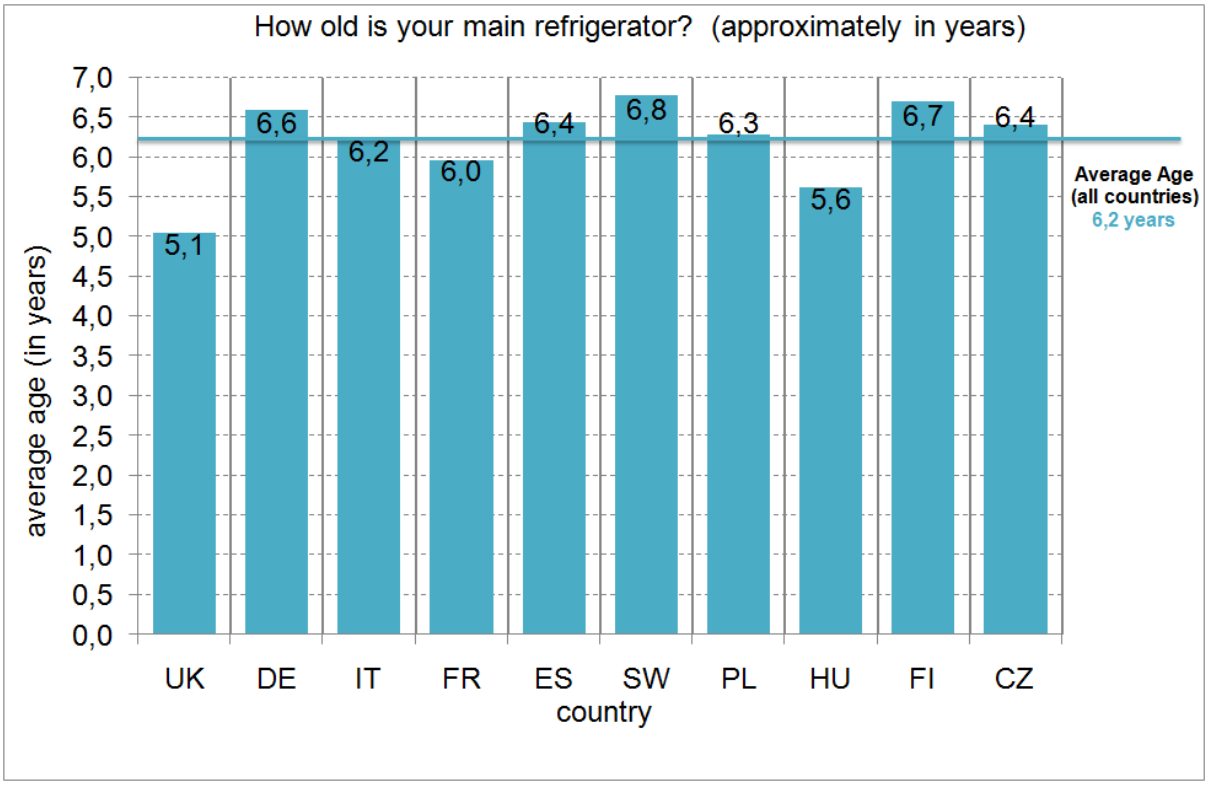


Figure 3.21: average age of the main refrigerators of all questioned households per country

About 21 % of the participating households own a second refrigerator, particularly approximately 30 % of all Italian and Hungarian households (Figure 3.22).

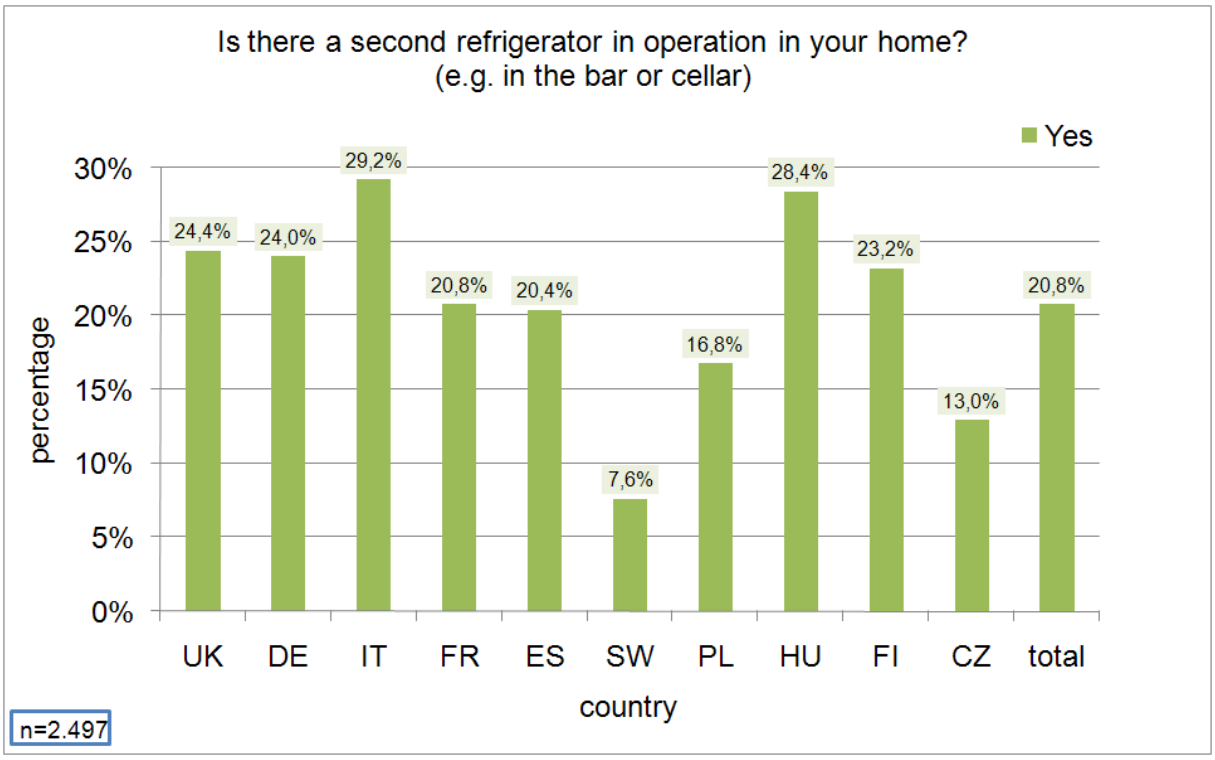


Figure 3.22: share of second refrigerators in all questioned households

50 % of the second refrigerators are less than 5 years old and 10 % are more than 15 years old (Figure 3.23).

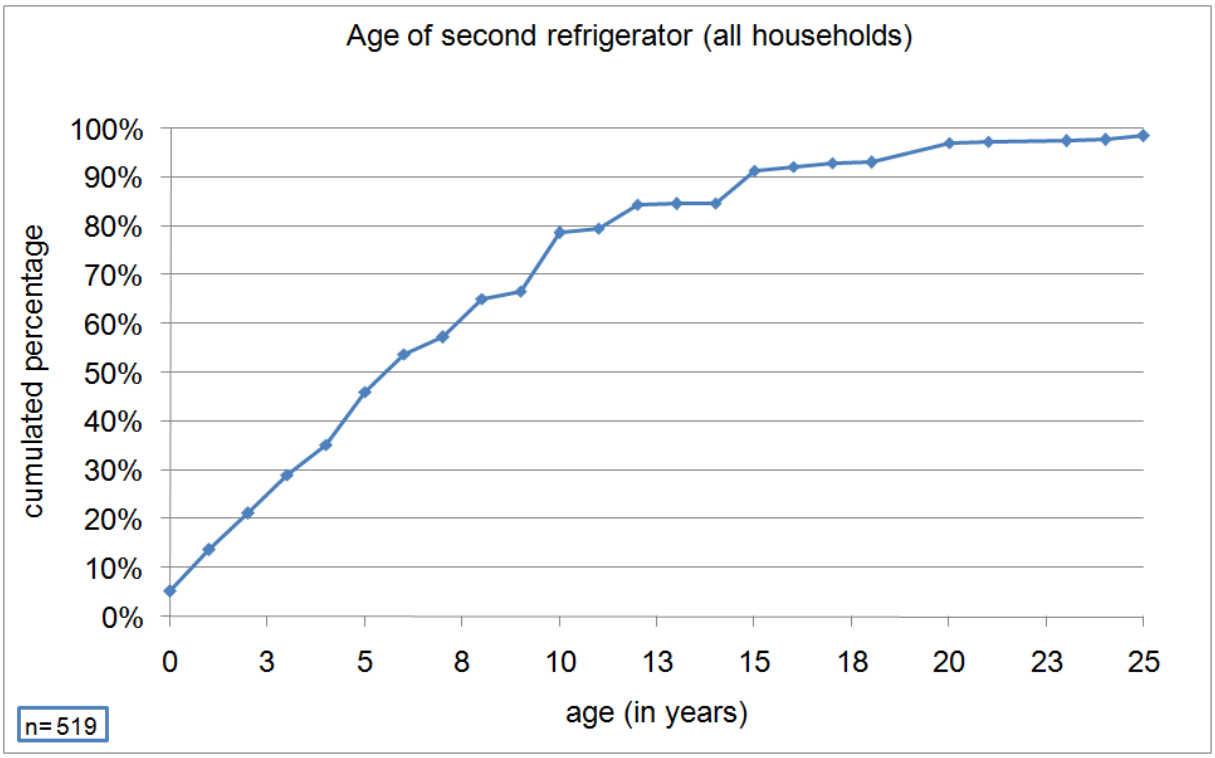


Figure 3.23: cumulated age of the second refrigerators of all questioned households

The age variations of the second appliances between the countries have a greater spread than age variations of main appliances (Figure 3.24). The average ages in comparison of countries range from 4,8 years (Spain) to 11,1 years in the Czech Republic (Figure 3.25). In the average of all countries second appliances tend to be older than the main refrigerator, but only by 1,4 years.

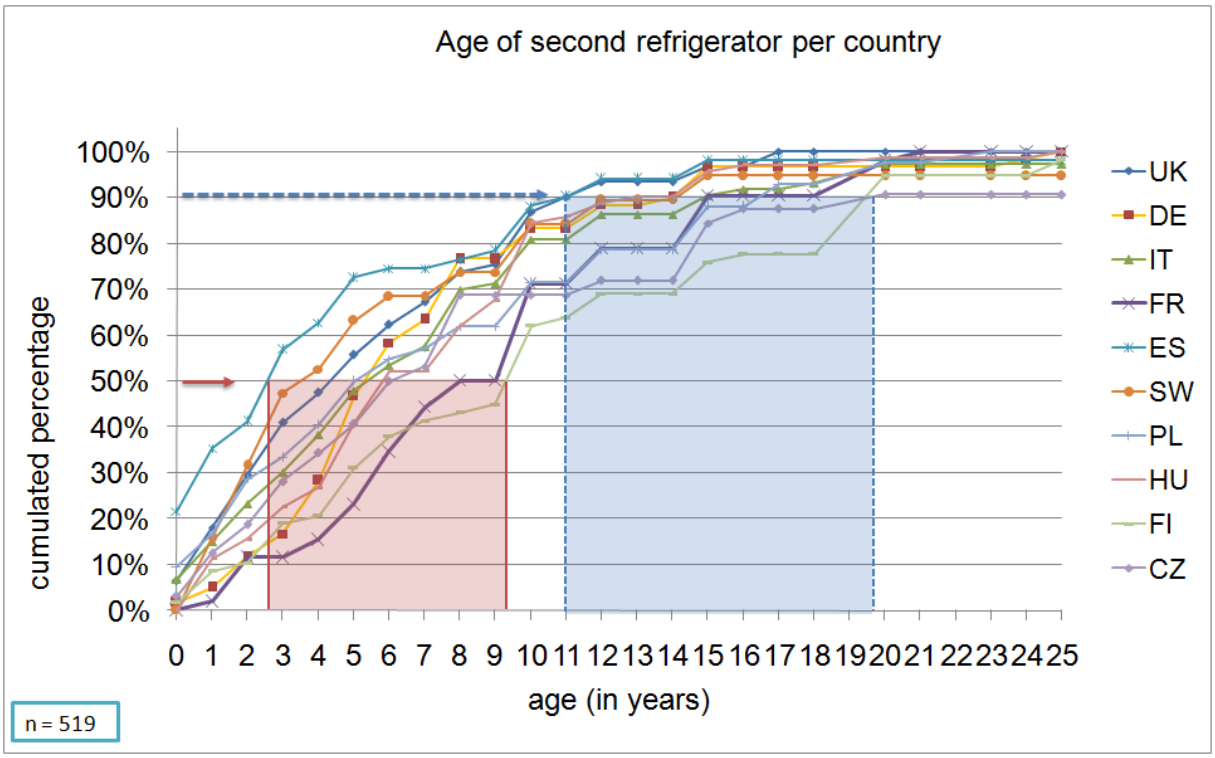


Figure 3.24: cumulated age of the second refrigerators of all questioned households per country

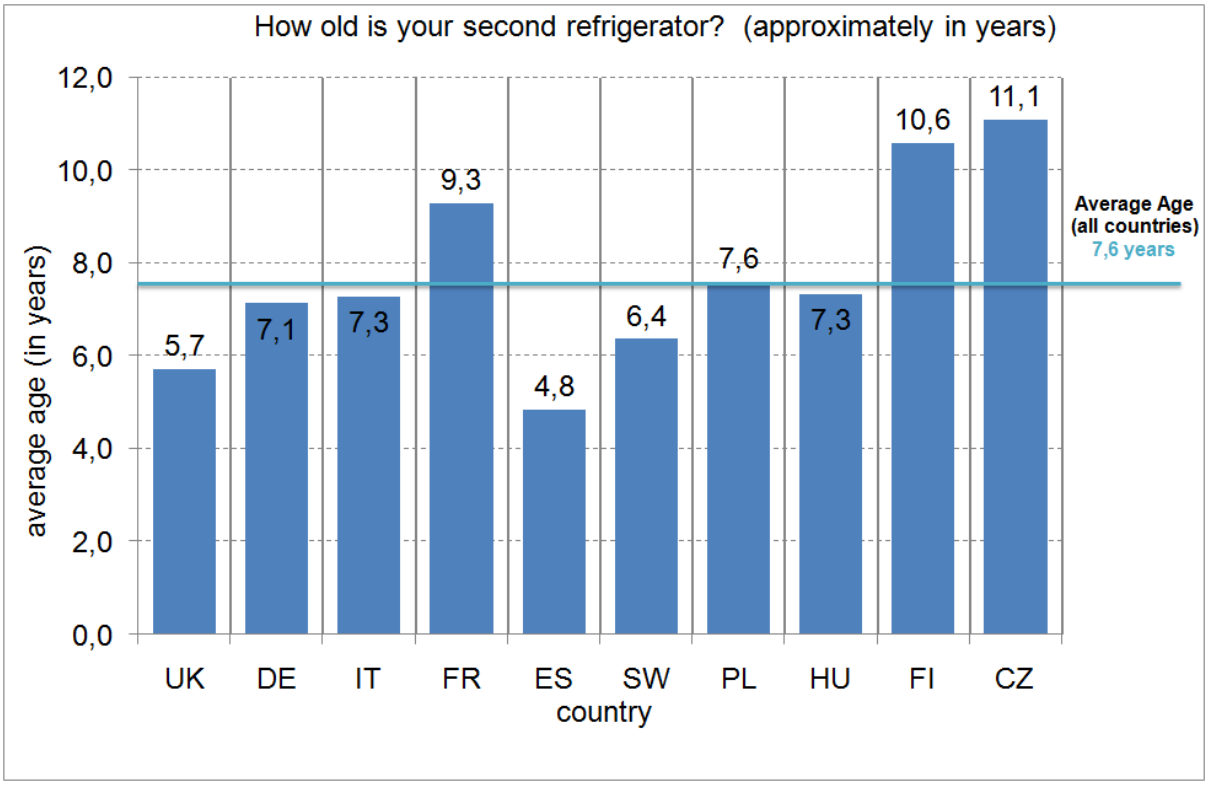


Figure 3.25: average age of the second refrigerators of all questioned households per country

Also the age of freezers was evaluated. The answers of all consumers which posses a chest freezer or upright freezer (n = 2 081) were analysed. The survey shows that 50 % of the freezers in all countries are younger than 5 years and 10 % older than approx. 15 years (Figure 3.26).

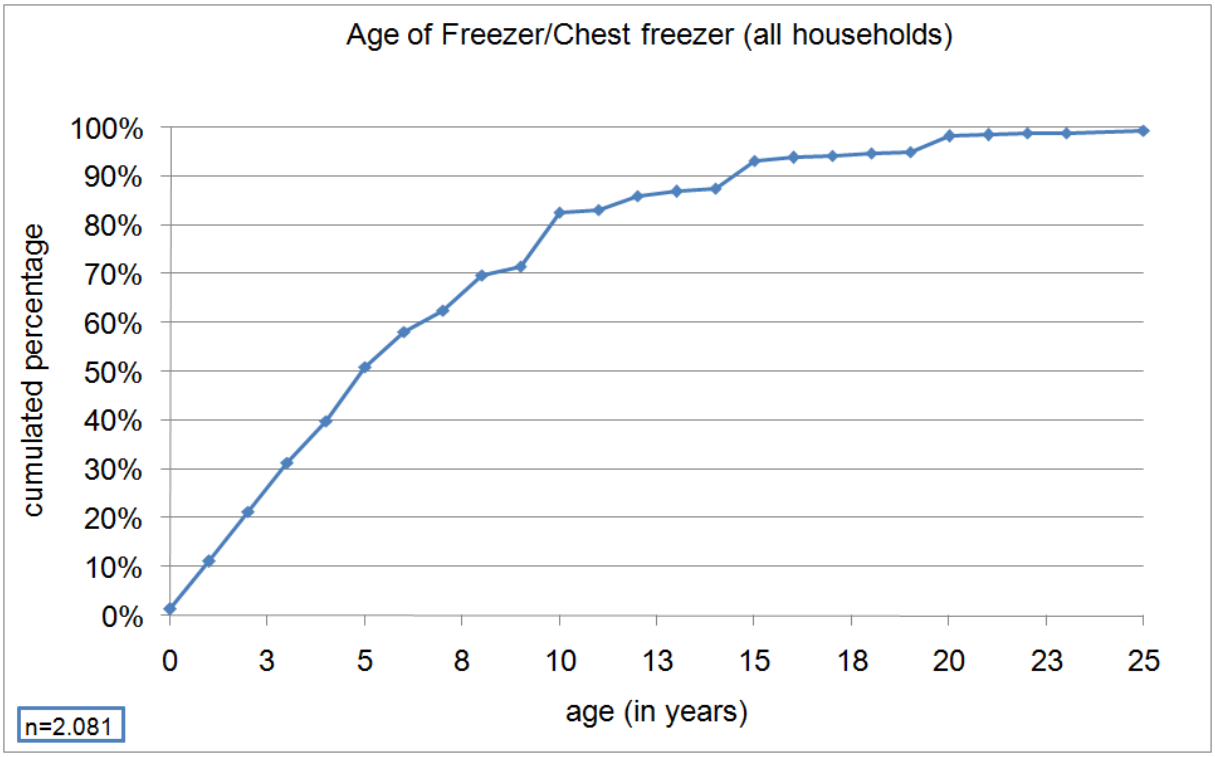


Figure 3.26: cumulated age of upright freezers/ chest freezers of all questioned households

A separated look at the average freezer ages in the different countries shows that they are very similar. 50 % of the appliances are less than 4 to approx. 6,5 years old. 10 % of the cold appliances are older than approx. 11 to 15 years (Figure 3.27).

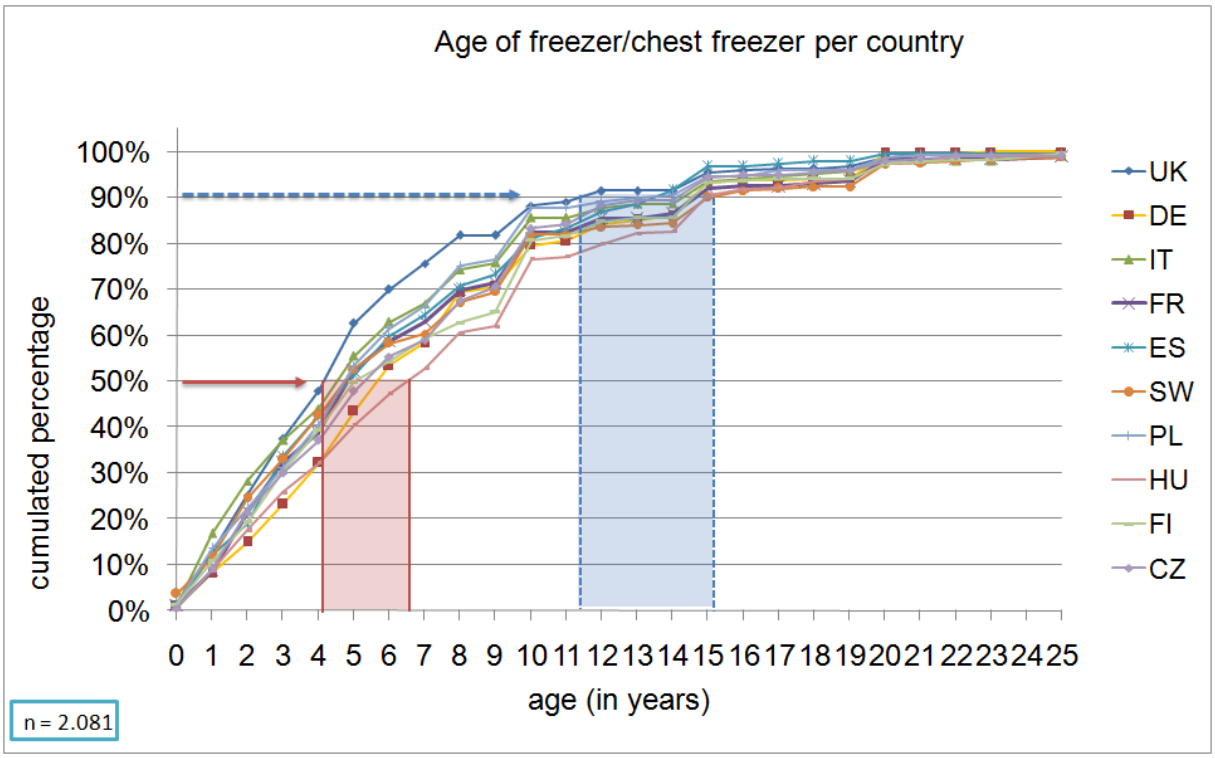


Figure 3.27: cumulated age of upright freezers/ chest freezers of all questioned households per country

The average age of upright freezers/ chest freezers in comparison between countries is very similar. The youngest freezers can be found in Italy (6,5 years), Spain (6,6 years) and Poland (6,7 years), the oldest are found in Hungary (8,0 years) (Figure 3.28).

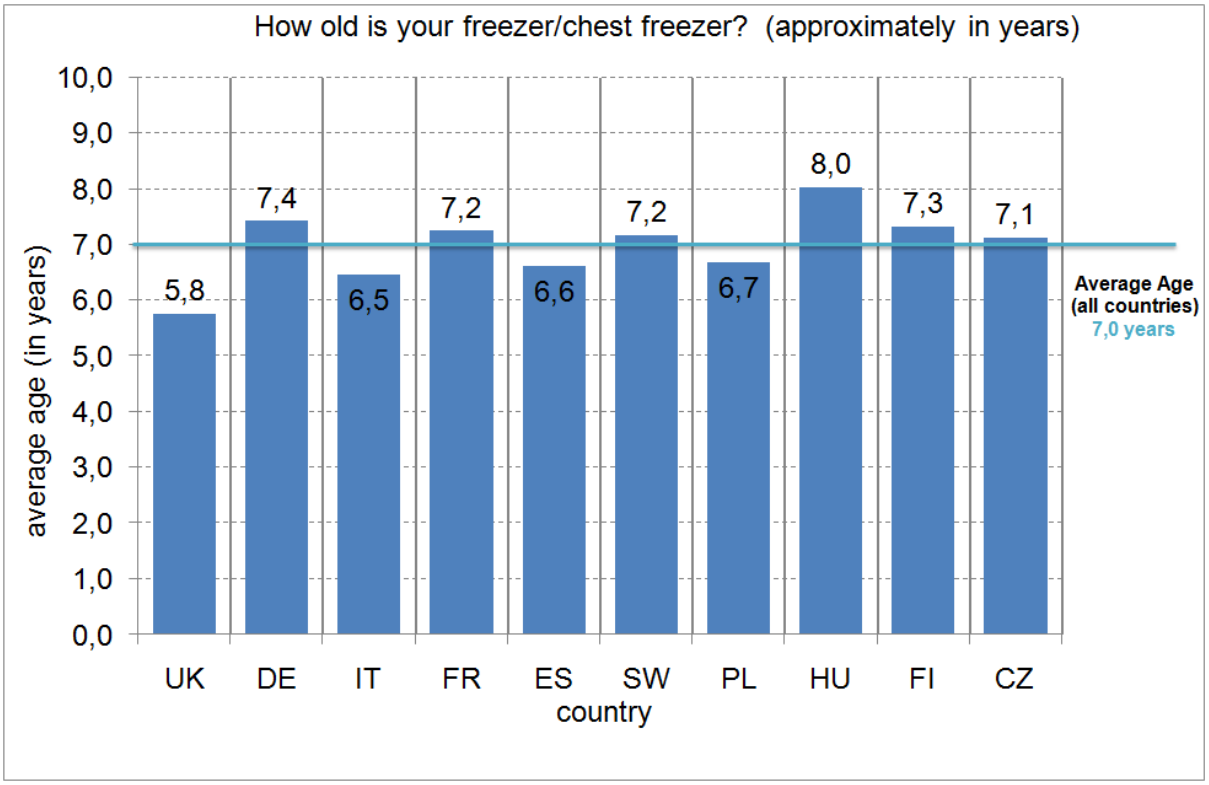


Figure 3.28: average age of the freezers of all questioned households per country

3.2.2 Repairs

In the survey consumers were asked whether their household appliances have been repaired or serviced. The analysis shows that 16 % (n = 1 611) of all appliances (n = 10 044) in all interviewed households have been repaired or serviced (Figure 3.29).

When looking at all countries the following figures show that only few cold appliances have been serviced. Approx. 12 % of the refrigerators (Figure 3.30) and 6,2 % and 4,2 % of the chest freezers and upright freezers, respectively have been repaired.

	total	**repaired/ serviced**
Dishwasher	1.722	309
Washing machine	2.497	750
Tumble-dryer	893	133
Refrigerator	**2.497**	**306**
Freezer	**1.871**	**78**
Chest freezer	**564**	**35**
Sum (repaired/serviced)		**1.611**
all appliances		10.044
% of all appliances		**16,0**

Figure 3.29: overview: repaired or serviced appliances

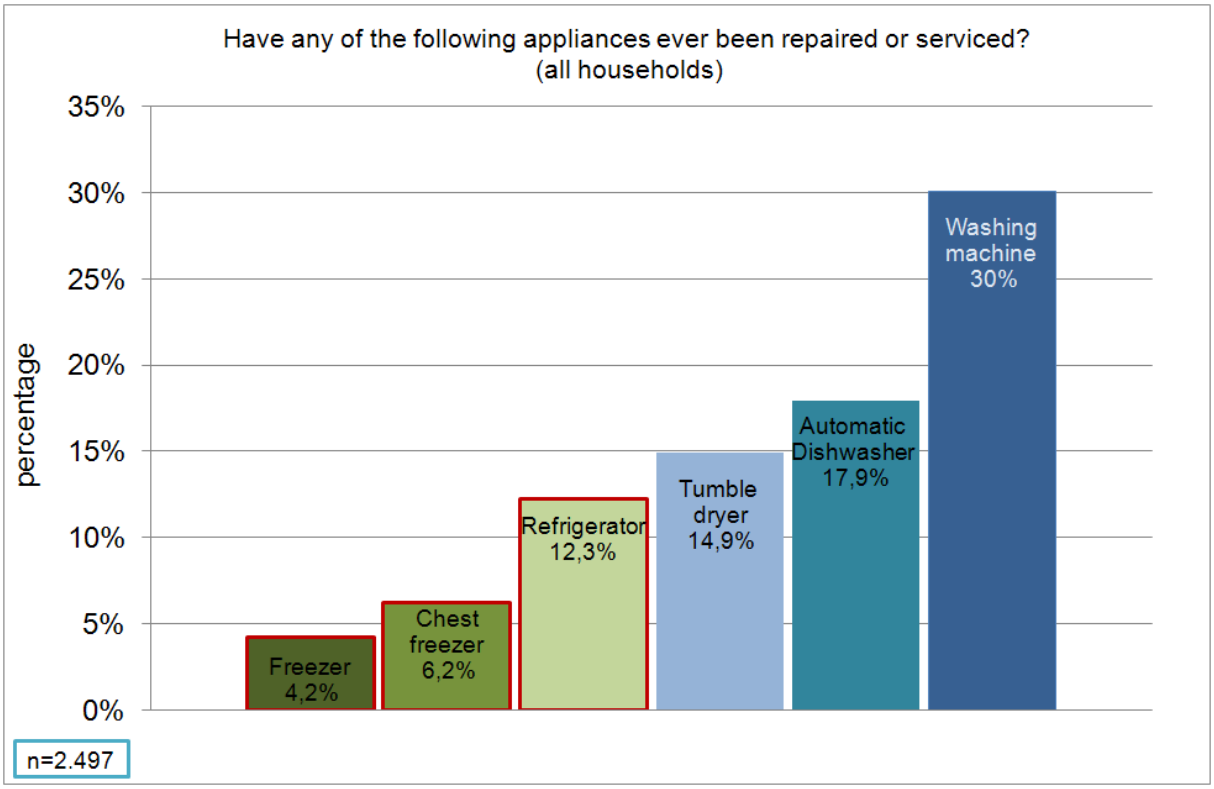
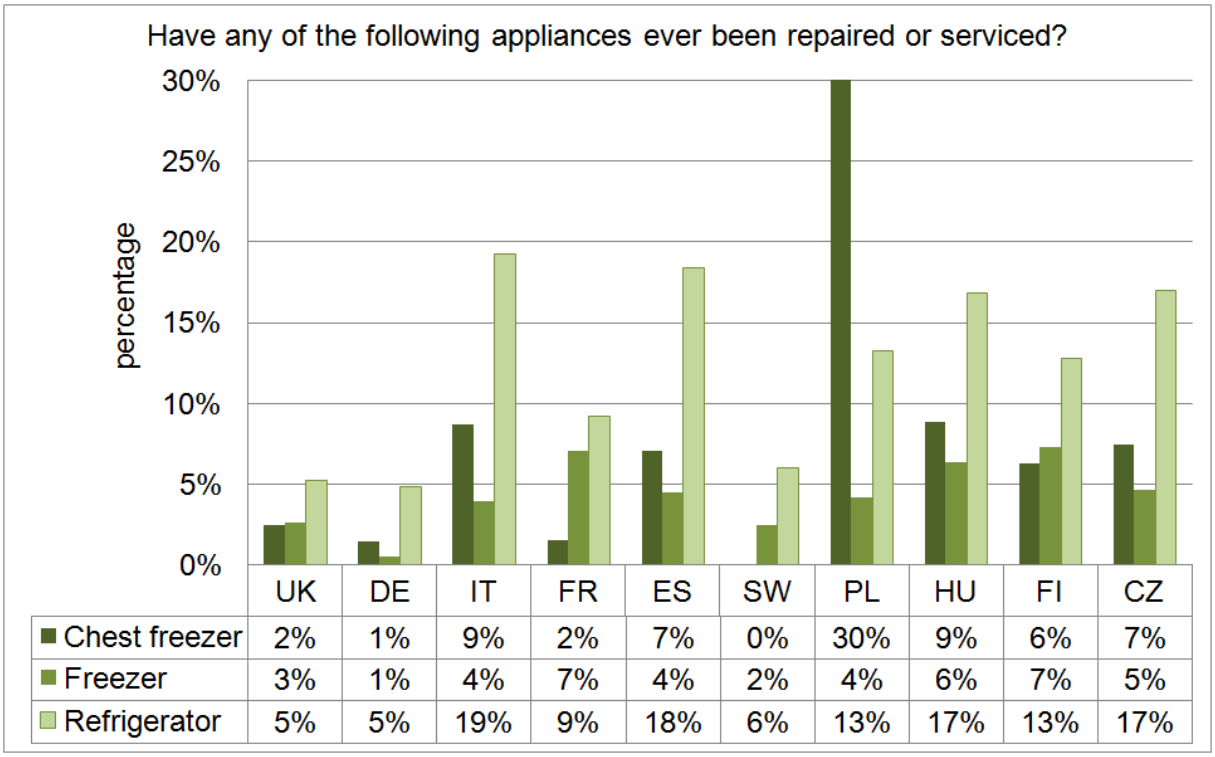


Figure 3.30: repaired or serviced appliances – cold appliances

Between 15 % and 20 % of refrigerators in Italy, Spain, Hungary and the Czech Republic have been repaired or serviced. The least share of appliances which have been repaired or serviced are determined in Germany and the UK followed by Sweden with less than or little more than 5 % (Figure 3.31).



	UK	DE	IT	FR	ES	SW	PL	HU	FI	CZ
Chest freezer	2%	1%	9%	2%	7%	0%	30%	9%	6%	7%
Freezer	3%	1%	4%	7%	4%	2%	4%	6%	7%	5%
Refrigerator	5%	5%	19%	9%	18%	6%	13%	17%	13%	17%

Figure 3.31: cold appliances repaired or serviced per country

The average age of repaired or serviced refrigerators in Europe is 7,5 years. 50 % of these appliances are younger than 5,5 years and 90 % are younger than 15 years (Figure 3.32).

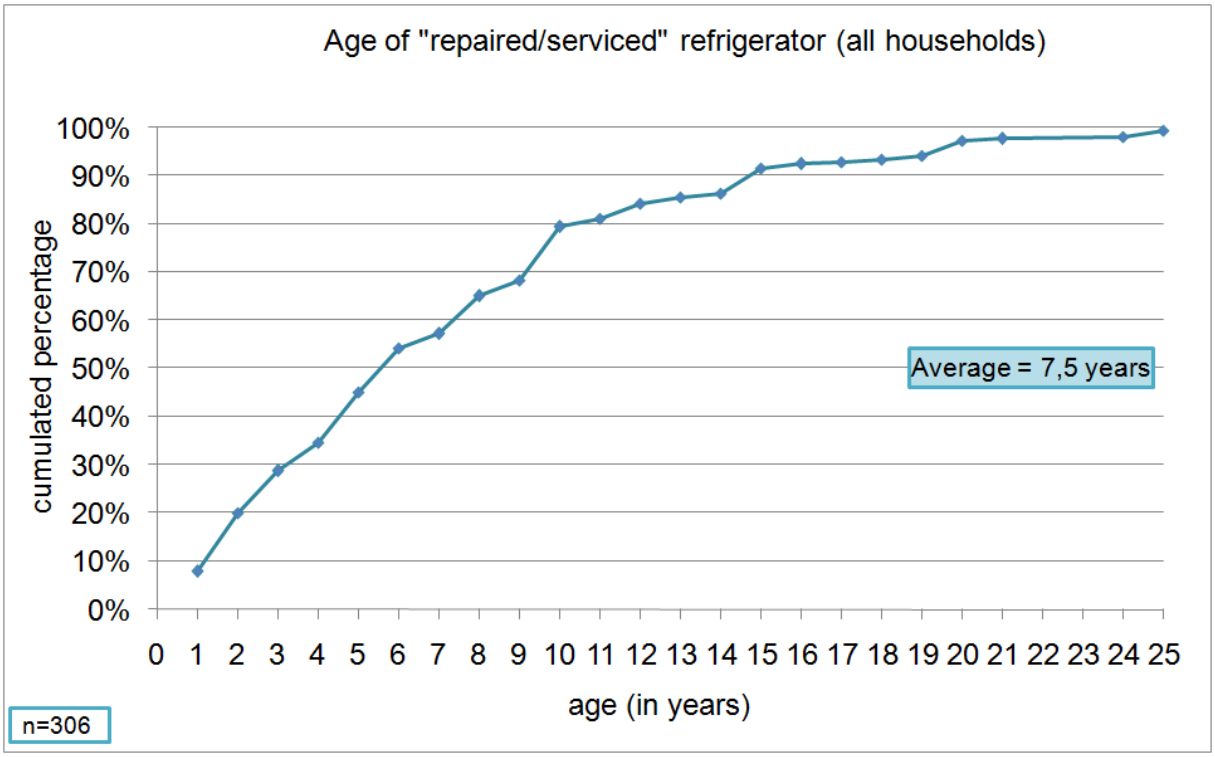


Figure 3.32 : age of repaired or serviced refrigerators in all households (EU)

The average age of repaired or serviced freezers in Europe is 8,5 years. 50 % of these appliances are younger than 6 years and 90 % are younger than 15 years (Figure 3.33).

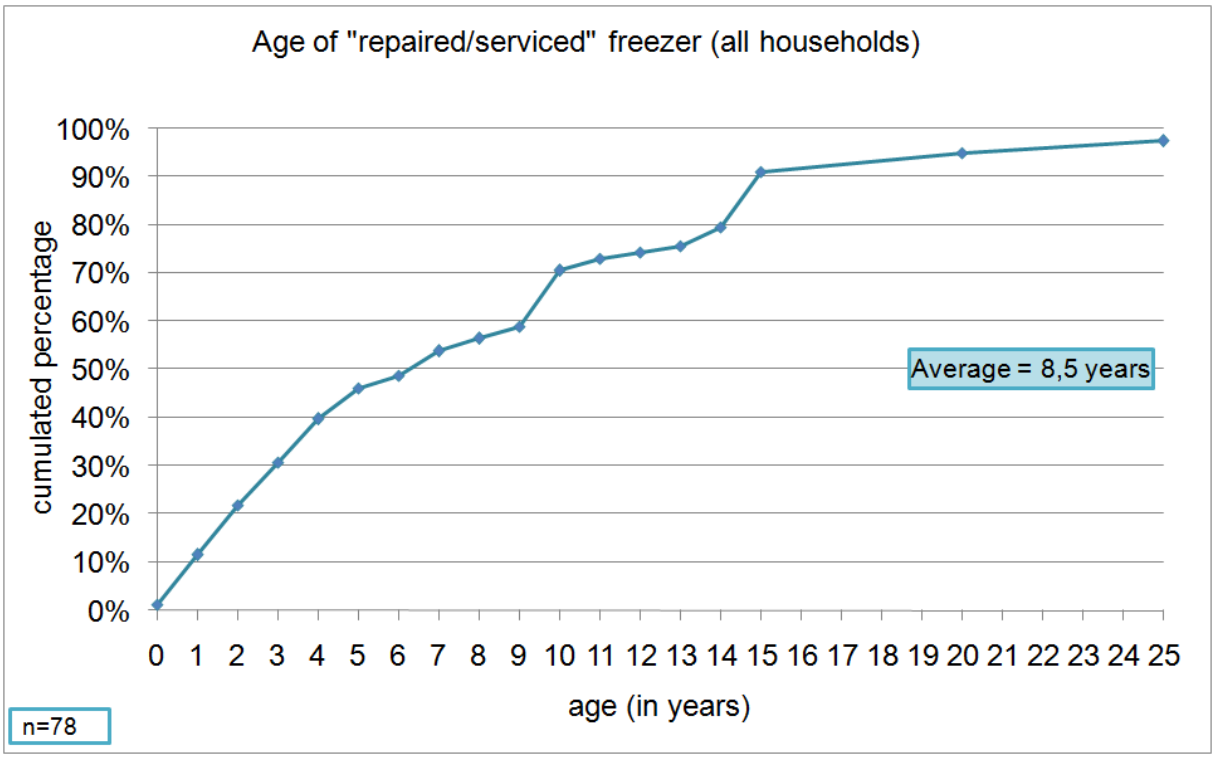


Figure 3.33: age of repaired or serviced freezers (chest/upright freezer) in all households (EU)

3.2.3 Second-hand market

Another possible barrier for the implementation of eco-design innovations is the stock of second-hand purchased appliances in households. Often consumers choose to replace broken or missing apparatuses by second-hand appliances. These are often older refrigerators/freezers with worse performances in comparison with new appliances on the market.

It is also possible that there is an existent kitchen with refrigerator/ freezer in the new apartment/ house when moving.

30 % of the questioned households in the study by LEPTHIEN[13] had a kitchen including a refrigerator already installed when they moved into their apartment/ house.

The survey shows that refrigerators are the appliances least frequently purchased second-hand of those evaluated. Only 4,9 % of the purchased refrigerators were pre-owned (Figure 3.35).

	total	**second hand**
Dishwasher	1.722	114
Washing machine	2.497	140
Tumble-dryer	893	59
Refrigerator	**2.497**	**122**
Freezer	**1.871**	**118**
Chest freezer	**564**	**80**
Sum (second hand)		**633**
all appliances		10.044
% of all appliances		**6,3**

Figure 3.34: overview: second hand appliances

[13] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

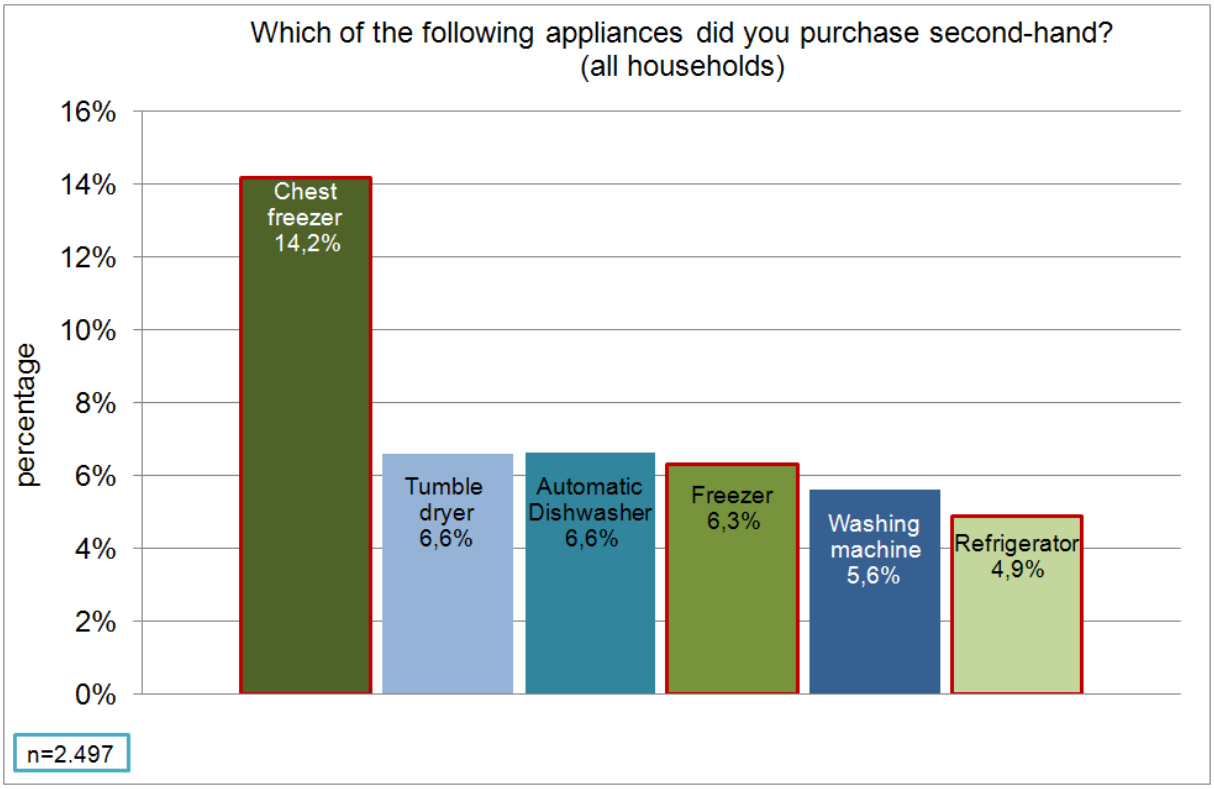
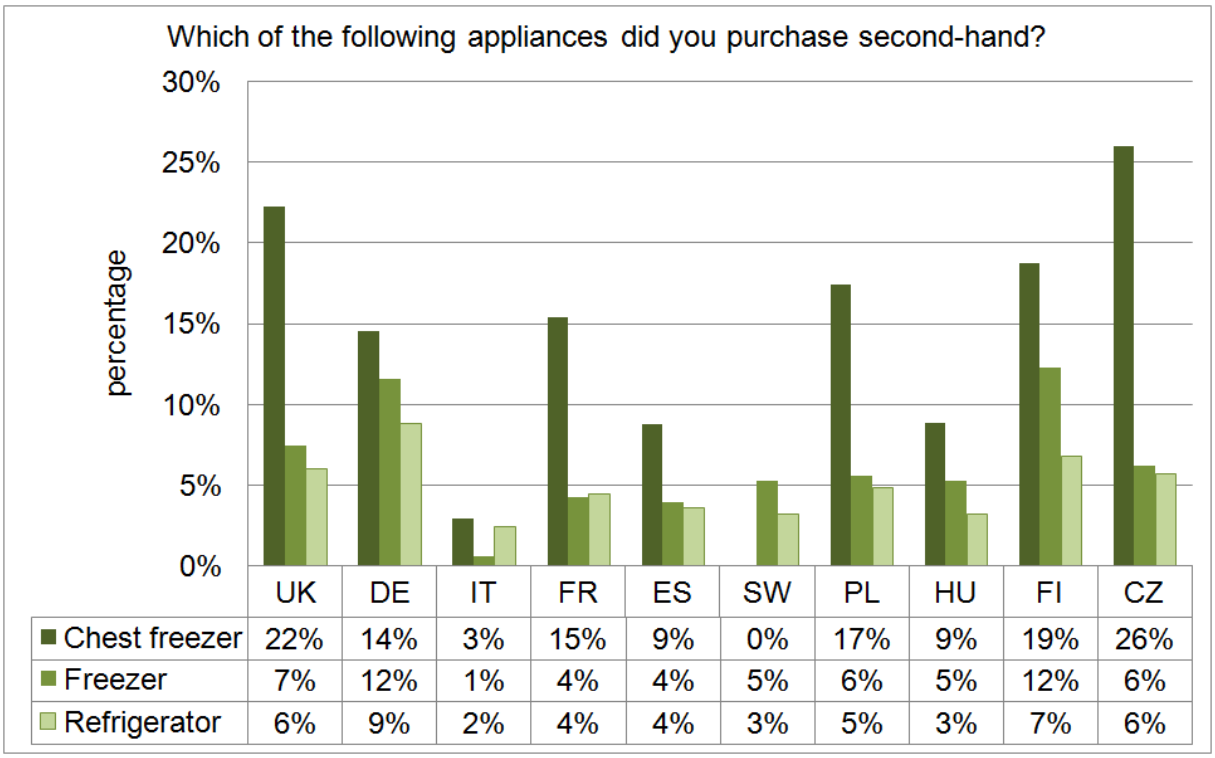


Figure 3.35: appliances purchased second-hand

Chest freezers are the appliances most frequently purchased second-hand 14,2 %. 6,3 % of all freezers were previously owned before purchase (Figure 3.35).

When comparing countries it can be seen that chest freezers are most often bought second-hand in the Czech Republic, with 25 % of the appliances, and the UK, with more than 20 %. In Sweden none of the chest freezers are purchased second-hand. Upright freezers are most often bought pre-owned in Finland and Germany (more than 10 %), and least frequently in Italy. German households are the ones with the most second-hand refrigerators (approx. 9 %) followed by Finnish and British households (Figure 3.36).



	UK	DE	IT	FR	ES	SW	PL	HU	FI	CZ
Chest freezer	22%	14%	3%	15%	9%	0%	17%	9%	19%	26%
Freezer	7%	12%	1%	4%	4%	5%	6%	5%	12%	6%
Refrigerator	6%	9%	2%	4%	4%	3%	5%	3%	7%	6%

Figure 3.36: cold appliances purchased second-hand per country

The average age of second-hand main refrigerators is 7 years. 50 % of the appliances are younger than 5 years, 90 % are younger than 13 years (Figure 3.37).

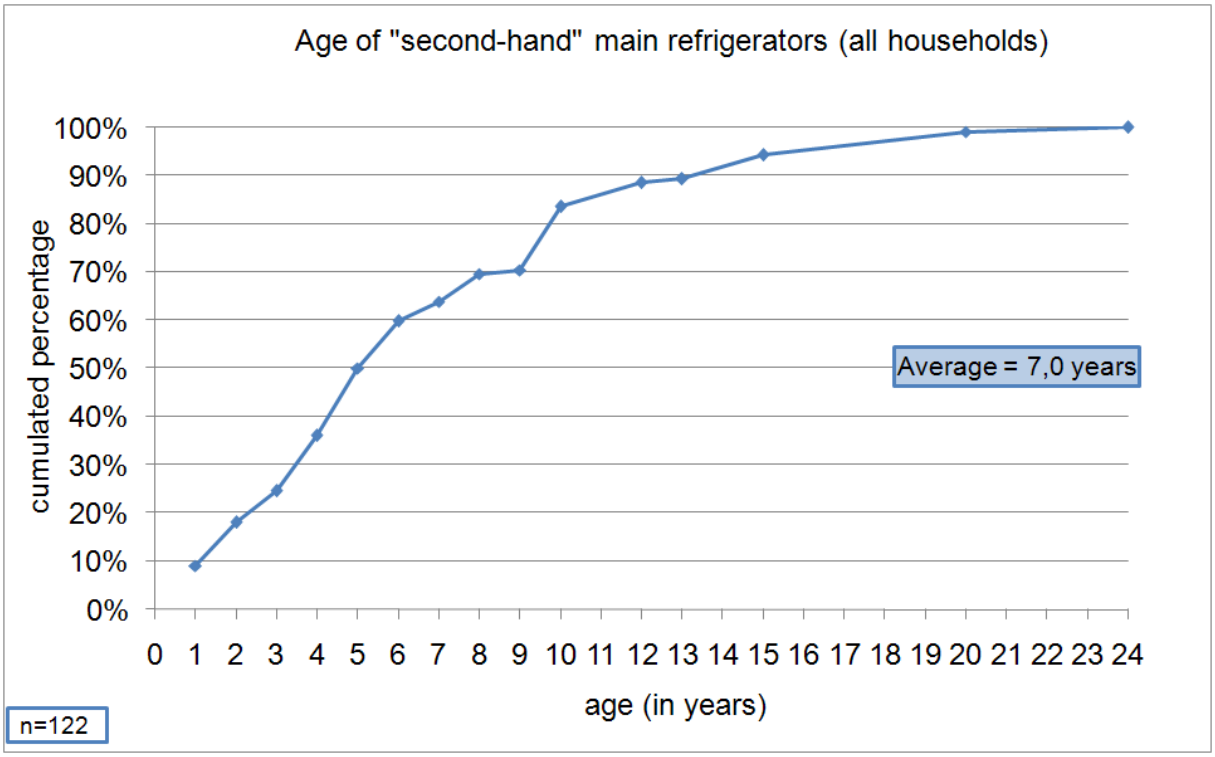


Figure 3.37: age of „second-hand“ main refrigerators in all households (EU)

The average age of second-hand freezers is 9 years. 50 % of the appliances are younger than 7,5 years, 90 % are younger than 17 years (Figure 3.38).

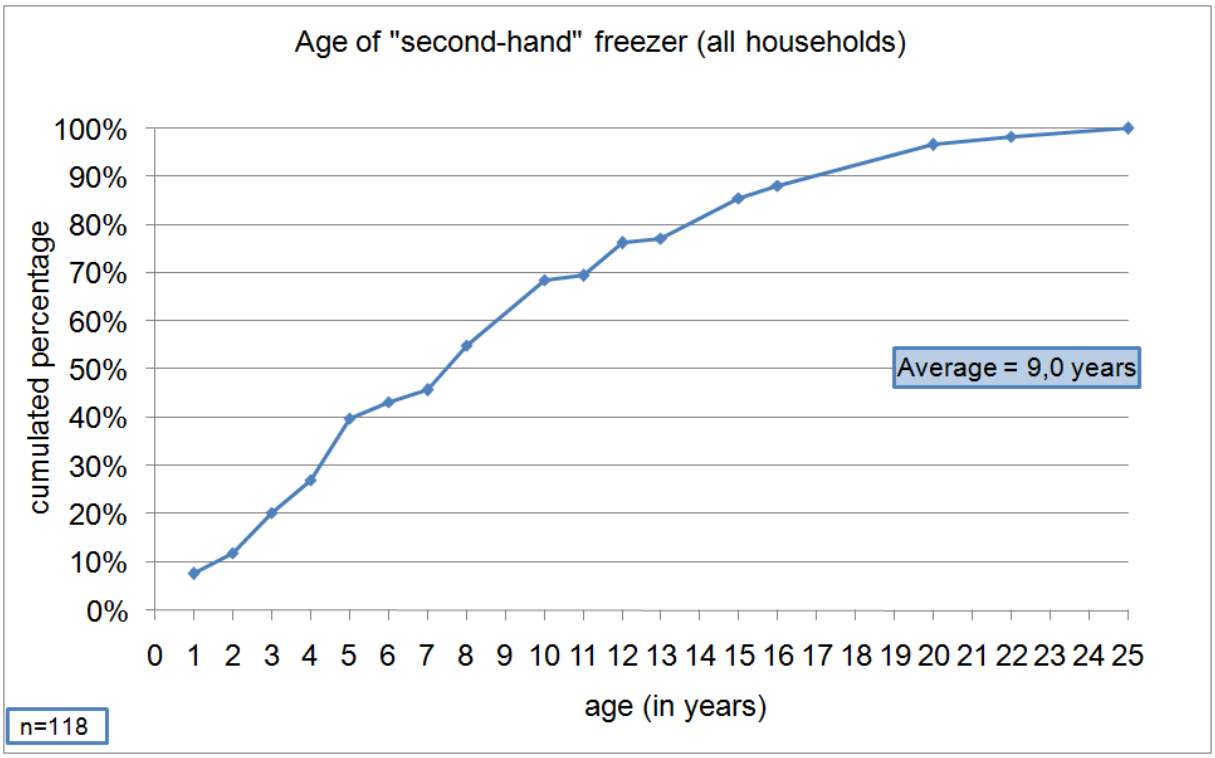


Figure 3.38: age of „second-hand“ freezers (chest/upright freezer) in all households (EU)

3.2.4 Food safety

Another possible barrier for energy saving innovations for cold appliances is the necessity of food protection. The decrease of energy consumption can only go as far as food safety is ensured.

This means that temperatures of 3 to 5 °C need to be accomplishable so that perishable food stuffs can be stored safely. Refrigeration temperatures for perishable foods for food businesses are regulated by different institutions. According to the (UK) Food Hygiene (Amendment) Regulations 1990[14], for instance, Listeria-sensitive food should be kept at a temperature below 5 °C, less sensitive foods should be kept below 8 °C. The BGVV[15] (1999) stated that perishable foods ought to be kept at temperatures below 7 °C to reduce microbial growth. In France it is regulated by decree no. 2002-478[16] from April 2002 that every domestic refrigerator has to offer a designated zone which maintains a temperature of max. 4 °C. The refrigerators need to be equipped with a binary thermometer with a gradation of max. 0,5 °C.

Some pathogenic micro-organisms can survive and reproduce at refrigeration temperatures (the lower the less) and are able to cause food borne diseases. Between 1992 and 1999 35,9 % of all

[14] MINISTRY OF AGRICULTURE, FISHERIES AND FOOD, THE SECRETARY OF STATE FOR HEALTH & THE SECRETARY OF STATE FOR WALES (1990): Food Hygiene (Amendment) Regulations 1990; Online: http://www.opsi.gov.uk/si/si1990/Uksi_19901431_en_1.htm [11/26/06]

[15] BGVV BUNDESINSTITUT FÜR GESUNDHEITLICHEN VERBRAUCHERSCHUTZ UND VETERINÄR-MEDIZIN (1999): Temperaturanforderungen und -empfehlungen für Lebensmittel Online: http://www.obersllgaeu.orgse_data-/_filebank/luew/temperatur.pdf [11/28/06]

[16] Décret no. 2002-478 (2002): DECRET NO 2002-478 DU 3 AVRIL 2002 RELATIF AUX REFRIGERATEURS A USAGE DOMESTIQUE, AUX THERMOMETRES ET AUTRES DISPOSITIFS DESTINES A INDIQUER LA TEMPERATURE DANS CES APPAREILS. FRANCE

registered intoxications were linked to consumption of contaminated food at home[17]. The WHO Surveillance programme for Germany evaluated the treatment of food which had been the cause of infection. It was found that in 1999 and 2000 the most frequently indicated treatment of the food was wrong storage in the refrigerator with 13 % and 23 %, respectively[18].

According to the WHO inadequate temperatures were the cause for 44 % of food borne diseases in Europe. This includes insufficient cooling[19].

3.3 USER DEFINED PARAMETERS

3.3.1 Consumer behaviour in terms of energy consumption and saving

a) Refrigerator

Different institutions have dealt with the questions of how consumer behaviour with refrigerators influences energy consumption and how to alter this behaviour to save energy.

Consumer organisations give information on this matter through their consumer magazines. In Germany these are, i.e. STIFTUNG WARENTEST, ÖKOTEST and the AGV (Arbeitsgemeinschaft Verbraucherverbände e.V.). In the USA this is, i.e. the US DEPARTMENT OF ENERGY, and in Canada the MINISTRY OF ENERGY. Different Universities also research this matter, i.e. the University of Bonn, Germany, the Mississippi State University and University of Florida, USA.

The factors said to influence the energy consumption of a refrigerator are:

- interior temperature of the refrigerator
- room temperature
- loading of refrigerator/ insertion of goods
- door openings
- location near a heat source
- possibility of ventilation
- condition of gasket seals

Refrigerator temperature

The interior temperature has a great influence on the energy consumption of the refrigerator. According to BÖHMER & WICKE[20] (1998) a 13 % reduction of energy consumption is possible by keeping the interior temperature at 7 °C instead of 5 °C. LEPTHIEN[21] (2000) showed that by increasing the refrigerator temperature from 5 °C to 7-7,5 °C energy use can be reduced up to 28 %.

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[17] Kraemer J. (2002): Lebensmittelmikrobiologie, Verlag Eugen Ulmer, Stuttgart

[18] WHO Surveillance Programme for Control of Foodborne Infections and Intoxications in Europe 8th Report 1999-2000 Country Reports: Germany, Online: http://www.bfr.bund.de/internet/8threport/CRs/deu.pdf

[19] WHO (2004): Food and health in Europe: a new basis for action, WHO Regional Publications, European Series, No. 96

[20] BÖHMER T. & WICKE L. (1998): Energiesparen im Haushalt – So schonen Sie Umwelt und Geldbeutel, Deutscher Taschenbuch Verlag

[21] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

Different European studies[22, 23, 24] show that the mean interior temperature of refrigerators lies between 6 and 7 °C. A study in New Zealand[25] evaluated a mean temperature of 4,5 °C and a study in Malaysia[26] found a mean temperature of 2 °C (Figure 3.39).

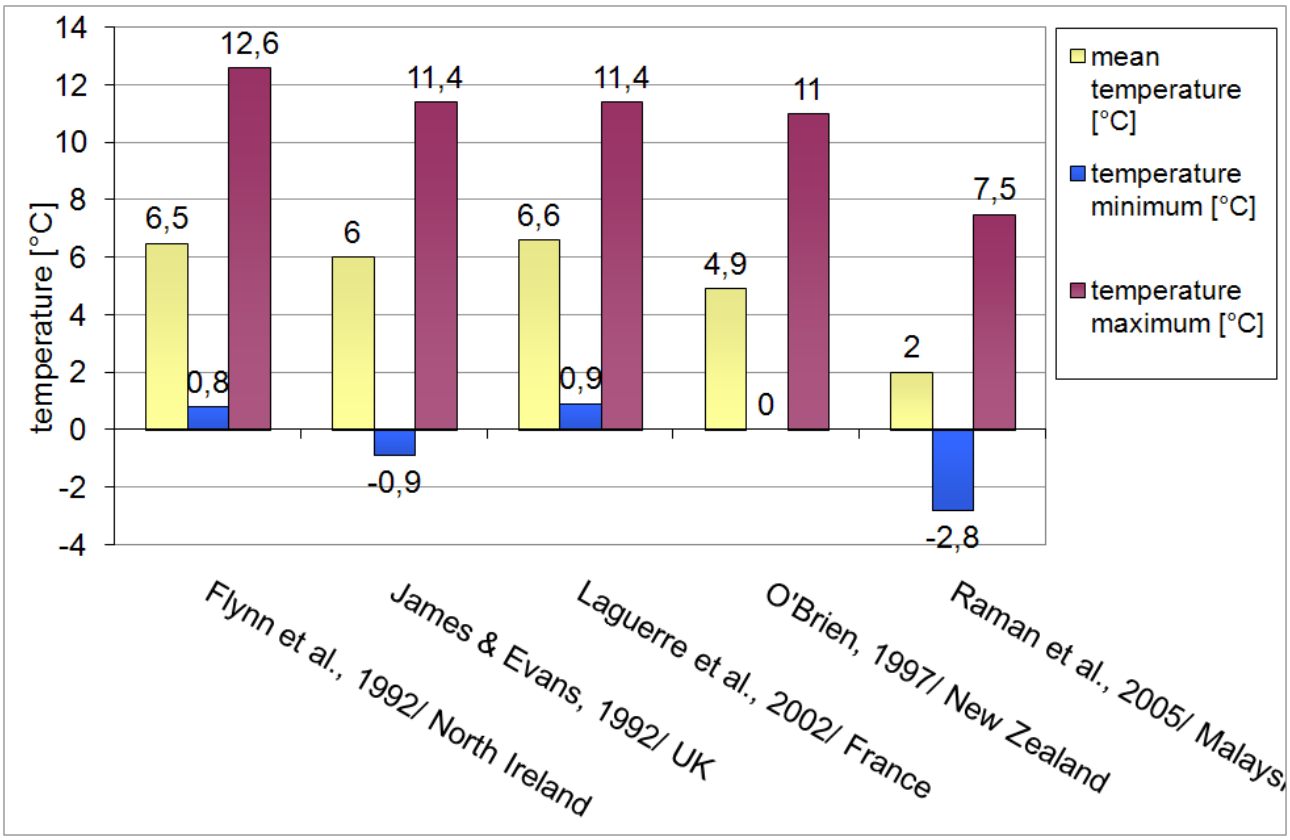

Figure 3.39: mean refrigerator temperature evaluated in different studies

According to JAMES & EVANS[27] (1992a) 32,8 % of the 252 study participants adjust their refrigerator temperature according to the weather, lowering the temperature in summer. A survey[28] in the UK showed that 50 % of the 1 093 questioned people adjust their refrigerators according to ambient temperature, whereas 35 % never alter the setting.

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[22] FLYNN O.M.J., BLAIR I. & MCDOWELL D. (1992): The efficiency and consumer operation of domestic refrigerators, *Int. J. Refrig.* **15**, 307-312

[23] JAMES S.J. & EVANS J. (1992a): Consumer handling of chilled foods: Temperature performance, *Int. J. Refrig.* **15**, 299-306

[24] LAGUERRE O., DERENS E. & PALAGOS B. (2002): Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French survey, *Int. J. Refrig.* **25**, 653-659

[25] O'BRIEN G.D. (1997): Domestic refrigerator air temperatures and the public's awareness of refrigerator use, *Int. J. Environ. Health Res.* **7**, 141-148

[26] RAHMAN S., MOHD SIDIK N., HASSAN M.H.J., MOHD ROM T. & JAUHARI I. (2005): Temperature Performance and Usage Conditions of Domestic Refrigerator-freezers in Malaysia, *Transactions* **12,** 30-35

[27] JAMES S.J. & EVANS J. (1992a): Consumer handling of chilled foods: Temperature performance, *Int. J. Refrig.* **15**, 299-306

[28] SPRIEGEL G. (1991): Food Safety in the Home, *Nutr. Food. Sci.* **133**, 14-1

Adequate temperature for food preservation

In France it is regulated by decree no. 2002-478[29] from April 2002 that every domestic refrigerator has to offer a designated zone which maintains a temperature of max. 4 °C. The refrigerators need to be equipped with a binary thermometer with a gradation of max. 0,5.

BEM & HECHELMANN[30] (1994) as well as KREYENSCHMIDT[31] (2003) show that the shelf life of poultry is highly reduced when kept at higher temperatures. When stored at 4 °C the quality of the meat samples was still acceptable after approx. 5-6 days whereas the same state of quality was reached after as little as 2-3 days at storage temperatures of 10 °C. According to ALMONACID-MERINO & TORRESE[32] (1993) shelf-life of foods can be reduced significantly (20-30 %) when stored at room temperature even when this period is only a small fraction of total storage time (2-3 %). GILL[33] (1986) reported that microbial growth is bisected when temperature is reduced by 10 °C.

Room temperature

Room temperature also influences the energy use of refrigerators.

The HESSIAN MINISTRY OF ECONOMY, TRANSPORT, URBAN AND REGIONAL DEVELOPMENT[34] (HMWVL 2005) stated that keeping a room temperature of 21-23 °C instead of 25 °C can save 16 % of energy use. As reported there a room temperature of 17-21 °C can save 32 % and a temperature of 13-17 °C can save 53 % of energy use. STIFTUNG WARENTEST[35] (1994) indicates a reduced energy consumption of 47 % when the refrigerator is located in a room with a temperature of 16 °C instead of 25 °C whereas a higher temperature of 32 °C instead of 25 °C increases energy use by 55 %. According to PEART[36] (1993) setting the house thermostat at approx. 18 °C in winter instead of 21 °C would save 12 kWh/ year. The Study of LEPTHIEN[37] (2000) shows that refrigerators use 18 to 19 % less energy in a room which has a temperature of 20 °C instead of 25 °C. According to BÖHMER & WICKE[38] (1998) a reduction of the kitchen temperature of 1 °C decreases the energy consumption by 8 % (Figure 3.40).

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[29] Décret no. 2002-478 (2002): DECRET NO 2002-478 DU 3 AVRIL 2002 RELATIF AUX REFRIGERATEURS A USAGE DOMESTIQUE, AUX THERMOMETRES ET AUTRES DISPOSITIFS DESTINES A INDIQUER LA TEMPERATURE DANS CES APPAREILS. FRANCE

[30] BEM Z. & HECHELMANN H. (1994): Kühlung und Kühllagerung von Fleisch – Mikrobiologische Vorgänge, *Fleischwirtschaft* **74**, 916-924

[31] KREYENSCHMIDT J. (2003): Modellierung des Frischeverlustes von Fleisch sowie des Entfärbeprozesses von Temperatur-Zeit-Integratoren zur Festlegung von Anforderungsprofilen für die produktbegleitende Temperaturüberwachung, Diss. Universität Bonn, Agrimedia Verlag, Bergen Dumme

[32] ALMONACID-MERINO S.F. & TORRESE J.A. (1993): Mathematical models to evaluate temperature abuse effects during distribution of refrigerated solid foods, *J. Food. Eng*. **20**, 223- 245

[33] GILL C.O. (1986) The Control of Microbial Spoilage in Fresh Meats, In: Pearson A.M., T.R. (eds.): Advances in Meat Research – Meat and Poultry Microbiology, Macmillian Publishers LTD, 49-88

[34] HMWVL HESSISCHES MINISTERIUM FÜR WIRTSCHAFT, VERKEHR UND LANDESENTWICKLUNG (Hrsg.) (2005): Strom effizient nutzen – Wegweiser für Privathaushalte zur wirtschaftlichen Stromeinsparung ohne Komfortverzicht

[35] STIFTUNG WARENTEST (1994): Umwelt geschont – Strom gespart, In: *Test* **3**, 36-39

[36] PEART V. (1993): The Refrigerator Energy Use Story, EES 51, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida

[37] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

[38] BÖHMER T. & WICKE L. (1998): Energiesparen im Haushalt – So schonen Sie Umwelt und Geldbeutel, Deutscher Taschenbuch Verlag

When reducing the surrounding temperature of a refrigerator-freezer it is important to know whether the appliance has two compressors or one compressor with a magnet valve controlling two separate circulations. If this is not the case, the compressor will stop cooling when the surrounding temperature is below about 16 °C and the freezing compartment will defrost. Some appliances have a so called "winter switch" with causes the refrigerator light to burn even with closed door to heat up the refrigerator compartment. This energy input into the cooling compartment will cause the compressor to start again, keeping the freezer compartment cold. This mechanism increases energy consumption[39, 40].

JAMES & EVANS[41] (1992a) found that 72,2 % of the 252 surveyed kitchens had an ambient temperature between 17 and 23 °C (mean 20,6 °C).

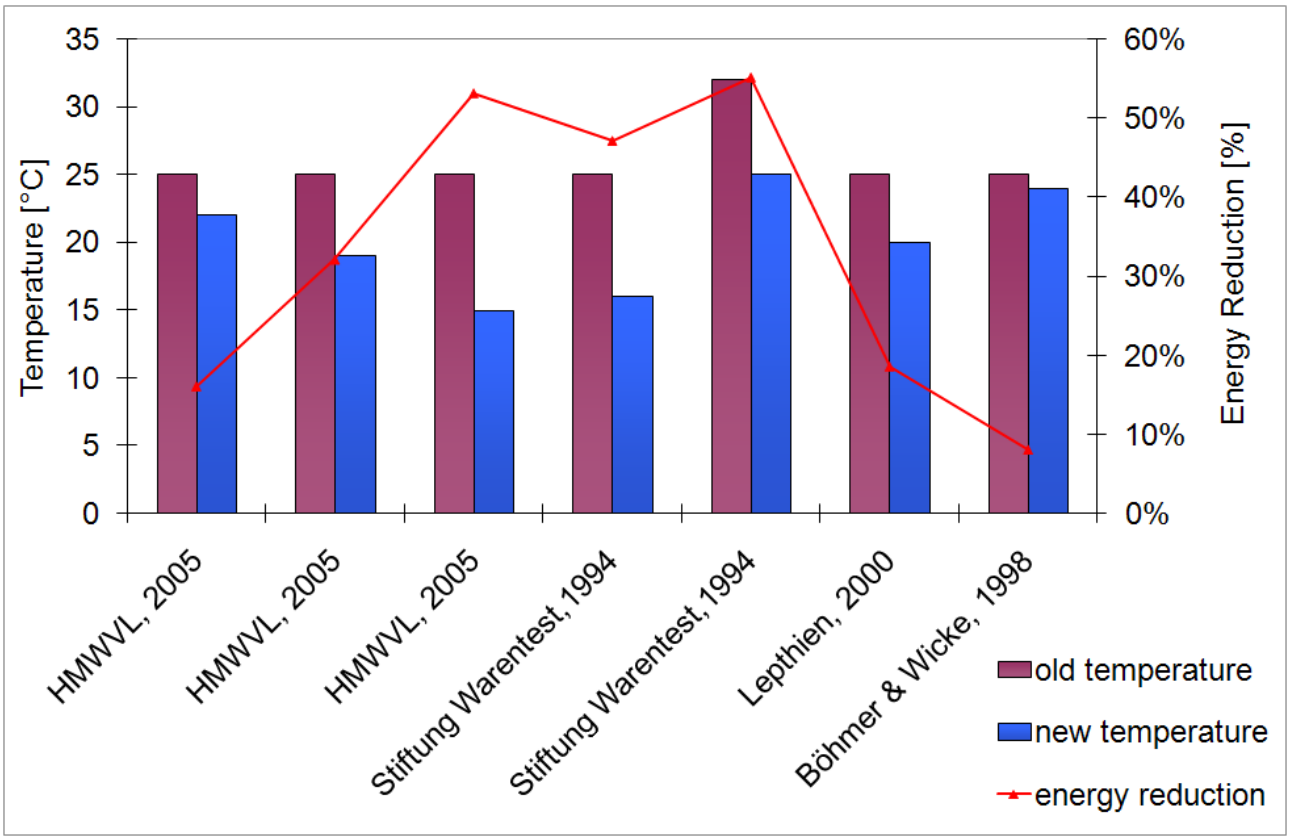

Figure 3.40: possible energy decrease after reduction of room temperature as evaluated in different studies

Insertion of goods

The insertion and storage of hot or cold goods in the refrigerator is also reported as having influence on the energy consumption of the refrigerator. BÖHMER & WICKE[42] (1998) stated that the insertion of food or storage containers into the refrigerator uses 10 % of the energy consumption. Bisecting

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[39] PLATZ B. (2007): Kühlgefrierkombinationen - heimlich brennt das Licht, broadcast from 03.02.2007 17:03 Uhr (NDR) http://daserste.ndr.de/ardratgebertechnik/archiv/haushalt_garten/t_cid-3646502_.html [02/20/2007]

[40] NIPKOW J. (2002): Klimaklassen von Haushalt-Kühl-/Gefriergeräten, S.A.F.E Schweizerische Agentur für Energieeffizienz/ Swiss agency for efficient energy use (www.energieeffizienz.ch)

[41] JAMES S.J. & EVANS J. (1992a): Consumer handling of chilled foods: Temperature performance, *Int. J. Refrig.* **15**, 299-306

[42] BÖHMER T. & WICKE L. (1998): Energiesparen im Haushalt – So schonen Sie Umwelt und Geldbeutel, Deutscher Taschenbuch Verlag

the insertion can only save 5 % of energy use. On the other hand a lot of energy can be wasted by setting hot goods into the refrigerator. Cooling of food with a temperature of 50 °C uses thrice the energy than cooling of food with a temperature of 20 °C. LEPTHIEN[43] (2000) found that thawing frozen food in the refrigerator can reduce energy consumption up to 26 %. Thawing of frozen foods inside the refrigerator also protects food from getting to warm and from increased bacterial growth[44].

A Study in New Zealand[45] shows that 48 % of the 50 questioned people rarely and 30 % never place hot foods into the refrigerator and that 70 % always cool their foods adequately before placing them into the refrigerator.

Door openings

Consumer information given by Ministries or Universities advises people to open the refrigerator door as infrequently as possible. According to PEART[46] (1993) forty door openings per day can add 50 to 120 kWh per year to the energy bill. GRAHAM[47] (1997) gives advice to install vinyl flaps to the refrigerator to keep cool air from escaping to save up to 10-20 % of energy use. BÖHMER & WICKE[48] (1998) report that losses through air change make up 3 % of the total energy consumption of a refrigerator. The study by LEPTHIEN[49] (2000) showed that 20 door openings per day generate an increase of energy consumption of 1 to 6 %. According to LIU et al.[50] (2004) 50 five second door openings within 10 hours generate an increase in energy consumption of 5-10 % at an ambient temperature of 15 °C. JAMES & EVANS[51] (1992b) evaluated the effect of door openings on the refrigerator temperature and found that after a 3-minute door opening it took one hour to reduce the temperature within 1 °C of the original temperature.

LIU et al.[50](2004) also evaluated the effect of door openings of the freezer compartment on the energy consumption of refrigerator-freezers with an ambient temperature of 30 °C. Depending on the model 15 door openings within 10 hours increase the energy consumption by 0,5-4 %.

According to the study by LAGUERRE et al.[52] (2002) 19 % of the 143 questioned people open their refrigerator less than 10 times a day, 43 % open the refrigerator 10 to 20 times a day and 38 % open

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[43] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

[44] SØRENSEN L.B.: Frozen Food Legilation, Bulletin of the IIR, No 2002-4

[45] O'BRIEN G.D. (1997): Domestic refrigerator air temperatures and the public's awareness of refrigerator use, *Int. J. Environ. Health Res.* **7**, 141-148

[46] PEART V. (1993): The Refrigerator Energy Use Story, EES 51, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida

[47] GRAHAM F. (1997): Refrigerators & Freezers, Mississippi State University Extension Service, Online: http://msucares.com/newsletters/housing/19970411.html (last modified 31-Aug-01) [11/03/2006]

[48] BÖHMER T. & WICKE L. (1998): Energiesparen im Haushalt – So schonen Sie Umwelt und Geldbeutel, Deutscher Taschenbuch Verlag

[49] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

[50] LIU D.-Y., CHANG W.-R. & LIN J.-Y. (2004): Performance comparison with effect of door opening on variable and fixed frequency refrigerator/freezers, *Appl. Therm. Eng.* **24**, 2281-2292

[51] JAMES S.J. & EVANS J. (1992b): The temperature performance of domestic refrigerators, *Int. J. Refrig.* **15**, 313-319

[52] LAGUERRE O., DERENS E. & PALAGOS B. (2002): Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French survey, *Int. J. Refrig.* **25**, 653-659

it more than 20 times. A study in Malaysia[53] found that 8 % of 26 questioned households open their refrigerator less than 10 times a day, 73 % 10 to 20 times a day and 19 % open the refrigerator more than 20 times a day (Figure 3.41).

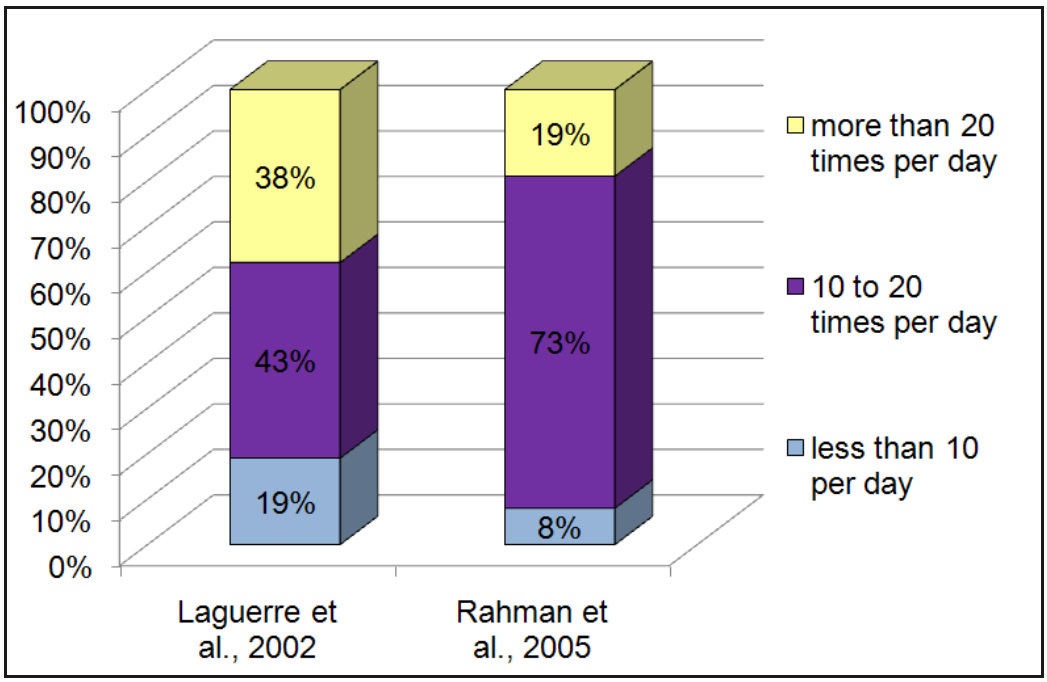

Figure 3.41: frequency of door openings per day as evaluated in two studies

Location

Another common advice is not to set the refrigerator next to a heat source, like an oven, dishwashing machine etc. or into direct sunlight[54, 55, 56]. LEPTHIEN[57] (2000) evaluated the effect of an oven next to the refrigerator on the energy consumption. It was found that the increase in energy use was very little (approx. 1 %).

JAMES & EVANS[58] (1992a) evaluated how frequently the refrigerator is placed near a heat source. Results are that in 25,5 % of the 252 surveyed households the refrigerator had potential heat sources on one side and in 1,2 % a potential heat source on both sides. 13,6 % of the refrigerators were free standing and 59,8 % were located away from heat sources but had a kitchen unit or wall on either one or both sides. In France[59] 30 % of the 143 questioned households had a refrigerator located near

[53] RAHMAN S., MOHD SIDIK N., HASSAN M.H.J., MOHD ROM T. & JAUHARI I. (2005): Temperature Performance and Usage Conditions of Domestic Refrigerator-freezers in Malaysia, *Transactions* **12,** 30-35

[54] PEART V. (1993): The Refrigerator Energy Use Story, EES 51, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida

[55] BÖHMER T. & WICKE L. (1998): Energiesparen im Haushalt – So schonen Sie Umwelt und Geldbeutel, Deutscher Taschenbuch Verlag

[56] HMWVL HESSISCHES MINISTERIUM FÜR WIRTSCHAFT, VERKEHR UND LANDESENTWICKLUNG (Hrsg.) (2005): Strom effizient nutzen – Wegweiser für Privathaushalte zur wirtschaftlichen Stromeinsparung ohne Komfortverzicht

[57] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

[58] JAMES S.J. & EVANS J. (1992a): Consumer handling of chilled foods: Temperature performance, *Int. J. Refrig.* **15**, 299-306

[59] LAGUERRE O., DERENS E. & PALAGOS B. (2002): Study of domestic refrigerator temperature and analysis of factors affecting temperature: a French survey, *Int. J. Refrig.* **25**, 653-659

a heat source and 14 % were built-in. RAHMAN et al.[60] (2005) found that 77 % of the surveyed refrigerators were positioned near a heat source (oven, rice cooker, microwave, kettle, etc.) and 23 % were standing away from a heat source.

There is not much literature on the availability of space for ventilation so the heat can be transported away from the back of the refrigerator. LEPTHIEN[61] (2000) found that a complete inhibition of air circulation did not alter the energy consumption although the temperature between the condenser and the wall increased 3 to 5 °C. O'BRIEN[62] (1997) found that 62 % of the 50 households questioned had inadequate space around the refrigerator, accordingly 38 % left adequate space.

Condition of gasket seals

The condition of gasket seals is another characteristic which is pointed out to consumers[63, 64, 65, 66]. Heat losses of refrigerators depend – amongst others – on the quality of the door seals[67].

JAMES & EVANS[68] (1992a) found that 60 % of the refrigerator door seals in the 252 observed households were in excellent or good shape while 10 % were described as poor (torn and perished).

Consumer attitudes towards buying an energy saving refrigerator model

A survey[69] of 1 000 Italian and 1 000 German consumers showed that 84 % of Italians and 63 % of Germans preferred a refrigerator with energy class A rather that class C, 8 % of Italian respondents and 21 % of German respondents indicated they did not. According to this evaluation between 76 and 80 % of the Italian consumers and 53 - 56 % of German consumers were interested in buying an energy efficient refrigerator for a higher purchasing price when this meant that they could save on the electricity bill.

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[60] RAHMAN S., MOHD SIDIK N., HASSAN M.H.J., MOHD ROM T. & JAUHARI I. (2005): Temperature Performance and Usage Conditions of Domestic Refrigerator-freezers in Malaysia, *Transactions* **12,** 30-35

[61] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

[62] O'BRIEN G.D. (1997): Domestic refrigerator air temperatures and the public's awareness of refrigerator use, *Int. J. Environ. Health Res.* **7**, 141-148

[63] PEART V. (1993): The Refrigerator Energy Use Story, EES 51, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida

[64] KNIGHT P.A. (1996): Your energy savings – a resident's handbook – Midwest edition, sponsored by U.S. Department of Energy, Illinois, Department of Commerce and Community Affairs, Chicago Rehab Network, Bickerdike Redevelopment Corporation, ComEd, and Argonne National Laboratory.

[65] GRAHAM F. (1997): Refrigerators & Freezers, Mississippi State University Extension Service, Online: http://msucares.com/newsletters/housing/19970411.html (last modified 31-Aug-01) [11/03/2006]

[66] ONTARIO MINISTRY OF ENERGY (2006): Refrigerator, Online: http://www.energy.gov.on.ca-/index.cfm?fuseaction=conservation.tips_refrigerator (© 2006) [11/03/2006]

[67] COLD II – The revision of energy labelling and minimum energy efficiency standards for domestic refrigeration appliances – FINAL REPORT 2000

[68] JAMES S.J. & EVANS J. (1992a): Consumer handling of chilled foods: Temperature performance, *Int. J. Refrig.* **15**, 299-306

[69] COLD II – The revision of energy labelling and minimum energy efficiency standards for domestic refrigeration appliances – FINAL REPORT 2000

LEPTHIEN[70] (2000) asked 100 people whether energy consumption and environmental compatibility of a refrigerator were important to them when buying a new appliance. This was considered very important to 58 % and 54 %, respectively.

Summary/ conclusion

Studies and literature show that a change of behaviour can help decrease energy consumption of cold appliances. From what has been found, the following recommendations can be given to consumers for energy saving purposes:

- Increasing of interior temperature of the refrigerator to approximately 7 °C, if no perishable food is stored,
- Place the refrigerator in a room of 20 °C temperature (or lower where applicable),
- Cooling of prepared food to room temperature before placing into refrigerator,
- Defrosting frozen food inside the refrigerator,
- Replacement of old by new and more efficient refrigerator or freezer,
- Selection of a refrigerator/freezer unit with two compressors or one compressor with a magnet valve controlling two separate circulations,
- Exchanging loose or torn gaskets to ensure leak-proof closing of the door.

Advising consumers to open the refrigerator door less frequently or to relocate the appliance further away from potential heat sources does not seem necessary because the influence of these factors is little.

b) Freezer

Because there is not much literature available dealing with the consumer behaviour with freezers in terms of energy consumption, it can only be assumed that consumers handle their freezers in a similar manner as their refrigerators.

[70] LEPTHIEN K. (2000): Umweltschonende Nutzung des Kühlgerätes im privaten Haushalt, Bonn, Rheinische Friedrich-Wilhelms-Universität, Diss. oec.troph

3.3.2 *Results of the consumer survey*

a) Refrigerator

An important role for the performance and energy consumption of a refrigerator plays the ambient temperature of the room where the appliance stands. Accordingly the participating household of the consumer survey in 10 European countries were asked what the minimum and maximum temperatures are of the room where the refrigerator is placed. The analysis of the answers of all households (n = 2 497) shows that the *average maximum temperature* is 24,4 °C (Figure 3.42). In approximately 30% of all households the maximum room temperatures is between 20 and 23 °C, especially in Germany more than 65 % of all consumers answered that the ambient temperature reached maximal 23 °C, and additional 24 % less than 31 °C. But in some countries like in Spain (10,8 %) or in Italy (6,0 %) the ambient room temperature in the room where the refrigerator stands reached values of over 36 °C (Figure 3.42).

The *average minimum ambient temperature* is 14,6 °C (Figure 3.43).

Approximately 44 % of all households have minimum temperatures in the room where the refrigerator stands of between 16°C - 19°C. In United Kingdom and Spain between 40 % up to over 50 % of all households have an ambient room temperature of under 11 °C and even in some countries like UK, Germany, Italy or Spain over 20 % of the consumers answered that the minimum ambient temperature lies at less than 7 °C.

Especially Italian, Spanish and Hungarian households presented the highest temperatures which also had the lowest temperatures (Figure 3.42). Interesting are also the results of northern countries. Here e.g. in Finnish and Swedish households the minimum temperature is higher in comparison with the other countries while these countries have the coldest maximum temperatures (Figure 3.42).

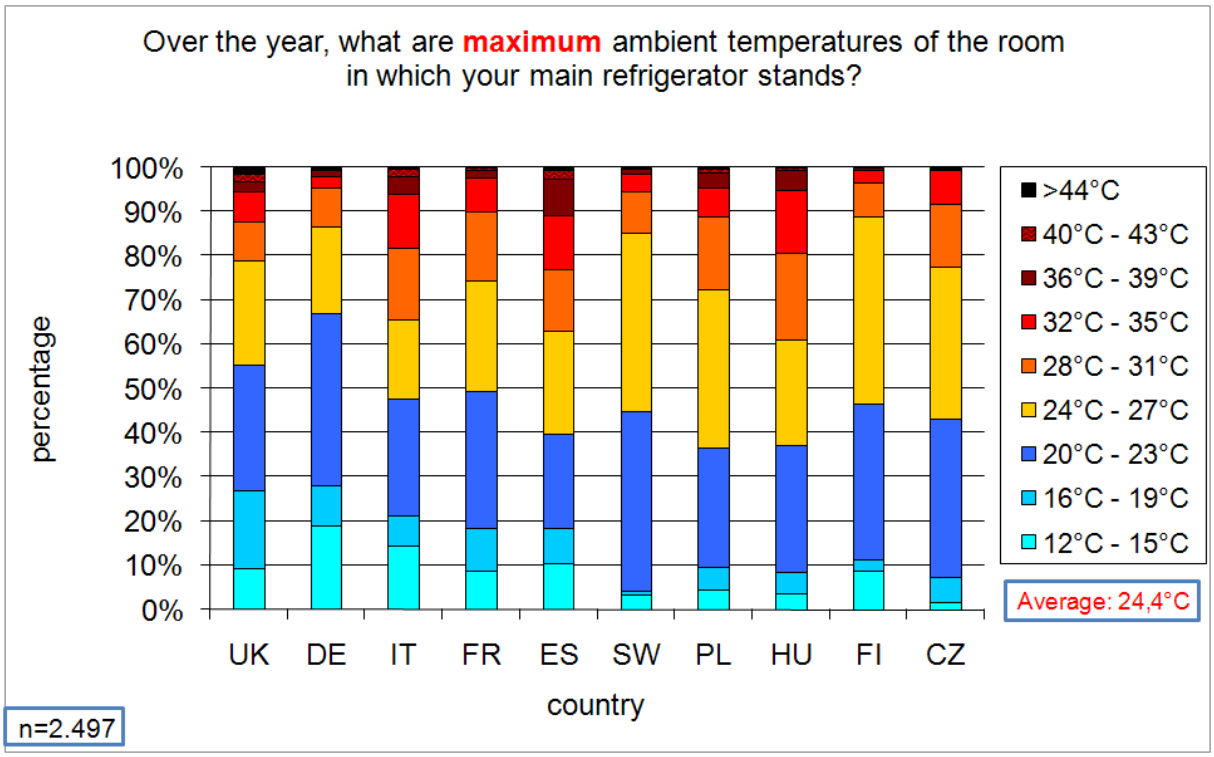


Figure 3.42: refrigerator: maximum ambient room temperature per countries

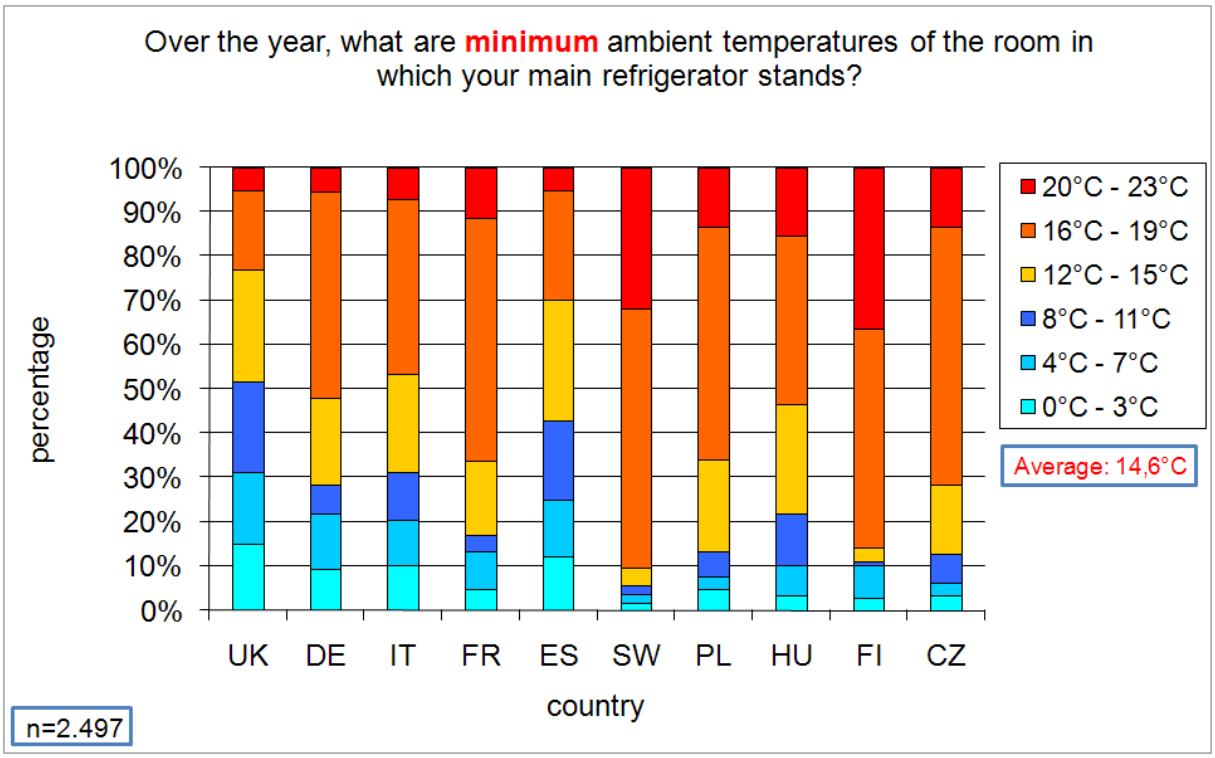


Figure 3.43: refrigerator: minimum ambient room temperature per countries

When the results of the data/statements of maximum and minimum ambient room temperatures are set in contrast with each other an average room temperature in all households of 19,5 °C can be calculated (Figure 3.44).

Furthermore a total of 49,7 % of all consumers said that they have a minimum respectively maximum room temperature of 15 °C or lower (Figure 3.44). Actually in 23,5 % of all households temperatures of 11 °C or lower are reached. On the other hand in 3,6 % of all interviewed households the room temperature lies at 36 °C or higher (Figure 3.44).

More than 40 % of all households mentioned a minimum temperature between 16 and 19 °C and over 30 % a maximum temperature of between 20 and 23 °C. But although a high share of consumers (28,6 %) answered that the maximum temperature of the room where the refrigerator stands reached more than 24 °C up to 27 °C.

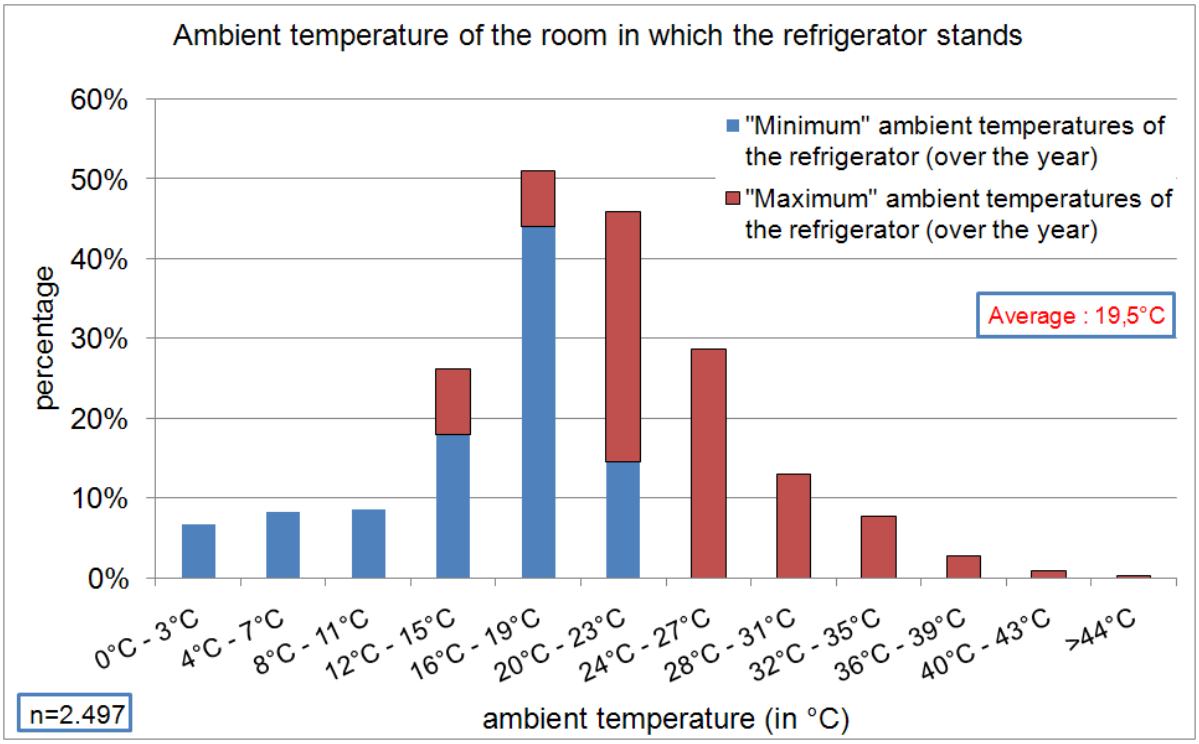


Figure 3.44: refrigerator: comparison of minimum and maximum ambient room temperature

A detailed look at the ambient room temperature differences of each individual household shows that especially in Spanish, British and Italian households the differences are higher than in other countries. Especially in Spain and United Kingdom differences of over 28 K could be determined in nearly 5 % up to 7 % of all households (Figure 3.45). The smallest temperature differences show the results of the statements of Swedish, Finnish, German, French and Czech households. From these countries, especially households of the northern countries (SW, FI), about 80 % of the households reached a temperature difference of maximally 8 K.

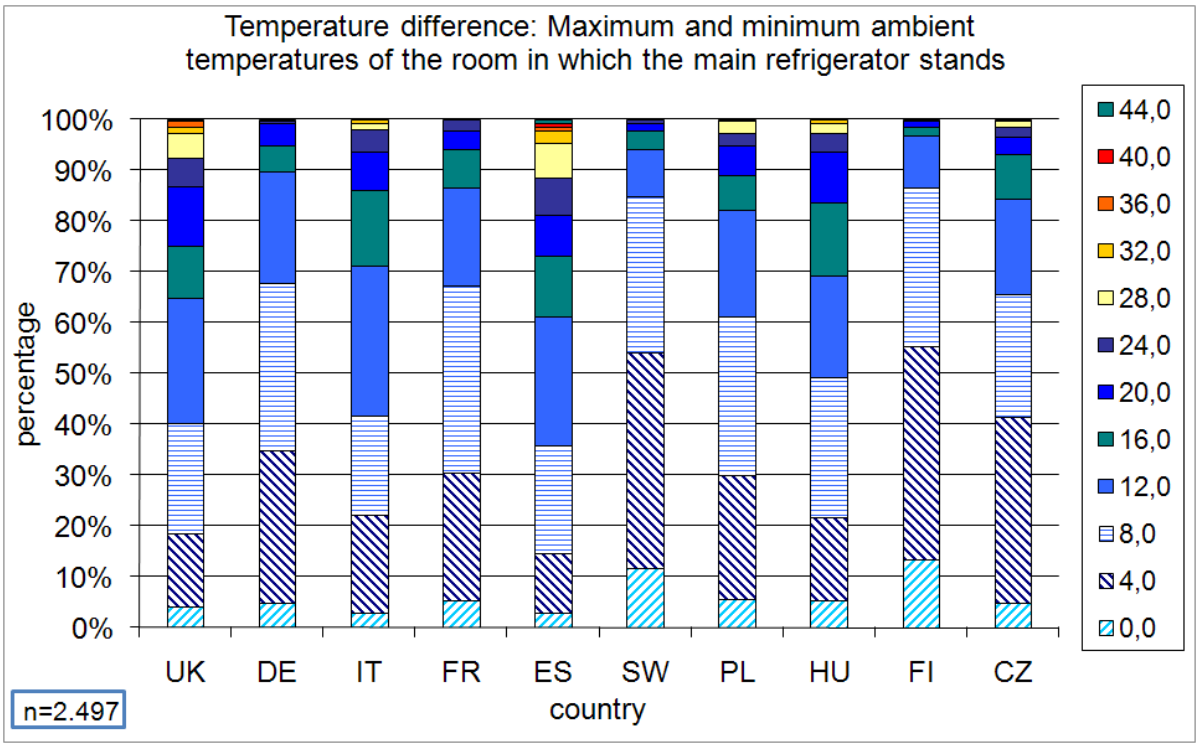


Figure 3.45: refrigerator: temperature differences - Location of the appliances

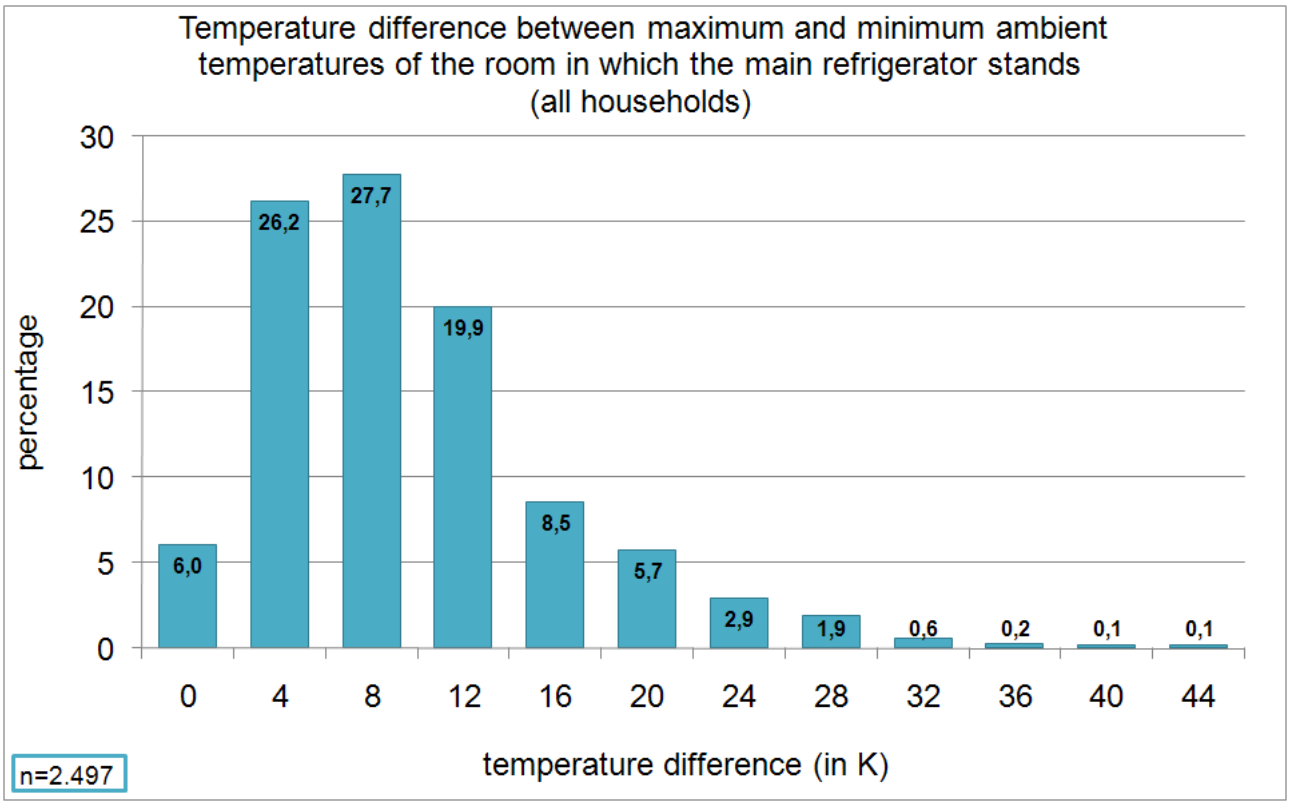


Figure 3.46: refrigerator: frequency of temperature differences - location of the appliances

About 32 % of all households can be characterized by a temperature difference of the ambient room temperature where the refrigerator stands of less than 8 K and about 80 % of all interviewed households show temperature differences of ≤ 12 K. In approximately 20 % of all participating households temperature differences are ≥ 16 K (Figure 3.46). These data can be interpreted as two different placements of refrigerators: either it is placed in a heated room (e.g. kitchen) with relatively constant temperatures over the year or it is placed in an unheated room (e.g. garage, balcony, household working room or cellar) with temperatures following more or less the ambient temperature change during the year.

To represent the real life behaviour of consumers in using a refrigerator, data about the actual temperature setting of the refrigerator were collected too. In average the actual temperature setting, when possible, adjusted in degree Celsius, is 5,0 °C (Figure 3.47). 20 % of all participants adjust their refrigerator to temperatures from 6,5 up to12 degree Celsius (Figure 3.48).

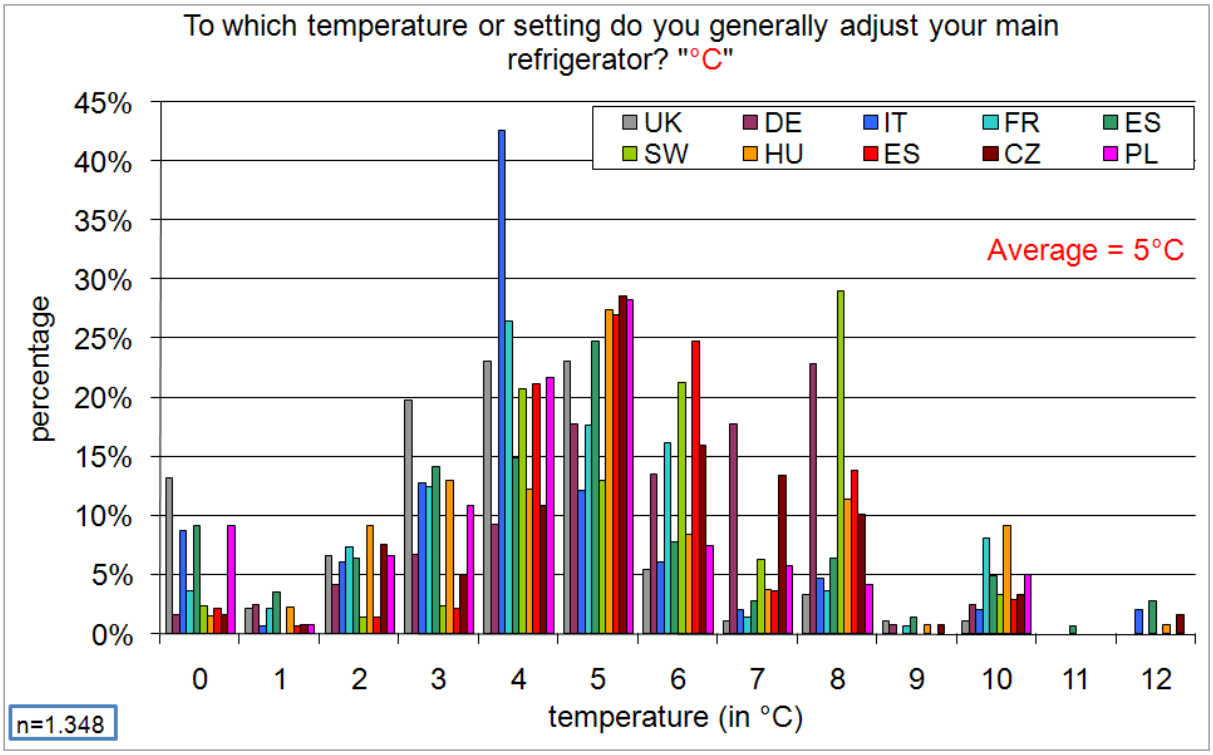


Figure 3.47: refrigerator: temperature adjustment in °C

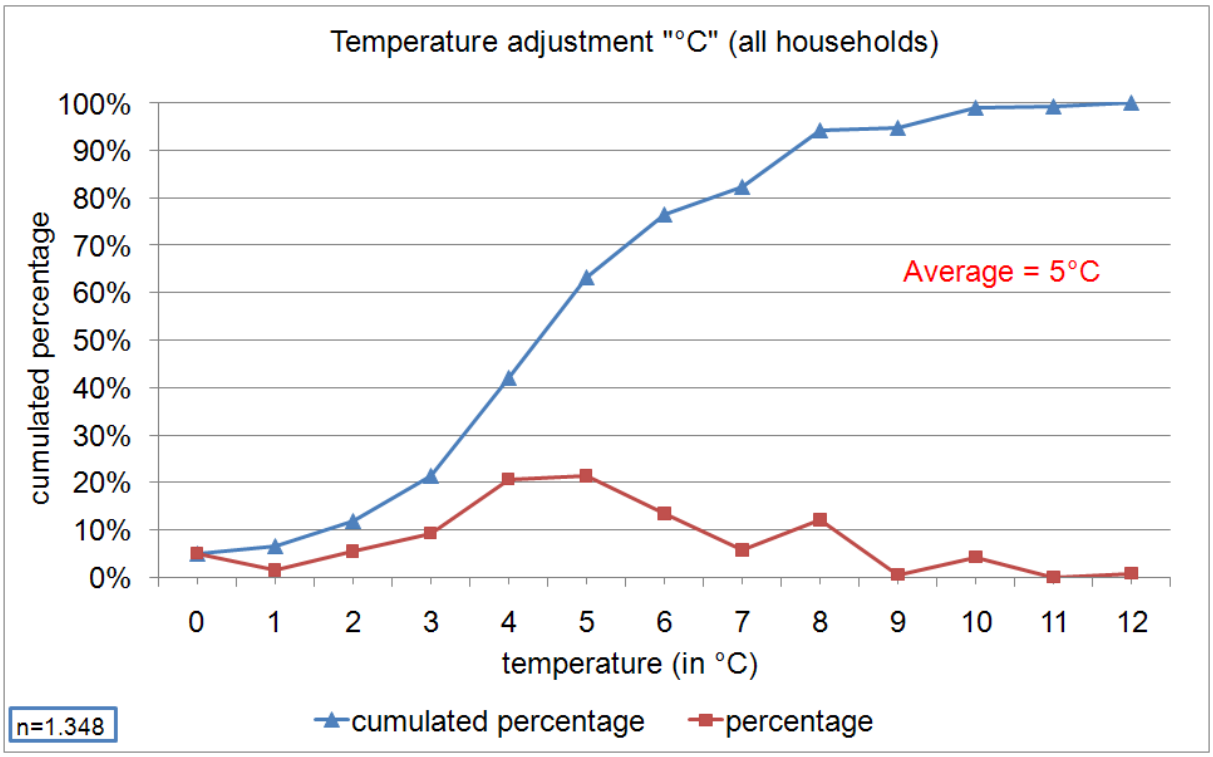


Figure 3.48: refrigerator: temperature adjustment in °C (all households)

The detailed analysis of the temperature adjustment of those consumers which could adjust their temperature in degree Celsius in all countries shows that the average values range between 3,7 °C of British and 6,0 °C of Swedish refrigerators (Figure 3.49). These average temperatures show that the adjustment in all countries is set mostly following recommended values. But anyhow a detailed look at the distribution of setting in all countries (Figure 3.47) shows that between nearly 5 % up to 30 % (e.g. Swedish households) choose temperatures in a critical range higher than 8 °C.

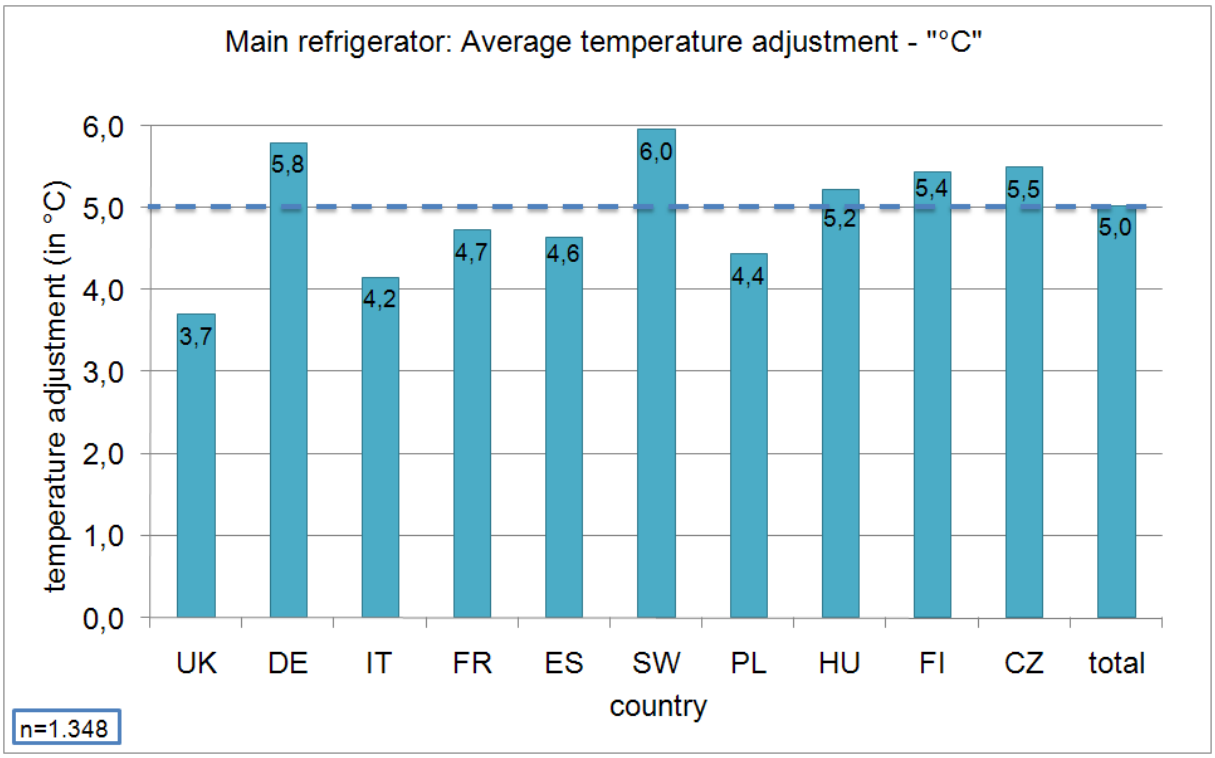


Figure 3.49: refrigerator: average temperature adjustment in °C (per country)

Those consumers which did not have the possibility to adjust the temperature by degree Celsius setting were asked to quote the number of their adjustment possibilities together with the minimum and maximum setting. Unfortunately a high share couldn't give an answer because they *don't know* (53,2 %) or they answered uncertainly (Figure 3.51). 32,2 % (n = 803 of 2 497 hh) of all interviewed consumers answered that they have a temperature and a number adjustment. The reason could be that these consumers didn't understand the questions.

48,5 % of all participating households owning a refrigerator mentioned that they change the temperature setting of the appliance (Figure 3.50). Especially Italian and French households show this behaviour with nearly 60 %. At least nearly 40 % of Swedish households (38 %) and German (39,6 %) and Czech (39,7 %) participants take care about changing the temperature setting conditions. The main reason for the consumers for changing the setting is the *outside temperature* (57 %) (Figure 3.51). Also the *grade of filling* (45,7 %) of the appliances plays an important role for the consumer when they vary the Celsius or numbered setting. One fourth mentioned that the *type of food* influences their behaviour too. Only a minor share of the interviewees (12,5 %) answered that they act *intuitively*.

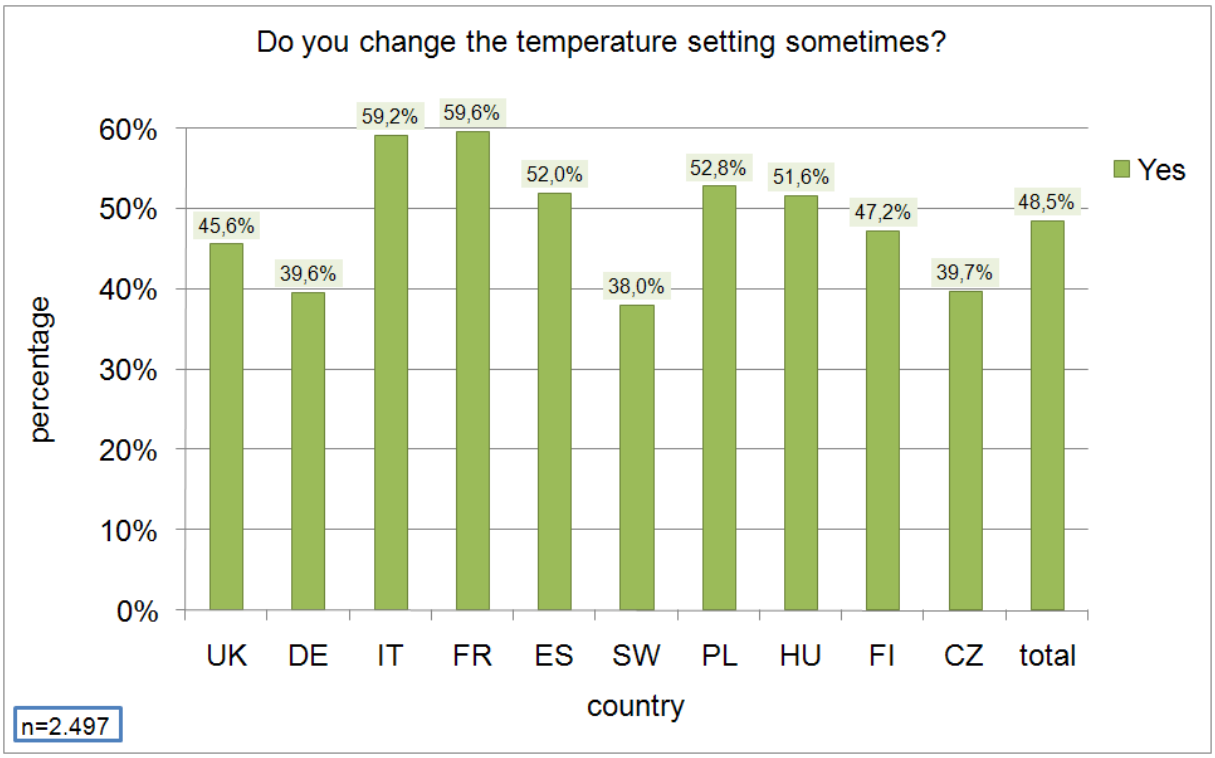


Figure 3.50: refrigerator: temperature changing (per country)

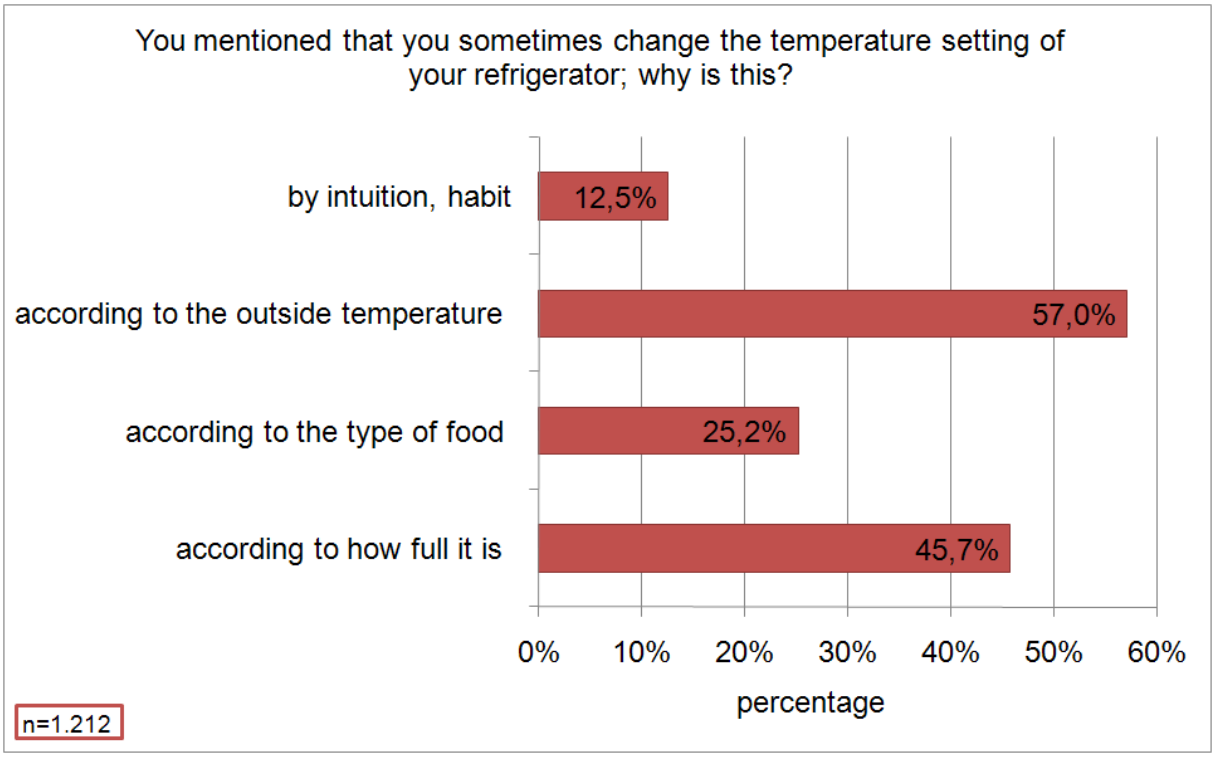


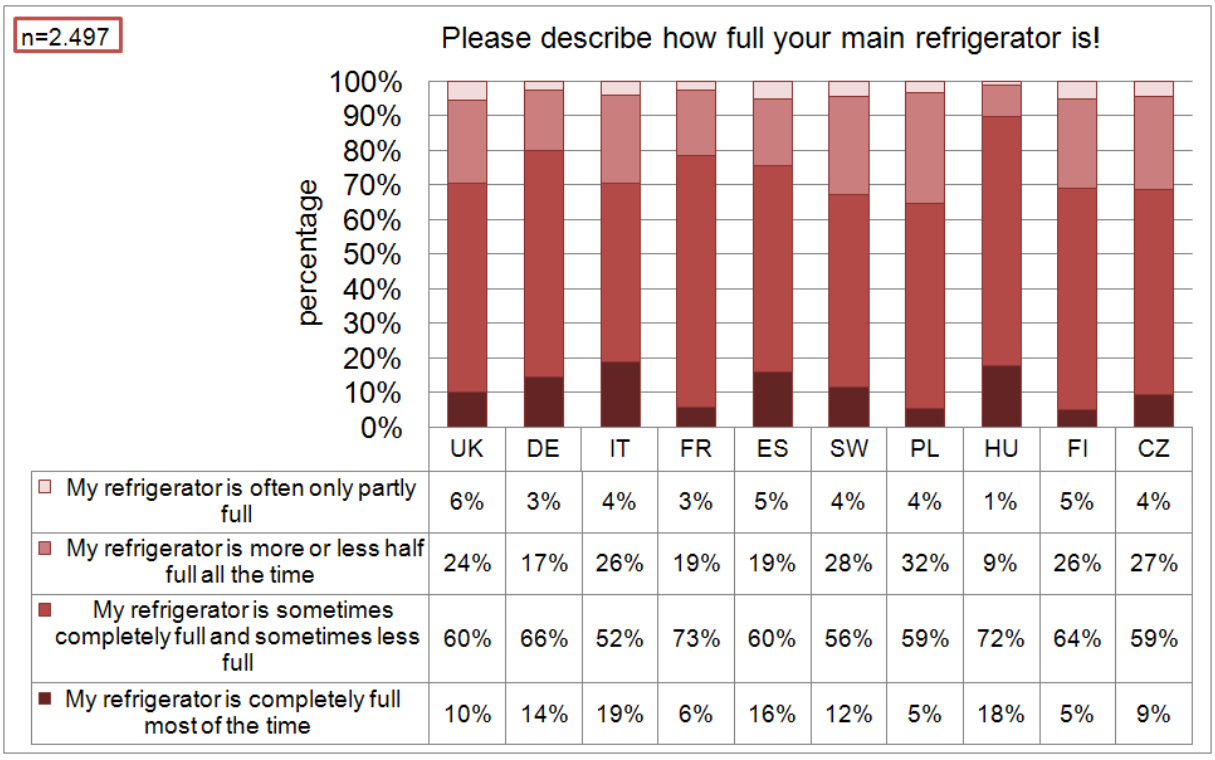
Figure 3.51: refrigerator: reasons for temperature changing (per country)

The most consumers described their charging of the refrigerator as *sometimes completely full and sometimes less full* (62 %) (Table 3.5). Especially the results for Spanish and Hungarian households show that here about over 70 % of all those interviewed agree with this statement (Figure 3.52). These households and additionally Italian households show the highest share of households which describe the refrigerator as *full most of the time*. Their values lie about 8 percentages above the average of all participating households with 11,3 %. Nearly a quarter of all households say that their

refrigerator is *more or less half full all the time* (Table 3.5), varying between 17 and 32 %. An exception is the result of Hungary where only 9 % of all households fill their refrigerator *more or less full all the time* (Figure 3.52).

Table 3.5: refrigerator: load size (n = 2.497)

My refrigerator is completely full most of the time	11,3 %
My refrigerator is sometimes completely full and sometimes less full	62,0 %
My refrigerator is more or less half full all the time	22,7 %
My refrigerator is often only partly full	3,9 %



	UK	DE	IT	FR	ES	SW	PL	HU	FI	CZ
My refrigerator is often only partly full	6%	3%	4%	3%	5%	4%	4%	1%	5%	4%
My refrigerator is more or less half full all the time	24%	17%	26%	19%	19%	28%	32%	9%	26%	27%
My refrigerator is sometimes completely full and sometimes less full	60%	66%	52%	73%	60%	56%	59%	72%	64%	59%
My refrigerator is completely full most of the time	10%	14%	19%	6%	16%	12%	5%	18%	5%	9%

Figure 3.52: refrigerator: load size per country

The analysis of the different household structures shows that especially in single-/one person households (35,4 %) only the half capacity of the refrigerator is used all the time (Figure 3.53). With increasing number of persons in households this behaviour decreases and the space of the refrigerator is used more completely. The share of households which described the charge of their refrigerator as *completely full most of the time* grows from 6,5 % in one-person household up to 16,5 % in a more than 4 person household. The same positive correlation can be noticed for the description of a *sometimes completely full and sometimes less full* refrigerator. Here the growth between single households and more person households which described their charge of refrigerator in this way reached nearly 22 %. If more people are living in the household probably also more exchange of food will happened.

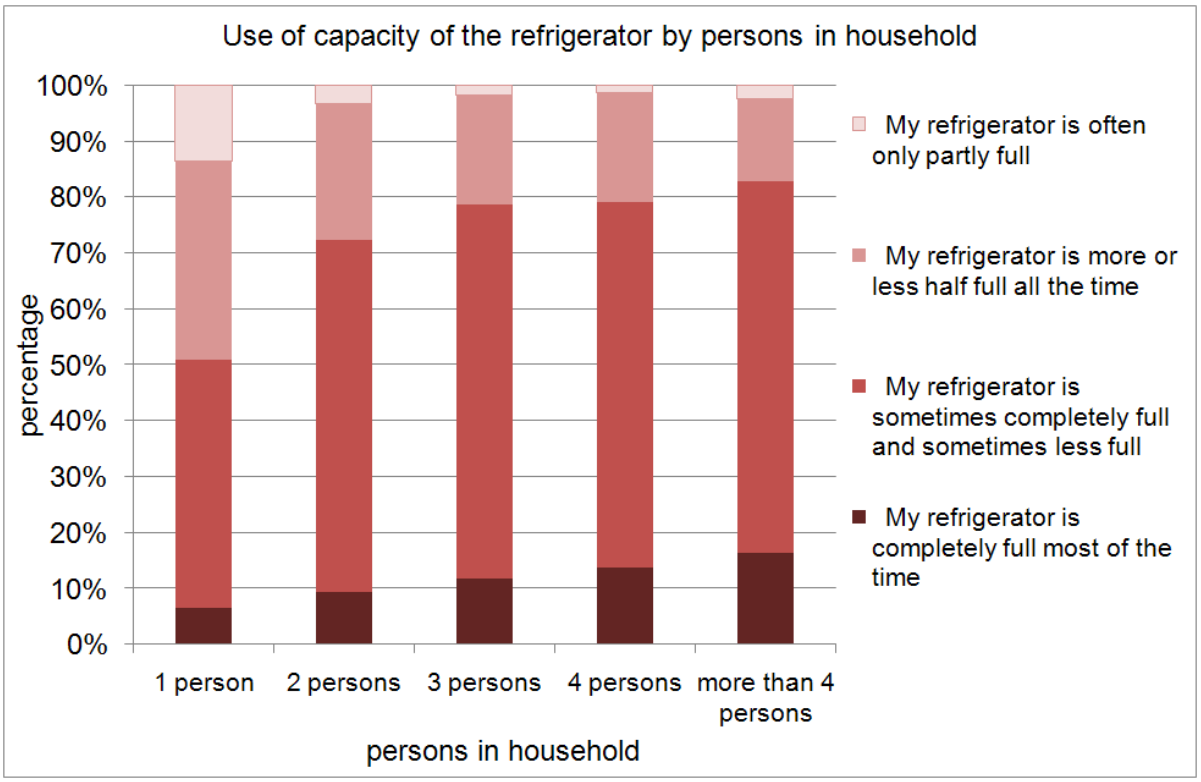


Figure 3.53: refrigerator: load size per number of persons in household

Concerning the object of investigation of "loading" a refrigerator the consumers were asked if they cool prepared food down before placing it into the refrigerator. Approximately 80 % of all consumers mentioned that they cool down prepared food, especially Hungarian consumers act in this way (93,2 %) (Figure 3.54). Most carelessly according to their answers behave Swedish, Polish and Spanish participants because of their lower agreement to this statement. Even 10 % of them answered that they never cool down food before placing it into the refrigerator (Figure 3.54).

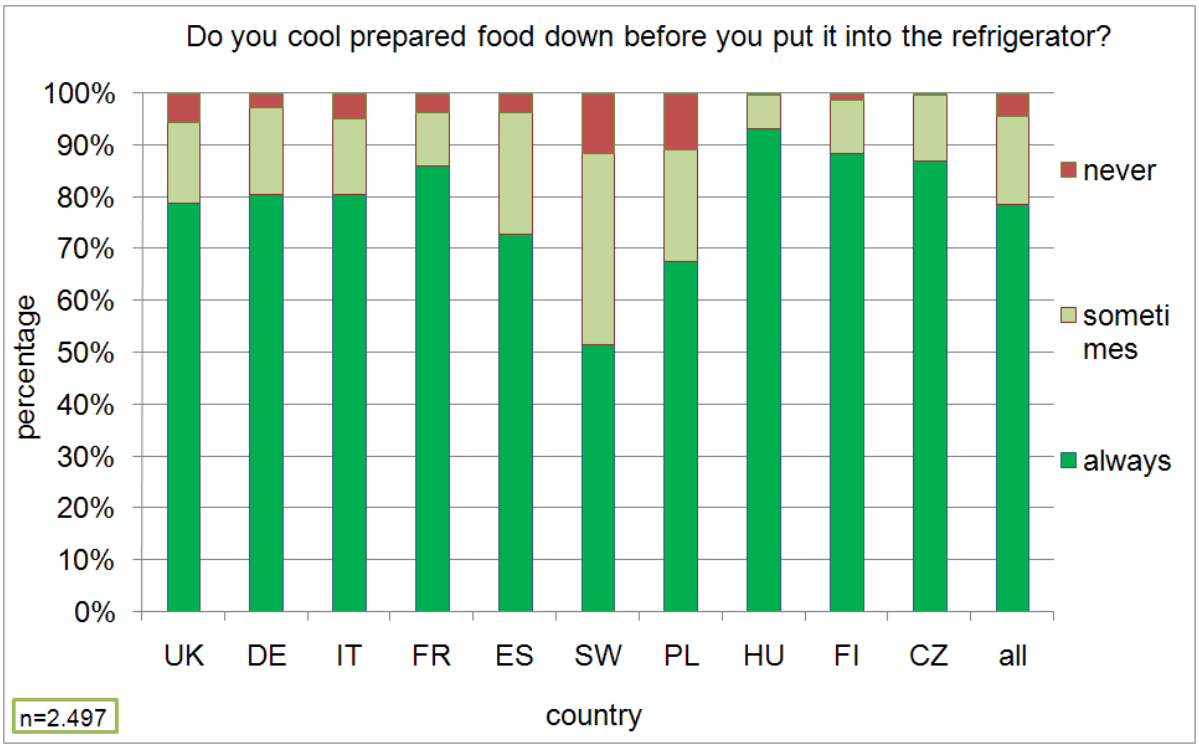


Figure 3.54: refrigerator: cool down of prepared food

b) Freezer

All participating households with a freezer (n = 2 081) were asked what the maximum and minimum temperature of the room is in which their freezer stands.

Following the analysis of all answers an average temperature of 18,1 °C could be calculated (Figure 3.55) as the arithmetic mean of the maximum and minimum temperature quoted. Over 30 % of all households have their freezers standing in a room with temperatures between 16 and 19 °C. In over the half of all households the freezer stands in a room with a maximum ambient room temperature between 20 °C and 27 °C (Figure 3.55). Together 38,6 % of all households mentioned that the minimum room temperature where their freezer stands reaches values below 11 °C down to 0 °C. Furthermore a total of 66,8 % of all consumers said that they have a minimum respectively maximum room temperature under 16 °C (Figure 3.55). Actually in 38,6 % of all households temperatures of 11 °C or lower are reached. On the other hand in 4,6 % of all interviewed households the room temperature lies at 36 °C or above (Figure 3.44).

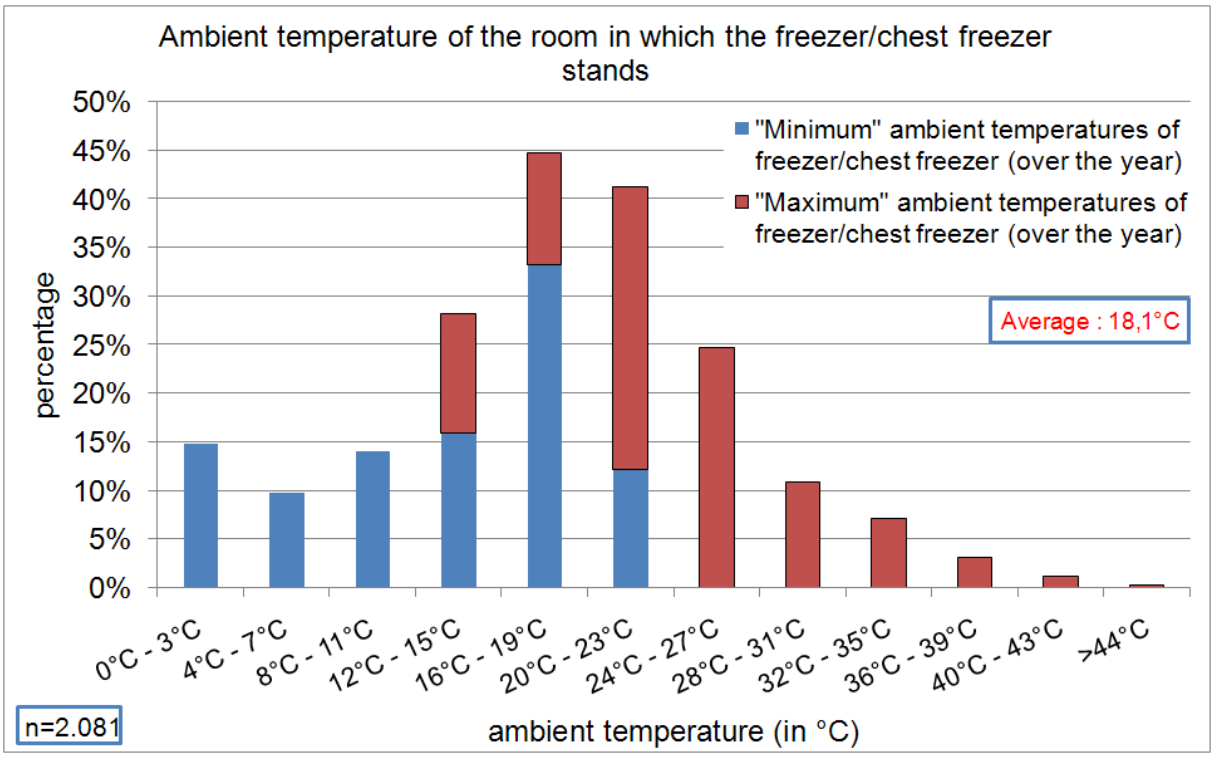


Figure 3.55: freezer: comparison of minimum and maximum ambient room temperature

The *average minimum temperature* reached 12,7 °C (Figure 3.56).

In some countries, especially United Kingdom or Spain, in over 50 % of all households the minimum temperature is below 11 °C. Interesting are the results for the northern countries like Sweden and Finland, where the minimum ambient temperatures in nearly 80 % of all households lay above 12 °C and even 30 % between 20 to 23 °C (Figure 3.56).

The analysis of the answers of all consumers to the question what the *maximum* ambient room temperature is results an *average temperature* of 23,6 °C (Figure 3.57). Especially in nearly 13 % of all Spanish households the maximum room temperature is even above 36 °C.

In contrast to that in one fourth of all German households a maximum temperature of 15 °C is reached.

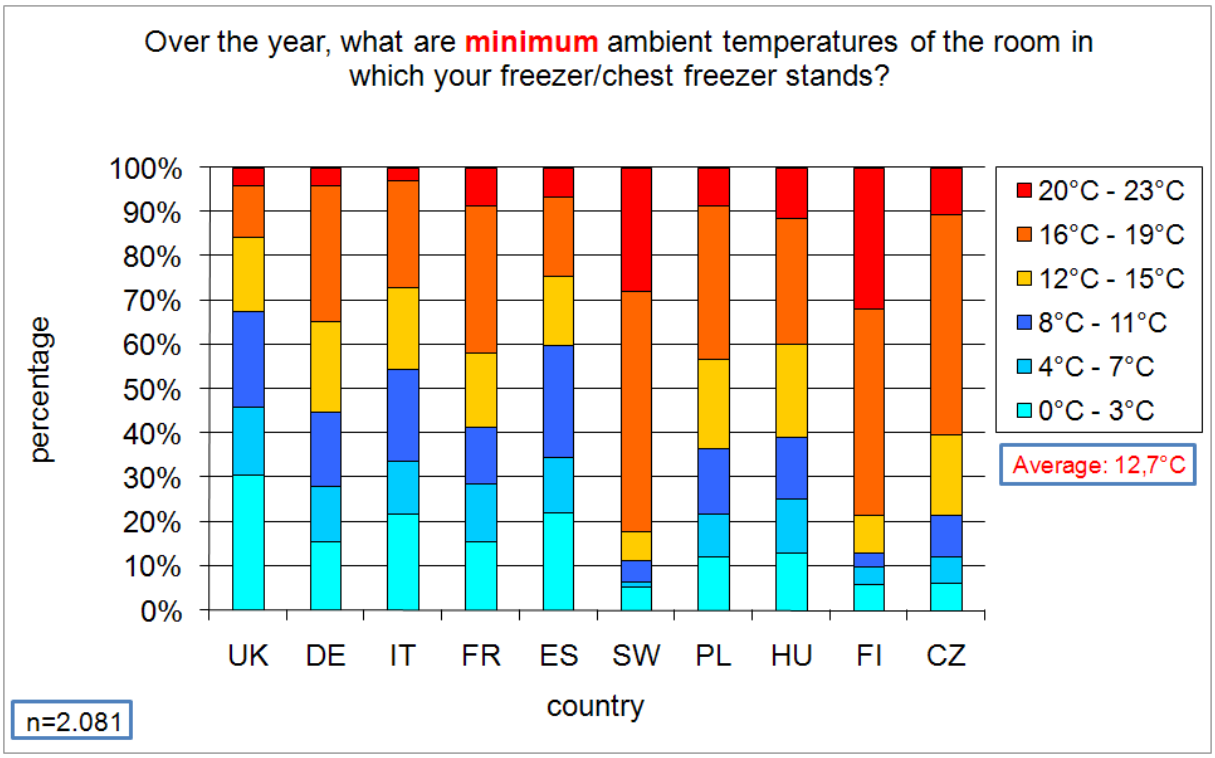


Figure 3.56: freezer: minimum ambient room temperature per countries

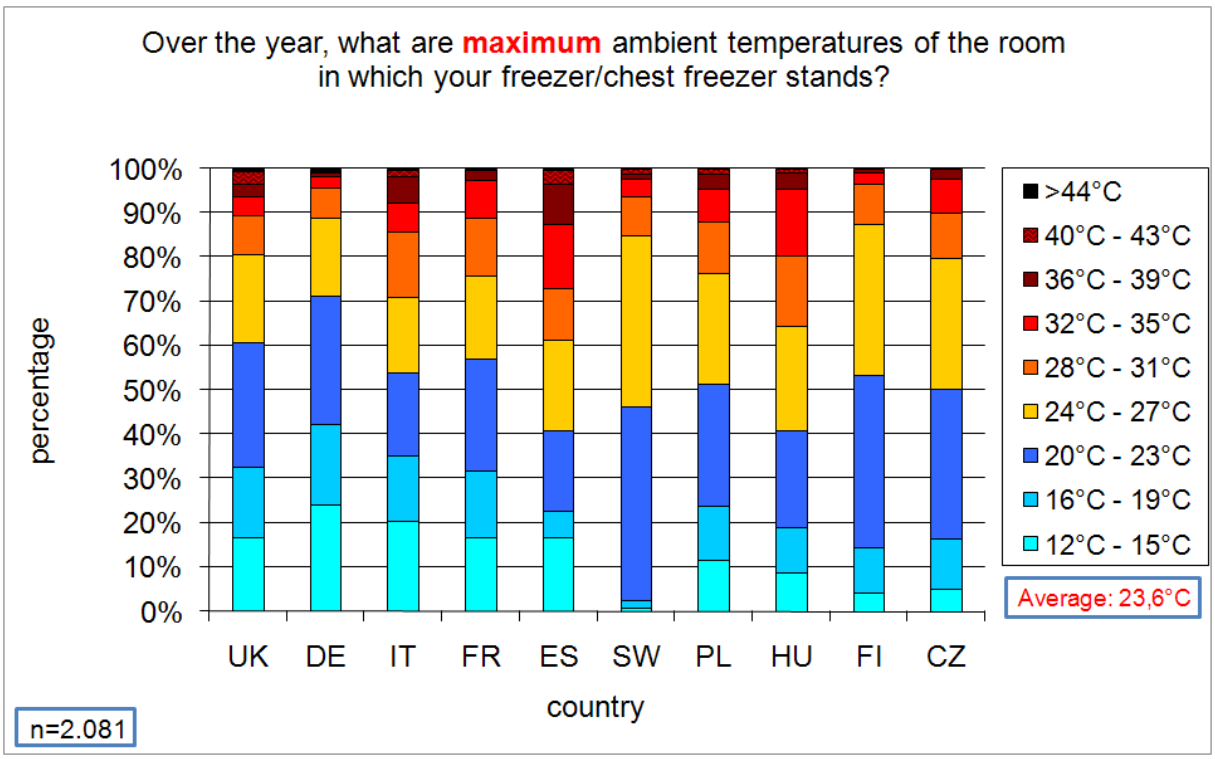


Figure 3.57: freezer: maximum ambient room temperature per countries

About 52 % of all households can be characterized by a temperature difference (Figure 3.58) of the ambient room temperature where the freezer stands of less than 12 K. In approximately 16 % of all participating households temperature differences are > 16 K.

The smallest differences could be calculated for northern countries like Sweden or Finland, where in approximately 80 % of all rooms temperature differences were maximally 8 K (Figure 3.59). The comparison with the results for southern households shows that e.g. in nearly 70 % of all Spanish

households the differences between the minimum and maximum room temperature reached between 12 K and even 44 K (Figure 3.59).

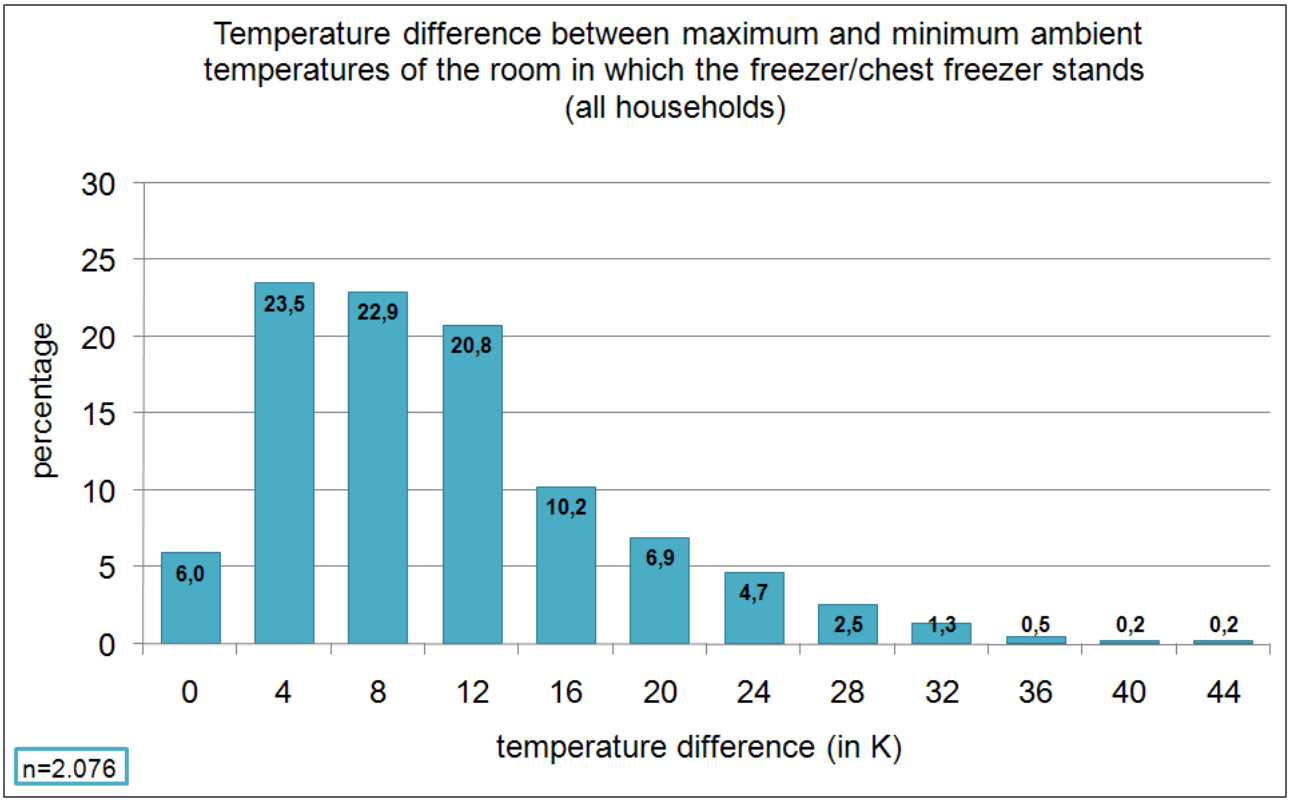


Figure 3.58: freezer: frequency of temperature differences - location of the appliances

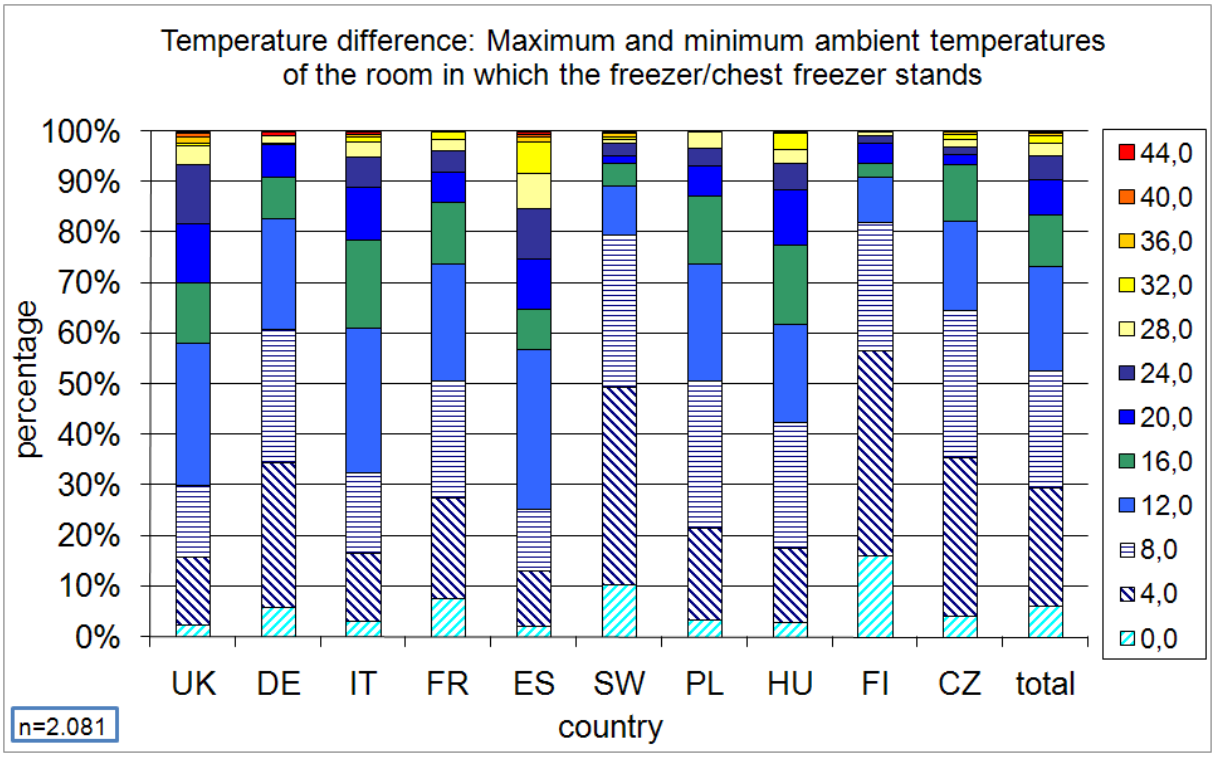


Figure 3.59: freezer: temperature differences - location of the appliances

These data can be interpreted as two different placements for the freezers: either it is placed in a heated room (e.g. kitchen) with relatively constant temperatures over the year or it is placed in an

unheated room (e.g. garage, balcony, household working room or cellar) with temperatures following more or less the ambient temperature change during the year.

In addition to the room temperature also the adjustment of the cool appliances plays an important role for the energy performance and efficiency. The analysis of the question what the actual temperature adjustment in degree Celsius of the freezer is results an average of -16,7° C (Figure 3.60). Between the interviewed countries only differences plus or minus one degree on the average temperature setting can be noticed. Just French consumers state a very low temperature setting with in average nearly -19 °C (Figure 3.60).

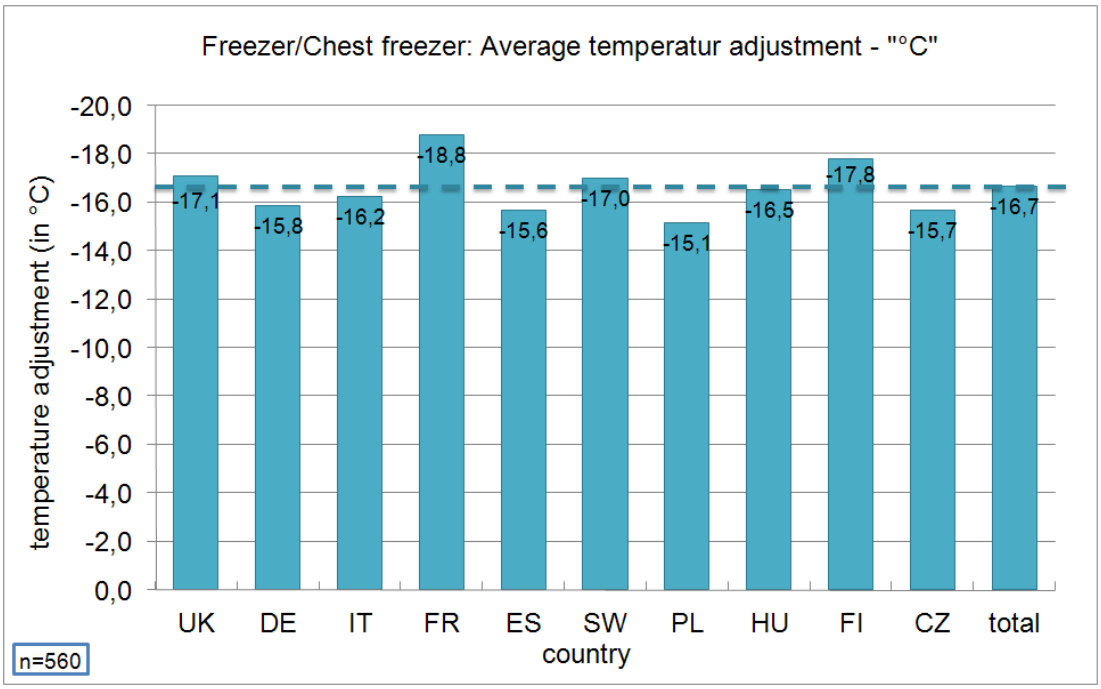


Figure 3.60: freezer: average temperature adjustment in °C (per country)

For consumers which have an appliance without an indicator showing centigrade the adjustment in numbered setting was asked too. Approximately 50 % of the participants *don't know* what possible settings their appliance has. Therefore this question was not analysed any further.

Only 23,4 % of all participating households say that they change their temperature setting sometimes (Figure 3.61). Mostly Finnish consumers change their temperature adjustment (39,5 %). Least frequently German and British households act in this way, with approximately 12,5 %. The share of the remaining countries lay between 22,1 and 28 %. Approximately 75 % of all asked consumers say that they change the temperature of their freezer according to how full it is (Figure 3.62). Also the outside temperature plays an important role for changing the adjustment for 35 % of all participants. Only nearly 10 % act by intuition or/and their habit.

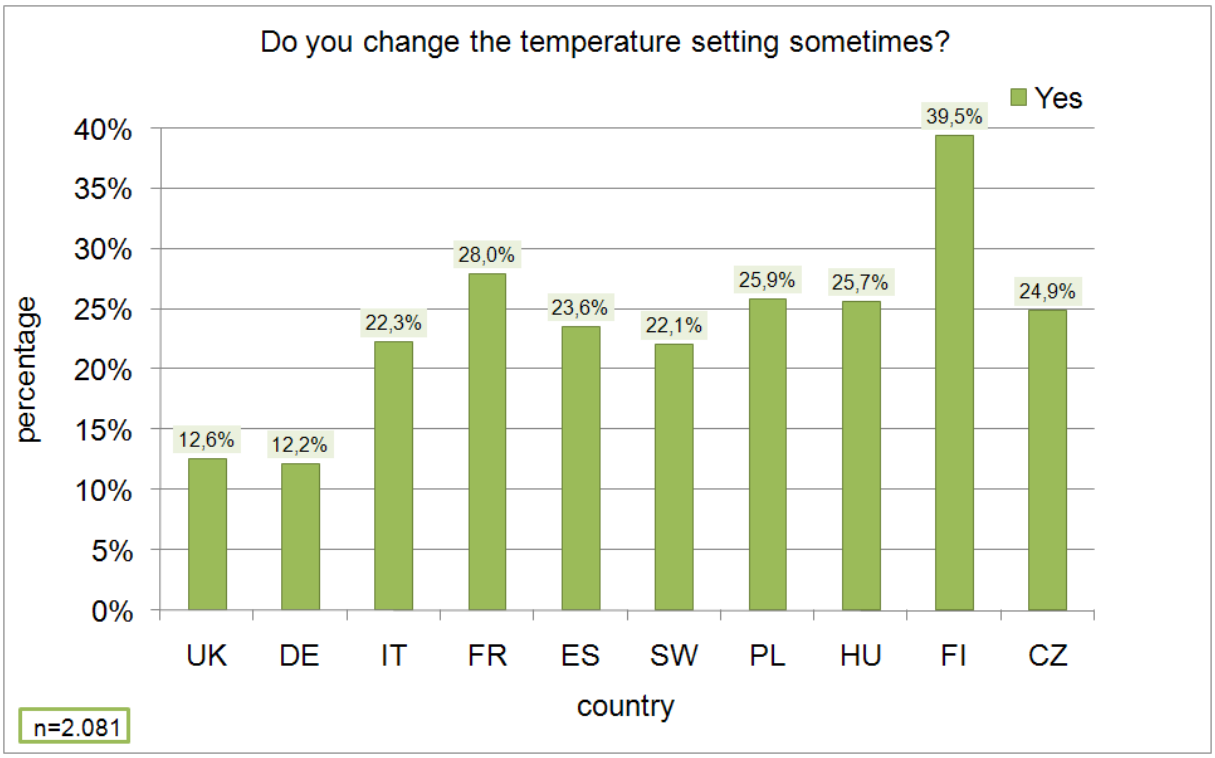


Figure 3.61: freezer: temperature changing (per country)

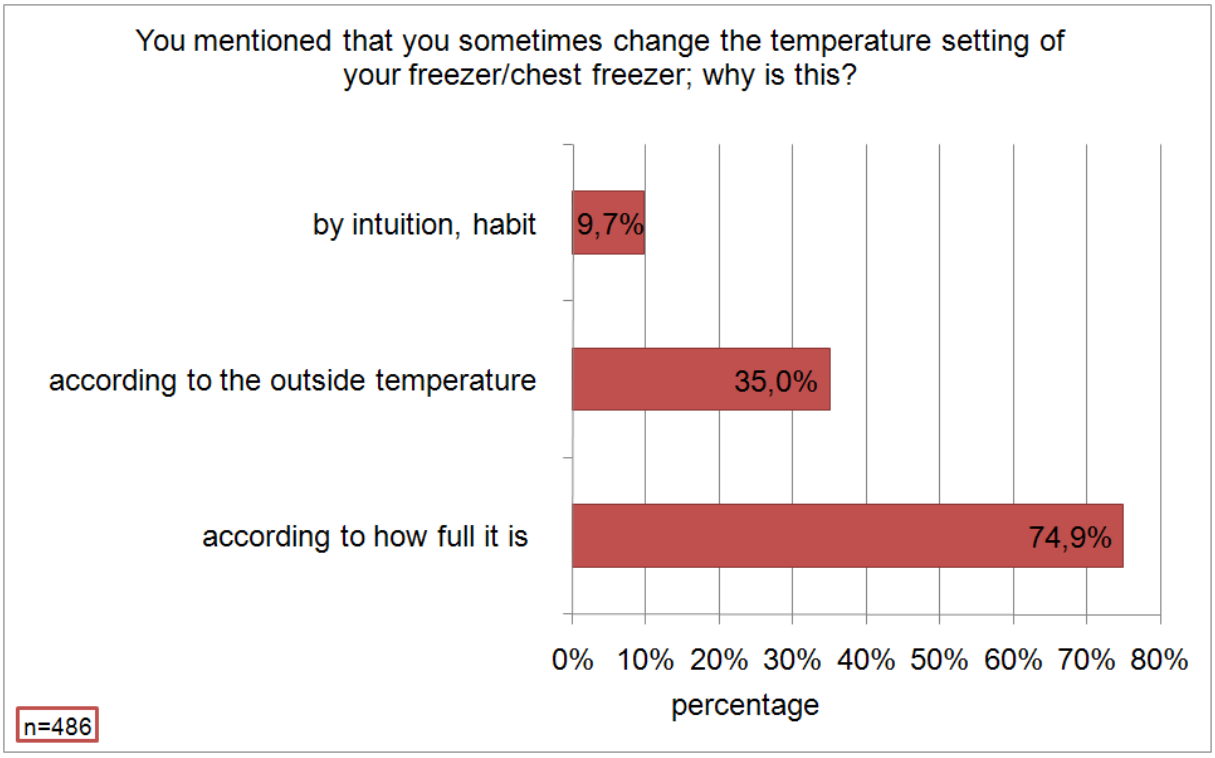


Figure 3.62: freezer: reasons for temperature changing (per country)

About half of all households describe the charge of their freezer as *sometimes completely full and sometimes less full* (Table 3.6). Also a high share of nearly 35 % of all asked consumers says that their *freezer is completely full all the time*. For nearly 20 % of the consumers the freezer seems to be oversized because they *used only a part* (3,5 %) *or the half size* (13,6 %) of the freezer.

Table 3.6: freezer: load size (n=2.081)

My freezer/chest freezer is completely full most of the time	34,6 %
My freezer/chest freezer is sometimes completely full and sometimes less full	48,4 %
My freezer/chest freezer is more or less half full all the time	13,6 %
My freezer/chest freezer is often only partly full	3,5 %

Especially in Hungarian and Czech households the most space of the freezer is used (*completely full most of the time* ~50 %) (Figure 3.63). The shares of households which used *only a part of the freezer* are marginal with between 1 % (UK) and 9 % (IT). French and Hungarian consumers never use the capacity of a freezer in this way (0 %).

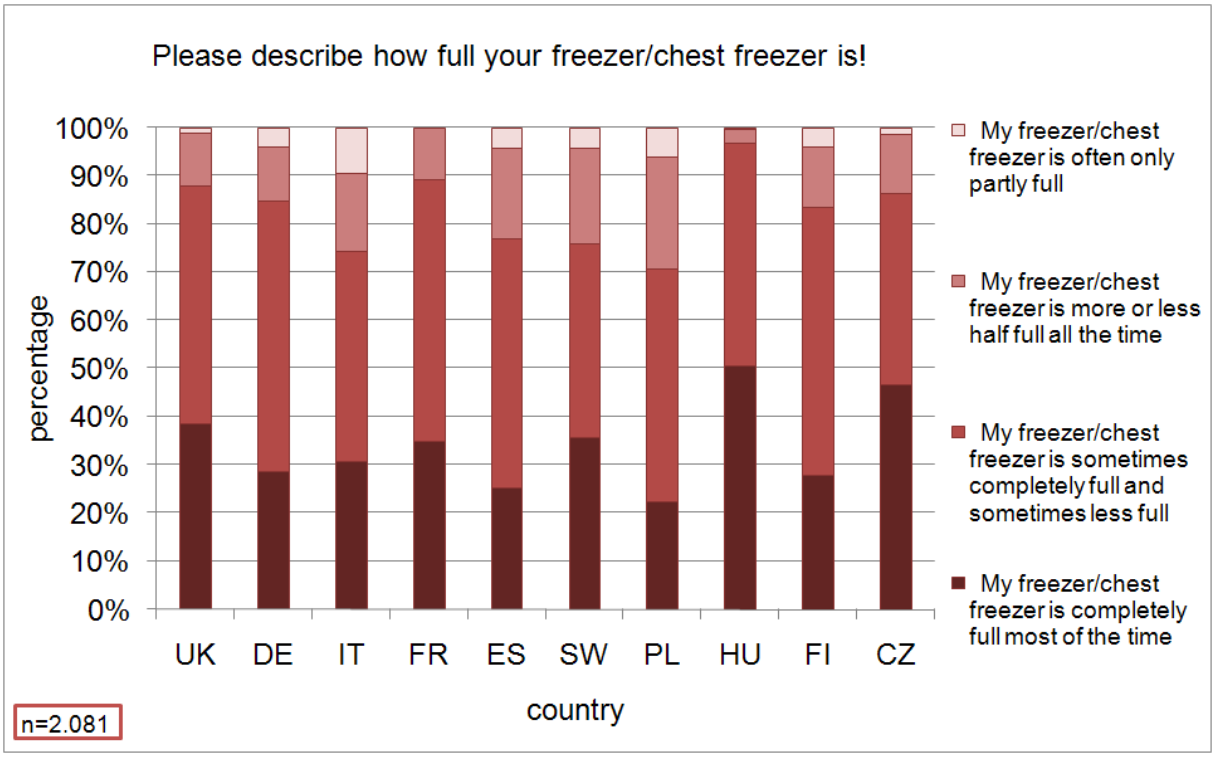


Figure 3.63: freezer: load size per country

In single-/one person households the share of freezers which are only filled partly reached nearly 8 %, more than thrice of the results of the other household types (Figure 3.64). 19,3 % of all single households also only use the half size of the freezer. With increasing number of persons in a household the share of freezers which are often *completely full and sometimes less full* grows. In comparison with this the share of *completely full freezers* decreases if more people live in the household. Maybe the exchange of food in households with a lot of people is higher than in only two or three person households, where the duration of storage may be longer.

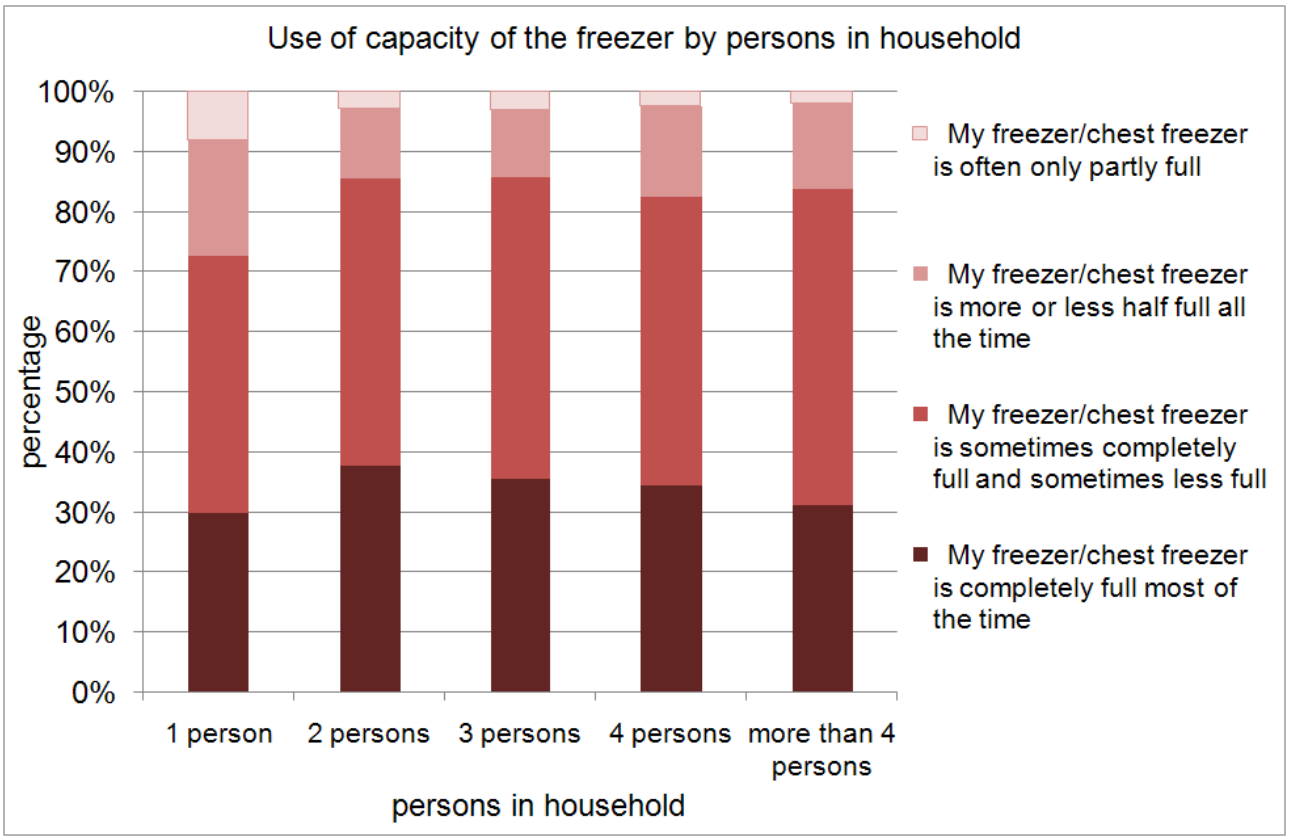


Figure 3.64: freezer: load size per number of persons in household

3.3.3 Definition of the real life base case

As it has been shown (s. chap 3.3.2) consumers' behaviour and usage is very different between themselves, but also between their behaviour and usage and what is defined in the standard base case, used for calculating the energy efficiency and energy saving. These differences are summarised here as far as they effect the energy consumption of refrigerators or freezers.

a) Refrigerator

All calculations and assumptions are based on the criteria of cold appliances of cat.7 and the behaviour of a 2,9 person household, which was the average household size of this consumer survey.

The factors which are seen as relevant for the energy consumption and which are not included in the standard base case but representative for the real life consumer behaviour are:

- Room/ambient temperature,
- The "cooling performance",
    - exchange of food
    - storage/insertion of hot items
    - door openings.

Room/ambient temperature

In real life the consumer survey (s. chap. 3.3.2) has shown that the average ambient room temperature where the refrigerator stands is 19,5 °C which is lower than the temperature used in the standard base case test (25 °C). The effect of a reduction of the room temperature examined in several studies and the results are summarised in Table 3.7. In average an energy reduction of 5,8 % per degree can be calculated. For a temperature difference of 5,5 K between the results of the consumer survey and standard base case conditions an energy reduction of 31,9 % can be calculated. Based on the annual energy consumption of the standard base case of cat.7 (= 324,4 kWh) the energy consumption in this 'real life base case situation' will be reduced to 220,9 kWh/year (Table 3.12).

Table 3.7: change of ambient temperature – effect on energy reduction

study	original ambient temperature in °C	new ambient temperature in °C	temperature difference in K	energy reduction	energy reduction per K
HMWVL, 2005	25	22	3	16 %	5,3 %
HMWVL, 2005	25	19	6	32 %	5,3 %
HMWVL, 2005	25	15	10	53 %	5,3 %
Stiftung Warentest,1994	25	16	9	47 %	5,2 %
Stiftung Warentest,1994	32	25	7	55 %	7,9 %
Lepthien, 2000	25	20	5	18,50 %	3,7 %
Böhmer & Wicke, 1998	25	24	1	8 %	8,0 %
Peart, 1993	*21*	*18*	*3*	*12 kWh/year*	*4 kWh/year*
average energy reduction per K					5,8 %
temperature difference (standard base case - consumer survey)					5,5 K
energy reduction					31,9 %

Regarding the ambient temperature the result of the consumer survey shows that nearly half of all households have temperatures below 16 °C (Figure 3.65). In detail 18 % of all households mentioned that the ambient minimum temperature reaches values between 12 and 15 °C (Figure 3.65). These temperatures are below the lower limit temperature of the climatic classes N, ST and T. Also approximately 24 % of the participants said that the room has a minimum temperature between 0 °C and 11 °C (Figure 3.65) what is below the lower limit of climatic class N.

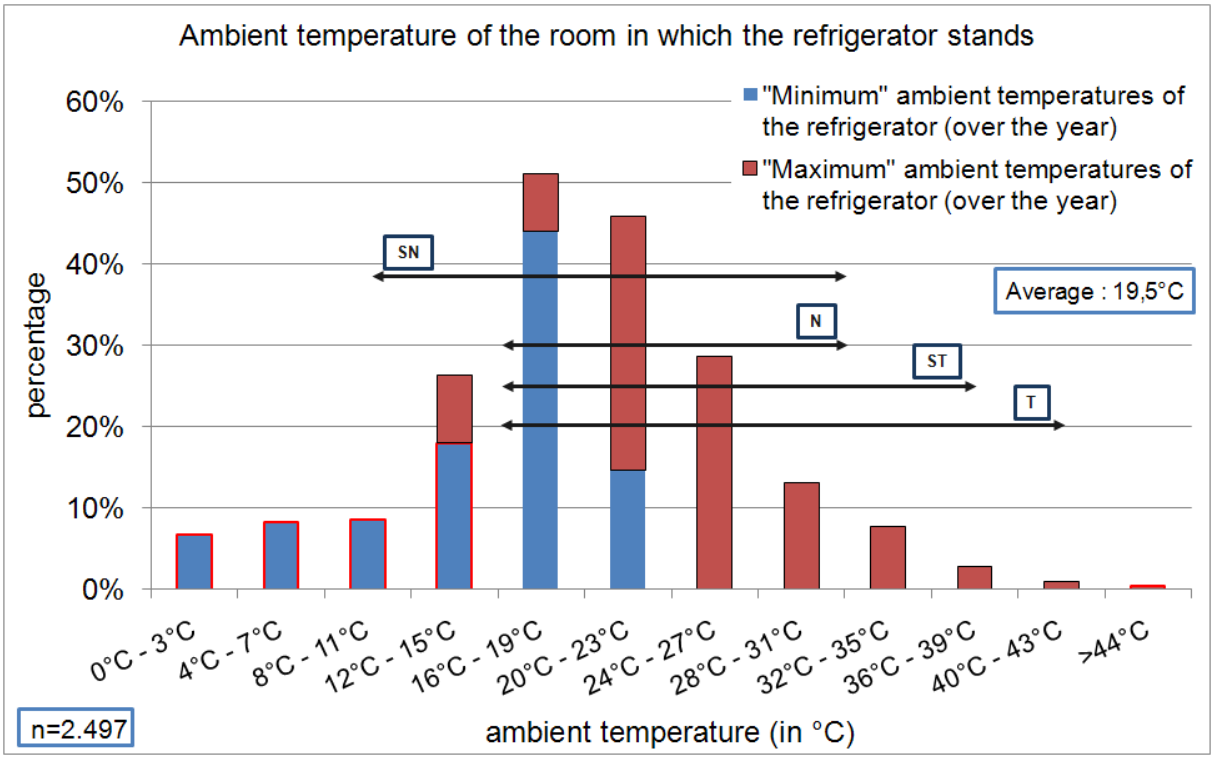


Figure 3.65: ambient temperature where the refrigerator stands (all households)

For appliances of cat.7 the climatic class ST (room temperature: + 16 to + 38 °C) is used for the standard base case calculations. As nearly 50 % of all households have minimum temperatures below 16 °C (Figure 3.65) these appliances would not fit their needs. If such an appliance would be operated under these conditions the consumer would risk to de-frost his frozen goods or have perishable goods stored under inadequate conditions. Consequently the food quality would suffer or even more serious food poisoning could happen. The same will happen with appliances of climate class SN placed at ambient conditions which allow temperatures below 10 °C, which is mentioned by the consumers to happen in 24 % of the cases.

In chapter 3.3.1 the function of an "ambient temperature switch" so called "winter switch" is mentioned, which is one solution to solve the problem of low ambient temperatures especially for appliances of cat.7 with only 1 compressor and 1 thermostat (one cooling cycle). As at low ambient temperatures the temperature difference between the ambient and the storage temperature in the fridge compartment is low, this would cause the compressor to only rarely operate. Consequently, in those gadgets with just one compressor and one thermostat, also the freezer compartment would get supplied with cold only rarely and would therefore not be able to maintain the required temperature of -18 °C. To avoid this, it is necessary to get the compressor to operate which is done, e.g. by having the indoor light of the fridge compartment switched on or by activating an internal heating device. By that heat, the temperature in the fridge compartment will raise and will cause the compressor to start. One disadvantage of this application is some additional energy consumption. Another point is that the consumer has to know when to switch it on and, more importantly, not to forget to switch it "off" when the ambient temperature is higher again. Not all appliances possess this application, but the negative effect of defrosting should be classified more critically than an additional energy consumption of an extra application. If it is assumed that light bulbs of 8, 10 or 15 Watt are used, additional energy consumptions can be calculated for periods during the year when the room would usually be heated. For the calculation the heating degree days[71] respectively heating days of each country are used. When the average temperature of the day is under the "heating limit temperature" of 15 °C this day is called "heating day". Heating degree days are summations of negative differences between the mean daily temperature and room (base) temperature of 18 °C. With published data[72] of average temperatures per month for each country the average temperature of the heating period was determined. As heating period these months are chosen which reached only temperatures ≤ 15 °C. For example for United Kingdom an average temperature of the heating period (outside temp. ≤ 15 °C) of 8,6 °C could be calculated using the changes of temperatures during the year (Table 3.8).

Table 3.8: e.g. calculation: heating days and average temperature of the heating period (e.g. UK)

Month	°C	The number of heating days Z [d] is calculated by the following formula:
JANUARY	4	
FEBRUARY	4	
MARCH	6	Z [d] = G/ (ti - tz)
APRIL	8	
MAY	12	

[71] World Resources Institute: Kevin Baumert and Mindy Selman (2003): Data Note - Heating and Cooling Degree Days. Online: http://cait.wri.org/downloads/DN-HCDD.pdf

[72] http://www.eurometeo.com/english/climate

JUNE	15	G [Kd] = number of heating degree days ti = 18°C (base temperature) tz = average outside temperature during the heating period
JULY	17	
AUGUST	17	
SEPTEMBER	14	
OCTOBER	11	
NOVEMBER	7	
DECEMBER	5	
average temp. heating period	**8,6**	

With the heating degree days' data published by the World Resources Institute (2003) the heating days were determined (Table 3.9).

Table 3.9: heating degree days and heating days

	2006		
	heating degree days[73]	**heating days**	**average temp. outside (heating period)[74]**
countries	**G**	**Z**	**tz**
	[Kd]	**[d]**	**[°C]**
Czech Republic	3569	270	4,8
Finland	5212	345	2,9
France	2478	253	8,2
Germany	3252	264	5,7
Hungary	3057	233	4,9
Italy	1838	167	7,0
Poland	3719	277	4,6
Spain	1431	154	8,7
Sweden	4375	319	4,3
United Kingdom	2810	299	8,6

Accordingly the additional energy consumption of the "winter switch application" can be estimated. Assuming the heating device (lamp or heater) is 'on' for 24 hours per day when the average ambient temperature is below 15 °C, an 8 Watt light bulb causes an average additional energy consumption of nearly 15 % (49,6 kWh) (Table 3.10) and a 15 Watt light bulb even nearly 29 % (92,2 kWh) of the energy consumption per year of the standard base case appliances of cat.7 (Table 3.10).

[73] World Resources Institute: Kevin Baumert and Mindy Selman (2003): Data Note - Heating and Cooling Degree Days. Online: http://cait.wri.org/downloads/DN-HCDD.pdf

[74] Own calculations based on data from http://www.eurometeo.com/english/climate

Table 3.10: additional energy consumption – „winter switch“-option

* based on cat.7: 324,4 kWh	winter - switch (15 watt light bulb)		winter - switch (10 watt light bulb)		winter - switch (8 watt light bulb)	
	kWh	additional energy consumption (%*)	kWh	additional energy consumption (%*)	kWh	additional energy consumption (%*)
Czech Republic	97,2	30,0 %	64,8	20,0 %	51,8	16,0 %
Finland	124,3	38,3 %	82,8	25,5 %	66,3	20,4 %
France	91,2	28,1 %	60,8	18,7 %	48,7	15,0 %
Germany	94,9	29,3 %	63,3	19,5 %	50,6	15,6 %
Hungary	83,7	25,8 %	55,8	17,2 %	44,7	13,8 %
Italy	60,2	18,5 %	40,1	12,4 %	32,1	9,9 %
Poland	99,6	30,7 %	66,4	20,5 %	53,1	16,4 %
Spain	55,5	17,1 %	37,0	11,4 %	29,6	9,1 %
Sweden	115,0	35,4 %	76,6	23,6 %	61,3	18,9 %
United Kingdom	107,6	33,2 %	71,7	22,1 %	57,4	17,7 %
average	**92,9**	**28,6 %**	**61,9**	**19,1 %**	**49,6**	**15,3 %**

In those appliances which only have one compressor and one thermostat unneeded energy is consumed also when the appliance is placed at an ambient temperature which is higher than the measurement temperature of the standard base case. As under these conditions the compressor will tend to operate more frequently than under the standardized testing conditions, the freezer compartment will get considerably cooler than -18 °C and may therefore have higher energy losses. No published studies are available which would allow estimating this effect in terms of additional energy consumption.

The “cooling performance”

Refrigerators are used to cool down food (used in general terms here for everything stored in a refrigerator) and to keep them at these conditions. The standard base case only covers the storage of food under a constant temperature. The daily exchange of food under the conditions of ambient temperature and temperature adjustment of the refrigerator plays an important role for the energy consumption too.

Important aspects, which are not covered in the standard base case, are the

- exchange of food,
- storage/insertion of hot items,
- door openings.

With the assumption of a daily exchange of food of 2 kg (here represented by water) per person and per household, a total amount of 5,8 kg needs to be cooled down from ambient condition to the storage temperature for an average household of 2,9 persons. The consumer survey analysis resulted an average storage temperature setting of 5 °C of the refrigerator and an average ambient temperature of 19,5 °C (Figure 3.65). A necessary energy of **23,8 kWh/year for a 2,9 person household** can be calculated by the following formula:

Energy needed = Heat load per day / COP[75] · 365 days/year

Heat load = 5,8 kg · 14,5 K · 4,19 kJ/kgK = 352,4 kJ
= 0,0979 kWh

Energy needed = 0,0979 kWh/day / 1,5 · 365 days/year
= 23,8 kWh/year

For single- and four persons households the necessary energy consumption for cooling down inserted food would result in 8,2 kWh and 65,6 kWh per year, respectively.

Storage of hot items:

The consumer survey analysis shows that nearly 20 % (Figure 3.54) do not always cool down hot items or cooked food before inserting them in the refrigerator *(15 % "sometimes", 5 % "never").* This behaviour causes an additional energy increase.

With the assumptions of an amount of 0,25 kg hot food (represented by water) at 40 °C inserted per person and per household, the refrigerator additionally has to cool this down about $\Delta T = 20,5$ K to the ambient temperature of 19,5 °C. Accordingly this allows to estimate an extra energy consumption for a **2,9 person household of 4,2 kWh/year** (1,4 kWh/year for a single person household and 5,8 kWh/year for a four persons household).

Calculation: Insertion hot items - Energy consumption per year

Energy needed = Heat load per day / COP[76] · 365 days/year

Heat load = 0,725 kg · 4,19 kJ/kgK · 20,5 K= 62,27 kJ
= 0,0173 kWh

Energy needed = 0,0173 kWh/day : 1,5 · 365 days/year
= 4,2 kWh/year

[75] COP (coefficient of performance) assumed to be 1,5

[76] COP (coefficient of performance) assumed to be 1,5

Door openings

With insertion and storage of food the door has to be opened and will be left open for some time. This will mainly cause cold air to pour out and to be replaced by air from the ambient. This effect and the additional energy needed to cool down the replaced air are not covered by the standard base case, as tests are done with closed door only. Table 3.11 summarises the results of studies which investigated the energy consumption increase depending on the door opening.

In average an additional energy consumption of 0,002903 kWh per door opening can be calculated.

Table 3.11: energy consumption studies with door opening

study	door opening/ household(/person))	increase energy consumption		energy consumption (standard base case)*	kWh/door opening
	[do]	[kWh/year]		[kWh/year]	[kWh/do]
PEART (1993)	40/hh	50-120 kWh/year	= 85	-----	0,005822
LEPTHIEN (2000)	20/hh	1-6 % (aver.3,5 %)	= 11,35	324,4	0,001555
LIU (2004)	50/hh	5-10 % (aver.7,5 %)	= 24,33	324,4	0,001333
THOMAS (2007)	8,2/p				
(cat.7)* **average energy consumption per door opening					**0,002903**

A recent consumer behaviour study about the storage of food in Europe[77] observed an average door opening of a refrigerator of 8,2 times per day per person. With the average energy consumption per opening and this frequency the **energy consumption for a 2,9 person household is 25,2 kWh/year (**single household: 8,7 kWh/year – four person household: 34,8 kWh/year).

The comparison of the energy consumption of the real-life base case (RLBC) and the standard base case (STBC) shows that the total amount of energy used is surprisingly similar (Table 3.12). This is especially due to the lower ambient temperature of the location of the refrigerator in the households, where the energy consumption is considerably reduced. All other factors not considered in the measurement according to the standard are not so relevant as to balance the high ambient temperature of the measurement conditions. Only for refrigerators/freezers of category 7 with mainly one compressor and one thermostat a considerable additional amount of energy is needed when they are placed in an unheated room and are therefore affected by low and high ambient temperatures. As this depends on the local conditions no definite answer about the additional energy can be given. It may even be much higher than estimated here. Unfortunately the consumer is hardly aware of this situation as at the point of sale of the gadget he is not informed about the

[77] Thomas, Simone (2007): Diss.: Erhebung des Verbraucherverhaltens bei der Lagerung verderblicher Lebensmittel in Europa [*Consumer behavior with the storage of perishable food in Europe*]. (will be published) Online: http://www.shaker.de/online-gesamtkatalog/booklist.asp?ID=1707429&CC=54012&Reihe=423

limitations regarding ambient temperatures and an eventual additional energy consumption. This may be changed either by including real life ambient temperature spans into the standard measurement procedure, in minimum by informing the consumer on the Energy Label about the range of temperatures under which the gadget is supposed to be operated and the declared energy consumption is a representative figure.

As all the additional energy consumptions caused by the actual use of the refrigerator are independent of the size or the energy efficiency of the gadget, the relevance of these additional amounts of energy used will increase as much as the absolute values of the energy consumption of the standard base case is reduced. This reduction happens as soon as more efficient appliances are compared or just in considering refrigerators with smaller volumes.

Table 3.12: refrigerator: annual energy comparison of real-life versus standard base case

Activity	Effect	Real-life base case (RLBC)	Standard base case (STBC)*
Average ambient temperature	19,5 °C vs. 25 °C ΔT = 5,5 K → Energy reduction of 31,9 %	220,9 kWh	324,4 kWh
Ambient temperature < 16 °C (Cat.7 with 1 compressor, 1 thermostat)	Heating on (light or heating element, e.g. 10 W) when heating day	61,9 kWh	
Ambient temperature > 25 °C (Cat.7 with 1 compressor, 1 thermostat)	Losses due to too low freezer temperature	???	
Temperature setting	Average temperature setting 5 °C / numbered setting 3,2	0 kWh	
Exchange of food	Exchange : 2 kg (represented by water)/day/person	23,8 kWh	
Cooling down of hot food	Insertion of hot food (40 °C): 0,25 kg (represented by water) per household/person/day	4,2 kWh	
Door openings	8,2 door openings per day per person	25,2 kWh	
	kWh per year	**336,0 kWh**	**324,4 kWh**

**of cat. 7*

b) Freezer

All calculations and assumptions are based on the criteria of cold appliances of cat.8 and 9 and the behaviour of a 2,9 person household, which was the average household size of this consumer survey.

The factors which are seen as relevant for the energy consumption under real life conditions and which are not included in the standard base case are the:

- Room/ambient temperature
- Temperature setting of the appliances
- Insertion of goods/loading of freezer

Room/ambient temperature and setting of the appliance

The average ambient room temperature where the freezer stands was reported to be 18,1 °C (Figure 3.66) which is lower than the ambient temperature used in the standard base case test with 25 °C. Taking a linear dependency between the temperature difference (ambient – storage) and the energy consumption an energy reduction of 2,3 % per degree can be calculated. For the ambient temperature difference of 6,9 K between the results of the consumer survey and standard base case conditions an energy reduction of 16 % would be reached. As the temperature setting in the freezer compartment was found to be at -16,7 °C (Figure 3.60) an additional reduction of the energy consumption of 3 % compared to the standard base case has to be incorporated.

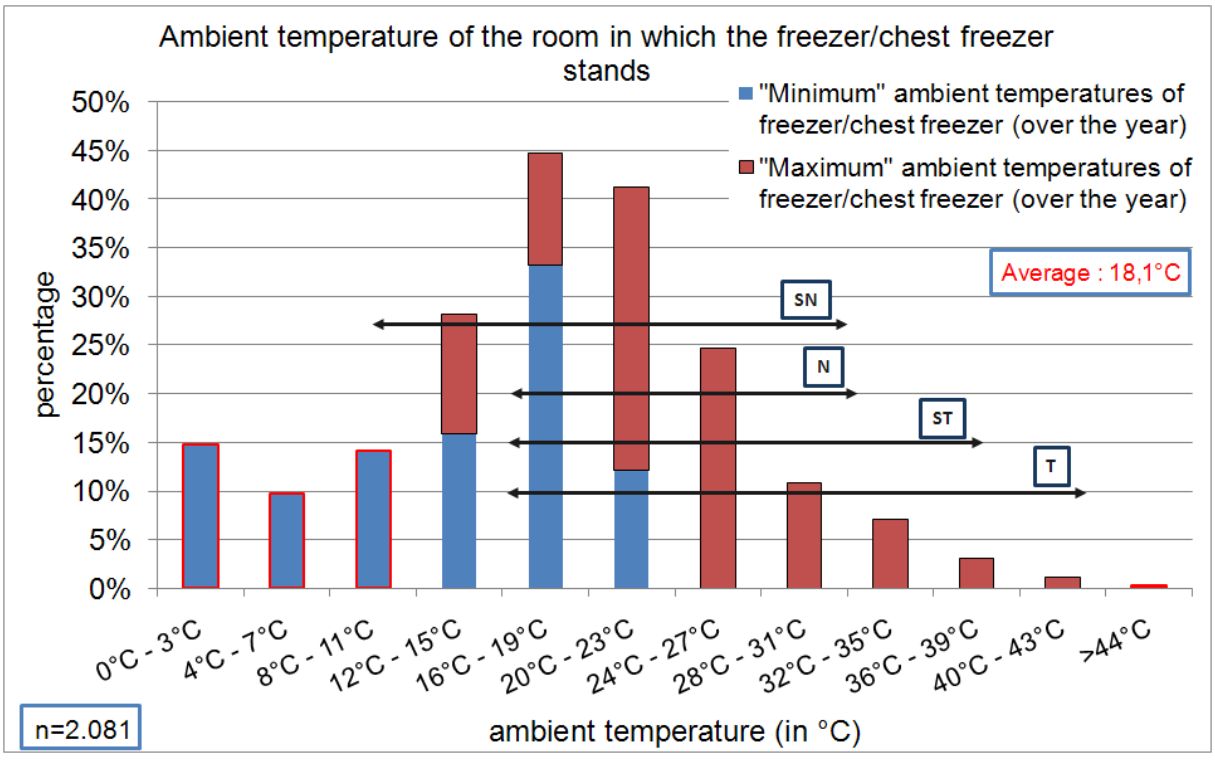


Figure 3.66: ambient temperature where the freezer stands (all households)

For appliances of cat.8 and 9 the average energy consumption, based on the values of the standard base cases, is 287,5 kWh/year. Under the circumstances of the results of the consumer survey with an average ambient temperature of 18,1 °C and a temperature setting of the freezer of -16,7 °C an energy consumption of 232,7 kWh could be determined (see calculation below) in comparison with the standard base case settings with an ambient temperature of 25 °C and a temperature setting of the appliance of -18 °C. On inspection of only the temperature difference of 6,9 K between the

results of the consumer survey and standard base case conditions of the ambient temperature an energy reduction of 16% would lower the annual consumption to 241,4 kWh/year (Table 3.13).

Calculation: Energy reduction per degree

Standard base case (cat.8 & 9)*:

- Room temperature = 25 °C
- Temperature setting = -18 °C
- ΔT = 25 °C - (-18 °C) = 43 K
- Energy consumption/degree: 287,5 kWh* / 43K = **6,7 kWh/K**

Results consumer survey:

- Average room temperature = 18,1 °C
- Average temperature setting = -16,7 °C
- ΔT = 18,1 °C – (-16,7 °C) = 34,8 K
- Energy consumption: **6,7 kWh**/K 34,8 K = **232,7 kWh**

Insertion of food / Loading of freezer

In assuming a daily exchange of food of 0,125 litre (represented by water) per day and person the additional energy needed to freeze this food (heating capacities for water assumed) from ambient temperature to average freezer temperature **for a 2,9 person household** can be calculated as follows:

Energy needed/year = Heat load/day / COP (coefficient of performance) · 365 days/year

Heat load:

1). 0,3625 kg · 18,1 K · 4,19 kJ/kgK = 27,5 kJ

2). 0,3625 kg · 16,7 K · 2,10 kJ/kgK = 25,4 kJ

3). 0,3625 kg · 332,5 kJ/kg = 120,5 kJ *(Freezing energy)*

Heat load/day = (27,5 kJ + 25,4 kJ +120,5 kJ)/day = 173,4 kJ/day = 0,0481 kWh/day

Energy needed/year = Heat load/day : COP[78] · 365 days/year

= 0,0481 kWh/day : 1,5 · 365 days/year

= 11,7 kWh/year

Regarding **door opening** of a freezer no real life consumer behaviour data were available. As this is assumed to be done seldom, no effect on the total energy consumption was considered.

Table 3.13: freezer: annual energy comparison of real-life versus standard base case

Activity	Effect	Real-life base case (RLBC)	Standard base case (STBC) aver. Cat 8/9
Average ambient temperature	18,1 °C vs. 25 °C ΔT = 6,9 K → Energy reduction of 16 %	241,4 kWh	287,5 kWh
Average temperature setting	-16,7 °C vs. – 18,0 °C ΔT = 1,3 K → Energy reduction of 3 %	-8,6 kWh	
Exchange of food ("Cooling performance")	Exchange (assumption): 0,125 kg (represented by water)/day/person	+11,7 kWh	
	kWh per year	**244,5 kWh**	**287,5 kWh**

[78] COP (coefficient of performance) assumed to be 1,5

Considering all effects (Table 3.13), the annual energy consumption under real life conditions seems to be somewhat lower than measured in the standard base case. This is based mainly on the lower ambient temperature in real life compared to standard conditions. It is only partly balanced by the extra energy needed to freeze loads exchanged in the fridge. As this was not measured anywhere but just assumed to be at 0,125 litres per day and per person, no real judgement about a significant difference can be made. Other factors like door opening were not considered, but seem to be of even less importance for freezers.

3.4 SUMMARY OF CONSUMER BEHAVIOUR

Consumer investigations done within this study on an almost representative sample of people from 10 European countries covering 75 % of the population reveal a very high level of awareness of the consumer towards the environmental aspects of household appliances. This is also reflected when buying decisions are done and the energy label as an informational tool is seen almost as important as the own experience and as the information available on the Internet.

In European households refrigerators are available in the local infrastructure for almost 100 % of the households and in even 21 % of the households in this report a secondary refrigerator is available. These refrigerators are in average 1,4 years older than the primary refrigerator. All refrigerators and freezers remain in the household for normally 10 years and more, keeping the status of efficiency of the appliance remaining as it was at the production of the gadget. Improvements will therefore take more than 10 years to get fully effective in the market. This time is even prolonged when second-hand appliances are used. As this investigation has shown, this second –hand market takes only a minor part of the market.

Another possible barrier for energy saving innovations for cold appliances is the necessity of food protection. The decrease of energy consumption can only go as far as food safety is ensured. There is common understanding that perishable food should be stored at temperatures below 5 °C in a refrigerator and at -18 °C in a freezer. Other important factors influencing the energy consumption in real life are identified especially by the temperature of the ambient where the refrigerator or freezer stands and the amount of new food loaded into the devices which needs to be cooled down. Recommendations to place the refrigerator and freezer at the lowest possible ambient temperature and not to place hot food into them are important ways to reduce the amount of energy used.

But refrigerators and freezers in consumer homes not always seem to be set to follow this recommendation. Ambient temperatures go up to 40 °C for a considerable amount of households investigated and down to temperatures of 0 °C. While the higher ambient temperatures are covered by the climate classes as defined, temperatures lower than 10 °C of the ambient are not foreseen at all. But more than 20 % of the households investigated in 10 European countries report to have minimum ambient temperatures lower than 10 °C where the refrigerator stands. One consequence of this is that the right temperature in the refrigerator and freezer is no longer maintained and the quality of food stored may suffer significant losses. In refrigerators/freezers of category 7 many gadgets only have one compressor which is used to provide cool for both compartments. These systems are optimised to provide the required temperatures under standard conditions, but will fail if the constant ambient temperature of 25 °C is not met. The consequence is, that at lower ambient temperatures these appliances may either fail to keep the right storage temperatures or activate additional heating devices to cause the compressor to provide cool. This may cause considerable additional amounts of energy (up to 29 %) used than compared to a similar appliance with two compressor circles. At higher ambient temperatures these machines will – while keeping the temperature in the refrigerator compartment at the right value – provide more cool to the freezer compartment as needed to keep the desired temperature. Also this may cause unnecessary energy consumptions. Only about one quarter of the consumers adjust their temperature setting according to the outside temperature to somehow balance this effect.

Consumer behaviour is also characterised by

- an average temperature of the refrigerator set at 5,0 °C at the correct level, but with relevant differences between countries,
- an average temperature of the freezer at -16,7 °C, again with differences between countries,
- the capacity of the refrigerator compartment which is used to a good extent by the consumers, but that of the freezer is even more filled.

Summarising all of this information about the consumer behaviour allows estimating the difference between the real life and standard base case energy consumption. Due to the lower ambient temperature in real life compared to the 25 °C used in the standard measurement will considerably reduce the energy taken by the gadgets. Part of this saving is balanced by cooling down food which is loaded and by cooling down the air which is exchanged when opening the door. So all in all the measured consumption following the standard is somehow taking care of this kind of real life behaviour.

Not covered are the additional consumptions which may be used by cat. 7 refrigerators/freezers with just one compressor (and one thermostat) not operated within the temperature range of 20 to 30 °C. Here significant amounts of additional energy are used about which the consumer was not informed at the point of sale of the gadget.

APPENDIX

Appendix 3.1- 1 population by household size and age group: comparison results own survey vs. Eurostat data[79]

United Kingdom		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	3,9%	7,1%	4,2%	15,1%
	2 persons	11,6%	12,2%	10,6%	34,4%
	3 persons	11,6%	10,9%	1,6%	24,1%
	4 persons	8,0%	8,7%	1,0%	17,7%
	more than 4 persons	4,8%	3,9%	0,0%	8,7%
	total	*39,9%*	*42,8%*	*17,4%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	4%	5%	5%	*14%*
	2 persons	10%	13%	12%	*36%*
	3 persons	10%	9%	2%	*21%*
	4 persons	10%	8%	1%	*19%*
	more than 4 persons	6%	4%	0%	*11%*
	total	*41%*	*39%*	*20%*	*100%*
		Age group			
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	0,1%	-2,1%	0,8%	-1,1%
	2 persons	-1,6%	0,8%	1,4%	1,6%
	3 persons	-1,6%	-1,9%	0,4%	-3,1%
	4 persons	2,0%	-0,7%	0,0%	1,3%
	more than 4 persons	1,2%	0,1%	0,0%	2,3%
	total	*1,1%*	*-3,8%*	*2,6%*	*0,0%*

France	Age group	total

[79]Own calculation: Population by household size and age group based on EUROSTAT data.

* Own calculations: crosstabs with EUROSTAT data of population by age group and household size

		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	5,9%	3,9%	3,9%	13,8%
	2 persons	9,1%	11,0%	11,8%	31,9%
	3 persons	9,8%	9,8%	2,0%	21,7%
	4 persons	11,0%	7,9%	1,2%	20,1%
	more than 4 persons	7,5%	5,1%	0,0%	12,6%
	total	*43,3%*	*37,8%*	*18,9%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	6%	4%	4%	*15%*
	2 persons	9%	11%	12%	*32%*
	3 persons	10%	9%	2%	*22%*
	4 persons	11%	8%	1%	*19%*
	more than 4 persons	7%	5%	0%	*12%*
	total	*42%*	*38%*	*20%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	0,1%	0,1%	0,1%	1,2%
	2 persons	-0,1%	0,0%	0,2%	0,1%
	3 persons	0,2%	-0,8%	0,0%	0,3%
	4 persons	0,0%	0,1%	-0,2%	-1,1%
	more than 4 persons	-0,5%	-0,1%	0,0%	-0,6%
	total	*-1,3%*	*0,2%*	*1,1%*	*0,0%*

Czech Republic		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	4,0%	5,3%	4,0%	13,4%
	2 persons	6,1%	10,9%	9,3%	26,3%
	3 persons	12,1%	11,3%	2,0%	25,5%
	4 persons	15,0%	10,1%	1,2%	26,3%
	more than 4 persons	5,3%	3,2%	0,0%	8,5%
	total	*42,5%*	*40,9%*	*16,6%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	

Eurostat*	1 person	5%	5%	5%	*14%*
	2 persons	6%	11%	10%	*27%*
	3 persons	12%	11%	2%	*25%*
	4 persons	15%	10%	1%	*25%*
	more than 4 persons	5%	3%	0%	*9%*
	total	*42%*	*40%*	*18%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	1,0%	-0,3%	1,0%	0,6%
	2 persons	-0,1%	0,1%	0,7%	0,7%
	3 persons	-0,1%	-0,3%	0,0%	-0,5%
	4 persons	0,0%	-0,1%	-0,2%	-1,3%
	more than 4 persons	-0,3%	-0,2%	0,0%	0,5%
	total	*-0,5%*	*-0,9%*	*1,4%*	*0,0%*

Germany		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	6,3%	6,0%	4,8%	17,2%
	2 persons	11,8%	14,8%	12,7%	39,3%
	3 persons	10,3%	9,4%	1,8%	21,5%
	4 persons	9,4%	6,0%	0,0%	15,4%
	more than 4 persons	3,9%	2,7%	0,0%	6,6%
	total	*41,7%*	*39,0%*	*19,3%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	7%	5%	5%	*18%*
	2 persons	8%	14%	16%	*38%*
	3 persons	9%	9%	2%	*21%*
	4 persons	9%	7%	0%	*17%*
	more than 4 persons	4%	3%	0%	*7%*
	total	*38%*	*38%*	*24%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	0,7%	-1,0%	0,2%	0,8%

	2 persons	-3,8%	-0,8%	3,3%	-1,3%
	3 persons	-1,3%	-0,4%	0,2%	-0,5%
	4 persons	-0,4%	1,0%	0,0%	1,6%
	more than 4 persons	0,1%	0,3%	0,0%	0,4%
	total	*-3,7%*	*-1,0%*	*4,7%*	*0,0%*

Spain		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	3,1%	2,0%	3,1%	8,2%
	2 persons	6,3%	5,5%	7,8%	19,5%
	3 persons	10,9%	7,8%	5,1%	23,8%
	4 persons	13,7%	11,7%	2,0%	27,3%
	more than 4 persons	11,7%	7,8%	1,6%	21,1%
	total	*45,7%*	*34,8%*	*19,5%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	3%	2%	3%	*7%*
	2 persons	7%	5%	8%	*20%*
	3 persons	11%	8%	5%	*24%*
	4 persons	14%	12%	2%	*28%*
	more than 4 persons	11%	8%	2%	*21%*
	total	*45%*	*35%*	*20%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	-0,1%	0,0%	-0,1%	-1,2%
	2 persons	0,8%	-0,5%	0,2%	0,5%
	3 persons	0,1%	0,2%	-0,1%	0,2%
	4 persons	0,3%	0,3%	0,0%	0,7%
	more than 4 persons	-0,7%	0,2%	0,4%	-0,1%
	total	*-0,7%*	*0,2%*	*0,5%*	*0,0%*

Finland		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	7,6%	7,2%	5,2%	19,9%

	2 persons	10,0%	13,9%	12,4%	36,3%
	3 persons	7,6%	9,6%	1,6%	18,7%
	4 persons	8,4%	7,6%	0,0%	15,9%
	more than 4 persons	5,2%	4,0%	0,0%	9,2%
	total	*38,6%*	*42,2%*	*19,1%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	7%	7%	5%	*20%*
	2 persons	10%	14%	11%	*35%*
	3 persons	8%	9%	2%	*19%*
	4 persons	8%	7%	0%	*16%*
	more than 4 persons	5%	4%	0%	*10%*
	total	*38%*	*43%*	*19%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	-0,6%	-0,2%	-0,2%	0,1%
	2 persons	0,0%	0,1%	-1,4%	-1,3%
	3 persons	0,4%	-0,6%	0,4%	0,3%
	4 persons	-0,4%	-0,6%	0,0%	0,1%
	more than 4 persons	-0,2%	0,0%	0,0%	0,8%
	total	*-0,6%*	*0,8%*	*-0,1%*	*0,0%*

Hungary		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	1,9%	3,9%	5,1%	10,9%
	2 persons	6,2%	10,9%	9,7%	26,8%
	3 persons	11,7%	10,9%	3,1%	25,7%
	4 persons	11,7%	9,3%	1,6%	22,6%
	more than 4 persons	7,8%	5,1%	1,2%	14,0%
	total	*39,3%*	*40,1%*	*20,6%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	2%	4%	5%	*11%*
	2 persons	6%	11%	10%	*27%*

	3 persons	11%	11%	3%	*25%*
	4 persons	12%	9%	1%	*23%*
	more than 4 persons	8%	5%	1%	*15%*
	total	*40%*	*40%*	*20%*	*100%*
		Age group			**total**
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	0,1%	0,1%	-0,1%	**0,1%**
	2 persons	-0,2%	0,1%	0,3%	**0,2%**
	3 persons	-0,7%	0,1%	-0,1%	**-0,7%**
	4 persons	0,3%	-0,3%	-0,6%	**0,4%**
	more than 4 persons	0,2%	-0,1%	-0,2%	**1,0%**
	total	***0,7%***	***-0,1%***	***-0,6%***	***0,0%***

Italy		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	4,2%	4,5%	3,2%	12,0%
	2 persons	8,4%	5,8%	7,5%	21,8%
	3 persons	12,0%	10,4%	4,2%	26,6%
	4 persons	14,9%	11,4%	1,6%	27,9%
	more than 4 persons	6,5%	4,5%	0,6%	11,7%
	total	*46,1%*	*36,7%*	*17,2%*	*100,0%*
Eurostat*	1 person	3%	3%	4%	*9%*
	2 persons	7%	6%	10%	*23%*
	3 persons	12%	10%	5%	*27%*
	4 persons	13%	12%	2%	*27%*
	more than 4 persons	6%	5%	1%	*13%*
	total	*41%*	*36%*	*23%*	*100%*
		Age group			**total**
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	-1,2%	-1,5%	0,8%	**-3,0%**
	2 persons	-1,4%	0,2%	2,5%	**1,2%**
	3 persons	0,0%	-0,4%	0,8%	**0,4%**

	4 persons	-1,9%	0,6%	0,4%	**-0,9%**
	more than 4 persons	-0,5%	0,5%	0,4%	**1,3%**
	total	***-5,1%***	***-0,7%***	***5,8%***	***0,0%***

Poland		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	3,2%	4,0%	3,6%	10,7%
	2 persons	4,0%	8,3%	7,9%	20,2%
	3 persons	9,9%	10,3%	3,2%	23,4%
	4 persons	11,9%	9,9%	1,2%	23,0%
	more than 4 persons	11,9%	9,1%	1,6%	22,6%
	total	*40,9%*	*41,7%*	*17,5%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	3%	4%	4%	*10%*
	2 persons	4%	8%	8%	*20%*
	3 persons	10%	10%	3%	*23%*
	4 persons	12%	10%	1%	*23%*
	more than 4 persons	12%	9%	2%	*23%*
	total	*42%*	*41%*	*18%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	-0,2%	0,0%	0,4%	**-0,7%**
	2 persons	0,0%	-0,3%	0,1%	**-0,2%**
	3 persons	0,1%	-0,3%	-0,2%	**-0,4%**
	4 persons	0,1%	0,1%	-0,2%	**0,0%**
	more than 4 persons	0,1%	-0,1%	0,4%	**0,4%**
	total	***1,1%***	***-0,7%***	***0,5%***	***0,0%***

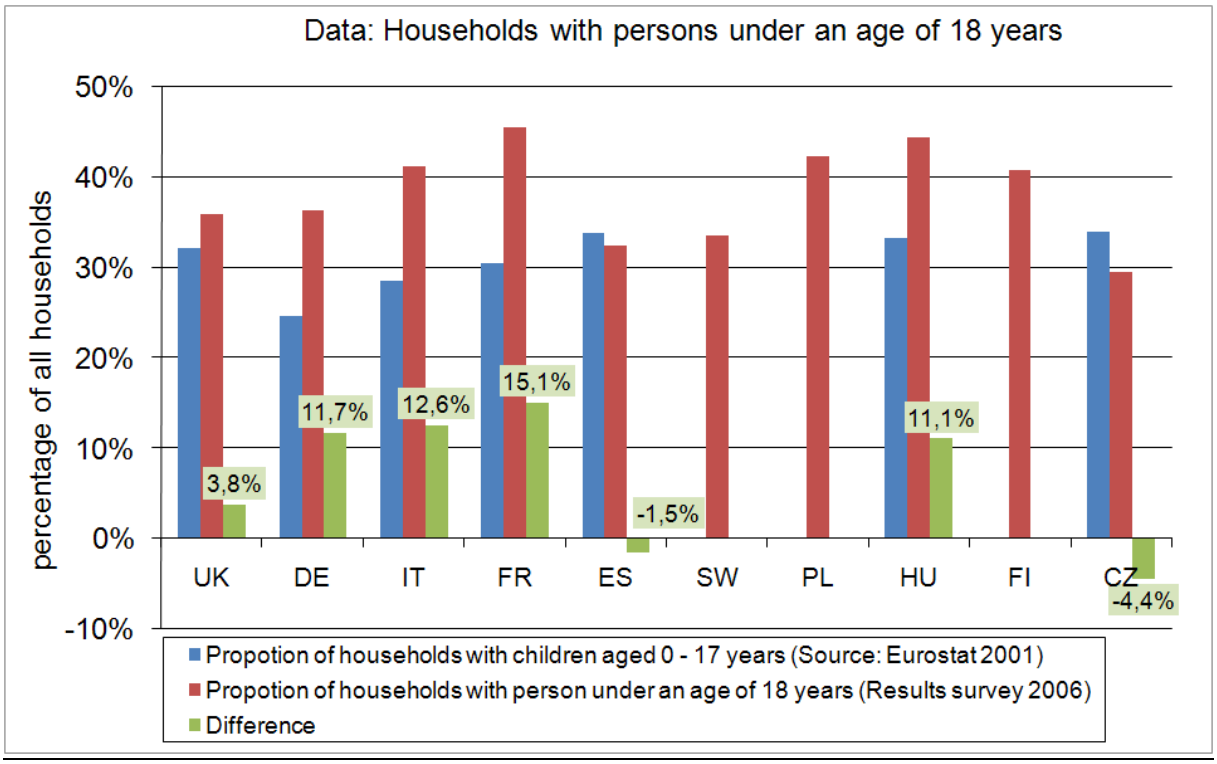
Sweden		Age group			total
		20-39 years	40-59 years	60 and 74 years	
results own survey	1 person	12,5%	8,6%	5,9%	27,0%
	2 persons	7,8%	12,1%	15,2%	35,2%
	3 persons	7,0%	7,0%	1,2%	15,2%

	4 persons	7,4%	7,8%	0,0%	15,2%
	more than 4 persons	3,5%	3,9%	0,0%	7,4%
	total	*38,3%*	*39,5%*	*22,3%*	*100,0%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Eurostat*	1 person	12%	9%	6%	*27%*
	2 persons	8%	12%	15%	*35%*
	3 persons	7%	7%	1%	*15%*
	4 persons	8%	8%	0%	*16%*
	more than 4 persons	3%	4%	0%	*7%*
	total	*38%*	*40%*	*23%*	*100%*
		Age group			total
		20-39 years	40-59 years	60 and 74 years	
Differences	1 person	-0,5%	0,4%	0,1%	**0,0%**
	2 persons	0,2%	-0,1%	-0,2%	**-0,2%**
	3 persons	0,0%	0,0%	-0,2%	**-0,2%**
	4 persons	0,6%	0,2%	0,0%	**0,8%**
	more than 4 persons	-0,5%	0,1%	0,0%	**-0,4%**
	total	***-0,3%***	***0,5%***	***0,7%***	***0,0%***

Appendix 3.1- 2 Population by household size (results of this survey vs. Eurostat data)

	People per household	CZ	DE	ES	FR	IT	HU	PL	FI	UK	SW
Source: EUROSTAT (2005)[80]	1 person	30,3%	35,8%	20,3%	31,0%	24,9%	26,2%	24,8%	37,3%	30,2%	no data
	2 persons	28,2%	33,8%	25,2%	31,1%	27,1%	28,8%	23,2%	31,5%	33,9%	
	3 persons	18,9%	14,5%	21,2%	16,2%	21,6%	19,7%	19,9%	13,6%	15,5%	
	4 persons	17,5%	11,5%	21,5%	13,8%	19,0%	16,5%	18,0%	11,1%	13,4%	
	more than 4 persons	5,2%	4,4%	11,8%	7,9%	7,5%	8,7%	14,1%	6,5%	7,0%	
		CZ	**DE**	**ES**	**FR**	**IT**	**HU**	**PL**	**FI**	**UK**	**SW**
Results survey	1 person	13,4%	16,0%	8,4%	13,2%	12,4%	11,2%	10,8%	20,0%	16,0%	26,8%
	2 persons	26,3%	40,4%	19,6%	32,4%	20,0%	26,8%	22,0%	36,4%	32,8%	35,6%
	3 persons	25,5%	22,0%	23,6%	21,6%	26,4%	26,4%	26,4%	18,4%	24,0%	15,2%
	4 persons	26,3%	14,8%	27,6%	20,4%	29,2%	22,4%	21,2%	16,0%	18,0%	15,2%
	more than 4 persons	8,5%	6,8%	20,8%	12,4%	12,0%	13,2%	19,6%	9,2%	9,2%	7,2%
		CZ	**DE**	**ES**	**FR**	**IT**	**HU**	**PL**	**FI**	**UK**	
Differences	1 person	-17%	-20%	-12%	-18%	-12%	-15%	-14%	-17%	-14%	
	2 persons	-2%	7%	-6%	1%	-7%	-2%	-1%	5%	-1%	
	3 persons	7%	7%	2%	5%	5%	7%	6%	5%	8%	
	4 persons	9%	3%	6%	7%	10%	6%	3%	5%	5%	
	more than 4 persons	3%	2%	9%	4%	5%	4%	6%	3%	2%	

80 http://epp.eurostat.ec.europa.eu/extraction/retrieve/en/theme3/cens/cens_nheco?OutputDir=EJOutputDir_1244&user=unknown&clientsessionid=2D0572A025FB02509B4413EF05D8A0DC.extraction-worker-1&OutputFile=cens_nheco.htm&OutputMode=U&NumberOfCells=72&Language=en&OutputMime=text%2Fhtml&



Appendix 3.1- 3 Population: Households with persons under an age of 18 years (results of this survey vs. Eurostat data. For Sweden, Finland, Poland no data available)