

Energy&Appliances 2015 project: a new approach for testing appliances with respect to end-users behaviour

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Abstract

The paper will deal with the characterization of the market of household appliances with particular attention to the role of the consumer in selecting the greatest eco-efficient products and to new requirements related to electronics.

Characteristic user profiles have been defined, based on literature data, laboratory experience and *ad hoc* investigations at national and local level with deep analysis of the main parameters such as dimensions and type of families, type of house, appliances in use, use habits, consciousness and sensitiveness about aspects concerning the environment protection and the rational use of energy, perception of the user about economic aspects, information for improving the service given by appliances.

New testing procedures have been determined and tests have been performed on "standard" appliances and they are in progress on the improved, more efficient ones. The paper will show in particular the testing results for refrigerator-freezers.

Introduction

In the framework of "Industry 2015 Energy Efficiency", funded by the Ministry of Economic Development - Area Technology B5.1 "Innovative technologies for the production of high efficiency appliances, with reduced environmental impact throughout the lifecycle in terms of reuse of materials also including the ease of assembly and disassembly", the project Energy&Appliances 2015¹ aims at creating of a family of highly innovative appliances, characterized by the use of materials and technology which so far have never been applied to the reference sector. These may greatly reduce energy consumption and environmental impact of their own, even at disposal and recycling. The main objective of the project is to develop a range of appliances within three years, characterized by a considerable reduction in consumption of energy and water, through the implementation of specific evidence. The various steps involved in the large enterprises, SMEs, research institutes, is located around the centers of Italian excellence ensuring access to skills necessary to consolidate the new solutions through research, validation, regulatory law and technological transfer.

In developing the project, across all product lines, the following main areas will be investigated:

- Innovative materials for improving energy efficiency and reducing environmental impact;
- Innovative technologies for cleaning clothes and dishes;
- Innovative technologies for the preparation and storage of food;
- Innovative Electronic Technologies (sensors, control logic, user interfaces);
- New methods for the qualification and certification of the products.

To achieve the objectives of the project, there are three main phases to be developed over the total duration: research on all macro-areas in order to demonstrate the potential applicability of the solutions through the development of prototype pre-engineered demonstrators (pre-technical,

¹ www.energyappliances2015.it

technological and economic); the final realization of demonstrators, including some most promising solutions, after verification of the technical, technological and economic aspects. The final phase involves energy impact analysis including product certification.

The EU energy label is designed to provide consumers with accurate, recognizable and comparable information on domestic household products regarding energy consumption, performance and other essential characteristics. It allows consumers to identify how energy efficient a product actually is and to assess a product's potential to reduce energy costs. The label is uniform for all products in a given category. Consumers can compare easily the characteristics of appliances in a given category such as energy or water consumption, or capacity. All the information the label contains is based on test standards prescribed in the European Legislation. The label initially classified products from A to G, A being the most efficient energy class and G the least efficient. The freshly revised European legislation introduces classes up to A+++ to adapt to technological developments and to allow further product differentiation in terms of energy efficiency.

New labels take into account the state of art of the market, but also is more linked with user habits; this process is at different stages of implementation, depending on the different appliances. E.g., for Washing machines, the label no longer includes a washing performance class as an A class washing performance is mandatory for all washing machines with a washing efficiency class greater than 3 kg. Annual energy consumption is in kWh (no longer per cycle), and the annual energy & water consumptions, and the spin-drying efficiency class indicated on the label, are calculated on the basis of: 60°C cotton programme at full and partial load, 40°C cotton programme at partial load, Left-on mode and in off-mode. This choice comes from the analysis of user's habits. While in the past the high-temperature cotton cycle was the reference cycle, today people use washing machines with a number of loads and prefer lower temperatures; furthermore, the actual washing machines include a lot of electronic devices – i.e. additional energy consumption - which operate also when no washing cycle is active.

Standards themselves are periodically reviewed, to take into account technological changes. For refrigerating appliances, the standard energy consumption is related to a "static" (e.g. without door opening or load operations) situation in a relatively severe boundary conditions (ambient temperature). It is considered a good approximation of the mean European kitchen, where ambient temperature is lower than the reference one, and simplifies the testing procedure.

Nevertheless, it is important to investigate user habits and define new testing standards, aimed to be more and more close to the real working conditions of appliances.

Moreover we observe that the standard conditions do not allow to exploit the energy saving potentials due to (new) technical solutions able to limit the air changes (by openings) within the cold compartments (e.g. some appliances switch on the controls immediately after each door opening, other appliances may use fuzzy logic or other devices to improve energy savings). This is the case of a new Indesit's prototype that ENEA will monitor in next few months, also defining *ad hoc* user schedules.

Characterizing the market of household appliances and the user profiles

General

To assess the effectiveness of the EU energy efficiency policy measures for household appliances on the national market an enquiry was developed by ENEA in the second half of 2010 to investigate the presence and the main energy efficiency and technical characteristics of the domestic appliances installed in the Italian households. The enquiry was developed in the framework of the Agreement between ENEA and the Italian Ministry for Sustainable Development [1].

The enquiry was realised through an on-line Questionnaire. It included questions with closed answers and was designed to last no more than about 20 minutes. The content of the questions was prepared by ENEA while the questionnaire layout and adaptation to the on-line environment and collection of the answers was done by the society ODC Services, a firm specialized in on-line interviews with a panel of 425.000 households in Europe. Among those having answered to the Questionnaire, and therefore owning a PC and able to use Internet, a sample of 3 000 answers was selected.

Within the participation in the Energy&Appliances 2015 project the Ispra Working Group of ENEA has promoted a monitoring campaign in the domestic and European context by involving the researchers of the European staff by the Commission DG JRC² of Ispra. JRC and ENEA have been collaborating in the promotion and implementation of their own researches especially in the energy sector within Memorandum of Understanding ENEA-JRC. The Institute for Energy and Transport - Renewable Energy Unit, the External Relations and the Green Team have supported this initiative.

Starting from a survey launched by ENEA in 2010, the questionnaire was revised focusing on the new target and the household appliances object to the project, while adapting the relative questions to the new European legislation on energy efficiency. The 2012 questionnaire was written both in Italian and English languages and made available online thanks to the collaboration with the ICT Technical Unit of ENEA in Casaccia (Rome) and Saluggia (VC). The survey was launched by the involvement of the Green Team within the JRC.

In order to find some similarities between this survey 2012 within JRC Ispra and the previous one (2010) promoted within Italian families, it is necessary to point out that the questions are not completely comparable as they refer to different communities and they have been adapted to different occupation profiles: the first one is targeted to a standard Italian family and the other is composed of personnel working in JRC-Ispra, coming from countries of the European Union. The JRC researchers have a medium-high professional profiles, often live in the surrounding area of Ispra, in municipalities with different population groups, overall only during the work week, some in residence and are aged 18-54 years.

The 25 participants in the survey were invited to apply to the monitoring campaign of the use of three kind of appliances during a week. Therefore during the month of January 2012 a logbook was filled in by 9 families. In accordance with the Company Indesit, only fridge-freezers, washing machines and dishwashers have been included in this monitoring campaign. The sheet was arranged to get back general information about the appliances and a weekly report of the use of it.

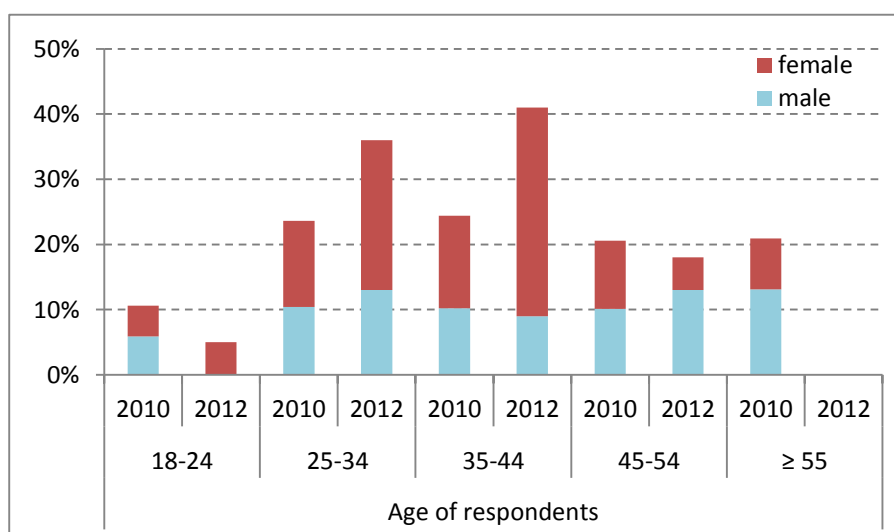


Figure 1 - Age and gender of the respondents to the 2010 and 2012 surveys.

Referring to Fig. 1 showing age and gender it is important to point out that the ODC investigation received the largest number of responses raised from the South and Islands with 35,4%, followed by North West regions with 25,5%, Central Italy with 20,3% and North-East regions with 18,8%. Participants in the 2012 survey lived near Ispra but came from different EU Countries.

² <http://ec.europa.eu/dgs/jrc/index.cfme>

Object of the survey 2012

The 2012 questionnaire was composed of two parts. The first section listed questions for private data of the compilers:

- Sex;
- Age;
- Nationality;
- Profession;
- Educational qualification;
- Composition of the family unit;
- Years of residence in Italy;
- Type of housing situation;
- Population of the town of residence;
- Types and quantity of household appliances own;
- Types and quantity of household appliances in wireless;
- Weekly use of the kitchen nook;
- % of energy consumption of the different appliances in the electric bill;
- Most energy consumers appliances;
- Relevance of the habits for energy savings;
- Behaviour of the family to save energy;
- Respect of the environment.

The second part, reported a new list of questions on the basis of the appliances used; in particular, for cold appliances (refrigerating and wine storage) we asked for:

- Volume (estimated and real);
- Age of the appliances (estimated or real);
- Type of installation;
- Type of cooling system;
- Use;
- Automatic defrost system and frequency of use;
- Refrigerator:
 - Presence and quantity of low temperature compartments (refrigerator);
 - Quantity of stars at the low temperature compartments (refrigerator);
- Freezer:
 - Type of loading door;
 - Type of cooling system;
 - Freezing of fresh food;
- Refrigerator-freezer:
 - Number of opening doors;
- Wine storage appliances:
 - Number of compartments at different temperatures;
 - Range of available variable temperatures;
 - Type of wine storage appliances.

Moreover additional questions (same for all types of appliances) were proposed about:

- Purchase through Governmental incentives;
- Noise level;
- Energy Efficiency Class;
- Knowledge of energy labelling;
- Use of Operating Manual;
- Usefulness of the Operating manual;
- Interpretability of commands;
- Criteria adopted for choosing a new appliance;
- Criteria adopted for the disposal of the old appliance;
- Comments on information provided by TV, internet, advertising materials.

During the monitoring campaign by logbook on the use of washing machine, dishwasher and cold appliances a list of information were asked. In particular, for refrigerator and freezer:

- Model and brand;
- Type of installation and location;
- Class of energy efficiency;
- Date of purchase (real or estimated);
- Dimension and volume;
- Equipment of devices (inner LED, humidity control, inner shelves, door pockets, fruit and vegetable drawers, tempered glass shelves, chill compartments);
- Cooling system;
- Controls (display and selector of program).

In the weekly diary the users were asked to report for each day their behaviours:

- Maintenance: cleaning of back of the appliance, of inner compartments and drawers for freezer and refrigerator respectively, cleaning of gasket.
- Daily actions: storage of cold food, freezer of fresh food, use of closed containers, storage of food according to different level of chill, number of opening.

General results

The following table lists 2010 and 2012 survey results, focusing only on appliances analysed in both surveys.

Table 1 – Sharp look at ownership and remarks to household appliances (2010-2012 surveys).

	Survey 2010	Survey 2012
Subject	Italian families	JRC community in Ispra
N. of questionnaire	3000 families out of 60,6 Mio of citizens	25 families out of 1600 researchers
Most owned appliances	Fridge-freezer or Fridge+freezer → 100% Washing machine → 95.3% Oven → 94.4% Cooker → 86.6% Dishwasher → 60%	Fridge-freezer or Fridge+freezer → 100% Oven → 84% Washing machine → 84% Dishwasher → 60%
Household appliances networking	Washing machine → 20.6% Oven → 18.2% Fridge-Freezer → 15.3% Dishwasher → 12.7% Cooker → 13.6%	Oven → 18% Fridge-Freezer → 17% Dishwasher → 13% Washing machine → 13% Cooker → 9%
Use of cooker	More time each days → 66.3% One time a day → 27.7%	One time a day → 59% More time each days → 36%
Incidence of appliances consumption on own energy bills	More than 75% → 7.3% Between 50% and 75% → 37.9% Between 20% and 50% → 46.2% Less than 20% → 8.7%	More than 75% → 14% Between 50% and 75% → 41% Between 20% and 50% → 27% Less than 20% → 18%
Most energy consumer appliances	Washing machine Electric Oven Dryer Dishwasher Fridge-freezer	Electric Oven Washing machine Dryer Fridge-freezer Dishwasher
Relevance of habits for saving energy	Yes → 60.1% Enough → 39.6% Other → 0.3%	Yes → 60% Enough → 32% Other → 8%
Behaviour of the family	Adoption of common rules → 72.5% Individual behaviour → 25.1%	Adoption of common rules → 72% Individual behaviour → 28%
Respect of environment	Enough → 60.5%	Enough → 59%

	Always → 32.6% Sometimes → 6% Low → 0.9%	Always → 41%
Knowledge of the energy labelling	Yes → 35.7% No → 34.5% I have heard → 29.8%	Yes → 97% No → 3%
Purchase incentivated by tax allowance³	Refrigerators – No → 33% Fridge-Freezer – No → 62.3% Freezer – No → 34%	Refrigerators – No → 63% Fridge-Freezer – No → 61% Freezer – No → 89%
Higher level of noise	Washing machine Fridge-Freezer Refrigerators Freezer	Freezer Wash-dryer Washing machine Dishwasher
Consultation of Operating Instructions	Often → 51.9% Always → 33.1% Sometimes → 13.3% Almost never → 1.7%	Always → 32% Often → 32% Sometimes → 20% Almost never → 16%
Remarks to Operating instructions	Useful → 55.1% Complex → 27.1% Incomplete → 21.6% Easy → 9.4% Exhaustive → 5.6% Useless → 1.8%	Useful → 52% Incomplete → 28% Exhaustive → 9% Complex → 8% Easy → 3% Useless → 0%
Criteria for purchasing a new appliance	Consumption Cost Brand	Consumption Brand Cost
Disposal of the replaced appliance	Retailer Garbage dump Leave it to other person	Retailer Garbage dump Leave it to other person
Judgment on information by media	Useful → 39% Tendentious → 34% Incomplete → 11.3% Often false → 8.4%	Incomplete → 42% Tendentious → 39% Useful → 11% Often false → 8%

In particular, we observed that:

- the vast majority of respondents judge themselves as people careful (very or fairly) to the energetic (92%-99%) and environmental (93%-100%) issues, implying that the nominal energy consumption of a new appliance is the most important criteria for purchasing;
- often (especially after purchase and until the useful programs are chosen) the respondents searching for information in the manuals, that they consider useful (52%-55%), but also incomplete (22%-28%) and complex (8%-27%);
- the information by media is often judged as tendentious or false (42%-47%) and incomplete (11%);
- the respondents of both samples did not recognize the cold appliances as the most energy consumer ones. Because, in general, the main household consumptions are due to these appliances [2] we impute these erroneous responses to an interesting misunderstanding

³ In April 2010 the Italian Government issued a National decree promoting the replacement of dishwashers, electric ovens, hobs and other Household Appliances with energy labeling of the highest classes or more efficient ones. The incentives had been applied to buyers as a discount of 20% or reduction on price up to 2010. Even in the previous year a 20% tax deduction was issued for the purchase of low energy consumption appliances.

between energy and power, that don't allow a complete comprehension of the household energy consumptions.

Results about Cold appliances

2010-2012 surveys

The present paper will analyse in details only cold appliances. While considering the two surveys not comparable for the reasons mentioned before, an effort was made to find out their analogies.

Table 2 – Sharp look at characteristics of the installed refrigerating appliances (2010-2012 surveys).

Question		Refrigerator		Refrigerator-freezer		Freezer		Wine storage appliance	
		2010	2012	2010	2012	2010	2012	2010	2012
Energy efficiency class	A++	15%	20%	18%	8%	13%	11%	13%	0%
	A+	28%	20%	35%	33%	28%	11%	21%	100%
	A	24%	40%	21%	25%	22%	56%	21%	0%
	don't know	25%	20%	20%	33%	26%	22%	40%	0%
Installation	freestanding	51%	33%	62%	38%	82%	64%	n.a.	n.a.
	built-in	47%	67%	38%	62%	17%	36%		
	other	2%	0%	0%	0%	1%	0%		
Cooling system	static	30%	9%	20%	15%	36%	20%	n.a.	n.a.
	air-circulation	21%	9%	21%	15%	13%	0%		
	no-frost	27%	18%	38%	31%	20%	10%		
	don't know	22%	64%	21%	38%	31%	70%		
Low temperature compartments	4-stars	0%	0%	100%	n.a.	100%	n.a.	n.a.	n.a.
	3-stars	41%	14%	0%		0%			
	2-stars	11%	14%	0%		0%			
	1-star	4%	15%	0%		0%			
	0-star	8%	0%	0%		0%			
	don't know	37%	57%	0%		0%			
Number of doors and configuration	combi	n.a.	n.a.	49%	42%	n.a.	n.a.	n.a.	n.a.
	2 doors			45%	58%				
	side-by-side			4%	0%				
	>2 doors			1%	0%				
Purchases with state incentives?	No	89%	62%	88%	48%	91%	45%	n.a.	n.a.
	Yes	11%	38%	12%	52%	10%	55%		
Noise	No	78%	75%	80%	62%	70%	91%	n.a.	n.a.
	Yes	18%	25%	16%	23%	12%	9%		
	don't know	2%	0%	3%	0%	1%	0%		
	installed in another room	2%	0%	2%	15%	18%	0%		
Average age	Years	6.8	5.5	6.0	5.3	6.5	4.5	5.3	

Average volume	Litres	128.2	n.a.	159.2	201.7	129.1	89.4	n.a.	n.a.
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In particular, we consider interesting to note that:

- on average, the most common energy class of cold appliances in use at home is A+, and class B and C are no longer represented unlike samples of period 2007-2008 [3]; the lower presence of appliances at the highest level of energy classes in 2012 is justified by the different sample analysed;
- many users do not know the energy class and the type of cooling system of their own cold appliances, as well the quantity of stars of the refrigerator units;
- the purchases with state incentives of the JRC Community (in 2012) result significantly higher (+30-35%) than the Italian ones in 2010;
- that the average age of cold appliances was reduced (from 6-7 years to 4.5-5.5 year) moving from national to local community (over the period 2010-2012).

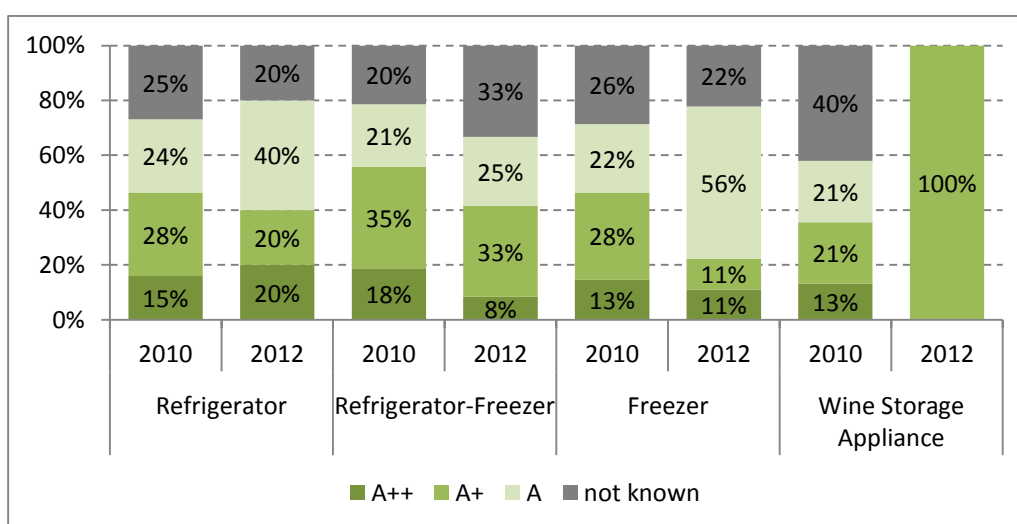


Figure 2 – Sharp look at energy class of cold appliances (2010-2012 surveys).

As shown in Table 3 the survey 2012 aimed also at analysing the personal habits in the use of the appliances.

Table 3 – Personal habits in the use of the cold appliances (Questionnaire 2012).

Question		2012
freezer of fresh food	always	6%
	often	50%
	sometimes	31%
	never	13%
use of freezer for fresh food	lower of the temperature of thermostat	0%
	use of fast freezer / super cool switch	27%
	neither of them	73%
automatic defrost	yes	43%
	no	57%

defrost frequency	once a month	0%
	once every 3 months	15%
	once every 6 months	23%
	once a year	54%
	never	8%

Monitoring activities by logbook 2012

All 9 participants have reported the brand of their appliances; only more than half of them reported the model.

All but one model was built-in, the other were self-standing, with freezer on the bottom. Most of them are in class A+ (45%), one in class A++. Bought in 2005 - 2011 with an average age of 4 years, all refrigerating appliances are in the kitchens.

All appliances are 2-5 shelves, 67% in tempered glass, have door pockets (75%), fruit and vegetable drawers (89%) and a fresh food compartment (50%). 56% of them do not have inner LED. The humidity control is installed in 38% of the refrigerators. Often the users do not know some features, over all inner LED (56%) and the humidity control device (25%).

Table 4 – Features and functions of the refrigeration appliances monitored by logbook.

	Inner LED	Humidity control	Door pockets	Fruit and vegetable drawers	Tempered glass shelves	Fresh compartments
Yes	22%	38%	75%	89%	67%	50%
No	56%	38%	13%	11%	22%	38%
Not known	22%	25%	13%	0%	11%	13%

Programs are selected by manual switch by 75% of users, the remaining 25% by touch control. 71% of the appliances do not have a display, while 29% has a LED display.

Elaborating the data of the logbook we obtained the results shown in Figure 3.

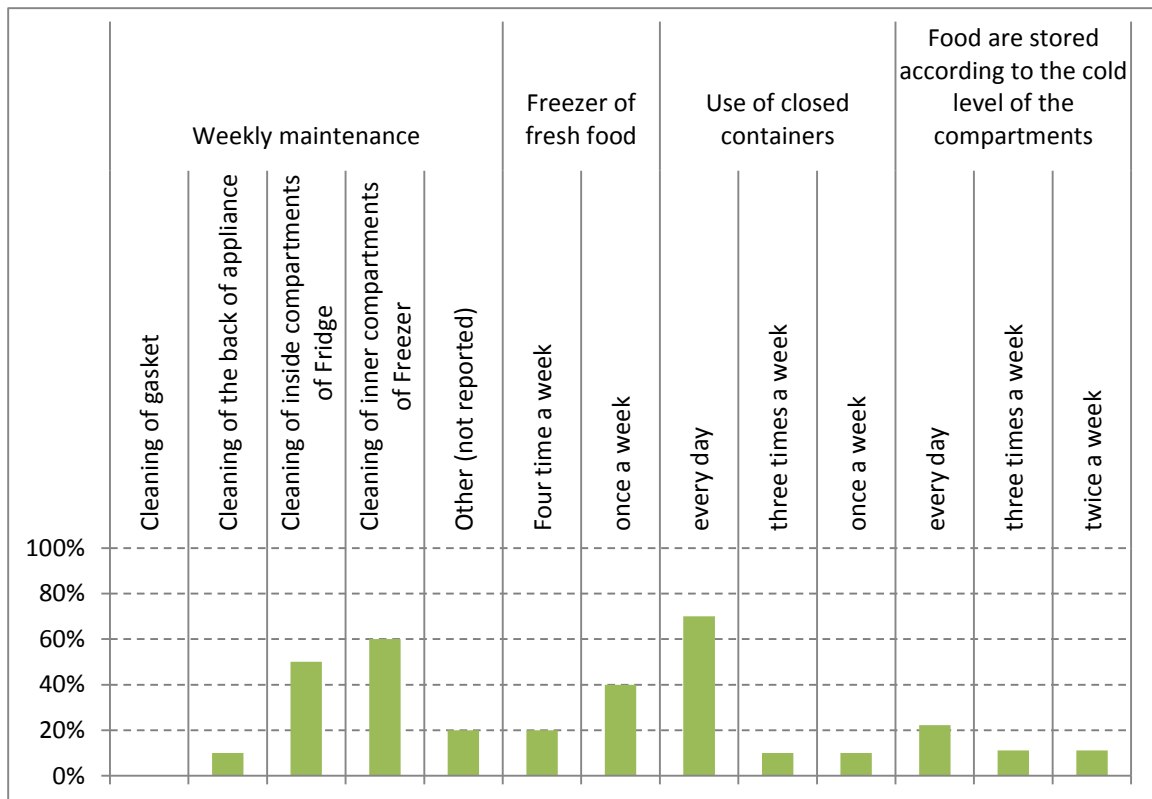


Figure 3 – Personal habits in the use of the cold appliances (Logbook 2012).

The form sheet of the weekly recordings shows that 40% of users do not freeze fresh food and the same percentage don't freeze ever. All users use airtight containers to store food, 78% of them on a daily base. Half of the users does not place the food into the specific cold level of the compartments, 22% performs this operation daily while 11% respectively 2 or 3 times a week. 10% of the users store hot food in the refrigerator for up to 4 times a week.

Cold appliances have been opened 512 times, with a weekly average per unit of 57 times and 8 times daily. Under item "other" a user reported the number of openings in the freezer, with an average of one day opening.

Defining common user profiles for energy assessment

Starting from the data collected we defined new test procedures, able to consider standard user profiles unlike the standard methodologies (EN ISO 15502:2005 [4] and EN 153:2006 [5]) used to certify the cold appliances.

In general, the main factors that affect the energy consumption of a cold household appliance are:

- external air temperature (environment);
- air temperature within the unit (setting of thermostat);
- opening of doors (frequency and duration);
- inserting of loads (food or drink) and their temperature;
- proximity to other heat sources;
- ventilation conditions;
- condition of the seals.

Aware of this, we decided to set up a weekly user schedule for a family of 3 people, defined as follow:

- intermediate setting of the thermostats with respect to the two standard tests of energy consumption;

- opening of refrigerator and freezer doors during the day (Figure 4); insertion of thermal loads in the refrigerator, simulated by test packs and trays of water (Figure 5);
- insertion of thermal loads in the freezer, halved compared to standard tests (Figure 5);
- rotation of the loads in the fresh food compartment and freezer;
- freezing (with function super-freezing) of a mass equal to the freezing capacity declared (5 kg) once a week (on Wednesdays).

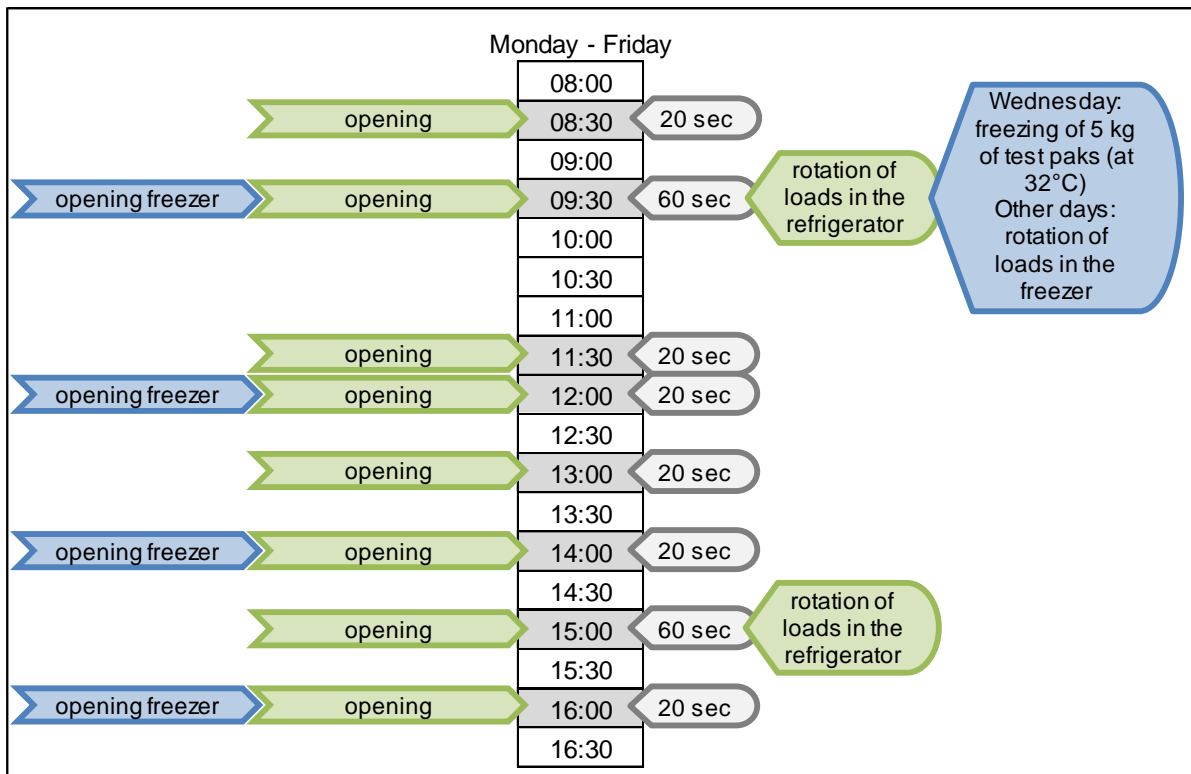


Figure 4 – Weekly user schedule.

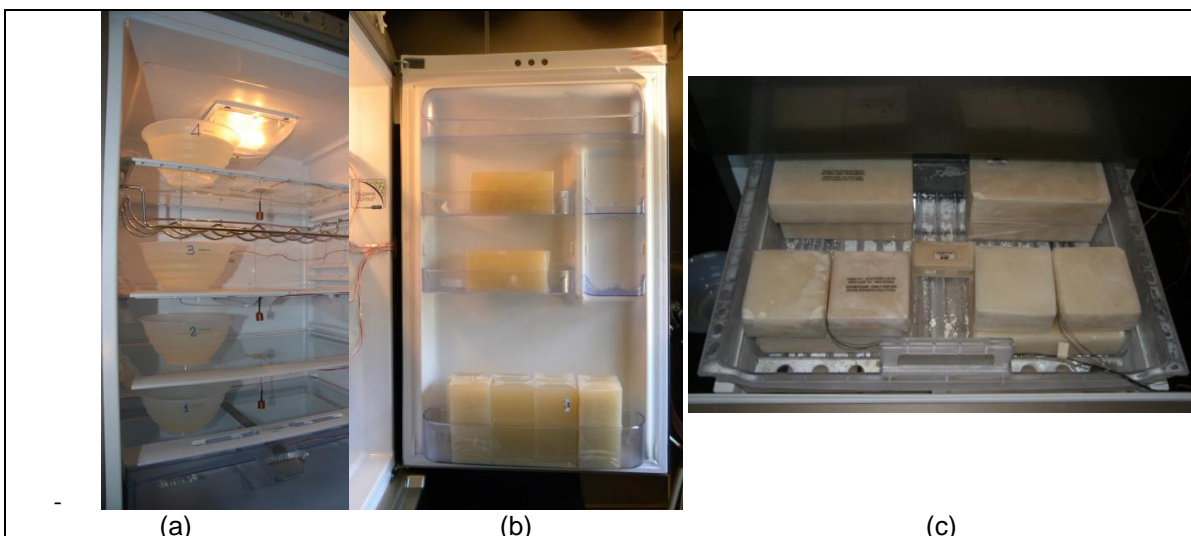


Figure 5 – Thermal loads used within the refrigerator (a, b) and the freezer unit (c).

Setting different environmental air temperatures (19°C, 25°C and 32°C), several tests have been carried out on a testing appliance, obtaining the energy consumptions shown in the following table.

Table 5 – Results obtained applying the new test procedure.

[kWh/day]	Test 1	Test 2	Test 3
	T _{env} = 25°C	T _{env} = 19°C	T _{env} = 32°C
Monday	1.45	1.12	2.08
Tuesday	1.45	1.16	2.10
Wednesday	1.71	1.50	2.24
Thursday	1.57	1.17	2.30
Friday	1.41	0.91	2.14
Saturday	1.17	0.89	1.84
Sunday	1.28	1.00	1.82
Daily average consumption	1.43	1.11	2.07
% difference respect the declared consumption	34%	4%	93%

Conclusion

Within the Energy&Appliances 2015 project, ENEA characterized the Italian market of household appliances and defined characteristic user profiles, also to evaluate the deviation between the real and the standard conditions now applied for energy certification.

Starting from the results of surveys here presented, some general recommendations can be provided:

- The contents of the manuals must be implemented, perhaps with an additional booklet for quick reference. However, it should contain all technical specifications of the appliance and practical tips to reduce energy consumption. Often the user has indicated a lack of knowledge of the requested information or adopted a more efficient use of the device.
- It would be more appropriate to carry out checks on the information transmitted by the media, having been judged often false and misleading, as required by the Framework Directive 2010/30/EC, as well as to perform more targeted and widespread information campaigns at sale's points by trade associations and independent third parties.

About the monitoring analysis carried out, we observe that the simplifying assumptions of standard measurement procedure have a small impact (-4%) only if a low ambient temperature (19°C) is considered applicable (e.g. freestanding appliances, away from other heat sources): the imposition of a high standard T_{env} (25°C) balances failure to consider door openings, thermal load insertions, freezing operations, etc.

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