The costs and benefits of replacing older household's appliances

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1. Abstract

The efficiency of households' appliances has increased significantly in the last years [1]. For instance, the average consumption of a refrigerator is now about 40% less it was 10 years ago [2][3]. The stock of household appliances is very large and the continuous increase in their efficiency means that a huge energy savings potential exist in the residential sector [5] by replacing older equipment by more efficient one. There are many measures aiming at promoting more efficient equipment, but despite these programs and the natural replacement of older (not functioning) equipment, the stock of older equipment seems to be large [3] and about one third of households appliances are 10 or more years old. When the target of the measures is older equipment the expected savings increase substantially in comparison with savings obtained when the measure is applied without taking into consideration the age of replaced equipment. However, the implementation of the measure becomes harder and more expensive than a typical replacement due to the end of life of a given appliance and the social perspective on economic costs of the measures is at risk. In this text it is explored the capability of using public funds to accelerate the replacement of older equipment.

Key words: Energy efficiency, residential sector, appliances labeling, replacement of household appliances.

2. Introduction

Many programs aiming at promoting energy efficient technologies and behaviors on the demand-side have been carried out over the course of the time. Despite there are many well succeed energy efficiency programs, further improvements are needed and possible [3][5], in the sense of improving the effectiveness of such programs and thus increasing the achieved energy savings. According to the EU directive on energy efficiency and energy services, 2006/32/CE, the EU Member States should reduce energy use by 9% in a 9 year time period 2008-2016. Member States should prepare Energy Efficiency Action Plans (EEAP) every three years, establishing targets for annual energy savings of, at least, 1% until 2016, and describing the measures planed to reach the targets. Some indicative measures that can be implemented in order to accomplish the targets of the EU directive are: new efficient devices (refrigerators, freezers, dish and clothes washing machines), domestic generation of renewable energy, labeling, training and education and demand response demand. The Portuguese National Energy Efficiency Action Plan (NEEAP) has been approved by government in 2008 [6] being focused on four specific areas: transportation, households, industry and public sector. Some of the key elements are:

1. Implementing measures aiming at reducing 9.8% of energy consumption by 2015 in accordance to the EU Directive 2006/32/EC
2. Estimates on energy savings by 2015 due to the implementation of NAPEE are 1792 ktoe. The electricity savings by 2015 will be about 4777 GWh (7% of total national electricity consumption).
3. In the residential sector, one of the measures is the acquisition / replacement of domestic cold equipment
    a. 1 000 000 freezers and refrigerators will be subsidized
    b. 75 M€, being 50 M€ to promote class A++ devices and 25M€ to promote class A+
    c. Expected savings with this measure are about 97.5 ktoe
    d. It is expected to increase the penetration of class A+ and class A++ equipment to 37% (refrigerators) and 25% (freezers) in 2015
4. Other measures in the residential sector are: promoting the acquisition of efficient washing machines, efficient windows and insulation, and space heaters using biomass

The following table shows some of the key elements do NAPEE.

Table 1 – Some goals of portuguese NAPEE (residential sector – refrigerators and freezers).

Acquisition/replacement Subsidy (€) per equipment		Number of equipments (thousands)		Costs (M€)			Expected savings	
A+	A++	A+	A++	A+	A++	Total	ktoe	GWh
50	100	500	500	25	50	75	97.5	453

The main targets with the replacement of refrigerators and freezers by efficient devices (A++ and A+ classes) are summarized in the following table.

Table 2 – Estimates of the efficient equipment penetration.

	Savings by 2015 (ktoe)	Targets (penetration %)			
			Actual	2010	2015
Acquisition of A++ and A+ refrigerators and freezers	97.5	Refrigerators	8%	18%	37%
		Freezers	1%	7%	25%
Washing machines	14,6		1%	10%	25%

3. Brief overview

In EU major end-uses consumption are electric heating (22%), domestic cold (15%), lighting (12%) and electric water heating (9%) [10]. In the last decades there has been a continuous improvement in the efficiency of most appliances. According to [10], between 1992 and 2005 the average efficiency of refrigerators and freezers has improved about 40%, while the best available technology in 2005 (A++) is 70% more efficient. As far as washing machines efficiency is concerned between 1996 and 2004 an improvement of about 23% was achieved and an extra energy savings potential of about 12% still exists with the present technology [10]. Despite these broad and high improvement in households appliances' efficiency, electricity consumption in the residential sector has increased about 12,6% between 1999 and 2006 in EU. In the same period of time in the residential sector in Portugal, the increase in the energy consumption was about 12,1%, while the electricity consumption increased about 41%. Among the factors driving this grow of consumption are [10]: increasing number of electric households appliances (e.g. washing machines, air conditioners, computers, printers), new electric end-uses (ty-boxes, routers, DVDs) and the demand for higher levels of comfort.

In Portugal the household sector accounts for about 30% of energy consumption. In Figure 1 the energy consumption disaggregated by end-use is shown. Domestic cold (freezers and refrigerators) accounts for about 33% of household's electricity consumption, follows heating 15%, lighting 12% and washing machines 10%.

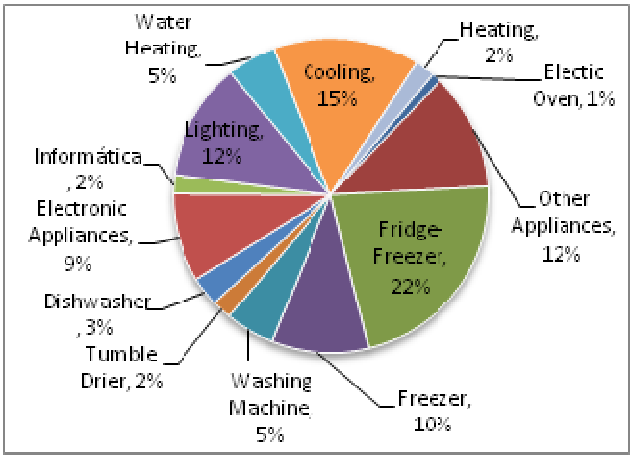

Figure 1 – Consumption in the residential sector in Portugal [General Directorate for Energy and Geology].

According to National Action Plan for Energy Efficiency (NAPEE) the savings obtained by 2015 in the residential sector should be about 330 ktoe, and refrigerators and freezers should account with about 97,5 ktoe. With regard to this equipment the NAPEE aims to support the replacement or acquisition of 1 000 000 devices class A++ and class A+ until 2015. Some should be for replacing old equipment (both old equipment still working and old equipment that reaches the end of life) and the remaining of the budget will be for acquisition of new equipment. The total cost of this measure is 75M€, being 50M€ for subsidizing A++ devices (100€ for each device) and 25 M€ for acquisition of A+ devices (50€ subsidy for each equipment).

The continuous improvement of household appliances efficiency and the sustained energy consumption grow makes this sector a target for energy efficiency programs. And the Action Plan for Energy Efficiency [5] has identified a potential to save energy of about 27% in the household sector. In general, the programs / measures implemented financed by public funds should be chosen according their societal impacts and also having into account the likelihood of its implementation. Promoting more efficient end-use of energy costs money and due to the finite nature of the available money these funds must be used in such a way that maximizes its social benefits (energy savings and avoided emissions). Assessing energy efficiency programs using several axis of evaluation and according different perspectives (individuals, consumers, utilities, society) is a complex problem and different ways to deal with it can be encountered in the literature [1][3][4][11]. A top issue is how to maximize the utility of "available" funds.

4. Analysis

In average 300 000 domestic cold devices are sold in Portugal every year meaning that by 2015 2 100 000 have been sold (maintaining the average sales). According to NAPEE by 2015 about 1 000 000 devices will be subsidized. The acquisition process has no rules meaning that any consumer owning an old refrigerator still working can get the subsidy for acquiring a new one.

According to [1][6][8] the efficiency of refrigerators has increased about 50% between 1994 and 2004, meaning that modern equipment consume in average less 360 kWh/year. Despite equipment bought before 1994 is (in theory) in average near the end of its useful life, some studies [1] indicate that in the refrigerators/freezers stock there are about 33% of devices older than 10 years, meaning a huge savings potential exists in the sector. The arising question is it is possible to subsidize the substitution of older equipment and maintaining the societal interest of this kind of programs? That is, the benefits are higher than costs in a societal perspective. Market value for this equipment is really small; however the value-in-use depends on the owner. Thus, in order to make the replacement of a still working device attractive to the owner, the incentives (rebates, subsidy) should be higher when compared with the situation in which the device reached the end of life. The characteristics (consumption, efficiency, …) of the install equipment are diverse and the energy savings obtained with the replacement of a class D equipment different from the savings obtained when a class G device is replaced. So, instead of using 75 M€ to financing the indiscriminate acquisition of class A+ and class A++ equipment with potential savings of 97,5 ktoe if this money is used for replacing older equipment then higher average individual energy savings could be obtained.

Taking into account the information available at the European Appliance information System site, the average consumption according to the age of equipment is shown in the following figures. The percentage values indicate the rate of ownership according to the age of the equipment [9].

Figure 2 – Average consumption of 2 doors refrigerators (freezer on the top).

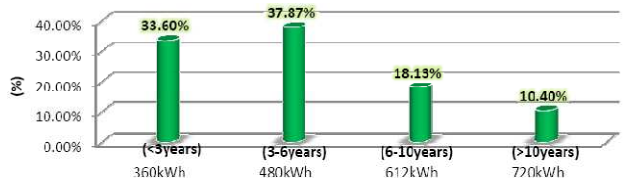

Figure 3 – Average consumption of 2 doors refrigerators (freezer on the bottom).

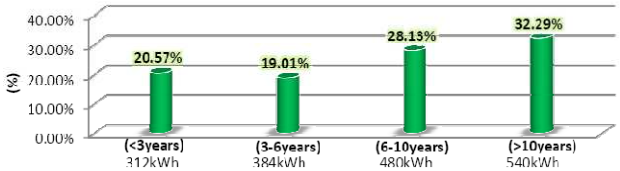

Figure 4 – Annual average consumption of freezers according to their age.

For example, replacing a 2 doors refrigerator with the freezer at the top older than 10 years (average consumption = 600 kWh) by a class A+ refrigerator (average consumption = 187 kWh) the energy saving is about 413 kWh. Replacing a refrigerator 3-6 years old (average consumption = 408 kWh) by the same A+ device the energy savings are about 221 kWh.

Taking into consideration the penetration of different appliances and considering that one third of the appliances stock is older than ten years [2] than the savings obtained by replacing devices older than 10 years by a class A device are shown in the following table.

Table 3 – Savings by replacing all devices older than 10 years by a class A equipment.

Appliance	Annual savings (GWh)
2 doors refrigerator (freezer at the top)	212.8
2 doors refrigerator (freezer at the bottom)	210.3
Freezers	163.5
Washing machines	138.9

Follows the analysis of replacing one appliance, considering the costs and benefits during the average life of the appliances according to the net present value (social perspective) and considering a discount rate of 5%. The calculations are done considering the replacement of one device by a class A++ equivalent device.

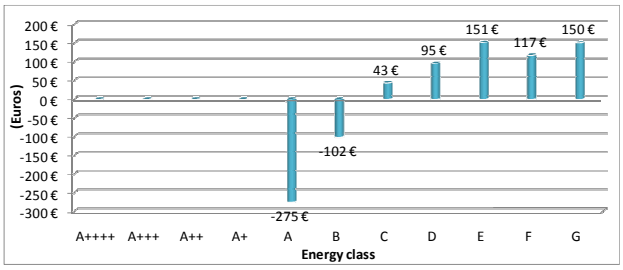

Figure 5 – Net present value for refrigerators with freezers at the top (replacng on inneficient refrigerator by a class A++ refrigerator).

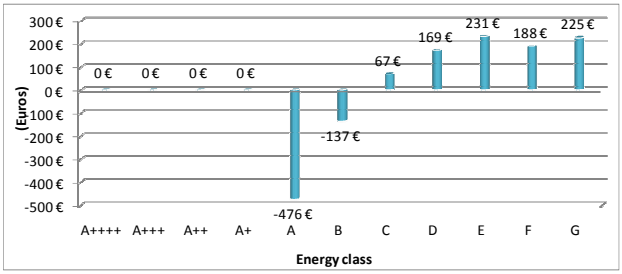

Figure 6 – Net present value for refrigerators with freezers at the bottom (replacing on inneficient refrigerator by a class A++ refrigerator).

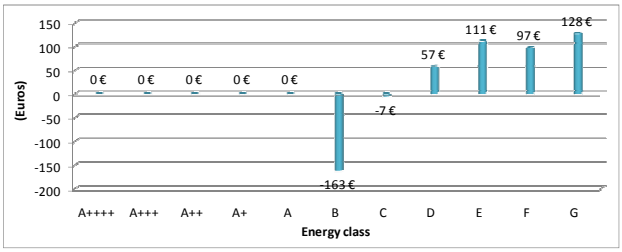

Figure 7 – Net present value for freezers (replacing one inneficient freezer by a class A++ freezer).

For the calculations shown in figures 5-7 the following parameters have been used.

Table 4 – Some values for computing net present value.

	Refrigerators with freezer at the top	Refrigerators with freezer at the bottom	Freezers
Standard technology	Class A 268 kWh/year 320 €	Class A 268 kWh/year 320 €	Class A 268 kWh/year 320 €
Efficient technology	Class A 268 kWh/year 320 €	Class A 268 kWh/year 320 €	Class A 268 kWh/year 320 €
Discount rate = 5%			
Average kwh price = 0.111 €			

Table 5 shows the ratio benefit/cost of replacing a device of a given class (left most column) by an efficient equipment (class A++ for 2 doors refrigerators with the freezer at the top; class A+ for 2 doors refrigerators with freezer at the bottom and freezers).

The measures under NAPEE focused on refrigerators and freezers aims at reducing about 97.5 ktoe with a 75 M€ budget. That is, each replacement allows to save, in average, 97,5 kgoe or 453.5 kWh in 2015! However, with more focused measures higher energy savings could be obtained with lower budget. Eventually a more narrow and focused usage of economic incentives would provide better results. In table 6 the costs of replacing equipment (refrigerators with freezer at the bottom) of class E/F/G are shown. These values can be even more impressive if we take into consideration some studies that say about 1/3 of household appliances are over 10 years old.

Table 5 – Benefit/cost ratio.

	Ratio benefit/cost		
Energy class	Refrigerators 2 doors with freezers at the top	Refrigerators 2 doors with freezers at the bottom	Freezers
A++++	NA	NA	NA
A+++	NA	NA	NA
A++	NA	NA	NA
A+	NA	NA	NA
A	0.28	0.19	NA
B	0.63	0.59	0.50
C	1.24	1.36	0.97
D	1.73	2.99	1.33
E	2.51	5.20	1.77
F	2.30	5.17	1.72
G	2.70	6.50	1.81

Table 6 – Costs of replacing older refrigerators.

Class	Number of devices	Costs - subsidy	Savings (kWh)
E	137 576	13.8 M€	64.7 (18.8 ktoe)
F	78 904	7.9 M€	43.5 (12.6 ktoe)
G	78 904	7.9 M€	51.2 (14.9 ktoe)

The potential for energy savings of full replacement of class D and lower refrigerators is large. Typically a class D refrigerator (with 2 doors) consumes in average more 389 kWh per year than class A+ equipment. If we consider all the devices as being class D (this is a conservative approach since in reality there many equipment belonging to classes E/F/G thus the savings are higher) and all of them are replaced by class A+ equipment than savings higher than 607 GWh (127 k toe) per year could be obtained (following table).

One of the most important barriers to such focused measure is the need for accurately identify devices belonging to class D or lower. However, an alternative is to focus the measure in the age of the equipment.

Table 7 – Estimated consumption.

	Existing equipment		Estimated consumption	
	%	Number (thousands)	GWh	K toe
2005	44	1 560	607	131
2015	16	250	97.3	28.2

5. Conclusions

In average equipment 10 years old consume more 473 kWh than a A+ device, meaning than the replacement allow to save 607 GWh (131 ktoe), which is almost 40% of the expected savings in the residential / services sector in the NEEAP. However, identifying and selecting older equipment for being replaced by efficient one can be a hard task.

In order to increase the success chances a campaign informing consumers that with the replacement of old equipment they are saving big quantities of energy and if they take the 100 € subsidy then the payback of acquiring new equipment is between 8 and 9 years. Consumers can start saving money to buy new equipment when the class A+ equipment reaches the end of its life. This massive replacement costs 100 M€. Implementing the NAPEE as it is now means that 250 thousand devices worst than class D still exist by 2015 with an extra 97.3 GWh (28.2 ktoe) annual electricity consumptions.

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