Electricity consumption of cold appliances, washing machines, dish washers, tumble driers and air conditioners. On-site monitoring campaign in 100 households. Analysis of the evolution of the consumption over the last 20 years

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Abstract

Monitoring campaigns have shown since 20 years that domestic electricity consumption structure has drastically changed and is in constant and rapid evolution. Unitary consumptions of most appliances have decreased, mainly thanks to EU directives. But these energy savings have been compensated by new additional consumption, possibly because of increase of ownership level, appliance size, as well as emergence of new devices.

To explore in detail the structure of electric household consumption in France, massive monitoring campaigns have regularly been carried out. In 2015/2016 a campaign has been done in 100 French households in which the electricity consumption of cold appliances, washing machines, dish washers, tumble driers and some air-conditioners has been monitored at 10 minute intervals for 1 year.

This study assesses the different factors that influence the consumption:

- Technical features due mainly to stock renewal and European Eco design and Energy Labelling Regulations.
- Possible behavior changes related to evolution of social practices.
- It shows that during the last 20 years:
- The total household electricity consumption is stable.
- Cold appliances consumption has been divided by a factor 2, but reduction in energy consumption is not the same for all types of appliances.
- Washing machine and dish washer electricity consumptions have been reduced by respectively 65 % and 41 %.
- The share of total household electricity consumption covered by cold and washing appliances has been reduced by a factor 2.

As the total household electricity consumption is more or less constant and the one of the main appliances has decreased it raises questions about the current distribution of electricity consumption between the different household equipment.

Introduction

During the last ten years, numerous programs have been implemented in order to reduce buildings energy consumption, focusing mainly on heating use (dominant energy load), and successfully leading to significant reduction in heating consumption. But on the other hand, households' specific electricity consumption has followed an opposite trend despite proactive EU framework directives (see Figure 1[1]).

Households' specific electricity consumption plays therefore automatically an increasingly important role.

Very few monitoring campaigns of household electricity consumption have been conducted so far at the European

1. Source: Energy Efficiency Trends for households in the EU, Lessons from the Odyssee-Mure Project, 2013.

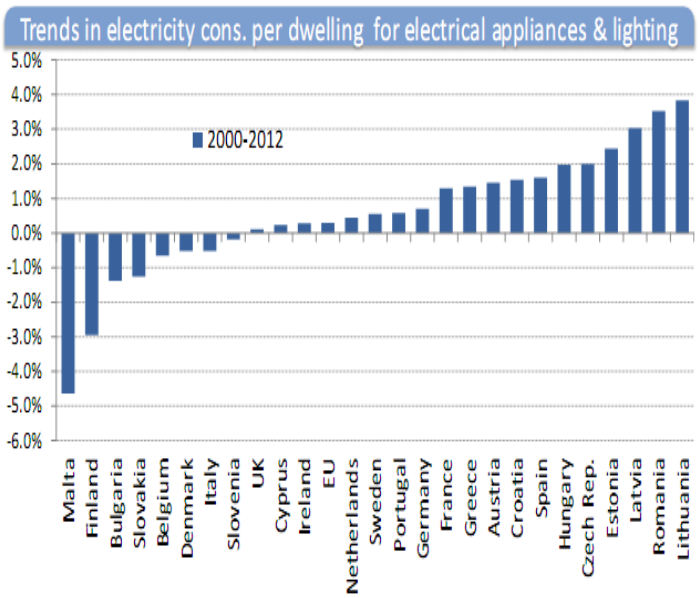

Figure 1. Evolution of households' specific electricity consumption.

level. In France, monitoring programs have been carried out regularly since 1996.

This paper presents the results of a project that aims at updating knowledge on energy consumption of cold, washing, drying appliances and on air conditioning systems. Previous data available for France is given in Table 1.

During the last years, the stock has naturally been replaced but in addition European Labeling and Ecodesign regulations[2] have been implemented, which significantly influenced the global EU electricity consumption[3]. The main goal of the study is to estimate actual consumption of targeted specific household equipment and to analyse evolution over the last 20 years.

The first section provides more details on the method (sample selection and monitoring equipment). The following sections present the results. The two last sections draw some conclusions on the evolution of household electricity consumption and give some recommendations on possible actions to be implemented at European level.

Method

SAMPLE DESCRIPTION

107 households have been monitored for one year. In order to select the sample, the most representative data of the French residential sector (from INSEE – national institute of statistics and economics study) have been used, focusing on the following criteria:

- Geographic location
- Type of residence: house or flat
- Household location: city, suburban area or countryside
- Number of people of the household (adults and children)
- Socio-professional category.

It can be seen on Table 2 that the equipment rate of the sample is very close from the national values therefore its representativeness is satisfactory.

MONITORING EQUIPMENT

Electricity consumption has been monitored with the help of dataloggers (Figure 2). They measured and stored electricity consumption of plug loads at a ten minute intervals throughout one year.

During one month, participants also filled follow-up questionnaires in order to describe the different washing/drying programs they use. The results have been cross-analysed with electricity consumption.

Unitary Electricity consumption of the monitored appliances

Table 3 gathers the main results of *Froid Lavage* monitoring campaign (Enertech 2016) and compares them to previous programs.

In the next paragraphs, detailed analysis is given for each appliance.

COLD APPLIANCES

Energy consumption of cold appliances has been halved since 1996, and has decreased by 21 % since 2008 (Figure 3). But reduction in energy consumption is not the same for all types of appliances.

Fridge

The average consumption of a fridge is nowadays 211 kWh/year (17 % reduction compared to 2008). The most energy consuming equipment (old appliances sold prior the implementation of regulation) has been phased out. They have all been manufactured after the introduction of first regulations on cold appliances (1995). The monitored performances are not directly related to the energy label: the best rated appliances are not the less consuming. The two main determinants of electricity consumption are now the adjusted temperature set point and the volume of the appliance. What is surprising, however, is that as we can see in Figure 4 the biggest fridges (net volume) consume less electricity than the small volume models which are mostly built-in refrigerators. VHK and Armines (2016) indicate that the built-in appliances are less insulated and ventilated than stand alone models leading to worse performance.

Fridge freezer

The average consumption of a fridge freezer, except American style, is 386 kWh/year (18 % reduction compared to 2008). Despite the fact that they comply with European energy standards, two types of appliances remain high energy consumers: American style and air-ventilated models (Figure 5).

2. Regulation 643/2009 OJ July, 23rd 2009, p. L191/53–56; Regulation 1060/2010 OJ November, 30th 2010, p. L314/17–20; Regulation 1015/2010 OJ November, 11th 2010, p. L293/21æ23; Regulation 1061/2010 OJ November, 30th 2010, p. L314/47–50; Regulation 1016/2010 OJ November, 11th 2010, p. L293/31–33; Regulation 1059/2010OJ November, 30th 2010, p. L314/1–4.

3. Energy efficiency of White Goods in Europe: monitoring the market with sales data. Changes and trends regarding energy efficiency, energy consumption, size and price in the markets of refrigerators, washing machines and tumble driers in the EU, France and Portugal, 2004 to 2014 – Topten ADEME, WWF 2015. Available at www.topten.eu.

Table 1. Sample size and duration of previous monitoring campaigns on cold/washing appliances and air conditioning

			Number				
	Year	Duration	Cold appliances	Washing machines	Dish washers	Tumble dryers	Air conditioning
CIEL*	1996	1 month	130	80	36	30	–
ECODROME**	1997	1 year	28	20	8	5	–
EDF 100***	1999–2000	1 year	81	47	28	20	–
REMODECE ****	2008	Cold: 1 year Washing: 1 month Air conditioning: 5 months	149	87	65	–	20

** Sidler (1996), ** Sidler (1998), *** EDF (2000), **** Almeida (2009).*

Table 2. Total number of monitored appliances (sample: 107 households).

	Total number of appliances	Sample equipment rate (%)	Insee equipment rate (%) 2011	TNS Sofres equipment rate (%) 2013
Fridge	35	101.9	99.1	98 %
Fridge freezer	74			
Freezer	48	44.9	52.3	59 %
Wine cellar	8	7.5	7.2*	–
Washing machine	100	93.5	92.6	96 %
Dish washer	60	56.1	50.2	59 %
Tumble dryer	23	21.5	30.5	31 %

** 2015 data (source: Frio group).*

American style fridge freezers consume more because they are larger and they integrate a defrost system (daily activated). Note that some conventional fridge freezers are also equipped with an automatic defrost heater.

Air-ventilated equipment draws permanently between 25 and 40 watts due to the consumption of the fan (Figure 6 – left). One of these appliances is a recent model (less than 2 years old), rated A++.

Concerning the remainder of the sample, the most efficient appliances (best energy label) consume the least. They have no stand-by consumption (power drawn when the compressor is turned off), no fan, no defrost heater (Figure 6 – right).

Freezer

The average consumption of a freezer is 354 kWh/year (36 % reduction compared to 2008). Some high consuming appliances remain (Figure 7). These are small volume freezers (less than 60 liters) that are more than 10 years old (without energy label). The consumption of the worst freezers is about 7 to 20 times higher than the most efficient one which is however 7 times larger.

The conditions of use (temperature set point and location) are, after the level of insulation, the second main determinants of consumption.

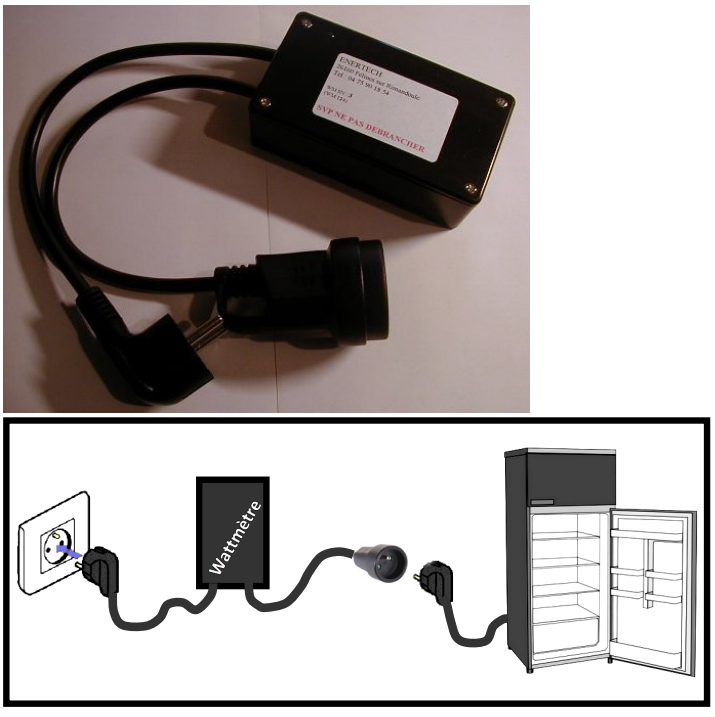

Figure 2. Picture of a serial wattmeter – datalogger used for the monitoring campaign.

Table 3. Main data of the monitoring campaign and comparison with previous similar projects.

		Ciel (1995) *	Ecodrôme (1996) **	EDF100 (1999) ***	Remo-dece+ (2008) ****	Froid Lavage (2015) *****
Fridge	Sample size		15	21	32	35
	Yearly consumption (kWh/year)		362	281	253	211
	Average volume (liters)				286	209
Fridge freezer (American style excepted)	Sample size		6	25	66	68
	Yearly consumption (kWh/year)		721	543	460	386
	Average volume (liters)					(+) 237/ (-) 76
American style fridge freezer	Sample size				6	6
	Yearly consumption (kWh/year)				796	976
	Average volume (liters)					(+) 360/ (-) 167
Freezer	Sample size		12	35	45	48
	Yearly consumption (kWh/year)		619	617	556	354
	Average volume (liters)					235
All cold appliances	Yearly consumption (kWh/year)		1062	765	686	541
Refrigerated wine cellar	Sample size					8
	Yearly consumption (kWh/year)					154
Washing machine	Sample size		20	47	87	100
	Yearly consumption (kWh/year)		262	232	169	92
	Yearly cycle number	258			242	174
	Consumption per cycle (Wh) → 100 Wh	875			658	569
Dish washer	Sample size		8	28	65	60
	Yearly consumption (kWh/year)		290	284	273	171
	Yearly cycle number				213	189
	Consumption per cycle (Wh) → 100 Wh	1,624			1,250	900
Tumble dryer	Sample size	30	5			23
	Yearly consumption (kWh/year)	480	373			199
	Yearly cycle number					140
	Consumption per cycle (Wh) → 100 Wh					1,402
Air conditioner	Sample size				20	10
	Yearly consumption (kWh/year)				262	366 #

** Sidler (1996), ** Sidler (1998), *** EDF (2000), **** Almeida (2009), ***** Enertech (2016). # 211 kWh/year if floor cooling system is not taken into account. Such system has not been monitored in REMODECE project.*

Refrigerated wine cellar

Refrigerated wine cellars have been monitored for the first time. The average consumption is 154 kWh/year. The most consuming appliance of the sample uses more electricity than an average refrigerator. Operating time varies greatly from one household to another (cf. Figure 8 from 67 to 365 days/year).

WASHING MACHINES

Washing machine consumption is only 92 kWh/year. It has decreased by 45 % since 2008. It is very dependent on the use. Both average consumption and number of cycles have decreased, respectively by 14 % and 28 % (Figure 9).

The cycle consumption reduction is due to technological improvements and change in washing practices. Percentage of cycle made at 40 °C or lower temperatures went from 69 % in 1995 (CIEL) to 81 % in 2015 (in which 2 % are "cold" cycles).

The fact that the number of cycles has decreased can be explained as following:

- Change in practice: users probably fill up more their washing machines as cycle temperature is more uniform than earlier (almost all clothes are washed at 30/40 °C).
- Increase of washing machine capacity: people wash more clothes per cycle, which implies a reduction of number of cycles for a same amount of laundry.

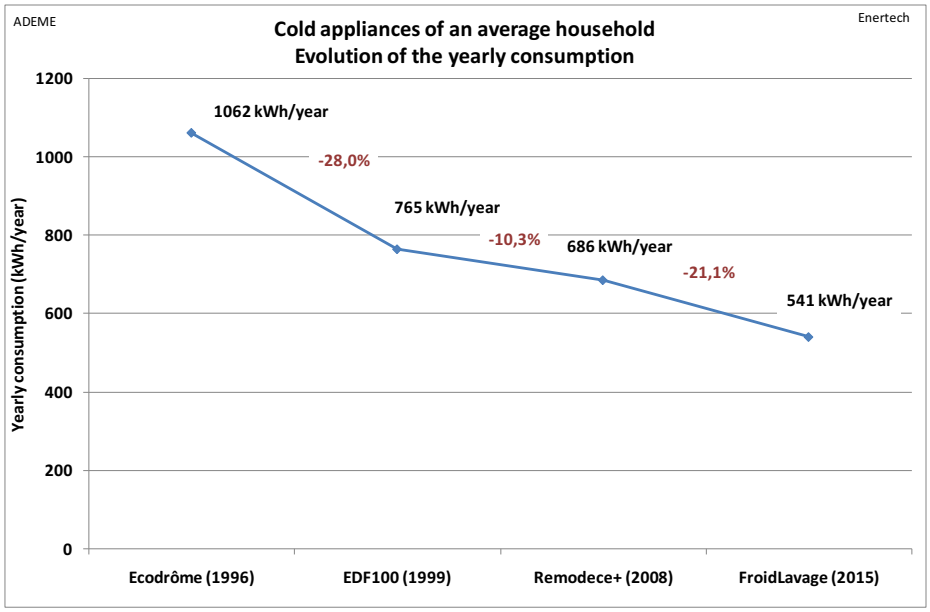

Figure 3. Evolution over the last 16 years of electricity consumption of the whole cold appliances of an average household.

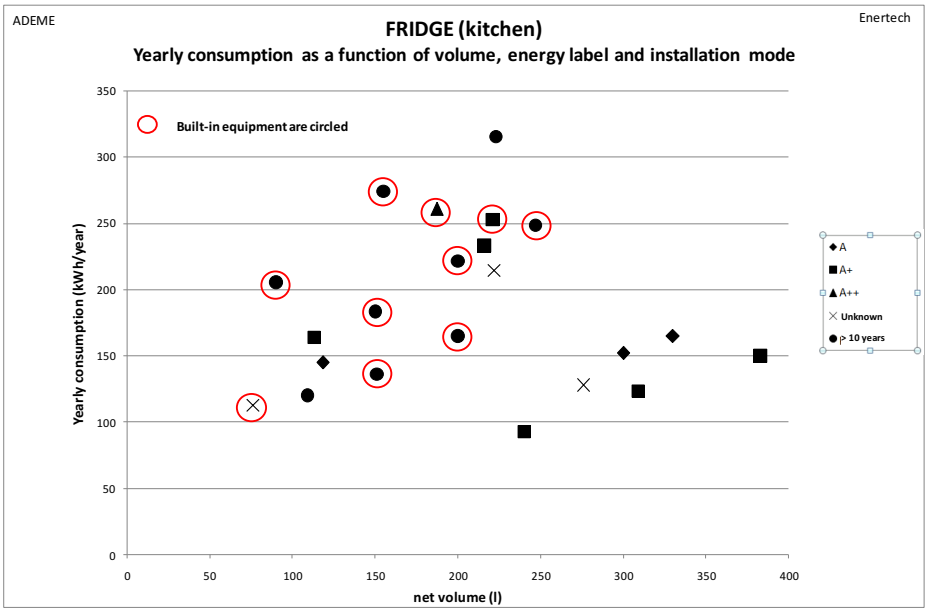

Figure 4. Yearly consumption of fridges as a function of volume, energy label and installation mode.

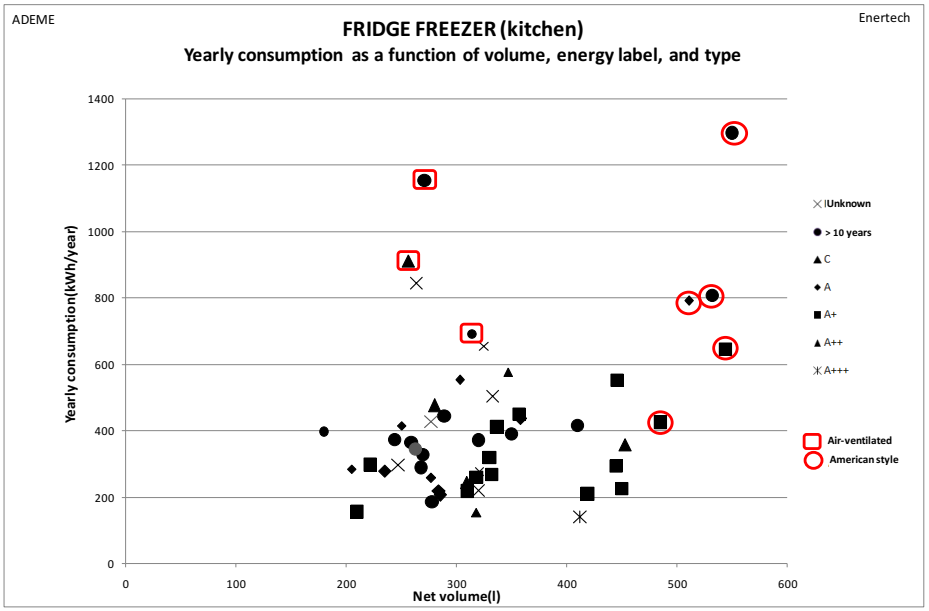

Figure 5. Yearly consumption of fridge freezers as a function of volume, energy label and type.

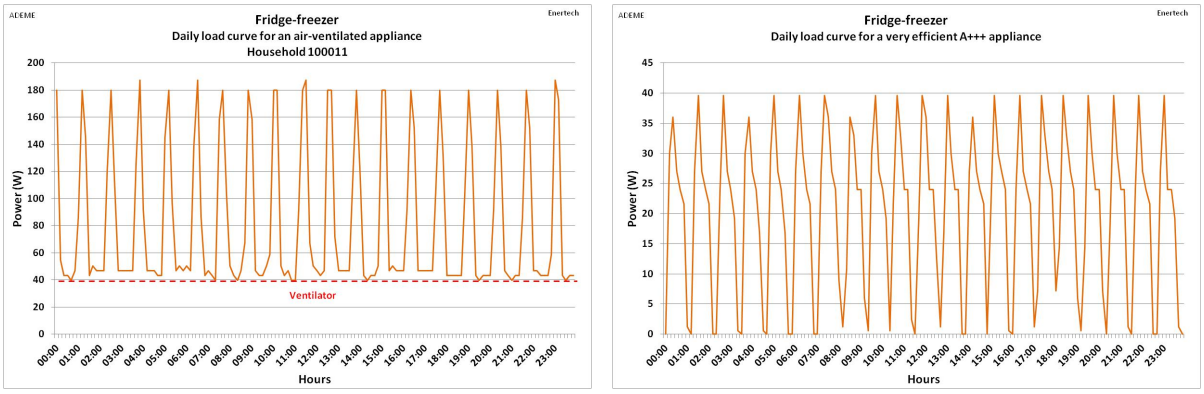

Figure 6. Daily load curve of an air-ventilated – 40 W permanent fan power – (left) and a very efficient – A+++ with no fan, no defrost heater – (right) fridge freezers.

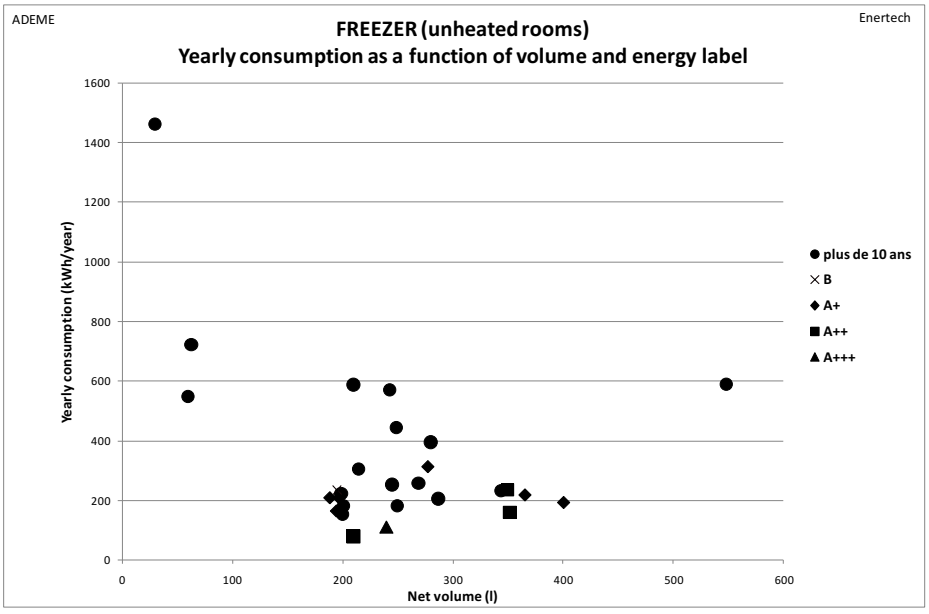

Figure 7. Yearly consumption of freezers as a function of volume and energy label.

DISH WASHERS

The observations are the same for dish washers: average yearly consumption has decreased by 37 % compared to 2008. It is now 171 kWh/year. The yearly number of cycles has decreased by 11 % (but increased compared to 1995) and the consumption per cycle by 28 % (Figure 10).

TUMBLE DRIERS

Concerning tumble dryers, existing data are relatively limited and old (Ciel project 1995 and Ecodrôme 1996). The actual average consumption is 199 kWh/year. Electricity consumption depends greatly on the use. But the sample is too small to draw any conclusion. The confidence interval at 95 % is [118; 280] kWh/year.

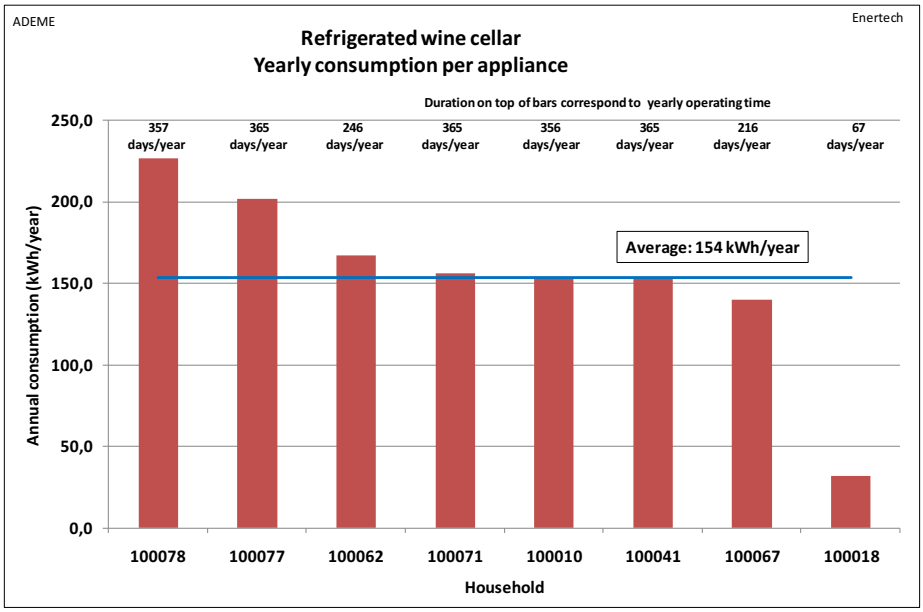

Figure 8. Yearly consumption of refrigerated wine cellar.

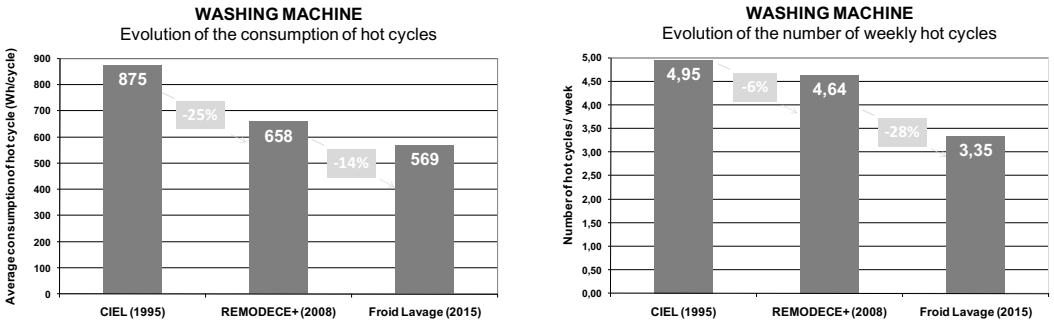

Figure 9. Evolution over the last 20 years of electricity consumption and number of hot cycles (consumption >100 Wh/cycle) for washing machines.

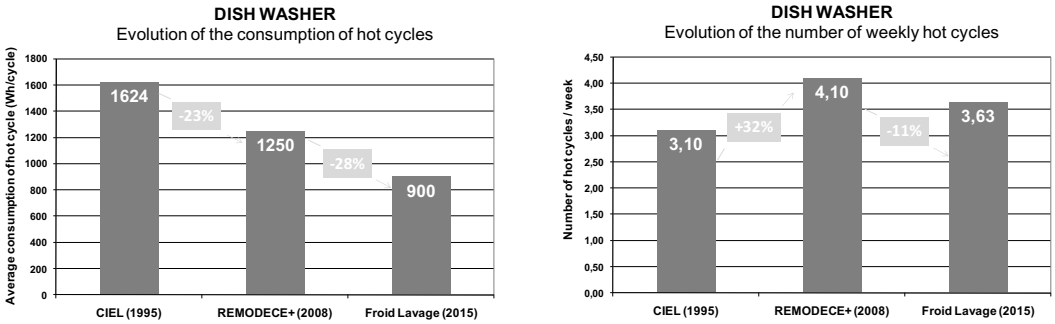

Figure 10. Evolution over the last 20 years of electricity consumption and number of hot cycles for dish washers.

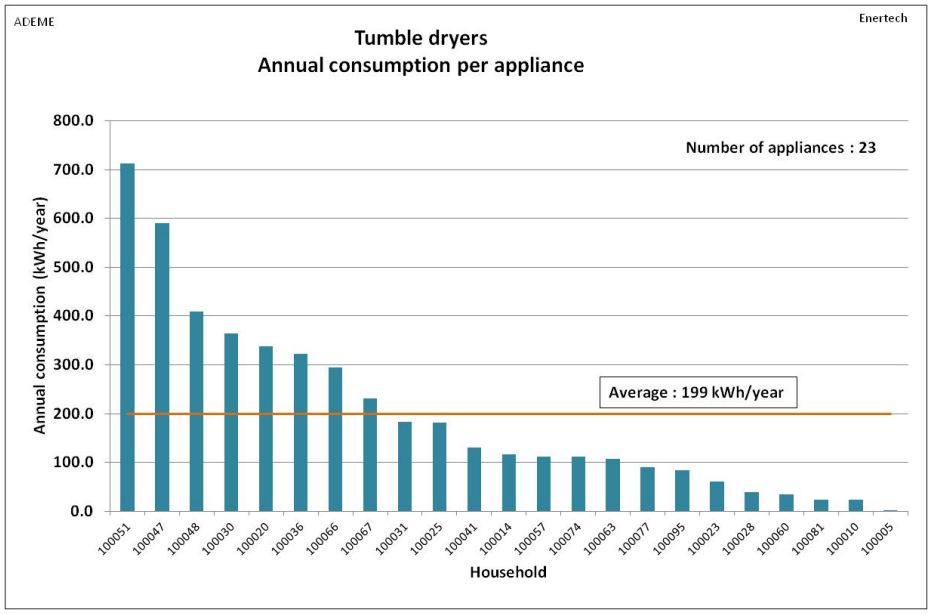

Figure 11. Yearly consumption of tumble driers.

AIR CONDITIONING

Monitored air conditioning consumption is 366 kWh/household/year (households are located in south of France). It is almost as important as fridge-freezers average consumption. However, from electrical network side, this use is very different from cold household appliances. Most of its consumption occurs during summer (less than 2 months, end of June to mid-August). Furthermore, within a given geographic area, the hottest days in summer are the same for every household. Thus the diversity factor is limited. This leads to local constraints on the electrical network.

The individual consumption is almost the same as in 2008 (REMODECE). It greatly depends on behavior: start and stop are manual, the system is most of the time turned off during holidays, set point temperature is different from a household to another.

It is necessary to consider these results with caution because the sample is 10 times smaller than the one used for other appliances.

Part of the total consumption covered by the monitored appliances

Cold/washing/drying equipment represents today only 23 % of the total household specific electricity consumption (see Figure 12[4]). 20 years ago (Ecodrome program) it represented 46 %.

Unitary consumptions of cold and washing appliances have decreased, mainly thanks to EU directives. But these energy savings are offset, at household level, by an increase of ownership, appliances size, as well as emergence of new devices. Overall, total electric household consumption is stable.

4. In order to know their total yearly electricity consumption, the 36 households read out meter at the beginning and the end of the monitoring campaign.

Conclusions

Except for a few freezers and tumble dryers, appliances are today energy efficient (even very efficient in some cases). They have been purchased after the introduction of energy label (1995) and after the phase-out of the most inefficient equipment (2001: E, F, G class, 2010: B, C D class, 2012: A class).

This study shows that during the last 20 years:

- The total household electricity consumption is stable.
- Cold appliances consumption has been divided by factor 2 (reduction in energy consumption is not the same for all types of appliances).
- Washing machine and dish washer electricity consumptions have been reduced by respectively 65 % and 41 %.
- The part of total household electricity consumption covered by cold and washing appliances has been reduced by factor 2.

In this context, conditions of use mainly explain consumption differences. Energy consumption also depends on financial, cultural (environmental concerns), sociological (comfort requirement) and psychological (ability to understand equipment features) drivers. Consumption patterns also depend on lifestyle. Technological improvement is not sufficient to reduce consumption.

Recommendations

To enhance effectiveness of energy reduction programs, it is necessary to act simultaneously on technology and behavior. Numerous experiments with behavioral incentives emerge in Europe. Long-term relevant assessments are necessary in order to find out the most efficient behavioral incentives. One should learn from these first experiments.

Presently, nobody seems to know precisely how the current electricity consumption of an average French household is broken down or at what time of the day it is consumed. We can for

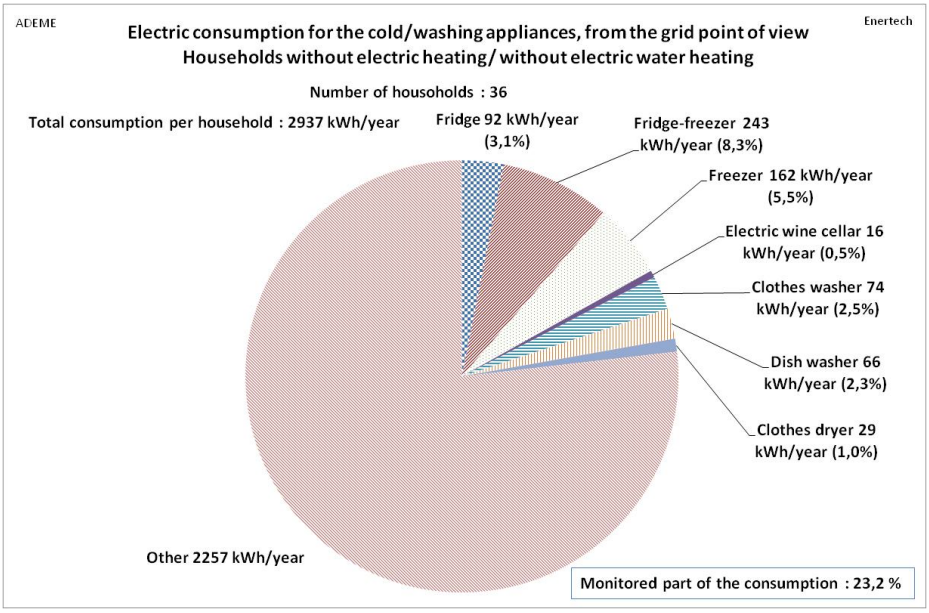

Figure 12. Distribution of household electricity consumption (households without electrical heating and hot water).

example not assess the real impact of continuous introduction of new household equipment related to modern comfort. Only few monitoring campaigns have been carried out so far (EURECO, REMODECE …) and their results rapidly become outdated. This structural lack of information affects the capacity to implement pertinent actions. There is a definite need of permanently up-to-date data. Ongoing performance monitoring is a prerequisite to understand how energy consumption changes and subsequently tailor and evaluate action.

It seems necessary to assess the impact of changes (technological and behavioural) enabling policy reorientation. The impact of predictable reinforcement of certain uses related to modern comfort and the introduction of new household equipment will thus be monitored upstream and will allow acting at an earlier stage. As penetration of new appliances or new habits is gradual, new trends are only visible on the basis of a dynamic analysis.

Feedback from the field should guide evolution of the European policy and funding opportunities. The understanding of the existing situation is a prerequisite for the design of future action levers. Permanent audit fieldwork should be done for each product subject to EuP directives in order to evaluate the concrete results of the legislative process and its potential adverse events.

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