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Analysis of Energy Saving and Efficiency Action Plan 2008-2012 in Spain for the Residential Sector (Heating, Appliances and Lighting)

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Abstract. Energy efficiency is considered one of the most cost effective ways to enhance security of energy supply and reduce greenhouse gas emissions. According to Europe's Energy Efficiency Plan, the biggest energy saving potential in the EU lies in the built environment. Spanish authorities, aiming to guarantee the energy supply and also to abide with the environmental restrictions, have established the National Energy Efficiency Action Plans (NEEAP), the 2008-2012 Plan is the first one and the 2011-2020 Plan lends continuity.

In this paper, we will analyze the measurements proposed by the 2008-2012 Plan for home thermal systems (heating and domestic hot water) and home electric systems (light and appliances). Three scenarios are established to quantify approximately the energy saving for Spanish dewellings in 2012. This paper evaluates, using data currently available, the saving to the year 2012 and compares it with the official Plan results presented. The results show the actual margins of improvement and the success or failure of the Plan measures.

Key words

Efficiency, Energy Saving, Energy Policy, Residential Sector, Spain.

1. Introduction

Traditionally, Spain has had very little gas and liquid hydrocarbons, or they have low quality. The national coal is a similar example with the additional problem that it is obtained at a higher cost than in any other countries. Recently, renewable energies have turned up to slightly lessen this situation. [1]

Spain imports approximately 76% [2] of the primary energy and 50% of the electricity is generated from imported raw materials.

Energy efficiency is considered as one of the most cost effective ways for society to enhance security of energy supply and reduce greenhouse gas emissions [3]

Spain has enacted policies to encourage energy efficiency such as the Saving Energy Efficiency Strategy (E4+) 2004-2012 [4] which comprised two Action Plans for the periods 2005–2007 and 2008–2012 [5] [6].The latter was presented as the first National Energy Efficiency Action Plan (NEEAP) to the EU according to the Energy Services Directive [7]. Additionally, for the period 2011–2020, Spain has presented to the EU its 2nd NEEAP [8] that lends continuity to the previous one.

The main objective of this paper is to analyze the final energy consumption (FEC) prevision for 2012 of the 2008-2012 Plan to the Residential Sector, specifically in Heating, Appliances and Lighting, and compare it with the FEC calculated using data of actual saving measurements (number of refurbish houses, number of replaced appliances and number of replaced lamps)

2. Methodology

The 2008-2012 Plan defined two scenarios:

- The Baseline scenario, is the FEC for 2012 not realizing any effort of reduction or improvement in the use of energy (maximum consumption)
- The efficient plus scenario, is the FEC for 2012assuming that the energy saving previsions are achieved.

The energy saving for 2012 is the FEC difference of both scenarios.

To compare and contrast the 2008-2012 Plan previsions with actual results, it is calculated the FEC for 2012 using actual data available of energy saving measurements.

The 2008-2012 Plan measurements considered in this paper to increase the efficiency in the Residential Sector are:

- Improving the thermal envelope of existing buildings to reduce loses in heating
- Renewing of electrical appliances [9]
- Replacing incandescent lamps by low consumption ones.

Specifically, the Plan established, for 2012, the Baseline and Efficient plus scenario for the Building sector and for the Domestic and office equipment sector. According to actual available data and taking into account that domestic sector represent 60% of the building sector [10]. The FEC for Residential Sector can be approximately calculated by Equation 1:

$$FEC_{Residential} = 0.60 * FEC_{Building} + FEC_{Equipment} \quad (1)$$

where,
$FEC_{Residential}$, is the FEC for Residential sector for 2012
$FEC_{Buiklding}$, is the FEC for Building sector for 2012
$FEC_{Equipment}$, is the FEC for the domestic and office equipment sector for 2012

Table I shows FEC specified by the plan and FEC obtained using Equation (1) for 2012.

Table I: Base and Efficient FEC established in 2008-2012 Plan for 2012.

Sector	Base FEC (ktoe)	Efficient FEC (ktoe)	Saving (ktoe)	Saving (%)
Building	23,584	21,194	2,390	10.13
Equipment	4,687	4,190	497	10.60
Residential	**18,837**	**16,906**	**1,931**	**10.25**

According to the IDAE (Energy saving and diversification Institute) [11] FEC for Heating, Appliances and Lighting in the residential sector is distributed for an average household: heating (72.31 %), appliances (21.54%) and lighting (6.15%). According to these percentages and assuming that these three have to achieve the energy saving target for 2012 for the Residential Sector, FEC and saving by use have been calculated (Table II).

Table II: Objectives for 2012 by use in Residential sector

Use	Base FEC (ktoe)	Efficient FEC (ktoe)	Saving (ktoe)
Heating	13,621	12,225	1,396
Appliances	4,057	3,642	416
Lighting	1,159	1,040	119
Total	18,837	16,906	1931

Heating, Appliances and Lighting unit consumption (UC) is firstly calculated taking into account any effort of reduction or improvement in energy efficiency (Baseline scenario) and then applying the correspondent saving whenever necessary.

3. Results

A. Heating

Table III shows the saving target for heating systems for 2012.

Table III. - Saving Target for Heating in 2012

Base FEC (ktoe)	Efficient FEC (ktoe)	Saving (ktoe)	Saving (%)
13,621	12,225	1,396	10.25

Thermal envelope retrofits in existing buildings improves their efficiency reducing the energy demand for heating.

It is important to know the housing stock in 2012 [12] [13] and their UC according to the building normative (Table IV).

The UC's per dwelling according to the building normative are calculated taking into account that FEC for heating in 2012 is 13,621 (Baseline scenario) and considering that buildings built according to the Technical Building Code (TBC) [14] can save about 43.65% respect to a building built before 1979 and buildings built according to NBE CT-79 normative [15] can save about 3.25% respect to a building built before 1979 [16]

The UC's per dwelling according to their building normative is calculated by Equations (2):

$$FEC_{HeatingBase} = (UC_1 * V_{1979}) + (UC_2 * V_{1980-2006}) + (UC_3 * V_{2007-2012})$$
$$UC_2 = 0.9675 * UC_1 \quad (2)$$
$$UC_3 = 0.5635 * UC_2$$

where,

$FEC_{HeatingBase}$ is the FEC Base for heating
UC, is the UC of dwellings built before1979
V_{1979}, is the number of dwellings built before1979
UC_2, is the UC of dwellings built between 1980 and 2006
$V_{1980-2006}$, is the number of dwellings built between 1980 and 2006
UC_3, is the UC of dwellings built between 2007 and 2012
$V_{2007-2012}$, is the number of dwellings built between 2007 and 2012

Most of the energy consumption in heating is due to the dwellings built before 1979, because of their higher percentage in number as well as their worse isolation. [17] Therefore we will focus on retrofitting possibilities of these homes and we consider that retrofitted homes meeting the TBC can save about 44%. Therefore, their UC is UC_3.

Table IV: Main homes in 2012 according to building normative.

Building period	Number	%	UC (tep/dwelling)
Before 1979	9,731,892	53,73	0.785
1980-2006 (NBE CT-79)	7,165,315	39,56	0.76
2007-2012 (TBC)	1,215,230	6,71	0.442

In the period 2007-2012 in Spain 335,507 homes were refortified [18] meeting with the TBC [14]. It implies a Heating FEC of 13,507.2 that is a 113.8 ktoe energy saving regarding Base FEC (the 0.84% respect the10.25% objective)

B. Appliances

The main solution to achieve the energy saving in the energy consumption of electrical appliances is the replacement of the equipment for more efficient one.

Table V shows the appliances saving target for 2012

Table V. – Saving Target for Appliances in 2012

Base FEC (ktoe)	Efficient FEC (ktoe)	Saving (ktoe)	Saving (%)
4,057	3,641	416	10.25

The Renove Plan [9] for electrical appliances was aimed at incentivizing the withdrawal of existing electrical appliances which have a higher energy consumption, replacing them with others of Class A (or above) that have less consumption than average conventional appliances (class E) (Figure 1). These plans were organized by the Autonomous Communities. Knowing the consumption rate per appliance we calculate the correspondent base consumption to each appliance (Table VI).

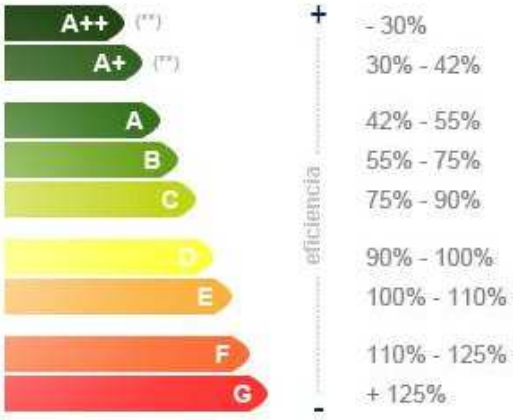

Figure 1. - Energy label and Energy consumption respect to an average consume (E label)

We only consider the following electrical appliances: refrigerators, washing-machines and dishwashers, because they have high consumption rate and are object of subsidies granted by the Government

Table VI. –Appliances Consumption rate (%) in Residential sector considering all appliances and considering only refrigerators, washing machines and dishwashers (*) [21]

Appliance	Consumption (%)	Base Consumption (tep)	Consumption (%) (*)
Refrigerator	30.6	1,241,442	63.09
Washing machine	11.8	478,726	24.33
Dishwasher	6.1	247,477	12.58
Dryer	3.3	133,881	
Stove	8.3	336,731	
TV	12.2	494,954	
Computer	7.4	300,218	
Standby	10.7	434,099	
Freezer	6.1	247,477	
Others	3.5	141,995	
Total	100	4,057,000	100

Then, we assume that these three appliances have to achieve the energy saving target for 2012 for all of them. Table VII shows the new base and efficient FEC target for considered appliances to achieve the same saving.

Table VII. - Saving target for considered electrical appliances in 2012

Appliance	New Base FEC (ktoe)	New Efficient FEC (ktoe)	Saving (ktoe)	Saving (%)
Refrigerator	1,241.4	979.0	262.5	21.14
Washing machine	478.7	377.5	101.2	21.14
Dishwasher	247.5	195.1	52.3	21.15
Total	1,967.6	1,551.6	416	

The obligation to provide information to buyers on the energy consumption of electrical appliances by way of the energy label came into force after 1995. This measure aims to promote the replacement of these electrical appliances with a low energy label by others with a better level of labelling available on the market [4].

In order to carry out calculations we need to know:

-The presence of these appliances in dwellings in Spain and the total number of dwellings (18.112.437 main homes and 3.768.757 secondary homes) (Table VIII)

Table VIII. - Presence of appliances in Spanish dwellings [19]

	Refrigerator	Washing machine	Dishwasher
Presence (% dwellings)	99.9	99.1	43.5

-The number of Class A appliances and above and inferior to Class A. According to INE (Instituto Nacional de Estadística) [19] we know the number of appliances per Class in 2008 and according to IDAE [20] the number of replacements in 2008, 2009 and 2010. We supposed that the renovations had the same tendency in 2011 and 2012 (Table IX).

The Renove Plan in the period 2008-2012 achieved the replacement of approximately 988.264 refrigerators, 1.629.958 washing machines and 530.747 dishwashers (Table IX).

Table IX. – Number of appliances per Class in 2008 and number of replacements 2008-2010 and estimations for 2011 and 2012.

	Refrigerator	Washing machine	Dishwasher
Class A or above (2008)	7.865.193	8.118.514	4.378.169
Inferior Class A (2008)	13.392.085	12.968.535	4.878.003
Replacements 2008	146.619	439.765	118.649
Replacements 2009	238.994	426.168	114.980
Replacements	222.651	397.025	107.118

2010			
Replacements 2011 (estimated)	200.000	370.000	100.000
Replacements 2012 (estimated)	180.000	340.000	90.000
Total Replacements 2008-2012	988.264	1.629.958	530.747

-The efficient and non efficient UC per appliance. To calculate the non efficient UC, it is considered that the FEC for these three appliances in 2012 are 1,241.4, 478.7 and 247.5 ktoe respectively (New Baseline scenario for each appliance), taking into account any replacement. The efficient UC is calculated taking into account that the class A or above appliances save 58% respect to inferior class A appliances (Figure 1).

Non efficient UC per appliance is calculated by Equations (3)

$$NonEfficientUC_{Refrigerator} = \frac{NewBase_{Refrigerator}}{N_{Refrigerators}}$$

$$NonEfficientUC_{WashingMachine} = \frac{NewBase_{WashingMachine}}{N_{WashingMachine}} \quad (3)$$

$$NonEfficientUC_{DishWasher} = \frac{NewBase_{DishWasher}}{N_{DishWasher}}$$

where,
$NonEfficientUC_{Refrigerator}$, is the non efficient UC to refrigetors.
$N_{Refrigerator}$, is the total number of refrigerators in Spain.
$NonEfficientUC_{WashingMachine}$, is the non efficient UC to washing machines.
$N_{WashingMachine}$, is the total number of washing machines in Spain.
$NonEfficientUC_{Dishwasher}$, is the non efficient UC to dishwashers.
$N_{Dishwasher}$, is the total number of dishwashers in Spain

Table X represents the total number of these appliances in 2012 (per class and type) and their UC [19].For such calculation we have considered the occupied homes (main and secondary) and that since 2008 the new appliances bought are all of them class A or above. We also have considered the class A as representation of this class or above and class E as representation to inferior to class A appliances to do calculations.

Table X. – Number of electrical appliances (per class and type) in 2012 and their UC (in main and secondary homes).

	Refrigerator	Washing machine	Dishwasher
Total appliances	21.859.313	21.684.263	9.518.319
Class A or above	9.308.873	9.905.921	5.052.415
Inferior Class A	12.550.440	11.778.342	4.665.905
Non Efficient UC (tep/appliance)	0.057	0.022	0.026
Efficient UC (tep/appliance)	0.024	0.009	0.011

Taking into account previous data, Appliances FEC is 3548.1 ktoe, which is 508.9 energy saving regarding Base Consumption (the 12.5% higher than the 10.25% objective)

C. Lighting

The replacement of incandescent lamps by low consumption ones is the main saving measurement in this area. The European Union has banned the production of incandescent lamps since 2012.

Table XI shows the Lighting saving target for 2012.

Table XI. - Saving Target for Lighting in 2012

Base (ktoe)	Efficient (ktoe)	Saving (ktoe)	Saving (%)
1159	1040	119	10.27

According to the IDAE [21] every dwelling has an average of 23 lamps with the distribution indicated in Table XII. This table shows the saving of each kind of lamp related to the incandescent, as well as the UC per type of lamp [22]

Even though the manufacture of incandescent bulbs was banned in 2012, up to this moment the user has been able to continue buying traditional bulbs and they will probably do because of their low cost. Despite this, some lamps are being replaced because of public campaigns and the increasing of the people awareness in energy efficiency. Some campaigns consisted of giving two low consume lamps for every home throughout 2009 and 2010. Another one was 2x1 packs to have more low consume lamps sales. [8]

The incandescent lamp UC is calculated considering that FEC for lighting in 2012 is 1159 ktoe (Baseline scenario), taking into account that all lamps are incandescent. The other lamps UC are calculated applying the correspondent saving.

Table XII. - Average of lamps (per type and dwelling) and saving respect the incandescent lamp [21]

	Incandescent	Halogen	Fluorescent	Low Consume	LED
Average	8.3	6.1.	1.4	7	0.2
UC (tep/ lamp)	0.0028	0.0025	0.0025	0.0006	0.0003
Saving (%)	0	10	10	80	90

Taking into that the average lamps (per type and dwelling) in 2012 are the same as in 2010 (Table XII), and the number of main dwellings in 2012 (18,112,437), the total number of lamps per type in 2012 are shown in Table XIII.

Table XIII. – Total lamps per type in 2012

Incandescent	Halogen	Fluorescent	Low Consume	LED
150,333,227	110,485,866	25,357,412	130,409,546	3,622,487

Knowing the total number of lamps per type, the Actual Lighting FEC in 2012 is 837.6 ktoe, which means 321.4 ktoe energy saving regarding Baseline scenario (the 27.7%, much higher than the 10.27% objective.

4. Conclusion

The calculations made in this paper show that energy saving goal is very well-achieved in Lighting and in lesser extent achieved in Appliances. Otherwise, the energy saving in Heating is not achieved by far.

It should be notice that saving in Lighting are probably going to increase in following years because of the introduction of LED lamps because they are the most efficient ones and have larger useful life ()

Saving in Appliances can be expected to follow the same tendency in the future, going on with the replacement old appliances for more efficient ones.

More effort is necessary to achieve significant savings in Heating. It is really important to promote refurbishment of the thermal envelope in old buildings as the Government promotion building refurbishment program [23]. Nowadays, the economical crisis does not allow the increasing of these refurbishments because it means high investment.

The Plan predicted 10.25% saving respect to the Baseline scenario in 2012. According to this study, energy saving in the residential sector in 2012 (Heating, Appliances and Lighting) is 944.1 ktoe, 5% regarding Baseline scenario. It is an Actual FEC of 17,832.6 ktoe (13,507.2+3,548.1+837.6=17,832.6 ktoe).

As we can see, even though it represents an important saving it is insufficient. Therefore, more measurements and higher intensity in their application are necessary to achieve the saving goal.

It is important to emphasise that data obtained in this paper can't be compared with actual official results in the Residential Sector because we didn't consider all Plan measurements, we only considered Heating, Lighting and Appliances measurements. Furthermore, the improvement in energy efficiency is connected to the economic recession and the higher renewable generation. Even though, Spain is nine points below the European average in energy efficiency [24].

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