ENERGY EFFICIENCY MEASUREMENTS GUIDED TO REDUCE CARBON EMISSIONS IN THE URBAN RESIDENTIAL SECTOR FROM ARGENTINA

INTRODUCTION

Currently, there is a scientific consensus related to world-wide climate change, which is pronounced significantly in this century. This change is the result of the increasing green house effect gases concentrations such as carbon dioxide, methane, nitrous oxides and chlorine fluor carbon. These gases are retaining a big portion of terrestrial infrared radiation increasing the planetary temperature between 1.5°C and 4.5°C to the end of the XXI century. Because of this, it is possible that the global precipitation patterns can also be altered. Associated to these temperature and precipitations increases, alterations in the global ecosystems are foreseen, generating world-wide economic imbalances.

These conclusions led to a world-wide governmental reaction, resulting in the meeting of 165 countries in the Marco Convention on Climate Change (New York, 1992). They began to make themselves responsible for "stabilizing green house gases concentration in the atmosphere at levels that avoid entropic interferences with the climatic system" with the objective to obtain for the year 2000 an emissions reduction so as to reach 1990 levels.

Afterwards, and being aware of the low involvement of the industrialized nations, measurements were taken in the Kyoto protocol (1998) based on a reduction of the green house effect gasses for the period between 2008 and 2012. This meant a reduction of not less than 5% of the ones emitted in 1990. As part of the policies applied for the proposed goals, the promotion of the energy efficiency has been considered by introducing appropriate reforms in the different sectors of the national economy with the purpose of promoting policies and measurements that limit or reduce the emissions of green house effect gases.

In this context, and in the occasion of the elaboration of *Second National Communication* from our country to the Marco Convention on Climatic Change, programs and projects of energy efficiency promotion were analyzed, as well as the energy behaviour of the residential, public and industry sectors from Argentina. This study allowed proposing some measurements, to implement in some cases and to deepen and to continue with its development in others, that made possible a reduction of energy consumption and green house effect gasses emissions. The obtained results showed an interesting possibility of energy and emissions savings with variable investment costs based on the measurements and application sectors. Table 1 shows the measurements implemented for the efficient use of energy discriminated by source and application sector. To make it possible, it should be adapted to the legal and normative framework.

Consequently, the present work summarizes the aspects relative to the energy saving in the residential sector. In this context the urban residential sector was characterized in relation to its buildings type diversity and to its geographic regions. According to the 2001 Census (INDEC 2001), the total population of the country was 35,923,907 inhabitants in 10,075,814 homes. Of the total homes, houses represented 77.8% and 15.8% were flats and 3.8% farms and huts. As expected, only houses and flats have complete domestic energy equipment (air conditioning, cooking, hot water, illumination, etc.)

Regarding the analysis of the population by regions, it must be considered that the Metropolitan Region of Buenos Aires (RMBA) concentrated the 31.3% of the population; the rest of the Buenos Aires province the 13.9%; the Argentinean North East 11%; the Argentinean North West 9.2%; the Patagonia 4.7%; the Centre region 19.5%; and Cuyo the 7.8%. (INDEC 2001).

On the other hand, the homes analysis by regions, showed that the Metropolitan Region of Buenos Aires (RMBA) concentrated the 33.8%; the rest of the Buenos Aires province 15.2%; the Argentinean North East 11.2%; the Argentinean North West 7.6%; the Patagonia 4.7%; the region Center 20%; and Cuyo 7.2%. (INDEC 2001).

Nº	MEASUREMENT	SECTOR	APPLICATION	SOURCE
1	Improvement of the envelope	Residential sector	50% universe of the country	GAS
2	Improvement of the envelope	Residential sector	10% universe of the country	
3	Improvement of the envelope	Residential sector	3.4% annual growth	
4	Improvement of the envelope	Residential sector	14% annual growth	
5	Improvement of the envelope	Federal Houses I plan	120,000 houses	
6	Improvement of the envelope	Federal Houses II plan	300,000 houses	
7	Improvement of the envelope	Education Sector	Plan 700 schools	
8	Improvement of the envelope	Education Sector	Total of the country	
9	Substitution of lighting equipment	Health Sector	Compact Fluorescent lamps	ELECTRICITY
10	Substitution of lighting equipment	Education Sector	Compact Fluorescent lamps	
11	Substitution of lighting equipment	Administrative sub sector	Compact Fluorescent lamps	
12	Substitution of lighting equipment	Administrative sub sector	Compact Fluorescent lamps and TFT	
13	Substitution of lighting equipment	Commercial sub sector	Compact Fluorescent lamps and TFT	
14	Substitution of lighting equipment	Commercial sub sector	Compact Fluorescent lamps	
15	Substitution of lighting equipment	Residential sub sector	Compact Fluorescent lamps	
16	Substitution of lighting equipment	Residential sub sector	Compact Fluorescent lamps	
17	Substitution of lighting equipment	Public lighting system	Sodium lamps A. Public	
18	Substitution of lighting equipment	Public lighting system	Sodium lamps A. Public	
19	Labelled	Refrigerators	Useful Life	
20	Labelled	Refrigerators	Annual growth	
21	PURE (Rational Use of the Energy Program)	Residential and Commercial sector	All the country	Gas
22	PUREE (Rational Use of Electrical Energy Program)	Residential sector and SG	EDELAP, EDESUR and EDENOR Companies	Elec.
23	Industry co-generation	Industrial sector	- Co-generation in a great scale. - Industries co-generation potential. - Installation of co-generation systems	

Table 1. Mitigation adopted measurements.

In relation to the energy consumption, of the total homes (10,075,814) in 2001, 97.7% had electrical energy, whereas in the year 2004 this percentage was reduced to 94.3% on a total of 10,305,711 homes. The network gas provision took in 5,712,233 homes (56.7%) in the 2001 and 6,025,768 homes (58.4%) in 2004.

With the objective to reduce green house effect emissions produced by the residential energy consumption, a briefcase of mitigation measurements was proposed which tend to obtain a greater efficiency in the use of energy vectors. The possible energy saving with the consequent green house effect gases reduction was taken into account: i. improvement houses envelopes; ii. replacement of incandescent lighting equipment by low consumption equipment and iii. progressive substitution of refrigerators by labelled units.

MITIGATION STRATEGIES FOR THE RESIDENTIAL SECTOR

1. *Envelope improvement in houses*

This measurement points out to the natural gas saving for heating, through the improvement of the thermal quality of the building’s envelope, mainly in ceilings and walls. Such a measurement also contributes to solve constructive pathologies and fundamentally to improve population’s quality of life. For its evaluation, consumption associated to heating demand was focused, which was considered in a global and in a detailed form. The first one was analyzed by province and the second one by bioenvironmental zones.

From the research results of the country on global natural gas consumption by home, discriminated by use, gas consumption for heating houses discriminated by province, was estimated. For example, for Buenos Aires province and its surroundings, homes´ consumption for the 80th and the 90th decade, were taken as a reference indicator, whose disintegration concluded that a 42% of the gas consumption is for heating. With these data and with the information provided by the ENARGAS (National Gas Regulating Agency) balances, the gas consumption by user was inferred for 2004. This mechanism was implemented for the rest of the provinces which had the same information.

1.1. Gas consumption estimation for heating by bioenvironmental region.

With the values obtained from the analysis of the gas consumption estimation in heating by bioenvironmental region, a model was developed with the data from ENARGAS (for the year 2004), taking into account the total consumption by province and the number of connected residential users. This model considers as independent variable, the heating degree days in base 20° (GD_{20}) for all those counties that have IRAM information on this indicator. As dependent variable, this model considers the interpolation of GD_{20} isolines for those localities without information for the cold period. Five hundred and twelve (512) localities were calculated. The estimated error by province from the disintegrated calculation by locality is of +/- 5%. The obtained information corresponds to: consumption by locality (mm^3, 9300 $Kcal/m^3$); consumption by connected user (mm^3/user); consumption by connected user (TOE/user); Mean consumption by province (M m^3), GEI emissions (kg/TOE).

1.2. Scales and scenes of intervention

For the regionalization of the consumptions, the electric energy measurements and the GEI emissions, a Geographical Information System (GIS) was used. A model was developed to simulate indicators and indices quantification related to consumption, saving and emissions, in order to obtain maps representing the energy consumption and global GEI emissions for the Argentine Republic or by sector: locality, province or region. This methodology allows to make the data operative, to quantify and to visualize the information with an important level of disintegration, as much at local as territorial level. It also facilitates the detection of critical energy consumption areas from the use of global indicators (consumption/m^2; consumption/user, etc.) and GEI emissions.

Energy saving was calculated from energy balances of the buildings in the different locations from the country and in the different bioenvironmental zones according to Norma IRAM 11.603. Recycled buildings measurements with which the thermal loads were calculated and that determined the gas consumptions, are fundamentally based on the improvement of the technological characteristics of the building envelope, with the incorporation of thermal insulation in walls and ceilings, according to IRAM 11605, “B” category. The percentage of saving for each bioenvironmental zone were determined for this category, which can be improved with additional or more rigorous measurements, some of them through investment, others with “zero” cost, such as behaviour habits.

Three mitigation measurements in the residential sector were evaluated formulating different hypotheses in each one. The main ones related to energy efficiency are exposed in this work. The first measurement addresses the recycling of existing houses; the second measurement involves the increase of houses by population increase and the third one is related to the implementation of energy conservation criteria in the Federal Plan of Houses (PFV).

a. Recycling of existing houses

This measurement proposes the recycling of houses by its owners. To calculate the total amount of this implementation (materials and manual labour) a traditional technology and December costs (2005) were considered. For this work neither costs nor enterprise benefits were contemplated.

The proposed measurement was implemented on the 50% of the total of users connected to the gas network of the whole country (3,668,747). Saving percentages were considered according to the proposed measurement in relation to the bioenvironmental zone, obtaining a saving of 339.10 kTOE/year corresponding to the 10.71% of the total heating consumption.

Figure 1 shows gas consumption for heating with improvements, without improvements, and the energy saving. Figure 2 shows its distribution in the country. On the other hand, Table 2 shows the costs of the houses with and without measurements of energy saving, and the obtained savings in energy consumption and GEI emissions.

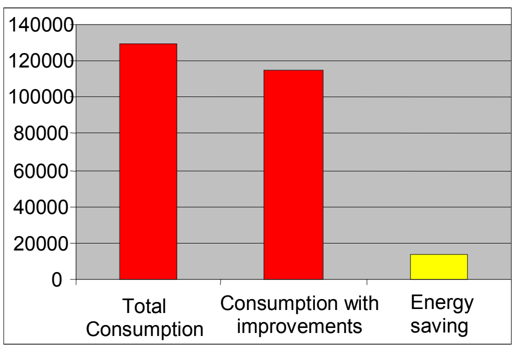


Figure 1. Gas consumption for heating. (TJ)

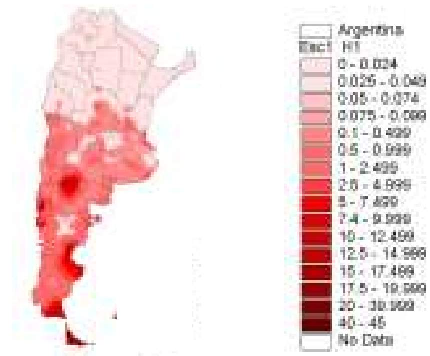


Figure 2. Network gas consumption for heating. Whole country. (TJ)

Houses (x100)	Env. Zone	Original Cost	Improved Cost			Consumption			CO_2 Emissions (x100)		
		Total	Measurement	Total Cost	Measurement	kTOE/Year			Original	Improved	Mitigation
		$(x100)	$ (x100)	$(x100)	%	Original	Improved	Saving			
367	I	20562640	1578917	22141557	7.68	1.63	1.332	0.293	38	31	7
2155	II	120692040	9267424	129959464	7.68	8.31	6.810	1.500	195	160	32
24241	III	1,35752E+9	104237934	1461755214	7.68	773.16	634.060	139.100	18171	14902	3269
5219	IV	292264000	25573100	317837100	8.75	420.25	344.605	75.640	9877	8099	1777
4141	V	231903000	20291512	252194512	8.75	103.98	70.710	33.270	2443	1661	781
563	VI	31559080	2761419	34320499	8.75	241.37	152.070	89.300	5672	3574	2098
36687		2,0545E+9	163710307	2218208347	7.97	1548.69	1209.587	339.103	36399	28429	7970

Table 2. Investment costs for the original, improved situations and obtained savings.

b. Houses to be built

If we consider the implementation of the proposed measurements to the houses that are annually incorporated to the market, the considered saving is of 92.88 kTOE/year, corresponding to 3% of the total heating consumption. According to the Synthetic Index of the Building Activity, this represents 14% of the total of houses, based on the potential area where they can be built taking into account 42 municipalities.

Figure 3 shows gas consumption for heating with improvements, without improvements and the energy saving. Figure 4 shows the distribution of those consumptions in the whole country. On the other hand, Table 3 summarizes the calculation methodology for obtaining the investment for different situations and geographic zones.

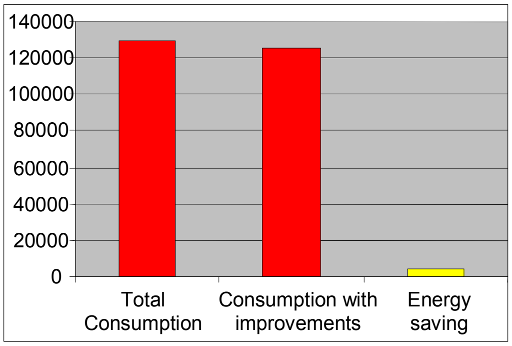


Figure 3. Gas consumption for heating. (TJ)

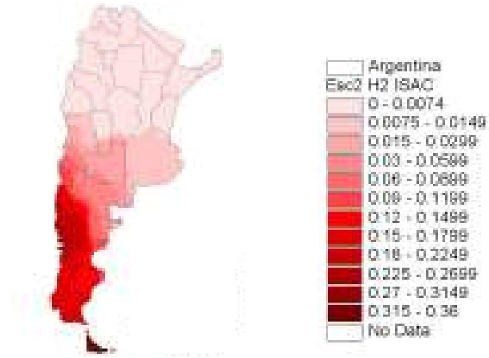


Figure 4. Network gas consumption for heating. Whole country. (TJ)

Houses (x100)	Env. Zone	Original Cost	Improved Cost			Consumption			CO2 Emissions (x100)		
		Total	Measurement	Total Cost	Measurement	kTOE/Year			Original	Improved	Mitigation
		$(x100)	$(x100)	$(x100)	%	Original	Improved	Saving			
102	I	7196924	719692	7916616	10.00	0.46	0.373	0.082	10	8	2
603	II	42242214	4224221	46466435	10.00	2.33	1.908	0.419	54	44	9
6787	III	475131048	47513104	522644152	10.00	216.48	179.682	36.803	5087	4223	864
1461	IV	102292400	10959900	113252300	10.71	117.67	96.409	21.260	2765	2265	499
1159	V	81166050	8696362	89862412	10.71	29.11	19.798	9.317	684	465	218
157	VI	11045678	1183465	12229143	10.71	67.58	42.584	25.000	1588	1000	587
10272		719074314	73296746	792371060	10.19	433.633	340.7532	92.880	10191	8008	2182

Table 3. Investment costs for the original, improved situations and obtained savings.

c. *Federal Plan of Houses.*

This measurement is addressed to houses corresponding to population with a medium and low-medium socioeconomic level. Nowadays, in the country, a Federal Plan of Construction of Houses 1 (PFV 1) of social interest with 120,000 units has been implemented. In the near future, another Plan (PFV 2) involving 300,000 units is going to be carried out. These plans are guided to palliate the historical deficit in this sector, as well as to stimulate the building industry, which is recognized to be the economic motive. This measurement appears like a good implementation to reduce consumption, as long as these new buildings will adequate their technological system to the present norm (Norma IRAM 11605).

Considering PFV 1 a saving of 12.61 kTOE/year is estimated, corresponding to the 0.41% of total heating consumption.

Figure 5 shows gas consumption for heating with improvements, without improvements and the energy saving. Figure 6 shows the distribution of those consumptions in the whole country and CO_2 emissions. Table 4, summarizes the calculation methodology for obtaining the investment for the different situations and geographic zones and the incremental cost.

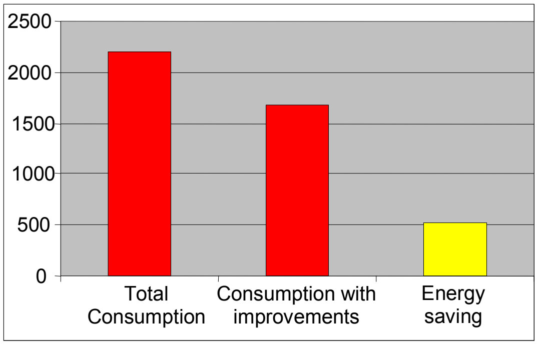


Figure 5. Gas consumption for heating. (TJ)

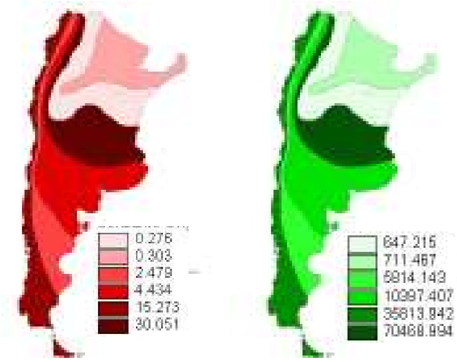


Figure 6. Natural Gas consumption for heating and CO_2 emissions. (PFV 1).

Houses (x100)	Env. Zone	Original Cost		Improved Cost			Consumption			CO2 Emissions(x100)		
		Unit	Total	Measurement	Total Cost	Measurement	kTOE/Year			Original	Improved	Mitigation
		m²	$(x100)	$(x100)	$(x100)	%	Original	Improved	Saving			
158	Ia-b	545	10370478	951420	11321898	9.2	0.300	0.250	0.050	7	5	1
144	IIa-IIb	545	9435258	865620	10300878	9.2	0.280	0.227	0.053	6	5	1
230	IIIa	545	15050502	1380780	16431282	9.2	9.740	8.050	1.690	228	189	39
480	IIIb	545	31392000	2880000	34272000	9.2	20.310	16.790	3.520	477	394	82
102	IVb	700	8583960	674454	9258414	7.9	4.430	3.620	0.810	104	85	19
22	V	950	2527380	146322	2673702	5.8	2.48	1.68	0.800	58	39	18
37	VI	950	4322880	250272	4573152	5.8	15.27	9.580	5.690	358	225	133
1175		747	105349410	7148868	112498278	6.8	52.81	40.197	12.613	1241	944	296

Table 4. Investment costs for the original, improved situations and obtained savings.

As for PFV 2 a saving of 25.93 kTOE/year is estimated, corresponding to the 0.49% of the total heating consumption.

Figure 7 shows gas consumption for heating with improvements, without improvements and the energy saving. Figure 8 shows the distribution of those consumptions in the whole country and CO_2 emissions. Table 5, synthesizes the calculation methodology for obtaining the investment for the different situations and geographic zones and the incremental cost.

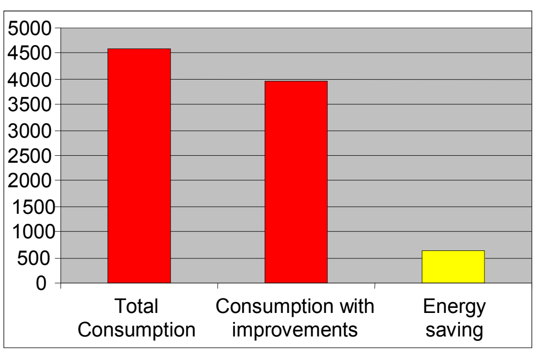


Figure 7. Gas consumption for heating. (TJ)

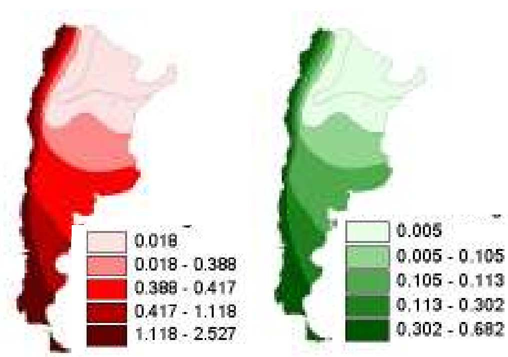


Figure 8. Natural Gas consumption for heating and CO_2 emissions. (PFV 2).

Houses (x100)	Env. Zone	Original Cost		Improved Cost			Consumption			CO2 Emissions (x100)		
		Unit	Total	Measurement	Total Cost	Measurement	kTOE/Year			Original	Improved	Mitigation
		m²	$(x100)	$(x100)	$(x100)	%	Original	Improved	Saving			
522	Ia-b	545	34164960	2131392	36296352	6.2	0.916	0.755	0.161	21	17	3
447	IIa-IIb	545	29233800	1823760	31057560	6.2	0.784	0.646	0.138	18	15	3
618	IIIa	545	40417200	2521440	42938640	6.2	24.030	19.860	4.170	564	466	98
985	IIIb	545	64419000	4018800	68437800	6.2	38.210	31.600	6.610	897	742	155
258	IVb	700	21708120	1178440	22886560	5.4	10.790	8.700	2.090	253	204	49
52	V	950	5942820	237712	6180532	4.0	5.8	3.94	1.860	136	92	43
116	VI	950	13269600	530784	13800384	4.0	29.41	18.500	10.910	691	434	256
2999		747	282305761	12442329	294748091	4.4	109.94	84.001	25.939	2583	1974	609

Table 5. Investment costs for the original, improved situations and obtained savings.

2. Substitution of illumination equipment.

The efficient use of electric energy in the residential sector, mainly the one corresponding to illumination, represents a good mitigation strategy to diminish the electric energy demand and consequently to reduce the emissions through mitigation measurements. In order to improve the consumption, the substitution of incandescent lamps for low consumption lamps is proposed. Percentages of energy saving and GEI reduction are calculated. The replacement of the 100% of incandescent lamps for high efficiency lamps was considered to evaluate the total impact of this measurement at a national level.

Once the consumptions in illumination for the original and improved situations were obtained and considering the power and useful life of the lamps, the amount and the replacement rates for the analyzed universe was calculated. From these results, the annual investment was calculated for both situations. In the case of the improved situation, the investment was calculated taking into account the substitution of equipment.

The analysis allowed establishing the possibility of obtaining an energy saving of 28% of the total in illumination for the residential sector and a 0.03% with respect to the total consumption of electric energy.

Figure 9 shows the illumination consumption and the energy saving obtained by the implementation of the measurement. The calculation methodology for the obtaining of the incremental cost from the investment for the original and improved situations is synthesized in Table 6.

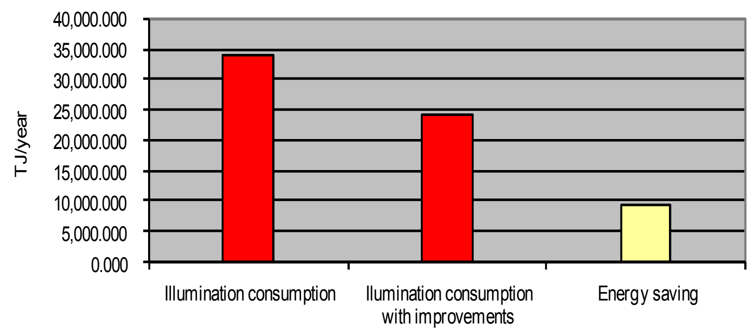


Figure 9. Illumination consumption.

Consumption (kWh)	P (kW)	H	P/year	AL	Useful Life (h)		Replacement		Lamp		Investment ($/year)		
					OS	IS	OS	IS	OS	IS	OS	IS	IC
5,815,843,640	0.10	5	182.50	31,867,636	1,000	8,000	8.76	1.10	1.00	9.00	279,160,494	314,055,556	-34,895,061

P=Power of the lamp (kW); H= Hours of daily use; P/year= annual energy of the lamp (kWh/year); AL= Amount of lamps; OS= original situation; IS= improved situation; IC= incremental cost

Table 6. Calculation of the incremental cost and the investment for the original and improved situations.

3. Substitution of non-labelled equipment.

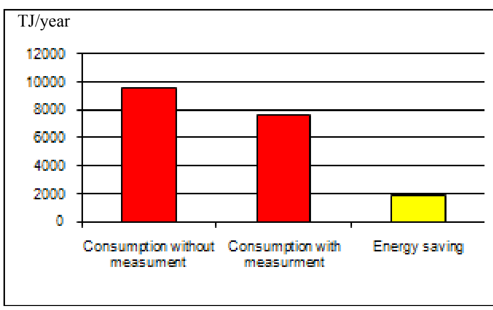
The National Secretary of Energy, through the Quality of Home Electrical Devices Program (PROCAEH), which worked from 1995 to 1999, set up a product list with the purpose of improving the energy efficiency. In 1996 a labelled program was implemented, adopting the label design of energy efficiency from the European Union with the intention of making it compulsory in Argentina. These backgrounds gave the framework to the Resolution 319/99 of the ex-Secretariat of Industry, Commerce and Mining, together with the Argentinean normative referring to the commercialization of electric equipment and information to the consumer.

These instances made possible the application of the labelled program from August 2005, settling down procedures and time limit for the certification. Refrigerators were the first one in which the labelled norm has been applicable. Two hypotheses of substitution of conventional refrigerators to labelled ones were considered. The first measurement outlines the incorporation of a new home device to a new home and the second measurement puts forward the normal substitution by useful life.

a. *Labelled refrigerators for homes. According to annual growth.*

This hypothesis outlines the incorporation of refrigerators with efficiency certification in all those new homes due to vegetative growth. It takes into account only the population's growth (0.9%) and not those new homes connected to the electric network.

If we consider that the total number of users in the residential sector is of 9,947,545 homes and that it has been registered a growth of 0.9% in the 2004-2005 period (INDEC), we obtain a total of 89.528 homes. The following consumption indicators are adopted: Labelled refrigerators "A" type = 332 kWh/year: "B" type = 398 kWh/year, adopting an average rank of 350 kWh/year. Refrigerator without labelling, = 436.8 kWh/year. The application of this measurement throws a saving of 45.34 TOE/year. This represents a saving of 19.8% on the consumption in this equipment and a 0.035% on the consumption of electrical energy in the residential sector. The results are shown in Figure 10. This measurement consists on the substitution of non labelled refrigerators by labelled ones, evaluating different alternatives for its substitution. The reduction of consumptions is considered in 68.1 kTOE/year and 160,056.4 tons CO_2 equivalent.



Number	Power (kWh/year)	Cost ($)	ORIGINAL SITUATION Investment ($)	Consumption (kTOE/year)	CO_2 Emission (TOE/year)
89,528	436,8	1,300	116,386,400	3.4	535,969

Number	Power (kWh/year)	Cost ($)	IMPROVED SITUATION Investment ($)	Consumption (kTOE/year)	CO_2 Emission (TOE/year)
89,528	350	1,800	116,150,400	2.74	429,405

SAVING	Measurement cost	Incremental cost ($)	(kTOE/year)	CO_2 Emission (TOE/year)
	500	44,764,000	0.7	106,564

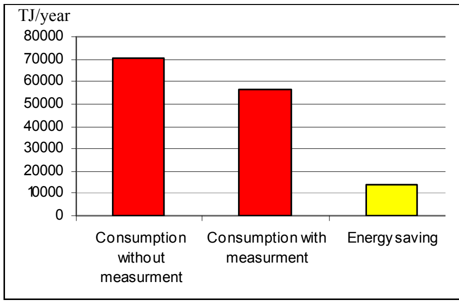
Figure 10. Consumption and saving. Labelled refrigerators according to annual growth.

b. *Labelled refrigerators for homes. According to its useful life.*

This measurement considers the substitution of the existing refrigerators taking into account that this equipment has a useful life of 15 years. This implies a progressive substitution of the total of the refrigerators in the country.

Taking into account that the total of users in the residential sector is of 9.947.545 homes and considering a substitution in 15 years, the application of this measurement is of 663,170 homes per year. The following consumption indicators are adopted: Labelled refrigerator "A" type =332kWh/year; "B" type = 398kWh/year, adopting an average rank of 350kWh/year. Refrigerator without labelling = 436,8Kwh/year.

The application of this measurement throws a saving of 335.62 kTOE/year (14,029 TJ/year). This represents a saving of 23.5% of the consumption in this equipment and a 0.31% reduction of the electrical energy consumption in the residential sector. The results are shown in Figure 11.



Number	Power (kWh/year)	Cost ($)	ORIGINAL SITUATION Investment ($)	Consumption (kTOE/year)	CO_2 Emission (TOE/year)
663,170	436.8	1,300	862,121,000	25	3,971,189

Number	Power (kWh/year)	Cost ($)	IMPROVED SITUATION Investment ($)	Consumption (kTOE/year)	CO_2 Emission (TOE/year)
663,170	350	1,800	193,706,000	20	3,182,371

SAVING	Measurement cost	Incremental cost ($)	(kTOE/year)	CO_2 Emission (TOE/year)
	500	331,585,000	5	788,818

Figure 11. Consumption and saving. Labelled refrigerators according to its useful life.

CONCLUSION

From the obtained results it is concluded that the measurements that produce energy savings and less GEI emissions with low significant marginal costs, are those associated to substitution of illumination equipment, with the replacement of Incandescent Lamps (LI) by Fluorescent Compact Lamps (LFC) and of Fluorescent Tube (TF) by three Phosphorus Fluorescent Tube (TFT). Figure 12.

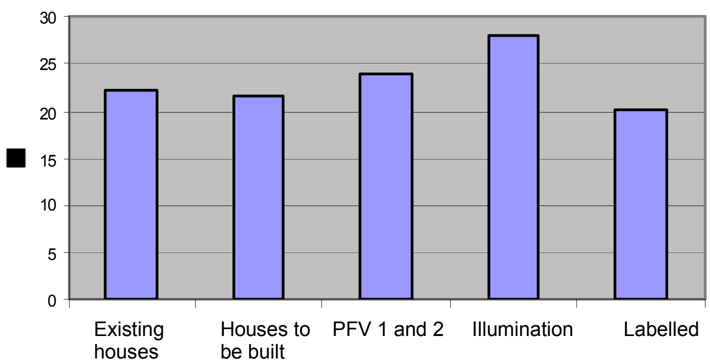


Figure 12- Energy saving.

If we analyze the envelope improvement measurement, tending to save natural gas for heating by the incorporation of thermal insulation according to level "B" of the IRAM Norm 11605, we conclude that economic savings are not significant, in the Centre regions. Nevertheless if we consider the amount of houses considered for the application of the measurement, the saving becomes more important as it is shown in Figure 13. We must also stand out that its habitability improves. In the coldest regions there is an important saving of energy since consumption values are really important.

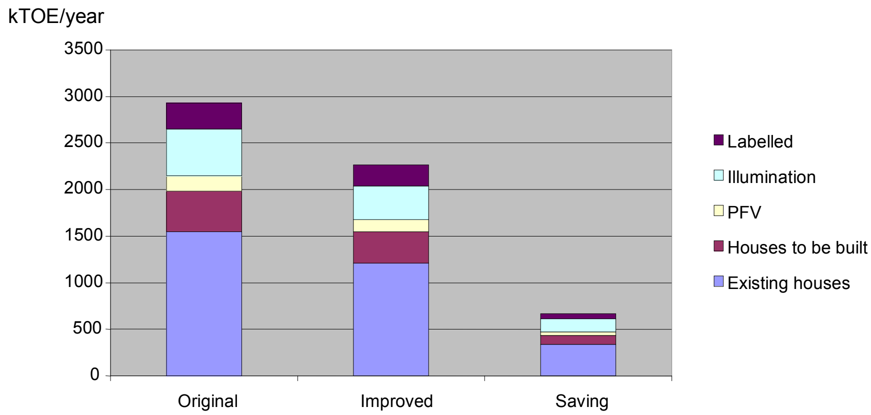


Figure 13- Distribution of the energy efficiency measurements in the total saving.

The measurement of substitution of non-labelled equipment is viable since they offer important savings in emissions with an economically profitable equation. The decisions on this item must tend to the application of the two proposed measurements. On one hand, all new home must be stimulated and "be helped" to incorporate a certified equipment. In the other hand, all family in an approximated period of 15 years must replace their equipment, by a labelled one.

It is verified that the application of energy efficient use policies in different sectors is of extreme importance in a context of increase energy demand due to the economic and industrial growth and to greater exigencies of comfort with low levels of habitability, which has had as consequence the need to palliate this increase with the purchase in international costs of energy vectors. It must be considered the accelerated diminution of the reserves, deepened by the mentioned demand and affected by the non investment, compromising in the future decades the National energy matrix.

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