ENERGETIC SAVING POTENTIAL AND AIR POLLUTANTS REDUCTION IN THE RESIDENTIAL SECTOR. THE CASE OF THE METROPOLITAN AREA OF BUENOS AIRES.

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SUMMARY

The conservation policies and Rational Use of Energy (RUE) developed until the present, had their origin in the search of a smaller energetic consumption in order to reduce economic costs in a growing prices market of the fuels. Consequently methodologies were developed for the **energy saving dimensionment** for the residential sector with energetic supply nets. Its implementation is based on the typological-buildings analysis of the housings park, supported by a plan of audit - energetic diagnosis, and the validation by comparison between the audited consumptions and the one registered by the companies services lenders.

From the typological analysis of representative housings and from the global and detailed energetic audits on a basic sample of 2000 households of the area, the segregated information of each energetic vector is obtained (electricity and natural gas) and of the way of use (heating, boiling, hot water, lighting and others). The integration of representative typologies, consumption, intervention and validation measures, allows to quantify the **energy potential saving** of the residential sector.

What concerns to the environmental effects that those consumption were generating - expressed to local scale by the gases emission and to regional scale by the need of widening energy production - were not taken into account.

This work advances on these topics quantifying the contribution of the energetic consumption of the residential sector of the Metropolitan Area of Buenos Aires to the atmospherical pollution, evaluating its decrease upon adopting measures of RUE in the considerated sector.

REFERENCIAL AND HISTORICAL FRAMEWORK.

The emerging conditions of the energetic crisis of the years 70, impelled in the Argentina, through governmental entities (Housing and Energy National Secretariats), projects refered to **conservation and rational use of energy**. The **AUDIBAIRES** project (1987) was framed within that context and made possible to qualify the use and quantify the consumption of energy in the residential sector of the Metropolitan Area of Buenos Aires, that encompasses the metropolitan more important region of the Argentine Republic. It involves Buenos Aires City; the Great

Buenos Aires (includes 19 municipalities); La Plata City, (Buenos Aires Capital, first Argentine state); and the Great La Plata (including the adjacent municipalities). The set involves 11.445.290 inhabitants, approximately 30% of the national total, concentrated in an equivalent area to the 0,001% of the country area. It includes 3.251.118 housings (INDEC 91) in those which is consummated approximately 40% of energy destined to the residential sector of the country.

The vastness of the universe in study led to implement technics that allow to obtain a good representation with the smaller cost -time. This means to certify a representative sample of the smaller possible size reducing the identification and classification, taking into account the great dispersion of types and edilic models that characterize these sectors of our country, especially in its areas more densely inhabited. This is important not only in the analysis and evaluation stages but in those of policies and diffusion implementation, in how much makes it possible to concentrate the efforts minimizing the costs.

Therefore we appeal to the **typological analysis**, existing similar experiences, in Italy, France and EEUU. The typological classification techniques allows, the organization and simplification of the complex sets of data related to a population, permitting to concentrate the representation in that of its principal types (ROSENFELD, 1987). The treatment process used was first by concentration and then by partial concentration (ROSENFELD,1992). We are actually working in improving these techniques and studying the variables as a previous step to the calculation of the distances between the types.

It has been defined an original sample of 2.000 housings, being implemented 360 global energetic audits and 91 detailed; classified according to similar types concerning to estructuration, architectural models and different constructive technology.

Seventeen basic typologies were detected whose different characteristics were summarized in normalized charts (ROSENFELD,1992). Types and variants were also included. It encompasses from individual to collective housings, of high density originated from the private initiative and of the official plans.

The audit process encompassed the following stages: **a. - constructive characteristics and energetic equipment report:** it was carried out on documentation provided by municipal offices, proprietaries, reports and verifications *in situ*. It is realized at a necessary detailed level to carry out a thermal balance. It includes location of heat and lighting sources. **b. - Evaluation Model:** The model is composed by: a constructive and thermal characteristics data base of different types of insulation; a thermal balance program in steady state conditions and files of the registered segregated consumption, of associate - energetic characteristic of the users, and of their housings and of the measurements realized in them. The balance was validated globally comparing the calculated and measured consumption.

VALIDATION OF THE METHODOLOGY BY TYPOLOGICAL ANALYSIS

To validate the implemented methodology, using typological buildings analysis, we contrast the types of use and energetic consumption for each type detected according to its representation in the analysis universe, with the records of the companies lenders and distributive of energy. The used procedure was the following :

i. - The quantity of users and residential consumption registered in the year 1991, of the lenders SEGBA and the State Gas respectively, was obtained from ENRE, Regulatory National Entity of Electrical Energy and of the ENARGAS, Regulatory Entity of Gas. The data of population and housing, also correspond to the National Census of Population and Housing that were realized in the same year. Table 1.

Table 1 - Consumption in housings (1991), according to lenders

	CONSUMERS	RESIDENTIAL CONSUMPTION REGISTERED TEP/year
NATURAL GAS	2.428.800	2.294.745
ELECTRICITY	3.415.706	465.650

Of the analyzed housings universe were taken those of greater statistic weight, resulting eight types from single dwellings and seven from multistories dwellings.

In base to the registered consumption (Table 1), to the typological representation percentual and the disagregation between single dwellings with a 57,2% and multistories dwellings with a 42%, Table 2 was elaborated exposing the consumption by typology according to the way of energy.

Table 2 - Single dwellings consumption by typology and form of energy

Designation	Natural Gas		Electrical Energy	
	m³	TEP/year	KW/h	TEP/year
Houses - Mean Values for housing	1.312	1,22	1.591	0,14
Multistories dwellings - Mean Values for housing	753	0,70	1.192	0,10

ii.- The data obtained by typology with the audit - diagnostic (360 global and 91 detailed) and its degree of participation in the universe, allowed us to deduce the total consumptions of the residential park, integrating typological sectors (houses and multistories dwellings) and ways of energy. These results can be observed in Table 3 for natural gas and in Table 4 for electricity.

Table 3 - NATURAL GAS. Consumption deduced by typological sectors

Designation	Users	Global Consumption Deduced (TEP/year)

HOUSES	1.389.274	1,10	1.528.201
MULTISTORIES DWELLING	1.039.526	0,66	686.087

Table 4 - ELECTRICAL ENERGY. Consumption deduced by typological sectors

Designation	Representation	Users	Global Consumption Deduced (TEP/year)	
HOUSES	100,0%	1.953.784	0,13	253.992
MULTISTORIES DWELLINGS	100,0%	1.461.922	0,08	116.954

iii.- Taking as basis the means values sampled for Natural Gas 1,22 TEP/year/h. (individual housings) and 0,70 TEP/year/h. (multistories dwellings) and for Electrical Energy 0,14 TEP/year/h. and 0,10 TEP/year/h. respectively, it is related the consumption audited for typological analysis and the one registered by the companies supplier of energy, verifing a difference of approximately 3,6% between both gas values and 25,5% for electricity. Table 5.

Table 5 - Comparison between the consumption audited (deduced) and the registered (real)

Total users Metropolitan Region	Users (91)	Deduced TotalConsumption Region (TEP/year)	RealConsumption (TEP/year)	Difference (%)
NATURAL GAS	2.428.800	2.214.288	2.294.745	3,6
ELECTRICAL ENERGY	3.415.706	370.946	465.650	25,5

The relative difference of the 25,5% in electrical energy does not envisage its clandestine consumption. The levels declared by the lenders companies of the service, for the considerated periods, oscillate between 15% and 20% of the total consumption, depending on the considerated zones. If we incorporate this factor into the deduced value, we observe that the relative difference is reduced to 5,5%.

With these values the methodology to dimension the potential energy saving was considered validated.

ENERGY SAVING POTENTIAL

Validated the methodology, we proceeded to implement for each building typology, a serie of corrective measures for the purpose to evaluate the energy saving potential by energetic and total vector.

It is quantified in primary energy in order to consider the transformation efficiency . In the case of electrical energy we consider a transformation efficiency of 25%. From the obtained data we had elaborated tables that summaries the primary energy consumption discriminated in gas and electricity and that relate the consumption audited and deduced from the study and the one registered by the companies lenders of each service. Table 6.

Table 6 - Consumption in primary energy

	Deduced consumption of the study in annual TEP	%	Real consumption in annual TEP	%
TOTAL	**3.698.072**	**100**	**4.157.345**	**100**
Gas	2.214.288	60	2.294.745	55
Electricity	1.483.784	40	1.862.600	45

In Table 7 we synthesize the consumption discriminated according to uses from the obtained data. (AUDIBAIRES, 1987)

Table 7 - Consumption according to uses in Primary Energy in TEP/year.

TOTAL	**4.157.345**	**100%**
HEATING	963.793	23%
HOT WATER / BOILING	1.330.952	32%
LIGHTING	633.284	15%
HOME APPLIANCES	1.229.316	30%

The potential energy saving in gas has been dimensioned taking into account the 58% of the consumption corresponding to boiling and hot water and 42% to heating. It was considered that the principal saving would come from the implementation of conservation measures for heating. It was not included the possible saving originated from the penetration of solar hot water by requiring a deeper study not available yet.

The considerated measures were the following: For individual housings: a. - thermal insulation increase in ceiling - cover, adding the equivalent to 2,5 cm of expanded polystyrene (R=0,61 m² ºC/W) and 5 cm (R=1,22 m² ºC/W); b. - Infiltrations reduction through sealing leakages, considering a renovations decrease of 1,5vol./h to 1vol./h; c. - double glass and heavy curtains location and d. - insulation increase in walls, adding R=0,61 m² ºC/W. For multistories dwellings: a. - infiltrations reduction through sealing leakages; b. - Double glass and heavy curtains and; c. - thermal insulation increase in walls (R=0,61 m² ºC/W).

With these interventions, balances of steady state conditions were realized, considerating them in individual and collective form. The necessarry energy consumption for heating could be evaluated, and as it has already been mentioned, it is where the biggest savings are foreseen. This consumption has been compared with the one the building had required in its originate state. The difference between both situations is the possible energy saving that can be obtained.

Table 8 shows the total and the segregated consumption according to the different measures of saving.

Table 8 - Effect of the saving hypothesis by year and by measure.

Measured of Saving and/or energy conservation						
Denomination	Ceiling 2,5 cm	Infiltration control	Windows Heavy curtain	Windows DoubleGlas s	Walls 2,5 cm	TOTAL p/housing
Houses	0,056 TEP	0,012 TEP	0,036 TEP	0,036 TEP	0,055 TEP	0,159 TEP
Multistories dwellings		0,0041TEP	0,0127 TEP	0,0131 TEP	0,0136 TEP	0,044 TEP

The potential energy saving in electrical energy has been dimensioned taking into account the existing technology in the market with the corresponding cost-benefit study for each case. Consequently it has been considered in this instance the lighting aspects, through the incorporation of appliances of less consumption, since they envisage an important saving with an acceptable investment of acquisition and installation. The considerate saving in this case is estimated in a 27% (AUDIBAIRES, 1987), the values are synthesized in Table 9. It was not included the possible saving originating from other equipments of last generation (home appliances) because of being most of them incorporated to the usual equipment or being considered an important investment.

Table 9 - Effect of the saving hypothesis

ELECTRICAL ENERGY	1.862.600 TEP/year	100%
Electrical Energy intended for Lighting	633.284 TEP/year	34%
Saving energy in lighting	170.986 TEP/year	27%

The global potential energy saving is synthesized in Table 10.

Table 10

Total Energy Consumption	4.157.345TEP/year	100%
Potential saving in heating	316.128 TEP/year	7,6%
Potential saving in lighting	170.986 TEP/year	4,1%
Global potential energy saving	487.114 TEP/year	11,7%

The good adjustment obtained between the consumption deduced by audit - diagnostic and the real registered by the companies that supply energy, seemed to indicate that the methodology is correct for the study of the segregated consumption of energy .

The potential energy saving more meaningful correspond to heating with a 7,6% of the total of primary energy. What concerns to lighting, the saving represents 4,1%. Both savings represent 487.114 TEP/year (11,7%).

AIR POLLUTANTS REDUCTION.

The current situation of urban pollution registered in the last years, makes us think seriously about the reduction and control of the pollutants emited to the ambient. The development of the daily life in these centers implies energetic consumption based fundamentally on the use of fossil fuels, not renewable; where transportation, the domestic equipment and the own construction of the city make critical this situation.

In the last decades it has been attempted in all sense to make efficient the developed technologies in order to obtain smaller energy consumption (fundamentally from operation) and to reduce the gases emission to the atmosphere.

In such sense and having as base the "Potential of Conservation of Energy in the Residential sector", it was quantified the atmospherical pollution by gases emission. It was evaluated the decrease of those emissions as adopted measures of Rational Use of Energy (RUE).

The energetic consumption with domestic purposes reaches, 4.157.345 TEP/year (10% of the energy that produces the country), (**AUDIBAIRES**), fundamentally in the use of natural gas and electrical energy. Except for the NOx, its gaseous emissions are of the same order of magnitude that the industrial emissions and it is the second responsible in particulate matter emissions behind the industrial sector, (**DIAZ de HASSON**, et al, 1994).

The implementation of rationalization measures of the energy consumption based on improvements of the building insulation and lighting appliances, implies important reductions in the natural gas consumption for heating and electrical energy. This saving would impact favorably in two forms:

i. In a direct form and to local scale by the reduction of the operation costs, as well as by the decrease of the gases emission to the urban environment;

ii. As an indirect manner and in the regional area in a decrease of the fuels requirement not renewable. They would be avoided, thus, greater demands to the central thermal existent, reducing, furthermore, the emission of pollutants to the atmosphere.

For the case of Natural gas:

The domestic consumption of this fuel reaches 2.294.745 TEP/year, of those which 1.330.952 TEP/year (58%) are destined for boiling and hot water and 963.793 TEP/year (42%) to heating. It was considered that it is in this last use (as was mentioned before) where it can be achieved a reduction of the consumption levels, for something which were defined measures of easy implementation energy conservation in existing housings. These measures were centered in individual (houses) and collective (multistories dwellings) housings, being considered the following:

a. increase of the thermal insolation in ceiling and cover;
b. location of sealing leakages on doors and windows, reducing the air infiltration;

c. double glass location and heavy curtains in windows;
d. increase of the thermal insolation in walls.

The whole application of all of them result in a saving of the 13,8 % in the energetic consumption of the total of the residence park and a 32,8 % of the consumption intended for heating. This decrease implies reduction on the development of the resource and pollutants decrease emited to the atmosphere.

The coefficients of pollutants emission considered for the residential - commercial - public sector in Kg/TEP (1TEP = 1.070m3) are the following: Particulate matter*:* 0,19 Kg/TEP; SO_2 : 0,005 Kg/TEP; NOx: 1,8 Kg/TEP; Hydrocarbons: 0,38 Kg/TEP; CO: 0,38 Kg/TEP; it was considered also the contribution of CO_2 since it contributes to the increase of the greenhouse effect CO_2: 2.120 Kg/TEP .

In Table 11 we observe the total and for heating consumption in primary energy and the emissions generated by that consumption for the study area.

Table 11: Emission of pollutants of the final consumer in primary energy Kg/year for Natural Gas.

	TEP/year	Partic. (Kg/year)	SO_2 (Kg/year)	NOx (Kg/year)	HC (Kg/year)	CO (Kg/year)	CO_2 (Kg/year)
TOTAL	2.294.745	436.000	11.473,7	4.130.541	872.003	872.003	$48,6 * 10^8$
Heating	963.793	183.120,7	4.819	1.734.827	366.241	366.241	$20,4 *10^8$

For the case of electrical energy:

This vector has three sources of generation with different participation level and different effects on the environment: 10% of nuclear origin, 30 % of hydroelectric origin and 60% of thermal origin. It is adopted this last source of generation to calculate the emissions in the Metropolitan Area of Buenos Aires (AMBA), due to the type of gases sent to the atmosphere. The thermal central have increased in the years '90 the burn of natural gas in detriment of the burn of fuel oil, carrying the participation of this to the 76% of used energy. For the calculation of the gaseous emissions, we took into account these percentages since natural gas and fuel oil emite in different degree. They have already been mentioned the values of natural gas emission; for fuel oil it has been considered the following (in kg/TEP): Particulate matter: 0,38 Kg/TEP; SO_2:10 Kg/TEP; NOx:2,7 Kg/TEP; Hydrocarbons: 0,19 Kg/TEP; CO:0,77 Kg/TEP; CO_2: 3.050 Kg/TEP. Since for this energetic vector the pollution is in the source of generation and not in the final consumption, they have been considered primary energy values.

According to these considerations, electricity consumption of the area is of 1.862.600 TEP/year, corresponding to lighting 633.284TEP/year (34%). It is in this use where it can be obtained energetic saving through the utilization of appliances of less consumption, being estimated such saving in 170.986TEP/year (27% of electricity intended for lighting). In Table 12 the values of electricity consumption, are shown as well as the gases emission produced by the generation of energy.

Table 12: Emission of pollutants of the final consumer. Primary Electrical Energy in Kg/year.

	TEP/year	Partic. (Kg/ year)	SO_2 Kg/ year)	Nox (Kg/ year)	HC (Kg/ year)	CO (Kg/ year)	CO_2 (Kg/ year)
TOTAL	1.862.600	438.828,5	4.470.947,8	3.755.002	622.853,5	882.127	$43,0*10^8$
LIGHTING	633.284	149.201	1.522.280,9	1.276.695	211.769,2	299.922	$14,8*10^8$

The energetic saving obtained for both cases:

The energetic savings obtained through the implementation of the already mentioned measures, would reach 418.719 TEP/year, of those which 84 % correspond to heating and 16 % remaining to lighting.

In Table 13 such savings are exposed and the kg/year of pollutants that such saving would avoid to be sent to the atmosphere .

Table 13: Energetic saving synthesis and pollutants reduction in Kg/year.

	TEP/year	Partic. (Kg/year)	SO_2 (Kg/year)	NOx (Kg/year)	HC (Kg/year)	CO (Kg/year)	CO_2 (Kg/year)
Heating	316.128	60.064	1.581	569.030	120.129	120.129	$6,7*10^8$
Lighting	102.591	24.170,3	246.608	206.823	34.306,4	48.587,1	$2,4 *10^8$
Total	418.719	84.234	248.189	775.853	154.435,4	168.716,1	$9,1*10^8$

The emission to global scale of the total CO_2 is of 116 to 177 Pg (Pg=petagramo=10 15g), where the involved sources of emission correspond to agriculture and forestry (2,6 Pg/year), natural ecosistema (111-169 Pg/year), energy (4,5Pg/year) and other human activities (0,1 Pg/year). And for NOx of 80-210 Pg/year, 1-3 Pg/year, 3 Pg/year and 6 Pg/year (energy) respectively. If we compare its annual emission in the study zone important reductions from approximately 17% are obtained and what concerns to global level 0,03 and 0,02 o/oo for CO_2 and NOx respectively. In Table 14 such values are synthesized.

Table 14: Global emission and reduction for the AMBA of CO_2 and NOx in kg /year.

	Energy Global Emission	Gas Emission AMBA	E.Elect. Emission AMBA	Total Emission AMBA	Calefacc Reduction AMBA	Iluminac Reduction AMBA	Total Reduction AMBA
CO_2	$4,5*10^{12}$	$48,6*10^8$	$43,0 *10^8$	$91,0 *10^8$	$6,7 *10^8$	$2,40 *10^8$	$9,1 * 10^8$
NOx	$6,0*10^{12}$	$0,04*10^8$	$0,03*10^8$	$0,07*10^8$	$0,005*10^8$	$0,002 *10^8$	$0,007 * 10^8$

CONCLUSIONS

On a total consumption of 1,5 TEP/year/per capita (maximum value reached in the years 87-88), the energetic consumption with domestic purpose for the Metropolitan Area is of 0,38 TEP/year/per capita. From this value 14,6 % is destined for heating and lighting, what implies an emission of 0,65 kg/per capita on an approximated total of 1027 kg/per capita for the year 1988, (DI PACE, M. et al.1992).

The energetic saving expected with the adoption of the measures proposed is of the order of the 10 %. This reduction in the consumption is translated in a reduction in the gases emission pollutants, that it can be discriminated as continues:

*The reduction in the emission of CO_2 would be of the 13,80%, for the natural gas and 6 % for electricity.

*In the case of the NOx the values are 12,5 % of reduction for natural gas and 6,6% for electrical energy.

*It is important the reduction of SO_2 (16 %) because of the electricity saving, by the high sulphur content that have the flammable liquid used for the generation.

The implementation of energy conservation standards in the construction allows the improvement of the quality of life in two important aspects. On one hand the thermal interior confort of the housings is increased with the consequent confort for the users. On the other hand it contributes to a greater rationality in the generation, distribution, transformation and final consumption of the energetic resources, reducing negative environmental impacts.

A greater energetic saving would be obtained through the optimization in the design and use of the domestic equipment.

The possibility of making effective these reductions depends of the existence of an energetic policy that envisage the existence of conservation procedures and rational use of energy. These should be of obligatory fulfillment in the area of the construction in particular and for all the sectors as a rule.

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