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Article

Energy Subsidies in Argentina Lead to Inequalities and Low Thermal Efficiency

Alejandro D. González *

Research Institute on Biodiversity and Environment (INIBIOMA), CONICET and Universidad Nacional del Comahue, Centro Regional Universitario Bariloche, 8400 Bariloche, RN, Argentina

* Author to whom correspondence should be addressed; E-Mail: agonzalez@crub.uncoma.edu.ar; Tel.: +54-2944-423-374; Fax: +54-2944-422-111.

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Abstract: Natural gas is the main energy resource for buildings in Argentina. Since 2002, subsidies have kept the prices of this fuel between 9 and 26 times lower than regular prices in other countries. The lowest prices are the result of climate-related subsidies. In cold areas, heating uses several times more energy than locations in Europe with a similar climate. A potential for consumption reductions of up to 70% suggests a very low building thermal performance. The main barriers to finding a solution are the heavy subsidies and public unawareness. Users, government officials, and construction professionals do not identify the very low thermal efficiency. Energy policies to encourage improvements are proposed.

Keywords: energy subsidies; thermal efficiency; improvements; savings

1. Introduction

The building sector in Argentina accounts for one of the largest industrial activities in the country. In the period 2003–2008, the residential building sector has had an average annual growth of 11%. Materials such as bricks of different sorts, cement, metals, tiles, ceramics, wood, thermal insulations, and a diversity of accessories and appliances are readily available on the market. Moreover, the large majority of these building materials are made in Argentina to high quality standards. Both the relatively convenient price and a feeling of a solid durable home determine that the most common construction materials for houses are cement and bricks.

On the other hand, several studies have shown that the energy consumption in residential buildings in Argentina is very high compared to buildings in similar European climate zones. For example, in the cold region of Patagonia, a study showed that one-family houses in the city of Bariloche (mean temperature 8 °C) spend nearly four times more heating energy than the same type in Stockholm (Sweden, mean temperature 7 °C) [1]. In Bariloche, the average annual gas consumption for heating in one-family dwellings was 410 kWh/m^{2}year, contrasting with the average 120 kWh/m^{2}year in Sweden or other north European locations [2,3]. In Argentina, even in a warm temperate location like La Plata (the capital of Buenos Aires Province, mean temperature 15.5 °C), the annual consumption in heating for one-family houses, ranging from 150 kWh/m^2 to 250 kWh/m^2, can be higher than in Stockholm, Sweden [4,5].

Due to exposure indexes, apartment buildings spend less energy in heating and cooling than houses. For a location in La Pampa Province, with a mean temperature of 15.4 °C, studies showed that the average annual heating load for a conventional apartment building was 104 kWh/m^2. This value would match thermal standards of Germany from 1983 [6]. Other researchers investigated the gas consumption in Río Grande [7,8], located in the southern province of Tierra del Fuego. This location presents a mean temperature of 5.5 °C, with requirements of 4,450 Celsius Heating Degree-Days (HDD is a climate-related variable that roughly estimates the heating needs of a building; it is usually defined as the sum of differences of the mean temperature with respect to a base of 18 °C [9]). This heating requirement is only 10% higher than in Stockholm (Sweden), however, heating loads for apartment buildings reached 850 kWh/m^{2}year in Río Grande, with average consumption for a 100 m^2 dwelling of 7,000 m^3 of natural gas per year [8]. The study also concluded that even a moderate refurbishment consisting of 5 cm insulation would lower gas consumption 2.5 times. Argentinean norms include different levels of thermal quality, but the norm is not obligatory and only used as a reference.

In the cases investigated, the buildings were structurally of good quality construction, and most were in the range of mid-income households. In Bariloche, for instance, seismic codes are strict, leading to costly structural options (in their majority concrete with brick walls). However, the use of thermal insulation in this cold location is alarmingly rare, found in only 3% of dwellings in a recent survey [1].

On the other hand, insulation materials, such as expanded polystyrene, glass wool and polyurethane, as well as several options for their installation (anchoring and siding), are readily available in the Argentinean market, and at reasonable prices. Given the present thermal status, a moderate external insulation that would cost between 10% and 15% of the total cost of the house leads easily to a 60% reduction in heating. This level of energy reduction by refurbishment with local materials is in agreement with several studies in Argentina [10–12]. When improved design and passive solar are also considered, the reductions can reach 70% to 75%, with low cost investment [9,13]. Most areas in Argentina have a winter season and heating load, but it is in cold regions where the absolute reductions would be larger. For example, at the cold location of Bariloche the potential saving in one-family dwellings may average 2,500 m^3 of natural gas per year, which represents greenhouse emissions equivalent to driving a car 30,000 km. The cold region of Patagonia accounts for 5% of households in the country, but uses 21% of natural gas consumed in the residential sector [14].

Why then do not owners and builders choose the available thermal improvement options? The present paper analyses the direct effect of the extremely low price of subsidised natural gas on the actual household-energy status in Argentina.

Through almost a decade of frozen energy bills for natural gas and electricity, a large part of the population has developed a strategy of solving comfort conditions based on high energy consumption. Since 2002, the price of natural gas in Argentina (the main energy source for households) has been set at 9 to 26 times lower than regular household market prices in other countries. Moreover, in the period 2005–2008, Argentinean households paid for end-use gas between 3 and 10 times less than the well-head price in the US [15] (a commodity in the New York Mercantile Exchange), for Buenos Aires and Bariloche, respectively. Nationwide, government subsidies have helped to keep prices at these low levels. The range of values given here are due to regional subsidies: the coldest locations benefited from the resource at the lowest price.

In 2002, Argentina suffered a social and economic crisis. The banks and financial institutions were not able to return deposits to customers and cash flow was severely constrained, pushing the government to an emergency plan, including the printing of local bonds to pay salaries. For both internal and external debts, the country came into default. Previously, from 1992 till 2002, the dollar ($) rate was fixed 1 to 1 to the Argentinean Peso (AR$). But in 2002, the inevitable devaluation made the rate changed to almost 1 to 4, which then stabilised around a value of AR$ 3 per $ 1 until the end of 2008. To moderate the effects of devaluation in internal prices, in 2003 the government enforced a set of measures to fix energy prices. The measures were mostly designed on heavy subsidies and agreements with private companies. Some of the relevant features were: the regulation of well-head price for oil and natural gas for all domestic transactions, the fixing of natural gas prices for households, and giving heavy subsidies on diesel for public transportation. In fact, natural gas prices for households were fixed in pesos to the 2001 prices [16].

Energy is generally perceived as money to pay, and low energy bills discourage investments in technological improvements. Furthermore, the subsidies are not income sensitive, i.e., all households enjoying natural gas pay the same unit price of heavily subsidised energy. This is probably the single most convincing reason for middle-high and high income households to not choose better thermal performance buildings, even though they can afford them.

Nevertheless, fuel availability and subsidies are not equally distributed in Argentina. Around 40% of households are not connected to natural gas, and use instead Liquefied Petroleum Gas (LPG), firewood, electricity and other minor fuel contributors. The majority of households not connected to natural gas supplies are of middle-low and low incomes, and pay per unit of energy a price 5 to 20 times higher than that of natural gas. Since 2002, the regulatory energy policy did not include LPG, kerosene or charcoal, so LPG prices then raised a factor of three following the dollar rate, in contrast with natural gas prices which were fixed in pesos. The sectors not connected to natural gas also paid with their taxes benefits that are enjoyed by richer parts of the society. This shows that the subsidies on natural gas in Argentina were not directed to alleviate poverty. For details on these measures and the social implications see for instance Bravo *et al*. [16].

Policies for energy efficiency in Argentina focused on electricity. The main Program for Rational Use of Energy (PURE in Spanish spelling) contains the usual recommendations for lamps, refrigerators, and other electrical appliances. However, in households provided with natural gas electricity accounted for only 4% of household energy used in Bariloche [1] and 12% in the warmer location of La Plata [17]. Regarding gas, there was a set of recommendations for cooking on low flame, keeping heaters clean, and similar ones, but none on energy efficiency of buildings or conservation measures [18]. So far, energy policies in Argentina were oriented to price regulations and to guarantee the availability of fuels, more than on the efficiency in their use. The effect of these policies was then a promotion of consumption [18].

The objectives of this article are: (1) to present evidence and the consequences of an energy policy based on heavy subsidies for natural gas in Argentina; (2) to demonstrate the environmental and social injustices derived from subsidies that reach only 60% of the population and leave most poor sectors outside; (3) to demonstrate that subsidies to natural gas have contributed to very low thermal efficiency; (4) to show that improvements are readily available and at affordable costs; and (5) to propose energy policies to encourage households and authorities to start building thermal improvements.

2. Energy Resources and Prices

2.1. Natural gas, the main household energy supply in Argentina

Natural gas and oil are the main energy resources used in Argentina, with about equal share in the provision of energy. The country is almost self sufficient in these two resources. Electricity generation consumes 38% of the natural gas, while industry and residential require similar amounts at around 22%. Transport, in the form of Compressed Natural Gas for vehicles, uses 12%; and other sectors the rest [19]. Nationwide, nearly 60% of households are connected to the natural gas network [14].

Until 2008, Argentina could provide their domestic customers with natural gas from its own wells, plus a minimum amount, less than 4%, imported from Bolivia, which was usually compensated by exports to other neighbouring countries. Nevertheless, natural gas reserves have been dropping steadily for the past five years. Summing up the confirmed reserves and half of the probable ones, the decrease between 2004 and 2007 was 30% [20]. From another source [21], the reduction of reserves was 22% between 2004 and 2007, and 38% between 2003 and 2007. Thus, the winter of 2008 (June through September) has seen the first imports of Liquefied Natural Gas (LNG), unloaded from vessels at the port of Bahía Blanca, in the south part of Buenos Aires province, then gasified and injected into the main nationwide pipeline. Although, there was no official information of the price paid, press releases [22] reported a value near $\$0.52/m^3$. This price is in agreement with international trade at the time, \$14 per MBTU, where 1 MBTU (Mega British Thermal Unit) equals 252 Mcal, and it is the energy available in 27 m^3 of gas (Gross Calorific Value of 9,300 $kcal/m^3$). At the same time, households paid $\$0.026/m^3$ in the region of Patagonia and $\$0.075/m^3$ in the Buenos Aires area.

In households with provision of natural gas the energy derived from it surpasses several times that derived from electricity. In La Plata, with a warm-temperate climate, households use eight times more energy derived from natural gas than that from electricity [17]. In a cold location like Bariloche, space heating load leads to around 20 times more energy derived from gas than that from electricity [1].

Table 1 shows the prices of natural gas, electricity, premium gasoline, and automotive diesel, for two locations in Argentina, and for different countries, in 2008.

Table 1. Prices of households' energy and vehicle fuels, in Argentina and other countries.

	Natural gas, households, $/m^3 (1)	**Natural gas commerce, $/m^3 (1)**	**Electricity households $/kWh**	**Premium gasoline $/litre**	**Automotive diesel $/litre**
Argentina, Bariloche	0.026 (2)	0.043 (2)	0.10	0.95	0.69
Argentina, Buenos Aires	0.075 (3)	0.063 (3)	0.08	0.9	0.61
Canada (4)	0.41	0.23		1.14	1.08
Chinese Taipei (4)	0.42	0.47	0.074	0.96	0.86
Finland (4)	0.45	0.32	0.17	2.12	1.50
France (4)	0.83	0.50	0.17	2.03	1.56
Italy (4)	0.94	0.47	0.27	2.05	1.61
Korea (4)	0.66	0.52	0.096	1.73	
México (4)	0.67	0.39	0.11	0.48	0.66
Netherlands (4)	1.14		0.24	2.28	1.54
Poland (4)	0.70	0.42	0.18	1.79	1.40
Spain (4)	0.90	0.41	0.19	1.64	1.40
Turkey (4)	0.54	0.48	0.16	2.60	2.18
United Kingdom (4)	0.71	0.37	0.23	2.07	1.85
USA (4)	0.45	0.32	0.10	0.82	0.93

1 One m^3 of natural gas is priced as 9,300 Kcal Gross Calorific Value (38.9 MJ/m^3).

2 Tax included, in 2008, supplied by Camuzzi Gas del Sur (www.camuzzigas.com)

3 Tax included, in 2008, supplied by Gas Natural Ban (www.gasnaturalban.com.ar)

4 Natural gas, electricity, gasoline and diesel for end-use customer, in 2008, with tax, from IEA [23]

Table 1 shows the very low price of natural gas in Argentina. Prices paid for natural gas by households in different countries present a range between $0.41/m^3 to $1.14/m^3. These prices will be considered here the regular household prices paid in countries other than Argentina. The residential average of the 13 countries listed in Table 1 is $0.68/m^3. This average price is nine times higher than the price for householders in Buenos Aires and 26 times higher than in Bariloche. The same average for natural gas supplied to commerce and industry is $0.38/m^3, which is a factor of six higher than paid by commerce in Buenos Aires, and a factor of nine in Bariloche. On the contrary, prices for electricity and automotive fuels in Argentina fall in the same range as those in the different countries listed in Table 1. In a previous work [1], the medium salary energy purchase power was compared between Sweden and Argentina. In 2005, the medium salary in Argentina was nine times lower than in Sweden. Nevertheless, households with provision of natural gas in Bariloche enjoyed a three to four times larger amount of energy per salary as those in Sweden. This holds true for natural gas, but it is not the case if the resource considered is electricity, LPG, or automotive fuels. We will come back to this point in Section 2.2, when discussing alternative fuels other than natural gas.

In Table 1, it is interesting to note the exception to the rule for the ratio of commerce/household price of natural gas in Bariloche: the commercial cost is much higher. This is caused by a regional subsidy on consumption that applies only to households in Patagonia. It is an amount directly deducted in the billing, consisting of 60% of the gas consumed. Federal government subsidies periodically compensate the private supplier for the amount not paid by households.

The comparison between Argentina and Mexico shows a very different pricing for two countries with a similar energy situation regarding reserves and demand. Canada is the second largest worldwide natural gas exporter, and in most locations has a similar climate severity as in the region of Patagonia; nevertheless, the price for natural gas in households is 16 times higher in Canada than in Bariloche. The Netherlands, being the fifth largest natural gas exporter, is an interesting example of using prices as a tool to encourage fuel efficiency.

In Argentina, Compressed Natural Gas (CNG) for vehicles is widely used, accounting for nearly 12% of natural gas consumption in the country. The price is around $\$0.30/m^3$, with no significant variations across climatic regions. The net calorific value of 1 m^3 of natural gas closely equals that of 1 litre of either diesel or gasoline (within 5% estimate), and therefore, the price of CNG is between two and three times lower than that for diesel and gasoline, respectively.

Due to climate-related regional subsidies the price for natural gas in the cold location of Bariloche is 65% lower than in Buenos Aires. However, the price in Buenos Aires is already much lower than regular households prices in other countries, and even lower than well-head prices in international markets [15]. Therefore some sort of subsidies must have been applied to it as well. The details of these general subsidies or any other compensatory measures are not public information and government websites keep them confidential. Extraction and production of natural gas in Argentina has been privatised in 1992. At present the well-head price paid in Argentina for imported gas is uncertain. According to the news, reporting interviews with officials [22], the imports from Bolivia were set in around $\$0.22/m^3$ ($6/MBTU), and those for imported Liquefied Natural Gas by vessels from Trinidad-Tobago in 2008 at $\$0.52/m^3$ ($14/MBTU). Clearly, both wholesale prices are much higher than what is paid by households, so large subsidies must compensate for the differences. At the same time, the well-head price paid to the local producers, according to the government website [24] was around $\$0.06/m^3$ ($1.6/MBTU), and country-wide transport and local distribution should be added for the product to reach households. Natural gas well-head prices in the US were between $6 and $8 per MBTU in the period 2004–2007, and reached up to $14/MBTU in 2008 [15].

In this section, the price of natural gas in Argentina was compared to other countries for both well-head and end-use households. It was found that, for all regions, natural gas prices in Argentina are very low, to the extent that household end-use prices are several times lower than even well-head prices in other countries.

2.2. Other household energy resources

As mentioned earlier, around 60% of households in Argentina are connected to the natural gas pipelines. At each location, availability usually depends on the distance to a large consumption node, like a city or an industrial area. Most households without natural gas are located in the outskirts of cities and in rural areas. There are regions with higher percentage of availability, and others with none, for instance, the northeast part of the country.

The sectors not connected to the natural gas use instead Liquefied Petroleum Gas (LPG), electricity, firewood, and in much less proportion kerosene and diesel. Of these, only LPG presents another direct subsidy: depending on location and limited availability. The refill cost of a 10 kg LPG bottle in 2008 was $5.30, i.e., $0.53/kg. Without the subsidy, the regular price was around $0.90/kg, which was paid in Bariloche for 45 kg LPG bottles [25]. This fuel can also be delivered by bulk and be stored by households in a tank. With this option, the subsidised price in Bariloche was $0.70/kg in 2008 [26] for delivering 2,400 kg/year per household and $0.90/kg for provision of larger amounts (all prices are given at the exchange rate of 3.04 pesos per $1). The supplier explained that the subsidy on LPG is limited to a maximum request of 2,400 kg/year per household [26]. In contrast, there were no such limitations for natural gas.

The calorific value of 1 kg of LPG equals that contained in 1.28 m^3 of natural gas (the gross calorific value of natural gas in Argentina is 38.9 MJ/m^3 and of LPG is 49.7 MJ/kg). Therefore, the price per unit of energy of subsidised LPG results between five and six times higher compared to natural gas if bought in Buenos Aires, and around 16 times higher than natural gas if in Bariloche. When households bought LPG by bulk in Bariloche, the price for the first 2,400 kg/year was 21 times higher than the equivalent in natural gas, but 34 times higher for larger amounts. Even CNG for vehicles ($0.30/$m^3$ with road taxes included) has a consumer price near half of that paid by households for subsidised LPG.

Clearly, the magnitude of the subsidy on LPG does not equal that on natural gas for households. To be equal, the recharge of a 10 kg LPG bottle should cost $0.33 in Bariloche, and $0.96 in Buenos Aires, instead of the actual price of $5.30 for all locations regardless of climate conditions.

A recent survey of one-family households in Bariloche showed an average consumption of natural gas of 4,800 m^3 per year, with around 85 % used in space heating [1]. The equivalent amount of LPG would be 3,750 kg. In Table 2, a comparison of the cost of energy and other household's expenses is shown. The cost for 4,800 m^3 of natural gas is compared with the price in Buenos Aires and in other locations cited in Table 1.

The cost for LPG in Bariloche is taken from the major supplier in the area, delivered by truck and pump into a house tank. The subsidised price is considered for the first 2,400 kg and the rest at the regular one [26]. For Buenos Aires, the LPG cost is calculated at the lowest price possible for the 10 kg bottle. To give an idea of other common household expenses, the cost of items like cable TV, along with gasoline and insurance for a car are included.

The second column of Table 2 shows the different local cost of natural gas for households in Bariloche and Buenos Aires, and how this compares with the cost that would result in other countries for the same consumption. The cost of using LPG instead of natural gas is shown in the third column. The cost of LPG in Bariloche is higher than in Buenos Aires, and both fall into the range of energy prices paid by households in other countries listed in Table 1.

Table 2. Natural gas cost compared with LPG and other households' common expenses (2008).

	Cost for the use of 4800 m^3 of natural gas in households	**Cost for the use of 3750 kg of LPG in households**	**Cost for the use of cable TV during one year**	**Cost of gasoline for a medium car driving 10,000 km**	**Cost of a basic car's insurance liability**
Bariloche	$125	$3,000	$400	$700	$300
Buenos Aires	$360	$2,000	$400	$650	$450
Canada	$1,990				
Mexico	$3,200				
Average of countries listed in Table 1; $0.68/m^3	$3,260				
France	$4,000				
Netherlands	$5,450				

Due to the cost of LPG, to the income of the majority of households not connected to natural gas, and to the large amounts of energy needed, households not connected to natural gas do not choose LPG for space heating. In cold areas like Bariloche, this situation has led households to use firewood for heating, and some electricity for other thermal purposes (the use of electricity would result in slightly higher costs than LPG; see Table 1 for unit prices). Firewood can be purchased in Bariloche at an energy unit price around 10 times higher than natural gas, but at less than half the price for LPG. Heating efficiency with firewood can be assumed the same as for the most common balanced-flue gas space heater made in Argentina [27], and therefore, firewood leads to lower costs for heating than LPG. In a previous work [1], it was shown that in 2006 the amount of firewood energy bought with a medium salary in Argentina felt in the same range as the energy per salary purchased in Sweden.

The connection to the gas network requires households an investment in piping from the distribution line from the street into the dwellings. In order to get connected, the piping must be approved by authorities and be done by registered plumbers. This procedure, surely needed, leaves poor neighbourhoods out of the gas pipelines for two main reasons: first, cost; second, lack of minimum building requirements to sustain the approval procedure. In the suburbs, neighbour communities can be connected or not depending on housing and income. For instance, during the past 20 years, in the suburbs of most cities in Argentina a growing number of private gated neighbourhoods were developed (locally called "country clubs") [16]. Due to the price of the lots, to the house style requirements, and to the high cost of maintaining a guarded gated community, these neighbourhoods are only for middle-high and high income families. In Bariloche and Buenos Aires, suburb neighbourhoods may include high-income gated communities benefiting from subsidised natural gas, alongside with low-income households which are not connected to the natural gas network.

The situation obviously creates social stress. On the one hand, a dramatic case of environmental injustice is clearly seen, although the analysis of this matter is out of the scope of the present article. On the other hand, it is well understood that subsidies are not directed to low-income families. In spite of accounting for some low-income households that may eventually benefit from natural gas subsidies, the large majority of households not connected to natural gas are in low-income neighbourhoods.

Even in the capital city of Buenos Aires, the numerous favela-like communities (in Argentina called “villas miseria”), use LPG, firewood and charcoal for their energy needs [16].

The fourth to sixth columns of Table 2 depict some common household expenses. The cost of natural gas in an average one-family household either in Bariloche or Buenos Aires is a small fraction of the common expenses listed. In addition, considering the medium income of $8,360/year for a household in Argentina in 2007 (www.indec.gov.ar), the gas bill would represent 1.8% of total household income in Bariloche, and 4.3% in Buenos Aires.

In 2009, some increases in natural gas prices were applied. They are generally on the order of 30%, but for consumers of large amounts the increase would be larger, reaching up to 200% for more than 7,400 m^3/year in Bariloche. The new rules are not yet clear and even the companies still post the 2008 prices in their websites (see for instance http://www.camuzzigas.com/htm/clientes_resid/index.htm, accessed 20 May 2009). With the possible price increase of 2009 the amount of $125 for Bariloche in Table 2 would be around $350, while the $360 corresponding to Buenos Aires would rise to approximately $700.

Only assuming an even distribution of house and equipment quality this approach to raise prices might result in a fair method (though made gradually and not send as a shockwave through the economy). But this is not the actual situation. Middle-low and low income families connected to the gas network live in small houses which usually have the consumption of larger ones. Besides, in many cases several small dwellings are set in the same lot and plugged to the same meter. Therefore, increasing tariffs to the meters consumption would result in a high individual price for real low household consumption. Meanwhile, the public is reacting with strong opposition to the price increase, to the extent of legal action against the government and postponing paying bills. The case is also considered by the Federal Ombudsman [28]. At the moment, the government took a step back with part of the increase for certain regions, but it does not consider other possibilities.

Since 2002, energy policies were designed to expand the gas network, and promote consumption by keeping the customer price low and fixed. Even during the escalating rise in oil and gas prices of 2007 and 2008, natural gas prices in Argentina were fixed. This policy has set in the public the idea that the resource is infinite and cheap. For example, regarding the average consumption of natural gas in one-family houses in Bariloche, it seems like the public is not aware of the actual very low cost for such a large amount of energy [a medium car would drive almost 60,000 km on 4,800 m^3 of natural gas, which is, incidentally, also equivalent to 48,000 kWh (Net calorific Value)]. Nevertheless, the reality of 2009 calls for some changes. On the one hand, funds for subsidies were depleted as a consequence of the global crisis, and it seems that the government budget can no longer sustain large subsidies. On the other hand, the natural gas reserves are at the lowest in the last decade, showing stress from high consumption [20,21].

The analysis presented here demonstrated the unequal opportunities of households connected or not to natural gas. For all regions, prices for LPG are several times larger than those for natural gas. In Argentina, LPG users paid for energy a similar price than regular prices paid by households in other countries. It was also shown here that natural gas bills are very low even compared to common household expenses like cable TV, car insurance, and gasoline. Let us see next how the low pricing of natural gas has driven households to reject investments in thermal efficiency for their dwellings, even for those income sectors that could indeed have afforded it.

3. Building Thermal Quality in Argentina

3.1. Present status

Several studies have shown the low thermal efficiency of Argentinean buildings, both in the residential [1,4–14,17,18] as well as in the public and business sector [29–31]. Basically, this can be summarised as follows:

- Floors on heavy concrete with no insulation to the ground
- Metal and wood roofs with the minimum 2 cm insulation, or none
- Reinforced concrete structures exposed by thermal bridges
- Use of bricks of large transmittance (between 1.5 and 2.5 W/ °Cm^2)
- Ceramic tiles on walls and floors without insulation
- Single glass windows
- Infiltrations in doors, windows, roofs and parts of structures
- Designs that disregard climate zones and solar power

For example, in the cold area of Bariloche (medium temperature 8 °C, with 3,600 HDD, and average wind speed around 25 km/h), the residential sector is built with the same materials and techniques used in the warm-temperate parts of the country. In surveys done in 2006, only 3% of houses showed some kind of thermal insulation [1]. The consequence is that even in summer, with medium monthly temperatures of 14 °C, most households are reported to have their heaters on.

In addition to the building envelope quality, the most common gas heater widely use in Argentina (balanced-flue type) presents very low thermal efficiency. Research has shown that these heaters' efficiencies range between 40% and 60%, depending on the chimney installation [27]. Around 85% of one-family households use this type of heater.

The consequences of low thermal quality are seen in all areas of the country. In the cold ones, heating requirements produce high fuel demand, and in warmer areas cooling leads to high demand of electricity [18]. In recent years, this pattern was reflected by winter gas provision shortages, followed by summer electricity crisis. The usual winter gas crisis also lead to supply shut off to part of industry and to CNG for vehicles. Besides, the gas export obligation to Chile was limited during winters, creating conflicts with that country.

The actual thermal quality in the residential sector can be assessed quantitatively in many ways, and it is well documented in the references given so far. Besides, the ratio between the consumption in heating and the climate-related requirements is a good indicator of thermal quality. Table 3 depicts, for three locations in Argentina and one in Sweden, the local climatic conditions, the consumption of gas in heating one-family households, and the specific energy per climate unit.

The climate-adjusted heating energy of one-family households is similar in the three cities of La Plata, Bariloche and Río Grande (40, 42, and 46, respectively), even though these are located in very different climatic zones. This comparison shows that thermal quality is not climate dependent in Argentina. The specific energy use for heating in Stockholm (value of 13 in Table 3), is more than three times lower than in any of the shown locations in Argentina. This comparison explains the high consumption widely reported for dwellings in Argentina [1,4–14,17,18,29–31].

Table 3. Energy use for heating in locations in Argentina and Sweden.

	La Plata	**Bariloche**	**Río Grande**	**Stockholm**
Latitude	34°S	41°S	54°S	59°N
Annual medium Temperature (°C) [1]	15.5	8	5.5	7
Heating degree-days (°C, base line 18 °C) [1]	1,170	3,620	4,560	4,070
Energy for heating (MJ/year)	50,000 [4]	144,000 [1]	210,000 [7,14]	53,000 [1]
Specific heating energy per unit of climatic heating degree-day (MJ/year. °Cdegree-day)	42	40	46	13

[1] Data from Servicio Meteorológico Nacional (www.smn.gov.ar) and World Meteorological Organization (www.wmo.org).

Already in the 1980s, researchers at the School of Architecture, Universidad de Buenos Aires, taught the need to consider climate in building design [32]. At the same time, in Bariloche, physicists gave thermal quality courses to architects, engineers and builders. One of the professors reported that there was great interest in the subject until the first large gas pipeline arrived in Bariloche in 1988 [33]. Before this date, space heating was done mainly by firewood, coal, and diesel. At times, diesel was also subsidised in Argentina, being its price for all users less than half of that for gasoline. The aim was not to provide cheap household heating energy but to help wholesale transport. From 2003, diesel is also heavily subsidised but only to passenger public transportation, with a tariff around one third of the general one given in Table 1.

Building codes in Argentina do not include regulated thermal quality. The norms are already made and different levels of insulation quality are defined; however, they are not mandatory and are only used as a reference [18].

3.2. Potential for reduction in energy use

Given the present energy status in the building sector in Argentina, the potential for change and improvement is enormous. Concerning the thermal quality of buildings, we are in a minimum baseline and even moderate improvements would readily lead to a large effect. The main reduction in absolute values of energy consumed would be obtained with the first few centimetres of thermal insulation. In several studies, a reduction in consumption between 50% and 75% was estimated for different locations and building types in Argentina [4–14,18,29–31]. Let us see below that a moderate refurbishment with existing materials and know-how would easily lead to a 50% reduction.

Recently, researchers in Bariloche have identified what caused the very low performance of the most commonly used gas heater in Argentina [27], and tested improved prototypes [34]. With simple modifications, implying an extra cost of 10% in purchase price, existing heaters' thermal efficiency would rise between 35% and 80% [34]. The improved designs even included a novel passive chimney control, and garnered the authors the Science Ministry 2007 Award for innovative technical solutions. However, when the findings were announced by the researchers, neither the authorities nor the manufacturers were interested in introducing improvements [35].

The typical construction of bricks with reinforced concrete structure, no floor insulation, single glass, and minimum roof thermal insulation (or commonly none), has a Heat Loss Coefficient near 500 W/°C (HLC, is the energy loss or gain of a building envelope per unit of in- and out-temperature difference, and it is measured in W/°C). Brick walls are usually covered with stucco on both sides, and have a heat transmittance between 1.5 and 2.5 W/°Cm^2. A 5 cm insulation set on the outside, e.g., with a siding finishing, would reduce the wall transmittance to 0.5 W/°Cm^2. Roofs can be improved with the same type of insulation but installed from inside as a ceiling chamber, leading to a transmittance of 0.4 W/°Cm^2. Double pane glass windows can be installed at least on the south side, changing the transmittance from 5 to 2.5 W/°Cm^2 [9–12,18].

With these basic changes, plus some improvement in air infiltration, the HLC would easily be decreased to near 250 W/°C, and the consequent energy use in heating would be substantially reduced [9–11]. European standards are far below this HLC [2,3]. However, a realistic first step to encourage households and policy makers to improve efficiency should show that technical and economic means to perform refurbishments are readily at hand in Argentina.

By considering current prices for materials and labour, a 5 cm wall insulation including siding and humidity barrier cost between $30 and $35 per square meter in Argentina. A similar price can be considered for extra ceiling insulation. Besides, the installation of double glazing cost around $60/m^2. Thus, by investing $8,000 to $10,000, an average one-family house of 100 m^2 in the city of Bariloche could be thermally improved to have an HLC smaller than 250 W/°C. In 2008, a common price to build a one-family house of 100 m^2 in Bariloche was around $80,000. Therefore, the moderate refurbishment leading to around 50% energy reduction would cost between 10% and 12% of the building cost.

In a previous work, it was found that the average one-family household in Bariloche used 4,100 m^3 of natural gas per year in heating [1]. The reduction by the thermal refurbishment would thus represent savings of more than 2,000 m^3 of natural gas per household per year. When the average of regular prices in other countries ($0.68/m^3, Table 1) is considered, the extra cost of this thermal refurbishment would be paid with the gas savings of six to seven years. However, at 2003–2008 gas prices in Argentina, the reduction in natural gas use represented only $52/year in Bariloche, and therefore between 154 and 192 years were needed to return the investment in refurbishment. If prices of natural gas in Buenos were considered, between 53 and 67 years would be required to recover the investment in thermal refurbishment.

Since the current gas consumption is so high, the moderate retrofitting would lead to a substantial reduction of environmental emissions. The achievable annual reduction of 2,000 m^3 of gas would save 5.7 tons of CO_2 emissions per household (natural gas emissions are 0.075 kg CO_2/MJ [36]), which is almost 2 tons per person in the city of Bariloche [1].

Further improvements would surely be sought and encouraged. In the next section we will see that tariff reform for middle-high and high income households could in fact result in a significant number of households investing in any of the many possible improvements at hand.

4. Policy Measures

The analysis presented in the previous sections has shown different aspects related to the application of heavy subsidies for natural gas in Argentina: (a) it discouraged users to choose for efficiency; (b) it played a role in spreading unawareness on the advantages of efficiency; (c) it brought up injustice because not all households enjoy the same benefits; (d) it lowered the economic efficiency of the country because high consumption in households prevents uses in production activities and exports; (e) it had negative environmental consequences.

In this section some energy policy measures will be proposed. The goal is to discuss a possible way to deal with different targets which appear correlated in the complex social reality of Argentina. The problem thus requires measures that approach differently the very distinct sectors. As previously pointed out by other works [1,18], education is a key action to deal with unawareness, which is the most probable strongest barrier and it is common to all sectors [37]. To raise energy prices without hurting low and middle income families is a challenge that would encourage mid-high and high incomes to improve thermal quality. Reduce consumption by better thermal quality in housing will simultaneously lead to reduction in consumption and help in establishing a sustainable solution, in contrast to the ephemeral benefits from subsidies. Some of the measures that have to be taken call for private initiatives, and they do not need government subsidies to start and function. Others, however, consider a redirection of state funds for education, technical assistance, and efficiency improvements.

In this context, it has to be emphasised that according to official figures natural gas reserves in Argentina are at a historical low [20,21], and other works predict the end of reserves by as soon as 2015 [18]. The energy policies proposed are as follows.

4.1. Schedule a price increase of 100% per year in energy prices for households in middle-high and high income sectors

At present, all residential users of natural gas in Argentina benefit from energy subsidies of diverse magnitude, with those in cold areas receiving larger discounts (see Section 2.1). Nevertheless, there is no difference in energy prices by income or other social condition. The benefit makes a large part of society having large discounts which they do not actually need. For instance, gated neighbourhoods around major cities, with land and house prices that in many cases surpass those in Europe or the US, receive subsidised natural gas [16]. The expenses to run the gated neighbourhoods are many times higher than energy bills. Besides, a large portion of the population in cities, either in one-family houses or in apartment buildings, does not need subsidies to pay for energy. For a further comparison, buying an apartment in the city of Buenos Aires requires between $1,000/m^2 to $2,000/m^2, depending on location. Apartments are billed monthly for common expenses to run the building. For a 100 m^2 apartment the common expenses would generally cost around $1,500 per year, while their gas bill could only reach $150/year, and the electricity bill another $150/year.

Houses and apartments with high standards of comfort belonging to middle-high and high income populations are numerous in cities and suburbs of Argentina. Subsidising energy to this sector completely discourages the only part of the society that it is able to afford thermal improvements with their own economical resources. This may be the main mistake in energy policy in Argentina, namely subsidising energy to sectors that do not need subsidies. In addition, the funds would be much better used for improving housing of the vast low income sectors in Argentina.

As mentioned before, due to the economic crisis of 2008–2009, it seems like the government will be short of economical resources to keep subsidies at the levels of 2003–2008. Consequently, the government announced an intention to increase tariffs in both gas and electricity according to level of consumption. These increases are of a very different sort of the ones suggested here: they are yet no income sensitive, leaving lower incomes with larger relative bills (see Section 2.2 for details). These sectors and middle incomes as well, are currently protesting the raise and brought the case to courts [28]. The strongest protests are yet to occur after August 2009, when winter gas bills will reach households.

A price increase by income criteria of 100% per year (which is not excessive given the very low starting price) is proposed, until parity with the average price paid by households in other countries is reached. The 100% increase per year considers that the savings with a moderate refurbishment would return the investment in thermal quality in less than 10 years (see Section 3.2 for details). Information and technical help to this sector is included in another part of the general program below.

The increase in price should not start before clear explanations and education are provided to the public (see Sections 4.3 and 4.4 below). Consumers that become aware of energy-efficient options will request professionals to incorporate them in their homes [37]. Behind policies there are reasons, and people understand these very well. This is the case if policies are coherent and they are set with the goal to improve society and protect citizens from possible supply failures.

4.2. Subsidise house improvements in low and middle-low income families, with more emphasis in those disconnected from the natural gas network

Around 40% of households in Argentina are not connected to the subsidised gas network [14]. Most households not connected to natural gas are of middle-low to low income. As we have seen in detail in Section 2.2, they pay five to 20 times more for the same amount of energy for which their neighbours enjoy cheap gas. This is an injustice that calls for immediate reparation.

Subsidies directed to improve thermal quality of households not connected to natural gas would somehow compensate this sector from decades of paying taxes to subsidise cheap fuel for the richer part of society. Before the devaluation of Argentinean currency in 2002, the energy unit price for natural gas was around two times higher than LPG in Buenos Aires, and eight times higher for residences in Bariloche. Even though in 2002 these price differences between LPG and natural gas have been tripled, the injustice of sectarian subsidies has been in place much before 2002.

Turning to give the same benefits of low price fuel to households not connected to natural gas would even deepen the problem, resulting in large unsustainable consumptions. Thus, a better strategy would be to start immediately with a housing refurbishment program in middle-low and low income families which are not connected to natural gas. The program does not mean building new homes, but improving as much as possible the existing ones. In Argentina new homes for low income families are mostly built by government programs. Their thermal standards, with very few exceptions, are even lower than the average, leading to high needs of fuel. This housing usually comes along with natural gas provision, enlarging the consumption problem.

4.3. Establish educational groups to provide the public with information and solutions

In Argentina, unawareness of the advantages of good thermal insulation does not occur only among the public, but also within a significant percentage of professionals working in the building sector. It would be relevant to have educational groups organising talks and workshops for the general public and in schools. Several efforts by universities in Argentina have been done to educate on efficiency (see www.asades.org.ar), but the necessary government and social coordination was not achieved so far. At present, at the Centro Regional Universitario Bariloche, the extension office is organising this task, in which I am in charge of talks and workshops on energy efficiency. We have started with an attendance of a few interested neighbours, but the general news about rise in gas prices and possible future supply problems pushed the attendance to fill the classroom. Prices are so critical in triggering interest that in a radio interview a journalist asked me if I was giving the talks because of the rise in energy. “No”, I said, “I have been doing this for very long, but I see that you are coming because of the rise.” This is anecdotic but clearly shows that education and economic tools must be coordinated.

Our experience in reaching the public was excellent. The talks are made for everyone but do not lack technical details. Households as well as professional builders and designers are attending, and the level of the talks and workshops are designed to fit all. Briefly, the talk starts with the problem of heating, followed with the actual high consumption, posing two basic questions: how households in Bariloche can afford such a high consumption? And, are improvements possible? Then it shows where to look for heat loses, and proposes simple measurements with both commercial materials and do-it-yourself solutions, some with recycling materials and with the natural building concept. The talks include debate and all together usually last almost three hours. The public is very eager to learn and to understand. At present, I am the only one giving this educational background in a town of 200,000 people. We plan to extend the education to schools and put more effort in 1-day workshops, with the hope to multiply the interest of professionals in the program. The experience has convinced me that the public does want to focus on good solutions, but, as pointed out in previous publications [18,37], awareness is a key factor in triggering interest. Once this interest started, it seems to trigger a snowball effect with people looking forward to making a change. Therefore, an energy policy program should have an informal educational part. Furthermore, this should be discussed with school authorities, both primary and secondary schools, to include the subject in physics with practical real calculations and designs. Most of the basic physics and math to understand energy resources, heat loss and how to solve the problem is taught in schools, but the real needs and examples are absent.

The educational program serves also as the first step in creating consensus for establishing future obligatory building thermal quality codes. To make codes mandatory would not work if the people do not rationally accept them.

4.4. Establish local technical offices, with skilled personal to advice households on energy consumption and ways to improve efficiency

This is connected with the educational program, but helping on more daily hands-on problems encountered when actually deciding the refurbishment to be carried out. The technical offices are mainly intended for neighbourhoods of middle to low income households, who may not have the means to pay for advice, but should be available to all sectors. In Argentina, people of low and mid-low incomes do a significant amount of work by themselves to build or modify their houses. Furthermore, building codes in most regions allow the owner to be the official responsible to do the work, providing there is a professional to make the technical design and being responsible for it. There exist numerous informal business relations in the building sector, and this can be an opportunity to achieve house improvements with low budgets. There is also the custom among neighbours to help each other in building tasks.

Thus the proposed technical offices would support individuals, promote and organise the formation of helping groups, and in cases lending key tools to achieve the work in an easier manner. It would also be useful to have these advising technical offices in middle-high and high income neighbourhoods, where they could work on both, supporting households and builders, and promoting refurbishments.

The technical groups, as well as the educational ones, could also be recipients of possible aid from private foundations and international organisations. In this case, some particularities of Argentina must be considered. According to different agencies investigating corruption levels, Argentinean official institutions are regarded as highly corrupt [38,39]. Besides, there exists a well-established political characteristic called clientelism, for which public resources are used to favour people who then turn to support the givers [40]. This way of approaching households is driven by the so-called "punteros" (the ones heading the cause), who generally are not interested in providing permanent solutions to people but to have them hooked on their aide. The present proposal would give perfect excuses to potentially corrupt political officials to promote clientelism through it. This can be bypassed by avoiding government institutions overtaken by political parties and rather fund programs that are based on well known NGOs with solid background an reputations, and collaborations from universities and schools with professionals well known by their previous work. Fortunately, there is a good distribution of university Research and Extension centres in Argentina dedicated to energy efficiency and renewable energies, in the provinces of Mendoza, La Pampa, Salta, Buenos Aires, Catamarca, Santa Fe, and others. The researchers and teachers can be found in free-access publications in Spanish at www.asades.org.ar. The majority of social workers in Argentina are honest people with the best intentions. Finding them to support well intended energy efficiency programs is a challenge for the future. The technical office should also make a record of what needs to be done and how it progresses.

4.5. Existing heating equipments can be improved with minimal cost

The most common gas heating device used in Argentina is the balanced-flue space heater. Researchers in Bariloche found that the efficiency of these equipments is very low, between 40% and 60%, depending on chimney options [27]. They have also identified the basic design failures: bad air convection between the hot chamber and the room; poor radiation transfer to the room; extremely large chimney flow that surpasses oxygen needs for combustion [27,34]. Models sold in Europe by the same manufacturers that supply the local market present extra features, which make the heaters' performance higher to match European minimum standards. The upgrade either to the existing devices or to new ones is simple and would cost less than 10% of the purchase value [34]. For instance, upgrading a 6,000 W balanced-flue gas heater would require between $20 and $30. This type of heater is widely used with natural gas, but due to cost of fuel it is not convenient with LPG. The combined house refurbishment and the heater's improvement would make it also useful running on LPG.

Nevertheless, no gas equipment can be modified without the government gas authority approval (www.enargas.gov.ar). This official institution has not reacted yet to the results found by researchers in 2006 and 2007 [35]. As published in local journals in Spanish, explained to manufacturers and to the public in conferences, TV and newspapers, and even awarded with the 2007 Science and Technology winning prize, the simple innovative solutions found for the balanced-flue gas heater could immediately improve the end-use efficiency between 35% and 80%, depending on chimney options [34]. The official institution in charge should call for discussion on new regulations for improving gas heaters, and pass the regulations to encourage changes as soon as possible.

4.6. Solar design of buildings and use of renewable energies should be a priority

Large portions of the cold regions of Patagonia and the high elevations at the Andean side of Argentina enjoy high average radiation during a significant part of the year. For example, in Bariloche, a daily average solar radiation greater than 3 kWh/m^2 is found for at least eight months of the year, including four months above 6 kWh/m^2. Research and development in solar energy in Argentina has a long history and significant achievements in design and manufacturing (see for instance www.inenco.net). It only needs to be better known by the public and put into practice massively. Many features of solar building design can have a great impact on energy efficiency in buildings in Argentina, both for households and for public buildings [13,30,31]. Taken advantage of orientation and climate-related effects is also relevant in planning energy reductions. Solar and energy conservation design can lead to lower energy consumption without extra cost [18]. The matter should also be included in educational programs and working groups.

5. Conclusions

It was shown that the price of natural gas in Argentina was driven by heavy government subsidisation since 2002. The subsidy on natural gas benefits households disregarding income, but leaves out around 40% of the population not connected to the gas network. Fuels alternative to natural gas cost between five and 20 times more (the range depends on regional subsidies). Most populations not connected to natural gas belong to low and middle-low incomes, and are settled in poor neighbourhoods in the suburbs or in rural areas. Additionally, the number is also significant in the favela-like neighbourhoods of the capital district Ciudad Autónoma de Buenos Aires. It was shown that the large poor sectors not enjoying natural gas actually pay with their taxes the benefits of subsidies given to the richer part of society. The conclusion is unambiguous in that this particular way of subsidising residential energy consumption has created environmental injustice and deepened inequalities.

On the other hand, the analysis of consumption patterns demonstrated low thermal efficiency in the Argentinean residential building sector. Actual consumption can potentially be reduced by 50%–75%. It was shown that this range of reduction can be achieved with a moderate or a deeper refurbishment, respectively. Middle-high and high income households could afford refurbishments, but very low energy prices discouraged investments in thermal quality.

Energy policies with focus on improving efficiency and restoring equality were studied. Education and technical assistance appears to be a key factor to create consensus for a change in fuel prices and house improvements. Since inequalities are well established, priority should be given to house refurbishments in sectors disconnected from cheap natural gas. Subsidised programs to make urgent house improvements in this sector were proposed. It was also suggested that natural gas prices should rise according to income. This increase would encourage middle-high and high incomes to install thermal insulation. Besides, the authorities should consider the results obtained by research done in Argentina, regarding the improvement of low-efficiency common heaters. Finally, no difference in building thermal quality was found across the country (latitude 23 °S in the north border to latitude 55 °S in the south one). Therefore, climate-related and solar design should be considered as key factors for energy reductions in Argentina.

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