Fuel switching: a history of Portuguese energy transition

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Introduction

Long-run energy transition in developed economies is often presented in a too simplistic way: coal substituted firewood, muscle power and water; and oil, natural gas and electricity substituted coal because the energy sources that triumph are superior and more efficient that the ones that succumbed. One of the main reasons for the persistence of this discourse is the lack of quantitative sources for traditional energy carriers. Kander (2002) made one of the first attempts to account for firewood, water, wind and muscle power in estimations of energy consumption in Sweden: the results showed that although transitions occur, they were much less abrupt than what can be expected when we analyse the consumption of modern energy carriers alone, and that much of the adoption of new technologies supplemented rather than totally substituted the old technology.

A second reason, not always stated, can be found in the difficulty of analysing energy consumer changes at a sector level from a historical point of view. This happens because it is very hard to depict from total energy figures the proportion that goes for each energy sector (industry, transportation, services and household) and translate primary energy figures into final or useful energy ones, more adequate to this kind of analysis.

Much of the discussion today on theories of energy transition is taking place between scholars that study energy consumption patterns at the level of community in developing countries. Some decades ago, the concept of “energy ladder” gained relevance: as income rises households tend to switch to modern fuels, considered more efficient, clean and convenient than traditional ones (Leach, 1992). The transition is usually described as follows: in a first phase there is universal reliance on biomass (dung, firewood or charcoal); in a second stage population growth, wood fuel scarcity and rise of income drives households to transition fuels like kerosene; at a later stage individual’s trust only in superior fuels like LPG (Liquefied Petroleum Products) or electricity. At an aggregate level the model seems to explain a lot just by income. However if energy transition is analysed at the more detailed level of the community, the outcomes of the model are not evident.
Later studies discovered however that energy transition does not occur in a series of discrete steps and that multiple fuel use was common (Masera, 2000). Others have found that the diversity of transitions can cause the households to jump directly from a first stage to the last, due to the existence of cheap electricity and subsidised fuels. (Barnes, 1999).

It is generally assumed that some variables may affect the speed of energy transition: relative fuel prices, income, distance to the markets, urbanization, cost of equipment are the variables most intensively used.

The present paper tries to find some of the main causes of switching energy carrier in a long-run perspective. Based on quantitative and qualitative data I try to analyse household fuel-switching in a southern European country, Portugal, during the last 150 years. This article is structured in the following way: in the first part, it is introduced a graph for primary energy in Portugal in the last 150 years that incorporates traditional fuel consumption. In the second part, it is analysed the energy transition observed in Portuguese cities until the 1950s. And, at last, in the third part, I also include the rural areas and analyse the energy evolution until the present. Fourth section concludes.

1. Portuguese primary energy in the long-run: a country picture of the last 150 years

If we take into account only the modern fuels, the history of energy consumption in Portugal in the past 150 years is marked by recurring references to the dependence on the exterior, to the slow diffusion of the new energy sources, and to the low per capita consumption.

In the steam era, Portugal was not particularly favoured: coal was the ideal fuel for the motor force; however, Portuguese reserves consisted mostly of low quality coal, which had a little more than half the heating power of English coal.

Until World War I, national fuels accounted for a very small percentage of the total commercial energy consumption in Portugal, rarely exceeding four percent. However, in 1890, 77% of the installed power was either direct working water or wind power. Later, between the two world wars, Portugal failed the conversion to a new source of energy, the hydroelectricity, despite having access to as much hydro resources as Italy (Bartolomé, 2005)\(^1\). In fact, Portugal ended up being quite dependent on coal until the eve of World War II. The only change in the dependency trend would take place in the 1950s and in the 1960s, thanks to a governamental plan aiming at the replacement of coal imports by national resources, through the building of dams and a better use of national coal. However, in the 60s, the investment curve on new dams would meet its end; and new levels of dependence would arise from then onwards, with the extensive adoption of oil.

\(^1\) From the economic potential of each GWh, according to the author.
The degree of analysis can be deepened once the traditional fuels are accounted for in matters of energy consumption in Portugal. According to figure 1, the most surprising finding is the persistence of firewood as the main fuel in Portuguese economy, as late as the mid-1960s, when it was surpassed by oil. This persistence did not take place in other countries; in Sweden, Spain and Italy coal had become more dominant in 1910, 1894 and 1904, respectively [Kander (2002); Malanima (2006); Rubio (2006)].

Until the 1950s, the per capita firewood consumption decreased at a quite moderate rhythm, insufficient to make a significant difference in total consumption figures. Only in 1988 coal consumption was able to surpass firewood.

However, the great majority of firewood consumption took place in the household sector, which means that, although it is possible to observe in the Portuguese economy a phenomenon of energy transition to modern fuels, it is not as clear whether or not this was a phenomenon of substitution. Since firewood assumes a quite relevant position in the context of Portuguese economy, it is impossible to understand the energy system in the country without grasping the degree of substitution of firewood by other energy resources.

Firewood’s main applications in residential use were heating and cooking so it is necessary to focus in the transitions observed in Portuguese households for a better understanding of fuel evolution in general.

Source: Appendix 1
2. Urban energy transition 1856 - 1950

2.1. Charcoal and coke in Lisbon: a matter of relative prices?

2.1.1 Early transitions in Lisbon

In Von Thünen model, the firewood supply of a pre-industrial city was made relatively near to the city centre because of transportation cost constraints: due to a high volume in relation to its energy content, firewood could only be profitably produced within a 30 km stretch. In this way, only horticulture products are cultivated more near to the city centre. This logic of ring production is valid for most of Portuguese cities, until the beginning of 20th century. However, in Lisbon, fuel shortages due to multiple consumers (industry, population, services, ship construction) and the existence of a navigable river, the Tagus, originated different models of supply (Gaspar, 1970). In the 14th century, firewood supply was conducted from the left margin of the river (Almada and Montijo), but charcoal was already referred to as fuel used by local populations. Charcoal was more flexible than firewood in terms of transportation. In the 18th and 19th centuries most of the firewood came from places relatively close to Lisbon and it seems to have been mostly used for the activities that could not substitute easily firewood with charcoal: bakeries, roof tiles and whitewash factories. Lisbon households consumed charcoal with more intensity: the areas of supply were the same of the firewood but there existed other possibilities. In the late 17th century, besides Almada, Moita and Alcochete, charcoal was also fabricated for more than twenty years in localities far away from the city but close to the river side: Samora, Chança and Montemor-o-Novo, Abrantes. When there was shortage of fuel in the city, charcoal could also be transported by sea to distances sometimes greater than 200 km, like Aveiro or Algarve (Freire de Oliveira, 1882).

It is possible to presume that in 1850’s a vast majority of households in Lisbon were consuming charcoal by historical descriptions of house interiors. At the beginning of the 19th century, most houses in the capital lacked the heating comforts of the modern life. Inside the houses that were rebuilt after the 1755 earthquake there was no room for fireplaces, probably for safety reasons (Couto, 2004). The foreigners that visited the city in the late 18th century wrote about the inefficiencies of the heating methods, restricted to the use of braziers in the coldest days of the winter (Nogueira, Rodrigues e Santos, 1992). Without heating stoves or fireplaces, households tended to use the greater proportion of their energy expenses for cooking in clay charcoal little stoves, not appropriated to burn firewood.

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2 A brazier or “braseira” and “escalfeta” in the Portuguese language is a metal or copper box, working with firewood ashes or charcoal, and mostly used for feet heating. It is a very dangerous device because it frees carbon monoxide, sometimes lethal.

3 In this paper, I designated little stove as a cooking equipment that does not include an oven and that does not have enough space to cook several meals at the same time due to its reduced dimension. For an idea of a charcoal little stove it is available a draw in the Appendix 2, Figure II. This early preference for the use of charcoal in Lisbon can also be derived for the preponderance of sardine in the lisboner diet.
2.1.2 Charcoal, coke and coal competition (1856-1922)

One idea that sometimes appears in the energy historiography of countries lacking mineral energetic resources is that foreign coal replaced almost automatically the domestic wood fuels, when its price per energy unit become cheaper than the traditional energy carrier. Cities with sea harbours were, by this logic, the ones that would benefit more from the transition, while industries located in the inland territories, which were in the past prosperous due to availability of water power, would suddenly be excluded from the modernisation process, because of the cost of land transportation. Most of this transition is referred to have happened in the industry and transportation, but it is usually believed that households accompanied the general trend. And in fact, there was fuel switching from firewood to coal in some industrialised countries: London was the first city to use coal for household purposes in the middle of the 17th century, due to shortage of wood fuel (Wright, 1970), followed by the USA and the Nordic countries4.

Being the most important harbour of the country, Lisbon gained early access to modern and inexpensive fuels, and it was the country pioneer in the adoption of coal for new technologies. Steam engines were adopted in Lisbon several years before other cities in the country; the first train line departed from Lisbon, which was also the first Portuguese city to have gas light, in 1848. Mineral coal imports rose dramatically: 95 tons in 1856, 376 tons in 1900 and 839 tons in 19135. In which extension can this increase in imports be associated with household fuel switching?

From 1854 until 1922 charcoal consumption in Lisbon city was recorded for taxation purposes, which helps to draw a picture of household energy consumption during almost seventy years6. In the light of the traditional theories, charcoal consumption per capita should have dropped with the switching to more inexpensive fuels. However, as we can observe from the figure 2, charcoal consumption per capita was relatively stable until the 1890s. Only after the 1890s, charcoal consumption per capita began to decrease, but the decrease was not as severe as one may think. In 1913, a citizen from Lisbon consumed on average 70 kg per year, against 104 Kg per year in the period of 1856-1860. During most of this period, charcoal supplies responded to the growth of the population in the city, meaning that the production capacity in the country was not saturated.

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4 In Sweden, it is estimated than in 1850, 53% of all the imported coal was used for the heating of dwelling and service premises (Kander, 2002).
5 These figures report the coal quantities received in the Customs in Lisbon.
6 Firewood and brushwood were also recorded for taxation purposes during the period of 1854-1888. In calorific values the amount of firewood subject to taxation was between 10-20% of charcoal consumption during this period. I do not deny here that firewood was consumed by households, but I believe that industry (for example, bakeries) is the main consumer of firewood.
The results are even more surprising if we compare the prices of the available fuels in the market. Here the relative prices are less important than the absolute ones. Along this period, and according to figure 3, charcoal was between 1.5 and 4.5 times more expensive than coal per energy unit and, in the majority of this period, the price of charcoal was between 1.5 and 2.5 times the price of coke. If transition took place so slowly, even with the existence of a huge price difference, other factors must have been delaying the process of substitution. Why was there a lag of 30 years before charcoal consumption per capita started to decrease in relative terms?
Several factors explain why the shift to coal and coke was not very pronounced in the capital dwellings: fuel characteristics, cost of equipment and improvement of charcoal supply.

i) Fuel characteristics
In the first place charcoal and coal were not perfect substitutes for cooking. Mineral coal is much dirtier and smokier than charcoal and it was only recommended in large kitchens because it would be unhealthy to use in the typical urban dwellings where the kitchen was very close to the other rooms (Ferreira, 1885). Warde (2006) confirms this idea – the market for coal in England only developed when firewood price double coal price in the late 16th century.

ii) Cost of equipment
The poorest houses rejected coke and mineral coal, even if they were less expensive per energy unit, because their adoption required the acquisition of new equipment. Ferreira (1885) states the difference: “coke doesn’t burn well if it is not used in a stove, and it requires iron pots as the common pots get ruined too easily”.

The need to acquire a stove, not seen as particularly impressive equipment is a drawback to the expansion in the markets of cooking and heating. The evolution of coke sales in Lisbon, in the last decade of the 19th century is difficult to analyse due to the importance of industrial consumption but it reflects, probably, the moment of the first acquisition of a stove. In Portugal, stove supply developed with much less intensity than in other countries. Only in the last quarter of the 19th century the prices
started to decline: in 1865 a modest stove cost 17$000; but in 1885 a modest family could acquire one by 6$000\(^7\).

iii) Improvement of charcoal supply

According to Rosenberg (1972), one of the reasons for the delay in the diffusion of an innovation is the necessary improvement of the old technology. While no improvement in charcoal production efficiency or drastic reduction in prices were recorded, differences were felt in the distribution process. From 1856 until World War I, the areas of traditional supply of firewood and charcoal changed completely, from near the navigable rivers to close to railway stations. The advantages in supply are evident: the train allows the enlargement of the supplier area to the city, the drop of production stress in the regions of traditional charcoal fabrication, and a more regular supply to the city. Charcoal transportation before the diffusion of railways was conditioned by the course of the river, floods and draughts that delay the navigation and restricted the load that boats could transport. In the case of the supply of charcoal to the city of Lisbon, the region of Alentejo would emerge as the most important supplier. In 1913, more than 47 thousand tons of charcoal charcoal were transported through the two main railways lines (Linhas Sul e Sueste and Caminhos de Ferro do Estado), of which more than half was destined to supply the Lisbon area. The districts of Évora, Portalegre and Beja\(^8\), in the Alentejo region, were the main suppliers, accounting for 80\% to the total of charcoal shipments (Relatório de Exploração CCFE, Sul e Sueste).

Thus, the new energy carrier, coal, improved the old energy carrier in a way that made possible the sustainable increase of charcoal production to the cities.

2.2. The two World Wars and their impacts on household energy consumption

Whoever makes their way through the pages of the *Anuário Comercial de Lisboa* or *Porto* from the first decade of the 20\(^{th}\) century, will probably be surprised with the advertising of several kinds of fuels. In fact, it is possible to find several ads for illumination systems powered by kerosene, acetylene, gas or electricity; and for stoves powered by gas, wood, coke and electricity.

\(^7\) A quick remark on Portuguese currency: up to 1910 the currency was the “Real”, pl. “Réis”. The symbol $ (cifrão in Portuguese) is placed to indicate one thousand (e.g. 6$000 reads six thousand réis). In 1910, with the implantation of the Republic, the currency changed to Escudo with the equivalence 1 escudo = 1000 réis. The symbol $ now is placed at the unit, and the two figures at the right meaning the submultiple, “centavo”, i.e., cent. (e.g. 2$50 reads two escudos and fifty centavos).

\(^8\) “Distrito” is the main administrative division in Portugal. Apart from the islands of Madeira and Azores, there are 18 districts, named after the head city.
Any illusion one might have about those cities being technologically advanced will quickly disappear upon the reading of the Figure 4. On one hand, the percentage of consumers with electricity is very low when compared with other cities in Europe. On the other hand, the proportion of consumers (covered by gas) decreased dramatically in Oporto after World War I and recovered quite slowly in Lisbon.

An explanation of the more relevant transitions in this time period will be developed in the next pages.

2.2.1. The First World War and the disappearance of gas factories

Until World War I, coke was important enough in the household market for, contrary to city gas, its price had been collected for price consumer index construction, in most mainland cities. On the other hand, in the two main cities of the country, the gas stove had been adopted slowly during the 20th century. Being coke dependent of gas production and being gas production dependent of coal, household urban consumers suffered the consequences of price escalation in WW I. Due to the international conflict, the price of a tonne of coal spiked from 1915 onwards; in the most critical year, 1918, it was 16 times more expensive than in 1913 (INE, *Comércio Externo*, 1913-1918). Industry and transportation were, clearly, the most injured, and the situation in the domestic sector was not the best either. How did domestic consumers react to this abrupt change in prices? May there have been

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9 In 1930, Helsinki and Oslo had almost 100% of their inhabitants electrified and Berlin had 55% (Myllyntaus, 1991).

10 For instance, there existed 4970 stoves for 13,848 gas consumers in Lisbon, what indicates an adoption superior to 30%. (CRGE, Relatório da Direcção…, 1893).
some change in behaviour that allowed for the arrival of a new fuel after the war? Or was the war simply a temporary event, without much significance in the evolution of the domestic market?

In fact, gas factories could not be more injured. In industrial applications, steam engines and boilers could in some cases work with firewood and national coal. However, gas, in order to conserve its quality, could not be obtained with any fuel and, usually, coal use was mandatory as per the guidelines in contracts with the city councils. Both in Oporto and in Lisbon, the gas companies went through quite desperate times, because of two factors: the difficulties with coal supply, aggravated by the inexistence of a national merchant fleet; and the disagreements with the city councils regarding the raise of the tariffs.

In 1917-1918, the CRGE’s annual report informed the stockowners of the war situation. “The average of coal price was 5$79 in 1913/1914, increases to 8$37 in the following exercise, (...) finally reaching the price of 23$14 in 1916/1917”. However, the city did not allow the gas price to raise during this period and the Companies could not cover the deficit originated by the coal price, without rising the gas price: that was done only on December 30th, 1916, when a government decree allowed companies to increase the price of gas from 55 to 75 cents, but that was not a salvation to the companies. Despite the rise in prices, the CRGE had to negotiate, months later, with the municipality regarding the suspension of gas supply during the time of the conflict due to new increases in coal prices. The situation was even more precarious in other cities of the country, mostly due to the location of the factories. In some cities, some of the factories had either stopped working in the beginning of 20th century (Leiria, i.e.), due to the lack of clients and capitals and the poor quality of service, or have been municipalized (Coimbra, i.e.). However, WWI was a defining moment for most of the companies: cities like Oporto or Évora municipalized their services due to contract failures. With the exception of Oporto, and with great losses (Matos, 2003), factories suspended production during the conflict. What were the responses of household consumers to this conflict in the short and long run?

**The impact of the conflict on household consumers**

In the short term, for the household consumer, the inexistence of coke or gas for kitchen and heating applications stopped the expansion of modern fuels inside the house. Urban consumers returned to firewood and charcoal in most cases.

In Lisbon, charcoal consumption increased considerably from 1917 onwards, due to the gas factory shutdown. In that year, more than 44 000 tons enter the city of Lisbon, contrasting strongly with the

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11 Companhia Reunidas de Gás e de Electricidade, gas company in Lisbon.
12 Gas and electricity prices were fixed by a contract with the municipality and the monopolistic company. The municipality tried to act in the defence of consumers. Furthermore, the municipality was also an important gas consumer.
13 The CRGE was also a electricity provider, what eased the suspension of gas service, once the company substituted the public lighting gas lamps for electricity ones.
28,000 tons of the previous year. Consumption would grow steadily and uninterruptedly until 1920, when it reaches a maximum of 138,000 tons.

Perhaps the most surprising result is not the wartime increase in charcoal consumption itself, but the per capita increase or stabilization during the subsequent years. Actually, according to a survey conducted in Lisbon, charcoal consumption of a household in the eve of World War II does not differ much from consumption in the years when the charcoal tax was still active. Railways statistics during the interwar period show that charcoal was still very important in the major cities of the country.

In the meanwhile, in lighting, the troubles in gas factories made the emergence of another competitor—electricity. The electricity expansion was, in the first decade of the century, delayed in Portugal. The viability of electricity for household purposes was conditioned by the existence of enlarged consumption markets. However, the implantation of thermoelectricity had been successively delayed not only by the shortage of capital, but also for the fears of lighting companies in damaging their main business, gas. On the other hand, gas consumers, belonging to the upper-middle and the upper classes of the population, faced electricity with expectations, not knowing which energy source would succeed. When World War I began, the rise in gas prices, along with the decline in supply quality, encouraged gas consumers to turn to electricity.

Aside from charcoal (in heating and cooking) and electricity (in lighting), the country would witness the appearance of a new fuel, which would dominate the post-war years, in the absence of coke and abundant gas supply: kerosene.

Since the 1920s, kerosene started to be used in domestic kitchens as well, thanks to the acquisition of an iron little stove (Ap.2, Figure II), which was quite affordable for the lower classes. One of the reasons for this was a change of charcoal prices in comparison to kerosene, benefiting the latter. According to Figure 5, relative prices of charcoal in relation to kerosene remained constant until I World War, to rise dramatically from then on. This change can be partly explained by a fiscal relief in Kerosene import duties: in the first decades of the 20th century, the fiscal load was between the 140 and 200% of product price, probably to protect existing gas companies; in the 20s and 30s, it decreased to a more normal value in the range 2% - 10%.

14 Kerosene’s importance in the kitchen was recognized in Paris World’s Fair (Exposition Universelle) in 1878. Besnard and Maris (who also invented the paraffin lamp (Forbes, 1958) introduced the prototype of the kerosene stove to the public. However, large-scale sales of kerosene burners only started taking place in the 20s (Cowan, 1983). In our country, these equipments were commercialized in small quantities in the beginning of the 20th century.: in 1909, the merchant Charles Doner, sold a little “Flame Bleu” stove, which is said to have been awarded in the Paris World’s Fair in that same year (“Almanach das Senhoras”, 1909).

15 Gas companies were before WWI an important pressure group in the parliament.
The only drawback of kerosene in comparison to the other fuels was that it could not be used in meals requiring high preparation temperatures, as well as oven recipes (Amigo do Lar, 1932). Thus, kerosene was not a perfect substitute of charcoal, its direct competitor. However, for the consumers in the lower and middle classes in the 20s, kerosene was a quite appealing alternative, economically wise, and ideal for small-sized families.¹⁶

In 1942, a parliament deputy calculated that in the previous years, about 450 000 kerosene stoves had been sold (Câmara dos Senhores Deputados, December 12th, 1942), which shows the newfound importance of kerosene in the working classes households in the period between wars.

In figure 6, it is possible to confirm the increase in Kerosene imports and Charcoal railway transportation after the IWW. Still, Kerosene imports did not surpass charcoal railway transportation (not representative of the total charcoal consumed in the cities) what indicates the persistence of the traditional energy carrier as the main fuel in the cities.

¹⁶ In 1916, kerosene importance was recognized: “For small-sized households, the kerosene stove is quite suitable” (Costa, 1916).
2.2.2. World War II and its impact in household consumers

In the middle of the 1930s, only 17% of Portuguese households had electricity in their homes, meaning that more than 80% of the population relied only to kerosene, olive oil, acetylene or candles for lighting purposes. Electricity was still a privilege of urban populations, and of wealthier dwellers; but even in these cases electricity rarely surpassed other energy carriers. The cities of Lisbon and Oporto were the most advanced in the electrification process, with 50% of the dwellers connected to the grid. However, electricity consumption was mostly directed to lighting purposes, as indicated by the less than 200 kWh/year acquired by an average low voltage consumer in those cities.

The only electric equipments relatively diffused among electricity consumers were the electric iron (11%-15%) and the radio (14%). In Lisbon, appliances for cooking, water heating and space heating are merely acquired for curiosity, reaching 1%, 1% and 5% of electricity costumers.

Following the same consumption patterns in electricity diffusion, the two cities differed considerably in the development of gas market. In Oporto, the future of gas consumption was already doomed: from about 6000 consumers in 1920, there were only 1074 left in 1935. In Lisbon, the number of consumers in 1935 was 62% of those in 1915. Despite the great investments in advertising from the gas company, the results were somewhat disappointing. In fact, annual growth rates of gas costumers in the 1928-1935 period (1-2%) were much lower than in 1907-1915 (3-6%).

However, from 1940 onwards, the patterns of energy consumption in the two main cities of Portugal changed drastically, as we can see from the Figure 7. In Oporto, a clear option was taken for electricity, with an early derivation from the Lisbon trends. At Lisbon, electricity consumption per capita remained very low, but on the other hand gas consumption rose significantly. What were the main causes for this divergence between the two cities and the spectacular rise in consumption of
modern energy? Could the Oporto phenomenon be applied to other urban cities in the country? As we will see, the shift to electricity in Oporto and to gas in Lisbon could be only understood by two major events: the institution of the possibility of discount tariffs and the World War II.

Figure 7 - Electricity and gas consumption per capita in Lisbon and Oporto

![Graph showing electricity and gas consumption per capita in Lisbon and Oporto.](image)

**Sources:** SMGE, “Relatório da Direcção sobre os Resultados Obtidos com a Exploração dos Serviços de Gaz e Electricidade” (1917-1955); DGSE, “Estatísticas das Instalações Eléctricas”, (1935-1955); CRGE, “Relatório do Conselho de Administração e Parecer do Conselho Fiscal”, (1907-1930); CRGE, “Elementos Estatísticos” (1951-1955). Conversion m³ to kWh – 1 m³ = 4.2 kWh (conversion factors DGE). Note: numbers referring to total population. Gas Oporto is missing because the exploration of gas in that city ended in 1941, when only 600 consumers existed.

A) Public policy in electricity pricing

Since the ending of the 19th century the municipalities agreed on the price of kWh of electricity with the supplier companies and the length of time that this price should be in force. This situation originated an impressive regional price disparity as well as different profit margins to several companies with similar cost structure. In general electricity prices indicated the quality of electricity as a lighting service, what make it virtually impossible to compete with traditional energy carriers for another demands.

However, in 1936 the Salazar government took in hands some of the responsibility in the management of electricity prices, strongly suggesting the application of degressive tariffs to household consumers. The basic idea of this tariff was to award all the consumption beyond lighting, charging decreasing costs per kWh every time electricity consumption surpassed a certain level. Industry interests motivated this new government policy, as it was believed that industrial electricity prices could only go down if there was an increase in household electricity consumption. Households were expected to
lower exploration costs consuming surplus energy in off-peak periods, and to finance industrial consumption, by paying a higher than average rate per kWh.

The CRGE was the first distribution company of the country to follow the guidelines of the government, in the city of Lisbon and adjacent municipalities in 1937. In mid-1939, the city of Oporto followed the path of Lisbon, after intense negotiations towards a profitable deal with the usual hydroelectricity provider, the UEP. The figures 8 and 9 show the monthly expenses for several kinds of fuel in both cities for a family of four or five in 1936, 1940, 1943 and 1950.

**Figure 8 & Figure 9**: Lisbon and Oporto- price of cooking meals

<table>
<thead>
<tr>
<th>Year</th>
<th>Lisbon</th>
<th>Porto</th>
</tr>
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<tbody>
<tr>
<td>1936</td>
<td>Charcoal: 100 Escudos, Electricity: 50 Escudos, Kerosene: 20 Escudos, Gas: 20 Escudos</td>
<td>Charcoal: 150 Escudos, Electricity: 100 Escudos, Kerosene: 50 Escudos, Gas: 50 Escudos</td>
</tr>
<tr>
<td>1940</td>
<td>Charcoal: 150 Escudos, Electricity: 75 Escudos, Kerosene: 30 Escudos, Gas: 30 Escudos</td>
<td>Charcoal: 200 Escudos, Electricity: 150 Escudos, Kerosene: 70 Escudos, Gas: 70 Escudos</td>
</tr>
</tbody>
</table>

**Source**: The magazine “Amigo do Lar”, June 30th, 1936 elaborates a price comparison for a family of 4/5 people in Lisbon using different energy carriers. As they give the quantities used by each fuel, it was possible to construct the expenses for the following years according to variations in price data. Electricity prices: We considered that the cost of cooking with electricity was given by the last price level of electricity tariff. In 1936 electricity price for Lisbon refers to the price before the introduction of special tariffs.

In Lisbon, in the year of 1936, charcoal and kerosene were still cheaper than gas, but the later was turning into a competitive fuel. The advertisements of the company address mostly coal users in opposition to gas, “The coal stove is dirty, hard to handle, its anti-hygienic”; “coal its paid before, gas later” (Amigo do Lar, 1932). In Oporto, for the same period, gas price was much higher, which was a reflection of municipal lack of interest in developing this market. This led to a greater difference between modern and traditional fuels. In 1940, as evidenced in the graphs above, cooking with gas in
Lisbon and electricity in both Lisbon and Oporto, was already much cheaper than using charcoal for the same purposes.

However, it is known that both cities would end up following distinctive paths after the war? How can this distinction be explained?

**B) The Lisbon situation: gas**

In Lisbon, like in other Portuguese cities that produced thermoelectric energy, the impact of the war was felt in the price of electricity, since it depended on coal production. In 1942, the government released a decree, which established restrictions in electricity use. The restrictions involved: abridging of public events; the prohibition of electric advertising signs; the reduction of tram schedules, and the imposition of maximum monthly limits for use of electricity for industry, business and domestic consumers (CRGE;1944).

In May of 1942, the Lisbon metropolitan area was also covered by this rationing plan, which meant that the special heating rates were terminated and the domestic consumers were then divided in 30 ranks according to their consumption in the previous year. The new maximum limits required reductions up to 25% of the previous year’s consumption values and each additional kWh would be punished with a heavy fine: 10$00 per kWh, whereas the regular rate was 1$89 (CRGE, 1944). However, this decree did not make any mention of gas (Bussola, 2004) in spite of its greater dependence on foreign fuel. While the restrictions took place, gas became the most appealing fuel for the Lisbon households. This is confirmed by the increase in consumption; between 1941 and 1946, gas consumption practically doubled and the growth taxes were particularly high in the years after the degressive rates: 15% in 1942, 27% in 1943 and 18% in 1944.

As for the number of installed electricity counters, the growth taxes were about 2% before 1936, increasing to 4-7% afterwards (CRGE, *Elementos Estatisticos*). Gas adoption as a fuel would be a continuing trend in the post-war years; even after traditional fuels prices had lowered comparatively to gas.

The reduction was felt in the charcoal market: in 1938, consumption was of around 100 kg per person but in 1948 it had decreased to around one third of that figure.
C) The Oporto situation

While the thermoelectric areas were subjected to such heavily restrictive regimes that electrical appliances could not be used, the cities provided with hydroelectric energy were offered a unique chance. At those times the main regional systems (CRGE in Lisbon and Electra del Lima/UEP in the North) were not connected through transmission lines, so Lisbon could not have used electricity from other regions in the country. In industrialised countries interconnections of this kind were being made since the early 20’s and 30’s (Kaijser, 1995; Hughes, 1983). In Portugal, even regional systems were in the early developing years. One of the explanations is institutional: in the beginning of the 30’s the new dictatorial government cancelled the awarding of new concessions in production and high-voltage transmission lines (Madureira and Bussola, 2005), in order to plan their project of the establishment of a National Grid.\footnote{The National Grid started to be constructed only in the 1950’s. Madureira and Bussola (2005) state that in the 30’s the UEP applied for the construction of a high –tension line between North and South which was refused by the government.}

Oporto had access to the Lindoso dam, constructed in 1909 by the Spanish Company Electra del Lima. From the 20’s electricity of Lindoso dam was distributed by the Portuguese União Eléctrica Portuguesa (UEP) to the city of Oporto. It was the biggest dam in Portugal at the time of Second World War, representing almost 1/3 of the total installed hydroelectricity power and 1/10 of the total one, but its dimension was far from impressive (28 MW) (Estatísticas das Instalações Eléctricas, 1939).

During the war, in the second city of the country, while traditional fuel prices spiked dramatically, the new electricity rates\footnote{The new degressive tariffs were significantly low when compared to the previous: 1$7/kWh first level; $90/kWh in the second level and $22 in the third level in 1939 – in 1938 a uniform rate of 1$9/kWh was charged to the consumers.} attracted the poor and the lower middle class as the months went by. The first impact of war in Oporto, translated into an increase of the number of consumers, especially since the new consumers were mostly from the lower classes and used only electric energy for lighting. This was facilitated by the city council, which created, along with the regressive rate, a social rate option of 1$00/kWh.

However, as coal and kerosene got more and more expensive, Oporto citizens resorted to electricity for cooking and water heating, a trend that the SMGEP\footnote{Serviços Municipais de Gás e Electricidade (Municipality Gas and Electric Services).} observed in 1943:

“\textit{The popularity that electricity use enjoys nowadays can be proven by the citation of some concrete examples. In 1940, a lower class consumer spent 69$00 for lighting purposes, consuming 27 kWh; in 1942, after the special domestic rate, he used, also for lighting, 35 kWh, which cost him only 48$00. Later on, [the consumer], unable to acquire and/or afford fuels for cooking his meals, acquired for one or two hundreds of escudos, a small electrical stove with one plate. In January of the current year, he applied for the return to the general domestic rate and then he consumed, in a total of four months}
(from February to May), 158 kWh that cost him 130$00. In other words: at a 32$50 monthly rate, this household was able to provide for both lighting and meals preparation”. (SMGEP, 1943)

The change happened so quickly that the conclusions brought up in the 1944 Municipal Services report are quite different from those on the 1940 one: the third tariff segment accounted already for 46.4%20 of the total consumption of electricity in the general domestic rate. While the upper classes favoured hygiene and comfort, the lower classes were attracted to electricity for the cheaper rates, especially in which regarded the cooking costs. (SMGEP, 1944).

The first household appliances purchased by Oporto citizens must have been the electric stove, a small stove which had just one plate and could be used for the quick boiling of liquids and the preparation of food, as long as the power demanded did not exceed 500 W.

Stoves with two or more plates and an oven were still reserved for the well-off families, since the equipment cost was excessive (Almeida, 1948).

Between the purchase of the little electric cooking plate and the electric stove, with an oven, the Oporto inhabitant acquired thermal accumulators for water heating, with a 10, 30 or 50 liters capacity. However, while “the demand and the use of energy in the city of Oporto was enormous (...), washing, heating and cooling equipment did not have much influence yet. (...) Up to the present date, the main domestic application consisted of cooking and water heating” (SMGEP, 1945).

The conclusion that can be drawn from this experience is the following: the first increase in household electricity consumption was possible only because kerosene, coal and wood turned out to be quite expensive fuel choices for cooking and lighting, in comparison to electricity.

This perception of the price difference is considerably acute because it shows that not only electricity was getting cheaper but also that the alternative fuels were more expensive. Electricity was seen as a substitute, not as a necessity in itself. However, the increase in electricity consumption in Oporto was a goal that the SMGEP had aspired to ever since before the war, when degressive tariffs were introduced. War was influential in that it accelerated the rhythm of Oporto citizens’ adoption of the new technology. The influence of the war and degressive tariffs in the pattern of household electricity consumption in Oporto is best summarized in figure 9.
In 1950, ten years after the introduction of the degressive rates in the city of Oporto, 78.4% of the families had access to electricity. (INE, 1954): 38,559 customers were registered in the general domestic rate and 10,598 were in the special rate for the poor (reserved for lighting only). From the customers registered in the general rate, one third (33%) owned stoves with one or more plates; one fifth (20%) owned a radiator and 13% of the customers acquired water heating devices.

The specific consumption per capita was, by a large margin, the highest in the country: 907 kWh/year per family, contrasting with the 160 kWh/year in the city of Lisbon, in the same period (DGSE, 1950). Oporto was not exactly a unique case in which concerns electricity adoption as a substitute of traditional fuels; it was simply the place where this adoption was more expressive.

Coimbra and the Oporto adjacent councils of Vila Nova de Gaia and Matosinhos, among others, also registered similar substitutions. In 1950, 75 councils in the country were applying degressive rates plans, which had a very important role in lifestyle change during wartime.

Source: SMGEP, “Relatórios Anuais” (Annual Reports).
3 . Urban and rural energy transition (1950-)

3.1. Looking at the other side: the rural and urban compared

We have focused until now in energetic substitution in the Portuguese cities until World War II, with special relevance for Lisbon and Oporto, but now we must turn our attention to the other side. It was verified that the transition was slow and mostly conditioned by the WW II events. However, it should not be forgotten that, even in 1940, Portugal is a poorly urbanized country, with 78% of population living in rural areas and more than half the active population working in agriculture. In these areas, the energy transition had not yet arrived to their households.

In the 40s, rural households relied on two types of fuel to satisfy their needs: firewood and kerosene. Kerosene was used in only minimal doses and for lighting, its acquisition being reduced to some tens of liters per year. Firewood was abundantly used for meals, to heat the house and also for lighting the long winter evenings. The Portuguese rural house had two main equipments for cooking and heating: the open fireplace and the oven (see Appendix 2, figure III). The poor state of rural habitations (due to the lack of mortar or glasses in windows, and to the frequent breaches in roofs, walls and doors) and the inexistence of efficient equipment, such as stoves, contribute for the much higher firewood consumption in comparison to the urban families at the time.

However, this was not of concern for farmers, as firewood was a quite minor factor in the family expenses. Woods owners could, obviously, take care of their daily needs; they would also supply their employees—as a supplement to their wages—and neighbours with firewood carts. Those who did not own woods either searched for firewood in wastelands and surrounding hills or “stole” it from neighbouring properties, with the tolerance of their owners.

This was the situation of most workers (60%) from a sample of 52 families that where interviewed for the Inquérito à Habitação Rural I e II of North\(^{21}\) and Central Areas\(^{22}\) of the Country (Barros, 1947; Basto, 1943). In fact, this fuel would be totally purchased only in extreme cases, as shown by the results of this survey: only 26% of the Central families and 9% of the Northern families bought all the firewood they consumed. Anyway, the fuel expenses were still low for those who purchased their firewood, much lower than the prices paid in the city.\(^{23}\).

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\(^{21}\) North Area: Aveiro, Braga, Bragança, Guarda, Porto, Viana do Castelo, Vila Real and Viseu, as per our methodological definition.

\(^{22}\) Central Area: Castelo Branco, Coimbra, Lisboa, Leiria and Santarém, as per our methodological definition.

\(^{23}\) In 1938, firewood cost between 0.4esc. and 0.6esc./Kg in the district capital cities. In the countryside, those who had to purchase firewood spent from 10 to 50 esc. per load (500 – 800 Kg).
Table 1- Comparison between an urban and rural family energy requirements

<table>
<thead>
<tr>
<th>Final energy* (Unit= kgce**)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1938</td>
</tr>
<tr>
<td>---</td>
</tr>
<tr>
<td><strong>Urban</strong></td>
</tr>
<tr>
<td>Total Expenses</td>
</tr>
<tr>
<td>Energy expenses (%)</td>
</tr>
<tr>
<td>Electricity (kgce)</td>
</tr>
<tr>
<td>Gas (kgce)</td>
</tr>
<tr>
<td>Kerosene (kgce)</td>
</tr>
<tr>
<td>Charcoal (kgce)</td>
</tr>
<tr>
<td>Firewood (kgce)</td>
</tr>
<tr>
<td>Total consumption kgce</td>
</tr>
<tr>
<td>Cost of kgce (Esc)</td>
</tr>
</tbody>
</table>


* Final energy is a concept different from primary energy. Final energy = Primary energy - Transformation losses. Thus, losses in transformation of firewood into charcoal or coal into electricity are not taking into account. ** To make the figure easier to understand the unit Kgce (kg of coal equivalent) is used here: Conversion factors to kgce according to the Direcção Geral de Energia (DGE): 1 kg firewood =0.43 kgce; 1 kg Kerosene =1.493 kgce; 1 kWh =0.123 kgce; 1 m³ gas=0.6 kgce; 1 kg charcoal=0.985 kgce. Kgce= kilogram of coal equivalent. 1 Kgce=29.3 MJ.

The Table 1 establishes a comparison between the differences in fuel use in the cities and in the countryside, in the 1940s and early 1950s.

In fact, an urban consumer has options; he can choose from traditional and modern fuels and make a decision according to prices and quality of the fuels. A rural consumer does not face this choice because firewood is virtually free. In the worst case scenario, the kgce price would be about 4% of the Lisbon rates in 1948, and 7% of the Oporto rates in 1950. An urban family would spend six to seven times more money than a rural family on both lighting and heating. However, a rural family would consume, in energy units, 3 to 4 times more than an urban family in terms of final energy.

3.2. The introduction of LPG

In the 50s, having city gas or house electrification was a reality that only a minority could access, determined rather by “where we live” than by “how rich we are”. Pursuing city gas meant living in Lisbon, as having an electric stove or cylinder meant living in a city with accessible tariffs.

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24 The term virtually free it has of course to be interpreted with caution because the time an individual’s spend collecting firewood means also an opportunity cost, time. However, in some cases, the time spent in collecting was no alternative to any available job.
For the vast majority of inhabitants, electric light was not available. In 1950 only 4 out of 18 districts in mainland and the Azores region can pride themselves in having more than 20% of electricity connections. Even in the cities, with the exception of gas consumers in Lisbon and electricity consumers in the Oporto region, firewood, charcoal and kerosene were still the main fuels found in an urban dwelling. However, equipment conditions of Portuguese households began to change thanks to the reality of butane. Butane started to be commercialised only at the beginning of the 30s in USA – before it was lost in the process of refining due to its high volatility (Wright, 1970). Some of the advantages of butane in relation to traditional energy carriers were: higher energy density and cleanness. The constraints were the cost of the equipment itself and the cost of the product. However, it doesn’t demand the existence of a previous technology in the locality or house, as gas or electricity does.

In Portugal, LPG (Liquefied Petroleum Products) started to be commercialised in 1939 by CIDLA (Combustíveis Industriais e Domésticos), a company that had been recently established in the country. This company had an exclusive import license for the sale of butane, but until 1951 the market developed very slowly, reaching only 8000 consumers at that time. This was mainly explained by the government-imposed limits in imports; by war situation and the subsequent increase in kerosene prices and, finally, by the absence of refineries. However, in 1952, the company started to be supported by SACOR, the new refinery and, after 1954, butane began to be fabricated in the country. Butane adoption by Portuguese families since then was nothing short of impressive. In 1958, CIDLA could boast of 156434 clients, mostly domestic, who acquired in average ten 13 Kg bottles a year. This means that butane managed to achieve in solely eight years what neither electricity nor gas were able to in several decades (CIDLA, 1958). This expansion would go on for the next three decades, being facilitated by the entrance in the market of new competitors such as Mobil, Shell and BP, Sonap and Esso, in the 60s (Marques, 2002). In the initial phase, butane adoption was restricted to the cities; in 1960-1961, a survey conducted by INE in the city of Faro would register this evolution: 54 kg of butane per family, indicating this fuel was already replacing coal, whose consumption decreased to a mere 50 kg.

In 1965, after completing 20 years of activity, “the actual number of butane gas consumers exceeds 1 million; and this value, added to the city gas consumption figures, accounts for 40% [using this fuel] of the total of dwellings” (CIDLA, 1965).

22
This unusually high number of consumers can be explained not only by the appealing rates in comparison to other energy sources (Figure 10), but also several other factors which allowed for a reduction of consumption costs for the poorest families: the canceling of the annual bottle rental fee, the release of smaller bottles for the lower-classes and the developing of household appliances production.

Although gas stoves preceded the acquisition of electrical equipment, there was a great sales boom also in the market of cylinders, radiators, convectors and electric stoves. This expansion was particularly notable in the period of 1971-1980: nearly 400 thousand thermo accumulators, 1 657 000 electrical heaters and 485 000 cooking appliances (stoves, little stoves, and ovens). Taking into account the nearly 843 000 gas heaters sold and a production of 1 321 000 gas stoves, it can be said without fear of error that the 70s were a decade of great consumption expansion, mostly urban. (*Estatísticas Industriais e Comércio Externo*, several years).

What happened to the other traditional fuels? Did not they offer any sort of competition against butane?

Charcoal consumption must have been one of the first to fade away. In 1962, a deputy analysed the depression in the Alentejo region (main charcoal supplier): “[This was caused by] consecutive bad harvest years, specially in cereal production; a lower cork value; consumers’ lack of interest, now solicited by electricity, the butane gas and mineral oils, by firewood and charcoal; the highly disproportionate cost of liquid fuels in comparison to other activities” (*CSD*, 11/12/1962). Coke commercialization met its end in the 50s, when the CRGE changed their gas production system. Sales figures were very low, due to the competition offered by not only the butane gas but also city gas itself.
In spite of the favourable conditions, butane gas took a little while to arrive to the rural areas of the country. In 1961, in the Western region of the country, consisting of Alcobaca, Nazaré, Caldas da Rainha, Óbidos e Peniche, the number of consumers was still low and “consumers from outside the municipalities did not matter much, while rural populations, mostly farmers, relied on chips of wood, (…) and the traditional pine and eucalyptus coals” (Alasão, Cardoso e Silva, 1961). At the beginning of the 60s, the valuation of firewood along with the income raise, led to the gradual and slowly introduction of bottled gas in the countryside. The GAZCIDLA – “Rural gas” (as CIDLA themselves advertised it in 1960) was a fuel that was first commercialized in the small towns and later on was also expanded to the villages.

But how did regions where firewood was practically priceless witness the adoption of another fuel?

To understand the transformation observed in the rural areas another study would be needed, but it is still possible to equate synthetically some of the possible factors that led to butane adoption in rural areas.

First, there were deep changes in the access of rural populations to their usual fuel sources, the commons. In fact, starting in 1944, the Salazar administration developed a plan to forest about 407 000 hectares of commons (recognized in 1938) in the Tagus Northern Area. According to Esteves (1983), industrial interests motivated this plan: the forestation of these wastelands would benefit the lumber and wood industry (and cellulose), and the chemical industry, thanks to the increased need for fertilizers. It would also eliminate the animal farming economy, thus freeing cheap labour for a growing industry. Until 1972, the total area covered by this plan would reach 280 000 hectares, changing the traditional agricultural structure; the wastelands were then subjected to a partial forbidden access policy, enforced by the Forestal Services.

In the second place, rural areas witnessed a mass exodus (about 1 million Portuguese emigrated in the sixties), motivated by an industrialization policy based on low farming wages; poor living conditions and colonial war, to countries like Germany and France. In the 1960’s the emigrant would become one of the most significant agents in the purchasing power of rural populations. Not only the remittances of money from abroad improved the welfare of the original population but also the dramatic decrease of agricultural actives led to a greater inflation of industrial products in comparison to those of rural origin (Rocha, 1984). Furthermore, the emigrant will also contribute in a social level to the desire of the rural population to better living conditions. When they return on holidays or permanently to their village, they will construct new houses with more efficient materials in a European fashion and they will acquire the most modern devices, becoming a model to follow to their neighbours.

**3.3. The extension of firewood displacement in the country – Present situation**

It is interesting to understand how the degree of introduction of modern fuels in Portuguese households during the period the decades of 50-80 replaced firewood for heating and cooking.
Does access to more efficient fuels (in the perspective of the energy ladder theory) eliminate the use of less modern fuels?

The Table 2 lists the cooking, heating and water heating equipments used in Portuguese households in 1988 and in 1995, registered when two periodic studies on consumption habits in Portugal were conducted by DGE. These studies confirm the expansion of cooking and water heating equipment in the following way: city gas in Lisbon, electricity in the Northern Region and butane everywhere else.

The low numbers of households with heating and water heating systems are partially explained by the mild climate in Portugal, and for the lack of access to plumbed water by a considerable fraction of the
population. In what concerns cooking equipment, though, butane adoption was extremely high even in the rural areas. In 1988, only 7% of rural households did not own any kind of stove; from those who did, 88% used a butane gas stove while 7% relied on an electric stove.

### Table 3– Firewood consumption by type of household

<table>
<thead>
<tr>
<th>Households</th>
<th>Total</th>
<th>Single family dwellings</th>
<th>Flat</th>
<th>Rural Households</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>2937123</td>
<td>1299973</td>
<td>995103</td>
<td>552048</td>
<td>89999</td>
</tr>
<tr>
<td>With firewood consumption</td>
<td>45%</td>
<td>58%</td>
<td>4%</td>
<td>93%</td>
<td>31%</td>
</tr>
<tr>
<td>with acquired firewood</td>
<td>14%</td>
<td>24%</td>
<td>59%</td>
<td>16%</td>
<td>8%</td>
</tr>
<tr>
<td>with picked firewood</td>
<td>61%</td>
<td>53%</td>
<td>31%</td>
<td>73%</td>
<td>72%</td>
</tr>
<tr>
<td>Other</td>
<td>7%</td>
<td>23%</td>
<td>10%</td>
<td>10%</td>
<td>20.7%</td>
</tr>
</tbody>
</table>

**Source:** DGE (1988) "Inquérito no Sector Doméstico".

However, the 1988 results show a different reality, as evident from table 4. The percentage of firewood consuming families was still 45%, being particularly high in rural households; the majority of the families reported that they picked, not bought, their firewood. The picked firewood figures corresponded to 70% of total domestic firewood consumption. Both in 1988 and in 1995, the firewood consumption figures per family assumed relevant proportions: the two surveys show that a Portuguese family would consume, on average, between 1.2 and 1.6 tons of firewood per year. Translating those figures into per capita consumption, the following values are obtained: 1.38 kg/day in 1988 and 1.1 kg/day in 1995.

In other words, and assuming that these estimates are correct, the per capita consumption decreased only 45% from 1950 until 1988. While it is certain that there was some tendency of substitution with the adoption of modern fuels, the firewood consumption quantities are still quite high, being very close to those observed in Spain and in Italy in the beginning of the 20th century. However, the difference between Portugal and those two countries relies more on the different proportion of firewood consumers than in the amounts actually used (in average). In fact, in 1999, a survey conducted in Italy verified that firewood consumption was about 3.07 tons per firewood user, which does not differ much from the Portuguese situation, with 3.66 tons in 1988.

How is the modern fuel adoption determined by the decrease in firewood consumption in both heating and cooking? The two surveys cannot provide a clear-cut answer, as they do follow different

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25 The definition of rural household in this survey concerns remote households inhabited by one family and where some or all of its members are engaged in agriculture.
methodologies in which concerns the appraisal of consumption per utilisation, mostly regarding firewood in kitchen fireplaces.\textsuperscript{26}

Despite this, thanks to the data on equipment ownership, it is known that the first change did occur in the kitchen. However, this change was slow in the rural areas and it was always partial. Valagão (1986), in an anthropological study about the eating habits of Alto-Douro rural populations, verified that gas was mostly used in summer, since agriculture required more work and there was little time left to prepare meals. In winters, though, families would resort to the fireplace, which allowed for both cooking and heating.\textsuperscript{27}

Finally, another explanation for the high per capita figures for wood products in Portugal these days can be given by the low efficiency of open fireplaces, the most popular equipments for firewood burning. Unlike other countries, Portugal did not register any significant improvement in household firewood equipment during the period covered by this analysis.

\textbf{Final remarks}

The idea of doing an analysis on energy consumption in the residential sector in Portugal in the past 150 years resulted from the realisation that the importance of firewood in the context of the energetic system was much greater than in other countries where traditional fuels were no longer a significant factor.

The goal was then to explain how the energetic substitution evolved in Portuguese households; and to test some published theories on energy transition and the relevance of the variables that affect the adoption of a new fuel in Portugal.

It is quickly verified that the transition to modern and more efficient fuels was not a uniform process: it was slow or inexistent in some cases, fast in others, while some periods witnessed some drawbacks.

One of the most obvious variables in this transition process seems to be the level of urbanization of the country. Ruralism, associated to a high participation in agriculture, and the subsistence economy and the nearly unlimited access to free fuel, are the ingredients which keep the consumer at the margin of the network.

In Portugal, these ingredients were present until the 60s, where they started to lose their relevance due improvements in accessibility, the industrialization of some rural areas, and also to emigration and the progressive disappearance of the wastelands.

However, even while some of those ingredients disappear, others will persist. The adoption of a new technology, such as the butane gas stove, does not necessarily imply the elimination of the old

\textsuperscript{26} Actually, it is assumed that, in the year of 1988, 85% of total consumption took place in the kitchens; in 1995 that number decreases to 39%. This means that firewood consumption decreased 58% for cooking, purposes, while heating witnessed an increase of 186%.

\textsuperscript{27} See App. 2, Figure IV for a picture of a rural kitchen in the present.
technology. Traditions, preferences and cost-benefit factors were very present in the daily use of each fuel.

The existence of natural resources and the lack thereof are also significant factors in how energy transition develops. In the mid-50s, Portugal was a country without coal resources. For example, coal gas was unsuccessful in many cities due to the poor access to foreign fuel, even in peacetime. Cheap electricity was made possible in the 40s and the 50s only in the cities supplied by hydroelectric dams.

The consumers’ preferences also explain the adoption or rejection of a specific fuel, such as mineral coal, which was not significant in our country as consumers favoured the more hygienic charcoal and coke. Charcoal was ranked above kerosene as well, despite kerosene being referred to as a transition fuel in developing countries.

High prices also do matter, but mostly in situations of scarcity of supplies and high expectations of raise in prices. Usually, the adoption of a fuel is associated to a significant decrease of relative prices (such as the cases of kerosene and of butane).

However, one must be careful with the interpretation of relative prices. In the 20s, electricity costs lowered considerably in comparison to all the other products, but that factor alone does not make electricity an acceptable fuel for uses other than lighting. On the other hand, any substitutions that require great expenses would be made use of by the rich, not the poor. Such was the case of the replacement of charcoal and firewood by coke, since only the richest were able to afford the equipments. If the equipment were sold at moderate rates, like with butane gas equipment in the 60s, the transition would be quicker.

Energy crises are the most fundamental factors in adopting or rejecting a technology; while the crisis periods are short, context and expectation drive the prices up. This expectation leads to opposite behaviours; the entrance or exit of the system is anticipated in face of the lack of alternatives. However, the number of agents that get in the system contributes for a behaviour change in the outsider agents. For example, when gas factories shut down during World War I, even those that reopened later were not able to recover their clients quickly. On the other hand, both electricity and gas persisted in World War II in face of the drastic price alterations of traditional fuels, managing to achieve a larger number of clients and consumption in the post-war years than before the war – even if those numbers were still lower than those observed during wartime. This is a case of pathway dependence.

Public policies are other considerable factors that affect the tendencies in energy consumption. The State can tax a product to benefit another one, as it happened before the war with kerosene, in benefit of city gas. It can also suggest the use of degressive rates to favour electricity consumption, or impose energetic restrictions to electricity, aiding gas.
The energy ladder theory, in its simplest version, is not confirmed – the assumption that consumers are in a certain level of consumption is not confirmed by facts. Nowadays, and mostly in rural areas, the multiple fuel use is still present.

On the other hand, the assumption that the consumer does have to pass through transition fuels to reach the modern fuels is not totally confirmed. Most firewood rural consumers did not use neither kerosene nor charcoal for cooking, jumping directly to butane gas.

So, energy transition to modern fuels in Portugal can be summed up in the following way: in urban areas, until the mid-1890s, charcoal was the preferred fuel in detriment of coal and coke, because coal was considered to be a worse fuel, and coke required a stove. With World War I, the coke and the gas factories were gone from most urban areas due to the foreign fuel supply difficulties along with the trouble in carrying out their contracts. Until World War II, charcoal consumption increases slightly along with kerosene; wartime would witness a pathway dependence phenomenon -- in relation to gas in Lisbon, and to electricity in the hydro-electrical areas.

In the post-war years, butane would end some of the asymmetries between the city and the countryside, reaching most rural households in the 80s. Even so, firewood consumption is particularly high thanks to the preference for open fireplaces.
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APPENDIX 1

Primary energy index construction (Portugal 1856 – 2000)

Modern energy carriers (Coal, Hydro, Oil)

1856 – 2004

For the period of 1856 to 1889, the statistical data regarding foreign coal and kerosene net imports was taken from Extern Commerce (Estatísticas do Comércio Externo) from INE. The figures concerning national Coal from 1856 to 1890 were depicted from several sources: Madureira (1997); Inquérito Industrial (1890), Matos (2002); Guedes (2000), Rocha (1997) and Valério (2001).

For the period of 1890 to 1970, the reference used was the commercial index built by Madureira and Teives (2005). However, instead of calculating hydroelectricity according to the equivalent coal that would be needed to produce the same amount of electricity, the focus here was on the heat content of electricity. Furthermore, the import and export figures from Figueira (2003) were also used for reference.

As for 1970-onwards, the data was inferred from the Energy Balance Sheets from 1971-2004, published by Direcção Geral de Energia.

Muscle Energy

Animals - From 1852 to 2000 there were 10 national censuses, which allow us to determine the number of horses, donkeys, mules, oxen and cows at the time.

Since only working animals are of interest for our purposes, 15% of the absolute value of donkeys, mules and horses were deducted, so that foals wouldn’t be accounted for.

In which concerns bovines, foals up to two years old and non-working cows were eliminated from the total. The percentage of working cows in Portugal is quite considerable, similarly to the Spanish situation: in 1870, more than 60% of adult cows worked; in 1955, that figure decreased to 44%. As for 2000, it was assumed that the number of working cows was zero.

The weight of the animals was determined, until 1910, by the weight variation in the slaughterhouse. The period from 1910 until the present, Kander and Warde’s recommendations (2006) for animals’ daily caloric intake were followed.

Humans – In which concerns the period from 1960 until 2002, the average daily caloric intake figures are provided by FAO (2004). In these years, the average daily caloric intake of the Portuguese varied from 2473 to 3741 calories. The 1960 figures were used for the remaining period.

FIREWOOD ESTIMATION

1. HOUSEHOLD FIREWOOD CONSUMPTION

a) Lisbon:

1856-1922 – Being the richest city in the mainland, Lisbon was severely taxed in many products when compared to other cities in the mainland. In other cities, some food products required the “Real da Água” tax, but Lisbon paid an additional tax, called “consumption tax”(“imposto do consumo”)). In some years, the revenue of this tax in Lisbon was higher than the total revenue of the Real da Água, a tax that was applied to all the population of Portugal. This consumption tax comprised not only food goods but also energetic ones. Charcoal is the only energy carrier that is
covered in all of this period. From 1856 until 1888 there are records of different subtypes of firewood, but in June of 1888, taxation of these products came to an end. Not all the inhabitants were covered by the consumption tax when Lisbon was enlarged in 1886. In 1887, the taxed zone was larger than in 1856-1886: Estrada de Circunvalação from Algés to Benfica and comprising Ameixoeira, but excluding Charneca and ending in Asilo Dona Maria Pia (Beato).

To built a per capita series of firewood for the Lisbon region in the period of 1856-1922, the following criteria were used:

1) Firewood figures were not considered since they are only covered for the period of 1856-1888 and they are believed to be an expression of industry consumption.

2) Charcoal figures were inferred from the figures of the population arguably exposed to charcoal taxation. In 1886, the Lisbon metropolitan area included Olivais and Belém as well. As the road used for taxation had yet to be built, the following assumptions were made: Belém was incorporated into the Lisbon area until 1890 – 25% in 1887, 50% in 1888, 75% in 1889 and 100% in 1890. Olivais was incorporated from 1891 to 1900 until it reaches the 100%. The other estimates were done with linear interpolation.

Until 1884, a bag of charcoal (reported as such) is assumed to weigh 98.5 kg. This is simply the average between the highest and the lowest weight per bag, as reported by Alfândega do Consumo.

1938 – An inquiry on household expenses was conducted in the years of 1938-1939 by INE, with a sample of one thousand families. The goal of this inquiry was to update prices per weight at a regional level. Several energy products are included in the final report: Coal, Gas, Electricity and Kerosene. The proportion of people using gas at the time was matched with the correspondent city proportion.

Then, it was assumed that 25% of the coal being consumed by Lisbon families was of mineral origin (coke). This assumption relies in coke production by gas factories at that time, since the Gas Company had more or less the monopoly of coal sales in the city. From 1922 to 1938, the inquiries were connected with the variation in train charcoal transportation.

1948 – INE conducted another inquiry with the same goals as the 1938 one. The data concerning the years of 1938 and 1948 were connected by linear interpolation.

b) Porto

Per capita consumption was assumed to be the same as in Lisbon, since there is no data available for Oporto, the only other big city in Portugal. The 1856-1936 series was connected with a 1950 inquiry conducted by INE in Oporto.

The Charcoal consumption per family was much higher than in Lisbon within more or less the same period (1948-1949).
c) Other urban areas – Firewood consumption was considered to be equal to 430 kg/per capita until 1925, decreasing linearly from 1925-1938 to account for some kerosene substitution until it reaches 410 kg/per capita in 1938, remaining constant afterwards.

It is believed that consumption figures (in the cities of Évora, Viseu and Coimbra in the early 1950s) are close rather the figures of Lisboa and Oporto than to those of the rural areas, according to the INE inquiries on household expenses and a survey on lighting and cooking expenses in the years of 1916, 1918 and 1920.

The per capita figures are almost similar to the Oporto ones in the 1950-1951 period. The population covered by this estimate varies between 75 and 100% of the registered value for Lisbon and Oporto. Also, the population belonged for the most part to the adjacent areas to the two cities.

d) RURAL AREAS

In the period of 1939-1945, some monographic inquiries on Agriculture were conducted by the Agricultural School of the Technical University of Lisbon (Instituto Superior de Agronomia) in the Northern and Central rural areas of Portugal. Families were inquired on how much firewood they consumed.

Those figures (mostly the number of firewood oxen cars) were then converted into Kilograms; one car being equivalent to 500 kg of firewood. This leads to an average of 857 per capita/year. The same value was assumed for the rural population since, even in the 50s, firewood was the only fuel used for cooking and heating.

1990-2000: Recent surveys

The Direcção Geral de Energia (DGE) conducted two studies in 1988 and 1996 on household energy consumption in the mainland; these studies perform the basis for recent estimates on firewood quantities. In the past, household firewood consumption had been estimated by reports from the production sector according to firewood sales figures. The DGE reports were far more accurate than the previous estimates, which were proven outdated and underestimated.

The DGE gives the average of about 1.19 kg per capita/day in 1990 and of 1.01 kg/day in 2000. These series were connected with the 1950 figures (2 kg/per capita), with the basis in decade variation of sales of LPG in 1950-1960, 1960-1970, 1970-1980 and 1980-1990.

2. Industrial – Firewood data was taken from the Industrial Statistics 1943-1970 and the Energy Balance – Sheets from 1971-2004. For the first period, the poorly covered data was corrected with basis on the GDP of each industry. Data from 1856-1942, non-inexistent was varied with industrial product from Baptista et al. (1997) and Lains (1990).

3. Railways – During World War II the railways used firewood due to shortage of mineral coal. The total tonnage consumed by the railway sector is reported in the Anuário Estatístico.

4. Electricity Production - Data on Firewood use in electric companies has been reported since the 1930s in Estatística das Instalações Eléctricas. The daily reports from the CRGE Electric plant (1914-1918) on firewood consumption were used to estimate electricity production: it was assumed that the percentage of firewood burnt by CRGE was equal to the percentage of the power capacity of CRGE in the country.
**Conversion Factors**
Charcoal – In terms of primary energy, charcoal is a very low-efficiency fuel because 55% of the energy content of the firewood is lost in the combustion process. Lopes (1928) performed some experiences with different kinds of firewood and arrived to the conclusion that only 20% of the total weight of firewood would remain in the end. This means that a ton of charcoal is equivalent to 5 tons of firewood in terms of primary energy.

Firewood – conversion factors were taken from the Direcção Geral da Energia (National agency for energy) official guidelines – 0.3 toe/ton. This value is confirmed by other reliable sources, one of them being the Companhias Reunidas de Gás e Electricidade (CRGE). In World War II, the company started to burn firewood at their electrical central and 0.3 is the value referred for half-dry and half-green fuelwood (CRGE, Relatório Annual 1938-1945).
Figure I – Portuguese map
Figure II – Advertisement of CRGE (193?) contrasting the old way of cooking (charcoal and kerosene little stove on the left and on the right of first figure) with the new one (city gas).

Source: Museu de Electricidade, Lisbon.
Figure III – Celorico de Basto, rural houses: poor (left) and standard(right).

Figure IV – Montalegre, rural house, 2004. A modern but still open fireplace and a firewood stove. Not visible in the photo, a butane stove.
Source: Author's photo.