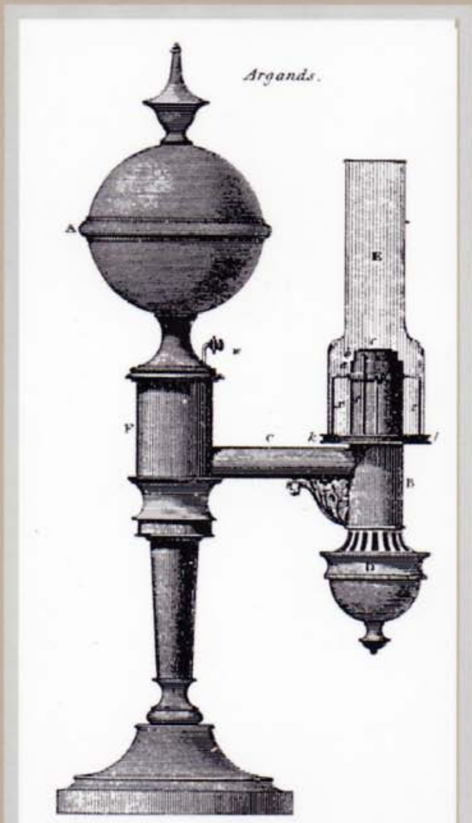
Energy Consumption in Portugal

1856-2006

Sofia Teives Henriques



Consiglio Nazionale delle Ricerche
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Series on
Energy consumption

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In copertina: Argand's lamp; developed in 1870 by the Swiss chemist named Amie Argand.

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Elaborazione ed impaginazione a cura di
Aniello Barone e Paolo Pironti

ISBN 978-88-8080-109-2

INDEX

FOREWORD

This book is the third in a collection of works whose purpose is to quantify long-run energy consumption in a range of European countries, using similar methods. The primary aim of this book is to set out the data and the methods for energy consumption in Portugal for the years 1856-2006.

To facilitate comparison between different countries each book is presented in a similar fashion. After some introductory remarks on the purpose of this study and on definitions (Ch. 1) we explain statistical methods and sources employed in the construction of traditional energy carrier series (Ch. 2) and modern energy carrier series (Ch. 3). Structure, trend and energy intensity are analysed in Chapter 4.

1. The energy sources

1. The energy sources

1.1. The energy transition

The availability of fossil energy has been considered as one of the most important foundations of modern economic growth. Societies around the world have gone through a generalized process of energy transition from vegetable and animate sources to mineral forms of energy. This passage meant that societies are no longer dependent on the renewable but limited supply of land to grow food, fodder and firewood for their energy needs but that can augment their energy basis through the use of non-renewable but vast and dense subterranean forms of energy amassed over millions of years in the form of coal and oil[1]. The use of fossil energy sources has shaped our society and allowed for great increases in income per capita, industrialization, urbanization and globalization. However, the magnitude and speed of the process have varied in different regions of the world. While the developed countries are today almost totally dependent on fossil fuels, most of the underdeveloped regions in the world still rely mainly on traditional energy carriers such as biomass and muscular energy. The transition to fossil energy was also very different for European countries. For the British and Dutch economies, this process can be traced back to the 16th or 17th century, while for others it occurred only in the 19th or 20th century. Until very recently, however, no attempts were made to quantify traditional energy carriers; most of the research has concentrated only on modern sources. Without a quantification of traditional energy sources it remains difficult to understand the nature of the transition itself. Was the transition process a revolutionary

[1] On this subject see Cipolla (1978); Wrigley (1988) and Sieferle (2001).

break, with fossil fuels quickly replacing the old ones? Or was the energy transition a slower and smooth process, with traditional sources coexisting with modern ones? Energy quantification cannot explain *per se* the reasons behind adoption or rejection of different energy carriers by different strata of society, but it is an important step to identify the main uses, the speed and the magnitude of the transition and the relation between energy use and economic growth.

The purpose of this research is to quantify all energy carriers of the Portuguese energy transition from 1856 to the present day. In 1856 Portugal was, along with the majority of the European countries, an essentially organic society. The steam machine, steam ship, railways and the brilliant gaslight were already introduced in the country, but the traditional energy carriers still accounted for 95 per cent of total energy consumption. It was still the windmill that ground the majority of the cereals of the nation, the fireplace that heated the houses and cooked the meals, the ox and cow that performed the work in the fields. In the beginning of the 21th century a very different situation emerges, and 90 per cent of energy consumption is from modern energy carriers; 86 per cent from fossil fuels. Fossil fuels and electricity replaced firewood and muscular energy in every dimension of daily life. New energy carriers enabled the Industrial Revolution and an economic and social growth never imagined. However, fossil fuels also bring pollution and environmental damage. While societies in the past were concerned with the capacity to grow according to the limited availability of vegetable energy, the world today is increasingly aware of its limits to growth due to a non-renewable and environmental damaging energy basis. This new context of environmental degradation, global warming and the prospect of high oil prices has given rise to other questions. Industrialized countries are now attempting to begin another energy transition, from fossil fuels to renewable sources. Hydrogen, biofuels, wind, wave and solar electricity seem to be the energy of the future. Technology is developing, but most of the denominated new energy sources were considered traditional ones earlier. Can economic growth still be maintained with the transition to renewable sources? Smil gives five reasons for the transition to be more difficult than expected: the scale of the shift; the lower energy density of renewable fuels; the lower power density of energy production; the intermittency of supply due to climatic variation dependence; the uneven geographical distribution of renewable sources and the difficulty to making it available to all regions in the world[2]. All those constraints to growth were present in *pre-fossil* fuel societies. From an historical point of view, this shift is to be followed with attention, since fossil fuel use seems to have been a necessary but not a sufficient condition for modern economic growth[3]. Thus, the quantification and the study of the role of *traditional* sources of energy in the economic growth of past societies provide economic historians with tools to participate in the environmental debate.

This work is part of a larger comparative study of the issues outlined above across several European countries. It owes a great debt to the inspiration and data provided by my colleagues. I would like to thank participants in the EGP workshops: Silvana Bartoletto, Ben Gales, Astrid Kander, Kerstin Enflo, Magnus Lindmark, Paolo Malanima, Maria Mar del Rubio, Lennart Schön, Paul Warde and Tony Wrigley for methodological discussions and exchange of information. To Paul Sharp and Mar Rubio my thanks for quickly giving me access to UK trade statistics. Part of the disaggregated data presented in the appendixes is unpublished material collected while working on the project "Electricity and the question of energy in Portugal" FCT/ISCTE 2002-2004 coordinated by Nuno Madureira. The continuation of this work after 2006 was eased by the

[2] Smil (2006).
[3] Malanima (2006b).

existence of the INE digital library, which provides online all the institute publications since 1864[4]. Above all, I would like to thank Astrid Kander, my supervisor, for guidance and earlier comments on previous versions of this work and for her remarkable thesis which inspired the work in the EGP group and this series of booklets. Paolo Malanima has encouraged the writing of this booklet. His first volume and Paul Warde's second volume in this series of books have provided a model on which this work is at times very closely based.

1.2. Definitions

The objective of this investigation is to provide an account of every form of energy exploited directly by human beings in the past and in the present. The intention is to quantify on an annual basis the following list of primary energy carriers.

1. *Food for human beings*
2. *Firewood*
3. *Feed for work animals*
4. *Wind*
5. *Water*
6. *Fossil sources*
7. *Primary electricity.*

It is important to emphasize that we only take into account energy sources that have a cost (not just in monetary terms) for human beings. The effect of solar light is not included as this imposes no costs to humans. Wind and flowing water are recorded in the following series, since, although free, their exploitation is possible only by utilizing a machine, such as a ship or mill, which has a cost. Even if part of the firewood consumed did not require any monetary payments

[4] http://inenetw02.ine.pt:8080/biblioteca/index.jsp

from its users, time spent on collecting, transporting and cutting wood should be seen as an opportunity cost. In the same way, biomass not collected by human beings in a forest (or collected for construction purposes), or the grass of a meadow not consumed by the animals exploited by human beings for food or work, is not accounted for. On the contrary, the grass eaten by a cow becomes part of human energy consumption, either as “fuel” for the animal, if the animal is used for work, or as food if it or its products are eaten (whether in the form of milk, cheese, or meat).

1.3. Primary sources

In the following time series, to avoid duplications -always a risk in reconstructions of this kind- only *primary energy* will be considered. By primary energy source, we mean *a source of energy we can find in the natural environment useful to human beings and exploited, at a cost, for conversion into heat, light or mechanical work. A secondary source of energy* is the transformation of a primary source. The energy content of electricity or gas, produced by means of coal or oil is not included, as it is a transformation, with some losses, of the energy content of oil and gas. In the same way, charcoal is a *secondary source as it is a result of firewood combustion.* Charcoal should be excluded from the following series, whereas firewood to produce charcoal should be included.

In many other cases, it is less clear how one should recognize a primary source. Since bread could be produced by means of cereals ground by exploiting the energy of an animal, one may wonder if we should not subtract the animal muscle energy from the calories of bread to avoid duplication. However, we are not dealing with the same energy undergoing a transformation, as in the case of firewood-charcoal. Bread is a transformation of the calories of cereals, and not of the calories burned by the muscles of the animal pulling the plough. In this way, we must include both the energy of the bread and the animals' muscle energy in our calculations, as well as the calories of the bread.

The statistics detail the input of energy into the economic system, regardless of how efficiently that energy is exploited. Thus, I will estimate the calories consumed by human beings as food, the feed consumed by working animals, the flow of wind driving a sailing ship and the flow of water driving a mill wheel. A large part of these inputs will be lost in the process of conversion and transmission and not actually be employed to do useful work. Here, I do not calculate energy yields, although improvements in the efficiency of energy use are an important chapter of energy history. Instead, I use the ratio of energy divided by GDP (energy intensity) to assess the evolution of the economic efficiency of the energy system.

1.4. Territory, population and GDP

The territory used in this study comprises the current borders of Portugal. Fossil fuel consumption derived from Trade Statistics is accurately determined, as the borders of the territory did not suffer any modification during the period this study concerns. Estimates produced by the demand side (food for humans, firewood for households) account for all the resident population. Some adjustments are made for animal energy in order to correct a few Census years that only include the number of animals on the mainland, excluding the Madeira and Azores Islands. It is not possible to account for firewood for industrial and power use in the Islands before 1970. This is due to the fact that statistics omit islands, a problem also encountered in the reconstruction of national accounts[5]. This is not a seri-

[5] For example the reconstruction of Portuguese GDP of Batista et al. (1997) for 1910-1958, used here, also refers to mainland Portugal.

ous issue as the share of the Islands in industrial production is admittedly much smaller than the population share[6].

Regarding population figures, official census have been conducted in interval years[7] since 1864. For 1864 to 1991 I use the work of Valério in which annual data is given[8]. For 1992 to 2006 estimates of INE (National Statistic Agency), available online, are used[9]. The Population figures for 1856 to 1864 are estimated through linear interpolation from 1849[10] and 1864 figures.

GDP figures until 1990 are taken from the work of Pedro Lains[11],in turn derived from three main GDP historical reconstructions: Lains[12] and Lains and Sousa[13] for the period 1856-1909; Batista et al.[14] for the years 1910-1952 and Pinheiro[15] from 1953 until 1989. Maddison[16] values are used for the post 1990 years.

[6] Population shares were 7-8% during the period of 1864-1970. However, energy figures are much smaller, for example electricity production was only 1.4% in 1970.

[7] Official censuses comprise the following years: 1864, 1878, 1890, 1900, 1911, 1920, 1925, 1930, 1940, 1950, 1960, 1971, 1981, 1991 and 2001.

[8] Valério (2001).

[9] Can be found at www.ine.pt, section of products and services/time series/População e Condições Sociais.

[10] Leite (2005).

[11] Lains (2003), pp. 247-266.

[12] Lains (1990).

[13] Lains and Sousa (1998).

[14] Baptista et al. (1997).

[15] Pinheiro (1997).

[16] Maddison (2008).

2. Traditional sources

2. Traditional sources

2.1. Earlier studies

The International Energy Agency (IEA) has reported energy statistics for OECD countries since 1960 and for non-members since 1971. Historically, consumption of fossil fuels and hydroelectricity has been elaborated for a considerable range of countries and has been reproduced in well known publications[1]. On the other hand, long-run estimates of non-commercial energy are only available for a limited set of countries. Schurr and Netschert[2] were the first authors to include firewood in their analysis of the role of energy in the American economy since 1850. They discovered that firewood, being preferred to coal in the beginning due to its abundance, had a very important role in the industrialization of the country until the 1860s. In the end of the seventies, Steward made estimates for Canada dating back to the beginning of the confederation, including commercial energy, water, wind, firewood, human and animal work[3]. He used fuel-equivalent concepts to aggregate series, converting hydroelectricity and water energy into the quantities of coal that would be required to do the same work in a thermo-central; animal direct work into the amounts of oil that would be required for an internal combustion engine to do the same job; wind energy from vessels into a steam ship. This method is used in order to not overemphasize the consumption of more inefficient energy sources in the energy structure as no efficiency losses are considered at the point of primary energy use. However, the method makes tempo-

[1] Mitchell (2007), Darmstader (1971), Etemad and Luciani (1991).
[2] Schurr and Netschert (1960).
[3] Steward (1978).

ral or spatial comparisons difficult to interpret, since the level of consumption of non-fossil energy carriers is based on the time and space dependent efficiencies of the main energy carrier. How do we interpret a country having the same level of hydro–electricity in 1900 and 1950? Was it because production stagnated? Was it due to an improvement in thermo efficiency, despite growth of production? Or did production actually fall but a decline in thermo efficiency occurred due, for example, to the reactivation of old utilities or by a substitution of coal for oil? As one can see, the information that is gained with this procedure does not really compensate for the information that is lost.

More recently, estimates on materials and energy use have been done for Austria and the United Kingdom on the basis of land use changes[4]. The authors seek to identify the major biophysical characteristics of agrarian societies as opposed to industrial ones. However, for the purposes of our study, which only focuses on energy, these studies can be a limitation due to the fact that wood for construction purposes is included. My study relates more to the methods employed for England &Wales[5], Italy[6], Spain[7], Netherlands[8] and Sweden[9]. The authors show that the inclusion of traditional energy carriers alters the dominant paradigm of an inverted U-shaped relationship between energy consumption and income.

Portuguese research on energy history developed slowly until a few years ago. In the last fifteen years of the 20th century the research consisted of a few master´s theses on coal production of specific mines in the 19th and early 20th centuries and on two or three generic books on electricity. Most

[4] Kraussman and Harbel (2002).
[5] Warde (2007).
[6] Malanima (2006b).
[7] Rubio (2005).
[8] Gales (2007).
[9] Kander (2002).

of the works, though valuable, address only specific regions, carry poor statistical information and cover short periods of time.

In the last five years, although most of the works are still focused mainly on one energy carrier, some historical synthesis has started to emerge. At company level, researchers developed studies about the electricity, gas and oil companies in the country from their foundations to the present days. From the quantitative point of view, Madureira and Teives made the first attempt to aggregate oil, coal and hydroelectricity figures in a study covering the period of 1890-1982[10]. This study will produce major revisions on these estimates and enlarge the period from 1856 to 2006[11]. However, my main direct contribution is to incorporate and estimate traditional energy carriers.

Inevitably, any research on pre-modern energy carriers is subjected to a high degree of uncertainty. We will see, however, that it is indeed possible to determine a range of magnitudes, and thus evaluate the contribution of these carriers. A range of magnitudes is already a good result when we are proceeding over untrodden ground, such as the quantification of pre-modern energy sources.

I will not present information here on candles or vegetable and animal oils employed in both public and private lighting. Their contribution to primary energy consumption would be negligible and its calculation better fits more specific studies[12]. Vegetable and animal oils lost importance in public lighting in the 1860s with the introduction of kerosene and coal gas[13]. Olive oil, however, remained an important source of lighting for rural households and could still be found in use, though in very small quantities, in the 1940s

[10] Madureira and Teives (2005).

[11] See Chapter 3.

[12] See Fouquet and Pearson (2006), who quantified those energy sources when studying energy use for lighting in the UK.

[13] Cordeiro (2007).

and 1950s[14]. Candles are the only item of artificial lighting still in use today when electricity is cut off, but especially for decoration and religious purposes. The subsequent sections will be devoted to the methodology and information available for firewood, wind, water, human and animal energy.

2.2. Food[15]

Modern statistics do not include food in their energy balance sheets. Nowadays, industrialized societies have a major part of the population employed in sedentary activities, and although an adequate nutrition is essential to survive and thus perform work, the work output, in terms of muscular power, is almost negligible. This was not true in pre-industrial years, when most of the population was employed in non-mechanized agricultural activities. At those times, the amount of muscular work one man could perform was usually compared with a horse or an ox. One draught animal would work at power rates of 500 to 800 W while a man could not sustain more than 100 W per hour, making one horse or ox as valuable as 8 men[16].

There is some discussion on the manner in which one should account for food for human beings. For our purposes the aim is to include all the food intake of the whole Portuguese population, disregarding the amount that would be spent on working. There are some justifications for this methodology. Even if not all the food intake is spent while working, it is absolutely necessary for the labour force to receive nutrition to be kept alive between working hours. Even if a share of the population is not economically active,

[14] Basto (1943); Barros (1947).
[15] App. I, 1, col. 1, and App. II, 1.
[16] Smil (1994).

i.e., the children, the elderly, the housewives, etc; they occupy positions in the society necessary for it to function[17].

I consider as *primary energy* all the digestible food that is available for consumption by the Portuguese population in a given year. This means that for a matter of convention and comparability with the other books in the series all animal derivates and meat will be accounted by their edible content, not accounting for conversions at the top of the food chain[18]. *Final energy* will be equal to *primary energy* minus wastage, that is, all the edible food that is effectively consumed by the population and not discarded as a residual. At the level of final energy consumption, all the extra food that is required to perform work should be distributed by productive sectors based on occupation data. On the other hand, all the food that is consumed for other motives than work- either by a working or non-working population- should be considered as household energy. Households are a final demand sector that is included in modern energy statistics in order to account for energy consumed for reasons other than economic production. This includes all energy consumed at home to provide services such as heating, lighting, cooking, leisure or even personal transportation[19]. Households differ from other final demand sectors in the sense that their economic output equals zero, so interpretations of the shifts in energy intensity (energy consumption/GDP) should be handled with extra care.

There are several ways to approach the issue of human food consumption.

[17] See Warde (2007) for a lengthy discussion on this issue.

[18] Hence the feed that is necessary to breed the domestic animals of the country involved in food production will not be accounted for, which will make figures somewhat smaller that in Kraussman and Harberl (2002), for example.

[19] For difficulties in dividing transport fuel in personal and economic activities, household transportation is in practice included in the transportation sector.

One way of calculating food requirements is by the supply side, accounting for agricultural output and external trade. This was the way in which Food National Balances for mainland Portugal were done, starting in the year 1938, and produced on an almost yearly basis from 1947 onwards. This measure requires a certain level of sophistication as several corrections are required in order to reach edible consumption. Seeds, industrial uses, animal consumption, non-digestible food and stock variations have to be subtracted in order to obtain figures for edible consumption. With this method food wastage in the retail and household sector is considered as an *energy input*. In the Portuguese case, wastage is only likely to be relevant in recent decades. Back in time, food was not an abundant item, so discarding was not an option.

A desirable option would be to reconstruct Food Balances for the rest of the period (1856-1940). I have decided not to employ this method for two main reasons. First, production statistics are poorly covered. Before World War I, the most recent agriculture estimate is from Lains and Sousa[20]. The authors calculated an index of agricultural production value from 1845 to 1915, including production of wheat, rye and corn, wine, olive oil, meat and potatoes. Unfortunately, legumes, milk, cheese, eggs, beans, fish and fruits are missing from this report. Batista et al. estimated agricultural GDP for the period 1910-1958, including more products, but adjustments would still be necessary to account for islands production. The way that some series were calculated (ex: fish, milk) reflects the absence of good national quality statistics for the period. Secondly, to the best of our knowledge, no one had systematically compiled import and exports figures for food products. It will take a long time to compile annual food figures for international trade with no guarantees of better results. We would still have to make assumptions on the consumption of certain foodstuffs, on ani-

[20] Lains and Sousa (1998).

mal consumption and on the usage of food in the fabrication of industrial goods. The study of food consumption via the supply side will remain an open issue for Portuguese historians. Although I do not use this method here, taxation data for 1880-1910 can improve the knowledge of consumption of products like vinager, legumes, fish and animal products (milk, butter and cheese, for example)[21].

A second hypothesis would be to estimate food consumption through national direct inquiries. Such inquiries have been tried in Portugal, but most of the time at a local level, including few families. The majority of inquiries done before 1940 are summarized by Correa[22]. Conclusions are different with some authors arguing that caloric intake was sufficient, others the opposite. The most significant survey, which took place in 1916, was an inquiry into the household expenses of industrial workers families and average caloric consumption was recorded as 2,373 Kcal/p.c./day[23]. The majority of the studies done in this period agreed that the Portuguese spent a large proportion of their income on food (60-70 per cent) and that there was a huge deficit in animal proteins[24].

A third approach is to estimate food consumption through a set of population characteristics. Here, the most basic estimation is to hold an average per capita figure constant over time. This kind of approach is mostly used when data is lacking, but it is dubious because it does not reflect

[21] See for example Administração Geral das Alfândegas e das Contribuições Indirectas, Estatística do Real da Água e outros impostos indirectos, Lisboa: Imprensa Nacional (1888 to 1901). It includes, depending on the year, some statistics on beer production, vinegar, and fishing. It is interesting to check, only for Lisbon, Ministério das Finanças, Direcção Geral de Estatística (1916), O ventre de Lisboa e os géneros que aqui pagam impostos de consumo ou Rial da Água. Eggs, butter, cheese, olives and fruits are included in this report for the years 1890-1914.

[22] Correa (1951).

[23] Ministério do Trabalho (1916).

[24] Corrêa (1951).

the age and gender structure of the country or the level of activity, which can imply different food requirements. A simple way to overcome the first two problems is to convert the structure of the population into consumption units, giving different shares to population strata according to their age or gender. However, this second method still does not reflect the different working intensity of the labour population. A more sophisticated population method is to use the information generally available in the census, the food requirements according to sex, age and activity. This method is very useful to use in the absence of other data. It has a pitfall; it only indicates how much a society should consume, not how much it consumes. It ignores periods when the population was poorly fed like, in the times of wars or famine crisis. In the case of the Portuguese population, if applied to the present, it will indicate a lower consumption level than the real one as wastage and obesity in the general population has increased. This means that the population has become less efficient in converting energy inputs into work output. However, if applied to earlier periods, I do not expect significant underestimations. Ideally this method should be used in conjunction with a supply method or food inquiries, for reason of checking-up, at least in some years.

The method employed here to calculate food consumption is then a mixture of two methods: a supply method and a population method. For 1938 onwards, employing linear interpolation in the missing years, we use the results of National Food Balances. For 1961 to 2002 the average daily caloric intake figures are provided by Food and Agricultural Organization of the United Nations - FAO (2004). The figures derived by FAO follow the same method as National food balances. In these years, the average daily caloric intake of the Portuguese population varied from 2,470 to 3,740 calories. This data includes wastage in restaurants or at home, which in recent years has been high. However, wastage is a part of my definition of primary energy consumption.

For the period 1850-1938 I have followed a population method, adjusting for changes in economic activity, gender, age and physical composition. In the first place, I have calculated the *Basal Metabolic Rate* (BMR) of adult women and men. The BMR is an indicator that gives us the daily amount of calories that would be needed if a person with certain physical characteristics spent all day resting. The BMR should be multiplied by a *Physical activity level* (PAL), in order to give the total energy requirement. BMR depends exclusively on physical indicators (weight, height, age), while PAL depends on the nature of activities you perform during the day. Several authors have suggested different formulas to calculate BMR. I have followed a recent joined report by FAO/WHO[25]/UNU[26] (2004) in calculating the BMR, which supports the use of Schoefield equations, proposed in 1985 for women and men:

*BMR male Kcal/day (18-30 years old) =15.057 * Weight (kg) + 692.2*

BMR female Kcal/day (18-30 years old) =14.818 Weight (kg) + 486.6*

It is difficult to assess the weight of Portuguese population from 1850 to 1940. However, we have reasons to believe that it was lower than what is considered standard nowadays (70-75 kg). Just like cattle increased their weight as a result of better food intake, human size also increased with better nutrition. The military recruits measured in 1904 had a mean height of only 163 cm, one of the lowest in Europe[27]. By contrast the recruits examined in 1998 had a height of 172 cm[28]. Much of the increase in height seems to have occurred after 1960. In 1960 the Lisbon recruits measured 167 cm, only 4 cm higher than in 1904[29]. In 1960, the

[25] World Health Organization.
[26] United Nations University.
[27] Padez (2002).
[28] Padez (2002).
[29] Padez (2002); Aleixo et al. (1998).

weight of Lisbon recruits was reported as 61 kg[30]. For our analysis we assume that the average weight of a Portuguese male was 60 kg, which seems to be consistent with the height evolution and Body Mass Index (BMI) figures[31]. For women we have even scarcer information. We assume that the average BMR of a woman was 0.8 times that of a man, which is also consistent with their probable heights[32]. The BMRs proposed by Schoefield are adapted to the adult population in the case of males (which includes a proportion of 10-14 year-old children who worked, and were considered as adults); and from the age of 15 in the case of women[33].

The second step is to distinguish the Physical levels of adult population by its occupation. Recently, authors have preferred to classify the Physical Activity Level (PAL) in relation to lifestyle intensities (and not specific occupations). We reproduce here the PAL values followed by the FAO/WHO/UNU in their 2004 study (*Table 1*).

Table 1. Physical activity levels according to lifestyle intensity

Category	PAL value
Sedentary or light activity lifestyle	1.4-1.69
Active or moderately active lifestyle	1.70-1.99
Vigorous or moderately active lifestyle	2-2.4

Source: FAO/WHO/ONU (2001).

I have assumed a different PAL for different population occupations taking into account the indications of Table 1. Therefore, individuals working in the primary sector and

[30] Aleixo et al. (1998).

[31] BMI is a statistical measurement which compares a person´s weight and height (weight (kg)/height (m^2)) and is a useful tool to determine if a person is overweight (BMI > 25) or underweight (BMI< 18.5).

[32] See Baten (2006) for an estimation of male heights in relation to females. According to the author Male height =24.9879 +0.9175 x female height. There are other indications that women´s weight was lower in previous periods in time. For example, the age at menarche (strongly connect with a weight of 46-48 kg) declined from 15 years (girls born in 1880-1890) to 12 years (girls born in 1970-1980), Padez and Rocha, (2003).

[33] Age structure was taken from Baganha and Marques (2001).

construction works are assumed to have a vigorous or moderately active lifestyle; people working in manufacturing are assumed to have an active or moderately active lifestyle. The remaining population is given a PAL value that corresponds to a sedentary or light activity lifestyle and Table 2.

Table 2. Physical Activity Levels per occupation

Occupations	PAL
Agriculture, Fisheries, Mining and Forest, Construction	2.25
Manufacturing	1.76
Transports/Commerce/Administration and Defense	1.69
Services and Inactive Population	1.53

In order to obtain total energy requirements, the figures for the adult population divided by occupation and sex are multiplied by the respective BMR and PALs[34]. Occupation PALs are considered during 300 days of the year. A PAL of 1.53, corresponding to sedentary population, was considered for the remaining 65 days. The distribution of PALS is only partially connected with the length of the working year. Reis assumed an agricultural year of only 200 days, but during the remaining days agricultural workers also performed strenuous physical activities as collecting wood or water, non-mechanic domestic activities, etc[35].

Finally, I employ the daily energy requirements of boys and girls under 15 as recommended by the joint report (*Table 3*).

Table 3. Daily energy requirements Boys and Girls (Kcal)

Group age	Boys	Girls
0 to 4	1,129	1,035
5 to 9	1,450	1,325
10 to 14	2,175	1,925

Source: FAO/WHO/ONU (2004).

Benchmark results for some years in the period 1856-2006 are shown in the table bellow *(Table 4)*.

[34] Census figures given by Nunes (1989), Valerio (2001) and Reis (2005).
[35] Reis (2005).

Table 4. Food intake per capita (1864-2000)

Year	Kcal /day
1856-1878	2,268
1890	2,302
1900	2,276
1910	2,238
1920	2,228
1930	2,222
1938	2,202
1948	2,379
1961	2,473
1970	3,002
1980	2,786
1990	3,441
2000	3,751

Sources: see text.

The results for the years 1864-1930 show an almost static level of per capita food consumption. As in other figures, major changes can only be observed from the World War II onwards. The improvement in income situation, an increase of obesity, height and wastage and the ageing of the Portuguese population offsets changes in the activity level. Recent studies reveal that the status of Portuguese nutrition is not healthy. The results of a National Health Inquiry in 2003-2005 showed that 38.6 per cent of adults (males and females) were overweight and 13.8 per cent were obese[36]. It was recently estimated that about two thirds of the children were overweight/obese, a percentage that seems to be the second highest in Europe, only behind Italy[37].

2.3. Firewood[38]

Inedible plants have been combusted by human societies since the Palaeolithic Age. Until the discovery of fossil fuels, firewood was almost the only source of energy that pro-

[36] Carmo et al. (2008).
[37] Padez et al. (2004).
[38] App. I, 1, col. 2, and App. II, 3.

vided heat for the population and industries[39]. In developing countries, biomass still accounts for about 75 per cent of final energy demand[40].

Firewood is one of the traditional sources of energy in which quantification is subject to the highest degree of uncertainty. Food consumption is normally limited to a fixed degree of variability; wind and water energy consumption is very small when compared with total consumption. Wrong firewood consumption figures, on the other hand, may compromise very easily an otherwise correct figure for total energy consumption. In fact, biomass consumption per capita in early modern Europe could vary from 12.5 to 125 MJ/p.c./day depending on climatic conditions, accounting for 25 to 80 per cent of total primary energy consumption[41]. The risk of seriously under or overestimating energy consumption is of course higher in countries where firewood has a major importance; and among those where most of the consumption is not recorded by the market. Average per capita firewood consumption figures are harder to obtain if most of the fuel is consumed by households, if there are major regional differences in patterns of consumption and if a certain amount of charcoal, dung and crop residuals is also consumed. Firewood consumption can be estimated by the demand side or the supply side. In Europe, there are well known attempts to estimate firewood consumption from the supply side or demand side, according to the available data. For Sweden, Kander[42] preferred to make an estimate based on the demand side, due to a very good data set on the industrial sector and because household firewood consumption figures were available for a set of benchmark years from the beginning of the twentieth century. For the nineteenth century the author was able to reconstruct household firewood consumption based

[39] With the major exception of peat.
[40] Victor and Victor (2002).
[41] Malanima (2006).
[42] Kander (2002).

on assumptions related to equipment efficiency, urbanization, number of heated rooms and migration figures that changed the South/North population. For England & Wales Warde adopted a different method based on recorded and estimated yields of firewood cutting on woodlands, standing trees and hedgerows[43]. Malanima used estimations from economists in different benchmark periods but included some demand benchmarks in the recent years of his series in order to calculate the Italian consumption[44]. The most serious problem with the demand side concerns the availability of disaggregated data, while the most serious problem with the supply method is related to the difficulty of knowing precisely the extension of biomass coverage, yields of woodlands and proportions of firewood versus wood cuttings.

For Portugal, adopting land-use areas as a ceiling for the maximum firewood consumption in the country is rejected. First, we have few benchmarks for land use and forest yields[45]. Second, most of the firewood did not come from conventional forests but from the commons or wastelands (in the form of fallen biomass). It is an inglorious task to know precisely the size of the unconventional forest, but it is clear that it was considerable. Table 5 indicates some of the few benchmarks for land usage that are available for mainland Portugal.

Conventional forest grew to more than twice its value from 1867 to the 1950s, following the increase in population, representing 13 per cent of the territory in 1867 and 31 per cent in the 1950s. However, trees and bushes also grew elsewhere. Arable land also included fruit trees such as vines, olives or hazelnuts which could be partially used to satisfy the needs of the population. On the heaths, *charneca*,

[43] Warde (2007).

[44] Malanima (2006b).

[45] A study performed by INE for the years 1938-1963 indicated annual yields per hectare varying from a minimum of 2.3 m^3/ha in 1938 to a maximum of 2.9 m^3/ha in 1963.

covering a large part of the non-arable south of the country, there were cork and holm oaks that supplied most of the charcoal to the capital. In the category of wastelands, considered non-productive territory, and covering 38 per cent of the area of the country in 1867 and 17 per cent in 1902, were included many communal forms of property, from where the rural population, mostly from north-central Portugal, freely collect firewood for their household needs.

Table 5. Land use in Portugal (mainland), benchmark years, thousand hectares

	1867	1902	1926-1930	1951-1956	1980
1. Arable	1,886	3,111	3,283		
2. Pastures, fall and heaths	2,072	1,922	1,560		
3. Agriculture (1+2)	3,958	5,033	4,843	4,833	
4. Forests	1,240	1,957	2,332	2,773	3,047
5. Productive (3+4)	5,198	6,990	7,175		
6. Wastelands	3,329	1,538	1,353	1,094	1,296
7. Social	351	340	340	152	
Total	8,868	8,868	8,868	8,852	

Source: Lains and Sousa (1998); Fabião (1987); Marques (1991).

It is not surprising then, that the few firewood or wood figures extrapolated by agrarian engineers or policymakers at some point of time seem clearly underestimated when contrasted with demand side figures[46]. So the figures that they achieve are closer to the industrial and urban consumption than to the total consumption in the country[47].

[46] One of the examples is the INE study for calculation of wood extraction (not disaggregated by uses) in the 1938-1963 period. Production varied from 7 million m^3 in 1938 and 9.4 million m^3 in 1963. Firewood and wood consumption in the mainland was about of 0.92 m^3 per capita in 1950 and 1 m^3 in 1950, or 1.5-1.7 kg per capita a day. As a ceiling it seems extremely low when compared with my figures from the demand side, which only include firewood. If the same exercise is conducted for 1867, a per capita figure of only 0.67 m^3 per capita will be reached, an implausible value (INE).

[47] For 1938 and 1947-1950, my demand side estimates of commercial firewood consumption (manufacturing, urban households) represent 27% and 36% of the estimated figures for wood extraction by INE. However, if my rural firewood consumption estimates are included, we

In contrast to the supply-oriented approach, richer sources advise the use of a more demand side approach. Total firewood consumption in a given year can be calculated applying the general formula:

$$F_{(t)} = fH_{(t)} + f\,I_{\,(t)} + fTr_{\,(t)} + fEp_{\,(t)}$$

where:

F Total Firewood consumption
fH Household firewood consumption
fI Industrial firewood consumption
fEp Firewood consumption as a fuel for electricity production
fTr Firewood consumption in the transportation sector
t Year

There are various subtypes of wood that can be used as fuel, with different energy contents. I only distinguish charcoal from firewood. Firewood energy content was set in 3,000 kcal/kg[48]. Charcoal is a secondary energy, made from firewood. As the goal is to estimate the primary energy consumption, we measure charcoal consumption as the amount of firewood that was necessary to fabricate it. An experience of charcoal production made in the 1920's with different wood species showed that about 5 tonnes of wood were needed in order to produce one tonne of charcoal[49]. Charcoal production was

see that conventional forests could only in maximum (assuming that 100% of the wood cuttings are for firewood, which is implausible) supply 70 and 80% of the firewood demand.

[48] As indicated in national energy balances. The energy content of firewood is equal to the one applied by Malanima (2006a) to Italy. The energy content of the firewood employed in the electrical utility of Lisbon in World War II was approximately 3,000 Kcal/kg (Relatórios da Central Tejo). Early studies of the average energy content of Portuguese biomass also confirm the chosen firewood energy content (Carvalho, 1964). Early industrialists seemed to be more sceptical, as four firewood tonnes were reported to be needed to substitute one coal ton (Inquérito Industrial, 1881), but this could be due to the fact that steam engines were optimized to consume coal.

[49] Lopes (1929).

more efficient in Portugal than in other parts of the globe. In Italy, the firewood needed to produce charcoal is assumed to be 5.5 tonnes for each tonne of charcoal[50]; in Uruguay charcoal production required 7 tonnes of firewood[51].

2.3.1. Household firewood consumption

Household firewood consumption is perhaps the most difficult source of consumption to determine. Today, a major energy issue in developing countries is to determine accurately the level of residential firewood use. For these countries it is crucial to know not only the level of firewood use, but also firewood expenditures, major firewood consumer groups, etc, in order to implement correct energy policies or to test the effect of the same policies. These energy policies can be of different order. Some tend to promote the use of modern and convenient energy carriers, some address indoor pollution problems; others focus on energy efficiency by easing the access to efficient stoves[52]. Some policy makers are worried with biomass stocks and require energy figures in order to implement supply policies. There is also a purely statistical concern in calculating firewood consumption that can result in major revisions of energy use, household income and GDP figures.

Accounting for firewood use is difficult to achieve from the supply side, as most of the firewood is collected from a nearby area by family members. Most of the firewood consumption is extrapolated by a range of surveys. This is also difficult as most of the consumers do not know precisely how much firewood they consume. Firewood figures are normally given as volumes, but metric volume measures are rare. Usually it is given in ox carts, but a different set of traditional measures that nobody knows precisely how to convert to

[50] Malanima (2006).
[51] Bertoni and Róman (2006).
[52] Elias and Victor (2005).

calories or GJ are often used[53]. The inquirer has to deal with the fact that rural consumers have a poor educational background and cannot give accurate answers. However, most of the statistical institutions of these countries are becoming increasingly aware of these problems. As a result, better figures are being produced for a wide range of countries[54].

Firewood consumption figures in developed countries are perhaps even more poorly established. Basically, for a long period of time, firewood was not recorded because it was not relevant for energy policies. It was assumed that firewood use was basically a residual and not worth accounting for. Most of the rough accounts assumed that the market was providing most of the firewood, so firewood consumption is accounted for based on firewood market supplier's reports or expenditures surveys. Some European countries discovered only 10 or 15 years ago that household firewood consumption was clearly underestimated. Portugal was one of these countries. From 1971 to 1989, the series of energy balance sheets assumed a residential firewood consumption of 400 - 600 thousand toe (tonnes of oil equivalent). However, two major energy-specific household inquiries conducted in 1988 and 1995 tripled this figure. A 66 per cent underestimation of firewood consumption was found in 1999 in Italy when the results of a telephone inquiry determined that 22 per cent of Italian families still relied on firewood[55].

Concerning the estimates for Portuguese households' biomass consumption, we have to rely on both qualitative and quantitative evidence.

Until the end of World War II most of the Portuguese population lived in rural areas. From 1864 till 1950 there was no strong change in population distribution. In 1864 88 per cent of the Portuguese population lived in rural areas; in

[53] Bhatia (1987).
[54] See Victor and Victor (2002).
[55] Malanima (2006a); ENA (2001).

1950 the share declined to 77 per cent[56]. Approximately 2/3 of the labour population was engaged in agriculture in 1950, a proportion not substantially different from 1890. Lisbon and Oporto were the two main urban centers, the only ones with more than 100,000 inhabitants in 1940, accounting for approximately 90 per cent of the urban population[57].

Energy consumption patterns varied widely between rural and urban populations. I have decided to consider three major groups of consumers in my estimations: Rural, Lisbon, Oporto and remaining urban areas. Qualitative descriptions and quantitative figures from the rural areas in 1950 give an idea that standards of living were low. Most of the rural population did not have access to electricity, gas, plumbed water or sewage[58]. An open fireplace and a firewood oven were the only equipment of the Portuguese rural house. The houses lacked mortar and glass windows and it was frequent to have fissures in roofs, walls and doors[59]. 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. Urban areas of Lisbon and Oporto contrast with rural areas in energy conditions. In Lisbon, in the middle of the 18th century, the houses that were built after the earthquake did not incorporate fireplaces, probably for safety reasons[60]. Charcoal, instead of firewood, was the major fuel in Lisbon in the beginning of the 19th century. Energy transition in those two cities occurred at an earlier date due to several reasons: access to the sea, this is, foreign coal and kerosene;

[56] Silva (1970).

[57] Silva (1970).

[58] For example only 8% of rural population used electricity; none used gas. INE (1954).

[59] Basto (1943); Barros (1947); Oliveira and Galhano (2003).

[60] On the first of November 1755 a major earthquake, followed by a tsunami, destroyed the downtown Lisbon and claimed several victims. This earthquake was followed by a major fire, which caused the majority of the injuries.

considerable distance from firewood suppliers; earlier adoption of town gas and electricity (potential firewood substitutes). The remaining urban areas can be considered a third distinct group in firewood consumption patterns. Although gas and electricity usage in cooking or heating was an exception in the 1950s, it is presumed that urban dwellers were likely to use less firewood than rural dwellers. The better insulation of urban dwellings, the use of more efficient equipment, and the need to acquire the fuel in the market are some of the reasons for this assumption.

The way I calculate residential firewood consumption until the year of 1950 is expressed by the following formula:

$$fH_{(t)} = Lx_{\,res.\ cons.\ pc\ (t)} * Lx\ Pop._{(t)} + Op_{\,res.\ cons.\ pc\ (t)} * \\ * Op\ Pop._{(t)} + Rural_{\,res.\ cons.\ pc\ (t)} * Rural\ Pop\ (t) + \\ + OUA_{res.\ cons.\ pc\ (t)} * OUA\ Pop._{\,(t)}$$

Where:

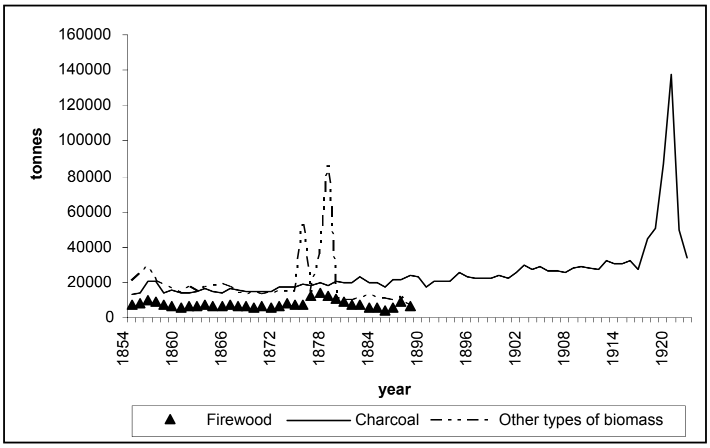
fH household firewood consumption
Lx Lisbon
res residential
cons. consumption
pc per capita
Pop population
t year
Op Oporto
OUA other urban areas

We can follow the sources for each region in the following pages:

Lisbon

Until 1922 the city of Lisbon was subjected to a consumption poll tax that included, among other products, charcoal, coke, vegetable oils and firewood. Charcoal is the only energy carrier that is covered in all of this period. For 1854 until 1888 there are records of different subtypes of firewood, but taxation of these products came to an end in June of 1888. This tax should represent accurately what was consumed in the city, as the city did not have any relevant forests. Most of the charcoal and firewood would enter into the river ports or train stations where strategic polls were located, so no serious underegistration happened[61]. Figure 1 presents the raw results of this tax for the years 1854-1922, expressed in tonnes[62].

Figure 1. Firewood and charcoal consumption in Lisbon (1854-1922)



Source: *Mapa Estatístico...*(1854/1855 till 1865-1866); *Estatística da Alfândega...* for remaining years. Conversion measures (until 1884-1887): charcoal bag 98.5 kg[63]; "talha de pinho", 307 kg, "faxina de lenha" 19 kg, "talha de carqueja" 232.5 kg; "talha de tojo" 120 kg (Pauta de 30/06/1867, Estatística da Alfândega Municipal no ano económico de 1867).

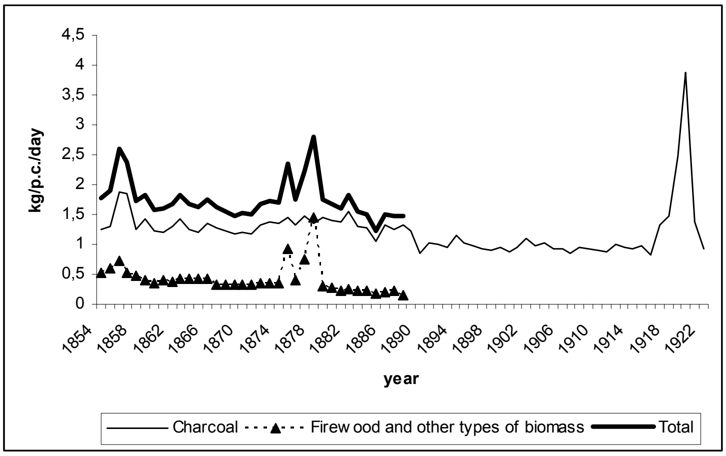
[61] The city had also terrestrial polls where compliance could be worse. This was the case with some foodstuff products such as olive oil.

[62] Here, I have not done an energy conversion.

[63] Simply the average of the values indicated for the conversion of a charcoal (cork tree) bag (dimensions 1.15m height and 0.76m large or 1.32m height and 1.10m large) in Kg, on 30/06/1867 (*Estatística da Alfândega Municipal no ano económico de 1867*). There are some doubts as to whether the true value of the bags changed according to the epoch. Gonçalves (1922) reports 90 kg.

Not all the Lisbon inhabitants were covered by the consumption tax when the Lisbon area was enlarged in 1886. I took this fact into account when calculating the population subjected to this tax. Figure 2 shows the per capita values of both charcoal and firewood. This time, charcoal figures are converted into primary figures, to account for the amount of firewood that it took to produce.

Figure 2. Firewood consumption per capita and per day, Lisbon, (Primary energy)



The figure shows a steady decline of firewood consumption from the 1870s[64] and charcoal consumption from the 1890s. During WW I (and immediately after) charcoal consumption rose to a record of 3.8 kg /p.c/day reflecting a serious supply crisis of fossil fuels. Firewood and other types of biomass represented 20-30 per cent of total consumption in the 1860s and 10-15 per cent in the 1880s.

It is possible to compare the firewood requirements of Lisbon city with the ones registered in other pre-industrial European cities. From 1854 to 1888 firewood consumption

[64] With the exception of some years, when "carqueja" (a plant used to ignite fire) is causing a strong increase in biomass figures.

in Lisbon was about 1.8 kg/p.c./day. In Madrid, in the end of the XVIII century consumption was about 2.15 kg/p.c./day[65]. Lisbon also compared well with the results obtained to the 18th century in Italy: from 2.3 kg in Piedmont to 1 kg in Sicily[66].

To build a per capita series of household consumption of firewood for Lisbon in the period 1856-1922, I have used a strong assumption. Firewood and other types of biomass have not been considered since they are only covered for the period of 1856-1888 and they are believed to be an expression of industrial consumption. On the other hand, charcoal is assumed to be consumed only by the household sector. This is of course a simplification, as some households could consume firewood and some industries could consume charcoal. There are some reasons to assume this division that go beyond the mere convenience of the available data set. There are no complete industrial inquiries for those dates that can definitely resolve this question. However, none of the 75 factories of various branches visited by an Industrial Inquiry Commission in 1881 reported the use of charcoal[67]. While in other countries, like in Sweden, charcoal was widely used in iron works, Portuguese industries that worked with iron reported the use of coal and coke, but not charcoal in that 1881 Inquiry. Tailors were known consumers of charcoal but there was no potential benefit for other industries to use this fuel, as it was more expensive than both firewood and coal per energy unit. On the other hand, some of the ceramic and glassworks reported the use of firewood. Bakeries may also be appointed as a major consumer group, although they are not reported in this survey. A majority of Lisbon dwellings, as already stated, did not have fireplaces. Contrary to industry, there

[65] Warde (2006).
[66] Malanima (2006a).
[67] Inquérito Industrial (1881).

was a health and hygienic benefit from the use of charcoal, as charcoal is less smoky than both firewood and coal.

We have ways of connecting the 1854-1922 series with other sources. An inquiry was conducted in 1938-1939 by INE on the household expenses to a sample of one thousand families[68]. 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 (both mineral and vegetable)[69], gas, electricity and kerosene. As the report does not distinguish between mineral coal and charcoal, some rough calculations have to be made. We know from other studies that most of the mineral coal consumed in Lisbon came from gas works[70]. Based on the coke production figures of the Lisbon gas factory, it is assumed that 25 per cent of the total coal (charcoal and mineral) reported by the inquiry was of mineral origin[71]. For 1922 (0.97 kg/p.c./day) to 1938 (1kg/ p.c./day), I have taken into consideration the variation in the charcoal quantities transported by railways by on line that supplied Lisbon. Lisbon's consumption represented an important share (about 60 per cent) in total shipments of this train route.

[68] INE (1942).

[69] It is confusing when we are referring to charcoal or coal in Portuguese. Charcoal means "carvão vegetal" and coal means "carvão mineral". If we use the word *carvão* in Portuguese (literally translated: coal) this can be both charcoal and coal. This means we have to be careful with the wording in the inquiries. In this case the word *carvão* is used. The author of these inquiries – INE –uses charcoal (from cork oak) prices in order to calculate expenses with "carvão", but is stressed that there are other coal/charcoal qualities.

[70] Teives (2006).

[71] We can attest that charcoal continued to be the main solid fuel of the Lisbon population for two reasons: 1) Magnitude of charcoal quantities dispatched to Lisbon by railways; 2) Existence of price indexes for charcoal, non-existence of coal price indexes and intermittence in coke price indexes.

During the season 1948-1949[72], INE conducted another inquiry with the same goals as the 1938 one. Charcoal consumption had dropped from 1 kg/p.c./day in 1938 to 0.43 kg/p.c/day, a result of an increase in gas and kerosene consumption. The data concerning the years 1938 and 1948 is connected by linear interpolation. The same *per capita* consumption *of 1948* -1949 is assumed for 1950.

Oporto

Per capita consumption is assumed to be the same as in Lisbon for 1856-1938, since there is no data available for Oporto, the only other large city in Portugal. The 1856-1938 series is connected to a household expenses' 1950 inquiry conducted by INE in Oporto. Charcoal consumption in 1950 (1.1 kg/p.c./day) was higher than in 1948-1949 (0.43 kg/p.c./day)[73]. It is assumed that this divergence appeared after 1938, as a result of a more rapid energy transition in the capital[74].

Other urban areas

Three surveys were conducted by INE in the mid 1950's for the cities of Évora, Viseu and Coimbra[75]. Families bought on average 900 – 1200 Kg of firewood a year (expressed in primary energy). As we are already in the midst of the energy transition that occurred after WW II, I just taken these values as a reference for modelling the period 1856-1950[76]. Firewood consumption was assumed to be 430 kg/p.c./year (1.17 kg/p.c/day) until 1925, decreasing linearly from 1925-1938 to account for some kerosene substitu-

[72] INE (1953).

[73] INE (1955).

[74] For the history of energy transition during the WW II see Teives e Bussola (2005), and Teives (2006).

[75] INE (1958); INE (1960b), INE (1963).

[76] Transition was very quick in the city of Faro, reporting only 60 kg p.c./year in firewood equivalents in 1960. INE (1970).

tion until it reached 410 kg/p.c./year (1.12 kg/p.c./day) in 1938, remaining constant afterwards until 1950. The per capita figures are almost similar to the Oporto ones in the 1950-1951 period.

Rural areas

In the period 1939-1945, some monographic inquiries on rural households were conducted by agronomists in the Northern and Central rural areas of Portugal[77]. Among other questions, families were also asked on how much firewood they consumed. Those figures were normally given in ox carts. I have converted them into Kilograms; one cart being equivalent to 500 kg of firewood[78]. This leads to an average of 857 per capita/year, or 2.4 kg/p.c/day. The same value is assumed for the rural population during the entire period since, even in the 1950s, firewood was the only fuel used for cooking and heating. This constant figure relies on the assumption that there were no major changes in the efficiency of equipment. This is likely as the description of a rural house interior in 1950 confirms the use of open fireplaces.

Residential energy transition to modern fuels was particularly impressive in the post-war years. In Lisbon there was an increase of gas consumption leading to the quick disappearance of charcoal, the major fuel. In Oporto and Centre-North urban centers there was a major fuel switch from firewood, kerosene and charcoal to electricity. In the rural areas, there was a slow but persistent change to butane.

[77] Basto (1943), Barros (1947).

[78] It is important to stress that ox-cart-weight figures are subject to uncertainty. I have used a figure that is similar to the ox cart in the Oporto region. Higher estimates may be produced with a greater and also plausible weight (800 kg). We prefer to risk underestimation of firewood consumption than overestimation, as both figures give higher shares of firewood consumption.

Two major studies on household energy consumption were directed by the national energy agency (DGE) in 1988 and 1996[79]. These studies form the basis for recent estimates of 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. Their inquiry in 1988 showed that sales were a poor indicator of firewood consumption: 45 per cent of the population used firewood but only 30 per cent of the firewood quantities were bought. Among users, consumption was rather high, at the level of 3,661 tonnes per family and 3 kg p.c./day. These values make me believe that figures for firewood consumption in rural areas before 1950 are not overestimated despite the fact that conventional forest statistics do not agree with these estimates.

The DGE gives the average of about 1.19 kg/ p.c. /day in 1990 and of 1.01 kg/day in 2000 on their balance sheets[80]. These series are connected to the 1950 figures (2 kg/p.c./day), on the basis of decade variation of butane sales, 1950-1960, 1960-1970, 1970-1980 and 1980-1990[81].

Firewood consumption per capita declined by more than half in relation to 1950. The importance of firewood within the Portuguese households at present is very high. From all the countries in EU-15, Portuguese families are the ones with a higher share of firewood consumption in final residential energy (42 per cent), followed by Austria (21 per cent), Finland (18 per cent) and Spain (17 per cent)[82].

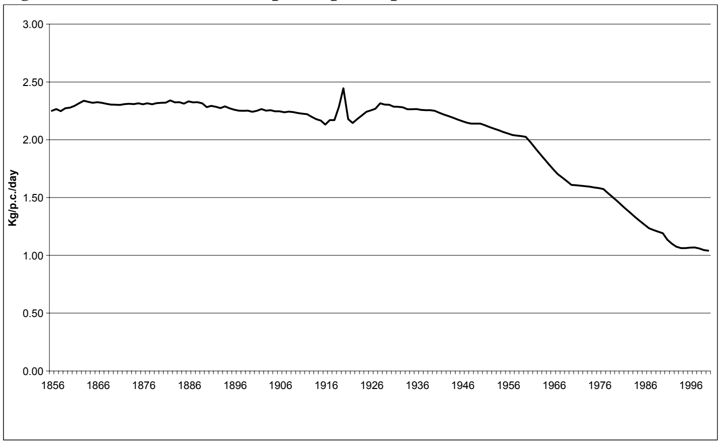
[79] DGE (1989), DGE (1996).

[80] The figures of DGE are somewhat lower than the ones in the surveys. For example, the 1988 survey indicates 1.38 Kg/p.c./day.

[81] Butane has been reported as the main substitute for firewood consumption after 1950. See Teives (2006b).

[82] Griffin and Fawcett (2000).

Figure 3. Firewood consumption per capita 1856-2000



Sources: see text.

2.3.2. Industrial firewood consumption

Energy Balance sheets provide information on firewood consumption by main industrial branches from 1971 to 2006. The main industrial consumers in 1971 were the glass and ceramic industries and food industries, accounting for more than ¾ of industrial consumption. Textiles, paper, wood and cork are the other major consumers[83]. For 1943 to 1970 energy consumption of main fuels (including firewood) is reported by branch in Industrial Statistics[84]. Data from 1943 to 1970 cannot be used without corrections, as total industrial production is poorly covered. Adjustments for industrial production have been made in GDP historical reconstructions by growth accounting economists such as Batista et al. (1997). However, due to the fact that coverage of GDP may be different to coverage of intermediate consumption, I adjust the statistics by comparing branch by branch the figures

[83] DGE (1986).
[84] INE (1943-1973).

for electricity consumption given in Industrial Statistics with the figures of industrial electricity consumption in Electrical Utilities Statistics, which are considered to be very complete. This is done for a set of benchmark years: 1943, 1948, 1953, 1958, 1963 and 1968. In the case of a homogenous industrial branch it is possible to assume that electricity coverage is approximately equal to firewood coverage. Below, I present the results for each branch, as sometimes I take into consideration other factors in the correction.

Ceramics and glass

Coverage in electricity consumption is checked in the glass industries and ceramics and cements against a set of benchmark years. The coverage of Industrial statistics is good. Nevertheless, I have corrected the raw data in order to take into account small differences.

Table 6. Firewood consumption in Clay and Glass Industry

	1943	1948	1953	1958	1963	1968
	Coverage electricity consumption in Industrial Statistics (per cent)					
Glass	83	87	99	97	97	96
Ceramics, cement	89	89	92	93	95	88
	Firewood consumption (1000 tonnes)					
Raw	309	296	249	307	369	554
Corrected	359	333	265	328	388	625

Sources: see text.

Textiles

In the first years of industrial statistics, the textile industry is clearly underestimated in terms of electricity consumption. However, in this case the underestimation of firewood consumption is lower than that of electricity consumption because an important branch, the wool industry, is missing until 1950. Electricity shares of the wool branch in the textile industry are much higher than its firewood shares. The chosen option is to change the firewood consumption in the wool branch in the same manner as the rest of the sector for the 1943-1949 period. After this procedure, I still adjust for firewood consumption in 1943-1953 to account for energy coverage (85 per cent). In 1958, coverage of electricity consumption was 99 per cent.

Table 7. Firewood consumption textiles

	Firewood consumption (1000 tonnes)					
Textiles	1943	1948	1953	1958	1963	1968
Raw data	49	58	87	88	102	167
Corrected data	83	119	101	89	102	167

Sources: see text.

Cork and wood

For 1949 to 1970, coverage of firewood consumption is assumed to be 60 per cent. Cork was not represented before 1948, so I have made a correction to include cork firewood consumption, based on cork production figures.

Table 8. Firewood consumption Cork and wood industries

	Firewood consumption (1000 tonnes)					
Cork and wood	1943	1948	1953	1958	1963	1968
Raw data	11	17	33	38	71	43
Corrected data	50	54	50	63	118	72

Sources: see text.

Paper

I have applied a coverage coefficient of 90 per cent for the whole period, equivalent to the electricity consumption coverage in this industry.

Table 9. Firewood consumption Paper industry

	Firewood consumption (1000 tonnes)					
Paper	1943	1948	1953	1958	1963	1968
Raw	59	33	22	28	30	56
Corrected	65	37	24	31	50	61

Food industries

The food industries are clearly underestimated. In 1953 there is a strong increase in the number of branches covered[85]. From 1953 to 1958, the branches included in 1943-1948 accounted for only 40 per cent of firewood consumption in the sector. I assume that the branches entered in 1953 already existed but were not reported in the Industrial Statistics. I have made a first correction in order to incorporate those branches, assuming that the share of firewood consumption in the 1943-1952 periods was equal to the one in 1953-1958. Still, for 1958 the electricity coverage is only 70 per cent. The report on bakeries' consumption appears in 1971. This industry is responsible for 77 per cent of firewood consumption in the food sector, but for only 7 per cent of electricity consumption. I adjust the coverage to be 77 per cent for 1943-1958 and 81 per cent from 1963 to 1970, and apply this ratio to rectify food consumption (excluding bakeries). Bakeries' energy consumption is calculated from 1943 to 1970 by and index of flour consumption[86]. The following table shows the raw and the corrected data for benchmark years.

Table 10. Firewood consumption food industries

	1943	1948	1953	1958	1963	1968	1971
Food industries	Firewood consumption (1000 tonnes)						
Raw data	77	31	89	87	59	66	69
Corrected data	457	101	117	113	69	82	69
Bakeries	Firewood consumption (1000 tonnes)						
Raw data	n.a.	n.a.	n.a	n.a	n.a	n.a	235
Corrected data	178	180	192	193	207	222	235

[85] Branches included by date: rice husking/peeling (1943), Grain milling (1943), sugar refining (1944), canned fish (1944), beer (1943), Milk (1944), Chocolate (1948), Cigarettes (1943), Sausages (1955), mineral water (1953), cookies (1953), Sweets (1953), Roasting (1953), Pasta (1954), Powders and yeasts (1954), Spirits (1953), spirits oil (1954), olive oil refining (1953), animal food (1953), table waters (1953), bakeries (1971).

[86] Given in Industrial statistics, several years.

Other industries & charcoal

Firewood consumption in other industries has been compiled but is not corrected. Its proportion varies between 1 and 7 per cent of total firewood consumption. A small series for charcoal consumption by industrial manufactures exists for the years 1943 – 1952 but is not included due to methodological difficulties[87].

There are no industrial surveys that can help us in the estimation of industrial firewood consumption before 1943. Qualitative evidence indicates that firewood was employed in steam machines in rural areas where transportation costs would have made coal a very expensive fuel[88]. Industrial firewood consumption represented only 12 per cent of household energy consumption in 1950. The evolution of industrial indexes in the period 1850-1950 suggests that this proportion was even lower in the past. I have applied a rough measure to estimate firewood industrial consumption for the period before 1943. For 1910-1942, I have varied firewood consumption according to the GDP of each industry[89] and as a proportion of total industrial GDP[90] for the period prior to 1910. This method assumes the same firewood intensities for each branch during 1910 and 1942; and the same global firewood industrial intensity for the period 1856-1909. The results give only 76 thousand tonnes in

[87] Charcoal is included with mineral coal from 1958-1970 and it is not disaggregated or converted into primary energy requirements after 1971. Annual average charcoal consumption (tonnes) 1943-1947- 21984; 1948-1957 – 13745.7 tonnes; INE, Estatísticas Industriais, several years.

[88] Inquérito Industrial, 1881. Motor reports from the South of the country (Algarve and Alentejo) indicate that in 1905 36% of the motors consumed firewood and 20% consumed firewood and coal. In 1913 the percentage of motors that used both coal and firewood had declined to 42%. A national steam generator inquiry showed that 17.1% used coal, 34% firewood; 3% residuals, 6% both coal and firewood, 39% unknown fuel in 1927 (Santos, 2000).

[89] Batista et al. (1997).

[90] Lains (1990).

1856. Lisbon firewood consumption in that year was reported to be 30 thousand tonnes.

2.3.3. Transportation

Only during World War II did the railways use firewood due to shortage of mineral coal. The total tonnage consumed by the railway sector is reported by INE[91]. Firewood consumption was registered from 1942 to 1952, being expressive until 1947. In 1943, one of the worst years for foreign supply, firewood represented ¾ of fuel consumption on railways. Reports of charcoal production for use by wood gas generators in internal combustion engines are also included for 1943-1947[92].

2.3.4. Firewood as a fuel for electricity and gas production and cogeneration

Firewood was not a main fuel for power production but shortages of coal lead to a heavy consumption during the First World War. The daily reports from the Lisbon electric plant (1914-1918) and the annual reports of Oporto (1917-1918) electric plant on firewood consumption are used to estimate firewood used for electricity production during those years[93]. Thus the amount of firewood used for electricity production in the two cities was multiplied by the inverse of their share in total production[94] (1/0.5) to reach a figure of total firewood consumption used in Portugal during First World War. Firewood was also distilled during the years 1918-1920 in order to produce town gas in Oporto

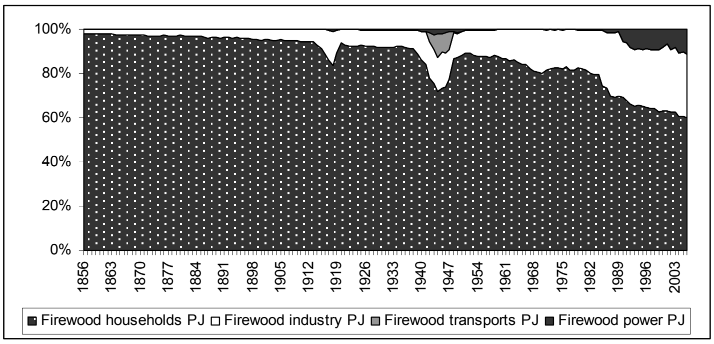
[91] INE, Anuário Estatístico, several years.
[92] INE, Anuário Estatístico, several years.
[93] CRGE (1914-1918); SMGEP (1917-1918).
[94] Thermo production is estimated for the years 1918-1930. See Appendix.

city. Consumption figures have been taken from Annual reports of Oporto electricity and gas services[95].

Data on firewood consumption for power production is lacking from the end of the World War I until 1931, when official electrical statistics begin[96]. Firewood consumption for the years 1919-1930 has been obtained from 1931 data, which means assuming that electricity production using firewood accounted for 2.2 per cent of total electricity production, and that each kWh was produced with 7.5 Kg firewood.

For 1971 onwards I connected Electrical Statistics series for 1931-1970 with the values for firewood and other solids (rice peels, olive seeds, etc) reported in Energy Balance Sheets for power uses. After 1990, firewood to cogeneration is included in this rubric. The figure below reproduces the shares for firewood consumption during the period studied here. Household figures make the bulk of consumption. Only in the last quarter of the century did manufacturing figures approach household figures.

Figure 4. Firewood consumption by major groups, Portugal 1856-2006



Sources: see text.

[95] SMGEP (1918-1920). No adjustments are made to cover firewood use for gas production in other parts of the territory as 1) The Lisbon coal gas factory was closed from 1917 until 1922 as a result of a government agreement to save coal. 2) Other gas plants had very small dimensions and there is only sparse information on their production values.

[96] DGSE (1929-1970).

2.4. Animals[97]

Animals have been domesticated by humans since the onset of the Neolithic Revolution and were an important source of power in agriculture, industry and transportation. In order to quantify for their contribution, some historical studies calculate the direct energy expense of the animal while working, i.e., the work output of the animal. However, as we are interested in energy inputs we must regard an animal as a living organism that converts chemical energy from fodder into mechanical energy. Like humans, only a portion of the fodder consumption of the animal is used in order to perform work. Most of the fodder ration is given to keep the animal alive. However, all fodder must be taken into account in our calculations, since it is impossible for an animal to survive and thus work without a minimal survival ration. Not all domesticated animal are of interest, since most of them are bred in order to provide for meat and dairy products. To calculate primary energy consumption from an animal we need to know the number of working animals. The food ration depends on the type of animal, its weight and the type of work it perform, so stratified data on cows, oxen, donkeys and mules must be produced as well as some assumptions of animal weight and intensity of work.

In order to estimate primary energy consumption from the fodder intake by working animals, we benefit from the previous work of Kander and Warde (2006). The authors suggest a standard conversion of cows, donkeys and mules into oxen or horses, a table of diary fodder requirements according to the size of the oxen and horses, and an assumption of average work intensity. According to the authors, a working cow must be converted into 1/3 of an ox, as their work is only a complement of other activities (dairy

[97] App. I, 1, col. 3, and App. II, 3.

production, breeding)[98]. It is assumed that donkeys and mules have an energy requirement of ¾ of a horse and the same as a horse of identical size, respectively.[99] Assuming that working animals worked on average all year round we reproduce here the daily fodder units of digestible energy (1 f.u. = 3,000 Kcal) that the authors suggest *(Table 11)*.

Table 11. Fodder units day in relation to animal size

Weight (kg)	Oxen	Cows	Horse/Mules*	Donkey**
300	4.2	1.4	4.7	3.5
400	5.6	1.9	6.2	4.7
500	7	2.3	7.8	5.9
600	-	-	9	6.8

Source: Kander and Warde (2006).

In order to obtain primary energy consumption from fodder intake all we need to know is the number and size of working animals.

For 1852 to 2000 there are about ten national censuses which allow us to determine the number of horses, donkeys, mules, oxen and cows at the time[100]. Since only working animals are of interest for our purposes, 15 per cent of the absolute value of donkeys, mules and horses are deducted, so that foals are not accounted for. Calves up to two years old and non-working cows are eliminated from the total. At the end of the nineteenth century oxen were the most important source of draught power in the country. For some European regions an important improvement in agriculture was the substitution of horses for oxen. Although a horse was more expensive to maintain, it was faster and could endure longer working hours. However, the equines were

[98] This would assume in practice that only energy requirements for work would be accounted for in the case of cows.

[99] The fact that donkeys consume about 75% of an animal of the same size is confirmed in the literature, see Aganga,Letso and Aganga (2002).

[100] MOPCI (1873); Justino (1986); INE- Estatísticas Agrícolas, several years. Adjustments to include the islands are made for some benchmark periods.

never important in agriculture, but more reserved for the transportation and leisure of wealthier individuals[101]. More necessary were the cows: in 1870, 66 per cent of adult cows worked; in 1955, that figure decreased to 44 per cent[102]. This was probably one of the higher percentages in Occidental Europe, which is also connected with the almost vegetarian diet of the Portuguese population. Besides, the use of cows could be an optimal solution as it allowed for a saving of feed resources as fewer animals could sustain both the milk and working needs of a farm[103].

Concerning the size of the animal I have assumed 400 Kg for horses and mules and 350 kg for donkeys as proposed by Kander and Warde for Mediterranean countries[104]. The value of 400 Kg per horse/mule assumes lighter horses than in Northern Europe.

Donkeys were common in the South of the country and assumed to be similar to the Andalusia breed which has an average weight of 370 kg for females and 400 kg for males. The only recognized Portuguese breed comes from the North of Portugal, Miranda. The breed is related to the Spanish Zamorano-Leones with an average weight of 350 kg[105].

The choice of the weight of the bovine cattle is influenced by the weight records of bovines at the slaughterhouses in the two main Portuguese cities. Both slaughterhouses show an increase of bovine weight until WW I. I

[101] In 1870, only 13% of the working horses worked in agriculture.

[102] For 2000 it is assumed that the number of working cows was zero.

[103] Zerbini and Gemeda (1994).

[104]. The value of 350 kg per donkey is considered large by Smil (1994) who gives a common range of 200-300 Kg per donkey.

[105] Data on Spanish breed characteristics is given in the Domestic Animal Diversity Information System from FAO, available in http://lprdad.fao.org

have assumed 370 kg per bovine head in 1856 and a linear rise until 450 Kg in 1910[106].

In summary, energy consumption from fodder intake can be calculated by the following formula:

$$E = aD^* f.u.d_{(x)} + (bO+1/3\ eC)^* f.u.o_{(y)} + (cH+dM)^* f.u.h_{(z)}$$

where:

D number of donkeys
O number of oxen
C number of cows
H number of horses
$f.u.d_{(x)}$ average yearly unit intake of a donkey with weight x
$f.u.o_{(y)}$ average yearly unit fodder intake of an ox with weight y
$f.u.h_{(z)}$ average yearly unit fodder intake of a horse with weight z
a proportion of working donkeys
b proportion of working oxen
c proportion of working horses
d proportion of working mules
e proportion of working cows

Working animal numbers increased from 1852 to the 1900s, stabilized until the 1960s and decreased thereafter with the introduction of tractors and decline of traditional agriculture (Table 12). It is not possible to obtain census data for animals after 2000. The same percentual decrease in feed consumption (58 per cent) of the precedent decade (1989-1999)is projected for 2010. Annual figures for the years 2001-2006 are obtained by linear interpolation between the 2000 figures and the projected 2010 values.

[106] Justino (1986); At 1849 the average weight of adult bovine cattle was 366 kg. After 1913 statistics at Lisbon slaughterhouse show a strong decline. I assume this was due to World War I – poor breeding, import restrictions, etc. Statistics recovered after the beginning of the 1920s to reach pre-war levels in 1935.

Table 12. Draught animal numbers for Census years

Year	Donkeys	Mules	Cows	Oxen	Horses	Horse equivalents
1852	112	35	128	282	61	440
1870	123	52	123	285	70	493
1906	129	50	180	285	77	558
1925	209	77	214	204	72	564
1934	234	104	220	156	77	566
1940	209	104	240	156	72	552
1955	201	108	240	176	63	562
1972	103	75	147	94	30	318
1979	101	54	109	77	25	261
1989	63	34	54	93	31	221
1999	33	18	0	22	31	94

Source: See text.

2.5. Wind & Water; solar & geothermal heat[107]

Wind and water were the only important sources of energy, apart from firewood and muscular energy, used before the advent of coal. The main consumers of these energy carriers were mills and sailing ships. In most of the cases, wind and water energy represents only a tiny portion of the total energy consumed by the country at a given time, and a per capita consumption in the range of 0.4 – 2.9 MJ /pc/day108. It is very hard to calculate wind and water energy on an annual basis, as it is not possible to know with exactitude the number, power, efficiency and intensity of use of the converting machines. Due to the small amounts of energy involved and the poor quality of the benchmarks, I have decided for reasons of convenience to treat water and wind in the same section, distinguishing them by type of driver (mills and sailing).

Sailing ships

Portuguese history from the 15th and 16th centuries showed that the country was one of the few to benefit from the knowledge of navigation techniques in acquiring an empire

[107] App. I, 1, col. 4 and App. II, 4.
[108] Malanima (2006b).

overseas. However, our series begins in the 1850s and at that time the Portuguese fleet was unable to compete with the foreign constructors. Statistics on the number and tonnage of sailing ships are available from 1864 onwards. In that year there were only 582 vessels. Due to the advantages of steam and internal combustion motors, the fleet decreased to 315 vessels in 1899, although tonnage peaked in that year, to 200 vessels just before the WW II and to 3 vessels in 1969.

One way to estimate the power of those vessels is to follow the calculations from Malanima. The author made an estimate, for Italy for the period, 1862-1975 of merchant Italian sailing ships' power with basis in Barberis' (1908) assumption that for the same net tonnage a sailing ship would have 1/3 of the power of a steamship. The ratio of steamship net tonnage to its power was reported to be 2.8. To obtain the power of sailing ships he divided the tonnage of sailboats per 3 x 2.8 =8.4. Then he multiplied the power of those sailing ships by their intensity of use assuming that a ships power was fully exploited 10 hours a day for 365 days a year. One of the problems with this method is that it assumes that energy can be transmitted from the sails to motion in a perfectly efficient way.

Lindmark has proposed an alternative method to calculate energy consumption by making an estimation of wind energy hitting the rig and accounting for 50 per cent energy losses in the sails. Lindmark calculates that primary energy from wind is approximately 0.6 KW per tonne[109]. I have applied this coefficient in terms of gross tonnage, and assumed a coefficient of use of 3,650 hours year for merchant sailing ships in line with the previous booklets in this series. Wind could also be used by smaller boats in coastal navigation and by fishery boats. There are no reliable statistics for the first type of boats, but statistics record the tonnage of registered fishery boats that employed wind as their source of energy. Fishery boats tonnage was 65 per cent of vessel ton-

[109] Lindmark (2007).

nage in 1860. Tonnage reached a peak of 48,000 in 1912. In terms of numbers, fishery boats continued to grow until 1961, when they numbered 15,600 units but tonnage was decreasing due to competition with internal combustion motors. There were still 11,000 in 1986 but decreased quickly to 2,330 due to the rules of the Common European Fishery Policies that financially supported the removal of small and obsolete units. In order to calculate primary energy we employ the same method we use to estimate vessel energy. I assume a coefficient of use of 2,000 hours a year. This also reflects the fact that an unknown proportion of boats was not in use.

Mills

Windmills and watermills appeared in Portugal. The first written reference about a windmill dates from 1182 and there were only 46 watermills inventoried in 1258.[110].

Data on the number and power of windmills is very scarce along the period of 1856-2006. Due to the low quality of the information available, the option is to produce an acceptable benchmark figure for the only year which enough information is given (1890) and to depart from this year to derive long-run estimates for the remaining years.

Mills, benchmark estimates 1890

It is easiest to begin the calculations with the most reliable survey, the industrial census of 1890. This inquiry is the only one that reports the number and power of both industrial and cereal mills. The crude information is far from optimal, but Santos improved the reliability of the inquiry by making an estimate of the mean power of watermills and windmills based on the incomplete information of that inquiry[111]. The census records 2,394 windmills and 7,894 watermills in ope-

[110] Marques (1987).
[111] Santos (2000).

ration. About ¾ of the installed power in industrial and non-industrial premises came from water and wind. Cereal grinding was the most important activity of windmills (97 per cent) and watermills (90 per cent) *(Table 13).*

Table 13. Number, Power and mean power of Windmills and watermills per industry, 1890

	Windmills			Watermills		
Industry	Number	HP	Average power (HP)	Number	HP	Average power (HP)
Cereals	2,313	9,479	4.1	7,221	18,237	2.5
Wood	16	137	8.6	227	2,649	11.7
Textiles	28	192	24.0	347	4,282	12.3
Metals	34	146.2	4.3	3	21.8	7.3
Paper	1	1.8	1.8	56	712.3	12.7
Chemicals	1	2.3	2.3	16	72.5	4.5
Printing	1	1.8	1.8	1	1	1
Chemicals	0	0	0.0	16	72.5	4.5
Total	2,394	9,960.3	4.2	7,894	26,093	3.3

Source: Santos (2000).

The calculation by Santos is of course only a first step. In order to estimate energy consumption from power we have to know how long the mills actually worked in a year. Statistics record only the power of the mills, that is, the capacity to produce work per unit of time. As we are interested in inputs, that is, the water falling on the wheel or captured by the blades, we must add the energy which was lost in the process of transmission. Thus, the calculation of the primary energy of water and wind can be given by the following formula:

$$E = P \cdot h \cdot \frac{1}{i}$$

where:

E energy consumption;
P power
h hours of use per year
i efficiency

I have decided to estimate the intensity of use of cereal watermills and windmills based on the figures for the cereals ground in water and windmills. I calculate the apparent consumption of grain in water and windmills adding to the 1890 production figures of wheat, rye and corn[112] the quantities of wheat imports[113], and subtracting one tenth of this gross value to account for animal intake[114] and the grain consumption in steam-mills[115]. Knowing that each HP installed in a traditional mill grounds 14 kg/cereal hour[116], we obtain a use coefficient of 1,997 hours/year[117]. This value is clearly compatible with the 2,000 hours/year that Reis suggested for agricultural work in this period of time[118]. The next step is to calculate the intensity of use of industrial mills. According to Reis (2005), industrial workers worked for 293 days a year, 10 hours a day at the end of the 19th century. However, windmills and watermills did not always operated during industrial work. Summer droughts could substantially decrease the use of watermills as the need of water for agriculture works increased. Windmills could be even less reliable, sometimes merely used as a poor substitute for water power. Probably, the power indicated by Santos was not reached throughout the year. To address these constraints, we assume that watermills only worked at full power in 9 months of the year. In the remaining three months, power was reduced to half. This means that we assume that a watermill was working at full power for 2,200

[112] Lains and Sousa (1998).
[113] INE (1890).
[114] Serrão (2005).
[115] Magalhães (1890).
[116] Malanima (2006).
[117] Grain consumption water and windmills = Grain imports + grain production – animal consumption – steam consumption = 87,971+828,525- -91,650-50,000 =774,846 tonnes. Intensity of use = Water and windmill grain consumption: Power: technical coefficient per hour = 774,846: 27,715.7:0.014 = 1,997 hours.
[118] Reis (2005).

hours a year and 730 hours at half the power. In the case of industrial windmills we use an intensity of use coefficient of 2,000 hours/year at full power, reflecting a lower usage of windmills in relation to watermills.

After calculating the energy consumed it is also necessary to understand the efficiency of both windmills and watermills. Some authors use a very high estimate of 70 per cent efficiency for windmills but this is an exaggeration. In 1919 a German physicist proved that no wind turbine can convert more than 16/27 (59.3 per cent) of the kinetic energy of the wind into mechanical energy to turn a rotor[119]. This law, called today the *Betz´s limit* has to do with the nature of wind turbines that extract energy by slowing down the wind. Thus, for a wind turbine to be perfectly efficient it would need to stop the wind, but then the rotor would not turn. The actual motors have 30 to 45 per cent efficiency and the old windmills did not reach more than 10-15 per cent. In the case of watermills the efficiency was dependent not only on the materials and design of the wheel and transmission equipment but also on the manner in which the water ran into the wheel. A theoretical maximum of 15 per cent of efficiency for undershot water wheels was established in the early 18th century, but in 1759 Smeaton showed that yields could be increased to more than 50 per cent with resource to overshot wheels[120]. In the 1830s water technology was improved with the invention of Fourneyron turbines, which could be easily adapted to different torrents and could achieve 70-80 per cent of useful energy. Despite all these improvements, it was not the best technology that was in use in Portugal. In 1881, it seems that the majority of industrial watermills were still driven by mixed wheels (wood and iron). It is not possible to know

[119] http://en.wikipedia.org/wiki/Albert_Betz.

[120] Cardwell (1996). The wheel is designed as undershot when the water ran at the bottom of the wheel and overshot when the movement is given by the falling water.

the proportion of overshot and undershot wheels, but it seems the two systems co-existed for a long time in precarious conditions. The number of turbines is mentioned in the 1890 Industrial Census. They were only 418, a tiny proportion of the 7,894 watermills. Power is assumed to be 3,655 HP[121], 14 per cent of total watermill power. An efficiency of 15 per cent for windmills, 30 per cent for watermills driven by wheels and 80 per cent for watermills driven by turbines is used. I assume that turbines were employed in the industrial sector, where a higher intensity of use coefficient is used. In the aggregate, this gives a global efficiency of 25 per cent. In 1890, windmills and watermills consumed 221.1 GWh. It is worth nothing that despite windmills representing only 28 per cent of the installed power, in terms of primary energy consumption they spent almost as much energy as watermills (44 per cent). Adding the wind used in transportation to the energy spent by mills, we reach the conclusion that water and wind accounted only for 1 per cent of total consumption in 1890.

Mills, remaining years

Only rough figures on the use of windmills and watermills can be inferred for the rest of the period.

In relation to industrial mills, there is no information available on their number before our benchmark year, 1890. Therefore, we just assume the same amount of energy use in industrial mills for the period 1856-1890.The industrial survey of 1917 records the number and power of industrial watermills. It says nothing about windmills so I just assume that their industrial activity disappeared at the end of

[121] Cordeiro (1993), table does not show accurately the total turbines power, as power for some districts is missing. I calculate the average power for the districts where power information was given and assume the same average power for turbines with unknown power information. His figures show a total power of 1,294 HP, less than half of what I roughly estimated.

World War I. Excluding hydro-electricity industries[122] and cereal grinding industries,[123] watermills had an installed power capacity of 6,822 HP, 87 per cent of the 1890 power for the same industries. Turbines provided 67 per cent of the installed power, more than the 49 per cent of 1890. We can only obtain other benchmarks four decades later, with the publication of industrial statistics. It seems that absolute water power may have grown after 1917. By 1950 the statistics report 10,223 HP; by 1958 11,330 HP. By 1965 waterpower had began to diminish: 9,612 HP, 80 per cent from turbines. Efficiency around that period had grown with the substitution of turbines for wheels but intensity of use had probably dropped. At the early 1930s the length of a working week in industrial premises had dropped to 48 hours/week due to labour legislation. Furthermore, water was used more and more as a complement to steam.

It is even harder to calculate the energy spent in cereal grinding. While apparent consumption of grain can be used to calculate primary energy in the early part of the series 1856-1890, things get complicated after 1890. The statistics report the number of watermills and windmills subjected to the industrial tax until 1918. The absolute number of watermills may have increased from 8,000 in 1890 to 11,000 in 1918 while windmill numbers remained constant. However, in terms of HP, steam already had the capacity to grind all the grain consumption of the country around the 1920s[124]. The situation of the sector in 1960 was elucidative of its overcapacity. At that time the industrial statistics reported

[122] Production of primary electricity is represented in section 2.6.

[123] Poorly represented in the 1917 survey as this census only accounted for major units.

[124] Steam-mills accounted for 20164 HP installed in 1917 and 24184 HP in 1927. Applying the same production rates as in 1890, capacity clearly exceeded production.

the existence of 3,441 factories[125], 2,953 windmills (2,687 with no extra motor) and 32,047 watermills (31,274 with no extra motor) on the mainland. From this number, and for public consumption, there were 1,819 factories, 1,707 windmills and 10,440 watermills operating. An extra 946 factories, 180 windmills and 14,798 watermills produced in regime of own consumption. In terms of power all factories and motorized mills had a power of 56,583 HP[126]. If the average power of a cereal windmill and watermill was the same in 1960 as in 1890, water and wind power in use accounted for 2.5 times the 1890 values. As we do not know the quantities of grain grinded by the motorized units, it is inglorious to attempt any calculation for 1960. I assume then, that despite the overcapacity of the industry, water and wind energy use were related to the number of people employed in the agricultural sector. With this assumption, primary energy use from wind and water cereal mills varies little from 1856 to 1965: 0.5 PJ in 1856; 0.7 PJ in 1890 and again 0.5 PJ in 1965.

Below is a summary of the results of our calculations (*Table 14*). In the period the most important use of water and wind energy was cereal grinding. Water and wind energy represented along the period a very tiny proportion of total energy consumption.

Table 14. Summary of wind and water energy calculations

	Wind, sailing ships %	Wind, fishery boats %	Wind & Water: cereal mills %	Wind & Water: Industrial mills %	Wind & Water PJ	Wind & Water % of the Total
1856	19	7	59	15	0.907	1.2
1890	20	8	59	13	1.105	1.1
1917	20	8	61	13	1.08	0.9
1965	0	13	73	13	0.69	0.3

Source: see text.

[125] The statistics regard premises with motors as factories. Windmills and watermills were not considered factories if their production was lower than 10 tonnes of flour per month.

[126] INE, Estatísticas Industriais, 1960.

Solar and geothermal heat

Solar and geothermal energy for heating purposes has been reported by DGE since 1998. It is included under this heading in the Appendix.

3. Modern sources

3. Modern sources

3.1 Coal[1]

Coal was already used by the Chinese in pre-industrial times but it was in England that its usage reached major importance, accounting for more than half of British energy consumption by 1600[2] and being strongly associated with the Industrial Revolution.

Domestic Coal Production

In Portugal the first coal mines started to be explored at the end of the 18th century. Coal reserves were very limited and the mean calorific content of Portuguese coal was only 50-60 per cent of British coal. In the 19th century the low quality of the coal never attracted the industrial consumers and production reached only a few thousand tonnes. During WW I coal extraction increased to 100-200 thousand tonnes as a result of a shortage of foreign coal. Domestic coal was mixed with foreign coal in the interwar period to improve its quality; after the Second World War its usage was almost mandatory in thermoelectric utilities. Since the end of the 1980s there has been no coal extraction in the country. In times of peace domestic coal never amounted to more than 10 per cent of the total coal consumption. Coal extraction figures from 1890-1970 are taken from Madureira and Teives[3], which are based on official sources[4].

[1] App. I, 1, col. 5 and App. II, 5.

[2] See Warde (2007) on this subject.

[3] Madureira and Teives (2005). However I did not apply a 3- year moving average of the series (as the authors) and extraction figures are given as reported by official statistics.

Coal extraction from 1882 till 1889 is taken from Valério, who also uses official sources[5]. From 1856 to 1881 I aggregate data from a variety of sources and studies that give partial information about specific mines[6].

Coal imports

The first registers of coal imports cover the period of 1796-1831[7] but less than 20,000 tonnes a year were imported during that period. Our series begins in 1856, and from that year until 1970 coal imports are taken from the yearly books of International Trade from INE[8]. For the periods 1857-1860 and 1862-1864, official statistics are missing. In the first period (1857-1860), data for the two most important Customs Offices (Lisboa and Oporto) was used as representative of total consumption in the country[9]. For the second period (1862-1864), data is interpolated from 1861 and 1865 official figures[10]. Data for 1875 is changed due to an error in reporting[11]. Although Mitchell reports coal imports for Portugal from 1875 using Portuguese sources, this series is an improvement of Mitchell data as for some years not all

[4] Anuário Estatístico, DGE – Direcção Geral de Esttística, 1906-1934; Anuário Estatístico, INE – Instituto Nacional de Estatística, 1935-1982; Boletim de Minas, DGOMP – Direcção Geral de Obras Públicas.

[5] Valério (2001).

[6] Inquérito industrial (1890), Matos (1997) and Guedes (2000).

[7] Madureira (1997).

[8] INE, Comércio Externo. Data for 1890-1970 was earlier recorded by Madureira and Teives (2005), using the same methods as here.

[9] Mappas Estatísticos do Rendimento da Alfândega Grande de Lisboa (1857-1860), Mappas Estatísticos da Alfândega do Porto (1856-1859). There is no major problem in not including the Customs of Madeira and Azores as most of the imported fuel would be re-exported to bunkers.

[10] Although British statistics could be used for missing years they would include bunkers, so corrections would have to be performed anyway.

[11] Reported coal imports by Portuguese statistics are 426 thousand tonnes have been corrected to 226 thousand tonnes after comparison with UK trade statistics.

coal imports are registered in his series[12]. Furthermore, I assumed different coefficients for coke, coal, brown coal, turf and peat (*Table 15*). After 1971 Energy Balances from DGE are used. Imports are not always homogenous series as they can include (or not) bunker fuel[13].

Table 15. Conversion coefficients – toe/ton

Coal	toe/ton
Imported coal (Anthracite/bituminous)	0.70
Lignite	0.27
Turf	0.23
Agglomerates	0.68
Coke	0.67
Domestic coal	0.41

Source: DGE (values indicated for 1971-1982).

Bunkers

Portuguese coal was not exported so the majority of corrections that we have to make to Imports, refers to supplies to international navigation. International organizations such as IEA do not account for fuel consumption consumed by international marine bunkers (fuel delivered to sea-going ships) when reporting the primary energy of a country. If one intends to account for bunkers using the same method as IEA one should include the domestic travel between domestic ports and airports, but not the international ones, in primary energy consumption. Bunkers are a tricky issue in energy accounting and not all the countries report them in the same manner. For example, they are considered part of domestic consumption by most Middle East countries but treated as exports in the majority of Latin Countries[14]. Even between IEA countries, definitions are not entirely consistent. The main problems with bunker reporting is the lack

[12] Mitchell (1980), for example, does not account for coke consumption for earlier periods; in some years only coal imports from England are given. For 1937-1960 Mitchell does not include imports to the Portuguese navy, included in a special table.

[13] See correction of imports in bunkers section.

[14] Karbuz (2006).

of distinction between deliveries for international and domestic purposes, overestimation of bunkers in order not to have to hold stocks or inclusion of fishing fuel consumption, which is due to the fact that data is obtained by suppliers who do not know precisely the ultimate use of their sales[15]. The issue of bunkers has become more relevant nowadays due to the introduction of greenhouse gas inventories. In order to ascertain responsibility for bunker emissions for each emitting country, detailed information on a country by country basis on the fuels sold domestically and abroad to planes[16] and ships should be available. This is a concern, as the way statistics are made today, at least part of the bunker emissions are lost, with no owner. While the Kyoto Protocol article recommends that Annex I parties pursue the limitation of bunker fuel emissions, bunker fuel emissions are not subjected to emission targets[17].

Portuguese modern statistics do not account for bunkers in the same way as international organizations. Instead, they adopt a territorial concept, accounting for the fuel that is consumed by national aviation and marine ships and excluding the fuel that is consumed by foreign carriers[18]. From an historical point of view it is more interesting to adopt the Portuguese accounting method as it gives more information on the uses of energy by all the sectors in the economy. Besides, wind energy consumed by vessels is also part of our calculations, so it would be inconsistent to treat coal consumed by steam ships in a different way. With this methodology only the fuel acquired by national companies on international territory would not be accounted for.

[15] Det Norske Veritas (1999).

[16] United Nations energy statistics are different from IEA ones, in the way that they subtract also aviation bunker figures.

[17] Technical workshop on emissions from aviation and maritime transports, 4-5 October 2007, www.eionet.europa.eu/training/bunkerfuelemissions. For further information on the latest developments in marine and aviation bunker fuels see.

[18] DGE, Balanço Energético 1987-1991.

The choice of the Portuguese method will not imply a major problem when comparing with other European countries, as the proportion of the fuel used by national navigation and air carrier companies on international travel was or is undoubtedly small.

In the case of coal, considering only imports would significantly overestimate Portuguese coal consumption in earlier periods. As any coastal country an important proportion of coal imports was destined to supply foreign ships, being only remotely associated with the level of industrialization of the country. There were some important ports used by foreign ships, especially British ones, on international routes to Africa, the Americas and India since the mid 1850's: Lisbon, the port of Funchal on the Island of Madeira and the ports of Ponta Delgada and Horta on the Islands of Azores[19].

In order to correct for supplies to foreign navigation, it is necessary to understand clearly how Portuguese trade statistics were generally presented and also their modifications, errors and inconsistencies. There were three main categories in Portuguese trade statistics: imports for consumption; national and nationalized exports and re-exports. Imports for consumption included as a general principle only the commodities that would be consumed within the country, that is, they would be net of re-exports. However, a proportion of the commodities that entered the country ports under the regime of imports for consumption was afterwards sold to foreign territories[20]. Thus, they would then figure in export figures as nationalized exports. Re-exports comprised the imported goods that were not subjected to a consumption dispatch and that were sold to foreign territories. This genera-

[19] Miranda (1991). The importance of coal trade in the ports of Atlantic (Madeira, Azores, Canary Islands and Cape Vert) is discussed by Bosa (2008).

[20] Due to a maximum time that companies were allowed to keep the merchandise in deposit, unanticipated exports or to an improvement of the merchandise.

lized principle was followed by Madureira and Teives in their estimate of coal and oil consumption in the country[21]. However, as we will see, Portuguese official statistics do not always follow their definition of imports for consumption, export or re-exports in the case of coal for navigation purposes and some errors and inconsistencies need to be corrected[22].

1856 - 1922

Prior to 1923 the coal consumption to foreign ships is difficult to track. From 1889 to 1916 almost all supplies to both national and foreign steam ships were given in re-exports. As mentioned earlier, re-exports should not be included in imports for consumption, but a detailed analysis shows that some errors in reporting occurred. In that period imports, exports and re-exports are also disaggregated by main ports so it is easy to see that only fuel ship supplies in the islands were accounted as re-exports. However, the re-exports figures of the ports of Madeira and Azores are almost equal to their "imports for consumption" figures. Those islands had almost no industrial development so accounting for imports would mean attributing them the higher per capita figures of coal consumption in the country, which would be impossible. Re-exports must then be subtracted of imports for consumption[23]. We do not have Portuguese registers of each port for earlier periods than 1889 but UK trade statistics have separate figures for coal exports to mainland Portugal, Madeira and Azores going back in time. As the UK was the almost exclusive supplier of coal to Portugal we can get some additional information

[21] MadureiraandTeives (2005).

[22] The main reason for these inconsistencies was the decentralized nature of customs statistical information methods in the earlier part of the period and differentiated tax regimes.

[23] I double checked the import data for Madeira and Azores with UK trade statistics for the same Islands (which always include future re-exports from Portugal to other countries) and they matched quite well which gives support to the argument.

from those statistics. Comparing UK coal exports for Azores and Madeira and coal exports and re-exports figures in the Portuguese trade statistics, all fuel in exports from 1856 to 1874 and in re-exports from 1875 to 1888 was for the islands of Azores and Madeira[24]. From 1916 to 1920 fuel supply was also reported as re-exports to the Island of Madeira and in Ponta Delgada (Azores), but Horta (Azores) changes the report of fuels to exports, which is nothing more than the adoption of a new statistical procedure. In order to achieve a figure of coal consumption net of foreign bunkers for the islands in the period 1856-1922, one still needs to distinguish between exports and re-exports that were destined for national or foreign ships. Until 1875 exports distinguish if coal is going to foreign or domestic ships, and the proportion of national marine coal consumption in the islands was approximately zero. I assume that 0 per cent of the coal re-exported went to national ships prior to 1880, 5 per cent between 1880 and 1889, 10 per cent between 1890 and 1913 and 15 per cent from 1914 to 1922.

As for other ports in the country, Lisbon customs reports only a small fraction of its bunker consumption to exports[25]. Only after 1916 did Lisbon start to account for coal supplies to both national and foreign ships as exports[26]. There is a strong possibility that import for consumption before 1916 was given net of bunkers even if they were not registered in export or re-export as an exit. Isolated statistics for the

[24] Annual Statement of the trade of the United Kingdom, several years. Coal for navigation in the islands was also included in imports in an earlier period. For 1856, by reasons of late report, the customs of Funchal (Madeira) is treated separately from the ones in Mainland and Azores and we can see an importation figure almost identical to the re-exports figures.

[25] Most of the exports of Lisbon in the period 1889-1915 are actually re-exports to Spain or colonies.

[26] Figures for Lisbon in 1916 indicate a total bunker consumption (destined for foreign and national steam ships) of 80,000 tons.

commercial movement of the port of Lisbon in 1883 indicates 67,013 tons of coal supplied to steam vessels are clearly stated as being outside the imports, exports and re-exports figures[27]. I have not performed any correction in order to account for coal supplies to domestic steam ships in Lisbon port before 1916 due to the scarcity of data involved[28].

1923-1936

For 1923 to 1936 coal supplies to foreign and national ships are included in exports. Exports distinguish the coal for foreign consumption within the mainland but not the islands where an aggregate figure for coal supplies to national and foreign ships is given. I assumed that 15 per cent of the bunker fuel exported from the islands between 1923 and 1936 was to domestic ships, consistent with the proportion of Portuguese ships (measured in tonnage) that cleared from islands ports in that period.

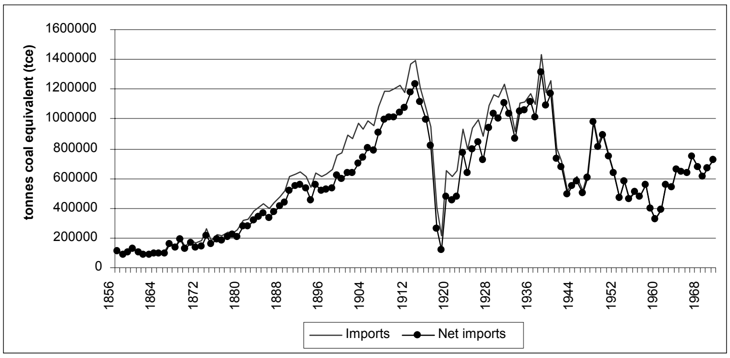
[27] Included in the diaries of the sessions of parliamentary debates, session 04/25/1884, p. 1243, table 17. I searched for additional information in the few Lisbon customs statistics that I could find and no records for the totality of navigation coal supply is given. For the period of 1875-1880 about four thousand tons of coals are reported in exports as consumption for bunkers but this did not represent all consumption by ships. Direcção Geral das Alfândegas e Contribuições Indirectas, 1881. The exception is the period 1859-1860 for which a figure of 3,694 loading of coal to 6 foreign ships is given outside the importation or exportation maps as an addition. Mappas Estatísticos do rendimento da Alfândega Grande de Lisboa no ano económicos de 1859-1860, 1860.

[28] I compared the UK coal exports to mainland Portugal and Azores and Madeira with Portuguese coal imports for the XIX century and the first are higher than the second in almost all periods of the series. The difference is about 30,000 tonnes per year but it is lower in the decade of 1890s (about 15,000 tonnes per year). As it is not possible to find stronger evidence of bunker consumption in the Port of Lisbon we leave the statistics like they are. Contrary to the Islands, the majority of ships that entered and cleared the Lisbon port were not supplied with coal. Due to the existence of numerous nearby ports, bunker consumption depended mainly on the price of fuel and route of ships.

1937-

It is straightforward to correct for fuel to foreign ships and aviation after 1937. From that year onwards, part of this kind of consumption is reported in exports, so subtracting this value from coal imports would give an accurate measure of coal consumption within the country[29]. The figure below (Figure 5) presents both general imports and net imports.

Figure 5. Coal imports and net imports 1856-1970



Sources: see text. Note: 1 tce= 0.7 toe.

Coal destined for foreign navigation had an important share in coal imports. Considering only imports would overestimate coal figures by about 15 per cent-20 per cent for the period 1880s-1929. However, the correction does not change the overall picture of continuous increase in imports until 1913 and a slow recovery and instability after World War I.

[29] Exports do not include all the bunker fuel sold to foreign ships as some of this fuel would not be included in imports for consumption. United Nations energy statistics for Portugal after 1950 do not reflect this particularity. While their import figures match the Portuguese ones they subtracted the whole total for bunkers (included or not in the import figures) to reach a figure for primary energy consumption.

3.2. Oil[30]

The country lacks oil reserves, so all the crude oil has to be imported. The first use of oil was in public and private lighting. Kerosene imports started in 1861 followed by gasoline in the early 20th century and gas-oil and fuel-oil in the 1920s. Non-energy oil derivates such as paraffins[31] or lubricant oils can be found in import trade statistics since the 1890s. Butane imports started in 1938. From the eve of World War II crude oil imports began as the first oil refinery, in Lisbon, opened for production in 1940. In the first fifteen years the refinery had only the technology to produce low octane gasoline, high sulphur gas-oils, kerosene, fuel-oil and lubricants[32]. In Jannuary 1955 a major modernization that included the installation of one catalytic cracking unit allowed, besides the production of a higher octane gasoline, the production of LPG (butane and propane), jets, sulphurs and white spirits, among others. However, as the country had lower indexes of motorization at the time, the new refinery process could not be fully optimized and low octane's naphtas remained as production surplus[33]. This fact leads to the emergence of the petrochemical industry. Three units for naphtha gasification for the production of ammonia and urea were installed by 1961. In the early 1960s the refinery started to supply naphthas as a feedstock for the production of ammonia by fertilizer industries. Most of the hydrogen produced by naphtha treatment was used in ammonia production but a small part was returned to the refinery for feedstock. Town gas for the city of Lisbon was produced after 1961 from a mixture of the petrochemical gas, derived from naphtha gasification and ammonia production and re-

[30] Appendix I, 1, col. 6 and Appendix II, 6.

[31] Paraffin is here considered non-energy due to its recent applications although, its usage in the late nineteenth century was mostly confined to candle making (not accounted for in this work).

[32] Production of lubricants was discontinued in 1947.

[33] Vaz and Almeida (2003).

finery gases, propane or butane, replacing the old process of town gas production obtained from coal or coke[34]. This process was maintained until the closing of the refinery in the late 1990s, when town gas was substituted by natural gas. Two other refineries, in Oporto and Sines, started refining crude oil in 1969 and 1979. Besides the production of fuels, the Oporto refinery included, from the beginning, a factory for the production of basic oil, (which has employed atmospheric gas-oil as a feedstock since 1984) and an aromatic factory since 1981 for the production of benzene, tuolen, naphtha, solvents and aromatics. The Sines refinery was constructed having in mind the external market. A new steam cracker was constructed downstream of the factory in 1981 using naphtha as a feedstock and producing ethylene, hydrogen, propylene, etc. Presently the refinery produces gasolines, petrols, gas-oils, fuel-oils, asphalts and sulphur.

Fundamentally, oil consumption figures are presented in three ways in historical or official publications. International organizations such as the IEA, United Nations and Eurostat include non-energy uses of oil in their primary energy consumption definition, preferring to disaggregate between energy and non-energy uses at the level of final energy consumption. Although this first method is interesting from a point of view of resource use dependency[35], it overstresses the share of fossil fuels in the energy balances. It is also inconsistent with the treatment given to other energy carriers such as firewood, since energy balances do not include wood for construction purposes, for example. A second method that has been presented in some historical reconstructions is to exclude the primary energy consumption of non-energetic derivates such as lubricants, asphalts, sol-

[34] Teives (2003).

[35] A more complete way of calculating the resource dependency on fossil fuels is to account for the embodied energy content of all consumption goods.

vents, paraffins or chemical naphtha[36]. It has only the inconvenience of excluding the trade flow of non-energy products (which can be positive or negative), while it includes the production flow. A third method is to exclude not only the non-energy derivates of oil, but also the proportion of crude oil that is employed by the country´s refineries in order to produce non-energy derivates. This method has been employed in historical reconstructions for Sweden[37], UK[38] and Spain[39], among others – and it is also the chosen method in this work. It has the visible advantage of expressing the consumption of energy. The disadvantages are methodological. First, there are intensive data requirements that can almost never be entirely fulfilled in historical reconstructions like this one. For disaggregating between non-energy and energy uses of crude oil one needs to have access to refinery production figures, which are not easily available for earlier periods. On the other hand, petrochemical processes are closely interconnected with oil refinery ones, which makes separation difficult. A classical example is naphtha which can have energy and non-energy uses. Although non-energy uses of naphtha are reported in energy balances as a feedstock to the chemical industry, some of this naphtha is returned to the refinery in form of refinery feed stocks such as hydrogen, for example. To convert those refinery feed stocks derived from naphtha in terms of primary crude oil, since naphtha production is excluded, is practically impossible as we lack disaggregate information on feedstock and intermediate products refinery use[40]. Finally, it is impossible to determine the efficiencies of

[36] Due to the fact that naphtha can be used in energy uses (in raising heat or town gas production) it is often considered as an energy vector.

[37] Kander (2002).

[38] Warde (2007).

[39] Rubio (2005).

[40] Refinery feedstock's primary energy consumption (net trade and stock variation) and use in refineries (includes production of intermediary products) have been presented in energy balances since 1971. It is not

individual derivatives produced by the refinery with the scarce information given in the statistics. Even though most of the methodological problems can be only partially solved, this method will provide figures closer to what we seek to determine, this is, the primary oil used for energy purposes.

Data concerning oil derivatives is taken from the yearly books of International Trade from INE until 1970 and Energy Balances after that date. Crude oil figures are taken from reports of treated oil by the refinery company from 1940 to 1958; from Industrial Statistics from 1959-1970 and from Energy Balances thereafter[41].

In order to exclude non-energy uses of crude oil, I simply deduct from the primary crude oil the refineries production figures for lubes, paraffins, solvents, asphalts and propylene. Non-energy use of fuel oil in the chemical industry has been reported since 1985 and is deducted from the crude oil figures. Naphtha production figures are also subtracted, except for the energy uses reported. Before 1971 there are no Energy Balances but production from refineries is reported in other publications[42]. Naphtha production is only reported after 1963, a 2-3 year difference from its

possible to collect this information for previous years due to the diversity of products considered, although some of them might be incorporated in fuel trade. According to information given by DGGE, refinery feed stocks are obtained directly from the refineries and include naphtha SR, components used in fuel production (gasoline, gas-oils, basic oils, etc) and also other intermediary products such as fuel gas, MTBE, hydrogen, etc. The agency does not supply disaggregation of those products at a lower level, so sophisticated measures were not employed.

[41] SACOR (1940-1958); Estatísticas Industriais (1958-1970). DGE, 1971-2006. Although the company reports have data on the treated crude oil for most of the period, I could not find data on treated crude oil for the years 1945, 1949, 1953-1956 and 1958. For the period 1954-1956 I have used imports of crude oil from the company reports. For the remaining years Trade Statistics are used (INE, Comércio Externo).

[42] Anuário Estatístico for 1957-1958 (only production figures); Estatísticas Industriais for 1959-1970 (materials, energy consumption and production figures).

industrial use so a short time omission occurs. Uses of naphtha for town gas production are only reported after 1971. In the first three years of energy balances the ratio of on naphtha/gas production measured in energy units was approximately 3 to 1. Energy uses from naphtha in the period 1963-1970 are interpolated from gas production figures,[43] assuming the same relationship. Before 1956 non-energy usages are not deducted due to scarce information[44]. From 1971 till 1989 energy uses of naphtha are reported in town gas production and refinery losses. After 1990, heat is included in energy balances so naphtha used in order to raise heat in the petrochemical industry and in cogeneration utilities was considered as an energy use. The uses of naphtha for heat purposes represented only 3 per cent of naphtha production so I abstain myself from correcting for previous years. Data was collected at the disaggregated level and the following coefficients were applied (Table 16):

Table 16. Conversion coefficients–Oil

Products	toe/ton
Crude Oil	1.007
Fuel-Oil	0.969
Gas-oil	1.045
Gasolines	1.073
Kerosene	1.045
LPG	1.140
Naphta	1.073
Petrol Coke	1.070
Non-energy oil derivates	0.960

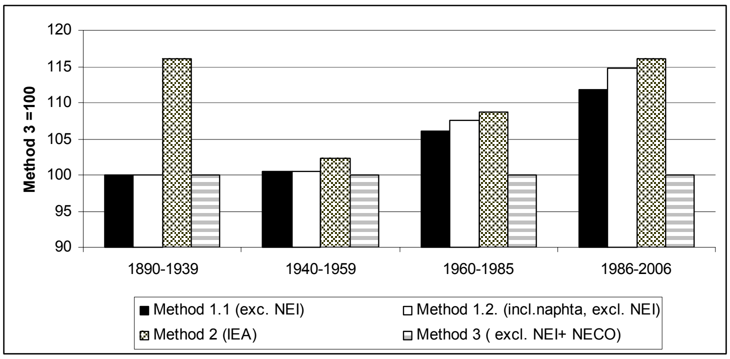
Source: DGE (values indicated for 1971-1982).

[43] Estatísticas Industriais for 1965-1970 figures. The proportions of gas from petrochemical and gas from coal are graphically presented in Matos (2005) for the transition period of 1963-1965. About 85% and 60% of town gas in 1963-1965 was produced using naphtha.

[44] There are discontinuous reports from the oil company in the period pre-1957 but they do not provide complete information. The only non-energy product that appears on sales is lubricants for the years 1940-1944, but I opt not to deduct once since a part of those sales could derive from imports. After 1944 lubricant production finished as a result of an agreement between the government and SACOR, in order to allow an increase of the fuel-oil production.

Contrary to coal, bunker correction is not a problem as oil supplies to foreign ships started when statistics already corrected for it. Figures for energetic crude oil and its derivatives are presented in the Appendix. In order to ensure comparability with other methods primary consumption of non-energy uses and non-energy crude oil are also presented[45].

Figure 6. Comparison of four oil accounting methods (1890-2006)



The figure bellow (Figure 6) shows the difference between four methods of accounting oil: excluding non-energy imports (Method 1.1.); excluding non-energy imports, but considering naphtha an energy vector (Method 1.2.); International Energy Agency method (Method 2); excluding non-energy imports and crude oil (Method 3).

In the period that precedes the installation of the oil business in the country, there is a difference of more than 15 per cent between methods 1-3 and method 2, which accounts for non-energy imports. In the first 20 years of refining, the differences between IEA method and the others are lower, due to the fact that fuel consumption grew at an accelerated rate,

[45] Net imports of non-energy products of oil include asphalts, oil waxes, paraffins, lubricants, solvents (after 1971) and propylene (after 1990). Natural asphalts are not considered.

diminishing the weight of non-energy derivatives. After the 1960s the difference between our default method and the others grew again to 6-9 per cent. Nowadays, the crude oil that is refined for non-energy products lowers method 3 in relation to method 1 by 11 per cent. Most of the imports of products not considered in method 3 are from naphtha, which makes methods 1.2 and 2 very similar.

3.3. Natural Gas

Although it is known that the Chinese had already used natural gas before 1000 BC for lighting, heating and cooking[46], the low density of the fuel made transportation and storage a difficult task, so it was normally treated as an undesirable residual. It was discovered in England in 1659, but due to the developments in manufacturing gas, was not used until 1958[47]. In the USA, after the late 1920s innovations in pipeline design, natural gas ceased to be confined to local use and began to be economically viable to transport as far as 1.000 miles in the mid 1930s[48]. After WW II there was a steady growth in the consumption of natural gas but it was only after the 1970s oil crisis that industrialized countries started to use it as an alternative to oil and coal. Natural Gas consumption has a very recent history in Portugal as the country lacks reserves. It was introduced in 1997 and consumption had grown to 12 per cent of all energy consumption by 2004. As the country does not have a tradition in the use of manufactured gas, significant investments in infrastructure have to be made. Nowadays 60 per cent of the natural gas is used to produce electricity and 30 per cent in manufacturing, especially in the ceramic industry. Substitution of natural gas for fossil fuels has been one of the

[46] Ray (1979).
[47] Warde (2007).
[48] Schurr and Netschert (1960).

main goals of Portuguese energy policy, especially in electricity production. This is because natural gas is, from all fossil fuels, the one that emits less CO_2 per energy unit. Natural gas consumption figures are taken from national energy balances[49].

3.4. Primary electricity[50]

Electricity is always a secondary form of energy, even if it is produced by water, wind or geo power. However, national statistics make a distinction between secondary electricity (produced by coal, oil, natural gas, firewood and wastes) and primary electricity (wind, hydro, solar, geo and nuclear). In this way, the hydro and wind power are not included under the sections "water" and "wind" although they could easily be so; we include them in this section for the sake of comparison with national sources. Primary electricity is simply computed as:

$$E = (H+G+N+W+P) * \frac{1}{i} + Imp - Exp$$

where:

E primary electricity
H hydroelectricity
G geoelectricity
N nuclear electricity
W wind electricity
P photovoltaic electricity
i efficiency
Imp electricity imports
Exp electricity exports

[49] www.dgge.pt
[50] App. I, 1, col. 8, and App. II, 7.

Portugal has never had nuclear energy. Geo, Wind and Photovoltaic electricity are all new ways of producing electricity so hydroelectricity is the only source where estimates are needed.

Until the end of the 1880s electricity use was confined to telegraphs, telephones, medical applications, lighthouses and private space lighting. The main streets of Lisbon started to be lit in 1889 by thermo-electricity. Regarding hydroelectricity, the first place to have public lighting from a water-power central (88 KW) was the small city of Vila Real in 1894. Before that year, we lack knowledge whether an auto-production central was built.

Detailed information about hydro-electricity production on the mainland is only possible in 1927[51]. In that year there were 59 hydro utilities that produced 54.7 GWh, representing 29 per cent of total electricity production (*Table 17).*

Table 17. Selected indicators, electricity

	Hydroelectricity			Thermoelectricity Total		
	n.	KW	GWh	n.	KW	GWh
Public Service	36	27, 815	45	104	66, 901	91.1
Auto-Production	23	5, 515	9.7	151	33, 925	41.2
Total	59	33, 330	54.7	255	100, 826	132.3

Source: DGSE.

Before 1927 we only have partial information about the electricity sector. For 1918 Enginner Apolinário compiled information on both the power of hydro and thermo utilities but did not include the factories that employed electricity for their own use. Apolinário records 18 hydro-electricity utilities on the mainland with 2,335 KW, 8 per cent of the 1927 values for public service. In 1923, a magazine published information on the denomination, localization and power of electric distribution companies, without reference to their energy input[52]. Comparing this information with the

[51] DGSE, Estatísticas das Instalações eléctricas, several years.
[52] Revista de Obras Públicas e Minas, 1923, p. 71.

official statistics of 1929 we are able to distinguish which ones produce hydroelectricity and which ones produce thermoelectricity. Hydro-electric power in that year amounted to 12,835 KW. Madureira and Baptista have compiled information on the initial power of the most important utilities (both public and private service)[53]. The reconstructions of hydroelectric power for 1923-1927 and 1894-1923, for the public service, and for 1894-1927 for the private service can be performed taking this information into account. As authors only report the main hydroelectric power plants only part of the increases in power is covered. I distribute the power difference in benchmark years assuming a constant growth rate. In order to calculate production, we need to know for how long the utilities were working. This not only depends on the consumer demand but also on the quantity of precipitation in each year. Apolinário estimates a use of 20 hours a day during 365 days a year to calculate the 1918 production, but this could not be further from truth. I assume an average of 1,700 hours/year consistent with the late 1920's statistics[54]. Since 1927 there have been official reports on hydroelectricity production[55] but until 1969 only mainland Portugal was included. Madeira has only had hydro-power since 1953 and statistics on production until 1961 can be found elsewhere[56]. I have connected the two benchmark production data years 1961 and 1970 for

[53] Madureira and Baptista (2002), pp. 12-14. If power is expressed in KVA conversion to KW follows such that 1 KVA= 0.8 KW.

[54] In the year of 1927 intensity of use was 1,700 hours; in 1928 2,022; in 1929, 2,038. I took the 1927 value as the early twenties were particularly dry years, see Marques, (1991). In order to check my assumptions on power (Island and Mainland) just divide estimate hydro-electricity production 1894-1926 (Appendix) by 1700.

[55] DGSE, several years. From 1971-2004 I used Energy Balances from DGE.

[56] MOP (1962). Only approximate values are given as they were taken from a graph: 1953 – 4.9 GWh; 1954 – 10.5 GWh; 1955- 12.7 GWh; 1956 – 14.5 GWh; 1957 -16.2 GWh, 1958 – 17. 8 GWh, 1959 – 19.8 GWh, 1960 – 21 GWh, 1961 – 21 GWh.

that island assuming a constant growth rate. Azores´ hydropower production until 1970 has to be reconstructed with based on power registers that can be found in Simões and online[57]. The power of Azores´ plants is multiplied by the time of use in mainland hydraulic plants. As the intensity of use of Azores´ power plants is systematically lower than mainland power plants during the 1970s, the estimated production is reduced by 20 per cent for the years 1951-1969[58].

In order to calculate primary energy we should account for the loss of energy at the turbines, which is not done in Energy Balances. In order to be consistent with both wind and water series, I assume, as Malanima, that 25 per cent of primary hydro-electricity was lost at the turbines before 1960 and 15 per cent after that date. Other sources of electricity are only present after 1980. I assume 40 per cent of efficiency for eolic production and an efficiency of 15 per cent for photovoltaic and geothermic production[59]. Net imports of electricity are added after 1927[60].

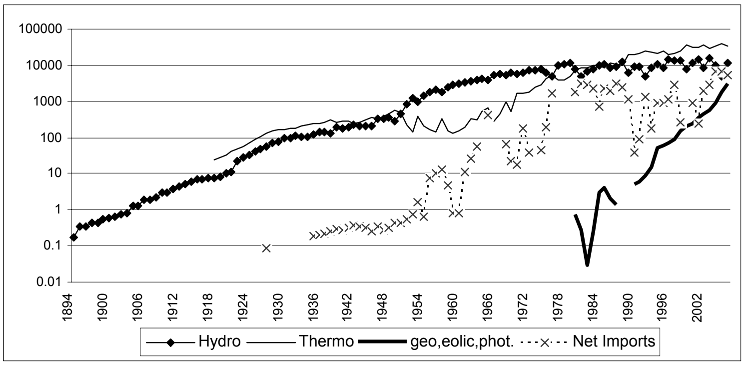
[57] Simões (1997) and www.arena.com.pt/hidrica.html. Power for 1923-1926 – 680 KW, 1927-1928 – 2,104 KW, 1929-1934 – 2,899 KW; 1935 – 1950 – 3,371 KW, 1951-1953 – 4,779, 1954-1965 6,531.2; 1966-1970 – 7,675 KW. Accumulated power since 1894 was 8,011 KW in 1966 but was reduced to 7,675 KW in order to match DGSE statistics for 1970. Conversion of 1 KVA =0.8 KW which can produce small differences between sources.

[58] 1970 Azores hydro production was 22.3 GWh. Applying the intensity of use in mainland Portugal (3,723 hours) to the installed power, the production of that islands would be 28.5 GWh. Correction is only applied to the years 1951-1970, when intensity of use varied from 2,500-4,000 hours.

[59] Eolic and photovoltaic electricity values suggested by Roth (2005).

[60] Net imports 1927-1970 and 1971-2006 from Figueira (2003) and from DGE (1971-2006).

Figure 7. Thermo, hydro, geo, eolic, photovoltaic electricity production and imports (1894-2006), log scale



Sources: See text and appendix. Negative values of net imports (1964, 1966-67, 1973, 1977-79 and 1999) are not shown in the graph.

There are three phases in hydroelectricity growth. Until the Second World War, hydroelectricity shares were 30-40 per cent of total electrical production. Investments in dams were left to the private sector. In the absence of strong urban centres, entrepreneurs did not respond, and what emerges into 1930s is a multiplicity of small thermo-power utilities. The 1950s and 1960s were the golden years of hydro-power, with strong governmental investment. At the end of the sixties there occurred a shift in investments, and large fuel plants were considered to be a better option. Thermo-electricity has been growing in importance ever since. In the last decade, drought years have contributed to irregularity of hydro-power production, which has to be supplemented by imports. There has been an increasing investment in renewable electricity other than hydro power. In 2005, wind accounted for more than 1/3 of hydroelectricity production. Other sources are still in an experimental period. Portugal inaugurated its first wave power plant in September 2008, which when completed will supply 15,000 families. The construction of the worlds biggest solar plant is planned for Moura, with a project power of 45 MW and the capacity to supply 30,000 homes.

3.5. Others[61]

This rubric includes energy use of sulphite liquors and bleaches (residuals from the paper industry), solid urban wastes and biogas. These energy sources are entirely consumed by the electricity and cogeneration power plants. Registers from solid urban wastes and biogas can be found in Energy balances after 1998. Sulphite liquor and dark bleach records came from Electrical Utilities Statistics after 1954[62] and from Energy Balances after 1971[63].

[61] App. I, 1, col. 9 and App. II, 8.

[62] DGSE, several years.

[63] After 1990, the inclusion of heat in energy balances led to a series break, resulting in an increase in sulphite liquor energy consumption.

4. Structure, trend and level

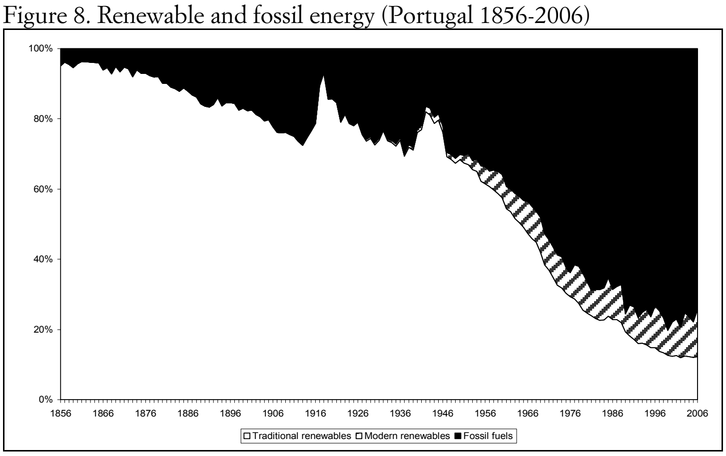
4. Structure, trend and level

4.1. Structure

The calculations performed in the section above allow a much more accurate picture of the energy system of the Portuguese economy in the period 1856-2006. For most of the period in study estimations surpass direct observable data. Naturally, the reliability of the data increases over time as society transits from a vegetable state to a mineral one. However, even if the exact level of firewood or animal energy remains conjectural, I believe that only radical shifts in the assumptions would change the estimates of the general level of energy consumption, or the structure of different energy carriers that made up that consumption.

In terms of structure, a major long-run transition, from traditional renewables towards fossil fuels, took place during the 150 years of the study (see Figure 8).

Figure 8. Renewable and fossil energy (Portugal 1856-2006)



Note: Traditional renewables includes firewood, muscle, water and wind energy. Modern renewables includes primary electricity, wastes and all the traditional renewables used for the production of thermal electricity.

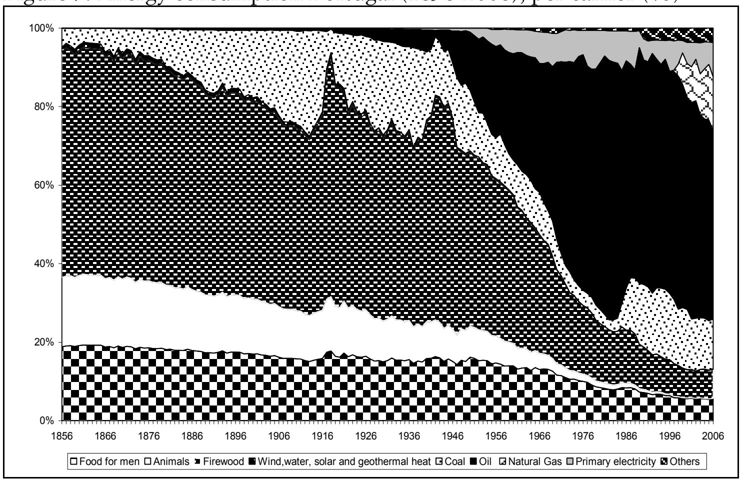
This transition progressed at different paces. Fossil fuel share increased from only 5 per cent in 1856 to about 28 per cent, on the eve of the World War I, but the interwar years were a period of stagnation in energy transition and on the eve of the World War II modern sources still accounted for only 30 per cent of the energy total. After World War II, there was a rapid expansion of fossil fuels and a stagnation of the traditional renewable energy basis. Fossil fuels accounted for 53 per cent of total energy in 1970 and peaked at 80 per cent in 2000. Subsequent to this major energy transition, another transition from fossil fuels towards "modern renewables" seems to be beginning to take shape in the 21st century. The expansion of modern renewables was visible after the 1950s, with the investment in hydro-utilities but stopped at the end of the 1970s. The oil shocks were not enough to modify the structure of energy consumption since they coincided with a period of spectacular increases in personal income that lead to the acquisition of home appliances and personal vehicles. However, the change of energy policy that took place in the 1990s with the signing of Kyoto Protocol, had an impact in recent years on the diversification and growth rate of modern renewables.

Table18. Composition of energy consumption in Portugal (1856-2006) (%)

	1856	1913	1950	1970	1990	2006
Food	17.0	15.1	16.2	11.6	7.2	5.5
Fodder for draught	17.6	11.7	8.0	2.9	0.8	0.1
Firewood & Others	57.4	44.7	44.2	25.2	13.5	11.1
Wind, water, heat	1.2	0.9	0.5	0.1	0.0	0.1
Coal	4.9	26.9	15.4	7.7	16.0	12.7
Oil	0.0	0.7	14.8	45.1	57.1	47.9
Natural Gas	0.0	0.0	0.0	0.0	0.0	13.7
Primary electricity	0.0	0.0	1.1	7.3	5.5	8.8

If we look at the energy structure in more detail (*Table 18*), there were very weak signals of an Industrial Revolution in Portugal in 1856. Firewood was the major energy carrier with 57 per cent followed by muscular energy which accounted for 35 per cent of the total. Water and wind supplied 1 per cent of the total and coal accounted for only 5 per cent. The first transition to be noticed occurred between 1880 and 1913. Coal expanded significantly, becoming the second most important energy carrier on the eve of World War I. This first expansion of modern energy carriers had less to do with substitution, and was mostly driven by urban industrialization and investments in railways, ports and town gas infrastructures. The transition towards coal was severely interrupted by the two World Wars. At the end of the thirties coal consumption was almost similar to 1913, and firewood was still the most dominant fuel.

Figure 9. Energy consumption Portugal (1856-2006), per carrier (%)



The second transition occurred only after World War II and coincided with a long period of economic growth and convergence to the European Core. In this period, oil and primary electricity expanded to most of the economy at an impressive rate. Oil became more important than coal in 1951, an early transition in European terms. However, it only surpassed firewood in 1965, which shows the importance of the informal sector of the economy for energy consumption. Due to environmental constraints, oil has been losing its share of the energy basket in favour of natural gas. There has been an increased interest in the promotion of renewable sources, but outcomes from these policies are still not evident.

The Portuguese energy transition can be compared with other nations, where the same methodology is employed to account for traditional energy carriers (*Table 19, 20 and 21).*

Table 19. Composition of Energy Consumption in 1850, Europe (%)

	1850					
	England & Wales	Sweden	Netherlands	Italy	Spain	Portugal
Muscle	7	25	38	41	50	35
Firewood	0	73	11	51	46	57
Wind, Water	2	<1	10	1	2	1
Fossil Fuels	91	2	41	7	2	5

Source: Gales et al. (2007) and Warde (2007).

Table 20. Composition of energy consumption in 1950, Europe (%)

	1950					
	England & Wales	Sweden	Netherlands	Italy	Spain	Portugal
Muscle	3	6	10	27	27	24
Firewood	0	21	0	17	12	44
Wind, Water	0	<1	0	0	0	1
Fossil Fuels	97	64	90	47	59	30
Primary electricity	0	9	0	10	2	1

Source: Gales et al. (2007) and Warde (2007).

Table 21. Composition of energy consumption in 2000, Europe (%)

	2000					
	England & Wales	Sweden	Netherlands	Italy	Spain	Portugal
Muscle	2	2	2	4	4	7
Firewood	0	23	0	2	0	11[1]
Fossil Fuels	89	40	88	88	88	77
Primary electricity	9	33	10	6	7	4

Source: Gales et al. (2007) and Warde (2007).

In 1850 the Portuguese energy structure contrasted with England and to a lesser extent with Netherlands, where the Industrial Revolution occurred sooner, but not with Spain,

[1] Includes others.

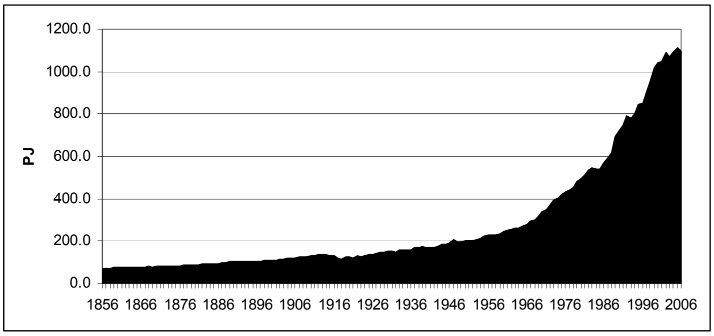
Italy or Sweden. The most important contrasting result was obtained in 1950, when the Portuguese energy structure was still 70 per cent dependent on firewood and muscle force, while Italy, Spain and Sweden have more than 60 per cent of their energy consumption satisfied with modern sources. This energy structure reflects also the structure of Portuguese society in 1950, when most of the population was employed in agriculture and the vast majority of the households lived in rural areas, without access to modern fuels.

On the other hand, in 2000, most of the nations (with the exception of Sweden, due to the abundance of natural resources) are very dependent on fossil fuels.

4.2. Trend and level

The previous reconstructions allow one to depict the long-term trend of energy consumption from a different perspective. Global energy consumption rose by a factor of 15 in 150 years with two distinctint phases as presented in Figure 10.

Figure 10. Energy consumption in Portugal 1856 – 2006 (PJ)



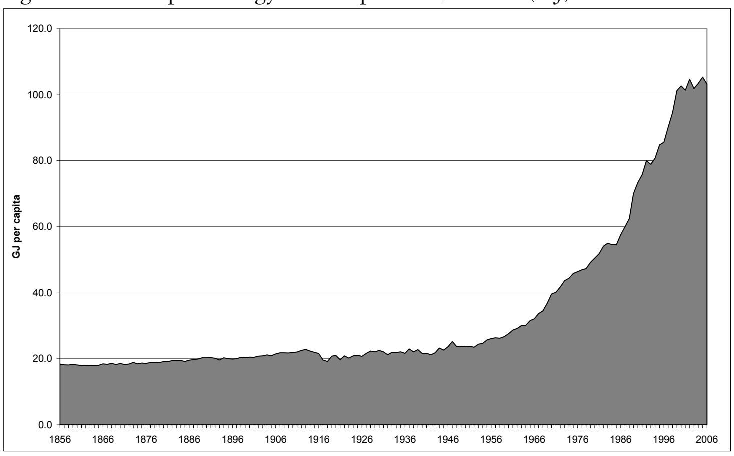
1. From the beginning of the period until the end of World War II: in 90 years, total primary energy consumption rose by slightly more than 1 per cent a year (1.1 per cent).

2. From the end of World War II to the end of the period: energy consumption rose at a much higher rate of almost 3 per cent a year (2.89 per cent).

The differences between the two phases are accentuated when measured in per capita terms, since the population grew at a higher rate (0.8 per cent a year) in the first period than in the second period (0.4 per cent).

As we can see above (Figure 11) population growth smoothes consumption increase, which in the very long-run grows only by a factor of 5.6. Until the end of World War II annual growth in per capita terms is very small (0.2 per cent) and is at the level of 20 GJ per capita/year. The vast majority of the increase in per capita energy therefore takes place after the end of the World Wars and is clearly associated with the late industrialization of the country. In that period per capita consumption grows at an annual rate of 2.5 per cent.

Figure 11. Per capita energy consumption 1856-2006 (GJ)



In the long-run the increase in final consumption of useful energy is much higher than this data (on primary energy consumption) suggests, due to great efficiency improvements in equipment and technical differences between different energy sources. In a traditional economy efficiencies were not much higher than 10-20 per cent. For example, traditional fireplaces were only capable of converting into heat about 10-20 per cent of the energy content of the firewood used in them. In the same way, the efficiency of a working animal hardly reaches 10 per cent as most of the fodder was used for keeping the animal alive, not producing mechanical energy. However, we cannot deny that in the long-run modern fuels have acquired higher efficiency rates than traditional ones. Nowadays, modern energy systems are credited with efficiencies of about 35 percent. The historical evolution of efficiency of thermo-electricity production, for example, seems to have been an important factor for gains in efficiency, as secondary energy increased its importance in the energy system. In Portugal, efficiencies in power generation were in the order of 3-4 per cent before World War I, 12 per cent in the 1930s and around 40 per cent in the 2000s[2]. However, it is interesting to note that general electricity production efficiency also depends on the composition of the sources used to generate electricity. In the Portuguese case, the peak of general efficiency was obtained at the end of the 1960s, due to the high share of hydro power, declining thereafter to 46-55 per cent in the 21st century. Some of the later decline in efficiency is also attributed to the introduction of cleaner but less efficient sources in electricity production: sun, wind and geothermal energy, for example. In the same way, in the very first phases of industrialization global energy efficiency might even have declined in some pioneer countries due to the introduction of fossil fuels. In fact, the very first steam engines had an efficiency of about 1-5 per cent, far less than muscle or water energy. When there were gains in global efficiency, they were not necessarily due to improvements in the modern energy system. For example, the improvement in 19th century Swedish energy efficiency can mostly be credited to improvements inside the

[2] Appendix I, 1, col. 8.

"traditional economy", such as the substitution of stoves for open fireplaces.

As both composition of the energy system and efficiency of the technology can affect levels of energy consumption at any given moment, it is interesting to compare the level of Portuguese per capita energy consumption in relation to attained per capita GDP in a broader context (*Table 22*).

Table 22. Per capita energy consumption at different per capita GDP levels

GDP 1990 $	1,100		1,500		3,000		6,000		12,000		18,000	
Countries	year	GJ	year	GJ	Year	GJ	year	GJ	Year	GJ	year	GJ
Engl. & W	1560	19	1682	31	1851	88	1936	138	1973	189	1997	176
Netherlands	1555	-	1616	-	1880	43	1951	69	1972	141	1994	174
Sweden	1800	47	1869	36	1911	57	1946	62	1969	165	1997	169
Germany	1830	12	1858	19	1903	71	1956	129	1974	178	1998	168
France	1820	18	1844	21	1907	53	1954	78	1971	139	1990	137
Italy	1820	-	1865	18	1916	22	1961	48	1978	113	1999	132
Spain	1852	15	1873	16	1957	35	1969	51	1990	89	2005	141
Portugal	**1886**	**20**	**1927**	**22**	**1961**	**29**	**1972**	**42**	**1997**	**86**	**-**	**-**

Note: These estimates use data from Maddison.
Source: Warde and Lindmark (2006) and author calculations.

Among the countries represented in Table 22, Portugal is has been in all the period the most backward country, the one that attained levels of GDP per capita later in time. Comparing Portugal with the most advanced economies at each per capita GDP level, it took for Portugal 326, 225 and 26 more years than England and Wales to reach a *per capita* GDP of $ 1,100, $ 1,500 and $ 3,000, respectively, and 28 more years than Sweden to reach a per capita GDP of $ 12,000. This hiatus suggests a strong possibility of leapfrogging, benefiting from a more efficient level of technology than the most advanced countries at each GDP level, which would be confirmed by lower levels of per capita energy consumption at the same GDP *per capita*. The advantages of being the later one in terms of stress for the environment are only partially confirmed by Table 22. As

Warde points out, English and Welsh energy consumption is consistently higher after $ 2,000 of income per capita than the rest of Europe due to the "pioneer factor" (obtaining high levels of income with still inefficient technologies) and the "vintage technology factor" (technology is not so easily changed after acquiring importance in the energy system). However, at lower GDP levels divergences result in radically different energy structures, climatic conditions, etc. At levels of $ 1,100 and the level of per capita energy consumption in Portugal is only lower than Sweden, known for high levels of energy consumption due to the very large firewood consumption in the household sector, mainly because of climate differences. At levels equal to or higher than $ 2,500, Portugal seems to benefit from the internation technological improvements in the stock of technology. Portugal attains $ 3,000 per capita at levels of consumption only higher than Italy and at levels of $ 6,000 and $ 12,000 is already the country with lower energy consumption levels.

4.3. Energy Intensity in the long-run

A widely used concept to evaluate the relationship between energy and product is the ratio between energy consumption (measured in calorific units) and Gross domestic product (measured in monetary units).

Comparing this ratio over time gives us a rough picture of the evolution of energy productivity. If the ratio increases over time, this means that the country in question needs more units of energy to produce one unit of GDP; if the ratio decreases, the inverse is true.

The need to understand the correlation between energy and growth emerged as a result of the oil crisis of the 1970s. The perception that energy was a scarce resource, and that economic growth could be at stake, motivated the carrying out of long-run studies about the evolution of the ratio between energy and GDP (energy intensity). When researchers analysed the one or two decadal data for energy and GDP for a few industrialized countries, it seemed that there was an almost perfect correlation between the two variables. In this way, there was a primary conviction that energy consumption was coupled with economic growth: the achievement of high product growth rates would only be possible through a proportional increase in energy consumption, and thus to a progressive and accelerating degradation of our planet's environment. The only way to decouple growth from the environment was through measures of conservation.

However, several studies first published during the 1990s began to show that these relations were not as simple as they were first believed to be, at least in a significant number of developed countries. Statistical data available for countries like the US, England, Canada, France and Japan indicated that the evolution of energy intensity assumed the shape of an inverted U with peaks in 1880, 1900, 1920, 1929 and 1970. This evidence led to a theorization of a general pattern of energy intensity evolution, dependent on the stage of development of each country. In a first phase of industrialization, the energy intensity will grow as a result of structural effects related to the transformation of an agriculture society into an industrial one. In this stage, countries invest in infra-structures and direct their productive structure to heavy industries. Economic growth depends on an intensification of energy use[3]. In a second stage, after an inefficiency peak, there is a decline in energy intensity that is explained by technological reasons (improvements in the efficiency of the energy chain), substitutions between energy carriers and by the transition of an industrial society to a service one, less energy intensive[4]. Concepts such as *dematerialization*, that is, decoupling materials from growth due to a transition to post-industrial growth, emerged. In this

[3] Percebois (1989).
[4] Idem

post-industrial growth scenario, materials become confined to replacement markets, the rate of recycling increases and a broad spectrum of new products such as processing equipment, and communications satellites replace the existing products and old materials[5]. All the countries will follow this path, and it is expected that developing countries will reach the peak of the inverted U-shaped curve with lower energy intensity levels than their predecessors due to the appropriation of new technologies[6]. With influential articles by Reddy and Goldemberg, Grossman and Krueger [7] and Shafik and Bandyopadhyay [8] the concept of an Environmental Kuznets Curve (EKC)[9] emerged and was applied to the field of pollutant emissions and energy. Their proponents argued that in earlier stages of development the environmental indicators improve but that, in later stages, structural changes to information technologies and improvement of environmental awareness lead to the gradual relative decline in environmental degradation[10].

In this formulation, more refined due to the existence of long-run data, there was an *historical context* in this EKC pattern of a relationship between economic growth and energy consumption, because the peak of inefficiency is reached at lower levels by catching-up countries; they can leapfrog, that is benefit from a different institutional and technological setting. It is a weak hypothesis of improvement of the environment; energy consumption or CO2 emissions can improve relative to GDP but can worsen in absolute terms.

[5] Bernardi and Gali (1993).

[6] Reddy and Goldemberg (1990).

[7] Grossman and Kruger (1991).

[8] Shafik.

[9] Environmental Kuznets Curve is inspired in the work of Kuznets that theorized a U-shapped relation between inequality and personal income, also with basis in empirical data.

[10] Stern (2004).

This theorization has been criticized by some subsequent studies. In the energy field, Pagá e Gürer[11] (1996) noticed that developing countries relied mainly on non-commercial fuels (such as firewood, dung and crop residues, animal and human energy, water and wind) for their energy consumption. This was never accounted for in the statistics, which included only oil, coal, natural gas and electricity, i.e., modern fuels. Without traditional fuels it was impossible to distinguish between energy consumption increase and energy substitutions. Long-run statistics in developed countries also needed to account for non-commercial sources. A new challenge was posed to historians; as long-run commercial data was available on statistics, historians needed a sound methodology to produce yearly data on this non-commercial energy, which would allow coal or oil to be added to food,wind and animal energy in the same unit and same level of specification. Some of the long-run studies that include non-commercial energy were recently published and are available to some European countries[12]. These studies do not confirm the hypothesis of an EKC as a general pattern of development, since only UK´s energy intensity exhibits an EKC shape. Most of the case studies show a continuous decline in energy intensity, the result of continuous technical change surpassing the effects of structural change (industrialization).

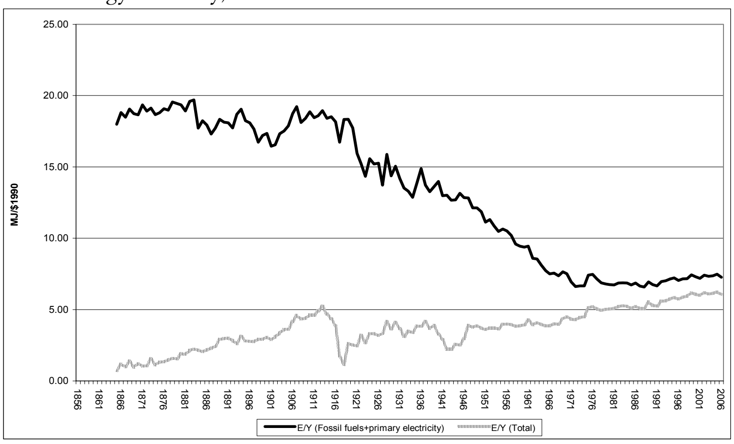
In the Portuguese case, whether including or not including traditional energy carriers, there is no evidence of an Environmental Kuznets Curve (Figure 12). In the case where only modern energy carriers are considered, there is a long-run growth in energy intensity with a break in trend

[11] Pagá and Gurer (1996).

[12] Kander (2002) for Sweden; Malanima (2006a) for Italy, Rubio (2005) for Spain, Gales (2007) for Netherlands, Warde (2007) for England and Wales. For different methodology, see for example Kraussman.; Schandl and Schulz (2003) on Austria or UK or Kunnas and Myllintaus (2007) for Finland.

during the interwar period. The growth of commercial energy intensity is very high (ca. 3 per cent year) until World War I due to the fact that the levels of diffusion of modern energy were low. After World War II increases in energy intensity were at 0.5 per cent a year. After the oil shocks, and against European trends, Portuguese energy intensity grew at a rate of 0.9 per cent a year.

Figure 12. Energy intensity 1856-2006 (Commercial energy intensity vs Total Energy Intensity)



If, on the other hand, we consider modern and traditional energy carriers together, three phases can be observed. The first is the period until the First World War, when energy intensity remains at the level of 18-20 MJ per dollar of GDP; the second is from 1920 to 1973 where energy intensity drops spectacularly to 6.68 MJ per dollar produced and a third phase is observed after 1973 with an increase in energy intensity to levels of 8 MJ per dollar. What was the cause of the decrease of energy intensity before 1973 and subsequent increase after the oil shocks? Energy intensity can be affected by many factors such as technological efficiency, energy mix, economic structure or trade patterns, and it would require more sophisticated analysis to determine the reasons for the variation of the ratio. Despite all this, certain characteristics allow us to distinguish the decreasing trend from the upward trend. During most of the part of the decreasing period non-productive energy dominates the energy system. In this agrarian society fossil fuels are inexistent and most of the energy is consumed within the household sector to satisfy the basic needs of food and shelter. In 1856, household energy (excluding food) had an importance of 57 per cent in the energy system, a position that had only slowly declined in importance until the 1950s, 40 per cent, when 49 per cent of the population was still employed in the agricultural sector. In this phase it is very likely that the growth rate of this type of energy is lower than GDP growth, especially if GDP grows at a higher rate than population. Because of the high share of household energy on total energy consumption, the transition from biomass (less efficient) to fossil fuels (more efficient) in the household sector that took place during most of the 20t^h century was very important in determining the declining growth rate of energy intensity. However, as the country develops, changes within the formal sectors start to be more important. Within those sectors energy intensity is still increasing. This is not only applicable to Portugal. Spain showed some of this evidence after the 1990s and Italy also experienced a short period of increasing energy intensities in the period 1960-1973. This suggests that after major transitions within the informal sector have occurred, a period of structural changes within the formal economy can offset gains in efficiency.

It is interesting to compare the Portuguese levels of energy intensity in relation to the European Countries for which long-run data exists. Did Portugal, being the most backward of the set of countries in Table 23, attain a level of GDP per capita with higher energy efficiency?

Table 23. Energy intensity (MJ/$ 1990 PPP) at different per capita GDP levels ($ 1990 PPP)

GDP (1990 $)	1100	1500	3000	6000	12000	18000
Engl. & W	19.4	20.7	27.5	21.1	15	8.8
Netherlands			13	11.5	12.3	9.6
Sweden	80.8	38.1	25	12.1	13.9	9.4
Germany		16.4	25.5	19.9	14.8	9.3
France	15.4	13.1	16.5	12.9	11.5	7.6
Italy		11.1	6.7	7.2	9.2	7.1
Spain	17.7	11.9	11.6	8.5	7.3	7.9
Portugal	17.9	13.7	9.4	6.6	7.2	-

Source: LEG database.

The results in the table point to the fact that Portugal might indeed have benefited from being the most backward economy. At the level of $ 6,000 PPP and $ 12,000 PPP Portugal had the lowest energy intensity of the group of 8 European countries. There is also the question of how Portuguese energy intensity is going to behave in the future. With a level of $ 14,000 PPP per capita in 2006, the Portuguese economy is diverging in the last decade from the rest of Europe, while energy intensity grew to a level of 7.3 MJ/$ 1990. If energy intensity continues to grow, it is very likely that the Portuguese economy attain at higher energy intensity levels than Italy or France at $ 18,000 PPP.

How does Portuguese energy intensity compare with other European countries in the last 35 years? In this period energy intensity has decreased in most of the European economies. Portugal had one of the lowest energy intensity in Europe in 1971, along with Spain and Greece. In the beginning of the period intensities ranged from 89 toe per $ 2,000 PPP in Greece to 584 toe per $ 2,000 PPP in Luxemburg (Table 24).

The three low energy intensity economies of Portugal, Spain and Greece were the only ones that increased their energy intensity during the period 1971-1990. A part of the decreases in the most advanced economies was due to a process of substitution of high energy intensive industrial branches with lighter ones, following the oil shocks of the 1970s. East European economies, which were very high energy intensive, due to a very heavy industrial composition, spectacularly decreased their energy intensity by a process of transition to a market economy. While Greece followed the path of all the other European economies after 1990, Portugal and Spain are still increasing their energy intensities. In 2007, the differences in the level of energy intensity were smoother than in 1971. Energy intensity now ranges from 98 toe/$ in Ireland to 201 toe/$ 2,000 in Finland. Portugal now has more than the average energy intensity of OECD Europe, being more inefficient than Spain, Sweden, United Kingdom, Italy, Ireland, Greece, France, Denmark and Austria.

Table 24. Energy intensity in some European countries in 1971, 1990 and 2007 (koe per product in 2000 dollars PPP)

	1971	1990	2007
Austria	0.177	0.138	0.124
Belgium	0.288	0.185	0.157
Czech Republic	0.439	0.312	0.197
Denmark	0.240	0.151	0.118
Finland	0.316	0.232	0.201
France	0.218	0.137	0.111
Germany	0.288	0.190	0.134
Greece	0.089	0.140	0.114
Hungary	0.282	0.226	0.151
Ireland	0.280	0.187	0.098
Italy	0.154	0.119	0.120
Luxembourg	0.584	0.248	0.147
Netherlands	0.244	0.194	0.156
Poland	0.410	0.358	0.185
Portugal	**0.120**	**0.131**	**0.135**
Slovak Republic	0.383	0.351	0.173
Spain	0.120	0.126	0.128
Sweden	0.268	0.177	0.129
United Kingdom	0.268	0.170	0.120

Source: IEA, 2008.

Note: 1971 CRW Portuguese data is corrected; nuclear energy measured by heat content.

List of abbreviations

BP	Banco de Portugal
DGE	Direcção Geral de Energia
EDP	Electricidade de Portugal
FAO	Food and Agriculture Organization
INE	Instituto Nacional de Estatística
MOPCI	Ministério das Obras Públicas, Comércio e Indústria

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APPENDIX

I

Aggregate Series

1. Energy consumption in Portugal 1856-2006

	1	2	3	4	5	6	7	8	9	
	Food for men	**Animals**	**Firewood**	**Wind & Water**	**Coal**	**Oil**	**Natural Gas**	**Primary electricity**	**Others**	**TOTAL**
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1856	13.716	12.852	41.797	0.907	3.560					72.832
1857	13.816	12.935	42.076	0.922	2.805					72.553
1858	13.916	13.018	41.711	0.937	3.319					72.902
1859	14.016	13.101	42.174	0.951	4.020					74.263
1860	14.116	13.185	42.239	0.966	3.218					73.724
1861	14.216	13.268	42.492	0.981	2.741	0.000				73.698
1862	14.316	13.351	42.949	0.996	2.813	0.000				74.426
1863	14.417	13.434	43.401	1.010	2.912	0.000				75.174
1864	14.517	13.518	43.542	1.025	3.002	0.000				75.604
1865	14.603	13.601	43.759	1.026	3.092	0.029				76.110
1866	14.690	13.684	44.178	1.027	4.768	0.048				78.396
1867	14.777	13.768	44.393	1.029	4.165	0.062				78.194
1868	14.865	13.851	44.533	1.030	5.688	0.077				80.044
1869	14.953	13.935	44.766	1.031	3.888	0.150				78.722
1870	15.042	14.018	45.182	1.032	5.196	0.166				80.637
1871	15.131	14.067	45.268	1.034	4.110	0.119				79.730
1872	15.221	14.117	45.905	1.035	4.499	0.134				80.910
1873	15.312	14.166	46.417	1.036	6.542	0.161				83.634
1874	15.403	14.216	46.618	1.037	4.788	0.191				82.253
1875	15.494	14.265	46.976	1.038	5.781	0.128				83.683
1876	15.587	14.315	46.955	1.040	5.746	0.162				83.804
1877	15.679	14.365	47.574	1.041	6.370	0.217				85.245
1878	15.772	14.415	47.636	1.042	6.732	0.248				85.845
1879	15.930	14.465	48.092	1.043	6.571	0.305				86.405
1880	16.088	14.515	48.322	1.044	8.436	0.301				88.706
1881	16.248	14.565	48.763	1.041	8.468	0.361				89.446
1882	16.410	14.615	49.514	1.038	9.713	0.340				91.631
1883	16.574	14.666	49.479	1.034	10.283	0.238				92.273
1884	16.739	14.716	49.824	1.031	10.975	0.418				93.703
1885	16.905	14.767	49.833	1.041	10.026	0.397				92.969
1886	17.074	14.817	50.940	1.049	11.156	0.413				95.448
1887	17.244	14.868	51.282	1.062	12.443	0.433				97.332
1888	17.415	14.919	51.795	1.075	13.182	0.454				98.840
1889	17.588	14.970	51.885	1.089	15.524	0.480				101.536
1890	17.763	15.021	51.886	1.105	16.312	0.534				102.621
1891	17.870	15.072	52.383	1.133	16.739	0.544				103.741
1892	17.978	15.124	52.595	1.162	15.847	0.620				103.325
1893	18.086	15.175	52.951	1.190	13.608	0.603				101.612
1894	18.194	15.226	53.601	1.218	16.607	0.641		0.001		105.489
1895	18.304	15.278	53.845	1.246	15.552	0.597		0.002		104.823
1896	18.414	15.329	53.988	1.274	15.590	0.576		0.002		105.173
1897	18.524	15.381	54.528	1.298	16.000	0.623		0.002		106.356
1898	18.635	15.433	54.888	1.330	18.614	0.618		0.002		109.520
1899	18.747	15.485	55.380	1.354	17.916	0.644		0.003		109.529
1900	18.860	15.537	55.773	1.331	19.097	0.597		0.003		111.198
1901	19.016	15.589	56.245	1.317	18.851	0.703		0.003		111.723
1902	19.173	15.641	57.093	1.320	20.851	0.647		0.004		114.728
1903	19.332	15.693	57.349	1.292	21.814	0.736		0.004		116.220
1904	19.492	15.746	57.922	1.272	23.899	0.627		0.006		118.963
1905	19.653	15.798	57.853	1.236	23.403	0.679		0.006		118.628

(segue)

	1	2	3	4	5	6	7	8	9	
	Food for men	**Animals**	**Firewood**	**Wind & Water**	**Coal**	**Oil**	**Natural Gas**	**Primary electricity**	**Others**	**TOTAL**
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1906	19.816	15.851	58.313	1.226	26.599	0.702		0.009		122.515
1907	19.980	15.885	58.749	1.207	29.258	0.742		0.009		125.830
1908	20.146	15.919	59.278	1.193	29.713	0.743		0.011		127.002
1909	20.312	15.952	59.645	1.226	29.681	0.757		0.014		127.587
1910	20.481	15.984	60.248	1.216	30.692	1.084		0.015		129.720
1911	20.620	15.987	60.639	1.232	31.728	1.086		0.019		131.311
1912	20.611	15.990	61.143	1.215	34.716	0.817		0.021		134.514
1913	20.602	15.993	61.115	1.196	36.673	0.967		0.025		136.572
1914	20.593	15.996	61.995	1.179	33.223	0.714		0.029		133.730
1915	20.584	15.999	63.023	1.127	30.203	0.695		0.033		131.665
1916	20.575	16.001	64.399	1.128	26.722	0.992		0.035		129.852
1917	20.566	16.004	68.131	1.080	11.126	1.025		0.036		117.969
1918	20.557	16.007	70.889	1.084	6.856	0.349		0.037		115.778
1919	20.547	16.010	69.854	1.100	16.445	1.400		0.039		125.395
1920	20.538	16.013	71.252	1.099	16.354	1.709		0.049		127.014
1921	20.788	16.016	64.249	1.094	16.923	1.590		0.052		120.712
1922	21.041	16.019	63.858	1.119	25.076	1.853		0.109		129.074
1923	21.297	16.021	64.731	1.109	21.450	2.128		0.138		126.874
1924	21.557	16.024	65.778	1.119	25.695	2.348		0.159		132.680
1925	21.819	16.027	66.777	1.090	27.195	2.224		0.201		135.334
1926	22.085	16.034	67.536	1.109	25.213	2.698		0.231		134.906
1927	22.354	16.042	68.120	1.102	31.155	3.096		0.280		142.148
1928	22.626	16.049	70.260	1.120	34.299	4.298		0.347		148.999
1929	22.901	16.056	71.266	1.124	33.271	4.225		0.381		149.225
1930	23.180	16.063	71.973	1.095	36.679	4.862		0.463		154.315
1931	23.441	16.071	72.568	1.135	34.149	4.912		0.480		152.755
1932	23.705	16.078	73.355	1.077	29.010	4.868		0.523		148.616
1933	23.972	16.085	74.090	1.074	34.630	5.537		0.494		155.883
1934	24.242	16.092	74.147	1.084	34.695	6.474		0.519		157.253
1935	24.515	16.028	74.950	1.013	36.678	6.995		0.589		160.768
1936	24.791	15.964	76.351	1.033	33.783	6.847		0.665		159.433
1937	25.070	15.899	77.402	0.996	43.308	7.904		0.699		171.279
1938	25.352	15.835	78.243	0.968	37.482	8.246		0.632		166.758
1939	25.873	15.771	81.380	0.957	39.902	8.825		0.916		173.625
1940	26.404	15.707	84.578	0.946	28.902	9.293		0.894		166.723
1941	26.851	15.725	87.547	0.952	28.663	8.273		0.957		168.969
1942	27.304	15.744	94.562	0.953	24.867	2.679		1.083		167.191
1943	27.763	15.763	98.503	0.962	24.598	4.865		1.018		173.472
1944	28.228	15.781	104.191	0.961	26.303	10.248		0.988		186.701
1945	28.699	15.800	102.464	0.958	24.953	9.078		0.971		182.924
1946	29.176	15.819	102.714	0.957	26.754	15.779		1.563		192.762
1947	29.660	15.837	98.372	0.911	36.887	24.656		1.613		207.936
1948	30.150	15.856	88.334	0.951	32.325	26.934		1.741		196.291
1949	30.008	15.875	88.540	0.919	35.712	26.546		1.355		198.956
1950	32.288	15.893	88.278	0.920	30.691	29.603		2.145		199.819
1951	32.105	15.912	87.568	0.908	27.186	34.191		3.945		201.815
1952	30.617	15.931	87.417	0.896	22.564	37.522		5.783		200.729
1953	32.215	15.949	88.785	0.861	26.362	40.589		4.863		209.623
1954	32.394	15.968	89.430	0.854	22.169	44.632		7.075		212.522
1955	32.191	15.987	89.474	0.848	23.355	50.862		8.434	0.796	221.948

(segue)

	1	2	3	4	5	6	7	8	9	
	Food for men	**Animals**	**Firewood**	**Wind & water**	**Coal**	**Oil**	**Natural Gas**	**Primary electricity**	**Others**	**TOTAL**
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1956	33.300	15.578	90.120	0.844	23.595	52.675		9.942	0.835	226.887
1957	33.138	15.169	90.651	0.832	27.978	52.296		9.020	0.810	229.893
1958	31.916	14.759	90.011	0.817	24.044	55.425		12.208	0.651	229.831
1959	32.875	14.350	90.446	0.809	21.415	60.919		13.912	0.858	235.585
1960	34.195	13.941	91.656	0.800	21.565	66.113		15.076	0.961	244.307
1961	33.345	13.532	90.155	0.781	27.045	72.539		14.684	1.120	253.201
1962	34.443	13.123	89.302	0.758	25.375	77.343		15.129	1.137	256.609
1963	35.613	12.714	87.073	0.735	28.863	80.068		17.326	1.231	263.623
1964	33.687	12.305	86.460	0.715	28.155	82.861		18.008	1.474	263.664
1965	37.274	11.896	85.380	0.690	27.492	91.695		18.593	2.308	275.327
1966	36.381	11.487	83.769	0.576	29.991	91.331		22.647	2.699	278.881
1967	38.566	11.077	83.907	0.557	28.064	103.263		23.317	3.089	291.841
1968	38.963	10.668	83.503	0.535	25.290	112.674		22.561	3.499	297.692
1969	40.041	10.259	82.087	0.513	28.297	124.188		27.131	4.257	316.771
1970	39.306	9.850	80.834	0.493	25.967	153.089		24.859	4.743	339.140
1971	40.245	9.441	78.895	0.483	19.808	170.465		26.933	3.219	349.490
1972	40.558	9.032	78.005	0.467	17.472	190.952		30.433	1.529	368.448
1973	41.068	8.824	77.193	0.455	20.397	209.174		31.113	2.251	390.475
1974	42.640	8.589	76.650	0.440	16.110	222.580		33.573	1.888	402.470
1975	42.940	8.355	76.271	0.426	16.671	246.488		27.984	2.567	421.702
1976	43.185	8.120	75.200	0.412	16.388	259.147		26.913	2.517	431.883
1977	43.280	7.885	75.853	0.404	16.792	256.357		40.438	2.582	443.591
1978	41.531	7.650	74.975	0.394	18.098	263.097		45.240	2.536	453.522
1979	41.094	7.416	73.643	0.386	18.177	287.906		46.932	2.876	478.429
1980	41.943	7.301	73.377	0.377	17.667	313.440		40.792	3.119	498.014
1981	42.002	7.186	73.132	0.362	15.489	336.212		33.128	3.216	510.727
1982	42.472	7.071	73.819	0.066	13.527	351.981		40.268	3.641	532.844
1983	42.550	6.956	73.383	0.064	16.327	356.472		42.899	4.225	542.878
1984	43.129	6.841	72.666	0.066	17.829	349.084		44.499	4.080	538.196
1985	45.157	6.727	76.506	0.064	32.564	318.685		54.141	4.100	537.944
1986	47.408	6.612	76.644	0.062	60.786	328.583		43.025	4.440	567.560
1987	49.707	6.497	80.028	0.041	79.215	321.815		49.835	4.799	591.937
1988	49.920	6.382	79.695	0.039	87.394	326.575		60.722	5.029	615.756
1989	50.431	6.267	77.797	0.036	107.501	414.833		29.822	4.836	691.523
1990	51.865	5.906	77.850	0.032	115.571	413.637		39.657	19.731	724.249
1991	51.897	5.546	75.980	0.028	121.680	428.579		39.345	24.927	747.982
1992	52.209	5.185	75.258	0.026	123.493	482.007		26.538	24.686	789.401
1993	52.959	4.824	74.445	0.023	131.562	454.253		38.001	24.106	780.173
1994	53.567	4.463	72.939	0.013	139.345	455.878		49.756	25.110	801.072
1995	53.786	4.103	73.781	0.012	150.883	493.678		40.076	27.142	843.460
1996	54.173	3.742	74.825	0.011	143.625	482.441		68.079	25.927	852.823
1997	52.721	3.381	75.467	0.011	147.062	523.411	3.625	67.519	29.266	902.463
1998	55.263	3.020	75.038	0.756	135.316	563.057	29.295	58.061	28.976	948.781
1999	57.540	2.659	75.590	0.776	156.886	580.230	81.871	31.678	32.592	1019.823
2000	58.181	2.351	74.527	0.797	159.649	562.385	89.615	55.793	38.483	1041.780
2001	59.268	2.215	74.743	0.808	134.017	577.244	94.927	65.746	37.836	1046.804
2002	59.497	2.078	75.384	0.829	146.557	603.565	114.842	46.591	40.223	1089.566
2003	59.881	1.942	77.067	0.850	140.468	551.659	110.897	83.948	40.356	1067.069
2004	60.193	1.806	80.077	0.888	141.306	552.524	138.854	74.969	38.620	1089.236
2005	60.424	1.669	80.326	0.959	140.209	569.450	157.469	63.303	40.021	1113.830
2006	60.593	1.533	81.295	1.382	138.597	524.367	150.501	95.824	40.624	1094.715

2. The structure of Energy Consumption in Portugal, 1856-2006 (percentages)

	Food for men %	Animals %	Firewood %	Wind & Water %	Coal %	Oil (energy uses) %	Natural Gas %	Primary electricity %	Others %
1856	18.83	17.65	57.39	1.25	4.89	0.00	0.00	0.00	0.00
1857	19.04	17.83	57.99	1.27	3.87	0.00	0.00	0.00	0.00
1858	19.09	17.86	57.22	1.29	4.55	0.00	0.00	0.00	0.00
1859	18.87	17.64	56.79	1.28	5.41	0.00	0.00	0.00	0.00
1860	19.15	17.88	57.29	1.31	4.36	0.00	0.00	0.00	0.00
1861	19.29	18.00	57.66	1.33	3.72	0.00	0.00	0.00	0.00
1862	19.24	17.94	57.71	1.34	3.78	0.00	0.00	0.00	0.00
1863	19.18	17.87	57.73	1.34	3.87	0.00	0.00	0.00	0.00
1864	19.20	17.88	57.59	1.36	3.97	0.00	0.00	0.00	0.00
1865	19.19	17.87	57.49	1.35	4.06	0.04	0.00	0.00	0.00
1866	18.74	17.46	56.35	1.31	6.08	0.06	0.00	0.00	0.00
1867	18.90	17.61	56.77	1.32	5.33	0.08	0.00	0.00	0.00
1868	18.57	17.30	55.64	1.29	7.11	0.10	0.00	0.00	0.00
1869	18.99	17.70	56.87	1.31	4.94	0.19	0.00	0.00	0.00
1870	18.65	17.38	56.03	1.28	6.44	0.21	0.00	0.00	0.00
1871	18.98	17.64	56.78	1.30	5.16	0.15	0.00	0.00	0.00
1872	18.81	17.45	56.74	1.28	5.56	0.17	0.00	0.00	0.00
1873	18.31	16.94	55.50	1.24	7.82	0.19	0.00	0.00	0.00
1874	18.73	17.28	56.68	1.26	5.82	0.23	0.00	0.00	0.00
1875	18.52	17.05	56.14	1.24	6.91	0.15	0.00	0.00	0.00
1876	18.60	17.08	56.03	1.24	6.86	0.19	0.00	0.00	0.00
1877	18.39	16.85	55.81	1.22	7.47	0.25	0.00	0.00	0.00
1878	18.37	16.79	55.49	1.21	7.84	0.29	0.00	0.00	0.00
1879	18.44	16.74	55.66	1.21	7.60	0.35	0.00	0.00	0.00
1880	18.14	16.36	54.47	1.18	9.51	0.34	0.00	0.00	0.00
1881	18.17	16.28	54.52	1.16	9.47	0.40	0.00	0.00	0.00
1882	17.91	15.95	54.04	1.13	10.60	0.37	0.00	0.00	0.00
1883	17.96	15.89	53.62	1.12	11.14	0.26	0.00	0.00	0.00
1884	17.86	15.71	53.17	1.10	11.71	0.45	0.00	0.00	0.00
1885	18.18	15.88	53.60	1.12	10.78	0.43	0.00	0.00	0.00
1886	17.89	15.52	53.37	1.10	11.69	0.43	0.00	0.00	0.00
1887	17.72	15.28	52.69	1.09	12.78	0.44	0.00	0.00	0.00
1888	17.62	15.09	52.40	1.09	13.34	0.46	0.00	0.00	0.00
1889	17.32	14.74	51.10	1.07	15.29	0.47	0.00	0.00	0.00
1890	17.31	14.64	50.56	1.08	15.90	0.52	0.00	0.00	0.00
1891	17.23	14.53	50.49	1.09	16.13	0.52	0.00	0.00	0.00
1892	17.40	14.64	50.90	1.12	15.34	0.60	0.00	0.00	0.00
1893	17.80	14.93	52.11	1.17	13.39	0.59	0.00	0.00	0.00
1894	17.25	14.43	50.81	1.15	15.74	0.61	0.00	0.00	0.00
1895	17.46	14.57	51.37	1.19	14.84	0.57	0.00	0.00	0.00
1896	17.51	14.58	51.33	1.21	14.82	0.55	0.00	0.00	0.00
1897	17.42	14.46	51.27	1.22	15.04	0.59	0.00	0.00	0.00
1898	17.02	14.09	50.12	1.21	17.00	0.56	0.00	0.00	0.00
1899	17.12	14.14	50.56	1.24	16.36	0.59	0.00	0.00	0.00
1900	16.96	13.97	50.16	1.20	17.17	0.54	0.00	0.00	0.00
1901	17.02	13.95	50.34	1.18	16.87	0.63	0.00	0.00	0.00
1902	16.71	13.63	49.76	1.15	18.17	0.56	0.00	0.00	0.00
1903	16.63	13.50	49.35	1.11	18.77	0.63	0.00	0.00	0.00
1904	16.39	13.24	48.69	1.07	20.09	0.53	0.00	0.01	0.00
1905	16.57	13.32	48.77	1.04	19.73	0.57	0.00	0.01	0.00

(segue)

	Food for men %	Animals %	Firewood %	Wind & Water %	Coal %	Oil (energy uses) %	Natural Gas %	Primary electricity %	Others %
1906	16.17	12.94	47.60	1.00	21.71	0.57	0.00	0.01	0.00
1907	15.88	12.62	46.69	0.96	23.25	0.59	0.00	0.01	0.00
1908	15.86	12.53	46.68	0.94	23.40	0.59	0.00	0.01	0.00
1909	15.92	12.50	46.75	0.96	23.26	0.59	0.00	0.01	0.00
1910	15.79	12.32	46.44	0.94	23.66	0.84	0.00	0.01	0.00
1911	15.70	12.18	46.18	0.94	24.16	0.83	0.00	0.01	0.00
1912	15.32	11.89	45.45	0.90	25.81	0.61	0.00	0.02	0.00
1913	15.09	11.71	44.75	0.88	26.85	0.71	0.00	0.02	0.00
1914	15.40	11.96	46.36	0.88	24.84	0.53	0.00	0.02	0.00
1915	15.63	12.15	47.87	0.86	22.94	0.53	0.00	0.03	0.00
1916	15.85	12.32	49.59	0.87	20.58	0.76	0.00	0.03	0.00
1917	17.43	13.57	57.75	0.92	9.43	0.87	0.00	0.03	0.00
1918	17.76	13.83	61.23	0.94	5.92	0.30	0.00	0.03	0.00
1919	16.39	12.77	55.71	0.88	13.11	1.12	0.00	0.03	0.00
1920	16.17	12.61	56.10	0.87	12.88	1.35	0.00	0.04	0.00
1921	17.22	13.27	53.22	0.91	14.02	1.32	0.00	0.04	0.00
1922	16.30	12.41	49.47	0.87	19.43	1.44	0.00	0.08	0.00
1923	16.79	12.63	51.02	0.87	16.91	1.68	0.00	0.11	0.00
1924	16.25	12.08	49.58	0.84	19.37	1.77	0.00	0.12	0.00
1925	16.12	11.84	49.34	0.81	20.09	1.64	0.00	0.15	0.00
1926	16.37	11.89	50.06	0.82	18.69	2.00	0.00	0.17	0.00
1927	15.73	11.29	47.92	0.77	21.92	2.18	0.00	0.20	0.00
1928	15.19	10.77	47.15	0.75	23.02	2.88	0.00	0.23	0.00
1929	15.35	10.76	47.76	0.75	22.30	2.83	0.00	0.26	0.00
1930	15.02	10.41	46.64	0.71	23.77	3.15	0.00	0.30	0.00
1931	15.35	10.52	47.51	0.74	22.36	3.22	0.00	0.31	0.00
1932	15.95	10.82	49.36	0.72	19.52	3.28	0.00	0.35	0.00
1933	15.38	10.32	47.53	0.69	22.22	3.55	0.00	0.32	0.00
1934	15.42	10.23	47.15	0.69	22.06	4.12	0.00	0.33	0.00
1935	15.25	9.97	46.62	0.63	22.81	4.35	0.00	0.37	0.00
1936	15.55	10.01	47.89	0.65	21.19	4.29	0.00	0.42	0.00
1937	14.64	9.28	45.19	0.58	25.28	4.61	0.00	0.41	0.00
1938	15.20	9.50	46.92	0.58	22.48	4.94	0.00	0.38	0.00
1939	14.90	9.08	46.87	0.55	22.98	5.08	0.00	0.53	0.00
1940	15.84	9.42	50.73	0.57	17.34	5.57	0.00	0.54	0.00
1941	15.89	9.31	51.81	0.56	16.96	4.90	0.00	0.57	0.00
1942	16.33	9.42	56.56	0.57	14.87	1.60	0.00	0.65	0.00
1943	16.00	9.09	56.78	0.55	14.18	2.80	0.00	0.59	0.00
1944	15.12	8.45	55.81	0.51	14.09	5.49	0.00	0.53	0.00
1945	15.69	8.64	56.01	0.52	13.64	4.96	0.00	0.53	0.00
1946	15.14	8.21	53.29	0.50	13.88	8.19	0.00	0.81	0.00
1947	14.26	7.62	47.31	0.44	17.74	11.86	0.00	0.78	0.00
1948	15.36	8.08	45.00	0.48	16.47	13.72	0.00	0.89	0.00
1949	15.08	7.98	44.50	0.46	17.95	13.34	0.00	0.68	0.00
1950	16.16	7.95	44.18	0.46	15.36	14.82	0.00	1.07	0.00
1951	15.91	7.88	43.39	0.45	13.47	16.94	0.00	1.95	0.00
1952	15.25	7.94	43.55	0.45	11.24	18.69	0.00	2.88	0.00
1953	15.37	7.61	42.35	0.41	12.58	19.36	0.00	2.32	0.00
1954	15.24	7.51	42.08	0.40	10.43	21.00	0.00	3.33	0.00
1955	14.50	7.20	40.31	0.38	10.52	22.92	0.00	3.80	0.36

(segue)

	Food for men %	Animals %	Firewood %	Wind & Water %	Coal %	Oil %	Natural Gas %	Primary electricity %	Others %
1956	14.68	6.87	39.72	0.37	10.40	23.22	0.00	4.38	0.37
1957	14.41	6.60	39.43	0.36	12.17	22.75	0.00	3.92	0.35
1958	13.89	6.42	39.16	0.36	10.46	24.12	0.00	5.31	0.28
1959	13.95	6.09	38.39	0.34	9.09	25.86	0.00	5.91	0.36
1960	14.00	5.71	37.52	0.33	8.83	27.06	0.00	6.17	0.39
1961	13.17	5.34	35.61	0.31	10.68	28.65	0.00	5.80	0.44
1962	13.42	5.11	34.80	0.30	9.89	30.14	0.00	5.90	0.44
1963	13.51	4.82	33.03	0.28	10.95	30.37	0.00	6.57	0.47
1964	12.78	4.67	32.79	0.27	10.68	31.43	0.00	6.83	0.56
1965	13.54	4.32	31.01	0.25	9.99	33.30	0.00	6.75	0.84
1966	13.05	4.12	30.04	0.21	10.75	32.75	0.00	8.12	0.97
1967	13.21	3.80	28.75	0.19	9.62	35.38	0.00	7.99	1.06
1968	13.09	3.58	28.05	0.18	8.50	37.85	0.00	7.58	1.18
1969	12.64	3.24	25.91	0.16	8.93	39.20	0.00	8.56	1.34
1970	11.59	2.90	23.83	0.15	7.66	45.14	0.00	7.33	1.40
1971	11.52	2.70	22.57	0.14	5.67	48.78	0.00	7.71	0.92
1972	11.01	2.45	21.17	0.13	4.74	51.83	0.00	8.26	0.41
1973	10.52	2.26	19.77	0.12	5.22	53.57	0.00	7.97	0.58
1974	10.59	2.13	19.04	0.11	4.00	55.30	0.00	8.34	0.47
1975	10.18	1.98	18.09	0.10	3.95	58.45	0.00	6.64	0.61
1976	10.00	1.88	17.41	0.10	3.79	60.00	0.00	6.23	0.58
1977	9.76	1.78	17.10	0.09	3.79	57.79	0.00	9.12	0.58
1978	9.16	1.69	16.53	0.09	3.99	58.01	0.00	9.98	0.56
1979	8.59	1.55	15.39	0.08	3.80	60.18	0.00	9.81	0.60
1980	8.42	1.47	14.73	0.08	3.55	62.94	0.00	8.19	0.63
1981	8.22	1.41	14.32	0.07	3.03	65.83	0.00	6.49	0.63
1982	7.97	1.33	13.85	0.01	2.54	66.06	0.00	7.56	0.68
1983	7.84	1.28	13.52	0.01	3.01	65.66	0.00	7.90	0.78
1984	8.01	1.27	13.50	0.01	3.31	64.86	0.00	8.27	0.76
1985	8.39	1.25	14.22	0.01	6.05	59.24	0.00	10.06	0.76
1986	8.35	1.16	13.50	0.01	10.71	57.89	0.00	7.58	0.78
1987	8.40	1.10	13.52	0.01	13.38	54.37	0.00	8.42	0.81
1988	8.11	1.04	12.94	0.01	14.19	53.04	0.00	9.86	0.82
1989	7.29	0.91	11.25	0.01	15.55	59.99	0.00	4.31	0.70
1990	7.16	0.82	10.75	0.00	15.96	57.11	0.00	5.48	2.72
1991	6.94	0.74	10.16	0.00	16.27	57.30	0.00	5.26	3.33
1992	6.61	0.66	9.53	0.00	15.64	61.06	0.00	3.36	3.13
1993	6.79	0.62	9.54	0.00	16.86	58.22	0.00	4.87	3.09
1994	6.69	0.56	9.11	0.00	17.39	56.91	0.00	6.21	3.13
1995	6.38	0.49	8.75	0.00	17.89	58.53	0.00	4.75	3.22
1996	6.35	0.44	8.77	0.00	16.84	56.57	0.00	7.98	3.04
1997	5.84	0.37	8.36	0.00	16.30	58.00	0.40	7.48	3.24
1998	5.82	0.32	7.91	0.08	14.26	59.35	3.09	6.12	3.05
1999	5.64	0.26	7.41	0.08	15.38	56.90	8.03	3.11	3.20
2000	5.58	0.23	7.15	0.08	15.32	53.98	8.60	5.36	3.69
2001	5.66	0.21	7.14	0.08	12.80	55.14	9.07	6.28	3.61
2002	5.46	0.19	6.92	0.08	13.45	55.39	10.54	4.28	3.69
2003	5.61	0.18	7.22	0.08	13.16	51.70	10.39	7.87	3.78
2004	5.53	0.17	7.35	0.08	12.97	50.73	12.75	6.88	3.55
2005	5.42	0.15	7.21	0.09	12.59	51.13	14.14	5.68	3.59
2006	5.54	0.14	7.43	0.13	12.66	47.90	13.75	8.75	3.71

3. Population, total and per capita energy consumption, GDP and Energy Intensity, 1856-2006

	Population	Total energy consumption (PJ)	Per capita consumption (GJ)	GDP (million $1990)	Energy intensity (MJ/$1990)
1856	3,957,349	72.8	18.4	3,705	19.7
1857	3,986,231	72.6	18.2	0	
1858	4,015,114	72.9	18.2	0	
1859	4,043,997	74.3	18.4	0	
1860	4,072,879	73.7	18.1	0	
1861	4,101,762	73.7	18.0	3,903	18.9
1862	4,130,645	74.4	18.0	0	
1863	4,159,527	75.2	18.1	0	
1864	4,188,410	75.6	18.1	0	
1865	4,213,303	76.1	18.1	4,229	18.0
1866	4,238,344	78.4	18.5	4,169	18.8
1867	4,263,533	78.2	18.3	4,230	18.5
1868	4,288,873	80.0	18.7	4,199	19.1
1869	4,314,363	78.7	18.2	4,205	18.7
1870	4,340,004	80.6	18.6	4,325	18.6
1871	4,365,798	79.7	18.3	4,120	19.4
1872	4,391,745	80.9	18.4	4,280	18.9
1873	4,417,847	83.6	18.9	4,373	19.1
1874	4,444,103	82.3	18.5	4,408	18.7
1875	4,470,516	83.7	18.7	4,453	18.8
1876	4,497,085	83.8	18.6	4,395	19.1
1877	4,523,813	85.2	18.8	4,494	19.0
1878	4,550,699	85.8	18.9	4,393	19.5
1879	4,590,330	86.4	18.8	4,442	19.5
1880	4,630,307	88.7	19.2	4,583	19.4
1881	4,670,631	89.4	19.2	4,726	18.9
1882	4,711,307	91.6	19.4	4,674	19.6
1883	4,752,337	92.3	19.4	4,684	19.7
1884	4,793,725	93.7	19.5	5,290	17.7
1885	4,835,473	93.0	19.2	5,096	18.2
1886	4,877,584	95.4	19.6	5,323	17.9
1887	4,920,062	97.3	19.8	5,624	17.3
1888	4,962,910	98.8	19.9	5,581	17.7
1889	5,006,131	101.5	20.3	5,538	18.3
1890	5,049,729	102.6	20.3	5,656	18.1
1891	5,085,882	103.7	20.4	5,734	18.1
1892	5,122,294	103.3	20.2	5,829	17.7
1893	5,158,966	101.6	19.7	5,440	18.7
1894	5,195,902	105.5	20.3	5,538	19.0
1895	5,233,101	104.8	20.0	5,747	18.2
1896	5,270,567	105.2	20.0	5,813	18.1
1897	5,308,301	106.4	20.0	6,028	17.6
1898	5,346,305	109.5	20.5	6,548	16.7
1899	5,384,582	109.5	20.3	6,365	17.2
1900	5,423,132	111.2	20.5	6,406	17.4
1901	5,469,876	111.7	20.4	6,787	16.5
1902	5,517,022	114.7	20.8	6,932	16.6
1903	5,564,575	116.2	20.9	6,707	17.3
1904	5,612,538	119.0	21.2	6,788	17.5
1905	5,660,915	118.6	21.0	6,633	17.9

(segue)

	Population	Total energy consumption (PJ)	Per capita consumption (GJ)	GDP (million $1990)	Energy intensity (MJ/$1990)
1906	5,709,708	122.5	21.5	6,533	18.8
1907	5,758,922	125.8	21.8	6,546	19.2
1908	5,808,560	127.0	21.9	7,016	18.1
1909	5,858,626	127.6	21.8	6,932	18.4
1910	5,909,123	129.7	22.0	6,879	18.9
1911	5,960,056	131.3	22.0	7,114	18.5
1912	5,968,116	134.5	22.5	7,236	18.6
1913	5,976,187	136.6	22.9	7,212	18.9
1914	5,984,269	133.7	22.3	7,266	18.4
1915	5,992,362	131.7	22.0	7,109	18.5
1916	6,000,466	129.9	21.6	7,153	18.2
1917	6,008,581	118.0	19.6	7,047	16.7
1918	6,016,706	115.8	19.2	6,320	18.3
1919	6,024,843	125.4	20.8	6,840	18.3
1920	6,032,991	127.0	21.1	7,166	17.7
1921	6,107,947	120.7	19.8	7,569	15.9
1922	6,183,835	129.1	20.9	8,481	15.2
1923	6,260,666	126.9	20.3	8,844	14.3
1924	6,338,451	132.7	20.9	8,523	15.6
1925	6,417,203	135.3	21.1	8,896	15.2
1926	6,496,933	134.9	20.8	8,840	15.3
1927	6,577,653	142.1	21.6	10,363	13.7
1928	6,659,377	149.0	22.4	9,378	15.9
1929	6,742,116	149.2	22.1	10,382	14.4
1930	6,825,883	154.3	22.6	10,255	15.0
1931	6,910,616	152.8	22.1	10,778	14.2
1932	6,996,402	148.6	21.2	10,988	13.5
1933	7,083,252	155.9	22.0	11,719	13.3
1934	7,171,180	157.3	21.9	12,213	12.9
1935	7,260,200	160.8	22.1	11,576	13.9
1936	7,350,325	159.4	21.7	10,713	14.9
1937	7,441,589	171.3	23.0	12,490	13.7
1938	7,533,945	166.8	22.1	12,574	13.3
1939	7,627,468	173.6	22.8	12,743	13.6
1940	7,722,152	166.7	21.6	11,926	14.0
1941	7,791,221	169.0	21.7	13,022	13.0
1942	7,860,907	167.2	21.3	12,850	13.0
1943	7,931,217	173.5	21.9	13,695	12.7
1944	8,002,156	186.7	23.3	14,708	12.7
1945	8,073,729	182.9	22.7	13,915	13.1
1946	8,145,942	192.8	23.7	14,990	12.9
1947	8,218,801	207.9	25.3	16,224	12.8
1948	8,292,312	196.3	23.7	16,176	12.1
1949	8,366,480	199.0	23.8	16,400	12.1
1950	8,441,312	199.8	23.7	16,862	11.9
1951	8,481,440	201.8	23.8	18,128	11.1
1952	8,521,759	200.7	23.6	17,742	11.3
1953	8,562,270	209.6	24.5	19,299	10.9
1954	8,602,973	212.5	24.7	20,280	10.5
1955	8,643,870	221.9	25.7	20,869	10.6
1956	8,684,961	226.9	26.1	21,588	10.5

(segue)

	Population	Total energy consumption (PJ)	Per capita consumption (GJ)	GDP (million $1990)	Energy intensity (MJ/$1990)
1957	8,726,248	229.9	26.3	22,551	10.2
1958	8,767,731	229.8	26.2	23,973	9.6
1959	8,809,411	235.6	26.7	24,925	9.5
1960	8,851,289	244.3	27.6	26,057	9.4
1961	8,822,616	253.2	28.7	26,807	9.4
1962	8,794,036	256.6	29.2	29,854	8.6
1963	8,765,548	263.6	30.1	30,841	8.5
1964	8,737,153	263.7	30.2	32,545	8.1
1965	8,708,850	275.3	31.6	35,629	7.7
1966	8,680,638	278.9	32.1	37,196	7.5
1967	8,652,518	291.8	33.7	38,606	7.6
1968	8,624,489	297.7	34.5	40,368	7.4
1969	8,596,551	316.8	36.8	41,399	7.7
1970	8,568,703	339.1	39.6	45,134	7.5
1971	8,689,199	349.5	40.2	50,325	6.9
1972	8,811,389	368.4	41.8	55,710	6.6
1973	8,935,297	390.5	43.7	58,626	6.7
1974	9,060,948	402.5	44.4	60,397	6.7
1975	9,188,366	421.7	45.9	56,882	7.4
1976	9,317,576	431.9	46.4	57,898	7.5
1977	9,448,602	443.6	46.9	62,151	7.1
1978	9,581,471	453.5	47.3	65,993	6.9
1979	9,716,209	478.4	49.2	70,340	6.8
1980	9,852,841	498.0	50.5	73,801	6.7
1981	9,853,810	510.7	51.8	75,850	6.7
1982	9,854,780	532.8	54.1	77,701	6.9
1983	9,855,750	542.9	55.1	78,966	6.9
1984	9,856,719	538.2	54.6	78,510	6.9
1985	9,857,689	537.9	54.6	79,917	6.7
1986	9,858,659	567.6	57.6	82,639	6.9
1987	9,859,629	591.9	60.0	88,952	6.7
1988	9,860,599	615.8	62.4	93,489	6.6
1989	9,861,570	691.5	70.1	99,730	6.9
1990	9,862,540	724.2	73.4	107,427	6.7
1991	9,863,510	748.0	75.8	112,120	6.7
1992	9,867,768	789.4	80.0	113,341	7.0
1993	9,885,593	780.2	78.9	111,025	7.0
1994	9,915,301	801.1	80.8	112,096	7.1
1995	9,938,671	843.5	84.9	116,897	7.2
1996	9,961,843	852.8	85.6	121,143	7.0
1997	9,994,621	902.5	90.3	126,210	7.2
1998	10,031,459	948.8	94.6	132,300	7.2
1999	10,079,090	1019.8	101.2	137,341	7.4
2000	10,150,092	1041.8	102.6	142,770	7.3
2001	10,329,340	1046.8	101.3	145,636	7.2
2002	10,407,470	1089.6	104.7	146,782	7.4
2003	10,474,685	1067.1	101.9	145,636	7.3
2004	10,529,255	1089.2	103.4	147,841	7.4
2005	10,569,592	1113.8	105.4	148,905	7.5
2006	10,599,095	1094.7	103.3	150,708	7.3

II

The energy carriers

1. Food for men (Appendix I, 1, col. 1)

	Population (resident) (000)	Food per c. Kcal per day	Total PJ Per year
1856	3957	2268	13.716
1857	3986	2268	13.816
1858	4015	2268	13.916
1859	4044	2268	14.016
1860	4073	2268	14.116
1861	4102	2268	14.216
1862	4131	2268	14.316
1863	4160	2268	14.417
1864	4188	2268	14.517
1865	4213	2268	14.603
1866	4238	2268	14.690
1867	4264	2268	14.777
1868	4289	2268	14.865
1869	4314	2268	14.953
1870	4340	2268	15.042
1871	4366	2268	15.131
1872	4392	2268	15.221
1873	4418	2268	15.312
1874	4444	2268	15.403
1875	4471	2268	15.494
1876	4497	2268	15.587
1877	4524	2268	15.679
1878	4551	2268	15.772
1879	4590	2271	15.930
1880	4630	2274	16.088
1881	4671	2276	16.248
1882	4711	2279	16.410
1883	4752	2282	16.574
1884	4794	2285	16.739
1885	4835	2288	16.905
1886	4878	2291	17.074
1887	4920	2293	17.244
1888	4963	2296	17.415
1889	5006	2299	17.588
1890	5050	2302	17.763
1891	5086	2299	17.870
1892	5122	2297	17.978
1893	5159	2294	18.086
1894	5196	2291	18.194
1895	5233	2289	18.304
1896	5271	2286	18.414
1897	5308	2284	18.524
1898	5346	2281	18.635
1899	5385	2278	18.747
1900	5423	2276	18.860
1901	5470	2275	19.016
1902	5517	2274	19.173
1903	5565	2273	19.332
1904	5613	2273	19.492
1905	5661	2272	19.653

(segue)

	Population (resident) (000)	**Food** per c. Kcal per day	**Total** PJ per year
1906	5710	2271	19.816
1907	5759	2270	19.980
1908	5809	2270	20.146
1909	5859	2269	20.312
1910	5909	2268	20.481
1911	5960	2264	20.620
1912	5968	2260	20.611
1913	5976	2256	20.602
1914	5984	2252	20.593
1915	5992	2248	20.584
1916	6000	2244	20.575
1917	6009	2240	20.566
1918	6017	2236	20.557
1919	6025	2232	20.547
1920	6033	2228	20.538
1921	6108	2227	20.788
1922	6184	2227	21.041
1923	6261	2226	21.297
1924	6338	2225	21.557
1925	6417	2225	21.819
1926	6497	2224	22.085
1927	6578	2224	22.354
1928	6659	2223	22.626
1929	6742	2223	22.901
1930	6826	2222	23.180
1931	6911	2220	23.441
1932	6996	2217	23.705
1933	7083	2215	23.972
1934	7171	2212	24.242
1935	7260	2210	24.515
1936	7350	2207	24.791
1937	7442	2205	25.070
1938	7534	2202	25.352
1939	7627	2220	25.873
1940	7722	2237	26.404
1941	7791	2255	26.851
1942	7861	2273	27.304
1943	7931	2291	27.763
1944	8002	2308	28.228
1945	8074	2326	28.699
1946	8146	2344	29.176
1947	8219	2361	29.660
1948	8292	2379	30.150
1949	8366	2347	30.008
1950	8441	2503	32.288
1951	8481	2477	32.105
1952	8522	2351	30.617
1953	8562	2462	32.215
1954	8603	2464	32.394
1955	8644	2437	32.191
1956	8685	2509	33.300

(segue)

	Population (resident) (000)	**Food** per c. Kcal per day	**Total** PJ per year
1957	8726	2485	33.138
1958	8768	2382	31.916
1959	8809	2442	32.875
1960	8851	2528	34.195
1961	8823	2473	33.345
1962	8794	2563	34.443
1963	8766	2659	35.613
1964	8737	2523	33.687
1965	8709	2801	37.274
1966	8681	2743	36.381
1967	8653	2917	38.566
1968	8624	2956	38.963
1969	8597	3048	40.041
1970	8569	3002	39.306
1971	8689	3031	40.245
1972	8811	3012	40.558
1973	8935	3008	41.068
1974	9061	3079	42.640
1975	9188	3058	42.940
1976	9318	3033	43.185
1977	9449	2997	43.280
1978	9581	2836	41.531
1979	9716	2768	41.094
1980	9853	2786	41.943
1981	9854	2789	42.002
1982	9855	2820	42.472
1983	9856	2825	42.550
1984	9857	2863	43.129
1985	9858	2998	45.157
1986	9859	3147	47.408
1987	9860	3299	49.707
1988	9861	3313	49.920
1989	9862	3346	50.431
1990	9863	3441	51.865
1991	9864	3443	51.897
1992	9868	3462	52.209
1993	9886	3506	52.959
1994	9915	3535	53.567
1995	9939	3541	53.786
1996	9962	3559	54.173
1997	9995	3452	52.721
1998	10031	3605	55.263
1999	10079	3736	57.540
2000	10150	3751	58.181
2001	10329	3755	59.268
2002	10407	3741	59.497
2003	10475	3741	59.881
2004	10529	3741	60.193
2005	10570	3741	60.424
2006	10599	3741	60.593

2. Animals (Appendix I, 1, col. 2)

	Num. Work. Cows (000)	Num. Work. Oxen (000)	Num. Work. Horses (000)	Num. Work. Mules (000)	Num. Work. Donkeys (000)	Consum. Work. Cows PJ	Consum. Work. Oxen PJ	Consum. Work. Horses PJ	Consum. Work. Mules PJ	Consum. Work. Donkeys PJ	Consum. Total PJ
1856	127	283	63	46	115	1.018	6.812	1.794	1.100	2.128	12.852
1857	127	283	64	47	115	1.020	6.841	1.808	1.127	2.139	12.935
1858	126	283	64	48	116	1.021	6.870	1.822	1.155	2.150	13.018
1859	126	283	65	49	117	1.022	6.899	1.836	1.182	2.162	13.101
1860	126	283	65	50	117	1.024	6.928	1.850	1.210	2.173	13.185
1861	125	284	66	51	118	1.025	6.958	1.864	1.237	2.185	13.268
1862	125	284	66	52	118	1.026	6.987	1.878	1.264	2.196	13.351
1863	125	284	67	54	119	1.028	7.016	1.891	1.292	2.208	13.434
1864	124	284	67	55	120	1.029	7.045	1.905	1.319	2.219	13.518
1865	124	284	68	56	120	1.030	7.074	1.919	1.347	2.231	13.601
1866	124	284	68	57	121	1.031	7.104	1.933	1.374	2.242	13.684
1867	124	285	69	58	121	1.033	7.133	1.947	1.402	2.253	13.768
1868	123	285	69	59	122	1.034	7.162	1.961	1.429	2.265	13.851
1869	123	285	70	60	123	1.035	7.192	1.975	1.457	2.276	13.935
1870	123	285	70	61	123	1.036	7.221	1.989	1.484	2.288	14.018
1871	124	285	70	61	123	1.053	7.246	1.995	1.482	2.291	14.067
1872	126	285	70	61	124	1.070	7.272	2.001	1.480	2.293	14.117
1873	128	285	71	61	124	1.088	7.297	2.006	1.479	2.296	14.166
1874	129	285	71	61	124	1.105	7.322	2.012	1.477	2.299	14.216
1875	131	285	71	61	124	1.123	7.347	2.018	1.475	2.302	14.265
1876	132	285	71	61	124	1.140	7.372	2.024	1.473	2.305	14.315
1877	134	285	71	61	124	1.158	7.398	2.030	1.471	2.308	14.365
1878	135	285	72	61	125	1.176	7.423	2.036	1.469	2.311	14.415
1879	137	285	72	61	125	1.193	7.448	2.041	1.468	2.314	14.465
1880	139	285	72	61	125	1.211	7.473	2.047	1.466	2.317	14.515
1881	140	285	72	61	125	1.229	7.498	2.053	1.464	2.320	14.565
1882	142	285	72	61	125	1.248	7.524	2.059	1.462	2.323	14.615
1883	143	285	73	60	125	1.266	7.549	2.065	1.460	2.326	14.666
1884	145	285	73	60	126	1.284	7.574	2.071	1.459	2.329	14.716
1885	147	285	73	60	126	1.303	7.599	2.076	1.457	2.332	14.767
1886	148	285	73	60	126	1.321	7.624	2.082	1.455	2.335	14.817
1887	150	285	74	60	126	1.340	7.649	2.088	1.453	2.338	14.868
1888	151	285	74	60	126	1.358	7.675	2.094	1.451	2.341	14.919
1889	153	285	74	60	126	1.377	7.700	2.100	1.449	2.344	14.970
1890	155	285	74	60	126	1.396	7.725	2.106	1.448	2.347	15.021
1891	156	285	74	60	127	1.415	7.750	2.111	1.446	2.350	15.072
1892	158	285	75	60	127	1.434	7.775	2.117	1.444	2.353	15.124
1893	159	285	75	60	127	1.453	7.801	2.123	1.442	2.356	15.175
1894	161	285	75	60	127	1.473	7.826	2.129	1.440	2.359	15.226
1895	163	285	75	60	127	1.492	7.851	2.135	1.438	2.362	15.278
1896	164	285	75	60	127	1.511	7.876	2.141	1.437	2.365	15.329
1897	166	285	76	59	128	1.531	7.901	2.146	1.435	2.368	15.381
1898	167	285	76	59	128	1.551	7.926	2.152	1.433	2.371	15.433
1899	169	285	76	59	128	1.570	7.952	2.158	1.431	2.374	15.485
1900	171	285	76	59	128	1.590	7.977	2.164	1.429	2.377	15.537
1901	172	285	76	59	128	1.610	8.002	2.170	1.428	2.379	15.589
1902	174	285	77	59	128	1.630	8.027	2.176	1.426	2.382	15.641
1903	175	285	77	59	129	1.650	8.052	2.181	1.424	2.385	15.693
1904	177	285	77	59	129	1.670	8.077	2.187	1.422	2.388	15.746
1905	178	285	77	59	129	1.691	8.103	2.193	1.420	2.391	15.798

(segue)

	Num. Work. Cows (000)	Num. Work. Oxen (000)	Num. Work. Horses (000)	Num. Work. Mules (000)	Num. Work. Donkeys (000)	Consum. Work. Cows PJ	Consum. Work. Oxen PJ	Consum. Work. Horses PJ	Consum. Work. Mules PJ	Consum. Work. Donkeys PJ	Consum. Total PJ
1906	180	285	77	59	129	1.711	8.128	2.199	1.418	2.394	15.851
1907	182	281	77	60	133	1.734	8.031	2.190	1.459	2.472	15.885
1908	184	277	77	62	137	1.756	7.933	2.181	1.499	2.550	15.919
1909	185	272	76	64	142	1.779	7.834	2.173	1.539	2.627	15.952
1910	187	268	76	65	146	1.802	7.734	2.164	1.579	2.705	15.984
1911	189	264	76	67	150	1.819	7.611	2.155	1.620	2.782	15.987
1912	191	259	76	69	154	1.837	7.487	2.146	1.660	2.860	15.990
1913	193	255	75	70	158	1.854	7.363	2.138	1.700	2.938	15.993
1914	195	251	75	72	162	1.872	7.240	2.129	1.740	3.015	15.996
1915	196	247	75	74	167	1.889	7.116	2.120	1.781	3.093	15.999
1916	198	242	74	75	171	1.906	6.992	2.111	1.821	3.170	16.001
1917	200	238	74	77	175	1.924	6.869	2.103	1.861	3.248	16.004
1918	202	234	74	79	179	1.941	6.745	2.094	1.901	3.326	16.007
1919	204	229	73	80	183	1.959	6.621	2.085	1.942	3.403	16.010
1920	205	225	73	82	188	1.976	6.498	2.076	1.982	3.481	16.013
1921	207	221	73	84	192	1.993	6.374	2.068	2.022	3.558	16.016
1922	209	217	72	85	196	2.011	6.251	2.059	2.062	3.636	16.019
1923	211	212	72	87	200	2.028	6.127	2.050	2.102	3.714	16.021
1924	213	208	72	89	204	2.046	6.003	2.042	2.143	3.791	16.024
1925	214	204	72	90	209	2.063	5.880	2.033	2.183	3.869	16.027
1926	215	198	72	94	211	2.069	5.728	2.049	2.267	3.921	16.034
1927	216	193	73	97	214	2.076	5.576	2.066	2.351	3.973	16.042
1928	216	188	73	101	217	2.082	5.424	2.082	2.436	4.025	16.049
1929	217	183	74	104	220	2.088	5.272	2.099	2.520	4.077	16.056
1930	218	177	74	108	223	2.095	5.120	2.115	2.604	4.129	16.063
1931	218	172	75	111	225	2.101	4.969	2.132	2.688	4.181	16.071
1932	219	167	76	115	228	2.107	4.817	2.148	2.772	4.233	16.078
1933	220	162	76	118	231	2.114	4.665	2.164	2.857	4.285	16.085
1934	220	156	77	122	234	2.120	4.513	2.181	2.941	4.337	16.092
1935	224	156	76	122	230	2.152	4.512	2.160	2.945	4.260	16.028
1936	227	156	75	122	225	2.183	4.511	2.138	2.949	4.182	15.964
1937	230	156	75	122	221	2.215	4.510	2.117	2.953	4.104	15.899
1938	234	156	74	122	217	2.247	4.509	2.096	2.957	4.026	15.835
1939	237	156	73	123	213	2.279	4.508	2.075	2.962	3.949	15.771
1940	240	156	72	123	209	2.310	4.506	2.053	2.966	3.871	15.707
1941	240	157	72	123	208	2.310	4.545	2.035	2.973	3.862	15.725
1942	240	159	71	123	208	2.310	4.584	2.017	2.980	3.853	15.744
1943	240	160	70	124	207	2.309	4.623	1.999	2.988	3.844	15.763
1944	240	161	70	124	207	2.309	4.661	1.981	2.995	3.835	15.781
1945	240	163	69	124	206	2.309	4.700	1.963	3.002	3.827	15.800
1946	240	164	68	125	206	2.309	4.739	1.945	3.009	3.818	15.819
1947	240	166	68	125	205	2.308	4.777	1.926	3.017	3.809	15.837
1948	240	167	67	125	205	2.308	4.816	1.908	3.024	3.800	15.856
1949	240	168	67	126	204	2.308	4.855	1.890	3.031	3.791	15.875
1950	240	170	66	126	204	2.308	4.894	1.872	3.038	3.782	15.893
1951	240	171	65	126	203	2.307	4.932	1.854	3.046	3.773	15.912
1952	240	172	65	126	203	2.307	4.971	1.836	3.053	3.764	15.931
1953	240	174	64	127	202	2.307	5.010	1.818	3.060	3.755	15.949
1954	240	175	63	127	202	2.306	5.048	1.800	3.068	3.746	15.968
1955	240	176	63	127	201	2.306	5.087	1.781	3.075	3.737	15.987

(segue)

	Num. Work. Cows (000)	Num. Work. Oxen (000)	Num. Work. Horses (000)	Num. Work. Mules (000)	Num. Work. Donkeys (000)	Consum. Work. Cows PJ	Consum. Work. Oxen PJ	Consum. Work. Horses PJ	Consum. Work. Mules PJ	Consum. Work. Donkeys PJ	Consum. Total PJ
1956	234	171	61	125	196	2.254	4.948	1.727	3.019	3.630	15.578
1957	229	167	59	123	190	2.201	4.809	1.673	2.963	3.522	15.169
1958	223	162	57	120	184	2.149	4.670	1.619	2.907	3.414	14.759
1959	218	157	55	118	178	2.097	4.531	1.565	2.851	3.307	14.350
1960	212	152	53	116	172	2.044	4.392	1.511	2.795	3.199	13.941
1961	207	147	51	113	167	1.992	4.254	1.457	2.739	3.091	13.532
1962	202	143	49	111	161	1.939	4.115	1.403	2.683	2.984	13.123
1963	196	138	47	109	155	1.887	3.976	1.348	2.627	2.876	12.714
1964	191	133	46	106	149	1.834	3.837	1.294	2.571	2.769	12.305
1965	185	128	44	104	143	1.782	3.698	1.240	2.515	2.661	11.896
1966	180	123	42	102	138	1.730	3.559	1.186	2.459	2.553	11.487
1967	174	118	40	100	132	1.677	3.420	1.132	2.403	2.446	11.077
1968	169	114	38	97	126	1.625	3.281	1.078	2.347	2.338	10.668
1969	163	109	36	95	120	1.572	3.142	1.024	2.291	2.230	10.259
1970	158	104	34	93	114	1.520	3.003	0.970	2.235	2.123	9.850
1971	153	99	32	90	109	1.468	2.864	0.916	2.178	2.015	9.441
1972	147	94	30	88	103	1.415	2.725	0.861	2.122	1.908	9.032
1973	142	92	30	86	103	1.363	2.652	0.841	2.066	1.902	8.824
1974	136	89	29	82	102	1.310	2.578	0.821	1.983	1.896	8.589
1975	131	87	28	79	102	1.258	2.504	0.801	1.900	1.891	8.355
1976	125	84	28	75	102	1.205	2.431	0.781	1.817	1.885	8.120
1977	120	82	27	72	101	1.153	2.357	0.761	1.734	1.879	7.885
1978	114	79	26	68	101	1.101	2.283	0.741	1.651	1.874	7.650
1979	109	77	25	65	101	1.048	2.210	0.721	1.568	1.868	7.416
1980	104	78	26	63	97	0.996	2.258	0.737	1.511	1.799	7.301
1981	98	80	26	60	93	0.943	2.307	0.752	1.454	1.729	7.186
1982	93	82	27	58	89	0.891	2.356	0.767	1.397	1.660	7.071
1983	87	83	28	55	86	0.839	2.405	0.783	1.339	1.591	6.956
1984	82	85	28	53	82	0.786	2.453	0.798	1.282	1.522	6.841
1985	76	87	29	51	78	0.734	2.502	0.814	1.225	1.452	6.727
1986	71	88	29	48	75	0.681	2.551	0.829	1.168	1.383	6.612
1987	65	90	30	46	71	0.629	2.599	0.844	1.110	1.314	6.497
1988	60	92	30	44	67	0.577	2.648	0.860	1.053	1.245	6.382
1989	54	93	31	41	63	0.524	2.697	0.875	0.996	1.175	6.267
1990	49	86	31	39	60	0.472	2.490	0.875	0.950	1.120	5.906
1991	44	79	31	37	57	0.419	2.284	0.874	0.904	1.064	5.546
1992	38	72	31	36	54	0.367	2.077	0.874	0.858	1.009	5.185
1993	33	65	31	34	51	0.314	1.871	0.873	0.813	0.953	4.824
1994	27	58	31	32	48	0.262	1.664	0.872	0.767	0.898	4.463
1995	22	51	31	30	45	0.210	1.458	0.872	0.721	0.842	4.103
1996	16	43	31	28	42	0.157	1.251	0.871	0.675	0.787	3.742
1997	11	36	31	26	39	0.105	1.045	0.871	0.630	0.731	3.381
1998	5	29	31	24	36	0.052	0.838	0.870	0.584	0.675	3.020
1999	0	22	31	22	33	0.000	0.632	0.870	0.538	0.620	2.659
2000	0	15	31	20	30	0.000	0.425	0.869	0.492	0.564	2.351

3. Firewood (Appendix. I, 1, col. 3)

	Firewood urban households	Firewood rural households	Firewood households	Firewood industry	Firewood transports	Firewood power	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1856	3.245	37.593	40.838	0.959	0.000	0.000	41.797
1857	3.260	37.867	41.127	0.948	0.000	0.000	42.076
1858	2.632	38.141	40.773	0.938	0.000	0.000	41.711
1859	2.831	38.416	41.247	0.927	0.000	0.000	42.174
1860	2.632	38.690	41.322	0.917	0.000	0.000	42.239
1861	2.620	38.965	41.585	0.907	0.000	0.000	42.492
1862	2.768	39.239	42.007	0.942	0.000	0.000	42.949
1863	2.910	39.513	42.423	0.978	0.000	0.000	43.401
1864	2.741	39.788	42.529	1.013	0.000	0.000	43.542
1865	2.707	40.003	42.710	1.049	0.000	0.000	43.759
1866	2.902	40.219	43.120	1.057	0.000	0.000	44.178
1867	2.864	40.436	43.300	1.093	0.000	0.000	44.393
1868	2.824	40.654	43.479	1.055	0.000	0.000	44.533
1869	2.785	40.874	43.659	1.107	0.000	0.000	44.766
1870	2.841	41.094	43.936	1.246	0.000	0.000	45.182
1871	2.856	41.316	44.173	1.096	0.000	0.000	45.268
1872	3.070	41.539	44.609	1.296	0.000	0.000	45.905
1873	3.141	41.764	44.905	1.512	0.000	0.000	46.417
1874	3.164	41.989	45.153	1.465	0.000	0.000	46.618
1875	3.314	42.216	45.529	1.446	0.000	0.000	46.976
1876	3.199	42.443	45.643	1.312	0.000	0.000	46.955
1877	3.403	42.673	46.076	1.498	0.000	0.000	47.574
1878	3.271	42.903	46.173	1.463	0.000	0.000	47.636
1879	3.503	43.175	46.678	1.413	0.000	0.000	48.092
1880	3.512	43.448	46.961	1.361	0.000	0.000	48.322
1881	3.571	43.723	47.294	1.468	0.000	0.000	48.763
1882	3.937	44.000	47.936	1.578	0.000	0.000	49.514
1883	3.643	44.278	47.921	1.559	0.000	0.000	49.479
1884	3.678	44.557	48.235	1.589	0.000	0.000	49.824
1885	3.414	44.838	48.253	1.580	0.000	0.000	49.833
1886	3.929	45.121	49.050	1.890	0.000	0.000	50.940
1887	3.902	45.405	49.307	1.975	0.000	0.000	51.282
1888	4.124	45.691	49.814	1.980	0.000	0.000	51.795
1889	4.048	45.978	50.025	1.860	0.000	0.000	51.885
1890	3.453	46.266	49.719	2.167	0.000	0.000	51.886
1891	3.833	46.544	50.378	2.005	0.000	0.000	52.383
1892	3.804	46.824	50.628	1.967	0.000	0.000	52.595
1893	3.769	47.106	50.875	2.076	0.000	0.000	52.951
1894	4.246	47.389	51.634	1.967	0.000	0.000	53.601
1895	4.035	47.673	51.709	2.137	0.000	0.000	53.845
1896	3.936	47.960	51.895	2.093	0.000	0.000	53.988
1897	3.909	48.248	52.156	2.372	0.000	0.000	54.528
1898	3.905	48.537	52.442	2.446	0.000	0.000	54.888
1899	4.048	48.828	52.877	2.504	0.000	0.000	55.380
1900	3.913	49.121	53.034	2.739	0.000	0.000	55.773
1901	4.217	49.387	53.604	2.641	0.000	0.000	56.245
1902	4.707	49.654	54.362	2.731	0.000	0.000	57.093
1903	4.518	49.922	54.440	2.909	0.000	0.000	57.349
1904	4.720	50.191	54.911	3.010	0.000	0.000	57.922
1905	4.598	50.461	55.059	2.794	0.000	0.000	57.853

(segue)

	Firewood urban households	Firewood rural households	Firewood households	Firewood industry	Firewood transports	Firewood power	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1906	4.695	50.732	55.426	2.887	0.000	0.000	58.313
1907	4.631	51.003	55.635	3.114	0.000	0.000	58.749
1908	4.998	51.276	56.274	3.005	0.000	0.000	59.278
1909	5.088	51.549	56.638	3.008	0.000	0.000	59.645
1910	5.127	51.824	56.950	3.298	0.000	0.000	60.248
1911	5.167	52.099	57.266	3.373	0.000	0.000	60.639
1912	5.575	52.086	57.661	3.482	0.000	0.000	61.143
1913	5.465	52.074	57.539	3.577	0.000	0.000	61.115
1914	5.463	52.061	57.524	4.471	0.000	0.000	61.995
1915	5.610	52.048	57.659	5.365	0.000	0.000	63.023
1916	5.211	52.036	57.246	7.153	0.000	0.000	64.399
1917	6.764	52.023	58.787	8.941	0.000	0.403	68.131
1918	7.292	52.009	59.302	10.730	0.000	0.858	70.889
1919	10.508	51.996	62.504	7.153	0.000	0.196	69.854
1920	15.020	51.983	67.003	4.102	0.000	0.147	71.252
1921	7.286	52.501	59.787	4.378	0.000	0.083	64.249
1922	5.951	53.025	58.976	4.783	0.000	0.100	63.858
1923	6.363	53.554	59.917	4.696	0.000	0.119	64.731
1924	6.786	54.087	60.873	4.759	0.000	0.146	65.778
1925	7.210	54.626	61.836	4.761	0.000	0.180	66.777
1926	7.117	55.169	62.287	5.027	0.000	0.222	67.536
1927	7.018	55.718	62.736	5.110	0.000	0.274	68.120
1928	8.581	56.272	64.853	5.098	0.000	0.308	70.260
1929	8.492	56.831	65.323	5.597	0.000	0.346	71.266
1930	8.724	57.395	66.119	5.500	0.000	0.354	71.973
1931	8.382	58.094	66.476	5.687	0.000	0.405	72.568
1932	8.411	58.801	67.212	5.734	0.000	0.410	73.355
1933	8.438	59.518	67.955	5.799	0.000	0.336	74.090
1934	8.040	60.242	68.283	5.380	0.000	0.484	74.147
1935	8.171	60.976	69.147	5.399	0.000	0.405	74.950
1936	8.304	61.719	70.022	5.962	0.000	0.366	76.351
1937	8.207	62.471	70.678	6.219	0.000	0.505	77.402
1938	8.244	63.231	71.475	6.219	0.000	0.549	78.243
1939	8.356	64.001	72.358	8.471	0.000	0.551	81.380
1940	8.261	64.781	73.042	10.723	0.000	0.812	84.578
1941	8.143	65.324	73.466	12.976	0.000	1.105	87.547
1942	8.020	65.871	73.891	15.228	3.977	1.466	94.562
1943	7.893	66.423	74.316	15.228	6.587	2.372	98.503
1944	7.762	66.980	74.741	16.018	11.125	2.306	104.191
1945	7.626	67.541	75.167	16.584	8.416	2.297	102.464
1946	7.487	68.107	75.593	16.201	9.178	1.742	102.714
1947	7.343	68.678	76.020	13.362	7.996	0.994	98.372
1948	7.194	69.253	76.447	10.516	0.377	0.995	88.334
1949	7.275	69.833	77.108	9.777	0.270	1.385	88.540
1950	7.353	70.418	77.771	9.596	0.056	0.854	88.278
1951	n.a.	n.a.	77.946	9.138	0.028	0.456	87.568
1952	n.a.	n.a.	78.122	8.864	0.000	0.432	87.417
1953	n.a.	n.a.	78.297	10.060	0.005	0.423	88.785
1954	n.a.	n.a.	78.472	10.449	0.000	0.509	89.430
1955	n.a.	n.a.	78.647	10.421	0.000	0.407	89.474

(segue)

	Firewood urban households	**Firewood rural households**	**Firewood households**	**Firewood industry**	**Firewood transports**	**Firewood power**	**Total**
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1956	n.a.	n.a.	78.822	10.963	0.000	0.336	90.120
1957	n.a.	n.a.	78.996	11.391	0.000	0.264	90.651
1958	n.a.	n.a.	79.171	10.570	0.000	0.270	90.011
1959	n.a.	n.a.	79.345	10.897	0.000	0.203	90.446
1960	n.a.	n.a.	79.520	11.993	0.000	0.143	91.656
1961	n.a.	n.a.	77.996	12.018	0.000	0.142	90.155
1962	n.a.	n.a.	76.481	12.653	0.000	0.169	89.302
1963	n.a.	n.a.	74.975	11.952	0.000	0.146	87.073
1964	n.a.	n.a.	73.478	12.854	0.000	0.128	86.460
1965	n.a.	n.a.	71.989	13.239	0.000	0.152	85.380
1966	n.a.	n.a.	70.510	13.152	0.000	0.107	83.769
1967	n.a.	n.a.	69.040	14.758	0.000	0.109	83.907
1968	n.a.	n.a.	67.578	15.863	0.000	0.061	83.503
1969	n.a.	n.a.	66.125	15.851	0.000	0.111	82.087
1970	n.a.	n.a.	64.681	16.036	0.000	0.117	80.834
1971	n.a.	n.a.	64.344	14.329	0.000	0.223	78.895
1972	n.a.	n.a.	63.984	13.998	0.000	0.023	78.005
1973	n.a.	n.a.	63.601	13.377	0.000	0.215	77.193
1974	n.a.	n.a.	63.194	13.419	0.000	0.036	76.650
1975	n.a.	n.a.	62.764	13.237	0.000	0.270	76.271
1976	n.a.	n.a.	62.309	12.872	0.000	0.019	75.200
1977	n.a.	n.a.	61.829	13.886	0.000	0.138	75.853
1978	n.a.	n.a.	61.323	13.642	0.000	0.009	74.975
1979	n.a.	n.a.	60.791	12.561	0.000	0.291	73.643
1980	n.a.	n.a.	60.232	12.813	0.000	0.332	73.377
1981	n.a.	n.a.	59.590	13.150	0.000	0.392	73.132
1982	n.a.	n.a.	58.948	14.462	0.000	0.409	73.819
1983	n.a.	n.a.	58.305	14.654	0.000	0.424	73.383
1984	n.a.	n.a.	57.663	14.654	0.000	0.349	72.666
1985	n.a.	n.a.	57.020	19.079	0.000	0.406	76.506
1986	n.a.	n.a.	56.378	19.217	0.000	1.049	76.644
1987	n.a.	n.a.	55.735	23.255	0.000	1.038	80.028
1988	n.a.	n.a.	55.092	23.561	0.000	1.042	79.695
1989	n.a.	n.a.	54.449	22.456	0.000	0.892	77.797
1990	n.a.	n.a.	53.806	19.841	0.000	4.203	77.850
1991	n.a.	n.a.	51.377	19.776	0.000	4.827	75.980
1992	n.a.	n.a.	49.811	19.316	0.000	6.131	75.258
1993	n.a.	n.a.	48.545	18.914	0.000	6.986	74.445
1994	n.a.	n.a.	48.032	18.657	0.000	6.251	72.939
1995	n.a.	n.a.	48.064	18.807	0.000	6.909	73.781
1996	n.a.	n.a.	48.204	20.011	0.000	6.610	74.825
1997	n.a.	n.a.	48.358	20.080	0.000	7.029	75.467
1998	n.a.	n.a.	47.939	20.293	0.000	6.806	75.038
1999	n.a.	n.a.	47.311	21.139	0.000	7.141	75.590
2000	n.a.	n.a.	47.102	21.276	0.000	6.149	74.527
2001	n.a.	n.a.	47.311	22.509	0.000	4.923	74.743
2002	n.a.	n.a.	47.311	21.285	0.000	6.789	75.384
2003	n.a.	n.a.	48.158	22.498	0.000	6.412	77.067
2004	n.a.	n.a.	48.509	22.807	0.000	8.761	80.077
2005	n.a.	n.a.	48.759	23.251	0.000	8.316	80.326
2006	n.a.	n.a.	48.609	23.682	0.000	9.003	81.295

4. Wind and water; solar and geothermal heat (Appendix I, 1, col. 4)

	Wind: sailing ships	Wind: fishery boats	Wind & Water: Cereal mills	Wind &Water: Industrial Mills	Solar heat	Geothermal heat	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1856	0.173	0.063	0.531	0.140			0.907
1857	0.184	0.064	0.535	0.140			0.922
1858	0.194	0.064	0.538	0.140			0.937
1859	0.204	0.065	0.542	0.140			0.951
1860	0.215	0.066	0.546	0.140			0.966
1861	0.225	0.066	0.549	0.140			0.981
1862	0.235	0.067	0.553	0.140			0.996
1863	0.246	0.068	0.557	0.140			1.010
1864	0.256	0.068	0.560	0.140			1.025
1865	0.253	0.069	0.564	0.140			1.026
1866	0.250	0.070	0.568	0.140			1.027
1867	0.247	0.070	0.571	0.140			1.029
1868	0.244	0.071	0.575	0.140			1.030
1869	0.241	0.072	0.579	0.140			1.031
1870	0.237	0.072	0.582	0.140			1.032
1871	0.234	0.073	0.586	0.140			1.034
1872	0.231	0.074	0.590	0.140			1.035
1873	0.228	0.074	0.593	0.140			1.036
1874	0.225	0.075	0.597	0.140			1.037
1875	0.222	0.076	0.601	0.140			1.038
1876	0.219	0.076	0.604	0.140			1.040
1877	0.216	0.077	0.608	0.140			1.041
1878	0.212	0.078	0.612	0.140			1.042
1879	0.209	0.078	0.615	0.140			1.043
1880	0.206	0.079	0.619	0.140			1.044
1881	0.198	0.080	0.623	0.140			1.041
1882	0.191	0.080	0.626	0.140			1.038
1883	0.183	0.081	0.630	0.140			1.034
1884	0.175	0.082	0.634	0.140			1.031
1885	0.181	0.083	0.637	0.140			1.041
1886	0.184	0.083	0.641	0.140			1.049
1887	0.193	0.084	0.645	0.140			1.062
1888	0.202	0.085	0.648	0.140			1.075
1889	0.212	0.085	0.652	0.140			1.089
1890	0.221	0.089	0.656	0.140			1.105
1891	0.248	0.093	0.654	0.138			1.133
1892	0.275	0.097	0.653	0.136			1.162
1893	0.303	0.100	0.652	0.135			1.190
1894	0.330	0.104	0.651	0.133			1.218
1895	0.358	0.108	0.649	0.131			1.246
1896	0.385	0.112	0.648	0.129			1.274
1897	0.413	0.111	0.647	0.127			1.298
1898	0.440	0.119	0.646	0.125			1.330
1899	0.468	0.118	0.645	0.123			1.354
1900	0.453	0.114	0.643	0.121			1.331
1901	0.439	0.118	0.641	0.120			1.317
1902	0.424	0.140	0.638	0.118			1.320
1903	0.410	0.131	0.636	0.116			1.292
1904	0.386	0.138	0.633	0.114			1.272
1905	0.363	0.130	0.631	0.112			1.236

(segue)

	Wind: sailing ships	Wind: fishery boats	Wind & Water: Cereal mills	Wind &Water: Industrial Mills	Solar heat	Geothermal heat	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1906	0.353	0.134	0.628	0.110			1.226
1907	0.343	0.130	0.626	0.108			1.207
1908	0.334	0.130	0.623	0.106			1.193
1909	0.324	0.177	0.621	0.105			1.226
1910	0.314	0.181	0.618	0.103			1.216
1911	0.304	0.212	0.615	0.101			1.232
1912	0.294	0.212	0.611	0.099			1.215
1913	0.284	0.209	0.606	0.097			1.196
1914	0.274	0.208	0.602	0.095			1.179
1915	0.264	0.172	0.597	0.093			1.127
1916	0.268	0.177	0.592	0.091			1.128
1917	0.271	0.132	0.588	0.090			1.080
1918	0.274	0.136	0.583	0.090			1.084
1919	0.277	0.152	0.579	0.092			1.100
1920	0.281	0.153	0.574	0.091			1.099
1921	0.284	0.150	0.569	0.092			1.094
1922	0.287	0.176	0.565	0.092			1.119
1923	0.290	0.166	0.560	0.092			1.109
1924	0.293	0.178	0.555	0.093			1.119
1925	0.297	0.150	0.551	0.093			1.090
1926	0.300	0.169	0.546	0.094			1.109
1927	0.303	0.163	0.542	0.094			1.102
1928	0.346	0.143	0.537	0.094			1.120
1929	0.326	0.172	0.532	0.094			1.124
1930	0.327	0.145	0.528	0.095			1.095
1931	0.332	0.172	0.536	0.095			1.135
1932	0.312	0.127	0.544	0.095			1.077
1933	0.310	0.118	0.552	0.095			1.074
1934	0.308	0.121	0.560	0.095			1.084
1935	0.234	0.115	0.568	0.096			1.013
1936	0.232	0.128	0.576	0.098			1.033
1937	0.186	0.128	0.584	0.099			0.996
1938	0.140	0.137	0.592	0.100			0.968
1939	0.135	0.122	0.600	0.101			0.957
1940	0.129	0.107	0.607	0.102			0.946
1941	0.124	0.112	0.612	0.103			0.952
1942	0.119	0.114	0.616	0.104			0.953
1943	0.114	0.123	0.620	0.106			0.962
1944	0.109	0.122	0.624	0.107			0.961
1945	0.103	0.118	0.629	0.108			0.958
1946	0.098	0.117	0.633	0.109			0.957
1947	0.052	0.112	0.637	0.110			0.911
1948	0.084	0.114	0.641	0.111			0.951
1949	0.051	0.110	0.646	0.113			0.919
1950	0.043	0.114	0.650	0.114			0.920
1951	0.040	0.110	0.645	0.114			0.908
1952	0.035	0.108	0.639	0.115			0.896
1953	0.008	0.103	0.634	0.115			0.861
1954	0.006	0.104	0.629	0.115			0.854
1955	0.006	0.103	0.623	0.116			0.848

(segue)

	Wind: sailing ships	Wind: fishery boats	Wind & Water: Cereal mills	Wind &Water: Industrial Mills	Solar heat	Geothermal heat	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1956	0.008	0.101	0.618	0.116			0.844
1957	0.006	0.097	0.613	0.117			0.832
1958	0.001	0.093	0.607	0.116			0.817
1959	0.001	0.093	0.602	0.113			0.809
1960	0.001	0.092	0.597	0.110			0.800
1961	0.001	0.094	0.578	0.107			0.781
1962	0.001	0.093	0.560	0.104			0.758
1963	0.001	0.091	0.541	0.101			0.735
1964	0.001	0.093	0.523	0.098			0.715
1965	0.001	0.092	0.504	0.093			0.690
1966	0.001	0.089	0.486				0.576
1967	0.001	0.089	0.467				0.557
1968	0.001	0.085	0.449				0.535
1969	0.000	0.082	0.431				0.513
1970		0.080	0.412				0.493
1971		0.081	0.402				0.483
1972		0.075	0.392				0.467
1973		0.073	0.382				0.455
1974		0.069	0.372				0.440
1975		0.064	0.362				0.426
1976		0.061	0.351				0.412
1977		0.062	0.341				0.404
1978		0.063	0.331				0.394
1979		0.065	0.321				0.386
1980		0.066	0.311				0.377
1981		0.061	0.301				0.362
1982		0.066					0.066
1983		0.064					0.064
1984		0.066					0.066
1985		0.064					0.064
1986		0.062					0.062
1987		0.041					0.041
1988		0.039					0.039
1989		0.036					0.036
1990		0.032					0.032
1991		0.028					0.028
1992		0.026					0.026
1993		0.023					0.023
1994		0.013					0.013
1995		0.012					0.012
1996		0.011					0.011
1997		0.011					0.011
1998		0.010			0.703	0.042	0.756
1999		0.010			0.724	0.042	0.776
2000		0.010			0.745	0.042	0.797
2001					0.766	0.042	0.808
2002					0.787	0.042	0.829
2003					0.808	0.042	0.850
2004					0.846	0.042	0.888
2005					0.917	0.042	0.959
2006					0.963	0.419	1.382

5. Coal (Appendix 1, 1, col. 5)

	Production	Imports	Foreign navigation, exports	Net imports	Stock variation	Total
	PJ	PJ	PJ	PJ	PJ	PJ
1856	0.229	3.555	0.223	3.331	n.a.	3.560
1857	0.229	2.576	0.000	2.576	n.a.	2.805
1858	0.229	3.091	0.000	3.091	n.a.	3.319
1859	0.229	3.791	0.000	3.791	n.a.	4.020
1860	0.220	2.997	0.000	2.997	n.a.	3.218
1861	0.203	2.647	0.110	2.537	n.a.	2.741
1862	0.186	2.796	0.169	2.627	n.a.	2.813
1863	0.194	2.945	0.228	2.717	n.a.	2.912
1864	0.194	3.094	0.286	2.808	n.a.	3.002
1865	0.194	3.243	0.345	2.898	n.a.	3.092
1866	0.194	4.862	0.288	4.574	n.a.	4.768
1867	0.194	4.269	0.298	3.970	n.a.	4.165
1868	0.203	5.780	0.296	5.484	n.a.	5.688
1869	0.203	4.184	0.499	3.684	n.a.	3.888
1870	0.212	5.481	0.497	4.985	n.a.	5.196
1871	0.175	4.876	0.941	3.936	n.a.	4.110
1872	0.185	5.291	0.977	4.314	n.a.	4.499
1873	0.209	7.631	1.298	6.333	n.a.	6.542
1874	0.200	5.439	0.851	4.588	n.a.	4.788
1875	0.209	6.630	1.058	5.572	n.a.	5.781
1876	0.269	6.379	0.902	5.477	n.a.	5.746
1877	0.218	6.996	0.844	6.152	n.a.	6.370
1878	0.218	6.681	0.167	6.514	n.a.	6.732
1879	0.409	7.424	1.262	6.162	n.a.	6.571
1880	0.241	9.306	1.111	8.195	n.a.	8.436
1881	0.279	9.566	1.377	8.189	n.a.	8.468
1882	0.275	11.306	1.868	9.439	n.a.	9.713
1883	0.309	11.856	1.882	9.973	n.a.	10.283
1884	0.206	12.695	1.925	10.769	n.a.	10.975
1885	0.258	11.743	1.974	9.768	n.a.	10.026
1886	0.275	12.947	2.066	10.881	n.a.	11.156
1887	0.309	14.048	1.914	12.134	n.a.	12.443
1888	0.326	15.148	2.293	12.855	n.a.	13.182
1889	0.258	17.878	2.612	15.266	n.a.	15.524
1890	0.285	18.392	2.366	16.027	n.a.	16.312
1891	0.299	18.790	2.351	16.439	n.a.	16.739
1892	0.291	18.061	2.504	15.557	n.a.	15.847
1893	0.387	15.797	2.576	13.221	n.a.	13.608
1894	0.369	18.767	2.529	16.238	n.a.	16.607
1895	0.328	18.073	2.849	15.224	n.a.	15.552
1896	0.288	18.371	3.068	15.303	n.a.	15.590
1897	0.298	19.414	3.711	15.703	n.a.	16.000
1898	0.387	22.218	3.992	18.227	n.a.	18.614
1899	0.381	22.705	5.170	17.535	n.a.	17.916
1900	0.413	26.119	7.435	18.684	n.a.	19.097
1901	0.277	25.499	6.925	18.574	n.a.	18.851
1902	0.288	28.351	7.789	20.563	n.a.	20.851
1903	0.216	27.380	5.782	21.598	n.a.	21.814
1904	0.220	28.854	5.175	23.679	n.a.	23.899
1905	0.192	28.011	4.800	23.211	n.a.	23.403

(segue)

	Production	Imports	Foreign navigation, exports	Net imports	Stock variation	Total
	PJ	PJ	PJ	PJ	PJ	PJ
1906	0.088	31.787	5.276	26.511	n.a.	26.599
1907	0.107	34.760	5.609	29.151	n.a.	29.258
1908	0.098	34.738	5.124	29.614	n.a.	29.713
1909	0.154	35.212	5.685	29.526	n.a.	29.681
1910	0.140	35.933	5.380	30.552	n.a.	30.692
1911	0.182	34.596	3.051	31.545	n.a.	31.728
1912	0.263	40.226	5.773	34.453	n.a.	34.716
1913	0.431	40.751	4.509	36.242	n.a.	36.673
1914	0.506	35.456	2.739	32.717	n.a.	33.223
1915	1.138	31.370	2.304	29.065	n.a.	30.203
1916	2.603	27.826	3.708	24.118	n.a.	26.722
1917	3.530	11.787	4.191	7.596	n.a.	11.126
1918	3.409	6.295	2.848	3.447	n.a.	6.856
1919	2.537	19.118	5.211	13.907	n.a.	16.445
1920	3.100	17.862	4.608	13.254	n.a.	16.354
1921	2.905	19.171	5.152	14.018	n.a.	16.923
1922	2.433	27.363	4.721	22.643	n.a.	25.076
1923	2.764	23.241	4.555	18.686	n.a.	21.450
1924	2.468	27.565	4.339	23.226	n.a.	25.695
1925	2.413	29.230	4.448	24.781	n.a.	27.195
1926	3.994	25.978	4.759	21.219	n.a.	25.213
1927	3.510	31.957	4.312	27.644	n.a.	31.155
1928	3.915	34.140	3.756	30.384	n.a.	34.299
1929	3.888	33.572	4.189	29.384	n.a.	33.271
1930	4.238	36.189	3.748	32.441	n.a.	36.679
1931	3.900	32.513	2.264	30.249	n.a.	34.149
1932	3.568	26.826	1.384	25.442	n.a.	29.010
1933	3.724	32.444	1.537	30.907	n.a.	34.630
1934	3.767	32.669	1.742	30.928	n.a.	34.695
1935	4.098	34.245	1.665	32.580	n.a.	36.678
1936	4.051	32.165	2.434	29.732	n.a.	33.783
1937	4.898	42.078	3.669	38.410	n.a.	43.308
1938	5.600	34.537	2.654	31.883	n.a.	37.482
1939	5.629	36.828	2.556	34.273	n.a.	39.902
1940	7.434	23.576	2.108	21.468	n.a.	28.902
1941	8.911	21.029	1.276	19.752	n.a.	28.663
1942	10.412	15.146	0.692	14.454	n.a.	24.867
1943	8.567	16.518	0.487	16.031	n.a.	24.598
1944	9.224	17.912	0.833	17.079	n.a.	26.303
1945	10.327	15.267	0.641	14.627	n.a.	24.953
1946	8.975	18.620	0.841	17.779	n.a.	26.754
1947	8.207	29.228	0.549	28.680	n.a.	36.887
1948	8.416	24.553	0.645	23.909	n.a.	32.325
1949	9.588	26.618	0.494	26.124	n.a.	35.712
1950	8.800	22.141	0.251	21.891	n.a.	30.691
1951	8.621	18.785	0.220	18.565	n.a.	27.186
1952	8.912	13.751	0.099	13.652	n.a.	22.564
1953	9.441	16.989	0.068	16.921	n.a.	26.362
1954	8.539	13.714	0.084	13.630	n.a.	22.169
1955	8.452	14.972	0.069	14.903	n.a.	23.355

(segue)

	Production	Imports	Foreign navigation, exports	Net imports	Stock variation	Total
	PJ	PJ	PJ	PJ	PJ	PJ
1956	9.610	14.056	0.071	13.985	n.a.	23.595
1957	11.721	16.330	0.073	16.257	n.a.	27.978
1958	12.426	11.676	0.058	11.618	n.a.	24.044
1959	11.793	9.677	0.054	9.623	n.a.	21.415
1960	10.145	11.434	0.013	11.421	n.a.	21.565
1961	10.786	16.349	0.090	16.259	n.a.	27.045
1962	9.579	15.845	0.049	15.796	n.a.	25.375
1963	9.592	19.300	0.028	19.272	n.a.	28.863
1964	9.358	18.804	0.007	18.796	n.a.	28.155
1965	8.884	18.615	0.007	18.608	n.a.	27.492
1966	8.088	21.907	0.003	21.904	n.a.	29.991
1967	8.267	19.800	0.002	19.798	n.a.	28.064
1968	7.343	17.954	0.007	17.947	n.a.	25.290
1969	8.607	19.694	0.004	19.690	n.a.	28.297
1970	4.652	21.332	0.017	21.315	n.a.	25.967
1971	4.344	11.730	0.000	11.730	-3.733	19.808
1972	4.866	14.758	0.000	14.758	2.152	17.472
1973	3.790	13.681	0.000	13.681	-2.926	20.397
1974	3.952	12.145	0.000	12.145	-0.013	16.110
1975	3.804	12.520	0.000	12.520	-0.347	16.671
1976	3.321	12.418	0.000	12.418	-0.650	16.388
1977	3.352	14.466	0.000	14.466	1.025	16.792
1978	3.092	15.152	0.000	15.152	0.145	18.098
1979	3.073	14.133	0.000	14.133	-0.970	18.177
1980	3.046	14.305	0.000	14.305	-0.315	17.667
1981	3.154	10.650	0.000	10.650	-1.684	15.489
1982	3.065	11.184	0.000	11.184	0.722	13.527
1983	3.180	15.337	0.000	15.337	2.189	16.327
1984	3.334	17.100	0.000	17.100	2.604	17.829
1985	4.068	43.878	0.000	43.878	15.382	32.564
1986	4.049	54.785	0.000	54.785	-1.952	60.786
1987	4.473	78.529	0.000	78.529	3.787	79.215
1988	3.946	80.495	0.000	80.495	-2.953	87.394
1989	4.429	97.817	0.000	97.817	-5.254	107.501
1990	4.826	125.538	0.220	125.318	14.479	115.571
1991	4.640	114.742	0.562	114.180	-3.100	121.680
1992	3.792	120.075	0.813	119.262	-0.787	123.493
1993	3.386	128.599	0.378	128.222	-0.116	131.562
1994	2.526	135.146	0.236	134.910	-2.010	139.345
1995	0.000	161.711	1.445	160.265	8.763	150.883
1996	0.000	141.929	0.960	140.969	-3.068	143.625
1997	0.000	156.434	1.298	155.136	7.519	147.062
1998	0.000	139.045	1.555	137.490	1.508	135.316
1999	0.000	159.001	1.571	157.430	-0.129	156.886
2000	0.000	166.506	1.571	164.935	4.613	159.649
2001	0.000	123.871	0.000	123.871	-10.146	134.017
2002	0.000	146.462	0.000	146.462	-0.095	146.557
2003	0.000	140.158	0.000	140.158	-0.310	140.468
2004	0.000	134.528	0.000	134.528	-6.778	141.306
2005	0.000	135.053	0.000	135.053	-5.156	140.209
2006	0.000	146.450	0.115	146.335	7.689	138.597

6.1. Energetic Oil (Appendix I, 1, col. 6)

	Crude Oil	Feed-stocks	Kero-sene	Gaso-lines	Jets	Gas oil/ Diesel/Fuel oil	Gasoil/ diesel	Fuel-oil	Petrol coke	LPG	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1861			0.0002								0.000
1862			0.000								0.000
1863			0.000								0.000
1864			0.000								0.000
1865			0.029								0.029
1866			0.048								0.048
1867			0.062								0.062
1868			0.077								0.077
1869			0.150								0.150
1870			0.166								0.166
1871			0.119								0.119
1872			0.134								0.134
1873			0.161								0.161
1874			0.191								0.191
1875			0.128								0.128
1876			0.162								0.162
1877			0.217								0.217
1878			0.248								0.248
1879			0.305								0.305
1880			0.301								0.301
1881			0.361								0.361
1882			0.340								0.340
1883			0.238								0.238
1884			0.418								0.418
1885			0.397								0.397
1886			0.413								0.413
1887			0.433								0.433
1888			0.454								0.454
1889			0.480								0.480
1890			0.534								0.534
1891			0.544								0.544
1892			0.620								0.620
1893			0.603								0.603
1894			0.641								0.641
1895			0.597								0.597
1896			0.576								0.576
1897			0.623								0.623
1898			0.618								0.618
1899			0.644								0.644
1900			0.597								0.597
1901			0.703								0.703
1902			0.647								0.647
1903			0.736								0.736
1904			0.627								0.627
1905			0.679								0.679

(segue)

	Crude Oil	Feed-stocks	Kero-sene	Gaso-lines	Jets	Gas oil/ Diesel/Fuel oil	Gasoil/ diesel	Fuel-oil	Petrol coke	LPG	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1906			0.702								0.702
1907			0.742								0.742
1908			0.743								0.743
1909			0.757								0.757
1910			1.084								1.084
1911			1.086								1.086
1912			0.817								0.817
1913			0.967								0.967
1914			0.714								0.714
1915			0.695								0.695
1916			0.686	0.306							0.992
1917			0.762	0.263							1.025
1918			0.269	0.08							0.349
1919			1.014	0.38		0.006					1.400
1920			0.782	0.447		0.48					1.709
1921			0.707	0.404		0.479					1.590
1922			0.941	0.512		0.4					1.853
1923			0.863	0.397		0.868					2.128
1924			0.871	0.496		0.981					2.348
1925			1.058	0.634		0.532					2.224
1926			1.283	0.928		0.487					2.698
1927			1.34	1.232		0.524					3.096
1928			1.691	1.755		0.852					4.298
1929			1.542	1.798		0.885					4.225
1930			1.823	2.087		0.952					4.862
1931			1.79	2.129		0.993					4.912
1932			1.782	2.074		1.012					4.868
1933			2.094	2.286		1.157					5.537
1934			2.554	2.645		1.275					6.474
1935			2.299	3.104		1.592					6.995
1936			2.2	3.008		1.639					6.847
1937			2.247	3.257		2.4					7.904
1938			2.203	3.314		2.729					8.246
1939			2.169	3.282		3.37				0.004	8.825
1940	4.866		1.03	1.577		1.819				0.001	9.293
1941	4.612		0.623	1.546		1.48				0.012	8.273
1942	0.905		0.764	0.592		0.409				0.009	2.679
1943	0.000		0.763	1.394		2.702				0.006	4.865
1944	4.421		1.163	1.748		2.909				0.007	10.248
1945	1.215		1.468	2.024		4.363				0.008	9.078
1946	4.337		2.011	2.752		6.668				0.011	15.779
1947	11.135		1.917	3.153		8.433				0.018	24.656
1948	12.515		2.534	3.764		8.1				0.021	26.934
1949	11.783		2.177	3.574		8.992				0.02	26.546
1950	11.910		2.317	2.832		12.519				0.025	29.603
1951	14.825		2.781	3.527		13.033				0.025	34.191
1952	20.005		2.689	2.332		12.443				0.053	37.522
1953	5.574		5.133	5.775	0.133	23.896				0.078	40.589
1954	31.033		2.017	-0.36	0.081	11.738				0.123	44.632
1955	37.706		1.759	-2.265	0	13.6				0.062	50.862

(segue)

	Crude Oil	Feed-stocks	Kero-sene	Gaso-lines	Jets	Gas oil/ Diesel/Fuel oil	Gasoil/ diesel	Fuel-oil	Petrol coke	LPG	Total
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1956	40.619		1.808	-2.273	0	12.502				0.019	52.675
1957	39.172		1.262	-1.589	0.001	13.450				0.000	52.296
1958	46.605		0.549	-3.880	0.005	12.146				0.000	55.425
1959	51.582		0.141	-3.026	0.002	12.209				0.011	60.919
1960	53.663		0.827	-3.247	0.000	14.321			0.473	0.076	66.113
1961	55.631		-0.749	-2.456	0.000	19.001			0.590	0.521	72.539
1962	55.107		0.509	-1.074	0.000	21.205	11.237	9.968	0.693	0.903	77.343
1963	59.631		-1.119	-1.165	-0.319	21.079	11.826	9.253	0.633	1.328	80.068
1964	62.354		0.094	-0.269	-2.845	20.285	11.234	9.050	0.417	2.825	82.861
1965	65.497		0.513	2.144	-4.216	23.554	12.208	11.346	0.009	4.194	91.695
1966	66.876		0.787	2.417	-5.551	21.793	10.853	10.940	0.017	4.992	91.331
1967	69.418		0.710	4.725	-6.279	27.310	14.348	12.962	0.020	7.359	103.263
1968	68.328		0.238	7.837	-4.810	33.125	17.273	15.851	0.008	7.948	112.674
1969	78.994		0.234	11.781	-4.247	28.599	15.418	13.180	0.091	8.736	124.188
1970	145.008		-5.085	0.842	-1.969	4.188	7.629	-3.442	0.044	10.061	153.089
1971	154.352	1.952	-3.858	1.331	-3.352	9.738	4.494	5.245	0.000	10.302	170.465
1972	169.738	0.498	-3.904	3.510	-2.756	12.380	3.796	8.584	0.000	11.487	190.952
1973	164.216	2.379	-3.157	7.671	-0.892	26.010	9.829	16.181	0.000	12.948	209.174
1974	223.578	3.560	-0.429	-0.729	-1.465	-13.590	-3.222	-10.367	0.000	11.654	222.580
1975	221.161	1.775	0.049	2.448	-4.097	12.527	-0.528	13.054	0.000	12.624	246.488
1976	227.794	-0.748	0.243	-0.460	-6.186	23.894	3.013	20.880	0.000	14.610	259.147
1977	226.169	2.502	0.162	0.538	-7.804	20.000	5.915	14.085	0.000	14.790	256.357
1978	255.475	-15.626	0.056	-0.810	-5.401	13.783	10.412	3.371	0.000	15.618	263.097
1979	330.323	-1.257	-2.008	-12.710	-9.040	-32.294	-9.499	-22.795	0.000	14.891	287.906
1980	302.885	1.599	-0.188	-9.968	-9.488	15.175	1.404	13.771	0.000	13.424	313.440
1981	322.687	2.782	-0.066	-15.112	-15.201	28.483	-2.019	30.502	0.000	12.639	336.212
1982	315.452	-2.313	-0.310	-3.315	-9.256	37.136	7.839	29.297	0.000	14.588	351.981
1983	321.634	5.028	0.087	-1.966	-12.079	30.455	-8.574	39.030	0.000	13.312	356.472
1984	294.390	-0.108	0.086	1.216	-15.259	54.620	4.096	50.524	0.000	14.139	349.084
1985	270.025	11.456	0.192	0.639	-13.839	36.486	1.939	34.547	0.000	13.726	318.685
1986	316.533	3.520	0.115	-5.137	-18.455	18.835	-10.145	28.980	0.000	13.171	328.583
1987	287.860	4.540	-0.058	2.208	-14.102	24.711	12.510	12.201	0.000	16.656	321.815
1988	300.170	29.390	0.095	-10.046	-17.050	6.254	8.987	-2.733	0.000	17.763	326.575
1989	387.619	20.358	-0.029	-12.466	-19.276	22.770	-16.615	39.385	0.000	15.857	414.833
1990	406.560	33.767	0.002	-14.550	-28.145	-4.018	-16.225	12.207	0.000	20.021	413.637
1991	373.176	14.637	0.074	-5.209	-21.030	42.350	16.278	26.072	0.000	24.581	428.579
1992	438.976	29.257	-0.107	-7.547	-24.843	21.275	-4.961	26.235	0.000	24.995	482.007
1993	417.416	32.144	0.371	5.202	-18.187	-11.359	-15.645	4.286	0.000	28.665	454.253
1994	526.808	27.095	-0.146	-23.600	-34.204	-66.878	-49.492	-17.386	0.000	26.803	455.878
1995	493.541	43.402	0.007	-38.432	-31.685	-6.982	-33.571	26.589	3.111	30.715	493.678
1996	448.817	43.932	0.053	-27.692	-25.091	0.290	-12.047	12.337	4.794	37.338	482.441
1997	476.781	63.751	-0.007	-38.785	-29.072	4.090	-11.596	15.686	10.021	36.632	523.411
1998	511.659	40.626	-0.091	-34.235	-27.754	31.437	-13.274	44.711	15.215	26.200	563.057
1999	481.903	42.273	0.100	-25.448	-22.467	48.452	3.029	45.423	20.640	34.779	580.230
2000	432.150	35.849	0.216	-9.289	-14.576	66.773	45.069	21.704	16.504	34.757	562.385
2001	458.281	39.514	0.167	-27.152	-8.423	62.639	28.829	33.809	21.104	31.115	577.244
2002	425.591	62.134	0.170	-20.931	-3.281	80.499	22.680	57.820	26.247	33.135	603.565
2003	462.008	51.829	0.178	-32.870	-11.275	31.399	21.372	10.026	24.470	25.920	551.659
2004	460.717	45.093	0.108	-28.679	-14.137	33.735	38.115	-4.379	28.893	26.793	552.524
2005	481.088	43.182	0.037	-31.250	-14.868	35.208	24.374	10.834	33.481	22.573	569.450
2006	493.703	70.760	0.057	-48.794	-15.880	-28.961	10.818	-39.779	32.129	21.355	524.367

6.2. Oil: non-energy uses

	Crude oil (non energy uses)	Naphtha	Asphalts	Lubricants	Paraffins	Solvents	Propylen	Total non-energy uses
	PJ	PJ	PJ	PJ	PJ	PJ	PJ	PJ
1892				0.056				0.056
1893				0.055				0.055
1894				0.052				0.052
1895				0.072	0.007			0.079
1896				0.078	0.003			0.081
1897				0.082	0.004			0.086
1898				0.071	0.017			0.088
1899				0.097	0.006			0.102
1900				0.108	0.008			0.116
1901				0.099	0.019			0.118
1902				0.107	0.013			0.120
1903				0.147	0.015			0.163
1904				0.111	0.020			0.131
1905				0.171	0.022			0.193
1906				0.186	0.016			0.202
1907				0.210	0.004			0.213
1908				0.165	0.017			0.182
1909				0.176	0.012			0.187
1910				0.175	0.022			0.196
1911				0.237	0.013			0.250
1912				0.286	0.012			0.298
1913				0.274	0.018			0.292
1914				0.289	0.014			0.304
1915				0.270	0.039			0.309
1916				0.372	0.012			0.384
1917				0.257	0.016			0.273
1918				0.097	0.030			0.127
1919				0.447	0.013			0.460
1920				0.322	0.049			0.371
1921				0.153	0.009			0.162
1922				0.329	0.015			0.345
1923				0.401	0.055			0.456
1924				0.302	0.022			0.324
1925				0.327	0.018			0.345
1926				0.366	0.048			0.415
1927				0.469	0.047			0.516
1928				0.784	0.046			0.831
1929				0.631	0.046			0.676
1930			0.027	0.674	0.037			0.738
1931			0.216	0.641	0.041			0.898
1932			0.142	0.599	0.034			0.775
1933			0.103	0.763	0.045			0.911
1934			0.092	0.771	0.039			0.901
1935			0.276	1.054	0.062			1.392
1936			0.144	0.730	0.036			0.910
1937			0.036	0.691	0.041			0.767
1938			0.016	0.567	0.049			0.632
1939			0.074	0.633	0.046			0.753
1940			0.002	0.326	0.000			0.328

(segue)

	Crude oil (non energy uses) PJ	Naphtha PJ	Asphalts PJ	Lubricants PJ	Paraffins PJ	Solvents PJ	Propylen PJ	Total non-energy uses PJ
1941			0.000	0.090	0.029			0.120
1942			0.000	0.072	0.005			0.077
1943			0.000	0.242	0.032			0.274
1944			0.000	0.281	0.012			0.292
1945			0.000	0.314	0.032			0.346
1946			0.000	0.591	0.081			0.671
1947			0.000	0.651	0.038			0.689
1948			0.004	0.849	0.075			0.928
1949			0.002	0.573	0.076			0.651
1950			0.003	0.483	0.061			0.548
1951			0.008	0.866	0.085			0.959
1952			0.006	0.679	0.058			0.743
1953			0.008	0.585	0.056			0.649
1954			0.012	0.710	0.076			0.798
1955			0.018	0.789	0.094			0.902
1956	0.049		0.018	0.983	0.091			1.141
1957	0.048		0.025	0.046	0.106			0.224
1958	1.969		0.044	0.009	0.087			2.108
1959	0.551		0.029	1.042	0.091			1.713
1960	0.684	0.002	0.629	0.051	0.124			1.489
1961	0.627	0.000	0.785	0.057	0.153			1.622
1962	0.767	0.003	0.929	0.054	0.122			1.876
1963	4.739	0.000	0.784	0.059	0.123			5.705
1964	6.119	0.000	1.127	0.066	0.157			7.470
1965	6.479	0.000	1.028	0.078	0.135			7.720
1966	6.391	0.000	1.681	0.078	0.146			8.295
1967	7.403	0.000	1.429	0.085	0.216			9.132
1968	7.345	0.000	1.270	0.087	0.171			8.873
1969	11.115	0.000	1.588	0.097	0.157			12.957
1970	14.696	-0.973	1.916	0.113	0.279			16.030
1971	15.697	0.626	1.889	-0.458	0.100	0.543		18.396
1972	14.711	2.331	1.776	-0.975	-0.027	0.696		18.512
1973	13.067	4.014	1.788	-0.677	0.028	0.943		19.162
1974	17.098	0.007	1.536	-0.893	-0.118	0.722		18.352
1975	16.121	-0.205	1.314	0.115	-0.131	0.735		17.950
1976	14.966	0.642	1.596	-0.197	-0.010	0.914		17.912
1977	17.936	0.311	2.281	-0.115	-0.054	1.002		21.360
1978	18.876	-1.606	3.022	0.569	-0.032	0.980		21.809
1979	19.400	-1.395	1.628	1.077	-0.026	1.183		21.867
1980	15.478	3.745	0.453	1.129	0.034	1.020		21.858
1981	10.411	6.622	2.153	0.349	-0.123	0.901		20.313
1982	9.238	24.663	2.425	0.580	-0.055	-1.437		35.415
1983	18.008	11.245	1.682	0.011	-0.077	-2.377		28.491
1984	18.122	16.784	2.321	0.466	0.013	-1.243		36.464
1985	33.128	5.077	1.508	-0.388	-0.014	0.553		39.865
1986	39.413	16.742	2.476	-0.600	-0.065	0.223		58.188
1987	32.691	19.710	3.166	-0.351	0.033	0.187		55.435
1988	39.787	26.447	6.109	-0.257	-0.043	-0.103		71.939
1989	43.181	26.369	6.869	-0.403	0.029	0.176		76.222
1990	42.633	28.099	7.039	-0.164	0.049	-0.155	0	77.502

(segue)

	Crude oil (non energy uses) PJ	Naphtha PJ	Asphalts PJ	Lubricants PJ	Paraffins PJ	Solvents PJ	Propylen PJ	Total non-energy uses PJ
1991	37.143	15.691	11.787	-0.419	-0.017	-0.121	0	64.063
1992	42.199	16.882	9.695	-0.539	0.043	0.197	0	68.476
1993	44.008	14.843	10.878	-1.310	0.067	-0.257	0	68.229
1994	53.028	14.072	7.806	-1.630	-0.052	-0.029	0	73.196
1995	57.384	16.287	8.973	-1.428	0.016	-0.212	-3.255	77.766
1996	53.135	9.493	8.770	-0.546	-0.056	-0.043	-2.765	67.988
1997	50.206	21.711	13.022	1.259	0.015	-0.432	-4.451	81.331
1998	65.687	16.122	12.217	0.464	-0.153	-0.409	-2.405	91.525
1999	70.161	15.126	9.744	-0.804	-0.135	-1.010	-3.710	89.371
2000	66.836	17.197	11.564	-1.433	-0.252	-1.239	-3.237	89.436
2001	72.822	1.678	15.175	-0.622	-0.269	-0.536	-4.008	84.240
2002	78.312	2.270	10.979	-2.780	-0.432	-0.807	-3.780	83.762
2003	78.259	6.703	8.025	-1.186	-0.322	-0.968	-3.395	87.116
2004	81.625	9.309	7.796	-2.263	-0.309	-1.003	-2.439	92.716
2005	80.170	8.294	12.813	-1.694	-0.170	-1.136	-2.992	95.286
2006	72.040	5.857	7.655	-2.410	-0.283	-1.048	-3.135	78.676

7. Primary electricity (Appendix I, 1, col. 8)

	Hydro (1) GWh	Geo, eolic, solar (2) GWh	Losses before production (3) GWh	Imports (4) GWh	Exports (5) GWh		Primary electricity (6)[1] GWh	Thermo (7)[2] GWh
1894	0.172	0.057			0.229	n.a.		
1895	0.342	0.114			0.456	n.a.		
1896	0.343	0.114			0.457	n.a.		
1897	0.425	0.142			0.566	n.a.		
1898	0.453	0.151			0.605	n.a.		
1899	0.536	0.179			0.715	n.a.		
1900	0.598	0.199			0.798	n.a.		
1901	0.633	0.211			0.845	n.a.		
1902	0.753	0.251			1.004	n.a.		
1903	0.793	0.264			1.058	n.a.		
1904	1.245	0.415			1.660	n.a.		
1905	1.292	0.431			1.722	n.a.		
1906	1.903	0.634			2.538	n.a.		
1907	1.958	0.653			2.611	n.a.		
1908	2.262	0.754			3.016	n.a.		
1909	3.006	1.002			4.008	n.a.		
1910	3.076	1.025			4.101	n.a.		
1911	3.907	1.302			5.210	n.a.		
1912	4.450	1.483			5.933	n.a.		
1913	5.242	1.747			6.989	n.a.		
1914	6.108	2.036			8.144	n.a.		
1915	6.951	2.317			9.268	n.a.		

[1] Primary electricity (6) = Hydro Production (1)+ Geo, wind, photovoltaic production (2)+ Losses in production (3)+ Imports (4) –Exports (5). Hydro and geo, wind, photovoltaic production figures are comparable to official statistics as losses in the turbines are reported separately. From 1971-1989 geo production is included in hydro production.

[2] Thermoelectricity figures are a secondary form of energy and do not appear on primary energy consumption. Column 7 represents the produced electricity by mean of fuels and it is comparable with column 1. Termoelectricity in primary equivalents can be deducted from 1931 dividing column 7 (Thermo) by column 8 (thermo efficiency). Some estimations were performed for the period prior to official statistics. For 1918 thermo figures were estimated with basis on consumption figures for Lisbon (CRGE,1918) (transformed in production figures assuming 15% of losses in transmission) and Oporto production figures (SMGEP,1918). The installed power of the two main companies in the country represented 79% of the power installed in public service in 1918, and was assumed that the production proportion was the same. For 1923 I assumed 1385 hours of use for the power installed in the public service (Revista Obras Públicas e Minas, 1923), equal to the one reported for 1927 by official statistics (DGSE, 1927). On 1927 autoproduction of electricity was 50% of the electricity produced by the public service. The same proportion was assumed to 1918 and 1923. Benchmark years were connected assuming a constant rate of growth. Until 1969 data reports to Mainland Portugal.

(segue)

	Hydro (1) GWh	Geo, eolic, solar (2) GWh	Losses before production (3) GWh	Imports (4) GWh	Exports (5) GWh		Primary electricity (6) GWh	Thermo (7) GWh
1916	7.239	2.413			9.652	n.a.		
1917	7.570	2.523			10.093	n.a.		
1918	7.726	2.575			10.302	23.721		
1919	8.209	2.736			10.945	28.300		
1920	10.259	3.420			13.678	33.762		
1921	10.850	3.617			14.467	40.279		
1922	22.628	7.543			30.171	48.054		
1923	28.673	9.558			38.231	57.329		
1924	33.082	11.027			44.110	70.654		
1925	41.817	13.939			55.756	87.077		
1926	48.183	16.061			64.245	107.316		
1927	58.225	19.408	0.088		77.721	132.260		
1928	72.298	24.099	0.000		96.397	148.824		
1929	79.327	26.442	0.000		105.770	167.010		
1930	96.429	32.143	0.000		128.571	170.707		
1931	100.025	33.342	0.000		133.366	174.924	12.0	34.9
1932	108.914	36.305	0.000		145.218	183.383	12.9	36.1
1933	102.816	34.272	0.000		137.088	204.506	12.7	33.5
1934	108.183	36.061	0.000		144.244	222.175	13.5	33.7
1935	122.457	40.819	0.185		163.461	239.151	13.7	34.4
1936	138.367	46.122	0.203		184.693	238.088	14.0	36.4
1937	145.439	48.480	0.219		194.137	267.076	14.6	35.9
1938	131.525	43.842	0.248		175.615	299.588	16.2	34.1
1939	190.669	63.556	0.288		254.513	264.801	16.0	40.7
1940	185.986	61.995	0.284		248.264	281.325	14.6	38.7
1941	199.187	66.396	0.321		265.903	288.100	13.5	38.6
1942	225.268	75.089	0.369		300.726	248.436	14.1	43.1
1943	211.847	70.616	0.345		282.807	272.422	14.0	40.7
1944	205.657	68.552	0.322		274.531	306.074	12.8	37.8
1945	202.099	67.366	0.249		269.714	349.949	13.8	36.2
1946	325.296	108.432	0.349		434.077	321.684	14.3	44.8
1947	335.823	111.941	0.277		448.042	394.157	14.6	42.4
1948	362.478	120.826	0.325		483.629	457.240	15.2	41.6
1949	282.018	94.006	0.423		376.447	560.595	16.0	35.7
1950	446.424	148.808	0.427		595.658	504.821	16.4	43.9
1951	821.300	273.767	0.559		1095.625	230.509	16.2	62.1
1952	1203.916	401.305	0.749		1605.970	147.715	17.1	68.7
1953	1011.643	337.214	1.673		1350.530	380.697	18.1	59.4
1954	1473.286	491.095	0.642		1965.023	207.801	16.8	67.8
1955	1750.812	583.604	7.831		2342.247	164.684	16.6	70.0
1956	2063.213	687.738	10.103		2761.053	140.280	17.3	71.3
1957	1868.679	622.893	13.421		2504.992	328.130	14.0	65.9
1958	2539.313	846.438	4.657		3390.407	158.169	14.1	71.4
1959	2897.179	965.726	0.826		3863.732	130.175	15.2	72.4
1960	3139.719	1046.573	0.826		4187.118	158.612	14.8	72.1
1961	3457.295	610.111	10.778		4078.184	189.248	17.6	81.5
1962	3548.670	626.236	26.862		4201.768	321.910	19.5	79.6
1963	4043.107	713.490	55.180		4811.777	300.102	19.5	80.5
1964	4261.207	751.978	43.150	55.031	5001.304	540.360	21.2	77.8
1965	4023.047	709.949	441.806	11.119	5163.683	651.620	21.6	76.2

(segue)

	Hydro (1) GWh	Geo, eolic, solar (2) GWh	Losses before production (3) GWh	Imports (4) GWh	Exports (5) GWh		Primary electricity (6) GWh	Thermo (7) GWh
1966	5355.775	945.137	3.458	14.536	6289.834	285.088	15.6	81.5
1967	5550.206	979.448	26.863	80.805	6475.712	439.503	18.6	80.1
1968	5269.605	929.930	91.389	25.183	6265.741	998.040	23.7	75.2

Note: Data on thermo power efficiency is reported here for 1931-2006.For 1931-1970 efficiency is taken from Madureira & Teives (2005) and reports on efficiency in conventional coal and oil power plants (excluding firewood and residuals). For 1971- 1989 data is taken from energy balances and all fuels and electricity are included in order to determine efficiency. After 1990, efficency is taken from all the fuels consumed for producing all thermo power other than used for cogeneration utilities. The differences are not significant due to the small portion of non-conventional electricity. Dividing hydro, geo, photovoltaic production in this appendix by thermo-efficiency allows hydro-production to be expressed in terms of fuel equivalents. For earlier dates than 1931 lower efficiencies need to be applied, i.e, in 1917 the efficiency of the Lisbon plant was around 5% (CRGE,1917) and during 1918-1920 Oporto plant had efficiencies of 3-4% (SMEGP,1918-1920). The total efficiency of power production is a combination of the efficency of hydro, geo,wind and photovoltaic electricity.

	Hydro (1)	Geo, eolic, solar (2)	Losses before production (3)	Imp. (4)	Exp. (5)	Primary electricity (6)	Thermo (7)	Thermo efficiency (8)	Total efficiency electric power production (9)
	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh	GWh
1969	6385.189		1126.798	57.653	34.697	7534.943	511.877	20.8	80.2
1970	5853.534		1032.977	60.731	43.207	6904.034	1634.340	27.3	72.4
1971	6206.570		1095.277	204.826	26.512	7480.161	1726.174	27.6	72.5
1972	7151.349		1262.003	150.488	111.663	8452.177	1753.442	32.0	74.6
1973	7353.872		1297.742	67.535	78.151	8640.998	2467.314	31.5	71.6
1974	7888.244		1392.043	338.953	295.174	9324.066	2857.128	34.0	71.4
1975	6436.837		1135.912	465.674	266.488	7771.936	4290.942	34.2	64.7
1976	4887.360		862.475	1845.256	120.500	7474.592	5258.384	35.2	59.2
1977	10009.930		1766.458	381.674	927.267	11230.795	3808.547	37.2	71.8
1978	10864.942		1917.343	871.605	1089.512	12564.378	3788.058	35.4	72.2
1979	11251.500		1985.559	931.221	1133.919	13034.361	4901.744	35.7	70.0
1980	8072.091	0.723	1428.584	2346.000	518.419	11328.979	7190.640	37.2	62.5
1981	5094.713	0.275	900.625	3344.767	139.779	9200.602	8804.535	36.8	54.5
1982	6982.110	0.030	1232.307	3369.430	400.314	11183.563	8435.884	36.8	58.6
1983	8131.232	0.252	1436.351	2372.942	26.512	11914.266	10026.907	38.5	59.3
1984	9882.000	3.117	1761.545	2077.000	1365.000	12358.662	9602.198	39.6	62.6
1985	10848.721	4.135	1937.912	3529.663	1283.872	15036.558	8260.000	37.7	64.5
1986	8543.105	2.002	1518.951	2873.872	988.742	11949.188	11814.360	38.0	57.7
1987	9186.000	1.413	1629.066	3699.000	675.000	13840.479	10949.000	37.2	59.0
1988	12303.000		2171.118	3417.070	1027.000	16864.187	10185.000	38.1	63.8
1989	6049.000		1067.471	2436.000	1270.000	8282.471	19727.000	38.4	49.3
1990	9302.000	5.000	1669.863	1733.000	1696.000	11013.863	19195.570	38.4	53.6
1991	9176.000	6.000	1653.294	1712.000	1620.000	10927.294	20649.660	38.9	53.1
1992	5074.000	9.000	946.412	2538.000	1197.000	7370.412	24951.050	39.5	47.2
1993	8737.000	15.000	1626.824	2077.000	1902.000	10553.824	22443.200	39.4	52.1
1994	10702.000	51.000	2177.588	2257.000	1369.000	13818.588	20658.843	38.2	54.1
1995	8454.000	59.000	1703.203	2655.000	1741.000	11130.203	24740.645	38.1	50.0
1996	14857.000	71.000	2868.455	4116.000	3005.000	18907.455	19582.680	37.4	57.8
1997	13175.000	90.000	2587.803	5376.000	2477.000	18751.803	20827.526	36.8	55.4
1998	13054.000	148.000	2649.096	3974.000	3700.000	16125.096	25736.419	37.3	53.3
1999	7631.000	204.000	1822.760	3628.000	4488.000	8797.760	35385.925	40.3	48.1
2000	11715.000	249.000	2600.388	4698.000	3767.000	15495.388	31737.023	41.3	53.0
2001	14375.000	362.000	3283.494	3741.000	3502.000	18259.494	31771.999	41.8	55.1
2002	8257.000	460.000	2323.531	5329.000	3430.000	12939.531	37333.943	41.6	49.3
2003	16054.000	589.000	3877.765	5898.000	3104.000	23314.765	30209.000	40.9	56.0
2004	10147.000	903.000	3289.882	8612.000	2131.000	20820.882	34047.961	43.8	53.0
2005	5118.000	1847.000	3792.074	9626.000	2802.000	17581.074	38858.553	41.4	46.2
2006	11467.000	3015.000	6690.117	8624.000	3183.000	26613.117	34559.000	41.9	51.8

8. Others (Appendix I, 1, col. 8)

	Sulphite liquor and bleachs	Urban Solid Wastes	Biogas	Total
	PJ	PJ	PJ	PJ
1955	0.796			0.796
1956	0.835			0.835
1957	0.810			0.810
1958	0.651			0.651
1959	0.858			0.858
1960	0.961			0.961
1961	1.120			1.120
1962	1.137			1.137
1963	1.231			1.231
1964	1.474			1.474
1965	2.308			2.308
1966	2.699			2.699
1967	3.089			3.089
1968	3.499			3.499
1969	4.257			4.257
1970	4.743			4.743
1971	3.219			3.219
1972	1.529			1.529
1973	2.251			2.251
1974	1.888			1.888
1975	2.567			2.567
1976	2.517			2.517
1977	2.582			2.582
1978	2.536			2.536
1979	2.876			2.876
1980	3.119			3.119
1981	3.216			3.216
1982	3.641			3.641
1983	4.225			4.225
1984	4.080			4.080
1985	4.100			4.100
1986	4.440			4.440
1987	4.799			4.799
1988	5.029			5.029
1989	4.836			4.836
1990	19.731	0.000	0.000	19.731
1991	24.927	0.000	0.000	24.927
1992	24.686	0.000	0.000	24.686
1993	24.106	0.000	0.000	24.106
1994	25.110	0.000	0.000	25.110
1995	27.142	0.000	0.000	27.142
1996	25.927	0.000	0.000	25.927
1997	29.266	0.000	0.000	29.266
1998	28.976	0.000	0.000	28.976
1999	30.191	2.384	0.017	32.592
2000	31.129	7.296	0.057	38.483
2001	30.477	7.309	0.051	37.836
2002	32.536	7.633	0.053	40.223
2003	32.380	7.927	0.049	40.356
2004	30.620	7.921	0.079	38.620
2005	30.905	8.667	0.450	40.021
2006	31.810	8.404	0.411	40.624

Finito di stampare
nel mese di ottobre 2009
dalla stamperia M. Armano srl
Napoli

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ISBN 978-88-8080-109-2

€ 20,00