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Energising Mexico: Historical Energy Consumption, Transitions and Economic Growth 1880-2015

This paper employs archival data to reconstruct the historical pattern of primary energy consumption in Mexico during the 1880-2015 period. The study highlights the characteristics of the energy transitions between different primary energy sources and offers the first account of both traditional and modern energy carriers. It performs a trend and level analysis to explain how the economic structure, population and economic growth have impacted energy intensity and productivity. Thus, the paper provides a first approximation to the long-term relationship between economic growth and energy utilisation in Mexico. The period 1880- 1920 saw both growths in population and income increase energy consumption, the period 1921-1960 is mostly driven by income growth, 1961-2000, both growths in population and income drive consumption, and finally, between 2001 and 2015, population growth is the dominant force.

Keywords: Energy, Energy Transitions, Mexico, Economic Growth, Energy Consumption

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I. Introduction

Economic growth is one of the foundational topics in economic history (Bairoch 1985, Maddison 2007), accounts from the Industrial Revolution to the development paths of developed and developing countries emphasise growth. However, energy importance is often underplayed on several of those accounts. Energy impacts structural and technological changes, and as a growing literature suggests, the long-term relationship between economic growth gives us insight into the materialisation and "dematerialisation" of the economy thought time (Kander, Malanima and Warde 2013).

Traditional economic theories such as the Solow-Swan model (Solow 1956, 1974, Swan 1956) or the endogenous growth models (Romer 1986, Aghion 1992) focus on different sorts of capital accumulation but neglect the role of energy, thus avoiding thinking about it. In the traditional growth literature, capital accumulations play the central role as if capital could be accumulated without energy. These theories take energy as given and not as a constraint that influences the structure of the economy. On the other hand, proponents of ideas such as degrowth argue that economic growth goes hand in hand with increased energy utilisation as an inescapable fact and thus argue for less growth. Both accounts are mistaken. Growth needs energy, as all activities, productive or otherwise require it. Traditional growth theorists are optimistic for future energy transitions because they do not consider the constraining power of energy systems, and de-growers are too negative, denying that growth can occur without endlessly growing energy services. Both mistakes have the same root; they fail to recognise how energy shapes the economy and, therefore, how its structure and technology also influence the intensity in which we use our natural resources. For example, we can look at Allen (2009) account of the First Industrial Revolution.

The present paper tries to avoid those mistakes and looks to economic growth, technological and structural changes through the eyes of historical energy consumption. The study focuses on Mexico and its energy history; it is only the second Latin American country (After Uruguay, Bertoni 2011) to join a growing literature of energy historical national accounts that so far includes only a few countries (Canada, Germany, Netherlands, Sweden, Portugal, Spain, France, Czech and Slovak Republics, England, and Uruguay).

The study reconstructs traditional and modern primary energy carriers employing archival and statistical sources following the methods pioneered by Kander (2002), Malanima (2001, 2006), Warde (2007) and Henriques (2009, 2011). This historical national energy accounts reconstruction is divided for analysis into four periods: 1880-1920, 1921-1960, 1961-2000 and 2001-2015. It starts in 1880, just at the beginning of Mexico's electrification after its first electric plant was inaugurated in 1879. In a period of rapid capitalist development in which the economy began its industrialisation process. From 1880 to 1920, we see the early industrialisation in a context of mostly traditional energy carriers. We saw the birth of the oil industry in 1901 and its first boom in the 1910s. The textile and mining industries were the first to employ electricity generated through hydropower and thermal energy (coal) to enhance their production and substitute fuelwood, water/windmills, and draft animals to perform their work.

From 1921 to 1960, we see the modern Mexican economy's development and how rapid per capita income and population growth increased energy consumption, exploiting modern energy sources' new availability. In this period, the expansion of the oil and electric industries takes place and power the country's rapid industrialisation; this is when the economy reaches its peak energy intensity levels and then a rapid decrease.

From 1961 to 2000, we observe a change. Population growth relegates income growth and takes the lead as the main factor behind energy consumption and slightly reverts the downward trend of energy intensity. This period is a crucial period of Mexican economic history as it contains the final years of the so-called "Mexican miracle" and its high rates of economic growth, the dreadful crisis years of the 1980s, and the beginning of the structural change from the peak industrialisation of the early 1980s to service economy in the 1990s.

Finally, the 2001-2015 period continues the dominance of population over income growth. However, in a very different context: an economy much more oriented towards services and more energy productive result of the Third Industrial Revolution's structural and technological changes. Therefore, this paper tells the economic history of Mexico as viewed from its energy transitions. In a period in which globally we debate the need for a new energy transition, the paper engages briefly in discussing what trends in the relationship between economic growth and energy consumption can be reasonably anticipated and how to reconcile them with our environment.

The paper is divided into the following sections: Data and methods, Structural Changes, Trend and level analysis, Energy consumption decompositions, Discussion and extensions, References, Appendix 1.

II. Data and methods

Historical national energy accounts' reconstruction is an extremely time demanding activity, especially for developing countries that began collecting quality statistics around the last fifty years. The Mexican case is not different; it required the extensive revision of old statistical sources going back to the end of the 19th century, historical accounts of the period, reports, industry bulletins and secondary sources of the relevant period that had access to data. The reconstruction of the statistical series for energy consumption in Mexico closely follows the methodology pioneered by Kander (2002), Malanima (2006), Warde (2007) and Henriques (2009), but departs slightly when the available data did not allow us to follow it straightforwardly.

Some assumptions were made regarding the numbers for some traditional energy sources, such as windmills and watermills, draft animals, sailing ships, and fuelwood, for which data is scarce. Modern sources are less problematic as records exist from them, and the challenge is related more to the archival research to collect a vast number of statistics about the details of energy production, for example, the non-energy oil products such as lubricates and asphalts, and the different sources of electric power (hydroelectric, geothermal, thermoelectric).

i. Traditional carriers

Traditional carriers encompass the sources of energy available to men that have been used for centuries. The food we humans eat to perform work and survive, the fodder our draft animals eat to sustain their lives and perform the work we set for them. Fuelwood the likely older energy source for humanity, burn to heat us, cook and produce steam to move machines. Traditional sources also include two sources that are coming back, although in different ways: the wind that powered the sail ships for our trade, our wars, our fishing, that moved the vanes of windmills to grind our cereals and finally the water that with the help of the force of gravity energised old machines employing in grain production and textiles.

Food:

Food is perhaps the easiest to estimate, for the entire 1880-2015 period, we have good population statistics, we have estimates for 1880-1894 from the national historical statistics of Mexico and then from 1895 from the national censuses conducted by the Dirección General de Estadística and then by its successor institution Instituto Nacional de Estadística y Geografía

(INEGI). We also have reconstructions of the standard of living among the population that goes back to colonial times, here we employ the bare bones basket of food estimated by Challú and Gómez-Galvarriato (2015) of 1,800 Kcal per day up to 1933, then we use their respectable basket of 1941 Kcal p.c per day up to 1960. From 1961 forward, we employ actual measurements of the Mexican population's caloric intake (Ortiz-Hernández, Delgado-Sánchez, and Hernández-Briones 2006) that steadily rises from 2407 Kcal p.c. per day in 1961 to 3139 Kcal p.c per day in the present.

Fodder:

For some countries that keep good statistics of cattle and draft animals, this calculation should be straightforward. It is the same logic as food, the caloric intake of the draft animal multiplied by its population. However, for the Mexican case, it is a little bit more complicated than that, agricultural censuses are scarce, particularly over the last 50 years; however, this is not a big problem because overall, the energy contribution of draft animals to the total energy consumption of a modern economy is small. However, for the pre-1930 period, some assumptions are required as statistics are not good. We have for some year's statistics of overall cattle for horses, donkeys, and cows; we start following Henriques (2009, p.56) and assume about the number of working horses and donkeys, we assume that 85% of the population worked. For cows, Henriques (2009) assumes that 66% of the population were working; we deviate the assumption since the Mexican economy in 1880-1910 was characterised by the hacienda economy and was exporting numerous heads of cattle to the U.S. For that reason, we believe it is a reasonable assumption that only 30% of those animals were draft animals. For the missing years, we relied on simple linear interpolations. It is important to mention that during the Mexican Revolution (1910-1920), the revolution was financed by cattle expropriation and increased exports to the United States; horses' death in battles diminished their numbers. Thus, we assume just 10% of animals were working in those years. We assumed 400 kilos of weight for horses and donkeys and a Kcal intake of 31,000 p.c per day. For cows, 24,000 Kcal p.c per day according to FAO manuals

Fuelwood:

As pointed by several authors in different fields from economic history, ecology, and forestry, accounting for the quantity of fuelwood consumed is full of uncertainties. Fuelwood has always been relatively easily accessible to rural populations, for most rural Mexico, at zero or near zero monetary cost. Overall estimation methods are either supply side or demand side. Supply-side counting methods rely on the yield by a hectare of wood of different species of trees, on well-documented deforestation observations or a combination of both. The demand side relies on observations of actual consumption by rural populations in different climates and geographical areas. For the years between 1960 and 2015, we take the estimates of Díaz Jiménez (2000) and the statistics of the Secretaría de Energía (SENER). Before 1960 we consulted several sources, such as Masera (1993). However, the estimates for fuelwood p.c consumption did not reach far enough, we decided to use the estimates mentioned by Warde (2019) for Northern Spanish North America territories 3.1 kg p.c per day and subtracted 35% to account for the warmer climate of Mexico compared to the U.S. We arrived at an estimate of 2 kg p.c per day. To avoid overestimating fuelwood consumption, we did not multiply the number by the whole population. We employed the urbanisation rates reported in the national censuses to count the rural population. It is essential to recognise that further explorations can improve these estimates from the sources or by modelling consumption from populations' observations in similar climates, but we consider the current ones as good enough.

Table 1: Urbanisation Rates of Mexico 1895-1960

Year	Total population	% urban population living in cities exceeding 5000	% rural population	Rural population
1895	12,632,000	0.1054	0.8946	11,300,587
1900	13,607,000	0.1054	0.8946	12,172,822
1910	15,160,000	0.1176	0.8824	13,377,184
1921	14,335,000	0.1454	0.8546	12,250,691
1930	16,553,000	0.1747	0.8253	13,661,190
1940	19,654,000	0.1998	0.8002	15,727,130
1950	25,791,000	0.2791	0.7209	18,592,731
1960	34,923,000	0.365	0.6351	22,179,597

Source: Population census 1895-1960, Dirección General de Estadística e INEGI.

Wind and Water:

Traditional wind and water energy are among the most complicated to estimate. It requires detailed records for windmills and watermills for grain, textile, and mining industries. It also depends on comprehensive statistics on merchant navies, number of ships, their class and tonnage.

For all these energy uses, sailing ships are the best-preserved statistics. The commerce and statistical yearbooks since 1892 include the reports of all commercial ships navigating Mexican waters and their class (vessels, sail ships, steams) and their tonnage up to the 1960s. Their number steadily declines from the 1880s with about 2,000 ships and practically disappear by the 1940s with just four ships. With these numbers, we apply Lindmark (2007) coefficient of 0.6 KW per tonne and follow Henriques (2009, p.60) in assuming 3,650 yearly hours of use for commercial ships. There are no official records of fishing ships on the statistics, and therefore the estimate for sailing ships should be taken as a lower bound estimate.

For windmills and watermills, the situation is worse. There are scarce data. The early registry of mills is from 1857 in the document *Las Memorias de Fomento del Siglo XIX*. In this document, around 130 mills appear, without distinction of the type (wind or water) but based on the locations, is reasonable to assume watermills. Morales Moreno (2010, p.105) mentions that in the year 1828, in Puebla, there were 38 mills in Mexico City, 17 mills and Jalisco 45. Watermills for grain were disappearing at the end of the 19th century in Mexico City due to rising water conflicts and the new technologies.

To estimate the number of watermills, we start with the number registered in *Las Memorias de Fomento del Siglo XIX* and assume that it represents watermills for the textile industry. To calculate the possible number of watermills, we assume their number is growing at the same rate as the number of looms in the textile industry from 1879 to 1930 employing Gómez-Galvarriato data (2016, p.37-38). We assumed an average of 30 HP for industrial watermills (based on Puebla's textile industry). To convert these values to the energy, we assumed efficiency of 15% and 2,400 yearly hours of work using equation 1:

$$E = P * h * \frac{1}{i} \quad (1)$$

Where:
E = Energy consumption,
P = Power,
h = Hours per year and
i = Efficiency.

Since no windmills nor watermills for grain could be identified on the records, we do not account for them. Further improvements can be made on traditional wind and water estimates.

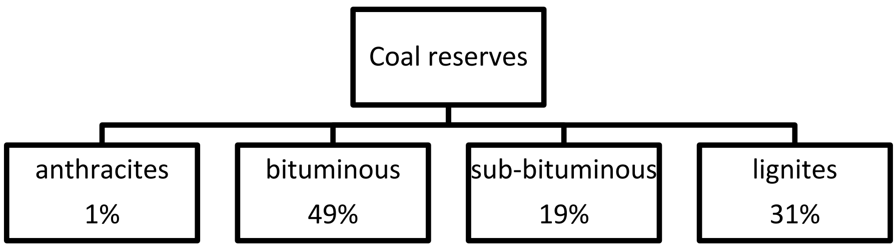
ii. Modern carriers

Modern carriers include the energy sources of the industrial revolutions, coal, oil, natural gas, the so-called "primary electricity" or hydropower, geothermal energy, biogas, nuclear energy, solar and modern wind power. We are focusing on primary energy; therefore, fuels like gasoline or diesel produced are not counted as their energy was already inside the oil, and we would be double-counting, but it does include fuel imports converted to back to barrels of oil equivalent. It counts the imports of electricity and accounts for the energy losses due to the different efficiencies in the electricity plants. Modern energy carriers enable us to achieve modern economic growth with the First Industrial Revolution and the subsequent ones, therefore, are responsible for our modern world and the freedom to use labour and capital in more productive ways than just feeding us or performing manual work.

Coal:

The Historical Statistics of Mexico include mining statistics that go back to 1891. The statistical yearbooks and international trade yearbooks include data about coal exports and imports, and the national mining industry yearbooks provided by the *Servicio Geológico Nacional* (SGN) contained detailed statistics since the 1950s. A common problem in counting coal production is establishing the type of coal produced. Old statistics often ignore these details. Different types of coal have different efficiency coefficients according to their carbon content. For example, anthracite coal has a coefficient to convert it to tones of oil equivalent of 0.7 and lignite coal of 0.27. Luckily, the American Society for Testing and Materials (ASTM) estimates that coal reserves around the world are divided into the following shares according to their type:

Figure 1: Mexican coal reserves



Source: ASTM.

We divide total production by each category and convert to tonnes of oil equivalent using the conversion coefficients, then we add the imports and subtract the exports according to their classification in the yearbooks.

Oil:

Oil production in Mexico started in 1901 with roughly 10 thousand barrels but rapidly grew since then. By 1913 Mexico exported close to 70% of its 25 million barrels production, 90% around the first global oil shortage 1918-1922 (Rubio 2006). In those years, Mexico represented around a quarter of world production with its 185 million barrels. During the decades of 1920-1930, production expanded and started to dominate the country's primary energy production. In 1938, the oil industry nationalisation year, oil represented 43% of the total primary energy consumption. After nationalisation, the country's imports of the oil industry increased, becoming a crucial revenue source. As a share of primary energy consumption, it reached its peak in 1994 with 63%. Oil accounting is a straightforward procedure. Historical statistics, yearbooks, Pemex reports and the British Petroleum historical statistics account for the same production from 1901 onwards. Since we are looking only at primary energy production, we do not count production fuels, such as gasoline. We deduct oil derivatives such as lubricates or asphalts as their production is not for energy purposes. We count the fuel imports and convert them to barrels of oil equivalent using the BP Statistics conversion rates.

Natural Gas:

Natural gas is also easy to count. Historical statistics and yearbooks register the first imports of natural gas at the end of the 1940s, and production increases since that time. Natural gas production in Mexico is not as important as oil, but since the late 1960s, it has increased its share of total primary energy consumption from around 5% to around 20% in recent years. We add the production statistics and the import statistics and subtract the exports.

Primary Electricity:

Electricity is a secondary form of energy, but the economic history literature has always grouped non-fossil generated electricity under the label "Primary electricity" to facilitate economic analysis. We follow that tradition and group as "Primary electricity" the electricity generated by hydropower, geothermal power, wind power, solar power, and nuclear power.

Statistics from hydropower go back to the first electrification of the country in the 1880s when 38.8% of electricity was hydropower (Garza Toledo et al. 1994, p. 19). From 1880 to 1932, we base our estimates on Garza Toledo et al. (1994) and from 1932, we rely on the statistical yearbooks and SENER. The official statistics do not account for the losses. To account for losses and produce a better estimate, we assume following Henriques (2009, p.90), 25% losses between 1880 and 1960, 15% between 1961and 1990, and 8% losses from 1991 to 2015 (the percentage of loses reported by SENER), those percentages reflect the technological change in hydropower plants. Finally, we add imports and subtract exports.

Nuclear, geothermal, solar, and wind energies started to be developed in Mexico from the mid-1980s. SENER statistics exist since the 1980s and 1990s; thus, it is not difficult to count them. We follow the same procedure as before but with different efficiency levels to account for energy losses. We assume a 15% efficiency for solar power, for wind power a 40% efficiency, for geothermal a 12% efficiency and finally, for nuclear energy, we assume 37% efficiency.

Biogas:

Biogas statistics by SENER exist since 1999. We do not perform any adjustment.

III. Structural changes

After all the estimates presented above, it is possible to discern the country's energy transitions. Even if some estimate might need revision and improvements, the overall picture can hardly be contested; it would require massive energy consumption differences to alter the transitions' shape.

Figure 2: Transition from traditional to modern energy

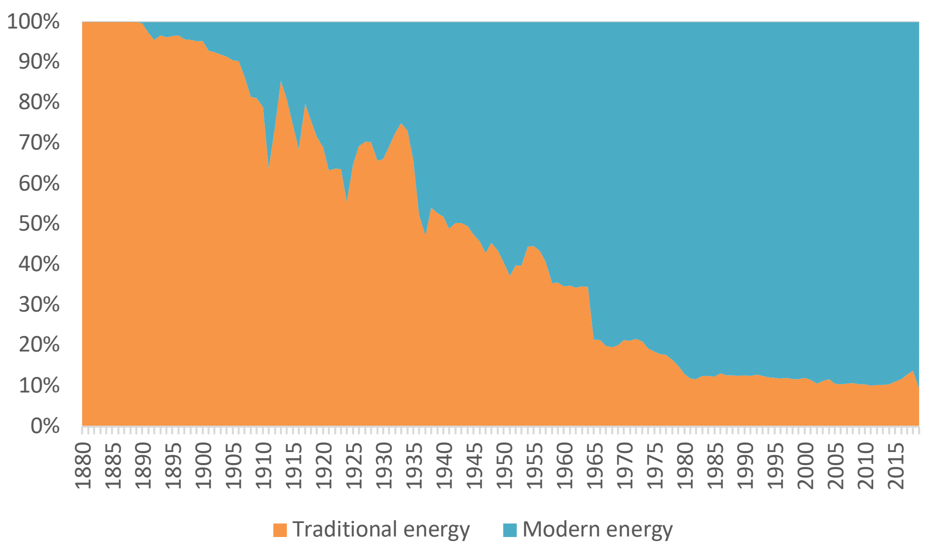
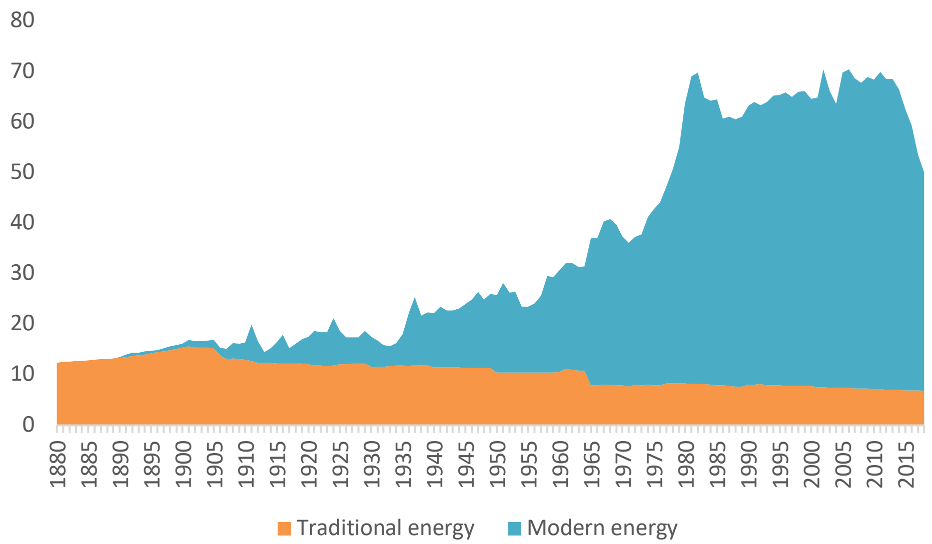
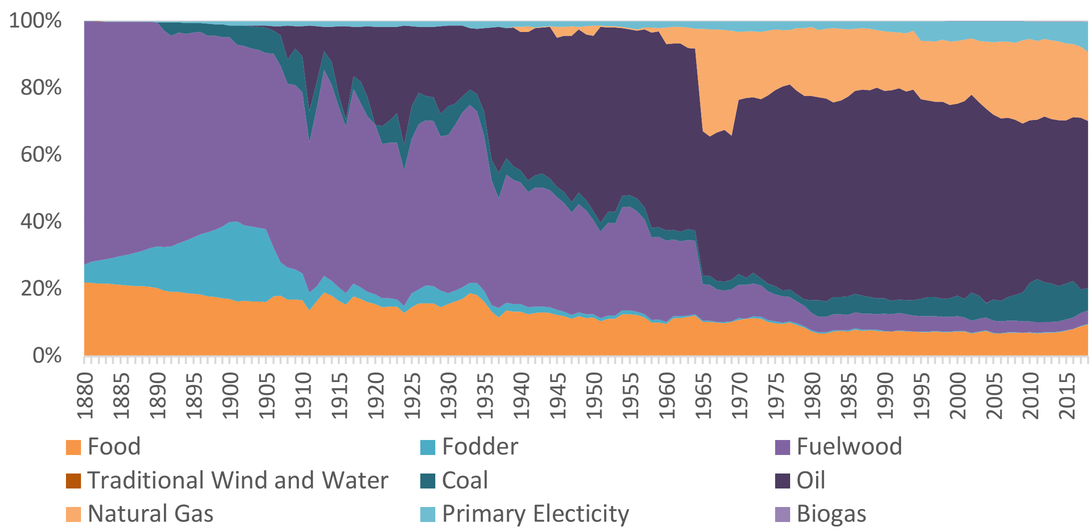


Figure 3: Per capita energy consumption (PJ) 1880-2015



Figures 2 and 3 above show how, in terms of energy consumption sources, Mexico skipped the first and second industrial revolutions. Modern energy sources did not overtake traditional ones up until 1944. However, structural change starts to show at the end years of the 19th century. A closer look at the transition, observing all carriers, demonstrates that energy transitions have been a continued and long-term process for Mexico.

Figure 4: Mexico's energy transitions



In 1880 energy consumption was entirely dominated by food, fodder and fuelwood. Mexico was a rural country with small industries and huge communication barriers due to lack of infrastructure and geographical constraints (lack of navigable rivers and rough terrain). Mexico starts to be more connected in the 1890s with the construction of railroads between the north and the centre of the country, and with them came increased urbanisation. New towns and growing cities provided for the inner demand that stimulated some industrial progress. For example, we see the expansion of brewery, mining, and textiles. Is not a coincidence that coal enters the energy matrix around this time. In 1891 coal represented just 2.4% of total primary energy consumption, and by 1910 the year of the Mexican Revolution, it peaked at almost 11%, a level it will not reach again until 2010.

Coal never was for Mexico what it was for England and other European countries with comparable data. Mexico leapfrogged coal development and instead rapidly developed its oil industry. As mentioned before, the exploitation of oil started in 1901 and by 1914-1922, driven by the Great War, Mexico became the second world producer (Rubio 2006). Oil provided the energy resources to start the new rounds of industrialisation. Although electricity started in 1879 by the 1920s, it was stile mostly used for lighting purposes. According to Garza Toledo (1994), only 10% of electricity was used for industrial activities. In the 1930s, with the creation of the state energy enterprises, Pemex and CFE, Mexico embraced the Second Industrial Revolution's catching-up process and, as Haber (1989) argues, Mexico started to utilise its idle industrial capacity. Modern energy liberated Mexico's industrial prowess.

By the 1940s, oil was the dominant energy carrier. It accounted for almost 50% of all energy consumption. By the 1950s and 1960s, it was nearing 60%. This acceleration is not a surprise. Mexico experienced its fastest industrial growth, accelerating both the transition from a rural economy dominated by agriculture and traditional energy such as draft animals and fuelwood towards dominion by industry and modern energy. These are the years that see Mexico complete its transition from agrarian to industrial. In the 1960s and 1970s, we see natural gas enter the equation at full force. Factories increasingly imported natural gas, and national production also rose. By the late 1970s and the beginning of the 1980s, fossil fuels (oil, natural gas, and coal) represented more than 86% of all primary energy consumption.

Table 3: Mexico and European countries 1950

Source	Mexico	Italy	Spain	Portugal	Sweden	England & Wales
Food + Fodder	13%	27%	27%	24%	6.00%	3%
Fuelwood	28%	17%	12%	44%	21.00%	0%
Traditional Wind and Water	0%	0%	0%	1%	<1	0%
Fossils (oil+natural gas + coal)	58%	47%	59%	30%	64%	97%
Primary Electicity	1%	10%	2%	1%	9%	0%

Table 2: Composition of primary energy consumption in Mexico (1880-2015)

Source	1880	1910	1940	1970	2000	2015
Food	22.20%	17.28%	13.36%	10.78%	7.40%	7.61%
Fodder	4.99%	8.21%	2.20%	0.58%	0.17%	0.14%
Fuelwood	72.80%	55.87%	36.31%	9.94%	4.40%	3.31%
Traditional Wind and Water	0.001%	0.00003%	0.000001%	0%	0%	0%
Coal	0%	10.92%	3.60%	3.22%	6.08%	10.60%
Oil	0%	9.32%	41.36%	52.09%	57.36%	48.33%
Natural Gas	0%	0%	1.48%	20.17%	18.58%	22.83%
Primary Electricity	0.01%	1.52%	1.69%	3.14%	5.88%	6.51%
Biogas	0%	0%	0%	0.00%	0.0002%	0.02%

Source: Mexico: Author's estimates. Italy (Malanima 2006), Portugal (Henriques 2009), Sweden (Kander 2002), England and Wales (Warde 2007), Spain (Kander, Gales, Rubio and Malanima 2007). Note* numbers are rounded at the nearest integer.

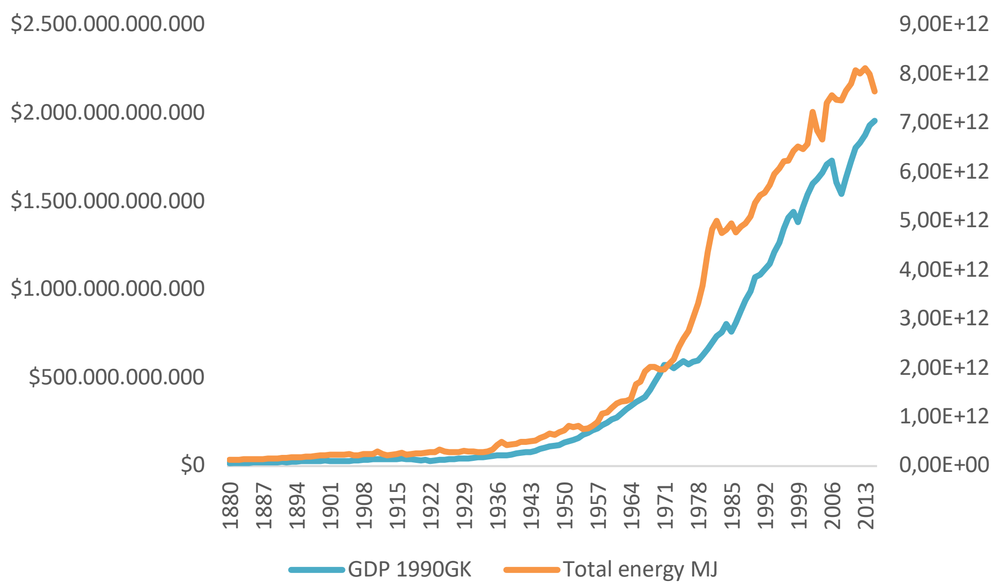
In Tables 2 and 3, we can see the full extent of Mexico leapfrogging transition between energy carriers. In 1880 the country was a pre-industrial economy. By 1940 it was starting to catch up to a level comparable to the Europeans in terms of oil. By 1950, it was at comparable levels of fossil fuels consumption as a share of their respective energy matrixes with Spain and Sweden, had a higher level than Italy and was well above Portugal. Although a late starter, Mexico catches up with the European countries in terms of the oil transition.

By the 1980s, the debt crisis hit the country at its peak in industrial employment and started a new structural change process. Informality rose as the public sector dwindle, and large nationalised businesses were privatised and rationalised. The country began a process of slow deindustrialisation and started to move towards the service sector. In 1984, for the first time, oil accounted for nearly 60% of the primary energy consumption and steadily rose to 62% in 1994. At the period we see the so-called primary electricity start its climb and reaches 3%. The first nuclear plant in 1991, the beginning of the wind, solar and geothermal energy sources from the mid-1980s to the end of the 1990s, takes primary electricity to 6% of total consumption.

At the beginning of the XXI century, we see primary electricity stagnate and fluctuate around 6% until 2015. The new century brought instead what might be considered the age of natural gas, “the fuel of the 21st century,” as Vaclav Smil (2015) calls it. Since the turn of the century, the country has shifted towards the service economy while maintaining a declining but still strong industrial base in high tech sectors such as the automotive, aerospace and metal mechanic. The 21st century sees a double transition, a transition from industry to services and oil to gas, and a little bit of a resurgence for coal. This double transition has feedback effects on structural change and energy.

The Third Industrial Revolution has made the industry more efficient with intelligent systems and automation. Cheaper energy sources such as natural gas have increased electric availability and reliability with combined cycle power plants and, as we will see in section IV, without increasing energy intensity.

Figure 5: GDP (1990GK) and total energy consumption (MJ), 1880-2015



To what extent this 135-year history of consumption is the result of structural changes in the economy? Is economic growth responsible for rising energy consumption? Figure 5 appear to suggest that, yes, income growth is positively correlated with energy consumption. However, could that correlation be the whole story?

Of course not, and there is an easy way to check it. How economic growth and the structural changes that allow it to have impacted energy consumption? A way to find the answer is to perform the famous Commoner-Ehrlich decomposition (Ehrlich and Holden 1971, Commoner 1972), a simple breakdown of energy consumption into its components. Equation 2 presents the decomposition:

$$E = P * \frac{Y}{P} * \frac{E}{Y} \quad (2)$$

Where:

E = Energy consumption,

P = Population,

Y = GDP.

Equation 2 can also be expressed as growth rates:

(3) $$e = p + y + e_y$$

Where:

e = the growth rate of energy consumption,

p = the growth rate of population,

y = GDP per capita growth,

e_y= energy intensity[1] growth rate.

Although this type of decomposition does not tell us the precise cause of the changes in energy consumption, it gives us a first approximation of what is behind energy consumption. We are dividing our 135 years into four periods that roughly match the historical developments. We observe that per capita income growth is not always behind rising energy consumption. Table 4 breaks it down.

Table 4: Commoner -Ehrlich decomposition for Mexico

Period	e (average)	p (average)	y (average)	ey (average)
1880-1920	0.01940496	0.00882982	0.00977851	-0.00255194
1921-1960	0.04132881	0.0241269	0.0293697	-0.02465936
1961-2000	0.04466644	0.02409613	0.01977966	0.00158377
2001-2015	0.01211421	0.01303616	0.00677701	-0.00718666

From 1880 to 1920, income growth dominates, followed by population growth. Energy intensity decreases, and this slightly mitigates energy consumption. The negative rate of change in energy intensity reflects the beginning of a shift between traditional and modern energy sources. In the 1921-1960 period, we see that economic growth dominate population growth; in fact, the negative rate of intensity change more than compensates for population increases. This period sees Mexico catch up to the European countries, see Table 3, and when Mexico finally transited to modern energy carriers and from a pre-industrial economy to an industrial one. This evidence strongly suggests structural change. From 1961 to 2000, we observe rapid population growth (2.4% per year), at that rate population doubles roughly every 29 years. Population growth dominates income growth, and energy intensity increases, temporally reverting the diminish trend

[1] E/Y in equation 2 refers to energy intensity. Energy consumption in energy units divided by GDP. An economy with high energy intensity means it requires more energy per dollar, an economy with low energy intensity gets more dollars per energy unit, which means it has higher energy productivity.

in energy intensity. The enormous discoveries of oil ensured cheaper energy and thus, disincentivised energy savings. Mexico reached its highest industrialisation level in the 1980s and endured the hardest economic crisis in his modern history. Finally, the 2000-2015 period is again dominated by population growth, not income. Energy intensity return to its diminishing trend. In figure 5, we can corroborate this as the gap between energy consumption and GDP increases for most of the 1960-2015 period.

The fact that population rather than economic growth is behind the changes over the last 50 years can have different explanations. It tells us something about the relative stagnation in living standards that the country has endured since the 1980s, in which per capita income growth has been barely around 1%. Nevertheless, it also suggests that there are technological and structural reasons behind diminishing energy intensity.

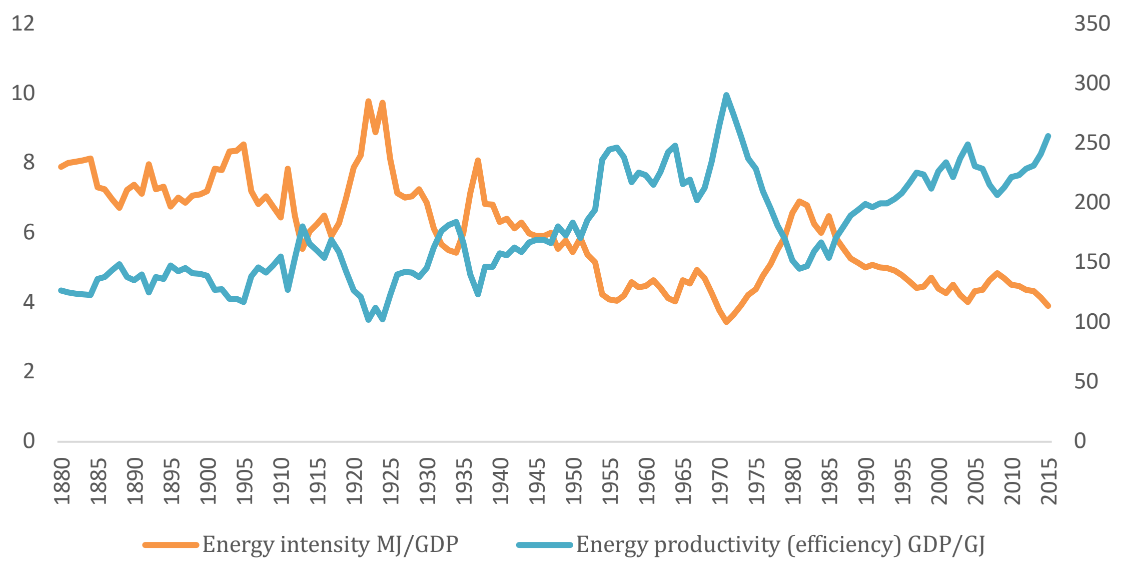
IV. Trend analysis

To further explore the relationship between economic growth and energy, we can analyse economic output and energy consumption. That is looking at energy intensity and energy productivity (efficiency).

$$(4) \qquad Energy\ Intensity = E_y = \frac{E}{Y},$$

$$(5) \qquad and\ its\ inverse, energy\ productivity = P = \frac{Y}{E}$$

Figure 6: Energy intensity and energy productivity, 1880-2015



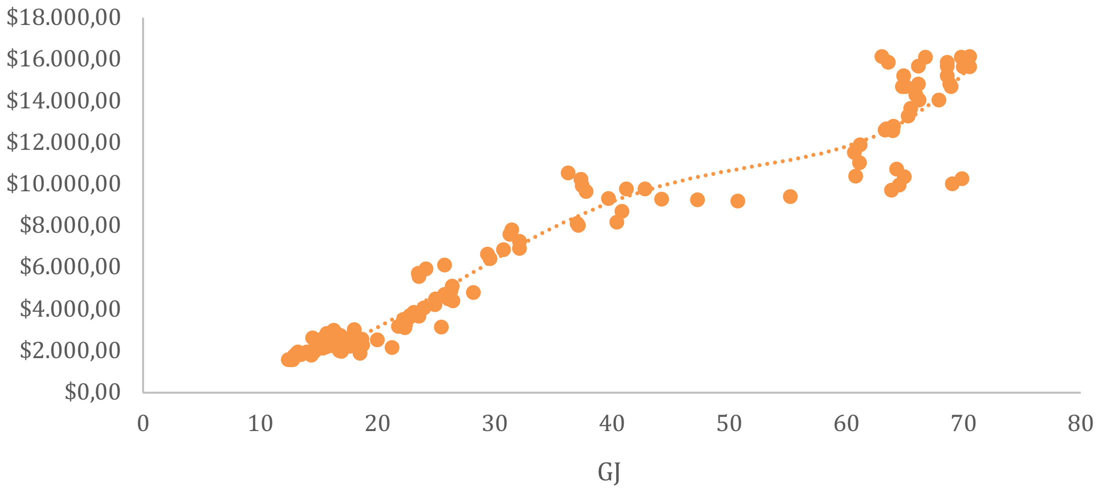
Note* MJ in the left axis, 1990GK dollars per GJ in the right axis. Energy productivity is expressed in dollars/GJ to facilitate interpretation.

As we can see in Figure 6, the trend of energy intensity is downwards. It does not exhibit the inverted U pattern of an environmental Kuznets curve (Penayotou 1993) that is possible to observe in England (Warde 2007). That rapid decline in intensity is most likely the result of a combination of factors, the higher GDP achieved through industrialisation and enabled by the change in energy carriers. There are only two breaks in that pattern. In the 1910s, the Mexican Revolution produced a fast decline in the economy, and at the same time, the massive increase in oil production for exports in the context of the Great War. During the 1920s, the slow recovery from the revolution and the Great Depression at the end of that decade. Energy productivity hits its lowest point during this period. The second is during the 1970s and 1980s. Mexico's colossal oil discoveries came in 1971, and public investment raised increasing GDP, which is reflected in the peak in energy productivity. The oil crisis of 1973 and the subsequent economic difficulties, combined with a massive increase in oil production from 1978 onwards, productivity collapses and intensity rises, temporarily reverting its long-run declining trend. The 1980s, with the economic decline, deindustrialisation, and rising energy production, ensured a rising energy intensity. After the 1980s, the 1990s see a return to the long-term trend. Not even the crisis of 1995 and 2009 had the reversal effects of the revolutionary period of the 1980s.

This reversal of the trend in itself provides evidence of how severe the 1980s was for Mexico, in energy terms and not counting exceptional times such as the revolution. It is the harder crisis in modern Mexican history.

Looking at the economic output as a function of energy confirms this narrative. Figure 7 displays the energy consumption and GDP per capita; it draws a fourth-degree polynomial[2] as the best fit and shows a clear inverse S shape.

Figure 7: Per c. GDP and Energy Consumption 1880-2015 (1990GK and GJ)



The S shape of the curve can be interpreted in the following way, at the beginning of the transition from agrarian to industrial, substituting draft animals and firewood for machines and mineral sources of energy increases the energy productivity. The rising slope of the curve points towards a high elasticity between GDP per capita and energy consumption. After Mexico catches up to European levels (see Table 3), the slope decreases, signalling lower elasticities and a propensity to save less energy, this combines with the crisis and the stagnation of the economy. After the 1990s, when the economy started transitioning towards services and shifting towards natural gas, the slope became steeper again, pointing to higher elasticity. In this later period, energy productivity returns to its rising trend.

i. Logarithmic mean divisia index decomposition, 2005-2017.

One critical aspect of the relationship between economic growth and energy consumption is if decoupling is possible. General trends suggest that the structure of the economy and technological changes make this possible; however, it is hard to test in a historical setting due to the lack of full sectoral energy accounts. Nevertheless, at least it is possible to test for as long as sectoral energy statistics exist. For the period 2005-2017, SENER publishes full detailed sector energy statistics. We can test if the service transition and its technological underpinnings provide

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[2] $e = \alpha + \beta_1 y + B_2 y^2 + B_3 y^3 + B_4 y^4 + \varepsilon$

evidence for the economy's dematerialisation. We use the logarithmic mean divisia index decomposition method (Ang 2005, 2015).

Following Ang (2015), we perform a multiplicative decomposition of activity, structure, and energy consumption intensity. The Model is expressed in the following equations:

$$(6) \qquad D_{str} = \exp\left[\sum_i w'_i \ln\left(\frac{S_i^T}{S_i^0}\right)\right]$$

$$(7) \qquad D_{int} = \exp\left[\sum_i w'_i \ln\left(\frac{I_i^T}{I_i^0}\right)\right]$$

$$(8) \qquad D_{pcons} = \exp\left[\sum_k w'_k \ln\left(\frac{\frac{E_k^T}{Y^T}}{\frac{E_k^0}{Y^0}}\right)\right]$$

Where:

Dstr = structural decomposition,

Dint = intensity decomposition,

Dpcons = consumption decomposition,

w' = sectorial weights of energy intensity,

St = value added share of a sector,

It = energy intensity of a sector,

Et = energy intensity of the residential sector.

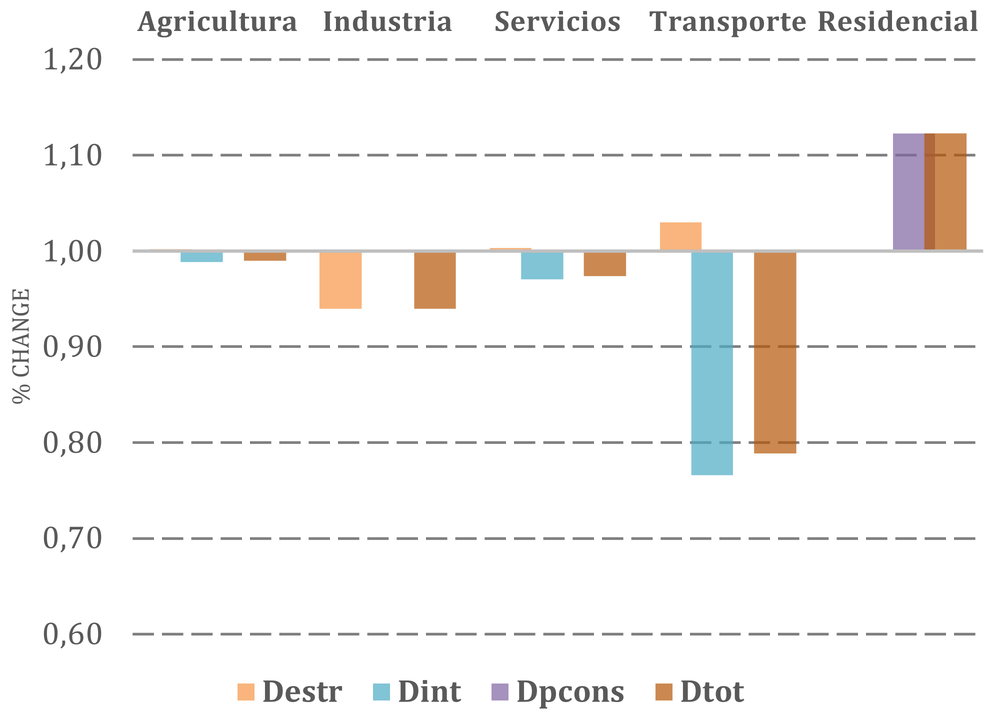
Table 5: LMDI decomposition results, Mexico 2005-2017

Sector	% change (constant pesos 2013)
Agriculture	
Structure	1.001842888
Intensity	0.988341603
Industry	
Structure	0.939492389
Intensity	1.000123059
Services	
Structure	1.003457274
Intensity	0.970569696

Transport	
Structure	1.030238196
Intensity	0.765846465
Residential	1.122830953
Total productive sector	
Structure	0.973037143
Intensity	0.734732003
Total household	1.122830953
Total	0.802736022

Note* The results are presented in constant prices to account for Baumol's disease, see Kander (2005).

Figure 8: LMDI decomposition, México 2005-2017.



The LMDI decomposition results for the period 2005-2017 are presented in Table 5 and Figure 8. How to interpret the results?[3] The agricultural sectors show a marginal structural increase in the export of agricultural products such as avocados, blueberries and blackberries has enjoyed a boom. Simultaneously, its intensity has shown a small reduction of 1.2%, signalling technological improvements in agriculture. The industrial sector shows clear signs of structural change as it decreases 6.1% but marginally increases its intensity 0.0001%; since Mexico has increased its manufacturing exports and venture into some advanced manufacturing, we could interpret this result as better technology offsetting the production increases. The service sector also shows a marginal structural increase and a 3% decrease in intensity; a growing sector that reduces intensity is likely the result of the information and communication revolution. Transportation exhibits significant structural change, a 3% increase; this phenomenon can have different explanations; increasing trade volume, rising urbanisation and the growing numbers of cars per capita. However, intensity shows a significant reduction of 23.5%; this results from technological change, more efficient motors, and better fuels.

[3] A different version of this analysis of the LMDI decomposition was first presented in Castañeda, D. (2019). Consumo de energía y el crecimiento económico de México. https://economia.nexos.com.mx/?p=2198

Overall, the LMDI decomposition showcases a 19.8% reduction in energy intensity, a modest sign of dematerialisation of the economy. Most of it driven by technological change, with structural change having a minor role. The Third Industrial Revolution with the information technologies has accelerated the transition to services creating new services, making more efficient previously existing ones, and making manufacture more efficient. We cannot disentangle the technological revolutions from the structural changes in the economy and energy consumption. Much like the First Industrial Revolution show us that industry, cheap energy, and innovations went hand in hand (Allen 2009); what we observe in the 21st-century displays similar relationships.

The decomposition performed in this subsection offers the same interpretation of the energy intensity and productivity trends. It supports the argument that energy relationship with the economy is complicated, causality flows in both directions, energy creates opportunities for economic growth and economic growth, and its nature (structure, technology) changes how we use energy. If we could construct complete sectoral statistics for energy consumption for the whole 1880-2015 period, in theory, we could observe how these changes in structure and technology drive the long-term trends we analyse in this section. Develop historical sectorial statistics remains an extension to be made to this work.

V. Discussion and extension

This paper contributes to the historical national research accounts literature by developing the first iteration of primary energy consumption trends for 135 years in Mexico. It adds an essential example of literature that mostly concentrate on developed economies. It also analyses structural and trend changes that display the complexity of the relationship between economic growth and energy consumption. It finds evidence that suggests a possible interpretation of Mexican economic history as seen through the eyes of energy.

Mexico energy transitions fit well to the development stages of the economy on those 135 years. It reflects its backwardness in pre-industrial times. Its accelerated catching-up process in the middle of the 20th century. The catastrophic 1980s and its recent double transition from industry to services and from oil to natural gas.

The finding that population growth has dominated economic growth over the last 50 years as the primary source behind energy consumption highlights, on the one hand, the positive side that the economy can grow without putting more pressure on resources. However, on the other hand, the negative side that attests to how long the Mexican economy has stagnated. The LMDI decomposition performed for the 2005-2017 period suggests how the dynamic forces of structural and technological change can shape the economy's materialisation or dematerialisation.

Thinking about our current debates and need for a new energy transition, México is an example for the developing world, is an example that is possible to leapfrog between energy sources. Our historical energy consumption reconstruction demonstrates the leapfrogging from traditional energy sources to oil, almost entirely bypassing coal. However, modern energy systems are so intertwined with their infrastructure and their technical systems (transmission networks) that any transition requires enormous capital investment as it requires to renew infrastructure. The choosing of energy carries produces path dependency, is not easy to switch between energy sources. This fact leaves us with the crude reality that unless the capital energy relationship increases, it will be unrealistic to expect a fast transition. Without more capital, any transition will be gradual. In that sense, a diversified energy matrix that combines more primary electricity sources with natural gas and oil appear to be the feasible path for the near future.

As Kander, Malanima and Warde (2013) suggest, industrial revolutions and energy transitions are linked. Changes in technical systems compound changes in technology that themselves produce changes in demands of energy. Technical systems are often where critical innovation occurs. Just attempting to change energy carriers without thinking on the infrastructure side and without entirely reframing the production methods and consumption patterns will be an obstacle to any idea of a fast transition. Large investments around general-purpose technologies and economies of scale are necessary to the appearance of developing blocks (Dahmén 1950, Enflo, Kander and Schön 2008). In this understanding, nothing short of an industrial revolution will produce the next transition. Maybe one of those revolutions is on the horizon, as Niels Bohr said and later was popularised by the Yankees catcher Yogi Berra: "Prediction is very difficult, especially if it's about the future!"

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VI. Appendix 1. Statistical series

Energy consumption in Mexico, 188-2015. Petajoules.

Year	Population	Food	Fodder	Wind and Water	Fuelwood	Coal	Oil	Natural Gas	Primary Electricity	Biogas
1880	10399000	28.5856863	6.42275717	0.0016	93.717872	0	0	0	0.014044643	0
1881	10524000	28.9292973	8.24218519	0.0026	94.844397	0	0	0	0.016432233	0
1882	10652000	29.281155	9.06640371	0.0029	95.9979587	0	0	0	0.019225712	0
1883	10781000	29.6357615	9.97304408	0.0027	97.1605325	0	0	0	0.022494083	0
1884	10912000	29.9958659	10.9703485	0.0011	98.3411308	0	0	0	0.026318078	0
1885	11044000	30.3587191	12.0673833	0.0017	99.5307412	0	0	0	0.030792151	0
1886	11178000	30.7270701	13.2741217	0.0019	100.738376	0	0	0	0.036026816	0
1887	11313000	31.0981699	14.6015338	0.0018	101.955023	0	0	0	0.042151375	0
1888	11450000	31.4747676	16.0616872	0.0040	103.189695	0	0	0	0.05058165	0
1889	11589000	31.856863	17.6678559	0.0042	104.44239	0	0	0	0.050997253	0
1890	11729000	32.2417074	19.4346415	0.0006	105.704098	0	0	0	0.468154779	0
1891	11904000	32.7227628	21.3781057	0.0006	107.281234	3.99755664	0	0	0.524333352	0
1892	12083000	33.2148137	23.5159163	0.0006	108.894417	6.99572412	0	0	0.587253355	0
1893	12263000	33.7096135	25.8675079	0.0006	110.516614	5.19682363	0	0	0.657723757	0
1894	12447000	34.2154089	28.4542587	0.0007	112.174858	5.99633496	0	0	0.736650608	0
1895	12663000	34.8091687	31.2996845	0.0006	114.121494	5.39670146	0	0	0.898713742	0
1896	12822000	35.2462419	34.429653	0.0006	115.554434	5.05898788	0	0	1.096430765	0
1897	13014000	35.7740284	37.8726183	0.0010	117.284776	7.17701331	0	0	1.337645533	0
1898	13209000	36.3100616	41.6598801	0.0000	119.042155	7.33937408	0	0	1.63192755	0
1899	13406000	36.8515925	45.8258681	0.0006	120.817559	8.1775018	0	0	1.990951611	0
1900	13607000	37.404119	50.408455	0.0005	120.956672	7.75480016	0	0	2.75385164	0
1901	13755000	37.8109544	55.4493005	0.0007	122.272288	13.3918147	0.06	0	2.808928673	0
1902	13904000	38.2205388	52.4587146	0.0006	123.596794	14.1844103	0.24	0	2.865107246	0

1903	14055000	38.6356208	52.4587146	0.0001	124.939078	15.5904709	0.46	0	2.922409391	0
1904	14208000	39.0562007	52.4587146	0.0001	126.29914	16.6250785	0.77	0	2.980857579	0
1905	14363000	39.4822783	52.4259635	0.0001	127.676981	18.3887605	1.54	0	3.040474731	0
1906	14519000	39.9111049	32.282323	0.0001	129.063712	15.3478992	3.07	0	3.101284225	0
1907	14676000	40.3426803	22.2220811	0.0001	130.459332	20.4790829	6.15	0	3.16330991	0
1908	14836000	40.7825024	24.3122688	0.0001	131.881619	17.3157564	24.06	0	3.226576108	0
1909	14997000	41.2250733	22.6922115	0.0001	133.312796	25.9841182	16.61	0	3.29110763	0
1910	15000000	41.23332	20.2621256	0.0001	133.339464	26.0662879	22.24	0	3.623489	0
1911	14990000	41.2058311	16.2119824	0.0016	133.250571	27.9828965	76.815717	0	3.540234971	0
1912	14980000	41.1783422	11.3518105	0.0016	133.161678	19.6359183	40.532	0	3.57599492	0
1913	14970000	41.1508534	10.7845343	0.0018	133.072785	11.9926699	15.726	0	3.612116081	0
1914	14960000	41.1233645	10.2453076	0.0003	132.983892	15.5904709	24.084	0	3.648602102	0
1915	14950000	41.0958756	9.73304219	0.0012	132.894999	8.99450244	50.355	0	3.685456668	0
1916	14940000	41.0683867	9.24639008	0.0008	132.806106	5.99633496	74.442	0	3.722683503	0
1917	14930000	41.0408978	8.78407058	0.0014	132.717213	8.61113676	33.839	0	3.760286367	0
1918	14920000	41.013409	8.34597369	0.0014	132.62832	15.6276482	39.063	0	3.798269058	0
1919	14910000	40.9859201	7.96965545	0.0023	132.539427	14.5585816	53.283	0	3.836635412	0
1920	14900000	40.9584312	7.57416384	0.0032	132.450534	0	76.9008	0	4.262928235	0
1921	14895000	40.9446868	7.19851875	0.0037	128.234636	14.6906209	82.852	0	4.305988117	0
1922	15129000	41.5879266	6.84173505	0.0048	130.249198	18.6396072	78.078411	0	4.349482946	0
1923	15367000	42.2421619	5.88803577	0.0033	132.298197	25.215408	73.227449	0	4.393417117	0
1924	15609000	42.9073928	6.66400701	0.0030	134.381633	24.5189337	118.1699	0	4.437795068	0
1925	15854000	43.5808704	12.0561521	0.0016	136.490897	28.8723129	70.690228	0	4.482621281	0
1926	16103000	44.2653435	12.0577779	0.0014	138.634598	26.1703643	55.378114	0	4.527900284	0
1927	16356000	44.9608121	15.2040847	0.0010	140.812736	20.6135607	58.861268	0	4.57363665	0
1928	16613000	45.6672763	15.1990403	0.0002	143.025311	20.4370086	61.380344	0	4.619835	0
1929	16875000	46.387485	15.1939958	0.0001	145.280932	21.0710611	82.038303	0	4.6665	0
1930	17175000	47.2121514	9.63801439	0.0002	142.79419	25.8693683	72.563725	0	3.708	0

1931	17480000	48.0505622	9.6238899	0.0002	145.329982	18.4345526	68.73888	0	3.5226	0
1932	17790000	48.9027175	9.62331265	0.0001	147.907344	13.8076606	60.222226	0	3.452148	0
1933	18115000	53.6968011	8.73836593	0.0001	150.609418	12.9288577	52.013842	0	5.711666688	0
1934	18445000	54.6749929	11.2845188	0.0002	153.353062	15.6335646	58.388493	0	6.65395808	0
1935	18781000	55.67097	10.6861166	0.0002	156.14659	25.0858272	83.716331	0	6.805153647	0
1936	19040000	56.4387023	7.97627945	0.0002	158.299935	26.1423215	168.20625	0	7.535222726	0
1937	19370000	57.4168941	13.8328544	0.0002	161.043579	37.5018127	214.7981	0	8.199523706	0
1938	19705000	58.409907	10.0910006	0.0001	163.828793	21.851684	166.28873	0	8.419857237	0
1939	20047000	59.4236694	10.308202	0.0000	166.672205	17.5263077	185.52157	1.18741625	7.27965104	0
1940	20393000	60.4492887	9.97023672	0.0000	164.351266	16.3081722	187.17299	6.69074272	7.642599561	0
1941	20955000	62.115179	10.2981347	0.0000	168.880536	17.1034861	218.64389	8.32145318	7.436137788	0
1942	21532000	63.8255325	9.41115275	0.0000	173.530694	18.2742106	215.10496	1.07623825	8.719448666	0
1943	22125000	65.5833135	9.09304525	0.0000	178.3098	21.1353112	218.28689	0.89585898	8.511864597	0
1944	22734000	67.388522	9.11720171	0.0000	183.217853	18.1347592	237.67817	0.95309431	7.745712791	0
1945	23724000	70.3230974	8.93475856	0.0000	191.196461	16.8298657	253.32244	18.5855609	9.412829793	0
1946	24413000	72.3654433	9.12484201	0.0000	196.74925	19.5680399	282.69032	17.1956279	9.544820301	0
1947	25122000	74.4670735	7.62454655	0.0000	202.463222	20.7944901	330.22304	19.1433676	9.350170119	0
1948	25852000	76.6309524	8.10699688	0.0000	208.346438	21.1316041	315.11724	4.42506764	10.48216442	0
1949	26603000	78.8570797	8.12130429	0.0000	214.398898	21.519292	341.28894	18.3462418	9.383647001	0
1950	28485180	84.4362708	7.43849989	0.0000	206.610986	18.2410733	384.00689	23.0815535	8.772539981	0
1951	29296235	86.8404142	7.43849989	0.0000	212.493795	22.3605329	483.18182	2.61378987	10.49463875	0
1952	30144317	89.3543138	7.43849989	0.0000	218.645172	26.3203322	434.10242	2.86111915	12.19374864	0
1953	31031279	91.9834621	7.66379094	0.0000	225.078555	28.6287956	449.23691	3.31127578	11.79893597	0
1954	31959113	94.733764	7.8647598	0.0000	231.808395	26.2561319	374.95622	3.43577059	12.39675372	0
1955	32929914	97.6114293	7.8647598	0.0000	238.849887	26.8256238	381.99052	3.47942396	15.582699	0
1956	33945886	100.622991	8.74655423	0.0000	246.219016	29.8631106	410.07834	4.14585499	19.4476185	0
1957	35015548	103.793702	9.06265036	0.0000	253.977574	32.7239548	478.82633	4.68478446	16.74	0
1958	36141955	107.132618	9.39026761	0.0000	262.147719	30.566451	623.19217	15.6282362	20.026737	0

1959	37328466	110.649694	9.69048421	0.0000	270.753816	31.6985854	641.00607	10.72	21.8080575	0
1960	38578505	114.355082	7.08962447	0.0000	289	35.4912873	659.21518	59.15	21.42088164	0
1961	39836230	146.439051	6.97464455	0.0000	292	37.8003931	711.59645	62.7469833	21.15700632	0
1962	41121485	151.163682	6.86437736	0.0000	295	39.2160837	740.80477	64.6377676	22.68792864	0
1963	42434264	155.989493	6.75894583	0.0000	298	43.0323073	717.54773	81.8544293	24.93950904	0
1964	43774575	166.879602	6.65848997	0.0000	301	42.7250459	747.85117	82.3414994	29.29231746	0
1965	45142399	172.094088	6.5631683	0.0000	181.711859	41.6548885	724.65141	511.662	35.64050652	0
1966	46537832	177.413827	6.4731594	0.0000	184.673485	43.8000702	717.32977	550.707	41.88931074	0
1967	47995559	193.862965	6.38866357	0.0000	187.686897	49.4689413	857.07062	596.800268	45.60935742	0
1968	49518803	200.01563	6.30990473	0.0000	190.761578	54.0749658	915.45494	601.569	52.33646826	0
1969	51110928	206.446518	6.23713236	0.0000	193.881775	55.9204055	874.04115	635.803	55.49915088	0
1970	52775158	213.168652	11.4701042	0.0000	196.504518	63.5713302	1029.616	398.713342	62.06836626	0
1971	54406901	219.759565	0.56629685	0.0000	199.12079	42.9991355	1057.2352	390	60.1055343	0
1972	55984294	238.921295	12.2551546	0.0000	201.783872	68.2816808	1092.2884	410	63.7235631	0
1973	57557303	245.634345	8.99997796	0.0000	204.479944	48.4641369	1159.7846	440	67.19950296	0
1974	59122839	252.315502	12.9067526	0.0000	207.216979	55.6096707	1367.7197	470	69.1724655	0
1975	60678045	258.952575	13.2428581	0.0000	209.99574	63.1329683	1518.3635	470	62.67758796	0
1976	62219964	265.532944	13.6101666	0.0000	212.824798	49.464147	1676.704	460	71.16257592	0
1977	63759976	303.010946	14.0091929	0.0000	215.689499	71.7306882	1840.5323	489.999993	78.97433364	0
1978	65295990	310.310652	14.4456272	0.0000	218.598332	69.2647327	2012.3044	620	66.91868262	0
1979	66825878	317.581245	14.9164794	0.0000	221.552138	74.4014209	2234.3685	750	74.027961	0
1980	68347479	324.812454	15.3617262	0.0000	223.415351	163.758263	2661.914	900	69.3036	0
1981	69969263	332.519771	15.2610355	0.0000	224.442444	240.634698	2924.7029	970	121.3979305	0
1982	71640904	345.638983	15.7508053	0.0000	225.478691	232.404996	3029.0381	1040	111.323667	0
1983	73362881	353.94684	16.0451751	0.0000	226.524243	247.78247	2766.751	1050	99.0007235	0
1984	75080138	362.231925	12.9885215	0.0000	227.582152	252.875725	2828.0894	1030	109.2335755	0
1985	76767225	370.371451	13.4652396	0.0000	228.646792	270.253258	2951.66	1000	114.616692	0
1986	78442430	378.453652	15.0677539	0.0000	229.721191	262.076432	2885.134	890	101.856258	0

1987	80122492	374.83721	14.7806938	0.0000	230.805507	268.170215	3005.2988	900	97.654081	0
1988	81781816	382.600029	14.4346801	0.0000	231.902919	245.295745	3065.6061	910	109.194652	0
1989	83366836	390.015231	14.1404998	0.0000	233.007588	242.833678	3206.5989	880.561836	129.208285	0
1990	84913652	397.251703	9.907841	0.0000	276.461839	251.039883	3327.068	950.493009	160.6435665	0
1991	86488032	404.617128	8.87056511	0.0000	278.695399	228.837403	3477.8193	962.008947	170.2454444	0
1992	88111030	420.61998	9.74320921	0.0000	289.089174	231.727038	3516.1617	933.061243	183.1769586	0
1993	89749141	428.439912	9.77399749	0.0000	277.80537	244.63495	3580.0209	1001.18067	199.5065917	0
1994	91337896	436.02423	9.93520837	0.0000	278.596068	275.735753	3738.8548	1051.52726	167.1936909	0
1995	92880353	443.387533	10.2978259	0.0000	279.336996	311.916918	3625.9792	1052.11836	356.6356858	0
1996	94398579	450.635164	10.4791347	0.0000	280.207899	356.275327	3650.2963	1111.01946	363.1040005	0
1997	95895146	459.756438	10.5697891	0.0000	281.181445	349.996238	3638.6871	1121.40367	375.0373286	0
1998	97325063	466.611983	10.6151163	0.0000	282.32842	346.368629	3777.4261	1191.86844	355.7426828	0
1999	98616905	472.805547	10.6377799	0.0000	283.591175	368.045748	3756.604	1231.82408	397.361925	0.002269
2000	99926620	479.0848	10.6974909	0.0000	284.97633	393.355441	3712.5007	1202.83029	380.3888916	0.01576
2001	101246961	485.414998	10.6974909	0.0000	267.093824	368.90974	3876.0895	1193.56924	364.3607688	0.025123
2002	102479927	491.326288	10.6974909	0.0000	266.239001	611.599045	4264.4086	1217.22617	361.2151555	0.020279
2003	103718062	497.262361	10.6974909	0.0000	267.027501	467.701965	3956.917	1259.26418	396.8156299	0.413603
2004	104959594	503.21472	10.6974909	0.0000	266.652379	277.062132	3869.1111	1339.36401	405.8572248	0.708128
2005	106202903	509.175598	10.6974909	0.0000	266.433609	475.499025	4084.9042	1605.90081	456.5686797	0.688518
2006	107449525	515.152361	10.6974909	0.0000	264.600482	462.03024	4119.0692	1745.50885	454.024553	0.675775
2007	108700891	521.151867	10.6974909	0.0000	263.238403	531.198363	3995.0163	1694.71143	454.5448271	0.651122
2008	109955400	527.166443	10.6974909	0.0000	262.048823	561.761402	3902.8497	1705.47851	482.9383228	0.808913
2009	111212000	533.191043	10.6974909	0.0000	260.677582	657.048291	3867.567	1895.16503	437.521152	1.067139
2010	113748671	545.352773	10.6974909	0.0000	259.310907	892.338834	3778.8003	1890.54773	412.8417804	1.298023
2011	115367452	553.113801	10.6974909	0.0000	258.085751	1046.58331	3833.2842	1897.67372	470.165961	1.507667
2012	116935670	560.632413	10.6974909	0.0000	256.742845	946.299621	3963.853	1843.31839	427.1635675	1.823098
2013	118453929	567.911502	10.6974909	0.0000	255.422397	925.868751	3991.1161	1905.77089	456.8177267	1.972003
2014	119936411	575.019064	10.6974909	0.0000	254.116775	838.476393	3948.9166	1866.61673	481.5559292	1.925703

2015	121347800	581.785779	10.6974909	0.0000	252.840472	810.537222	3695.9441	1746.2678	497.7852988	1.867721

Energy and Product

Year	Energy per capita, GJ	Energy intensity MJ/GDP	Energy productivity (efficiency) 1990GK dollars per GJ
1880	12.3802274	7.895553187	126.6535702
1881	12.54607826	8.001325423	124.9792937
1882	12.61430695	8.044838614	124.3033015
1883	12.68848033	8.092143066	123.5766585
1884	12.7689467	8.143460908	122.7979125
1885	12.85669865	7.317415282	136.6602771
1886	12.95200375	7.256024507	137.8165136
1887	13.05565821	6.951894678	143.8456775
1888	13.16861946	6.722113047	148.7627466
1889	13.29038827	7.242718402	138.0697059
1890	13.45802772	7.3864038	135.3838792
1891	13.93687811	7.121552432	140.4188215
1892	14.33491102	7.981576294	125.2885349
1893	14.34794809	7.253765464	137.8594338
1894	14.5881106	7.323348694	136.5495543
1895	14.73002987	6.766205729	147.7933188
1896	14.92640209	7.007700512	142.7001622
1897	15.32557563	6.866297327	145.6389015
1898	15.59417107	7.07860693	141.2707345
1899	15.93794109	7.102469293	140.7961033
1900	16.11512017	7.194250075	138.9998943

1901	16.85161367	7.837959848	127.5842208
1902	16.65464484	7.815412876	127.9522932
1903	16.72048211	8.343553945	119.8530035
1904	16.7645041	8.353016492	119.7172304
1905	16.88745673	8.537642433	117.1283534
1906	15.3437844	7.203654646	138.8184261
1907	15.18237723	6.838908664	146.2221604
1908	16.28328427	7.055149164	141.7404476
1909	16.21093481	6.757371741	147.9865306
1910	16.4509846	6.446310582	155.1274931
1911	19.94721881	7.847056967	127.436312
1912	16.65135651	6.499358514	153.8613385
1913	14.45161875	5.541264857	180.4642127
1914	15.21897979	6.032096628	165.7798377
1915	16.50569216	6.252156121	159.9448223
1916	17.89040576	6.491438954	154.0490494
1917	15.32177072	5.91574159	169.0405142
1918	16.11783191	6.283755132	159.1405106
1919	16.98024788	7.005052754	142.7540998
1920	17.59396668	7.87907151	126.9185079
1921	18.67943522	8.236082551	121.4169472
1922	18.49105751	9.78362831	102.211569
1923	18.43352684	8.900785534	112.3496343
1924	21.21100868	9.747706196	102.5882377
1925	18.68138318	8.125873503	123.0636927
1926	17.45236901	7.14090385	140.038295
1927	17.42645238	7.021133111	142.427153
1928	17.47601231	7.049621747	141.8515824

1929	18.64523994	7.254957174	137.8367888
1930	17.57121564	6.86375611	145.6928224
1931	16.80209575	6.136631025	162.9558622
1932	15.95927817	5.665345463	176.5117426
1933	15.66100452	5.506682322	181.5975467
1934	16.26396102	5.424936964	184.3339391
1935	18.00283013	5.982994394	167.1403873
1936	22.30036141	7.138399939	140.0874157
1937	25.44103963	8.089360772	123.619162
1938	21.76554753	6.827336114	146.4700116
1939	22.34344468	6.82034331	146.6201853
1940	22.19316921	6.322840231	158.1567719
1941	23.51700411	6.402669237	156.1848603
1942	22.7541445	6.139812333	162.8714276
1943	22.68095304	6.296766529	158.8116687
1944	23.05952839	5.987932586	167.0025481
1945	23.96750188	5.903325586	169.3960439
1946	24.87356504	5.904003095	169.376605
1947	26.43364011	6.003552148	166.5680543
1948	24.9203337	5.536621573	180.6155589
1949	26.00892388	5.783616606	172.9021939
1950	25.71820913	5.445312117	183.6442023
1951	28.17507052	5.86125869	170.6118178
1952	26.2376356	5.375463143	186.0304821
1953	26.35088713	5.148668842	194.22496
1954	23.51291149	4.232747343	236.2531753
1955	23.44993513	4.087490872	244.6488644
1956	24.13027268	4.055508013	246.578233

1957	25.69741294	4.190706612	238.6232425
1958	29.55247452	4.594601138	217.6467488
1959	29.36972299	4.430490721	225.7086321
1960	30.73530344	4.471890505	223.6190709
1961	32.09928579	4.643993894	215.3318938
1962	32.10911787	4.425181624	225.9794252
1963	31.29834928	4.119830102	242.7284561
1964	31.4508621	4.03164493	248.037716
1965	37.11581478	4.633106327	215.8379129
1966	37.03147639	4.554356953	219.5699657
1967	40.37535453	4.937673294	202.5245375
1968	40.83003561	4.698508126	212.8335151
1969	39.69761868	4.26535067	234.4473122
1970	37.4563023	3.772414372	265.0822262
1971	36.27088544	3.441913592	290.5360559
1972	37.31559058	3.644100642	274.4161312
1973	37.80004283	3.914668893	255.449446
1974	41.19775301	4.213741742	237.3187683
1975	42.80670595	4.374727231	228.5856803
1976	44.20803979	4.762257868	209.9844292
1977	47.28773607	5.108873819	195.7378544
1978	50.73927914	5.519338534	181.1811314
1979	55.19048685	5.87632952	170.1742553
1980	63.81037702	6.579067637	151.9972214
1981	69.03310923	6.897413122	144.9818914
1982	69.82247489	6.803843447	146.975751
1983	64.9134606	6.267091317	159.5636555
1984	64.27126328	5.994889836	166.8087367

1985	64.49768715	6.485469462	154.1908424
1986	60.74683473	5.848634273	170.9800875
1987	61.08963126	5.538325529	180.5599896
1988	60.63965525	5.268030677	189.8242553
1989	61.13181545	5.139631149	194.5664915
1990	63.27446419	5.01644949	199.344178
1991	63.95213359	5.089515805	196.4823449
1992	63.36981028	5.011252408	199.5509144
1993	63.9712242	5.000113031	199.9954789
1994	65.22886173	4.909002544	203.7073705
1995	65.45703482	4.793350025	208.6223612
1996	65.9121923	4.613257987	216.7665461
1997	65.03595048	4.428815479	225.7940085
1998	66.11911857	4.46506732	223.960789
1999	66.18034203	4.718071869	211.9509892
2000	64.77176673	4.40705266	226.90902
2001	64.89194921	4.266400343	234.3896305
2002	70.49324939	4.507529215	221.8510302
2003	66.10323754	4.2157677	237.2047207
2004	63.57367528	4.009439662	249.4114102
2005	69.77086019	4.334670737	230.69803
2006	70.47047948	4.368095177	228.9327406
2007	68.79451813	4.645738803	215.2510166
2008	67.87703771	4.839031234	206.6529335
2009	68.92334316	4.689524744	213.2412248
2010	68.56555648	4.507926133	221.8314965
2011	69.9759889	4.474454179	223.4909466
2012	68.56030171	4.372468221	228.7037777

2013	68.56787451	4.324411864	231.2453188
2014	66.71411371	4.144763526	241.268288
2015	63.02606104	3.906654748	255.9734772