COMPARATIVE ANALYSIS OF THE EVOLUTION OF ENERGY INDICATORS IN CUBA AND SPAIN FROM 1990 TO 2016

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1. Introduction

This chapter aims to make a comparative analysis of the evolution of some basic energy indicators in Cuba and Spain from 1990 to 2016. In this period of profound changes in energy generation technologies around the world, two in particular stand out. First, the breakthrough of renewable electricity generation technologies (wind and solar) led their generation costs (investment, operation and maintenance) to fall dramatically. While in 1990 they were practically non-existent, by 2016 they were already clear competitor technologies to other generation alternatives. In this process, while most countries initially opted to provide significant regulatory support for these technologies (in the form of feed-in tariffs), it was gradually withdrawn across the board once the journey through the learning curve made them competitive.

Second, liquid hydrocarbons and to some extent coal have partially been replaced by natural gas. This has been highly evident in industrial sectors, which often require a heat source for many production processes. Use in the residential sector has also spread, although to a large extent conditioned by each country's climatic conditions and heating needs. Natural gas has also become the alternative to coal and oil derivatives in electricity generation, through combined cycle plants. Nevertheless, oil is still generally used where its replacement is not straightforward, particularly in transport.

In this global technological context, Cuba and Spain's energy trajectories differ in crucial aspects. Of particular importance is the institutional context. In Spain, the energy pathway is determined by European regulations on the creation of the single energy market and the international commitments acquired first in the Kyoto Protocol and since December 2015 in the framework of the Paris Agreement within the United Nations Framework Convention for Climate Change (COP21). Cuba also has an ambitious target for renewable generation penetration based on meeting the commitments of the Paris Agreement. While starting from a very low base, it has considerable potential for growth due to natural conditions.

Obviously, it is impossible to summarise all the particularities of the energy evolution over such a long period in a few pages. This chapter therefore describes the general features of the energy evolution in both countries since 1990, focusing mainly on primary energy consumption and the electricity generation mix, but also pointing out some specific features of the use of the different energy vectors and the institutional and regulatory context. This allows a comparative analysis of some interesting energy indicators to be conducted in the final part of the work.

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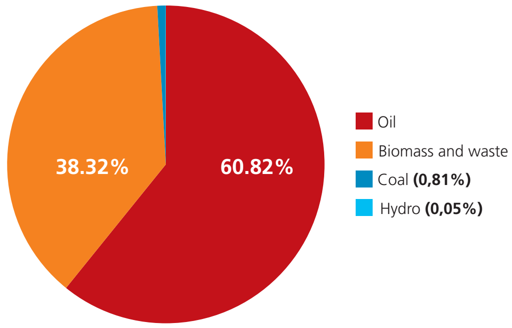
2. Energy evolution in Cuba from 1990 to 2016

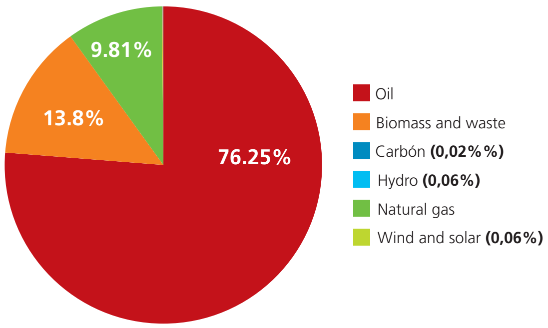
Figures 1 and 2 show the total amount of primary energy used in Cuba, indicating the percentage for each of the energy sources for the years 1990 and 2016, respectively. The time period studied begins in 1990, the starting point for the International Energy Agency data used in this study.

Figure 1. Primary energy supply in Cuba in 1990: 17.41 Mtoe*



* Million tonnes of oil equivalent.
Source: International Energy Agency (IEA).

Figure 2. Primary energy supply in Cuba in 2016: 9.60 Mtoe



Source: International Energy Agency.

A strong dependence is noted on oil and biomass, with an almost total absence of other primary energy sources.

Comparing Cuba's primary energy supply data for 1990 and 2016 shows that:

- The total supply of primary energy decreased by 44.8% – from 17.41 Mtoe in 1990 to 9.60 Mtoe in 2016 – very different from what has taken place in the rest of the world.

- The percentage contributed by oil has grown considerably, rising from 60.82% in 1990 to 76.25% in 2016, which is also unusual when compared with the OECD and global totals.
- The proportion of biomass and waste decreased significantly, from 38.32% in 1990 to 13.8% in 2016.
- The share of natural gas, minimal in 1990, rose considerably and contributed 9.81% in 2016.
- The share of coal decreased (from 0.81% to 0.02%), the proportion of hydroelectric energy is steady (from 0.05% in 1990 to 0.06% in 2016) and wind and solar emerged, but at almost negligible levels (together they represented 0.06% in 2016).

In short, the energy mix in Cuba is very different from that found around the world. That it is an island (both geographically and energetically) goes some way towards explaining this different pattern. In general, isolated territories have less diversified generation mixes and a greater presence of hydrocarbons in the mix. In the case of Cuba, this is compounded by the irrelevance of hydroelectric generation, the lack of nuclear generation and, most strikingly, the near absence of wind and solar generation.

Next, some features of the evolution of primary energy consumption and the generation mix in Cuba are studied in depth.

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2.1. Total amount of primary energy

Cuba's primary energy use peaked in 1990 and its low-point came in 2016. However, the trajectory is not constantly downward throughout the period under study, as will be seen later.

The precursors to the early 1990s collapse of the Cuban economy were the fall of the Berlin Wall in November 1989 and the dissolution of the Soviet Union in December 1991: trading oil for sugar with the Soviet Union had played a very prominent role over the previous three decades (Alonso and Galliano, 1999). In 1991, primary energy supply in Cuba fell by 17.23% compared to 1990, and the decrease between 1990 and 1993 was 39.46%. In the same years, Cuba's GDP fell in real terms by 10.7% between 1990 and 1991 and by 32.8% between 1990 and 1993. These years fit squarely within what is called the "Special Period" (Worsham and Vargas Esposito, 2017). Piercy, Granger and Goodier (2010) analyse the changes made in Cuba to adapt to the new situation in terms of transport, agricultural production, and electricity generation and consumption policies.

2.2. Oil

In each year of the period under consideration, oil is by far the most used primary energy source in Cuba. The highest level was in 1990 (10.6 Mtoe), followed by 2010 (9.2 Mtoe), with 1993 the year in which least was used (6.5 Mtoe).

The amount of imported oil fell from 10.06 Mtoe in 1990 to 8.01 Mtoe in 1991, 6.1 Mtoe in 1992 and 5.5 Mtoe in 1993 (54.7% of the quantity imported in 1990).

Cuba's own production has been increasing considerably since 1993. Its peak oil production was 3.84 Mtoe in 2003, and its highest share of the total oil used was 47.3% in 2002.

In October 2000, the presidents of Cuba and Venezuela, Fidel Castro and Hugo Chávez, signed a Comprehensive Cooperation Agreement. Cuba would provide support and cooperation through services and programmes for the social development of Venezuelans, and in return Venezuela would provide Cuba with oil in highly favourable economic and financial conditions (Worsham and Vargas Esposito, 2017; Corrales et al., 2005).

Data from the International Energy Agency indicate that between 2006 and 2016 Cuba exported approximately 2 Mtoe of oil every year from 2010 to 2015 (peaking in 2012), and lower amounts in the other years.

2.3. Natural gas

As mentioned, natural gas went from having a minimal presence in the Cuban energy mix in 1990 to contributing 9.81% in 2016. Cuba produces the natural gas it uses.

Natural gas production in Cuba was 15,000 TOE (tonnes of oil equivalent) in 1996. In the following years (1997, 1998, 1999 and 2000) this amount multiplied, respectively, by 2, 6.6, 24.3 and 30.4. It continued to grow until 2007, when it reached 968,000 TOE. From there it decreased until 2011 (810,000 TOE), increased to reach its highest level in 2015 (989,000 TOE) and fell again in 2016 to 942,000 TOE.

In 2016, 65.76% of the natural gas was used to generate electricity, 28.67% was used in industry, 5.17% in the residential sector and 0.40% for unspecified uses.

2.4. Coal

According to International Energy Agency data, Cuba supplied 140,000 TOE from coal in 1990, a figure that fell significantly in the following years towards a 50% reduction by 1994. This decline continued, with consumption in 1999 of 30,000 TOE and a steady decrease from 2000 to 2016 to stand at 1,000 TOE in 2014, 5,000 TOE in 2015 and 2,000 TOE in 2016.

All the coal used (entirely anthracite) in the period was imported and used in industry, and never in the production of electricity.

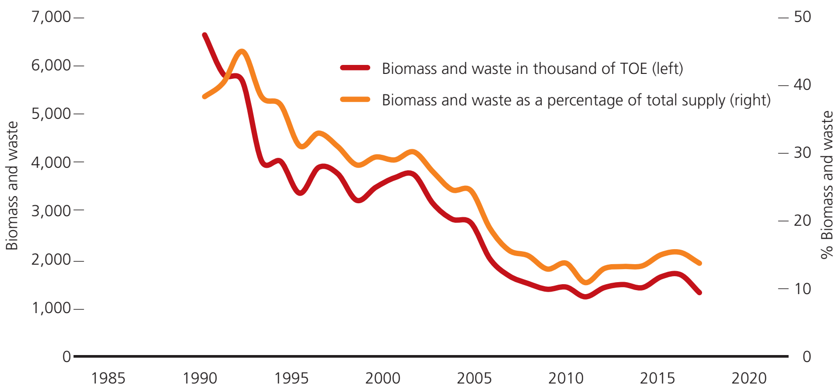
2.5. Biomass and waste

Figure 3 shows the evolution of the contribution of biomass and waste to the supply of primary energy in Cuba in the period studied. As the graph clearly shows, the contribution of biomass and waste has been decreasing over the years, from 38.2% of the primary energy used in 1990 to 13.8% in 2016.

Currently, biomass represents 99.3% of total energy from renewable sources in Cuba. It is likely to continue dominating in this area for the foreseeable future due to the amount of waste produced by agriculture and agricultural product processing, such as by-products of the sugar industry, sawmills, wood brushing, coffee and rice, and other waste like firewood, chips, pellets, charcoal and plants that can be used to obtain biofuels (Suárez et al., 2016).

Currently, the potential energy production from biomass comes from sugar cane bagasse (48.2%), wood fuels (31.3%), biogas (10.15%), sugar cane straw (6.7%), charcoal (2.25%), rice husk (1.3%), sawdust (0.06%) and coffee husk (0.04%) (ibid.). However, as the authors themselves point out, not all the potential is exploited.

Figure 3. Biomass and waste volume and percentage of energy supplied



Source: Produced by the authors using International Energy Agency data.

Table 1 provides data on sugar cane cultivation's use of agricultural land, its production and the amount of bagasse obtained in Cuba in each of the years analysed. The data in Table 1 are closely related to the data on the amount of energy obtained from biomass and waste in Figure 3. From 1990 to 2016, the amount of energy obtained in Cuba from biomass and waste fell by 80%, the agricultural area in which sugar cane was grown decreased by 70%, the production of sugar from sugar cane dropped by 81% and the amount of bagasse obtained fell by 84%. In the period under consideration, the amount of energy obtained from biomass and waste reached its lowest point in 2010, the same year the quantity of bagasse fell to its lowest. Regarding sugar cane production, the lowest volume was reached in 2005, followed by 2006 and 2011.

Sugar exports fell by 48.9% between 1990 and 1993, and 55.64% between 1990 and 1995 (Alonso and Galliano, 1999). Exports grew by 47% from 1995 to 1996, and have not reached that year's level since. On the other hand, non-sugar agro-exports have grown since 1993, reaching and even later exceeding the levels of 1990. The balance of agricultural foreign trade in Cuba was positive between 1958 and 2000, reaching its highest value in 1990 and was negative from 2001 to 2017 (García and Anaya, 2019).

From 1990 to 2016, the amount of energy obtained in Cuba from biomass and waste fell by 80%, the agricultural area in which sugar cane was grown decreased by 70% and the production of sugar from sugar cane dropped by 81%.

Table 1. Evolution of sugar cane production and its share of agricultural land in Cuba

Year	Harvested area (ha)	Production (tonne)	Bagasse (tonne)
1990	1,420,300	83,646,720	23,261,900
1991	1,452,200	79,698,330	19,473,800
1992	1,451,700	55,253,520	10,093,300
1993	1,211,700	44,960,400	12,921,200
1994	1,248,900	40,738,040	12,902,700
1995	1,177,400	35,468,250	10,208,100
1996	1,244,500	41,377,160	12,423,200
1997	1,246,300	32,713,200	11,859,500
1998	1,048,500	31,168,540	10,070,300
1999	995,800	35,494,690	10,673,300
2000	1,040,900	35,852,760	11,038,700
2001	1,007,100	32,693,680	11,599,000
2002	1,041,200	21,438,540	8,952,000
2003	643,800	22,672,300	7,100,700
2004	661,000	18,619,200	6,950,500
2005	517,200	8,895,040	4,787,300
2006	397,100	9,226,000	3,605,800
2007	329,500	13,728,830	3,415,100
2008	380,300	17,953,110	3,863,300
2009	434,700	14,797,020	3,719,000
2010	431,400	13,512,870	3,027,300
2011	506,100	11,272,560	3,949,600
2012	361,300	15,971,970	3,959,900
2013	400,300	16,329,560	3,637,100
2014	405,200	19,300,000	4,604,200
2015	435,600	19,297,080	4,942,000
2016	-	15,806,667	3,793,600

Source: Sagastume *et al*. (2018b).

2.6. Hydroelectric energy

International Energy Agency data indicate that the production of hydroelectric energy in Cuba was 91 GWh in 1990 and 64 GWh in 2016, and varied in that period between 48 GWh in 2015 (lowest) and 151 GWh in 2009 (highest).

The first hydroelectric power generation plant in Cuba, with a capacity of 800 kW, was installed on the Guaso River in the province of Guantánamo in 1917. Currently, the Hanabanilla hydroelectric plant, located in the province of Cienfuegos, with an installed capacity of 43 MW (approximately 74% of country's total hydroelectric capacity), is the largest in Cuba (Suárez et al., 2016). In total, 180 hydroelectric power plants have been built, reaching a total capacity of 58 MW in 2009. The production of 151 GWh in one year represents an annual saving of 12,970 TOE (ibid.).

2.6. Wind energy

The first wind farm in Cuba, located on the island of Turiguano in the province of Ciego de Ávila, was built in 1999. The park has two 225 kW turbines (model: Ecotecnia 28/225, Spain) (ibid.).

The second is located in Los Canarreos in the Isla de la Juventud municipality and has been in operation since February 2007. It has six 275 kW turbines (model: Vergnet GEV-MP 32/275, France) (ibid.).

The third farm (Gibara 1) is located in Gibara in the province of Holguín. It was built in 2008 and has six 850 kW turbines (model: Gamesa, Spain), giving a total capacity of 5.1 MW (ibid.).

A fourth park (Gibara 2) was in construction in Punta Rasa near the city of Gibara with six 750 kW turbines (model: Goldwing, China) (ibid.).

On the other hand, there is a long tradition in Cuba of using wind energy to pump water mechanically. There are currently over 4,850 established mills, enabling a saving of approximately 340 TOE per year, although not all of them are operational due to breakdowns, maintenance failures or the lack of spare parts (ibid.).

2.7. Solar energy

At latitudes between 20° 12' and 23° 17', Cuba's location gives it great solar energy potential. Its average annual number of hours of sunshine is 1,700 and average annual solar radiation is 5.5 kWh/m^2 per day, enough to provide adequate energy for photovoltaic and thermal applications (ibid.).

Until 2012, photovoltaic facilities totalled less than 3 MW in around 9,000 low-power photovoltaic systems, almost all in remote locations the electricity grid did not reach (schools, clinics, houses and cultural centres with significant social impact). The driving force behind global photovoltaic development is grid-connected photovoltaic energy and in 2013, Cuba made a leap forward with the installation of 11 MW in grid-connected photovoltaic parks (Stolik, 2014).

Solar thermal energy has been used in Cuba for several decades to heat water in homes and to dry wood, various crops such as coffee, tobacco, coconut, cocoa and seeds, as well as fish and medicinal plants, allowing diesel to be saved and helps avoid greenhouse gas emissions (Suárez et al., 2016).

3. Evolution of energy in Spain 1990–2016

Figures 4 and 5 show the total amount of primary energy used in Spain, indicating the percentage for each of the energy sources for the years 1990 and 2016, respectively. The series starts in 1990 so that the comparison may be drawn with Cuba.

Comparing the primary energy supply data for Spain from 1990 to 2016 shows that:

- Total supply has increased by 32.3%, rising from 90.1 Mtoe in 1990 to 119.2 Mtoe in 2016.
- The contribution of oil has decreased, from 50.46% in 1990 to 42.54% in 2016. Coal use has also been reduced – from a 21.39% share to 8.8%; and nuclear has also fallen: from 15.69% to 12.82%.

- The share of natural gas increases considerably (from 5.51% to 21%).
- Renewable energy use increases considerably, from 6.95% to 14.9%. Above all, the contribution of wind and solar has increased (from 0.01% to 6%). Biomass and waste rise (from 4.5% to 6%) as does hydro, albeit slightly (from 2.4% to 2.7%).

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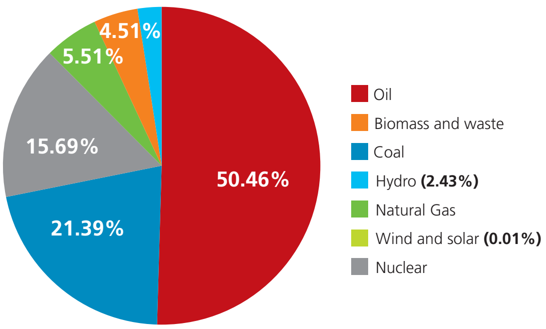
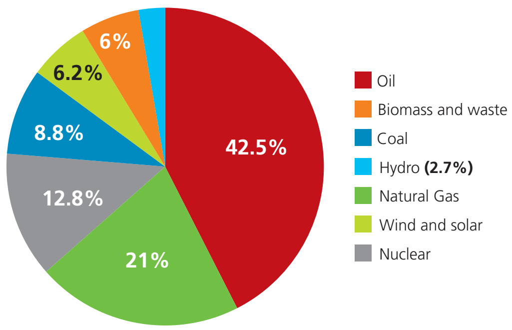
Figure 4. Primary energy supply in Spain in 1990: 90.1 Mtoe



Source: International Energy Agency.

Figure 5. Primary energy supply in Spain in 2016: 119.2 Mtoe



Source: International Energy Agency.

3.1. Changes in the Spanish energy sector within the European Union framework since 1990

The Single European Act approved in February 1986 set the date of January 1st 1993 for achieving a single internal market in the European Union and a single market in the energy sector. This market was presented as a way to appropriately allocate resources, reduce the cost of energy and contribute to providing security of supply through competition between companies (UNESA, 2010).

In Spain, the process of liberalising the electricity sector began in December 1996 with the signing of a protocol between the companies in the sector, supervised by the government, which established the main points of the framework in which competition would take place from January 1st 1998 (Sáenz de Miera, 2009).

Law 54/1997 on the electricity sector is the transposition of Directive 96/92/EC, which establishes the "common rules for the internal market in electricity". Among the main elements the law introduces, several should be highlighted: the establishment of an authorisation regime for new generation plants, with the bidding process ruled out; the creation of a mandatory organised daily market for most generation facilities; the express authorisation of commercialisation activity, and the creation of a single operator for the entire transmission network with responsibility for the safety and technical quality of the electricity supply, which is also the main transmission company (Red Eléctrica de España) (ibid.). The law introduced the principle of the vertical separation of activities between generation, transmission/distribution and commercialisation, a principle that would be developed in regulation over subsequent years. The idea is that generation and marketing are market activities, while transportation and distribution have the features of natural monopolies, justifying their treatment as activities subject to regulated remuneration.

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Two new institutions were also created in 1997: the Spanish electricity market operator, responsible for matching electricity supply and demand every day, with its market rules, matching algorithms, and communication and settlement procedures; and the National Commission of Energy, a regulatory body of an advisory nature with competence in the electricity, gas, oil and derivatives markets (created based on Law 54/1997 on the electricity sector and Law 34/1998 on the hydrocarbons sector). In 1998 the first agreement was made between the governments of Spain and Portugal to establish the Iberian Electricity Market (MIBEL).

The purpose of Law 34/1998 on hydrocarbons was to renew, integrate and standardise the different regulations in force on hydrocarbons. The intervention of public authorities in the markets was limited to emergency situations. Regulation should expand the scope for entrepreneurship. The law introduced environmental protection criteria. Consideration of the gas sector as a public service was abolished. The state established obligations for the maintenance of minimum security stocks of oil and gas products.

The White Paper on renewable energy sources published by the European Commission in November 1997 set an indicative target of a 12% renewable energy contribution to primary energy consumption in 2010, compared to the 6% of that time.

The Plan for the Promotion of Renewable Energies in Spain of December 1999 was drawn up in response to the commitment stemming from Law 54/1997 on the electricity sector. It set a target of 12% of renewables in total primary energy consumption in Spain for 2010 (the same target the White Paper established for the whole of the EU). This plan primarily commits to biomass and, secondly, to wind energy.

Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market set indicative targets of 12% primary energy consumption from renewable sources in 2010 in the EU and 22.1% for electricity production. This target (of 22.1%) for the EU-15 became 21% for the EU-25. Member states were obliged to set their own targets for a time horizon of ten years, taking into account the European objective and the national commitments made in the Kyoto Protocol. According to EurObserv'ER, the share of renewable energies in electricity generation was 19.8% in 2010, thereby achieving 94.3% of the goal set in the directive. Spain was among the countries to meet its target in this regard.

Directive 2003/30/EC of the European Parliament and of the Council on the promotion of the use of biofuels or other renewable fuels for transport to replace petrol and diesel establishes an indicative target for the EU of 5.75% replacement of conventional transport fuels with biofuels by December 2010. A level of 4.7% was achieved, 82% of the target set in 2003.

Furthermore, Directive 2003/87/EC was transposed in 2004, establishing a regime for trading in greenhouse gas emission rights in the EU. The EU Emissions Trading System (EU ETS) has become the largest such system in the world, followed in recent years by the development of regional equivalents in Canada, the United States and China.

Spain's first Energy Saving and Efficiency Plan 2005–2007

Spain's Renewable Energy Plan (PER) 2005–2010 was a revision of the Plan for the Promotion of Renewable Energies in Spain 2000–2010 that made significant downward revisions for biomass and upwards for wind and above all photovoltaic solar energy.

Royal Decree 1370/2006 approved the 2008–2012 National Allocation Plan establishing a limit of 54.6 Mt of CO_2 for the electricity sector, 11.2% lower than the reference year of 1990.

In the Europe 2020 strategy, the following binding energy and climate targets were set to be achieved in the EU by 2020: reduce greenhouse gas emissions by 20% compared to 1990 levels, achieve 20% of energy production from renewable sources in final energy consumption and increase energy efficiency by 20%.

The Renewable Energy Plan 2011–2020 approved in November 2011 establishes targets in line with Directive 2009/28/EC on the promotion of the use of energy from renewable sources.

In December 2016 the European Commission launched "Clean energy for all Europeans", an in-depth review of the entire legislative body on energy in the European Union, shaped by the commitments acquired in the context of the 2015 Paris Agreement. The various directives, regulations, guidelines and associated communications were approved between 2017 and 2019. Among many other changes, new renewable generation penetration and efficiency targets were set for 2030 in an ambitious strategy to achieve net zero CO_2 emissions by the second half of the century. Of singular importance is the fact that member states are obliged by the new Governance Regulation to develop integrated energy and climate plans under European Commission supervision and subject to evaluation and modification mechanisms.

3.2. Evolution of renewable energy in Spain in recent years within the EU framework

Table 2 shows renewable primary energy production in Spain by technology in 2005 and 2017, using Eurostat data. Hydropower production varies according to the rainfall in the year in question, meaning that in 2016 hydroelectric energy production was 3.12 Mtoe, while in 2017 it was 1.61 Mtoe.

Table 2. Renewable primary energy production in 2005 and 2017 by technology in Spain measured in Mtoe		
	2005	**2017**
Bioenergy*	4.9 (58.4%)	7.28 (44.15%)
Hydropower	1.6 (19.1%)	1.61 (9.79%)
Wind Power	1.8 (21.5%)	4.22 (25.62%)
Solar	0.06 (0.7%)	3.36 (20.32%)
Geothermal	0.007 (0.1%)	0.02 (0.12%)
Total	**8.4 (100%)**	**16.49 (100%)**

* Bioenergy includes solid biomass, biogas, the organic fraction of urban solid waste and biofuels.
Source: Produced by the authors with Eurostat data.

Table 3 shows the share of renewable energy in gross final energy consumption in the European Union and in Spain for 2005 and 2017. The combined figure shows that both the EU and Spain are approaching the target of 20% foreseen for the year 2020. Spain is above the EU level in renewable electricity, but lags in its use for heat production and transport.

Table 3. Renewable energy as a percentage of gross final energy consumption in 2005 and 2017				
	Year 2005		**Year 2017**	
	European Union	**Spain**	**European Union**	**Spain**
Combined	9%	8.4%	17.52%	17.51%
In electricity	14.9%	19.1%	30.75%	36.34%
In heat and cooling	10.8%	9.4%	19.50%	17.52%
In transport	1.4%	1%	7.4%	5.9%

Source: Sagastume *et al*. (2018b).

4. Comparison of some energy indicators for Cuba and Spain in the 1990–2016 period

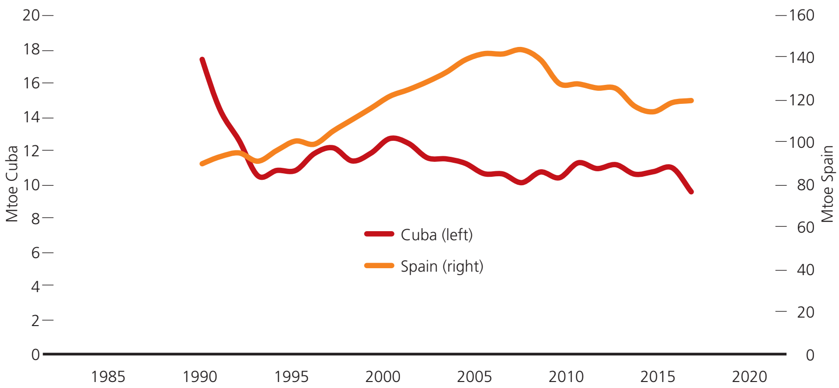
4.1. Total primary energy supply

Figure 6 presents the data for the total primary energy supply in Cuba and Spain between the years 1990 and 2016.

In the case of Cuba, the highest amount in the series corresponds to 1990 and the lowest to 2016. There is a very marked decrease between 1990 and 1994 (years corresponding to the so-called "Special Period"). Then levels rise slightly between 1995 and 2001, only to fall again as of that year, with some minor fluctuations.

In Spain, the amount of energy grows from 1990 to 2007, with minor exceptions in 1993 and 1996. In this case, it is an evolution that closely follows the economic expansion in that period. The high-point in the series is in 2007, with the low in 1990. The effect of the economic crisis is very clear, starting in 2008.

Figure 6. Total primary energy supply in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

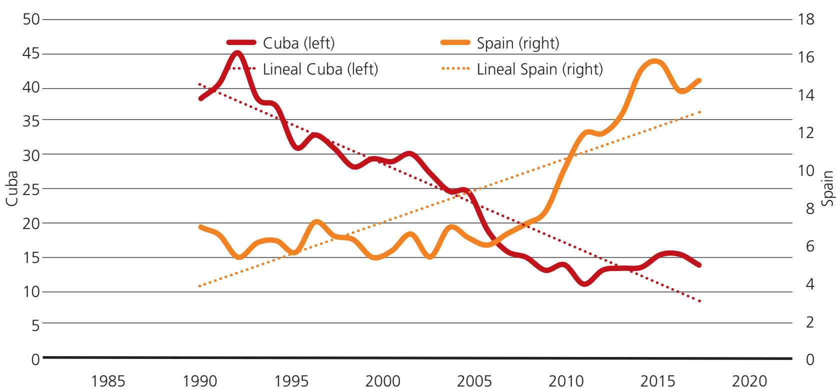
4.2. Renewables as a proportion of total supply (in percentage)

Renewable energy as a share of total primary consumption shows a downward trend in the case of Cuba and an upward trend in the case of Spain, as Figure 7 shows. The percentage, very far apart at the beginning of the period under study, is tending to even out, as Spain increases and Cuba decreases.

In 1990, the percentage of renewable energy as a share of the total was 38% for Cuba (due to the contribution of biomass and waste) and only 6.95% for Spain. However, in 2016 the corresponding percentages were 13.46% for Cuba and 14.74% for Spain. Cuba's change seems to be based almost exclusively on biomass, while in Spain the supply of primary energy from wind and solar sources is gaining importance.

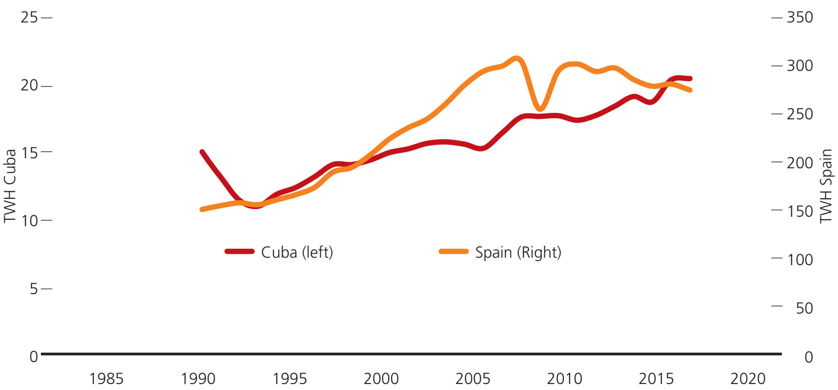
Cuba's highest percentage was reached in 1992, with a 45% share of renewables, while the lowest was 11% in 2010. For Spain, the highest percentage (15.68%) was reached in 2014 and the lowest was 5.40% in 1999.

Figure 7. Renewables as a share of total supply (in %) in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

Figure 8. Electricity generation in Cuba and Spain (in TWh) from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

Renewable energy as a share of total primary consumption shows a downward trend in the case of Cuba and an upward trend in the case of Spain.

Table 4. Energy mix used in electricity generation (in percentage) in Cuba and Spain in 2016

	Cuba	Spain
Oil	81.7%	6.16%
Natural Gas	14.3%	19.22%
Biomass and waste	3.4%	2.34%
Hydroelectric	0.3%	14.51%
Solar	0.2%	4.97%
Wind Power	0.1%	17.80%
Coal	-	13.66%
Nuclear	-	21.34%
Total	**100%**	**100%**

Source: Produced by the authors using International Energy Agency data.

4.3. Electricity generation

Figure 8 presents the data for electricity generation (in TWh) in Cuba and Spain between 1990 and 2016.

In Cuba, the amount of electricity produced fell between 1990 and 1994, after which it followed an upward trend for the rest of the period. In Spain, the trend clearly rises until 2007, with a significant decline in 2008 as a result of the impact of the economic crisis. There is some recovery in 2009 and 2010, and another decrease after that.

Table 4 shows the energy mix for electrical power generation in Cuba and Spain for 2016. What is most striking is the contribution of oil in electricity generation in Cuba, which is 81.7%, when for the same year, 2016, the global figure for the contribution of oil to electricity generation was 3.7%. In Spain, oil plays too large a part (6.16%) compared to the worldwide data. This is due exclusively to the use of the fuel in electricity generation in non-peninsular electrical systems (Canary Islands, Balearic Islands, Ceuta and Melilla), since liquid hydrocarbons are not used for electricity generation on the peninsular.

The data in Table 4 indicate that the energy mix for electricity generation in Spain is much more varied and balanced than in Cuba. As noted above, larger and more connected systems also facilitate a more diversified generation mix.

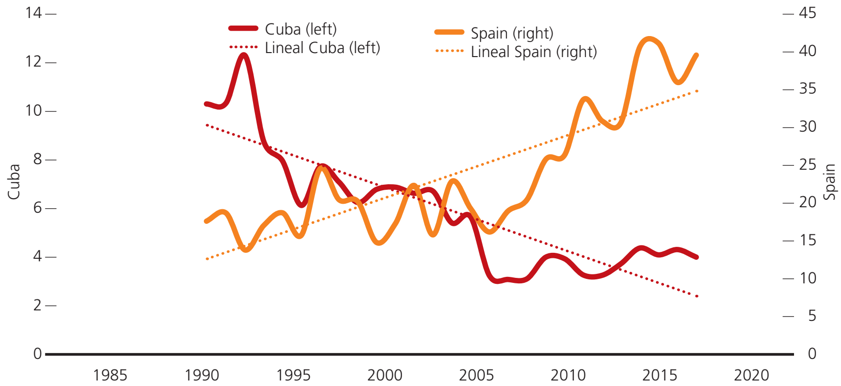
4.4. Electricity from renewable sources as a proportion of the total electricity generated (in percentage)

As with the percentage of renewables as part of the total energy supply, the trend lines showing electricity from renewable sources as a proportion of the TWh of electricity generated are rising for Spain and falling for Cuba (Figure 9).

In this case, unlike the situation studied in part 2 of this section, the starting point for Spain (17.7%) was higher than for Cuba (10.3%).

Cuba's highest percentage in the period studied was 12.3% in 1992, while the lowest was 3.04% in 2006. For Spain, the maximum percentage was 41.2% in 2014 and the minimum was 13.7% in 1992. The graph shows a significant increase starting in 2005, in line with the incorporation of wind (which started a few years before) and solar generation (both photovoltaic and concentrating or thermosolar).

Figure 9. Electricity from renewable sources as a share of total electricity generated in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

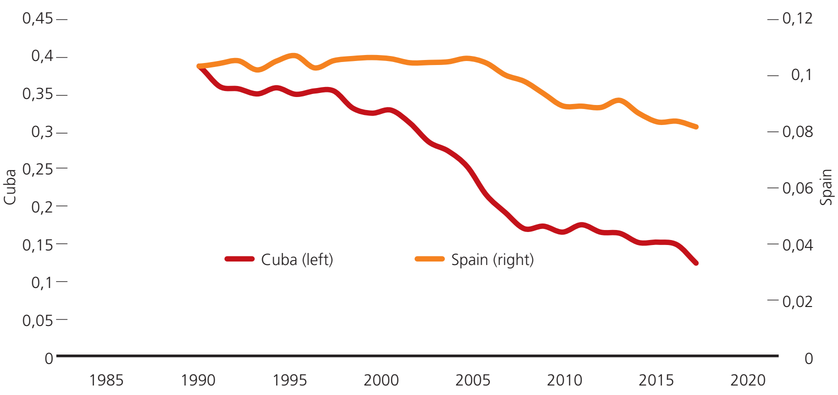
4.5. Energy intensity

Energy intensity is an indicator that is related to the efficiency with which an economy uses its energy resources. It is defined as the amount of energy used in an economy divided by GDP. Improvements in energy efficiency are reflected in smaller and smaller values.

Figure 10 shows the trajectories of the respective energy intensities of Cuba and Spain in the time frame analysed.

As Figure 10 shows, over time the indicator improves for both countries. The improvement is more pronounced in the case of Cuba, as it changed from 0.39 in 1990 to 0.12 in 2016, while in Spain it improved from 0.10 in 1990 to 0.08 in 2016.

Figure 10. Energy intensity (TOE/GDP [in thousands of 2010 USD]) in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

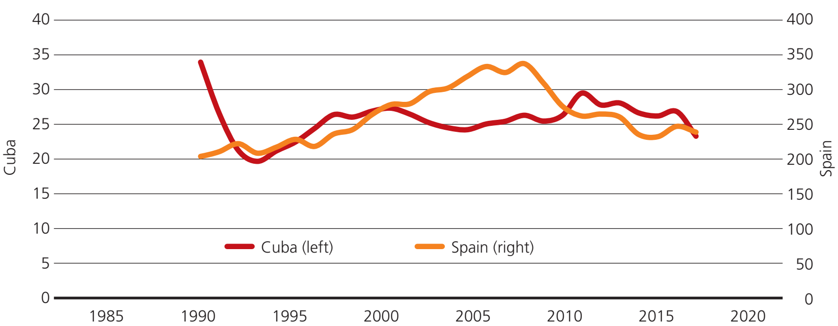
The most recent Eurostat data for the European Union, referring to 2017, indicate that Spain has an energy intensity similar to that of the EU-28 as a whole, and higher than that of the group of eurozone countries and countries such as Germany, Austria, Denmark, France, Ireland, Italy, Luxembourg and the United Kingdom.

4.6. CO_2 emissions (combustion only)

Figure 11 shows the data for CO_2 emissions (combustion only).

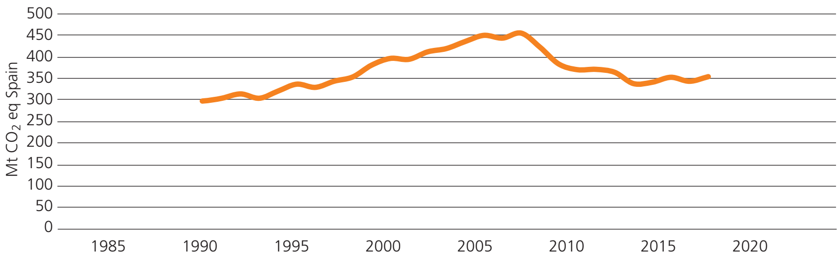
For Cuba, the first year in the series, 1990, shows the highest emissions, with 34.12 million tonnes, while 1993 is the year with the lowest (19.64 Mt). In Spain, these data once again reflect the enormous impact of the economic crisis, which caused a significant reduction in emissions from 2008. Emissions grow until 2007 and decrease after 2008.

Figure 11. CO2 emissions (in millions of tonnes) from combustion only in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

Figure 12. Greenhouse gas emissions (in million tonnes of CO2 equivalent) in Spain from 1990 to 2017



Source: Produced by the authors using Eurostat data.

Figure 12 presents the Eurostat data on all greenhouse gas emissions (in millions of tonnes of CO_2 equivalent) for Spain between the years 1990 and 2017.

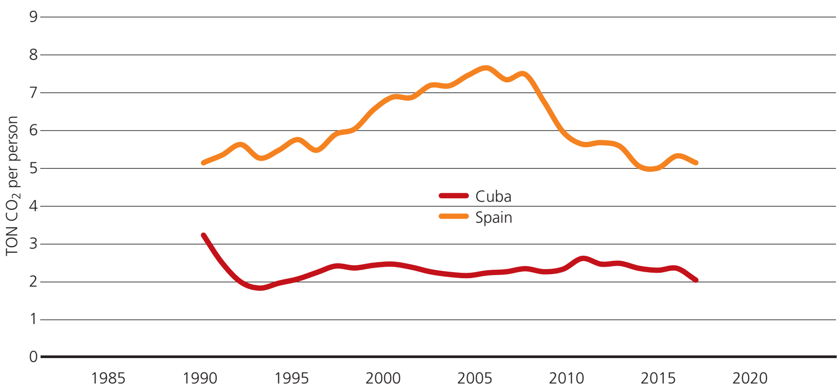
The emissions trajectories shown in Figures 11 (the part corresponding to Spain) and 12 are very similar from 1990 to 2016. The figures for greenhouse gases in Spain correspond to the respective values from CO_2 emissions (from combustion only), showing an increase that ranges between 39% and 44%, approximately.

4.7. CO_2 emissions (combustion only) per person

Figure 13 shows the trajectories for tonnes of CO_2 emitted per person (from combustion only). The amounts were obtained by dividing the emissions by the population.

Spain's trajectory is very similar to those observed in Figures 11 (for Spain) and 12. Cuba's trajectory is very similar to that in Figure 11, although in this case it appears smoother.

Figure 13. CO2 emissions per person (in tonnes per person) from combustion only in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

If, instead of dividing the emissions by the population we divide by GDP (kg of CO_2/2010 US$) the following results are obtained:

Cuba starts with a value of 0.76 in 1990, which decreases to 0.6 in 1992, grows until reaching 0.77 in 1997 (highest in the period), decreases to 0.41 in 2008, grows to 0.46 in 2010 and falls to its lowest point in the period (0.3 in 2016).

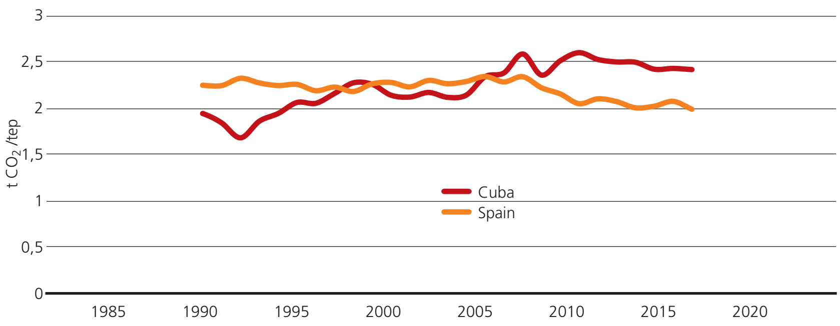
For Spain it falls from 0.23 in 1990 to 0.16 in 2016 (the lowest value in the period analysed). The highest value reached is 0.25 in the years 1992 and 2005.

4.8. CO_2 intensity of the energy mix

Figure 14 shows the values for the corresponding indicator for Cuba and Spain between 1990 and 2016.

The indicator is obtained by dividing CO_2 emissions (in this case from combustion only) by the corresponding amount of energy supplied. With this indicator lower values are therefore better for the economy and the environment.

Figure 14. CO2 intensity of the energy mix (in tCO2/toe) in Cuba and Spain from 1990 to 2016



Source: Produced by the authors using International Energy Agency data.

The indicator is more stable for Spain than for Cuba. In Spain, the value ranges between 2.35 in 2005 and 1.99 in 2016. In Cuba, the value of the indicator ranges between 2.60 in 2010 and 1.68 in 1999.

The trajectories of the indicators for Cuba and Spain intersect in the years 1997, 1999 and 2005. At the beginning of the time period the indicator is more favourable for Cuba, and more favourable for Spain at the end of the period analysed.

5. 2030 energy visions in Cuba and Spain

This section presents the energy targets for 2030 for Cuba and Spain.

5.1. Cuba

On November 19th 2015, Cuba presented its Intended Nationally Determined Contribution (INDC) as part of the United Nations Framework Convention on Climate Change, which contained specific references to adaptation and mitigation.

The specific measures proposed on climate change adaptation are not directly related to energy.

Specific mitigation measures:

Based on the potential renewable sources available in the country, the installation of 2,144 MW of power connected to the national electricity grid is envisaged, including the construction of:

- 19 bioelectric facilities attached to sugar plants, producing 755 MW from sugar cane and forest biomass;
- 13 wind farms with 633 MW capacity;
- 700 MW photovoltaic capacity;
- 74 small hydroelectric plants.

It is estimated that implementing these programmes will enable over 7,000 GWh to be generated per year from renewable sources, a saving of over 6 million tonnes of CO_2 of atmospheric emissions.

Work is also ongoing on other projects, including:

- The installation of 200,000 m^2 of solar heaters in the residential and industrial sectors;
- The installation of solar pumps in agriculture;
- The use of organic waste for biogas production and to obtain biofertilisers to replace chemical fertilisers, which will contribute to reducing emissions and the pollution of hydrographic basins and bays. Particular attention is given to waste from animal production, industry and urban solids.

On the other hand, to increase energy use efficiency the new energy policy envisions, among other actions:

- The installation of LED technology through the distribution of 13 million lamps in the residential sector and 250,000 luminaires for public lighting.
- The replacement of 2 million electric cookers with induction cookers.

The time horizon for the national contribution is 2030.

As Table 4 shows, in 2016 4% of Cuba's electricity generation came from renewable sources, in the following forms: biomass and waste 3.4%; hydroelectric 0.3%; solar 0.2% and wind 0.1%.

With the specific mitigation measures expressed in Cuba's Nationally Determined Contribution, it is estimated that in 2030, 24% of electricity generated will come from renewable sources, distributed in the following way:

- Biomass and waste, 14%
- Wind, 5%
- Solar, 4%
- Hydroelectric, 1%.

(Morales Pedraza, 2019; Sagastume et al., 2018a; Vázquez et al., 2019).

5.2. Spain

The Spanish energy and climate policy framework is determined by the European Union. In 2016, the European Commission presented the so-called "winter package" Clean energy for all Europeans (COM2016 860 final). This has been developed through various regulations and directives, including legislative revisions and proposals on energy efficiency, renewable energies, electricity market design, security of supply and governance rules for the Energy Union, all of which aim to reduce greenhouse gas emissions, increase the proportion of renewables in the system and improve energy efficiency in the EU by 2030 (Ministry for Ecological Transition, 2019).

The EU regulatory framework sets the following binding targets for the EU for 2030:

- 40% reduction in greenhouse gas emissions compared to 1990;
- 32% share of renewables in the total gross final energy consumption for the whole EU;
- 32.5% improvement in energy efficiency;
- 15% electricity interconnection between member states.

To this must be added that on November 28th 2018 the European Commission updated its roadmap towards a systematic decarbonisation of the economy with the intention of making the European Union carbon neutral by 2050.

In Spain, the National Integrated Energy and Climate Plan proposes the following targets for 2030:

- 21% reduction in greenhouse gas emissions compared to 1990;
- 42% of renewables in the final use of energy;
- 39.6% improvement in energy efficiency;
- 74% renewable energy in electricity generation.

In 2050 the objective is to achieve climate neutrality, with the reduction of at least 90% of greenhouse gas emissions and in coherence with the European Commission. In addition, a 100% renewable electricity system is proposed to be achieved by 2050 (ibid).

Conclusions

The analysis in this work reveals the different energy consumption trajectories of Cuba and Spain. The two countries' situations at the starting point in 1990 are relatively similar if one takes into account, among other features, their different sizes and energy interconnection

With the specific mitigation measures expressed in Cuba's Nationally Determined Contribution, it is estimated that in 2030, 24% of electricity generated will come from renewable sources.

capacities. As noted, smaller isolated systems tend to show less energy diversity, particularly in the field of electricity generation.

However, their courses since 1990 differ markedly. In Cuba, the fall in the relative share of the use of biomass – basically taking advantage of agricultural waste – has not been offset by an increase in renewable wind and photovoltaic generation, which is practically non-existent. The positive aspect of this situation is that Cuba possesses substantial renewable resources that it could incorporate now that the costs of wind generation and, especially, photovoltaic technologies, have dramatically reduced in cost and become the most competitive of all. Given the possibility of scaling up generation (from self-consumption to large centralised facilities) and developing the transport and distribution networks usually required to integrate them, these technologies are particularly important in the Cuban case. Cuban electricity generation, which continues to revolve largely around liquid hydrocarbons, is a high emitter of CO_2 and environmental pollutants with local effects. This shift would therefore allow rapid progress towards decarbonisation targets.

The case of Spain is configured by the European context (although notable differences exist between European Union members), characterised by a very solid commitment to the process of decarbonising energy consumption. The Spanish experience has not been without problems, but it shows a way forward that with some adaptations could be of use in Cuba.

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