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The Transition towards a Renewable Energy System – Political, Economic, Social and Environmental Factors

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TABLE OF CONTENTS

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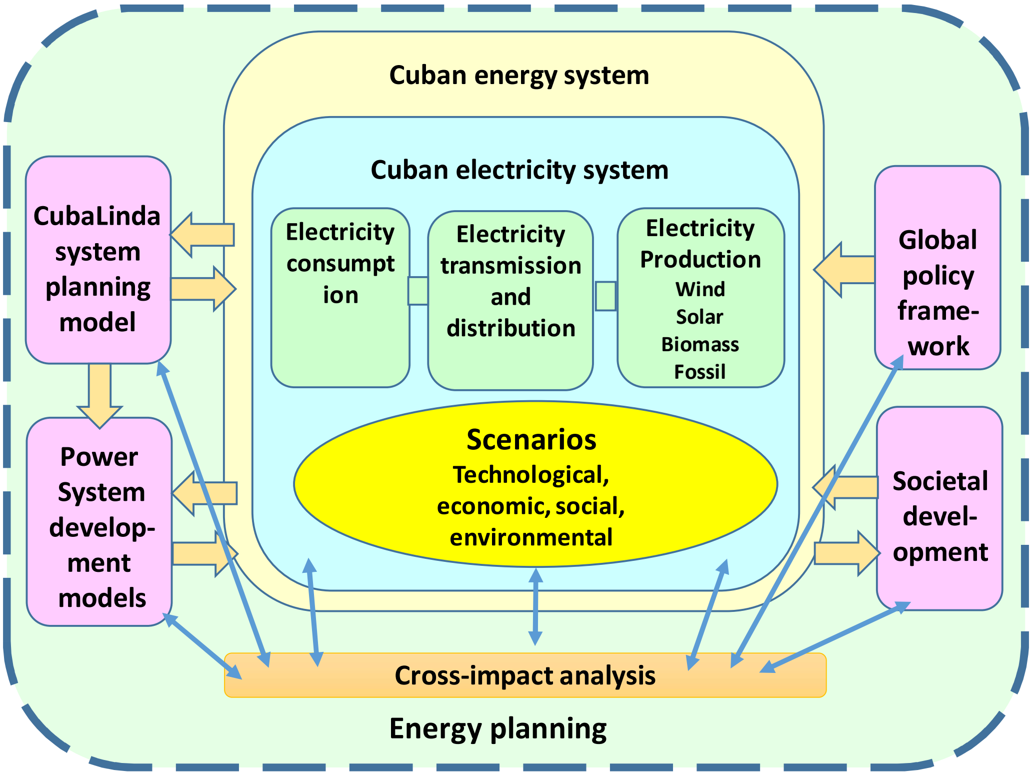
Foreword

This book is an outcome of research work carried out in cooperation with Finnish and Cuban researchers in a research project “Cuban energy transformation. Integration of renewable intermittent sources in the power system (IRIS)”. The project is funded by the Academy of Finland for the period of 1.1.2019 - 31.12.2022. The objectives of the project are:

- ✓ Develop a scenario construction tool for Cuban future energy development analysis and scenario building (CubaLinda) and carry out comparisons with other international energy planning models.
- ✓ Develop planning tools for integration of intermittent renewable energy sources (wind, solar, biomass) in the Cuban electricity system and improving energy efficiency.
- ✓ Develop planning tools for grid development in Cuba in order to be able to integrate the distributed intermittent renewable energy sources in the system and to improve the system efficiency.
- ✓ In a participatory workshop process, develop transformative future scenarios for the Cuban energy system, acknowledging their societal impacts in the context of inclusive and sustainable development.
- ✓ Carry out cross-impact analysis of interlinkages of the Cuban energy system in PESTEC framework (PESTEC = Political, Economic, Social, Technical, Environmental, Cultural).
- ✓ Develop the research capacity in the participating Cuban institutions and link them better with national energy sector actors and decision-makers.

A general view of the project is illustrated in the following figure.



The participating researchers come from two Finnish universities and several Cuban universities and research centres:
University of Turku (coordinator), Tampere University, University of Oriente (Santiago de Cuba), Technological University of Havana (CUJAE), Moa University, University of Pinar del Rio, University of Camagüey, Pontificia Universidad Católica de Chile, Universidad Central "Marta Abreu" de Las Villas, University of Sancti Spíritus "José Martí Pérez", and CIES (Solar Research Centre) and CUBAENERGIA.

I. Introduction

I.1. Introduction

Jyrki Luukkanen and Miriam Lourdes Filgueiras Sainz de Rozas

This book about the Cuban energy futures, its transition towards a renewable energy system, dealing with political, economic, social and environmental factors is a result of research work carried out in a project "Cuban energy transformation. Integration of renewable intermittent sources in the power system (IRIS)". The Academy of Finland finances the project.

Heredia Street view, Santiago de Cuba

Cuba has been undergoing a constant transformation process during the presidencies of Raúl Castro Ruz (2008-18) and Miguel Díaz-Canel (since 2018). Cuba is modernising and adapting to a range of development challenges while keeping its political system and the achievements of the revolution, such as universal free healthcare and education. The energy sector is central in modernisation and restructuring the economic production of society. The Cuban energy system is highly dependent on fossil fuels large share of which is imported increasing the economic burden of the society. The Cuban government has responded to this problematique developing policies for, on the one hand, to increase the use of domestic renewable energy sources and, on the other hand, to improve energy efficiency through the chain from production and utilization.

The national development plans have given a high priority to energy, socio-economic development and the environment. Cuba has large resources of domestic renewable energy (solar, wind and biomass) which can be used to reduce the dependency on imports, production costs, environmental emissions and improve access to energy services. The development of the large-scale use of renewable energy sources will require modernisation of the energy system and large investments. The role of foreign investments will be crucial in the process of transformation to the renewable energy system and the new investment law in Cuba is one response to this issue.

The Cuban government has a plan to increase the share of renewable energy sources to 24 % of the energy supply by 2030. The plan is to increase, by 2030, wind power capacity to 656 MW, solar power capacity to 700 MW, biomass capacity to 872 MW, and small hydropower capacity to 56 MW. The Ministry of Energy and Mines (MINEM) is willing to increase the target of renewable energy sources for electricity generation to 29% for the year 2025. The target for 100% renewable energy in electricity generation has been discussed by Cuban authorities and it is seen as possible in the longer term. The electrification of the transport system is another long-term target.

The large increase of the share of intermittent, distributed generation by solar PV and wind power will inevitably raise the question of stability, security and reliability of the electricity system. This has to be taken into account in the planning of the production, transmission and distribution system.

Distributed production with renewable energy sources can have several positive impacts on society. It can create new employment opportunities especially in the rural areas which easily lack behind in the investments. It also improves self-sufficiency and increases possibilities for equitable access to energy sources. Distributed energy production in parallel with the greater autonomy of the municipal governance system, in accordance with the new constitution, can have positive impacts on the development of the local societies. Decentralized energy production is less vulnerable to climate change impacts such as the increasing occurrence of hurricanes, droughts and floods, sea-level rise, etc. The sustainable governance of natural resources extraction and land use should, however, be emphasized. Production based on renewable energy sources will also reduce the import expenses on fossil energy having an important impact on the trade balance.

Energy is essential for the social and economic development of any country. It supports a wide range of activities and services, contributes to life quality, and promotes labor productivity. However, the current energy model based on fossil energy is in question, causing a hazardous impact on the environment locally and worldwide. The local environmental impacts of energy production can be seen as local air pollution in cities of Cuba. The levels of particulate emissions are considerably high in some parts of the cities, especially along the main traffic streets, but electricity production in old facilities burning high sulfur content oil produces significant emissions. Cuban environmental management is governed by the Ministry of Science, Technology, and Environment (CITMA), while the energy policy is under the Ministry of Energy and Mining (MINEM). Therefore, close cooperation of these ministries to consolidate the activities in these sectors is essential.

Cuba has opted for renewable energy sources. Dependence on imported fuels has directed the government interest towards better use of domestic resources in order to enhance Cuban energy security and independence, which would make it less vulnerable to external changes. At the same time, the Cuban country is an archipelago that faces problems related to insularity, while the geo-

graphical and climatic conditions allow it to take advantage of the important potential that this archipelago has, to generate energy through renewable energy sources, mainly photovoltaic solar and wind energy. The resilience of the energy system is of great importance.
For many countries, rediscovered renewable energy sources are favored because they have an unlimited nature, not to mention their unique territorial distribution. They also do not generate hazardous waste or harm the environment. A continuous and quality supply of energy enables domestic, industrial and all fields activities. It is a critical input in economic sectors and is vital for essential social services such as education and healthcare. Consequently, achieving universal access to affordable, reliable, sustainable, and modern energy for all is one of the Sustainable Development Goals (SDGs) established by the United Nations (United Nations, 2015). Cuba is no exception to this.
However, the development of any country depends on a specific context, defined by political, economic, industrial, historical, social, and environmental environments. This pattern is considered when technological resources and knowledge are developed over time. Therefore, existing resources are not always sufficient to ensure the development of different countries. In addition, each country requires developing capacities to exploit opportunities and improve/generate new capacities, as well as exploiting its resources through local knowledge, learning, and creativity (Jansson and Waxell, 2011; West et al., 2008).
Participation in the planning of energy development, especially at the local level, by a large number of people representing different social spheres is important to integrate different emphasis and values in the process. Community empowerment, local autonomy will enhance the inclusion of aspects related to social impacts, the role of women, food security, social vulnerability, inequity, fair and equitable distribution of resources and human potential development in the planning process. This type of planning process should be based on interdisciplinary and transdisciplinary research work to provide information on the various aspects that are seen as relevant by the communities. This can form the basis for democratic, sovereign and liberating technological development.
The structural changes in Cuban society will have profound impacts on future development. The population structure in Cuba is changing. Cuban society is ageing and the chare of active workforce is reducing. At the same time, the urbanization trend is continuing and the share of the population active in rural areas for food production is diminishing. This lays strong requirements on agricultural mechanisation to improve food security. The economic structure in Cuba is changing similarly to other countries where the share of industrial production in the formation of GDP is reducing and the role of the service economy is increasing. The education system in Cuba is strong providing a good background for the adaptation to the structural changes in the economy. However, the planning of the education system has to anticipate the future changes in the society and be prepared to reallocate the resources according to the future needs.
Cuban society does not develop in a vacuum, but international and global changes have to be considered. Geoeconomics and geopolitical changes impact Cuban relations with other countries and its space of maneuverability. The US blockade sets harsh limits for economic cooperation. Cuban trade balance on goods has been negative partly due to the restrictions, while the trade

balance on goods and services used to be positive before the actions by the Trump administration and the Covid-19 pandemic. The role of tourism increased considerably in the Cuban economy during the Obama administration. The recovery of the tourist industry after the pandemic is essential for the whole economy. Regional economic cooperation can also have an essential role in the future of the Cuban economy.

Universities and research centres have an important role in the future of Cuban energy development by improving/generating capacities to make use of renewable resources through innovation, through the knowledge, learning and creativity of the country's engineers and researchers. For this reason, the international project entitled IRIS is being developed. Cuban energy transformation: Integration of Renewable Intermittent sources in the power system is conducted with the support of the Government of Finland through the Academy of Finland, for the purpose of building and improving capacities in this field.

This book is the result of cooperation between researchers and doctoral students from Cuban universities and the Universities of Turku and Tampere University in Finland. Its objective is to analyse energy transformation in Cuba through the integration of intermittent renewable sources in the electricity system.

This book has five chapters that evaluate Cuba's energy future from the political, economic, social, environmental and cultural perspectives analysing the role of renewable energy. The technological perspective of the energy transition is discussed in the sister book "Cuban energy system development - Technological challenges and possibilities".

The first chapter provides an introduction to the topic and gives a general view of the literature related to the topic (by Joshua Hurtado) as well as the historical development of the Cuban energy sector (by Jyrki Luukkanen, Miriam Lourdes, Anaely Saunders and Arielys Martínez).

Chapter II discusses the politics of energy in the Cuban context. First, the changes in the global political system and the impacts on the Cuban energy system are discussed (by Jasmin Laitinen, Jari Kaivo-oja and Jyrki Luukkanen). Next, a review of the organisations and programmes to support Cuban energy policy is discussed (by Anaely Saunders). This is followed by an analysis of the role of renewable energy in local development (by Dunia Barrero and Gabriel Hernández). The structural political change after the changed constitution is discussed (by Anaely Saunders). Next, the methodology of cross-impact analysis is presented with an example of Cuban development (by Jyrki Luukkanen and Jari Kaivo-oja). Finally, an outlook on Cuban energy politics from the past to the future is discussed (by Miriam Lourdes and Mika Korkeakoski).

Chapter III analyses the socio-economic development in Cuba. The chapter begins with an analysis of the energy economy in Cuba and the future challenges (by Anaely Saunders, Jyrki Luukkanen and Jari Kaivo-oja). Next, economic development trends and future possibilities are discussed (by Amilcar Roldan). The foreign investment opportunities in Cuba are presented next (by Analely Saunders). Local and provincial energy governance is discussed (by Arielys Martínez). Next, the energy consumption trends in households are analysed (by Reineris Montero). Possibilities for 100% renewable power production are modelled using the CubaLinda model (by Jyrki Luukkanen, Anaely Saunders, Yrjö Majanne and Mika Korkeakoski). Next, political, economic, social, environmental and cultural factors related to the transition towards renewable energy system are discussed (by Vivian Basto, Aymara Reynes and Dunia Barrero). Finally, a case study of the social dimension of renewable energy sources in a rural community is presented (by Rosabell Pérez, María Echevarría, Yudelkys Ponce, Yenima Martínez, Carlos Sebrango and Ernesto Barrera).

Chapter IV analyses the linkage of environmental management and energy policy (by Arielys Martínez).

Chapter V presents two analyses of the transport sector. First the electrical vehicles in the Cuban transport system are discussed (by Miguel Castro) and next the control of energy efficiency of cargo transport is analysed (by Yanet Pita and Arielys Martínez).

Chapter VI provides conclusions of the book (by Jyrki Luukkanen)

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I.2. Literature review of Cuban development. Insight from a PESEC framework

Joshua Hurtado Hurtado

The study of energy transitions and the assessment of their potential requires a holistic understanding of the context in which they take place, as the political institutions, economic dynamics, social practices, environmental conditions, and cultural frames condition which alternatives and pathways for the transition to take place are deemed as feasible and worthwhile. What makes the case of Cuba particularly relevant for the study of energy transitions is that, due to its 20th-century history and the emerging trends of the island country in the current century, it is uniquely positioned to reach a sustainable state which might be further propelled by undergoing a transition towards intermittent renewable sources at a national scale.

This chapter provides an overview of the current Cuban context within which a transition towards renewable, intermittent sources of energy could occur. This is necessary because it helps identify structural challenges that would need to be managed and windows of opportunity that could be exploited to incite such a transition. This overview takes the form of a literature review of Cuban development in the 21st century, although references to previous events will be made when necessary for further contextualization. In this review, the term "development" does not refer only to economic growth that fuels social welfare and is done sustainably but also considers the kind of development that is central for Cuba: that which allows freedom via emancipation from oppression and exploitation, as well as fuels the capacity to organize collectively for the public interest (Veltmeyer and Rushton, 2012:209). From this perspective, issues from different spheres of Cuban social life that affect the possibility of an energy transition towards renewable, intermittent sources of energy are addressed. Finally, such a transition is considered necessary for Cuba's development goals in their emancipation framing.

In line with the title of the book and the rest of the chapters, this literature review is structured according to Political, Economic, Social, Environmental, and Cultural dimensions, which offer a framework that facilitates obtaining meaningful insights on heretofore underexplored issues regarding the unique position of Cuba concerning sustainability transitions, in general, and to the transition to renewable, intermittent sources of energy, in particular. This framework, hereafter called PESEC (Political, Economic, Social, Environmental and Cultural), is an analytical device that, though artificial, nonetheless invites systemic thinking into an issue that might initially seem technical. Furthermore, it hopes to establish a holistic outlook of the different dimensions within which interventions for the energy transition could occur, with subsequent chapters in the book examining the challenges and opportunities for change in more detail.

Political Dimension: The rearrangement of political power assemblages

Although distinguishing between domestic and foreign issues is often artificial, as events occurring in the international sphere can affect the domestic sphere and vice versa, it is helpful to draw this distinction as the phenomena in both spheres. They both have their dynamics and impacts on the possibilities for an energy transition. In this analysis, domestic issues revolve around the behavior of the political elites and bureaucrats and updates to the legal and institutional framework that regulates this behavior. They also include the relationships between political actors and institutions. International issues, in contrast, focus on how Cuba, as a sovereign state, relates to other states and geopolitical regions in the world. Both domains are discussed in the broad definition of development provided earlier.

The events with the most far-reaching effects on internal politics in Cuba in the second decade of the 21st century, and arguably for the social organization and economic activity of the island country as a whole, are the new measures found in the Guidelines for the Economic and Social Policy of the Party and the Revolution for the Period 2016 – 2021 (PCC, 2017:23–32), and the promulgation of Cuba's new Constitution in 2019 (ANPP, 2019). The Guidelines introduce directions to modernize economic and social life in Cuba while fostering sustainable development. Among the principal changes that are being implemented by the Guidelines are moving away from centralist state socialism and introducing new forms of ownership and management (such as supporting cooperatives that have been allowed in urban areas since 2012 in recognition of their role in rural development), reducing state bureaucracy, decentralizing authorities to provinces and municipalities, and expanding different forms of self-employment (such as medium, small and micro enterprises).

For Fernández Ríos (2018) these new measures have ramifications and three themes. The first is that of perfecting institutionality in the country, with greater precision being brought to the roles of the Party (making methods and styles of leadership more participatory), the State (consolidating the legal system and restructuring the government apparatus), and organized sectors of civil society (granting greater autonomy to local grassroots communities and eliminating direct State administration of enterprises). The second relates to the necessary expansion of popular participation, which involves conducting mass consultations of national and strategic scope, increasing popular participation in local public management, and promoting initiatives and community, labor, and sectoral projects. The third and final theme is the accentuation of social differences due to these new measures, which allow for new forms of income for the Cuban population and reduce state paternalism while increasing underground markets. Specific institutional measures have accompanied these effects. These measures include the formation of new Cuban political cadres in order to renew Cuban leadership and become more genuine representatives of Cuban society while maintaining a deep and strategic understanding of the Cuban Revolution and its aims(Torres Díaz and Bardina Torres, 2019), as well as the effort aimed at de-bureaucratizing the government structures, with increased autonomy for middle-management, less involvement of the state in the management of the economy (and expansion of other productive entities), decentralization and optimization of formalities and administrative procedures (Sorolla Fernández, 2017). Additionally, this de-bureaucratization may contribute to the gradual separation of the governing and administrative purposes of the state, thereby facilitating the deepening of the democratic quality of citizen participation (Chaguaceda and González, 2015).

In turn, the Constitution of the Republic of Cuba of 2019 (ANPP, 2019), introduced changes to the political structure of Cuba that would facilitate a transition to a post-Castro era while maintaining the ideals of the Cuban Revolution. In the top-level structures, one of these is the decision to include a Prime Minister in the executive branch, which separates the governing duties by establishing the Prime Minister as the head of government and the President of the Republic as the head of state (ANPP, 2019: Article 109, Article 140). Furthermore, the President, Vice-President, and Secretary of the National Assembly of the Popular Power (ANPP, *Asamblea Nacional del Poder Popular*, the main legislative body of Cuba) occupy the same positions in the Council of State (the internal executive body of the ANPP that exercises the most legislative power within Cuba) (ANPP, 2019:26 Article 121). In addition, the President of the Republic, elected by an absolute majority of the ANPP for five years with the possibility of being re-elected only once for a second term (ANPP, 2019:28 Article 126), can propose to the Council of State the suspension of Agreements of the ANPP that affect the interests of other communities or the general interests of the country (ANPP, 2019:30–32 Article 137). The Constitution of 2019 also institutes that there can be no members of the Council of Ministers – the highest-ranking executive and administrative body of Cuba – that are simultaneously members of the Council of State (ANPP, 2019:26 Article 121).

In line with some of the changes introduced by the Guidelines, the Constitution of 2019 also furthers the decentralization process and aims to deepen democratic citizen participation. Municipalities have been granted autonomy and the faculty to decide on using their financial resources and exercising their competencies. The exercise of autonomy has to abide by solidarity, coordination, and collaboration without detriment to the rest of the country (ANPP, 2019:37 Articles 168 and 169). Similarly, particularly relevant for democratic life in the country is the creation of the National Electoral Council, which is now a permanent body, autonomous from other government entities, and is in charge of organizing elections, mass consultations, referendums, and other forms of democratic participation in the country (ANPP, 2019:45 Articles 211 and 212). The autonomy and permanence of the National Electoral Council might be successful in moving away from the system of Party authoritarianism and technocratic reforms that critics say have marked Raúl Castro's tenure as the top political figure in Cuba (González, 2017), leading to increased popular and communitarian participation in public life. For this to occur, however, bureaucratic inertia would also need to be overcome.

While the Guidelines and the Constitution of 2019 have had the most significant effects on domestic politics, addressing Cuba's foreign relations is needed to get a more comprehensive panorama of the opportunities and challenges for undergoing an energy transition. The relations between Cuba and the United States are possibly the most impactful because the historical antagonism between the two countries has resulted in severe economic crises for Cuba and the hardening of Cuba's anti-imperialist stance. However, according to de Bhal (2018), the reforms undertaken by the Raúl

Castro presidency signaled to the United States that a historic opportunity to promote its version of capitalist democracy was approaching, which resulted in the “thaw” of the relations between the two countries. In de Bhal’s view, the Obama administration laid the groundwork for promoting capitalist democracy in Cuba and pushed the Cuban government to open the economy to foreign direct investment (FDI) and further develop the private sector. Although the Trump administration initially threatened to end the thawing of relations between the United States and Cuba, the changes were minor, while most of the structural policy changes remained in place (de Bhal, 2018).

Similar to Cuba-United States' evolution, Cuba’s relations with the European Union (EU) have evolved from conflictive to pragmatic. Cuba-EU relations had been previously characterized by the “democratic clause” sought by the EU, which tried to set representative democracy as a precondition for initiating formal relations with third countries (Foces Rubio, 2018), but this changed the treatment of Cuba as an equal with the Political Dialogue and Cooperation Agreement (PDCA). The PDCA can be seen as a pragmatic approach from the EU to establish foreign relations with Cuba after the failure of the democratic clause failed to generate a regime and economic system change in Cuba. While discursively maintaining its support for representative democracy, which Cuba lacks, the PDCA has motivated both sides to recognize the agreement as a negotiation between equals and highlighting its respect for the principles of self-determination and non-intervention (Díaz Barrado, 2018).

Cuba has also continuously maintained some allies in the international arena, although the nature of these alliances and the motivations behind the support have shifted according to the main political actors in the allied countries. In the case of Mexico, its support for Cuba resides in the expectations of material and prestige benefits in Latin America and the Caribbean, which motivates the continuous assertion of mutual respect for the principles of sovereignty and non-intervention (Covarrubias Velasco, 2018). Cuba-China relations, in turn, are characterized by ideological affinity and cooperation in substantive and diplomatic issues, with Cuba positioning itself as China’s leading trade partner in the Caribbean region. Cuba depends significantly on China because of the barriers to access to international banks, the IMF, and the World Bank, which is believed to result from US hostility (MacDonald, 2019). Chinese cooperation with Cuba is significant for four sectors of the Cuban economy: telecommunications, infrastructure, renewable energy sources, and cutting-edge technologies (Regalado Florido, 2018). Finally, Cuba is the closest to Russia in the Caribbean region, and both countries maintain several commercial and economic agreements, such as investments in energy and offshore oil exploration, the canceling of 35 billion USD of Cuba’s debt, and more significant military links (Clegg and Clegg, 2018). Additionally, from a geopolitical standpoint, Cuba plays a crucial role in Russia’s goals of creating another multipolar world order (Bain, 2015).

Economic dimension: Structural changes, new opportunities and remaining challenges

Cuba’s economy has faced several challenges over the years, some due to external factors like the Special Period in the 1990s or the 2008-2009 financial crisis, and others as a result of structural tensions between the management of the economy and Cuba's political and social goals. For example, Torres (2016) has argued that the means to meeting Cuba's objectives of welfare and social justice clash with the requirements to sustain them in the medium-term, with previous successes in the social and health spheres deteriorating in the 21st century. Hence, the Raúl Castro presidency targeted two different fields to undergo structural changes: the correction of macroeconomic imbalances and changing the socio-economic model. This resulted in three main changes to critical areas in the country's economy: 1) ownership structure, where there have been changes in land ownership structure and authorisation for non-agricultural cooperatives since 2007, with newer reforms also promoting greater participation of foreign companies and management changes within state companies; 2) Resource Allocation Mechanisms (RAM), which hitherto have been characteristic of a centrally-planned economy (in Cuba's case, these are the Annual Plan of the National Economy, the state budget, the Central Hard-currency Fund and the dual monetary and exchange systems), and since the reforms some decentralised RAMs have been emerging (like financial resources coming from friends and families and individuals importing capital goods for business ventures); and 3) the introduction of new sources of accumulation, such as generous tax exemptions and the preparation of the Investment Opportunities Portfolio for FDI, and flexibility regarding remittances (Torres, 2016).

Some of the problems for the economy in Cuba reside in the lackluster role innovation has traditionally played for Cuban society. Given that enterprises are key actors in innovation ecosystems, the continued marginalization of state-owned enterprises, lacking autonomy in decision-making processes, and future orientation and capabilities to innovate hampers the possibility to consolidate a National Innovation System that revitalizes the Cuban economy (Diaz, 2019). Nonetheless, a specific form of innovation takes place in the island country and is driven by its population: the solidarity-based tourism industry. In Balslev Clausen and Velázquez García´s (2018), Cuban tourism represents a model of productive relationships that differ from those of neoliberal capitalism, wherein already existing social and economic forms of exchange are not necessarily monetized, such as in the case of homeowners renting rooms within their homes for tourists and mobilizing their trust and reputation across a network of relationships to offer tourists quality experiences and affordable accommodation with other service providers and homeowners in their network. In this manner, tourism in Cuba possesses a communitarian nature, and the exchange of social and cultural values across the network supersedes the exchange of individual economic values.

The reforms undertaken during Raúl Castro's presidency deepened the economic transformation that began in Cuba in the 1990s. These included measures like renegotiating Cuba's external debt and creating a more favorable institutional framework for FDI. Mainly, Law 88 on Foreign Investments allows a transformation of economic relations of production that orients them towards capitalism and has attracted investors like Spain in the hotel industry, Canada in the nickel production and generation of electricity, and Brazil in the Mariel port in Cuba (Fernández Hellmund and Romero Wimer, 2018). However, despite the more favorable economic environment for external investors derived from these reforms, several obstacles remain. These include a hostile environment from the United States, the crisis in Venezuela, and structural challenges that make it difficult for Cuba to fulfill its financial obligations to its creditors, as well as problems related to the traditional economic dynamics of a planned economy, such as information compartmentalization, lack of knowledge of standard market rules and excessive centralization of loan management for the entrepreneurial sector (García Ruiz, 2018).

There are also specific obstacles related to sustainability that Cuba must overcome if it wants to be viable for a transition towards intermittent energy sources. For example, on the theme of climate financing, an underdeveloped policy implementation framework and weak linkages to climate mitigation and adaptation strategies with policies in different areas (such as the Foreign Investment policy) constitute barriers to reaching sustainable forms of development in the country. Similarly, there are difficulties in accessing external financing sources due to the complex structure of international organizations (Sánchez Gutiérrez, 2017). While Multilateral Development Banks offer diverse sources of financing and may help Cuba reach its development goals, these institutions have membership conditions that the country may be unwilling or unable to meet. Additionally, Cuba lacks the economic resources to pay the membership fees and is reluctant to make transparent the necessary statistical data to become a member (Sánchez Gutiérrez, 2019). Nonetheless, some of the regulatory changes undertaken as part of the reforms may facilitate FDI for renewable energy projects. Specifically, Decree-Law 345 (Ministerio de Justicia, 2019) addresses investments in technology for renewable energy sources, with Article 8 (on tax-exempt prices and bank loans), Article 9 (exemptions and other fiscal benefits for foreign direct investment), Article 10 (exemptions and tariff bonuses for imports), and Article 11 (fiscal incentives) (Muñoz Alfonso, Rubio González, and Mentado Delgado, 2018) contributing to attracting investments in this matter.

Social dimension: migration flows, environmental education and women participation

Current economic and environmental dynamics in Cuba are linked to three emerging social issues: 1) the influence of Cuban emigrates as sources of finance for new businesses on the island managed by the local population; 2) environmental education as a form of addressing and mitigating ecological concerns, and 3) the increased participation of women in economic and environmental affairs. Cuba has been a migrant-sending country since the 1930s, although the Cuban Revolution in 1959 accentuated this tendency. Since 2012, Decree-Law 302 (Ministerio de Justicia, 2012) influenced some changes in migration flows: temporal and circular migrations have increased, and the role of transnational migrant networks has become more critical (Rodríguez Soriano and Cumbrado Muñiz, 2018). These migration flows affect the demographic traits of the Cuban population residing on the island, as Cuba's population is going to be one of the oldest in the coming years, thus resulting in a likely reduction of the able workforce (see discussion in Chapter III.1. “Energy economy in Cuba and future chagenges” in this book). Hence, some structural adjustments and policy plans need to be developed to address possible strains of the Cuban state. Along with migration, some factors affecting population aging are low fertility rates, sub-replacement fertility, and longer lifespans (Pérez Díaz, 2017).

Within the context of economic reforms in Cuba, the expansion of the self-employed sector has resulted in transnational migrant networks becoming necessary not only for the economic welfare of Cuban families but also for obtaining financial resources to open a private business. Decree-Law 302 (Ministerio de Justicia, 2012) has allowed Cuban emigrants to reclaim resident status in Cuba and open businesses on the island, while other individuals have used this flexibility to go to other countries looking for higher income opportunities and then come back (Rodríguez Soriano and Cumbrado Muñiz, 2018). Particularly important in this transnational migrant network are those Cuban emigrates who have settled in the United States. An analysis of the Cuban residents living in the United States from 2000 to 2014 revealed that 59% were employed, while only 5% were unemployed, and the rest were out of the workforce due to age, which might help explain why Cuban can send remittances to relatives still living in Cuba. The recent migration flows between Cuba, and the United States are more closely related to economic issues and the project of economic reforms in Cuba, as well as the international influences such as the thawing of relations between Cuba and the United States and the Trump victory in the United States elections in 2016 (Rodríguez Javiqué, 2018).

Night view from Casa Granda, Santiago de Cuba

Remittances are the most visible expression of Cuban migrant transnationalism and affect emerging economic practices in three ways: 1) by destining remittances for the design and management of the entrepreneurial initiative, as well as for acquiring capital goods; 2) by encouraging round trips of Cuban residents who simultaneously hold two nationalities and could import financial or physical capital and mobilizing networks of professional contacts who hold another nationality to help in the development of business; and 3) by using financial (money) remittances for upkeep and reparation of the business infrastructure (Rodríguez Soriano and Cumbrado Muñiz, 2018).

On the theme of environmental education, some key activities and sectors should be targeted to encourage sustainable dynamics. By its very nature and without the necessary regulatory frameworks, the expansion of the self-employed sectors generated negative environmental impacts. Hence, the harmonization of views and frameworks to ensure both environmental protection and the economic efficiency that is the purpose of expanding the self-employed sector is required. In this regard, the Ministry of Science, Technology, and Environment could play a key role in providing training for the self-employed sector to mitigate their negative environmental impacts and issuing operational licenses to those who meet environmental criteria for operation (Mesa Tejeda and Toledano Cordero, 2019). However, environmental education should not be focused exclusively on the self-employed, as broader projects that focus on cultivating sustainable ecological communities and infrastructures are needed. For example, the ARAP project conducted in the community of Oscar Lucero Moya in Holguín, Cuba, was based on a participatory approach to environmental education aimed at promoting human activities that preserve the natural environment. It contributed to strengthening social ties in the community, incorporating different worldviews in protecting natural resources, and community members renovated some households and historical buildings central to the community life (Gallardo Milanés, Martínez Gallardo, and Hardy Casado, 2018). Other holistic approaches, such as including topics on Renewable Energy Sources in university curricula, particularly architecture, have also been suggested (Collado Baldoquin et al., 2018).

Regarding the theme of increased participation of women in economic and environmental affairs, Caballero Reyes (2018) explains that, although new work opportunities for women have emerged in Non-Agricultural Cooperatives (NAC), employment in cooperatives also reproduces some gender roles and women experience more difficulty in mobilizing social capital for higher value-producing activities than men. Regarding environmental concerns, women are a social group uniquely affected by environmental degradation and, as such, are in the best position to promote environmental protection practices. The recognition of women's key role in ensuring environmental sustainability can be seen in several laws, public documents, and institutions, such as the 1993 approval of the Program of Environment and Development; the 1994 creation of the Ministry of Science, Technology, and Environment; and the approval in 1998 of the Law of the Environment, the National Strategy of Environmental Education, and the National Environmental Strategy (Carrión Cabrera, 2015). However, public policies in Cuba often address gender, development, and environmental management issues separately. Were these issues addressed jointly, women's insights could result in effective strategies for sustainable transformation and community environmental management (Hernández Becerra and Zabala Arguelles, 2019).

Environmental dimension: the challenges for the use of renewable energy sources

Although a comprehensive examination of Cuba's policies that link energy and the environment cannot be done here, Arrastía-Avila and Glidden (2017) offer a good summary of its context and impacts. In their view, one manner Cuba's government dealt with its economic crisis that had materialized on multiple fronts following the collapse in the 1990s of the Soviet Union was by undertaking the Energy Revolution, beginning in 2005-2006. Some specific measures taken as part of the Energy Revolution were the creation of Distributed Generation systems on the technical and infrastructure dimension and educational and communication campaigns on the social dimension. However, by 2015, Cuba remained entirely reliant on fossil fuels, with about 96% of its energy sources being based on fossil fuels. Renewable energy sources constituted a tiny percentage, with biomass contributing the most (3.46%), hydropower (0.24%), and wind and solar (0.25%) contributing the rest of the energy from renewable sources. The authors conclude that political will, massive investment, assessment of infrastructure development projects centered on renewable energy sources, and fiscal incentives are necessary to meet the 2030 policy goals. Additionally, continued exploration for fossil fuels and human resources development is needed (Arrastía-Avila and Glidden, 2017).

The desire to transition to a sustainable energy regime is motivated by the vulnerability of Cuba to extreme climate events. Allegue Losada (2017) has illustrated this by developing two scenarios for the island: one with the business-as-usual approach and one with a mitigation approach, and then evaluated the costs and benefits derived from taking the mitigation approach using renewable energy sources. By doing this, her study presents compelling evidence for the use of renewable energy sources, as the mitigation scenario implies lower costs and emissions of greenhouse effect gases. Aware of its vulnerability to climate change, the Cuban government drafted a Renewable Energy Development Plan for 2010–2030. Its relevant points include implementing research and development projects on renewable energy technologies, infrastructure and technological capacities, development of human resources, use of different financing models, and encouragement of private sector investment (Suarez et al., 2016). Although the government has announced its desire to reach a goal of 2,075 MW installed from renewable energy by 2030, thereby covering approximately 24% of the national electrical energy production (Suarez et al., 2016), there is still no clear path forward to reach this goal due to the number of technological and economic barriers at present, as well as the energy needs of different parts of the island.

For example, Havana faces increasing challenges related to electricity consumption due to the complexity and diversification of its economic and industrial activities and high population density and consumption. Coupled with the insufficiency of electricity production, the transmission of electric power from the East region of Cuba is required. Therefore, new projects, like the development of wind power parks in Cojímar, in East Havana, are being assessed, although complementing such projects with solar photovoltaic parks and developing Smart Grids may be needed to improve infrastructure performance (Torres Durán and Moreno Figueredo, 2018). Articulating initiatives from different actors would facilitate technology development for these large-scale infrastructure projects, with universities and technology parks occupying central roles. The former might align internal demands (like those in the Guidelines and the Constitution of 2019) with external demands (like those in the United Nations' Sustainable Development Goals), while the latter can develop and deploy Smart Grids to help the transition to low-carbon energy regimes (Hernández Morales, Morales Calatayud, and Álvarez Díaz, 2019).

Life in the park, Havana

Cultural dimension: The evolution of cultural praxis into a new era

Discussing cultural changes at a national level without anthropological and sociological concepts that anchor the discussion runs the risk of being too general and stereotypical instead of allowing for meaningful observations to be drawn. Based on this consideration, this section discusses two specific cultural changes and their effects in Cuba: the expansion of the cooperative culture and the new sources of cultural identification.

The cooperative culture implies going beyond the pursuit of self-benefit and embracing a culture of cooperative work, characterized by learning through collaboration, mutual help, participation, technical and cultural training, and the transformation of the human being into the main factor of production (as opposed to capital) and as an agent of social change. In this regard, the cooperative culture generates new social relations based on ethical principles radically different from those of capitalism (Donestévez, 2017). This culture has expanded parallelly to the expansion of cooperatives themselves as units of economic production due to the economic reforms, which have allowed their emergence in urban areas. Of the rural cooperatives, Cooperatives of Agricultural Production (CPA) have the best performance since they have the freedom to choose what they produce and where they market their goods, and their members behave in a manner consistent with the cooperative culture (Boillat, Gerber, and Funes-Monzote, 2012). Non-Agricultural Cooperatives (NAC), in contrast, face numerous challenges as a result of the involvement of institutions of the Cuban state in their constitutive phases and the high taxation regime to which they are subjected (Vuotto, 2015). However, their performance could be improved with training that enhances their management systems and strengthens the cooperativist work culture(Donestévez, 2017). For different forms of cooperatives to prosper sustainably, however, the cultivation of autonomy and local decision-making power is needed (Boillat et al., 2012).

Regarding the new sources of cultural identification, there has been a shift from objects and spaces of culture that produce a sense of belonging to newer cultural practices that generate a sense of identification and well-being in subjects. According to Kumaraswami (2016), from 1959 to 1989, cultural life was central in Cuba. It was reaffirmed by local cultural spaces such as the municipal networks of *Casas de la Cultura* (cultural houses), workshops for social transformation, and literary works in line with the ideals of the Revolution. After 1990, as a result of the Special Period, cultural identification for Cubans resided in the notion of nation, with specific markers of belonging being resilience and survivalism in adverse conditions. Since 2007, however, the increased presence of market forces has changed the dynamic between the moral and the material significantly, and subjective well-being has been associated with cultural participation in public debates about Cuba's economic and social future. These debates have been expressed in different media, such as in *Temas* magazine and the Cubadebate website, which continue to attract audiences interested in expressing themselves on this theme.

Conclusion: challenges and opportunities for the energy transition

This PESEC-structured literature review on the current state of Cuban development offered an overview of the current conditions in different spheres of life in Cuba and under which an energy transition might occur. Based on the previous analysis, some challenges and opportunities can be identified. The first is that a large-scale transition towards intermittent sources of energy is significantly tricky under current conditions since there is not enough investment going into renewable energy projects as a result of internal and external economic obstacles and the differences in energy needs between regions of the island would require meticulous coordination in restructuring the current energy infrastructure in the country. However, for small communities and villages, the opportunity exists for small-scale renewable energy systems to be built, thus allowing these communities and villages the possibility of being self-sustainable (Suárez Hernández, 2015).

Though the publication of the Guidelines for the Period 2016 – 2021 and the Constitution of 2019 updated the economic and social model and began to change the structure of the political system, the Cuban government will have to resolve some tensions. For Bye (2017), these tensions are a) continued acceptance of market illegality vs. well-regulated business practices; b) increased space for the private sector vs. opposition to market solutions; c) elite enrichment vs. entrepreneurial-driven growth. While some choices might derive from a neo-patrimonial system or a transnational neo-authoritarian system that obstructs an energy transition, a resulting system of mixed economy with participatory democracy may be uniquely suited for this goal (Boillat et al., 2012; Bye, 2017).

A final challenge relates to environmental justice. While Cuba could, under favorable circumstances, undergo an energy transition towards intermittent energy sources, technology development is embedded in global flows of resources and capital accumulation, which relies on resource and labor exploitation in other countries (Hornborg, Cederlöf, and Roos, 2019). The resolution to this contradiction might lead to the betrayal of socialist ideals by the Cuban State, or it might lead to the continued experience of environmental degradation and adverse climate effects on the island.

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I.3. Historical development of Cuban energy sector

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Key characteristics of the Cuban power sector include, on the one hand, a very high electrification rate but low energy consumption per capita, and on the other hand high dependence on fossil energy and imported oil but a long history of interest in harvesting domestic renewable energy sources. The dependence on subsidized, imported oil, first from the Soviet Union and later from Venezuela, has made Cuba vulnerable to outside changes in the political landscape as well as increased the will to look for domestic energy sources including solutions in energy-saving measures and renewable energy. Before the Cuban revolution in 1959, about half of the households had access to electricity. By 1989, the electrification rate had risen to 95 per cent and in 2019 the rate was 99.9 per cent. Several remote rural areas have been provided small-scale off-grid systems powered by gensets, small hydropower, or solar PVs (Suárez et al., 2012).

Cuba has been and still is heavily reliant on fossil energy in its power generation. In 2018, 97% of the power production was based on fossils (see Table 1). Most of the electricity in the country is produced by so-called termoelectricas, condensing steam power plants, that are powered by oil. Less than half of the oil is from domestic sources and the rest is imported (see Figure 1).

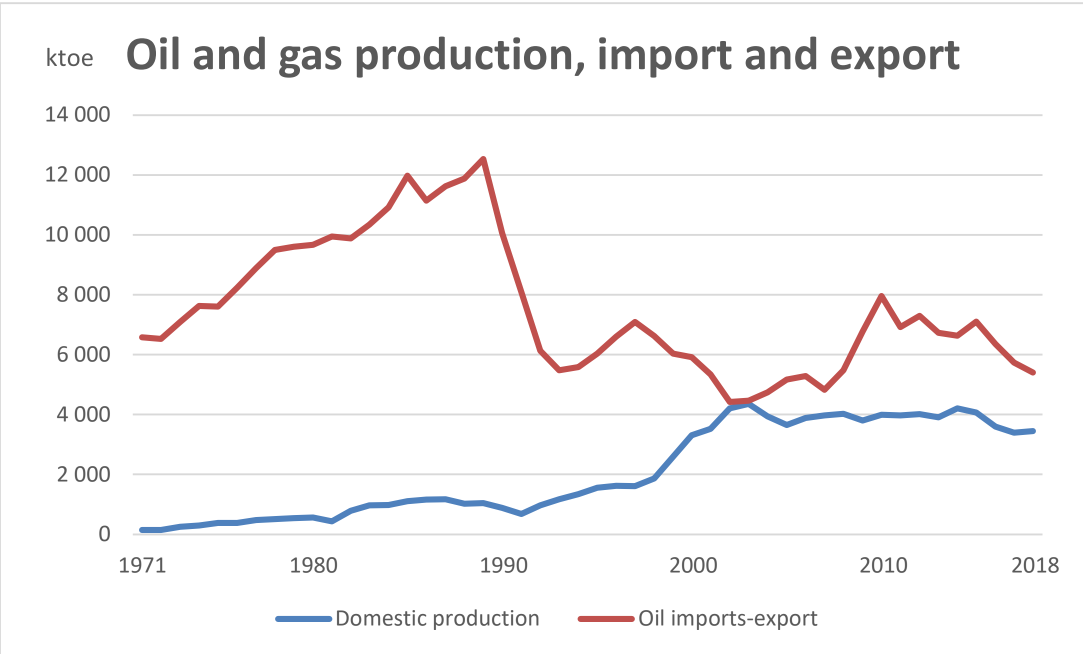

Figure 1. *Amount of domestic oil and gas production in Cuba and the amount of imported minus exported oil. Data source:* IEA Statistics (2019).

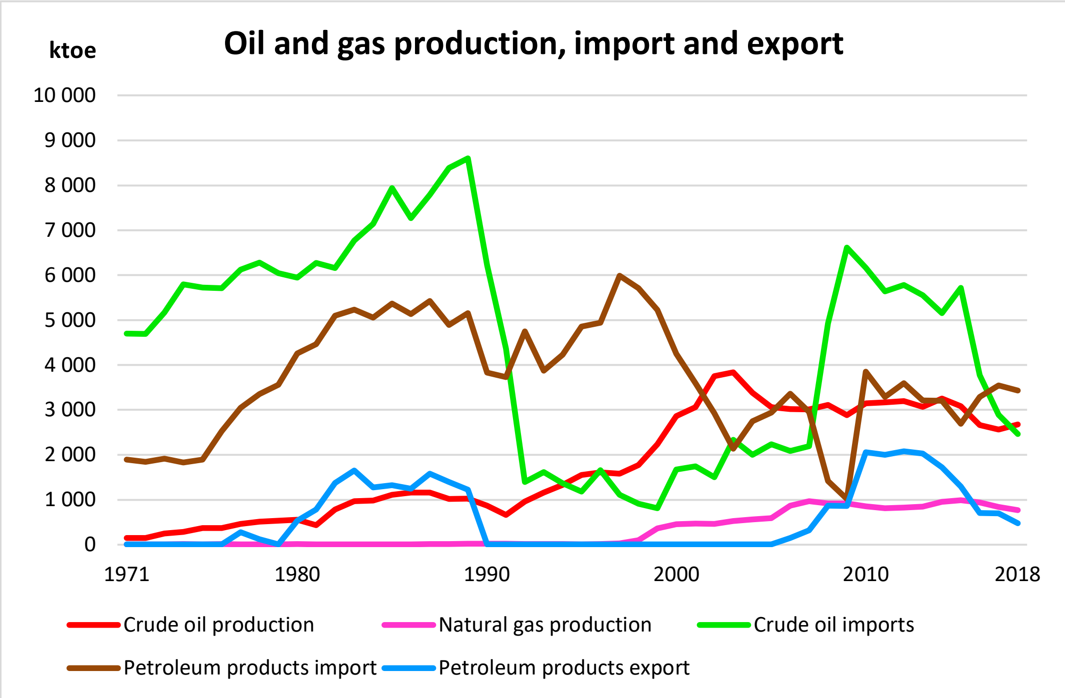

***Figure 2**. Crude oil and natural gas production in Cuba and import of crude oil and petroleum products and export of petroleum products. Data source:* IEA Statistics (2019)

In 2018 only 3 per cent of the electric power generated came from renewable sources (see Fig. 3, based on IEA statistics). The decrease in the share of renewable energy-based electricity production is caused by the reduction in sugar production, where bagasse based combined heat and power production provided previously a larger share of electricity. The structure of the power production in Cuba is shown in Table 1.

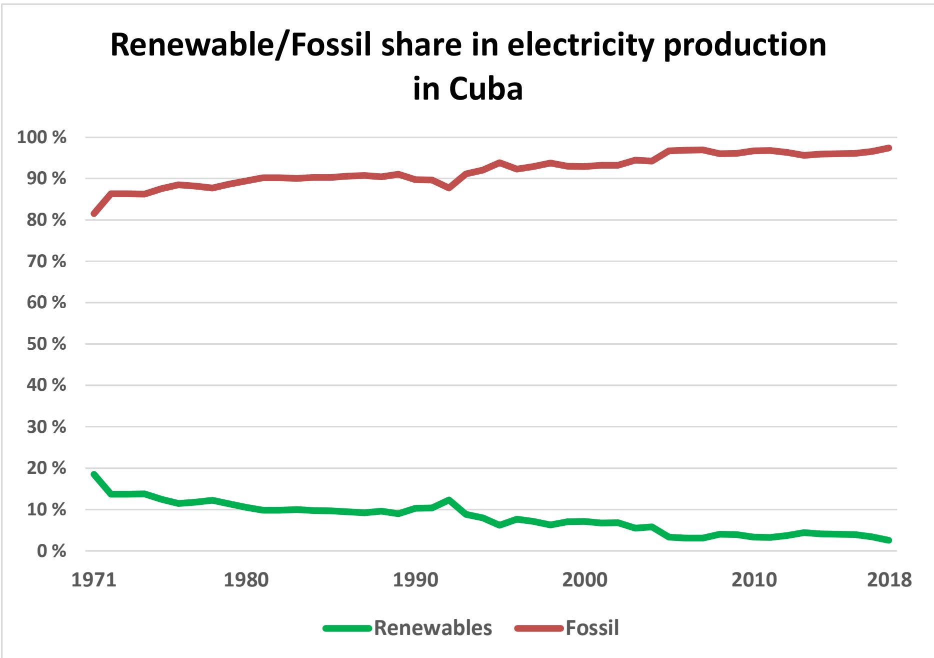

***Figure 3.** The share of fossil and renewable-based electricity in Cuba. Data source:* IEA Statistics (2019)

Table 1. Structure of power generation in Cuba in 2019 (ONEI, 2020)

Type of generation	Installed capacity MW	Production GWh	Share of production
Steam power plants (oil)	2 498	12 664	61 %
Gas turbines	580	2 450	12 %
Diesel plants and "new technology"	2 642	4 372	21 %
Hydro power	64	125	1 %
Solar and wind	159	251	1 %
Other thermal (industry)	459	842	4 %
Total	6 508	20 704	100 %

Table 2. Structure of renewable energy capacity installed (MW) in Cuba per year (IRENA, 2021).

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Total	621	594	555	596	629	610	675	758	1 085	1 198
Hydro	65	62	63	63	63	66	66	64	72	72
Wind	12	12	12	12	12	12	12	12	12	12
Solar	-	1	11	22	24	37	65	128	159	163
Bioenergy	544	519	470	499	530	495	532	554	842	951

In primary energy production, however, the share of renewable energy is much higher, accounting for up to 20%, due to the use of bagasse-fired energy in the sugar industry (see Figures 4 and 5).

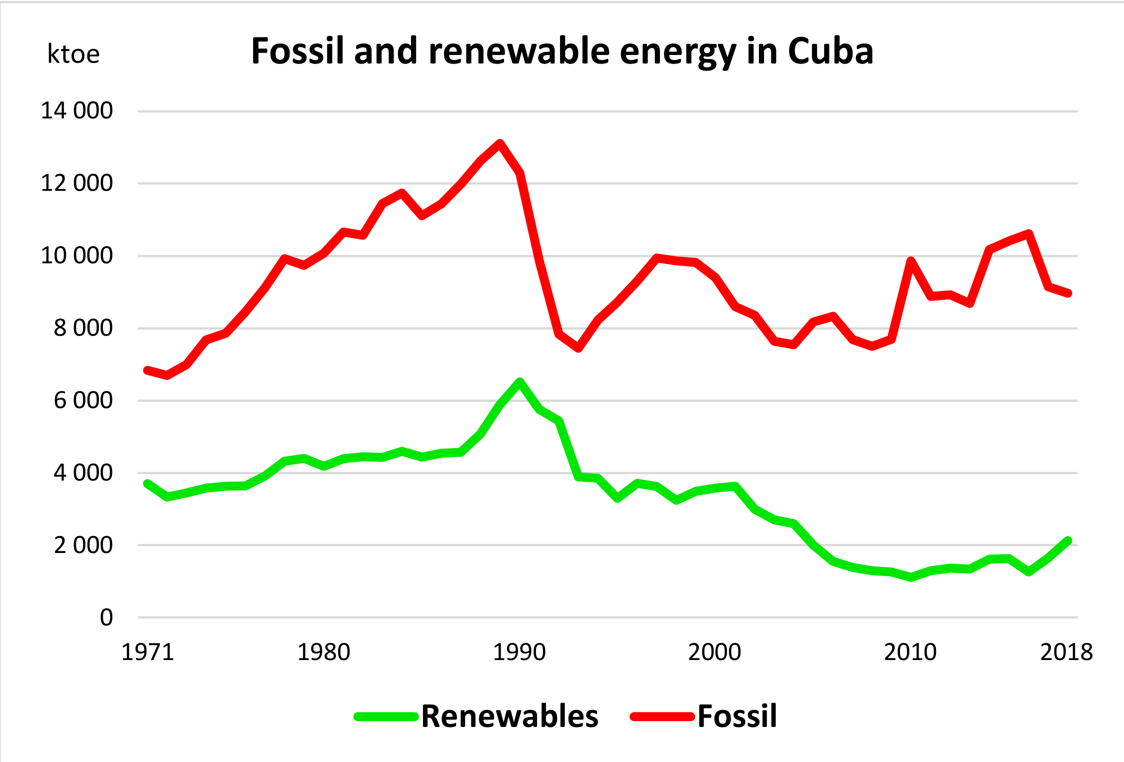

Figure 4. *Amount of fossil and renewable energy use in Cuba. Data source:* IEA Statistics (2019)

Table 3. Structure (%) of power generation in Cuba (IRENA, 2021)

Type of source	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
REN	10,5	10,4	9,1	9,6	10,0	9,4	10,4	11.4	16.6	17.6
fossil	89,5	89,6	90,9	90,4	90,0	90,6	89,6	88,6	83,4	82,4

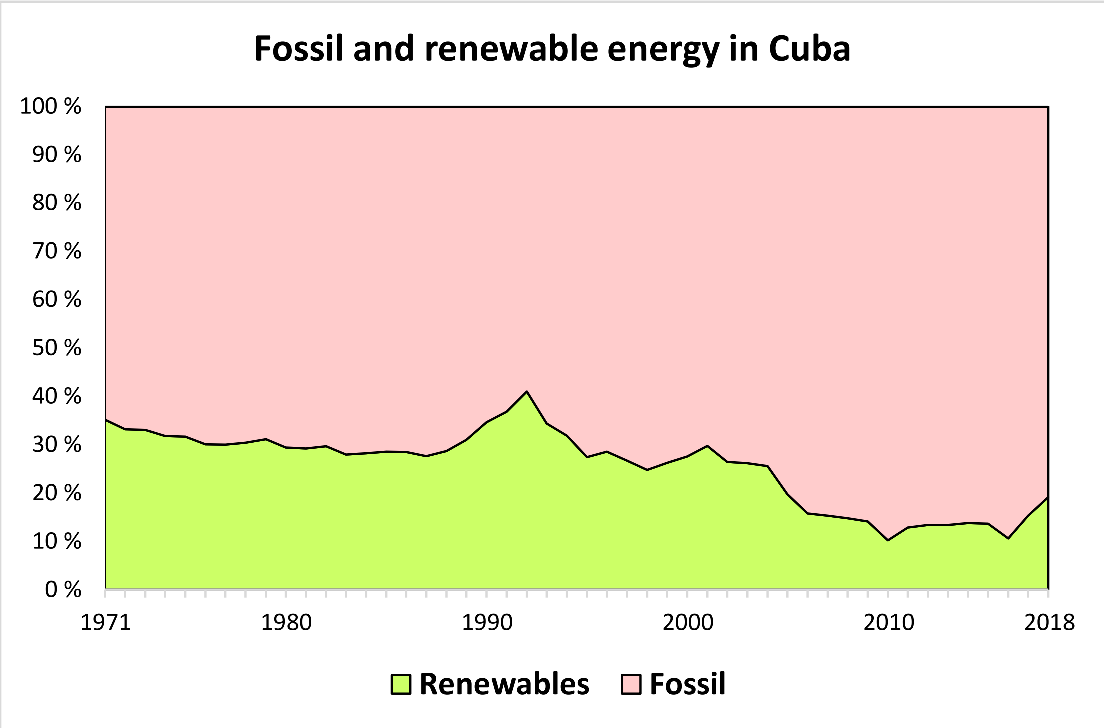

Figure 5. *Share of fossil and renewable energy in Cuba. Data source:* IEA Statistics (2019)

In electricity production, the role of renewables is greatest in off-grid systems used in remote areas of the country. But this will change in the future as several efforts have been underway to increase the role of renewables in electricity production. Another key characteristic of the Cuban energy sector is the relatively high share of distributed energy production, which partly has been developed as a response to high exposure to damages caused by extreme weather conditions, including hurricanes. The generalization of distributed generation has been part of the Energy Revolution Program launched in 2006.

Another concrete achievement of the program has been the energy-saving measures targeting mainly domestic energy use (Käkönen, Kaisti, and Luukkanen, 2014). This is relevant for the overall power consumption: in 2018 household power consumption was 59% and industrial consumption 20%. Part of the household consumption should be allocated in the statistics to the service sector because the private restaurants (paladar) and accommodation services (casa particular) are at the moment calculated in the statistics in the household sector.

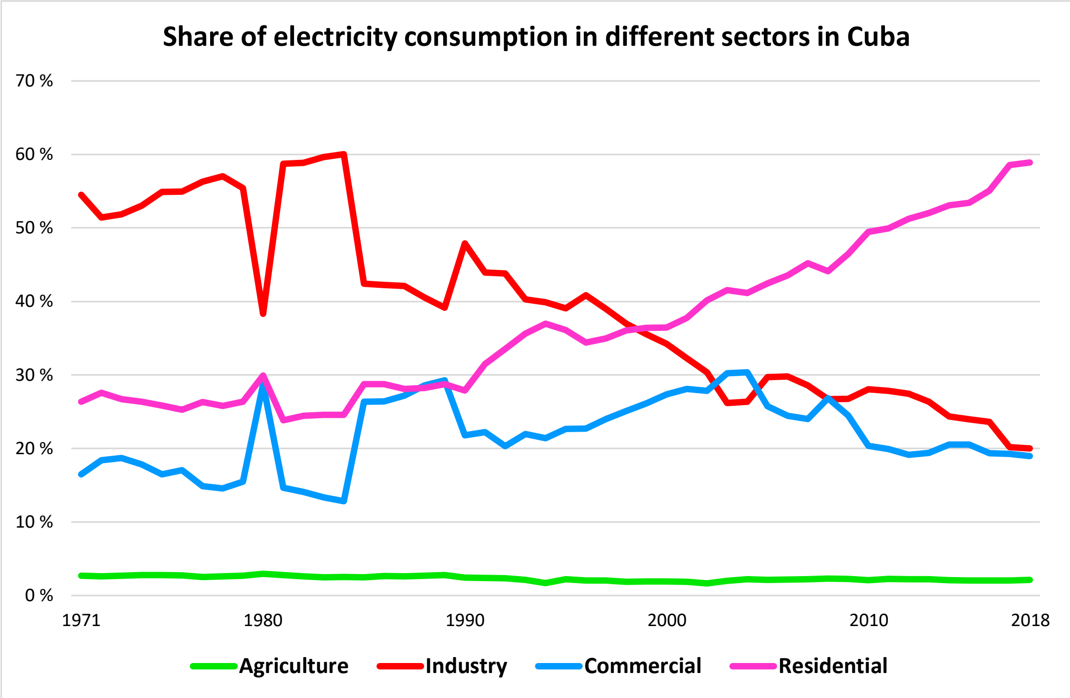

Figure 6. *Share of electricity consumption in different sectors of the economy in Cuba. Data source:* IEA Statistics (2019)

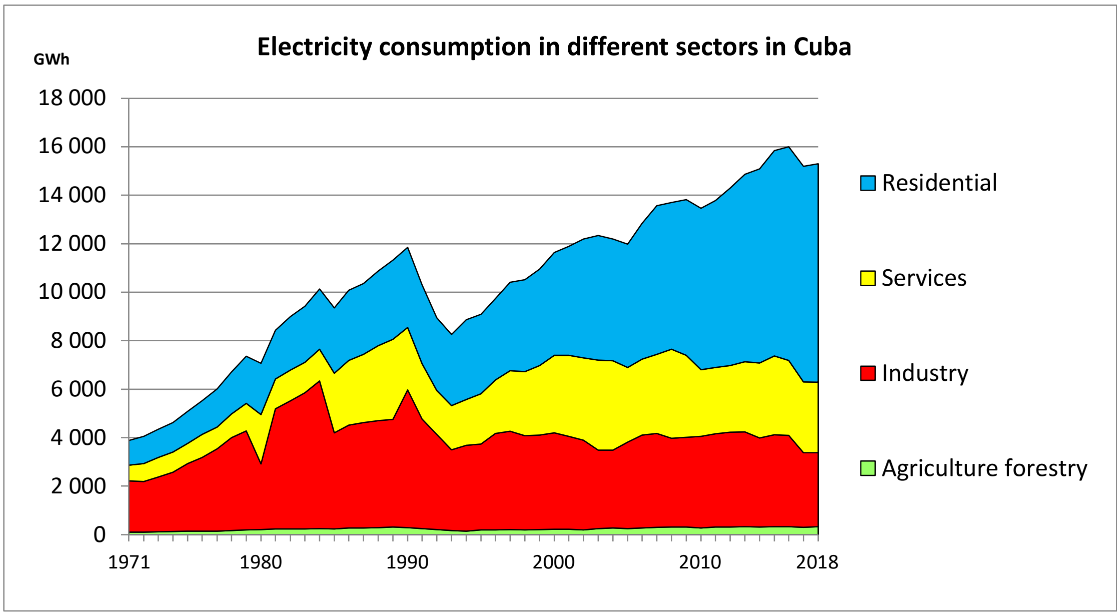

Figure 7. *Electricity consumption in different sectors of the economy in Cuba. Data source:* IEA Statistics (2019)

The energy intensity, as well as electricity intensity in Cuba, has been decreasing since 1997. This means that with the same amount of energy use more value-added can be produced. The structural change in the Cuban economy towards a larger share of producing value-added in the service sector is one factor reducing the electricity intensity. In the service sector the electricity intensity is lower than in industrial and agricultural sectors (see Fig. 9) and when the share of this sector is increasing the total electricity intensity is decreasing. We can see positive development also in the industrial sector where the electricity intensity is decreasing indicating improved efficiency or a shift to producing less energy-intensive products.

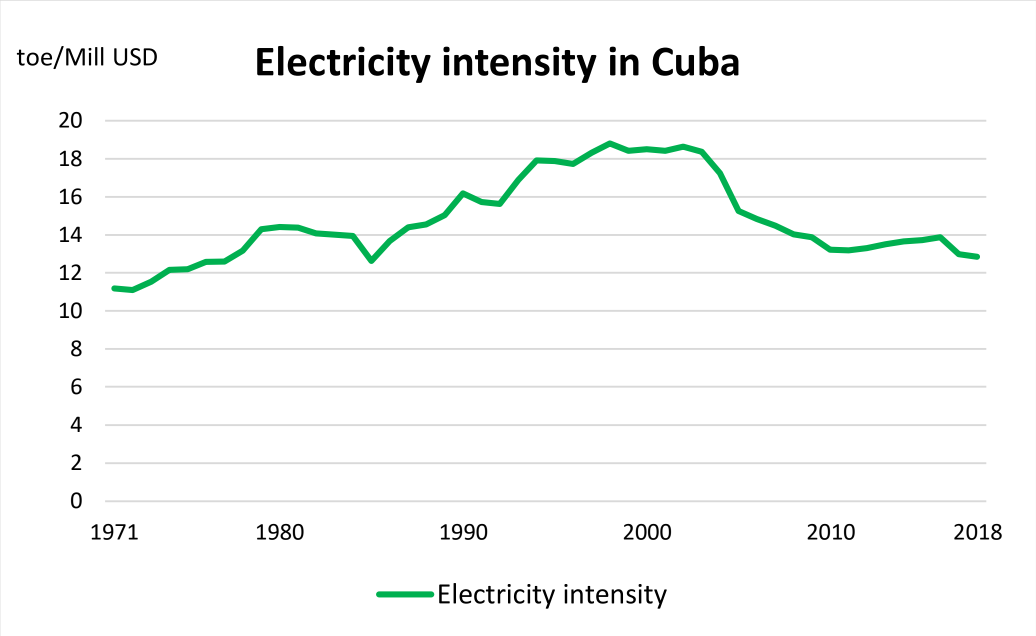

Figure 8*. Electricity intensity in Cuba, measured as energy use (toe) per GDP (Mill USD). Data sources:* IEA Statistics (2019); UNStats (2021)

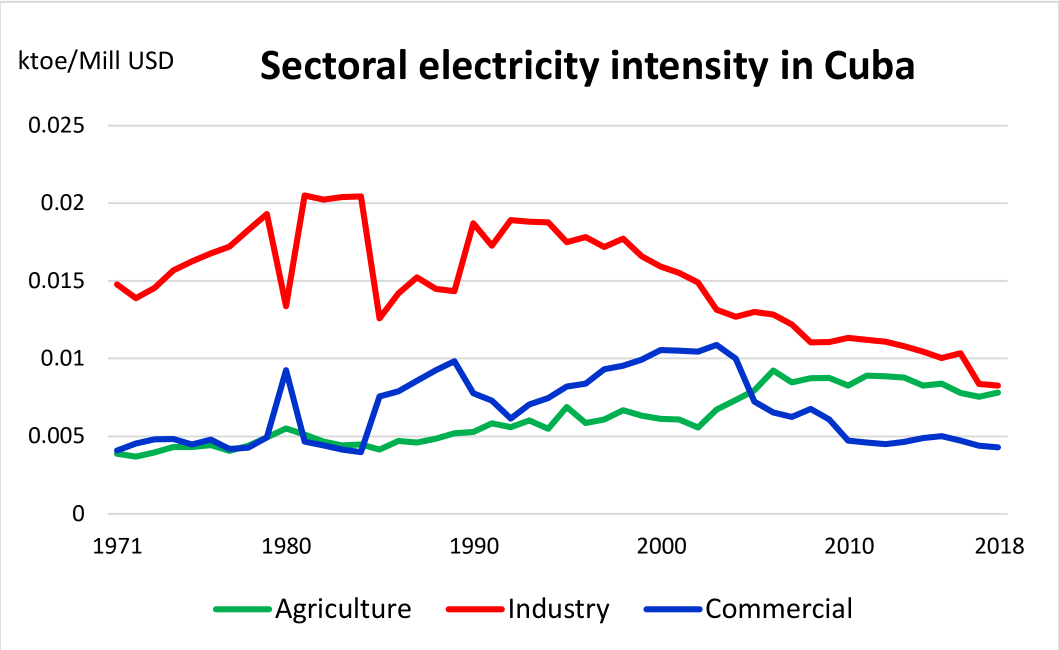

Figure 9. *Electricity intensity in different economic sectors in Cuba, measured as energy use (ktoe) per value added (Mill USD) Data sources:* IEA Statistics (2019); UNStats (2021)

To understand the changes in Cuba's energy sector it is important to look at the wider historical context. From 1958 until the collapse of the former Soviet Union, Cuba traded sugar for oil with the Soviet Union on very reasonable terms. When the Soviet Union collapsed in 1991 Soviet subsidies and trade links were rapidly withdrawn. This caused a shock for Cuba and its GDP fell 35% between 1989 and 1993 (see Figure 10). The era of cheap electricity ended. This period (1990-1994) was called by then-President Fidel Castro as “the Special Period in Peacetime”.

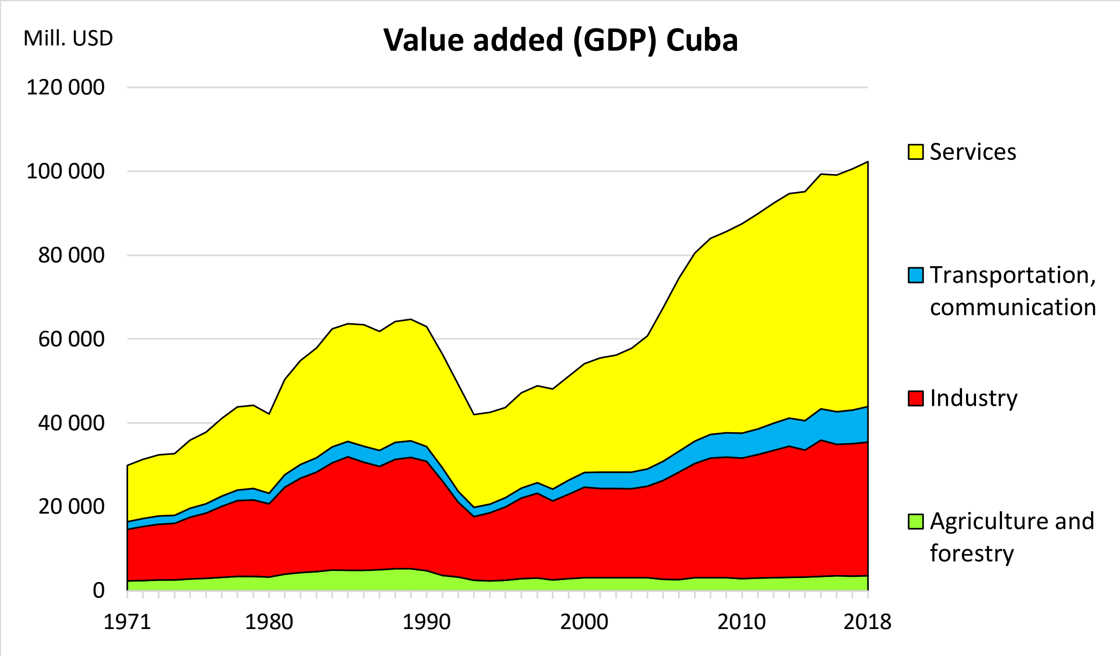

Figure 10. *Value added in different sectors in Cuba. Data source:* UNStats (2021)

The most severe reductions in production related to the collapse of the Soviet Union took place in the sectors of construction, manufacturing and wholesale, retail trade, restaurants and hotels (see Fig. 11). Also, the agricultural sector output reduced considerably and this together with the reduced import of food products caused severe nutritional problems in the country.

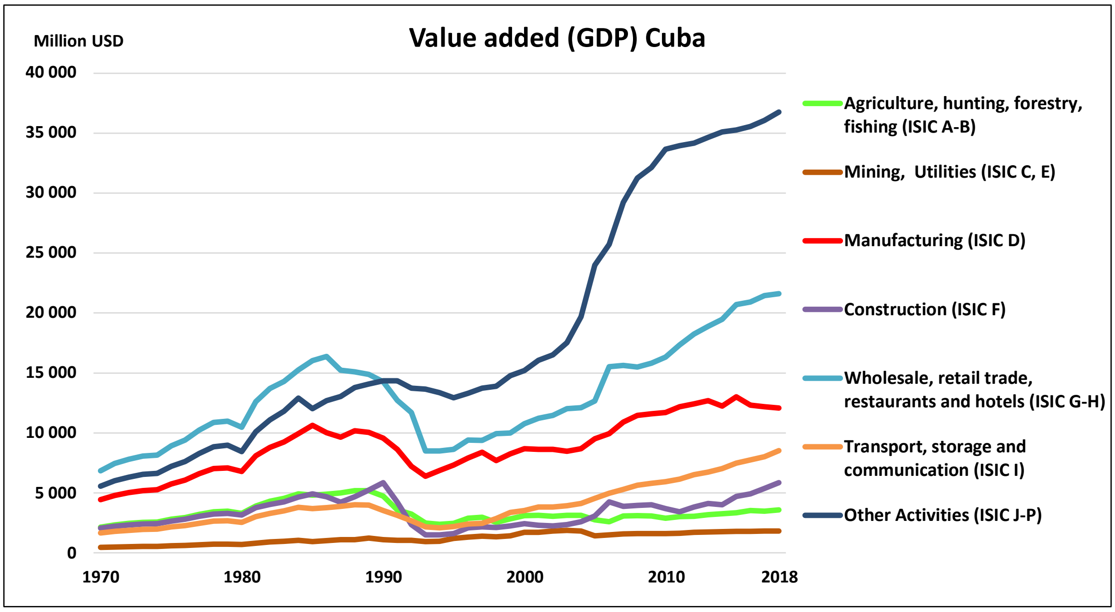

Figure 11. *Development of value-added in different economic sectors in Cuba. Data source:* UN-Stats (2021)

The Special Period was an emergency economic regime marked by extreme austerity and shortages. Oil, gas, and food all became scarce. Imports from Russia dropped by 50 per cent, and oil consumption dropped 20 per cent, from 225,000 barrels a day in 1989 to 180,000 barrels a day in 1992 (Arrastía-Avila and Guevara-Stone, 2009), (see Figure 12). Transport was hit hard, along with electric generation. Biofuels were mainly used in the sugar industry and due to the reduction in sugar processing the use of bioenergy decreased.

Oil refinery, Havana

In a special period, Cubans had to learn how to produce more of their energy and food locally. The response for the Special Period in the energy sector was the National Energy Sources Development Programme approved by the Cuban National Assembly in 1993 (Marín and Curbelo Alonso, 2005). Three areas of action were prioritized: 1) Energy efficiency and renewable energy, 2) The increase in national crude oil production (that is found together with gas) for electricity generation as a substitute for imported fuel oil and 3) the Sugar industry to achieve higher efficiency in the use of bagasse.

Several measures and efforts were made to reach the objective of increasing domestic crude oil production. The domestic production of oil started already in the 1970s, but it grew considerably after 1990 and the 1993 National Energy Development Programme (see Figures 12). In 2018 about one-third of the oil was domestically produced and the rest was imported (Figures 13 and 14). The problem is that the domestic oil is principally from shallow waters just off the coast and it consists of low quality, high-sulphur heavy oil.

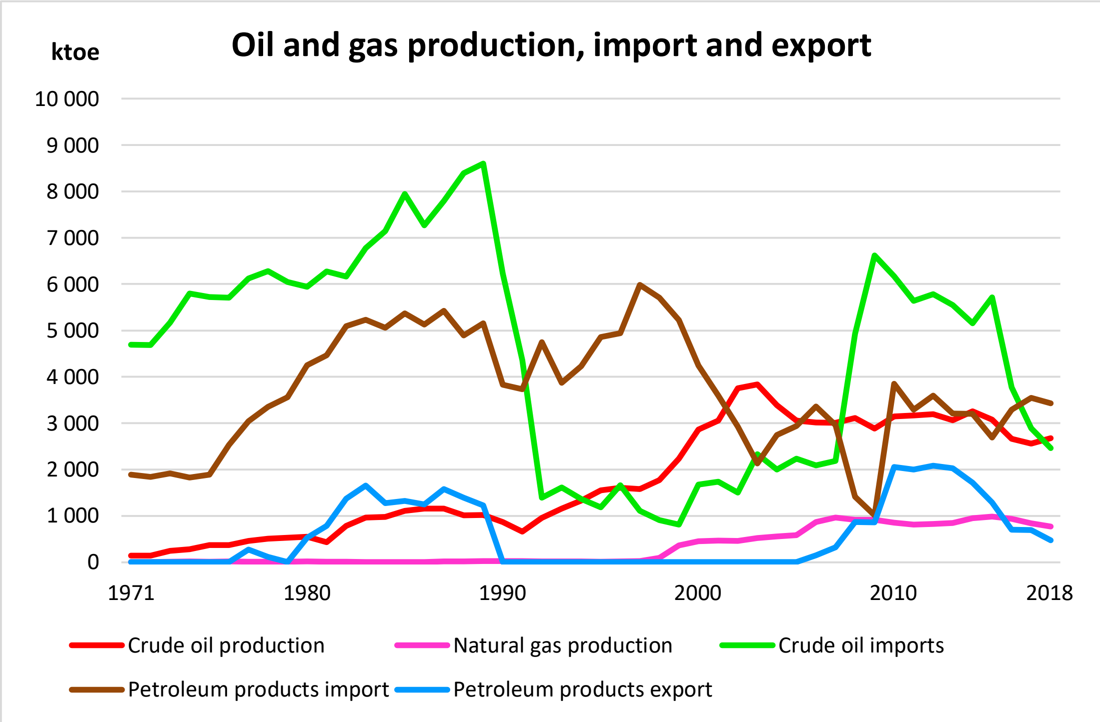

Figure 12. *Oil and gas production in Cuba and import and export. Data source:* IEA Statistics (2019)

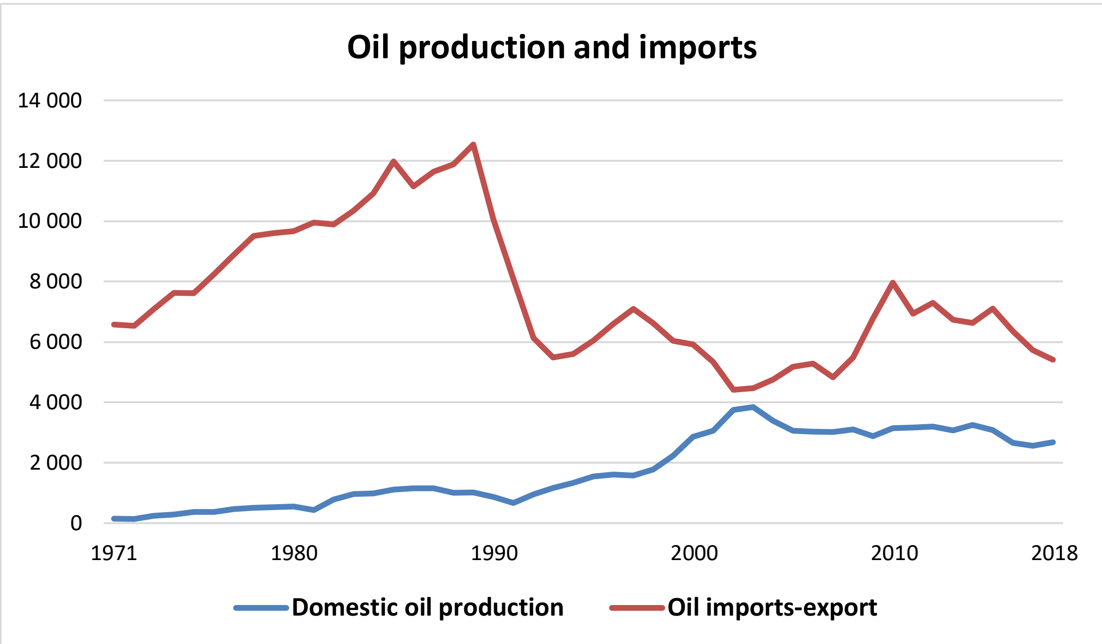

Figure 13. *Domestic oil production in Cuba and oil imports minus export. Data source:* IEA Statistics (2019)

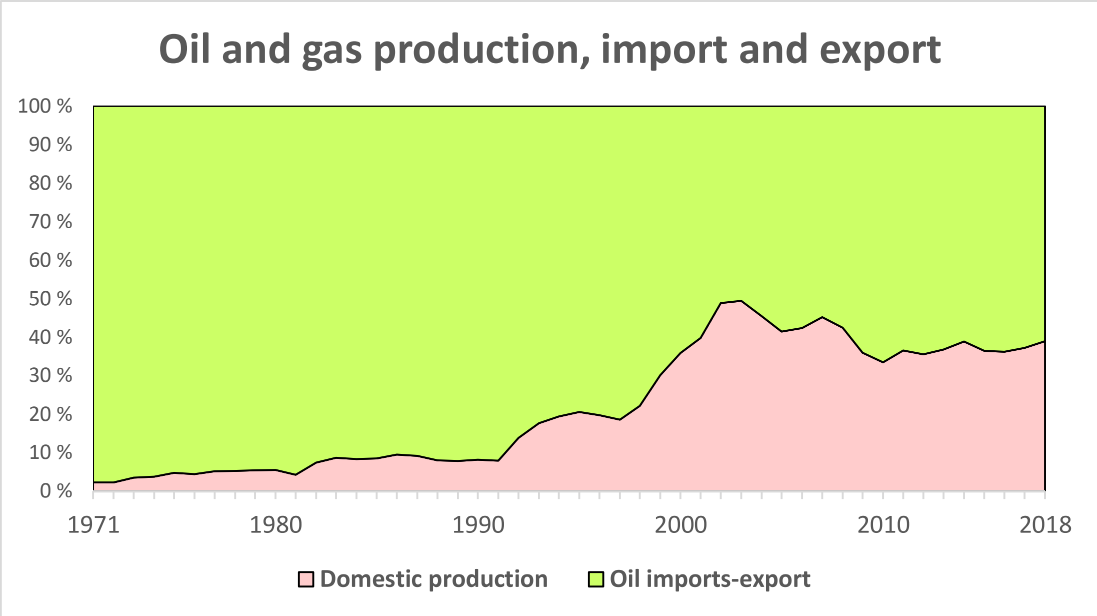

Figure 14. *Share of domestic oil and gas production and oil import minus export. Data source:* IEA Statistics (2019)

The thermal power plants in Cuba use this domestic low-quality oil. The high-sulphur content level of this oil is one of the main factors leading to failures in power stations. Cuba also has some offshore “high quality” oil and gas reserves of its own and the future potential for off-shore production is seen quite significant.

An old thermoelectric power plant in Santiago de Cuba.

Natural gas production has increased during the last years. The gas has been used mainly for commercial and residential purposes, but with increased production, gas is also used to produce electricity. In 2018 the share of gas in electricity production was 13 %.

In terms of imported oil, Cuba began first to buy oil from the open market at the beginning of the 1990s. Later on, a significant change with the oil imports was brought by the favourable trade terms developed with Venezuela (after Hugo Chavez was elected as president in 1998). Some of the oil from Venezuela was financed by loans, part was a barter trade involving about 20,000 Cuban medical professionals who worked in Venezuela, and some oil was provided as a grant (Soligo and Myers Jaffe, 2010). Although on the one hand, the deal with Venezuela was essential for the recovery of the Cuban economy, on the other hand, it once again made Cuba dependent on subsidized imported oil.

In terms of renewable energy, the Special Period and the 1993 energy program sparked mobilization in the Cuban scientific community to look at new alternatives. Besides, thanks to the new initiatives in renewable energy, the electrification rate increased despite the energy crisis. Rural schools, health clinics, and social centres in remote off-grid areas were provided electricity via solar PV systems or micro-hydro plants (Barclay, 2003). New actors also evolved a company Ecosol Solar and an NGO CUBASOLAR built a productive partnership in the 1990s with funding from overseas and since the end of the 1990’s they have been active in spreading solar PV systems especially to rural schools in remote areas. Making lights, computers and educational television programs accessible to every school child in the country won Cuba the Global 500 Award from the United Nations in 2001 (Guevara-Stone, 2009). By 2003 over 2364 schools, 350 doctors’ offices, and hundreds of hospitals had been equipped with solar PV systems (Barclay, 2003). After 2002 in addition to health stations and schools, also private homes have been electrified with solar PVs.

For the sugar industry, the efforts were not as productive. Cuba was unable to find a market for its sugar production after the Soviet Union collapsed and the industry suffered seriously in a special period. In 2002 major restructuring took place with the closure of 71 sugar mills and reduced planted area for sugar cane (Grogg, 2007). Altogether sugarcane production fell from 82 million tons in 1990 to 23.8 million tons in 2004. This resulted in a significant reduction of bagasse use as an energy source after 1990 which can be seen in Figure 15 and Figure 16 which describes industrial energy use.

The total primary energy supply in Cuba has reduced considerably from the peak year 1989 (see Fig. 15). The level of consumption in 2018 was 45 % lower than in 1989.

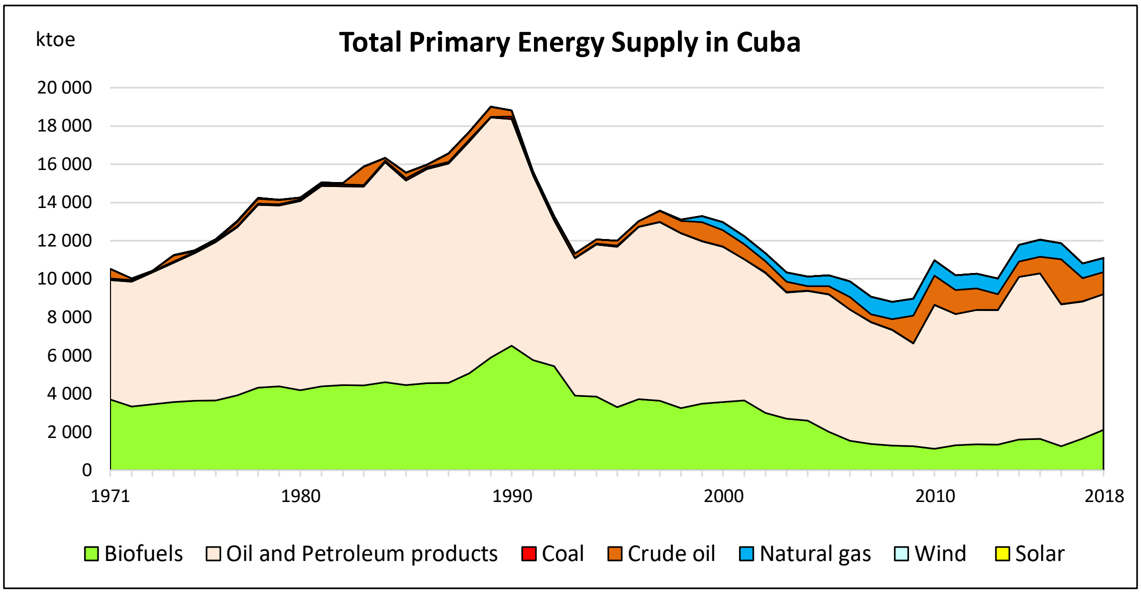

Figure 15. *Total primary energy supply in Cuba. Data source:* IEA Statistics (2019)

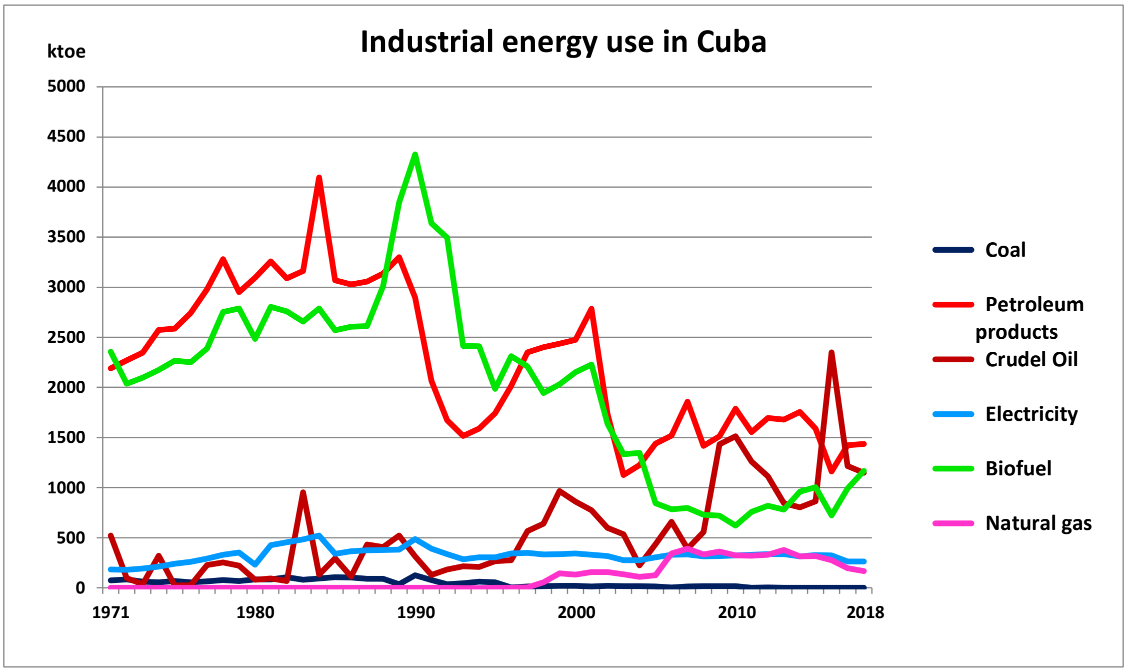

Figure 16a. *Industrial energy use in Cuba. Data source:* IEA Statistics (2019)

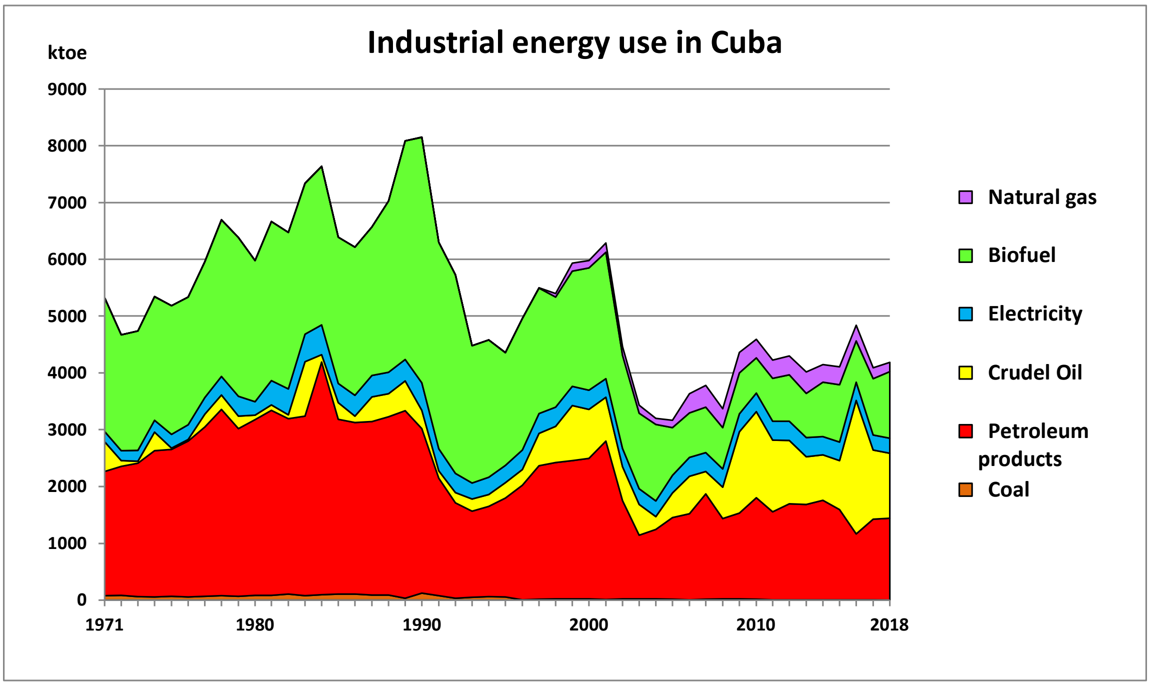

Figure 16b. *Industrial energy use in Cuba. Data source:* IEA Statistics (2019)

From the energy crisis to the energy revolution

"We are not waiting for fuel to fall from the sky, because we have discovered, fortunately, something much more important: energy conservation, which is like finding a great oil deposit." President Fidel Castro in 2006 (quoted in Guevara-Stone (2009)

In the early-2000s Cuba's energy situation was bleak. Cuba had centralized and inefficient power plants: 11 thermoelectric plants that functioned about half of the time. Power plant failures were partly caused by the widespread use of poor-quality fuel with a high content of sulphur but also the grid was in bad condition. The problems culminated when two hurricanes caused considerable damage to the transmission line in 2004 leaving a million people without electricity for 10 days. The worst year was 2005 when the national electricity system functioned at only 50 % of its installed capacity with blackouts lasting seven to twelve hours daily (Benjamin-Alvarado, 2010). Moreover, most Cubans had inefficient appliances, highly subsidized residential electricity rates did not encourage conservation, and 85 per cent of the population cooked with kerosene (Arrastía-Avila, 2008).

In the face of the energy crisis consisting of an antiquated and damaged system with power shortages energy sector was made a priority in Cuba (Guevara-Stone, 2009; Suárez et al., 2012). In 2006 Cuba embarked on Revolución Energética, Energy Revolution – an initiative or policy that aimed to save energy and use more sustainable sources more efficiently. It had the following main aspects:

- Energy efficiency and conservation
- Increasing the availability and reliability of the national grid
- The generalization of distributed generation with smaller electric power plants

- Incorporating more renewable energy technologies into its energy portfolio
- Increasing the exploration and production of local oil and gas
- International co-operation

The first step in the energy revolution was to decrease energy demand by energy efficiency and conservation measures.

Energy efficiency and conservation

An elemental part of the Energy Revolution was the replacement of household appliances with more efficient and safer equipment. These were supplied free or at low cost and also some social credit schemes were developed.

Households switched their incandescent light bulbs to more efficient compact fluorescents free of charge. This was done with the help of 13 000 social workers around the country. This made Cuba the first country in the world to phase out the use of incandescent light bulbs. The shift to energy-saving lamps has been estimated to result in an annual saving of around 3-4% of the total Cuban electricity consumption (354 million kWh) (Seifried, 2013).

Since 2006, 2 million refrigerators and one million fans have been replaced. The annual electricity savings for the replacement of old refrigerators have been estimated to amount to 1 147,5 million kWh (Seifried, 2013). The scheme for the refrigerators was that the government provided 50 per cent and the household 50 per cent of the costs. There was also a loan system created for this in which the interest rates and payback times were adjusted to the household's income level and payback ability. Besides, there was a cooperation program with Canada to store the gases in the final destruction of the old refrigerators to avoid CFC emissions.

Another problem area targeted by the energy revolution was the high use of kerosene in households for cooking. Before the revolution the main source of cooking energy was charcoal. Later on, the Soviet Union provided a cheap supply of kerosene which replaced charcoal use. With the energy revolution, the kerosene and LPG use were largely replaced by 3,2 million new electric stoves (a simple electric hotplate) and by distributing 3,5 million rice cookers and 5,5 million pressure cookers to Cuban households.

Cooking mariquitas with an electric stove

Additionally, a new residential electricity tariff was introduced to encourage electricity saving. The tariff was created with social fairness considerations. People consuming less than 100kWh per month continued to pay previous, significantly subsidized, low rate (0,38 US cents/kWh), but for every increase of 50 kWh per month the tariff progressively increased and the large consumers needed to pay around four times more than before (Arrastía-Avila and Guevara-Stone, 2009).
Along with the changes in appliances, technology, and the introduction of electricity tariffs, an important element of the energy revolution has been energy education. Educational efforts have included awareness-raising on energy-saving measures: special courses, contests, and festivals for students in schools; published books; courses for journalists; several types of printed materials, TV classes, radio, and TV spots as well as newspaper articles on climate change and renewable energy(Arrastía-Avila and Guevara-Stone, 2009).

Malecon Street, Havana

National grid and distributed electricity generation

According to Suárez et al. (2012), 90% of the national grid was rehabilitated after the Energy Revolution started, with upgraded electrical posts, utility service entrances, and electrical meters. But perhaps more importantly, the extension of distributed generation was carried out decisively. At the end of 2021, Cuba has a generating capacity of 2667 MW based on distributed generation – 1280 MW corresponds to diesel generators and the rest are fuel oil motors (540 MW), CHP (529 MW), and renewable technologies (239 MW). This means that 42% of the generation capacity is in distributed systems: a very significant shift away from a centralized power system. The distributed units are generally of a size of 3 to 10 MW.

Most of the new distributed generation installations in the country were emergency generators and motors that burn fossil fuels, both diesel and fuel oil. These technologies, however, have had a positive impact on the environment because they have lower specific consumption rates compared to old large oil-fired steam power plants (Herrera et al., 2013). It could also be expected that this transition from centralized to distributed system will contribute to fostering the future development of renewable energy sources.

Many of the results of the energy revolution were positive. The program helped Cuba to stabilize its power supply and to address the problem of country-wide blackouts. The emergency preparedness was significantly strengthened, and the new hurricanes have not caused such devastation for the electricity system anymore. Here the shift to a more distributed system has been essential.

The appliance replacement program has also materialized in concrete results. Two years after the Energy Revolution measures were introduced, in 2008, the kerosene consumption had decreased by 34 per cent, LPG (liquefied petroleum gas) consumption by 37 per and Cubans consumed 80 per cent less gasoline than before the Energy Revolution (Guevara-Stone, 2009). The results of these energy-saving and appliance switching methods can be seen in residential energy consumption (see Fig. 17). After the implementation of measures, the consumption of biofuels and petroleum products has decreased while electricity consumption has increased.

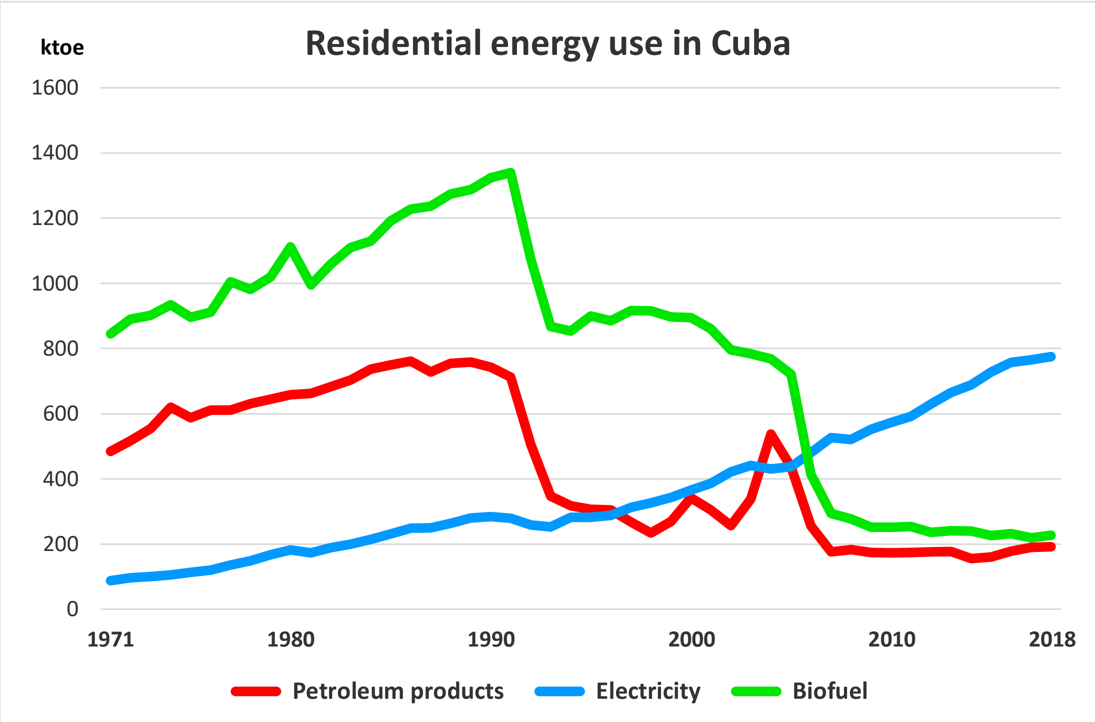

Figure 17*. Residential energy use in Cuba. Data source:* IEA Statistics (2019)

It has been counted that only in 2006–2007 Cuba saved over 961,000 tonnes of imported oil through the different energy-saving measures, including energy conservation and the improvements in the transmission and distribution networks (Guevara-Stone, 2009). One aspect to consider here is the general shift of the Cuban economy from industrial production to the service sector due to which the country's energy intensity overall has been decreasing.

The energy revolution has also been referred to as a good example of an environmental policy that addressed environmental justice (Bell, 2011). The household appliances were of no-cost or low-cost to all, the supporting social credit system was tailored according to the income level of the households and the new electricity tariff was a progressive one (the electricity price increases with increasing consumption). There have been also health benefits from phasing out the kerosene used in the Cuban kitchens.

In industrial energy use (see Fig. 16), the energy revolution measures cannot be seen as clearly as in the residential sector. Industrial energy consumption has increased after the energy revolution and it seems to be more dependent on oil use. The main conclusion thus is that while the energy-saving measures have been quite successful in residential energy consumption, a lot remains to be done in industrial consumption. Also, the country's overall energy mix remains to be still largely unaltered. Thus the results in terms of incorporating more renewable energy technologies into the country's energy portfolio have so far been far less concrete than the results from energy conservation, the rehabilitation of the national grid, and the generalization of distributed energy.

Renewable energy

The Energy Revolution in Cuba also aimed to increase the use of renewable energy technologies. The result was the creation of a Renewable Energies Directorate within the Ministry of Basic Industry renamed the Ministry of Energy and Mines; the articulation and integration of specialists and researchers from various ministries in the National Group of Renewable Energies, Energy Efficiency, and Cogeneration, which among its actions evaluated the national potential of different sources (wind, solar thermal, sugarcane and non-sugarcane biomass, geothermal, ocean energy, among others) and the possibilities of using different technologies.

All this contributed to the foundation and implementation of the National Plan for the prospective development of renewable sources and the efficient use of energy until 2030 (Extremera San Martin, 2019). This plan from 2014 to date has made possible several results with state and foreign investment, as well as the contribution of different organizations international organizations such as UNDP, IRENA, among others:

- **Solar PV:** The program, updated in early 2021, covers 803 MW of installed capacity in 191 photovoltaic solar parks. Until March 2021, the country has installed 227 MW in photovoltaic parks, 215 MW in 72 parks synchronized to the electrical system, and 12 MW installed on roofs and other areas of residential, private, and state clients. The provinces with the greatest progress on the subject are Artemisa, Granma, Cienfuegos, Sancti Spí ritus and Pinar del Río. Cuba has invested 250 million dollars in this program, achieving an annual generation of more than 340,000 MWh, saving 88,400 tons of fuel, ceasing to emit 285,600 tons of CO_2 into the atmosphere (Alonso Falcón, Figueredo Reinaldo, and Sifonte Díaz, 2021)

- **Wind power:** The existing capacity in four wind parks is 11,7 MW. The program plans to install 688 MW in 13 wind farms. Two new parks Herradura 1 and Herradura 2, with a total capacity of 101 MW, are under construction. The rest of the parks are in the preparation stage, nine of them will be executed with foreign investment. It was certified by the International Consultant Garran-Hassan and Partners of the National Wind Map carried out by Cuban experts.
- **Biomass power plants:** In Cuba, there are 57 sugar plants with 470 MW power plant capacity. The program is to install 25 biomass power plants which would provide 14% of the electricity of the country. An increase in boiler pressure and temperature enables a threefold increase in electricity output per ton of sugarcane. At the beginning of 2020, the installation and synchronization of the electrical system of the new 62 MW plant at the "Ciro Redondo" sugar plant in the Ciego de Ávila province were completed. Two new plants, of 20 MW each, are under construction in the provinces of Matanzas and Villa Clara (Extremera San Martin and Guerra de Silvestrelli Delgado, 2021).
- **Hydropower:** The plan is to install 56 MW of new capacity. The current capacity is 64 MW, consisting of 147 plants, of which 30 are connected to the main grid and 117 are isolated systems. 11 MW have been added, in three new plants; and another 13 plants will be built adding 10.1 MW of new installed capacity.
- **Biogas:** The plan is to build 500 industrial biogas plants and 9000 small agricultural facilities. There are 3,441 biodigesters in the 168 municipalities of the country, and 2,869 are in working condition, data reconciled between the Movement of Biogas Users, CUBASOLAR, and the Center for the Development of Biogas (Extremera San Martin and Guerra de Silvestrelli Delgado, 2021).
- **Energy Efficiency:** Integrate several subprograms
    - Replacing existing street lights with LED technology: 7.8 million LED lamps have been marketed to the population and more than 43,000 LED lamps have been installed in public lighting services
    - Water pumping with solar energy for agriculture.
    - Installation of 100 000 m^2 solar heater: More than 10 595 solar heaters have been installed in the tourism sector, and more than 600 of this equipment has been marketed to the population. The solar heater factory has a capacity of 18,000 heaters per year.
- **Foreign Investment:** increase the possibility of investing in the sector; Investors from Germany, Canada, the United Kingdom, China, and Spain currently operate in the country, as there are tax incentives under Law 118 on Foreign Investment.

The Decree-Law No. 345 was approved at the end of 2019 "On the development of renewable sources and the efficient use of energy" with resolutions and complementary instructions, to contribute to (Ministerio de Justicia, 2019):

- increasing the share of renewable energy sources in electricity generation**;**
- the progressive substitution of fossil fuels**;**

- diversification of the structure of fossil fuels used in the generation of electricity;
- increasing energy efficiency and saving;
- the stimulation of investment, research, and the improvement of energy efficiency, as well as the production and use of energy from renewable sources, through the establishment of incentives and other instruments that stimulate their development;
- the development of the production of equipment, means, and spare parts by the national industry, for the use of renewable sources and energy efficiency; and
- the establishment in the state sector of a working system that includes planning tasks that make it possible to meet the objectives set

At the same time, the aforementioned regulation of 2019 (Ministerio de Justicia, 2019) was complemented with the Instruction 6/2019 of the Central Bank of Cuba. That regulates the concession of credits to natural persons (not private businesses) for the acquisition of equipment using renewable sources as a support mechanism to accelerate the use of renewable (González Lorente et al., 2020).

In 2021, the government has given new steps promulgating a group of resolutions to enhance the participation of all sectors in renewable energies development

- Resolution 206/2021 by the Ministry of Energy and Mines (Ministerio de Justicia (MINJUS), 2021b) approves the import of photovoltaic systems for natural people.
- Resolution 208/2021 by the Ministry of Energy and Mines (Ministerio de Justicia (MINJUS) 2021a) approves the import of equipment, their parts and pieces that generate or they work as renewable sources of energy.
- Resolution 319/2021 by the Ministry of Finances and Prices (Ministerio de Justicia (MINJUS), 2021c) exempts the payment from the tariffs of customs to natural people, for the import without the commercial character of solar photovoltaic systems and their parts and fundamental pieces.
- Resolution 223/2021 by the Ministry of Finances and Prices (Ministerio de Justicia (MINJUS) 2021c) authorizes fiscal benefits to the companies of completely foreign capital that execute projects of electricity generation with renewable sources of energy.
- Resolution 322/2021 by the Ministry of Finances and Prices (Ministerio de Justicia (MINJUS) 2021a) exempts natural persons from payment of customs duties for non-commercial imports of certain equipment using renewable energy sources.

For the future, the forecasts indicate that starting from the increase of the use of renewable sources of energy, Cuba could substitute annually 2.3 million tons of fossil fuel in the electric generation, to what would be added 0.7 million tons for actions and installation of technologies of energy efficiency. That would indicate an annual reduction of eight million tons in the emissions of CO_2 to the atmosphere Click or tap here to enter text.Energy situation in Cuba and the Covid-19 pandemic

The crisis caused by the COVID-19 pandemic has forced governments around the world to take forceful measures to limit people-to-people contact. Although these measures differ from country to country, their implementation has led to and is leading to a reduction in the volume of activity in

a large number of sectors, as well as a change in people's social habits, with effects in general negatively in the economy of the countries (Sánchez Úbeda et al., 2021).
The electricity system is one of the most affected since when people remain in their houses in confinement they consume more electrical energy and consequently its generation increases.
Cuba's electricity system is going through a tense stage, marked by the failure of several high-generation thermoelectric plants and the lack of fuel. In addition, the Covid-10 pandemic has severe effects on the Cuban economy and the possibilities for investments. The process of generating electricity in Cuba is very expensive. Cuba is making an enormous effort to maintain electricity generation in the midst of the difficult economic situation that the world and the country are going through, exacerbated by the Covid-19 pandemic (Alonso Falcón et al., 2021).
The electricity generation situation in Cuba has been affected in 2021 in many ways and there have been several changes in the system operation. About 40.6% of the generation is produced in thermoelectric plants, 21.7% with fuel oil engines, and 21.9% with diesel engines. These last two technologies, in distributed generation sites, are installed in all the provinces of the country. Today, almost 8% of electricity is produced with the accompanying gas of oil production, 5% comes from renewable energy sources (water, sun and wind), and the remaining 3% is produced in floating units located in the Mariel (patanas) using oil (Alonso Falcón et al., 2021).
Since June 21, 2021, the national electricity service has been affected, caused by the low availability of generation capacities in the national electricity system. In the midst of all the severe economic situations investments are needed also for fuel and power plant maintenance, which have a significant impact on the economy. Of the scarce resources available, money needs to be allocated to electricity generation (Alonso Falcón et al., 2021)
The operating reserves of the electricity system are low and on occasions they have been below what is required to cover the energy demand of consumers, making an unavoidable impact on necessary electricity service. In the case of the Cuban electricity system, this required reserve must be equal to or greater than 500 MW to be able to meet any unforeseen contingency or maintenance needs for high-power generating units (Alonso Falcón et al., 2021).
In Cuba, there are eight thermoelectric plants with a total of 20 blocks in operation. These condensing power plants constitute the most important part of the base-load generation of the electrical system. The useful life of a thermoelectric plant is between 30 and 35 years. In the Cuban case, except for the two Felton blocks, which have been synchronized in the electricity grid for 25 and 21 years, the others have been operating for more than 30 years and seven of them have been operating for more than 40 years (Alonso Falcón et al., 2021).
"The thermoelectric plants, which are the base generation of the system, are assisted by the distributed generation groups: the fuel oil generators and the diesel engines installed in all the provinces. The generation with fuel in engines is part of the base generation of the system, while the generation with diesel is used to cover the peaks of maximum demand and cover the demand when there are breakdowns or maintenance of higher power units in the base generation", explained the Minister of Energy and Mines Liván Arronte Cruz (Alonso Falcón et al., 2021).

The limitations in acquiring the materials, supplies and spare parts of the generating units and the engines of distributed generation of fuel oil and diesel, have caused the reduction of the technical availability of these technologies and, therefore, the low reserve levels. Due to the emergency exit of the units that are in operation, there is a generation deficit resulting in annoying blackouts in cities and towns.

Edier Guzmán Pacheco, director of thermal generation at Electric Union (UNE), pointed out that the installed power in the thermal blocks is 2,608 MW, distributed in eight thermoelectric plants. In total, there are 20 generation blocks, of various technologies or manufacturers, including the new Mariel block. They are divided into 10 blocks from the former Soviet Union, two Japanese blocks, Hitachi brand; six blocks from former Czechoslovakia and a French block, from Alstom, in the Antonio Guiteras thermoelectric plant. These blocks, from their start-up to the present day, have an average age of 35 years, considering the oldest, Tallapiedra, with 49 years, and block 6 of Mariel, which is completely new (Alonso Falcón et al., 2021).

Another factor that influences the useful life of these facilities is compliance with maintenance cycles and technical rigour during their execution. This work is done considering the criteria of manufacturers, international practices and the experiences of Cuban engineers. Because of the use of Cuban crude oil, with between 7 and 8% sulfur, the maintenance cycles of the power plants must be shortened. Therefore, maintenance stops are now more frequent due to aggressive corrosion inside the boilers caused by sulfuric acid (Alonso Falcón et al., 2021).

Normally, the maintenance stops, planned shutdowns of 50 to 70 days annually, are planned for each block. These different maintenance types are scheduled between two to three of a light type, of 10 days each, and one of the partial or extended partial type, of 20 to 30 days.

Meanwhile, capital maintenance is planned every five years. These involve the main equipment and can last between 100 and 150 days, although they can be extended to eight months, depending on the conditions of the block.

These capital maintenances are very expensive and are in the order of between 40 and 80 million pesos, depending on the scope to be determined and the conditions of the block. When it is necessary to include the modernization and the change of the automatic control systems or many of the aggregates of the boilers and high-pressure pipes of special steels, the maintenance is expensive.

For a block to be considered in a maintenance cycle, a term used to declare that it is in optimal conditions for operation or use, it is not enough that capital maintenance has been carried out, but rather light maintenance and maintenance is necessarily partial.

Guzmán Pacheco reported that, of the 20 existing blocks in the country, 18 are out of the light and partial maintenance cycle, and 16 are out of capital maintenance cycles. Some even have more than two cycles of delay in the latter (Alonso Falcón et al., 2021).

The covid pandemic also impacted the termination of investments. We worked without the foreign technical assistance that normally participates in the start-up processes. Work was done by videoconference, although it does not replace the face-to-face and mechanical assembly adjustments carried out by specialized personnel (Alonso Falcón et al., 2021).

The complex situation of the country at the end of 2020 meant that, in February 2021, based on new analyzes and studies by specialists from the National Electricity Union (UNE) and different universities, it was decided to modify the proposed goal in the policy designed in 2014. As a result, the objective of reaching 24% of electricity generation with renewable energy sources in 2030 was modified by the goal of 37% of electricity generation with renewable energy sources in 2030. According to experts, that goal can be achieved by increasing the participation of solar photovoltaic up to 2000 MW and increasing the participation of bioenergy, with the use not only of sugarcane biomass but also with forest biomass (with the promotion of forests and energy crops) (Extremera San Martín, 2021).

On October 15, 2021, the National Innovation Council, a consultative body of the state that assists the President of the Republic, aimed at recommending decisions to promote innovation in the operation of the state, the government, the economy, and the society of coordinated and integrated way, analyzed the energy issue. At this meeting, when assessing the current state of investments in renewable energy sources, the Minister of Energy and Mines reported that currently, the implementation of the policy designed in 2014 is 40% behind. "We should have 506 MW in operation, but we have 302.6 MW", said the minister (Tamayo, 2021).

In the analysis, the President of the Republic explained that electricity generation from renewable energy sources involves conceptual, structural elements. He added that these are closely linked to sovereignty, the economy, the social, and the environment referring to the country's electro-energy development strategy. In the same way, he considered that achieving 100% of electricity generation from renewable energy sources is the strategic solution to which the Island is committed to achieving its sovereignty in an aspect that is transversal to all areas. “For Cuba to achieve one hundred per cent of electricity generation from the renewable energy sources, integrating them all, although keeping fossil fuel generation capacities in reserve, it is possible”, emphasized Díaz-Canel (Tamayo, 2021).

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II. Politics

II.1. Cuba's role in global power politics. Geopolitical and geoeconomic perspectives.

Jasmin Laitinen, Jari Kaivo-oja and Jyrki Luukkanen

This paper focuses on Cuba and its position in the world through the means of geopolitics and geoeconomics. These two concepts are used to describe the current international political dimensions and how different nations attempt to control their position within global power politics. This article will take a closer look at the phenomenon through dependency theory.

Geopolitics and geoeconomics

Geopolitics is not a new phenomenon. The official term "geopolitics" was first used by Rudolf Kjellén in 1899 (Dodds and Atkinson, 2000). Cowen and Smith (2009) posed the idea that geopolitics played a role in nation-building in Europe as early as in the 19th century (Cowen and Smith, 2009). Geopolitics as a concept has gone through many different stages throughout history and thus its past can be viewed as controversial. Its roots lie in European imperialism but geopolitics has emerged all over the world in different political contexts. David Livingstone (1992) highlighted the plurality of geopolitics and concluded that there is no singular geopolitical tradition. According to him, it is important to recognize the different geopolitical variants that have been constructed in different places and time periods. (Livingstone, 2000).

Geopolitics has always been related to energy economy and energy policy whether it can be considered renewable or none renewable energy. Energy geopolitics has primarily centred around fossil fuels throughout history due to their wide usage. Scholten (2018) specified that oil, coal and natural gas were the most used energy resources in the world in 2014, making up 86% of the entire energy mix. Renewable energy sources covered only a small proportion of the world's energy usage. (Scholten, 2018). Trend analyses indicate that electricity production and consumption developments are in transition process in China, in the USA and European Union. These regions are major players in global climate change and climate policy. Especially China is now a global trendsetter in climate change and climate policy. Upwards sloping trends were evident in the Chinese energy economy. However, the U.S. and the EU are still very important players. The structures of electricity production and energy mixes are changing. Global benchmarking studies indicate that the role of renewables is increasing in electricity production and the role of oil-based electricity production has drastically decreased. The "Golden age" of nuclear energy in electricity production seems to be over: at least, turning points can be found in recent global trend developments. (see e.g. Kaivo-oja et al. 2016).

In the Global Energy Review 2021, it can be seen that coal and natural gas demands are still increasing while the demand for oil did not reach as high as it was previously expected (6% increase). Despite this, the CO_2 emissions remained high, making the 2021 increase the second largest in history. (IEA, 2021) Thus, we can conclude that fossil fuels are still a big part of the nations' energy usage. However, the Review did highlight the fact that renewable energy sources are growing in every industry and are expected to grow even more in the upcoming years.

Edward Luttwak was the one to define geoeconomics for the first time in 1990. Instead of geopolitics, Luttwak shifted the focus to economics and markets. At the core of his geoeconomics is the idea of globalization and the formation of a global market that affects the nation-states and how they behave. (Cowen and Smith, 2009) Geoeconomics has traditionally been seen as a tool for geopolitics and another form of hard power. However, in order to properly examine economic geostrategies, it is important to approach geopolitics and geoeconomics separately. In this article, we'll use a framework created by Wigell and Vihmas (2016) to make a distinction between the two. In general, geopolitics can be seen as power politics through more confrontational means. This can be done through more overt foreign policy or military means for example. Geoeconomics on the other hand is less direct and can appear as a more subtle way to practise power politics. However, this doesn't automatically mean one is more effective than the other. Both can be considered as geostrategies but their focus is on different means. Countries usually do not stick with just one geostrategy and it is common for a country to practise both geopolitics and geoeconomics. The table below serves as a visual aid to highlight the differences between geopolitics and geoeconomics. (Wigell and Vihmas, 2016)

Table 1. Contrasting traditional geopolitics with geoeconomics (Wigell and Vihmas, 2016)

	Geopolitics	**Geoeconomics**
Operational (agent):		
Means	Military	Economic
Visibility	Overt	Covert
Logic	Confrontation	Selective accommodation
Effects (target):		
Threat perception	High	Low/medium
Action-reaction force	Centripetal	Centrifucal
Behavioural tendency	Counterbalancing bandwagoning	Underbalancing

Table 1 above explains that geopolitics and geoeconomics are by nature very different. Geopolitics focuses on military means and geoeconomics economic means. This explains their different qualities. When it comes to visibility, geopolitics tends to be more overt and geoeconomics covert. For example, a military operation is a lot harder to hide and can be seen as a very bold move while geoeconomic strategies can be masked a lot easier. Geoeconomics is not always embargos or sanctions; it can also be about building economic relations with other countries in the form of loans for example ("sticks" and "carrots"). This can create dependency and dependency makes countries more vulnerable to outside forces. Yet, these relationships can easily come off as mutually beneficial. This makes geoeconomics covert, subtle and they can be implemented in a variety of contexts and situations. By logic, geopolitics on the other hand is all about confrontation and creating a sense of threat. This can cause a strong reaction in the target country that often manifests itself as people viewing the threatening state as a common enemy. The threatened state will try to balance the situation by reacting to the aggressive state's advances. With geoeconomics, the situation is a little bit different. Since economic relations will automatically benefit parts of the country's population, the dependency can be brushed off and downplayed by certain groups of people. The reaction geoeconomic strategies create in the target country can thus vary and will most likely not be as unified as in the case of geopolitics. This fragmentation of opinions in the target country might also form instability at the local political level. (Wigell and Vihmas, 2016).

To sum up, geopolitics usually refers to countries, country groups and relations between them. Topics of geopolitics include (1) relations between the interests of international political actors focused within an area, a space, or a geographical element, and (2) relations that create a geopolitical system. For example, some authors have paid attention to petroleum geopolitics. They have noted often, that the importance of oil and gas for the finances and international relations of states is unquestionable. Export and export of energy products and other products is a geopolitical issue (Overland 2015). Oil and gas are the backbones of the economies of many petroleum-exporting countries, underpinning the foreign policies of countries such as Russia, Saudi Arabia, and Venezuela (Orttung and Overland, 2011). Many authors of recent environmental energy and climate policy studies have found that fair adaptation to climate change is a geopolitical question and fair adaptation is not happening without political and economic tensions. Climate adaptation research is expanding rapidly within an increasingly reflexive society, where the relationship between academia and other social institutions is in a state of flux. Scientific tensions exist between the two dominant research orientations of research about and research for adaptation. The academic research community is challenged to develop processes for successfully executing transdisciplinary research for adaptation when academic institutions and researchers are largely structured around traditional, disciplinary expertise and funding models. We need more reflexive, orientation toward adaptation research that is emerging in the literature. (Preston et al. 2015)

The key justice dilemmas of adaptation include (1) responsibility for climate change impacts, (2) the level and burden-sharing of assistance to vulnerable countries for adaptation, (3) distribution of assistance between recipient countries and (4) adaptation measures, and (5) fair participation in planning and in decision-making on adaptation. The current climate change regime largely omits responsibility but makes a general commitment to assistance. In many cases, the regime has so far failed to operationalise assistance and has made only minor progress towards eliminating obstacles for fair participation. The geopolitical changes one expects from unconventional oil and gas and climate policy depends on how one understands the current geopolitical situation in various parts of the world, and how strong the current geopolitical competition is seen to be (Paavola and Adger, 2006). In the Cuban energy and climate policy case the questions of fair adaptation are highly relevant, just because Cuba is an island state.

It is good to know that The European Commission states in its new policy statement that it will continue to actively mainstream climate resilience considerations in all relevant policy fields. The European Commission (2021) has noted that it will support the further development and implementation of adaptation strategies and plans at all levels of governance with three cross-cutting priorities: (1) integrating adaptation into macro-fiscal policy, (2) nature-based solutions for adaptation and (3) local adaptation action.

Geopolitics may also focus on two other kinds of states: de facto independent states with limited international recognition and relations between sub-national geopolitical entities. In this article, we discuss the special case of Cuba, which has always faced the hard realities of geopolitics and geoeconomics. At the level of international relations, geopolitics is a methodology of studying foreign policy to understand, explain, and predict international political behaviour through changing geographical variables. Geopolitics focuses on political power linked to geographic space. This is also a basic approach we adopt in this article.

One example of geoeconomics is China's use of geoeconomic strategies in its foreign policy. The nation has spread its influence all across different continents with the help of economic means. One such area is Central Asia. China has increased its influence in the region by loaning countries such as Kyrgyzstan 1,8 billion dollars. Loaning money can be a form of geoeconomic binding and constraining. (Tshkay, 2021) Especially constraining is a very effective tool of geoeconomics (Papic 2021). By using this strategy, the state is able to connect the target country closer to its own sphere of influence, making it more dependent on the provided capital and business opportunities. This can grant the country long-term benefits such as a political advantage in the target country. In addition, the more political power the state gains in the target country, the easier it is for the state to prevent the target country from forming other economic relationships with other states. This geoeconomic strategy is called wedging. By using both binding and wedging, the target country can be completely isolated from other economic policy options and thus starts to become heavily dependent on the only option it has. It can be argued that this is the case with China and the Central Asian countries. (Tshkay, 2021)

As mentioned above, geoeconomic strategies can work on a global level. Next, we are going to look at dependency theory that will highlight the dysfunctionality of the potential issues that come with economic dependency if implemented in an exploitative way and on a larger scale.

Cuban geopolitics and geoeconomics

Geopolitics and geoeconomics provide a framework for analysis of the role of Cuba in international power politics. Next, we shortly reflect on contrasting traditional geopolitics with geoeconomics based on the framework by Wigel and Vihmas (2016) in the special case of Cuba (see Table 2).

Cuban military forces are limited to defence operations and do not constitute a big threat to other countries, but is under continuous threat of interventions from the U.S. For example, the Guantanamo military base on the Cuban island has a function of hard power instrument of geopolitics. The military power index of the Cuban military is ranked 70/140 (GFP 2022).

Table. 2. Geopolitical and geoeconomic challenges and opportunities for Cuba.

	Geopolitics	**Geoeconomics**
Operational (agent):		
Means	Military: Limited military power	Economic: US-Cuba embargo, rise of China, EU collaboration
Visibility	Overt: Blockade	Covert: New trade partnerships, bi-lateral networking
Logic	Confrontation: US	Selective accommodation: China, EU countries, ECLAC
Effects (target):		
Threat perception	High: US	Low/medium: Other countries
Action-reaction force	Centripetal: ALBA	Centrifugal: Blockade
Behavioural tendency	Counterbalancing/ Bandwagoning: US	Underbalancing: Economic restructuring, new ownership structures

Our analysis in this article was focused on the geoeconomics of Cuba. Our basic hypothesis was linked to dependency theory and we got support to basic hypotheses of the theory. The U.S. embargo provides strong evidence to the dependency hypothesis. The economic dependency was earlier linked to the relations to the Soviet Union and Eastern Europe but now there are various signals that the role of China is going to be stronger in the future based on the trade relations. This will, no doubt, change the Cuban geoeconomic and geopolitical situation, too. It is difficult to forecast future development in this respect but the scenario tools based on the cross-impact analyses illustrated in this article provide potential development paths in different geopolitical and geoeconomic situations. In comparative terms, our analysis reveals that space for manoeuvring is the largest for Cuba in the Pan American Renaissance scenario among the analysed scenarios.

The visibility dimension is linked to the logic of the strategic priorities of geoeconomics and geopolitics. The cross-impact analyses show that the space of strategic leverage for Cuba is quite limited because of the current global geopolitics. It seems that U.S. politics is mainly based on tools of wedging while China's strategy is mainly based on tools of binding. The European Union approach to Cuba is emphasizing the multi-bi-lateral approach and geoeconomics. The current blockade policy of the U.S. is directly limiting the Cuban visibility efforts and as a result, the covert strategy dominates Cuban geoeconomics policy.

The U.S. – Cuba relations instantiate the logic of confrontation from the geopolitical perspective including the high threat perception. With other countries, Cuban relations can be seen to reflect selective accommodation logic and low threat perception.

The centripetal forces of geopolitics can be seen in the Cuban case in cooperation with Venezuela and other ALBA countries. The important role of the national heroes in Cuba acts as an example of centripetal forces of geopolitics. The blockade politics form an important field of centrifugal aspects of geoeconomics in the Cuban case.

The behavioural tendency of counterbalancing from the geopolitical perspective, emphasizing unity within the population, can be seen as a result of the conflicting relations with the U.S. The recent local restructuring of the economic structures in Cuba can be seen as an example of underbalancing in the geoeconomic sphere.

Dependency theory

Dependency theory emerged in the mid-1900s. It leaned heavily on the ideas present in Marxist literature (Kohli, 1986) and gained popularity especially in Asia, Africa and Latin America, also known as the Global South. (Smith, 1979) The growth of dependency theory can be seen as a reaction to modernization theories that were popular in the Western world at the time. Modernization theories approached the development (or the underdevelopment) of the Global South from the states' point of view. They underlined that political structures and cultural characteristic were the key aspects as to why the Global South could not keep up with the developing North. Dependency theories rejected this approach and started to form their own understanding of development. Just as Karl Marx viewed the capitalist society as exploitative and favoured the factory owners over the regular workers, dependency theories started to view the global economic and political order as unjust. Dependency theories put emphasis on the historical aspects of the world politics and economics. Colonialism in particular is seen as a determining factor as to how the country is placed in the world economic order. Countries with the colonial past tend to have formed societal structures that benefitted the colonizing power. And thus, resources and capital streamed from the Global South to the Global North. Dependency theories view these kinds of structures in the global economic dimension as unequal and they function as an explanation to the differences in development between the Global North and South. (Kufakurinani, 2017)

A street sign about the US blockade, Havana

Example of continued dependency in practice: U.S. – Cuba embargo

One of the most central geopolitical issues in Cuba has been the embargo policies of the US. The ECLAC estimates are indicating that the United States' decades-long trade embargo on Cuba has cost the island more than US$130 billion in economic loss, according to a financial estimate by the Economic Commission for Latin America and the Caribbean (ECLAC). Eighty per cent of Cuba's residents have lived all their lives under the sanctions stated, has been noted by Alicia Barcena, Executive Secretary of the Economic Commission for Latin America and the Caribbean (ECLAC) (see Ammachchi, 2018). The ECLAC has insisted on the need to move toward a new development pattern that allows for achieving a virtuous circle between growth, equality, and sustainability for present and future generations. From this perspective of the ECLAC, Cuba has been the champion country of sustainable development in the region of Latin America.

Alicia Barcena has also highlighted Cuba's great resilience; despite being subjected for more than 60 years to the largest series of sanctions that the United States has applied to any country in the world. It is possible to note that Cuba is the most punished state by the United States and in 64 years, those economic measures have caused damages amounting to 147 billion dollars: five per cent of the island's GDP (CubaSi, 2022). This has been a very big human cost for Cuba and for the Caribbean region too. Over the past few years, the UN has often adopted a non-binding resolution calling for an end to the embargo imposed by the United States. In the United Nations, US, Israel, and Brazil have been against the UN resolution calling.

There have been some updated analyses concerning the Cuban embargo. Jacob Rob has recently studied the Cuban situation in his senior thesis (Rob, 2021). Rob (2021) has noted that the Cuban embargo is the product of a long history of coercive, self-interested policy borne out of the tensions of the Cold War. Even as the U.S. governance has endeavoured to move past the Cold War, the economic embargo has remained; today it exists not merely as a relic of the era, but rather as the cornerstone of U.S. foreign policy towards Cuba. This issue has been a politically very sensitive issue in the U.S.

Given the embargo's ineffectiveness and its heavy costs upon Cubans and Americans alike, accumulated costs seem inexplicable. There are many obvious needs to solve the US-Cuba trade policy paradox and chart a path towards dismantling the embargo and creating a US-Cuba policy that is more effective and better serves both U.S. and Cuba interests. There is a need to gather an unbiased and comprehensive understanding of the US-Cuba policy situation.

A recent very important study of Rob (2021) for the Biden administration draws upon a broad collection of government publications, peer-reviewed scholarly literature, news sources, and primary sources. The Princeton University research reveals that the embargo originated from Cold War concerns over economic interests and regional influence and has since been perpetuated by hardline. According to this research report Cuban American lobbyists, who have outperformed and thus outweighed the anti-embargo influence of the agribusiness lobby and international pressure. Having established these salient factors, a reassessment of their current status indicates that the dynamic is shifting in favour of dismantling the embargo and normalizing relations. Undeniably, the US-Cuba embargo has had a failed policy model for over six decades. It has failed to dismantle the

Cuban regime yet inflicts heavy costs on the people of both Cuba and the U.S. Broad-scale human suffering has been caused. While this has not generated strong opposition to date, the costs to the U.S. are beginning to mount: (1) the embargo limits agribusiness profits, (2) erodes U.S. international standing, and (3) undermines the U.S.' regional hegemony by enabling China and Russia to establish a Latin American foothold within Cuba. This is the message to Biden´s administration of Rob´s study (2021). With the politics of the pandemic rendering Americans more sympathetic to the Cuban people's plight, and the funding of the Cuban American lobby — and therefore influence — faltering in recent years, we can see how problems, politics and policies are converging to produce what Kingdon (1984) in his book "Agendas, Alternatives and Public Policies" proffered as the quintessential "policy window" to change the status quo of U.S.-Cuba relations.

In the U.S. due to the Democrats' slim congressional majority, and Senator Menendez's support for the embargo, removing the embargo in toto remains unrealistic. However, the Biden administration could capitalize upon to achieve significant policy change through executive as well as more limited legislative action. In the U.S. Senate, Senator Boozman has expressed support for anti-embargo legislation that benefits agribusiness by targeting the Trade Sanctions Reform and Export Enhancement Act of 2000 (TSRA). (Rob, 2021)

Rob (2021) suggests three steps suggests for President Biden to take: (1) In the first nine months, the administration should inform the U.S. citizenry of the embargo's problematic nature and reengage Cuba diplomatically to foster goodwill and negotiate grounds on which anti-embargo policy would be implemented; (2) President Biden ought to restore the Cuban Assets Control Regulations and the Export Administration Regulations regarding Cuba to their status on January 20th, 2017; and (3) President Biden should promote legislation to amend the TSRA to remove the restrictions on agricultural exports. Through these measures, the Biden administration could take significant strides towards dismantling the embargo and normalizing relations (Rob, 2021).

In the geopolitical situation of the US-Cuba embargo, there is political momentum for the Biden administration. As an analysis of the study by Rob (2021), it can be summarized that the U.S. Senate is experiencing complex inner tensions in relation to the politics towards Cuba. Generally, conflicts in domestic political arenas have decisive impacts on foreign policymaking. Political speculation may destroy even rational decisions in this case. Lobbying forces are very often having impacts on critical decision-making. Domestic political agendas have direct impacts on foreign policy formulations. Although the principles of the global trading system have been agreed upon in the WTO agreements (trade without discrimination, free trade, predictability and transparency) it can easily be observed that the U.S. – Cuba embargo does not follow the said WTO agreements (WTO, 2022).

The U.S. blockade on Cuba is a case study example of long-term dependency continuing for more than 60 years. The blockade policy, a relic from the Cold War period, has radiated to the Caribbean region and worldwide. It remains to be seen how the increase of Chinese impact in the Latin American and the Caribbean region will change the geoeconomics and geopolitical situation. This aspect will be elaborated on in the following sections.

A cruise ship visiting Havana during the Obama Administration

Tourism constrained by dependency and blockade

One of the most affected economic fields suffering from the U.S. blockade is the tourism and hospitality sector. The growth of Caribbean tourism outside Cuba is partly a post-Cuban revolution phenomenon. After the Cuban revolution succeeded in taking power in 1959 and started nationalizing US assets in Cuba. After this event, the US imposed the economic embargo on Cuba in 1960 and imposed travel restrictions on the island in 1963. This political decision closed US tourism to one of the preferred Caribbean destinations of US travellers. Cuba received almost half of all tourist arrivals to the Caribbean; however, by 1980 Cuba had less than 3 per cent of the market compared to the same set of countries. Recent research work by Acevedo et al (2016, 2017) shows that countries in the region should not fear the loss of US flights once the US allows tourism to Cuba. Their results indicate that changes in US-Cuba flights (there were some 4,000 flights between the US and Cuba in 2014) do not have a negative impact on the availability of US flights to other Caribbean destinations. Their analysis leads them to conclude that the provision of airlift to the region is not a zero-sum game, where one destination's gain is another one's loss, and hence an orderly and gradual US-Cuba opening up should not affect the vital airlift services on which all Caribbean destinations depend for their tourism exports (see Romeu, 2008; Romeu, 2014; Laframboise et al., 2014).

In 2017, International Monetary Fund experts have estimated and showed that liberalizing US-Cuba tourism could result in US arrivals to Cuba of between 3 and 5.6 million, most of it coming from new tourists to the region (Acevedo Mejia, 2017). The trade restriction of Cuban tourism, hospitality and experience cluster has been one considerable negative impact of the US-Cuba embargo policy and shows the big power of geoeconomics and geopolitical measures. It is encouraging that the region is actively addressing some of these challenges. In the Caribbean region, the tourism authorities and local hoteliers are proactively embarking on efforts to enhance their tourism product by tapping into new markets; developing new products; promoting investment; building new partnerships, and; developing human capital (Acevedo et al., 2017, p. 17).

Recent economic analyses show that the Caribbean dependence on the US market is large, and while this dependence is understandable in terms of the proximity and size of the US national market, a diversification strategy that targets other advanced economies and large emerging markets in Latin America would be beneficial for Cuba and other Caribbean countries. Improving the competitiveness of the tourism and hospitality sector and its services will be crucial, and improving quality and reducing costs will help countries compete with a low-cost provider as Cuba. Finally, thinking of regional strategies to facilitate intra-regional travel would help bring the possibility of multi-destination vacations, which is an interesting option for Cuba, too. This would help the rest of the Caribbean to benefit from the new tourists that will start visiting the region when the US opens up free travel to Cuba. Finding win-win geoeconomics solutions and geopolitical win-win solutions is a very important policy target for Cuba.

This activity indicates, in practice, that the Cuban tourism, hospitality, and experience cluster has substituted US tourism flows with tourism flows from other countries (for example Canada) and other regions (for example Europe). It is obvious that the Cuban economy has not reached the full potential of its business opportunities and financial revenue flows.

The long and difficult journey towards normalizing US-Cuban relations began in December 2014 with the relaxation of economic sanctions by President Obama. What does this mean for the future of Cuba? Will normalization bring transition towards a market economy and political pluralism, or merely relieve economic hardship and strengthen an authoritarian regime?

Cuba and its population of 12 million were not able to follow the route of Eastern Europe in the 1990s. It has neither a West Germany willing to pay a high price for reunification, nor a European Union ready to embrace the reformed economy. Cuba is not a large resource-rich country that can sustain an oligarchy of privatized-enterprise tycoons, nor a cohort of high-level bureaucrats in exporting state monopolies. For Cuba, Vietnam might be a more plausible model, but its experience with export-oriented industrial parks and returning émigrés tells cautionary tales. From this perspective, Cuba is likely to chart its own course. The country's resilience and capacity to adapt make sudden regime collapse unlikely. We can expect that gradual, market-oriented reforms and slow political liberalization are more probable, though judicious external support could speed the pace of change. Cuba is one of the three Latin American countries in the UNDP "very high Human Development" Index (HDI), just below Chile and above Argentina, surpassing Uruguay, Costa Rica and Panama. It is good to note that Cuba's per capita income is about half of what it is in those countries. (see Sagasti, 2015).

Cuba- EU- cooperation

The relationship between Cuba and the European Union (EU) has been transitioning towards a more open diplomatic direction since the early 2000s. Political Dialogue and Cooperation Agreement (PDCA) was established in 2017, which is the basis of the current cooperation between these two actors. PDCA focuses on political dimensions as well as trade. Cuba and the EU both highlight the importance of bilateral cooperation as well as the strong presence of the United Nations (UN) in global politics. These diplomatic relations are supported by all 28 member states of the EU. (EEAS, 2017)

When it comes to trade and exports, the EU is the biggest partnering actor for Cuba. It is also heavily involved in the investments and tourism sectors. The aim of the cooperation is to create stable and predictable markets as well as opportunities for diversification for Cuba. (EEAS, 2017)

Among PDCA, the EU also practices development cooperation towards Cuba. This includes funding different programs that usually relate to sustainable agriculture, food security, modernization of the economy, renewable energy and climate change. (EEAS, 2017)

Despite some open-ended questions in regards to human rights, the EU sees the relationship with Cuba as a positive and still developing form of cooperation. With the absence of the US in the region, the EU sees this as an opportunity to deepen their bilateral relations and the opening of the Cuban state. (Engstrom and Bonacquisti, 2018)

China and Latin American Silk Road

The vacuum left by the commercial and investment withdrawal of the United States (US) from the Latin American region and its protectionist policy has been exploited by China, a country that invested more than 99 billion dollars in 2014 and whose trade with the region has grown exponentially over the past decade, currently exceeding 300 billion dollars in 2019. China is willing to strengthen ties with Latin American countries, thereby eroding US geopolitical hegemony in the region. This ambitious project, also called the "Belt and Road Initiative" (BRI), has already been signed by more than 90 countries around the world, especially in Asia, Africa, and Eastern Europe. According to the World Bank, it concentrates 30% of world GDP, 62% of the planet's population, and 75% of global energy reserves. (Ángel and Bayardo, 2019). There is maybe no need to underline the polarised views of Sino–LAC relations that are prevalent in much of the literature by carrying out a detailed analysis of recent trends.

According to the IMF Study (Dong et al., 2021), Chinese FDI outflows have surged in the past two decades from negligible levels in the early 2000s to US$140-200 billion a year since 2015. According to the official data published by MOFCOM, Asia remains the primary destination of Chinese FDI, while only a small share of Chinese FDI goes to LAC. In 2019, LAC attracted US$6.4 billion FDI from China, accounting for 5 per cent of China's total outward FDI. Out of this total, US$4.3 billion were registered as outflows to offshore financial centres (OFCs) in the Caribbean, including Cayman Islands, British Virgin Island, and The Bahamas, which in most cases were not the final destination of the FDI. The future of the China-LAC investment linkage will also be affected by the long-term

The effects of the COVID-19 pandemic, which have severely impacted flows of FDI due to the sudden disruption of global supply chains, demand contractions, and delayed investment owing to heightened economic uncertainty. Global FDI flows are estimated to have fallen by 42 per cent to US$859 billion in 2020 and are expected to remain weak in the near term. In terms of geographical distribution, the decline in 2020 was concentrated in developed economies, where FDI inflows fell by 69 per cent. While all sectors have been affected, demand cycles, such as airlines, hotels, restaurants, and leisure, as well as manufacturing industries and the energy sector have experienced the largest declines. Going forward, UNCTAD expects any increases in global FDI flows in 2021 to come not from new investment in productive assets but from cross-border mergers and acquisitions, especially in technology and healthcare. (Ding 2021:22; UNCTAD, 2021).

In LAC alone, China has set up three regional funds since 2015 to back up its investment in LAC: the China-LAC Industrial Cooperation Investment Fund (CLAI Fund) with a size of US$30 billion; the China-LAC Cooperation Fund (CLAC Fund) of US$10 billion; and the Special Loan Program for China-Latin America Infrastructure of US$20 billion (Myers and Ray 2021). A recent study argues that there have not been big changes in China's engagement in Latin America but rather a continuation of existing trends that have been evolving over the past two decades, particularly since the Global Financial Crisis (Jenkins, 2021).

The Digital Silk Road's extension to Latin America has had both advantages and potential risks for states in Latin America and the Caribbean. This political situation analysis is also relevant for Cuba. Originally, the Belt and Road Initiative (BRI) originated from Chinese President Xi Jinping's speech in Astana, Kazakhstan on September 7, 2013, where he referenced a new "Silk Road Economic Belt" that would stretch across Asia and Europe, among other regions. The Western Hemisphere was absent in the early BRI documents. Early DSR plans did not include countries from that region. In May 2017, however, the first Belt and Road Forum for International Cooperation was held in Beijing. Its joint communiqué stated that the BRI was open to other regions, including South America. The invitation for Latin American countries more broadly to join BRI was formalized at the China-Community of Latin American and Caribbean States Forum in January 2018. Chinese Minister of Foreign Affairs Wang Yi discussed the BRI and he said that Latin America would be a "natural extension" of the 21st Century Maritime Silk Road. Since then, BRI and its complementary programs have been opened to Latin American countries. This political agreement was known by its Spanish acronym China-CELAC. China's BRI seeks to improve infrastructure, trade, financial integration, and people-to-people bonds across the world. It has become widely known for its physical infrastructure projects like railways and ports, but there is a digital complement of it as well, called the Digital Silk Road (DSR). (Malena, 2021).

Cuba's position in the world

In this article, we attempt to look at Cuba and its geopolitical position in the world through these concepts.

Cuba has throughout history been heavily connected to the states located in its neighbourhood as well as the international power politics. The country was colonized by Spain in the 16th century and continued being under the control of the United States (US) after the war between the US and the Spaniards in 1898. Cuba gained its independence a few years later in 1902. The US was still heavily involved in the country's business which resulted in The Revolution in 1959, led by Fidel Castro. After the Revolution, the country formed a socialist state that was and still is led by the Cuban Communist Party as a single party. The country had strong connections to the Soviet Union (USSR)

A local bookstore, Havana

during the Cold War period. As the tensions rose between the US and the USSR, Cuba became the centre of attention in the Cuban missile crisis in 1962. After the crisis, Cuba continued its business with the Soviet Union but the relationship was not going to last. At the beginning of the 20th century, the Soviet Union collapsed which meant that the country's primary companion was no longer able to support them. This was a big setback to the Cuban economy and the country's economy fell into recession. Cuba has since found new partners in Spain, Venezuela, China and other Latin American countries. Cuba's relationship with the US has remained less than friendly throughout the years. The US has, for example, attempted to overthrow the country's socialist government, assassinate the president several times and still maintains the embargo it placed on Cuba during the missile crisis in 1962. During the Obama administration (2009-2014) the relationship between the two countries entered a new era and promises on lessening the embargo were made. Obama administration also lifted some of the travelling restrictions to Cuba and allowed the Cubans immigrants living in the US to send money to Cuba. All of this was reversed by the Trump administration between 2017 and 2021. The new Biden administration (2021-) has made little to no changes to the situation.

Geoeconomics of trade

If we look at Cuban history, we can see clear patterns of dependency. Being a colonial state, it provided Spain with sugar and tobacco especially and it was deployed to be part of the slave trade by taking in slaves from Africa. After its independence, Cuba formed a relationship with the USSR, which largely consisted of Cuba exporting sugar to Europe and the USSR sending infrastructure and processed products to Cuba. Thus far, the Cuban economy had been producing very few products for a few partnering countries. This made it dependent on the mentioned products like sugar as well as the partnering countries like the USSR. And, when the Soviet Union collapsed Cuba lost its main partnering country as well as the main buyer of sugar at that time. This tells us about the fragile state the country's economy was in. Traces of the past can still be seen in the country's current economic structure. This is illustrated in Figure 1. Tobacco and sugar are still the largest exports for Cuba. Raw materials such as zinc ore, nickel matter and lead ore play a big part in the country's economy as well. Thus, it can be argued that the Cuban economy still displays many of the traits it has obtained over the years that can be traced all the way back to colonial times.

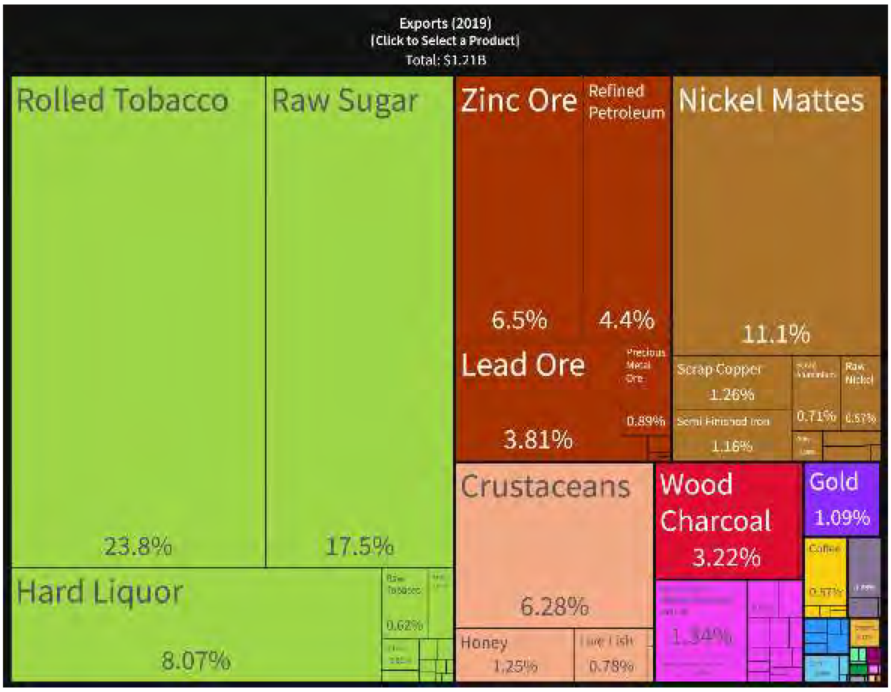


Figure 1. *Cuban export commodities in 2019 (OEC, 2022)*

Figure 2 tells us about the destinations of where the Cuban products are being exported. Most of the exports are sent to Asia and Europe. Spain remains one of the biggest partnering countries for Cuba. The two states have continued their cooperation despite changes in political and economic contexts over the years. However, the largest state to cooperate with Cuba economically is China, taking 38,2% of the Cuban exports. China being an influential actor in this sense isn't a surprise considering its growing economic power all over the world. And due to the US embargo, this has left China more room to establish itself in the Cuban market.

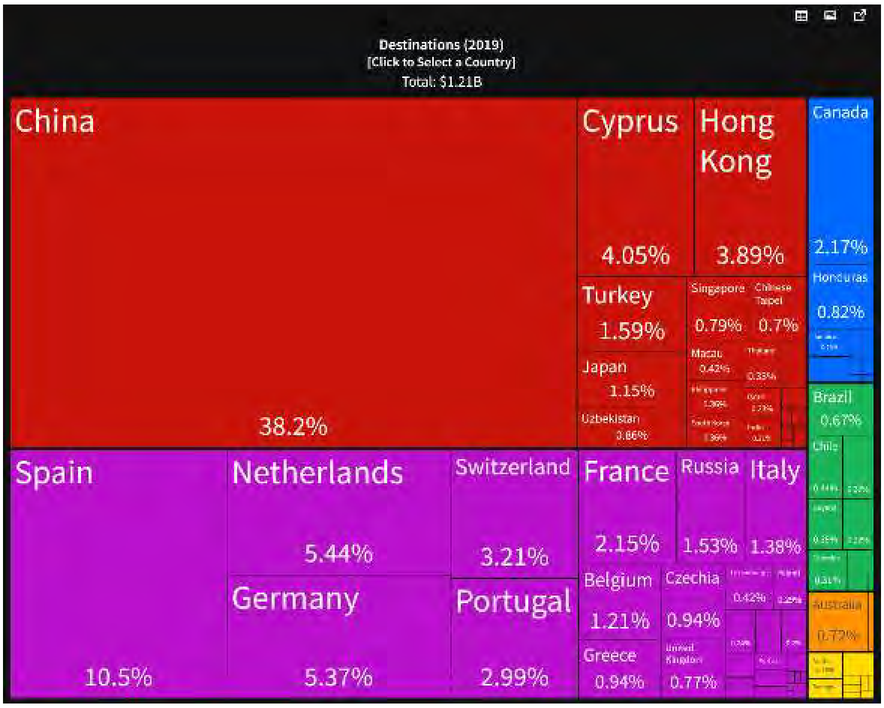


Figure 2. *Cuban export destination in 2019 (OEC, 2022)*

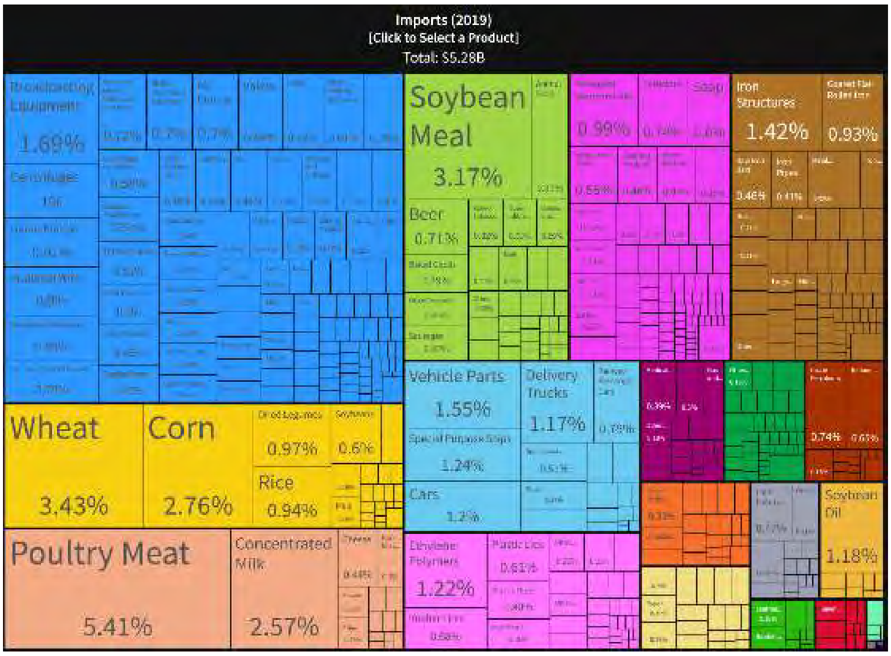


Figure 3. *Cuban import commodities in 2019 (OEC, 2022)*

Figure 3 displays the structure of Cuban imports. According to the table, Cuba is importing different kinds of food and agricultural products into the country. That consists of most of the country's imports. Electrical equipment and components are also one of the major imports to the country. It can be concluded that Cuba imports products that are highly processed and the country itself cannot produce. Food is something the country's population needs to survive and various technological equipment play a key role in the growth, development and well-being of the country. Because of this, it can be argued that the dependency of the Cuban state is tied to these products and getting them from the partnering countries.

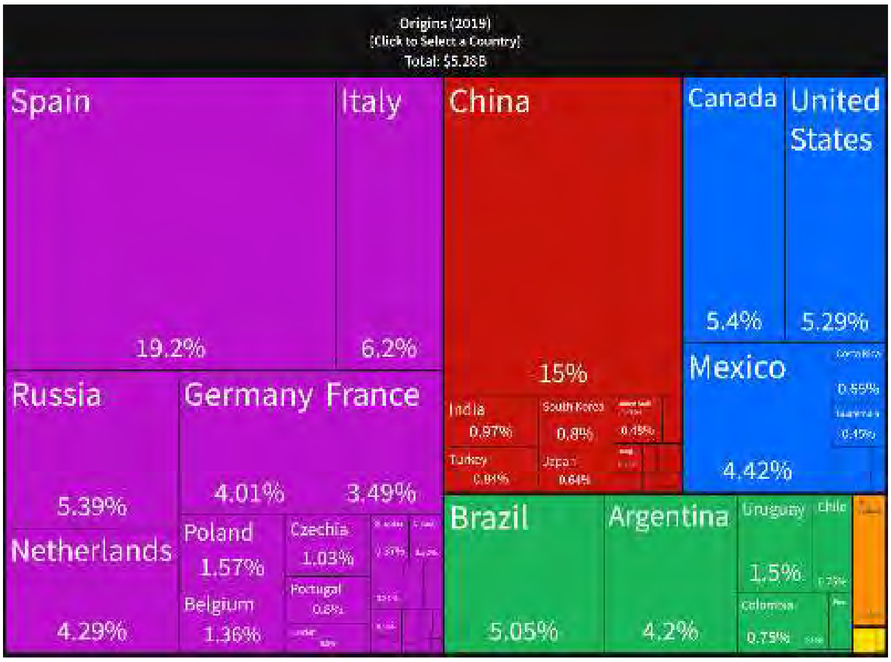


Figure 4. *Cuban origins of imports in 2019 (OEC, 2022).*

Figure 4 illustrates the origins of the products Cuba imports into the country. Like with exports, European partners are responsible for about half of the exports, Spain being the largest partner. China isn't as large in the field of exports but its percentage is still rather significant. Interestingly Cuba does export products from quite a variety of countries even if Spain and China still maintain their positions as the largest partners. The differences between countries aren't as drastic as in Figure 2. It could be argued that this is a good sign when it comes to the country's dependency. If for one reason or another the cooperation with one country ends, Cuba is still more likely to be able to obtain lost products from somewhere else.

Figure 5 illustrates export to Russia and import from Russia in 2000, 2005, 2010, 2015 and 2019.

Figure 5. *Export to Russia and import from Russia in 2000, 2005, 2010, 2015 and 2019. Data source: OEC (2022).*

Figures 6 and 7 illustrate export to Cuba and import from Cuba trade statistics with three key trade partners of Cuba, China, Spain and the Netherlands.

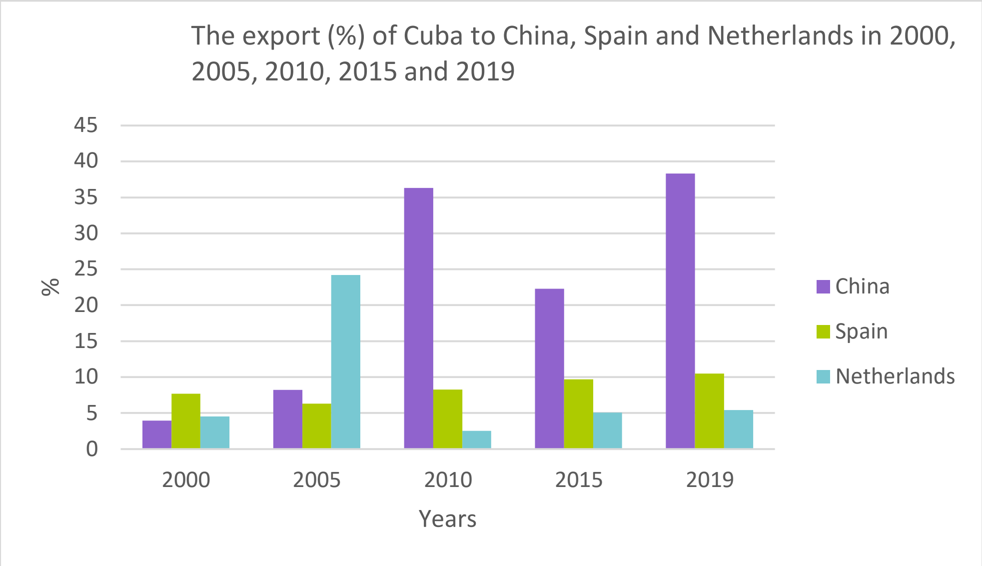


Figure 6. *The export (%) of Cuba to China, Spain and Netherlands in 2000, 2005, 2010, 2015 and 2019. Data source: OEC (2022).*

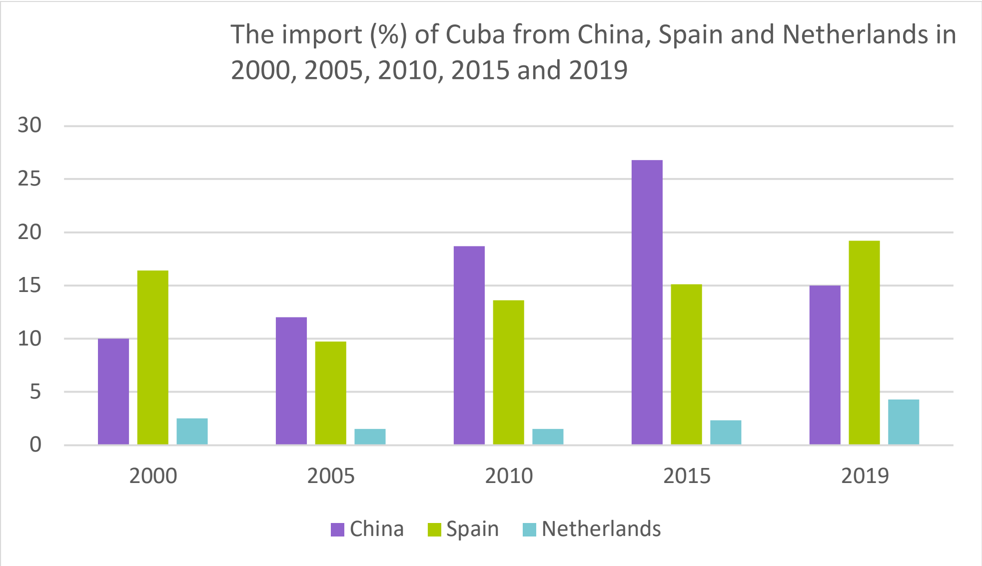


Figure 7. *The import (%) of Cuba to China, Spain and Netherlands in 2000, 2005, 2010, 2015 and 2019. Data source: OEC (2022).*

These three figures inform us about the fact that trade with China has become very important for the Cuban economy. We can clearly note that the geoeconomics of Cuba has changed in recent years. The of China as trade partner has grown in latest in 2000-2019.

Figure 8. *Variance of export and import shares of trade partners of Cuba in 2000, 2005, 2010, 2015 and 2019. Data source: OEC (2022).*

Figure 9 displays the trade structure of the Cuban economy in 2019. The most important trade partners are China, Spain the Netherlands and Germany.

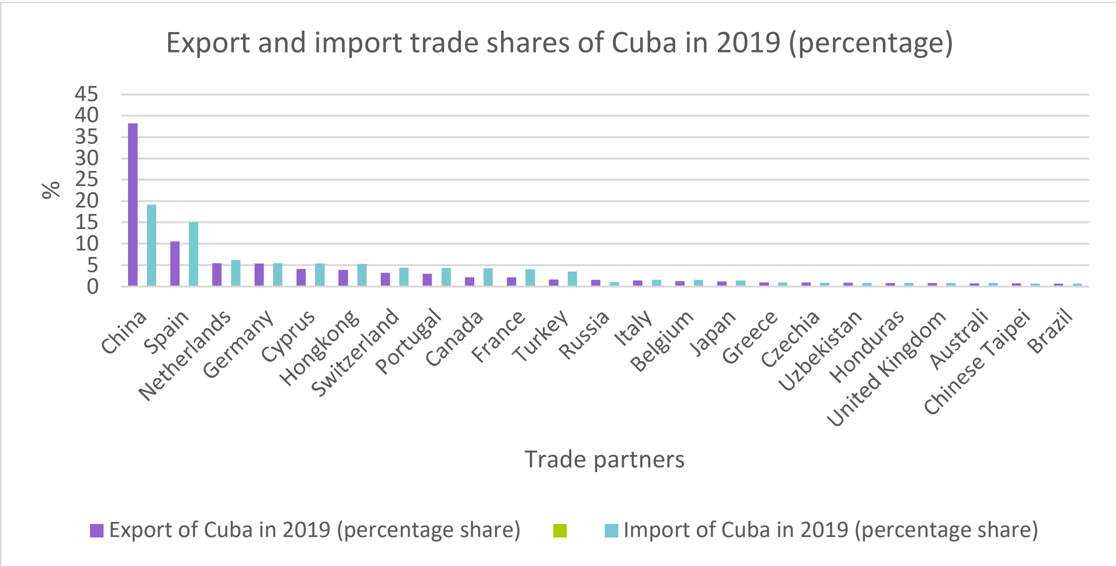


Figure 9. *Export and import trade shares of Cuba in 2019 (percentage). Data source: OEC (2022).*

We have also calculated a statistical indicator, the variance of trade volumes of import and export (Fig. 10). A positive finding is that Cuban export has increased its variance of country trade partners. The variance of Cuban import trade has not increased so much, which indicates some kind of dependency problem.

China's fast-growing economic and trade ties with a range of countries in Latin America and the Caribbean are increasingly intense and dynamic, as documented here also in the Cuban case. China´s Silkroad in LAC region seems to be strengthening. However, it is not easy to predict changes in the geoeconomics and geopolitical situation of Cuba. In general terms, some LAC states are more influenced than others by their growing economic and trade ties with China.

China’s trade with Latin America and the Caribbean has grown 26-fold between 2000 and 2020. In the future, LAC-China trade is expected to more than double by 2035, to more than $700 billion. This is a huge change The US and other traditional markets tend to lose participation in LAC total exports over the next 15 years. On the current BAU trajectory, LAC-China trade is expected to exceed 700 billion USD by 2035, more than twice as much as in 2020. China will probably approach and China could even surpass—the US as LAC’s top trading partner. In 2000, Chinese trade participation accounted for less than 2% of LAC’s total trade. In 2035, it could reach 25%. (Zhang and Lacerda Prazeres, 2021).

These kinds of changes are something, which can change political atmospheres and geopolitics in Cuba. It may be increasingly challenging for LAC to further develop its value chains and benefit from the regional market. From this global trade perspective, it is good to reflect potential global geopolitical scenarios of Cuba.

Figure 10. *Variance of export and import shares of trade partners of Cuba in 2000,2005, 2010, 2015 and 2019. Data source: OEC (2022).*

An important conclusion in this section on Cuba's export and import activities is that Cuba has recently succeeded in diversifying its export activities, but imports into the country have been unilateral and have not much diversified. In part, Cuba has managed to solve the problem of dependency (export diversification), in part, Cuba has not been successful (import structure and diversification). The major reasons for this can be linked to the challenges posed by the US-Cuba embargo. China's role as Cuba's strategic trading partner has gradually strengthened. More obviously, China's role can be gradually strengthened in the future, but it is fraught with many uncertainties, especially the investment problems posed by the COVID-19 crisis and new geopolitical cold war threats.

Art on Granma- newspaper

Geopolitics through Cross-Impact Analysis

In this article, we will illustrate the impacts of geopolitics and further explain the Cuban dependency on international global politics through Cross-Impact analysis (CIA). The Cross-Impact analysis is an umbrella term for a variety of different cross-impact methods that can be used to analyse events, as a tool for planning and to form several scenarios of different futures. In this method, modelling is formed and different variables are placed in it to display the relationships the variables have with each other. Instead of empirical data or statistics, the key feature of the CIA is that it relies on data harvested from experts in order to form its modelling. In this analyse, we are using the CIA called Express Cross-Impact Technique (EXIT) (see Juha Panula-Ontto et al., 2016 ; J. Panula-Ontto and Piirainen, 2018; Panula-Ontto et al. 2018). We form three different future scenarios that will explain the changing relations of the different nation-states while keeping our focus on Cuba in particular. Cuba has historically been in the middle of many big global events, notably for example during the Cold War. Thus, it is interesting how the position of Cuba might change along with the changing power politics.

In our modelling, we have 6 different variables in form of six different state(s); A: Cuba, B: Latin America and Caribbean, C: The United States, D: European Union, E: Russia and F: China. By changing the relationships of these nations, we can examine how dependent they are on each other and how influential they are compared to each other. The the impacts of the nations on each other are indicated in Figure 11. For instance, the Cuban impact on Latin America and the Caribbean is marked with A12 while the Latin American impact on Cuba is indicated with B21 and Russia's impact on the USA is indicated with E52. These direct impacts are collected in the Cross-Impact Matrix shown in Table 3, where the impacts of row variables on column variables are indicated.

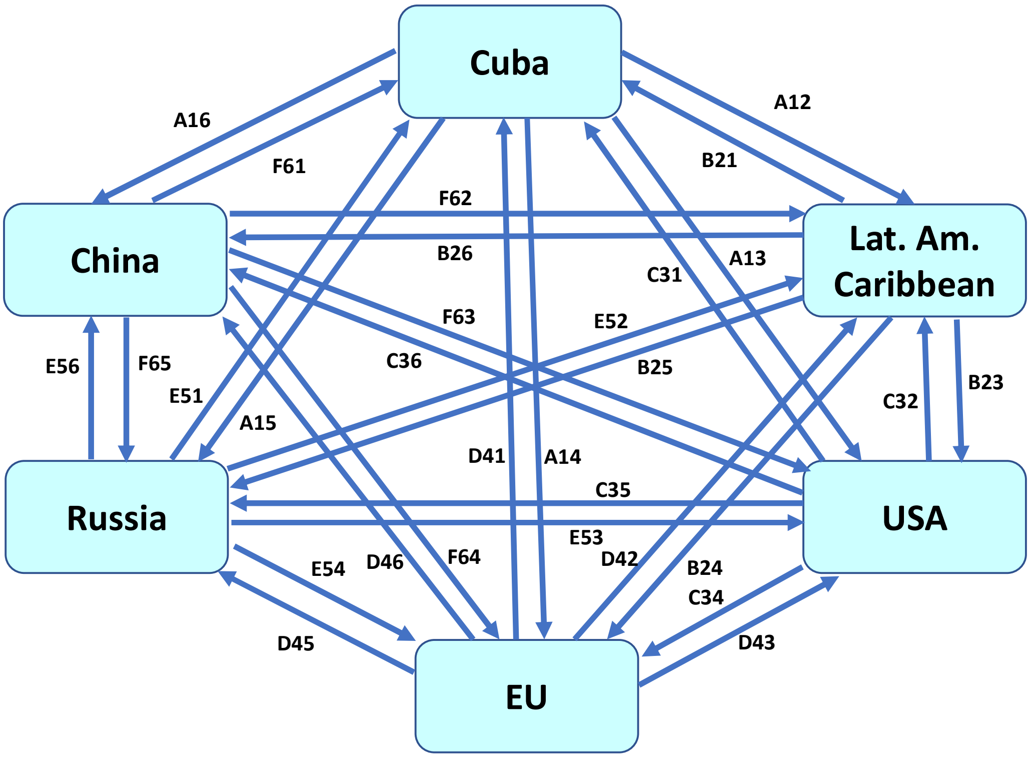


Figure 11. *Illustrations of cross-impacts between the variables in the analysis.*

Table 3. Cross-Impacts of the nations. Direct impact of the row variable on the column variable.

		A	B	C	D	E	F
Cuba	A		A12	A13	A14	A15	A16
Lat. Am. and Carib-bean	B	B21		B23	B24	B25	B26
USA	C	C31	C32		C34	C35	C36
EU	D	D41	D42	D43		D45	D46
Russia	E	E51	E52	E53	E54		E56
China	F	F61	F62	F63	F64	F65	

An expert group defined the assumed changes of the direct impacts of the variables on each other in each scenario. The direct impacts are placed in the Cross-Impact matrix and the EXIT algorithm calculates the chained cross-impacts between the variables. The algorithm calculates all possible chains of impacts (such as A->B->D->E->F->B->A) and constructs new values for the impacts between the variables taking into account all these possible cross-impacts. These cross-impacts change the driver-driven values of the variables providing interesting information about the dynamics of the system.

The states were selected because a) they are very influential in global power politics or b) they are expected to be affecting Cuba in some way due to their location in the world. Each impact is given a number between -4 to 4 depending on the expected state's ability to influence the other variables. For example, if the US is given a 4, it is expected that the impact of the state will increase considerably on the other variable, for instance, Cuba. And, if the US is given a -4, it is expected that the impact of the state is going to decrease considerably on the other variable, for instance, China. All of the variables are compared against each other and based on the overall score they get they are sorted into driver states and driven states. Driver states are the states that have the largest impacts on others in each scenario. Driven states on the other hand are impacted by other states. A state can be both a driver and driven if it is impacting the others but is also impacted by others. This type of state is a critical driver variable having both high influence and high dependence. If a state has high influence and low dependence it can be called an active variable. A state which has low influence and high dependence is called a reactive variable. And a state with low influence and low dependence is called the dependent buffer variable. The classification is illustrated in Figure 12.

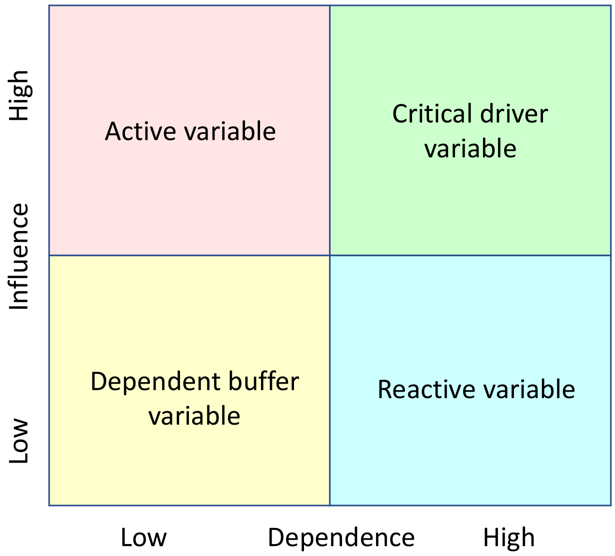


Figure 12. Classification of the types of variables in Cross-Impact analysis.

The three scenarios we have created are the **Two Red Flags**, the **Pan American Renaissance** and the **Cold War II**. The names of the scenarios reflect the nature of the narrative storylines of the scenarios.

sIn the Two Red Flags scenario, China and Russia will gain more influence in Latin America and the Caribbean. This could be due to the US backing away from the region and focusing its efforts somewhere else. China is already spreading its influence throughout the world and has caused the US to view it as a threat. It is a growing economy and the likelihood of its influence growing in the future is not unlikely. Russia has been China's long time partner and has provided the country with resources such as raw materials and oil. So, the two countries act as allies in this scenario while China takes the role of the most influential actor. In this scenario, the US and Europe stay further away from Latin America and thus their influence diminishes. The larger China and Russia grow in this scenario, the less the EU and US are expected to influence the two opposite states. In this scenario, Latin America and Cuba will grow closer to the China/Russia unite and both sides will affect each other in some sense. It is expected that China/Russia will be able to influence Latin America and Cuba more than vice versa. Latin America and Cuba's influence on the US and EU will be very neutral and the relationships will grow distant. The Cross-Impact Matrix of the direct impacts in the Two Red Flags scenario is shown in Table 4.

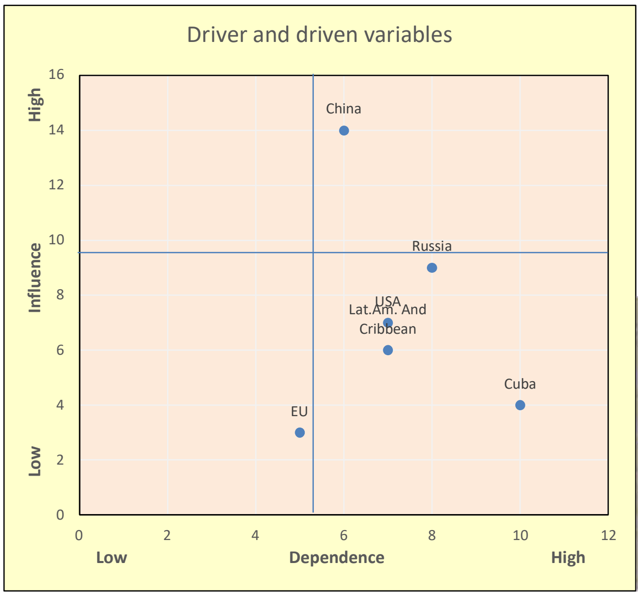
The Two Red Flags scenario

Table 4. Cross-Impact Matrix of direct impacts in the Two Red Flags scenario. Assessment of the increase of the impact of the row variables on the column variables.

Scale: -4, -3, -2, -1, 0, +1, +2, +3 +4		A	B	C	D	E	F
Cuba	A		1	-1	0	1	1
Lat.Am. and Caribbean	B	1		-2	0	1	2
USA	C	-2	-1		-1	-2	-1
EU	D	1	1	0		-1	0
Russia	E	2	1	-2	2		2
China	F	4	3	2	2	3	

In this scenario, China is the clear driver state. The driven state is Cuba. The Latin American states, The US and Russia are all rather strong drivers and driven states. The EU on the other hand doesn't appear to be a strong driver or driven state either. This setup will be the basis of the Cross-Impact Analysis.

After the Cross-Impact Analysis, we can predict the changing relationships of the different states. We will examine how influential the different variables are of each other and on the other hand how dependent they are on each other. The results are visualised in Figure 13 below and the changes caused by cross-impacts in Figure 14.



		Driven	Driver
Cuba	A	10	4
Lat.Am. And Cribbean	B	7	6
USA	C	7	7
EU	D	5	3
Russia	E	8	9
China	F	6	14

Figure 13*. Location of the states in the Influence-Dependence chart in the Two Red Flags scenario based on direct impacts.*

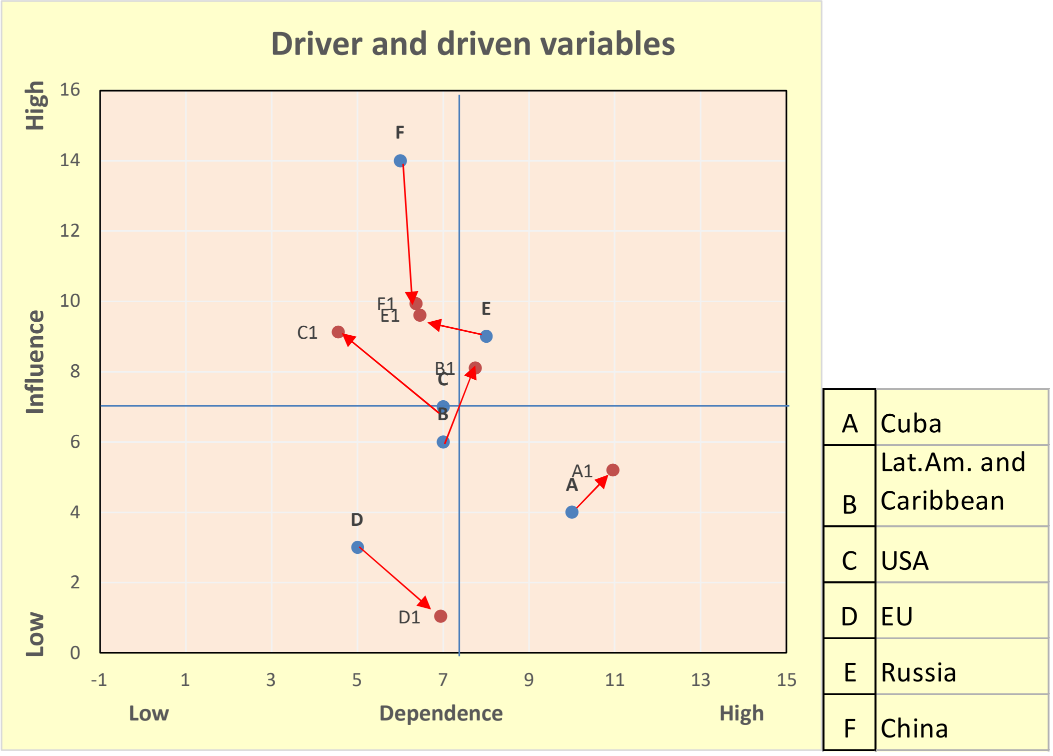


Figure 14. *Changes in the Influence-Dependence of the states when the cross-impacts are taken into account in the Two Red Flags scenario.*

The table above illustrates the results of the Cross-Impact Analysis. We can see that China's influence is getting smaller as a result of the cross-impacts while its dependence on other states remains largely the same. The opposite happens with Russia. Its influence does not grow by much but its dependence on other states is getting smaller. Although the change is not massive. The US gains a bit more influence and becomes less dependent on other states and the EU, in turn, loses influence while becoming even more dependent on other states. Finally, Cuba's influence grows slightly while it becomes more dependent on other states. Figure 15 illustrates the sensitivities of the position of different countries on the cross-impacts. This shows the change of the position from the direct impacts when the cross-impacts are taken into account.

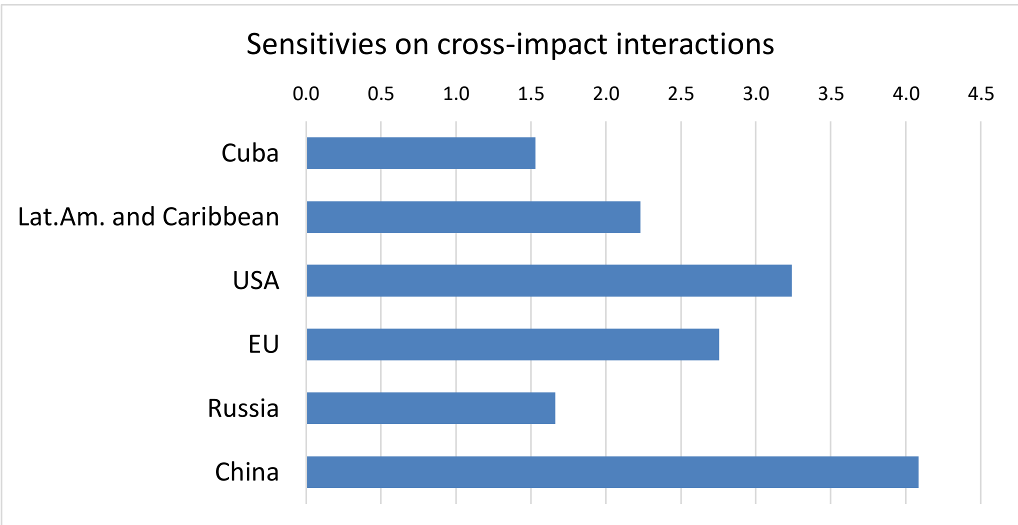


Figure 15. *Sensitivities of the position of different countries on the cross-impacts.*

The reasons for the results above can be explained by the fact that the states that are very involved in global politics are both influential and somewhat independent from outside influences. However, the more they are involved with other states less influential than them, the relationship itself seems to lift up the less influential states. They gain influence but in turn, become more dependent on others. This seems to be the case with the Latin American countries and Cuba. Countries like the US still hold a rather strong influence but by not involving themselves with other states the less dependent it will become. In the case of the EU it is not a strong driver or driven state, its influence diminishes and it grows more dependent.

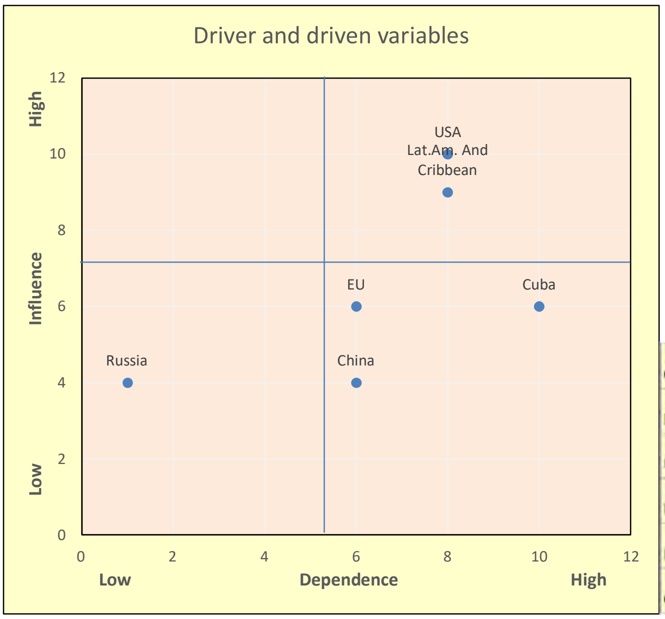
The Pan American Renaissance

In this scenario, the US will change its foreign policy strategy and form connections to Cuba. It will also focus its efforts on the Latin American states and gain more influence in this way. Its alliance with the EU will also strengthen. In this scenario, China and Russia will take a back seat and pull their forces from Latin America. On the contrary to the previous scenario, this time the US and EU are the powerful global actors with the lead of the US. The Latin American countries and Cuba will also be able to influence the US and the EU through the alliance. China and Russia will likely continue their long-lasting relationship but on a smaller scale. Their influence on the other state is neutral or negative.

Table 5. Cross-Impact Matrix of direct impacts in the Pan American Renaissance scenario.

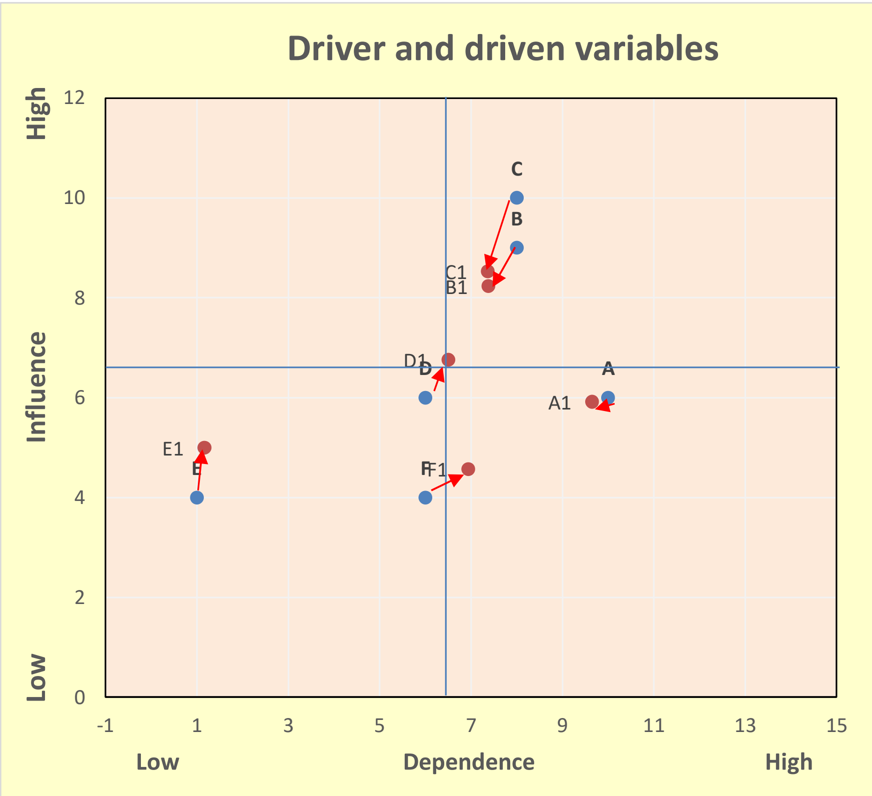
Scale: -4, -3, -2, -1, 0, +1, +2, +3 +4		A	B	C	D	E	F
Cuba	A		2	2	1	0	-1
Lat.Am. and Caribbean	B	2		3	2	0	-2
USA	C	4	3		2	0	-1
EU	D	2	1	2		0	-1
Russia	E	-1	-1	0	-1		1
China	F	-1	-1	-1	0	1	

In this scenario, the US is a clear driver state. Through the relationship with the US, the EU is able to gain more influence but is still rather dependent on other states. It is both a driver and driven state and not strong in either front. This is the case with almost all the variables in this scenario. Most of them are not clearly driver or driven states. Russia and China are the two that take the biggest hit in influence but remain largely independent. This can be seen in Figure 6 below.



		Driven	Driver
Cuba	A	10	6
Lat.Am. And Cribbean	B	8	9
USA	C	8	10
EU	D	6	6
Russia	E	1	4
China	F	6	4

Figure 16. *Location of the states in the Influence-Dependence chart in the Two Red Flags scenario based on direct impacts.*



A	Cuba
B	Lat.Am. and Caribbean
C	USA
D	EU
E	Russia
F	China

Figure 17. *Changes in the Influence-Dependence of the states when the cross-impacts are taken into account in the Pan American Renaissance scenario.*

Figure 17 explains the changes in the relationships between the different states when the cross-impacts are taken into account. In this scenario, the changes are smaller than in the Two Red Flags. Similar trends can be noticed in this scenario, although they are not identical. The US has the highest influence but it diminishes the more it is involved with the other countries. The same can be noticed in the case of the Latin American states. EU's influence grows as a result of the cooperation with the US. The same trend can be seen with Russia that in this scenario takes steps back in the global power politics. China gains little to no influence and grows more dependent on other countries. Cuba on the other hand grows slightly less dependent.

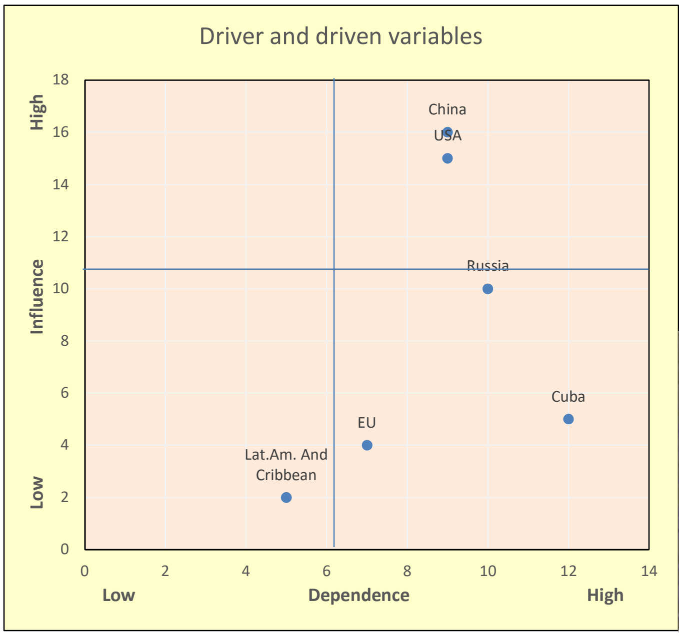
The Cold War II

In the last scenario, the tensions start to rise between the different alliance groups. In this version, the US and EU have formed one alliance group against Russia and China. Cuba is linked to the China/Russia alliance while the Latin American states appear as rather neutral. The powerful states; the US, the EU, China and Russia will mainly focus on each other while the US and China will act as the main aggressors. Cuba still stays in contact with the Latin American states and vice versa.

Table 6. Cross-Impact Matrix of direct impacts in the Cold War scenario.

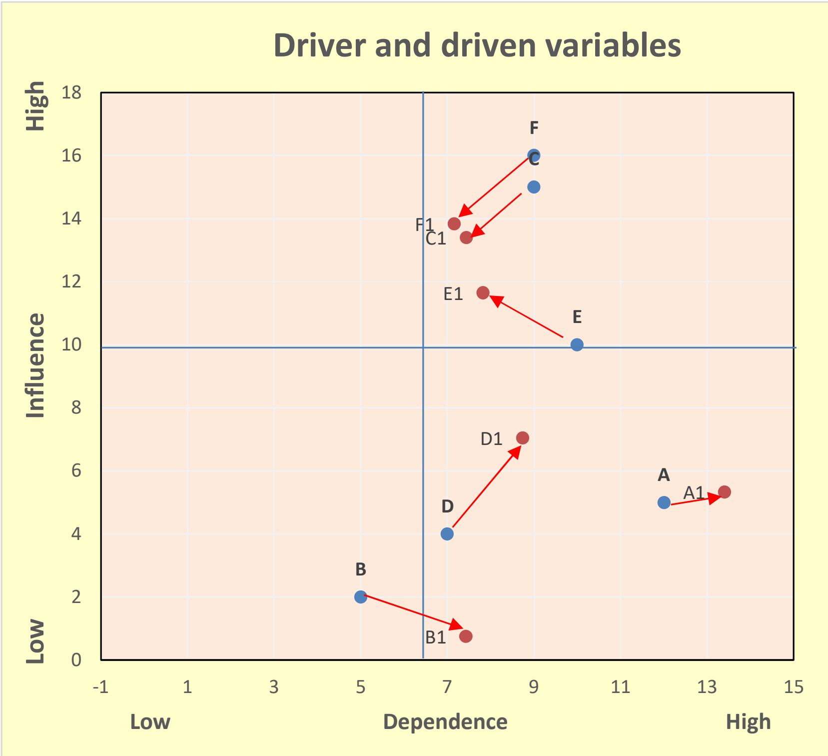
Scale: -4, -3, -2, -1, 0, +1, +2, +3 +4		A	B	C	D	E	F
Cuba	A		1	-1	-1	1	1
Lat.Am. and Caribbean	B	1		0	0	-1	0
USA	C	-4	-2		2	-3	-4
EU	D	0	0	2		-1	-1
Russia	E	3	0	-2	-2		3
China	F	4	2	-4	-2	4	

In this scenario, China and the US are two very close driver states. Russia is equally a driver and a driven state while the EU continues to obtain less influence. Latin America stays out of the conflict so its dependence and influence are not high. Cuba continues to be a driven state, even more so than in the previous scenarios. Figure 18 illustrates the direct impacts of the Cold War scenario and Figure 19 the changes caused by the cross-impacts.



		Driven	Driver
Cuba	A	12	5
Lat.Am. And Cribbean	B	5	2
USA	C	9	15
EU	D	7	4
Russia	E	10	10
China	F	9	16

Figure 18. *Location of the states in the Influence-Dependence chart in the Cold War scenario based on direct impacts.*



A	Cuba
B	Lat.Am. and Caribbean
C	USA
D	EU
E	Russia
F	China

Figure 19. Changes in the Influence-Dependence of the states when the cross-impacts are taken into account in the Cold War scenario.

Yet again, similar trends can be seen in the case of the strongest countries. Both China and the US lose their influence due to focusing on each other. Russia on the other hand gain influence and is less dependent on the other states. The EU will also appear as a more influential actor but will become more dependent. In both the case of Latin America and Cuba, their dependency increases.

Overall thoughts and the case of Cuba

The Cross-Impact Analysis paints an interesting picture of global power politics. The strongest states in each scenario while influential and rather independent actors are never completely independent and tend to lose some of their influence as a result of the complex interactions. The possible reason for this could be that these states often try to either defend their position in global power politics or try to gain more power in relation to the other states. These states will often form alliances with other countries at least in some form. Due to these reasons, they always have to think about their possible opponents and alliances while forming their foreign policy. This makes them less independent and leaves room for other countries to influence them. Countries that are still powerful but don’t take part in global power politics tend to gain more influence and are the most independent actors of the system. Some actors are heavily connected to the cooperation they have with other states so depending on how the cooperation is going, the more influence they gain and the more dependent they become. Smaller countries that are weaker actors in global power politics are automatically in a difficult spot. They are not automatically influential and will have to rely heavily on alliances to influence other countries. And this leads them to become heavily dependent. This is the case with Cuba.

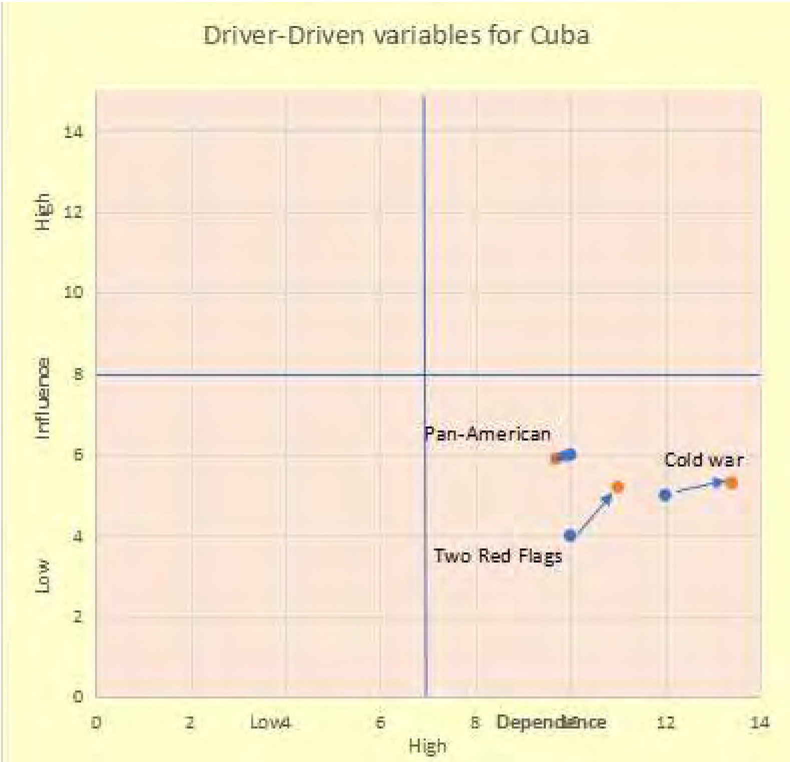


Figure 20. *Changes in the position of Cuba as a result of cross-impacts in the different scenarios on the Influence-Dependence chart.*

Figure 20 above displays the three different scenarios and how Cuba's influence and dependency change according to them. The changes are not major but they paint the picture of Cuba in the global power politics. There is no question about the fact that Cuba is a country that is heavily dependent on outside forces. In all of the three scenarios, Cuba's dependency has always stayed high. There have been some changes in Cuba's ability to influence other states but that has always resulted in the loosing of independence. The best scenario out of these three is the Pan American Renaissance. In that scenario, Cuba's influence remains rather high while it grows less dependent. The dependence seems to grow both in the Cold War II and the Two Red Flags scenarios.

The Cuban position in global power politics supports the arguments that can be made through geoeconomics and dependency theory. Cuba has always been dependent on other states and their political movements in many political sectors. This is due to Cuba's history, how the country has formed its own economy in the past, what kind of foreign policy decisions it has made and how the states close by and far away have reacted to its presence.

Conclusions

In this article, we explored the complicated role Cuba plays in global power politics through geopolitics and geoeconomics as well as from the viewpoint of dependency. There is no denying that the current global climate presents a challenge to the Cuban state. Cuba is still heavily impacted by dependencies thus making it vulnerable. Dependence is a corollary of dominance, a situation in which a developing country has to rely on a developed country's domestic and international economic policy to stimulate its own economic growth and development. The Cuban space for manoeuvering is limited and makes the policy forming ever so important. The situation of the state is partly a result of its historical context with path dependencies. Cuban economic structure is still dependent on old production structures established in the past and there is a lot of potential for development. The source of dependency comes from few export commodities as well as few partnering countries. In the case of import commodities, the variability is greater and the number of partner countries is larger resulting in less dependency. However, dependency on food and technology imports remains a significant challenge.

The US blockade creates major obstacles for Cuban development. This has given opportunities for other actors to strengthen their cooperation with Cuba. China has become a prominent actor in the region and has considerably increased its influence in the Cuban economy. The European Union has through its Political Dialogue and Cooperation Agreement (PDCA) pursued to develop a closer bond between the two actors. However, it is important to note that the dependencies have several different forms as illustrated by the cross-impact analysis. The results of the cross-impact analysis display the limitations of Cuban influence as well as high dependency on the global actors. The geopolitical and geoeconomic frameworks provide an intriguing approach to examine these power relations.

Yet, a variety of possibilities still exist for Cuba. Balanced cooperation with the Caribbean countries and the European Union could, for example, provide new opportunities for mutually beneficial collaborations. These partners come crucial in developing, for instance, the already promising fields of biotechnological and pharmaceutical industries. Utilizing these opportunities takes careful planning and smart investments. To reach their full potential it is necessary to take into account the different interactions of the complex domestic and global political processes. Cuba is on its own, facing challenging trade-offs to harmonize social and economic objectives. Especially, maintaining progress in education, health, life expectancy and other social indicators while providing incentives for personal advance, entrepreneurial initiatives and improvements in productivity call for an extremely difficult political balancing act in Cuba. Historically, Cuba's achievements in social services are real and undeniable. Since the 1961 nationalization of education, health and other services, all Cubans have enjoyed free access to education, health care and social protection. In Cuba social development has always been a political priority, even in times of severe economic crisis. About up to one-third of the national budget has been systematically allocated to the social welfare sectors.

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II. 2. Organizations and Programs that support the Cuban Energy Policy

Anaely Saunders Vázquez

With the signing and approval of Decree-Law no. 301 of 2012 (Ministerio de Justicia, 2012), the change of name and functions of the extinct Ministry of Basic Industry was approved, and the Ministry of Energy and Mines (MINEM) was created.

This ministry is in charge of proposing, directing, and controlling the policies of the State and the Government in the energy, geological, and mining sectors of the country regarding the activities of:

1) Generation, transmission, distribution, and commercialization of electrical energy.
2) Exploration and production of oil, gas, and other fuel minerals; production of lubricants; commercialization of lubricants, fuels and derivatives, alcohol as fuel, and liquefied and manufactured gas.
3) Management of knowledge and geological information, including the investigation, exploitation, and processing of solid mineral resources, mineral-medicinal waters, medicinal mud, and the commercialization of salt and its derivatives.
4) Preservation, exploitation, and rational use of mineral and energy resources favor sustainable and sustainable development.
5) Developing and using renewable energy sources (RES) contribute to energy security and environmental protection.

Concerning the RES, the MINEM has to:

1. Guarantee the implementation of the Strategic Policies approved by the state and the government to develop and use renewable energy sources.
2. Establish, implement and control regulations to promote the development and use of renewable energy sources (RES) in all sectors of the national economy and society, in general, to contribute to energy security and environmental protection.
3. Prepare guidelines, regulations, instructions, and regulations to prepare strategic and annual plans for the development and use of RES, which will be approved in the first instance and submitted for the approval of the corresponding organizations.
4. Elaborate and control the regulatory framework of the aspects related to the use of the RES and submit it for the approval of the corresponding Organisms.
5. Propose and evaluate R&D programs and research projects for this activity.
6. Elaborate and propose for its approval to the government the required financing scheme that propitiates the development of the RES.
7. Evaluate and project with the OACE the application of different incentive mechanisms that favor investments related to the use of RES, proposing them to the government for approval.
8. Prepare and implement strategies for dissemination and education, promoting programs in all sectors of the economy and services, social groups, and the population in general.

9. Promote technical, scientific research, and technological innovation in the use of RES, promoting that scientific research projects or technological innovations include considerations related to the use of RES.
10. Prepare and propose to the government a system based on energy licenses for new investments or modernization of installations throughout the national territory, guaranteeing that the technical-economic feasibility of the application of the development of the RES is evaluated, which allows for the total or partial substitution of the energy consumption from fossil energy sources.

In 2014, the Council of Ministers approved the Policy for the Perspective Development of Renewable Sources and the Efficient Use of Energy (Ministerio de Energía y Minas, 2021) to:

a) Increase the percentage of use of the RES up to 24%.
b) Reduce dependence on fuel imports for a generation.
c) Reduce the costs of energy delivered by the SEN.
d) Reduce environmental pollution.

In subsequent years, No. 204 was established as the main guideline to prioritize the future development of RES and energy efficiency in Cuba, which states that compliance with the approved Program should be accelerated until 2030 (PCC, 2017:30). Similarly, the policy outlined is in tune with what is established in the National Plan for Economic and Social Development until 2030, PNDES2030 (Ministerio de Economía y Planificación, 2020):

- One of the guiding principles of the PNDES2030 is to transform and develop the energy matrix rapidly and efficiently by increasing the participation of renewable sources and other national energy resources and the use of advanced technologies to consolidate energy efficiency and sustainability of the sector and, consequently, of the national economy.
- Strategic Axis: Infrastructure. This axis has the specific objective No. 7, which states that it is necessary to guarantee, in conditions of environmental sustainability, an adequate, reliable, diversified, and modern energy supply that substantially increases the percentage of participation of renewable energy sources in the national energy matrix, essentially biomass, wind and photovoltaic.
- Strategic Axis: Natural resources and environment. Specific objective No. 11 is established to increase energy efficiency and the development of renewable energy sources, which contributes, among other benefits, to reducing the generation of greenhouse gases, mitigating climate change, and promoting less carbon-intensive economic development.
- The PNDES 2030 also contemplates that the Electro-Energy Sector is strategic, transforming the energy matrix with greater participation of renewable sources and other national energy resources, ensuring the increase of efficiency and the exploration and refining of oil and gas.

Céspedes Park and the famous balcony where Fidel Castro gave his speech in January 1959

Legal Norms that support the Cuban Energy Policy

In 2019, **Decree-Law No. 345,** "On the development of renewable sources and the efficient use of energy," was approved (Ministerio de Justicia, 2019:2123–2128).In addition to this, a series of *Complementary Norms* have been elaborated:

- **Resolution No. 123/2019 of the MINEM** (Ministerio de Justicia 2019:2133–2136): The charge to the superior organizations of business management, the business systems of the provincial and municipal administrations, as well as the budgeted entities, the planning, the inclusion in the plan of the economy, the execution, sustainability and control of the necessary actions, aimed at increasing the use of RES in the companies, facilities, and territories of their competence, for which they take into account the cost-benefit country.
- **Resolution No. 124/2019 of the MINEM** (Ministerio de Justicia 2019:2136–2138): Regulations to increase energy management, efficiency, and conservation.
  - Entities that import, produce, or market equipment need to demonstrate their energy efficiency through the National Office for the Rational Use of Energy (ONURE) endorsement.
  - Entities large consumers of energy carriers certify their Energy Management Systems based on the current NC ISO 50001 standard requirements.
- **Resolution No. 141/2019 of the Ministry of Internal Trade (MINCIN)** (Ministerio de Justicia, 2019:2129–2133): Procedure for the commercialization of equipment that uses FRE

and the efficient use of energy through chain stores that collect taxes foreign exchange, Gelma, Copextel SA and provincial and municipal retail companies.

- **Instruction No. 6/2019 of the Central Bank of Cuba (BCC)** (Ministerio de Justicia, 2019:2128–2129): To grant credits to natural persons in Cuban pesos up to one hundred percent (100%) of the value of the solar water heaters and photovoltaic solar systems.
- **Resolution 206/2021 of the MINEM** (Ministerio de Justicia, 2021b:657–659): Approves the importation of photovoltaic systems by natural persons.
- **Resolution 223/2021 of the Ministry of Finance and Prices (MFP)** (Ministerio de Justicia, 2021a): Authorizes tax benefits for foreign capital companies producing electricity generation projects with renewable energy sources.
- **Resolution 319/2021 of the Ministry of Finance and Prices (MFP)** (Ministerio de Justicia, 2021b:660): Exempts natural person to pay customs duties for non-commercial imports of photovoltaic solar systems, its bits, and pieces.
- **Resolution 359/2021 of the Ministry of Finance and Prices (MFP)** (Ministerio de Energía y Minas, 2021a): This resolution approves the Tariff system for the purchase of electricity:
    a) Electricity purchase rate for services classified as renewable generators and co-generators (Sugar Plants) (C1C):
        - For each kWh delivered to the SEN during the day (from 5:00 a.m. to 5:00 p.m.), 2.7320 pesos/kWh.
        - For each kWh delivered to the SEN during peak hours (from 5:00 p.m. to 9:00 p.m.), 4.4833 pesos/kWh.
        - For each kWh delivered to the SEN at dawn (from 9:00 p.m. to 5:00 a.m.), 2.2520 pesos/kWh.
    b) Electricity purchase rate delivered to the SEN by producers in the non-residential sector through renewable energy sources:
        - Photovoltaic solar systems (C1F): 1.81 pesos/kWh delivered to the SEN on any day.
        - Biogas (C1B) produced with organic residuals: 2.1 pesos/kWh delivered to the SEN at any time of the day during the first four years. From the 4th year, the price will be 1.77 pesos/kWh delivered to the SEN at any time of the day
    c) Electricity purchase rate delivered to the SEN by the residential sector with the installation of photovoltaic solar systems:
        - Electricity purchase rate delivered to the SEN by the residential sector, with the installation of photovoltaic solar systems, 3.00 pesos/kWh delivered to the SEN at any time of the day.

MINEM and its organizations

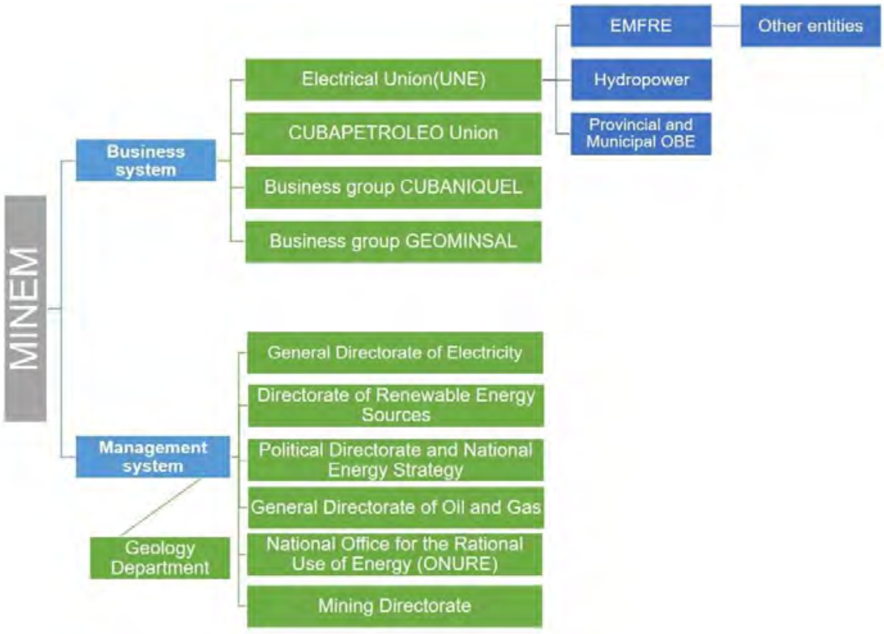

Figure 1. MINEM organization chart (Ministerio de Energía y Minas, 2021b)

Those most directly responsible for the coordination, implementation, and execution of the Policy for the Perspective Development of Renewable Sources and the Efficient Use of energy are the Renewable Energy Sources Directorate, the National Energy Policy and Strategy Directorate, and the National Office for the Rational Use of Energy (ONURE), and, from the business point of view, the Electric Union (UNE), with institutions such as the Renewable Energy Sources Company (EM-FRE), Hydropower, and the Basic Electric Organizations (OBE).

Electric Union sign, Santiago de Cuba

Other Organizations related to the country's energy policy

Decree-Law 345 specifies the role of the rest of the country's Central State Administration Organizations (OACEs) in the planning and execution of development, maintenance, and sustainability plans for technologies for the use of renewable energy sources.

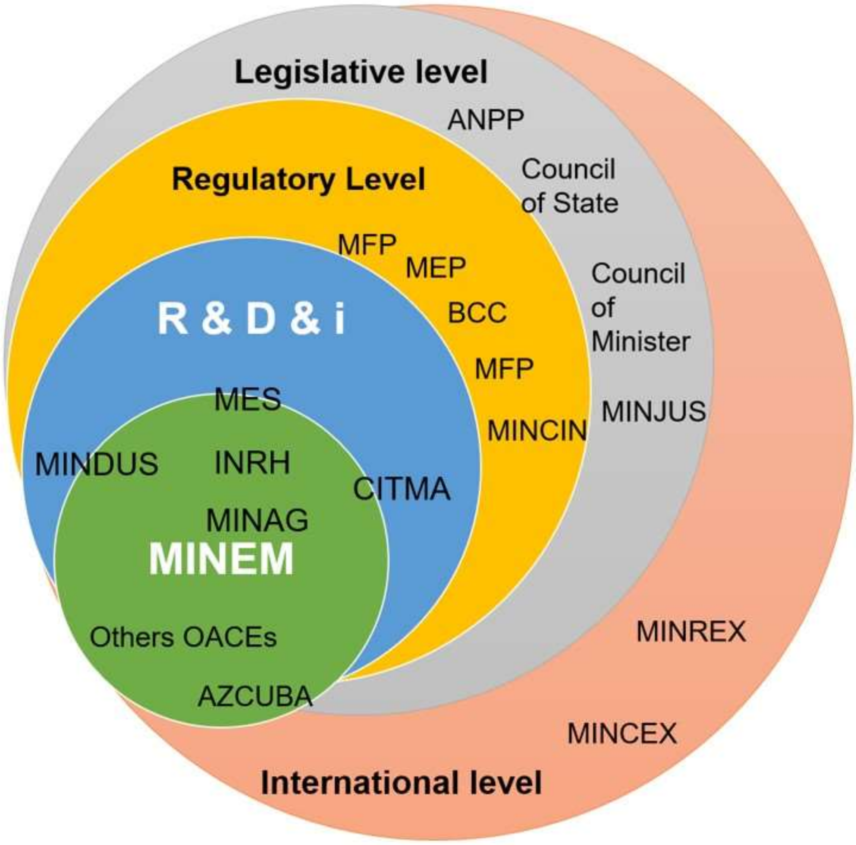

Figure 2. The OACEs in the implementation of the Energy Policy at different levels[1].

Some organizations have established specific tasks:

- The Ministry of Higher Education and the Ministry of Science, Technology and the Environment, with the coordination of the MINEM, must prepare the Program to develop scientific research and technological innovation.
- The Ministry of Industry (MINDUS) is in charge of preparing the Program for the development and production of spare parts, equipment, and means related to renewable energy sources and energy efficiency.

[1] *Organizations of the Central State Administration (OACEs) mentioned in addition to MINEM: CITMA: Ministry of Science, Technology and Environment; MES: Ministry of Higher Education; MINDUS: Ministry of Industry; MINAG: Ministry of Agriculture; AZCUBA: Sugar Business Group; INRH: National Institute of Hydraulic Resources; MFP: Ministry of Finance and Prices; MEP: Ministry of Economy and Planning; BCC: Central Bank of Cuba; MINCIN: Ministry of Domestic Trade; MINJUS: Ministry of Justice; ANPP: National Assembly of People's Power; MINCEX: Ministry of Foreign Trade and Foreign Investment; MINREX: Ministry of Foreign Affairs*

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II.3. Role of renewable energy sources in local development. Regulatory framework in support of the implementation of renewable energy

Dunia del Rosario Barrero Formigo and Gabriel Hernández Ramírez

Altieri and Toledo (2011) define Energy Sovereignty as the right of people, cooperatives, or rural communities to access sufficient energy within ecological limits. According to Berriz in CUBASOLAR (2020), it implies self-sufficiency by own energy sources, accompanied by the possession of knowledge and technologies for these sources. These authors recognize that sustainable development is not conceivable without energy sovereignty. It is based on energy sources that pollute the environment and cause climate change with possibly catastrophic consequences.

The transformation of the current energy scheme towards an energy mix based on energy efficiency and the use of renewable energy sources must encompass strategic axes such as local administration, mobility, urban planning, waste management, technological infrastructure, and production of goods and services.

Carrying out studies of the renewable energy potential of the territory and investing funds to use them is the way to energy efficiency and decarbonization, in line with social, economic, and environmental requirements for sustainable local development. Local development is based on sustainability and social and environmental well-being, based on the use of efficient infrastructure and renewable energy sources, the implementation of efficient management systems, participation, energy culture, and technological innovation.

The current Industry 4.0 or digital era provides the technological tools that allow energy management, as well as the achievements of sustainability and competitiveness goals, through the deployment of technological innovation, the digitization of systems to monitor variables in real-time, and the usage of data analytics and intelligent devices to optimize energy consumption.

In addition, the use of renewable energy technologies for energy generation that favor the reduction of polluting emissions and promoting energy culture contribute favorably to energy efficiency, more outstanding care for the environment, involvement, and sensitization of social actors.

Díaz-Canel Bermúdez and Delgado Fernández (2021) state that the development of strategic sectors and local development should be promoted based on government management, requiring the integration of plans, development programs, and policies with the active participation of the members of society.

The transition towards a more sustainable and resilient local energy model by increasing the use of renewable energy sources and the efficient use of energy in the energy mix will make it possible to reduce dependence on fossil fuels, which will generate considerable economic savings. In addition, the culture of energy saving will be promoted, favoring the satisfaction of the needs of society, developing skills, attitudes, and behaviors of responsibility, environmental awareness, and rational use of energy (Hernández Ramírez, 2021).

Challenges for local energy management in Cuba include:

- Disarticulation of actors to address the solution of energy problems on the local scale
- Insufficient knowledge of local stakeholders on energy issues
- Inefficient use of energy related to the low culture of energy saving
- Limited public participation in the definition, implementation, and evaluation of decisions
- Governments have not developed the mechanisms to manage the energy problem, nor do they take advantage of their local potential.
- The local government plans the energy needs of the buildings where its offices and vehicles are located.
- Only compliance with the energy plan assigned to local organizations is controlled.
- No actions are taken to improve local energy efficiency
- No energy production and sale experiences have been developed by the sector on its account, limiting energy services
- There is no tool available to monitor the role of local stakeholders in energy management.
- The division by sectors of economic activity and the lack of incentives hinder the development of energy value chains
- There are no instruments that allow the local government to manage the renewable energy sources
- There are no tools that allow the government to know the production of local energy carriers and their use as a substitute for conventional ones.

Promoting the use Biogas in Cuba

Regulatory laws for the installation of renewable energy sources

The priorities and main postulates of the country's policy that are associated with renewable energy sources and endorse the management model of Cuban organizations are:

- Law 81 of 1997 Environment Law: Rational use of energy resources, Promote the use of environmentally appropriate technologies according to the requirements and demands of sustainable development, use of renewable energy sources, efficient equipment, and technologies, Promote citizen participation regarding the protection of the environment and Develop citizen awareness about environmental problems (Ministerio de Justicia, 1997).
- State Plan to face climate change (Tarea VIDA): Task eight is directly related to the implementation and control of adaptation and mitigation measures to climate change derived from policies related to energy efficiency (sustainable use of energy and energy efficiency) (CITMA, 2017).
- Program for the perspective development of renewable sources and the efficient use of energy: Transition towards a sustainable energy mix where the objective is to achieve by 2030 a generation of electricity from renewable energy sources of around 24%. In addition, it relates to the efficient use of energy (Ministerio de Energía y Minas, 2021a).
- Electric Law of 1975: Regulates the relations between the entity that provides the electric service and the customers, for the rational use and exploitation of electric energy, without waste (Ministerio de la Industria Eléctrica, 1975).
- Decree-Law 345/2019 of the Council of Ministers: Development of renewable sources and efficient use of energy (Ministerio de Justicia, 2019d)
- Directive RS 1238 of the Ministry of Economy and Planning (MEP): Directed to the development, maintenance, and sustainability of renewable sources and the efficient use of energy
- Decree-Law 327/2014 of the Council of Ministers: Promote the use of renewable energy sources in the investment process (any new investment will include the use of renewable energy sources) (Ministerio de Justicia, 2015).
- Socio-economic strategy to boost the economy and face the global crisis caused by covid-19: Priority is given to national food production for food sovereignty, which can be promoted through renewable energy sources; In addition, energy constitutes the key area IX for the priority of the renewable energy sources, the application of incentives to technological and economic innovation and promoting savings in the state and private sector (Ministerio de Economía y Planificación (MEP), 2020)
- Resolution 208/2021 of the Ministry of Energy and Mines and Resolution 322/2021 of the Ministry of Finance and Prices: Approve the import of technology that generates or works with renewable sources of energy, its parts, and pieces (Ministerio de Justicia (MINJUS), 2021d).

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II.4. Political and economics transformations in Cuba, the main impacts of the new Constitution

Anaely Saunders Vázquez

Abstract

The transformation process in Cuba is not a current process, as it covers more than ten years. The most visible changes are in economic matters, with the introduction of new economic actors and the decentralization of the significant decisions. At the same time, critical political changes materialized with the approval of a new Constitution in 2019.

From the methodological, conceptual, and regulatory point of view, the analysis, debate, and approval of documents of strategic and legislative scope with the broad participation of various sectors of society and the general population, have been the expression of the interest of Cuban society to raise its levels of governance, participation, and inclusion, as well as maintaining the process of changes initiated. These strategic documents include the Economic Policy Guidelines and Social of the Party and the Revolution; the Conceptualization of the Cuban Economic and Social Model of Socialist Development; The Bases of the Economic and Social Development Plan until 2030: Vision of the Nation, Strategic Axes and Sectors and the Constitution of the Republic of Cuba.

This work aims to analyze some of the main changes in Cuba's political, economic, and social life and the significant impact of the new Constitution approved in 2019.

Keywords: Constitution, economy, municipality, local development

Capitolio, Havana

Introduction

In 2011, the process of updating the Cuban economic and social model began. “The current Cuban economic reform does not transform the intrinsic nature of the socio-economic system, but it does provide greater flexibility to its organization and operation, to boost the Cuban economy, eliminate obsolete conceptions and practices and favour the realization of the objectives of socialism." (García Rabelo, 2018)

The VI Congress of the Communist Party of Cuba discussed and analyzed the final draft of the Guidelines of the Economic and Social Policy of the Party and the Revolution to update the Cuban economic model, to guarantee the continuity and irreversibility of Socialism, development of the economy of the country and raising the standard of living of the population, combined with the necessary formation of ethical and political values of citizens. (PCC, 2011)

These guidelines reflect the main modifications introduced in the economic and social model,

> focused on promoting economic development with a long-term vision -with or without blockade-and adapted to the international field's technological, economic, commercial, and financial changes. This transformation must be capable of promoting higher and more stable rates of economic growth that make it possible to satisfy, progressively and thoroughly, the material and spiritual needs of all citizens, a fundamental objective of the socialist government. The most important and controversial of the approved transformations lies in recognizing and channelling the market's action in the economic process (García Rabelo, 2018)

The guidelines also state that:

> these principles should be harmonized with greater autonomy for state companies and the development of other management forms. Thus, the model will recognize and promote, in addition to the socialist state enterprise, the main form in the national economy, the modalities of foreign investment, cooperatives, small farmers, usufructuaries, tenants, own-account workers, and other shapes that could arise to help increase efficiency (PCC, 2011).

Rodríguez (2018) explains that it was not possible to advance in the creation of the bases for the development of the country - central axis of the economic strategy implicit in the 2011 Guidelines-, which was verified when in 2016 compliance with the 21 % of those planned, 77% in-process and 2% not implemented. This author also refers that the best results are achieved in consolidating the balance of payments through the renegotiation and paying the foreign debt, an essential requirement to obtain external financing and foreign direct investment.

In 2018, Army General Raúl Castro, First Secretary of the Central Committee of the Communist Party of Cuba, spoke before the National Assembly:

> We knew that we were beginning a process of enormous complexity due to its scope, which encompassed all elements of society, which required overcoming the colossal obstacle of a mentality founded on decades of paternalism and egalitarianism, with significant consequences in the functioning of the economy national (Castro Ruz, 2018).

Along with the resurgence of the blockade, Rodríguez (2018) explains that:

The economy achieved a growth of 2.3% between 2009 and 2016. In addition to the errors pointed out by President Raúl Castro - another set of factors that escape the most sophisticated forecasting techniques in any circumstance had an impact. Suffice it to mention the effect of the high-intensity hurricanes that hit the national territory in that period.

Guiding documents of Cuban economic and social life

In April 2017, the National Assembly of People's Power approved three widely debated documents by Cuban society in various spaces and received broad popular support before their discussion in the VII Congress of the PCC. These documents are:

- Conceptualization of the Cuban Economic and Social Model of Socialist Development;
- the Bases of the Economic and Social Development Plan until 2030: Vision of the Nation, Axes and Strategic Sectors;
- and the Guidelines of the Economic and Social Policy of the Party and the Revolution for the period 2016 - 2021.

Conceptualization summarizes the fundamental conceptions to promote socio-economic development by following the current aspirations and particularities of the Cuban revolutionary process. It serves as a guide to realizing the nation's vision: sovereign, independent, socialist, democratic, prosperous, and sustainable. (PCC, 2017:1–13)

This document has essential elements that specify the nature of the modifications undertaken (Rodríguez (a), 2018), among which are:

- A critical formulation of the difficulties faced up to 2016 was introduced, especially those associated with the increase in social and economic differentiation not from work and the impact on motivation and the erosion of values. Along with this, the strengths to face the challenges and difficulties were emphasized.
- The implementation of economic policy reinforces the concept of popular participation.
- It was reiterated that planning and not the market would guide the economy's management system.
- Foreign direct investment was defined not as a complementary element but as an essential factor for developing a series of sectors.
- A crucial conceptual element was the definition of the complementary role to be played by the non-state sector, limiting the appropriation of surplus-value and the concentration of private property.
- In the non-state sector, the expansion of employment is promoted in the same and the need to recognize medium, small, and micro-enterprises private companies for their proper functioning and social control.
- Regarding budgetary and fiscal policy, it also included the flexibility of subsidies, reducing public debt, and the financial market and budget units.
- Regarding monetary policy, the need to proceed with the unification of the currency and the exchange rates was reiterated, but gradually and without resorting to shock policies.

The Bases of the Economic and Social Development Plan until 2030, in its first stage, establish the main conceptual elements that serve as the basis for the elaboration of the National Plan, among which are: the guiding principles for the making of the development strategy, the vision of the nation, the strategic axes and sectors for the productive transformation (PCC, 2017:14–22). Besides, democratic, systematic, and public mechanisms for monitoring, control, evaluation, and accountability are established at different levels of society.

Museum of the Revolution, Havana

The strategic axes, driving forces of the plan, are Socialist, effective, efficient, and social integration government; Productive transformation and international insertion; Infrastructure; Human potential, science, technology, and innovation; Natural resources and environment; Human development,

equity, and social justice. These axes cover 22 general objectives and 106 specific objectives (PCC, 2017:16–21).
This document "gathers in its spirit and its letter the essential aspects of the 2030 Agenda for Sustainable Development and the Sustainable Development Goals" (Rodríguez (a), 2018).
Also, 11 strategic sectors are defined as productive transformation.

> Among these sectors are five directly linked to the country's productive and service infrastructure, such as construction; electro energetic; telecommunications; logistics of transport, storage, and trade; and logistics of waterways. In addition, net export sectors are added such as tourism and professional services and sectors that pay taxes on exports and also on import substitution, such as non-sugar agroindustry and the food industry; the sugar industry and sugar cane derivatives; the pharmaceutical, biotechnology, and biomedical production industries, as well as the light industry (Rodríguez (a), 2018).

In the Guidelines for the Economic and Social Policy of the Party and the Revolution for the period 2016-2021, 87.5% were updated, maintained, or modified. Fifty new guides were added, reaching 274, 39 less than the original version (PCC, 2017:23–32).

Constitution of the Republic of Cuba - 2019

This is not the first time that post-revolutionary Cuba has made reforms to its Constitution. After the Triumph of the Revolution, the first Constitution was proclaimed on February 24, 1976, after having the approval of 97.7% of the voters. After that date, three reforms were carried out (Legañoa Alonso, 2018):

- On June 28, 1978, the National Assembly of People's Power agreed that the Island of Pinos would be renamed the Isle of Youth (Isla de la Juventud).
- On July 12, 1992, the Constitutional Reform Law was approved. It was agreed to find ways to make the country's democratic institutions more representative, to perfect their structures, powers, and leadership functions at different levels. As a result, new forms of the election of the Deputies to the National Assembly and of the delegates to the provincial assemblies were established. Modifications were also made to guarantee and expand the exercise of numerous fundamental rights and freedoms, Cuban and foreign citizens' civil and political rights.
- June 10, 2002, the socialist content of the Constitution was ratified, confirming the irrevocable nature of Socialism, and the revolutionary political and social system, with the public signature of more than 8 198 237 voters; it was approved that economic, diplomatic, and political relations with another State cannot be negotiated under aggression, threat or coercion from a foreign power. Furthermore, the Constitutional Reform Law was approved.

In 2018, and based on the analysis of the results obtained with the application of the Guidelines of the Economic and Social Policy of the Party and the Revolution, reforming the Constitution began with a Popular Consultation. This consultation had the active and committed participation of all the people, taking advantage of the spaces for citizen participation that exist in the country, which allowed us to achieve a constitutional text with broad support, which was approved in a Constitutional

Referendum, on February 24, 2019, by 86.85% of the voters who exercised the right to vote (Periódico Granma, 2019).

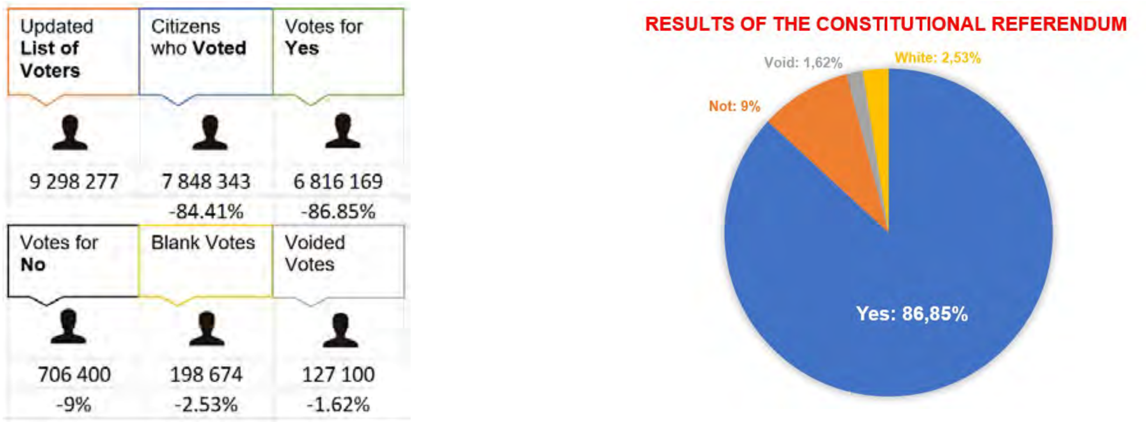

Figure 1: Results of the Constitutional Referendum (Doimeadios Guerrero, Carmona Tamayo, and Pérez, 2019; Periódico Granma, 2019)

According to experts (Figueredo Reinaldo and Carmona Tamayo, 2018), one of the reasons for carrying out this Constitutional Reform was the need to update the Constitution, incorporating the economic transformations that occurred in recent years to improve the economic, social model. Also, to subscribe principles and concepts and include the country's vision, all these fundamental postulates, contained in the Conceptualization of the Cuban Economic and Social Model of Socialist Development, in the Bases of the Economic and Social Development Plan until 2030, and in the Guidelines.

Almost 90% of the previous Constitution was modified (ANPP, 2019). However, the construction of the socialist society model is reiterated, and it is endorsed that the system is irrevocable:

> *Article 1: Cuba is a socialist state of law and social justice, democratic, independent, and sovereign, organized with all and for the good of all as a unitary and indivisible republic, founded on work, dignity, humanism, and the ethics of its citizens for the enjoyment of freedom, equity, equality, solidarity, well-being and individual and collective prosperity* (ANPP, 2019:71)

The principles of sovereignty, defence of the Homeland, jurisdiction over the national territory, the role of the state, the socialist property of all the people over the fundamental means of production, the rights, duties, and guarantees of citizens, social justice are also maintained, the preservation of the general interest, among other aspects.

Main novelties of the constitutional text

The most relevant modifications in the new constitutional text are related to:

- ***the economic fundamentals*** (ANPP, 2019:75–77), by adopting several of the precepts that appear in the Conceptualization of the Model, the Bases of the Development Plan, and the Guidelines. As a result, the exercise of economic activity is legitimized, various forms of property are recognized, and endorsing the role and responsibility of economic actors in the country's life. It also considers the role of the market, regulated through planning.

Finally, it makes explicit the forms of State intervention in the economic process and the measures that the public powers must adopt to control and order economic activity.

- ***The structure of the State*** (ANPP, 2019:88–103)***,*** by establishing that the Council of State and the National Assembly of People's Power will have the same direction; and reappear the figures of the President of the Republic and the Prime Minister.
- ***The territorial organization of the State*** (ANPP, 2019:103–111): the Provincial Assemblies of People's Power are eliminated, and the Provincial Governments are instituted, made up of the governors and a Council. The Mayor position is introduced at the municipal level, who presides over the Municipal Administration Council. The municipality is granted greater autonomy.

Regarding the Structure of the State, the National Assembly of People's Power, ANPP (for its acronym in Spanish), and its deputies continue to have the responsibility of electing and approving by direct vote - on behalf of the people - the main actors of the higher organs of the state: they will elect the President of the Republic; the members of the Council of State, its President, Vice President, and Secretary.

The ANPP appoints the Prime Minister and other members of the Council of Ministers. It is also their responsibility to elect the President of the Supreme People's Court, the Attorney General of the Republic, the Comptroller General, the President, and other components of the Electoral Council, among different positions in those bodies. The ANPP also appoints the provincial Governors at the proposal of the President of the Republic and can revoke or replace all the persons elected or appointed by it.

In Article 120 of the Constitution (ANPP, 2019:93), it is established that "the members of the Council of Minister, nor the highest authorities of the judicial, electoral and state control bodies may not integrate the Council of State", a complete change concerning the previous Constitution that promotes greater independence for the functions of control of the Assembly over the ministers.

In the 2019 Constitution, the legislative role of the National Assembly is reinforced.

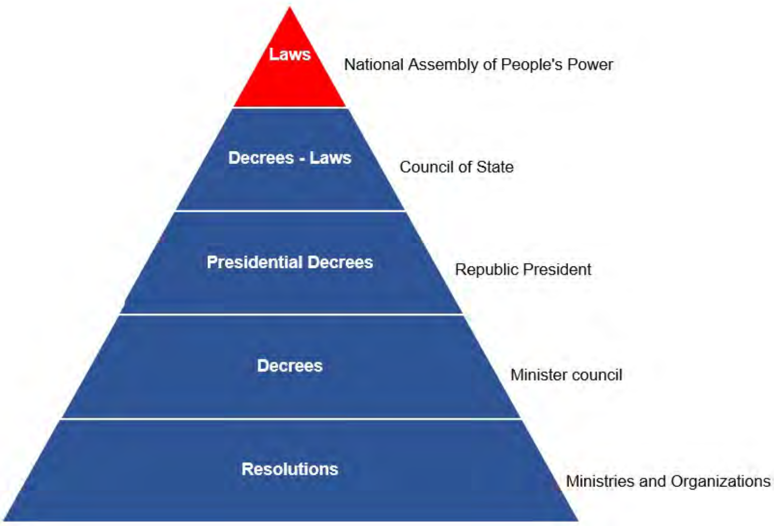

Figure 2: Legislative function of the Cuban State (Doimeadios Guerrero, Concepción, and Rubio A, 2018)

Municipal level

The municipality is granted autonomy in this stage, and integrated management with the territory's resources is possible. In this way, the municipality, as the primary political-administrative unit of Cuban society, with legal personality, and the purpose of achieving the satisfaction of local needs, will play an essential role in the country's development (ANPP, 2019:104).

These normative changes in the conception of the territory must become motors that promote the modification of the ways of territorial action in terms of structure, management, control actions, planning, and the execution and development of strategies in the short, medium, and long time.

The Municipal People's Power Assemblies are granted several prerogatives (ANPP, 2019:108–109):

- approval and control of the economic plan, the municipal budget, and the comprehensive development plan;
- approve the land and urban planning plan, and control its compliance;
- adopt agreements and regulations on matters of municipal interest and control their compliance;
- control of all institutions, local and national, established in each territory; of the economic, production and service, health, care, prevention and social, scientific, educational, cultural, recreative, sports and environmental protection activities in the municipality;
- to contribute to the execution of State policies in its demarcation and the development of production and service activities of entities located in its territory that are not directly subordinate to it.

Therefore, changes must occur in the municipal direction management models, generating new opportunities with more decentralized governance and planning methods. Furthermore, decentralized governance should cause the modification of the role of the political, economic, and social actors of the territory, with more participatory management.

Influence of the transformations in the change of the Cuban energy paradigm

When the Cuban Constitution is modified, it is imperative to update the entire system of laws of the country.

In the energy sector, the current Electricity Law dates from 1975 (Ministerio de la Industria Eléctrica, 1975); therefore, it does not include any changes in the Cuban electric energy system in more than 45 years. Thus, the current context indicates that this law must be modified, incorporating all the energy sources in use, the technologies for its use, and regulations related to generation, distribution and consumption, energy efficiency and savings, and environmental ones.

It is, therefore, necessary to change the entire regulatory framework related to energy and temper it to the international situation, incorporating the vision, transversality, and interdependence of the elements contained in the Sustainable Development Goals (SDG), promoted by the United Nations (UN/CEPAL, 2018), which includes a specific target on Affordable and Clean Energy.

In the Ordinary Official Gazette No.2 of January 13, 2020, Agreement IX-49 of the ANPP was published, taken in the session of December 21, 2019, corresponding to the Fourth Ordinary Period of

Sessions of the IX Legislature, through which the Legislative Schedule for the current Legislature was approved by the highest body of power of the state, made up of 39 laws and 31 decree-laws, for a total of 70 regulatory provisions (CUBAHORA, 2020).
However, in this legislative schedule, it is not planned, in the short term (2020-2022), to modify the Electricity Law or to promulgate a law referring to energy, although the Decree-Law No. 345 was approved at the end of 2019 "On the development of renewable sources and the efficient use of energy" (Ministerio de Justicia, 2019) with resolutions and complementary instructions, to contribute to:

- increasing the share of renewable energy sources in electricity generation;
- the progressive substitution of fossil fuels;
- diversification of the structure of fossil fuels used in the electricity generation;
- increasing energy efficiency and saving;
- stimulating investment, research, and raising energy efficiency. Also, the production and use of energy from renewable sources by establishing incentives and other legal instruments promote its development;
- the development of the production of equipment, means, and spare parts by the national industry, for the use of renewable sources and energy efficiency; and
- the establishment in the state sector of a working system that includes planning tasks that make it possible to meet the objectives set.

From the constitutional text, the energy issue is impacted by the strengthening of the municipality as the most important popular power entity. Suppose energy is considered as a cross-cutting element, which affects each of the development activities, plans and strategies, at all levels, not only as a resource. In that case, it will have an impact on territorial development. Other elements must also be considered, such as growth in demand and energy consumption, saving, and efficient use. Modifying energy management at all levels, increasing distributed generation, creating capacities for local energy planning, promoting the establishment of energy export and storage mechanisms in municipalities or territories may seem in the short term a chimera. However, they are aspects that need to be analyzed, investigated, implemented, not only to achieve the goal of energy independence but also the one established in the Bases of the Economic and Social Development Plan until 2030:

> Under conditions of environmental sustainability, guarantee an adequate, reliable, diversified, and modern energy supply that substantially increases the percentage of participation of renewable energy sources in the national energy mix, essentially biomass, wind, and photovoltaic (PCC, 2017:18)

Final thoughts

On July 27, 2020, the Policy to promote Territorial Development was discussed in the Council of the Minister. The Deputy Prime Minister and Head of Economic and Planning, Alejandro Gil Fernández, explained that local development is conceived as an endogenous, participatory, and innovative process and politics (...)

> (…) is aimed at fostering local development based on potential human management, science, innovation, and the use of appropriate technologies and physical planning; promote integration between state and non-state actors based on productive chains; and promote local development projects for food production destined for domestic consumption, as well as those that generate exports, import substitution and monetary-mercantile flows within the territory (Puig Meneses, 2020).

At this meeting, the President of the Republic of Cuba, Miguel Mario Díaz Canel Bermúdez, said that it is precisely in the town where there is "to manage all the processes, autonomously, comprehensively ... to seek the development we want" (Puig Meneses, 2020).

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II.5. Cross-Impact analysis of Cuban economic and energy development trends

Jyrki Luukkanen and Jari Kaivo-oja

Introduction

Cross-impact modelling and analysis techniques are tools to support planning, decision-making and foresight activities. In the cross-impact analysis, the real system components are represented as variables and their interactions The system components can represent system states, events and driving forces. It is normally seen that the cross-impact approach falls in between empirical data-driven computational models and argumentative systems analysis. The approach exhibits a high degree of disciplinary heterogeneity and focuses on expert-sourced soft system knowledge (Weimer-Jehle, 2006). In the cross-impact approach, the inputs for modelling the system are expert-sourced instead of empirical or statistical data. This characteristic of the approach enables the modelling of many domains and parts of modelled systems that are difficult to model using data-driven approaches.

There exist several different types of Cross-Impact Analysis (CIA) and they have been used for analysing the complex interactions of several processes. The central idea in the CIA is that they are based on expert judgments about these systemic interactions. These interactions are analysed to form a basis for future scenario construction. In this article, our analysis and results aim at facilitating the process of defining different paths in strategic political and policy actions of long-run electricity market policy in Cuba. Our idea is to use the CIA methodology as a group decision support system for energy policymakers. In the literature, this approach has been used in some renewable energy policy projects (see Blanning and Reinig, 1999). The Cross-Impact analysis is well suited for modelling complex systems and evaluating the interaction of subsystems.

Cross-Impact methods can be used in cases where computational models cannot be used due to the variety of utilized theoretical or methodological approaches or due to the unavailability of required numerical data. The Cross-Impact methods also provide possibilities to analyse systems, which have too complex interactions to be meaningfully analysed by qualitative reasoning (Bañuls and Turoff, 2011; Gordon and Hayward, 1968; Helmer, 1981; Medina et al., 2015; Thorleuchter and Van Den Poel, 2014; Weimer-Jehle, 2006).

Several Cross-impact methods are based on expert judgments of the a priori probabilities of events and their impacts. Sometimes CIA methodology is linked to the Monte Carlo Simulation (MCS) methodology. The MCS methodology, also known as the Monte Carlo Methodology or a multiple probability simulation, is a mathematical technique, which is used to estimate the possible outcomes of an uncertain event or events. The Monte Carlo Method was invented by John von Neumann and Stanislaw Ulam during World War II to improve decision making under uncertain conditions (Eckhardt 1987). Nowadays simulation methods can be linked to the fast development of Artificial Intelligence, which can be rooted in the original works of Alan M. Turing (1950). The objective of this paper is to determine the effect of marginal probabilities revision. A CIA system was originally developed and used to conduct the experimentation to determine the effect of marginal probabilities revision on the ranking of interdependent events (Enzer, 1971; 1981; Godet, 1994; Mphahlele et al., 2012; Panula-Ontto et al., 2016).

One of the methods, the Basics-method, uses trend extrapolations for defining descriptors of a model. When calculating scenarios, deterministic rules are used instead of random numbers as in Monte Carlo simulation. The BasicsPC is a commercial program produced by Battelle Columbus (USA) (Millet, 2011) and improved versions of it have also been developed (Luukkanen, 1993;1994).

In this article, we use *Express Cross-Impact Technique* (EXIT) (Juha Panula-Ontto et al., 2016) which is suitable for use in expert workshops for collecting input data and presenting the results. The EXIT tool can help organisations and agencies in the so-called boundary work between policy, strategy and knowledge about the future (Van der Steen and Van Twist, 2013). In the field of participative foresight research (see (Borch et al., 2013; Kaivo-oja, 2017) this kind of novel and flexible CIA methodology can be very useful.

Selling fruits in Havana

Methodology

The cross-impact method used in this study (EXIT) (see (Juha Panula-Ontto et al., 2016; J. Panula-Ontto and Piirainen, 2018) is a technique for processing expert input about the impacts that different events, phenomena and forces have on each other and how they affect each other over a complex system or network of effects. The method is useful for comparing the cross-impact items (variables) in terms of the magnitude of their total (direct and indirect) effect on any particular cross-impact item included in the cross-impact analysis setting. As direct impacts between items are the inputs to the analysis, the added value of the calculation is considering the indirect impacts of items on each other through the multi-nodal impact chains.

The inputs for the cross-impact analysis are the cross-impact items representing events, phenomena, drivers and forces, and the cross-impact matrix describing the direct impacts the items have on each other. The items have descriptions that should be evaluable by the experts contributing to the cross-impact analysis in terms of their probability. In practice, the description of a cross-impact item should take the form of a statement, with a yet unknown truth value, such as "The energy consumption will grow".

An example of a system with four variables (items) is shown in Fig. 1. These four variables A, B, C and D have direct impacts on each other shown with the arrows in the figure. The direct impact can be presented in a cross-impact matrix shown in Fig. 2. In the matrix, the impacting (driving) variables are on the left and the impacted (driven) variables are above the matrix. As a driver A has an impact a12 on B shown on the first row and second columns in the impact matrix.

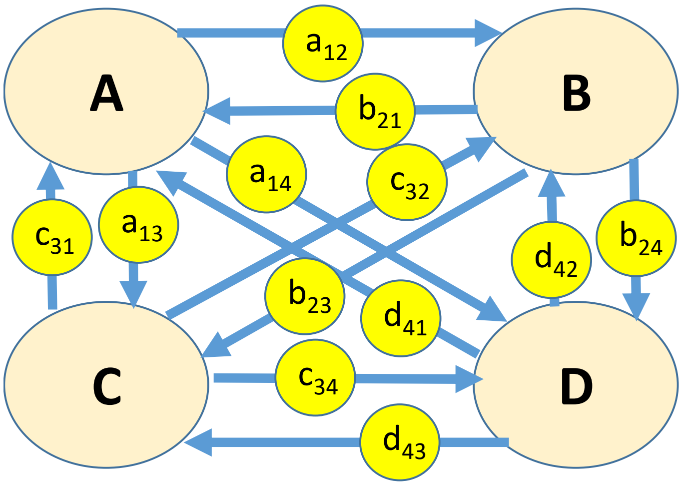

Figure 1. *A system represented by four variables (items) A, B, C and D and the direct impacts between them.*

		Driven variables			
		A	B	C	D
Driver variables	A		a12	a13	a14
	B	b21		b23	b24
	C	c31	c32		c34
	D	d41	d42	d43	

Figure 2. *Cross-impact matrix for the system illustrated in Fig.1.*

Often the impact values can range from -4 to 4. The impacts are interpreted so that an impact of 4 means a strong positive effect on the probability of the impacted cross-impact item, 1 means a slight positive effect, -1 a slightly negative effect and -4 a strong negative effect. If we have for example variable A as “The GDP will grow” and variable B as “The energy consumption will grow” the direct impact is thought to be positive and we could have a value of 3 for a12.

A panel of domain experts or individual experts should provide the impact values for the cross-impact matrix. The matrix should be constructed so that only direct impacts between items are considered when the experts give the values for the impacts. The indirect impacts are calculated later based on direct impacts supplied by the experts.

The calculation of indirect impacts could be done in several ways. In this application, to find out the total impact of a cross-impact item (e.g. A and B) all the possible item chains of intermediary items (such as A -> D -> C -B) are generated (not including A or B) and the sum the impacts of these chains to get the total impact of A on B. All of the summed impact chains start with A and have 0 or more intermediary items and end with B. The sum of the impacts represents the total impact of A on B, taking into account the direct impact and the indirect impacts.

As the number of possible impact chains grows fast as additional intermediary variables are introduced, only impact chains with 5 intermediary variables or less are taken into account.

Compared to similar cross-impact methods which aim to analyse an expert-provided matrix of cross-impacts and facilitate understanding of the importance of different drivers on the system examined with cross-impact analysis, this method is an improvement as it can consider the direction of the impacts between items (instead of just the magnitude of the impact) and it explicitly considers the impact chains, which previous methods involving summing the item impacts on a row-by-row basis are unable to do.

In addition to the direct impact values, the probability of an increase of the values is estimated by the experts. The probability of increase is thought to have a value between 0 % and 100 %.

With the cross-impact matrix, it is possible to calculate which variables are seen as driver variables and which are driven variables. The driver potential of the variables can be calculated as the sum of the absolute values of different rows. The values on a row indicate how much a variable is assumed to “drive” the other variables. The use of absolute value is necessary because even a large negative value has a driving potential. The driven aspect of the variables can be calculated as the sum of the absolute values of the columns. This indicates how much the variable is assumed to be driven by other variables.

In addition to the EXIT algorithm also AXIOM algorithm has been used for analysing the cross-impacts. AXIOM is an approach for modelling probabilistic causal relationships between system elements and their states. It is conceptually and functionally somewhat related to Bayesian belief networks. AXIOM is specifically designed for expert elicitation work mode in model parameterization. (Juha Panula-Ontto, 2016; Juha Panula-Ontto, 2019). A Bayesian network is a graphical model or probabilistic graphical model (PGM) or structured probabilistic model. It is a probabilistic model for which a graph expresses the conditional dependence structure between random variables or factors. They are commonly used in probability theory, statistics—particularly Bayesian statistics—and machine learning. We present such a Bayesian network in this empirical study.

Private shop keepers, Havana

Cuban case study

Cuban future societal development trends and factors impacting the trends were discussed within an expert group from the University of Oriente in Santiago de Cuba. The expert group consisted mainly of researchers and professors from the Faculty of Engineering. The selection of the expert group participants naturally impacts the process of selecting the variable for the cross-impact analysis and the cross-impact matrix developed by the team. This exercise was a first attempt to test the use of cross-impact analysis in the Cuban context and the idea is to carry out later larger cross-impact analysis with a more diversified group of experts.

The group of experts discussed potential items representing Cuban development until 2030. After a long and varied discussion, about 35 items were listed as candidates for the analysis to be selected for the cross-impact analysis. The selection of ten items for the analysis was carried out by voting and the final list of items is shown in Table 1. The data analytics included the key factors of change in Cuba that were assessed as the most important trend factors.

Table 1. *Selected cross-impact variables for the analysis.*

Cross-impact variables selected for analysis
1. Investments in Cuba will increase
2. US embargo will get stricter
3. The share of renewable energy sources will increase
4. Electric transport will increase
5. Domestic oil production will increase
6. Climate change impacts will increase

7. Electricity demand will increase
8. GDP growth will increase
9. Industrialisation will increase
10. Energy use will increase

The participants of the workshop filled in individually the cross-impact matrixes for a system of these ten variables. Table 2 shows the calculated average for the different evaluated direct impacts between the variables. One possibility of using this type of expert opinion based cross-impact analysis is to ask the participants their evaluation of their own expertise in the different fields of the analysis and use these evaluations as a weight coefficient when the cross-impact matrix is calculated. This approach was not utilised in this exercise.

Table 2. *Cross-impact matrix based on the average values of the expert group input data. The probability of increase is also an average value. The driver and driven potential of the variables are calculated from the row and column values.*

Probability of increase %			Investment	US Embargo	Share of Renewables	Electric transport	Oil production	Climate change impacts	Electricity demand	GDP growth	Industrialisation	Energy use	
			A	B	C	D	E	F	G	H	I	J	Driver
64,7	Investment	A		-0,5	2,2	0,9	1,6	0,3	0,4	2,1	1,4	0,9	10,13
72,0	US Embargo	B	-3,0		-1,5	-1,7	-1,3	-0,6	-1,4	-2,4	-2,2	-1,7	15,82
67,0	Share of Renewables	C	1,0	-0,2		0,8	-0,8	0,9	0,9	1,4	0,9	1,9	8,85
39,8	Electric transport	D	0,6	-0,2	0,6		-0,6	1,3	1,6	0,5	1,0	1,2	7,49
42,7	Oil production	E	1,5	-0,2	-1,4	-0,8		-0,7	1,3	1,6	2,2	2,4	12,03
46,7	Climate change impacts	F	0,5	0,0	2,1	0,7	-1,3		0,2	0,2	-0,9	0,2	6,05
61,5	Electricity demand	G	0,9	0,0	1,9	0,0	1,5	-0,3		0,6	1,4	2,4	8,97
36,8	GDP growth	I	1,6	-0,4	1,8	1,1	1,3	0,7	2,0		2,1	2,0	12,97
43,2	Industrialisation	K	2,1	-0,2	1,4	1,3	1,4	0,4	2,4	1,3		2,4	12,69
58,9	Energy use	L	0,5	0,0	1,6	0,7	1,6	0,6	1,7	1,7	1,9		10,26
		Driven	11,7	1,7	14,5	8,1	11,2	5,5	11,8	11,8	13,8	15,2	

When the driver and driven potential of the variables, based on the direct impacts, are plotted in xy-diagram we can illustrate the influence and the dependence of the variables. Figure 3. shows the values of the variables in these two dimensions. According to the results it can be seen that the US Embargo is seen as the strongest driver in the system and also as the least dependent variable. GDP growth and Industrialisation were also seen as having a high influence on other variables, but also higher dependence. Energy use and the Share of renewables seemed to be highly dependent variables according to the expert views. Climate change impacts seemed to have less impact on others but also less dependence on others according to the expert evaluations.

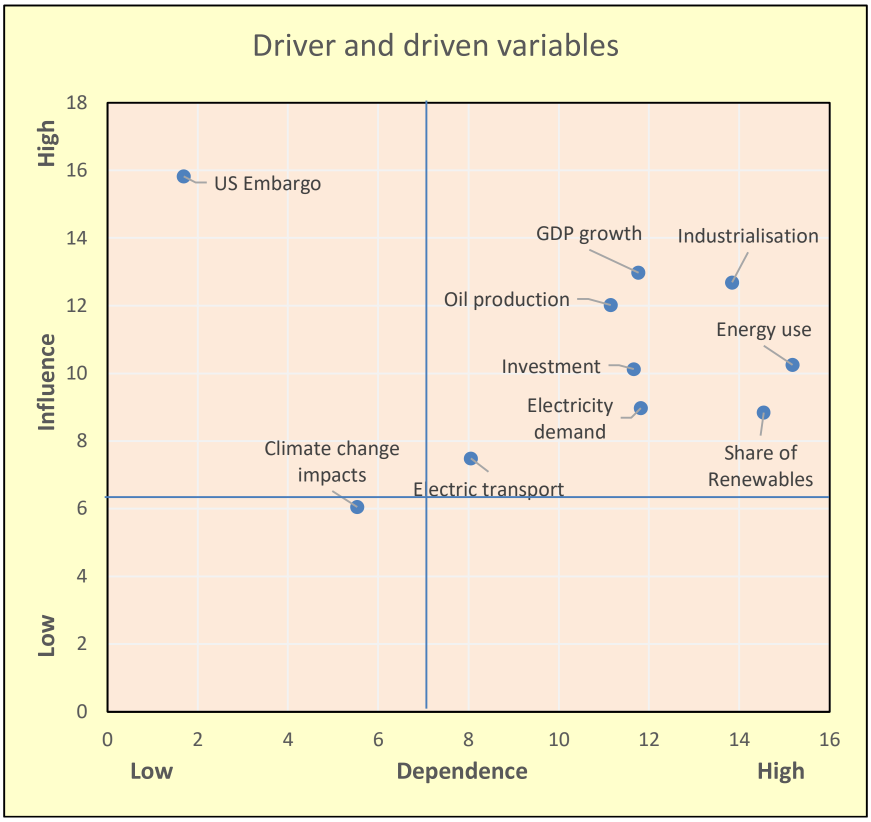

Figure 3. *The analysis of the Influence and dependence of the variables based on the expert inputs for the direct impacts in the cross-impact matrix.*

We can present the following interpretations of *direct impacts of variables* (see e.g. Alter, 1979). We can identify one **active variable** (high influence, low dependence), which is that the US Embargo will increase. Active variables allow effective changes in the system and thus have the potential to re-stabilize it in a new state. They are of major interest for the strategic process. The results of the CIA analysis is in this case quite straightforward.

Critical driver variables (high influence, high dependence) have to be handled with caution because they have very big potential for driving and changing processes, but they can easily get out of control, or destabilize the system. For the emergence of energy policy changes, these trend variables are very critical. According to the analysis critical variables are (1) industrialisation, (2) GDP growth, (3) oil production, (4) energy use, (5) investment, (6) electricity demand, (7) share of renewables and (7) electric transport.

Reactive variables (low influence, high dependence) in the reactive zone represent important indicators but have no steering potential. In this case, there are no such trend variables.

Dependent buffer variables (low influence, low dependence) have a limited effect on the system, and the neutral zone provides variables for self-regulation but again no good candidates for steering. We were able to identify Climate change impacts as such a dependent buffer variable.

The EXIT algorithm was utilized to calculate the indirect impacts of the variables. The modified cross-impact matrix, when the indirect impacts are taken into account, is shown in Table 3.

Table 3. *The modified cross-impact matrix when the indirect impacts are taken into account.*

		A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*J*	*Driver*
Investments will increase	*A*		-0,3	1,6	0,9	1,0	0,6	1,8	1,5	1,7	2,1	11,6
US Embargo will increase	*B*	-2,5		-2,7	-1,6	-1,8	-0,9	-2,8	-2,6	-2,8	-3,4	21,1
Share of Renewables will increase	*C*	1,0	-0,2		0,7	0,7	0,5	1,2	1,0	1,1	1,4	7,9
Electric transport will increase	*D*	0,8	-0,2	1,1		0,5	0,5	1,0	0,9	0,9	1,2	7,3
Oil production will increase	*E*	1,3	-0,2	1,4	0,6		0,3	1,5	1,3	1,5	1,7	9,7
Climate change impacts	*F*	0,1	0,0	0,5	0,3	-0,2		0,2	0,2	0,1	0,2	1,7
Electricity demand will increase	*G*	1,3	-0,2	1,3	0,7	1,0	0,4		1,4	1,5	1,7	9,6
GDP growth will increase	*H*	1,7	-0,3	2,0	1,1	1,3	0,7	2,0		2,0	2,5	13,5
Industrialisation will increase	*I*	1,6	-0,3	1,9	1,0	1,3	0,6	1,9	1,9		2,3	12,7
Energy use will increase	*J*	1,4	-0,3	1,5	0,8	1,0	0,5	1,6	1,4	1,5		10,0
	Driven	11,7	2,0	14,0	7,8	8,8	5,0	14,1	12,2	13,1	16,5	

From table 3 we can see that the values of the matrix and the driver/driven values have changed as the result of the interactions of the variables. We can illustrate the changes of the driver/driven variables in the xy-plot in Fig. 4. Here we can see that some of the variables are affected more by the indirect impacts and some variables are less dependent on the indirect impacts. It can be seen that the US Embargo has an even stronger influence on the system when the indirect impacts are taken into account. The Climate change impacts seem to be reduced by the indirect impacts according to the analysis. The dependence of Oil production on indirect impacts seems to decrease while the impact on the Electricity demand seems to increase the dependence as a result of the indirect impacts.

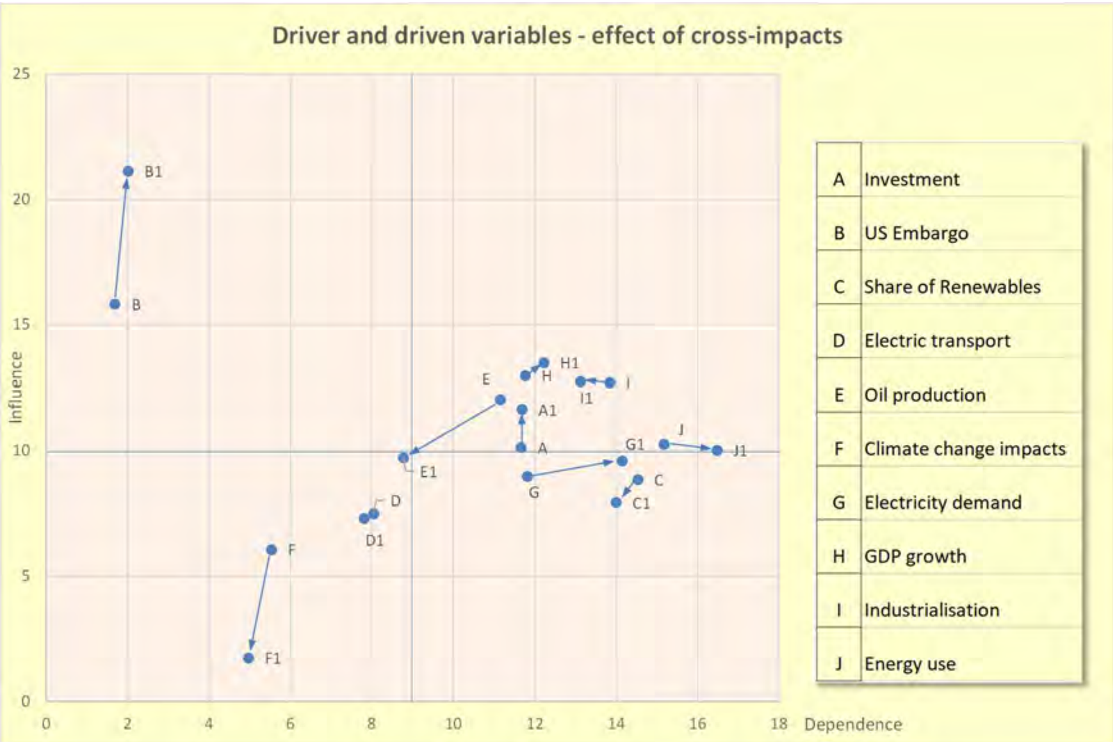

Figure 4. *The impact of indirect impacts on the different variables using the EXIT algorithm.*

We can present the following interpretations of *indirect impacts of variables* (see e.g. Alter 1979). We are able to identify only one **active** variable, which is US Embargo (increase). Indirect analysis reveals clearly that US Embargo will have an even bigger impact when indirect effects are evaluated using the EXIT algorithm.

When indirect impacts are evaluated the **critical variables** are (1) industrialisation, (2) GDP growth, and (3) investment,

When indirect impacts are evaluated the "Increase in energy use" moves close to **reactive variables** as well as the "Increase in share of renewables". These reactive variables have low steering potential. The variable "Oil production" moves close to the domain of driven buffer variables.,

Dependent **buffer variables** "Climate change impacts" and "Electric transportation" have a limited effect on the system, and the neutral zone provides variables for self-regulation but again no good candidates for steering.

The sensitivity of the different variables on the cross-impacts can be analysed from the results. The sensitivities are calculated based on the difference of the driver-driven values of the variables in the xy-plot (the length of the arrow in Fig. 4) based on the direct impacts and when cross-impacts are taken into account. The sensitivity of the different variables on the cross-impacts is illustrated in Fig. 5.

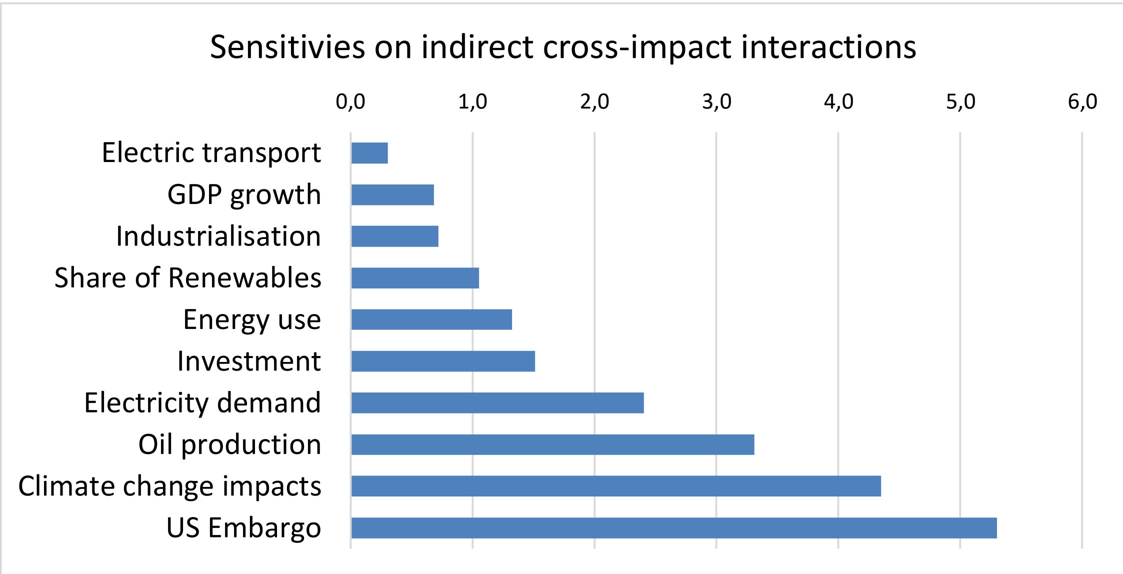

Figure 5. *Sensitivity of the different variables on indirect impacts.*

In addition to the EXIT analysis also the AXIOM analysis was carried out for the selected variables. AXIOM analysis, which uses Fuzzy Cognitive Map approach (see Panula-Ontto 2019), can be utilized for assessing the changes in the probabilities of different variables. Also, the a priori probabilities of the variables can be changed and the impact of the changes can be evaluated. In Fig. 6 the original probabilities of growth of the variables are shown together with the probabilities when the cross-impacts are taken into account using the AXIOM algorithm. According to these results, the cross-impacts seem mainly to increase the probabilities of growth of the variables except in the case of the US Embargo where the probability decreases.

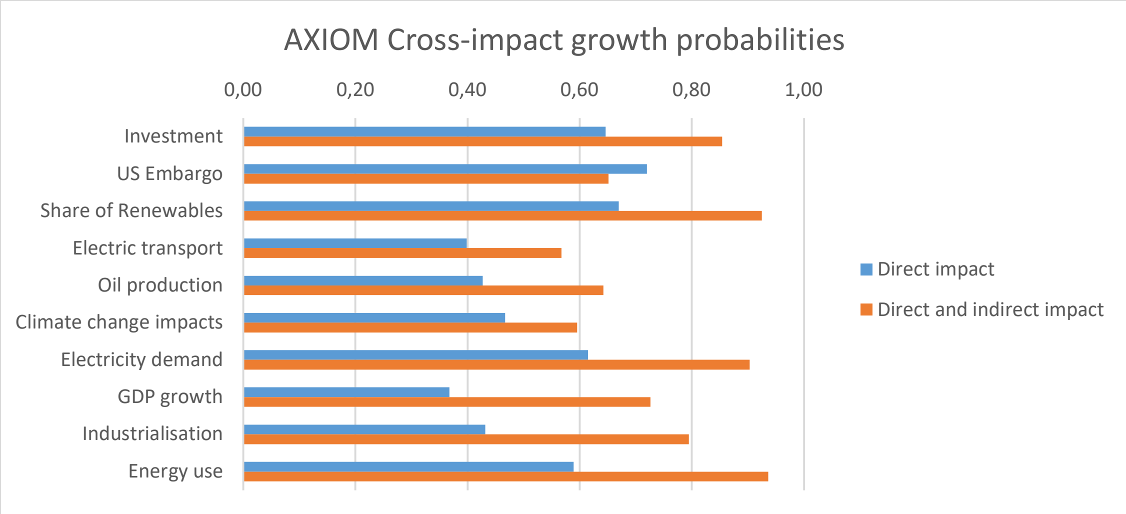

Figure 6. *A priori probabilities of the growth of different variables (based on expert evaluations) and the probabilities when the cross-impacts are taken into account with the AXIOM algorithm.*

The AXIOM tool can be used for analysing the impact of changes in the a priori probabilities of the variables. For instance, if we are sure that the 'GDP', 'Electricity demand' and 'Electric transport' will grow considerably in the future we can change their a priori probabilities to one and see the impacts on the changed probabilities of other variables. Fig. 7 illustrates this case.

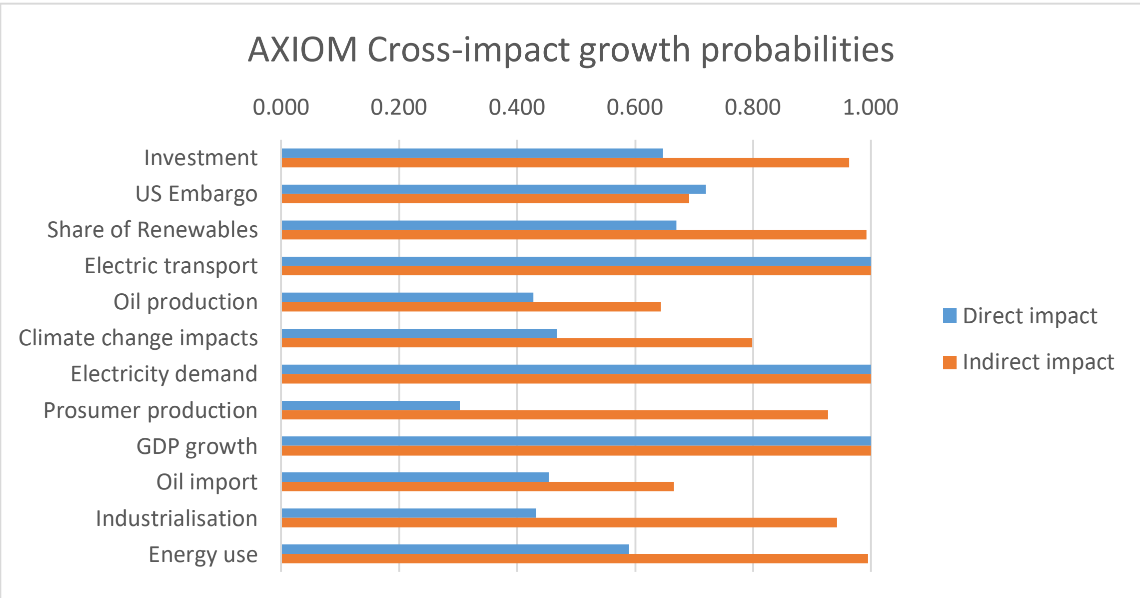

Figure 7. *Changes in the probabilities of growth of different variables when the probabilities of GDP growth, Electric transport increase and Electricity demand increase are given value 1 and the cross-impacts are taken into account.*

Conclusion

The Cross-Impact analysis provides a tool for utilizing expert knowledge in the analysis of a complex system, where the interactions cannot easily be modelled with quantitative modelling techniques. Cross-impact analysis tries to take into account the various impact chains of the interactions of the selected variables. In this study, the indirect impact chains were evaluated. Indirect effects, which are not always taken into account in the analysis of the effectiveness of policy actions, can be assessed using CIA analysis. Our results show clearly how important it is to evaluate the indirect impacts. When assessing indirect effects, many critical variables received new interpretations for updated forward-looking long-run strategy analysis. Some critical variables changed to the domains of “driven buffer” (electric transport) and “reactive” (share of renewables and energy demand) variables. It is interesting to note that the variable “US Embargo” stayed in the category of the active strategic variable.

The cross-impact analysis presented here for the Cuban societal energy system tries to illustrate the use of the method for analysing the system with complex interactions. In this CIA-analysis, we used three expert workshops to discuss the variables to be selected for the analysis and to construct the cross-impact matrix for the variables. The selection of the expert participants has a distinct impact on the selection of variables and the determination of their impacts. The use of experts with a large variety of background knowledge is advisable if the system under study has several features which cannot be covered with one field of expertise.

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II.6. Outlook on Cuban energy politics – from past to future

Miriam Lourdes Filgueiras Sainz de Rozas and Mika Korkeakoski

State of play of current Cuban (electric) power generation

Over 95% of Cuba's (electric) power is generated with fossil fuels, with roughly half of the oil imported from Venezuela to complement domestic fossil resources (UNE 2019). This results in a high cost of production of around 0,22 - 0,26 USD/kWh) and coupled with low energy efficiency in generation, transmission and use lead to high greenhouse gas emissions. Although Cuba's energy revolution introduced an emphasis on renewable energy, the decentralisation of electricity production in replacing the outdated technology has not had much impact on the industry, transportation and agriculture yet (Vazquez et al., 2015).

Cuban power sector characteristics include a relatively high electrification rate, a distributed energy production (around 70%) and low but increasing energy consumption per capita (still one of the lowest in the region) (UNE, 2019). However, reliance on imported fuels has geared the government interest towards better utilisation of domestic resources to increase Cuban energy security and independence, thus making it less vulnerable to external changes. Until recent years, Cuba has focused strongly on energy conservation through energy efficiency and savings (Käkönen et al., 2014). Energy intensity has decreased from 1997 onwards mainly due to economic crises and the growth of the service sector. Recently, Cuba's total energy consumption has been increasing with the Cuban economy opening and tourism expanding.

The overall installed energy production capacity in Cuba is configured through a combination of thermoelectric and combined heat and power (CHP) baseload, diesel and fuel oil decentralized power generation, bioenergy from sugarcane bagasse and small amounts of power from biogas, hydro, solar and wind sources (Figure 1).

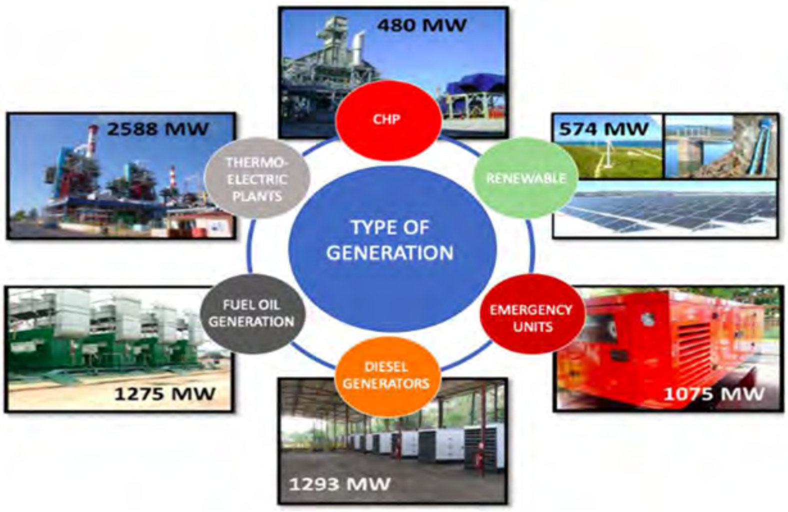

Figure 1: *The composition of Cuban electricity generation capacity. (Guerra García, 2016)*

Altogether, renewables accounted only for 4,65% (3,7% biomass, mainly from sugarcane bagasse, 0,5% hydropower, 0,2% solar photovoltaic and 0,1% wind energy) of the total electricity production of the country in 2018 (see Figure 2). Biomass clearly dominates over other renewables with 88% of renewable electricity (IEA, 2015; ONEI, 2018). Cuba has a vast renewable energy potential to be harnessed also in other renewables. According to IRENA, Cuba has a good potential in both solar and wind resources with an average solar irradiance of 223.8 W/m2 (5.4 kWh/m2/day) and an average wind speed of around 5.7 m/s (in the southeast above 7 m/s) (Zhao, 2017).

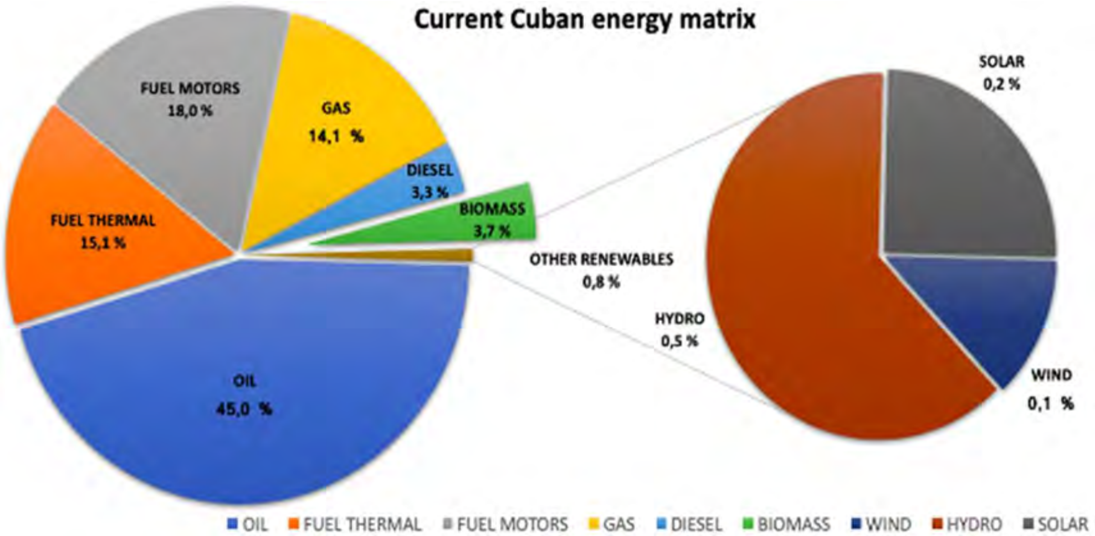

Figure 2: *Renewable energy supply in the total Cuban energy mix. (ONEI, 2018)*

The transition towards renewables: current policies and visions on implementation of energy efficiency and renewable energy

Over the last decades, Cuba has been remarkably successful in revitalising its energy sector by significantly increasing efficiency and reducing energy intensity and emissions. Achieving a comprehensive approach that targets infrastructure, consumption habits and people's understanding of energy issues can provide Cuba with a fertile ground to reach its 2030 energy policy goals. The Cuban government has rolled out a policy program to significantly increase its total power generation from renewables. In June 2014, the government approved a new policy for the development of renewable energy and energy efficiency in Cuba (Prospective Development of Renewable Energy Sources and the Efficient Use of Energy for 2014-2030[1], MINEM, 2017)

The main targets include increasing the penetration rate of renewables, reducing the electricity generation costs and dependence on fossil fuels, and environmental goals (see Figure 3):

- Produce 24% of electricity using renewable energy sources by 2030 (Note: from 4,3% in 2013)

[1] Política para el Desarrollo Perspectivo de las Fuentes Renovables y el Uso Eficiente de la energía 2014 – 2030" of 21st June 2014. MINEM, 2017).

- Renewable energy will be more than 50% of the increased power generation installed capacity by 2030
- Decrease dependence on fuel imports and reduce the proportion of imported fuels of the total electricity generation by 2% approximately by 2030.
- Reduce the production costs of energy delivered by the national energy system by 13% of the cost of the given kWh to decrease the price gap to consumer price (currently electricity is heavily subsidized, consumer price is much less than the production cost)
- Reduce environmental pollution by decreasing CO_2 emissions by roughly 4,5 million tons/year.

In 2013, 4.3% of the power installed in the energy mix corresponded to the renewable energy sources (majority from biomass with some wind, solar and hydro). The expected 24% share of the total production by 2030 in the programme is anticipated through (MINEM, 2017; UNFCCC, 2017):

- 755 MW from 19 bioenergy plants fueled by sugar-cane and forestry biomass
- 633 MW from 13 wind parks
- 700 MW from solar photovoltaic parks
- 56 MW from 74 small hydropower plants

The Cuban government estimates that $3.5-4.0 billion in investments is needed to achieve their 2030 renewable energy targets (Panfil et al., 2017) with a significant share of Foreign Direct Investments. The majority of the investments are foreseen in wind and solar photovoltaic investments. In addition, the government promotes investments in other renewable energy sources, for example in biogas, forestry biomass, agro-industrial residues and municipal solid waste.

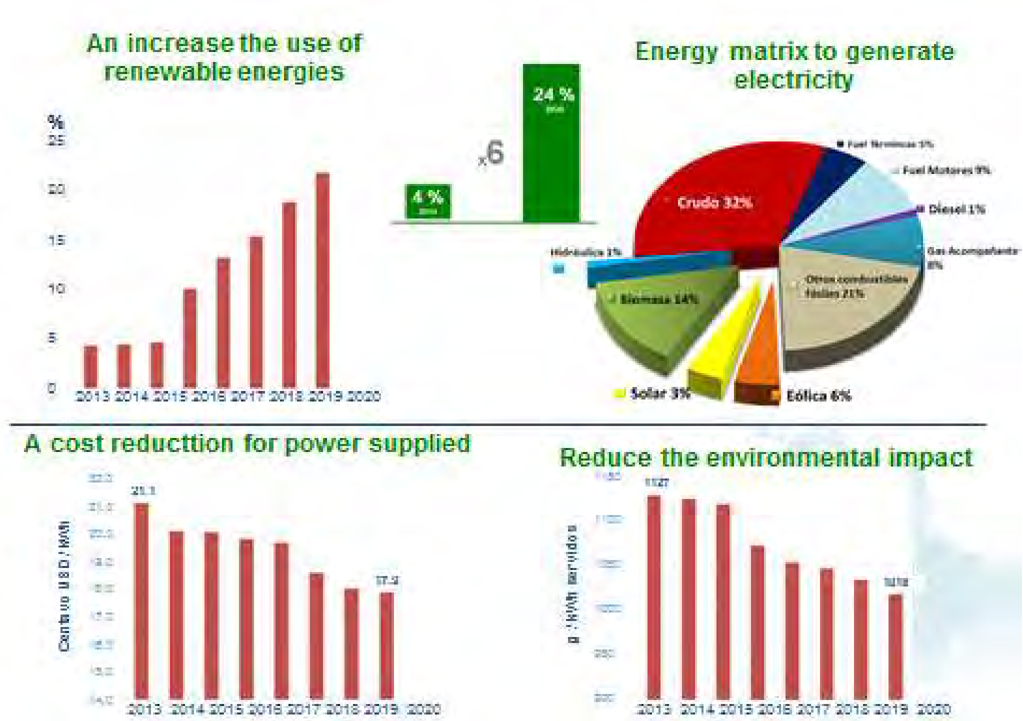

***Figure 3**: The Main Goals of the program to implement the Cuban policy for the development of renewable energy and energy efficiency. (Guerra García, 2016)*

The main guidelines of the Socio-Economic Development Plan until 2030 were discussed in the 7th Party Congress and approved by the National Assembly in June 2017. The guidelines of the Socio-economic implementation plan for 2016-2021 under the Energy Policy section state (PCC, 2017):

Guideline 201. Encourage cogeneration and trigeneration in all potential generation activities.

Guideline 202. Accelerate the execution of the Program approved up to 2030, for the development of renewable sources and the efficient use of energy.

Guideline 213. Continue prioritizing the repair, maintenance, renovation and upgrade of the tourist infrastructure and support. To apply politicies that guarantee the sustainability of their development, implementing measures to diminish the index of consumption of water and energy and to increase the use of renewable (…), in harmony with the environment.

The National Plan of Economic and Social Development until 2030: Vision of the Nation, Axes and Strategic Sectors (PCC, 2017) contemplate the guiding principles:

To propitiate that the scientific and creative potential of the country becomes a decisive productive force to reach the sustainability of the development, starting from stimulating the scientific investigation and the processes of technological development and innovation.

- *To transform and develop, quickly and efficiently, the energy mix by increasing the participation of renewable sources and other national energy resources and the use of advanced technologies.*
- *To conceive and promote foreign direct investment as an essential part of the country's development strategy and, in particular, of the economic sectors defined as strategic.*
- *Achieve an adequate territorial distribution of the productive forces, which combines the national and sectoral dimension with the local dimension and the development of modern, orderly, prosperous and sustainable cities and rural, coastal and mountainous areas.*

The six strategic areas/axis noted under PCC (2017) include: 1) Effectiveness and efficiency of the socialist government and social integration 2) Productive transformation and international insertion 3) Infrastructure (4) human potential, science, technology and innovation; (5) natural resources and environment; and (6) human development, equity and social justice. These are directly connected to energy transformation. One of the key strategic sectors for development, energy, is emphasizing *"transforming the energy mix with a greater participation of renewable and other sources of energy and other national energy resources, ensuring energy efficiency and exploring and oil and gas refining*". (PCC, 2017)

Making the change: Absorptive capacity of Cuban organizations and academia

It has been proven widely that the capacity to progress and develop a nation, a region, sector or a company depends directly on its capacity to adapt quickly to the changes in the environment, especially of the technological environment, and even to provoke modifications that favour them. Everything is obtained through the development of technological innovation processes, where this is not an end in itself but a means to achieve social development on the basis of a sustainable economy (Pérez, 2004:7) To transform, to mutate, to evolve, this process allows innovation: in the wide sense, it means problem-solving.

"The technology is the mean to transform ideas in products or services which allow to improve or develop processes" – Fidel Castro (2004).

According to their focus, innovation does not only reside in the methods, machines, procedures, instruments, materials and equipment that can be bought or to be exchanged, but rather it also constitutes a spiritual state, the expression of the creative talent and the capacity to systematize the knowledge to be best used by the society. In this sense, a strategy for the development of renewable energies in the country should consider all these aspects by focusing on Science, Technology and Society (Castro, 2004).

But without an adequate absorptive capacity in Cuban organizations participating in this program, it is impossible to attain these targets. The process of technology transfer is critical to deploy new technologies into organizations. The effective assimilation of technology depends on the absorptive capacity. Absorptive Capacity (ACAP) has been defined as "the ability of a firm to recognize the value of new external information (knowledge), acquire it, assimilate it, and apply it to commercial ends" (Cohen and Levinthal, 1990). In the same direction, Sun and Anderson (2010) defined ACAP as "a kind of organizational learning from external sources". This capacity emerges from the linkages – connections of the knowledge entangled in the organizational activities and the individual skills of the people who constitute these organizations. Due to the structural inherent complexity and the associated multidimensionality of the learning process during the technology transfer process, many authors (Lane et al. 2006; Volbreda et al. 2010) recommend the process/capabilities perspective as a broader approach.

Academia's role in Energy Transformations

At that point, the universities have an important role in order to develop strategies to increase the absorptive capacity in the productive sectors of the economy and policymakers. Their contribution is crucial for this program. Hence, an international collaboration to build capacity in the higher education institutions and doctorate studies for younger researchers and professors is imperative.

The academia should be prepared, not just to research, teach, acquire and install new technologies. They should be prepared to create and develop absorptive capacity in organizations of the productive sector involved in renewable energy in Cuba. They should help in the diagnosis process of these organizations by determining the level of ACAP. They have to find the technological, organizational and social gaps which are limiting the exploration, identification and assimilation of these technologies. They should establish strategies and actions to bridge the gaps. They will have to take into account the integration of knowledge provided by university-industry interaction and foreign suppliers of technology because these entities are considered the main external sources of knowledge. Additionally, they should help formulate strategies and action plans to improve the level of ACAP. Finally, universities would help the other organizations to establish a monitoring and management system for the ACAP process.

Morning in Santiago de Cuba

Ways forward

Cuba needs significant foreign investments both to finance renewable energy projects and to improve its highly inefficient grid. The production necessities and lack of sufficient infrastructure for the energy supply imply strong investment requirements. Consequently, the Cuban government cannot move at a faster pace in the development of renewables due, among other elements, to the country's enormous financial limitations.

Some analysts consider that with more financial resources Cuba could advance much faster on the path to increase the participation of renewable energy within the energy mix of the country. Even though, during the last 5 years, the Cuban Government has invested more than 500 million USD in this program the estimated total cost of the investments is $3.5-4.0 billion to achieve their 2030 renewable energy targets (Panfil et al., 2017)

Thereby, it is necessary to promote a decentralized way to increase renewables and reach the targets established by the policy. In that sense, the Cuban Government published the Decree Law 345 - *"For the development of the renewable sources and the efficient use of the energy*" (Ministerio de Justicia, 2019). This regulatory instrument accompanied with complimentary resolutions of the ministries of Energy and Mines and Interior as well as instructions of the Central Bank establishes those trade priorities and regulations that will govern this sector. Further, it introduces the sale of renewable energy units and appliances to the Cuban Electric Corporation (UNE) and the residential sector as well as larger commercialization of parts and equipment (Ministerio de Justicia, 2019).

Decree Law 345 is the mandatory norm that orchestrates the politics of the development of renewable and rational use of energy, and it gives guidance to each of the regulations for the implementation of the actions referenced in the policy itself.

Additionally, Instruction 6/2019 of the Central Bank of Cuba instructs the commercial banks to grant credit to individuals to acquire equipment for the use of renewable energy such as solar heaters and solar photovoltaic systems. This credit is granted in Cuban pesos up to 100% of the value of the equipment. The amount of the grant and the terms of payback is based on the risk analysis carried out by banks for each of the applicants (Extremera San Martín, 2019).

This ordinance Law states also that all the new constructions and the investment processes executed should have in their design the solutions of renewable and rational use of energy whenever the evaluation cost-benefit is in favour of that investment. This Ordinance law sets the benefits, tariff and fiscal incentives to juridical people with the purpose of stimulating the investments related to these technologies (Extremera San Martín, 2019).

For the first time ever, the Ordinance Law allows sales of energy production to the National Electric System; the Ministry of Energy and Mines promotes the consumer and residential driven production and the Cuban government's regulatory environment around the development of renewable energies is sending clear signals that the transition towards renewables is on its way. This is based on the realization that with exclusively centralized investment Cuba could not advance in its renewable energy transformation goals but had to find better ways to implement the policy (Extremera San Martín, 2019).

At the same time, Cuba promotes local development through the decentralization of governance to municipalities (ANPP, 2019). Within the framework of the process of administrative and economic reforms that are taking place in Cuba, based on political documents (Conceptualization of the Cuban Economic and Social Model of Socialist Development; The Bases of the National Plan of Economic and Social Development until 2030: Vision of the Nation, Axes and Strategic Sectors; and, Guidelines of the Economic and Social Policy of the Party and the Revolution for the period 2016-2021), significant importance is given to the improvement of the municipal level of governance and mechanisms of people's participation, as well as to the promotion of local development (ANPP, 2019).

This leads to a re-evaluation of the role of the municipality as the driving force of development and a fundamental link in supporting socialist democracy. The role of municipal governments has been recognized by the new Constitution of the Republic of Cuba As the municipal governments are already promoting rural regions to elevate the quality of life for everyone in Cuba, in the future this can also include the provision of modern access to affordable, reliable and safe electricity through renewables.

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III. Socio-Economic developments

III.1. Energy economy in Cuba and future challenges

Anaely Saunders Vázquez, Jari Kaivo-Oja and Jyrki Luukkanen

This article looks at the development of Cuba from economic and global perspectives. These two perspectives are directly in relation to one another. We discuss first the historical development, Cuban Revolution, cooperation with the Soviet Union and the aspects of bilateral trade. In this context, we also discuss the economic cooperation with Venezuela and the impacts of the US blockade. We base our analysis partly on the theoretical perspective of the island economy and dependency theory. We also carry out a decomposition analysis of the Cuban energy economy to illustrate the drivers of energy use and the CO_2 emissions in the country. Next, we will look at the aspects of regional development in Cuba and the rural/urban changes. Also, the changes in population structure will be discussed because it has an impact on future economic development.

Island economy theory

In the economic literature, there has been a lot of discussion on the special characteristics of island states. The discussion has intensified due to the climate change problematique. The island states are more vulnerable compared to other states. There is a large literature about the advantages and disadvantages of being a small economy. Briguglio (1995) notes that small island economies face challenges due to remoteness, insularity, and vulnerability to natural disasters. Economic vulnerabilities include size, natural resources, constraints to import substitution, dependence on export markets and a narrow product range, limited power to influence prices and inability to achieve economics of scale. Later Read (2004) suggested that islandness and globalization through trade have a significant impact on island economies. In the field of development theory, a classical way to explain the challenges of island economies has been the dependency theory. Santos (2019) explained dependency as a situation in which an economy of a certain country or a group of countries is conditioned by another economy. Economic history provides many examples of dependency in colonial relationships. For example, Kaufman et al. (1975) note that the peripheries (colonies) do not have the necessary resources to compete in the international markets. According to the authors, even the industrialisation process does not reduce the level of dependency between patrons and peripheries. This kind of dependency theory can be applied to the island economy of Cuba.

In the context of dependency theory discussions Read (2004) suggest that peripheries tend to concentrate on a few niche market exports which exacerbate the dependency problem of periphery economies. It is very important to understand those periphery economies, in general, experience a decline in domestic entrepreneurial activities while multinational corporations replace domestic ones (Kaufman et al., 1975).

The leadership in Cuba has taken the dependency theory seriously and tried to minimise the negative aspects and disadvantages of dependency. As an economic theory dependency theory provides a fruitful approach to explain the economic history of Cuba. The Cuban economy has developed in close relation with its colonies. Global politics have always played role in the Cuban island

economy and the cross-national product of the Cuban economy has been driven by a common stochastic trend and specific indicators with patron and collaborating economies (Spain, USA, Soviet Union, Venezuela). The national economic cycles in Cuba have reflected and co-moved with key economic partners. When the partners have been successful, the Cuban economy has been booming but when the partner economy had declined the Cuban economy has had problems.
The pursuit for the comparative advantage in the Cuban case has led to the increased production of sugar during the 1960s-1980s to the Soviet markets this led to lower resilience (see e.g., Perez-Lopez, 1989).
The cooperation among Latin American countries has not been as integrated as, for instance, in the European Union. EU has helped the island economies in the Mediterranean area. For Cuba and other Caribbean region economies, a closer economic collaboration could be beneficial to improve the resilience of island economies. All these economies meet the challenge of short-run business cycle dependency. Many recent study results imply that business cycles in patron and periphery economies follow perfectly synchronized regime-switching processes (Balcilar et al., 2017: 2).
If we want to link energy planning to economic planning in an island economy like Cuba one background approach could be dependency theory and its empirical applications. One potentially promising methodological approach is a trade-off and synergy analysis for analysing the cyclical dependencies in the economies (Kaivo-Oja et al., 2016; Kaivo-Oja et al., 2017; Luukkanen et al., 2012; 2018; Mainali et al.,2018; Vazquez et al., 2015; Vehmas et al., 2018).

Cuban economic development

The economy of Cuba has been a largely planned economy dominated by state-run enterprises. The government of Cuba owns and operates most industries. A large share of the labour force is employed by the state. After the collapse of the Soviet Union in 1991, the formation of worker cooperatives and self-employment has been encouraged. Greater private property and free-market rights were granted by the 2019 Constitution, which provides possibilities for foreign investments. During 2019, several projects have been concretized in promising areas, including the Mariel Special Development Zone (ZEDM) and key sectors of the economy, like tourism (Granma, 2019).

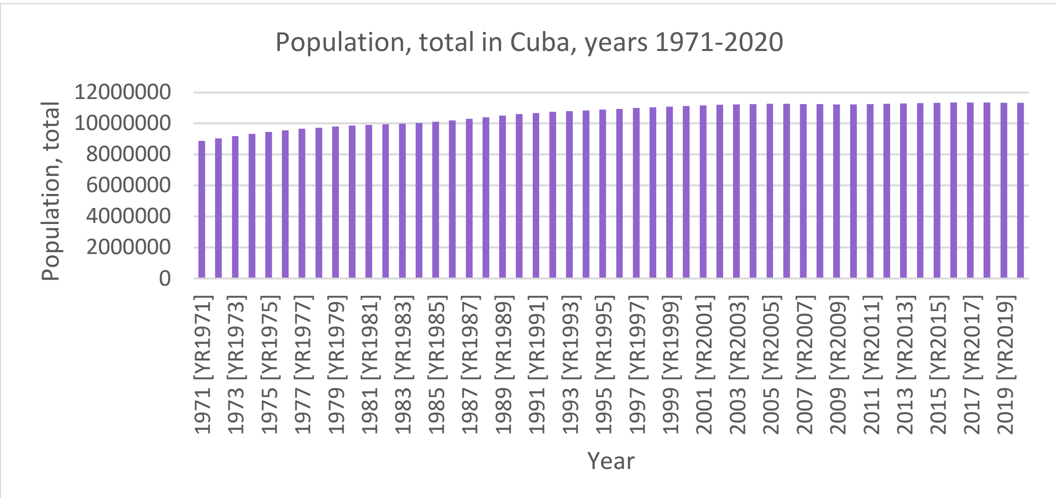

Figure 1. *Cuba population. Data source ONEI (2020)a; World Bank (2021)*

In Fig 2 we can see the structure of the Cuban population by age and sex. This figure is often called a population pyramid. It can be also called an “age-gender-pyramid”. Fig 2 is a graphical illustration that shows the distribution of various age groups in a population, in this case in Cuba, which forms the shape of a pyramid when the population is growing. In the case of Cuba, we do not see the shape of a pyramid. At the global level, we can still see variation between two worlds, one with large families and short lives, and one with small families and long lives (typical in European Union). The Cuban structure is between these two extremes.

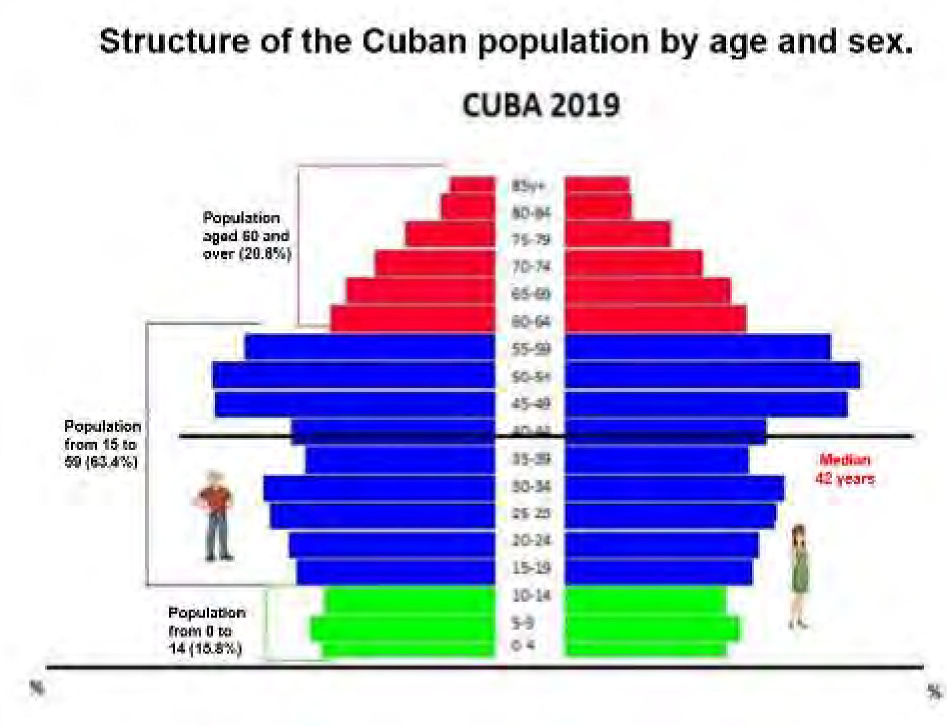

Figure 2. *Structure of de Cuban population by age and sex. (ONEI, 2020a).*

Global indicators of the Cuban population, such as mortality, fertility, age structure, among others, indicate that Cuban development is similar to developed countries. This is a characteristic of the island and is associated with the social development achieved. Cuba has very low levels of fertility (number of children a woman has in her reproductive life), infant mortality is very low and life expectancy is very high. In terms of population, only the group of 60 years and over is growing, the country has less population in school ages, less population in active ages, an emigration with a negative balance over the years, and there is an increase in social security expenses. (López and Valdés, 2020)

The Cuban population in 2019 was 11,193,470, of which the working-age population was 7,123,301, but the economically active population was 4,642,318 (Figueredo, et al., 2020).

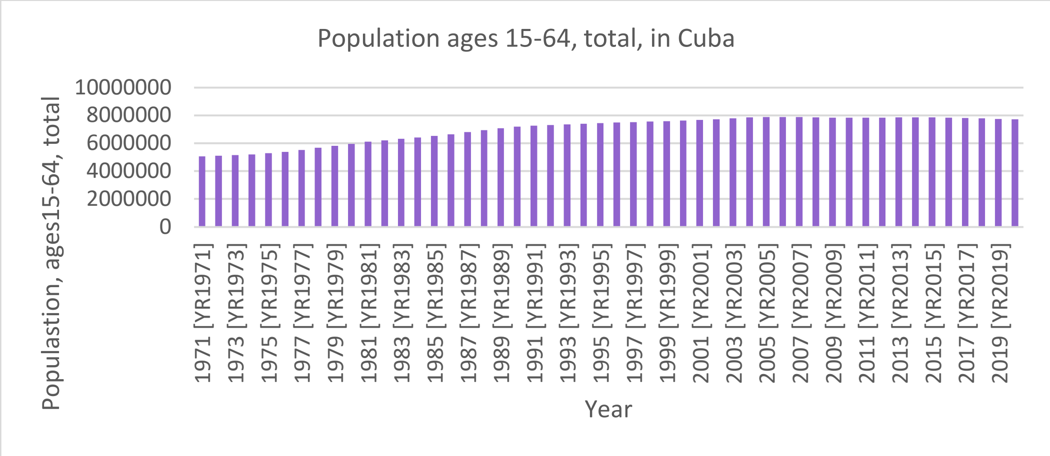

Figure 3. *Population ages 15-64, total, in Cuba Data source: World Bank (2021).*

In Fig 4 the trend line of the ratio of active population/total population is illustrated. The critical ratio is about 0,7 in Cuban society.

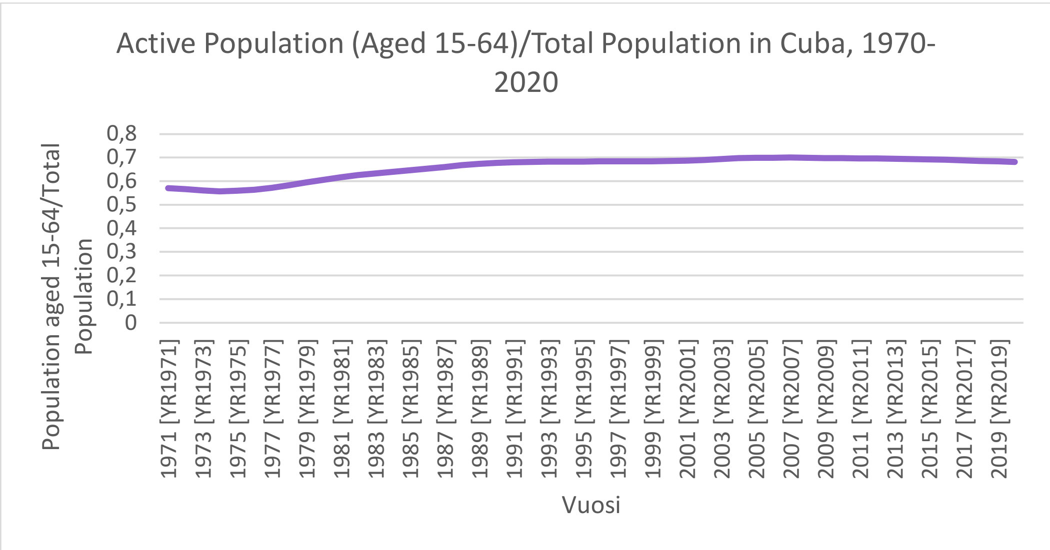

Figure 4. *Active Population (Aged 15-64)/Total Population in Cuba, years 1970-2020. Data source World Bank (2020).*

In Fig. 5 the changes in population in the cities of Cuba is reported. This information is vital for electricity planning in the cities.

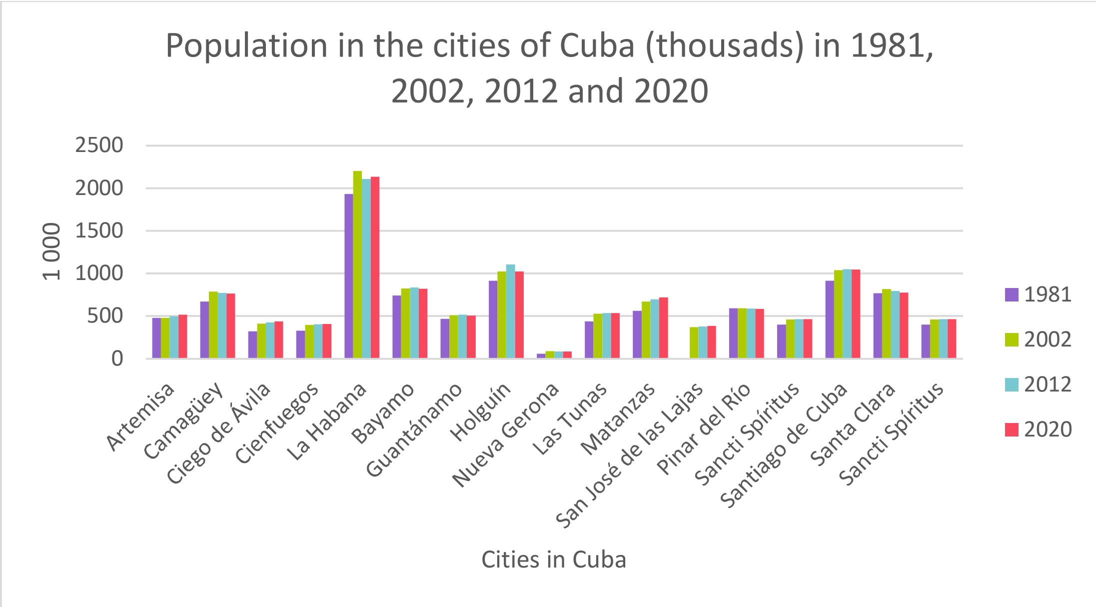

Figure 5. *Population in the cities of Cuba (thousands) in 1981, 2002, 2012 and 2020. Data source: World Bank (2020).*

The UN future scenarios for the Cuban population are shown in Figs 6a and 6b. UN estimation shows a fast decrease in the Cuban population after 2025. The reduction is estimated to be the fastest in the age group of 25-64, the active work age, which can cause lots of problems in economic production. When this is linked to the fast increase in the estimated number of older people (65+) the dependency ratio in the Cuban economy is assumed to increase considerably resulting increase in the support requirements. This is a big challenge for the Cuban economy in the future.

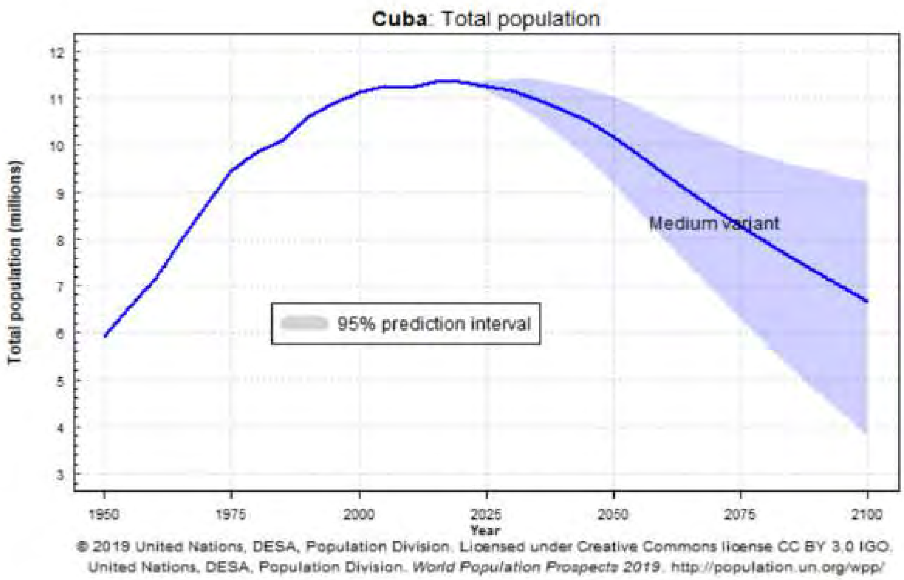

Figure 6a. *United Nations prediction for the development of the Cuban population (UN, 2019)*

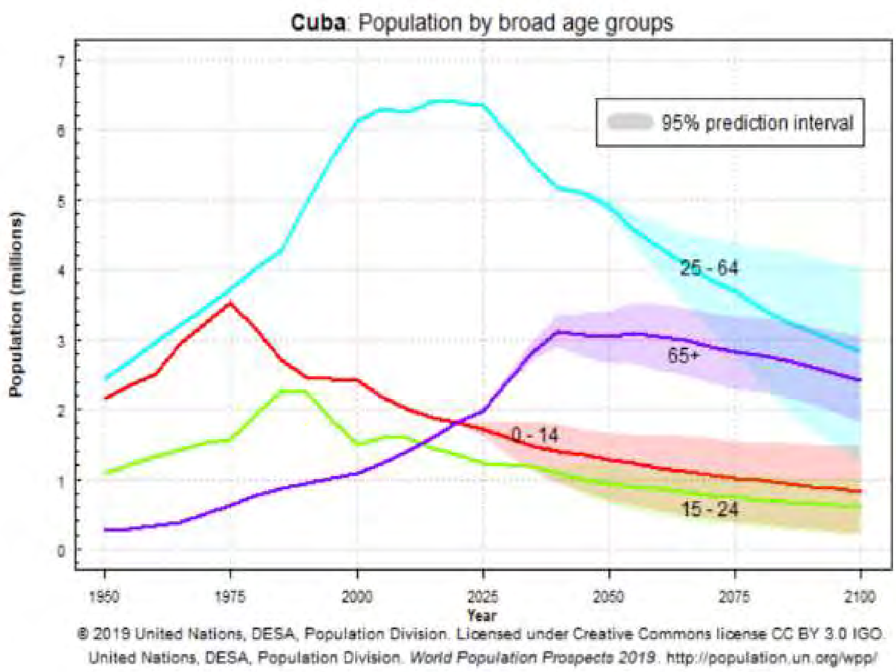

Figure 6b. *United Nations prediction for the development of the Cuban population in different age groups (UN, 2019).*

Figure 6a informs us that in the Cuban case we should plan energy system and electricity services for decreasing citizen numbers in Cuba, but tourism and other industries may require increasing electricity services. A critical question is how much electricity services must be delivered for tourism, hospitality and experience cluster. The service sector is important for the Cuban economy. The embargo of Cuba has been demanding for the Cuban economy and it has been problematic for tourism, hospitality and experience cluster as can be observed in Fig. 7. The embargo policy of the USA has dampened the growth of Cuba's service sector. The development was quite promising in 2004-2007 when growth was strong in Cuba. After that, the embargo began to dampen a promising development trend.

A local ATM, Santiago de Cuba

The U.S. embargo has been in place since the Cuban crisis (1962), but its lifting has been repeatedly discussed. The embargo is widespread and adversely affects all trade with companies in Cuba and the United States and other countries so that companies or their subcontractors cannot use raw materials or semi-finished products of Cuban origin in their production. One example is Toyota in Japan, whose subcontractors are not allowed to use nickel from Cuba in the parts it supplies to Toyota. The embargo has very far-reaching effects on the Cuban economy in almost all areas. The situation was exacerbated by Cuba's refusal in the aftermath of the hurricanes in 2008 to provide US humanitarian assistance in protest of the embargo and called on the United States to suspend the embargo, even temporarily. In 2008 Cuba experienced its most destructive hurricane season in recorded history (Messina Jr., 2008). The United States decided to make an exception to the embargo and sell $ 250 million in food and construction supplies to Cuba. Former U.S. President Barack Obama announced he was easing Cuba's embargo on U.S. travel restrictions. He also allowed Cuban immigrants living in the United States to send larger financial aid to their relatives in Cuba. This positive development was interrupted by the beginning of President Donald Trump's reign in 2016. In 2016 Cuban society faced on November 25, 2016, the death of Fidel Castro, which was also a serious backslash for positive developments with president Barack Obama. In June 2017 President Donald Trump announced that he will reinstate restrictions on Americans travelling to Cuba and U.S. business dealings with a military-run conglomerate but will not break diplomatic relations. (Timeline, 2021).

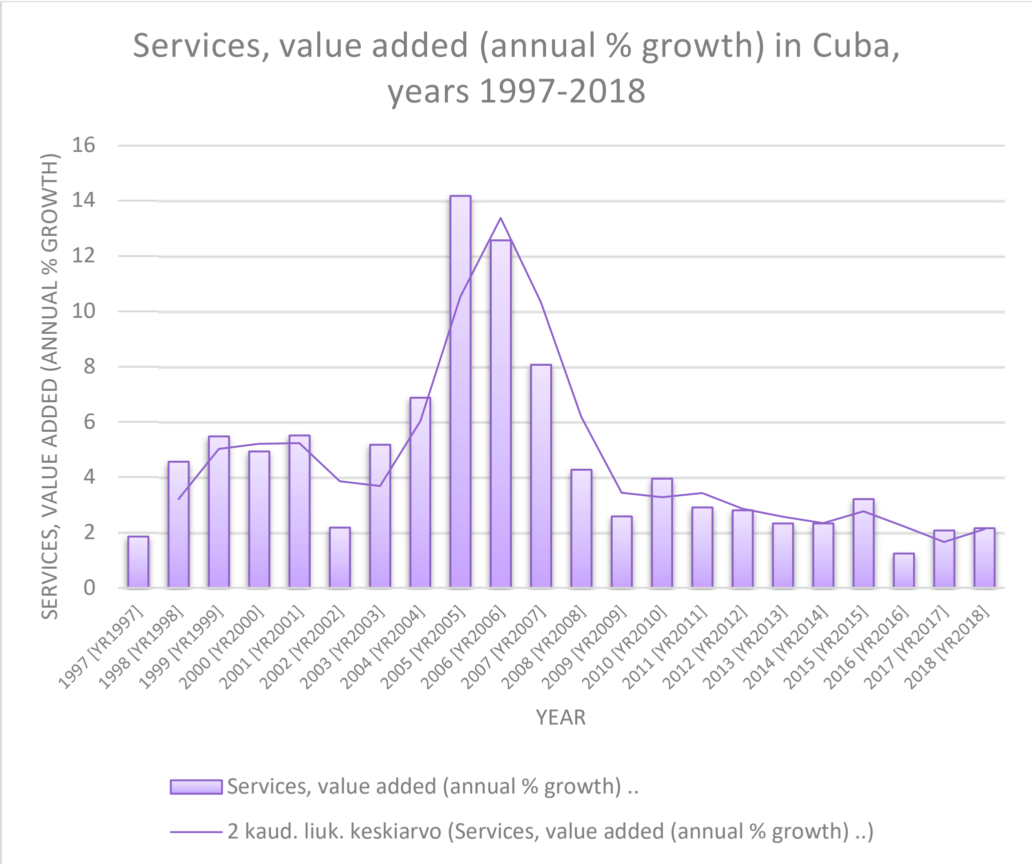

***Figure 7**. Services, value added (annual % growth) in Cuba, years 1997-2018. Data source: World Bank, Database, Cuba.*

As we see in Fig. 7, there have been large variations in the value-added of the Cuban service sector. This fact creates a big challenge for energy sector planning.

The employment to population ratio, 15+, based on ILO model estimate is shown in Fig. 3. This shows the ratio of the employed people to the adult population.

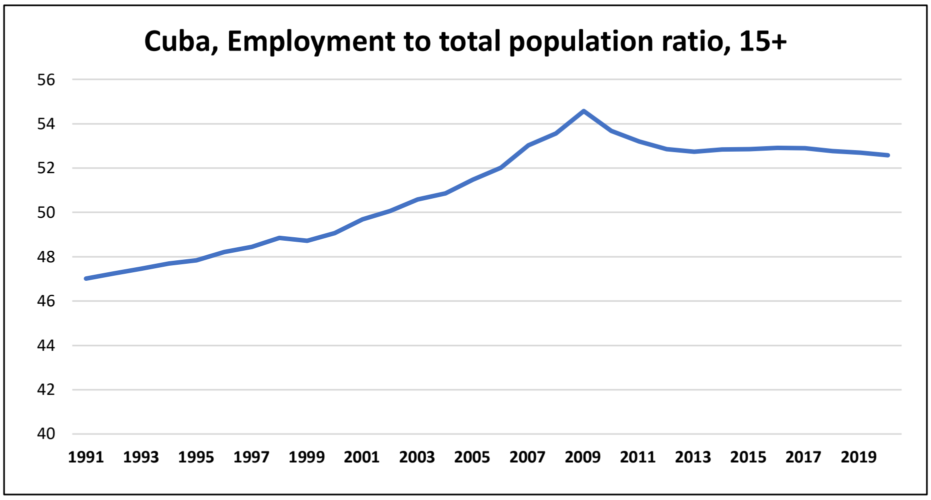

Figure 7. *Cuba, Employment to total population ratio, 15+ ILO modelled estimate (International Labour Organization, ILOSTAT database. Data retrieved on June 21, 2020)*

The number of people working in Cuba increased in 2019, following the increase in salaries in the state sector (Martínez and Puig, 2019). However, those employed in the economy represent only 41% of the total population (Figueredo et al., 2020). Figure 8 illustrates the allocation of the work-force in the State and Non-state sectors and Fig. 9 shows the allocation in the Non-state workforce.

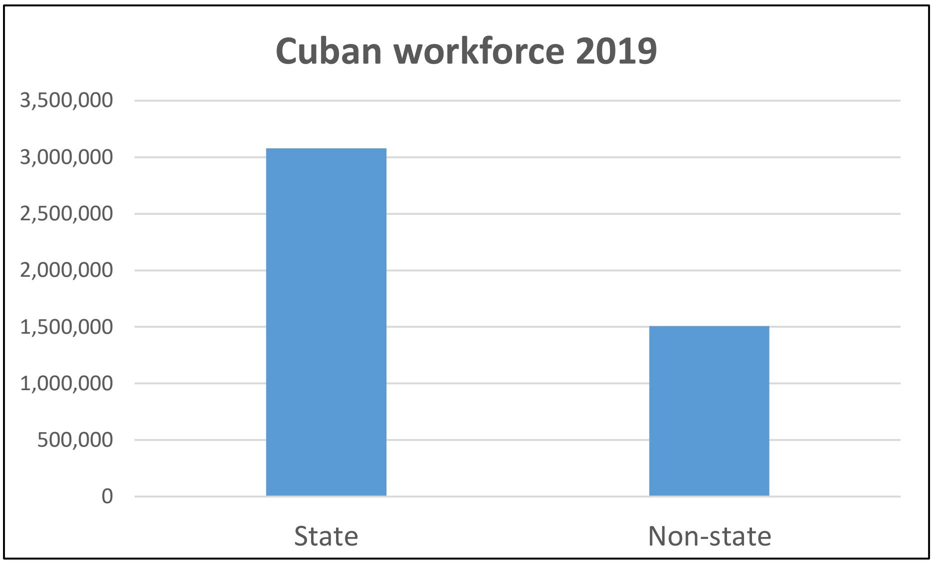

Figure 8. *Cuban workforce 2019. (Figueredo et al., 2020)*

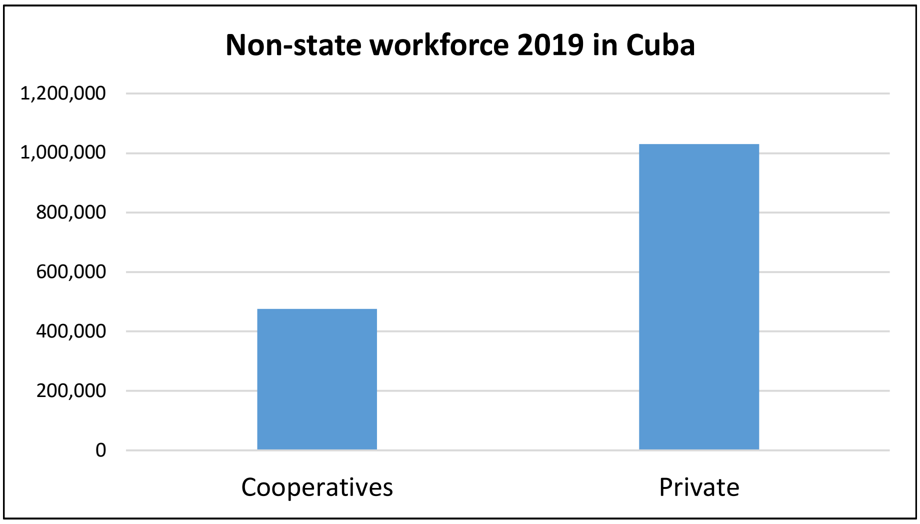

Figure 9. *Non-state workforce 2019 in Cuba. (Figueredo et al., 2020)*

The number of those who work in the non-state sector continues to rise, mainly self-employed workers, who already form 41% of that group. The sector that grows the most is the cooperative sector. (Figueredo, O., et al., 2020)

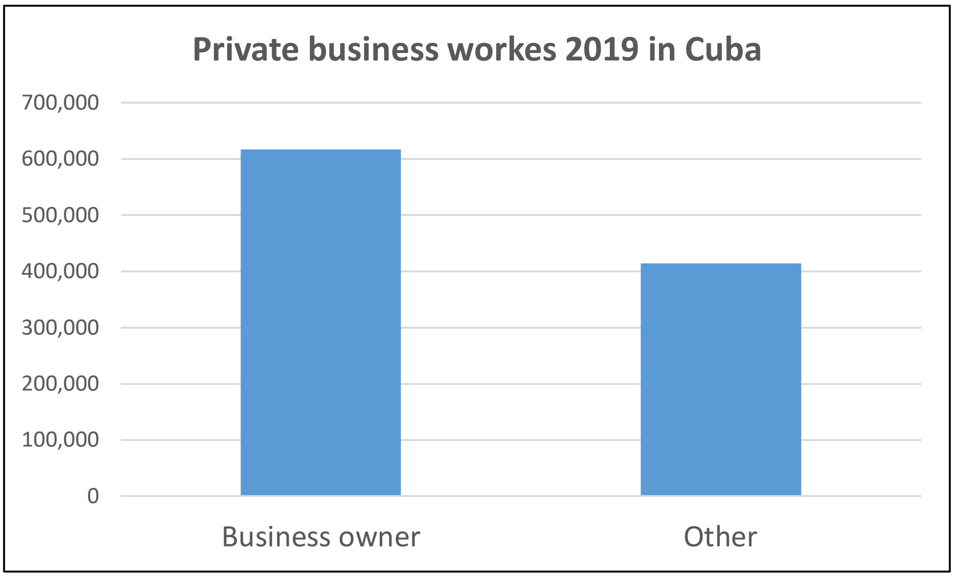

Figure 10. *Private business workers 2019 in Cuba. (Figueredo et al., 2020)*

Regarding employment by economic activities (see Fig. 7), the activity that employs the largest amount of labour force is Agriculture, forestry and livestock. However, this sector is not very productive since the country could produce 50% of the food that is imported today. This sector needs more investment and structure in production chains. (Figueredo et al., 2020)

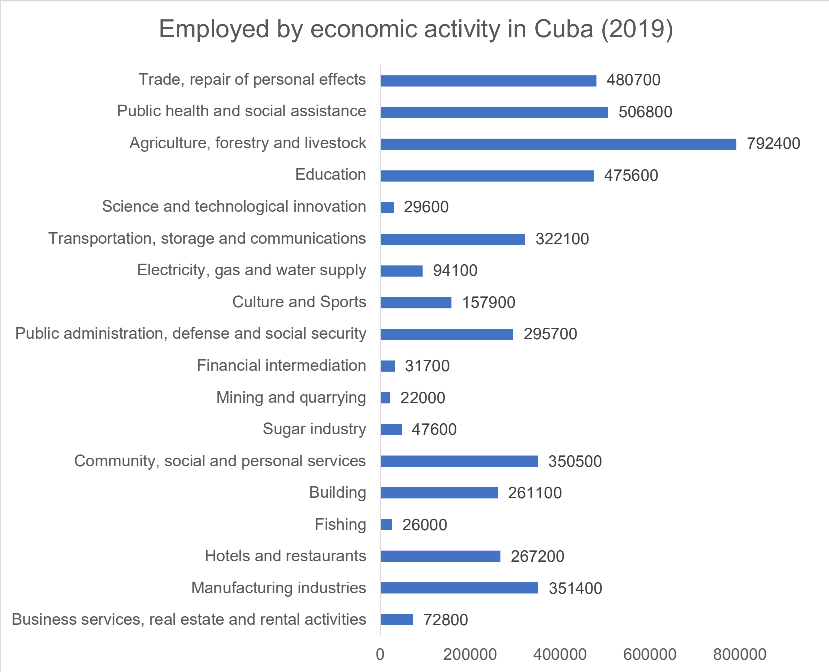

Figure 11. *Employed workforce by economic activity in Cuba 2019. (Figueredo et al., 2020)*

In Cuba, the urbanisation process has been going on for decades and the present share of the urban population is almost 80 %. Figs. 8a and 8b illustrate the development of the urbanisation process in Cuba and the estimates for future development. The urbanisation process is important for economic development in regards to infrastructure development, workforce availability and resource allocation.

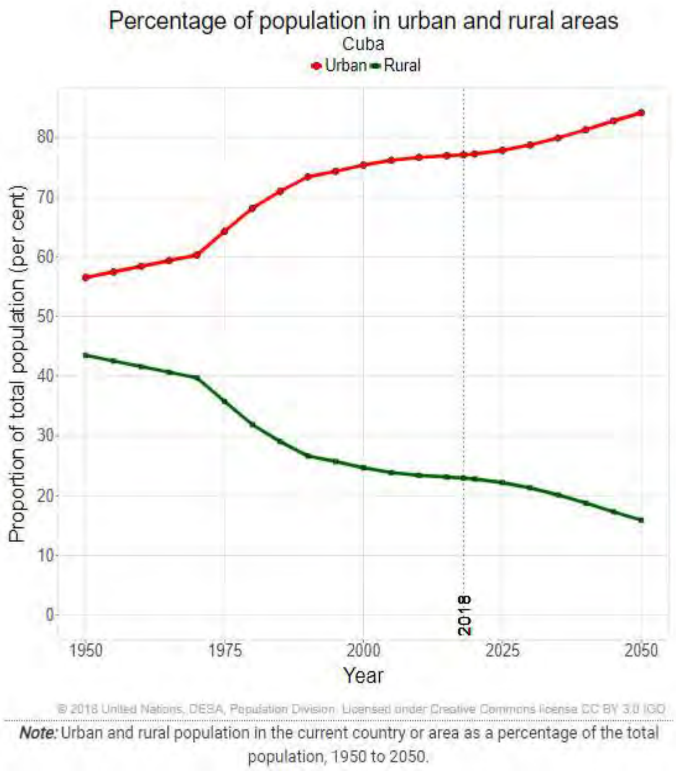

Figure 12. *Percentage of the population in urban and rural areas in Cuba. UN estimation (UN, 2018).*

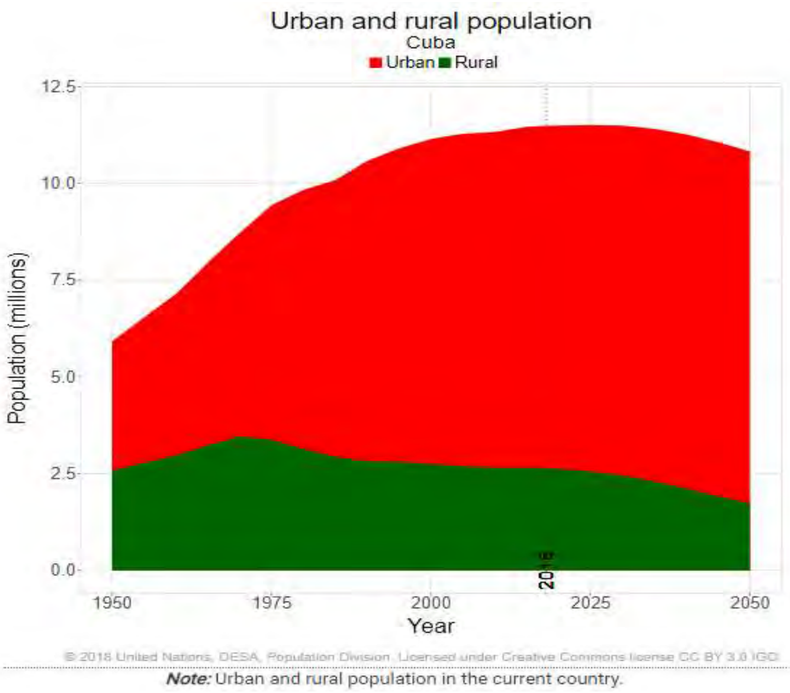

Figure13. *Population estimation for the urban and rural areas in Cuba. UN estimation (UN, 2018).*

Fig. 14 shows a comparative analysis of the percentages of the urban population in Cuba, Latin America and the Caribbean region.

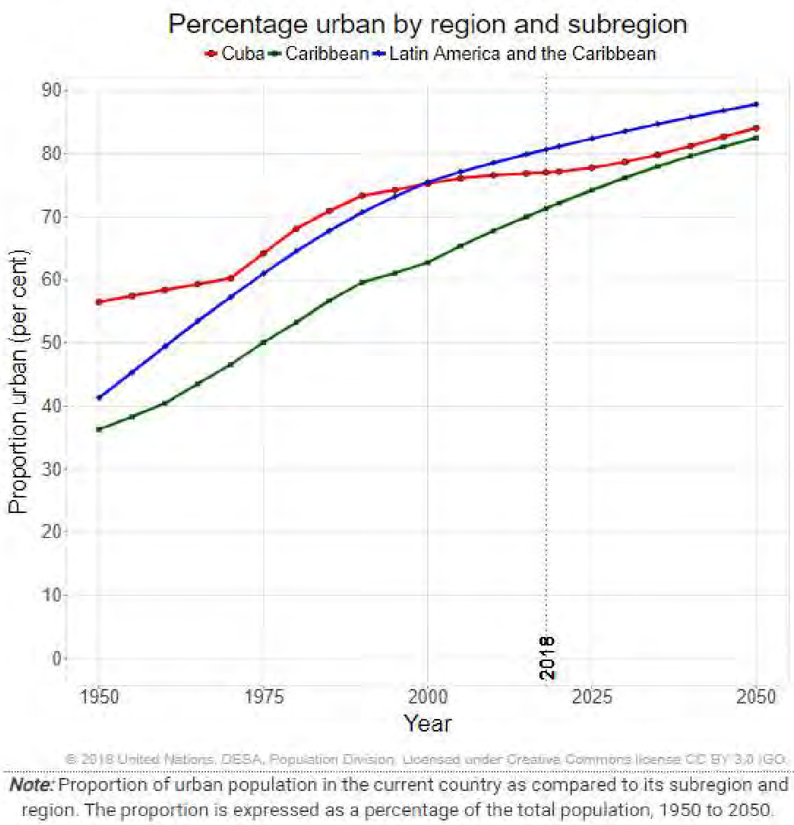

Figure 14. *Percentage of the urban population in Cuba, Caribbean and Caribbean and Latin America. UN estimation (UN, 2018).*

The urbanisation process in Cuba has an impact on the electricity demand and transmission and distribution system. The electricity demand and the related load curve is different in urban areas compared to rural livelihoods and this has to be taken into account in energy planning. The electricity transmission and distribution systems have to be developed taking into account the location of growth centres and the changing demand structure.

Economic development

The Cuban economy was growing after the Cuban Revolution in 1959 even though the United States started to blockade politics in 1960. One of the important factors behind the growth was the favourable trade with the Soviet Union. The economy was based on the export of Cuban sugar to the Soviet Union and other Eastern European countries and the import of oil and other commodities from these countries. The Cuban economic structure remained quite constant until the collapse of the Soviet Union in 1989 (see the sectoral economic output in Figs. 15, 16 and 17).

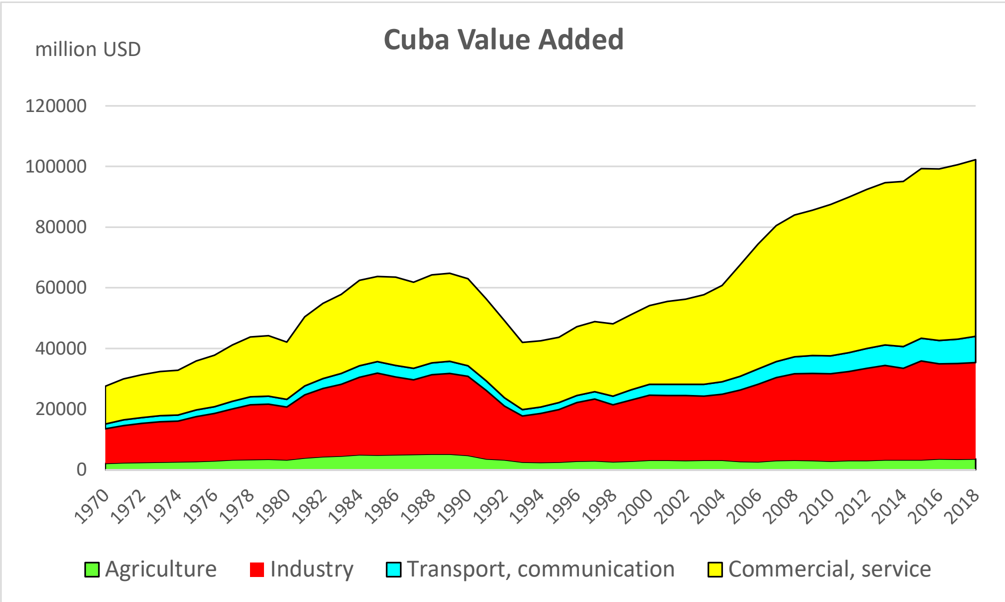

Figure 15. *Development of value-added in main economic sectors in Cuba. Data source: UN Statistics (2020).*

After the collapse of the Soviet Union, the GDP in Cuba reduced 35 % between 1989-1993 leading to a “special period” in the economy. The country's import capacity was reduced by 75%, affecting imports of raw materials and inputs for the operation of the industry, so that the use of the productive capacity of this sector was reduced to less than 30% (García Hernández, A., et al., 2012).
After 1990 the structure of the Cuban economy has slowly changed and the service sector has increased its share considerably while the share of industrial output has decreased (see Figs. 16 and 17). Traditionally the Cuban industry has been relying on sugar production and mining. The price fluctuation in international sugar prices has caused problems in the economy.

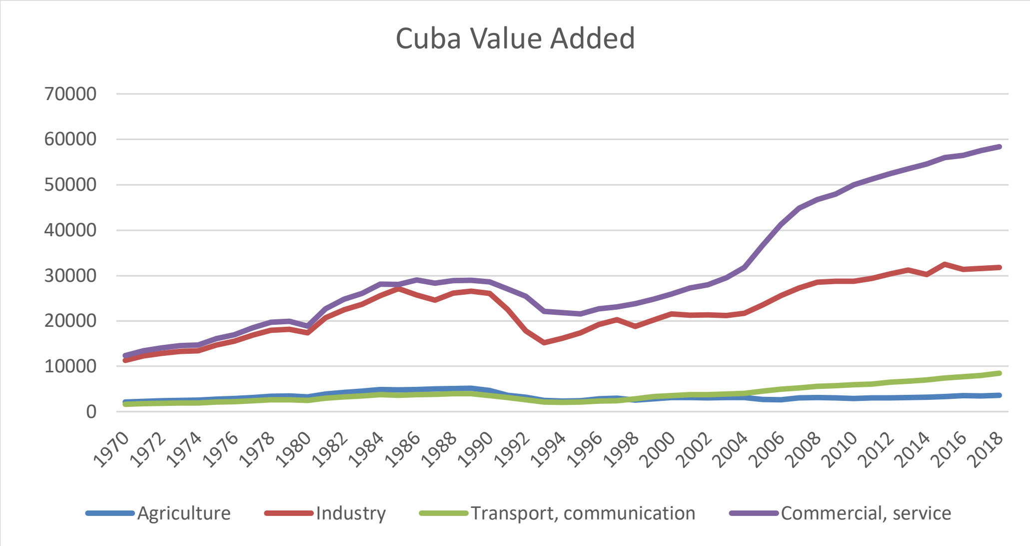

Figure 16. *Development of value-added in main economic sectors in Cuba. Data source: UN Statistics (2020).*

The crisis was faced with the combination of measures for macroeconomic stabilization and external opening for the economic and commercial reintegration of the country. Economic restructuring measures were applied aimed at promoting productive and technological development on the basis of competitiveness, and with the aim of preserving or rescuing as far as possible, the industrial platform created, as well as the technological, human and scientific-technical heritage reached before the crisis. (García Hernández, A., et al., 2012)

In the economic policy, the priority was given to tourism development and the application of economic and financial instruments aimed at promoting the integration of production chains that make the most of their potential knock-on effects. The promotion of energy development focused on import substitution and increased efficiency in the use of energy. The consolidation of state support was focused on scientific-technical development and its restructuring in search of greater efficiency. One area of emphasis was the Pharmaceutical and Biotechnological Development Program and other programs for export sectors as fundamental pillars of the new strategic conception of industrial policy. (García Hernández, A., et al., 2012)

The Cuban biopharmaceutical industry has been developed for more than 35 years and has been growing in importance. Since the beginning of modern biotechnology, based on genetic engineering techniques, Cuba concentrated on this emerging sector and established its own model of science and innovation that has obtained results recognized by the international community. This sector has more than 10,000 workers, 32 companies and supplies more than 800 products to the health system -including 349 medicines from the Basic Health Stock-, owns 182 patent objects, carries out more than 100 simultaneous clinical trials with its products in 200 clinicians and has exported its products to more than 50 countries. Cuba is developing vaccines against various viral and bacterial pathogens (including coronavirus) and is also pioneering in developing drugs for cancer treatment. (Martínez Díaz et al., 2020)

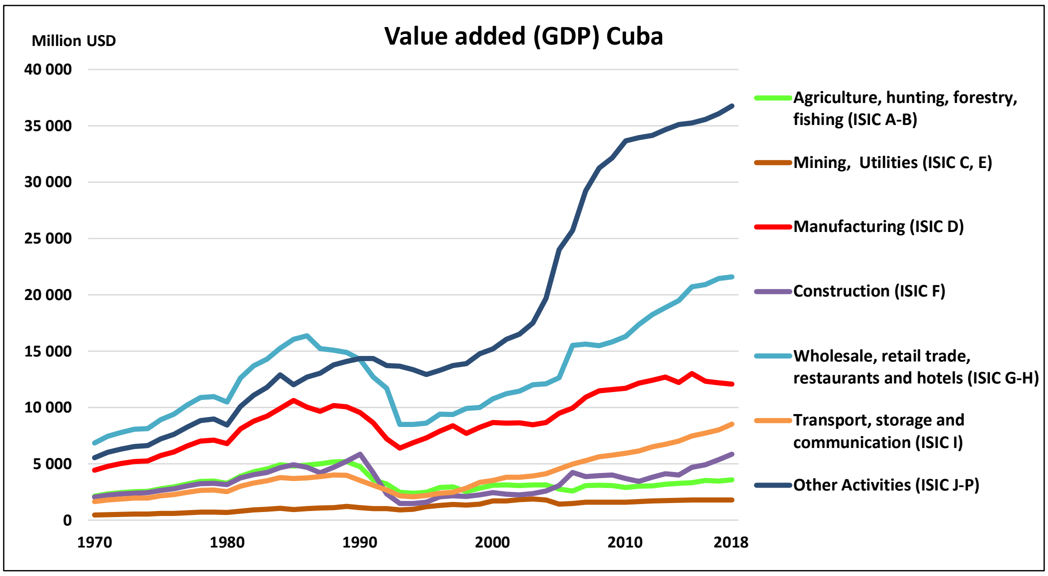

Figure 17. *Development of value-added in different economic sectors in Cuba. Data source: UN Statistics (2020).*

In addition to the productions of the biopharmaceutical industry, industrial productions have been recovering in recent years. The development of the mining and metal industry has been based on the large deposits of minerals in Cuba. The production of nickel and cobalt has been carried out together with the Canadian Sherritt company and the final processing of these metals is done in Canada. The production of lobster and shrimp (fishing industry), the production of containers and packaging, rum, tobacco, hygiene products and other manufactured products are examples of development areas.

The main structural and economic policy transformations adopted not only addressed the variables directly related to stabilization at the macroeconomic level but also specifically addressed aspects aimed at increasing the efficiency of the productive system. (García et al., 2012)

Cuban economic policy has been emphasizing the development of the health care and educations sectors having a large impact on the Human Development Index, where Cuba has successful results. According to the WWF analysis, Cuba is the number one country in combining human development and environmental footprint (National News 2020). The Human Development Index (HDI) has been increasing in Cuba (see Fig. 18) indicating improved human development. On a scale of zero to one, the U.N. Development Programme defines 0.7 as the threshold for a high level of development (0.8 for very high development). The ecological footprint of Cuba is 1.8 global hectares (Cabello et al., 2012), which is normally seen to be within the ecological sustainability limits.

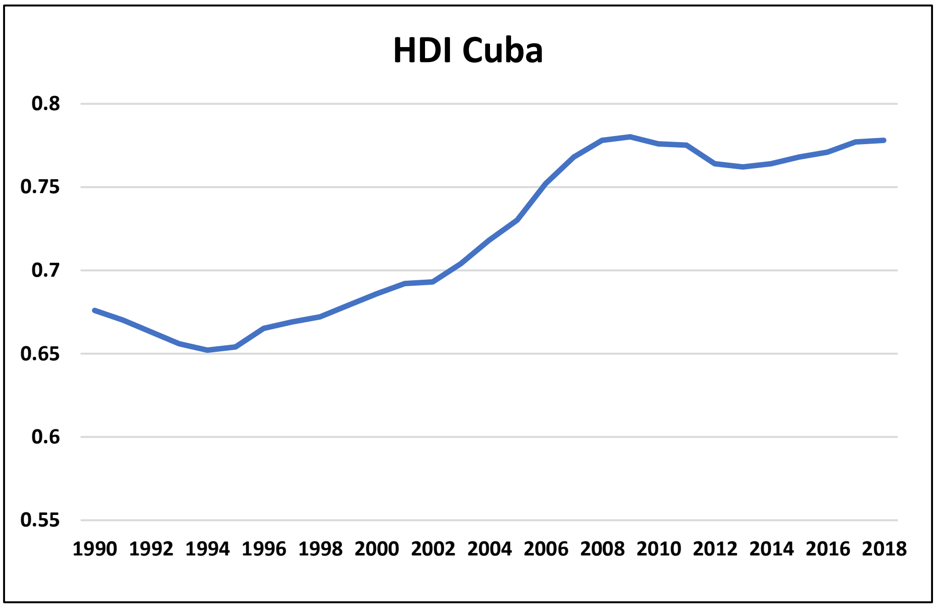

***Figure 18**. Human Development Index in Cuba. Data source: HDR (2020)*

Cuban foreign trade balance of goods has been negative during the last years (see Fig. 19). One of the main factors in the negative trade balance is the US economic blockade, which has prevented the investments in Cuba and hence reduced the production possibilities. The undeveloped industrial sector, which is not able to utilize the highly educated labour force has not been able to produce internationally competitive products reducing the possibilities for export earnings. Regarding foreign trade, the Cuban economy already showed a 24.5% reduction in exports of goods and services and a similar contraction in imports between 2012 and 2017, even when a positive balance was maintained in total trade (see Figs 19 and 20). (Rodríguez, 2019a)

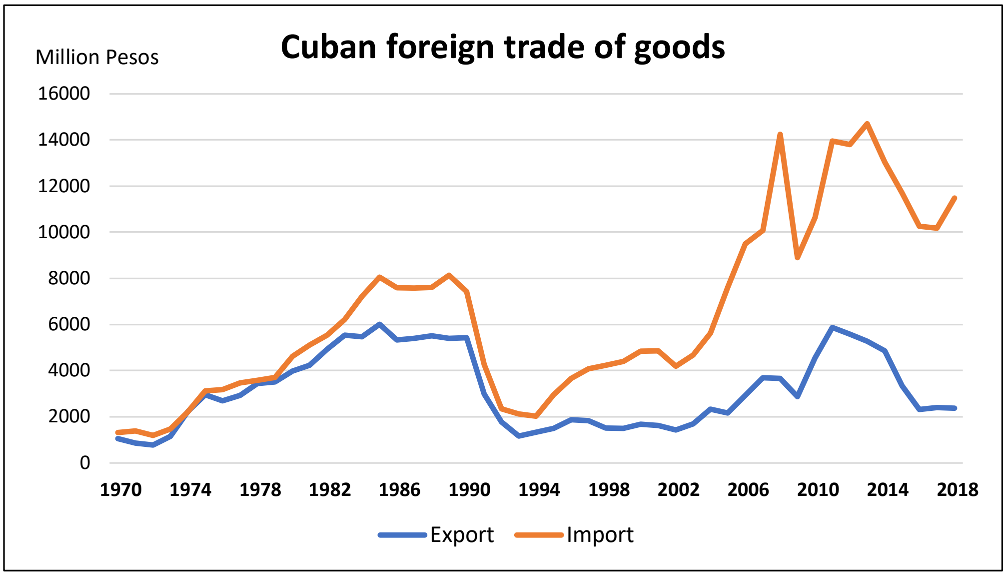

***Figure19**. Cuban export and import of goods Data source*: ONEI (2020a)

When we look at the total of foreign trade including also the services in the analysis we get quite a different view of the trade balance. Figure 20 illustrates the foreign trade of goods and services. The export of services in the Cuban economy has been remarkable and it has more than balanced the unbalanced trade of goods resulting in a positive balance of payments for the whole 21st Century. During the last years, the export of services has, however, reduced due to the activities of the Trump administration (and Bolsonaro in Brasil, and the coup in Bolivia in 2019) in reducing the possibilities of Cuban doctors to work abroad.

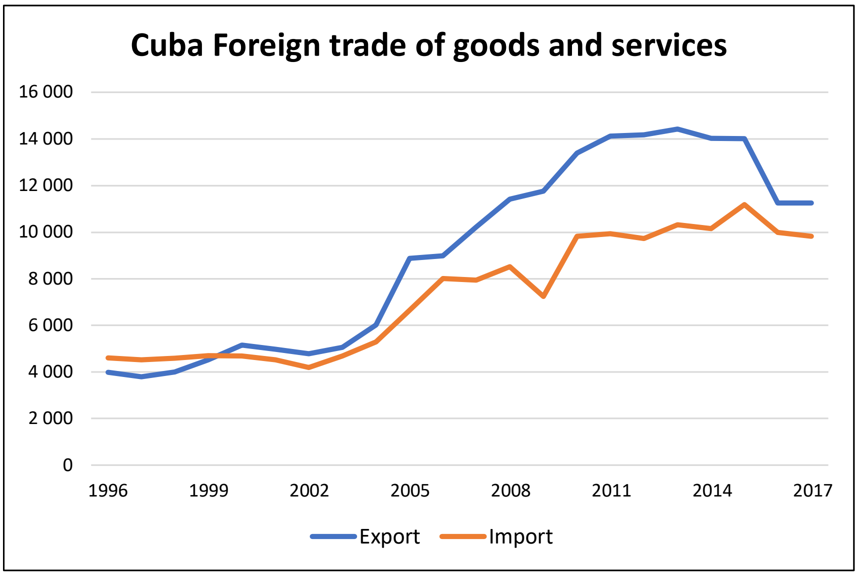

Figure 20. *Cuban export and import of goods and services. Data source: ONEI Statistics (2020c)*

The fall in export earnings has been marked by several elements. The decrease in nickel production has been caused due to the decapitalization of production plants and the lack of financing to stop this trend. The decrease in the production of sugar cane has been caused by weather problems and the decrease in the price of sugar. The export of services has also been seriously affected, not only income from tourism, but also income from the export of labour, mainly from the health sector. In both cases, the effects were partly caused by the measures to intensify the blockade approved during the presidency of Donald Trump. (Rodríguez, 2019a)

Concerning imports, the price of food has increased and the price of oil has also grown. The restrictions with traditional oil supply from Venezuela since 2016 have been tried to compensate with the purchase from Russia and Algeria, which increases the import expenses (Rodríguez, J.L, 2019a).

The tourism sector has been one of the fastest-growing sectors in Cuba and has the potential to link up with other economic sectors. (see Fig. 21 and 22). However, tourism activity is still affected by the low occupancy levels of 55.4% compared to a plan of 66%. This is partly due to the seasonal character of the tourism industry illustrated in Fig. 22. For each incoming foreign dollar in the tourism sector in Cuba, 67 cents are used for importing goods for the sector. This balance should be improved due to their immediate impact on the economy. (Rodríguez, 2019b).

The tourism sector has been the main foreign currency earning sector during the last years, but the corona pandemic has stopped the tourists coming to Cuba in 2020 (see Fig. 22). The recovery from the pandemic situation can be fast because the Cuban health care system seems to be functioning well even in this type of global crisis.

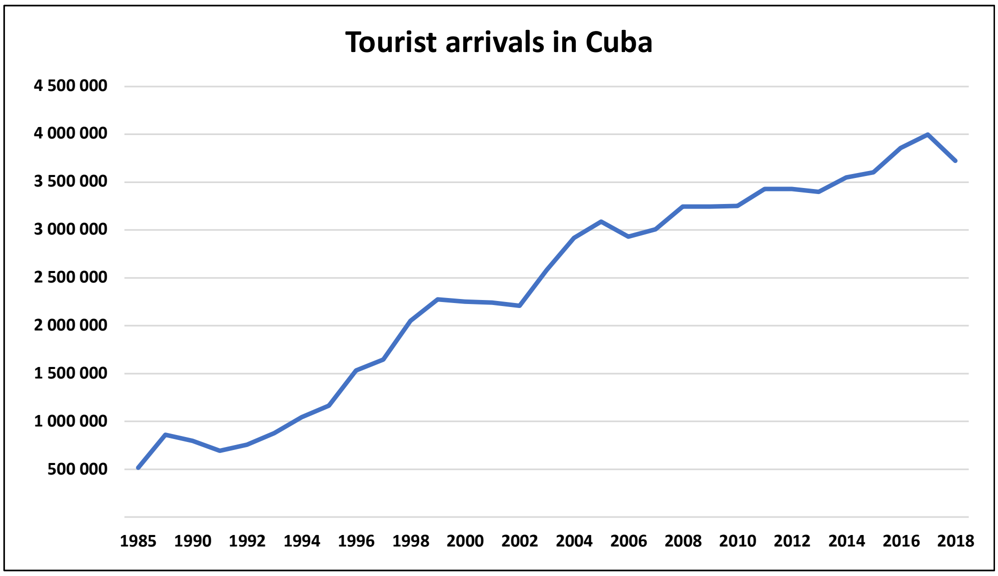

Figure 21. *Tourist arrivals in Cuba. Data source: ONEI (2020d)*

A cruise skip in Santiago de Cuba

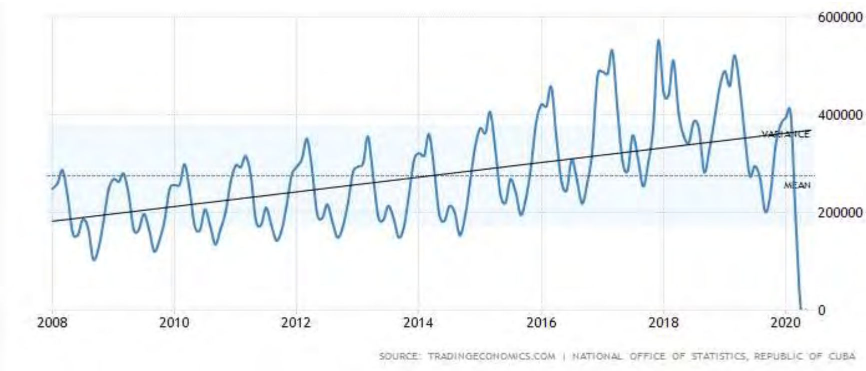

Figure 22. *Monthly tourist arrivals in Cuba 2008-2020. (Trading Economics, 2020)*

Cuba is not producing all the energy it consumes but has to rely on the import of energy products in a similar way as most countries in the world. Figure 23 shows the amount of oil and gas production in Cuba, the amount of crude oil and petroleum products import and petroleum products exports. Crude oil petroleum products imports increased in the 1970s and 1980s. Domestic crude oil production started to increase from 1970 and reached its peak in 2003. In the 1980s Cuba exported petroleum products when the domestic refinery capacity was increased. The crude oil imports from the Soviet Union collapsed in 1990 and so did the petroleum products export.

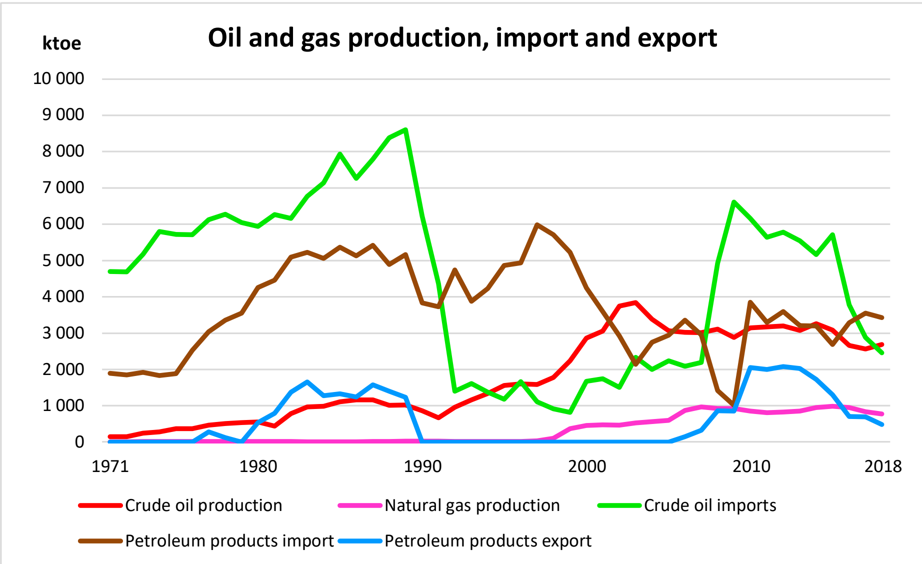

Figure 23*. Oil and gas production in Cuba, crude oil and petroleum products imports and petroleum products exports. Data source: IEA (2020).*

On the issue of fuels, the unfavourable situation of the 1990s began to change in 2000, thanks to agreements for the supply of crude oil from Venezuela and a new financing scheme in association with foreign firms to substantially increase the levels of refining activity. The country also began the process of substituting fuel imports, based on the reactivation of the national oil activity and the notable increases in the extraction of crude oil and accompanying gas. In the case of accompanying gas, it began to be used in the generation of electricity. (García Hernández, A., et al., 2012)

The import of crude oil from Venezuela increased considerably in 2008 and the export of refined petroleum products from Cuba started again. The import of crude oil from Venezuela decreased in 2016 and this led to a reduction in the export of petroleum products.

As part of the Cuba-Venezuela agreement, exports of petroleum products increased in 2010, as a result of an increase in refining capacities and the creation of a Petrochemical Pole. Since the US blockade of Venezuela, as well as the effects of US sanctions on the production of Venezuelan crude and its main company, PDVSA (Business Human Rights, 2019), imports and exports from Cuba have decreased.

Natural gas production in Cuba increased in 1999 and has remained at about the same level after that.

The amount of fossil and renewable energy consumption in Cuba is shown in Fig. 24. The use of fossil energy, oil, collapsed after the collapse of the Soviet Union and has remained at a considerably lower level after that. The use of renewable energy started to decrease after the trade of sugar with the Soviet Union ended because the use of bagasse as an energy source for the sugar industry decreased with the decreasing sugar production.

The structure of energy consumption changed between 1989 and 2000. During that decade the increase in the share of petroleum derivatives and electricity and the decrease in the share of bagasse use were most remarkable. In those years, consumption was reduced by some 6.0 million tons of conventional fuel, of which 59% corresponded to oil and its derivatives and 38% to bagasse; electricity reduces its consumption to a much lesser extent than the rest of the carriers. (García Hernández, A., et al., 2012).

The share of fossil and renewable energy consumption in Cuba is shown in Fig. 25. The share of renewable energy was highest in 1992 reaching 41 % of energy consumption.

From 2010, the share of renewable energy sources started to increase, with the approval of the National Plan for the prospective development of renewable sources and the efficient use of energy until 2030.

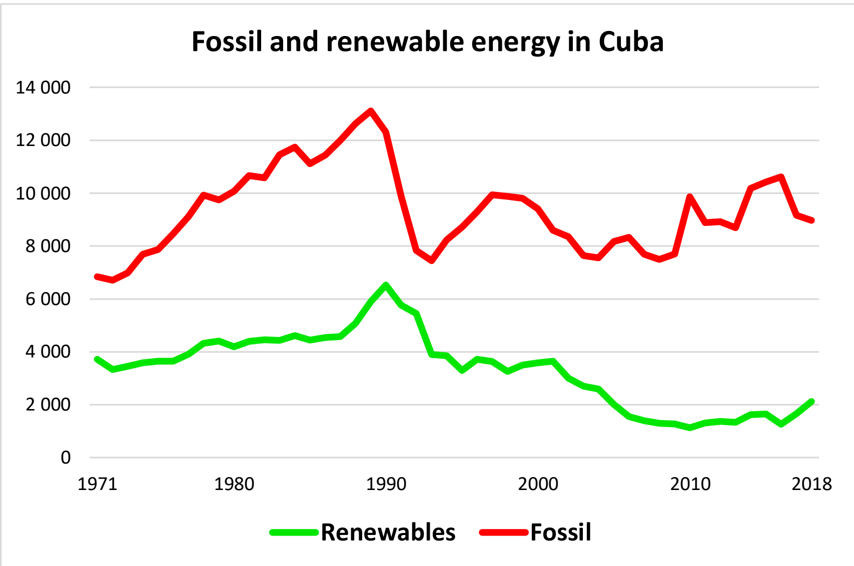

***Figure 24**. Use of fossil and renewable energy in Cuba. Data source: IEA (2020).*

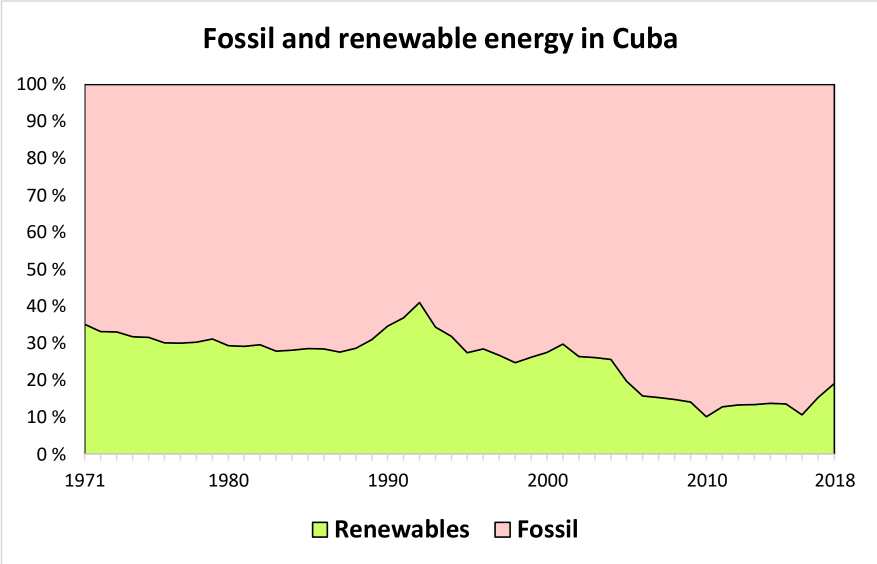

Figure 25. *Share of fossil and renewable energy in Cuba. Data source: IEA (2020).*

Energy system resilience

Herfindahl-Hirschman Index can be used for analysing the resilience of the energy system. It describes the diversification of production. The smaller the HHI index is the more diversified is the production palette. Figures 26a, b and c illustrate the HHI for the total energy supply, final energy consumption and imported energy in Cuba. Herfindahl-Hirschman Index for the total energy supply takes into account domestic production and import and export of energy (Total Primary Energy Supply TPES). It has developed positively (HHI value has decreased) until 2008 when it increased as a result of a considerable increase in crude oil import, which has reduced the diversity of energy supply. The index has, again, reduced after 2015 with the reduction of crude oil import and domestic production.

The HHI index for domestic final energy consumption has slowly decreased indicating a switch to more diversified energy consumption. The HHI index for energy import in Cuba has been quite high indicating the important role of crude oil import.

The key conclusion of resilience analyses of the energy sector is that the total energy supply is diversified and resilience level has improved in Cuba, which is a positive trend. Also, domestic final energy consumption has been diversified showing slightly improving resilience. A more challenging trend has been in energy import where resilience level has not been so stable and there has been stronger volatility in the energy import trend. The key explaining reason has been the collapse of Soviet Union trade. Peak levels of HHI have been close to 0,8 but in the last years, HHI has been close to 0,5. These latest observations indicate a better resilience level.

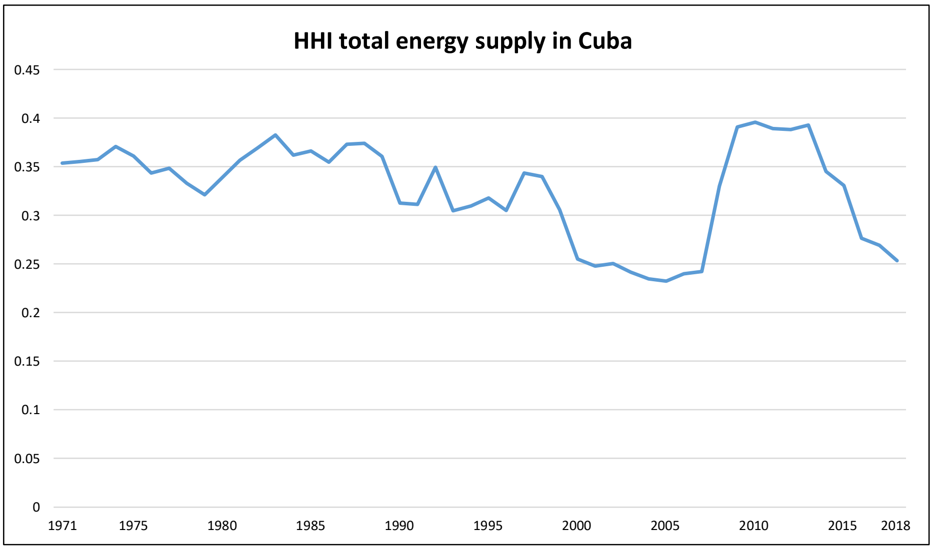

Figure 26a. *Herfindahl-Hirschman Index for the total energy supply in Cuba*.

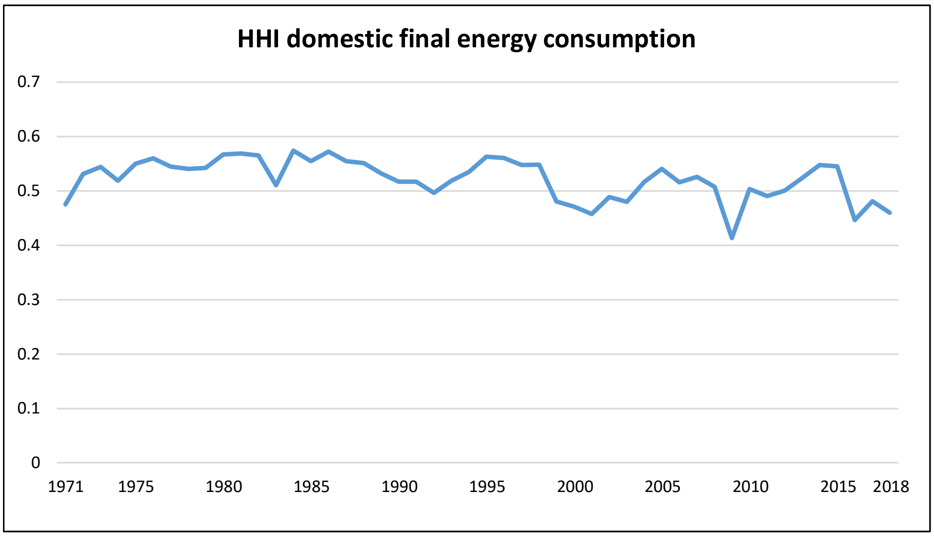

Figure 26b. *Herfindahl-Hirschman Index for domestic final energy consumption in Cuba.*

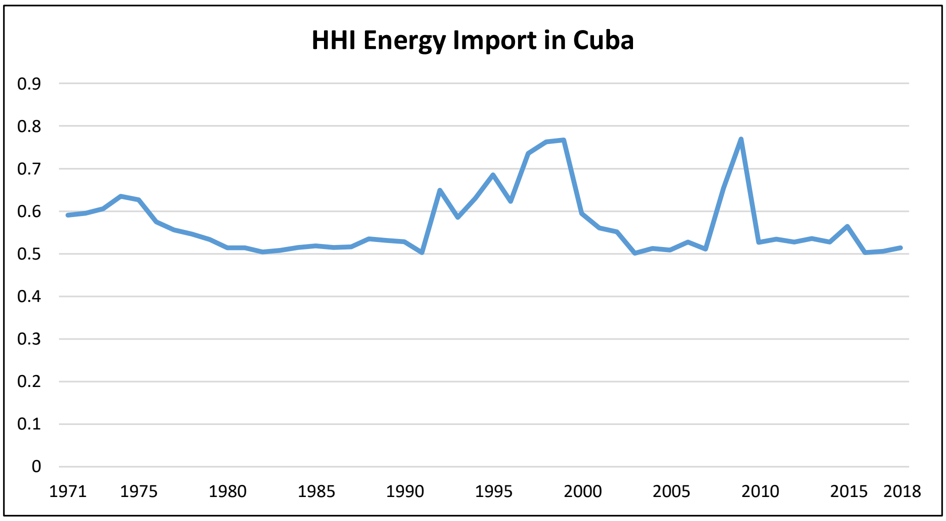

Figure 26c. *Herfindahl-Hirschman Index for energy import in Cuba.*

Decomposition analysis of energy use and CO_2 emissions

Decomposition analysis is used for analysing the role of the different factors of changes. Structural decomposition decomposes the changes in energy consumption in relation to the different economic sectors. The structural decomposition will divide the changes into three components: (i) activity effect, (ii) intensity effect and (iii) structural effect.

The structural decomposition model enables us to identify the structural changes in the economy and their impacts on energy consumption. The model enables the analysis of sustainability compared to the functioning of national economies and sectoral performance.

The aim of decomposition analysis is to model the changes in the use of production factors. The explanatory variables are the activity level in the economy, sectoral efficiency, and structural shift in the economy.

We have used a decomposition method developed by Sun (1996, 47-61), which has no residual term, unlike other methods. We have used this Complete Decomposition Model to analyse the impacts of different factors on energy consumption in Cuba. This model produces exact decomposition so that the total change in energy consumption is the sum of:

- Q_{effect} is the activity effect that describes the effect of the total economic growth on sectoral energy use. It does not directly depend on the sector's own production.
- I_{effect} is the intensity effect that describes the impacts of the technological change and the change of production systems on sectoral energy consumption.
- S_{effect} is the structural effect that describes the impact of the changes in the sectoral share of total production on energy consumption.

We have analysed the different sectoral effects on Cuban energy consumption for the time period of 1971-2018 using the sectoral energy data in IEA statistics and sectoral economic performance based on UN Statistics. Figure 27 illustrates the impact of the Activity effect on Cuban energy consumption in different economic sectors compared to the base year 1971. The Activity effect is largest in the industrial sector indicating its central role in energy consumption. In the Activity effect, we can see the impact of general economic changes in the Cuban economy.

The Intensity effect on energy consumption in different sectors in Cuba is illustrated in Fig. 28 compared to the base year 1971. The energy intensity in the industrial sector has decreased considerably reducing the energy use in this sector. The Government policy seems to have been impactful to improve energy efficiency in industry and services and refrigeration activities (CMHW, 2020). The improvement of energy efficiency (reduction in intensity) is also visible in the transportation and communication sector. In the commercial (service) sector and agriculture, the intensity has not reduced indicating that these sectors have not been able to reduce their energy consumption in relation to their economic output.

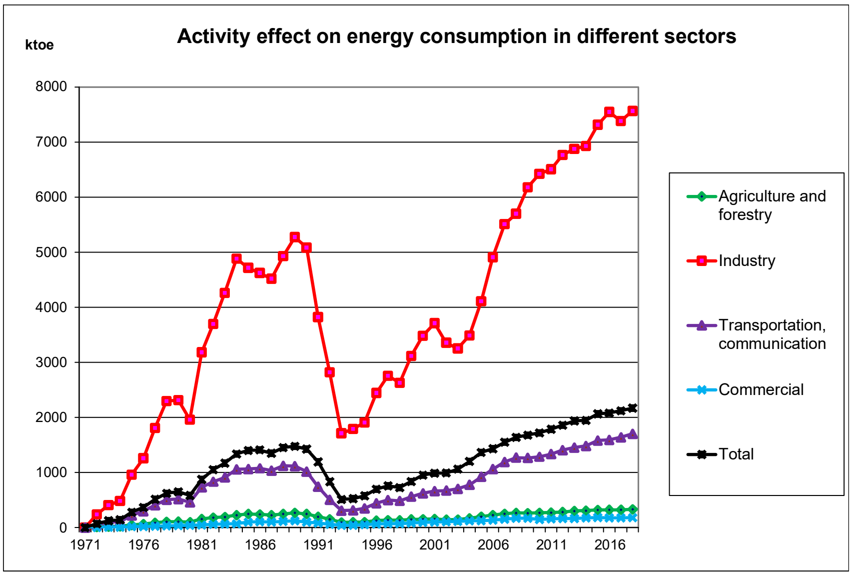

Figure 27. *The Activity effect on energy consumption in different sectors of the economy in Cuba compared to the base year 1971. Data source: IEA (2020); UN Stat (2019).*

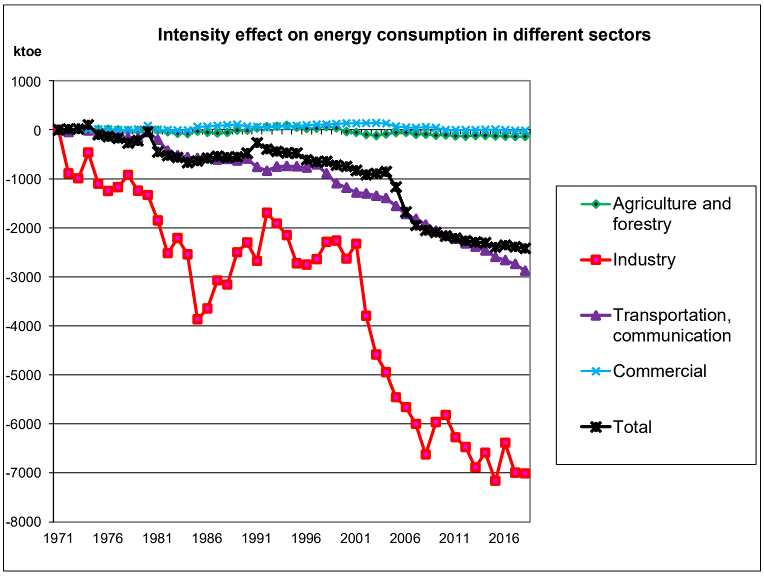

Figure 28. *The Intensity effect on energy consumption in different sectors of the economy in Cuba compared to the base year 1971. Data source: IEA (2020); UN Stat (2019).*

The structural effect on energy consumption in different sectors in Cuba is shown in Fig. 29 compared to the base year 1971. The figure illustrates that the structural changes in Cuba before 1990 were very small and for that reason the impacts on energy use between 1971-1990 were small. After the collapse of the Soviet Union, the structural changes in the Cuban economy have been considerable impacting also the energy use. The role of the industry has reduced in Cuban economic output remarkable after 1996 and this has reduced industrial energy use very fast. The transportation and communication sector has increased its impact on the economy which results in an increase in energy consumption. In the commercial (service) sector there is a slight increase in the share of economic output and hence a slight increasing impact on energy use. The agricultural sector has decreased in economic importance and the structural effect on energy use can be seen in reduction especially in early 2000.

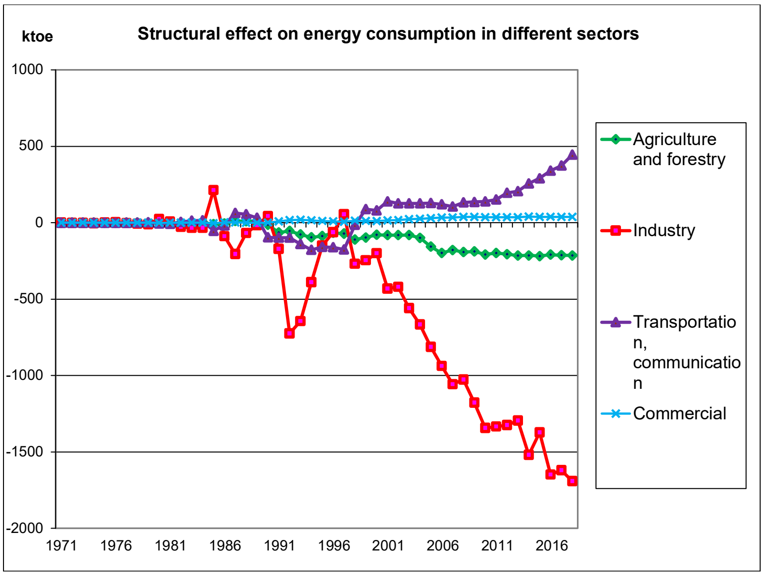

Figure 29. *The Structural effect on energy consumption in different sectors of the economy in Cuba compared to the base year 1971. Data source: IEA (2020); UN Stat (2019).*

The total change in energy consumption compared to the base year 1971 in different sectors is the sum of Activity, Intensity and Structural effect shown in Fig. 30.

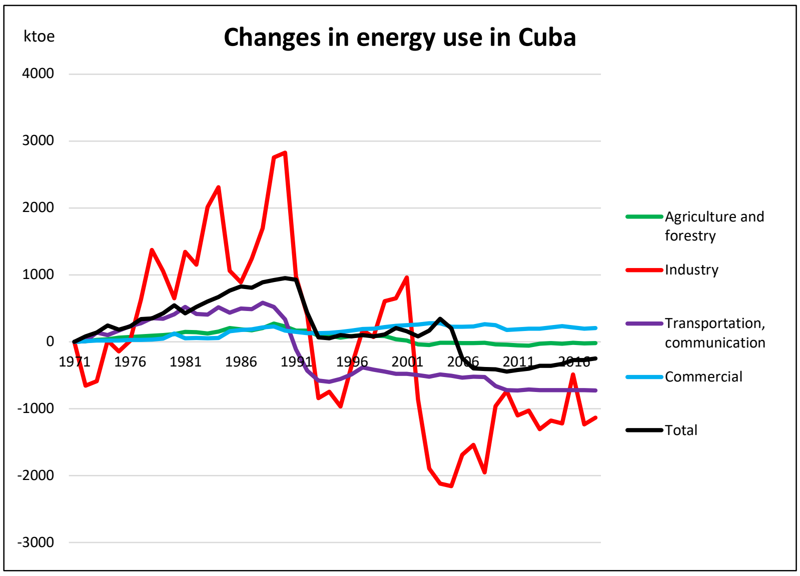

Figure 30. *The total effect (Activity + Intensity + Structural effect) on energy consumption in different sectors of the economy in Cuba compared to the base year 1971. Data source: IEA (2020); UN Stat (2019).*

In addition to the structural decomposition, we have carried out so-called chained decomposition to analyse the factors affecting the CO_2 emissions in Cuba.

The factors affecting the emissions of CO_2 can be analysed using the decomposition technique. In the decomposition analysis, the changes in CO_2 emissions are divided into different components the sum of which will be equal to the total change in the emissions. In this analysis we have used the following decomposition equation:

$$CO_2 = CO_2/TPES \times TPES/FEC \times FEC/GDP \times GDP/POP \times POP$$

where

CO_2 is CO_2 emissions

TPES is Total Primary Energy Supply

FEC is Final Energy Consumption

GDP is Gross Domestic Product

POP is the population.

The CO_2/TPES component indicates the changes in the share of different primary energy sources and their impact on CO_2 emissions. For instance, a shift from fossil fuel use to renewable energy sources will decrease this effect. Also, a shift from oil use to natural gas use will decrease this effect.

TPES/FEC component describes the energy efficiency of the conversion process from primary energy to final energy, such as the production of electricity with oil. If the conversion efficiency improves this effect will decrease.

FEC/GDP component describes the energy intensity of the production of the economic output (GDP) of the country – how much energy is needed for producing a certain amount of economic output. If the energy intensity decreases it will also decrease the amount of CO_2 emissions.

GDP/POP component describes the economic output per capita and POP describes the amount of population.

In this decomposition analysis, the changes (in percentage) in the different components are compared to the base year value, which is in this case 1971 (the first year of the data in the IEA statistics for Cuba).

Figure 31 illustrates the changes in the factor CO_2/TPES on the CO_2 emissions. Here we can see that the carbon content of the primary energy supply has been increasing after 2004. This is a result of the reduced share of renewable energy, mainly biomass (bagasse) in the primary energy supply.

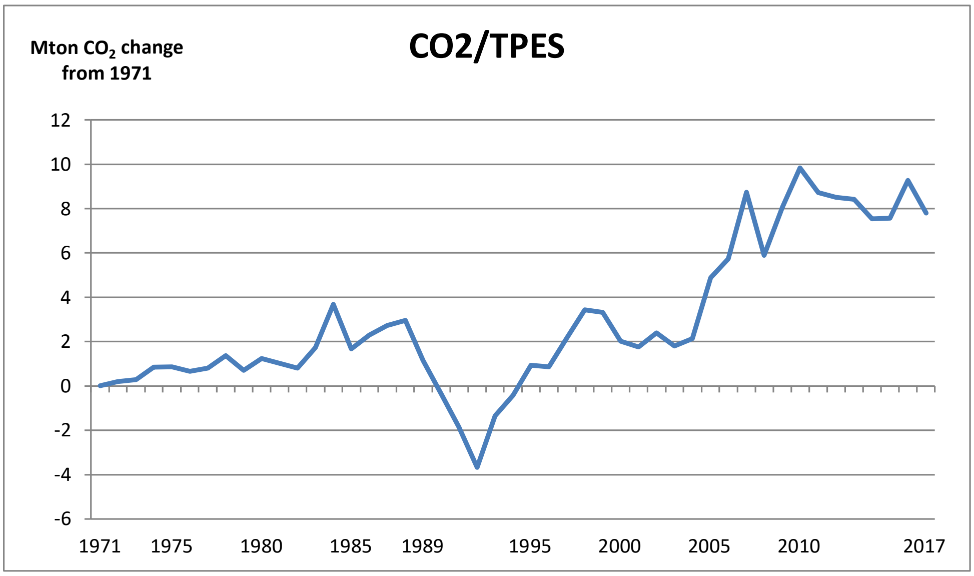

Figure 31. *Impact of the factor CO_2/TPES on CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

Fig 32 illustrates the impact of the relation of final energy use and total primary energy supply on the CO_2 emissions in Cuba. The impact of this factor has increased the emissions because more primary energy is needed for providing the same amount of final energy. This is related to the increased share of electricity production, where the efficiency of the condensing power plants is low. The increased share of electricity use in final energy means that more low-efficiency production is needed.

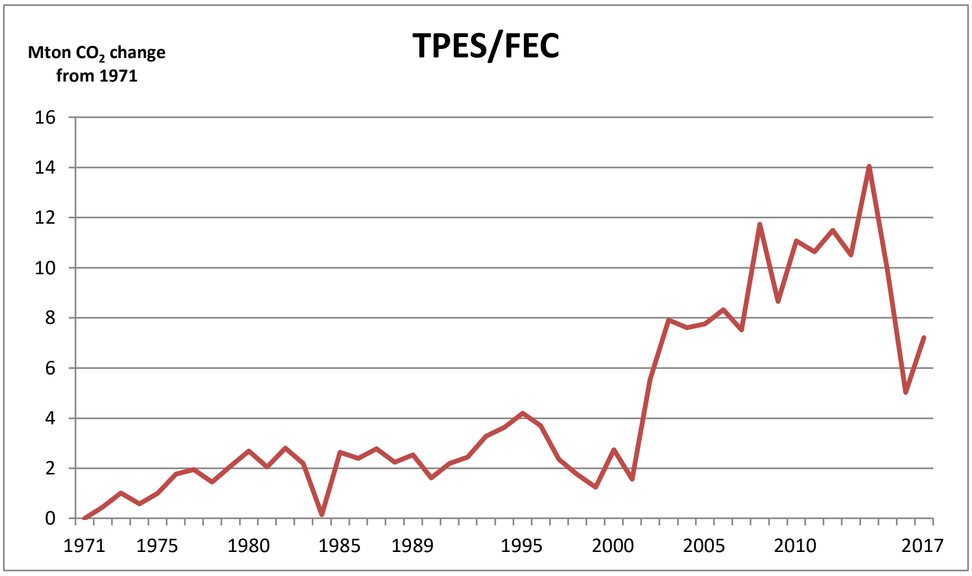

Figure 32. *Impact of the factor TPES/FEC on CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

Figure 33 shows the impact of factor FEC/GDP on CO_2 emissions. This factor defines how much energy is needed for the production of a certain amount of value-added (GDP) in the economy. This factor has been reducing significantly indicating that the production system has become much more efficient in energy use for economic output. The reasons behind this positive development are the use of more efficient technology and the structural change in the economy from energy-intensive production (especially in the industrial sector) to the more light production forms (especially in the service sector).

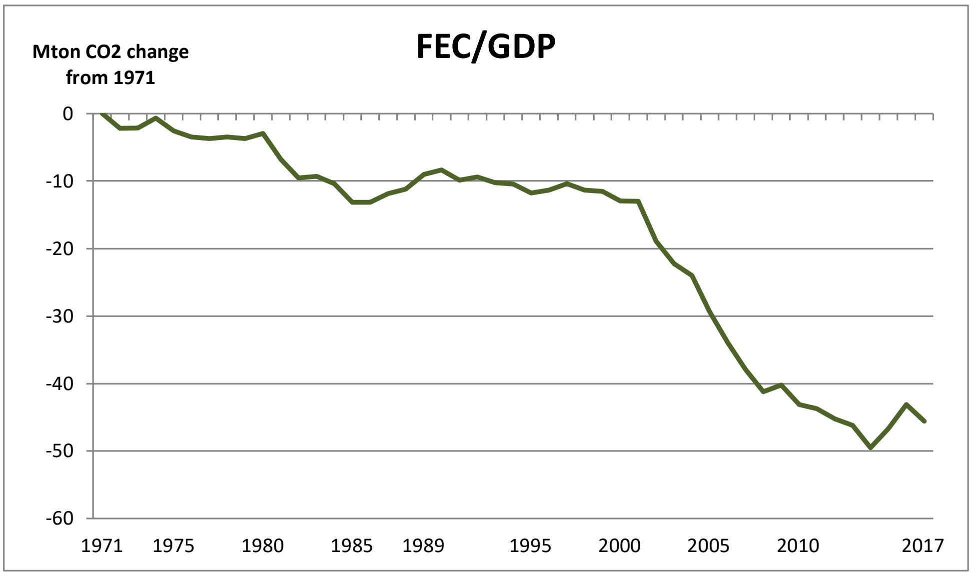

Figure 33. *Impact of the factor FEC/GDP on CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

Figure 34 shows the impact of changes in GDP per capita on CO_2 emissions. Here we see the impact of the reduction during the "special period" and the considerably fast growth starting from 1994.

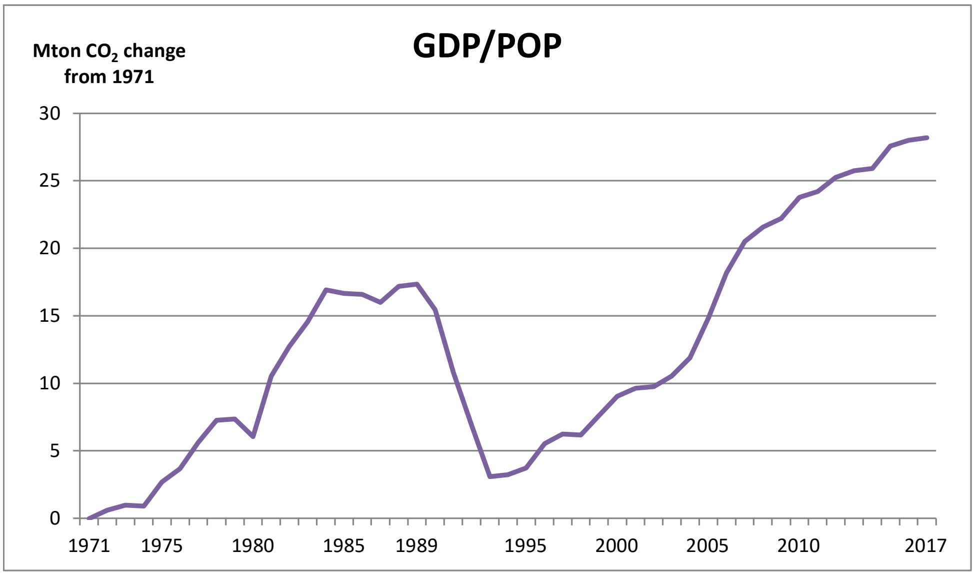

Figure 34. *Impact of the factor GDP/POP on CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

Figure 35 shows the impact of population growth on the CO_2 emissions in Cuba. Population growth has had quite a small impact on CO_2 emissions.

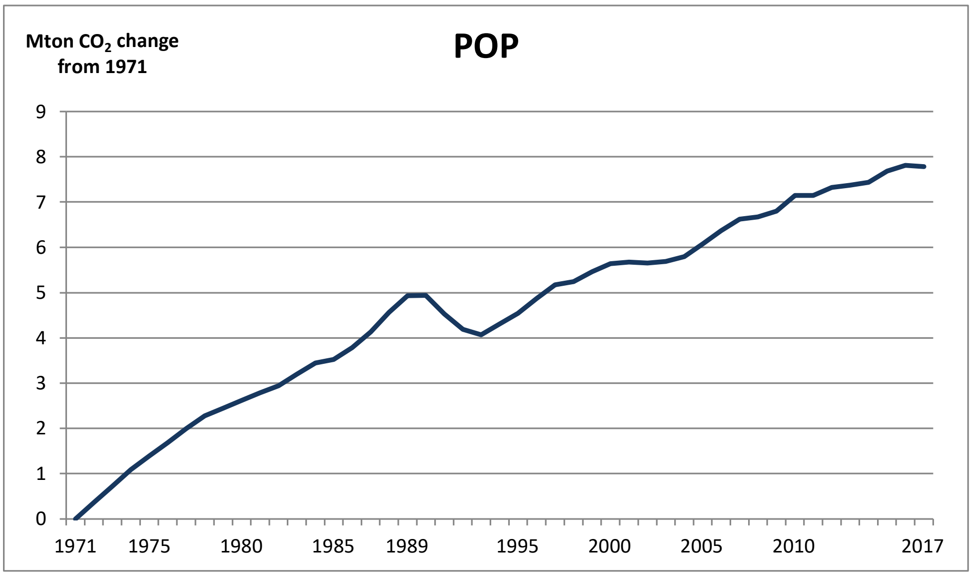

Figure 35. *Impact of the factor POP on CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

The total change in CO_2 emissions in Cuba compared to the 1971 level as a sum of the different factors is shown in Fig. 36.

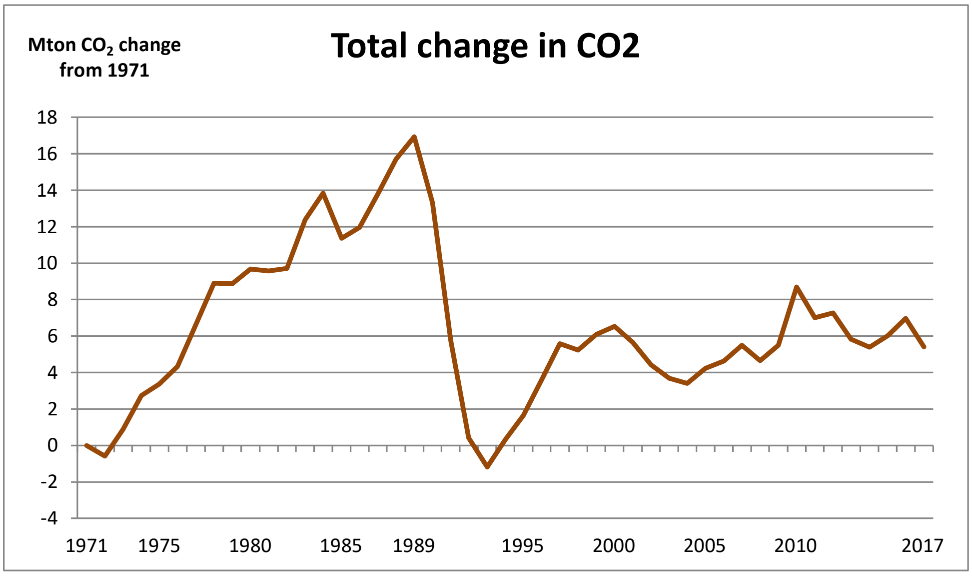

Figure 36*. Total change in CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

The impacts of the different factors affecting the CO_2 emissions are shown in Fig. 37. Comparison of the different factors shows the importance of the improvement of energy efficiency (FEC/GDP) in reducing CO_2 emissions and the role of economic growth (GDP/POP) in increasing the emissions. During the analysed period the changes in primary energy sources (indicated by CO_2/TPES) or energy transformation technology (indicated by TPES/FEC) have not had a very large impact on emissions. The planned shift to renewable energy sources will naturally in the future impact the CO_2/TPES relation.

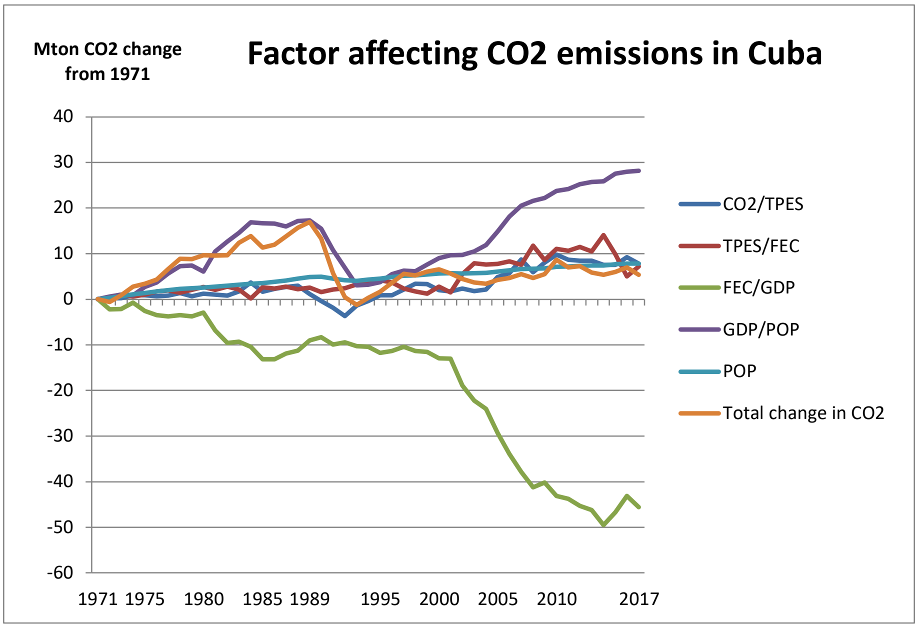

Figure 37. *Impact of the different factors on CO_2 emissions in Cuba compared to the base year 1971. Data source: IEA (2020).*

Economic changes

The new economic changes starting in 2020 include different measures. These include opening up to different forms of property, especially with the gradual and selective introduction of foreign capital. The measures also include the delimitation between the functions of the State as owner and the administrative functions through decentralization of the management and decision-making system to all entities capable of operating based on self-financing schemes and the promotion of their own sources of accumulation financially independent of the availability of budgetary resources.

The elimination of the state monopoly of foreign trade is important as well as the granting of powers for the direct realization in the business sphere of import and export operations and additionally the gradual implementation of a new tariff system. It is also planned to carry out a complete structuring of the financial and banking system. One important measure is the creation of a new tax system.

The creation of new internal markets to act as dynamizers of productive activity in foreign currency is one target. Other activities include the creation of the necessary microeconomic environment to promote business competitiveness, and in particular to gradually replace verticalized administrative management methods by methods that favour horizontal economic relations between the different economic actors. (García Hernández et al., 2012; Rodríguez, 2001)

Before the implementation of the Constitutional Reform and the approval of the Constitution in 2019, in the governing documents of Cuban society (the Guidelines of the Economic and Social Policy of the Party and the Revolution; The Conceptualization of the Cuban Economic and Social Model of Socialist Development and the Bases of the Economic and Social Development Plan until 2030: Vision of the Nation, Axes and Strategic Sectors), several changes were reflected and later endorsed in the new Constitution.

In a broad legislative and governmental exercise, new laws, decrees, norms and regulations were approved having a high impact on the Cuban economy. With the implementation of the Economic and Social Strategy, derived from the Development Plan, 16 key areas were established: (i) Food production, (ii) Sugar agribusiness and its derivatives, (iii) Tourism, (iv) Professional services, (v) Health, (vi) Pharmaceutical industry, biotechnology and biomedical productions, (vii) Telecommunications, (viii) Construction, (ix) Energy, (x) Integrated logistics of transportation, storage and efficient trade, (xi) Integrated logistics of networks and hydraulic and sanitary facilities, (xii) Manufacturing industry, (xiii) Domestic trade, (xiv) Foreign trade, (xv) Financial system, (xvi) Employment and salary policy, security and social care.

Legislative modifications in recent months contribute to these strategic areas, by establishing more flexible and decentralized mechanisms for the import and export of goods and services. They also support the granting of external financing linked to foreign investment and improve the operation of the state enterprise. The target is to stimulate innovation with the creation of high-tech companies and the creation of micro, small and medium enterprises.

Major transformations are expected in the coming months, such as a wage reform, changes in pensions and social benefits, and wholesale prices.

Impacts of the US blockade

After the approval in Cuba, in 1959, of the Agrarian Reform Law, the US government, as early as April 6, 1960, approved the blockade (ECURED, 2020). For the 28th consecutive year, the UN General Assembly has adopted a resolution calling for an end to the economic, commercial and financial embargo imposed by the United States against Cuba (UN News, 2019). Cuba's Foreign Minister, Bruno Rodríguez Parrilla, reported that Washington has begun to "escalate aggression", including prevention of international fuel shipments to the island, scaling down consular services, and attacking national programmes that support other developing countries. "The blockade has caused incalculable humanitarian damages. It is a flagrant, massive and systematic violation of human rights," he charged. "It qualifies as an act of genocide under Articles II (b) and (c) of the Convention on the Prevention and Punishment of the Crime of Genocide, adopted in 1948. There is not one single Cuban family that has not suffered the consequences of this."

Within the Caribbean, there is a worry that the Embargo threatens the development in the Caribbean countries. The 15 members of the Caribbean Community (CARICOM) highlighted Havana's support to the region (UN News, 2019). Cuba has deployed medical professionals to distressed areas, including those affected by natural disasters, among other initiatives.

Fig. 38 illustrates the calculated economic damages caused by the US blockade of Cuba.

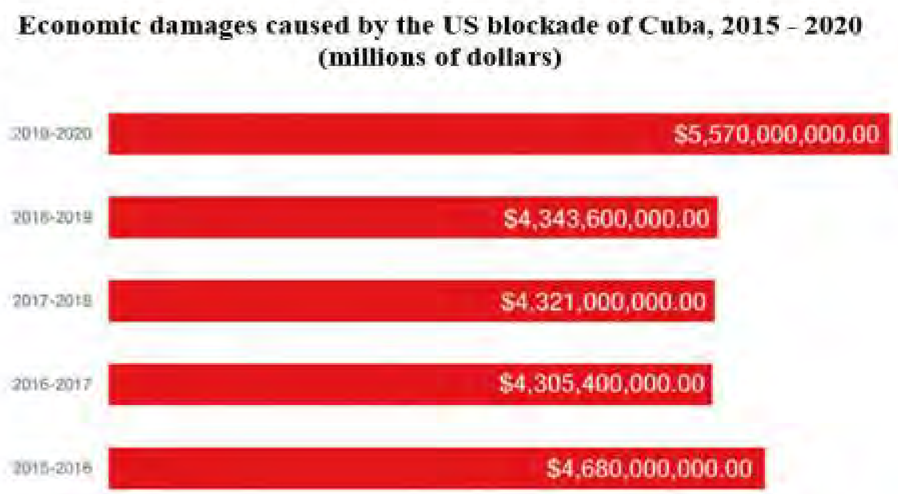

Figure38. *Economic damages caused by the US blockade of Cuba, 2015-2020. (Carmona et al., 2020)*

The blockade was reinforced during the administration of Donald Trump, which applied more measures, such as the suspension of flights from the United States to the rest of the Cuban provinces, the suspension of the sending of remittances or the importation of equipment, medicines and other necessary supplies in the Cuban Health System. Protected by the activation of Title III of Helms Burton, the United States government has not only prevented agreements with the US business sector but also from third countries. (Carmona et al., 2020) Fig, 39 shows the impacts caused by the US blockade on Cuban foreign trade.

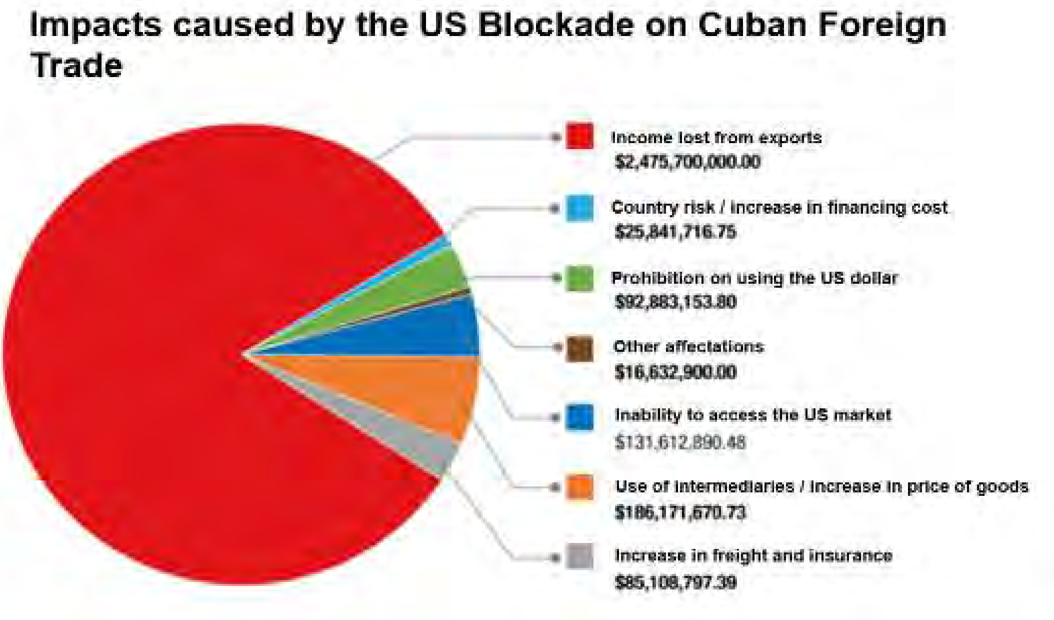

Figure 39. *Impacts caused by the US blockade on Cuban Foreign Trade. (Carmona et al., 2020)*

Regional Economic cooperation

For Cuba, international cooperation is very important with the objective of increasing its contribution to national and territorial development, and it is a principle included in the documents that govern its economic policy and in its Constitution. (ANPP, 2019).

The contribution in multilateral processes and international organizations is maintained in accordance with the Purposes and Principles of the Charter of the United Nations and International Law, as well as the commitment to a renewed and strengthened multilateralism. Likewise, broad and multifaceted relationships are developed with third world countries, based on solidarity, cooperation and mutual benefit; and with the industrialized countries on the basis of sovereign equality, non-interference in internal affairs and reciprocal advantages. Cuba actively participates in promoting the process of political agreement and integration of Latin America and the Caribbean, especially from the Bolivarian Alliance for the peoples of America - trade treaty of the peoples (ALBA - TCP) and the Community of Latin American and Caribbean States (CELAC). (PCC, 2017)

In the case of PETROCARIBE, it is a solidarity energy cooperation agreement proposed by the Government of Venezuela, to reduce inequalities in access to energy resources, through a favourable, equitable and fair exchange between the countries of the Caribbean region. To this agreement belong Antigua and Barbuda, Bahamas, Belize, Cuba, Dominica, Haiti, Jamaica, Saint Vincent and the Grenadines, El Salvador, Guyana, Grenada, Honduras, Nicaragua, the Dominican Republic, Suriname and Venezuela. Petrocaribe proposes a financing scale of 40% of the oil bill, taking the price of hydrocarbons as a reference. Likewise, it extends the period for financing from one to two years, and provides for an extension of the payment period from 17 to 25 years, reducing interest to one per cent, if the price of oil exceeds $ 40 per barrel. Short-term payment of 60% of the invoice is extended from 30 to 90 days. (CUBADEBATE, 2018)

Another of the international mechanisms to which Cuba belongs is the Economic Commission for Latin America and the Caribbean (CEPAL). Cuba held the pro-tempore presidency of that body from 2018 to 2020 and focuses on three fundamental lines of work: the advancement of the implementation of the 2030 Agenda on Sustainable Development in the region, the prioritization of the Caribbean and the strengthening of South-South cooperation. Cuba assumed the Vice Presidency of the Caribbean Development and Cooperation Committee for the two years (2021-22), a mechanism of ECLAC to implement its agenda specifically in the Caribbean area. (Rodríguez Derivet and Padrón Padilla, 2020)

Cuba was selected in 2020 to be a member of the Economic and Social Council of the United Nations. This allows the Caribbean Island to occupy a position in the following subsidiary bodies: Population and Development Commission, UNDP / UNFPA / UNOPS Executive Board and the Committee for Programme and Coordination (Cuba Business Report, 2020).

Although Cuba does not belong to CARICOM, there is a cooperation mechanism, CUBA - CARICOM, and over the years, joint cooperation projects have been developed in multiple spheres, including health, education, sports, agriculture, biotechnology, construction, confrontation and risk reduction of natural disasters. In the area of solidarity cooperation in the Caribbean nations, there

are approximately 1,723 Cuban collaborators working, and 6,739 students have graduated in Cuba and 727 Caribbean students are studying in Cuba. (CUBADEBATE, 2019)
The Latin American and Caribbean Economic System (SELA) is a regional intergovernmental body, created on October 17, 1975. SELA is made up of 26 Latin American and Caribbean countries and is aimed at promoting a consultation and coordination system to agree on common positions and strategies of Latin America and the Caribbean, in economic matters in countries, groups of nations, forums and international organizations, and to promote cooperation and integration among Latin American and Caribbean countries. (SELA, 2020)
The Latin American Integration Association (ALADI) is made up of thirteen countries: Argentina, Bolivia, Brazil, Chile, Colombia, Cuba, Ecuador, Mexico, Panama, Paraguay, Peru, Uruguay and Venezuela. Its general principles are pluralism in political and economic matters; progressive convergence of partial actions towards the formation of a Latin American common market; flexibility; differential treatments based on the level of development of the member countries; and multiplicity in the forms of agreement of commercial instruments. The agreements can cover diverse matters such as tariff reduction and trade promotion; economic complementation; agricultural trade; financial, tax, customs, health cooperation; preservation of the environment; scientific and technological cooperation; promotion of tourism; technical standards; and many other fields. (ALADI, 2020)
Bilateral cooperation is also being strengthened. The bases of the Cuba-Venezuela Comprehensive Cooperation Agreement CUBADEBATE, 2020a) have been renewed to promote a productive economy. The cooperation and signing of agreements by sectors with Russia and with China continue. In 2020, Cuba has signed the Treaty of Friendship and Cooperation in Southeast Asia (TAC), within the framework of the 37th Summit of the Association of Southeast Asian Nations (ASEAN). (CUBADEBATE, 2020b)

Conclusions and futures perspective

The global energy development with the fast increase in the production of renewable energy source, especially solar photovoltaic and wind energy have an impact on the Cuban energy system. The development of technologies in this field and the role of China, EU/Spain and the USA in the development can have an impact on the future investments for energy production in Cuba. The possibility to use climate funds for investments in renewable sources is one potential option if the blockade does not eliminate this option. The re-enter of the USA in the Paris Agreement can help in the future in this respect. One central question is how to make Cuba an attractive investment area and can the foreign investors expect a high enough return on their investments.
The fluctuations in oil price and the future uncertainty of oil imports are important factors that have to be taken into account in the formulation of Cuban energy policy. The impact of international climate policy on the future use and supply of fossil energy and its price will naturally have an impact on Cuban future energy plans, too. The Cuban dependence on oil imports is expected to continue long in the future even though the government plans to considerably increase the supply of renewable energy. The import substitution of oil with domestic renewable sources depends on the possibilities to invest in renewable sources. In addition, the control of the electricity supply and demand

balance in the electricity system, when the share of variable uncontrolled wind and solar supply is increasing, has to be managed technologically using, for instance, energy storages.

Opening the energy market in Cuba for prosumers (consumers who also produce electricity for instance with solar PV) requires new management strategies for the electricity system in the future. The future electricity price structure and the subsidies are important not only for the functioning of the electricity economy but also from the point of view of the social security of consumers. The present progressive pricing of electricity (lower price with lower consumption) can be seen as part of social policy and planning of the future tariff structure has to take the socio-economic aspects into account.

The highly educated Cuban population is a good basis for future economic development but the effective utilization of the workforce requires investments in production. The development of the energy sector can provide a means for improving the efficiency in production and better utilization of the knowledge capacity of the population. Digitalization can be seen as one driving force for the future development of the nation and the education here is needed for the realization of the full potential in this area. Improved efficiency of the workforce utilization is important in the Cuban case when the amount of future workforce is estimated to decrease fast. Digitalization and related improvement in efficiency can also have a central role in the reduction of emissions in the energy sector. Today the CO_2 emissions per capita are at a very low level in Cuba and with new technology and the use of renewable energy sources this positive development can be sustained also in the future.

The planning of the economic changes in Cuba has to have a systemic approach where the synergetic possibilities of development in the different sectors of the economy are taken into account and the present positive development trajectories are maintained.

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III.2. The economic development trends and future possibilities in Cuba

Amílcar Félix Roldán Ruenes

Main trends and characteristics of the world environment

There is a consensus among researchers that the world has never experienced such accelerated changes. Changes are happening at an unprecedented speed and intensity. The forces responsible for these transformations started to occur at the beginning of the 1990s and have created change in different societal dimensions such as the technological, geopolitical, socio-cultural and environmental spheres. As stated in the report of the European Strategy and Policy Analysis System (ESPAS), they are reshaping the world more and more firmly and rapidly and they make it… "systematically more complex, more challenging and also more insecure" (European Union, 2016). When referring to this situation, some authors proclaim that we are living in an era of disruption where transformations or revolutions are taking place. The European Union stands out in this context because of its revolutions in the fields of economics, technology, societal and geopolitical dimensions and in terms of democracy. VUCA environments (volatile, uncertain, complex and ambiguous) describe the current state of the world. They indicate that turbulence and instability are accentuated and prediction is replaced by reaction (Castiñeira, Á., 2019).

By considering these forces, a series of trends are identified that will shape the future of society. Authors such as Zueras (2019) identify 10 specific trends: robotization; telework; lack of talent (the workforce worldwide does not have the necessary skills that companies require to be able to cover jobs); inequality; sharing instead of having; fintech and the uberization[1] of banking; commerce around the cell phone; urban world; the cultural world grows, and sustainability increases profitability.

In the same way, Blanco Estévez, A. and Guerrero Blanco, T. (2013), identify ten trends that will determine the international economy for the coming years and these are: unconventional monetary policy; the international multi-currency monetary system; energy revolution and new materials; reshoring and return to the industry; openness and integration processes vs. protectionism; state capitalism; demographic pressures and sustainability; the consolidation of South-South relations; the rise of frontier markets, and savings-investment mismatches. Several of these coincide with those identified by Zueras (2019).

[1] *Uberization is a neo-euphemism that refers to the use of digital platforms and mobile applications, in order to facilitate peer-to-peer transactions between customers and service providers, often bypassing the central planning role of corporations*.

In the aforementioned essay by Castiñeira (2019) entitled: The trends that will determine a new economy from 2030, this author highlights the following:

1. The change in the economic model will be accompanied by a technological, social and energy change. The energy transformation will change geopolitics, as we know it.
2. The fourth industrial revolution (4IR) will lead us to an era of rapid innovation, catalyzed by info technologies and new biotechnological advances, which will maximize human potential (healthcare & biotech) by providing new physical and cognitive abilities in human beings and will contribute thus to extend life.
3. Technology based on AI (artificial intelligence) is also expected to transform the economy. Thanks to advances in deep learning, we have moved from the Age of Innovation to the Age of Deployment, where execution, product quality, speed and data are all important.
4. A decade from now, China will not only catch up with the United States, but it will also surpass them as the world's leader in AI. This will divide the world into a technological duopoly.
5. East-West demographic divergence will be accompanied by even more rapid East-West technological convergence.
6. Mobility and connectivity will continue to be two strategic themes. The new "connectography".

According to the different sources consulted, how KPMG International, and MOWAT Centre, (2014) and National Intelligence Council (2012), there is a great coincidence in the areas that are being developed. Those are the economy, society, technology, geopolitics and the environment. The following are highlighted in this study:

1. The ageing of the human race and the growth of social inequalities.
2. Weakening of globalization processes. Economic weight and political power are shifting to Asia.
3. The paradigm shift brought about by the arrival of the Internet and digitization is transforming societies in almost every aspect.
4. Increasing energy consumption and the use of renewable energy sources will mean changes in production models.
5. The growing fragility of the world order and a greater interdependence of countries.

Impacts on Cuban Developments

These broad trends will generate other trends that will have a direct impact on Cuba. Among these trends are the following:

First, individual empowerment, which will accelerate due to the reduction of poverty. Other trends are the growth of the middle class at a global level, higher educational achievements, the widespread use of new information and communication technologies (ICT), industrial production technologies and health improvements. These all of which will translate into:

- The growth of the economy.

- The widespread exploitation of new ICTs and manufacturing technologies.
- Improving the quality of health as well as life expectancy by 2030.
- There will be more ideological conflicts.

As for demographic patterns, an ageing population will make the battle to maintain living standards difficult and could be a brake on economic growth. Another factor to consider is migration and the growth of urbanization, which will drive economic growth but will lead to new conflicts between resources such as food, energy and water. Due to urbanization, the volume of urban construction for housing, offices and transportation services will grow and the demand for skilled and unskilled labour will expand. It is important to consider the link between water, food and energy. The growth of the urban population will increase the scarcity of critical resources such as water or food. Jobs will be more automated and new skills will be required to perform them, especially qualified ones, leading to the loss of jobs due to the incorporation of new technologies.

Energy demand will grow and with this climate change will accelerate, greenhouse gas emissions will increase, which will increase the planet's temperature by between 0.3 and 2.3 degrees and will affect us fundamentally due to the increase in the sea level and the increase in the number and frequency of extreme meteorological phenomena, in the Cuban case, extensive droughts and hurricanes (CITMA, 2017).

In turn, we must mention the potential black swans that will cause a disruptive impact:

Severe pandemics: climate change and the rise in temperature will cause an increase in pathogenic microorganisms that generate diseases and affect agriculture and the ability to feed the population.

A plate of fish in a local restaurant, Siboney

How does Cuba respond to these challenges?

In this sense, the elaboration of the theoretical conceptualization of the economic model and the identification of the strategic lines and sectors that make up the economic and social development program until 2030, constitute, together with the strategy designed for the post-COVID stage, the referents for the realization of any assessment about the future of the Cuban economy.

The President of Cuba Miguel Díaz-Canel Bermúdez has stated that at this time:

> *Together with defence, the fundamental task of the Revolution today is the economy. Not only because of the cruel, immoral, genocidal blockade it is getting worse and it is necessary to confront it with creativity at the level of the great professional mass available to the country. It is that we have not renounced and we will never renounce to make our economy, small and besieged 60 years ago, be prosperous and sustainable* (Díaz-Canel Bermúdez, 2019)

However, it is not possible to make an objective assessment of the situation if the effect of the United States blockade on Cuba is not considered. The global COVID-19 pandemic did not change the blockade between these two countries. According to the spokespersons from the Foreign Ministry of Cuba, the blockade has issued more than 40 provisions that were aimed at hindering all types of commercial and financial transactions on the island trying to stifle the economy and prevent the acquisition of medicine and supplies needed for its production. Since April of 2019, the island's economy began to face "additional restrictions" in the allocation of fuel for the persecution of the US administration led by Donald Trump. (Fernández Gil, 2019).

In recent years, after the VI Congress of the PCC, a new process regarding the Cuban national economy began. It aims to search for new sectors that would allow the economy to be more dynamic. However, the COVID-19 pandemic has left severe consequences in the Cuban economic, political and social spheres, which have caused the need to re-evaluate the objectives set until 2030 and the actions to achieve them. This re-evaluation has been constituted in the design of a post-COVID economic and social strategy that is defined as:

> *"An innovative Strategy that promotes the implementation of aspects approved in the Sixth and Seventh Congresses of the Party, in accordance with the Constitution of the Republic and implies the implementation of the Guidelines; of the conceptualization of the economic and social model and of the National Plan for Economic and Social Development 2030. They are part of the Strategy, the adjustment to Plan 2020 and the preparation of the Plan of the Economy for the year 2021*". (Ministerio de Economía y Planificación (MEP), 2020)

Actions aimed at eliminating double currency and exchange duality are maintained to eliminate the effects that this causes when evaluating the reality of the economy, the distortion of prices, as well as the negative impacts on the allocation of resources.

Given the new conjuncture, priority is given to the development of local development strategies (PCC, 2017:23, Guideline 17) that mark the intention of a decentralization process in correspondence with the newly approved constitution that places the municipal authority as responsible for decisions for the growth and development of the economy based on sustainability and on the municipalities' own resources (ANPP, 2019:104, Article 168). In this sense, it is a strategic line to achieve local industrial diversification and a productive chain. However, according to Ramos (2014) *"… combining national and territorial interests under the existing institutional and regulatory structure leads to high transaction costs and, often, to solutions well below what is desired"*, which is why work is being done on the institutionalization of this new field of management.

Local trade, Havana

In the current context and looking to the years to come, the need to reduce the size of the State is inescapable... *"the challenge is to continue being a socialist with "less State" directly exercising the management of the economy"* (Triana Cordoví, 2018). An important position should be placed on non-agricultural cooperatives in key sectors such as services, construction, small industrial productions as ways to activate productive development, considering that considerable flows of foreign investment are not foreseen.

In correspondence to this and aligned with the precepts of the new constitution and the documents approved by the VII Congress of the PCC, the management systems must be adapted to the realities of an economy where the growth of forms of property other than the state one exists and is stimulated. This is evidenced by the fact that the total number of employees in the state sector in 2018 in relation to the previous one decreased by 0.06% while in the same period those employed in the non-state sector grew by 2.04% and within them private ones by 3.88% (ONEI, 2020). In 2019, the number of those who work in the non-state sector continues to raise, mainly self-employed workers, who are already 41% of that group that accumulates 1,506,673 Cubans. However, the sector that is growing the most is the cooperative (296,192 more than in 2018), except for non-agricultural cooperatives that have 1,415 fewer members. (ONEI, 2021).

These facts undoubtedly call for defining what the relationship between the plan and the market should be. It should be formed in such a way that the plan does not stop the market and the market can support the purposes of the growth of the economy that are desired and prices emit adequate signals to producers.

In recent years, there has been a social differentiation creating a sector with high incomes. This situation has not occurred in previous years and currently represents a challenge for the government as it opposes the equity policy that the country has maintained throughout the existence of the revolutionary process. Associated with this, acts of corruption and illegalities have begun to occur and rebel. They have demanded more severe control and confrontation actions by the competent authorities.

A barber shop, Santiago de Cuba

2019 was a very tense year in both the economic order and the political order. In the economic sphere, the GDP decreased by 2% which shows that the country has been dragging very low growth rates because during the last 5 years the average growth was around 2 per cent. (ONEI, 2020). Moreover, judging by the impact of the COVID-19 pandemic and other factors, including the intensification of the North American blockade on the island, the downward trend in GDP has continued to decline in 2020 by 11.2%.

Figure 1. *Annual change in GDP in Cuba (GDP) at constant 1997 prices, for 2015-2020. (*Fernández Gil, A., 2019; ONEI, 2020)

In the new situation created by the intensification of the blockade by the Trump administration and the effects of the COVID pandemic, the country faced a complex situation characterized by the country's two currencies and two exchange rates. The Cuban peso has lost value and inflation of 399.6% has been forecasted in 2021 (EIU, 2021). The cost of the basket and basic services has increased and social expenses are reduced. The supply of basic necessities, as well as medicines, has decreased. This caused a price increase higher than the increase in wages, which has made the measures of the so-called economic order less effective. This has affected those related to wage reform and monetary unification in the extent to which the sale of basic necessities is being carried out in MLC stores (freely convertible currencies that are quoted at the dollar exchange rate). While examining the economic situation, it is evident that the sources of income have decreased, especially for tourism (-74.6% during 2020 and -95.5% in 2021) (ONEI, 2021). The country has had to close its borders due to the pandemic. The measures implemented by the Trump administration are still in force and the structural deformations persist in the economy. Within the framework of the strategy developed for this post-COVID stage, a set of actions have been designed that assume the character of systemic economic reforms aimed at freeing up productive forces, increasing efficiency, stimulating growth and promoting sustainable development. These measures include:

- The improvement of the management model of the agricultural sector and together with it, transform the role of the state company in agriculture by creating an environment that encourages the development of all forms of production and their linkages. Among the initiatives approved, according to Triana Cordoví (2021): there are two types of measures: short-term and long-term. The first began to be implemented within hours of being announced. They include the reduction of taxes and the rates and services offered by the state to producers, in addition to the correction of prices of agricultural products. Long-term measures address more structural problems. Among them, Triana highlights as relevant the empowerment of local governments, the resizing of cooperatives, the review of the structure and land tenure, and the use of scientific and technological advances in Cuban research centres.

Other measures include:

- The improvement of the management model of the agricultural sector and together with it, transform the role of the state company in agriculture by creating an environment that encourages the development of all forms of production and their linking.
- Encourage and make the export of professional services more flexible.
- Continue investing in the development of the Biopharmaceutical industry as one of the activities with the greatest export capacity.
- Promote the constitution of small and medium-sized private companies, which will be allowed to form alliances with state and foreign companies and carry out import and export operations.
- The creation of a wholesale market for the private sector, the expansion of non-agricultural cooperatives and self-employment, as well as granting greater decision and operational autonomy to state companies.
- Maintain the computerization strategy of the company.
- The use of renewable energy sources, maintaining the goal of achieving 24% electricity generation from them by 2030.

The strategy also indicates that the steps for the constitution of micro, small and medium enterprises will begin. These can be private, state-owned or mixed enterprises.

Fishing by the harbour, Havana

Future Possibilities in Cuba

In the near future, the new regulations approve of direct foreign investment. This will create opportunities and will start to realise the Mariel Special Development Zone and the investment project portfolio (MINCEX, 2021).

The accelerated development program for tourism and strong investments in the biotechnology and pharmaceutical sector are maintained. They will maintain their positions in the growth of the non-state sector of the economy, both in the generation of employment and in participation in the gross domestic production. Although today, they are highly affected by the impacts of the pandemic and the contraction that the economy has suffered. Other actions that would facilitate the use of the identified trends could be:

- Collaboration with East Asian countries, the European Union and the region is expanded.
- Use of renewable energy sources and introduction of new non-polluting and more efficient technologies.
- Introduce new technologies, high productivity construction systems and develop the construction materials industry.
- Expand the use of information and communications technologies. Expand connectivity and on the basis of the modernization of technology to achieve full computerization of society.
- Incorporate new and modern management systems and technologies that increase the efficiency of production processes in particular in agriculture and
- Establish collaboration agreements and develop exchanges with foreign universities and research centres for the research, development and innovation processes.

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III.3. Foreign investment in the Cuban energy sector

Anaely Saunders Vazquez

Introduction

Foreign investments are significant in increasing the technological availability of production processes, optimizing them and increasing their efficiency, increasing job skills and competencies, and searching for new markets. In the process of Cuban economic transformations, Foreign Direct Investment (FDI) was defined not as a complementary element but as an essential factor for developing a series of economic sectors (Rodríguez, 2019).

In the Conceptualization of the Cuban economic and social model of Socialist development, different non-state economic forms are linked to FDI, such as international economic association contracts, joint ventures, and foreign companies. These entities are important ways of attracting capital, financing, technologies, markets for inputs and the destination of production and services, sources of employment, managerial experiences, obtaining income, and other benefits, as fundamental elements for development (PCC, 2017:6)

The National Plan for Economic and Social Development until 2030 (Ministry of Economic and Planning, 2020) contains 24 guiding principles to consolidate the nation's vision. Among these principles is one related to foreign investment, which specifies: "Conceive and promote foreign direct investment as an essential part of the country's development strategy and, in particular, of the economic sectors defined as strategic" (PCC, 2017:15).

When making the summary of the year 2021, in the National Assembly, Rodrigo Malmierca Díaz, head of the Ministry of Foreign Trade and Foreign Investment (MINCEX), expressed that among the problems that affect the attraction of foreign investment to the country are the qualification of Cuba as a high-risk country, as a result of the US blockade, as well as the country's high levels of indebtedness (Rodríguez, 2021).

We must also add that the problems of convertibility of the Cuban peso, the low competitiveness of goods and services, the deficit of productive capacity, and the problems in the investment processes are other internal difficulties that threaten the attraction of foreign capital. The same happens with the development of the Cuban financial system, the absence of an internal financial market, and the delay in the automation of processes and connectivity (Prensa Latina, 2021).

Portfolio of Projects and Opportunities

At the end of 2021, the country has, in the new investment portfolio, 678 projects, with an estimated amount of 12 533 million dollars. Since 2014, 104 joint ventures, 54 foreign capital companies, and 144 international economic association contracts have been established (Martínez Rodríguez, 2021).

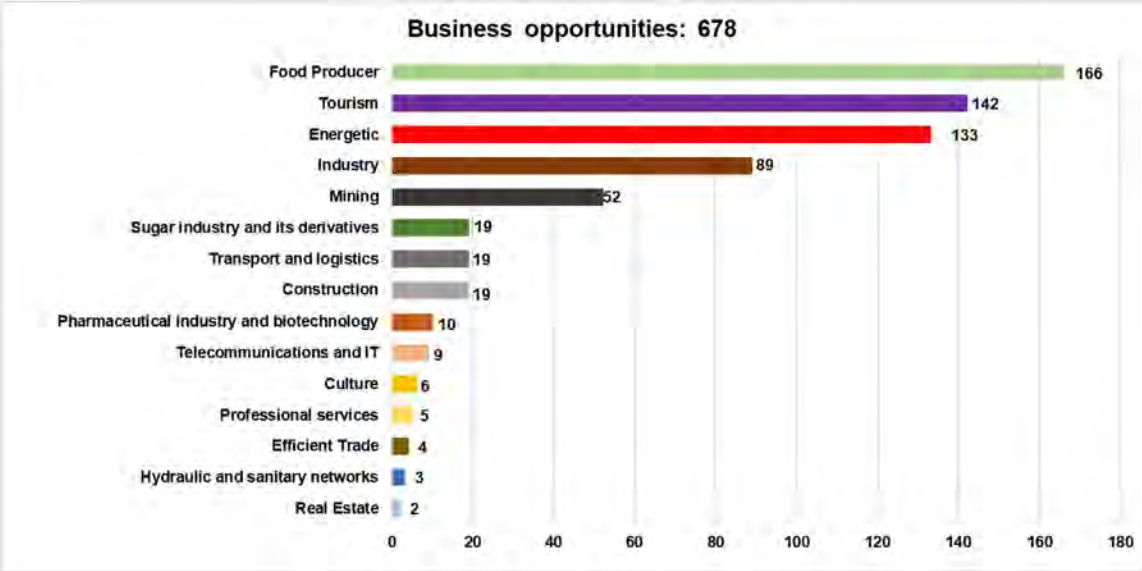

Figure 1: *Investment Opportunities in strategic sectors* (MINCEX, 2021).

Tourism, energy, food, and light industry are the sectors with the highest incidence of Foreign Investment, sectors that have a significant weight in the country's exports, despite the insufficient productive chains (Rodríguez, 2021).

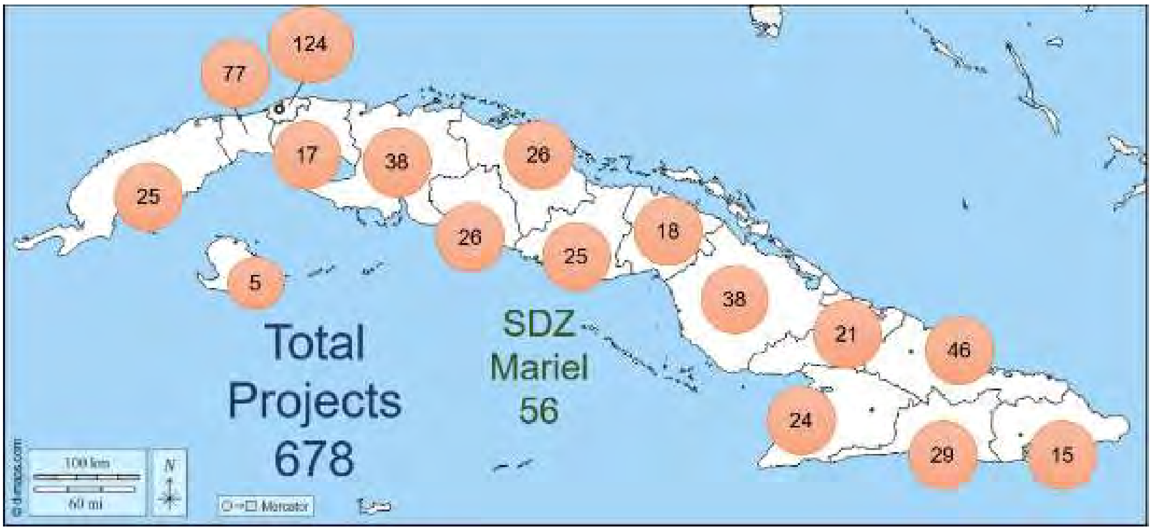

Figure 2. *Foreign Investment Projects by Provinces* (MINCEX, 2021).

In the Energy Sector, 16 projects proposed in the Portfolio of Opportunities have been identified (MINCEX, 2021a):

1. PHOTOVOLTAIC SOLAR PARKS (10 MW): Construction of photovoltaic solar parks in Pinar del Río and Artemisa (specifically in the Mariel Special Development Zone, SDZ) for generation and sale to the Electric Union. Amount of each investment: $15,000,000 USD. Total projects = 3.
2. PHOTOVOLTAIC SOLAR PARKS (25 MW): Construction of photovoltaic solar parks in Las Tunas for generation and sale to the Electric Union. Amount of each investment: $37,500,000 USD. Total Projects = 1

3. PHOTOVOLTAIC SOLAR PARKS (30 MW): Construction of photovoltaic solar parks in Ciego de Ávila, Camagüey, Villa Clara and Cienfuegos. Amount of each investment: $45,000,000 USD. Total projects = 2
4. PHOTOVOLTAIC SOLAR PARKS (35 MW): Construction of photovoltaic solar parks in Santiago de Cuba and Guantánamo. Amount of each investment: $52,500,000 USD. Total Projects = 1
5. PHOTOVOLTAIC SOLAR PARKS (45 MW): Construction of photovoltaic solar parks in Holguín for generation and sale to the Electric Union. Amount of each investment: $67,500,000 USD. Total Projects = 1
6. INSTALLATION AND OPERATION OF PHOTOVOLTAIC SOLAR PANELS ON ROOFS AND CHARGING STATIONS. Install and operate photovoltaic solar panels on the roofs of third-party buildings, bus stops, and the assembly and operation of photovoltaic stations to charge electric vehicles in the Special Development Zone. Investment amount: $1,000,000 USD. Total Projects = 1
7. PHOTOVOLTAIC SOLAR PARKS (15 MW): Construction of photovoltaic solar parks in Matanzas for generation and sale to the Electric Union. Investment amount: $22,500,000 USD. Total Projects = 1
8. BIOMASS POWER PLANT AT THE CIUDAD CARACAS, Cienfuegos. Construction and assembly of a biomass power plant adjacent to the sugar mill to increase electricity generation with renewable energy sources from sugar cane and forest biomass. Investment amount: $120,000,000 USD. Total Projects = 1
9. BIOMASS POWER PLANT AT THE GEORGE WASHINGTON, Villa Clara. Investment amount: $120,000,000 USD. Total Projects = 1
10. BIOMASS POWER PLANT AT THE QUINTIN BANDERAS, Villa Clara. Investment amount: $120,000,000 USD. Total Projects = 1
11. BIOMASS POWER PLANT IN BRAZIL, Camagüey. Investment amount: $140,000,000 USD. Total Projects = 1
12. BIOMASS POWER PLANT AT THE PANAMA, Camagüey. Investment amount: $140,000,000 USD. Total Projects = 1
13. BIOMASS POWER PLANT IN COLOMBIA, Las Tunas. Investment amount: $120,000,000 USD. Total Projects = 1

Wind turbines, Gibara

Regulatory framework for Foreign Investment

Over the years, as part of the improvement of the regulatory framework of the Investment Policy, laws, decree-laws, decrees and resolutions have been prepared. Among them are (MINCEX, 2021b):

- Law No. 118/2014, "Foreign Investment Law".
- Decree No. 325/2018, "Regulation of the Foreign Investment Law".
- Resolution No. 14/2018 of the Ministry of Labor and Social Security, "Regulation on the Labor Regime of Foreign Investment".
- Resolution No. 207/2018 of the Ministry of Foreign Trade and Foreign Investment, on the methodological basis for preparing technical-economic studies.
- Resolutions No. 46/2014 and No. 47/2014 of the Central Bank of Cuba on making contributions or contributions by foreign investors and the management of their bank accounts in Cuba.
- Decree No. 366/2019, modifying Decree 325 "Regulation of the Foreign Investment Law", of April 9, 2014.

- Agreement No. 8732/2019 of the Council of Ministers, delegating to the Heads of Bodies of the Central State Administration the power to authorize International Economic Association Contracts for productive administration and services, as well as their modifications during their validity period.
- Decree-Laws on commercial guarantees (Decree-Law No. 14/2020, "On Pledge and Mortgage", and Decree-Law No. 15/2020 "On Guarantee Trust").
- Decree No. 15/2020 "Regulation of the Single Window for Foreign Investment".

Added to these regulations are the possibilities offered by international agreements with the Latin American Integration Association (ALADI), the Caribbean Community (CARICOM), the Bolivarian Alliance for the Peoples of Our America (ALBA), the Southern Common Market (MERCOSUR), the European Union (EU) and the World Trade Organization (WTO), which serve as support for the development of the country's Investment Policy.

Regarding the energy issue, the Decree-Law No. 345 was approved at the end of 2019 "On the development of renewable sources and the efficient use of energy" (Ministerio de Justicia (MINJUS), 2019) with resolutions and complementary instructions to contribute to various objectives, including:

- the stimulation of investment, research, and the improvement of energy efficiency, as well as the production and use of energy from renewable sources, through the establishment of incentives and other instruments that stimulate their development;
- the development of the production of equipment, means, and spare parts by the national industry for the use of renewable sources and energy efficiency.

At the same time, as mentioned earlier in 2019, the regulation was complemented with the Instruction 6/2019 of the Central Bank of Cuba. That regulates the concession of credits to natural persons (not private businesses) for the acquisition of equipment using renewable sources as a support mechanism to accelerate the use of renewable (González Lorente et al., 2020).

In 2021, the government gave new steps promulgating a group of resolutions to enhance the participation of all sectors in renewable energies development

- Resolution 206/2021 by the Ministry of Energy and Mines (Ministerio de Justicia (MINJUS), 2021b) approves the import of photovoltaic systems for natural people.
- Resolution 208/2021 by the Ministry of Energy and Mines (Ministerio de Justicia (MINJUS), 2021a) approves the import of equipment, parts, and pieces that generate or work as renewable sources of energy.
- Resolution 319/2021 by the Ministry of Finances and Prices (Ministerio de Justicia (MINJUS), 2021b) exempts the payment from the tariffs of customs to natural people for the import without the commercial character of solar photovoltaic systems and their parts and fundamental pieces.
- Resolution 223/2021 by the Ministry of Finances and Prices (Ministerio de Justicia (MINJUS), 2021c) authorizes fiscal benefits to the companies of completely foreign capital that execute electricity generation projects with renewable sources of energy.

- Resolution 322/2021 by the Ministry of Finances and Prices (Ministerio de Justicia (MINJUS) 2021a) exempts natural persons from paying customs duties for non-commercial imports of specific equipment using renewable energy sources.

The COVID-19 pandemic, together with the new measures dictated by the US government that reinforce the economic and commercial blockade, have intensified Cuba's difficulties in accessing foreign investment. However, the country has to manage the process of economic transformations so that the social conquests express their development potential and achieve, among other things: recover the investment rate and improve the productive infrastructure (capital formation) and support the deployment of Cuban companies abroad, as well as foreign investment in Cuba (Lage Dávila, 2022).

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III.4. Local and provincial energy governance in Cuba

Arielys Martínez Hernández

Introduction

Energy management is a central challenge in Cuba. This article presents mechanisms and challenges on local and provincial levels.

The provincial government, with its resources and attributions, is called to be not only efficient in the operation of certain functions or services to the community but also has to contribute to development through special investment, mediation, evaluation and presentation efforts of pro-jects and information. This makes the need for the development and consolidation of local governments in different countries imperative; in order to be more efficient in attracting, investing and spending the resources committed to energy development (Rosas-Ferrusca, Calderón-Maya, and Campos-Alanís, 2012).

Ocman Azueta (2015), points out that attention should be paid to the actions of local governments (provincial or state) as fundamental actors in energy policy. This is because their strategies for the incorporation of Renewable Energy Sources (RES) imply the creation of territorial block that induce actions based on the integration of energy policies that are adapted to national policies while establishing relationships with actors at different levels to implement solutions.

Provincial energy governance is a space that borders, reinvents and gives a new dimension to energy governance by relocating authority and leadership, which is interpreted as a kind of fragmented sovereignty in different sectors of politics. It holds specific objectives in which co-operation between different levels of authority and actors is necessary to incorporate Renewable Energy Sources (Lopez-Vallejo, 2016; Ocman Azueta, 2015).

The role of local governments as main actors has made it clear that there is a disconnection between national politics and local problems caused by verticality in decisions and policies at the country level. The fact that governments act as central actors in the territory allows the de-sign of energy policies to be based more closely on problems. The fact that these governments are the entities closest to citizens and, therefore public representation. Consequently, common interests have been established around shared goals, for which differences and the levels of integration of state economies are considered (Ocman Azueta, 2015).

The governance of the provincial energy matrix (GMEP) essentially comprises the mechanisms of leadership, strategy and control of positions to evaluate, direct and monitor the performance of energy management with a view to the conduct of a provincial energy policy and the provision of services of interest to society.

However, according to the author, it cannot be assumed that energy governance is a process in which all actors participate equally, symmetrically and cooperatively It is possible that the actors involved will not be able to negotiate common objectives, that agreements are changed on the fly without the consensus of all, or that any of the sectors that intervene in the energy governance process tilt the balance of political and economic power in their favour and to the detriment of others.

In Cuba, in all provinces two areas coexist whose developments respond to specific logics:

- The one that responds to activities of national interest, which define the role of each province in the conception of the development of the country, and must be promoted through national policies, decisions and investments.
- That of activities of provincial interest, understanding as such those related to internal potentials and capacities that satisfy the demands and expectations of the population. These activities can be identified, decided and implemented by the provincial authority, mainly with the re-sources available to it. Both those are generated by the province and those captured from other national and international sources are framed in conditions that define the development of the nation and the regulatory framework established for this purpose.

The GMEP focuses on the two areas and it integrates the other instruments used for territorial planning at the provincial level. The government is in control of the GMEP process, the structure of the public administration that is subordinate to it is in charge of the executive component of this process. In addition, it is accountable to the government and the population for the management.

The foregoing implies a challenge for provincial governments and administrations since they must achieve a balance point in the level of priority given to activities of provincial interest with those located in their territory and that respond to national interests which is necessary to pro-vide them with skills, legal framework and access to resources at the appropriate level.

On the basis of the elements previously analysed, the concept of governance of the provincial energy matrix is defined for this research as: the process of participatory and coordinated decision-making between society and the government, based on the management of strategic energy that contributes to territorial development, where the renewable energy sources are incorporated for the generation of electricity.

It is a decision-making process, as it is a question of managing and directing the energy mix in such a way that maximum economic efficiency is obtained, in order to ensure more inclusive and co-responsible management compared to the traditional more centralized models.

And it is a participatory and coordinated process between society and the government, as society and government decide where they are going, energy values and goals, how they are organized, how work is divided and authority is distributed to be in a position to achieve the desired objectives.

Based on the management of an energy strategy that contributes to territorial development, governments must devise a medium and long-term energy strategy that allows fewer vertical and authoritarian structures, where government decisions and the execution of energy policies have the territories as their central scope and where the renewable energy sources are taken into consideration as part of the energy mix and for the generation of electricity.

In the author's opinion, and on the basis of previously systematized experiences, mainly those of BID (2013); (2014); Dutta and Mia (2011); Gaetani, Anício and Pires (2014); Gailing and Röhring (2016); Fudge, Peters and Woodman (2016); Shih, Latham and Sarzynski, 2016; OECD (2009) the following phases of the governance of the energy mix are proposed, as the tool that focuses the governance process of the provincial energy mix. They are: energy analysis, design of the energy strategy, implementation of the energy strategy and monitoring and evaluation of the energy strategy.

Next, it delves into two elements that are considered relevant in the foundation of this theoretical contribution: the role of local authorities and of public-private alliances in the governance of the provincial energy matrix.

The role of local authorities in the governance of the energy mix

Experts of energy systems (Bolton and Foxon, 2013; 2015; Geels, 2002; 2010; Loorbach, Frantzeskaki and Huffenreuter, 2015), describe that energy infrastructures represent complex technical systems that are influenced by a number of non-technical aspects and by technical factors. These include institutional changes, user practices, policies and regulations in force, technological innovations, changing ecosystems and business strategies.

As Calvert and Mabee (2014) argue, the "transition" poses particular challenges for the ways in which energy, social and environmental imperatives present to replace non-renewable energy with new sources of renewable energy. The problem, however, is that there is a systemic and self-referential preference for fossil fuels since energy resources have been embedded in social and political-economic activities, as well as their underlying institutional and physical structures. (Calvert, and Mabee, 2014).

For infrastructure change (Bolton and Foxon, 2013), the levels of the Multi-Level Perspective (MLP) can be defined as:

- Landscape (macro-level): this level is related to the general framework, it is political beliefs, world views; dominant social and cultural values and institutional elements of society. The land-scape-level encompasses the broadest set of factors. "... contextualizes activities within niches and regimes" (Bolton and Foxon, 2013). The landscape is based on "the world of life."
- Regime (meso-level): is the level at which the contextual environment of the landscape outlined above is articulated by the actors, groups and particular alliances. In transition, this do-main refers in particular to the influence of socio-technical systems. The regime is the level at which these systems manifest themselves through dominant practices, arrangements and technologies "aligned with each other and coordinated" (Geels 2002; Fudge et al., 2016).
- Niche (micro-level): this level refers to spaces of radical and innovative possibilities, where the usual market selection processes that take place in the regime are not affected. Niches can be considered the most flexible of the three domains and often catalysts for broader change. In this way, niches are seen as developments that are capable of challenging traditional ways of doing things and that offer alternative to the problems of the system (Fudge et al., 2016).

The transformation of energy systems is at the heart of trying to shape sustainable change. Calvert and Mabee (2014), argue that MLP provides a theoretical starting point through which "the physical properties or 'materialities' of emerging energy and its resources make sense." They suggest that a more sustainable energy future will emerge around "quality, quantity and location of emerging energy resources “and the ways in which these characteristics can be aligned over time and space with existing social, political and economic arrangements, quantity and location of emerging energy resources” and the ways in which these characteristics can be aligned over time and space with existing social, political and economic arrangements.

The dynamics of this model offers a particularly useful approach to examining how the regime of national energy markets continues to influence the reconfiguration and possibilities of more localized urban energy systems, including the role of local authorities in influencing governance of energy.

As Bolton and Foxon (2013) highlight, the MLP does not recognize or analyse niche activity in energy management and regulation.

Fudge et al. (2016), provide a contribution to this gap considering how the increased need for local energy governance has opened niche possibilities for local authorities to influence the ruling regime. The author assumes that a correct transition requires an analysis of the current energy governance system in order to rethink the mechanisms, standards, technology to be used with the goals that are intended to be achieved, taking into account the role of the provincial authorities to achieve the synergy of the actors at the different levels, that is, multilevel. Therefore, it is necessary to study the relationship between public and private actors.

Local electricity distribution, Santiago de Cuba

Relationship between public and private actors in the governance process of the provincial energy matrix

Mataix, Sánchez, Huerta and Lumbreras (2008) define a public-private partnership for development (APPD) as: when different actors from the public and private sectors, regardless of the number, establish objectives, expectations and rules of the game through reflection and negotiation, and commit them-selves to work together. It is in agreement with principles of co-responsibility to contribute to development, through the synergy of resources and capacities.

However, there are authors who disagree with these alliances (Cowell, Ellis, Sherry-Brennan, Strachan and Toke, 2017) refer to the horizontal levels in which the actors relate, responding mainly to hierarchical orders.

A public-private alliance is considered to exist when “government entities, state companies and/or private actors are linked, to achieve a common objective combining skills, sharing risks, responsibilities, resources, costs and benefits.” The actors, individuals or groups that interact and create collective action - agreement or decisions - are capable of formulating and reformulating norms, which guide the behaviour of said actors (Hufty, 2008).

According to Hufty (2008), to determine the type of actor -strategic, relevant or secondary-, three aspects must be taken into account: their resources; their willingness and ability to mobilize those resources, which includes both the effective mobilization of these -objective dimension- and the expected one -subjective dimension- and, lastly, strategic interaction with other actors in the governance process.

In summary, for the author, the relationships between public and private actors are when they establish objectives, interests and standards of action through deliberation and negotiation, and commit to working in accordance with principles of co-responsibility to contribute to development, through the synergy of resources and capabilities.

Energy governance, the territory and the relationship that they establish for a common future of the province, takes place when governments intend to move towards an energy transition where local authorities play a primary role. The Ministry of Mines and Energy (MME) of Brazil (2017), propose that the governance of the provincial energy matrix is conceived in three specific areas of action and nine basic principles, which are presented below. The areas of action are:

- **Efficiency**: The purpose of observing the principles of efficiency is to guarantee that society obtains the maximum benefit as a result of the use of resources in the electricity sector, considering the socio-environmental costs and gains. It is necessary to recognize and properly as-sess the different types of products or services that are delivered by agents in all segments of the electricity sector.
- **Equity**: ensuring that specific types of goods or services are available at appropriate levels for society as a whole or for specific strata of society. In addition, the regulation must lead to the establishment of fair and equitable competition of the economic agents and of the different energy sources evaluated on the same basis.

- **Sustainability of the regulatory framework**: ensuring that the regulatory framework of the energy sector itself is commercially sustainable, providing it with legitimacy and the ability to respond to the needs of different stakeholders in terms of creating an appropriate environment for commercial transactions.

On the other hand, the principles that are considered are the following:

- Cost-effectiveness and efficiency (productive and allocative in the short and long term)
- Transparency and participation of society in the acts carried out.
- Isonomy (represents the concept of equality of all citizens before the law)
- Assessment of the different levels of autonomy of local actors.
- Adaptability and flexibility.
- Consistency.
- Simplicity.
- Predictability and conformity of acts performed.
- Clear definition of competencies and respect for the role of institutions.

The governance of the energy matrix must be a function of the territorial development management process, which offers the possibility that public policies, linked to the energy matrix, corresponding to the different possible scenarios and strategic projections in the medium and long term. This helps the actors to avoid making decisions that respond to conjunctural situations and that could cause negative impacts. These analyses provide the basis for policymakers to make long-term sustainable decisions (Volkart, Weidmann, Bauer and Hirschberg, 2017).

The other criterion supported by the author is that the sustainability of the governance of the energy mix involves the use of renewable energy sources as a more viable and sustainable alternative to the world energy situation and the damage caused by oil extraction to the environment. This in turn supports the strategic importance of the incorporation of renewable energy sources in the energy mix (Ortíz García, 2018).

The aforementioned elements support the conception that the author assumes when proposing that the governance of the provincial energy matrix based on the generation of electricity should be a sustainable process. In the next table, we present several examples studied that reaffirm that governance must be sustainable.

Table 1. International experience of energy mix governance

Country	Governance of energy mix	
China (Hong Kong) (National Bureau of Statistics of China, 2020)	State control (local electricity sector)	Each province has territorial autonomy. The transmission and distribution of electrical energy are controlled by the government by natural monopolies. They have opened the sector to foreign investments and private agents in the area of electricity generation with vertical integration. Energy transitions can be carried out

		with the criterion of the population, with the aim of achieving sustainable energy governance.
United Kingdom (Fudge, Peters, and Woodman, 2016)	State control (local and autonomous electricity sector)	There is the synergy of actors, institutions and technologies in the reproduction and transfomation of infrastructure systems such as energy supply emphasize the potential of local authorities in energy governance.
Germany (Gailing and Röhring, 2016; Goldthau, 2014; Hauber and Ruppert-Winkel, 2012; Heinbach, Aretz, Hirschl, Prahl, and Salecki, 2014; Klagge and Brocke, 2012; Leibenath and Otto, 2013; Moser, 2011; Oteman, Wiering and Helderman, 2014)	Energy regions with decentralized models	Regional energy governance is driven by a number of actors with different interests, culminating in the development of collaborative and participatory governance structures. It focuses on "cooperative governance structures" in favour of the management of decentralized systems of energy structures and on a community-oriented model of government. Consequently, research on regional energy governance examines the role of collective actors and their activities. This includes network-based forms of regional energy governance as regionally adjusted modes of cooperation. Stakeholder synergies and modes of communication are crucial to understanding energy governance.
United States (Rabe, 2007; Carley, 2011; Houck and Rickerson, 2009; Shih, Latham and Sarzynski, 2016)	State control local	Energy program administrations emerge to support the state's energy efficiency and the inclusion of renewable energy at the state level. These energy program administrations have an essential role to play in the coordination of resources, information and networks between actors in the public sector, the private sector and society. Shih et al. (2016), show the coordinating role and functions of these energy administrations, the network of different sectors, as well as their influence on energy at the state efficiency and renewable energy level (hereinafter, EERE). Governance focuses on a few important actors in the public and private sectors. EERE repositions management and pro-vides consumers with a more active participatory role in energy-related public affairs.
Brasil (Cavaliero, and Da Silva, 2005; Ministério de Minas e Energia, 2017; Ruiz,	State control and private provincial generation	It has local autonomy in terms of power generation. It is private but controls states. There is the equity between public and private agents

Rodríguez and Bermann, C., 2007)		and sustainability of the electricity regulatory framework. In June 2017 the government of Brazil through its Ministry of Mines and Energy (MME) declared the principles, goals and basic structure that will guide the New Model of the Brazilian Electricity Sector. The principles are efficiency, equity and sustainability of the regulatory framework.

Conclusion

The governance approach of the energy matrix is based on the mobilization and participation of the territorial actors and on the conviction of their own effort to coordinate the development strategies to be followed territorially. This requires intermediation instruments from the territories that enable the efficient use of available resources.

To achieve a high level of implementation of the ideal of the energy matrix from that of governance, it is of vital importance for the institutionalization that the term is achieved, from the treatment of the category's autonomy, competencies and decentralization and the multilevel. The position that local administrations can only perform within the limits that they draw, which creates a relationship of direct proportionality between them.

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III.5. Trends in energy consumption in the residential sector in Cuba

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Abstract

This paper characterizes the electric energy consumption and energy policies in Cuba, with emphasis on the residential sector, which currently represents about 60% of the consumption. The article includes: an example of the energy demand of a primary distribution electric circuit where residential loads predominate; the characterization of electricity use in a secondary distribution circuit, particularly a multifamily building and the aspects related to the structuring of electricity consumption levels in residential customers, seen through the new electricity tariff. All these aspects favour the understanding of the sector's energy behaviour, in order to propose changes for the transition and change of the country's energy mix.

Keywords: electricity, energy policies, collective responses to electricity use, residential sector, electricity tariffs.

Introduction

From an economic, environmental, political and public policy perspective, households are central to energy markets, especially in Latin America and the Caribbean. Energy consumption has quadrupled in the region since 1971. This growth is associated with a sustained increase in income, as well as increasing urbanization and greater access to modern energy sources (Jiménez Mori and Yépez García, 2020).

The energy sector in Cuba, since the triumph of the Revolution in 1959, has been a constant concern for the country. It has been a priority to guarantee the energy carriers for the ever-advancing economic and social activities, which demand energy services to guarantee the production and the daily life of society. The energy base of the country with a total of 10,323 ktoe per year, characterized by the high dependence on imports of 54 % (CUBAENERGÍA, 2019), makes it necessary to outline strategies to ensure the satisfaction of non-residential and residential customers, through planning, determination and coordination of activities that favour the continuous improvement of the energy mix.

Currently, one of the strategies in which most work is being done is related to the development of electric power generation to cover the demands of primary, secondary and tertiary activities more efficiently in the country. Since 2018, there is 100% access to electricity in both the urban and rural sectors (BANCO MUNDIAL, 2019). However, studies of the collective responses of the use of the energy carrier electricity and the knowledge of the present loads are required, which allow drawing strategies in terms of energy policies and technical decisions for its better use.

To achieve an approach to the behaviour of energy consumption in Cuban households, the present work has been structured as follows: An analysis of the country's electric energy consumption is made, linking it with energy policies and presenting aspects of the historical development of the electricity system. Subsequently, the characteristics of consumption in the residential sector as the most important sector from the quantitative point of view are discussed.

In order to exemplify the characteristics of the residential sector, which distinguish it from the rest, a primary distribution electric circuit is selected and its demand is represented, in which residential loads have a high incidence. In this case, the behaviour of the main electrical variables of the circuit, the characteristic curves of the demand on the different days of the week, the difference between the behaviour during the winter and summer periods, etc., are shown.

To continue the analysis of the subject, an electrical circuit of secondary distribution is selected that coincides with loads of a multifamily building, showing for this case, the regularities of the electrical variables as an effect of the exclusively residential loads (household equipment). At this distribution level, trends in the demand curves similar to the primary distribution are observed.

All demand behaviour is the result of the individuality of each appliance and how residential customers use electricity in their homes. Thus the collective responses of consumption, with specificity in the behaviour of electricity tariffs, are analyzed as the last aspects of the work. By means of a technical and economic basis, these aspects and their systematization help in the decision-making process within the energy policies and the energy support program in Cuba.

The order of presentation of the topics and the results of the examples approached, independently of their statistical significance, in terms of the sizes of the data samples and the number of circuits analyzed, go from general analysis to the particular. All this, in order to expose the elements that influence and characterize the trends of energy consumption in the residential sector.

Energy consumption and energy policies

Among the 17 post-2015 Sustainable Development Goals of the United Nations, number seven, related to energy, states: ensure access to affordable, safe, sustainable and modern energy for all. Within this goal, three targets are framed for 2030: ensure universal access to affordable, reliable and modern energy services; substantially increase the share of renewable energy; and double the global rate of improvement in energy efficiency (ONU, 2015).

Electric power is a very particular case of energy services. In the case of Cuba, its production depends mostly on fossil fuels; therefore, it is a national priority to improve energy efficiency; increase generation with renewable sources; increase oil exploration and extraction; and maximize generation with national oil accompanying gas. It should be mentioned that in 2018, 54.04% of the total imports corresponded to petroleum products and by-products and 45.88% to crude oil (CUBAENERGÍA, 2019).

The background of energy in Cuba reflects that before 1959, the year of the revolutionary triumph, only 56% of the population had electricity service; there were several electrical systems that were not interconnected; oil and its derivatives were mostly imported; the energy industry was controlled by foreign capital.

Starting in 1959, the generating capacity increased significantly with new thermoelectric plants (condensing steam power plants). The National Electric System (SEN, Spanish acronym) was established with a stable generation, increasing the number of customers and the consumption of energy carriers. The graph in Figure 1 shows the behaviour of electric power generation in the period from 1980 to 2020.

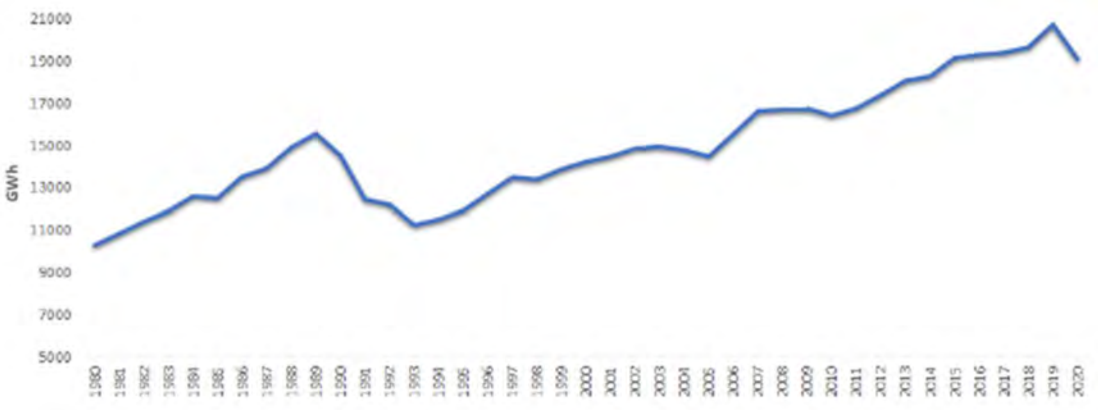

Figure 1. *The annual generation of electric energy in Cuba from 1980 to 2020.* (DATOSMACRO, 2021; ONEI, 2014)

In the 1990s, with the disintegration of the socialist bloc, imports of oil and oil derivatives and electricity generation fell. Since 1995, the extraction and use of domestic crude oil and accompanying gas have increased. The country was forced to generate with very low efficiency and burn crude oil with high sulfur content in the Thermoelectric Power Plants. At the end of the 1990s, the modernization and adaptation of the power plants began to improve their efficiency and optimize the burning of domestic crude oil.

In 1997, two energy efficiency programs were initiated at a national level. One of them is the Electricity Saving Program in Cuba (PAEC, Spanish acronym) which orients measures to save, reduce consumption and manage demand during the peak. Within this program, three million incandescent light bulbs were replaced by fluorescent lamps; a body of electricity load regulators was organized to work with consumers; efficiency standards were established for imported and domestic household appliances and a national communication campaign was intensified to enhance energy savings.

In 1997, the Ministry of Education's Electricity Saving Program (PAEME, Spanish acronym) was also implemented, which included different methodological actions and changes in the teaching and learning system at all educational levels, to promote an energy culture in line with the country's situation. These programs made it possible to reduce the maximum demand of the SEN by more than 150 MW between 1997 and 2001.

In 2005, the energy crisis in Cuba worsened due to the fact that the country's base generation was carried out with inefficient thermoelectric plants, with 25 years of operation and only 60% availability. There were also frequent breakdowns and the generating plants had high self-consumption. The state of the electrical system began to deteriorate with the occurrence of a large number of blackouts as a result of the low availability of generation. In addition to this, there were major breakdowns in transmission networks due to hurricanes and the sustained growth of fuel prices, which led to the beginning of the Energy Revolution.

A biogas stove

The energy situation was characterized by the existence of numerous inefficient appliances in homes; 75% of the population cooked with kerosene, with many difficulties to guarantee its availability; insufficient energy-saving culture in the residential and state sectors; and a residential electricity tariff that did not encourage saving. It is then that the Energy Revolution began, under the premise of reducing fuel consumption with the rational use of energy and increasing generation with more efficient technologies. They were structured in programs that aimed at saving and rationalizing the use of energy; increasing the availability of electric service; using renewable energies; increasing oil reconnaissance; oil and gas production; as well as intensifying international collaboration.

Within the Energy Revolution programs, the energy efficiency program in the residential sector involved the replacement of 9.4 million incandescent light bulbs (100%) for compact fluorescent lamps and 4.4 million inefficient household appliances were replaced (2.6 million refrigerators, 230 thousand air conditioners, 1.0 million fans, 247 thousand televisions, 260 thousand motor pumps). Resolution 190 was also issued prohibiting the importation of incandescent lamps and the existing ones were replaced in the population, which had its effect on the maximum demand, decreasing it by approximately 11% (MINBAS, 2012).

The electricity tariff was also changed. It was structured in different levels, in correspondence with the quantitative behaviour of consumption and the number of clients that were grouped percentagewise in these different levels.

The Energy Revolution was also supported by a communication strategy that included the press, radio, television, billboards, conferences, debates with the population and savings festivals. Particularly children, adolescents, and young people within PAEME learned how to use energy rationally and efficiently. They learned how to use each appliance and were told about electrical accidents and how to live with electricity.

In 2009, Resolution 139 established the energy efficiency regulations for end-use electrical energy equipment. Among the aspects covered are those related to: imported and domestic equipment, energy efficiency requirements, electrical safety and tropicalization, energy labelling of equipment and four authorized laboratories for testing and trials.

In order to be consistent with the development of renewable energy sources (RES) and energy efficiency (EE), on April 18, 2011, at the Sixth Congress of the Communist Party of Cuba, the guidelines of the economic and social policy of the Party and the Revolution were established. Based on its content, it is foreseen that the economy will move towards short-term solutions to the problems of greater immediate impact. In addition, steps are taken for sustainable development solutions in the longer term, leading to food and energy self-sufficiency.

There is a set of guidelines related to: energy policy; international collaboration; science, technology and the environment; industry; tourism; transportation; housing; and water resources, which show the main directions in which to work to achieve development in which EE and the use of RES are present (PCC, 2011). These guidelines are described below:

- Raise efficiency in electricity generation; prioritize maintenance.
- Prioritize the installation of combined cycle plants Boca de Jaruco, Calicito and Santa Cruz.
- Conclude the installation program of fuel oil generators.
- Maintain an active policy in the adjustment of the electric load to reduce peak demand and reduce its impact on generation capacity.
- Continue programs to reduce distribution and transmission losses through the rehabilitation and modernization of networks and substations. Elimination of low voltage zones.
- Advance in the electrification program for areas isolated from SEN, using the most economical sources.
- Promote cogeneration and trigeneration where possible, increasing biomass generation in the sugar agroindustry.
- Promote the use of different RES (biogas, wind, hydro, biomass, solar and others) prioritizing those with the greatest economic effect.
- Attain the saving potential identified for the state sector.
- Achieve the capture of efficiency reserves in the residential sector.
- Review current tariffs so that they fulfil their role as demand regulators.
- Apply electricity tariffs without subsidies to the non-state production and services sector.
- Increase the efficiency of repair services for electrical cooking equipment.
- Study the free sale of domestic fuel and other advanced cooking technologies, as an additional option and at non-subsidized prices.
- Pay special attention to energy efficiency in the transportation sector.
- Expand measurement elements and the quality of established efficiency indicators and consumption indexes.
- Project the educational system and the media according to the policy of saving, and efficient and sustainable use of energy.

- Within international collaboration: prioritize material and technological support for the use of RES.
- In science, technology and the environment: develop results and studies for the use of RES and promote the systematic modernization of technologies in terms of energy efficiency, production efficiency and environmental impact.
- In industrial policy: make investments in ferrous metallurgy to reduce energy consumption.
- In tourism: implement policies that guarantee the sustainability of its development, apply measures to reduce water and energy consumption rates and increase the use of RES and waste recycling.
- In transportation: modernization and reorganization of land and maritime transportation; increase efficiency and quality, based on rational use of resources, the use of more efficient schemes and means for each type of transportation, improve the country's cargo balance, take advantage of the benefits of railroads and cabotage and containerization to develop multimodal transportation.
- In housing: promote the introduction of new typologies and the use of construction technologies that save materials and energy resources.
- In water resources: prioritize and expand programs for the rehabilitation of networks, aqueducts and sewage systems to improve water quality, reduce losses, increase recycling and reduce energy consumption.

To comply with the objectives of the guidelines, in November 2012, the Ministry of Energy and Mines (MINEM, Spanish acronym) was created as the body responsible for proposing and, once approved, directing and controlling the policies of the State and the Government in the energy, geological and mining sectors of the country, in terms of:

- Generation, transmission, distribution and commercialization of electric power.
- Exploitation and production of oil, gas and other fuel minerals, production of lubricants and marketing of lubricants, fuels and derivatives, alcohol as fuel and liquefied and manufactured gas.
- Management of geological knowledge and information, including research, exploitation and processing of solid mineral resources, mineral-medicinal waters and medicinal muds, as well as their commercialization, salt and its derivatives.
- Preservation, exploitation and rational use of mineral and energy resources that favour sustainable development.
- Development and use of RES that contributes to energy security and environmental protection.

The use of renewable energies is part of the country's Economic and Social Development Program. According to MINEM, 95% of the national energy mix is composed of fossil fuels, while it is expected that by 2021 the generation of energy through RES will grow to 6.3% of the total produced by the country (Ramos López, 2021). Figure 2 shows the current electricity generation mix.

Figure 2. *Electricity generation mix in Cuba (*MINAL, 2020*).*

The fundamental problems of energy in Cuba refer to:

- High dependence on imported fuels for generation.
- The high average cost of delivered energy.
- High environmental pollution as the base generation is by thermoelectric power plants.
- Low use of RES.
- Low efficiency in a thermal generation: In 2018, it was 257.7 grams of toe/kWh (CUBAENERGÍA, 2019).
- High losses in distribution networks.

To provide a solution to these problems the country proposes some measures:

- Maintain oil exploitation so as not to increase dependence on fuel imports for a generation.
- Reduce environmental pollution to 993 g of CO_2 per kWh delivered by 2030.
- In the particular case of renewable energies, the action plan until 2030 consists of installing 750 MW in biomass plants, 633 MW in wind power, 700 MW in solar photovoltaic and 56 MW in hydropower of different capacities. These plans would lead to a change in the electric energy generation mix by 2030, where RES would represent 24%; however, the projections of the National Economic and Social Development Plan until 2030 propose to increase the participation of these sources to 37% (Martínez Rodríguez, 2021).
- Increase energy efficiency in electricity generation through: the replacement of nine obsolete thermal units and the introduction of Liquefied Natural Gas to recover installed capacity in ENERGAS' combined cycle plants.
- Increasing energy efficiency in electricity consumption through the gradual introduction of LED lighting and induction cooking in the residential sector.
- The progressive introduction of solar heaters and solar panels.

Residential electricity use

The approved Decree Law 345 (Ministerio de Justicia, 2019) regulates the development of renewable energy sources and the efficient use of energy. To complement it, resolutions 206 and 208 of MINEM, and 319 and 322 of the Ministry of Finance and Prices (MFP) have been approved, aimed at the importation of solar photovoltaic systems by natural persons, with exemption from the payment of tariffs, and the non-commercial importation of these systems, their parts and pieces. These resolutions were published in the Official Gazettes 67 and 68 of 2021 (Ministerio de Justicia, 2021a; 2021b).

Resolution 319, exempts natural persons from the payment of customs duties for the non-commercial importation of solar photovoltaic systems, their parts and fundamental pieces, in compliance with the provisions of Resolution 206/2021 of the MINEM. The purpose is to encourage people to have access to these systems and that this type of energy source can really replace the use of electric energy. Not only does it save fuel, but it also helps the country environmentally.

Likewise, Resolution 322 of the MFP was issued, which also frees natural persons from paying customs duties for the non-commercial import of other renewable energy equipment or equipment with high energy efficiency, in addition to their parts and fundamental pieces, complying with the provisions of Resolution 208/2021 of MINEM. According to the resolution, the equipment benefiting from this measure are: solar heaters, photovoltaic pumps, small wind turbines, geomembrane biodigesters, biogas motor pumps, solar lighting and solar air conditioning systems.

According to Liván Arronte Cruz, minister of MINEM (Alonso Falcón, Figueredo Reinaldo, García Acosta, Jorge Blanco, and Fariñas Acosta, 2021), in the last five years, investments in RES exceeding 500 million dollars have been made in the country, which is evidence of the priority given by the Cuban State to promoting RES and energy efficiency. Until August 2021, 72 photovoltaic solar parks had been installed in Cuba, with a capacity of 225 MW. The 62 MW Ciro Redondo biomass powerplant has already been completed. There is another important group of investments being developed in the national territory, which are in different phases. The minister explained that

the photovoltaic solar parks have a daily generation of 1100 MWh, which represents practically 2% of the generation in a day in the country. RES technologies installed to date will produce one million MWh by 2021, which will eliminate the consumption of around 250000 tons of fossil fuels. Progress has been made in other programs, such as biogas, with more than 2000 biodigesters already operating in the farming sector, and there are more than 1000 solar water pumps in livestock farming. In terms of energy efficiency, there are 904000 induction stoves, which are more efficient than resistance stoves; seven million LED lights, which replace fluorescent lamps; and 26700 solar water heaters have been installed, 4400 of them in the residential sector. Financing is available for industries to procure raw materials for manufacturing RES equipment and items, such as 1300 solar water heaters, 1.7 million LED lamps, 1000 one-kilowatt photovoltaic systems for grid connection and 130000 induction stoves, which should be ready by the end of 2021 (Alonso et al., 2021).
Among other measures recently implemented to boost RES in the residential sector are:

- The e-commerce of photovoltaic systems with installation service by the company Copextel.
- The sale in the freely convertible currency of photovoltaic systems and other RES technologies in specialized Cimex stores.
- The importation of photovoltaic systems by individuals through importing companies.
- The sale in national currency (Cuban pesos) of photovoltaic systems and other productions of the national industry, associated with renewable energies and energy efficiency.

The National Electric Union (UNE, Spanish acronym) also approved a bank account in freely convertible currency for exclusive use, with the purpose of providing the option of contracting a certain photovoltaic power in kilowatts by individuals and legal entities. The minimum is half a kilowatt. Once this power is contracted, UNE will deduct from the monthly bill the equivalent of the energy generated by the acquired power. With the money from this account, UNE will be able to continue increasing the installation of solar parks in the country. The Electric Company will deduct from the monthly electricity consumption in kWh, the value of the generic equivalent to the photovoltaic power contracted by the consumers (125 kWh per month for each kW contracted). Likewise, UNE will use this financing exclusively for the development of photovoltaic panels, and will be in charge of installing, operating and maintaining them. If the generation value of the contracted system is higher than the consumption of the house during the month, the electric company will pay the excess energy at 1.50 Cuban pesos per kWh. Consumers will be able to receive the benefits of the photovoltaic systems for a period of 20 years.

Energy consumption in the residential sector

In the last population and housing census of 2012, among multiple aspects, interesting data were revealed that help in decision-making and to outline policies according to the real situation of household appliances (ONEI, 2012).
Particularly, the census made reference to the issue of energy in the residential sector and asked the question: *What is the energy or fuel that you use most for cooking?.* The results refer to the

energy carriers: electricity, manufactured gas (piped), liquefied gas, kerosene, diesel, alcohol, firewood and charcoal. Another of the elements assessed in the census was the source of energy used for household lighting. From the information collected, it was possible to determine that 98% of houses with permanent residents used electricity for lighting (ONEI, 2012).

Since electricity is the main source of energy for lighting and also the energy carrier most used by the residential sector, it is worth highlighting some data regarding the household appliances where electricity is ultimately used. In the 2012 population and housing census, information was collected on the amount of equipment and its technical condition. From the data, it can be interpreted that there was 5.4% of broken equipment with respect to the existing total. Of the total broken equipment, only rice cookers and/or pressure cookers constitute 22%. In accordance with these results, efforts have been made to improve the equipment repair system within the framework of the Energy Revolution. Efforts should be directed to food cooking equipment since more than two-thirds of the population cook with electricity (CUBADEBATE, 2014).

Without considering the energy represented by losses and the electrical input used in the generation, the consumption of electrical energy in the residential sector is high; in 2019 it represented 60.39% of the total.

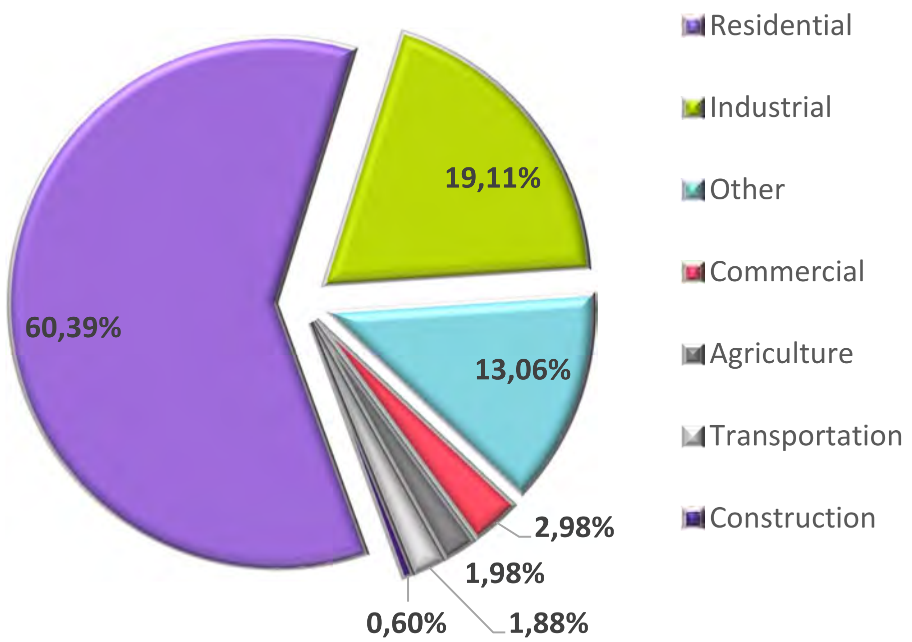

Figure 3. *Electricity consumption by sector. Data Source:* CUBAENERGÍA (2019)

On the other hand, out of a total of 1074.6 ktoe, electricity is the most used energy carrier in the residential sector with 74 % (see Figure 4), so that maximum efficiency is required throughout the chain from production to final use.

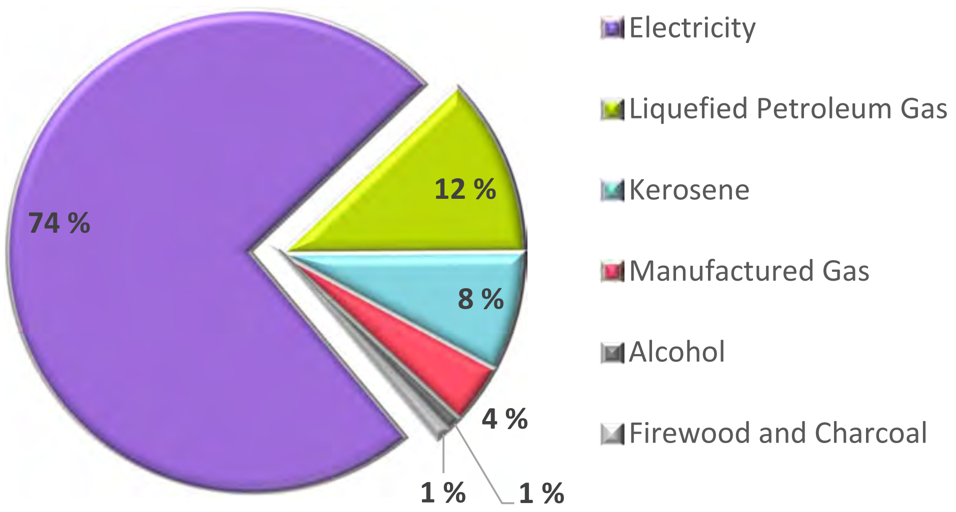

Figure 4. *Energy use in the residential sector in 2019. Data Source:* CUBAENERGÍA (2019)

To develop any plan related to energy in the residential sector, it is important to know the types of houses, since the characteristics of the electricity supply depend on their structure, among other aspects. For example, it is not the same to distribute electricity to a building as to several individual houses; it is not the same to implement renewable energies in houses as in multifamily buildings. Of the total housing occupied by permanent residents in Cuba, 80.57% are houses, 16.37% apartments, 2.21% huts, 0.49% rooms in quarters, 0.31 % improvised and 0.05 % classified as others (ONEI, 2012).

From an energy point of view, roof materials define in many cases a set of energy characteristics of the houses, especially heat gain. In addition, the roof constitutes the stage where renewable technologies can be installed in the future. The percentage of the predominant type of roofing material is distributed as follows: 52% concrete roofs, 22% fibre-cement sheets, 11% metal sheets, 8% wood and *guano*[1], 2% wood and roofing paper, 2% joists and slabs, and 1% other materials (ONEI, 2012).

On the other hand, heat gains through the envelope are also considerable, as in the case of exterior walls. Nowadays, with the increase in ambient temperature, maintaining comfort in homes is becoming more difficult as conventional construction materials predominate. In this sense, it can be mentioned that 80% of the predominant materials used in exterior walls of homes are concrete, block or brick, which do not guarantee the reduction of heat gains.

Particularly in the energy consumption of the residential sector, it has been characterized before 2005 by the use of petroleum derivatives, mainly kerosene, liquefied petroleum gas (LPG), fuels of

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[1] *Leaves of palm trees belonging to the* ***Arecaceae*** *family sometimes used for roofing in Cuban rural areas.*

vegetable origin (firewood and charcoal) and manufactured gas, to meet the thermal needs of the home (cooking, water heating). They will also be used to create electricity for lighting, cooling, conditioning of spaces and other household needs (Orta Rivera, 2014). It was in 2005 when the levels of electric energy use related to cooking food and heating water began to rise due to the sale to the population of electric stoves and modules for cooking and heating water, which led to the replacement of traditional carriers by electricity.

The increase in electricity consumption has depended on the increase in electricity generation, based primarily on thermoelectric plants to which new generating sources (generator sets) have been incorporated and the decrease in the offers of other carriers (Orta Rivera, 2014). Figure 5 shows the electricity consumption of the Cuban residential sector from 1989 to 2020. These data were obtained from different statistical yearbooks of Cuba, issued by the National Office of Statistics and Information (ONEI, Spanish acronym). The consumption of the residential sector with respect to the total production of electricity has changed in this period from 20% to 50% and has had a sustained annual average growth of approximately 2.6%.

Residential electricity meters, Havana

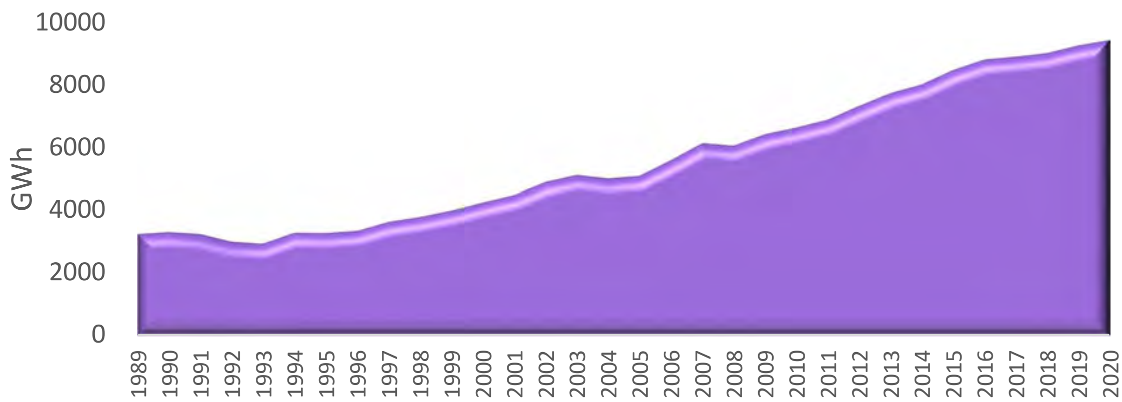

Figure 5. *Annual consumption of electricity in the residential sector in Cuba from 1989 to 2020.*

Other values of selected electricity indicators offered by ONEI enable to graph the average monthly consumption per residential customer (Figure 6), where an increase to values of 193.4 kWh in 2020 is noteworthy. The electrification level indicator has also grown to 99.98%. For this small number of customers who are not reached by SEN, different strategies are developed to increase the access to the electricity they currently have.

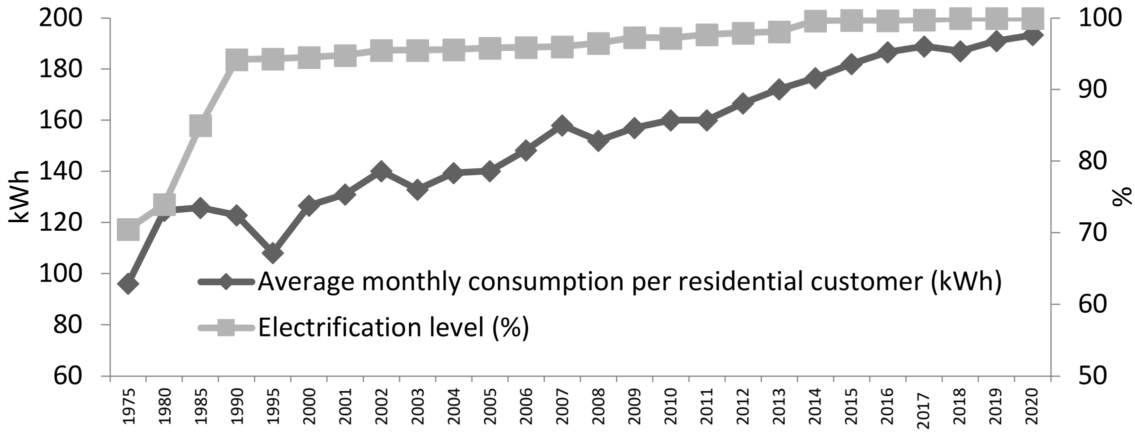

Figure 6. *Average monthly consumption per residential customer and electrification level from 1975 to 2020.*

The changes made in the electrical loads in the residential sector have led the use of electricity to a scenario different from that when fuels were used for cooking. In households using electricity for cooking (the majority), the percentage distribution of electricity use is shown in Figure 7. It is evident that cooking appliances alone accounts for 35% of consumption, followed by refrigeration with 23% and lighting with 12%, to sum up 70%. Therefore, the greatest efforts for savings or any technological change to improve energy efficiency in this situation should consider this consumption mix.

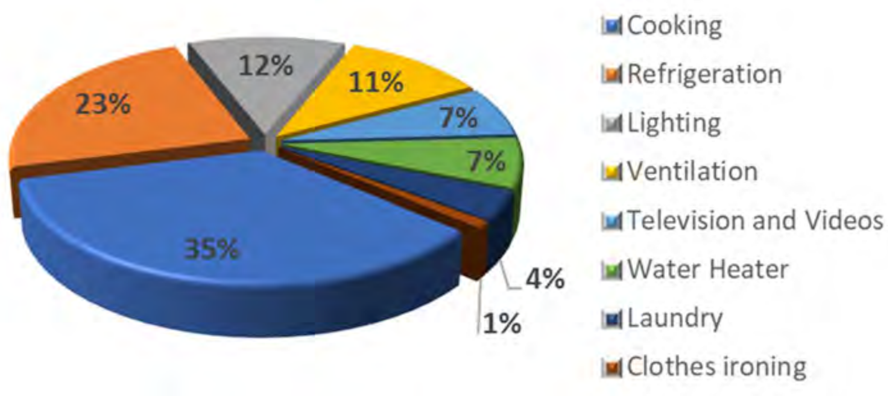

Figure 7. *End-use of electricity in the residential sector. (*CUBADEBATE, 2014)

Behaviour of a primary electricity distribution circuit with a high incidence of residential load

One of the most difficult variables to characterize when carrying out a study of distribution networks is undoubtedly the behaviour of demand. Among the most representative loads of the circuits are those of the residential sector. These loads are composed of elements of moderate or reduced consumption, such as electronic equipment, efficient lighting, among others, and equipment with high demands, such as those used in food processing (the latter are the ones that have the greatest influence on the load graph).

The substitution of domestic fuel by electric energy for cooking, an activity that is carried out in a very well delimited time interval, has introduced drastic changes in the demand, consumption, power factor and hourly charts of these customers. In this section, the characteristics of the typical load curves of the residential sector are presented, focusing on a primary distribution circuit, where most of the electrical loads belong to this sector, corresponding to multi-family buildings.

There are several methods to estimate the electrical demand, with which long-term studies are usually carried out. However, in order to determine the hourly behaviour, it is practically mandatory to analyze measurements in existing installations, verifying, in addition, the composition of the loads. The load charts of the residential sector are characterized by high demand in the early evening when most of the family returns home and the use of appliances is intensified.

On the other hand, the presence of NU-LECs (protection and metering devices) has become widespread throughout the country. The measurement facilities provided by these devices allow investigations to be carried out in the distribution circuits, improving the predictions of the variables, allowing the implementation of timely changes. The strong trend in relation to the uniformity of high consumption domestic equipment establishes similar graphs in residential circuits.

To perform the analysis of a distribution circuit, a 3 km (approximately) long circuit was selected and data was taken for one year of operation. The percentage that represents the demand is distributed in: 64% related to loads of the residential sector, 27% belonging to the state sector and approximately 9% to losses.

After analyzing the data characterizing the behaviour of the active power (kW), a valley can be seen in the early morning hours, and three peaks: minimum, medium and maximum, which are pronounced in the time intervals 7:00 - 8:00 h, 11:30 - 13:00 h and 19:20 - 20:00 h, respectively. This behaviour can be observed in Figure 8.

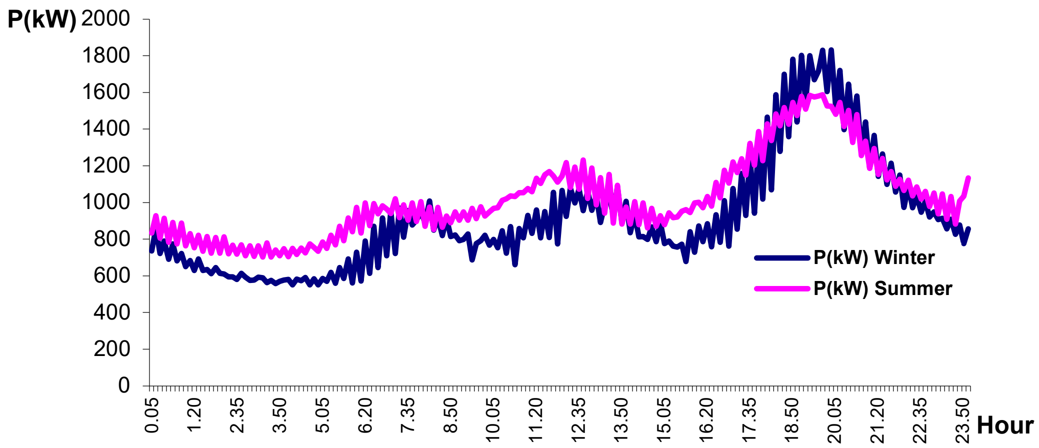

Figure 8. *Average winter and summer demand curves of a primary distribution electrical circuit with a high incidence of residential loads in Cuba.*

In Cuba, there are two standard times: winter and summer. The wintertime extends from November to February, and the summertime (or daylight saving time) for the remaining months. Summertime is implemented for better use of sunlight, and this establishes a difference between the demand curves. In summertime, the demand curve is practically higher than the winter curve from 0:00 to17:00 h. After this interval, it can be seen that the demand is lower than in the case of the winter curve for all the remaining hours of the day.

Analyzing the winter demand curve in the circuit under study, from the average value among all the days corresponding to these conditions, the minimum value that appears is 550.67 kW, while the maximum value is 1,833.00 kW. In the case of the summer demand curve, the minimum value is higher than the summer one, reaching 702.83 kW. Under these conditions, it can be seen that the maximum demand value is lower than in the wintertime and behaves around 1,587.50 kW.

In this circuit, there is permanently a small current unbalance between the phases. Phase C is the most loaded during the whole day, and the load in phase B is lower than the one in phase A, but with a small difference and in several hours they practically overlap. The average intensity (I) values for the day are I_a=48.0 A, I_b=47.06 A, and I_c=51.53 A. These average values comply with the norms for distribution systems, which state that the unbalance should not exceed 5%.

The power factor of an electrical system indicates the degree of energy utilization. In the case of residential circuits, due to the fact that loads of greater power are of resistive character, it implies that the power factor is elevated and tends more to 1. The minimum value is reached in the early morning hours, approximately at 3:35 a.m., with a value of 0.8. This is due to the fact that there is practically no use of resistive loads at that hour, with inductive loads such as fans, air conditioners, refrigerators, etc., predominating. The maximum value is reached at 18:50 hours, with values of 0.92, coinciding with the country's peak electricity demand (see all these details in figure 9).

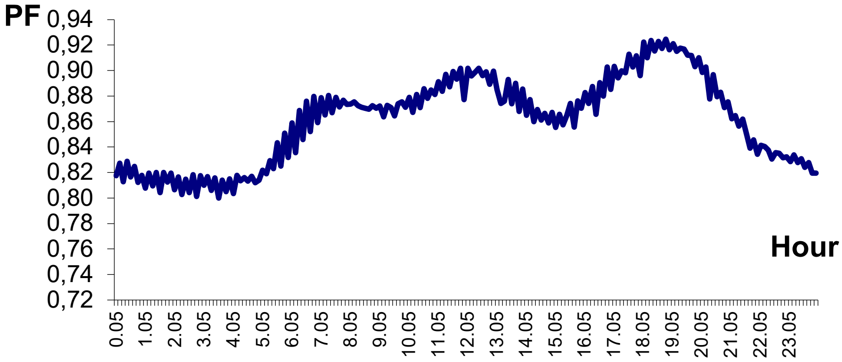

***Figure 9**. The curve of the average power factor for the year in the circuit.*

In the case of voltage, it is higher in phase C than in the other phases. The highest peak recorded is 8,002.60 V in the early morning hours, at approximately 4:50 am. The voltage in phase B is lower than that of phase A and is the lowest, dropping to 7,655.79 V, at about 21:55 hours. However, the voltage variations do not exceed 2 % in any of the three phases.

The details of the variables selected as explanatory factors of the load curve are discussed below:

The time of Day: it is evident that the electrical demand at 03:00 h, in the early morning, will not be the same as that at 18:00 h, in the evening. Figure 10 shows how the bulk of the electrical demand is accumulated in the period between 18:00 h and 22:00 h. For a demand model to be able to reflect this effect, a variable representing the time of the day must be included.

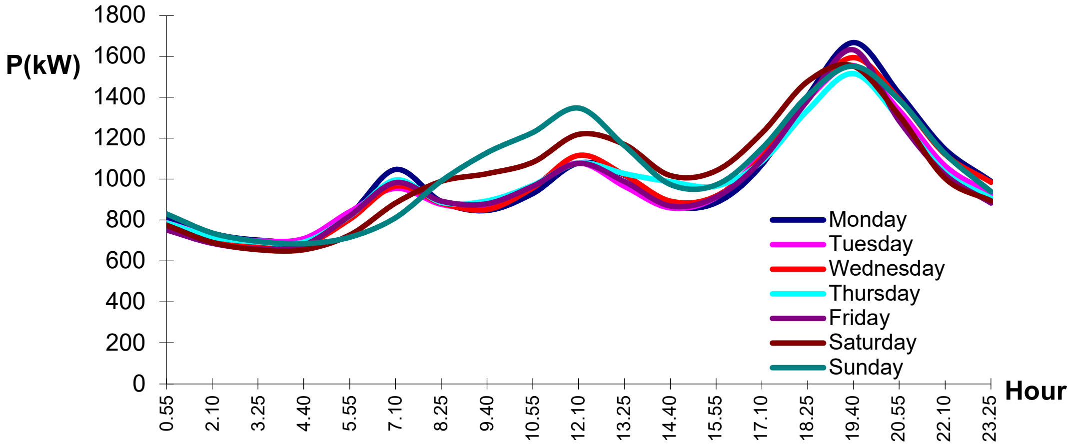

Figure 10. *Average demand graph for days of the week.*

The day of the week: Repeating the same approach, it can be intuited that the electricity demand made at the same time on different days will also be different. Thus, the demand on a Wednesday at 11:00 a.m. will probably not coincide with the demand on a Sunday at the same time. Figure 10 also shows that all weekdays have a very similar demand profile. Concerning weekends, it can be seen that the same hourly consumption pattern detected on weekdays is not repeated; in general, average consumption is much higher. For a model to be able to identify the load profile associated with each day of the week, a variable must be included to capture this effect.

The season of the year: This variable refers to winter and summer, the two seasons that exist in Cuba. Indeed, there is not the same electricity consumption in each of these seasons. In the analysis of the demand for summer and winter in the circuit, it was concluded that the highest energy consumption is manifested in the summer, except for the peak time, when the winter demand exceeds the summer one.

The month of the year: Depending on the month, the average daily demand varies significantly. This is mainly due to the effect of the seasons. In the winter months, apart from the climatic effects already considered (basically temperature), there are fewer solar hours available; people tend to spend more time at home, etc. In summer, energy consumption can also increase considerably as a result of the use of air conditioning systems. It has been shown that the winter and summer demand curves reach different maximum values and behaviours.

Given the level of disaggregation required (hourly values), obtaining the data series referring to the electrical load has been a particularly laborious task. This was obtained through the readings of the NU-LEC located in the substation from where the circuit under study is distributed.

As considerations of this epigraph, it can be summarized that from Monday to Friday there are three demand peaks at different times of the day with an average of 992.47 kW, 1,068.11 kW and 1,593.36 kW, respectively. In the case of Saturday and Sunday, the first peak disappears and only two peaks remain, with an average consumption of 1283.89 kW and 1553.11 kW. In the summertime, the demand curve is practically higher than the winter curve by almost 19% from 0:00 h to

almost 17:00 h. From 17:05 h to 21:55 h, winter consumption is 13% higher than summer consumption, and during the rest of the day, summer demand is 10% higher than winter demand.
Undoubtedly, the high percentage that represents the consumption of the residential sector in Cuba, makes the overall demand curve resembles the dynamics of the activities that occur in households. It is also an expression that food cooking activities, due to the high percentage of the population that cooks with electricity, cause an increase in demand, manifesting itself in three different peaks of the curve.

Secondary distribution of electricity in a multifamily building

For the selection of the building, it was taken into account that the power supply should be excluded from a single transformer. This element facilitated all the experimental work. The chosen building is a 24-apartment building. The transformer that feeds it has a power of 25 kVA and is connected to phase C of the primary distribution circuit (see Figure 11).

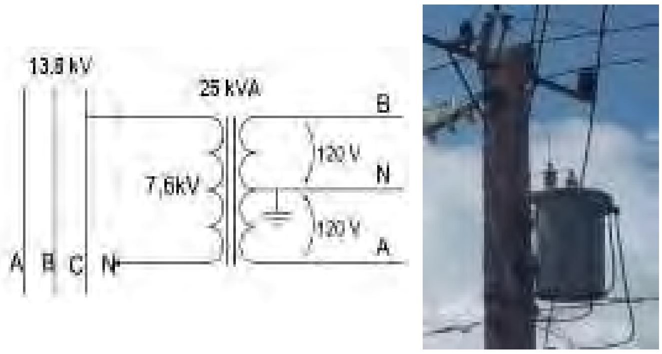

Figure 11. *Connection and partial view of the transformer feeding the building.*

To determine the building's energy consumption, it was necessary to obtain information from the electric company and to monitor the energy meters for six weeks. The meters in this building are of the DDS666 type. The current range that these meters can measure is 40A. The average electricity consumption of the building for each day of the week is: Monday 128.4 kWh, Tuesday 130.7 kWh, Wednesday 131.2 kWh, Thursday 131.9 kWh, Friday 132.5 kWh, Saturday 152.8 kWh and Sunday 156.9 kWh.
During weekdays, average values of 131 kWh are observed; however, on weekends consumption increases by approximately 15%. This increase is due to the fact that on these days similar tasks are performed collectively, such as washing, ironing, cooking, etc.
On the other hand, there are marked differences in the average daily electrical energy consumption of the different apartments. During the experimental tests, four apartments consumed average values of less than 2 kWh per day, due to the fact that there were no people in them or their dwellers sporadically visited them. Under the building's current operating conditions, eight apartments consume 50% of the electrical energy, which, added to six more apartments, make up 80% of the total.
To analyze the behaviour of the electrical variables in the building node, a network analyzer of the PQM (Power Quality Meter) type from Multilin, a General Electric company, was used. One of the logical information for the analysis of electrical circuits is the behaviour of each of the powers. For

the example under analysis, the behaviour of these variables is shown in Figure 12.

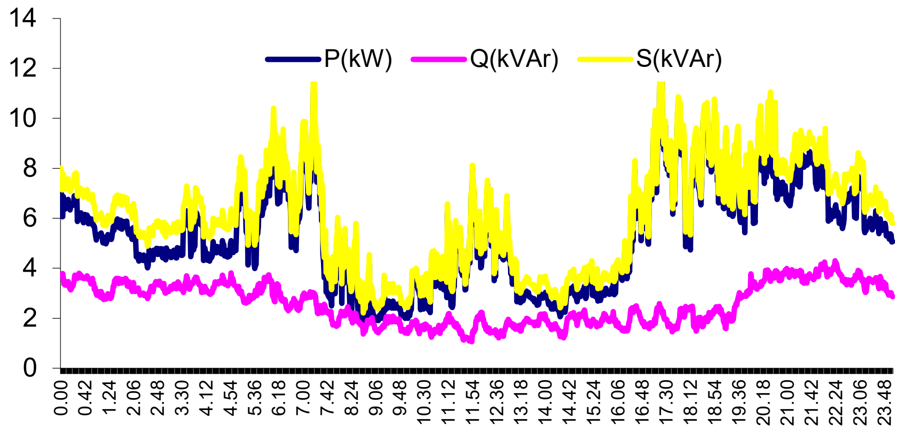

Figure 12. *Electrical power in the building's electrical circuit.*

Figure 12 shows that during the early morning hours between 00:00 h and 05:00 h, the active power demand decreases. In this interval, there is a difference between active and apparent power of approximately 20%, which is reflected in the fact that reactive power increases. This is due to the fact that in the early hours of the morning in most homes the most predominant equipment in operation are those that demand reactive power, as is the case of refrigerators, air conditioners and fans. Similar behaviours of these powers are also repeated between 21:00 and 24:00 hours. However, in the remaining hours it is evident that, in the three peaks of maximum demand, the active and apparent power reach similar values due to the fact that the majority of the load is purely resistive and corresponds to food cooking appliances.

In the case of weekdays, the first interval of maximum demand appears between 05:30 h and 07:00 h, reaching values up to 12 kW. Then, this situation is repeated in the food cooking time for lunch between 10:30 h and 13:00 h, but the values of maximum demand do not exceed 8 kW. The third peak of power demand begins to appear from 16:30 h and continues until approximately 21:00 h. Maximum demand values appear more appreciable than in the first peak, reaching values of up to 12 kW.

It is very easy to verify from the power factor graph the great number of resistive loads that currently exist in the residential sector. In coincidence with the three demand peaks observed in Figure 12, three power factor peaks appear with values of 0.98 (see Figure 13). The average power factor value is 0.89.

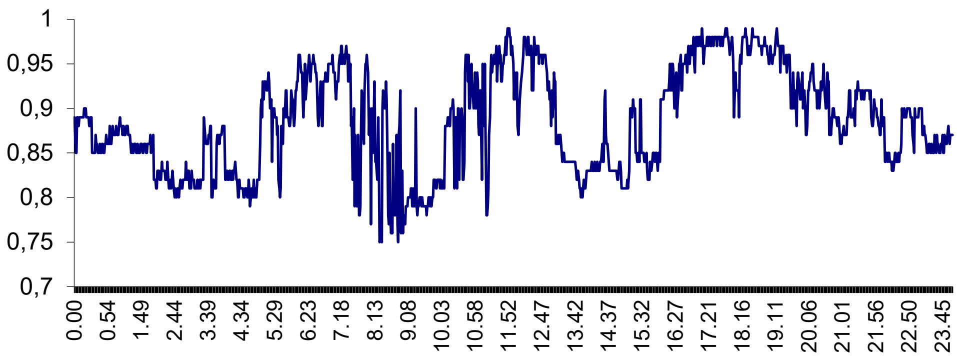

__Figure 13.__ Power factor behaviour.

In the case of the currents in the phases, they are characterized by the level of utilization of the electrical load. In the building under analysis, phase B, in spite of having similar current levels to phase A, maintains the load states for a longer period of time. In the early morning hours, the load levels of the phases are similar. In these hours the connected loads are very similar in characteristics. There are also times when the current unbalance reaches values of up to 60%, contributing to energy losses for this reason (see Figure 14).

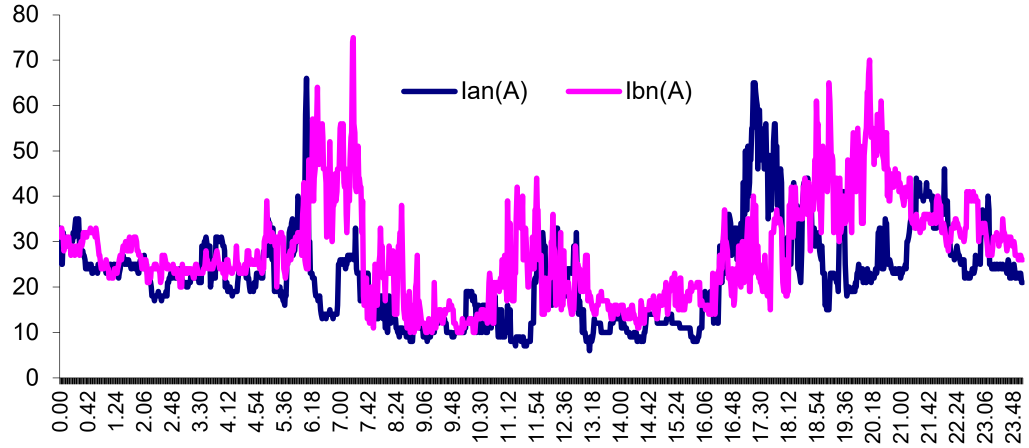

__Figure 14.__ Behaviour of phase currents.

A sample of the unbalance reached by the phases in the secondary distribution circuits can be seen through the current values in the neutral. Precisely in Figure 15, by means of the values reached by the current in the neutral, it is possible to identify the moments in which the unbalances are accentuated.

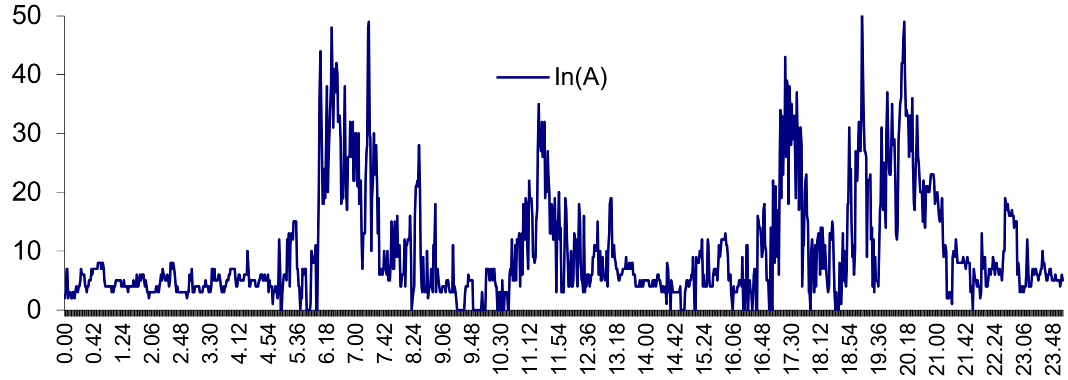

__Figure 15.__ The behaviour of currents in the neutral.

Due to the transformer load levels, which do not exceed 50%, it is, therefore, possible that the voltage variations with respect to the nominal value are very close to 10%, especially in the early morning hours when demand is lower. The phase voltage variations are between 114 V and 124 V.

Power quality

One aspect that characterizes power quality is the total harmonic current distortion (THDi), which reaches maximum values of up to 40% in both phases. It is evident that THDi is more sustained in phase B, especially between 11:30 and 16:00 hours. THDi remains similar in both phases during the early morning hours at average levels of 10%. Given the values reached by these magnitudes and according to IEEE519 and UNE-EN 50160 standards, there is significant contamination (THDi greater than 10% and less than 50%), which may indicate a malfunction of the distribution circuit. The values corresponding to the total harmonic current distortion can be seen in Figure 16. In domestic electrical loads, these harmonics are contributed by televisions, microwave ovens, computers, fluorescent lamps and audio and video equipment.

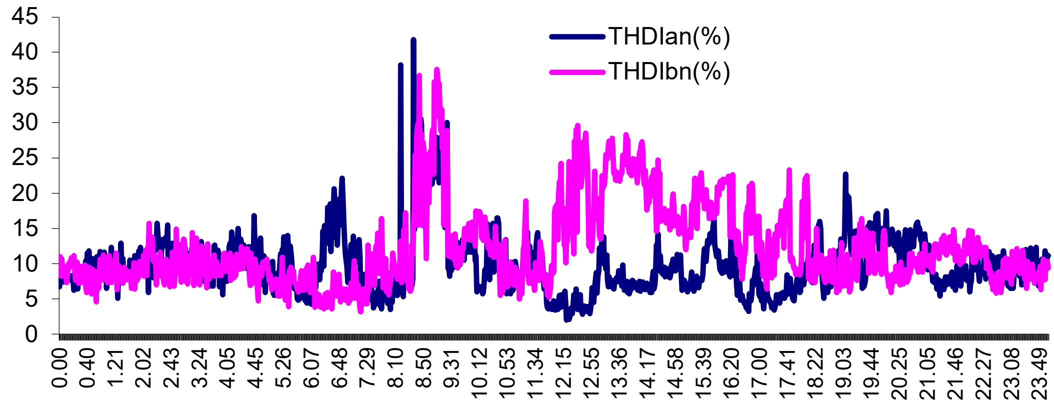

Figure 16. *Total Harmonic Current Distortion for each of the phases.*

In the case of the total harmonic current distortion present in the neutral, it is really alarming since the average values are 44%, often showing THDi higher than 50%, which means important contamination and according to the standards, it is necessary to use an attenuation device. When these harmonics circulate through the neutral, they create strong overheating, which can be the cause of serious faults with very unfavourable consequences in the distribution circuits. Neutral failure is one of the most damaging faults in distribution systems.

In total harmonic voltage distortion (THDu), according to the same IEEE519 and UNE-EN 50160 standards, there is a normal situation in the analyzed circuit because THDu values are less than 5%. The highest levels were detected in phase B, accentuating values higher than 1.7% from 10:00 h to 24:00 h.

A reflection of the total harmonic current distortion is shown in Figure 17, where a wave train of the phase A and B currents is shown. In the case of total harmonic voltage distortion, it does not have significant levels that could greatly deform the voltage sling shape.

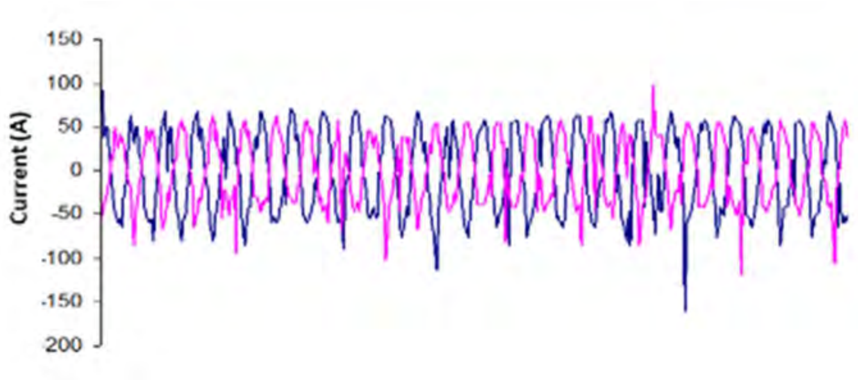

***Figure 17**. Wave train of phase currents.*

The network analyzer is capable of monitoring both current and voltage harmonic components. The non-linear behaviour of the loads present in the building indicates that the current harmonics of odd order 3, 5, 7 and 9 are accentuated. Harmonics of orders 3 and 5 are more accentuated in phase B (see Figure 18).

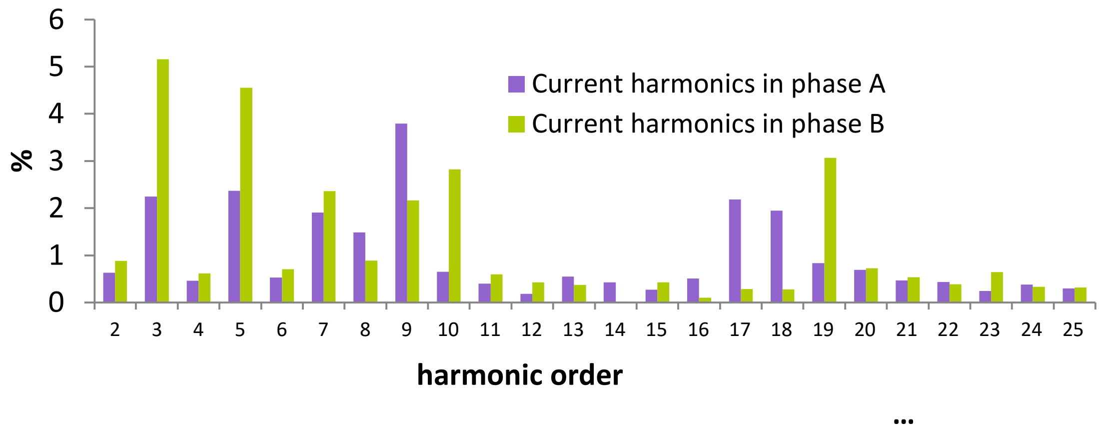

***Figure 18.** The behaviour of the levels according to the order of the current harmonic.*

A similar situation is reflected in the voltage harmonics where harmonics of orders 3, 5 and 7 are also representative. In particular, the harmonic of order 5 is the most accentuated, exceeding 1% in both phases.

Generation, electricity use and electricity tariffs

Households play a crucial role in shaping energy consumption and are of utmost importance for energy policymakers. Understanding household energy consumption behaviour is fundamental for long-term energy supply planning and for establishing the corresponding pricing and subsidy policies (Jiménez Mori and Yépez García, 2020).

As part of a socioeconomic strategy in Cuba, the Ordering Task began in January 2021, which includes four elements: resolving the monetary duality, resolving the exchange duality, eliminating subsidies and undue gratuities to the extent possible under the conditions of the economy, and transforming income.

In transforming income and eliminating subsidies, the change of the electricity tariff starting in January 2021 was considered. Electricity, a service required by the entire population, is the energy

carrier most used for cooking food. There are also used to a lesser extent liquefied petroleum gas (LPG) distributed in 10 kg cylinders, liquefied gas through distribution networks and kerosene in some isolated places.
It is in the country's interest that there are no changes in the food cooking mix, which is dominated by electricity. If electricity becomes extremely cheap and LPG in 10 kg cylinders, which is imported, becomes extremely expensive, everyone will abandon gas and cook with electricity. A balance must be found between the selling price of gas and the price of electricity in order to maintain current consumption levels. Currently, the price of a gas cylinder is 180.00 Cuban pesos.
To establish the new electricity tariff, many variables were taken into account with the purpose of not leaving anyone stranded. Specifically, for the new electricity tariff, there is a subsidy of 17.8 billion pesos. There were two ways; one of them was to raise the salary to higher levels than those proposed and remove all subsidies to the electricity tariff so that everyone would pay it with their salary, but economically it is not the most appropriate (Canal Caribe, 2020).
However, before analyzing the issue of the new proposed electricity tariffs in the country, which is maintained with a progressive character, it is necessary to comment on some elements related to the collective response of the use of electricity in the residential sector and other aspects related to its production.
Electricity is among the mass consumption products in Cuba and the level of electrification of homes in the country is very high. It is important to explain that the tariff is the price of service; therefore, tariff and price are the same things. The first starting point is the cost and then a profit margin. It was decided to subsidize electricity to ensure that those with lower incomes would have access to it. Fifty per cent of the electricity to be consumed by the residential sector will be paid to the electric company by the state budget (Alonso Falcón, Figueredo Reinaldo, García Acosta, Carmona Tamayo, Rodríguez Martínez and Carmenate, 2020).
In the current monetary unification, the cost of electricity was calculated and the kWh has a cost of 3.61 pesos (Canal Caribe, 2020). In Cuba, there are approximately 4 million residential customers. The new tariff covers through subsidies approximately 97% of customers (consumers up to 500 kWh per month), for which the electric company must seek all efficiency reserves so that the country does not have to increase the budget to subsidize electricity. It should be clarified that the plans for the economy had already been made before making the tariff price changes, and this considered growth in demand in the residential sector of 2.5%. In general, the residential sector consumed approximately 9,450 GWh in 2020, which represented 62.5% of the country's total consumption of approximately 15,065 GWh (Canal Caribe, 2020).
The premises considered for the change in the electricity tariff were to preserve the objective of encouraging savings policies; to maintain the objective of contributing to not modifying the structure of the residential consumption mix; to propose greater efficiency and cost reduction to UNE, in charge of electricity production and distribution; and to make a financial sacrifice in the interest of reducing tariffs.
With the new tariff, a greater opening to the consumption brackets is achieved, achieving a much greater differentiation with respect to the previous existing brackets, especially in the 351 to 500

kW bracket. A greater proportionality is also achieved in the tariffs applicable to 97% of residential customers. Figure 19 shows the percentage distribution of customers and residential electricity consumption in the different tariff brackets.

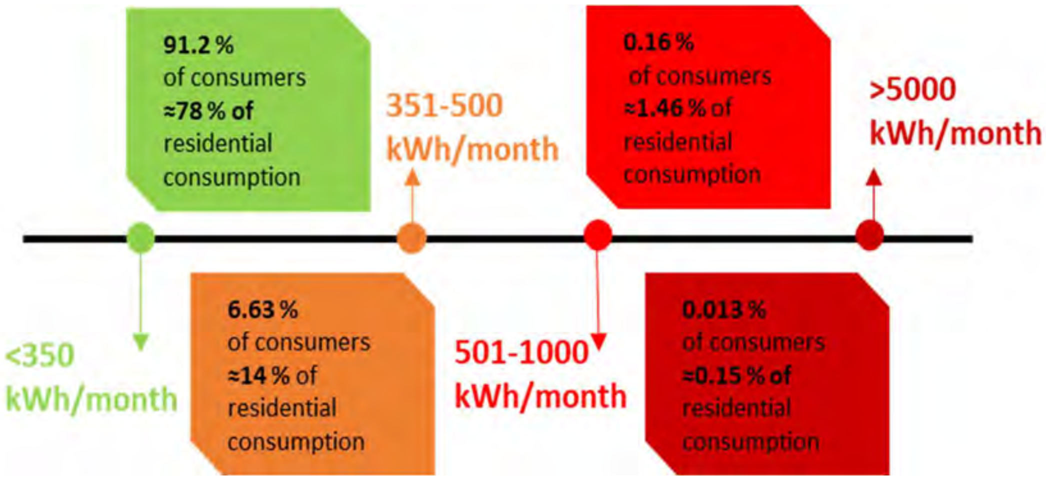

Figure 19. *Percentage distribution of consumption and number of customers by the tariff.*

The basic reference basket of goods and services conceived for the analysis in the Ordering Task supports electricity. Of the 1,528.00 pesos that were calculated to cover it in reference to a single person, about 750 pesos are for food, the rest has other consumption where electricity service is included. When the composition of the family nuclei in Cuba is reviewed, on average there are 2.87 people per nucleus and 1.3 workers per nucleus (Canal Caribe, 2020). Table 1 shows the ranges of the new tariff for the residential sector (UNE, 2021). The result of the monthly billing will be the sum of the amounts obtained in each of the consumption brackets. Other data of interest collected are also shown in table 1.

Table 1. New electricity price tariff for the residential sector.

Range in kWh	Old Price (Pesos)	New Price (Pesos)	% of customers in each bracket	Charge per bracket for new price (Pesos)
0-100	0,09	0,33	22,5	32,78
101-150	0,30	1,07	15,4	86,06
151-200	0,40	1,43	17,6	157,78
201-250	0,40	2,46	15,9	280,72
251-300	0,60	3,00	10,9	430,72
301-350	1,50	4,00	6,9	630,72
351-400	1,80	5,00	7,7	880,72
401-450	1,80	6,00		1180,72
451-500	1,80	7,00		1530,72
501-600	2,00	9,20	2,9	2450,72
601-700	2,00	9,45		3395,72
701-1000	2,00	9,85		6350,72
1001-1800	3,00	10,80	0,2	14990,72
1801-2600	3,00	11,80		24430,72
2601-3400	3,00	12,90		34750,72
3401-4200	3,00	13,95		45910,72
4201-5000	3,00	15,00		57910,72
More than 5000	5,00	20,00		97910,72

In this analysis of the collective response to the use of electricity, the complex situation of its production must be commented on, especially to ensure that all the necessary inputs, including fuels, reach the country. In a generation, different types of fuels are used; thermoelectric plants are the basis of the system, some work with domestic crude oil and others with fuel oil (a by-product of the refining of imported crude oil), and there is also distributed generation, which is grouped into a generation with fuel oil engines and another group with diesel engines.

Figure 20 shows how the electricity demand in Cuba is covered by using different technologies. It starts at the base with the use of RES and then it is completed with the other energy carriers, from the cheapest to the most expensive, in this case, diesel. (Alonso Falcón et al., 2021).

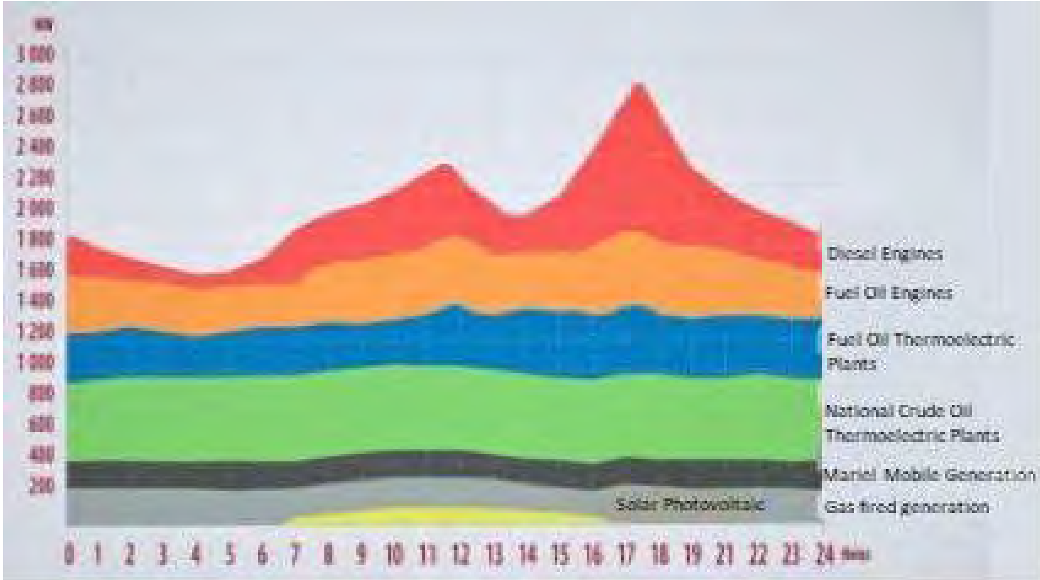

Figure 20. *Demand coverage by fuel and technology.*

In a daily generation, 4,100 tons of crude oil, 5,200 tons of imported fuel oil and 1,200 tons of imported Diesel are used, totalling 10,500 tons. Therefore, domestic crude oil is around 40%. Thus, in an annual balance, the participation of domestic crude oil in the generation of electricity is in the order of 40 or 45% (Alonso Falcón, et al., 2020).

In this sense, data from UNE, published on its official website, should be evaluated, explaining that to have one-kilowatt-hour in homes, thermoelectric plants have to produce approximately 1.2 kWh, since part of it is lost during the transformation, transmission and distribution processes in the lines.

Final considerations

Electricity has a significant weight among all the carriers of the energy sector. Its production throughout the world is mainly carried out through the use of fossil fuels, which is the reason for the necessary energy transition, aligned with energy policies and the particularities of the behaviour of demand and consumption. The residential sector has an important participation in the structure of energy consumption in the different countries; specifically in Cuba, it represents the greatest weight in electricity consumption, accounting for 62.5%.

Knowledge of the dynamics of electricity consumption in the residential sector, as well as its structuring in terms of the different consumption levels of customers and the specific characteristics of the electrical loads represented by household appliances, define the demand curves at all levels of the country's distribution circuits. The interpretation of these demand curves, together with the characteristics of the electrical system, must be integrated and studied in depth to make political and technological decisions to improve the performance of the electrical system.

Integrating RES technologies into Cuba's energy context defines a necessary path towards changing the energy mix in favour of sustainable development. The residential sector is projected to become a promoter of these changes, which requires a follow-up in its future development, due to the consequences in the exploitation of the energy system and its necessary integration with the energy culture of the population.

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III.6. Modelling Cuban energy system with CubaLinda model. Prospects for 100% renewable scenario

Jyrki Luukkanen, Anaely Saunders Vázquez, Yrjö Majanne and Mika Korkeakoski

Introduction

The Cuban electricity production system is based on 95% of fossil fuel combustion in condensing steam power plants (termoelectricas) and fuel oil and diesel-fuelled internal combustion engine (ICE) power plants. However, the global climate change politics set requirements also for the Cuban energy system, and even though the per capita greenhouse gas emissions in Cuba are very low, there is a clear need to transform the energy system to include more renewable energy sources. Therefore, in the Third National Communication to UNFCCC, Cuba states that in order to achieve a change in the energy mix, increase energy efficiency, and reduce the GHG emissions, the incorporation of renewable energy sources such as solar PV, biomass, and wind, in electricity production is needed (Instituto de Meteorología, 2020).

According to the National Communication, about 96% of electrical energy is produced using fossil fuels, with a high dependence on imports, high cost of generation, and technological infrastructure with high GHG emissions. In response to these situations, the Council of Ministers approved, in 2014, the "Policy for the prospective development of renewable sources and efficient use of energy", aimed at making the most of renewable resources available nationwide. (Instituto de Meteorología, 2020).

However, the integration of especially variable renewable energy sources, i.e., solar PV and wind power, in the electricity system faces some techno-economic challenges. In the electrical system, the electricity supply has to be equal to the electricity demand every second. When the load (electricity demand) varies throughout the day and year, and the supply of solar PV and wind power varies according to the weather conditions (available wind speed and solar radiation), the balancing has to be carried out using controllable power sources and loads. When the share of variable solar and wind production increases in the system, balancing power production faces larger challenges. The balancing of supply and demand can be carried out in several ways. Controllable power plants, such as fossil-based thermal, biomass, and hydropower plants, can change their power output to balance supply and demand. Different types of power plants can respond to the required changes at different change rates. Hydropower, gas turbines, and ICE power plants are faster than steam power plants. The output of the combined heat and power (CHP) plants depend on the heat demand in the manufacturing processes and cannot usually be changed to balance the electric network. The required change rate of balancing power depends on how fast the electricity demand changes (load curve changes) and how fast the variable energy sources change their outputs. In this article, we look at the required changes in electricity production from the point of view of balanced supply and demand in the future Cuban electricity system.

Energy storage can be an essential resource for balancing supply and demand in a system with a high share of variable renewable energy sources. The energy storage can be, for instance, in the form of batteries, pumped hydro storage, compressed air storage, flywheels, or a power-to-gas-to-power (P2G2P)[1] system. This article analyzes the use of pumped hydro storage for balancing the electricity system because it seems to fit the local requirements in the Cuban case.

The Cuban authorities have lately discussed possibilities to find ways to develop a 100 % renewable electricity system (Tamayo, 2021). In the Cuban case, where hydropower resources are very limited, and biomass resources cannot cover the electricity demand, the use of solar PV and wind power becomes crucial. This article analyzes possible scenarios for reaching a 100% renewable electricity system by 2050. We do not analyze the whole energy system and the fuel used in different sectors of the economy. The transport sector and its electrification can significantly impact the electricity system, especially on the load curve when charging and possibly discharging the vehicle batteries. This is, however, left out from the analysis of this article. We concentrate on constructing scenarios for electricity consumption in different sectors of the economy and building backcasting scenarios for electricity supply to meet targets for the share of renewable energy in the production mix.

The scenario construction in this article is carried out using the CubaLinda model (Luukkanen et al., 2015). The model structure is shortly presented in the next section. The CubaLinda model is used for constructing hourly consumption scenarios till 2050 and then looking at different options to cover the demand with renewable sources. The three different production scenarios are based on the increase in solar PV and wind power investments in different locations in Cuba and the wind and solar radiation potentials in these locations. The scenario approach used here is the so-called backcasting scenario (Robinson, 2003), where first the target, in this case, 100 % renewable electricity production, is set, and then different options for reaching the target are analyzed using the CubaLinda model by changing the different input data (like investments in power plants).

Street art, Havana

[1] *P2G2P technology involves using excess electricity to produce hydrogen that can be stored in the gas network and later converted into power again. The "clean gas" created through P2G2P technology enables storage of extremely long duration—weeks or even months*

CubaLinda model

CubaLinda model is a so-called accounting framework model with which scenarios can be constructed for the energy demand and supply sides. The electricity demand and supply are modeled hourly, and the fuel demand in other sectors annually. The model balances electricity supply and demand. The historical power plant data is from the National Statistical Office of Cuba (ONEI, 2021:19), and the sectoral energy consumption figures are from the International Energy Agency IEA statistics (IEA, 2020). The sectoral economic data of value added is from UN Statistics (UN, 2020).

The Linda model is based on the so-called intensity approach using the Kaya identity to calculate CO_2 emissions (Luukkanen et al., 2015). The main balancing components of the model are illustrated in Fig. 1. The energy demand for both electricity and fuels is based on the constructed scenario for economic growth in different sectors and electricity and fuel intensities in different sectors of the economy. The hourly electricity demand is constructed based on user-given load curves for sectors and the future scenarios of the changes in load curves and the growth in sectoral consumption. The sectoral load curves are constructed separately for weekdays and weekends and the different months of the year.

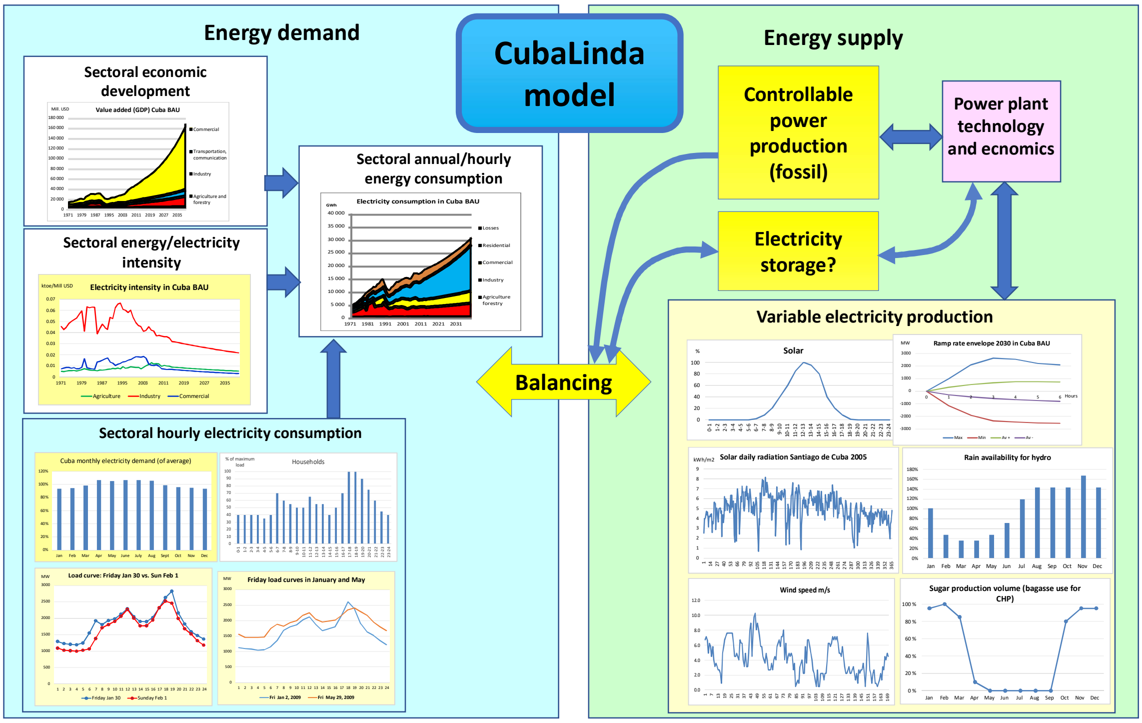

Figure 1. *Functioning of the CubaLinda model.*

Electricity supply scenarios are constructed based on user-given investments in different power plants. The solar PV power plants are situated in different provinces, and the incoming radiation is obtained from the MERRA database using renewables.ninja website (Renewables.ninja, 2021). The model uses hourly data from 2019 for different locations and combines the incoming radiation data with the installed PV capacity in different provinces defined in scenarios. The wind power production is based on wind speed information and its conversion to electricity output in the MERRA database for 2019 (NASA, 2019) for different planned wind farm locations (see Fig.2.). As a result, wind power capacity will be invested in these locations in the scenarios shown in Fig 2.

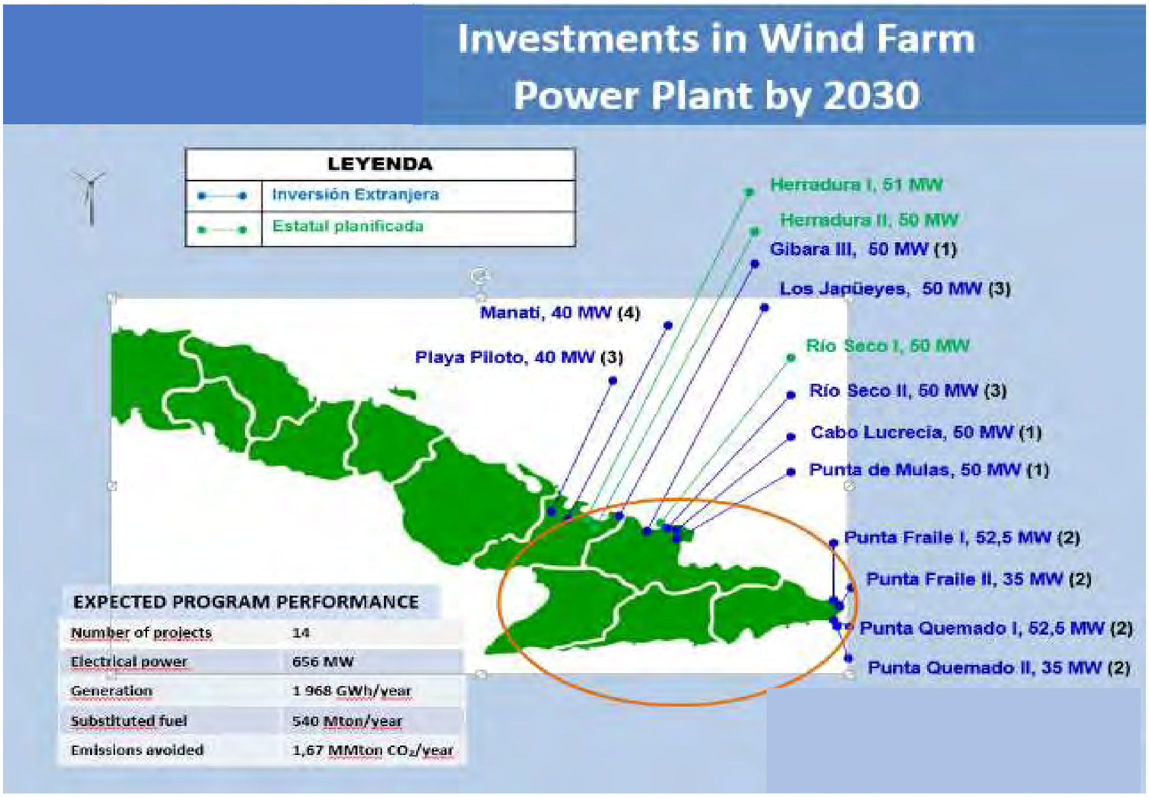

Figure 2. *The planned wind farm locations used in the CubaLinda model with variable power plant investment amounts.*

The model uses controllable power plants to balance the supply and demand of electricity. The first option for balancing is electricity storage, in this case, pumped hydro storage. It will carry out balancing, and if there is not enough capacity in the pumped hydro storage, fossil ICE and gas turbine power plants will be used. According to Montes Calzadilla (2019), there is a potential pumped hydro storage capacity in the Eastern part of about 7800 MW in 13 locations, in the central part about 1850 MW in four locations, and the Western part, about 3300 MW in eight locations. The estimated potential in these 25 locations is almost 20 000 MW with 5 hours of operation as an average in generation (discharge) mode, which could result in a maximum generation of 100 GWh/Day.

The CubaLinda model constructs scenarios for different sectors of the economy and calculates the fuel used in different sectors, related CO_2 emissions, and electricity production costs (Levelized Cost of Electricity, LCOE) based on user given information of future investment costs, operation and maintenance costs, and fuel cost for different power plant types and fuels. The model also calculates the required ramping rates (need for maximum change in power production per hour) and load duration curves to assess types of power plant capacity investments.

Scenario construction for renewable integration – towards 100% renewables

We have constructed several scenarios using the CubaLinda model. First, we have constructed a base scenario until 2050, and based on it, we have used the backcasting scenario method (Robinson, 2003) to analyze possibilities to reach the 100 % renewable scenario. In the backcasting scenario construction, the target for the end-year situation, in this case, the 100% renewable electricity system, is the starting point, and the model input data is modified to see what kind of possibilities there are for reaching the target.

Scenario 1

The economic development in Cuba in the first scenario is shown in Fig.3. The economic development in different economic sectors is partly based on the historical trends of growth rates and assumed changes in the production structures. In this scenario, solar and wind power investments are increased considerably. In this scenario, there is also pumped hydro storage with a capacity of 40 000 MWh. The installed power plant capacity of this scenario is shown in Figures 4 and 5.

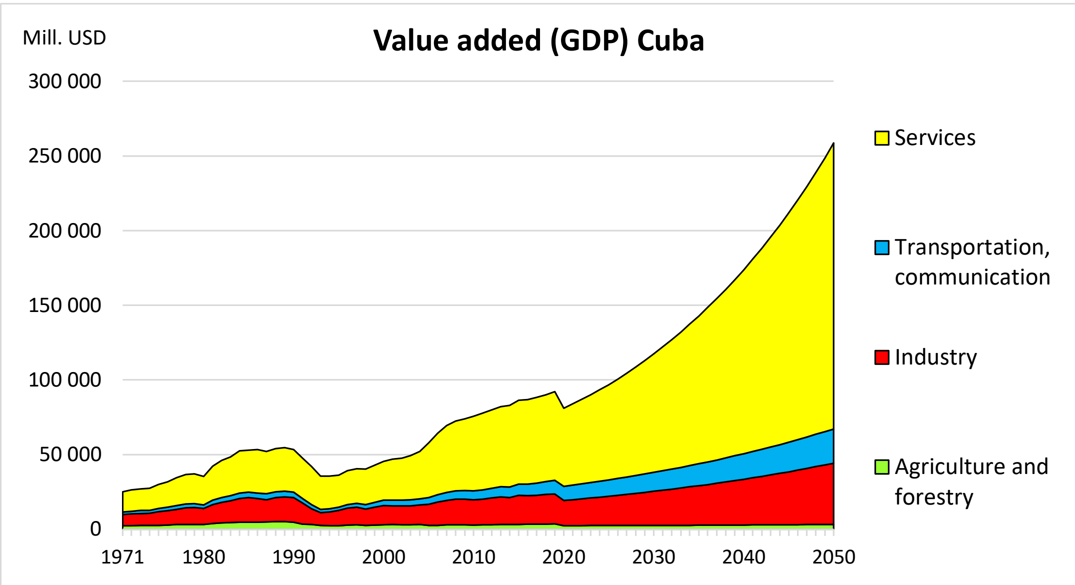

Figure 3. *Economic development in Cuba in different sectors of the economy in scenario 1.*

The electricity consumption in Scenario 1 is shown in Fig. 4. The growth in electricity consumption in different sectors is based on the economic development in these sectors and the changes in the electricity intensity in the sectors. Here we assume considerable growth in the residential sector, which also includes the consumption in the rented apartments for tourists (casa particular), private restaurants, and other small private businesses.

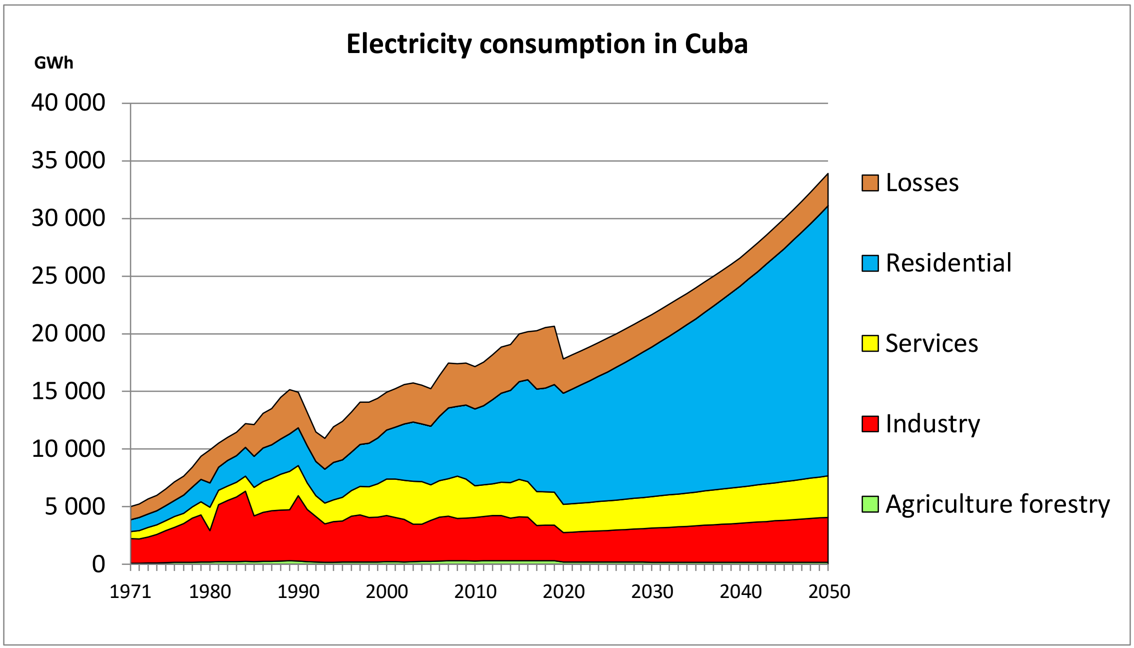

Figure 4*. Electricity consumption in different sectors in Cuba in scenario 1.*

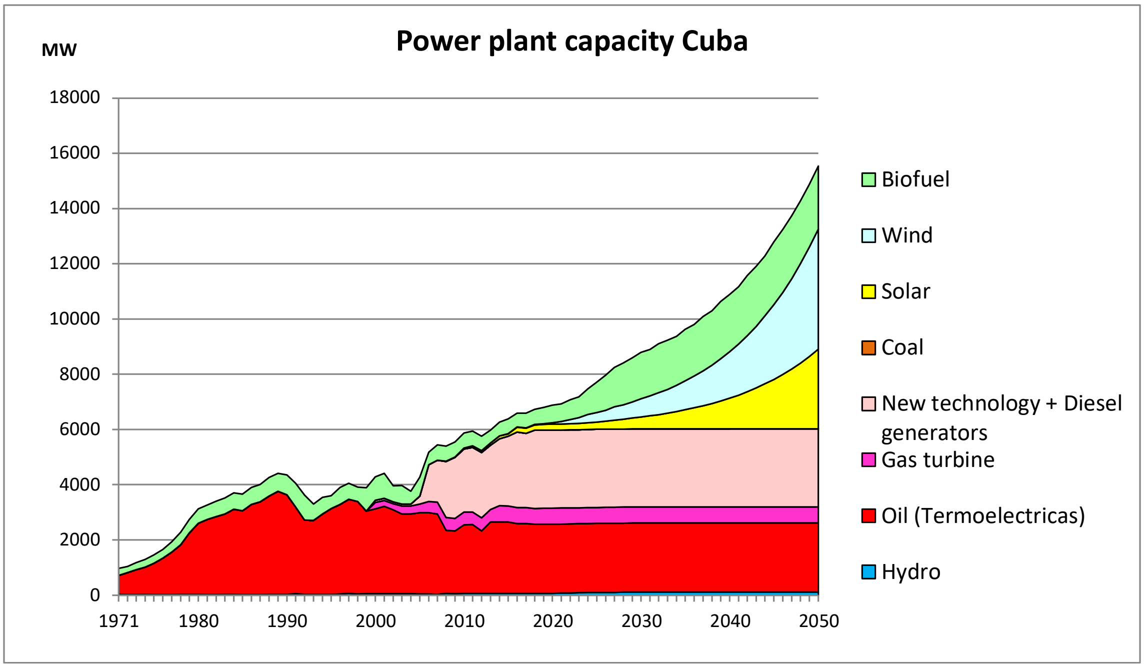

Figure 5. *Installed power plant capacity in scenario 1. 'New technology' here means internal combustion engines (ICE) using diesel oil or fuel oil.*

In this scenario, the electricity production by different power plants is shown in Fig. 6. Biofuel, wind, and solar productions are increasing considerably while oil-based production decreases fast due to the investments in renewable capacity. It is assumed that termoelectricas do not generate in this scenario in 2050 because of the fast response needed for the residual production and the form of the residual load duration curve, which implies that there is no room for baseload production (see Figs. 28 and 29 and the discussion about the load duration curve in Scenario 2). In this scenario, wind and solar capacity growth after 2024 is assumed to be 10 percent per year until 2050. The installed power plant capacity in 2050 in this scenario is shown in Fig. 7.

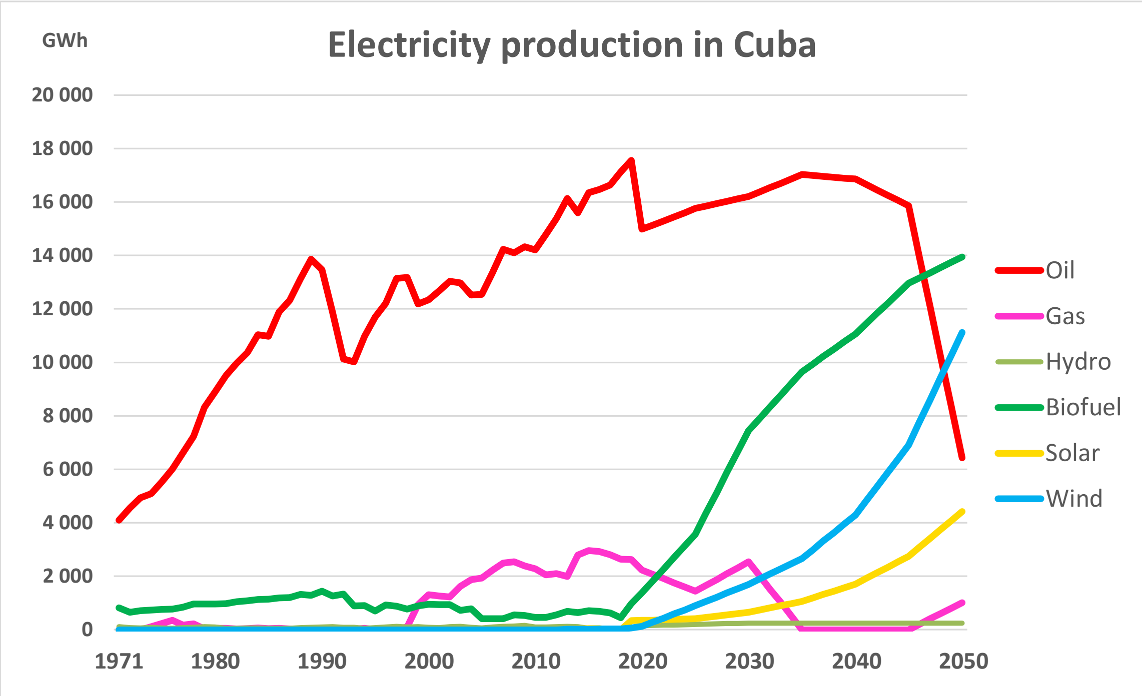

Figure 6. *Electricity production by different types of power plants in Scenario 1.*

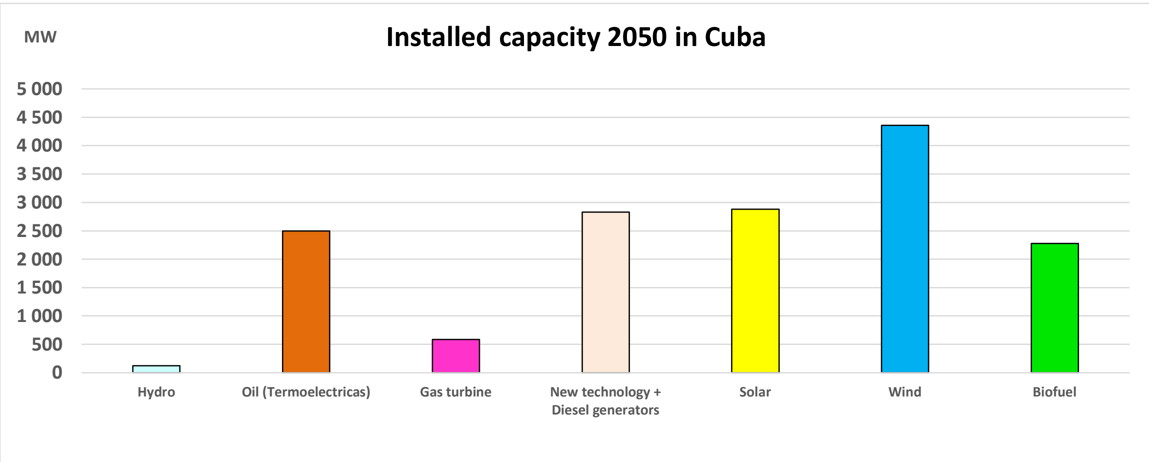

Figure 7. *Installed power plant capacity in 2050 in Scenario 1.*

In Fig. 8, we see the electricity production and consumption during the first two days in 2050. The wind speed (from the reference year 2019) is relatively high, enabling lots of wind power production. During the first seven hours of the first day, wind production exceeds the electricity demand, and the extra production is stored in the pumped hydro storage. Biomass is used for power production, even though wind production covers the demand because industrial Combined Heat and Power (CHP) production is needed for heat production. During the daytime, solar power increases production and enables additional electricity storage despite the increasing demand. During the evening peak consumption time, wind, solar, and biomass production are not enough to cover the demand, and that is why supply from the storage is needed for balancing. The second day of January is quite similar to the first day, and we can see that all the electricity consumption is covered with renewable sources during these days. The storage is not charged during the peak solar production on the second day because the storage capacity is complete (see Fig. 9).

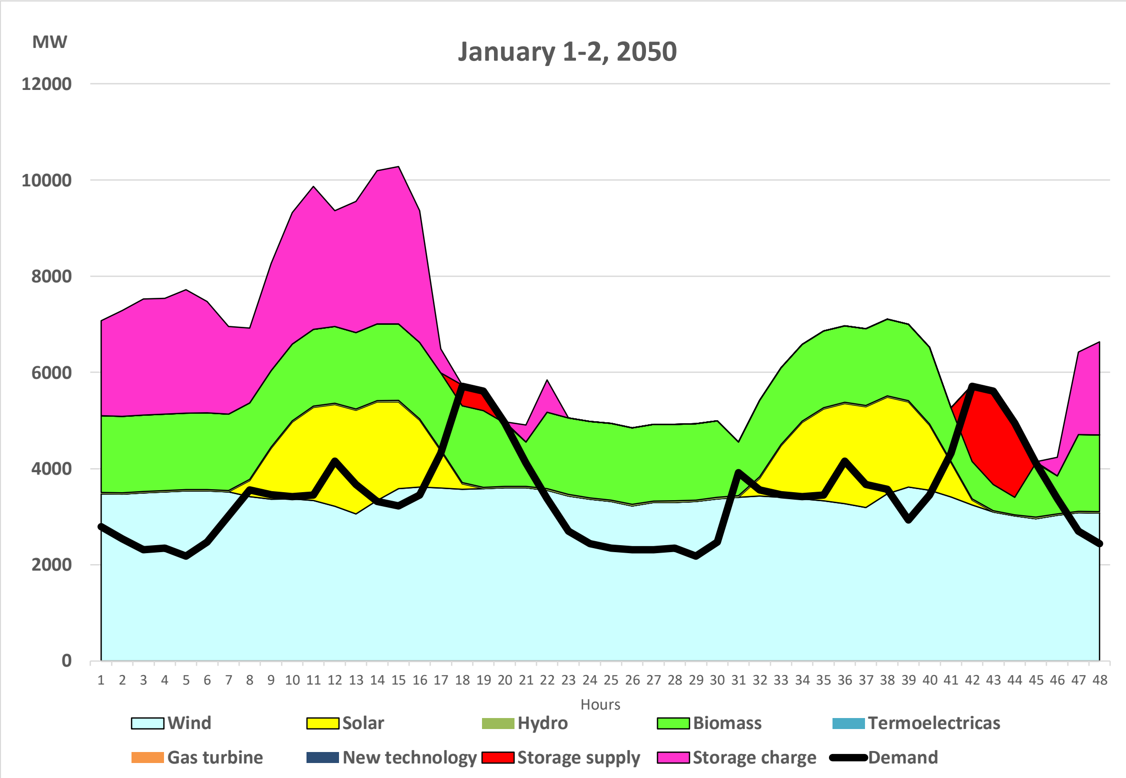

Figure 8. *Electricity supply and demand during January 1-2, 2050, in Scenario 1.*

When we look at the first week of January (see Fig. 9), we notice that the renewable sources cannot cover all the demand on the 5th, 6th, and 7th of January. During these days, the wind speed decreases (in the reference year), and renewables production is too low to cover the demand even though biomass production uses total available capacity. As a result, the storage capacity is too small to cover the needed products, and it runs empty on the fifth day, as shown in Fig. 10. Fossil fuel-based production (using ICE motors, the "New technology", and gas turbines) is thus needed to cover the demand and balance the grid.

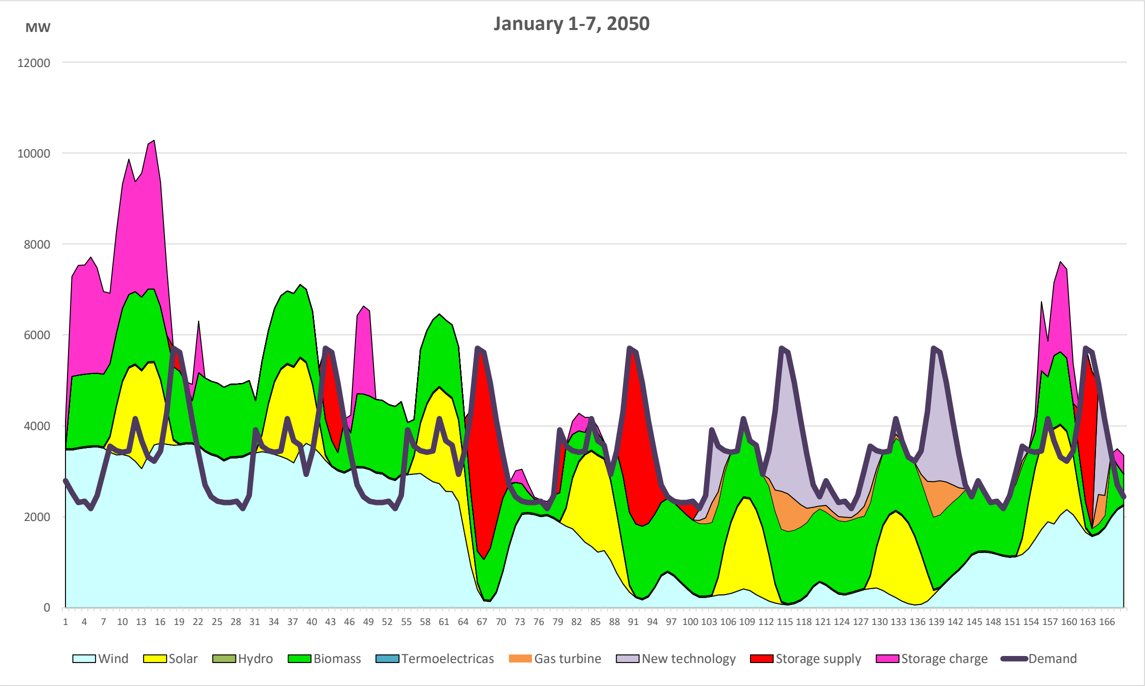

Figure 9. *Electricity supply and demand during January 1-7, 2050, in Scenario 1.*

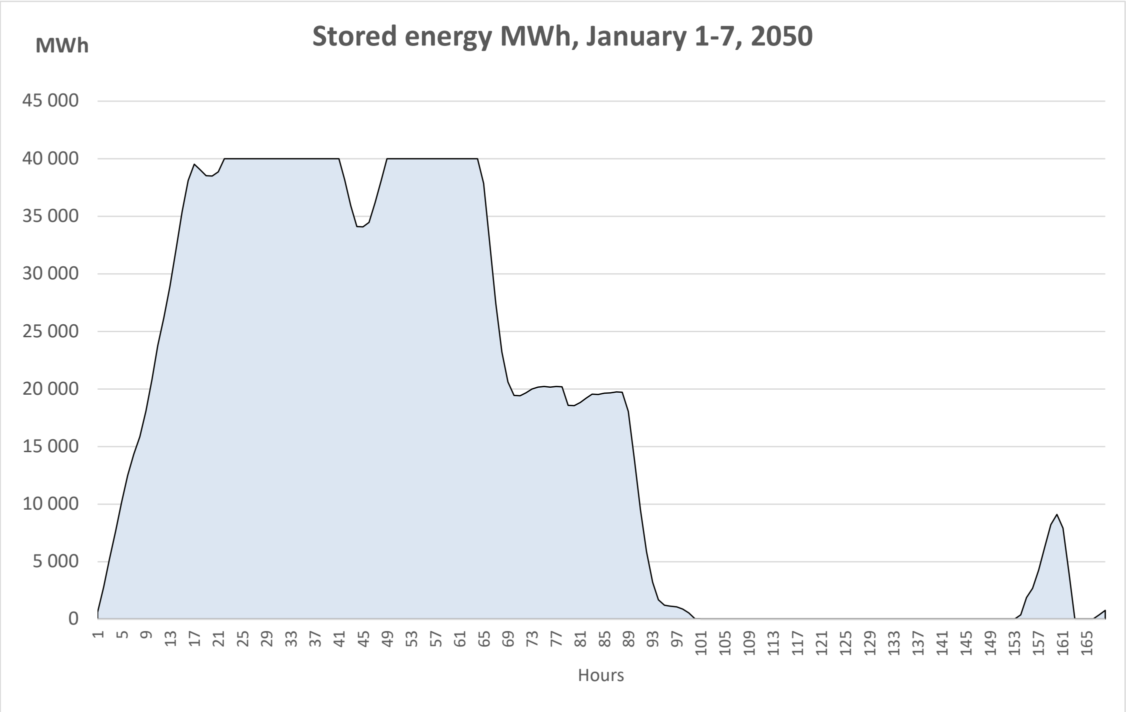

Figure 10. *Stored energy capacity during January 1-7, 2050.*

The scenario results show that this amount of wind and solar capacity, biomass capacity, and assumed storage capacity is not enough to reach the 100% renewable energy target. Figure 11 shows the situation on August 25-31 and indicates the need for fossil energy because the wind speed is meager during that period, and also the solar PV production is low, and the biomass production cannot cover the demand.

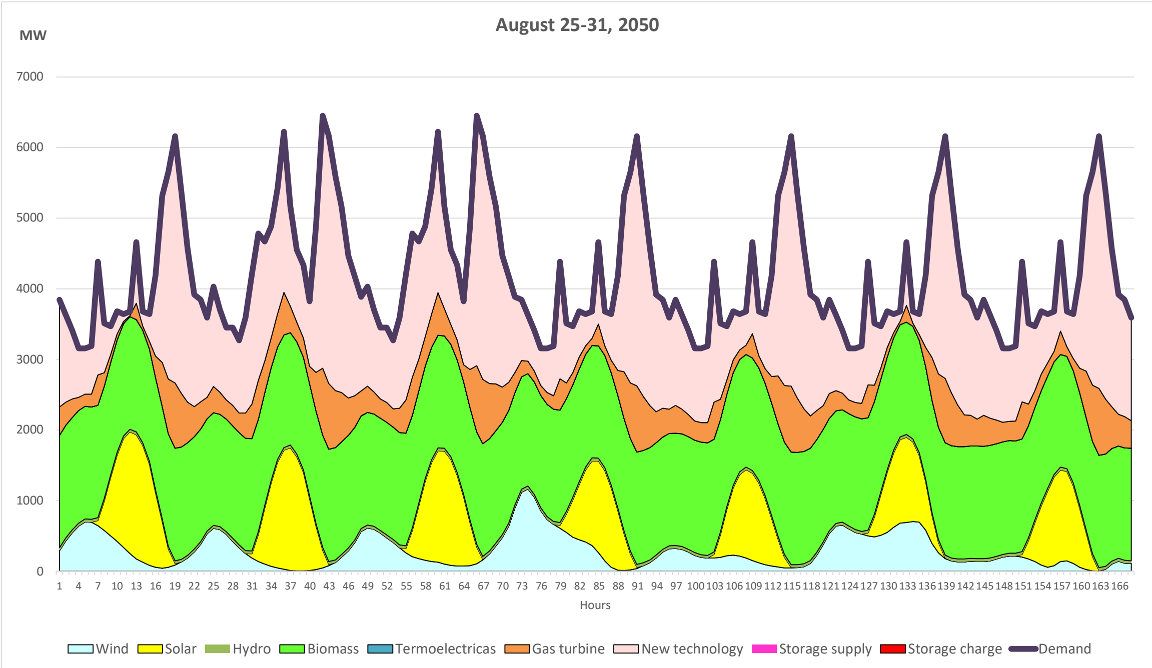

Figure 11. *Electricity supply and demand during August 25-31, 2050, in scenario 1. 'New technology' here means internal combustion engines (ICE) using diesel oil or fuel oil.*

The energy storage is empty during the August 25-31 period. However, the low wind period continues during the first days of September, and fossil energy supply is needed to balance the supply and demand, as is shown in Fig 12. During this week, the wind speed increases, and at the end of the week, the storage capacity will get some energy during the daytime (see Fig 13).

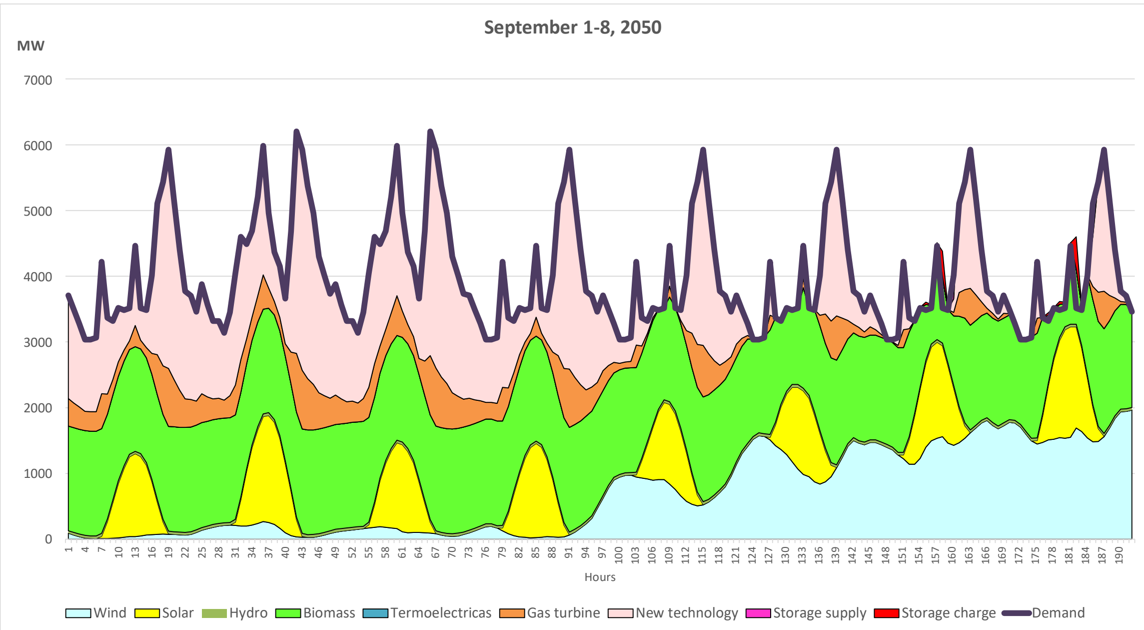

Figure 12. *Electricity supply and demand during September 1-8, 2050, in scenario 1.*

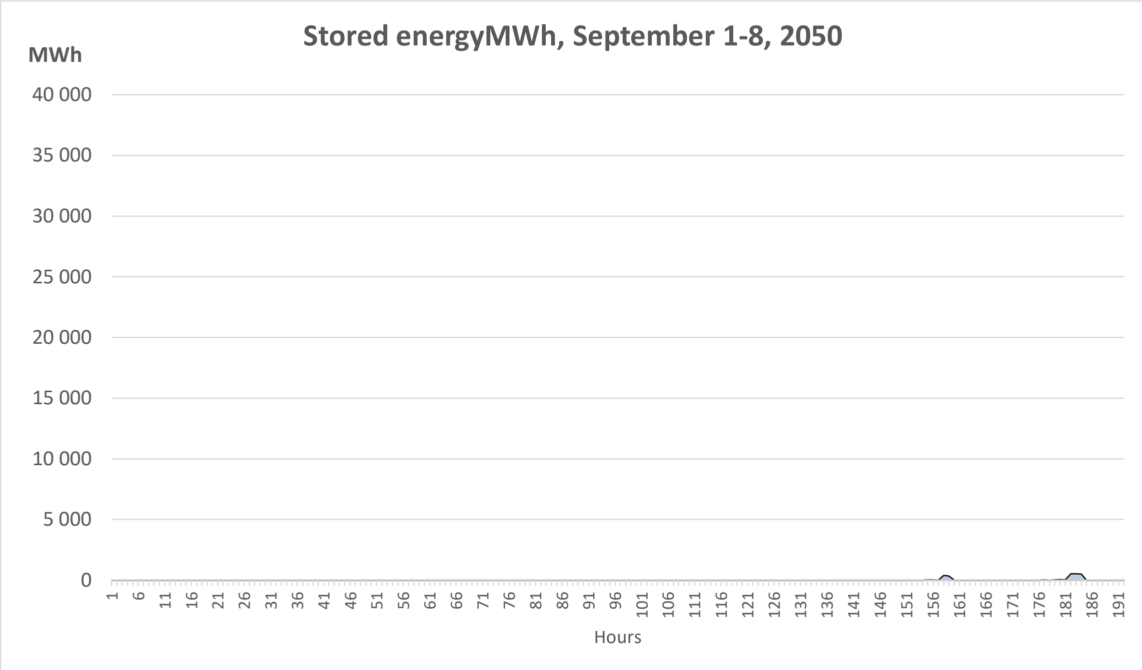

Figure 13. *Stored energy capacity during September 1-8, 2050, in Scenario 1.*

The annual electricity production of different energy sources in Scenario 1 is shown in Fig. 14. In this scenario, renewables already dominate the production, and their share of the total annual production is 80 %. Biomass has the highest share of production (about 12 000 GWh), followed by wind power (about 11 000 GWh). Solar PV production is about 4 500 GWh, fossil-based ICE production (New technology) about 5 500 GWh, and gas turbines about 1 500 GWh. The hydro production is very low due to the low installed capacity.

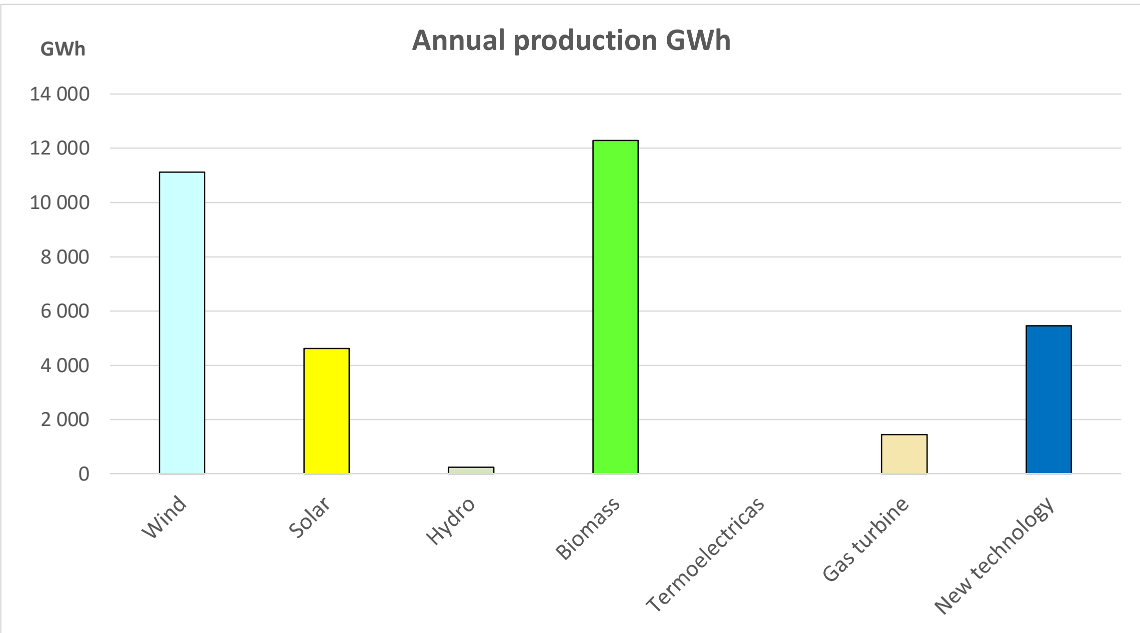

Figure 14. *Annual electricity production by different types of power plants in 2050 in Scenario 1.*

Scenario 2

In Scenario 2, we have increased the amount of wind and solar investments and have reduced a little bit of the growth of the residential electricity consumption compared to Scenario 1. Therefore, the economic development in this scenario is equivalent to Scenario 1. In this scenario, we have also increased pumped hydro storage capacity from 40 000 MWh to 100 000 MWh. The electricity consumption in this scenario is shown in Fig. 15.

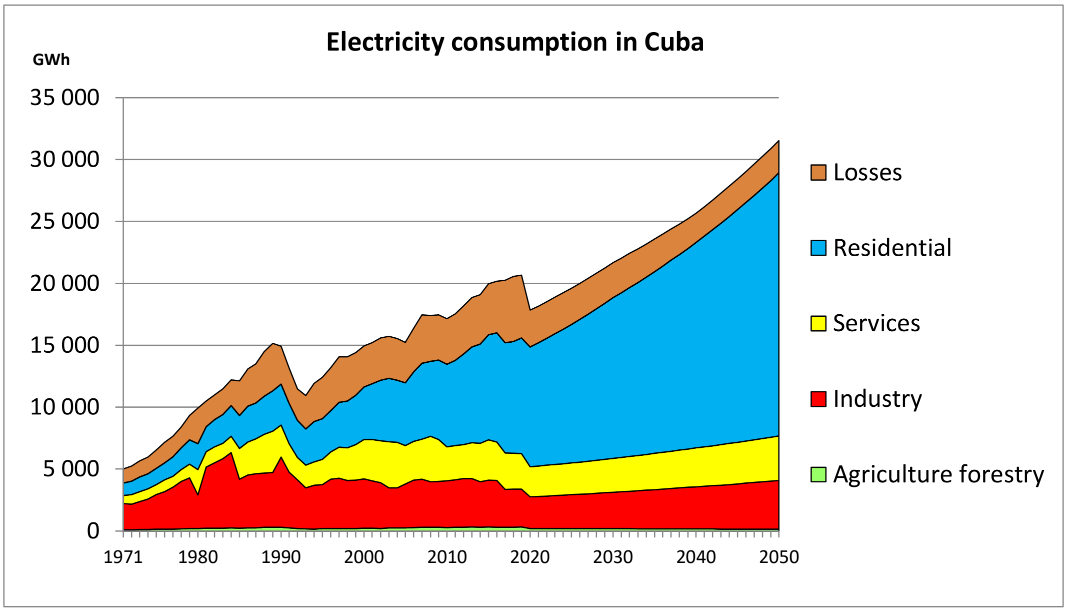

Figure 15. *Electricity consumption in Scenario 2*

The development of the power plant capacity in this scenario is shown in Fig. 16, and the total installed capacity in 2050 is shown in Fig. 17. The increase in solar and wind capacity in this scenario is considerable. The growth of solar PV capacity is assumed to be 14 percent per year after 2024, and wind capacity is assumed to increase 11 percent per year after 2024.

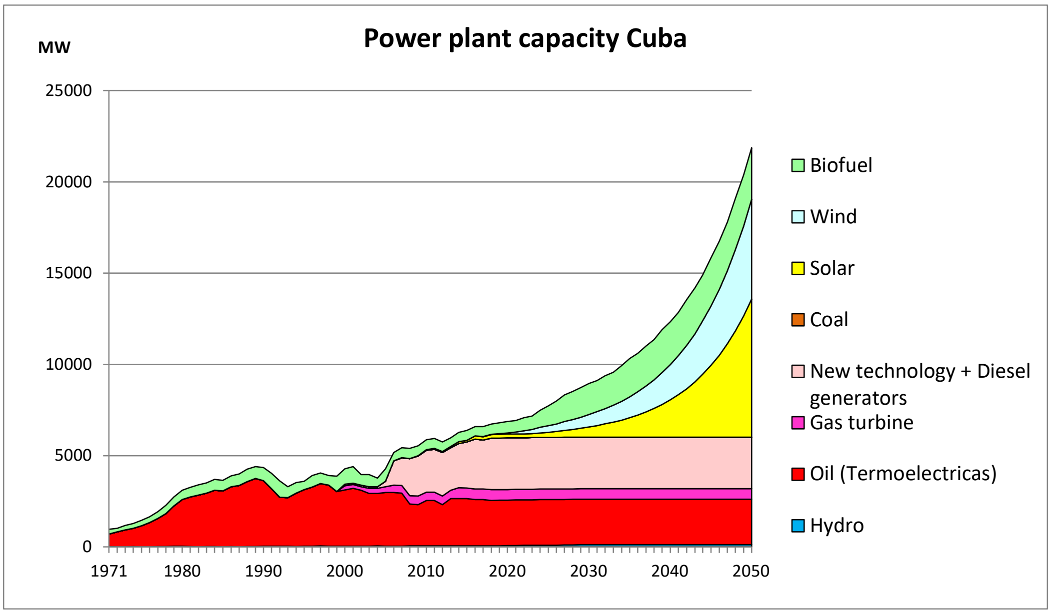

Figure 16. *Development of power plant capacity in Scenario 2.*

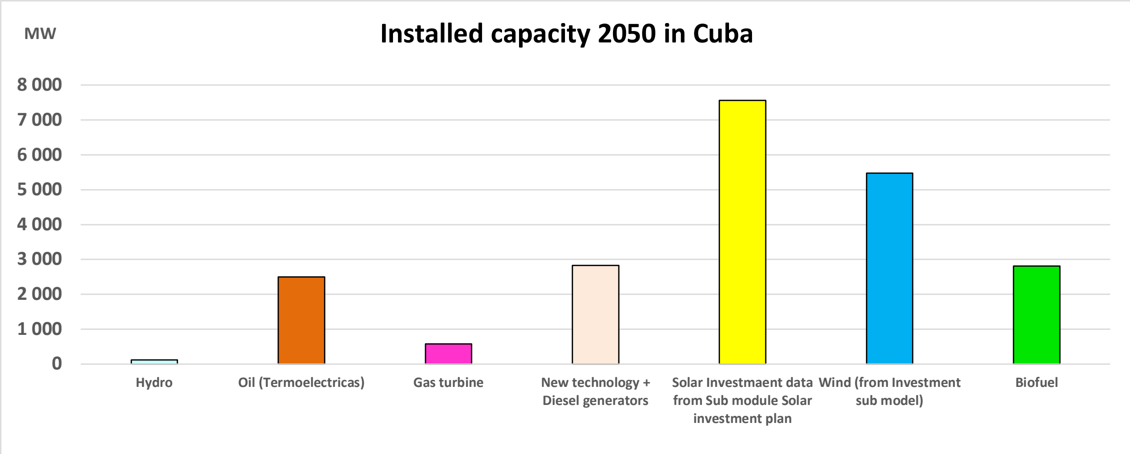

Figure 17. *Total installed power plant capacity in 2050 in Scenario 2.*

Electricity production with different power sources in Scenario 2 is shown in Fig. 18. Again, we can notice that the share of fossil production decreases fast after the introduction of added renewable capacity, but it does not quite reach zero by 2050.

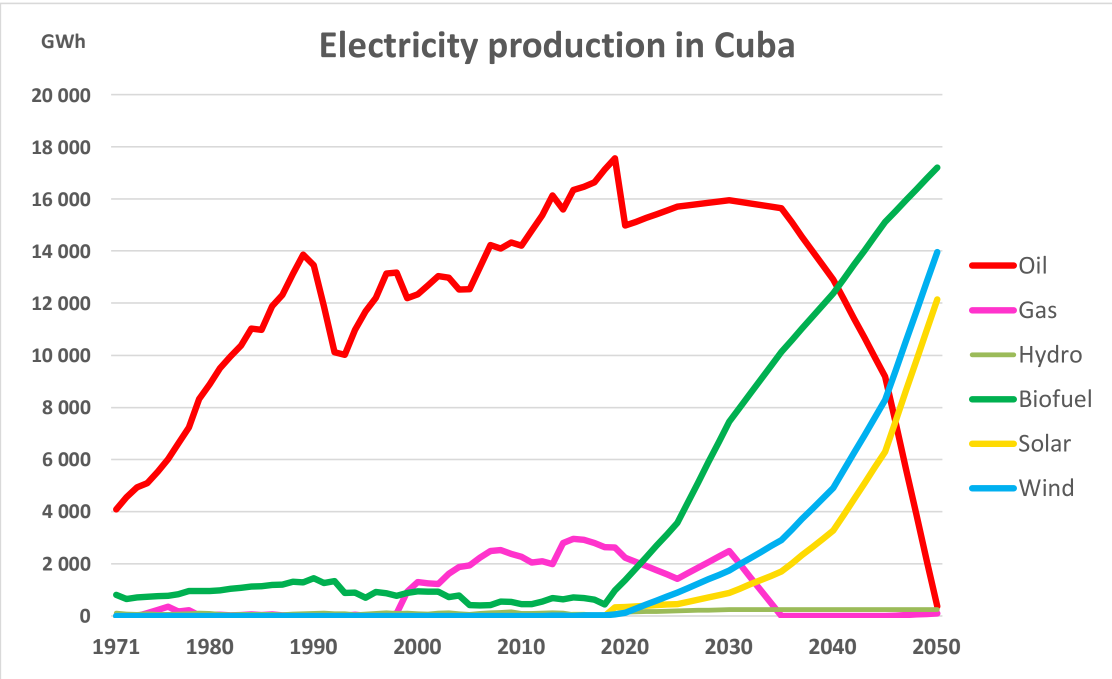

Figure 18. *Electricity production from different power sources in Scenario2.*

The annual electricity production in 2050 from different power sources in Scenario 2 is shown in Fig. 19. Fossil energy sources still cover part of the consumption, but the share of renewable sources in this scenario is already almost 99%.

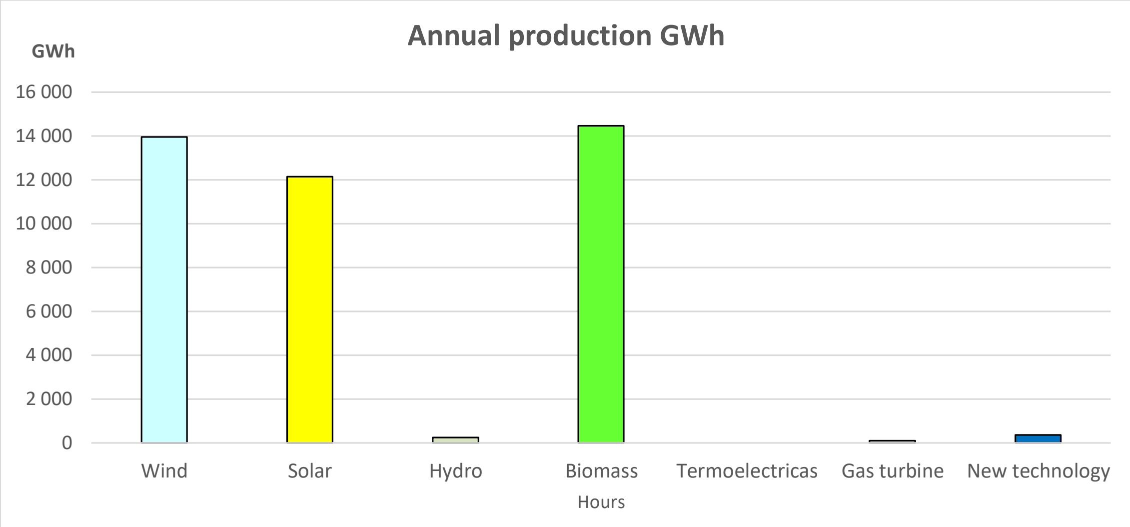

Figure 19*. Annual production of electricity in 2050 from different power sources in Scenario 2.*

When we look at the electricity production and demand in the first week of January 2050, in this scenario, we can find out that the renewable energy capacity, together with the increased storage capacity, is sufficient to produce all the needed electricity as can be seen in Fig. 20.

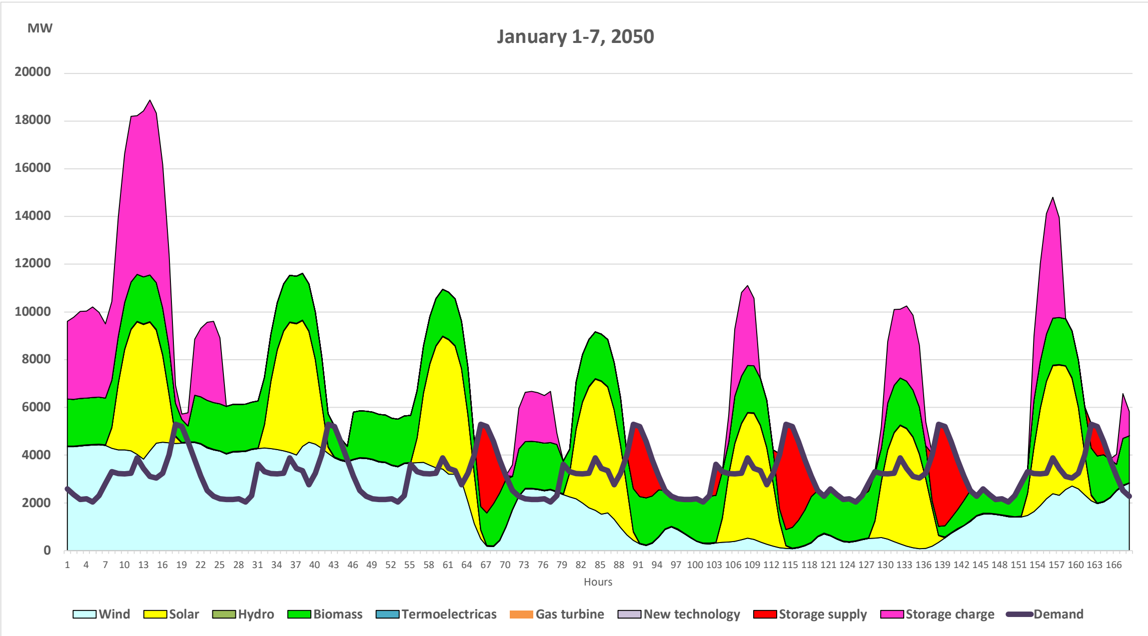

Figure 20. *Electricity supply and demand during January 1-7, 2050, in Scenario 2.*

There is considerable overproduction of electricity in this scenario on some days. The storage capacity is not large enough to store all the excess energy, as shown in Fig. 21, where the storage capacity reaches its maximum limit on the second day of the operation.

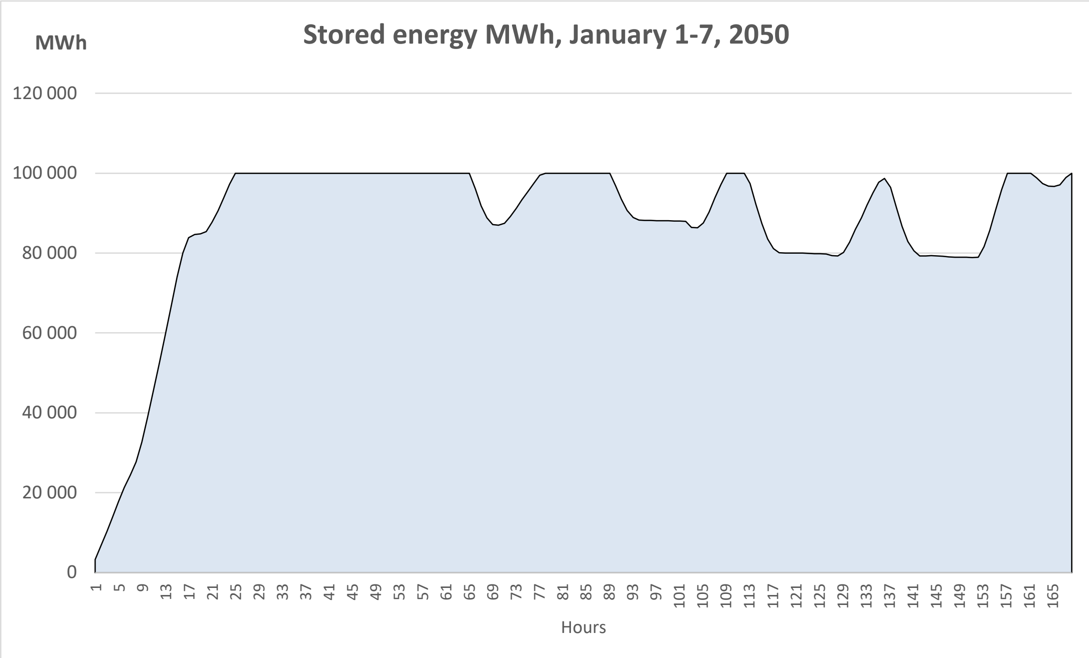

Figure 21. *Stored energy capacity on January 1-7, 2050, in Scenario 2.*

When the wind speed reduces during August-October (see Fig. 26), the renewable capacity is insufficient to produce all the required electricity, as shown in Fig. 22 for the last week of August 2050. During this period, the stored energy capacity is partly increased during the daytime (see Fig, 23) when solar production increases, but the low wind speed and the resulting low production of wind power cannot produce enough to cover the demand, and fossil production is required.

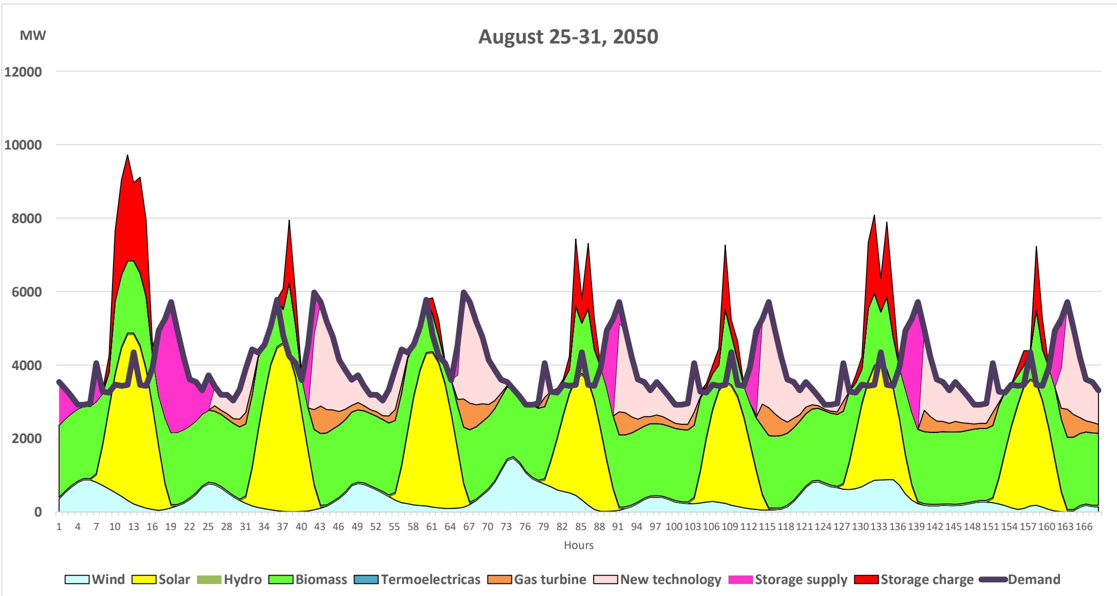

Figure 22. *Electricity supply and demand during August 25-31, 2050, in scenario 2.*

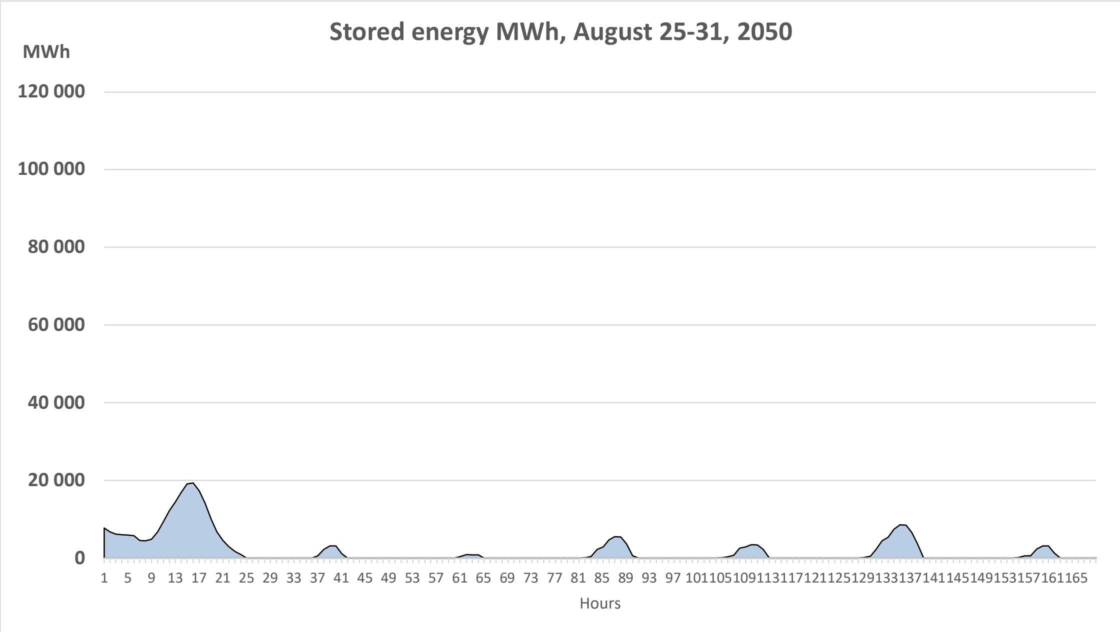

Figure 23. *Stored energy capacity on August 25-31, 2050, in Scenario 2.*

In early September, the wind speed is still meager (in the reference year data), and fossil energy is needed to cover the demand (see Figs. 24 and 25).

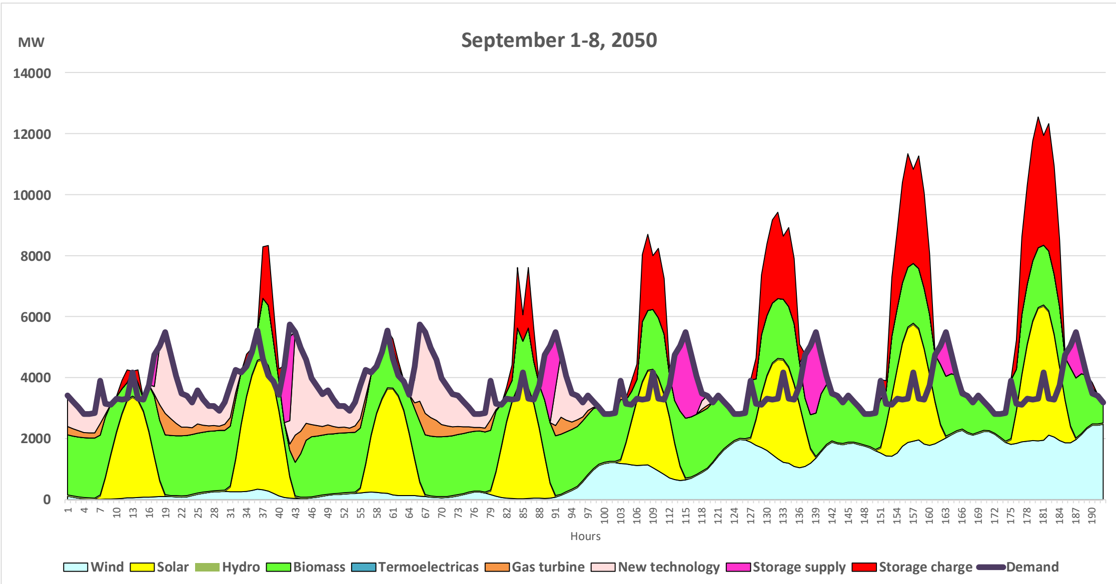

Figure 24. *Electricity supply and demand during September 1-8, 2050, in Scenario 2.*

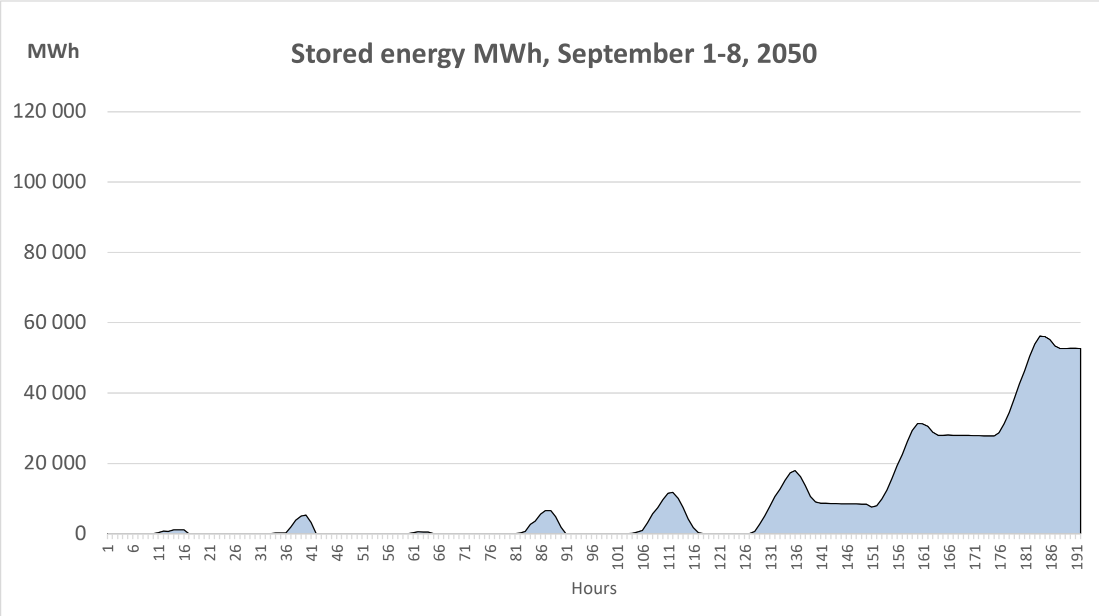

Figure 25. *Stored energy capacity on September 1-8, 2050, in Scenario 2.*

The wind power production for the year 2050 in Scenario 2 is shown in Fig 26. From this figure, we can see that the low wind speed occurs especially in August, September, and October, and it has a considerable impact on wind power production.

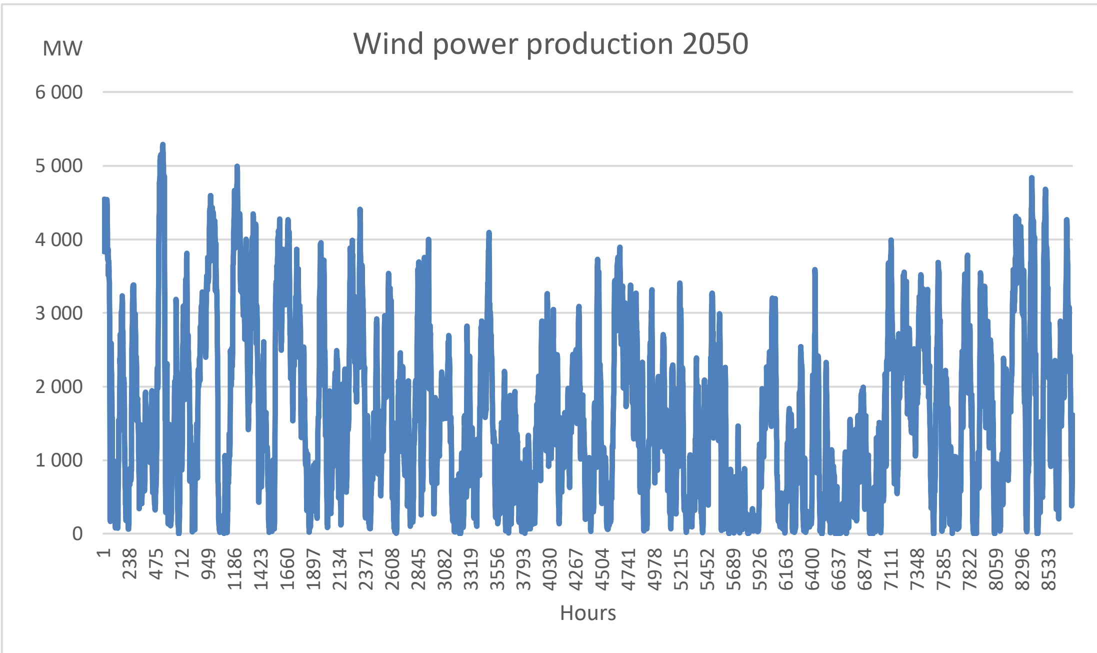

Figure 26. *Wind power production in the year 2050 in Scenario 2.*

Ramp rates and duration curves

Ramping rate describes the need to change power output from power plants during the changing load. Different types of power plants can change their power output at different change rates, and power plants using combustion engines or gas turbines are faster than steam power plants consisting of steam boilers and turbines. Hydropower also provides fast ramp rates, and in this sense, the pumped hydro capacity is good for balancing the supply and demand and compensating for the fast changes that occur in wind and solar production. Figure 27 illustrates the ramp rate envelope in Scenario 2 in 2050. The ramp rate envelope shows the required maximum rates for different time windows (1-6 in this case) for changing the power output up ad down. It also shows the average ramp rate up and down.

The ramp rate envelope for the residual power production (demand minus wind and solar, and biomass production) in 2050 in Scenario 2 can be seen in Fig. 27. Here we can see that the maximum ramp rate in one hour is about 1500 MW up and down in this scenario. In two hours, the maximum ramp rate up is close to 7000 MW/2h and down slightly less than 4000 MW/2h. In three hours, the maximum ramp rate up is over 9000 MW/3h. These ramp rates show how fast changes take place when lots of supply is from variable renewable sources, and at the same time, the consumption is also changing. The situation is especially problematic when the evening peak consumption takes place at the time when the solar production decreases fast. In this scenario, the maximum storage supply power is about 5500 MW, requiring a vast power plant capacity in the pumped hydro storage.

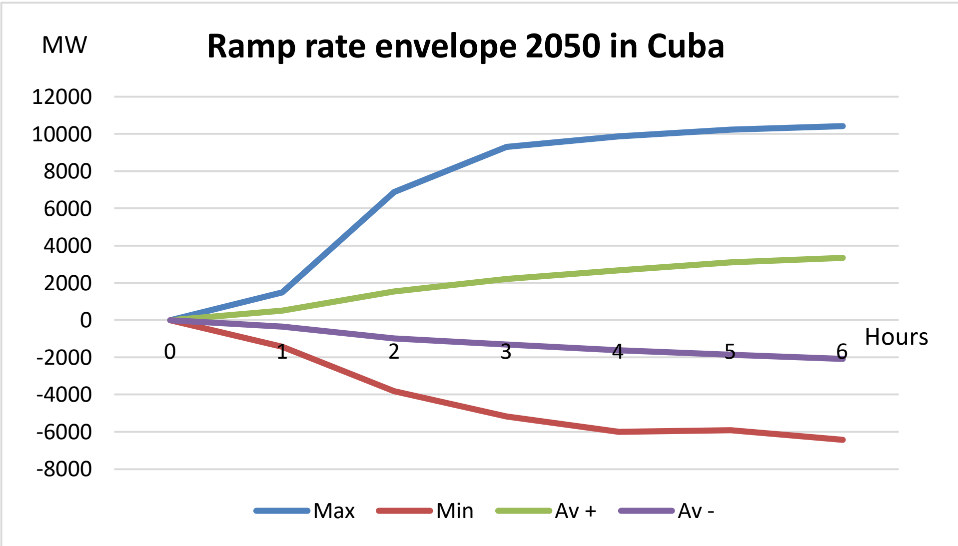

Figure 27. *Ramp rate envelope for residual load for 2050 in Scenario 2.*

The load duration curve provides interesting information for planning the energy system. The load duration curve is constructed by ordering each hourly demand in decreasing order of magnitude and plotting these to cover all the 8760 hours of the year. The load duration curve indicates how much baseload capacity, load following capacity, and peaking load capacity are needed. Fig. 28 shows the meaning of these concepts.

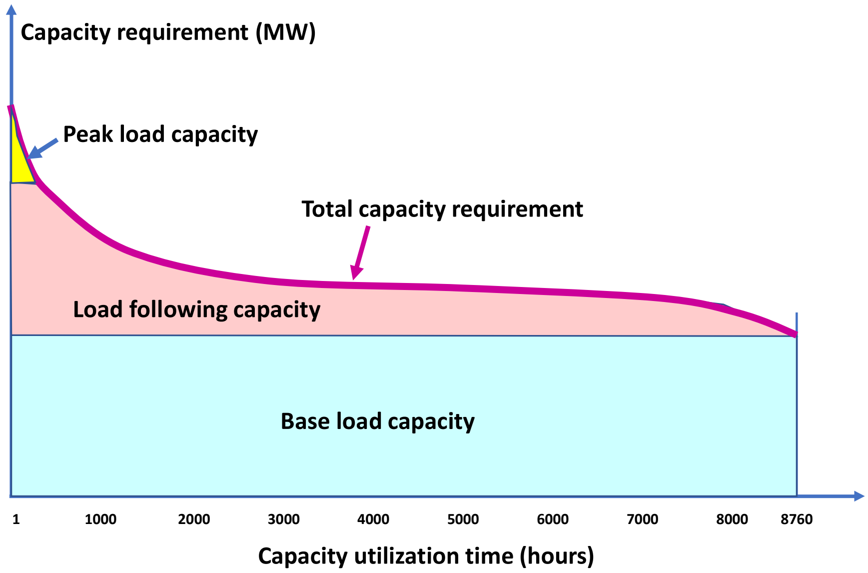

Figure 28. *Load duration curve and the different load capacities.*

The load duration curve for the case of Cuba in 2050 in Scenario 2 is shown in Fig. 29. In this figure, the blue curve shows the standard load duration curve, and the green curve indicates the residual load duration curve, which is constructed for power demand to be covered by other sources than hydro, biomass, wind, and solar power. The blue load duration curve shows that the 2000 – 3500 MW baseload could be covered by power plants that normally produce the baseload. This would mean the condensing power plants using crude oil (termoelectricas) in the Cuban case. However, from the green residual load duration curve, we can see that when lots of solar and wind power is installed, there is no need for baseload power production but more need for load following capacity and peak load capacity. This determines the type of power plant that is economically feasible to cover the residual load when much variable renewable power production is installed in the electricity system. The negative values in the curve mean that the production is larger than consumption, and energy storage is needed to avoid curtailing solar and wind production.

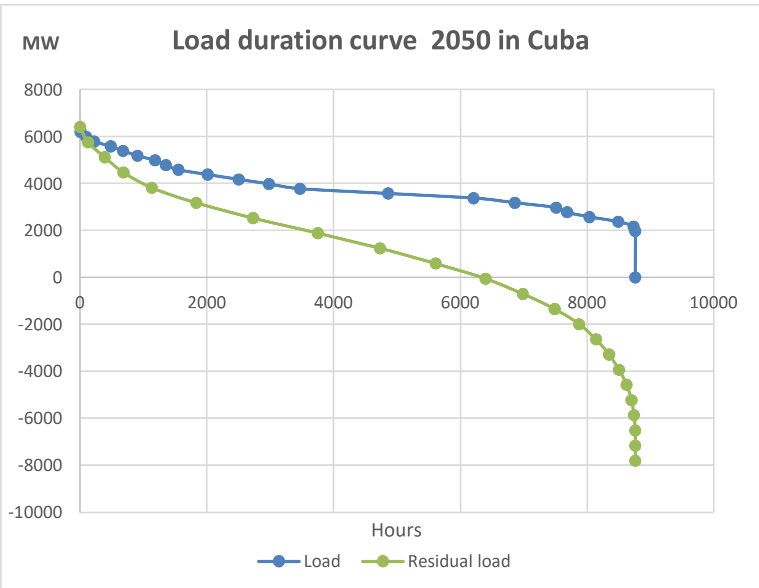

Figure 29. *Load duration curve and residual load duration curve in 2050 in Scenario 2.*

Scenario 3

In Scenario 3, we have increased the amount of installed solar power and biomass production capacity and increased the storage capacity from 100 000 MWh to 120 000 MWh to see how close to a 100% renewable electricity scenario we can get. The wind power capacity is not increased in this scenario because the low wind periods from August to October are the main problems from the point of view of reaching the 100% renewable target. The economic development and the electricity demand are in this scenario, similar to Scenario 2.

The development of power plant capacity in this scenario is shown in Fig. 30, and the installed capacity in 2050 is shown in Fig. 31. The total installed solar PV capacity is close to 10 000 MW in this scenario, the wind capacity is 5500 MW, and the biofuel capacity is 2800 MW.

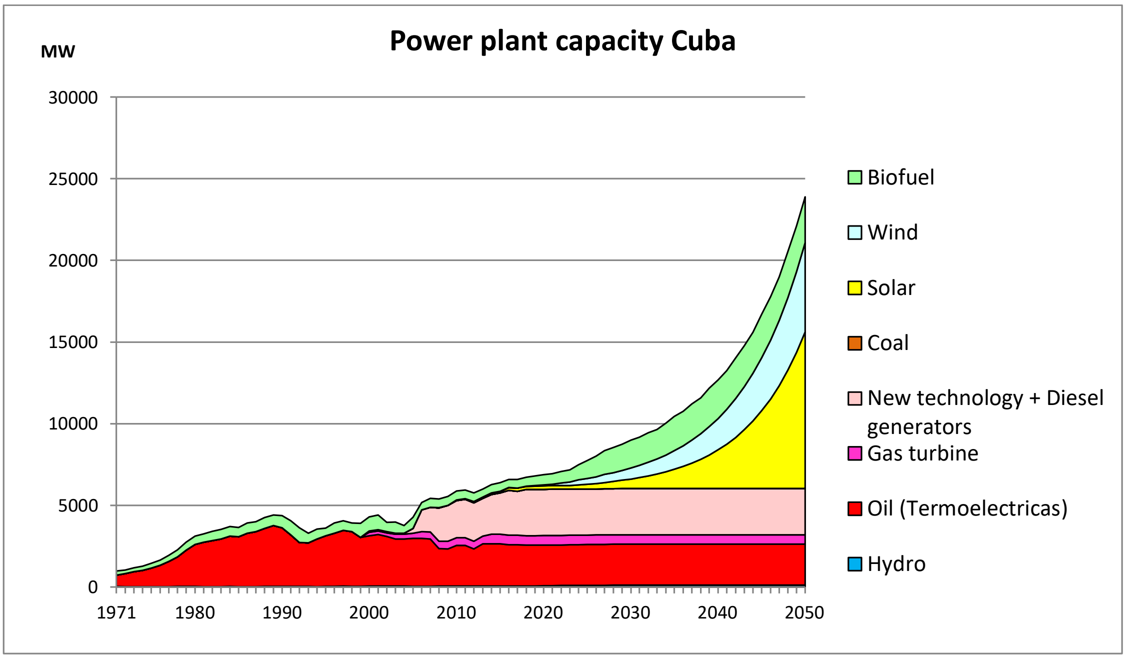

Figure 30. *Power plant capacity in Cuba in Scenario 3.*

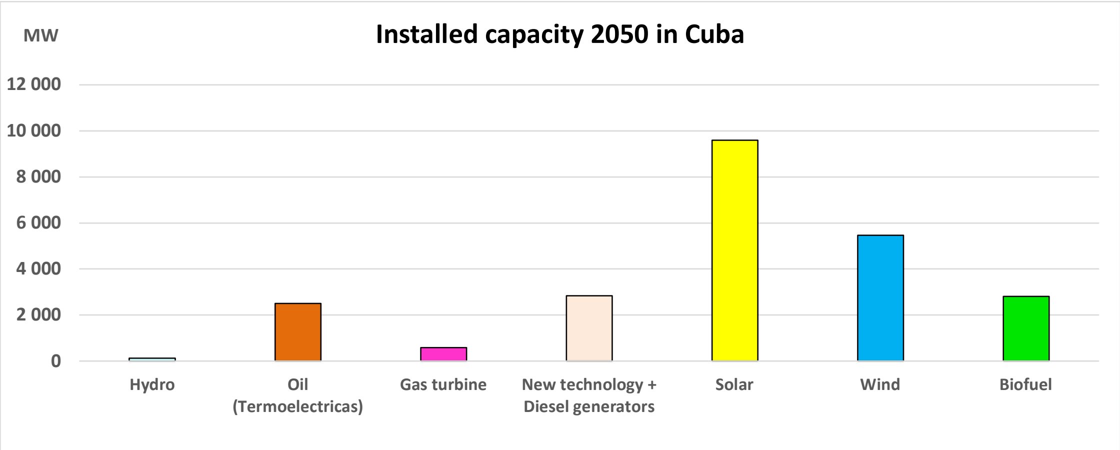

Figure 31. *Installed power plant capacity in 2050 in Scenario 3.*

Figure 32 illustrates the electricity production and demand in the first week of January 2050. The increased solar capacity leads to overproduction during most of the days, and the pumped hydro storage is charged to total capacity during the second day (Fig. 33). Later in the week, the storage is discharged during the peak consumption hours, and biofuel production is also needed to balance the supply-demand.

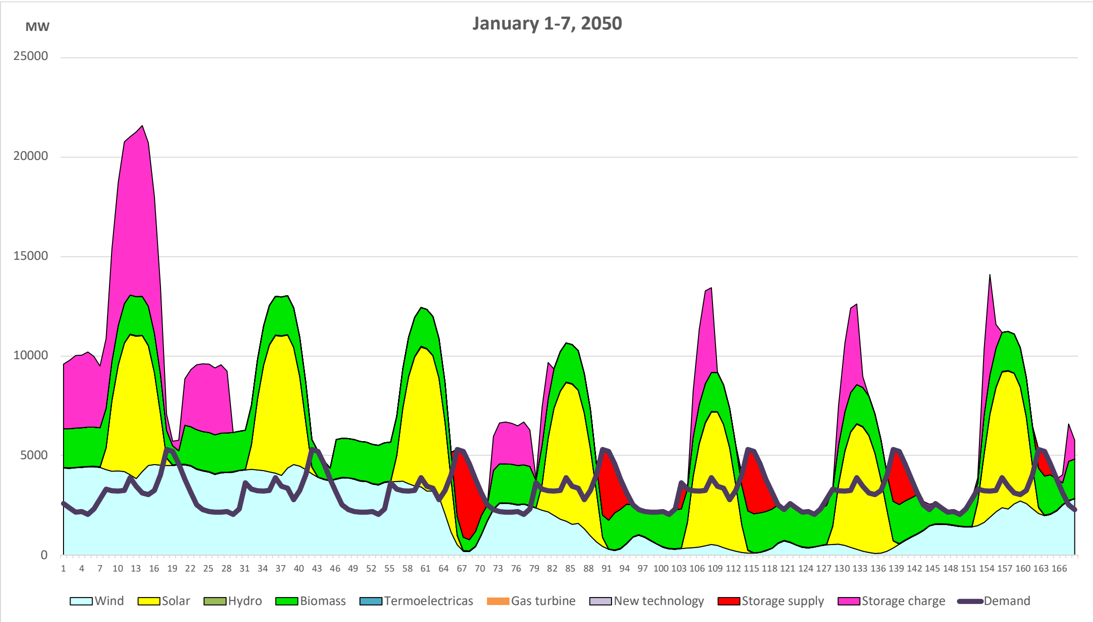

Figure 32. *Electricity supply and demand during January 1-7, 2050, in Scenario 3.*

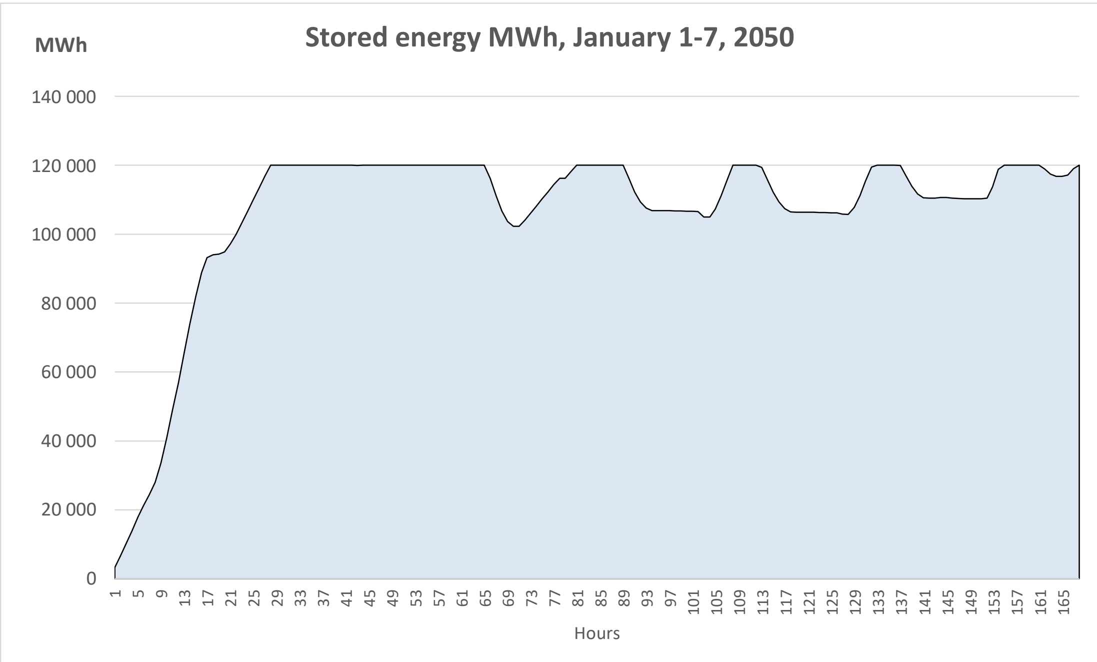

Figure 33. *Stored energy capacity on January 1-7, 2050, in Scenario 3.*

When we analyze the production during the lower wind speed period in late August, we can find out that the renewable energy capacity and storage capacity are insufficient to cover the demand,

and fossil energy is still needed (Fig. 34). Furthermore, during this period, the overproduction during the daytime is not sufficient to charge the storage to cover the evening peak (Fig. 35).

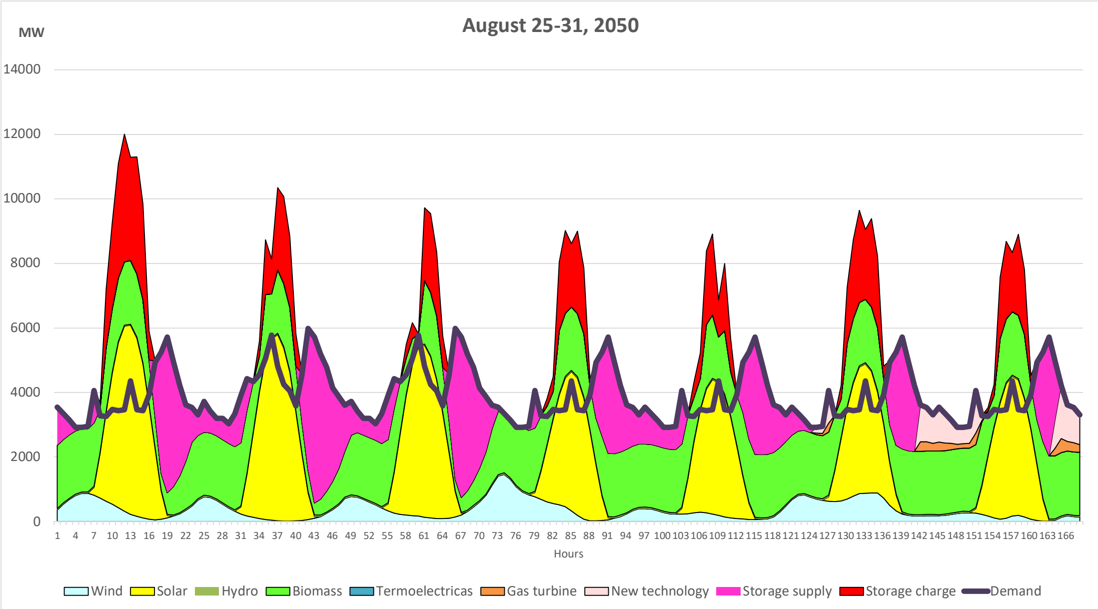

***Figure 34**. Electricity supply and demand during August 1-7, 2050, in scenario 3.*

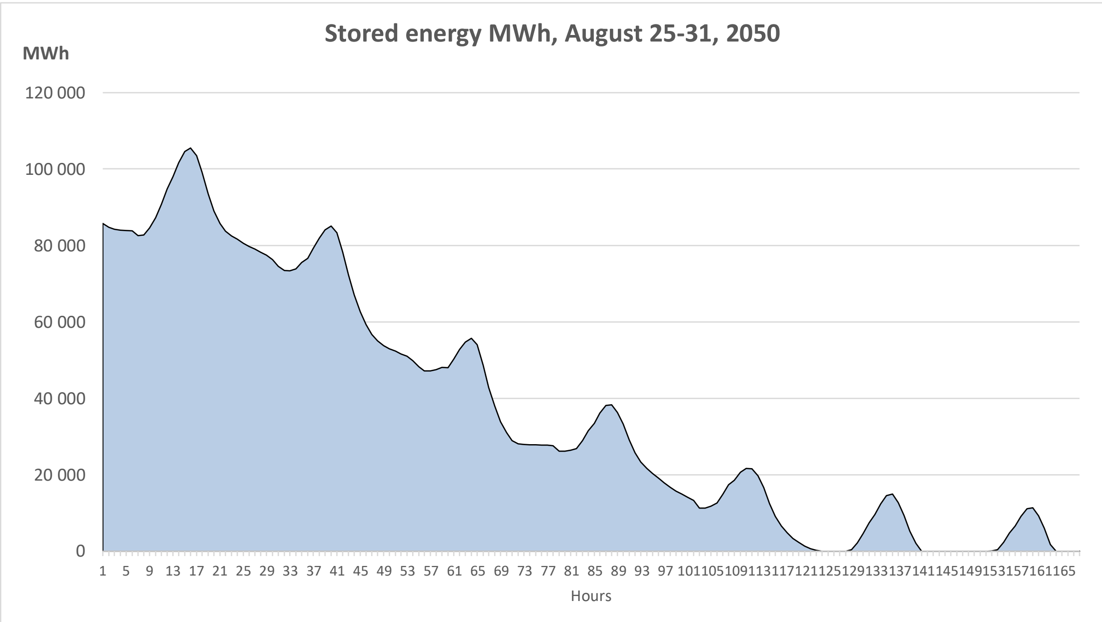

***Figure 35.** Stored energy capacity on August 1-7, 2050, in Scenario 3.*

At the beginning of the following week, September 1-7, the wind power production is still too low, and fossil energy is needed (Fig. 36). However, when the wind speed increases later in the week, the renewable energy production is sufficient to cover the demand, and the storage can be charged again (Fig. 37).

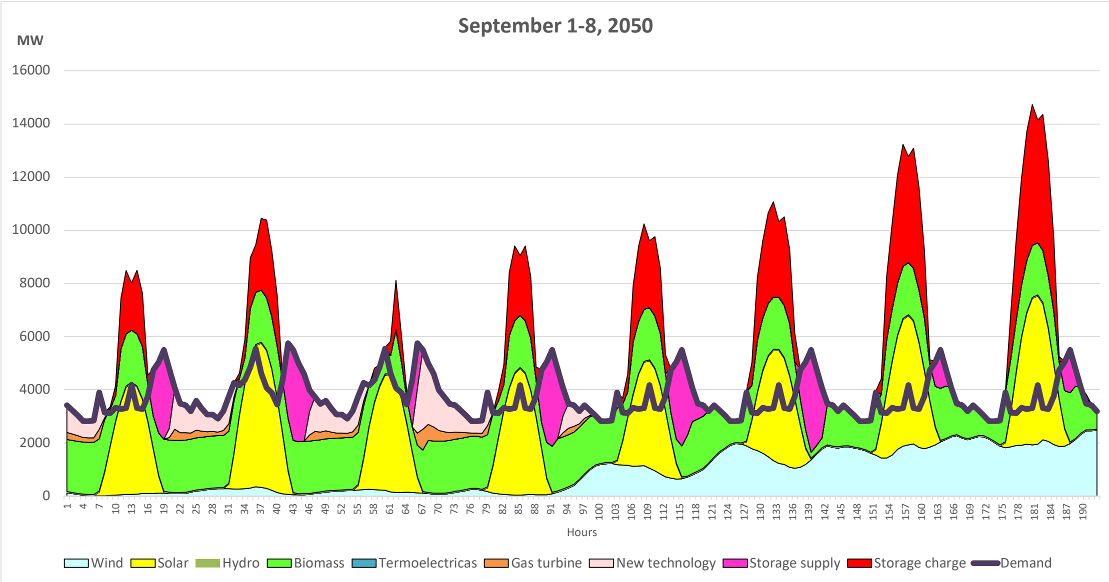

Figure 36. *Electricity supply and demand during September 1-8, 2050, in scenario 3.*

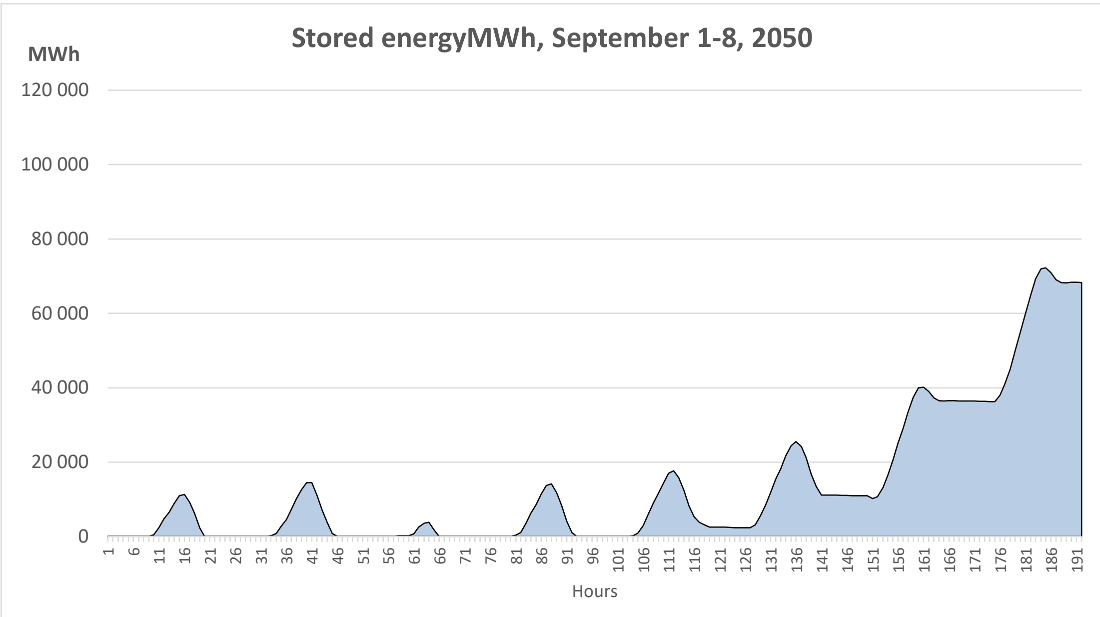

Figure 37. *Stored energy capacity on August 1-8, 2050, in Scenario 3.*

The low periods of solar PV production (see Fig. 38) coincide as low wind speed periods in August, September, and October. This makes it difficult to reach the 100 % renewable share in electricity production with these two sources.

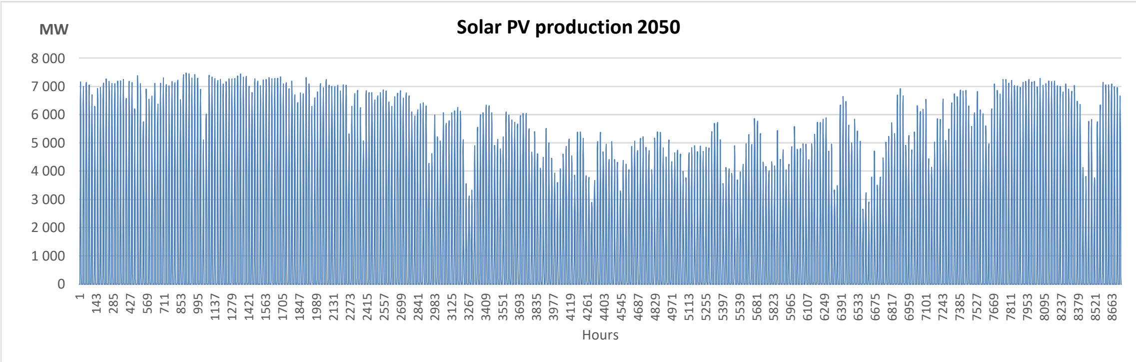

Figure 38. *Hourly solar power production in 2050 in Scenario 3.*

The total annual production in Scenario 3 by different power plants is shown in Fig. 39.

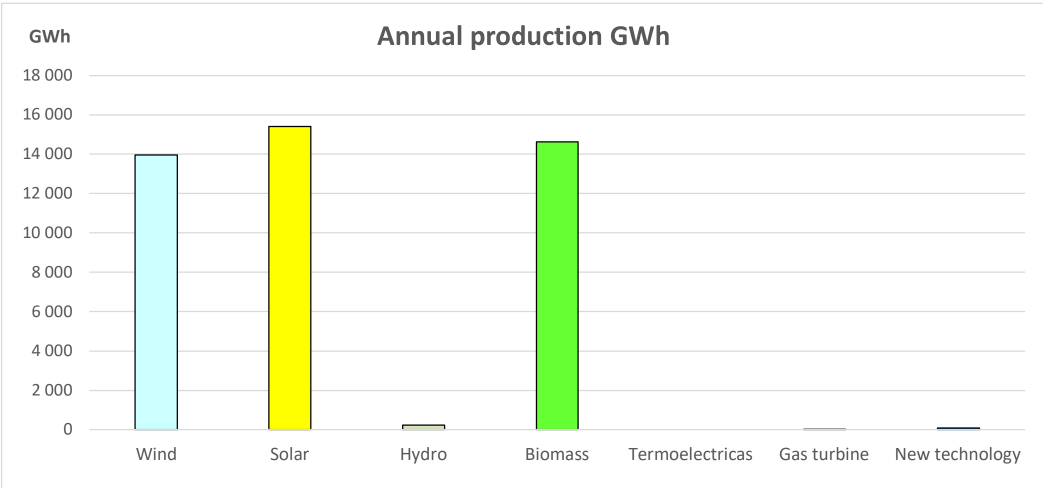

Figure 39. *Annual production of electricity in Scenario 3.*

In Scenario 3, the share of fossil energy in electricity production is only 0.2 %. In order to reach a 100% share of renewable energy, the investments in solar energy and storage capacity should be increased considerably, or the biomass capacity should be increased. The problem with the increase in biomass capacity is biomass availability (Tamayo Pacheco, Rubio González, Lorenzo Llanes, and Brito Sauvanell, 2022). Additional possibilities would be to use municipal waste for electricity production and to produce biogas for electricity generation. These resources are, however, relatively small in Cuba.

One possible option to increase the share of renewable energy in electricity production is to utilize biodiesel or bio-oil in the existing diesel generators and fuel oil plants. The amount of biofuel in this form is calculated with the CubaLinda model. In Scenario 3, the amount of electricity produced with fossil energy will be about 100 GWh in 2050. If this is produced with a diesel motor with an efficiency of about 40%, the fuel requirement is about 255 GWh which is about 22 ktoe. If the price of biodiesel is about 1500 USD per ton the fuel cost for the production would be about 33 million USD. This would, however, reduce the same amount of fossil oil consumption so that the total cost would not be very high. If we assume the regular diesel price to be 1000 USD per ton, the price difference to using biodiesel instead of regular diesel to produce 255 GWh would be about 11 million USD.

An approximation of cumulative investment costs for Scenario 3 during 2010-2050 is given in Fig. 40. The cumulative investment costs are calculated based on assumptions of sharply reducing costs of solar PV and wind power investments. Solar PV investment costs are assumed to reduce from 1500 USD/kW in 2010 to 400 USD/kW in 2050 and the wind power investment costs from 1500 USD/kW in 2010 to 600 USD/kW in 2050. In addition, the capacity factor of wind power production is assumed to increase due to the new types of wind power plants with considerably higher hub height. The investment costs of fossil and biofuel power plants are assumed to remain constant.

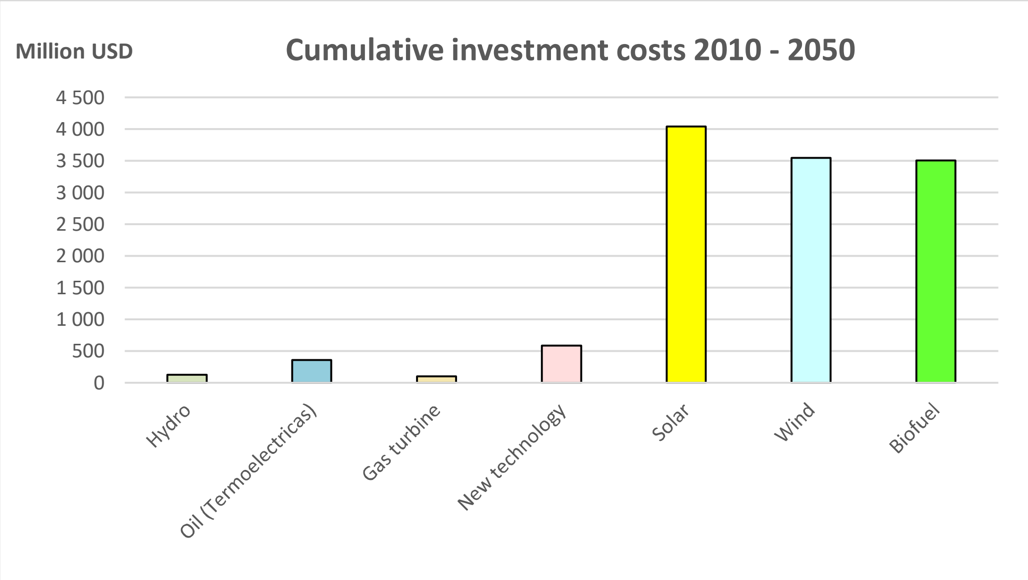

Figure 40. *Cumulative investment costs of power plants in Scenario 3 from 2010 till 2050.*

The load duration curve for Scenario 3 is shown in Fig. 41. In this case, the residual load duration curve starts from almost -10 000 MW and reaches the zero level at less than 6000 hours. This means that all the needed capacity for residual load production should be load-following capacity and peak load capacity, and there is no economic viability for baseload capacity in this scenario.

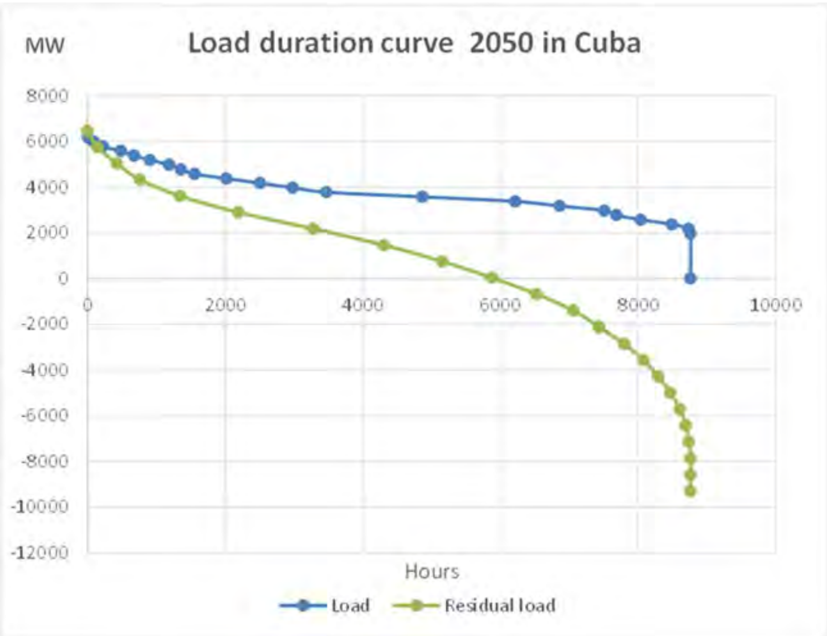

Figure 41. *Load duration curve and residual load duration curve in 2050 for Scenario 3.*

The ramp rate envelope, shown in Fig. 42, indicates a need for fast load-changing capacity. The maximum three-hour ramp-up requirement is more than 10 000 MW/3h which places intense demands on the functioning of the electricity system.

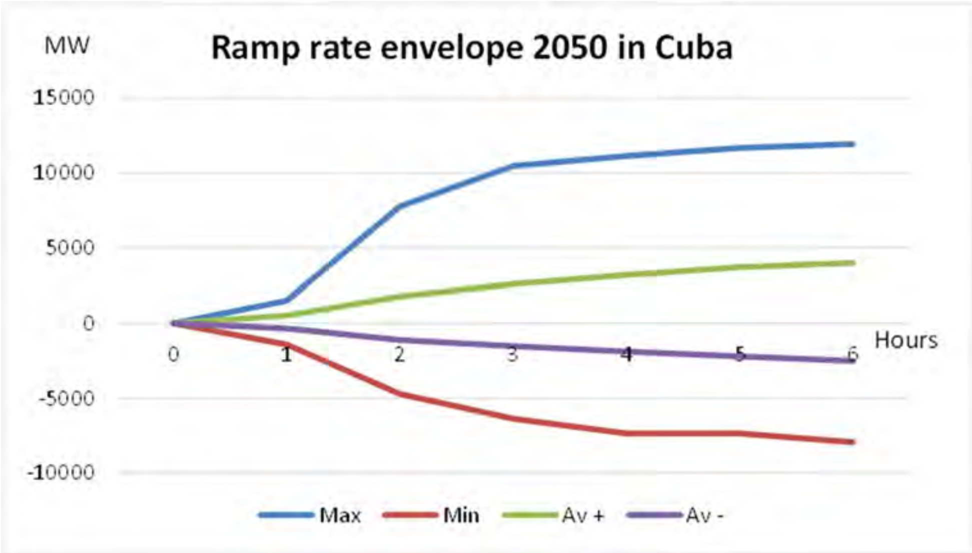

Figure 42. Ramp rate envelope in 2050 for Scenario 3.

The solar power plant, Abel Santamaría

Conclusions

The target of a 100% renewable electricity system is challenging for Cuba. Some of the challenges are related to the economics of the energy system. A switch to a 100 % renewable system requires significant wind and solar power plant investments. This is not easy for Cuba, which is struggling with economic problems caused mainly by the US embargo and the Covid-19 pandemic. International climate change funds could provide one possibility for obtaining resources for the investments if the industrialized countries will fulfill the obligations of the Paris Agreement and the promises given in the Glasgow COP26 negotiations. The use of renewable energy sources instead of fossil energy will naturally lead to a decrease in the fuel costs of electricity production. However, the required payback time of the investments depends on the future investment costs and the future fuel costs.

In addition to the investments in power production, there will be a need for investing in the electricity transmission and distribution grid. Most of the wind production potential and planned capacity are situated in the Eastern part of the country, while most of the consumption is in the Western part, and this will result in a need to increase the power transmission capacity. If part of the investments is carried out decentralized, especially in the case of solar PV, the need for increased transmission could even be reduced. On the other hand, the estimated increase in electricity consumption will naturally increase the need for added transmission and distribution capacity.

One of the challenges is the required investments in the energy storage capacity. Required ramp rates for balancing the power system with a high share of variable renewable generation require much controllable capacity both on the generation and consumption side. The analyzed amount of storage capacity is vast, especially compared with the total capacity of the generation system. In these scenarios, we assumed the use of pumped hydro storage to balance supply and demand. According to National Electric Union (UNE) estimations, the theoretical potential for large-scale pumped hydro capacity exists in Cuba, even up to 20 000 MW and 100 GWh (Montes Calzadilla, 2019). Battery storage can provide some advantages for the grid's fast balancing and frequency control, but their role in ample energy storage is implausible if their future prices will not decrease radically.

One possible technical solution to medium- and long-term energy storage is power-to-X-to-power technology (P2X2P), where electrolysis produces hydrogen and, together with carbon, converted to ammonia, methane, or some other storable medium to be reconverted back to electricity when needed. Conversion with carbon benefits from existing infrastructure like the natural gas network and internal combustion engines, but hydrogen can also be used without conversion, for example, in industrial sites. The challenges of conversion include high costs and poor efficiency. Produce the hydrogen required for producing 1 MWh of storable fuel energy takes 1.9 MWh of electricity. Conversion losses and costs of carbon capture increase the cost. Fuel cells can be used as part of this technology. Their conversion efficiency varies from 40% to 60% depending on the fuel (hydrogen or reformed fuel, for example, methane). The use of fuel cells is also possible in the transport sector where the decarbonization requirement exists.

The Cuban power system is an island system without connections to neighboring systems. This makes balancing supply and demands even more difficult because the isolated power system is relatively small and sensitive to disturbances. Moreover, this balancing task will become even more complicated when the synchronous generation of massive turbine-generator systems of termoelectricas will be replaced by switched converter-connected solar and wind generators having no natural inertia. This will make the system prone to severe frequency fluctuations in the system. Reduced system inertia results in the increased need for fast responding controllable capacity.

There are also many opportunities for developing the Cuban energy system towards a 100 % renewable electricity system. Cuba has vast solar and wind energy resources, and their utilization will become cheaper in the future with decreasing global prices. In addition, distributed production from renewable sources provides some protection against hurricanes and other impacts of climate change. However, the planning of the installations of renewable energy sources has to be carried out considering the increasing climatic disturbances.

Demand-side management can provide possibilities for balancing, especially if electric transport increases and the charging and discharging of vehicles is carried out using innovative technology. One possibility for demand-side management is to use variable electricity prices, which directs demand towards periods when renewable production is high. This type of policy requires hourly-based smart electricity metering and changes in the tariff structures.

The power system infrastructure in Cuba is old and needs new investments. Thus, investing in a new sustainable power system infrastructure does not replace adequate capacity.

The scenarios constructed with the CubaLinda model show that it can reach 100% renewable electricity production in Cuba. It requires significant investments in solar PV and wind production and investments in energy storage to balance the variable production and the variable demand. Nevertheless, the scenarios indicate that it is possible to construct a roadmap to a 100% renewable system.

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III.7. Cuban energy futures. Community social work and renewable energy sources.

Vivian Basto Estrada, Aymara Reyes Saborit and Dunia del Rosario Barrero Formigo

Introduction

The development of renewable energies globally is a priority for developed and developing countries. In the case of Cuba, the electricity sector (sector electroenergético) constitutes a strategic sector that contributes directly to four SDGs of the 2030 Agenda of the United Nations (UN/CEPAL, 2018):

- 7 (access to sustainable energy),
- 9 (industry, innovation, and infrastructure),
- 11 (sustainable cities and communities), and
- 13 (combat the adverse effects of climate change).

In correspondence with the above, national, territorial, and local policies respond to objectives established in the Agenda 2020-2030, which is reflected in the National Bases for the economic and social development of the country until 2030 and in all programmatic documents (PCC, 2017).

The Ministry of Energy and Mines is responsible for implementing and monitoring these policies. In this, the ministry is accompanied by universities, study centers, science and technical entities, and other actors in the energy sector. All these institutions and organizations must work together to reduce energy costs, enhance energy efficiency (EE), and improve the population's quality of life ***[1]***.

The dialogue of scientific, inter-, and transdisciplinary knowledge is a principle of the world energy and development programs. The perspective of sociocultural analysis is included in all spheres that promote human, local, and social development from the economic, social, environmental, and cultural dimensions.

In this sense, the present research aims to: identify needs and opportunities for energy development based on local development and its potential in the face of the vulnerabilities of rural communities in the eastern region of Cuba. Methods and techniques of the Social Sciences are used to enhance the sustainability of Renewable Energy Sources ***[2]*** for local community development in the face of social vulnerabilities ***[3]***. From the methodological tools provided by the Social Sciences: Sociology, Sociocultural Anthropology, Social Psychology, Philosophy, Community Sociocultural Management, Study of communities for work in human settlements, which allow deep knowledge of the natural environment and the sociocultural context in which energy technologies will be installed, and their sustainability monitored. Elements of the social reality of rural communities currently under study are exposed, such as Santa Rosa 1 in Granma and La Magdalena in the Guamá municipality of Santiago de Cuba province.

Development - A look at the energy sector in Cuba

The energy profile in Cuba is characterized by a high dependence on fossil fuels and a high cost of energy delivered to final consumers. At present, the development of Renewable Energy Sources is a matter of high priority in the economic plans of the Cuban State ***[4]***. Within the development plans until 2030 is the gradual change of the energy mix. In this sense, there are plans to generate 755 MW in sugarcane biomass, 633 MW in the wind, 700 MW in photovoltaic, 56 MW in hydro-energy, and 27 MW in biogas (Extremera San Martín, 2019). However, much more can be done. For example, suppose it is taken into account that the solar radiation received in Cuba varies very little from one month to another in the year, with an average value of 5 kWh on the day for each square meter. In that case, the conclusion is reached that taking advantage of any available area can allow the supply of an essential part of the energy demand of any institution.

The Ministry of Energy and Mines (MINEM) has the state commission to coordinate the program to support Cuba's energy sector. Among the tasks included in the program is the specific objective No. 4, “Support the local development of rural communities by facilitating access to renewable energy and stimulating efficient energy consumption”.

Currently, in Cuba, 4.3% of the country's electricity is produced by renewable sources. This is generated in 53279 facilities (solar heaters: 30988; solar panels: 9476; windmills: 9343; biogas plants: 3243; hydropower facilities: 147; sugar plants: 56; solar parks: 22; wind farms: 4). (Extremera San Martín, 2021).

At the end of the nineties, a strategy was approved to modernize existing power plants with potential reforms in energy efficiency, the construction, and exploitation of new capacities such as the use of accompanying gas and the development of the Electricity Saving Program in Cuba. The aim was to reduce the maximum demand and the annual growth rate of electricity consumption, develop habits and customs in the rational use of energy and protection of the environment in the new generations, and develop new regulations and pricing policies that guarantee energy efficiency of new equipment.

The period 2003-2005 marked the modernization of the country's energy infrastructure. Low-efficiency equipment was replaced by other high-efficiency equipment, mainly in the residential sector, although the process was extended to all sectors at other scales. One of the main results that impacted worldwide was the total elimination of incandescent lighting, which meant that Cuba was the first country in Latin America to eliminate such technology. Subsequently, the border regulation of the minimum requirements of Energy Efficiency in the equipment for the final use of electrical energy arises, with significant energy savings due to the regulation of efficiency standards, a regulation that is still maintained and that is in force renewal and update process.

In 2014, Decree 327: Regulation of the Investor Process appeared as a regulatory framework, with its complementary legislation for implementing energy efficiency and Renewable Energy Sources within the investment process, establishing the energy license that the Ministry of Energy and Mines grants. In addition, the local development support program is developed ***[5]***.

2020 marks a turn of reinforcement around the issues raised due to the impact of the economic crisis, the tightening of the economic and financial blockade in which Cuba is joining, and the impacts of the Covid-19 Pandemic on economies and development plans that place the SDGs on a challenging scale for nations.
Consequently, national, territorial, and local policies prioritize the strengthening of the links between the universities and the business system of the country, as well as concrete actions of the universities in the order of R + D + i, to increase its contribution, through projects, to the Research Programs of Energy Efficiency and Renewable Sources of Energy to use them as the primary source of supply in today's society.

Some sociodemographic characteristics of the Cuban population and national socioeconomic panorama

The current Cuban population is made up of 11,193,470 Cubans, of them 5,629,297 female (50.29%) and 5,564,173 male (49.7%). The main sociodemographic data place Cuba as a country with a crude birth rate of 9.8 per 1000 inhabitants, with a downward trend in the birth rate in recent years, a life expectancy at birth of 78.45 years, and a 20.8% of older adults (1,731,393 inhabitants are older adults), which typifies the Cuban population as aged, with an estimate that in 2030 it will reach 30.1% of the total population in the country (ONEI, 2021).
The low birth rate and the aging population place Cuba with a demographic behavior like that of countries in the first developed world and force the state to spend large sums of money on health care and social assistance. Likewise, this demographic situation has led to the design of a National Program to increase the birth rate, face the aging population, and improve the quality of care for the elderly (Ministerio de Economía y Planificación (MEP), 2019).
In Cuba, 77.1% of the total population (8,630,460 inhabitants) live in urban areas and 22.9% in rural areas (2,563,002 inhabitants), counting as a trend both human settlements (urban and rural coverage of basic and specialized levels of services, education, culture, and health, among others, that contribute to raising the quality of life of its inhabitants (Instituto de Meteorología, 2015).
Of the total population in the country, 63.6% (7,123,300 inhabitants) are of working age; however, national statistical records indicate that the economically active population is 4,642,300 for an economic activity rate of 65.2 %, where 98,77% have employment ***[6]***, with official unemployment rates of 1.3% ***[7]***. In addition, the average salary in state and mixed entities (cuban and foreign capital) has progressed from 584 in 2014 to 879 pesos in 2019. As a result, there are 3,262,100 workers in the State sector and 1,329,000 in the private sector, representing 29% of the economically active population ***[8]***.
The economically active population as a trend, reaches a higher level of average schooling, 2,435,600 have a high school level compared to the total of 4,642,300 of the employed.
The average salary in Cuba has been growing from 584 CUP in 2014 to 879 CUP in 2019, with a prevalence of operators (2,032.4 thousand workers) and technicians (1,134.1 thousand workers). Of the total workforce (4 585.2), the following graph shows the prevalence of women in technical

and administrative positions and men in operator, managerial, and service positions. (See Figure 1).

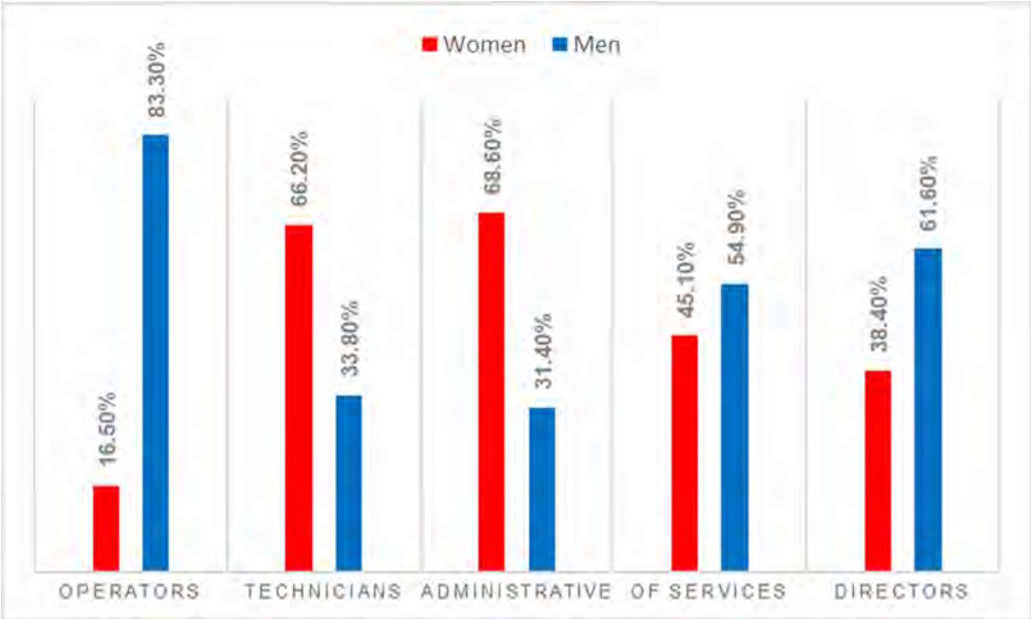

Figure 1. *Structure of employment by sex and occupation in Cuba. Data Source:* ONEI (2021)

Within its social policies, the state prioritizes the population's access to quality education, which justifies the high rates achieved at almost all educational levels and that the Sustainable Development Goal OSD 4 ***[9]*** is considered as already achieved in Cuba. The goal is then the elevation of the quality of the teaching-educational process, a fundamental objective of the Improvement of the National Education System that is currently being carried out in the country.

Different generations, Havana

The schooling in the educational levels of Pre-school, Primary, Special, Basic Secondary shows results between 99.4 percent to 99.8 percent. The Upper Average reaches the lowest results with the level of 87%. Gender equity is 1, which shows equality between girls and boys regarding access and transit through the education system (Centro de Investigaciones de la Economía Mundial and Programa de Naciones Unidas para el Desarrollo, 2020). As part of an inclusive educational policy, comprehensive care for people with disabilities is prioritized from an early age and throughout their lives. In the last Population and Housing Census of 2012, residual illiteracy was only 0.2 percent of the aged 10-49 years (Ministerio de Economía y Planificación (MEP), 2019).

Also remarkable is what has been achieved in the health sector, a work of the Revolution and a sector of highest priority for the Cuban state. In 1959 at the triumph of the Revolution, Cuba only had 6,286 doctors (Inhabitants per doctor: 1,076; concentrated in the main cities of the country, of which more than half emigrated, mainly to the United States.

In 2019 the country had 97 202 doctors (Inhabitants per doctor: 116) and 19,825 stomatologists (Inhabitants per stomatologist: 556). In general, for 2019 in Cuba, there was 294,723 health personnel among doctors: 97 202 (including family doctors: 26 173), nursing staff: 84 220, and other staff. The number of inhabitants per doctor has been decreasing exponentially since the triumph of the Revolution to the present, and similarly, the total number of doctors trained in the country (active in the country) has been increasing exponentially.

Universal health coverage and access are based on the model of the family doctor and nurse, a fundamental pillar of the Primary Health Care Program (PHC) in Cuba and its main results in public health with a character of preventive, health promotion and assistance in the community. Aspects that give this model unique values worldwide.

Schoolchildren practicing cooperation, Havana

All these elements allow us to locate the main aspects that characterize the Cuban population, with a prevalence of the female sex, a low birth rate, and an increase in life expectancy, which characterizes the Cuban population as aged, with high-level education, health care guarantees, free, affordable and universal, with a quality and accessible education system from primary to university level to which significant resources and expenditures of the State budget are dedicated to trying to maintain quality of education life of the population despite the Economic, Financial and Commercial Blockade ***[10]***.

General aspects of the socioeconomic conditions of current Cuban society

In terms of socioeconomic development, Cuba, after reaching an increased rate of 4.4% of GDP in 2015, Cuban economy reduced its average growth rate from 2016 to 2019 to only 1.3% and forecasted a rate of 1% for 2020. The primary indicators show the next evolution between 2018 and the 2020 plans (See Table 1). In general, the operation of the Cuban economy in recent years has been discreet.

Table 1. Indicators of the evolution of the Cuban economy 2018-2020.

Indicators	2018	2019	2020 (partial)
GDP growth (%)	2.2	0.5	1.0
Agriculture (%)	-4.9	1.9 (E)	--
Industry (%)	3.7	-0.5 (E)	--
Construction (%)	9.3	--	--
Sugar production (MTM)	1 100 (E)	1 516 (P) / 1 327 (E)	1 360 (E)
Investments (MMP)	9 300	10 200 (E)	-12 000 (E)
Tourism Visitors (Thousands)	4 712	5 100 (P) / 4 276	4 500
Tourism Income (MMUSD)	2 192	2 185	--
Oil Production (MTM)	3 500 (E)	3 500 (E)	--
Fiscal Deficit/GDP (%)	-9.9	-6.5 (P) / 7.1 (E)	-5.6 (E)
Average Wages (CUP)	777	877	989
Productivity (%)	--	1.9 (P)	0.6
Trade Balance (MMUSD)	1 937 (E)	942 (E)	372 (E)

During the last ten years, the GDP had an average growth of 2.4% per year, with a trend towards stagnation at 2 percent per year. This is less than half the minimum of 5% annual growth necessary for Cuba to achieve a path of sustainable economic growth. The growth was drastically reduced in

2019 due to two fundamental situations, the impact of the COVID 19 pandemic and the brutal intensification of the blockade, with more than 200 restrictive measures or sanctions from the US government in 2020.
One of the sectors that have grown despite the economic conditions in Cuba has been communications, which has been implementing policies to favor public access to the internet and social media, with sustained growth in users of the Internet services from 2,923.0 thousand in 2013 to 6,546.0 thousand in 2018. As for the Cuban subscribers to the cell phone service, this same increased from 2,140.6 thousand users in 2013 to 5,474.1 thousand in 2018, with a coverage of 85%. This means that 94% of Cuban adolescents and young people have access to some form of computer technology, the most widespread being the use of mobile phones.
Cuban society from the adoption in 2017 of the Conceptualization of the Cuban Economic and Social Model of Socialist Development, the Bases of the National Plan for Economic and Social Development until 2030: Vision of the Nation, Strategic Axes and Sectors and the Guidelines of the Economic and Social Policy of the Party and the Revolution for the period 2016-2021, using as references the SDGs of the UN 2030 Agenda (PCC, 2017), and where the characteristics of the sustainable development to which the Cuban nation aspires and the roads are defined fundamental to its achievement is constantly being refined.
In this context, the process of forming a development strategy proposal, known as the "National Plan for Economic and Social Development until 2030" (Ministerio de Economía y Planificación, 2020), with a systemic, comprehensive, and sustainable approach that responds to a strategic vision converged and agreed in the medium and long term, consistent with the documents as mentioned earlier and the Economic-Social Strategy to boost the economy and face the global crisis caused by COVID-19 ***[11]***.
The Republic of Cuba presented its first Voluntary National Report in 2019(Ministerio de Economía y Planificación (MEP), 2019), before the Third meeting of the Forum of Latin America and the Caribbean on Sustainable Development, where progress and challenges of the country in the implementation of the 2030 Agenda are collected.
In Cuba, guaranteeing education, health, and employment have been three priority objectives in social policy in the revolutionary period, with the educational sector assuming the essential dynamic role for progress in the rest of the social spheres, with a constant interest in continuing to raise and sustain the high educational level of the Cuban population, who as a result of their preparation will be able to assume roles as active agents and agents of change in the remaining social projects.
Another characteristic element of Cuban social policy is its universal, accessible, and planned nature, as well as that it is very closely linked to the country's economic policy. All this has been possible due to the particular characteristics of the Cuban social system, highlighting the role of planning to articulate the actions developed and allocate the scarce financial resources towards the established priorities. To this, the political stability has significantly contributed, allowing for long-term planning and a systematic and systemic approach to the country's economic and social development priorities.

The previous justifies why in Cuba, the country's development process assumes a simultaneous treatment of our environment's economic and social problems. However, there have been few occasions in which decisions have privileged social objectives over other exclusively economic ones.

Methodological contributions of Social Sciences to the national energy transformation from the nexus between Renewable Energy Sources and community sociocultural work: necessary dialogue

In Cuba, the energy sector's role is recognized as a fundamental source of the socioeconomic development of a country, pointing toward the guarantee of affordable, reliable, sustainable, and modern energy for everyone.

If it is intended to bet on sustainable development, the role of the development of cleaner energies, with less polluting potential than those traditional sources based on the extraction and production of hydrocarbons, cannot be ignored. All this commitment to developing a country or territory cannot be made apart from the socioeconomic, sociocultural, and socio-political elements that characterize a given population.

Interesting experiences of local community development, through the use of technological systems based on the use of RES, have been developed in the national context for isolated communities of the National Electricity System and in contexts where energy supply limits the increase of productive activities.

Due to the complexity currently presented by the design, implementation, and efficient exploitation of these technological systems, the action of teams with a varied disciplinary composition is required to carry out an integral control of the quality of technological projects, taking into account all its dimensions, where citizen participation in decision-making and evaluation appears as a distinctive feature. It is a general approach where not only scientific-technological factors are articulated but also economic, political, social, ecological, and ethical factors.

When these technological systems are inserted in a specific community social context, a dialectical relationship is established between their essential processes, namely, engineering design, practical implementation, and evaluation, where the interaction processes between technology and technology are synthesized. In the social environment, the result may be society's adoption, adaptation, or rejection of technology. Where the adoption manifests the social acceptance of the technology, and in it, the satisfaction of the expectation and the corresponding social acceptance, total or partial, of the technology is expressed. Adaptation, for its part, is understood as the process in which technology is modified in correspondence with real possibilities.

Community work is a practice of articulation of social actors, local actors, dialogues, and knowledge of the popular culture of the neighborhood, groups, and families in the joint practice of their development (Martínez Tena, 2017). In community sociocultural work, social reality is decomposed into essential parts that are systemically articulated and interconnected in natural and holistic functioning. Therefore, the social, economic, cultural, and environmental dimensions are studied.

In Cuba, there is a great diversity of methodologies for working in communities in sociocultural work. This research focuses on three contributions and results in the knowledge of reality and social transformation in the area of Latin America and Cuba. First, they are Research-action-participation, the qualitative research methodology, and Popular Education. Second, they place man, social relations, the social fabric, and society at the center of their object of study. Third, they are flexible in research design, describing, characterizing, exploring, explaining, and interpreting social processes to understand social reality.

Qualitative research proposes qualitative techniques such as participant observation, in-depth interviews, and life stories. In turn, decomposed into other parts or configurations that function as indicators: in the social dimension: sociodemographic data, the role of social organizations and institutions at the community level, the role of political organizations, educational services, level of education, the average number of families and individuals, the state of water services, leisure and recreation activities, access to technologies, access to energy, energy consumption, social relations, the state of health and sports services, needs felt and perceived cooking implements, among others necessary for the characterization and diagnosis of the community / comprehensive evaluation of the communities.

The economic dimension is broken down into the routes and average of individual and family income and finances, the production of land, livestock, soil, sources of employment, the per capita income of households and individuals, productive activities and state labor, self-employed and informal: opportunities, needs, and potentials of rural entrepreneurship.

The cultural dimension is broken down into the knowledge and characterization of traditions, behavior, and social action through the cultural practices of social actors: religious, funerals, food, traditional natural medicine, artistic, ideological, festivities, orality, rural architecture, farming, animal husbandry, fishing, rodeo, cultural traditions.

The environmental dimension is broken down into the indicators: the behavior of geographic variables, natural resources, environmental practices, environmental pollution, treatment of solid and liquid waste, and the natural sustainability of the environment.

Research-action-participation stands out for producing knowledge and practical actions for a group of people. At the same time that it is investigated, solutions are proposed: strategies, projects, systems of action. It intends that people become empowered and trained through building and using their knowledge. Participation is combined with research, theory and practice are united, political commitment is accentuated from a critical emancipatory vision, the educational nature of research and the need to return what has been investigated to the population is enhanced as a means of empowerment from a community perspective. (Reason, 1994)

In the case of the Popular Education Methodology, a nexus and a dialectical principle are established between the enriched practice-theory-transforming practice. Dialogue, reflection, and critical awareness are promoted. It intervenes from, with, for the community. Participative techniques and group dynamics are used that manage the above; group cohesion, the communion of interests, decisions, the negotiation and mediation of conflicts, and the exchange of roles. It starts from practice and returns to an enriched, transformed, and transformative practice.

Community projects, Havana

Stages of community sociocultural work as a theoretical-practical platform for Renewable Energy Sources

Community sociocultural work as a theoretical-practical platform for Renewable Energy Source Systems has an internal and systemic logic.

A management team must be created to guide the transformative research process to work in communities. It is made up of researchers, local actors, residents, formal and natural leaders, and experts on the central issues that are addressed. The management group members assume the roles and responsibilities that correspond to them, make visits to the community to establish contact with people, initiate emotional ties, and coordinate with decision-makers and local actors. At this time, the project, the strategy, the system of actions, its objective, and goals are presented, community co-participation is promoted, and the consent of voluntary participation is requested.

Subsequently, the methodological moment of elaboration and application of information collection instruments is reached to elaborate the participatory sociocultural diagnosis. Following the European Union, this second stage constitutes the Comprehensive Evaluation of the communities. This is essential for the strategic decisions that will be made later. Information gathering techniques such as questionnaires, in-depth interviews, participant observation, life stories, participatory techniques, document analysis, the Problem Tree are used: at the roots, at the base level, the causes are located; in the trunk, at the level of support, are located the problems, the needs and in the branches; at the level of analysis and rationality the potentialities and opportunities for change. It is a very effective technique for specifying problems, studying their causes, and projecting various solutions.

A plan of action consistent with the diagnostic needs, problems, opportunities, and potentialities is then designed to mitigate these difficulties and contribute to the local development of the territories. The actions must be expressed in a plan that contains the stages, those responsible, timing, objective, and the expected effects.

The actions' evaluation, control/monitoring, and impact are carried out in unison with the execution. When systematically evaluated, the risks, margins, and error probabilities are reduced. The impact of these actions is analyzed, the perception of the inhabitants before the effect of the actions, the mitigation of the needs of the community, the co-participation in subsequent actions are promoted, and the support for local development, the promotion of the socio-energetic identity, the sensitivity of the implemented technology and the need for training and the expected impact is strengthened in the community, is the real one that is obtained, and its sustainability is developed.

In the evaluation process, the dialectical contradiction between relevance is manifested, which relevance expresses the correspondence between the expectation and the result through the content of the innovation specified in the design and the implementation. On the other hand, the impact expresses the impact it has on the problem posed, the correspondence between the expectation and the result of the design together with the implementation of the Project, mediated by optimization, as a process to achieve the maximum possible efficiency and effectiveness.

In all stages, photos and videos are taken, and reports constitute real photographs of the moment experiencing: workshop, gathering, participatory technique, group technique, audiovisual viewing.

As a final result, the technological solutions implemented are appropriate if the community benefits and empowers, due to the efficient use that man makes of Renewable Energy Sources for individual, family, group, local and social development, raising their quality of life and participating from the stage of evaluating potentialities, opportunities and needs to training for the maintenance of technological proposals in the search for sustainable energy management.

Sociocultural overview of the El 1 communities of Santa Rosa and La Magdalena: keys to their local community development in the face of food vulnerabilities

The study starts from the sociocultural diagnosis of the rural communities El 1 de Santa Rosa and La Magdalena. First, social research techniques such as the survey, the in-depth interview, group dynamics, participant observation, and life stories were applied. They revealed that the main manifestations of social vulnerability were reflected in the food dimension. Then, starting from the budgets of Popular Education, Group Dynamics was applied that making it possible to design the problem tree of the communities. Finally, community intervention tools were used that made it possible to identify the needs, potentials, and opportunities for local development from the use of Renewable Energy Sources and to elaborate a series of methodological recommendations for the management

of local development at a community scale in the face of social vulnerabilities, being in the foreground the alimentary ones.
According to the criteria of Espina (2008), it is considered that the revolutionary process eliminated the structures that caused the existence of this social problem, but not the definitive disappearance of expressions of social vulnerability, which was eliminated as an effect of the socialist transformations were the sources of poverty that lie in exclusionary exploitation relations and helplessness. But since this is a multidimensional phenomenon, which includes and is generated, ultimately, in an extranational global matrix, it could hardly be eliminated by a peripheral and developing country with insufficient resources, which prevented solving some problems of access to goods at the individual and family level. (Espina, 2008)
Even with all the agricultural policies applied in Cuba from the revolutionary triumph to the present, agricultural diversification has not been achieved, production levels are insufficient, agroecological and biotechnology must be promoted, and local production systems are inefficient. Eating habits and traditional cultivation knowledge are lost. Together with environmental vulnerabilities, mainstreamed by the effects of climate change, risk and disaster management and with its effects on the cultural level, where vulnerabilities are manifested in the transformation of food practices, loss of culinary traditions, in nutritional education; elements that affect the levels of development and quality of life of the population ***[12]***.
According to the definition established by the World Food Program (WFP, 2020), a person is in a situation of food vulnerability when they face factors that place them at risk of becoming food insecure or malnourished, including those factors that affect their ability to deal with such risks.
Among the main risks that put a person in a situation of food vulnerability, the following can be mentioned:

- Not having enough food independently.
- Not having permanent access to the different food groups in the frequency indicated to have a healthy diet.
- Food is not acceptable from a physical and nutritional point of view.
- Food is not adapted to the cultural traditions and preferences of the different subjects and population groups.
- There are economic or geographical barriers to accessing food.
- There are discrimination mechanisms against subjects and groups of particular populations that prevent adequate access to food.
- The presence of disease vectors makes it difficult or impossible to transform the food intake of nutrients.
- Drinking water is not available permanently and in sufficient quantities.
- People do not have information on nutritional aspects.
- Subjects and groups with exceptional protection in the right to food do not receive preferential treatment.

The most significant vulnerabilities appear in those societies that have been exposed to significant crises and have left large fractions of their population without adequate mechanisms to face them. Inequality contributes to accentuating food vulnerability and causes economic instability. Extreme inequalities mean that increasing fractions of the population live in poverty, making them less able to cope with crises when they occur.

Food vulnerability emphasizes the impact caused by events and unexpected economic-social conditions on people's capacities (CONEVAL, 2014). It refers to insecurity, defenselessness, and exposure to risks caused by extreme socioeconomic events and the availability of resources and strategies developed by communities, households, and individuals to face adversity (Chambers, 1989).

It is crucial to appreciate that the concept of vulnerability makes it possible to account for the inability of a person or a household to take advantage of available opportunities in different socioeconomic settings to improve their well-being situation or prevent its deterioration (Kaztman and CEPAL, 2000). The most valued resources to face the various risk situations are work, family, and assets.

For its part, vulnerability to nutritional food insecurity includes physical, economic, social, and cultural threats or risks inherent to each region and refers to the response capacity of each family; assets, capabilities, strategies against the adverse event (Almeida, 2014). This process is interpreted as a state in which there is a risk, motivated by economic, social, and environmental conditions, that access to sufficient, safe food that meets people's food needs will be reduced. (Krithika et al., 2015).

It is also expressed in the concern for the study of social vulnerability that appears when the effects of the vicissitudes of the market, the withdrawal of the functions of the state, and the weakening of institutions such as the community and the family are combined in households. Vulnerability refers to "a state of households that varies inversely with their ability to control the forces that shape their destiny or to counteract their effects on well-being" (Kaztman and CEPAL, 2000).

Vulnerability directly refers to the level of risk that a family or individual faces to lose their way of life, assets, and properties in the face of a catastrophe (Busso, 2001).

In this sense, some international organizations such as ECLAC and CELADE agree when defining social vulnerability as a combination of events, processes, or features that constitute potential adversities for the exercise of the different types of civil rights or the achievement of projects of communities, households, and individuals.

Social vulnerability, a concept from which food vulnerability is derived, would then be the inability to respond to the materialization of these risks and the inability to adapt to the consequences of said materialization (Barudy and Dantagnan, 2010).

In this way, Max-Neef (1993) focuses the concept on the study of deficiencies and defines it as an individual or collective characteristics of their human condition that commit them to uncertainty, insecurity and risks, produced by a globalized market economic model, informal trade and the state's abandonment of regulated obligations regarding human rights, social protection, social inclusion, added to the lack of capacity and empowerment of individuals, families, and communities to manage them.

This coincides with the ideas of Arias Herrera (1995), who emphasizes the development of human capacities since critical deficiencies would not be determined only by goods and services but would be related to the opportunities and capacities of the individual. The development would occur when people can do more things and not when they can buy more goods or services (Terrapon-Pfaff et al., 2018).

The research results point to difficulties in the access and selection of food, the availability of food, the quantity, and quality of food, the stability of supplies and access, storage, and food consumption.

Through in-depth interviews with local and community actors, it was found that community members have their essential diet through the rationalization book and the basic family basket. Family self-sufficiency with the creation of crops, farms, raising pigs, and fishing as a fundamental economic activity are part of the local food system. They are communities that produce onions, mangoes, and vegetables. Food that is not consumed in all its productive capacity due to the lack of material resources for its industrial processing.

They have difficulties in storing food; they are not connected to the National Electricity Network. So, they have developed storage methods such as salted fish and frying meats. Country culinary traditions are preserved, such as exercising the act of eating as a family sitting at the table. The access roads to the communities, roads, and road infrastructure are deficient. What conditions isolation and difficulties in food distribution in the face of any weather event: hurricanes, floods, flooding of rivers, oil shortages. The mountainous and irregular relief is typical of these areas. They are intricate communities that place them in a situation of vulnerability ***[13]*** in the food and other dimensions of local development.

The agricultural productions of the Credit and Service Cooperative, the Local Agricultural Cooperative respond to national balances and do not satisfy the demand of the local population. There is not a diversity of large agricultural and livestock productions; the offers they receive for the primary family basket do not satisfy the food needs of the inhabitants. They have few food offerings. The woman is the protagonist of the preparation of food and suffers the impact on the health of fuelwood, kerosene, and charcoal as sources of fuel for cooking food. Elements that also cause environmental pollution.

The primary needs are concentrated in the order of preservation and conservation of food. The products are marketed according to the national price policy. The strategic projection of the local government at the municipality level for food development in both communities remains with the current characteristics. A condition that indicates that local self-sufficiency and the food empowerment of the community are eminent.

The efficient use of renewable energy sources in these rural settlements would significantly impact the food dimension and local community development. However, the local authorities themselves, local economic actors, and community members defend the idea that local Mini-industries strengthen forms of rural production: agriculture and livestock, specifically, currently depend on institutional support, sources of investment, such as international projects, among other variants.

The result of the empirical research also shows that there are potentialities for the use of Renewable Energy Sources in various dimensions; quality of the soils, the water resource (waterfalls with extensive channels come down from the mountains). Moreover, solar heating complies with the established parameters.

The Economic and Social Strategies of Cuba until 2030 and the one designed in the Post Covid-19 stage have as priorities: to develop the Energy and Food Sovereignty of the Cuban communities (Ministerio de Economía y Planificación (MEP), 2020b). The path is long and necessary. Based on these objectives, scientific training actions can be developed for energy and food autonomy in the communities.

Proposal of methodological recommendations for local community development at the community level

From the socio-technological study carried out, the following recommendations are derived for the Structures of local government in the studied communities, promoting the use of Renewable Sources of Energy, as well as the achievement of Food Sovereignty and Security in Cuban rural communities and based on scientific transdisciplinarity:

1. Development of a comprehensive social study that allows identifying opportunities, needs, and potential of the territories for the efficient use of clean energies.
2. Improvement of the Municipal Development Strategy design of the territory, promoting the energy and food dimensions.
3. Health promotion of nutritional habits is beneficial to human health through strategies and actions that articulate food, culture, and health.
4. Develop a system of scientific advice for social actors: local actors: presidents of Popular Councils, and Delegates of Circumscriptions on local development management from a local community perspective.

Conclusions.

From the exposed analyzes, the following conclusions are formulated:

- The scientific tools of the Social Sciences play an important role in the implementation of the Systems with Renewable Sources of Energy for the sustainability of the proposals. The analyses show that social reality is divided into sciences, scientific disciplines, areas of knowledge with methods, knowledge systems, and objects of various studies for its study, but they function systemically when they are interconnected for social development.
- Cuban communities and sciences need interdisciplinary and transdisciplinary dialogue for their self-development.
- Community empowerment and self-development are essential processes for successfully implementing Renewable Energy Sources in Cuban communities.
- In the studied communities, there are expressions of food vulnerability, mainly conditioned by drought, insufficient application of agroecological techniques, the population's demand

is not satisfied, the low levels of agricultural entrepreneurship from the perspective of self-sufficiency, the lack of energy investment.

- The use of renewable technologies would significantly impact the local development and quality of life of the inhabitants.

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Notes

[1] *The Guidelines of the Economic and Social Policy of the Party and the Revolution adopted in 2011 and updated in 2016 for 2016-2021 outline Cuba's medium-term strategic development objectives. Guidelines 197 to 208 establish the guiding principles for implementing the Energy Policy in the country. Specifically, Guideline 204 is pronounced for "Accelerating compliance with the Program approved until 2030 to develop renewable sources and the efficient use of energy". This policy seeks to transform the structure of energy sources on the island, promote energy efficiency, reduce dependence on fossil fuels and reduce the emission of greenhouse gases into the atmosphere, contributing to environmental sustainability. It has nine principles: 1. Satisfy the demand and consumption of energy as determined in the plan for economic and social development of Cuba until 2030, 2. Guarantee the security of energy supply in the short, medium, and long term. 3. Guarantee a national energy mix that is socially, economically, environmentally, and sustainably compatible, which reduces Cuba's dependence on imported fossil fuels. 4. Support Cuba's policy to develop renewable energy resources and apply energy efficiency in all sectors. 5. Strengthen the national crude oil and gas production and its refining by accelerating studies and research that include new technologies and production capacities. 6. Guarantee the optimal exploitation of national sources of energy. 7. Ensure considering all energy aspects (production, transformation, transportation, distribution, consumption, environment, costs) and energy efficiency in the selection process of technologies. 8. Guarantee broad participation of foreign investors in the development of the energy sector. 9. Strengthen international cooperation and regional integration for sustainable development.*

[2] *In 2014, the government released the political and economic plan to significantly diversify its Mix of Energy, to increase the use of renewable energy sources (RES) for the generation of electricity from approximately 4.3% in 2013 (including 3.5% of the sugar industry) to 24% in 2030, generating about 7,245 GWh of electricity, avoiding greenhouse gas (GHG) emissions equivalent to 4,463 tons of* CO_2*. Furthermore, the MINEM, in its conversations with the EU, has commented on its willingness to increase the 24% target of the renewable energy sources for electricity generation up to 29% by the year 2025. However, this objective can only be achieved by attracting 3.7 billion USD in foreign investment. That is why in the Foreign Investment Opportunities Portfolio 2017-2018, it is recognized that the renewable energy sources and energy efficiency are one of the main priorities of the country and are essential for the achievement of the objectives following: reduce the inefficiency of the electricity system, reduce dependence on fossil fuels, contribute to environmental sustainability, modify the energy matrix of generation and consumption.*

[3] *The research assesses scientific results of the Project Strengthening the capacities of local actors to achieve the inclusion of vulnerable groups in local development, generated by the José Antonio Portuondo Center for Cuban and Caribbean Studies of the Universidad de Oriente, Cuba. The study identifies the main manifestations of vulnerability in their dimensions of health/disease,* *environmental, cultural, educational, economic: access to health services, food security, state of the house and number of inhabitants in it, access to the cultural services, employment, access to drinking water and hydraulic networks, spaces for solid waste, school environment, and violence in Santiago communities. This research assumes the concept of social vulnerability when expressed as multiple concepts in terms of its determination and diagnosis, although its calculation is strictly impossible. (…) Beyond the importance of the notion or approach (vulnerability, poverty, marginality, exclusion), the theoretical model of the analysis is essential. Vulnerability is complex and comprises several dimensions since aspects related to households, individuals, and society's environmental, economic, cultural, and political characteristics converge. (Martínez Tena y Expósito García, 2018) Social vulnerability is associated with conditions of risk and difficulty, which immediately or in the future prevents affected groups from satisfying their well-being in socio-historical, territorial, and cultural contexts. (Rodríguez, 2006). It consists of the state of mismatch between the assets that individuals, households, institutions, and communities have and the structures of available opportunities. In this way, there are two disadvantageous situations: the assets available to individuals, households, institutions, and communities are insufficient, irrelevant, or challenging to manage to take advantage of the existing opportunity structures; or the structure of opportunities is deficient in fulfilling its functions of support to individuals, households, institutions, and communities. (Busso, 2001: 3)*

***[4]** The Economic-Social Strategy to boost the economy and face the global crisis caused by COVID-19 in Cuba reflects the ninth key result area where the primary efforts will be concentrated: Energy. It is stated: "It is vital to prioritize renewable energy sources, apply technological and economic innovation incentives, and promote savings, both in the non-state and state sectors." (Ministerio de Economía y Planificación (MEP), 2020).*

***[5]** This program aims to support the local development of rural communities by facilitating access to renewable energy and stimulating efficient energy consumption. It focuses on improving the quality of life in isolated and rural communities*

***[6]** According to ONEI (2021), the following will be considered as Employed: any person 17 years of age or over and those 15 and 16 years old who have exceptionally been authorized to work by the competent authorities, who on the day of closing of the information maintained an employment relationship formalized with a salaried job in cash or in kind, or an independent job (those employed who do not receive a salary).*

***[7]** According to ONEI (2021), the following are considered unemployed: They are people of working age (men between 17 and 64 years old and women between 17 and 59 years old) who did not work in the reference period of the National Occupation Survey (ENO), for not having a stable* *employment relationship, because they had lost it and have taken steps to find another job or because they were looking for it for the first time. Within this indicator, people who do not have a stable employment relationship and have worked at least 8 hours are considered.*

[8] *The state sector includes all state entities, mercantile societies, unions, companies, state economic organizations, budgeted units, and political and mass organizations. The non-state sector groups the cooperative and private sectors.*

[9] *Sustainable Development Goal 4 is considered fulfilled in Cuba and proposes: Guarantee an inclusive and equitable quality education and promote lifelong learning opportunities for all (UN/CEPAL, 2018).*

[10] *A loss of 5.57 billion dollars was experienced in Cuba between April 2019 and March 2020 caused by the damages of the Economic, Financial, and Commercial Blockade, taken from the Report on the impact of the Economic Blockade of the United States against Cuba to the General Secretariat of the United Nations and reported on October 22th, 2020 in the Ministry of Foreign Affairs of Cuba. Report prepared by a methodology audited by North American specialists.*

[11] *The United Nations points out that, for the first time in three decades, extreme poverty will increase, life expectancy will decrease, and deaths from HIV, Tuberculosis, and Malaria can double. $ 35 billion will be needed for aid amid a pandemic that has left tens of thousands of people in poverty and threatened by multiple famines. An estimated 235 million people worldwide will need some form of emergency assistance by 2021 (United Nations (UN), 2015).*

[12] *Feeding practices are understood as the set of activities carried out by individuals, families, and society as a whole to satisfy their feeding needs; They are a specific type of social practice, a product of the interaction process established between individuals during the access, storage, selection, preparation and consumption of their food. Considering the levels of interaction, they can be individual, family, or collective. Considering their level of systematicity, they can be every day or non-everyday. Taking into account the interaction spaces, they can be public or private. (Almeida, 2014: 33)*

[13] *The inequalities in the living conditions of the different population groups condition their vulnerability to the dynamics of the health-disease process. The so-called "vulnerable groups" are not vulnerable per se: the social conditions in which individuals and social groups live define their condition of vulnerability. (Basto et al., 2019).*

III.8. The social dimension of renewable energy sources in the rural community Los Alazanes, Sancti Spiritus municipality, Cuba. [1]

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Abstract

Cuban energy issues hold a privileged position in the nation's public agenda. These issues have substantial and complex impacts, especially on rural communities, so this study was carried out. This paper delves deep into the social dimensions of renewable energy sources in the rural community of Los Alazanes, in the municipality of Sancti Spíritus, Cuba. This article is descriptive and based on a case study. In order to obtain information, methods and techniques such as non-participant observation, in-depth interviews, document analysis, and questionnaires were used. Because of its practical nature, the research enabled us to describe the exchanges that sustain the fabric of relationships around technological change based on the representations and values of the agents in the process. We were also able to examine the prospects for community development associated with the implementation of renewable energy sources, taking into account the combined action of the potential of solar energy, water, forest, and animal biomass, producing activity for the development of mini-industries, the coexistence of a stable population and the human potential of the inhabitants, their resilience to face adversities, take on new projects, integrate as a social group and participate in the search for solutions.

Keywords: social dimension, renewable energy sources, rural community

[1] *This publication has been made with the financial support of the European Union. Its contents are the sole responsibility of FRE local Project and do not necessarily reflect the views of the European Union.*

Farmer in a malanga field, El Kaney, Santiago de Cuba

Introduction

Undoubtedly, modernization processes in their seeking for capital accumulation have also generated highly centralized productive dynamics with marked signs of inequity. Furthermore, as a result of the increasing appropriation of natural resources and the indiscriminate use of energy resources such as coal, oil, and natural gas, irreversible and unfavorable economic (high energy prices), social (energy inequity and poverty), and environmental impacts have been generated (Arencibia, 2012). The visible challenge imposed by climate change and the need for potentiating a transition towards a post-carbon era has increased the interest of social sciences, particularly those delving into the ethical and political character of science and technology, into the social challenges faced renewable energies[1] and their role in sustainable development.

The transition to a low carbon dioxide emission economy makes it possible to make a significant shift in the fight against climate change, improve energy safety and significantly reduce current geopolitical tensions. However, the paradox between the necessary environmental protection and the current domination of the energy mix implies an opportune reflection on the application of renewable energy sources (RES) (Caldeira Brant et al., 2016) and their implications beyond technology.

As a complex phenomenon, it calls for a multisector approach to production, distribution, and consumption processes, implying an authentic challenge in comprehending socioeconomic dynamics in favor of better governance in democratic societies.

The evolution towards sustainability will require profound economic and technological changes with implications in the social, energy, and environmental policies, enabling qualitatively modifying current consumption patterns. These changes demand a renovation of thoughts, values, norms, institutions, planning, management, and research.

A particularly relevant issue is related to the study of conflicts associated with the development of energy infrastructure and their relation with affected communities and collectives (Ariztía, Boso, and Tironi, 2017); researches that shed light on the need for delving into the social relation system surrounding and in a way determining the success of the implemented technology or project, beyond its performance.

Social commitment and ethical sense contribute to a democratic, sovereign, and liberating technological development. In the case of rural populations of underdeveloped or developing countries, the distances between the strategical actions of governments and the fundamental rights of people, among which access to energy is one of the most thorny, are examined.

Internationally, the rural areas' electrification process is associated with the low electric consumption level at a rural scale, the dispersion of the communities to be serviced, and the remoteness of the national electricity system. In many countries, the electrification projects are financed by the state, although governments, private enterprises, and the users also contribute.

This type of practice exhibits essential sustainability elements for its adaptability to the local environment; they are small-scale and generally preserves the natural resource base (Sánchez Olarte, Argumedo Macías, Álvarez Gaxiola, Méndez Espinoza and Ortiz Espejel, 2015). In this context, public administrations, the civil society, the existing networks of the territory, and the people´s capacities constitute vital factors in generating transformations in sectors such as agroindustry and tourism, both with great potential for rural development.

[1] *Renewable energy is defined as energy that is produced by natural resources –such as sunlight, wind, rain, waves, tides, and geothermal heat- that are naturally replenished within a time span of a few years. (From: Renewable Energy Systems. Second Edition, 2014).*

The rural worldview values electricity for its positive effects on health, education, and people´s safety, the increasing participation of women in the labor market, and reducing their social exclusion. The proper use of electric supply also affects the local economic activity by restoring the electric infrastructure for productive uses (Mendieta, Escribano and Esparcia, 2017). All these services are essential and have unmeasurable impacts on distanced rural areas.

Rural communities may play a fundamental role in developing Renewable Energy Sources (RES) as resources can be used not only for generating electricity and heat but also for treating waste and producing food. However, despite their multiple benefits, a part of the population remains reluctant to shift towards RES, primarily due to the lack of knowledge and limited appropriation processes.

Not exempt from limitations and challenges, such a shift has evidenced various problems: political, legal, and normative. These have caused social and territorial conflicts associated with privilege disparities between the enterprise system and the communities historically present in their territories. Peoples and communities perceive the various extractivist models as a menace to preserving their natural patrimony. The resistance to the local autonomy leads to the emergence of several socio-environmental conflicts.

Integrating the rest of the users into the construction of solutions implies that they need to collectively identify with the potential alternatives and consider the type of socio-productive dynamics wanted to be favored. Also, incorporating cultural practices and knowledge from the population proves to be an essential operation (Garrido, Lalouf, and Moreira 2013). Finally, inverting the power imbalance between the capital/state and the population puts the people at the center of these debates and communities in the center of the decision-making.

Only with an essentially participative, contextualized, and democratic vision could we conceive and implement energy policies satisfying the real needs of the whole population in favor of sustainable energy development. That is why according to dos Santos-Venes (2014:2):

> "*An aim for decentralized energy policies, associated to local economic dynamics, could be ways of walking towards self-determination processes, without imposing development models obeying to the capitalist agenda, the catalyst of ever-increasing needs*"[1]

In this sense, it will be necessary to re-think the economy and the societal structures from a local perspective, aiming at building up institutional models emerging from down upwards, breaking the prevailing mercantile and utilitarian logic. In the energy field, this would open the gates to a long and fructiferous cooperation between the academic sector and the community. Moreover, it could form strategic alliances that would undoubtedly favor the development of technologies adapted to local realities.

Thus, the social dimension of the energy sector implies stimulating and enhancing the effective participation of each of the actors involved in the energy transition process based on local demands and ensuring a fair and equitable distribution of the resources resulting from the transition process.

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[1] *All quotes originally in Spanish have been translated by the authors of this paper*.

The project Renewable Energy Sources in Support to Local Development (*FRE local*, Spanish acronym) falls within this scenario. It is a component of Cuba's Energy Policy Support Program, financed by the European Union (EU) and coordinated by the Ministry of Energy and Mining (MINEM). In addition, the project is implemented at the international level by the United Nations Development Program (UNDP) and at the national level by the Centre for Studies on Energy and Industrial Processes (CEEPI) of the University of Sancti Spíritus "José Martí Pérez" (UNISS).
Therefore, as a result of the actions implemented and documented in the social intervention methodology as part of *FRE local*, this paper describes the processes associated with the social dimension of renewable energy sources in the rural community of Los Alazanes Sancti Spíritus province, Cuba.

Materials and Methods

The case study was used as the methodological design of this research. Yin (1994), a leading author in the conceptualization and classification of case studies, conceives it as a form of research with its entity, where a contemporary phenomenon is investigated empirically within a real-life context, significantly when the boundaries between the phenomenon and the context are blurred.
The selection criteria for the design of this case study are those proposed by Yin (2009): a) the questions guiding the research are of the "How" or "Why" type, b) there is little control over the events, and c) the phenomenon is current, reflecting real life. Along with the mentioned criteria, typology establishes four possible basic types of study design, depending on the number of cases and the different levels of analysis. Therefore, type 1 was chosen for this study: designs for a single case considered holistically as a single unit of analysis (Yin, 2009).
The selection of the community as a single case study suited to the following criteria: the community needs to expand and improve its electricity supply since it is isolated from the Cuban national electricity system; it uses a generator set for electricity generation; it is located in a municipality that benefited from previous initiatives of international cooperation, so the capacities created will be used; it is located in a municipality with successful experience in piloting capacity building in management and planning at the local level, and the level of integration of the actors of the territory.
In addition, Jiménez and Comet (2016) conceive the case study as a methodological approach that intends:

> *”to answer how and why the event(s) occur, focusing on the phenomena under study from multiple perspectives, making the exploration deeper and the knowledge obtained broader" (Jiménez and Comet, 2016: 9).*

Thus, the case study can be associated with other research paradigms and perspectives, whether quantitative, qualitative, or mixed.
This case study was placed under the constructivist, participatory paradigm and was associated with the mixed research approach. The purpose of this mixed study was to describe and understand, from the conception of local development, the processes involved in the social construction of RES in the rural community of Los Alazanes, belonging to the province of Sancti Spíritus on the island of Cuba. This research is the result of implementing a methodology of social intervention for

isolated rural communities (Echevarría *et al*., 2020) developed by *FRE locals*. It was conducted in the period from January to December 2020.

Based on the quantitative approach, the community under study was evaluated by integrating socio-economic, environmental, and technical factors and identifying its inhabitants' needs, opportunities, and potential for the development of RES under equitable conditions. For data collection, two questionnaires were applied: one to more than 100% of the total number of families and the other to the community's formal leaders and informal leaders.

From the qualitative perspective, the perceptions, conflicts, challenges, and resistance that emerge from the development of RES and its impact on local development were studied in depth. Information was obtained through the analysis of documents and secondary data from the community and the application of in-depth interviews. In addition, non-participant observations, group dynamics, and other participatory techniques to the community's inhabitants and local stakeholders involved with the universities, projects, enterprises, formal and informal leaders, and government decision-makers related to the community and the territory where it is located, were conducted.

A non-probabilistic sample was used that granted us the opportunity to seek different perspectives and represent the diversity of the phenomenon in the whole context, where the inhabitants, social groups, local actors, contexts, events, and processes involved with the community were incorporated as holistic units of analysis. Specifically, chain or "snowball" sampling was used, in which the key informants indicated and facilitated the exchange with other people who contributed information and new knowledge until the information saturation limit was reached.

Successful case study research must overcome the traditional biases that accompany it to become a technically distinctive situation. This study was supported by methodological triangulation from researchers, multiple sources of evidence, quantitative and qualitative tools (documents, archival records, in-depth interviews, focus groups, participant observation and installations or physical objects), and theoretical propositions that guided the data collection and analysis.

Results

The results of the study of Los Alazanes integrate the social, economic, environmental, and technical viewpoints, emphasizing the gender equity perspective aiming at widening and improving access to and efficient use of energy contributing to local development.

The collection of empirical evidence related to families and individuals inhabiting the community and the identification of needs-problems-demands formulated by them are essential elements for the future design and implementation of energy and technological solutions using RES to support the community´s local development.

It followed a participatory assessment guide that took into account the location and geomorphological aspects of the community, its socio-demographic structure, sociocultural dynamics, socio-economic characteristics, habitat, electricity consumption profile, and potentialities for developing RES, which is described as follows.

Location and geomorphological characteristics of Los Alazanes

The Los Alazanes community is one of the eight population settlements that the Popular Council (PC) of Paredes has (Paredes, Entronque de Guasimal, Jarao, Petronila, San Ramón, Cafetal, Yaguá and Los Alazanes) in the Sancti Spíritus municipality. *Alazanes* (plural of *alazán*) is a Spanish word that refers to chestnut horses (horses with reddish-to-brown hair coats). It is bordered to the north by Paredes PC, to the south by Guasimal PC, to the east by La Junta community, and to the west by Banao PC, about 11 kilometers from the main settlement, which is Paredes.

The area is fundamentally flat, with an approximate extension of 2.21 km and an average annual temperature oscillating between 24 °C and 27 °C; the predominant winds are from the north to the northeast, with an average rainfall 1,538 millimeters per year. It is located at the coordinates 21°46,5.49 to the north and 79°24,47.33 to the west, with an elevation of 42 m above sea level (Figure 1).

The community has ten houses, proportional to the number of families living in the settlement, totaling 24 inhabitants. Of the total number of homes, six are relatively close together, within a 200 m, and the remaining (four) are far from the nucleus of the community.

The main access route is the dirt road that connects the adjacent PCs (Paredes and Guasimal), and the inter-municipal bus is recognized as the primary means of transportation, running two days a week (Tuesday and Thursday), with one departure in the morning and one entry in the afternoon.

Figure 1: *Satellite image of Los Alazanes with a graphic representation of its houses using Google Earth. DataSource: FRE local Project.*

Dynamics and socio-demographic structure of the population of Los Alazanes

According to the study on human settlements in Cuba carried out by the Center of Studies of Population and Development, appertaining to the National Office of Statistics and Information (Oficina Nacional de Estadísticas e Información, 2019), the community has the category of hamlet since its population does not exceed 200 inhabitants. This classification starts from the analysis of the structural and functional elements of the community and its correlation with the structure and dynamics of the population.

With an average age of 44, the population under analysis shows a predominance of men (15) in the intervals 0-30 and 40-70 years, over women (9) between 30-60 years, which is shown in the community's population pyramid (Figure 2).

It is crucial to study the small presence of young people under 30 years of age, representing 25% of the population and 20.8% of working age (Figures 2 and 3). The limited insertion of young people in the cooperative farmer sector, represented by 16.66% (Figure 3), is considered one of the most pressing problems within the agricultural sector, based on how these issues affect the development and sustainability of productive processes.

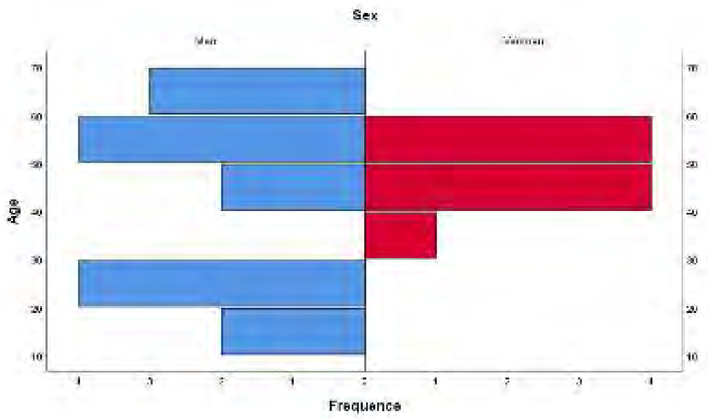

Figure 2. *Population pyramid of Los Alazanes. DataSource: FRE local Project database.*

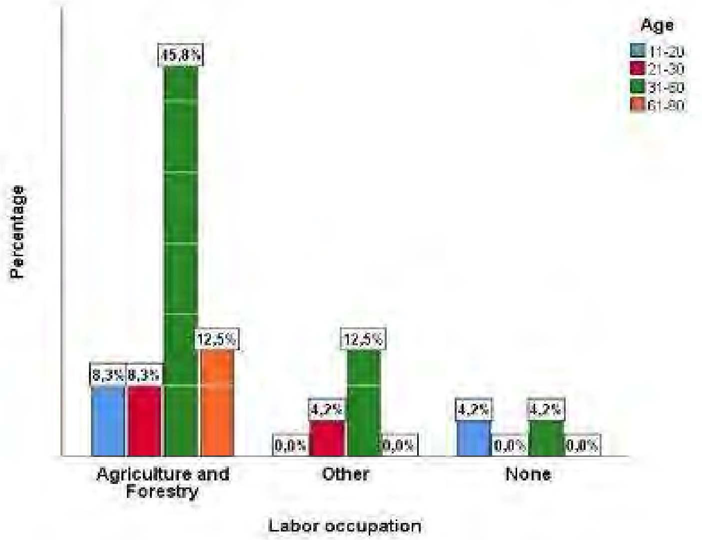

Figure 3. *Distribution of Los Alazanes population according to labor occupation disaggregated by age groups. DataSource: FRE local Project database.*

The issue of employment in rural areas reveals several issues that must be addressed in the new concept of development in the light of technological change. The results show inequities that could be associated with territorial factors, the contents and demands of work, the limited remuneration for work and household income, and the many sociocultural factors that shape the population's behavior in rural areas.

Despite the poor demographic representation of young people, it is encouraging to note that 75% of both genders are involved in the agricultural and forestry sector (Figure 4), with a male predominance of 54.2%.

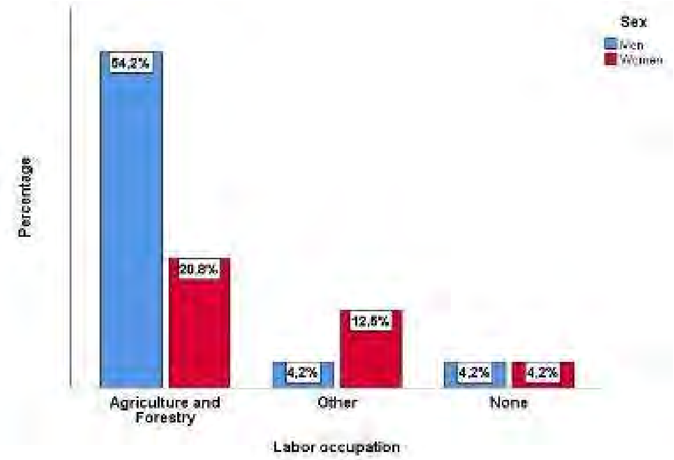

Figure 4. *Distribution of labor occupation in Los Alazanes disaggregated by sex. DataSource: FRE local Project database.*

Access to employment for men and women in rural areas generates public-private conflicts as an expression of their attachment to the patriarchal culture. In these scenarios, productive entities can play a relevant role in promoting new modalities of articulation between work and family life and access to employment and equal participation.

Equal opportunities between men and women respond to the imperative of correcting and reversing existing inequalities and disadvantages in the various spheres of society. It guarantees that women and men can participate in the spaces and activities of economy, politics, social participation, decision-making, leadership, education, training, employment, etc., based on equity.

As a part of the questionnaire, the "activity matrix"[1] was applied, taking into account the conceptualizations of productive work, reproductive work, and community work. The information obtained enabled us to understand the dynamics of gender relations in everyday life and the dynamics of mutual support, and the efforts of both. According to the roles assigned to men/women, it was found that 34.8% play reproductive roles, 47.8% are productive[2] , and 17.4% state not to play any of these roles.

The distribution of tasks by men and women in the home showed how the participants interpreted the place and role characteristics as different from those in society, where the differentiation pointed

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[1] *It describes the responsibilities and tasks carried out by men/women in each moment of the day.*

[2] *Productive role (activities and tasks destined to the production of goods and services: activities producing personal and household incomes. Incomes can be either in money or in kind). Community role (activities carried out to facilitate community development -volunteer work, promotion and management of services in the neighborhoods, organizational work within political organizations).*

to an overload of work in women and a subordination of them to offer services to the whole family. These distributions reflect women and men's roles historically assumed, expressed in physical and manual work and domestic and social work.

The conceptualization of women as "complementary" to men has hindered their recognition and autonomy in the performance of tasks of various kinds, particularly those related to the agricultural sector, such as agricultural harvesting and the care and feeding of small livestock, considered by many as a sector only for men. However, women are not paid for carrying out these tasks in this community.

The energy deficit directly impacts the quality of life in the community, particularly in women, both in terms of health and in terms of the loss of opportunities for improvement or family well-being.

In group work with women of the community, it was found that they suffer from an overload of activities related to the reproductive role (activities and tasks dedicated to the care and maintenance of the house: cooking, washing, ironing, caring for children, and the elderly), especially during the hours when they receive electrical energy.

Households are a crucial center for decision-making and power relations. Therefore, it is essential to identify the scope and limits that their adult members have to participate in decisions, especially the degree of autonomy. Regarding participation in decision-making, families are predominantly engaged in democratic dialogue (77.8%), while 22.2% are male-dominated.

This data does not disregard the fact that in the popular imagination, there are still vestiges of patriarchy insofar as they define as "help" the tasks they perform in the domestic space. Regarding the marital status of the population, whether by marriage or de facto (without legal or religious procedure), it was found that 41.7% of the population claim to be married, 45.8% accompanied, and only 12.5% unmarried; a reality that illustrates a characteristic behavior of rural areas.

The population shows low education levels: 37.5 % of the members reached the 9th grade, 12.5% finished technical middle school, and only 4.2% achieved a university degree. This reality expresses the lack of opportunities and the limitations of mobility that have marked the rural sector (Figure 5).

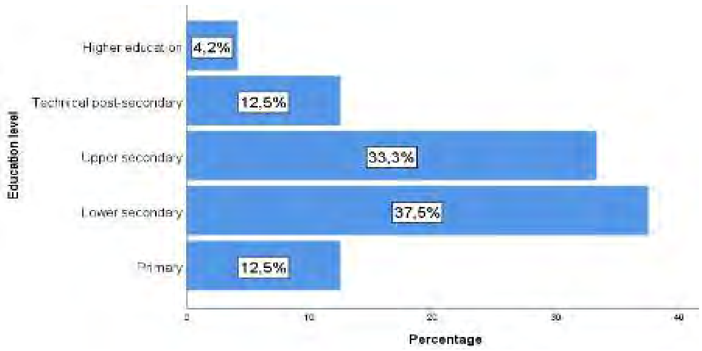


Figure 5. *Education level of Los Alazanes community members. DataSource: FRE local Project database.*

It is not only about achieving high levels of education or expanding study opportunities for the community's youth but also about strengthening the knowledge and skills based on their work activity.

> *"I have two children of school age still, but only one was able to become a middle technician. Fortunately, they do not want to leave, but it would be perfect*

for everyone if young people could train in something that benefits our community". (Testimony of a member of the community)

Training is a dynamizing factor for innovative processes with direct local implications for those who have responsibilities in the community.

Concerning the indicators associated with employment, it was possible to confirm that 54.2 % of the population is involved in the labor sector. Typical of the isolated rural communities, a not insignificant percentage of housewives and unpaid workers are expressed (16.7% in both cases) (Figure 6).

This data offers a comprehensive vision of the demands, needs, and employment opportunities, as relevant criteria to consider in the analysis of economic and socio-productive indicators of the community.

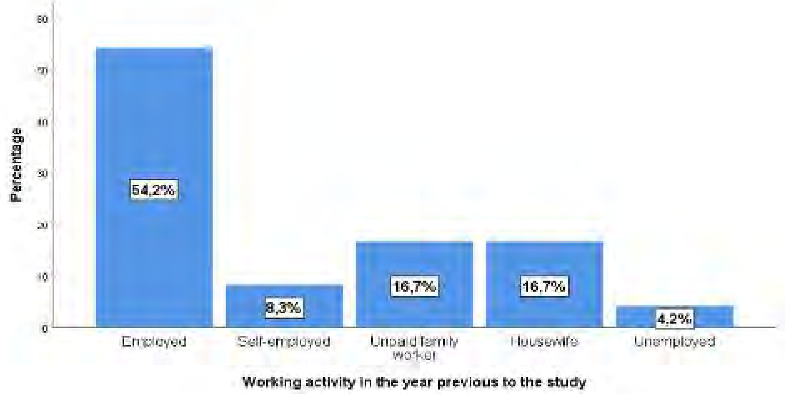


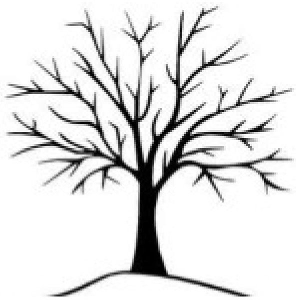
Figure 6. *The working activity of the Los Alazanes population in the year before the study. Data-Source: FRE local Project database.*

Historically, the community has shown rates of demographic decline that could be associated with sociocultural factors such as migration, access to goods and services, employment, and women's empowerment. However, with a tendency to stability in the last five years, the community must delve into the elements of conditioning mobility to guarantee the sustainability of the strategic actions conceived to implement RES technologies in the community.

Sociocultural dynamics of Los Alazanes

The founding origins of the Los Alazanes community date back to the beginning of the last century, and its first inhabitants settled in the nucleus of what is today the settlement of Paredes. However, due to strategic and mobility issues, its first settlers decided to move to the place where Los Alazanes is settled today, a place that is distinguished by its natural richness and the sense of identity of its people, of which more than 85% refer to have kinship ties (Figure 7).

Filiberto D. **Hernández** Blanco
Carlos **Hernández** Blanco
Ridelsy **Hernández** Reyes
Carlos **Pérez Cuellar**
Emiliano **Pérez Cuellar**



René **Rabelo Hernández**
Eduardo **Rabelo** Suárez
José F. **Rabelo** Casas
Nisdel A. **Rabelo** Fardales
Félix M. **Rabelo** Orellana

Figure 7. *Geodemographic tree of Los Alazanes.*

Its name is closely related to a deep-rooted cultural practice, the horse tournaments. Hence Los Alazanes pays honor to chestnut horses that are said to display bold behavior. Craftsmanship is part of the sociocultural map of the community. It symbolizes for the inhabitants and their families the energy of nature and the roots to the land, as a genuine expression of identity and tradition:

> *"I learned the craft with my mother since I was a little girl I started to make my yarey[1] things, then I incorporated other natural things like seeds and dry leaves. The corojo[2] came later (...)." (Testimony of a member of the community)*

As part of the peasant tradition of the country's center, the community units among its longest-lasting cultural practices: the weaving with *yarey* fibers and the elaboration of culinary products (sweets, preserves, jams, and others).

The development of political and social life within the community is reflected in the integration of its members into the prominent mass organizations existing in the country. There is a good performance on the part of the community leaders regarding these organizations, and they assume with enthusiasm the actions, responsibilities, and tasks correspondingly executed.

On the other hand, the community especially values the community celebrations of historical character (Day of the CDR[3], Day of the FMC[4], July 26[5], International Workers' Day, Anniversary of the Triumph of the Revolution, the Cuban Peasant's Day, among others...) as an expression of their commitment with the revolutionary social project of Cuba and their sense of community. Furthermore, 75 % of the families declare to have been born in the community or resided in it for more than 25 years, so the commitment and identification with their land are established as principles of co-existence for its inhabitants (Figure 8).

High levels of well-being and satisfaction are reported among community members and within families, representing 68%. The idea of well-being becomes the support of cultural processes based on dignifying the human being, the local autonomy, and the social participation.

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[1] ***Copernicia baileyana***
[2] *Fruit of **Acrocomia crispa**, from the **Arecaceae** family*
[3] *Spanish acronym for Committees for the Defense of the Revolution, network of neighborhood committees across Cuba founded in 1960.*
[4] *Spanish acronym for Federation of Cuban Women, founded in 1960.*
[5] *Commemoration of the Assault of the Moncada Garrison, officially named "Day of the National Rebellion".*

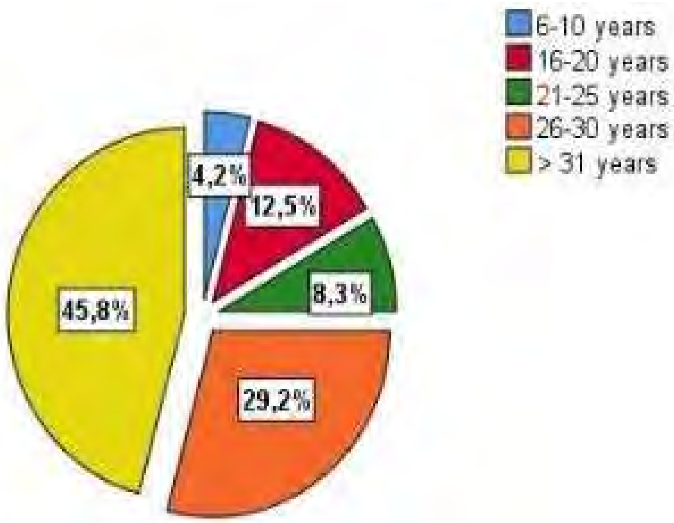

Figure 8. *Time of residence in Los Alazanes community. DataSource: FRE local Project database.*

However, community inhabitants explained that for some years, they had lacked some benefits that the social programs in force in the country offer to society in general that facilitate or enrich the process of integration and well-being. These services were moved to neighboring, more inhabited communities, which propitiates inequality.

Socioeconomic characteristics of Los Alazanes

Historically, the development of the Los Alazanes community has been based on agricultural activity, primarily dedicated to the production of sugar cane, coffee, livestock, and various crops such as rice and beans. Consequently, most community members are associated with the Credit and Service Cooperatives "Juan Manuel Almeijeiras" or "Paquito Rosales", considered the primary sources of employment and therefore the main source of income.

With an average salary of $3766.78, the family incomes range between 800 and 11,000 CUP per month, declared by the community as a high level of satisfaction. Therefore, this data expresses the growth perspectives of the community in good measure, based on the possibilities of development, innovation, and sustainability of the implemented actions.

Currently, the community lacks the most basic health and education services (school, doctor's office, pharmacy, etc.), so they must move 11 km to the communities of Paredes or Guasimal to meet these basic needs. The inadequate response to such a complex problem has generated some social discontent among the inhabitants, in parallel with reactions of mistrust towards the local authorities.

Despite the limitations to access health services, 77.8% of the inhabitants refer to having good health, and among the most recognized toxic habits is caffeine, which is present in 54.8% of the family members; in one case, it is combined with the consumption of narcotics, and only one case of alcoholism is referred.

The road leading to Paredes Popular Council is currently in poor condition, and in the rainy season, it is impassable. Therefore, it is a factor that limits the stability of public transportation (Figure 9). Accordingly, among the core issues to be addressed is precisely public transportation due to the lack of a safe and stable service that ensures the mobility of residents to the head municipality or at least to the closest communities.

Figure 9. *State of the road to Los Alazanes community. Source: FRE local Project.*

In an interview with the President of the Popular Council, Emeterio Carlos, it was noted that the issue of public transport is a significant problem that remains to be resolved. Over the years, communication routes have deteriorated considerably, and transport options are increasingly limited and unstable. He confirmed:

> *"The issue of transport is one of the most difficult problems we have here. We've been trying to improve that for years, but nothing... the people in the community have looked for some alternatives, but the road is very bad, and when it rains, the drivers don't want to go in." (Testimony of the President of the Popular Council)*

Currently, animal traction, in any of its variants, represents the most efficient means of transport in terms of mobility satisfaction.

As part of the variables addressed in the evaluation, a map of community actors was drawn up (Figure 10), showing relations with various organizations and institutions at the international, national (with specific provincial and/or municipal levels, depending on the area) and local levels. The community actors do not declare a history of working with projects and refer that the collaborative relationships between local actors that surround them, such as projects, companies, institutions, and the private sector, are unstable and of limited scope.

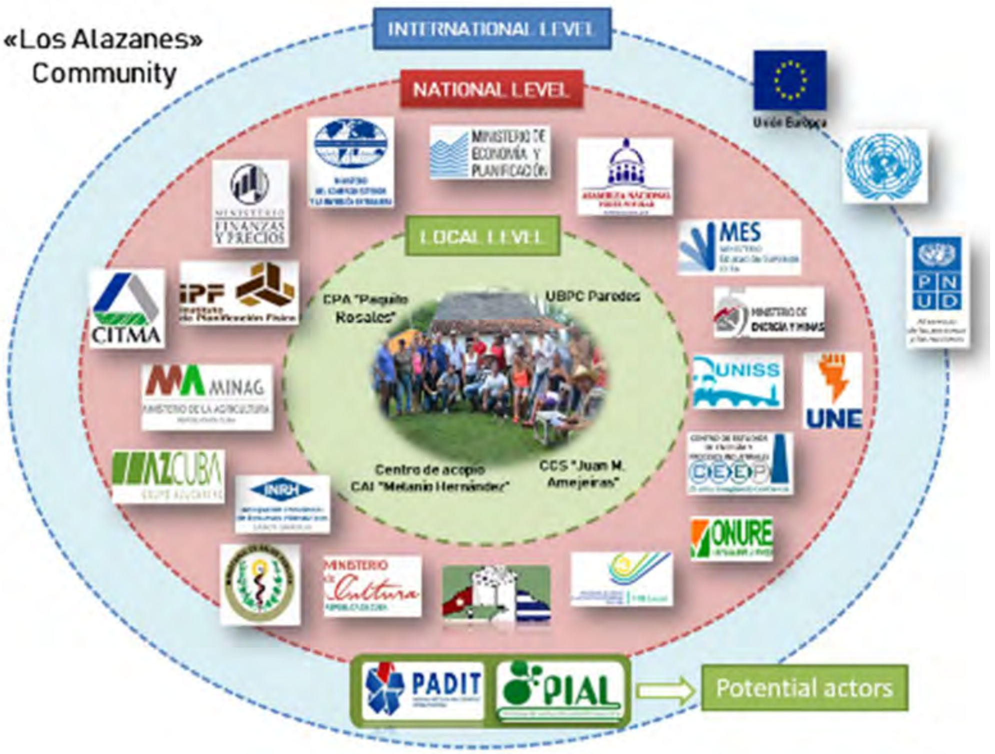

Figure 10. *Los Alazanes community actors map.*

It is perceived as a lack of connection among the responsible actors, from their actions to promoting strategic actions favoring local development. For example, actors as strong in the municipality as the Local Agricultural Innovation Project (PIAL, Spanish acronym) and the Articulated Platform for Integrated Territorial Development (PADIT, Spanish acronym) do not reach the community, so they are identified as potential actors for future synergies in the framework of the FRE local project.

These mediations are essential as they are based on the awareness processes of the social agents of change, "from scientists and technologists to politicians and educators, including communication professionals and the very reproductive agents of the culture of domestic life" (Ayús Reyes and Eroza Solana, 2007: 2). Therefore, open systems of dialogue and exchange, interleading, bridges between science advances, communication-information, and local knowledge should be promoted (Winder, Riveros, Pavez, Rodríguez, Lam and Herrera, 2009).

Habitat of Los Alazanes

It is important to note that families own 100% of the houses. They are made of wood, palm boards, and *guano*[1] roofs, although there are also (in their minority) wooden houses with tile roofs. Independent houses predominate, and 76.6% are in a normal state (Figure 11).

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[1] *Leaves of palm trees belonging to the **Arecaceae** family.*

Figure 11. *Housing in the Los Alazanes community. Source: FRE local Project.*

The inhabitants show moderate levels of satisfaction. The good hygienic condition of the houses is evident, marked by the hygienic-sanitary conditions and the cleanliness of the surroundings, favorable to the well-being of the community members.

The Los Alazanes community enjoys water supply in the homes, which the individual and community wells provide. However, 88.9% of the houses do not have running water or a network, and 11.1% outside the house (Figure 12a).

Los Alazanes does not benefit from an aqueduct or sewer system. There are individual and community wells near the houses, which provide drinking water for its inhabitants. However, none of them has running water inside their homes. 88.9% of the houses have improved pumping systems with hoses, while 11.1% depend on traditional outer rustic water pumps (Figure 12a). Regarding wastewater disposal, the drainage system of 66.7% of the families is through septic tanks or pits, while 33.3% claim to have none (Figure 12b).

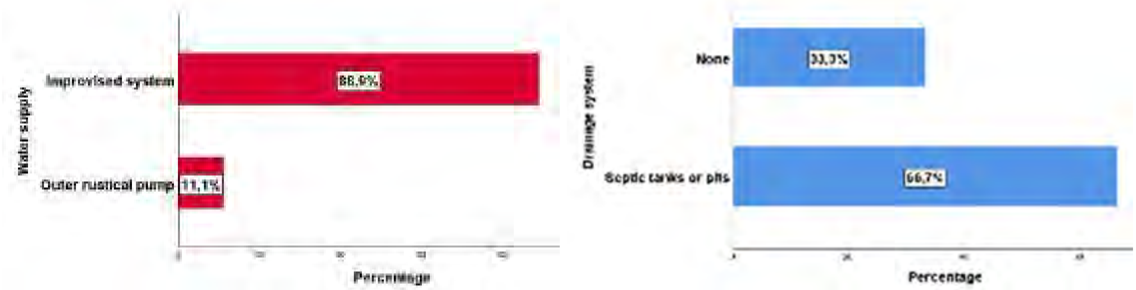

Figure 12. *Water supply and drainage system in Los Alazanes houses. Left panel: a) Water supply. Right panel: b) Drainage system. DataSource: FRE local project database.*

The impossibility of accessing running drinking water and the inexistence of wastewater systems is a limitation to the well-being of its population. Moreover, it is very relevant for the community due to its effects on the environment and human health.

According to peasants, soil management measures include a correct crop rotation, even if soil conservation and improvement measures are not widespread, which in some cases limits crop yields. This is a significant challenge since agricultural sustainability will only be achieved to benefit environmental resources, the economy, and the population's health by reducing agrochemicals and protecting the natural values of soils.

In any of its forms, the distribution and cultivation of land impact the individual forms of production and the identity of the peasant. It is essential to point out that 100% of families hold lands represented exclusively by men; six are usufructuary, and three are owners.

For women, the right to land is vital since it allows them to access financial resources, technological transfers, credits, and tax exemption benefits that, beyond economic aspects, contribute to dignifying their capacity and condition as women.

Land structure and tenure generate a change in the cultural dynamics of the peasant as a result of the interaction of multiple social and biophysical processes that occur at very different scales in space and time. The nine families surveyed state they hold land in any of its conditions, for 162.72 ha. The family with the least amount of land has only 2.5 hectares, and the family with the most has 40.26 hectares, for an average of 18 hectares per family.

Although the community shows high productive indicators, the land use index is low, marked by the insufficiency of hydraulic installations and irrigation systems, inadequate management technologies, and instability in the supply of equipment and inputs for the production process.

To assess the life model of the Los Alazanes community, an ecological footprint analysis was applied. It was defined as the "area of ecologically productive territory" (crops, pastures, forests, or aquatic ecosystems) needed to produce the resources used and assimilate the waste produced by a given population with a specific standard of living indefinitely wherever possible that area is located. It is expressed in global hectares per person per year. This indicator enabled us to compare the consumption of the population sector with the limited ecological productivity of the Earth. The footprint of this population was determined by its number of members, the volume of consumption, and the intensity of the use of resources to provide it with goods and services.

Based on studies from López Yanez (2003) and López Bastida and López Yanez (2014), it was possible to determine the ecosystem loading capacity and the ecological footprint of Los Alazanes. The analysis results express an ecosystem loading capacity of 2.30, a value that is considered in the appropriate range for isolated rural communities. Therefore, the total ecological footprint of this community in the current conditions is 0.0876 global hectares per person per year (gha/p*y), and it corresponds to the current footprint for Cuban rural settlements. Nevertheless, this value can decrease if the energetic Sub-footprint (0.009 gha/p*y), the cultivation Sub-footprint (0.066 gha/p*y), and the pasture Sub-footprint (0.006 gha/p*y) are reduced, as they are the ones that contributed the most to the total ecological footprint with the environmental, economic and social actions that are identified.

Of particular interest are the environmental problems, which the community inhabitants identify. They are emissions to the atmosphere of gases of the greenhouse effect, mainly carbon dioxide, methane, and nitrous oxide, derived from the burning of sugar cane in lands bordering the community; deforestation in the drainage basin and wooded areas due to the cutting of trees to use firewood as fuel (in times of the recent past); and the high consumption of fossil fuels, corresponding to the 1,000 liters of diesel that the generator consumes per month.

In addition to these issues, there is a lack of awareness, knowledge, and environmental education among the population, often due to the insufficient insertion of environmental issues in political agendas, programs and development plans at the municipal level.

Electricity consumption dynamics of Los Alazanes

As a primary energy source, the community has a Denyo D-45 KVA generator set, with a generating capacity of 42.2 kW and an output of 8 hours per day (Figure 13).

Figure 13. *Generator set of Los Alazanes community. Source: FRE local project.*

Its technical conditions are good, and it is adequately protected from the incidence of weather factors (atmospheric discharges, hurricanes, local storms, heavy rainfall, or other phenomena). However, the fuel consumption is 3.2 l/h, and there are difficulties in the supply of fuel due to the road's poor condition mentioned above.

The generator's attention and maintenance system is preventive and is carried out bi-monthly; it is coordinated by the Community Services Enterprise of Paredes community through the person of José A. Peña Nápoles (known as *El Chino*). In the community, Tomasa Nápoles, who is responsible for its operation in the foreseen schedules and must look for solutions to any problem that can occur, attend it.

> *"Since they brought the generator, I began to attend to it. Then El Chino came and taught me the general things; that is not difficult, but I was first a little afraid. Rene, my husband, also helps me, and when something happens, we immediately notify him. As the person in charge of the generator, I earn a pretty good salary, but I have never taken a course on that." (Responsible for the Generator)*

Of the ten families, nine were connected to the network (Generator) and one without connection. The technical state of the networks is terrible, with a predominance of electrical "clotheslines" (electrical wiring made by non-experts, usually with inappropriate wires). In addition, the community lacks public lighting, and inside the houses, the connections are in poor condition, with dimensions ranging from 4 to 50 meters. (Figure 14).

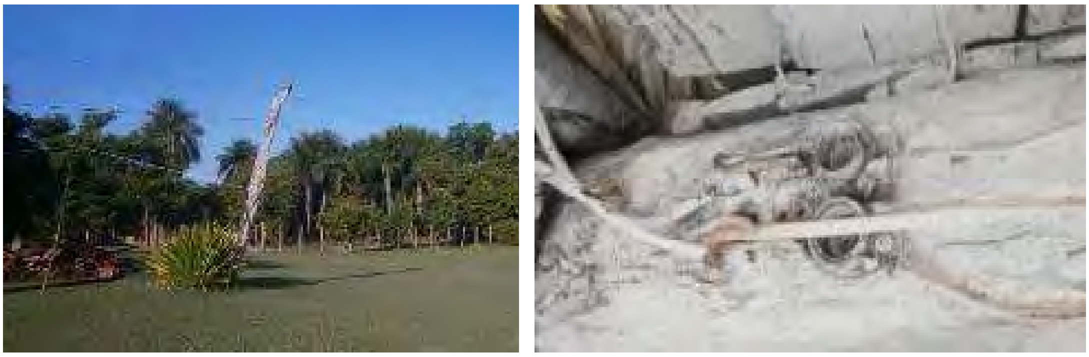

Figure 14. *Technical conditions of electric networks in Los Alazanes community. Source: FRE local project.*

The resource most used for cooking food is electricity with 77.8%, charcoal with 66.7%, and firewood being the least used resource with 11.1%. In three families, the equipment and devices for lighting are in normal condition. Home lighting is through electricity for 89.9% of the families; two cases refer they light their homes with candles, three with kerosene, and two with flashlights, with a tendency to use sunlight.

The predominant equipment for cooking food in homes is rice, pressure, conventional boilers, frying pans, and electric stoves. A high percentage of families also have a refrigerator, a television set, a washing machine, a DVD player, a fan, an iron, and a mixer. However, the limited power and instability of the current energy service limit the performance and useful life of the existing equipment.

According to the socio-economic conditions of the families, the quantity and quality of the available household appliances and the demand and distribution of the available electric energy could be foreseen as an energy coverage of 5.5 kWh/day from the development of RES.

Potential for the development of renewable energy sources in Los Alazanes

Information provided by the Provincial Meteorological Center of Sancti Spiritus enabled us to characterize the Los Alazanes community while considering some meteorological variables. The total daily incident short wave solar energy in the province of Sancti Spíritus, which reaches the surface of the Earth over a wide area, takes into account seasonal variations in the length of the day, the elevation of the Sun above the horizon, and the absorption of clouds and other atmospheric elements. Short wave radiation includes visible light and ultraviolet radiation.

Average daily incident shortwave solar energy has slight seasonal variations throughout the year. The brightest period of the year lasts 2.0 months, from March 13th to May 13th, with an average daily incident shortwave energy per square meter exceeding 6.5 kWh. The brightest day of the year is April 12, with an average of 7.0 kWh.

The darkest period of the year lasts 4.8 months, from August 30 to January 23, with an average daily incident short wave energy per square meter of less than 4.9 kWh. The darkest day of the year is December 12, with an average of 4.4 kWh.

Taking into account that on a sunny day, the Sun radiates around 1 kW/m^2 to the surface of the Earth and considering that the commonly used photovoltaic panels have a typical efficiency between 12 and 25%, this would mean an approximate production of between 120 and 250 W/m^2, depending on the actual efficiency of the panel. This enables us to affirm that this community has the potential to use solar energy to generate electricity. Besides, there are clear areas in the community, many adjacent to the houses, which would allow the use of this energy without interference from shadows.

The average wind speed has considerable seasonal variations throughout the year. The windiest part of the year lasts 7.0 months, from October 19 to May 18, with average wind speeds of more than 15.8 km/h (4.38 m/s). The windiest day of the year is November 25, with an average wind speed of 18.5 km/h (5.13 m/s). The calmest time of the year lasts 5.0 months, from May 18 to October 19. The calmest day is September 19, with an average wind speed of 13.0 km/h (3.61 m/s).

As for the water potential, it is noteworthy that the community is located about 3.66 km from the Cayajaná River spillway at its intersection with the Zaza Dam, which is well known for its strong currents and territorial extension. On the other hand, there are reserves of exploitable subway run-off, mainly dedicated to the water supply to the population and agricultural production. Along with the other water sources, eight wells are located near the houses and are owned by the area's largest producers of grains, food, and vegetables.

This community has a large amount of forest biomass used mainly for cooking. According to René Rabelo, formal leader of the community, they produce corn (from 40 to 70 tons per year), beans (40 quintals per year), coffee (12 cans per year), *corojo* (100 sacks per year), tomato, sweet potato, cucumber, beans, among other crops. Some of these crops need drying, and in the community, this is carried out in an area on the floor with potential damage from weather inclemency.

Of the ten families that live in the community, eight are dedicated to raising animals, including pigs, chickens, and *pelibuey* sheep, for 643 (Figure 15). In most cases, animal husbandry is non-stabled in the face of the adversities imposed on the animals to obtain food steadily and safely.

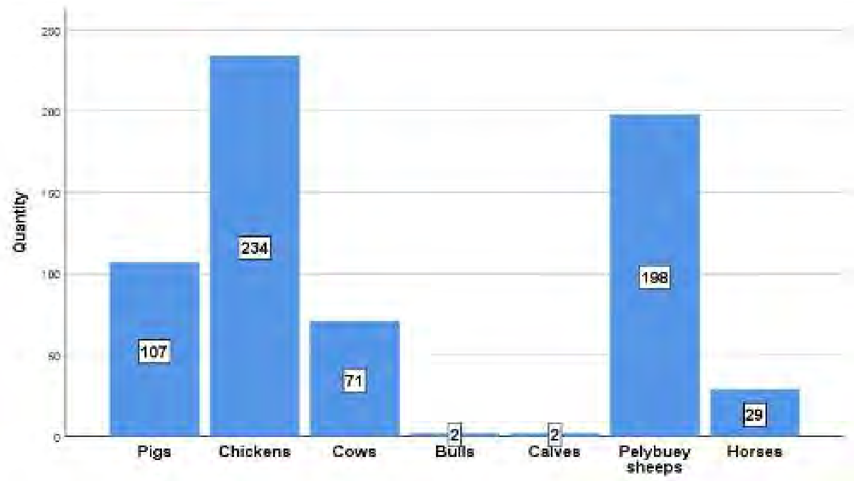

Figure 15. *Livestock at Los Alazanes. Quantity of animals. DataSource: FRE local project database.*

The community's livestock is rustically fed without the proper preparation of feed, which includes the milling of cassava and protein plants, thus contributing to increased milk and meat production. Under the protection of good relations between families and the absence of criminal acts (theft and sacrifice) in the community, keeping the animals free in open fields represents a more economical

option for producers. As a relevant criterion, we must emphasize the inhabitants´ willingness to stable them, an indispensable condition for using biomass as an energy source.
As a potential resource for the future development of mini-industries, the elaboration of products derived from *corojo* (soap and oil) and *yagua*[1] (loofah and craft products) stands out. In parallel, the high production of fruits offers strategic opportunities that privilege the production and commercialization of preserves such as tomato puree and fruit pulp (guava, mango, custard apple, banana, cherry, etc.).
Human potential is the main wealth of the Los Alazanes community, taking into account their resilience to face adversities, undertake new projects, integrate as a social group and participate in the search for solutions. Through group dynamics (Figure 16) supported in the problem tree technique, the inhabitants expose their felt needs regarding lacking access to electricity and their potential to assume the FRE local project, get involved, and socially construct RES appropriation processes.

Figure 16. *Group dynamics with inhabitants of Los Alazanes. Source: FRE local project.*

In terms of the levels of information, it was found that a high percentage of those surveyed feel informed about renewable energy sources (RES), either through the mass media or in spaces of consultation within their community or cooperatives; with the most significant knowledge on solar energy (87.5%) followed by biomass (62.5%) and hydropower (37.5%).
However, the level of information does not ensure mastery of the applications and benefits that this resource can have for the family and the community, expressed in the 86% who assert not feel prepared to work with RES. As a good criterion, they show motivation and interest in receiving training that allows them to develop the technology to be implemented adequately.
The community favors training courses as concrete proposals to enrich their knowledge about RES. Other proposed ways are support materials, technical assistance, and exchanges with producers

[1] *Palm leaf sheath.*

who develop this technology. These data clearly show the willingness of the community's inhabitants to improve themselves and develop their capacity to work with RES technologies.

Therefore, the socio-technical education/training conceived by the FRE local project should consider the value or relevance of the technology and the knowledge, experiences, conflicts, resistance, fears, and uncertainties as a guide for transformative action under the principles of participation and sustainability.

Undoubtedly, the electrification of rural areas contributes to the integration of the agricultural sector into national economic development, increases income generation through the introduction of clean technologies, improves the living conditions of families, and slows rural-urban migration.

From this understanding, technological possession starts with literacy and ends with the reconstruction of democratic procedures. The idea is to highlight the collective beyond the one-dimensional vision of the subject of social action. The political is found where people develop various strategies to confront the traditional rationality of exclusion and build a diversity of intersubjectivities that carry precise demands for participation.

Conclusions

The studies and social practices related to the electrification of rural communities from the use of technologies associated with RES are unique to each case, and present complex challenges, adjustment processes associated with the social dimension, intercultural dialogues, variable patterns, which must be addressed in a particular way in the achievement of transformative actions in the local space. Thus, the actors involved assume a proactive and participatory positioning in the project's design, implementation, and gradual evaluation.

The case study of the rural community of Los Alazanes shows the contextualized and eminently participatory vision of a socio-technical intervention, which integrates the end-users of the energy change in the construction of the solutions. The essence starts from the collective identification of felt needs to the evaluation of potential alternatives, taking into consideration the type of socio-productive dynamics to be favored and the incorporation of the knowledge and cultural practices of the people involved.

From this understanding, the technological appropriation starts from the evaluation of the localization and geomorphological aspects, the socio-demographic structure, the sociocultural dynamics, the socio-economic characteristics, the habitat, the electricity consumption profile, and the potentialities for the development of RES in the community. It ends with the reconstruction of democratic procedures. A diversity of intersubjectivities is built, carrying precise demands for participation where collectivity stands out beyond the one-dimensional vision of the subject of social action to confront the traditional rationality of exclusion.

The results of the critical evaluation of the Los Alazanes community offer a development perspective associated with RES implementation. This new perspective comes to fruition if the combined actions of its potentialities are considered. These aspects are solar energy, the water potential of the area, the forest and animal biomass, the productive activity for the development of mini industries, the coexistence of a stable population, and human potential. Furthermore, in addition to the previously mentioned, the resilience capacity of the inhabitants to face adversities, the willingness to take on new projects, and the willingness to integrate as a social group and participate in the search for solutions should also be considered.

Promoting the energy transition in a rural community based on the rational use of all the resources associated with RES imposes privileging the human dimension. This translates into achieving collaboration and coordination among all governmental, institutional, social and non-state factors to enhance joint work in the search for solutions that consider the complexity of this process in the community.

Energy present and future for Cuba set out a path towards the renewable development of each of our resources, particularly the human one. Only from an increasingly transparent, democratic, and decentralized positioning in local energy management can generate new conceptions, practices, and innovations for the local space's benefit.

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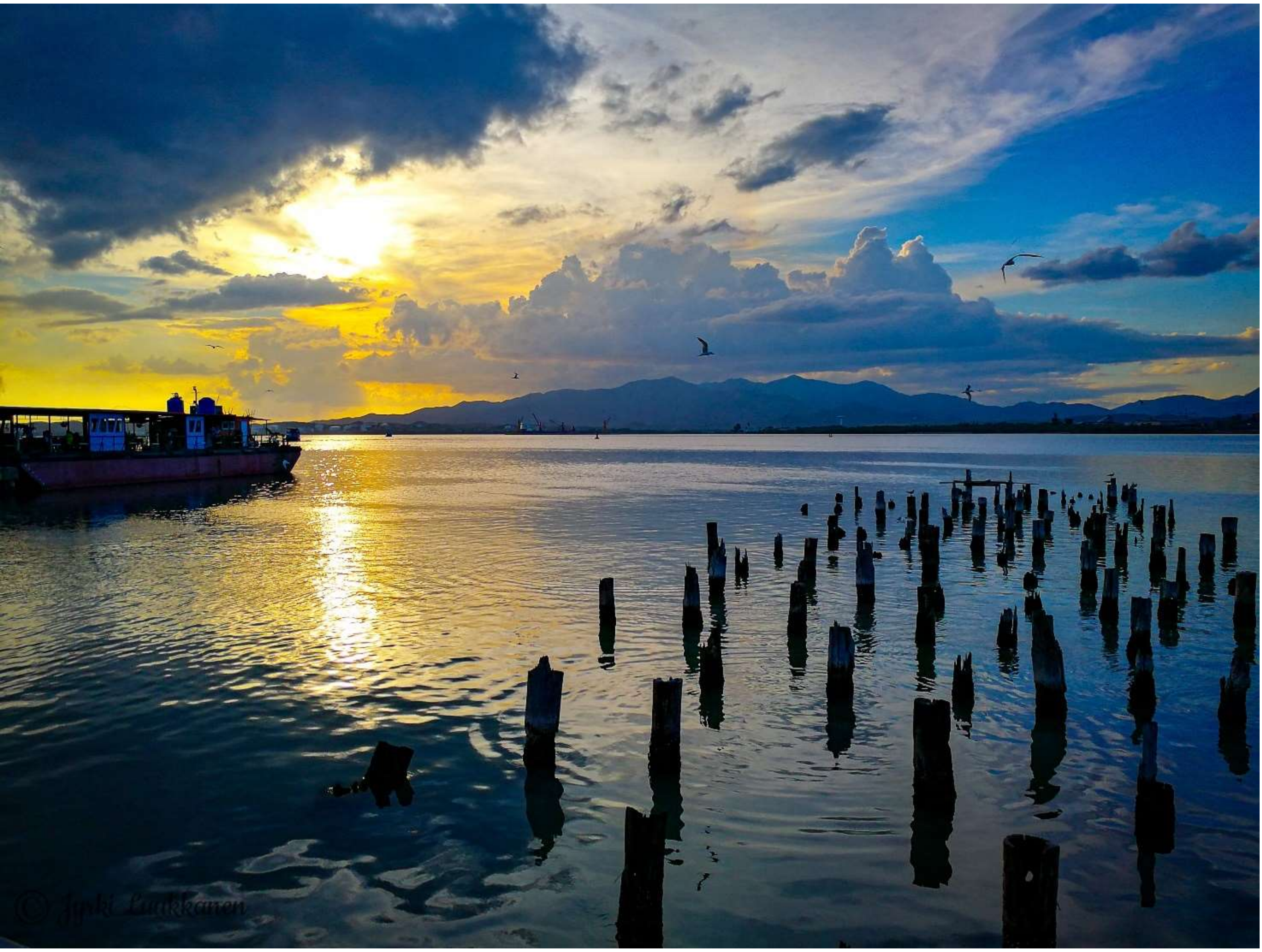

IV. Environment

IV.1. Environmental management and energy policy in Cuba

Arielys Martínez Hernández, Miladys María Garrido Cervera and Yanet Pita Peláez

The protection of the environment has been gaining relevance and has ceased to be a specific concern of isolated environmental groups, to become a priority of the entire society and form part of the development policies of most countries in the world. However, and despite the international efforts made in recent years, it has been possible to stop neither the process of depletion and inappropriate use of the resources provided by the earth nor the contamination of the environment. This shows the need to continue delving into this issue, which everyone can influence (Ocaña and Antúnez 2012).

Before dealing with any aspect related to the theme of the environment, it is necessary to define this term. In the doctrine, several concepts of the environment can be found, with consensus in the perceptions poured into it. According to the specialist in the field Gómez Orea, in 1988 he stated: Environment is the stimulating environment, that is, the set of physical-environmental, aesthetic, cultural, social and economic factors that interact with each other with the individual and the community in the one that lives, determining its form, relationship, character and survival (Ocaña and Antúnez 2012).

Law 81 on the Environment of the Republic of Cuba, approved in July 1997, establishes in article 12 as a fundamental concept that the environment is the "system of abiotic, biotic and socioeconomic elements with which man interacts, while at the same time adapts to it, transforms it and uses it to satisfy its needs" (Ocaña and Antúnez 2012).

The Ministry of Science, Technology, and Environment (CITMA, 2021) identifies the main environmental problems that Cuba has in the current strategic cycle 2021-2025, those with the most significant impact on a national scale and those that have not reached the projected goals have been considered, or its progress has been discreet. Consequently, the following criteria have been taken into account:

- Impact on significant areas of the national territory due to their size and/or values.
- Duration and intensity of the impact produced in the densely populated areas.
- Effects on the health and quality of life of the population.
- Impacts on food security.
- Effect on ecosystems and biological resources.
- The resources and processes on which the impacts of climate change are most strongly produced.
- Citizen perception (emergence of complaints, proposals, among others)

The main environmental problems identified show a complex and dynamic interrelation affecting natural resources linked with socioeconomic development. Therefore, its ordering does not imply any hierarchy:

- Soil degradation.

- Effects on forest cover.
- Pollution.
- Loss of biological diversity and deterioration of ecosystem goods and services.
- Lack of and difficulties with the management, availability, and water quality.
- Adverse effects of climate change.
- Deterioration of sanitary hygiene conditions in human settlements (CITMA, 2021).

Among its strategic directions, CITMA (2021) has the following objectives:

No. 1: Guarantee economic growth considering the rational use of natural resources, reducing environmental impacts and environmental degradation.

Actions of Objective No. 1:

1. Counteract soil degradation, desertification, drought, and other adverse processes by promoting sustainable management and land neutrality approaches.
2. Stop poaching and illegal trafficking of flora and fauna species and prevent the introduction of invasive alien species and reduce their effects on terrestrial and marine ecosystems.
3. Promote the sustainable management of forests, recover degraded ones and increase afforestation and reforestation, following the national goals.
4. Increase the efficient use of water resources in all socioeconomic sectors.
5. Promote the sustainable management of mineral resources, ensuring the rehabilitation of degraded areas and their ecosystems. Avoid and rehabilitate environmental liabilities (CITMA, 2021).

Actions of Objective No. 2:

Ensure the conservation, restoration, and sustainable use of terrestrial and marine ecosystems to avoid adverse effects, increase their resilience, and recover their health and productivity.

Actions of Objective No. 2:

1. Integrate the values of ecosystems and biological diversity into development planning processes.
2. Implement economic incentives (tax, credit, tariff, among others) to achieve the financial sustainability of ecosystems and natural resources (CITMA, 2021).

No. 3: Reduce/eliminate negative impacts on the environment and people's health through the development and reconversion of infrastructure, achieving the sustainable management and efficient use of natural resources.

Actions of Objective No. 3:

1. Advance in the modernization of infrastructure and the reconversion of industries, using resources more efficiently and promoting the adoption of a circular economy and clean industrial technologies and processes.
2. Reduce the negative per capita environmental impact of cities and urbanized areas, with particular attention to air quality, noise pollution, liquid waste treatment, and municipal and other solid waste management.

3. Strengthen the rational management of chemicals and hazardous waste, emphasizing single-use plastics throughout their life cycle and significantly reducing their release into the atmosphere, water, and soil.

4. Significantly reduce the percentage of untreated wastewater; and increase its reuse and recycling.

5. Prevent and face social indiscipline that affects environmental quality using comprehensive solutions and the participation of all sectors of society (CITMA, 2021).

During the 2021-2025 cycle, CITMA will work in three directions: restoring ecosystems that infrastructures have levels of reconversion to improve technology and preserve natural resources (Alonso, Arce and Izquierdo, 2021).

To measure the effectiveness of this strategy, the ecological footprint, climate resilience, and environmental quality will be used as indicators, the latter more linked to pollution issues (Alonso, Arce and Izquierdo, 2021).

A power plant, Santiago de Cuba (Termoeléctrica)

The State plan to confront Climate Change in the Republic of Cuba, known as “Tarea Vida”, is adopted by the Cuban Government in response to its national goals and its international commitments. It constitutes a broad and ambitious program to face climate change in the national territory through adaptation and mitigation measures (Tarea Vida, 2021).

The main objective of the Life Task (Tarea Vida) is to protect human life and its quality in conditions of a changing climate; For this, it involves all sectors of the economy and society and is applied at the national and local level (Tarea Vida, 2021).

Its implementation is supported by the Bases of the Country's Economic and Social Development Plan until 2030, where it is recognized as an objective to mitigate climate change and promote less carbon-intensive economic development (Tarea Vida, 2021).

Its actions include: Implementing and controlling climate change adaptation and mitigation measures derived from sectoral policies in programs, plans, and projects related to food security, renewable energy, energy efficiency, territorial and urban planning, fishing, agricultural activity, health, tourism, construction, transportation, industry and the integral management of forests (Tarea Vida, 2021).

In the treatment of environmental problems, this issue should receive special attention, emphasizing, based on the knowledge of its implications for Cuba, raising the knowledge and sensitivity of citizens regarding the imperatives of adaptation and mitigation opportunities. The issue should be approached as an umbrella element from which other closely related environmental problems or issues can be addressed. Sustainable energy use is defined among the remaining problems (Tarea Vida, 2021).

As can be seen, the use of energy and the care of the environment in Cuba are not closely linked. More importance is given in CITMA to the impact of drought and increased temperatures, which cause species substitutions, greater aridity, fire risks, and lower soil fertility and water availability.

Different ministries direct energy and the environment. In the case of the environment, it is directed by CITMA, and in the case of energy by the Ministry of Energy and Mines (MINEM), which are in charge of all aspects of the country's energy policy.

MINEM is the body in charge of proposing, approving, directing, and controlling the policies of the State and the Government in the energy and geological, and mining sectors of Cuba regarding:

1. Guarantee the preparation of application policy proposals in the Electricity branch, in coordination with the National Directorate of Energy Policy and Strategy, for submission to the Government's approval and their periodic updating and control of their implementation once approved.
2. Guarantee the preparation of proposals for the development programs of the Electricity branch, in the medium and long term, in coordination with the National Directorate of Energy Policy and Strategy, for presentation to the approval of the Government, as well as their periodicity update and its implementation once approved.
3. Control compliance with state and government policy on the generation, transmission, distribution, and commercialization of electric energy.
4. Collaborate with the National Directorate of Energy Policy and Strategy and the Ministry of Economic and Planning (MEP) to prepare electricity consumption plans for all sectors of the country.

Although among the Sustainable Development Goals proposed by the United Nations in its 2030 Agenda is to guarantee access to affordable, safe, sustainable, and modern energy for all, the most widely used sources continue to be oil, coal, electricity, and gas.

Cuba has encouraged the development of hydropower plants, wind farms, and solar panels and has drawn up policies for energy saving in the country (Ramos, 2021).

According to the MINEM, 95% of the national energy mix is made up of fossil fuels, while it is expected that in 2022 the generation of energy through renewable sources will grow to 6.3% of the total produced by the country (Ramos, 2021)

An industrial power plant, Moa

In 2019, four experimental wind farms with a total power of 11.8 megawatts (MW) were already installed in the Greater Antilles, in addition to another 70 photovoltaic solar parks, with 207 MW of power, reaching an electricity generation of 310 gigawatts hour (GWh) per year and replace approximately 81,000 tons of fuel in 12 months, according to the source (Ramos, 2021).
On the other hand, 24,081 isolated solar panels are installed in schools, polyclinics, isolated homes, and the family doctor's home, among others. As a result, the potential for solar radiation in the country is approximately five kWh per square meter per day (Ramos 2021).
Concerning hydropower, the MINEM indicates that there are, nationwide, 162 hydroelectric plants with a total installed power of 71.9 MW. The one with the highest power is the Hanabanilla Hydroelectric Power Plant, with 43 MW (Ramos, 2021).
By 2030, Cuba aspires to reach 24% of energy generation with renewable sources.
Today, environmental protection is about a whole. Economic aspects are covered, but many of the natural assets influence resources that can be used for life and development, such as raw materials,

renewable energies, and even medicines. This aspect is not considered in Cuba but is left to the management and energy policy to take charge of renewable energies.
Speaking of energy policy, we will see below how its inefficient management affects the emission of the greenhouse effect.
The use of energy in all its forms provides enormous benefits to society. However, it is also associated with numerous environmental and social challenges. The generation of electricity from fossil fuels produces different negative impacts. At a local level, the most significant is atmospheric pollution; at a regional level, acid rain and deposition, and at a global level, climate change (Roig, Meneses and Soto, 2018).
The current costs of electricity generation in Cuba (CUBADEBATE, 2014) are 21.1 cents USD/kWh and 6.5 cents CUC/kWh delivered, higher than those reported in the bibliography for the most common fossil technologies. The strategies until 2030 are aimed at reducing these costs by around 15% and changing the current energy mix, increasing the share of renewable sources from 4.6% to 24% (Meneses, Roig, Alonso, Paz and Alvarado, 2020).
Considering the high generation costs and without considering environmental costs, it is possible to evaluate various technologies for their introduction into the country's energy mix. However, it is crucial to evaluate the environmental costs of each technology, as there is no spotless one. These impacts caused by electricity generation are considered external costs or externalities when they are not included in the energy market prices and therefore distort optimal economic decisions. Modern societies are faced with the challenge of being able to "internalize" the costs associated with these impacts. However, even if they are not correctly internalized, knowing them helps create more favorable conditions for designing policies and strategies to reduce the emissions generated by this sector. These could include introducing emission reduction or control technologies and using more efficient and/or less polluting fuels. The studies have mainly focused on the damage caused by air pollution (Roig, Meneses and Soto, 2018).
The use of biomass in Cuba for electricity generation is carried out mainly in sugar plants with a dual purpose, the production of heat and electricity. During the so-called harvest periods, the current sugar mills produce the electricity they need from cane waste and deliver the surplus to the National Electricity System (Roig, Meneses and Soto, 2018).
An installed capacity of 755 MW is expected to be gradually incorporated until 2030 as part of the current strategy for introducing renewable sources. The sugar industry is called upon to change the current energy mix with a participation of 30% in 2030. Environmental impact assessments are essential for new investments, demonstrating that the new facilities comply with established environmental standards and do not aggravate the existing problems. In the case of sugar mills, air pollution problems are not dealt with, nor are they subject to regulations (Roig, Meneses and Soto, 2018).
Currently, no power plant has particle emission control technology, and there are complaints from the population about their emissions in towns near these facilities (Roig, Meneses and Soto, 2018).

The solar power plant, Abel Santamaría, Santiago de Cuba

Conclusions

Environmental management in Cuba deals with the mitigation of the greenhouse effect and climate change regarding the effects of economic activities on ecosystems.

Environmental pollution has negative impacts on society, so special attention has been given to the Life Task (Tarea Vida) plan.

In Cuba, environmental management and energy policy go their separate ways when they should be a single policy for the country's future.

The environmental impact costs per kWh of generation in the power plants are higher than direct economic costs, which shows a high volume of emissions from electricity generation, increasing the environmental costs. This makes an environmental, and economic study essential to control emissions from energy production.

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V. Transport

V.1. Electric vehicles in the Cuban transport system

Miguel Castro Fernández

Introduction

The Millennium Development Goals (MDGs), which were the United Nations (UN) working guide during the period 2000 to 2015, evolved in 2015 into the so-called 2030 Agenda for Sustainable Development, whose objectives and goals seek to stimulate actions for the period 2015 - 2030 in critical areas for humanity and the planet. Sustainable development is a concept closely linked, among others, to technological advances that can be applied to produce and use energy in an efficient and environmentally friendly way in the different spheres of life. One of the significant concerns of today's society is finding alternatives to reduce dependence on fossil fuels and their derivatives in the different facets of production, transport, marketing, and consumption of goods and services, which have contributed significantly to climate change.

An electric bus, Havana

In particular, in transport, the concept of sustainability has gone through improvements. This can be seen in the type of fuel that was used during the 2000-2015 stage, to the massive introduction of electric vehicles (EVs) as a substitute for automotive transport internal combustion, particularly in cities or urban areas. From this point of view, the introduction of EVs is closely linked to the sustainable development of cities. As reported by the UN, the percentage of people expected to live in cities by 2050 will be close to 66% (UNDESA, 2014), while the world population will reach almost 10 billion during the same period. This entire population will require mobility, and if urban

transport already causes much pollution, the outlook for the future is almost catastrophic if the concept of transport based on fossil fuel is continued.
On a regional scale, there have been efforts to reduce environmental pollution associated with the use of fossil fuels in transportation. For example, the European Union has promoted cleaner air in cities by adjusting particle emission standards from 0.648 g / km in 1992 (Euro I) to 0.018 g / km in 2013 (Euro VI) for vehicles in transit (Cooper et al., 2012). This trend has improved air quality in the last 20 years and will continue to do so in the coming years, but for public transport to achieve zero particle emissions, total system electrification is required.
According to the International Energy Agency (IEA) (International Energy Agency, 2017), cities such as Paris, Amsterdam, and London in Europe and San Francisco, Seattle, and Los Angeles in the United States, have developed efforts to propose policies and guidelines that will encourage the use of EVs, to reduce carbon dioxide (CO_2) emissions. As a result, by 2016, close to 2 million EVs were reported internationally. It would be worth asking, then, how these policies have changed the effect on the intensity of pollution associated with land transport, based on the introduction of EVs in the market and the technological improvements they have shown? Figure 1 shows precisely this evolution, based on an analysis carried out on the producers with the most significant weight of EVs in the period 2012-2017 (Staffell et al., 2018).

***Figure 1**. Evolution of environmental pollution associated with the introduction of EVs in the international market.* (Staffell et al., 2018).

Looking to another region of the planet, in October 2015, the Ministry of Industry and Information Technology of the People's Republic of China reported that the production of 100% electric vehicles grew 850% compared to the previous year. For this, the Chinese Government implemented a program of measures, with tax exemptions and subsidies, which have helped accept and spread sustainable mobility.
In March 2015, the Ministry of Transportation of China established a goal to meet, before 2020, the incorporation of 300 thousand commercial vehicles, 200 thousand buses, and 100 thousand taxis, all 100% electric. In addition, it approved a strategic plan until 2020 for the construction of infra-

structure through a nationwide recharging network, which includes stations equipped with photovoltaic solar panels and energy storage systems. Under this program, as of 2017, China has emerged as the undisputed world leader in collective electric transportation. 99% of the 385,000 electric buses on the roads around the world were of Chinese technology (it represented 17% of all the fleet of that country at that time), while every five weeks, Chinese cities added 9,500 zero-emission buses, equivalent to the entire operating fleet of London according to Staffell et al. (2018). From a global perspective, the initiative for the total electrification of public transport will contribute to the efforts being made in the direction of change in the energy mix at the international level. Local public transport in cities offers the opportunity to introduce electric mobility with electric buses. Two of the main arguments for introducing EVs in the private and individual transport sectors are broken when approaching the analysis of collective transport, since the driving profiles, ranges, and characteristics of the route are well known and clear. In the latter, charging can be carried out in well-defined places. Therefore, there is no need for comprehensive public charging infrastructure.

An electric car, Havana

Background in Cuba

In the 1990s, based on the idea of the historical leader of the Cuban Revolution, Fidel Castro Ruz, and with the support of the Automotive Development Institute (IDA), a version of EV was developed at CUJAE with an autonomy of 60 km and a translation speed of 80 km/h that demonstrated the possibility of its construction from national technologies.

In Cuba, a specific electrified transport market has begun, which began with the entry, by private parties, of more than 100,000 electric motorcycles for private use. On the other hand, since 2019, the Aguas de La Habana company has incorporated 22 vans, 100 percent electric, for maintenance and repair services of networks with excellent results and savings in fuel consumption of up to 70 percent. The charge of the EVs of Aguas de La Habana is carried out by the National Electroenergetic System (NES) in the early morning, and during the day, they plan to generate the equivalent electricity of the charge with photovoltaic solar panels. One of these vehicles has V2G technology available, which has allowed the use of this technology in media for work in the field, such as compressors, hammers and/or thermofusion technology for work in hydraulic networks, with an evident saving of the fuel also associated with these tools, in its diesel variant. As reported by directors of Aguas de La Habana, a necessary repair and maintenance brigade of said company, with EVs, can travel 1 million 100 km without consuming fuel, without consuming oil, without spare parts in storage for maintenance, with a total of 90,000 liters of diesel saved and maintaining the availability of the fleet of 95%.

An electric motorbike, Havana

On the other hand, companies such as ETECSA (Cuban Telecommunications Company) and other entities of the Ministry of Tourism have taken steps to have their vehicle fleet, or in the future, different technologies of EVs. However, although they are positive steps and demonstrate a vision of the future, they should be done under specific regulations and terms that allow the introduction of this technology to be made sustainable.

The impact of the introduction of this technology on Cuba

According to data that are handled in Cuba, the automotive fleet in Cuba is made up of about 569 thousand tractive vehicles, of which about 501 thousand vehicles are technically suitable, with an average age of 35 years (where 77 percent are over 20 years of operation). Annually that consumes around 992 thousand tons of fuel, of which 74 percent diesel and 26 percent gasoline, with a high emission of greenhouse gases into the atmosphere (pollution), mainly in the cities.

The electrification of this sector would be in the strategic direction of contributing to the security and energy independence of the country by reducing its dependence on oil. This could also result in increased energy efficiency and technical availability of means of transport to increase the quality of public passenger and productive transport. Furthermore, since this transformation also changes the country's use of fossil fuels, it foresees a considerable decrease in greenhouse gas emissions, better use of Renewable Energy Sources (FRE), and a possible more efficient operation of the National Electricity System (System Electroenergético Nacional SEN).

The electrification of transport in Cuba would contribute to the concept of sustainability of Cuban society within the United Nations 2030 Agenda program. If this is feasible to achieve, reaching a certain level of integration of the national industry to this process with the production of parts, components, and a possible product to offer, technically and economically feasible to be marketed in competition to those that would appear in the national market, the advantages of this process would be undeniable.

From the point of view of the business and/or private sector, the benefits could include the following:

- Ministry of Industries (MINDUS). - It would be able to produce and commercialize light electric transport to the residential, productive, and state and non-state service sectors at low cost and with a high level of after-sales service, in conjunction with the Ministry of Transport of Cuba.
- Ministry of Transport (MITRANS). - As the governing body of transport in Cuba, it would establish a technological base in this type of economic activity that is not negligible from the point of view of safety and comfort for passengers, as well as a technology that would improve the condition and operation of public transport would be introduced. Furthermore, with the associated use of Renewable Energy Sources to charge the batteries in the charging stations of the companies of said ministry, the consumption of energy from the electricity grid would decrease, thereby reducing the operating costs of national transport. At the same time, the expenses made by this ministry abroad to offer and maintain a stable and safe transportation service to the population would decrease.
- Ministry of Energy and Mines (MINEM) and the Electricity Corporation (UNE) .- the association to the charging stations, in the different organizations and public or private entities, of power systems from renewable energy sources (in particular photovoltaic systems and/or hybrids including wind turbines) would reduce the load or demand to the National Electric Power System (SEN) in hours. That could be crucial for demand peaks and allow the load curve to flatten and reduce the difference between the valley and the peaks in the SEN, improving its efficiency.
- Private sector. If low-cost EVs are achieved, it will allow a given group of legal entities to access this technology, improving their lifestyle by reducing the costs associated with the exploitation, operation, and maintenance of these vehicles.

On the other hand, the introduction of this technology, although it has associated a group of impacts from the point of view of scientific and technological knowledge given its novelty and its current introduction in the country, also offers an impact from the point of view of economic, social and environmental view. This could be indicated as:

- In the economic. Decrease in hard currency expenses abroad to purchase light transport equipment for the domestic market and introduce new products in the domestic market produced by the domestic industry.
- In the social. A new possibility will be offered to the state and non-state productive sectors and the private sector to access a technology that, based on comfort and price, helps improve the quality of life of the population. It will also reduce costs of operation, exploitation, and production, helping to reduce the prices of a group of essential products for daily life.
- In environmental matters. - reduction of CO_2 and NO_x emissions, fundamentally, to the atmosphere, which contributes to the concept of sustainability of the socialist society that is built in Cuba by reducing the consumption of fossil fuel for passenger transportation, with the production and sale of this type of technology in Cuban society.

The electrification of transportation in Cuba is very likely to be characterized by:

- Priority of conversion and/or introduction of technology in urban buses, taxis, and tricycles used for public transport in cities and in buses, cars, jeeps, motorcycles, and tricycles that are used to transport tourists within tourist poles. Cars that are used for the rental of tourism, and low-power utility vehicles, which do not have registration and provide services within entities, such as, for example, in hotels, hospitals, and airports, are also included.
- Promote and/or prioritize the fleets of the entities that carry out their activities in the cities and are composed of buses, minibusses, low tonnage trucks, panels, vans, cars, and tricycles that are dedicated to the repair and network maintenance, product distribution and marketing services and administrative functions.
- Normalization and/or standardization of types of connectors and communication protocols, taking into account potential supply markets and future developments.
- Use of renewable energy sources as a requirement for investments that seek the electrification of transport as a way to reduce consumption of the network and achieve a contribution from the stations and charging points, which are connected to the network, with the generation of the National Electroenergetic System.
- Encourage alliances between national industry and universities and research centers to introduce science and innovation in the electrification of transportation in Cuba.
- Promote strategic alliances with leading international manufacturers that allow conditioning the national industry to assemble and/or manufacture EVs and batteries for export and national consumption from national raw materials.

An electric motorbike, Havana

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V.2. Control of energy efficiency of cargo transport

Yanet Pita Peláez and Arielys Martínez Hernández

Introduction

The current energy model, based fundamentally on the use of fossil fuels, is unsustainable; therefore, energy savings and increased energy efficiency are required not only due to the continuous increase in energy prices but also due to environmental deterioration caused by energy production and consumption (Cleves, Prias, and Torres, 2015).

Energy efficiency is essential for the sustainable development of countries and significantly impacts both profitability and sustainability of industrial production. As global energy demand continues to grow to meet the needs and aspirations of people worldwide, actions to increase energy efficiency become more important. Reducing energy use responds to business logic: it reduces costs and greenhouse gas emissions and improves the image of companies. It also reduces exposure to the volatility of energy prices and helps to ensure its supply by reducing dependence on imported energy sources (Gómez and Chou, 2019).

So why is it often so difficult to implement energy-saving measures? Why not make small changes in the behavior of our organizations with which we could reduce the amount of energy we use? Nevertheless, unfortunately, many companies are reluctant to pay attention to energy management or invest in measures to improve energy efficiency (ONUDI, 2014).

Daily transportation in Havana

In Cuba in 2011, the updating of the Economic and Social Model was planned, approving the guidelines of the economic and social policy of the Party and the Revolution within the framework of the VI Congress of the Communist Party of Cuba. In June 2014, the Council of Ministers of Cuba approved the policy for the future development of renewable sources and the efficient use of energy, where it emphasized the need to increase energy efficiency by changing the structure of the current energy mix and its relationship with the competitiveness of the national economy; by reducing dependence on imported fossil fuels, energy costs and environmental pollution (Campillo, 2018).

In the context of updating the Cuban economic and social development model, there is evidence of a political will to promote the management processes of the energy mix, expressed in the Conceptualization of the Model, the National Plan for Economic and Social Development (PNDES) until 2030 and the Guidelines approved in the VI and VII Congress of the PCC. Specifically, one of the guiding principles of the PNDES until the year 2030 recognizes the country's aspiration to transform and develop, accelerate, and efficiently the energy mix by increasing the participation of renewable sources and other national energy resources and employment of advanced technologies to consolidate the efficiency and sustainability of the state sector and, consequently, of the national economy. On the other hand, in the strategic infrastructure axis of the Plan above, one of its specific objectives is to guarantee, in conditions of environmental sustainability, an adequate, reliable, diversified, and modern energy supply that substantially increases the percentage of participation of the renewable energy sources in the national energy mix, essentially biomass, wind and photovoltaic (Martínez, 2018).

An electric motorbike, Havana

In addition, in the preliminary version of strategic economic sectors, which was approved by the III Plenary of the Central Committee of the PCC and endorsed by the National Assembly of People's Power, it was defined that one of them is the electricity sector. This sector is conceived based on transforming the energy mix with greater participation of renewable sources and other national energy resources, ensuring increased efficiency and oil and gas exploration and refining. The elements mentioned above show the strategic importance of the topic addressed by this research for the development of Cuba. On this basis, there is a National Energy Knowledge Management Network (REDENERG), which allows the articulation of various actors linked, directly or indirectly, to the energy sector to accompany and advise decision-makers in the identification process of energy problems and their solutions (Martínez, 2018).

In the freight transport sector, energy efficiency can be evaluated by calculating an average energy consumption per equivalent vehicle, calculated as the ratio between the total consumption of land transport and the total fleet of motorized vehicles expressed in the equivalent vehicle. The difference between the energy consumption of land transport per vehicle and per equivalent vehicle corresponds to the effect of changes in the vehicle fleet. Therefore, the improvements in energy efficiency can be better evaluated with the variation of the unit consumption per equivalent vehicle since it can be inferred from the changes in the vehicle fleet. Although there are some discrepancies in the energy consumption of land transport by equivalent vehicles between countries with very similar fuel prices, the differences may be due to real differences in the energy efficiency of the vehicles or their size, in addition to statistical problems with the vehicle fleet in use (the over-estimate, which underestimates the specific consumption), or the over-estimate of land transport consumption (ADEME, 2016).

A local gas station, Havana

The efficiency of energy control in the exploitation of automotive freight transport in the province of Pinar del Río is a problem since this activity generates large consumption of energy carriers. This

sector also does not have the mechanisms for effective control of energy management, so it was decided to study the issue in-depth and correspond with the specific situations observed to create a procedure for the control of energy management in cargo transport.
Below are the indicators that evaluate changes in energy efficiency (Ministerio de Energía y Minas, 2017).

- Consumption indices:
  - Energy consumed / Production carried out
  - Energy consumed / Services rendered
  - Energy consumed / Built area

They relate the energy consumed (kWh, liters of fuel, tons of fuel, and equivalent tons of oil) with indicators of activity expressed in physical units (tons of steel produced, hectoliters of beer produced, rooms-days occupied, tons-kilometers transported, m^2-year of air-conditioned buildings).

- Efficiency Indices:
  - Theoretical energy / Real energy
  - The energy produced / Energy consumed

These are used mainly to monitor changes in the efficiency with which countries or branches of the economy use energy. For a company, the energy intensity would be the ratio between the total consumption of primary energy and the market production expressed in values.

- Economic-Energy Indices:
  - Energy Expenses / Total Expenses
  - Energy expenses / Income (sales)
  - Total energy consumed / Value of the total production carried out (Energy Intensity)

The broader concept of energy efficiency refers to reducing the amount of energy (electricity and fuels) used to generate a good or service without affecting the quality of the products, the comfort of the users, or the safety of the facilities, people, and goods. This reduction in energy consumption can be associated with incorporating new technologies, either by replacing existing equipment with high-efficiency units and electric motors or by optimizing processes, such as automation of operations that present high variability. Although additional investments may be required, these are offset in the medium term by lower energy-related costs (De Laire and Aguilera, 2017).

Transportation in a rural area, Carretera *La Gran Piedra*

Energy efficiency in Cuba

Energy efficiency in Cuba is implemented through the ISO 50001 standard. A committee has been created for its implementation, whose initial task is to prepare a training program to detect the need for training in energy efficiency in the business sector. The process starts with the most significant consumer companies in the country based on the experiences accumulated in energy management for more than 20 years, in addition to establishing the provisions for conducting an inspection of energy carriers in consumer entities throughout the country and serving as a methodology for developing control actions carried out by ONURE (ONURE, 2019).

This committee is made up of the National Office for Standardization (ONN), the National Office for the Rational Use of Energy (ONURE), and the Energy Efficiency Network of the MES (Table 1) (Lapido, Borroto, Gómez, and Montesinos, 2015). Below are the legal provisions that regulate the work of the ISO 50001 Implementation Committee.

***Table 1**. Legal provisions that regulate the work of the ISO 50001 implementation Committee.*

No.	Document Type	Number	Year	Name	Ministry or Entity
1	Resolution	20	2009		Ministry of Finance and Prices
2	Law	107	2009	Law of the Comptroller General of the Republic.	
3	Instruction	1	2011	Instruction of the General of the Army for planning the objectives and activities in the Organs, Organisms of the Central Administration of the State, National Entities, and the local Administrations of the People's Power.	Of the President of the Councils of State and the Minister
4	Resolution	60	2011	Rules of the Internal Control System.	Comptroller General of the Republic.
5	Resolution	12	2012	Creation of the Office for the Control of the Rational Use of Energy.	Ministry of Energy and Mines
6	Resolution	32	2012	Methodology for the evaluation and qualification of audits.	Comptroller General of the Republic.
7	Instruction	5	2015		Ministry of Economy and Planning
8	Resolution	152	2018	Energy Carrier Inspection Manual.	Ministry of Energy and Mines

Energy efficiency in the cargo transportation sector in Cuba.

In an efficient economy, the growth rate of material production must be higher than the growth of freight transport. The growth of transportation expenses should not be confused with the "development of transportation", which should go ahead of the economy to facilitate and promote its development (infrastructure, media, technology). It must be taken into account that transport does not develop for itself. It is a function of the producer and consumer, the economy, and the population.

In Cuba, after the confiscation of private companies in 1960, freight transport remained with a high degree of centralization until the end of this decade, when a process of specialization and decentralization of transport began. In the 1970s, the need to implement the load balance and control the shipment through EXPEDITRANS was extinguished in 1992 due to the beginning of the special period, in which transportation was reduced by 70%. About 5,000 trucks from the MITRANS system are transferred to different companies.

The change of paradigms in the field of transport became noticeable in 1991, when most of the transport equipment was Soviet, with notorious technological backwardness and of the problems raised by the then president of the republic Fidel Castro Ruz “we know them well and we can say that, at least, they worked and were strong teams; but, indisputably, the fuel cost was tremendous”. In 1993, the State Traffic Unit was created to demand compliance with the Balance execution process and guarantee state control over cargo dispatch, coordination, and delivery. However, load balances were not carried out. In parallel with decentralization, suppliers develop the practice of delivering products at the source, forcing each buyer to manage transportation to collect the products. These conditions make centralized transportation planning impossible. As a result, the diesel traffic or energy intensity indicator behaves as follows:

- MITRANS companies consume between 27 and 32 t / MMtkm (tons of fuel for every million tons of traffic kilometers).
- Railways consume 13 t / MMtkm.
- Professional transporters from other organizations consume between 45 and 80 t / MMtkm.
- Trucks scattered throughout the agencies consume between 300 and 400 t / MMtkm. Furthermore, more than 70% of the trucks are dispersed in non-professional transport organizations (Moreno, 2015).

With the introduction of GPS to cargo equipment in 2006, the companies obtained significant achievements in optimizing material, financial, fuel, lubricant, and motorcycle resources in general for the operation of the vehicle fleet. These achievements are obtained by the precision with which the distances traveled by these means can be quantified, which increases companies' economic and energy efficiency. To evaluate the economic and energy efficiency obtained, the behavior of the Diesel-Traffic index, diesel consumption, and expenses will be analyzed, making it possible to compare one period with another. The work procedures issued by MITRANS are used, which are applicable in the transport bases that quantify their production through the traffic indicator, expressed in millions of tons of kilometers traveled (MMtkm) (MITRANS, 2014).

Norelve Bombino Duardo, head of the Ministry of Transport Directorate, explained that the program's strategy is to promote the efficient exploitation of the available vehicle fleet, especially with fuel savings and increased transport discipline in the fight against spurious actions of some state vehicle drivers. He added that by this application, it is possible to calculate naturally the fuel consumed by the vehicles subject to the referred control and stated that, when comparing the energy efficiency indicators, before and after the incorporation of the transport bases into the system, "we see that from 2006 to the end of 2013, the national economy saved more than 105,427 tons of fuel" (MITRANS, 2014b).

The re-motorization of high-consumption equipment has been promoted through state plans and a reordering of the country's freight transport and planning by physical consumption rates in each economic sector. Thanks to these measures, fuel savings for transportation in the state sector during 2009 and 2012 reached an average of 662,000 tons of oil per year (FAL, 2010).

In 2013, the Sancti Spíritus Raw Materials Recovery Company (ERMPSS), based on a diagnosis of energy management (GE) using the Total Efficient Energy Management Technology tool, was possible to define the existing conditions before work. Furthermore, it analyzed the indicators that technically should be used to demonstrate the energy feasibility of the reorganization and how savings can be achieved by: rationalizing the park, relocation by municipalities based on the levels of each activity, and rigorous use of maintenance engineering. As a result, it saved 51,443.97 liters of diesel for an economic effect of 36,010.78 CUC (Requejo, Bravo, and Mendoza, 2013).

In an energy evaluation in the Construction Transport Company of Granma, based on the structure of its consumption, it was found that the primary energy carrier in the company is diesel fuel. Furthermore, when analyzing the Key Positions and Key Areas in energy consumption in the organization, it was determined that the Iron Harrows (RP) and the Tipping Harrows (RV) are the largest consumers. As a result, the curves of the consumption indices of the two transport activities that consume more than 80% of the diesel fuel in the entity were obtained, which allowed evaluation of the actual consumption indices and proposed a decrease in the consumption indices of 5%, which represents a saving of 29,933.7 liters of diesel fuel, equivalent to 29,634.4 CUC of savings in financial resources in three years. Therefore, when analyzing the results, it is concluded that the company has savings potential but must determine the current consumption rates and evaluate the possibility of reducing the consumption rates of both lines (RP and RV) by 5% for the next year (Sánchez, 2015).

In May 2014, the cargo transport policy in the country became part of the policy group of the Ministry of Transport (MITRANS) to comply with its mission and the PCC Guidelines, which can be highlighted in the following actions:

- Railroad recovery program.
- Re-motorization program, manufacture of semi-buses and Diana buses.
- Program for the generalization of taxi leasing to taxi drivers.
- The 11 transport cooperatives were established on an experimental basis.
- The policy for the regulation of passenger transport in Havana was approved
- Reorganization of passenger transport in Santiago de Cuba.
- Proposal to improve the structure and functions of MITRANS.
- Work is being carried out in parallel on seven proposals for transport development policies, a fundamental tool to channel the sector's efforts.
- Improvement of MITRANS social communication.
- The re-registration and badge change process continues.

- The fleet management and control system using GPS is applied to more than 12 thousand teams and more than 300 transport bases (MITRANS, 2014).

The president of the Councils of State and Ministers, Miguel Díaz-Canel Bermúdez, and ministers of the Cuban government appeared on September 12, 2019, at the Round Table to report on the country's measures adopted in the current energy situation. As a cross-cutting activity in the economy, transport impacts all sectors and, above all, the population. At this juncture, explained Eduardo Rodríguez Dávila, minister of the sector, main lines have been defined:

- Prioritize the use of the railroad due to its high energy efficiency.
- Ensure the mobility of fuel, food, and exports.
- Maintain communication with the Isla de la Juventud
- Maintain activity levels in ports.
- Guarantee the regulated family basket.
- Reorder public transportation and prioritize medical services.
- Extend the departure of the trains "because everyone will not be able to travel on the planned day," he said.
- A daily bus will be maintained between the provincial capitals and Havana, and those who do not wish to travel will have the value of their ticket refunded.
- Public transportation will be redesigned during peak hours, and bus sections will be shortened.

According to the bibliography consulted, no tools or established procedures have been found to control the efficiency of cargo transport.

However, the efficiency of energy control in the exploitation of automotive freight transport in the province of Pinar del Río is a problem since this activity generates large consumption of energy carriers. This sector also does not have the mechanisms for effective energy management control, so it was decided to study the subject in-depth and correspond with the specific situations observed to create a procedure for effective energy management control in cargo transport.

Given this, plans and economic programs for the modernization of transport vehicles are being undertaken to increase transportation efficiency and alleviate the low efficiency in the final use of fuel. However, although current vehicles are modernized, if not proper work procedures are used, what is improved by technique is lost in disorganization. The characteristics of automotive freight transport condition the need for strict planning, organization, coordination, and control so that it can be carried out with quality and efficiency at the times when it is demanded and is characterized by:

- High costs per unit of cargo, especially fuel.
- Low load capacity.
- High maintenance and repair requirements.
- The short useful life of the media (Moreno, 2015).

In November 2019, new legal regulations for developing renewable sources and the efficient use of energy came into force. Decree-Law No. 345, “On the development of renewable sources and the efficient use of energy”, accompanied by complementary resolutions from the ministries of

Energy and Mines and Internal Trade and instruction from the Central Bank, establishes the priorities and regulations that will govern this sector. It also introduces novelties in terms of the state and residential sector, with the sale of surplus energy to the Electric Union (UNE) and the marketing of equipment, parts, and pieces, whose main objectives are to increase the contribution of sources of renewable energy, in electricity generation, the progressive substitution of fossil fuels, the diversification of the structure of fossil fuels used in the generation, and the increase in efficiency and energy savings (Extremera San Martín, 2019).

A truck-bus, Camioneta, Santiago de Cuba

Cargo Transportation

The specific characteristics of cargo transportation determine the need for strict planning, organization, coordination, and control to be executed efficiently and well. Automotive transport is characterized by:

- High costs per unit of cargo, especially fuel.
- Low load capacity.
- High maintenance and repair requirements.
- The short useful life of the media.

➢ Organizational principles.

- Flat and agile business structure.
- Autonomy and professional responsibility.
- Performance of chief facilitators, who provide confidence and motivation to employees and clients.
- Customer orientation with quality services.

➢ The base of the business organization.

- Personnel with:
    - technical and commercial knowledge,
    - good communication skills,
    - good organizational skills,
    - a positive attitude to solve problems.

Close contacts and permanent communication with clients and other people and organizations related to the services. Need to have a NETWORK of offices or agents, which is formed at all times, for the management and control of transportation.

Modern theories suggest that organizations as a business structure, regardless of their size, must be "flat." The age of "one over one" administrative structures is over. The inefficiency of rigid bureaucratic structures, with many hierarchical levels, is no longer tolerable in companies that must serve customers and provide quality and efficient service. Current development requires eliminating bureaucracy, reducing hierarchical levels, avoiding filters and obstacles, and achieving direct communication between those who execute and those who lead (Cañizares, Rivero, Pérez, and González, 2014).

Any service company has only two focal points: customer service (external focus) and business administration (internal focus). The structures had to reflect these two focal points. Maintaining a solid interface between the two focal points is necessary: Customer Service and “Internal Administration”. Within the latter, the following stand out: the operations group, which maintains control over the movement of the media; the technical group, which must ensure the technical availability of the means and the economic or financial group. The success of any transport company depends on how its leaders and employees can provide the service required by its customers to meet their expectations. Therefore, it is essential to develop an "Energy efficiency control system for freight transport", which guarantees punctuality, speed, safety, and service costs, the fundamental attributes of transport (Durán, 2017).

Truck transportation, Havana

Advantages and disadvantages of freight transport

Advantages include (Fonseca, 2015):

- Direct transportation from the starting point to the destination.
- High maneuverability and speed.
- According to its characteristics, Cargo transportation capacity is general cargo, solid bulk, liquid bulk, equipment, and others.
- Cargo and passengers can be transported even where not all road network conditions exist, such as highways and roads.
- Diversity of teams with different capacities allows the use of the medium according to the quantity and characteristics of the loads.
- The costs of the facilities are relatively low compared to other means of transport.

Disadvantages include (Fonseca, 2015):

- Limited passenger and cargo transportation capacity.
- The costs of road infrastructure are high.
- High cost of maintenance and repair.
- Notwithstanding these disadvantages, automotive transport plays a determining role in the country's economic development.

The author defines the energy-efficient control system for freight transport as the control of the behavior of transport operation indicators that allow the transported cargo to be in the time established by the client, with the traffic produced, the average distance of a ton, the trips made and the energy intensity required. This contributes to optimizing transport operations for better decision-making. Each of the operating indicators is explained below.

Leading Indicators of Transport Operation

The leading indicators to take into account when operating cargo transport are the following:

Cargo Transported:

- It is the total weight of the goods transported by the vehicles in a given period. It is expressed in tons of 1000 kg. (The weight of the goods is certified by the weight or declared in the Drive or Remission) (Moreno, 2015).

Produced Traffic:

- Express the transport production in ton-kilometers. It is the sum that results after having multiplied the tons of cargo transported on each trip by the kilometers traveled by said cargo. Unfortunately, some mistakes multiply the tons transported by the total kilometers traveled with cargo and not the tons transported each trip by the distance with cargo corresponding to each trip (Moreno, 2015).

To better understand what has been explained, an example of the traffic of 5 trips of a 20t truck with a consumption rate of 2.1 km / l is shown.

Table 2. Example of the traffic of 5 trips of a 20t truck. with a consumption index of 2.1 km / l

Travels	Tons	Km Loaded	Ton-Km	Total Km	Empty
1	19	65	1235	250	185
2	15	50	750	90	40
3	8	30	240	80	50
4	16	80	1280	190	110
5	5	28	140	70	42
TOTAL	63	253	15939	680	427

The average distance was 15939/63 = 253 Km

Table 3. The traffic of 20 t in distribution

Km	X	Tons	Ton-Km
10		3	30
15		10	150
20		5	100
25		2	50
25		**20**	**330**

The mean distance was 330/20 = 16.5 km.

Average Distance of a Ton: The average distance in kilometers that a ton of cargo is transported; is obtained by dividing the sum of the traffic carried out by the transported cargo.

Trips Made: Total trips with cargo made in a given period. The trip is considered from when the vehicle is loaded at origin until the moment the transportation ends and is available to start a new operation.Energy Intensity (Diesel-Traffic Index): It expresses the number of liters of fuel consumed to produce one ton-kilometer. It is calculated by dividing the number of liters of fuel by the ton-kilometers produced. (Liters / TKm) It is also expressed as tonnes of fuel per million tons kilometers. (t / MMTKm).

From the theoretical analysis of the different conceptual areas, similarities are evident between the concepts that allow their articulation in the energy-efficient control system. The study carried out from various sources and practices shows the low relevance given to controlling the energy efficiency system of freight transport companies. The lack of a control procedure is revealed as an instrument contributing to decision-making.

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VI. Conclusions

VI. Concluding remarks

Jyrki Luukkanen, Jari Kaivo-oja and Jasmin Laitinen

The articles in this book, "*Cuban energy futures. The transition towards a renewable energy system – Political, economic, social and environmental factors,*" deal with several research questions. They try to analyze the energy transition from different perspectives and different contexts. The articles look at the Cuban transformation in the global political context, Cuban national context and provincial and local contexts, and consumer context. The transition in the energy use from fossil energy sources to renewable energy sources is seen as necessary from different points of view, and this fundamental transformation affects all aspects of life. This book concentrates on the transformation's political, socio-economic, and environmental aspects. The sister book "Cuban energy system development – Technological challenges and possibilities" looks at the transformation from a technological perspective.

Historical development provides a perspective for analyzing the changes in the society linked to the energy system. The historical analysis is complemented with a literature review of the Cuban development phases and processes in the book's first chapter. These articles emphasize the many-faceted processes that have taken place in Cuba and which are formulating the development paths in the future.

The second chapter looks at the political changes that have taken and are taking place in Cuba. One research question is how the different levels of political decision-making can be utilized for integrated and synergetic planning of the transition process. The coordination of policies at different levels of governance depends on several aspects, and the allocation of more decision-making power at the municipal level, according to the new constitution, poses questions about how to create capacity at the local level as well as how the decisions can be coordinated to have maximum synergy in the actions. The articles analyze the Cuban energy planning structure at different levels of administration, and the future perspectives are outlined. The context of the global operating environment is analyzed through the geoeconomic perspective using cross-impact analysis.

The economic development in Cuba creates the foundation for developing energy production and consumption. The Cuban economy is dependent on global economic development and foreign trade, which is severely restricted by the US blockade. The problematic economic situation of Cuba, constrained further due to the impacts of the Covid-19 pandemic, will reduce the possibilities for large investments in new technology and renewable energy sources. So far, foreign direct investments in Cuba have been considerably modest in the energy sector, and the climate change funds have not been available for new technology. The international targets of climate change politics aim toward zero-emission societies, and Cuba has also started discussions of pathways to a carbon-free energy system. Energy economic modeling using the CubaLinda model analyses possibilities for reaching a carbon-free electricity system in Cuba. Electricity consumption depends mainly on residential consumption in Cuba, and the trends and changes in the consumption patterns are essential for planning the electricity system. The community-level activities and the social dimension of renewable energy have to be considered in the planning work. The local and provincial governance system has an important role here.

Environmental aspects are crucial in energy planning. In addition to the greenhouse gas emissions, the local pollution of energy use needs special attention. The transport sector is an important source of local pollution in cities, and here the transition to electric vehicles can bring about meaningful improvements. The shift to electric transport naturally impacts the electricity system as well and has to be taken into account in the planning. The improvements in the efficiency of the transport system, especially cargo transport, can be significant in reducing energy consumption and environmental impacts.

The future perspective of the Cuban energy system transition has to be kept in mind. The changes at the system level are slow, and the numerous interactions and interlinkages in the system hamper the finding of easy solutions to the problems. Therefore, a multilevel, multidisciplinary systems approach is needed to reach a comprehensive plan for developing the energy sector

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