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Characterization of the energy matrix of Nickel Business Group in Moa

Caracterización de la matriz energética del Grupo Empresarial del Níquel en Moa

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Abstract: This work characterizes the energy mix of the nickel industry in Moa, considering factors such as infrastructure, available technologies, and the local environment specific needs. To this end, Cubaniquel group's renewable energy development programs and energy consumption plans were analyzed. Resolutions issued by the Cuban Ministry of Basic Industry were also consulted. According to the general energy diagnosis associated to consumption, Cubaniquel group is a high consumer of most energy carriers.

Keywords: energy transition, renewable energy sources, energy efficiency, circular economy

Resumen: En este trabajo se realiza una caracterización de la matriz energética de la industria del níquel en Moa, considerando factores como la infraestructura, las tecnologías disponibles y las necesidades específicas del entorno local. Para ello se analizaron los programas para el desarrollo de las fuentes renovables de energía del grupo Cubaniquel, así como los planes para el consumo energético. Fueron consultadas además las resoluciones dictadas por el Ministerio de la Industria Básica en Cuba. Según el diagnóstico energético general asociado al consumo, el grupo Cubaniquel es un alto consumidor de la mayoría de los portadores energéticos.

Palabras clave: transición energética, fuentes renovables de energía, eficiencia energética, economía circular

Introduction

Energy transition towards more sustainable alternatives is an imperative necessity in a constantly developing world. It is a process of change from one energy production form to another that includes both renewable and non-renewable energy sources. Among the changes is the replacement of fossil fuels, such as coal and oil, with renewable sources, such as solar and wind energy (Pérez Gutiérrez, 2023). Its main goal is to mitigate climate change consequences derived from years of disproportionate pollution. The response to all this involves using renewable energy sources and energy efficiency systems. It is necessary to stop investing in the fossil fuel sector and direct all our efforts towards building the infrastructure for harnessing renewable sources, which are both clean and inexhaustible (Bravo Hidalgo, 2015).

According to Martínez Collado (2022), Cuba does not have fossil sources to produce necessary energy; however, it is a country rich in renewable energy resources (González, 2013). Martínez & Casas (2016) point out that achieving energy self-sufficiency with renewable energy sources is a challenge for this generation, however, in spite of the importance given to renewable energy sources, an impact on Cuban industry has not been achieved (Vázquez, 2015; Korkeakoski & Filgueiras, 2022).

Mining plays a key role in energy transition; the commitments to transform land transportation, the massification of electronic means of communication, and the increase in human life comfort demand the acceleration of this process. Sustainability indicators in mining constitute a fundamental tool to achieve the desired sustainable development. They are developed to measure the progress achieved in this sector, with the purpose of serving as a basis for providing clear and precise information, promoting necessary concern and decision-making. They represent an information value about the state, trend, or change of the environment and mining activity (Vela-Almeida, 2021; Abad Vigoa, 2024). These instruments acquire relevance because they provide a synthetic image of the conflict between mining and the environment, facilitating the formation of opinion when making decisions to organize, change, project, extract, and rehabilitate useful minerals extraction lands.

Energy matrix is the combination of primary energy sources used in a geographical area. It includes not only the sources used but also each one's percentage. In some cases, it is possible to use primary energy indirectly. In others, it is necessary to transform it into secondary energy, normally electricity, which implies a loss of energy in the form of heat (Ruíz, 2021; Ruíz *et al*., 2023).

The nickel industry in Moa, responsible for nickel and cobalt production, faces the challenge of balancing the exploitation of natural resources with the need to preserve the environment and contribute to social well-being. Implementing renewable energies not only has the potential to reduce the carbon footprint of mining operations but can also decrease operational costs in the long term by diversifying the energy sources used. According to Martín Astorga (2015), it is necessary to advance in a transformation process to guarantee the economic, energy, and environmental sustainability of the Cuban nickel industry.

Strategies to enhance the competitiveness of the nickel industry in Moa (Guardiola, Cervantes & Rodríguez, 2018) can be assessed for the improvement of the nickel business group in pursuit of excellence for the development of industrial activity in the context of economic and environmental sustainability.

The circular economy has emerged as a key approach to address the environmental and economic challenges faced by business organizations today (Pons & Martínez, 2025). In a context of finite resources and growing concern about climate change, the circular economy presents itself as a sustainable alternative to the production and consumption linear model. The integration of the circular economy to the energy sector offers a promising route towards environmental, economic, and social sustainability. By adopting circular practices, dependence on finite resources can be reduced, waste minimized, and innovation in cleaner and more efficient technologies and processes fostered.

Considering factors such as the existing infrastructure, available technologies, and the local environment's specific needs, this work proposes to characterize the energy matrix of the nickel industry in Moa.

Methodology

Cubaniquel group programs for the development of renewable sources were analyzed, as well as the energy consumption plans obtained from the Nickel Union statistical sources. Likewise, resolutions issued by the Cuban Ministry of Basic Industry were consulted: Resolution 152 (2018) and Decree-Law No. 345 (2019).

Characterization of nickel business group

Nickel Business Group is formed on a permanent basis and with the participation of the companies that comprise it, which have legal personality and their own assets, independently from the economic, financial, organizational, and contractual order. The Superior Management Organization, called Nickel Business Group, abbreviated as Cubaniquel, under the purview of the Ministry of Energy and Mines, fulfills the functions of management, coordination, and control established in the current legislation.

In the Superior Business Management Organization, the prevailing structure is the formal one, where all interrelation standards between organs or positions are determined, defined by the organization's norms, guidelines, and regulations to achieve objectives. It consists of hierarchical scales or functional levels established in the organizational chart. It is rational and based on division of labour and, consequently, on workers' specialization, seeking a specialized functional organization, where authority and responsibility distribution exists.

The Superior Business Management Organization is structurally organized internally by functional directorates and groups: General Directorate, Technical-Productive Directorate, Human Capital Directorate, Economics Directorate, and five advisory groups subordinated to the General Directorate: General Directorate Secretariat Group, Security and Protection Group, Cadres Organ, Internal Audit Unit, and Legal Advisory Group.

Characterization of the nickel industry energy matrix, summary of the general energy diagnosis

The Cubaniquel Business Group was created to support the separation of state functions from business functions, to organize companies in correspondence with state interests and their technological and productive similarities; to rationalize management processes; to guarantee an effective link between research and production and the better use and preservation of scientific potential. It is an organization that groups together nickel-producing companies, their services supplying companies, and commercial societies that have been created to support the group's main businesses. Its main goal is to produce and commercialize nickel and cobalt. For this purpose, it counts on two production plants, Pedro Sotto Alba (PSA) company and Ernesto Che Guevara (ECG) company.

The business group also includes the Nickel Mechanical Company (EMNi, its acronym in Spanish) to ensure maintenance and repairs, the Company for Automation, Computing, and Informatics Services (SERCONI, in its acronym in Spanish), the Nickel Research Company (CEDINIQ, its acronym in Spanish) for research services, Nickel Union Services Company to provide workers with food and transportation services (ESUNI, acronym in Spanish), the Cuban Trading Company Commercial Caribbean Nickel S.A. (CCN) for business attention, the metal and mineral trading company (MITSA), and Puerto Moa Company (EPM, its acronym in Spanish) for port services. The group is completed by commercial societies with 100 % Cuban capital that have been created to handle foreign investment businesses.

Due to its organization, the Nickel Industry constitutes a productive cluster that provides 80 % of the technical and scientific services it needs. The companies comprising Cubaniquel Business Group have managed to reduce operational costs, increase their profitability level, innovation capacity, and lessen external vulnerability (Martín Astorga, 2018).

The largest diesel consumers are the producer companies Pedro Sotto Alba and Ernesto Che Guevara, consuming 71.19 % and 20.94 % respectively of the diesel consumed in the industry. In the case of gasoline, the highest consumers are the service companies, consuming 82.78 % of this carrier, in accordance with the country's real possibilities despite the real demand.

Regular oil and crude oil are fundamental fuels in the Ni+Co production carried out by Cubaniquel Business Group. They are consumed in power generation and thermoelectric plants boilers of producer plants. It represents 87.13 % of Ernesto Che Guevara company consumption and 12.86 % of Pedro Sotto Alba company consumption.

In the case of electrical energy, the highest consumers remain the production plants, with the Ernesto Che Guevara plant consuming 54.69 % of this carrier and the Pedro Sotto Alba company consuming 40.78 %.

The Ernesto Che Guevara company has an installed capacity of 60.618 MW. 59.355 MW of it is allocated for power and 1.263 MW for lighting. To meet this demand, it has two 30000 MVA converters linked to the National Power System (SEN, its acronym in

Spanish) and three turbogenerators, two of 12 MW and one of 25 MW. Furthermore, it shows high fuel oil, crude oil, and diesel consumption.

In recent years, energy efficiency of all carriers has been affected fundamentally by the following causes:

- Non-compliance with the production plan and metallurgical efficiency.

- Deterioration of consumption rates of Mineral Preparation, Reduction, Calcination and Sintering Furnaces.

- Water recovery system out of operation.

- Overdraft in the consumption of softened water in the leaching and washing plant.

- Overdraft in the consumption of high-pressure water during leaching.

- Overdraft in steam production, which implied overconsumption of drinking water.

Table 1 shows the accumulated consumption in 2024.

Table 1. Ernesto Che Guevara Company's actual physical consumption in 2024

Energy carriers	Unit	Total
Fuel oíl Total	t	282220,545
Electricity from SEN	MWh	138659,348
Diesel Total	t	4300,086

Pedro Sotto Alba company is characterized by being an energy-consuming entity in the country, and its main source of energy consumption has fossil origin. Oil is its main energy carrier, followed in importance, due to their consumption rates, by electrical energy, diesel, and special gasoline. It also consumes liquefied petroleum gas, but its final use is as a raw material in the production of H_2S, required for mixed Ni+Co sulfide precipitation.

The total electrical energy demanded by the company has grown by 5.8 % after the entry of new investments: a new sulfuric acid train, with a capacity to produce 2000 t/d, a sulfide train, a pulp preparation plant, and a mobile ore screen.

The company has 2 turbogenerators with capacity to produce 14.0 MW and the rest of the energy demand is assumed by the National Grid with 6.3 MW. Table 2 shows the accumulated consumption in the year 2024.

Table 2. Pedro Sotto Alba Company's Actual Physical Consumption 2024.

Energy Carrier	**UM**	**Total**
Fuel oil Total	t	100874.05
Electricity from SEN	MWh	85158.5
Diesel Total	t	27121.7

The rest of the companies maintain a consumption that represents 7.8 % of the diesel and 4.6 % of the electrical energy used by the Nickel Business Group in Moa (Table 3).

Table 3. Summary of consumption in 2024 for the Rest of Cubaníquel Group Companies

Energy Carriers	**Annual Consumption**
Diesel (t)	25147.17
Gasoline (t)	80.84
Fuel oil y Crude (t)	444552.38
Electricity (kWh)	155330219.0

In recent years, in most companies, regardless their consumption, several programs have been developed, such as changing inefficient lighting for LED lamps, installing capacitor banks for power factor improvement, installing photovoltaic parks, load adjustment, and shifting loads to off-peak electricity demand hours.

The greatest potential to reduce electricity consumption in terms of investments lies in the installation of photovoltaic panels on the factory roofs. Executed surveys and projects indicate that the group can manufacture, install, and maintain these systems using its own companies.

Although some of the companies have implemented an energy management system and have identified the key positions of energy consumption, there are still many constraints therefore, the implementation and certification of the energy management system according to Standard 50001 (ISO, 2011) is currently a priority for all companies. If these programs are executed, an improvement in energy intensity, a reduction in expenses and costs, and an improvement in the competitiveness of the products and services offered by the business group will be obtained.

The assessment for the development of renewable energy sources in the nickel industry with a circular economy approach, in Cubaníquel Business Group, can be carried out considering several key aspects that promote sustainability, resource efficiency, and waste reduction. Circular economy can significantly influence the renewable energy sources and energy efficiency development program in nickel industry in Moa, Cuba, through several mechanisms.

Integration of circular economy to renewable energy and energy efficiency

Promotion of renewable sources: circular economy promotes the use of renewable energy sources such as solar, wind, and biogas for energy production, thereby decreasing dependence on fossil fuels and reducing greenhouse gas emissions.

Reuse and recycling of materials: circular economy encourages reuse of raw materials and products, as well as recycling wastes to generate new materials. This reduces the need to extract virgin natural resources and minimizes waste generation.

Energy efficiency: circular economy drives energy efficiency by ensuring that the resources used are renewable, recyclable, or reusable. This decreases dependence on non-renewable energy sources and reduces waste generation.

Resource and waste management: circular practices in resource and waste management can lead to the creation of new renewable energy sources, such as biogas and biomethane (Bach Aleu, 2024; Cunningham, 2024). These renewable gases, generated from organic matter decomposition, can be transformed into electrical energy, thermal energy, or biofuels, offering a sustainable alternative to fossil fuels.

Cost reduction: The use of renewable energy decreases electricity expenses by reducing dependence on the general power grid. Furthermore, the possibility of self-consumption with surpluses, injecting excess energy into the grid and obtaining compensation, can generate additional income (Espinosa Rodríguez & Fernández

Guidelines for the development of renewable energy sources in nickel industry

1. To seek the maximum possible use of available roofs to install solar photovoltaic systems, with the objective of reducing the electricity consumption. With these actions, it is projected to achieve a two-percent minimum reduction in the annual electricity consumption.

After surveying the roofs in the group, studies are conducted to install solar panels (Table 4). For this purpose, an analysis of the available roofs in each company was carried out, an aspect incorporated into the feasibility study for its gradual fulfillment until 2030.

Table 4. Study for the Installation of Solar Panels in Companies of Cubaniquel Group.
FSP: Feasibility Study in Process

Company	Project	KWh	Date	Status
ECG	Installation of solar panels on roofs	63	-	In Operation
PSA	Installation of solar panels on roofs	189	-	In Operation
EMNi	Installation of solar panels on roofs	12	-	In Operation
MITSA	Installation of solar panels on roofs	40	2025	-
OSDE	Installation of solar panels on roofs	45	2025	-
CEDINIQ	Installation of solar panels on roofs	60	2026	-
CEPRONI	Installation of solar panels on roofs	-	-	FSP
SERCONI	Installation of solar panels on roofs	-	-	FSP
PSA	Photovoltaic solar park	20000	2027	-

2. To acquire new transportation means, requiring as a first option the use of battery electric vehicles, hybrid vehicles, or vehicles that run on biomethane.

The replacement of vehicles with electric and hybrid ones is projected. To date, eight cars, 54 motorcycles, 4 vans, 2 lifting platforms, and one forklift have been replaced. All companies include electric equipment in their FSP. The producer companies are in the review and study phase for the possible replacement of mining equipment (Table 5). By 2030, it is estimated that 30 % of the equipment will be replaced by electric equipment.

Table 5. Electric Automotive Equipment of Nickel Business Group

Projects	Company	General Scope	Acquired
Acquisition of electric equipment	ECG	Under study	1 car
Acquisition of electric equipment	PSA	Under study	4 vans, 1 car
Acquisition of electric equipment	EMNI	Under study	4 motorcycles, 1 car
Acquisition of electric equipment	MITSA	8	2 motos
Acquisition of electric equipment	SERCONI		4 tricycles
Acquisition of electric equipment	CEXNI	Under study	1 car
Acquisition of electric equipment	CEDINIQ		6 motorcycles
Acquisition of electric equipment	Headquarters	25	2 cars, 18 motorcycles
Acquisition of electric equipment	ESUNI	30 buses	0
Acquisition of electric equipment	ESUNI	Under study	0
Acquisition of electric equipment	PINARES S.A.		3 cars, 10 motorcycles
Acquisition of electric equipment	EPM	Under study	2 motorcycles

3. To project new works that generate organic waste, planning, from the conceptual ideas’ conception phase, the technologies for their energy use, avoiding the contamination of watersheds, rivers, bays, and the emission of greenhouse gases.

This is considered in new businesses and is included into the negotiation guidelines. It is also planned the execution of projects to improve waste treatment systems in processing centers and cafeterias in 2026.

4. To apply technologies to obtain biogas and biofertilizers that contribute to fossil fuels substitution and food production increase. They are meant to be used by the institution itself or by third parties.

There are two fixed-dome biodigesters at ESUNI. There is no projection for new biodigesters until the increase in animal stock is achieved.

Conclusions

The characterization of the energy matrix of Cubaniquel Business Group in Moa is carried out taking into account factors such as infrastructure, available technologies, and the local environment specific needs.

According to the general energy diagnosis associated to consumption, Cubaniquel group is a high consumer of most energy carriers, with the two production plants being the main diesel consumers. In the case of gasoline, the highest consumers are the service companies, using 82.78%.

The circular economy can significantly influence the program for renewable energy sources and energy efficiency development in the nickel industry, in Moa.

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