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Review Article

A Necessary and Planned Energy Transition towards Zero-carbon Emissions in Argentina: Challenges and Opportunities

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Abstract: This academic paper explores the necessary energy transition toward zero carbon emissions in Argentina, detailing significant challenges such as dependence on fossil fuels and the need for investment, as well as promising opportunities in renewable energy and economic development. It analyzes Argentina's current energy landscape and discusses key strategies, including public policies, infrastructure investment, the adoption of new technologies such as green hydrogen, and the promotion of energy efficiency to achieve a sustainable energy mix. The paper examines historical data and proposes priority actions for Argentina to move toward a cleaner energy future.

Keywords: zero-carbon; opportunities; challenges; energy transition; Argentina

1. Introduction

The global energy transition represents one of the most critical and urgent challenges of the 21st century, driven by the imperative need to mitigate the effects of climate change and achieve sustainable development. Carbon dioxide (CO_2) emissions from burning fossil fuels are the main contributor to global warming, with an increase of approximately 1.1°C in the global average temperature since the pre-industrial era. This increase has exacerbated extreme weather events, such as droughts, floods, and rising sea levels, threatening the stability of ecosystems and human societies [1]. In response, the international community has set ambitious targets, such as the goal of limiting global warming to 1.5°C, set out in the Paris Agreement [2], which requires a drastic reduction in CO_2 emissions and an accelerated transition to carbon-free energy systems.

There are many factors involved in the global emission of CO_2, which is why several studies have been developed on the subject, addressing different aspects [3 – 7]. Using a comparative approach, [8] examines the nexus among renewable energy consumption, economic growth, trade, urbanization and environmental quality in CO_2 emissions for Australia and Canada for the period 1960–2015. [9] analyzes the role of non-renewable energies and industrialization on the level of environmental pollution. On the other hand, [10] presents a probabilistic carbon emission flow model to calculate the distribution of carbon intensities for consumers. From the perspective of load contribution to new energy consumption, [11] proposes a time-space coupled discrete analysis method for carbon flow distribution in power systems. In [12], is highlighted the need to develop low-cost systems renewable electricity as the key driver of the global energy transition towards sustainability. This research highlights the technical feasibility and economic viability of 100% renewable energy systems including the power, heat, transport and desalination sectors. In this context, Latin America has abundant sources of mining natural resources, as well as renewable energy sources, which can be responsibly used to promote the clean energy transition in the region [13]. In [14],

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the objectives, approach and results of the Latin American Deep Decarbonization Pathways (DDL-LAC) project for decarbonization of countries such as Argentina, Colombia, Costa Rica, Ecuador, Mexico and Peru until 2050 are presented, considering energy systems, Agriculture, Forestry and Other Land Use (AFOLU).

In [15], different alternatives are proposed for the energy transition in Argentina where energy scenarios based on renewable energies are developed that lead to Greenhouse Gas (GHG) emission trajectories compatible with the objective of limiting warming to 1.5°C. These scenarios are modeled according to the potential for the use of different renewable energy resources, both concentrated and distributed, as well as the potential changes in energy demand through energy efficiency and the type of energy for final consumption. [16], explores deep decarbonization paths for Argentina until 2050 where the use of afforestation as an emissions sink is highlighted, which are aligned with several national Sustainable Development Goals (SDGs). In [17], the aimed to evaluate the dynamic effects of globalization, renewable energy consumption, non-renewable energy consumption, and economic growth on carbon-dioxide emission levels in Argentina over the 1970–2018 period. [18] demonstrates that a zero-carbon, reliable and affordable Australian electrical energy system can be built based on: (i) solar photovoltaics, wind turbines, existing hydropower and biomass for power generation; (ii) pumped hydro (off-river) and electric car batteries for energy storage; and (iii) high-voltage direct-current and alternating-current for electricity transmission.

The Group of G-20 (Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, United Kingdom, and United States) is responsible for about 75% of global GHG emissions. Therefore, the energy transition not only involves the adoption of renewable technologies, such as solar, wind and storage systems, but also a profound transformation of economic, political and social systems [19]. Recent studies highlight that the decarbonization of the energy sector is technically feasible, but requires unprecedented global coordination, significant investments, and robust public policies that foster innovation and equity [20]. In addition, the transition must address challenges such as the intermittency of renewable energy, the need for modernized infrastructure and social justice, ensuring that the most vulnerable communities are not marginalized in this process [21].

Argentina is at a crucial moment in its energy history, facing the need for a planned and strategic transition to a zero-CO_2 economy. This transformation is not only essential to meet international commitments on climate change, but also to ensure sustainable and equitable development in the long term. In this context, it is important to analyze the challenges and opportunities presented by this transition from an economic, political and social perspective. This article examines the progress, challenges, and opportunities in the transition to a global energy system with net zero CO_2 emissions. Thus, the technological, economic and political dimensions of this transformation are explored, highlighting the importance of collective and urgent action to ensure a sustainable and resilient future.

2. Scenarios and Methods

This section presents historical statistical data on the use of different fuel sources for electricity generation from 2021 to 2025 [22]. It can be observed that a distribution pattern that show a trend of reduction in the use of hydrocarbons for electricity generation in Argentina. This comes hand in hand with the increase in renewable generation sources such as wind and solar farms.

2.1. Fuel Consumption by Type

The evolution of the use of different primary energy sources in electricity generation allows for analyzing trends and supporting discussions on the challenges and opportunities of the energy transition toward zero carbon emissions.

Figure 1 shows the use of mineral coal per year expressed in thousands of tons (kTons). Its relevance lies in the fact that coal is one of the most polluting sources, and its reduction is key to decarbonization. The data demonstrate that Argentina is reducing its dependence on this fuel.

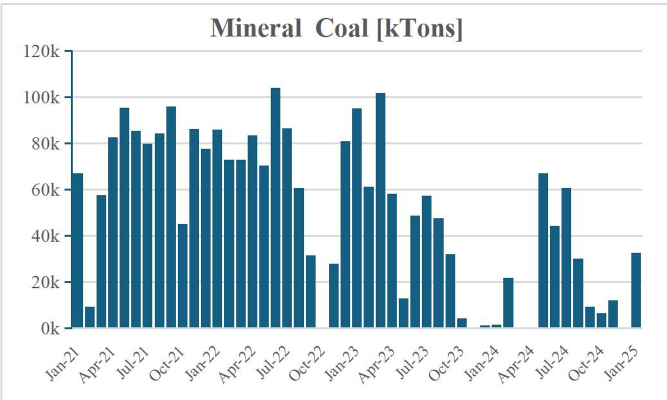

Figure 1. Mineral coal used to 2021–2024 period [22].

Figure 2 presents the use of Fuel Oil per year expressed in thousands of Tons (kTons), another highly polluting fossil fuel. This information is important because it reflects the transition to cleaner sources and helps evaluate the effectiveness of policies such as replacing liquid fuels in thermal power plants.

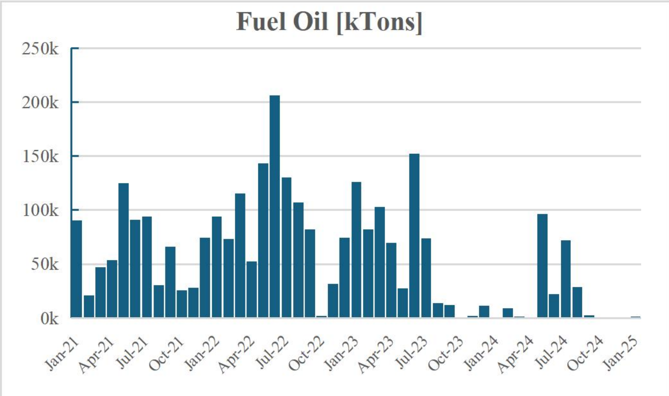

Figure 2. Fuel Oil used to 2021–2024 period [22].

Figure 3 shows the use of Natural Gas per year expressed in cubic megameters (Mm^3). Natural gas, although less polluting than coal or fuel oil, is still a source of emissions. Its analysis is crucial given Argentina's central role in the exploitation of Vaca Muerta and the ambivalence between its use as a "bridge fuel" and zero-emission targets.

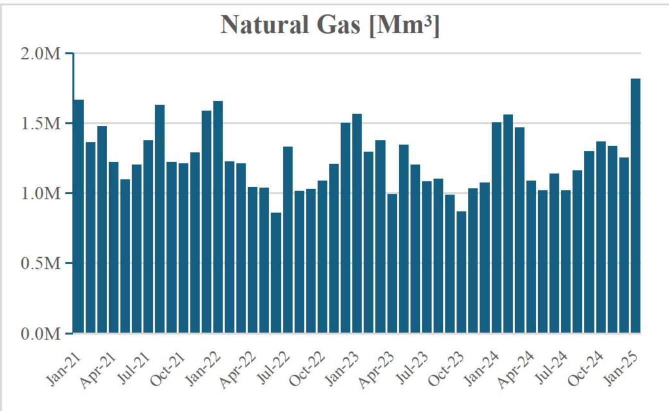

Figure 3. Natural Gas used to 2021–2024 period [22].

Figure 4 shows the use of Gas Oil per year expressed in thousands of m^3 (km^3). Its relevance is linked to the need to electrify sectors such as transport and reduce the use of petroleum derivatives.

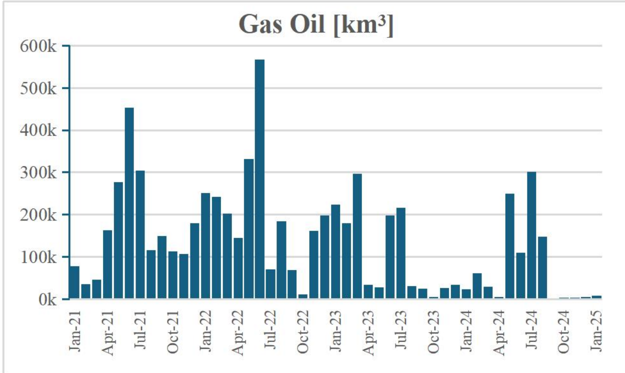

Figure 4. Gas Oil used to 2021–2024 period [23].

With this information presented in the figures above, it is possible to visualize whether Argentina is effectively reducing its dependence on fossil fuels, which supports discussions on challenges (e.g., persistence of hydrocarbon subsidies) and opportunities (e.g., growth of renewables). The data justify the urgency of strategies such as phasing out fossil fuel subsidies (Section 4.1.2) and investing in renewable infrastructure (Section 4.2). In addition, they contrast with later figures, showing the relative advance of clean energy compared to traditional energy.

2.2. Distributed Generation

By the end of 2022, the Distributed Generation (DG) regime (Law 27,424) [23], had 14 provinces adhered and 216 Distributors/Cooperatives registered. In 11 of the participating provinces, there are Generating Users (UG), with Neuquén, Corrientes, La Rioja and Catamarca registering their first UG during 2022. In turn, the program reached 2,290 UG with a total installed power of 58,996 kW in 2024. This power is equivalent to the annual electricity demand of 31,795 homes and represents a total of 37,294 tons of carbon dioxide (tCO_2) emissions avoided. Figure 5 presents the cumulative evolution of UG and Installed Power for the period 2019 – 2024 [24]. The exponential growth of DG shown in Figure 5 demonstrates the success of Law 27,424.

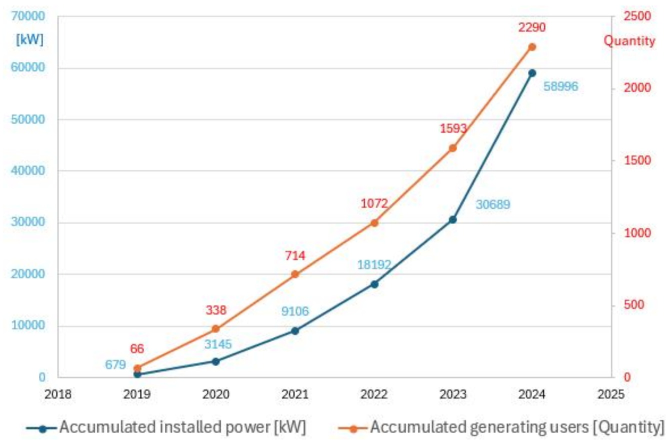

Figure 5. Evolution of DG implementation [24].

Figure 6 presents the distribution of installed DG power in kW per year [24], highlighting that 69% of it was carried out between 2023 and 2024. However, the concentration of DG capacity in just two years reveals that the system is still dependent on temporary incentives.

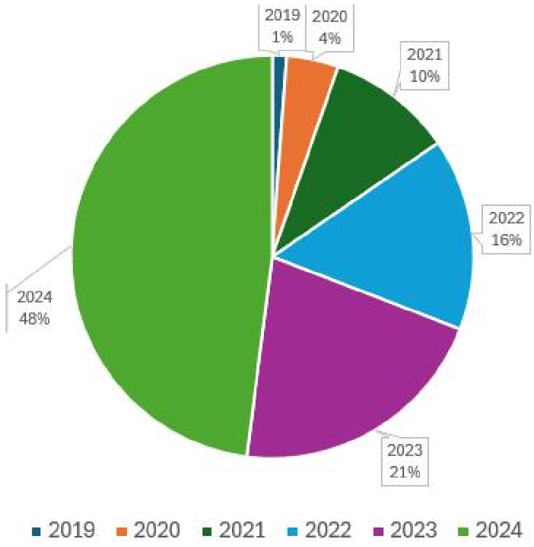

Figure 6. Evolution of DG installed power per year.

The data presented in [24] shows an important growth trend in installed DG capacity during 2022 in the Argentine Interconnection System (SADI), representing a 50% of the increase. This greatly helps the transition to zero CO_2 emissions. In this sense, the national government, through [25], extends the maximum limit of self-consumption from 2MW to 12MW of power. In this way, all homes, buildings, industries or SMEs (Small and Medium-sized Enterprises) that are currently self-sufficient with renewable energy, will have the possibility of expanding the power to be installed. It is expected that DG will increase substantially with this new limit, with which losses in the Transmission and Distribution systems will be reduced, promoting energy efficiency. These changes should facilitate the process of tariff recomposition and guide the transition to a system of targeted subsidies. Figure 7 shows the percentage share of Renewable Energy by technology in the supply of total demand for the period 2023–2024 [26]. The hydroelectric energy presented in this graph corresponds to plants with a power of less than 50MW.

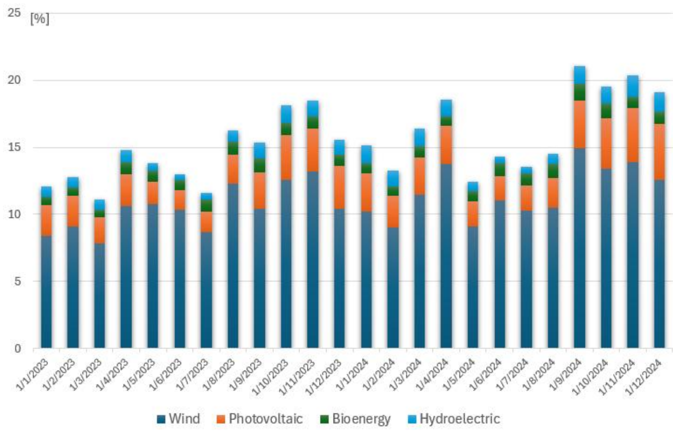

Figure 7. Percentage share in the supply of demand through Renewable Energy [26].

2.3. Scenarios Analysis'

The scenarios to energy transition towards zero-carbon emissions were performed considering aspect which better an energy system under certain constraints for a comprehensive set of energy, generation, storage, and transformation technologies. Thus, the electric power system actual model transformation is based on:

- applied new technologies
- investment and financial technical assumptions
- demand and resource potential for renewable technologies.
- regulation and public policies

3. Energy Transition Discussion

3.1. Challenges of the Energy Transition in Argentina

The Table 1 present a main challenge to planned transition towards zero-carbon emissions in Argentina. These are explained in this section.

Table 1. Challenges to energy transition in Argentina.

Challenges	Impact	Priority
Dependence on Fossil Fuels	High	High
Investment and Financing	Medium	High
Regulation and Public Policies	Medium	High
Technological Development	Medium	Medium

3.1.1. Dependence on Fossil Fuels

One of the main challenges facing Argentina is its heavy dependence on fossil fuels, especially Natural Gas (NG) and Oil (petroleum). These resources have been the backbone of the country's energy economy for decades, and reducing their use requires a deep and structural transformation of the existing energy infrastructure.

In 2010, the discovery in the south of the country of recoverable hydrocarbons (Oil and NG) in the Vaca Muerta formation has boosted the country's independence from fossil fuels while providing great potential for additional economic revenues. While there are some hydroelectric power plants, most of the electricity is produced through gas and oil thermal power plants, while the final energy demand of the residential sector is mainly met by NG supply. The AFOLU sector is the second largest source of emissions in Argentina and accounted for 37% of total GHG emissions in 2016. Unlike the energy sector, agricultural production is largely destined for external markets. The remaining emissions (10%) are due in equal measure to industrial processes and waste [16].

According to data from [27], in 2022 approximately 75% of the energy consumed in the country came from fossil sources. This dependence not only generates direct CO_2 emissions, but also limits the diversification of the energy matrix, making it difficult to transition to cleaner sources. Already in 2024, average oil production was 717.1 thousand barrels per day, a growth of 11% year-on-year, while gas production in December reached 124.4 MMm3/day, an increase of 9% compared to the same month in 2023. Vaca Muerta production accounted for 54.9% of all oil production and 50.1% of gas production nationwide. In December, 446.9 thousand barrels of crude oil were produced per day in Vaca Muerta alone, which meant a year-on-year growth of 26.9%. Vaca Muerta has heavily subsidized exploitation of unconventional fossil fuels is adding GHG emissions by a significant amount, far exceeding the estimated reductions from the use of renewable energy.

The national government, through resolution 15/2025, continues the process of deregulation of the Liquefied Petroleum Gas (LPG) market with the idea of having a more competitive system [28]. In addition, a key debate in Argentina's energy transition is to position the important role of NG and Renewable Energies in the transition process.

It is critically important for Argentina to reduce its monotonic reliance on fossil fuels for meeting the domestic energy demand. Although the Argentine government has decided to upscale investments for renewable energy development within the country, supporting policies have to be adopted and implemented to overcome the traditional barriers that have impeded renewable energy adoption in Argentina. Besides, it is also important for Argentina to significantly reduce its fossil fuel imports and try to utilize the indigenous renewable and relatively cleaner energy resources to bridge the local energy demand [17].

3.1.2. Investment and Financing

The transition to a zero-CO_2 economy requires significant investments in infrastructure, technology and training. This includes building renewable energy plants, modernizing electrical transmission and distribution networks, developing technologies for energy storage, and training the workforce in new skills. However, securing the necessary financing can be challenging, especially in a context of fiscal and economic constraints.

Argentina needs to invest approximately USD 8,000 million annually until 2030 to reach its renewable energy and grid modernization goals [29]. In addition, a report by [30] notes that financing costs in Argentina are up to 3 times higher than in other emerging markets due to macroeconomic instability, with interest rates for green projects exceeding 12% per year, compared to 4–6% in countries such as Chile or Brazil. Only 10% of the projects awarded in the RenovAr program were completed on time, due to difficulties in accessing foreign exchange and inflation, which reached 211% in 2023 [31].

This scenario of high macroeconomic risk, exchange controls, poorly controlled inflation, and lack of institutional credibility makes Argentina perceived as an unattractive destination for sustainable investments. Although there are sectors with potential (lithium, energy, agriculture), the general conditions require profound reforms (fiscal, monetary, labor) to regain investor confidence

3.1.3. Regulation and Public Policies

The implementation of a successful energy transition also depends on a coherent and effective regulatory framework and public policies. This includes creating incentives for investment in renewable energy, phasing out fossil fuel subsidies, promoting energy efficiency, and adopting stringent environmental standards. Coordination between different levels of government and sectors of the economy is crucial to ensure an orderly and just transition.

However, in a recent speech to the UN General Assembly, Argentine president rejected the Pact for the Future and the 2030 Agenda, a comprehensive global framework for sustainable development encompassing “people, planet, and prosperity”. This position undermines Argentina’s capacity to tackle urgent socio-environmental challenges like poverty, deforestation, biodiversity loss, and wildfires. By walking away from this international initiative, Argentina risks isolation and exacerbating these interconnected crises [32].

3.1.4. Technological Development

The development and implementation of new technologies are crucial for the energy transition. This includes the adoption of solar, wind, hydroelectric and biomass energy technologies, as well as the development of energy storage solutions to ensure a stable and continuous supply. Research and development in these areas are critical to improving efficiency and reducing the costs of these technologies. In this sense, Silicon heterojunction solar cells with up to 26.81% efficiency was achieved by electrically optimized nanocrystalline-silicon hole contact layers [33]. The Hywind Scotland wind farm reached a capacity factor of 54% (vs. ~35% for onshore wind). The LCOE (Levelized Cost of Electricity) for floating wind is expected to drop to €40/MWh by 2030 (compared to €80/MWh in 2020) [34].

3.2. Opportunities of the Energy Transition in Argentina

Table 2 presents a main opportunity to planned transition towards zero-carbon emissions. These are explained in this section.

Table 2. Opportunities to energy transition in Argentina.

Opportunities	Impact	Priority
Renewable Energy Potential	High	High
Prioritizing the Dispatch of Renewable Power Plants	High	High
Reduced Energy Control	Medium	High
Job Creation and Economic Development	High	High
Improving Public Health and the Environment	High	Medium

3.2.1. Renewable Energy Potential

Argentina has enormous potential for the development of renewable energies, especially wind and solar energy. The vast plains and high levels of solar irradiation in several regions of the country (Northwest Region -NOA: 2500–2800 kWh/m²/year) coupled with high wind speeds (Patagonia: 9–12 m/s) offer ideal conditions for clean energy generation. Harnessing this potential can reduce dependence on fossil fuels and provide a sustainable and reliable source of energy. In addition, creating financial and fiscal incentives is crucial to attract investment in renewable energy projects. This could include tax breaks, direct subsidies, and low-interest loans for companies developing clean technologies. The experience of South Australia demonstrates a means by which renewables transitions can be expedited by public policy initiatives in a privatised market system [35].

The program to promote the production of energy through renewable sources (RenovAr) in Argentina has had a significant impact on the increase in the installed capacity of renewable energies. Through various bidding rounds, numerous projects have been awarded that have contributed to diversifying the energy matrix and reducing dependence on fossil fuels. Through MEyM Resolution No. 136/2016 [36], the Ministry of Energy and Mining instructed CAMMESA (Administrative Company of the Electrical Wholesale Market S.A.) to carry out the National and International Open Call "RenovAr Round 1 Program" for the qualification and eventual award of bids for the execution of contracts for the supply of electricity generated from renewable sources. This was done in order to increase the share of renewable energy sources in the country's energy matrix as prescribed by Laws No. 26,190 [37] and No. 27,191 [38] and Decree No. 531/2016 [39].

Since the start of the RenovAr programme, more than 130 projects have been awarded, reaching 6,500 MW of installed renewable energy capacity. This represents an important step forward in meeting the targets set by [38], which seeks to reach a 20% share of renewable energy in the electricity matrix by 2025. The installed capacity awarded is distributed in different renewable energy technologies, with wind and solar being the most representative. Biomass, biogas and small hydroelectric projects have also been awarded, contributing to a more diversified and sustainable energy matrix.

It is important to note that the installed power allocated does not always translate immediately into energy injected into the SADI. Some projects may require development and construction time before entering commercial operation. The RenovAr program has driven a significant increase in renewable energy generation in Argentina, contributing to the reduction of GHG emissions and the development of a clean energy industry in the country. However, modernizing electricity transmission and distribution networks is essential to efficiently integrate renewable energy sources.

3.2.2. Prioritizing the Dispatch of Renewable Power Plants

In 2015, a treatment was established for the dispatch of electricity from renewable resources similar to that received by run-of-the-river hydroelectric plants and/or in dumping conditions and to forced generation due to various restrictions. In this case, if it is necessary to reduce generation for Frequency Control of the electricity system, the aforementioned plants would maintain dispatch priority over conventional generation [40]. Where it is ultimately necessary to reduce renewable generation, a particular order of priority should be respected for each type of contract, as defined by [41].

3.2.3 Reduced Energy Control

Reduced energy represents energy not generated due to limitations in the electrical system and is computed during the period in which a Transmission System Saturation remained active and/or the generation by System Frequency Control was reduced. In Argentina, 31.1 GWh of total energy was reduced during the month of December 2024 (1.6% of the possible energy to be generated). Of this total, reduced wind energy was 15.8% with 15 active restrictions and reduced solar energy was 15.3 GWh with 3 active restrictions [40]. Therefore, increasing generation through renewable energy sources and prioritizing their dispatch is not enough if the electrical infrastructure of the SADI is not improved to prevent the restrictions of the electricity system (unforeseen failures and/or scheduled maintenance) from impacting the energy available for dispatch.

3.2.4. Job Creation and Economic Development

The energy transition can be an important source of job creation and economic development. The construction and operation of renewable energy projects, the manufacture of technological components and the provision of related services can generate thousands of jobs and promote economic growth in various regions of the country. In addition, the energy transition can foster innovation and technological development, positioning Argentina as a leader in the clean energy sector.

The strategy adopted must give priority to the revitalization of the production system and the creation of industrial jobs promoted by local manufacturing. As Argentina is a country with a high poverty rate and a relatively low level of development, all activities, particularly in the energy sector, must be organized according to these priorities [16].

3.2.5. Improving Public Health and the Environment

Reducing GHG emissions and decreasing the use of fossil fuels can have significant benefits for public health and the environment. Improving air quality, reducing pollution, and reducing the negative impacts of climate change can contribute to a better quality of life for the population and the preservation of natural resources.

4. Strategies to Change the Energy Matrix

4.1. Public Policies

To achieve a successful energy transition towards zero CO_2 emissions, Argentina must implement several coherent and effective public policies. These include:

4.1.1. Incentives for Investment in Renewable Energy

Creating financial and fiscal incentives is crucial to attract investment in renewable energy projects. This could include tax breaks, direct subsidies, and low-interest loans for companies developing clean technologies. In this sense, the MATER program (Market in Terms of Renewable Energies) [42], is a program that seeks that Private Companies set up their renewable energy project and sell to other private companies, or that Private Companies invest/improve their infrastructure and use their own renewable energy. Its main objectives are the following:

a. Stimulate investments in electricity generation from renewable energy sources.

b. Regulate the contracts of the Forward Market and self-generation in electricity from renewable sources.

c. Manage dispatch priorities based on existing power grid capacities to avoid congestion of renewable projects.

In addition, a sovereign fund for clean energy with state guarantees can be created, financed by royalties from Vaca Muerta. In the same vein, it is necessary to simplify access to foreign currency for imports of renewable components (e.g., tariff exemptions for solar panels and wind turbines) in addition to attracting Foreign Direct Investment (FDI) with dollar contracts and 20-year fiscal stability, such as the Large Investment Incentive Regime (RIGI) for green hydrogen.

4.1.2. Phasing Out Fossil Fuel Subsidies

This is one of the great challenges of Argentina's energy transition. Therefore, reducing and eventually eliminating fossil fuel subsidies is an essential measure to discourage their use and encourage the adoption of renewable energies. This process must be gradual in order to minimize economic and social impacts. Vaca Muerta represented 54.9% of the country's oil and 50.1% of the country's gas in 2024, which generates a conflict between the exploitation of hydrocarbons and decarbonization goals. In this sense, investments in Vaca Muerta can be conditioned to the implementation of carbon capture and exclusive use for export.

4.1.3. Promoting Energy Efficiency

Implementing programs and regulations that promote energy efficiency in all sectors of the economy, from industry to homes, is critical. This includes adopting rigorous standards for appliances, vehicles, buildings, and industrial plants.

Argentina also has an opportunity to improve energy efficiency in key sectors such as industry, transport and housing. Through the implementation of more efficient technologies and the modernization of distribution networks, electrical losses and associated emissions could be significantly reduced. Public policies on energy efficiency, such as promoting LED (Light Emitting Diode) technology and improving efficiency in buildings, have shown positive results, and the government could step up these efforts to achieve further emission reductions.

4.1.4. Strict Environmental Standards

Setting and enforcing strict environmental standards for GHG emissions and other pollutants will help reduce the country's carbon footprint. These standards must be accompanied by monitoring mechanisms and sanctions to ensure compliance.

4.1.5. Use of Carbon Markets

Carbon markets are mechanisms that allow the purchase and sale of carbon credits, with the aim of reducing GHG emissions and combating climate change. In Argentina, the use of these markets has been gaining relevance in recent years, although it is still in an incipient phase of development compared to other countries. Argentina, as part of the Paris Agreement [2], has committed to reducing emissions by 19% compared to a scenario without climate policies by 2030. The country has also stated its intention to reach carbon neutrality by 2050. In 2021, Argentina passed the Law on Minimum Budgets for Adaptation and Mitigation to Global Climate Change [43], which establishes a framework for climate action and could lay the groundwork for the development of a regulated carbon market. In addition, the country is working on the creation of a National Emissions Traceability System, which will allow GHG emissions to be monitored and reported. In this sense, Table 3 presents the challenges and opportunities that Argentina has in this regard.

Table 3. Challenges and Opportunities in Carbon Markets.

Challenges	**Description**
Not Clear Regulatory Framework	Although there is progress, there is still no specific regulation that defines how a carbon market will work in Argentina.
Technical and financial capacity	The development of carbon projects requires investment and expertise, which can be an obstacle for small producers or local communities.
Risk of "double counting"	It is crucial to ensure that carbon credits are not accounted for in both the buying and selling countries, which could undermine market integrity.
Opportunities	**Description**
Investment attraction	Carbon markets can attract foreign investment for sustainable projects, especially in sectors such as renewable energy and forest conservation.
Rural development	Carbon projects can generate additional income for rural communities and encourage sustainable agricultural practices.
International positioning	Argentina could position itself as a regional leader in the generation of carbon credits, taking advantage of its natural potential and its climate commitment.

4.2. Investment in Infrastructure

The transition to a zero-CO_2 energy matrix requires significant investments in infrastructure. Such investments are essential to reduce emissions globally, but in emerging markets such as Argentina, financing costs are high [44]. These investments should focus on the following aspects:

4.2.1. Development of Smart Distribution Networks

Modernizing electricity distribution networks is essential to efficiently integrate renewable energy sources. Smart grids allow for more efficient energy management and facilitate the integration of technologies such as energy storage and electric vehicles.

4.2.2. Construction of Renewable Energy Plants

Argentina must invest in building more wind and solar power plants to take advantage of its vast natural resources. This will not only contribute to clean energy generation but will also help reduce dependence on fossil fuels.

Although globalization is found to be contributing to environmental prosperity in Argentina, it is essential to ensure that the globalization-induced rise in energy demand is met by renewable energy resources. In this regard, Argentina can look to trade renewable energy from its neighboring countries whereby the positive environ mental outcomes associated with trade globalization can be enhanced further. Simultaneously, the Argentine government should also think of attracting FDI for the development of its renewable energy sector. It can be expected that financial globalization-induced FDI inflows can result in technological spillover which, in turn, can relieve the technological constraints that have inhibited renewable energy adoption in Argentina [17].

4.2.3. Energy Storage Infrastructure

A great challenge that renewable energies (wind and solar) have compared to conventional energy is their natural variability, that is, they are not entirely manageable. This means that the resource that is not used at the precise moment it is available to generate energy or store it, is lost. Therefore, energy storage is crucial to ensure the stability and reliability of the electricity supply. Investing in storage technologies, such as high-capacity batteries, will make it possible to store excess energy generated by renewable sources and use it when demand is high. A method of optimizing a photovoltaic energy storage system for zero-carbon buildings is proposed in [45]. Here, a two-layer optimal allocation model of optical storage capacity for zero-carbon buildings with the objective function of the shortest cycle of recovery of the system investment cost and the maximum return of the system's typical daily operation is established with the realization of zero-carbon emission during the operation stage of the building as the core element.

4.3. New Technologies

Adopting and investing in new technologies is key to reaching the goal of zero carbon emissions. Some of the most promising technologies include:

4.3.1. Development of Green Hydrogen Technology

Green hydrogen, produced from renewable sources, has great potential as a clean fuel. Argentina must invest in the research and development of technologies for the production, storage and distribution of green hydrogen. Currently, the Argentine government is seeking to update the Law for the Promotion of Renewables [38] and extend the deadlines for submitting hydrogen projects to the RIGI. This seeks to extend the window of opportunity for hydrogen projects, from two to ten years, and with greater benefits for green hydrogen (produced by renewable sources) over blue hydrogen (produced with natural gas). For example, for green H_2 it will be 30 years of fiscal and tax stability, while for blue H_2 it would be for 20 years.

Argentina has enormous potential to produce green hydrogen due to its abundant renewable energy and port infrastructure for export. This resource could become a key source of revenue for the country, while also helping to reduce emissions from the industrial sector. In [46], is analyzes a techno-economic optimization tool developed in-house to size on-grid and off-grid green hydrogen plants and estimate their minimum production costs in a case study for energy transition in Argentina. [47] present a study to environmental and techno-economic viability of using hydrogen in the vehicle sector for a rapid energy transition in Argentina. The International Energy Agency estimates that green hydrogen could cover up to 15% of global energy needs by 2050 [48], presenting a significant opportunity for Argentina. The production of hydrogen for export from wind and solar energy, natural gas, and coal already is used in some countries [49].

4.3.2. Implementation of Offshore Wind Energy

Exploring the potential of offshore wind energy can offer an additional source of clean energy and contribute to diversifying the country's energy matrix. Investment in research and development in this field is essential.

4.3.3. Advancing Carbon Capture and Storage

Carbon capture and storage is a technology that reduces CO_2 emissions by capturing it at emission sources and storing it safely in underground geological formations. Encouraging the research and application of Carbon Capture and Storage will contribute significantly to reducing total emissions.

4.3.4. Electric Vehicles and Sustainable Transport

Promoting the use of electric vehicles and other forms of sustainable transport is crucial to reducing emissions in the transport sector. This includes incentives for the purchase of electric vehicles, the expansion of charging infrastructure, and the improvement of public transport. Results show in [50], present that the transport sector emission in 2050 drops by 43.75% due to the full electrification of the land vehicle population. The charging method of electric vehicles and the carbon trading mechanism can significantly reduce carbon emissions and improve the electric system operating cost [51].

4.3.5. Promoting the Development of Biofuels

The most relevant biofuels in the country are Biodiesel and Bioethanol, produced mainly from soybeans and corn. A large part of Biodiesel is exported to the European Union, while Bioethanol is destined for the domestic market. Law 26.093 [52] establishes the regulatory framework for the promotion of biofuels in Argentina. In this sense, significant progress has been made in the production and use of biofuel, however, there are challenges that must be faced. Among the main challenges can be cited: a) competition with the food used for its production, b) investment in production and distribution infrastructure and c) sustainability of production.

4.3.6. Promotion of the Circular Economy

The circular economy seeks to minimize waste and maximize the use of resources through recycling, reuse, and recovery of materials. Implementing circular economic strategies across sectors will help reduce emissions and use resources more efficiently.

5. Priority Strategies and Actions to Take

In section 4, some strategies to change the Argentine energy matrix were presented. Table 4 shows the order of priority and the action to be taken for each of the strategies that are priorities.

Table 4. Priority matrix of the proposed strategies.

Strategy	Accion Necessary
Investment in renewable energy infrastructure	• Expand the installed capacity of wind and solar farms. • Improve transmission networks to integrate these energies into the SADI.
Tax and regulatory incentives	• Promote public policies that encourage private investment in renewables. • Set clear energy transition goals (e.g., reaching 30% renewable energy by 2030).
Technology Development and Innovation	• Encourage research and development of clean technologies, such as green hydrogen or energy storage.
Education and Awareness	• Train the population and workers in renewable energy skills. • Promoting a culture of energy efficiency.
International cooperation	• Seek funding and collaboration with international agencies and other countries to accelerate the transition.

6. Conclusions

The world nations are trying to adopt and implement credible policies which can help to attain economic growth without degrading the environment. Argentina cannot go against this reality, and therefore, it must adopt policies that help reduce CO_2 emissions in the medium term.

The energy matrix in Argentina still relies on hydrocarbons, which is why must invest heavily in renewable energy (wind, solar, green hydrogen) and infrastructure modernization. Disparities between regions require differentiated strategies to decarbonize key sectors such as agriculture and transportation.

To orient its energy matrix towards zero CO_2 emissions, Argentina must articulate a comprehensive strategy that combines effective public policies, investments in infrastructure and the adoption of new technologies. Only by coordinating efforts between the government, the private sector, and civil society will the country be able to achieve a cleaner, healthier, and more prosperous future for all.

The paper presents a comprehensive analysis of the challenges and opportunities facing Argentina in its transition to a net-zero CO_2 economy. It highlights the urgent need to transform the country's energy matrix, currently dominated by fossil fuels (75% in 2022), and harness its vast potential in renewable energies (wind, solar, green hydrogen) to meet international climate commitments and promote sustainable development.

As for dependence on fossil fuels, the exploitation of Vaca Muerta and fossil fuel subsidies contradict decarbonization goals. Insufficient investment, macroeconomic instability, and the lack of clear regulatory frameworks discourage financing in renewable infrastructure. The lack of internal political agreements, the lack of political coordination, and the government's recent refusal to adhere to global agendas such as the Pact for the Future (2025) undermines international cooperation.

Argentina has a high potential for renewable energy generation due to its exceptional resources, such as solar radiation in the NOA and high Patagonian winds, which could position it as a regional leader in clean energy. Green hydrogen and distributed generation (58,996 kW installed in 2024) offer routes to diversify the matrix and reduce emissions, presenting themselves as emerging technologies in the country. In terms of economic benefits, the transition could generate jobs, attract foreign investment, and improve public health by reducing pollution.

Some strategic recommendations for Argentina to start its path towards zero carbon emissions are presented below. Within emerging policies, we could start by gradually eliminating fossil fuel subsidies and strengthening programs such as RenovAr by defining clear goals such as, for example, that the energy matrix is made up of 35% renewable energy by 2035. On the other hand, the modernization of electricity and storage grids is very important to integrate variable energies and avoid losses (31.1 GWh reduced in 2024 due to technical limitations). Recover global alliances of international cooperation to access financing and technology, especially in green hydrogen and carbon capture.

The energy transition can stimulate innovation and technological development in Argentina. Collaboration between the public and private sectors, as well as investment in research and development, can lead to the creation of new technologies and solutions that not only benefit the country, but also Latin America.

Argentina has the technical capacity and natural resources to lead a fair and sustainable energy transition. However, its success depends on political will, economic stability and the articulation between the public and private sectors and civil society. Decarbonization is not only a climate obligation, but also an opportunity to redefine the country's development model, guaranteeing economic growth, social equity and environmental preservation. Implementing the strategies proposed in the document—from tax incentives to energy efficiency education—will be crucial to achieving carbon neutrality by 2050.

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