energies

MDPI

Article

Analysis of Smart Energy Systems and High Participation of V2G Impact for the Ecuadorian 100% Renewable Energy System by 2050

Daniel Icaza [1,*], David Borge-Diez [2], Santiago Pulla Galindo [1] and Carlos Flores-Vázquez [1]

[1] GIRVyP Group Research, Faculty of Electrical Engineering, Catholic University of Cuenca, Cuenca 010111, Ecuador; gpullag@ucacue.edu.ec (S.P.G.); cfloresv@ucacue.edu.ec (C.F.-V.)
[2] Department of Electrical, Systems and Automation Engineering, University of Leon, E-24071 Leon, Spain; david.borge@unileon.es
* Correspondence: dicazaa@ucacue.edu.ec

Abstract: This research presents a 100% renewable energy (RE) scenario by 2050 with a high share of electric vehicles on the grid (V2G) developed in Ecuador with the support of the EnergyPLAN analysis tool. Hour-by-hour data iterations were performed to determine solutions among various features, including energy storage, V2G connections that spanned the distribution system, and long-term evaluation. The high participation in V2G connections keeps the electrical system available; meanwhile, the high proportions of variable renewable energy are the pillar of the joint electrical system. The layout of the sustainable mobility scenario and the high V2G participation maintain the balance of the electrical system during most of the day, simplifying the storage equipment requirements. Consequently, the influence of V2G systems on storage is a significant result that must be considered in the energy transition that Ecuador is developing in the long term. The stored electricity will not only serve as storage for future grid use. Additionally, the V2G batteries serve as a buffer between generation from diversified renewable sources and the end-use stage.

Keywords: smart energy; energy transition; renewable energy; vehicle-to-grid; EnergyPLAN

Citation: Icaza, D.; Borge-Diez, D.; Galindo, S.P.; Flores-Vázquez, C. Analysis of Smart Energy Systems and High Participation of V2G Impact for the Ecuadorian 100% Renewable Energy System by 2050. *Energies* **2023**, *16*, 4045. https://doi.org/10.3390/en16104045

Academic Editor: Benjamin McLellan

Received: 16 March 2023
Revised: 25 April 2023
Accepted: 27 April 2023
Published: 12 May 2023

1. Introduction

Climate change is a global problem that affects environmental deterioration caused by the progressive increase in Earth's temperature and by humans causing carbon dioxide (CO_2) emissions that contribute significantly to the greenhouse effect. Given the direct influence of electrical energy on the environment, most countries, aware of this adverse situation, have considered studying actions that lead to the sustainability and diversification of renewable energy sources. The technologies currently friendly to the environment are available and increasingly accessible due to their falling costs. The technologies that have had outstanding development to influence the energy mix of the countries directly are wind and solar photovoltaic. However, it is not lost sight that other environmentally sustainable technologies are of great value in shaping the generation structure in a more diversified way.

Some countries find it difficult to assimilate the necessity to firmly promote a transition from fossil fuels toward sustained environmental viability with high participation of renewable energies; however, some researchers, scientists, and academics warn of the severe problem ahead for those countries that resist change. Most highly developed countries and drivers of significant changes (both at the level of generation and consumption) are discarding an entire obsolete system based on oil. It gives rise to the fact that the countries that maintain these old systems can become host sites for technological waste. As it is known, oil is reaching its decline, and reserves are depleting and will last for a few more decades. Thus, it would be a severe mistake for decision makers to continue with the same generation processes based on fossil fuels; developing the guidelines in these countries, regions, and cities is vital. [1]. Currently, it may be a utopia in some still extractivist societies with a tight mental scheme, but in reality, this change will be beneficial to enable a healthier future [2].

In Ecuador, most citizens have environmental awareness; however, governments must firmly assimilate this commitment to allocate sufficient economic resources to further diversify the energy matrix [3]. Unfortunately, in most cases, government ministers and advisors lack updated knowledge on energy matters. In particular, they have yet to learn how to design a transition path based on diversified renewable energy. Although hydroelectric power has historically been a valuable help, different experts and researchers advise diversifying technologies. For example, the Minas de Huascachaca wind project, which is about to come into full operation, was conceived by the government of the Citizen's Revolution of former President Rafael Correa [4]. Since then, no significant new prospecting has been promoted, and resources have been committed in the last two governments that have opted for extractivism and continued depending on oil. Yuri V. Makarov et al. [5] suggest that energy systems can be feasible in vast territorial areas based on renewable energies and that the appropriate energy storage solutions (ESSs) will enable achieving environmental objectives to generate substantial economic advantages.

As a point of reference in Ecuador, the problem of planning generation in diesel-based microgrids with RES is already being analyzed in Galapagos, considering the electrification of transportation to reduce its environmental impact. Other authors have already discussed the importance of stopping the use of fossil fuels in the archipelago. Jean-Michael Clairand et al. [6] emphasize that hybrid systems, mainly based on wind and photovoltaic solar power, can be effective solutions and support for the electrification of transport. The analyses have been carried out in Baltra and Santa Cruz communities in the Galapagos archipelago in Ecuador. The study's results demonstrated the environmental and economic benefits of investing in RES for the Galapagos microgrid. It must, above all, electrify the local transportation system. It can be replicated in continental Ecuador, where the benefits in most provinces are much more significant.

In Ecuador, it is proposed to unite joint efforts between state institutions, decentralized autonomous governments, academia, and social and productive sectors to build the National Energy Plan projected for 2050, which contemplates the planning of 10 areas of the electric and hydrocarbon sectors of Ecuador. This South American country has set this reference, while some countries, especially European ones, are trying to decarbonize their systems by 2030. It is reasonable that countries directly dependent on oil cannot easily disengage themselves from a polluting structure; even their economy is directly dependent on exporting crude oil. For this reason, it is implied that direct positive impacts are not expected in the medium term; with efforts and allocating sufficient resources, it is achievable by 2050. Significantly, the approach made in this article with V2G is of great interest and impact on the Ecuadorian electrical system. The global energy mix is shifting from fossil fuels to renewables. As this energy transformation or 'Green Deal' gains momentum, new ecosystems are formed, and new technologies emerge.

The motivation of this research is to present the impacts that can be achieved in the long term by including V2G systems in Ecuador. This research aims to provide an overview of the integration of transportation and the electricity sector, in addition to proposing 100% renewable systems, taking advantage of the energy potential in Ecuadorian territory. The struggles between the governments of the day and the transportation sector have recently been acrimonious to obtain higher fuel subsidies for the transport sector. Additionally, this approach does not consider cooperating with oil extraction, which has historically been an element of social inequalities, and the communities where it is exploited continue to maintain poverty levels, as is the case in the Amazon. Even the native people of the uncontacted towns have experienced health problems, the destruction of their natural environment, and displacement from their habitat. The background of this research—compared to others that are presented worldwide—proposes a sufficient structure to displace oil without the need to eradicate the oil sector; strategically linking the transportation sector with the electric sector has a suitable effect on building a solid sector that has as its main ally the citizens who opt for this modern option and relegate fuel and pollutants.

1.1. Literature Review and State of the Art

David Borge-Diez et al. [7] highlight that the use of the storage potential of battery electric vehicles (BEVs) can contribute to vehicle-to-grid (V2G) stability. Among its main results is the use of energy to charge the vehicle battery at night at a low rate and to power buildings from the batteries of the employees' vehicles in high-rate time slots; in this way, the employees would receive interesting bonuses. Thus, the possible coupling of renewable energy generation and electrified mobility looks promising. In Ecuador, it is possible to make similar approaches in the long term until these processes and technological conditions mature; the year 2050 is a promising reference, but research is needed henceforth.

During the last few years, several investigations have suggested that electrified vehicles could offer substantial benefits based on a synergy between the transportation and energy sectors [8]. The V2G concept is used to refer to the bidirectional flow of efficient electricity between the various modes of transport and electrical networks to achieve mutual benefits [9]. Having batteries as elements of flexible interaction with energy systems is an essential requirement that the modes of transport must offer. In this way, greater efficiency and profitability of the electrical networks, more significant proportions of renewable energy, and reduction of greenhouse gas (GHG) emissions will be achieved. Additionally, the transportation sector will have a substantial economic income for being an integral part of these processes [10].

On the other hand, the smart charge is flexible since it allows vehicle batteries to be charged when there is an excess in electricity production or when the demand is relatively low [11]. The ideal moments to discharge the energy from the batteries to the grid occur during hours of the day when the demand exceeds the supply [12]. Such flexibility becomes more relevant when electricity generation systems have a high share of renewable energy in their energy mix. Typically the sources called to revolutionize these systems are wind energy and photovoltaic solar energy [13].

Several investigations have shown that higher EV rates can effectively manage variable renewable energy resources [14]. Sid-Ali Amamra and Marco James [15] introduced a system that can operate daily EV charging and discharging scheduling to remarkably reduce the charging cost by participating in voltage and frequency regulation services.

In their most recent publication, C. Crozier et al. [16] demonstrated how intelligent BEV charging can positively impact power systems and reduce peak charging profiles. In addition, smart charging using optimal V2G strategies can extend the life of lithium-ion batteries.

There are several studies that, motivated to analyze financing aspects of V2G processes, require making the best use of the crucial investment and financing flows [17,18], where, as fast as possible, the public and private sectors are integrated and, in a joint effort, promote the decarbonization of passenger transport; Europe is a case study that is expanded in reference [19]. There are still uncertain aspects regarding the incursion of electric vehicles, such as commercial models, the degree of obsolescence of the vehicle and its battery, and innovation activities that may be developed, among other aspects [20]. Any innovation that generates momentum could create or accelerate V2G technology [21]. Countries such as Finland, Denmark, Norway, Iceland, and Sweden have been concerned with making significant developments to propose innovations that promote V2G [22].

There are several proposals regarding vehicular electric mobility, among them: the shared use of vehicles, automation, and electrification, as aspects that transform mobility and society with more environmentally friendly solutions and a tendency toward low carbon emission and sustainability [23]. The positive and negative aspects are evaluated and, in some cases, widely discussed in forums, congresses, and scientific articles, among others [24]. It is highlighted that in society and the natural environment, it depends to a large extent on how people respond, which is still not evident within the road maps that are drawn up in the countries [25]. Meanwhile, it is worth addressing the uncertainties of the net impact of the resulting technologies. Amid changes in the electricity sector, drawing up roadmaps and proposing long-term solutions is necessary [26,27]. It would be a severe mistake to wait and be reactive; thus, it is appropriate to propose solutions hereafter [28]. In this sense, several countries are focused on building a long-term zero-fossil fuel route, including the transportation sector [29]. A synthesis of what 100% renewable systems imply is provided below.

Within the framework of the Paris Agreement, the European Union (EU) has begun to promote decarbonization objectives by 2050 firmly [30,31]. Aalborg University has been the architect of important developments and has promoted research in several countries [32,33], especially in Europe [34], such as those presented by Henrik Lund [35,36]. In this same line, there are significant developments of 100% renewable systems in the long term in Central Asia [37], Africa [38], the United States [39], and South America [40]. Various studies of "road maps" have also been developed on the islands regarding energy and climate [41].

The case study for long-term energy planning carried out in Cuba is one of the latest studies related to islands, including meteorological analysis [42]. Another case was developed on Tomia to evaluate photovoltaic solar energy [43]. The case of the Canary Islands [44] contemplates 100% renewable energy to be implemented in the long term. The island of Sulawesi has also been studied for planning hydroelectric power [45]. Finally, we can highlight the study of the Galapagos Islands, which is considered a world heritage site declared by Unesco [46]. The size of the islands and their natural constraints provide an opportunity to test these practices. In particular, new technological additions that often include solar PV and wind to an energy system, such as renewable energy technologies and their impacts, are studied by creating island models that allow for a natural modeling environment [47].

In order to decarbonize electric power systems, electric vehicles have gained popularity in the transportation sector, their production systems have grown, and they continue to be renewed because they are a clean and reliable energy source that has gained interest. However, it has been the subject of detailed studies concerning electric vehicle charging and the significant contribution of energy flows to the electrical distribution system. It is a notable development to achieve grid stability due to uncoordinated charging. Several world-renowned researchers, such as Carlos Sabillón et al. [48] and Kailong Liu et al. [49], have expressed their concern regarding EV users about the cost of EV battery replacement due to degradation. Solving this other aspect constitutes a vital solution to guarantee active participation in exchanges of V2G power. Battery degradation cost is formulated for real-time analysis by taking the depth of discharge at each time interval. V2G technology is beneficial for EV consumers with high RES penetration.

Within recent research, Tianyu Hu et al. [50] propose a probabilistic short-term charging demand forecasting model, the theory of mind Self-Service-Based Machine (SAMToM), to estimate the quantiles of future charging demand from a charging station 15 min in advance. SAMToM has considered both the historical charging habits of users and the current charging demand variation trend using the Machine Theory of Mind (MToM) framework and data-driven case studies. Real-world has verified its superiority in electric vehicles. Analyses show that SAMToM has the advantage of Continuous Ranked Probability Scoring (CRPS), allowing SAMToM to directly target the highest quality of predicted quantiles.

Kailong Liu et al. [51] assert that the battery inevitably ages over time, losing its ability to store charge and deliver it efficiently, which directly affects the safety and efficiency of the battery, making related health management necessary. Recent advances in automation science and engineering have sparked interest in AI-based solutions to extend battery life from a manufacturing and management perspective. In this study, the authors present efforts by designing suitable AI solutions to improve battery life. Additionally, it presents information on advanced and feasible AI for battery manufacturing, control, and optimization, considering health at different levels of technological readiness. Bowen Jia et al. [52]

state that it is crucial for predicting the state of health (SOH) of lithium batteries. In their study, the SOH of the target battery is estimated based on the transfer of different batteries. His experiment uses an extreme learning machine to train a single hidden neural layer network for fast training and easy setup. The results showed that the proposed framework has a suitable ability to predict the SOH of lithium batteries. Kailong Liu et al. [53] present, for the first time, a systematic review of transfer learning applications in the field of battery management, with particular emphasis on battery health estimation and aging forecasts. Specifically, transfer learning applications are summarized, possible solutions are also explained, and future trends of data-driven battery management with learning are discussed regarding crucial challenges and opportunities.

In Ecuador, certain investors are interested in these technologies. However, as they are not mature, they imply the lack of a specific V2G business model, which will surely take shape in the medium term. As a result, businesses that will expand in different cities will be considered. Although this approach is by 2050, it does not mean that adequate planning should be neglected, considering specific aspects such as the deficiency of adequate bidirectional battery charging units and standards, the excessive load on EV batteries during V2G, the possibility of non-economical and unscheduled V2G practices, and the injection of voltage and current harmonics into the electrical network. It is vital to develop possible solutions for these bottlenecks, and in some specific locations, there is a need for further research. V2G is considered an important solution for the electricity sector in the long term in Ecuador, but it first requires great financing, collaboration, and technological maturity.

1.2. Aspects of Artificial Intelligence (AI) to Benefit V2G

In recent years, the smart grid (SG) system has faced several challenges, especially the growing demand for energy, an enormous growth of RES that is detected worldwide, the extensive Internet of Things (IoT) devices adaptation, and the main objective of maintaining the stability, reliability, and efficiency of the electrical system [54]. The energy cloud management system combines energy infrastructure, intelligent energy use, and value-added services based on consumer demand, which helps to deal with these problems.

At present, there is a very eloquent trend toward using artificial intelligence (AI) models, which are suitable for complex non-linear problems, such as forecasting the demand for electric vehicle charging by 2050. Different models contemplate implementing the processes for optimizing charging times in their structure. Furthermore, artificial intelligence models, such as neural networks and reinforcement learning approaches, can derive non-linear relationships from historical data and learn through environmental interaction [55]. On the other hand, they do not require expert knowledge of a complex system to build a model from system developers due to the ability of AI to learn from the existing data set. Its online configuration allows models to learn the latest available data set to improve model performance. In addition, complex problems such as power demand forecasting and charge scheduling optimization are stochastic, requiring models to be continually updated. Energy management problems pose immense severity in the search for sustainable solutions through AI [56]. The techniques support various services, such as V2G energy load prediction, consumer classification, load management, and its analysis, where data immutability and a trust mechanism are provided for safe energy management.

1.3. Research Location

Ecuador is located in the North of South America; it borders Colombia to the north, Peru to the south and east, and the Pacific Ocean to the west, approximately 1000 km from the coast is the Galapagos archipelago, which is also part of Ecuador. The country has an approximate area of 256,370 km^2, one of South America's smallest countries. Ecuador is one of the countries with the world's highest flora and fauna resources per square kilometer. It has four central geographical regions: The Pacific Coast, the Sierra of the Andes, the Amazon Jungle, and the beautiful and heritage Galapagos Islands. Ecuador is an excellent paradise with various species of plants and animals due to its various regions and location, among many other benefits. It also has heritage cities such as Quito and Cuenca. It is a country that, from the social conglomerates, exerts pressure on the central state so that favorable public policies are issued to protect the environment and water over mining and oil exploitation. This study aims to promote the use of renewable energies and, mainly, analyze the impacts of the high participation of V2G in the 100% renewable energy system. Figure 1 shows the geographic location of Ecuador.

Figure 1. The geographic location of Ecuador.

2. Methodology

In this research, a 100% renewable energy system is designed, examining a scenario with energy storage solutions (ESSs). Thus, the participation of V2G will affect the energy system and the network due to including the participation of electric vehicles. This design, which is currently not active in Ecuador but may prove promising in the future, could not only help enable higher shares of renewable energy but could preclude the need for other forms of storage, especially the storage of seasonal energy. The sustainable mobility (SM) scenario under analysis focuses on the mobility sector, and various countries, such as Spain, are being studied with great interest. Consequently, it was assumed that the electrification of passenger vehicles would be achieved in the long term with the respective incentives and policies of the electric sector 100% until 2050. Certain aspects are accepted and based on the experiences of studies developed in avant-garde countries, such as France [57] and Spain [7]; the scenarios are drawn according to the recommendations specified by the reference [58]. For the layout of the V2G system, it is specified in the methodology that the country has sufficient energy potentials that entail using new feasible renewable technologies and that the impacts of the V2G system can be evaluated.

Three phases have been foreseen in the scientific methodological analysis: the first phase is data entry and available energy potentials; the second consists of the calibration or adjustment phase, which depends on collateral aspects, such as regulations and state policies, among others, that have a direct impact on the takeoff and increase in renewable systems, budget allocations, and motivations to accelerate an orderly energy transition at the country level; finally, in the third part, the technologies and the socioeconomic results, valued according to the demand, are presented. Additionally, indirect aspects, such as worldwide technological development and the special effects of international pressure, are considered based on the agreements reached(i.e., those of the United Nations Conference on Climate Change). Another transcendental aspect in the world, from which Ecuador is not excepted, is that it allows affordable access to products and services, ensuring flexibility in financial operations. It is a priority in low-income countries to satisfy aspects of the main demands of civil society, including health, food, education, and housing. With the availability of accessible technological conditions for products and services, the energy sector will surely opt to transform its systems with a high share of renewable technologies, knowing that eventually, the few available oil reserves will be depleted; not renewing its systems may result in being destination countries for technological scrap.

Long-Term Projection Model

To evaluate the system's design in the long term, specifically the impacts of the high participation of V2G in Ecuador until 2050. It takes advantage of the free software EnergyPLAN, considered a consolidated tool to carry out these types of evaluations of energy systems in the long term. EnergyPLAN will provide an hourly energy mix on the basis of your input assumptions of load, energy mix target, etc. In this regard, there are several case studies on the official website (https://www.energyplan.eu/ (accessed on 1 April 2023)) regarding the study of electric vehicles and their impact in the medium and long term [59]. This model, in its recently available version 16.1, is shown in Figure 2. The model has excellent features, is versatile and easy to use, and allows technical and feasibility analysis. In the final part, the energy balance results are shown.

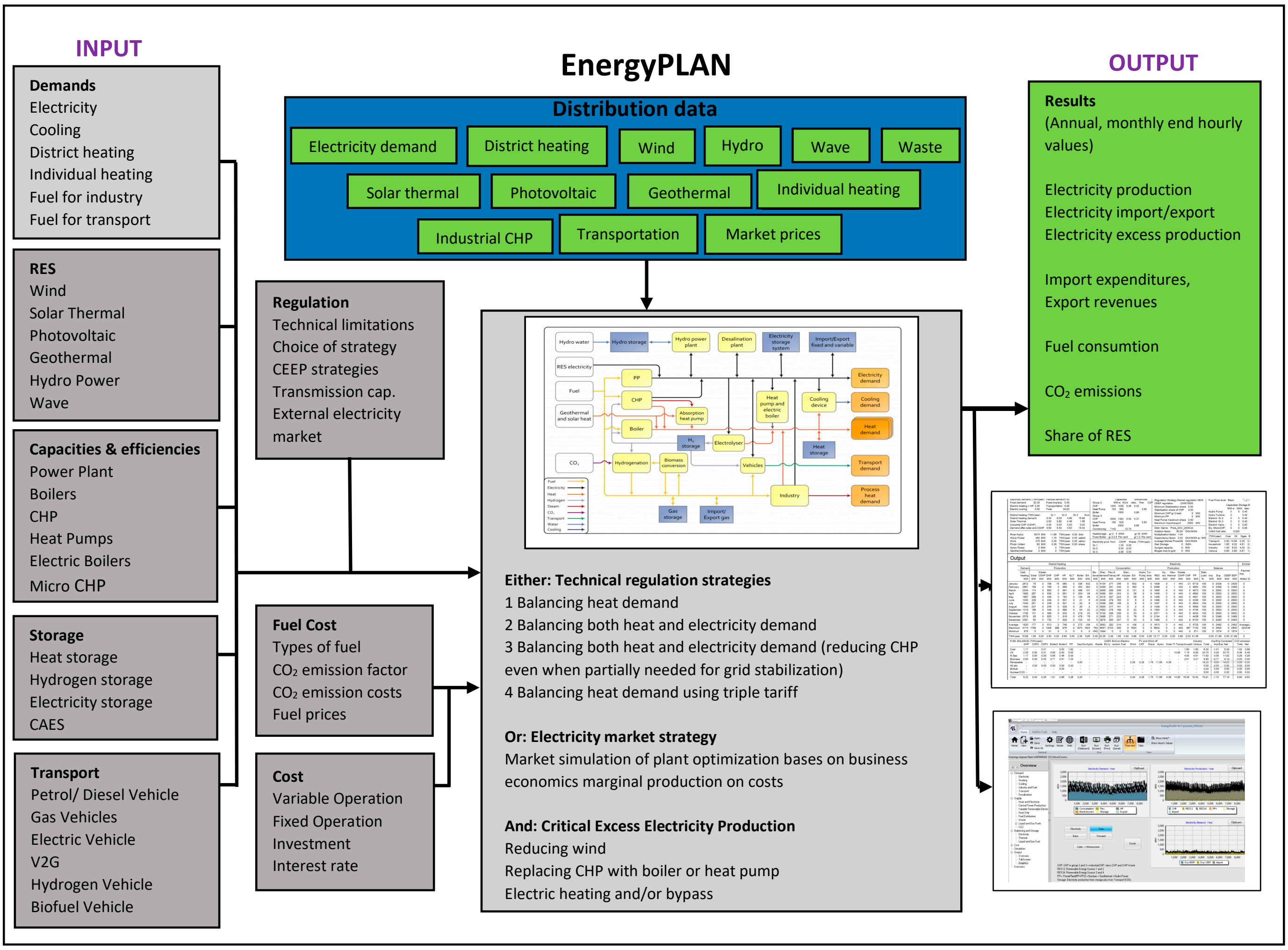


Figure 2. EnergyPLAN V16.1 analysis model for smart energy planning, inspired in [60].

3. Base Year and Its Input Parameters

In Ecuador, the electricity coverage rate is 97.33%, according to the report presented by [61]; actually, its coverage is significant concerning Latin America and the Caribbean. However, this is not the problem; the situation is that it is necessary to diversify the Ecuadorian energy system and put aside the use of fossil fuels. In addition, taking advantage of storage systems using V2G techniques extensively addressed in the literature review is necessary. Table 1 below presents the base state of the Ecuadorian energy system that will serve as a reference to enter the main parameters into the EnergyPLAN model.

Table 1. Detailed installed power by source.

	Installed Power in Generation				**Production and Imports**			
					Total		**Only SIN**	
Electric Power	**Nominal Power**		**Effective Power**		**GWh**	**%**	**GWh**	**%**
	MW	**%**	**MW**	**%**	**32,558.72**	**100.00%**	**28,525.34**	**100.00%**
National (Renewable + Non-Renewable)	8734.41	100.00%	8100.68	100.00%	32,206.88	98.88%	28,173.50	98.73%
Renovable	5308.27	60.77%	5263.78	64.98%	26,088.42	80.10%	26,063.96	91.34%
Hydraulic	5106.85	58.47%	5072.26	62.62%	25,574.61	78.52%	25,555.53	89.56%
Wind	21.15	0.24%	21.15	0.26%	62.01	0.19%	60.06	0.21%
Photovoltaic	27.65	0.32%	26.76	0.33%	36.87	0.11%	33.44	0.12%
Biomass	144.3	1.65%	136.4	1.68%	372.80	1.14%	372.80	1.31%
Biogas	8.32	0.10%	7.2	0.09%	42.13	0.13%	42.13	0.15%
Non-Renewable	3426.14	39.23%	2836.90	35.02%	6118.46	18.78%	2109.54	7.39%
MCI	2020.67	23.13%	1614.85	19.93%	4335.56	13.31%	671.95	2.35%
Turbogas	943.85	10.81%	790.55	9.76%	911.82	2.80%	594.53	2.08%
Turbosteam	461.63	5.29%	431.5	5.33%	871.07	2.67%	843.06	2.95%
Import	650.00	100.00%	635.00	100.00%	363.80	1.12%	363.80	1.27%
Colombia	540.00	83.08%	525.00	82.68%	363.80	1.12%	363.80	1.27%
Peru	110.00	16.92%	110.00	17.32%	0.00	0.00%	0.00	0.00%

Concerning the nominal national power, 5308.27 MW (60.77%) corresponds to plants with renewable energy sources and 3426.14 MW (39.23%) to plants with non-renewable energy sources, see Figure 3.

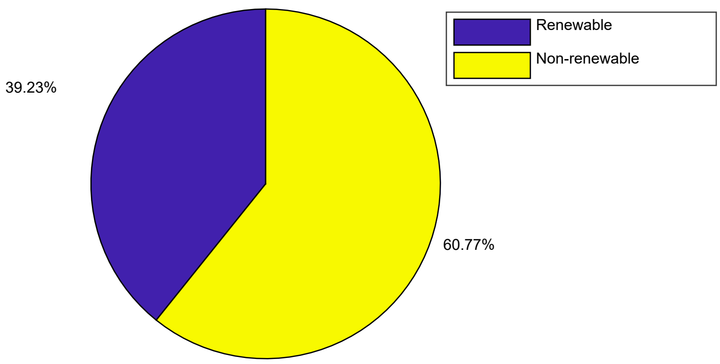


Figure 3. Ecuadorian generation system identifying renewable and non-renewable energy [62].

Next, in Figure 4, the Sankey diagram [63] presents a graphically clear transportation structure in Ecuador, which is based on an oil-dependent system at its maximum expression. A transition toward electric mobility means eliminating oil, which is not impossible.

However, it is necessary to start changing this energy matrix quickly so that it can affect demand, not only at the transport level but also in other sectors.

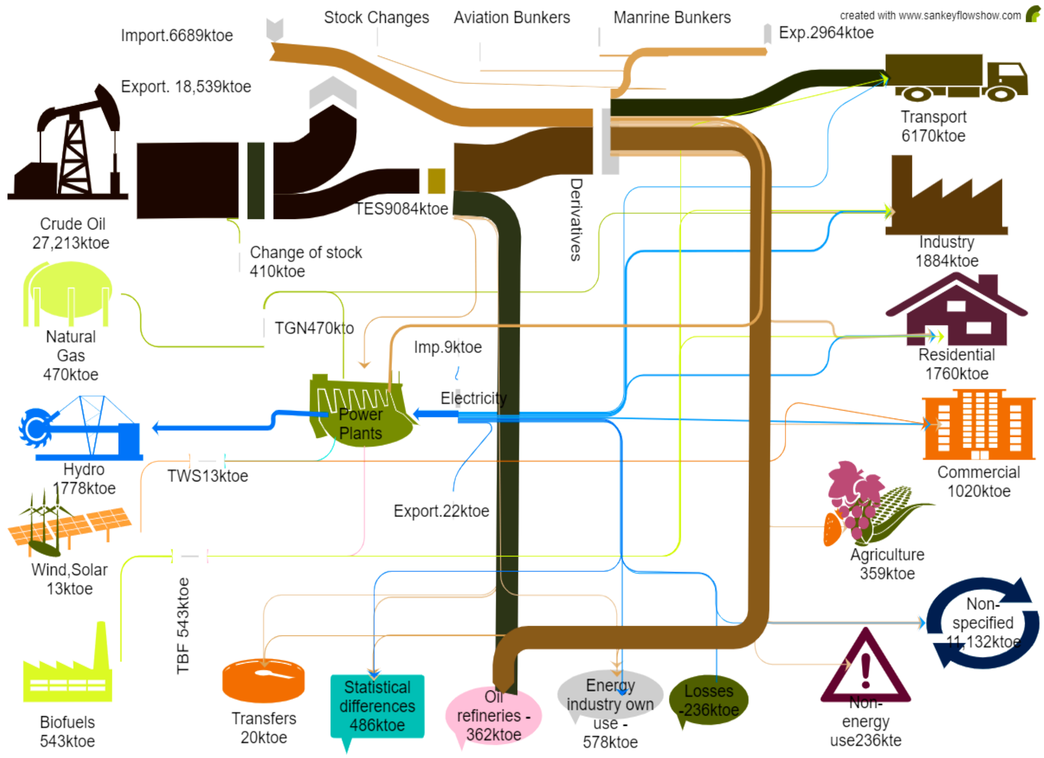


Figure 4. Sankey diagram of Ecuador, developed from the reference data [64].

3.1. *Renewable Energy Potentials in Ecuador*

Ecuador has enormous potential for the development of non-conventional RE, according to what was pointed out by a panel of energy experts. Most of the energy (93.2%) generated in Ecuador in 2021 was renewable, based mainly on water resources due to the continuous operation of hydroelectric plants such as Coca Codo Sinclair, Paute, Sopladora, Minas San Francisco, and Delsitanisagua, among others [65]. The president of the Ecuadorian Association of Renewable Energies and Energy Efficiency (AEEREE), Eduardo Rosero, said in an online seminar organized by the Institute of the Americas that the energy sector would gain prominence in the post-pandemic scenario and that the challenge will be the development of technologies [66]. Ecuador's non-conventional renewable energy potential: photovoltaic, wind, bioenergy, and others will help complement hydroelectric production and, in the long term, are expected to be the technologies that will revolutionize the Ecuadorian electrical system, substituting energy from fossil fuels [67].

3.2. *Location of Renewable Energy Projects with a View to an Energy Transition*

The central government, through the MERNNR, promotes and develops public selection processes (PPSs) and has created public policies to strengthen the electricity sector, for, among various purposes, the generation of electricity in Ecuador [68]. Some projects have been defined; it does not mean that the projects cannot be carried out in other sites with a similar potential for generating solar, wind, and biomass energy, among others. The locations of the projects destined for the exploitation of electrical energy are in different provinces, detailed below.

3.2.1. Hydropower

Previous investigations have already determined that the Amazon slope has the most significant hydraulic potential in continental Ecuador, with approximately 9.93 GW; it has been the main base for power generation, and projects continue to be pursued on the

Pacific slope (3.5 GW) to solve the deficit in energy in summer [69]. The main hydroelectric projects in Ecuador are in Figure 5.

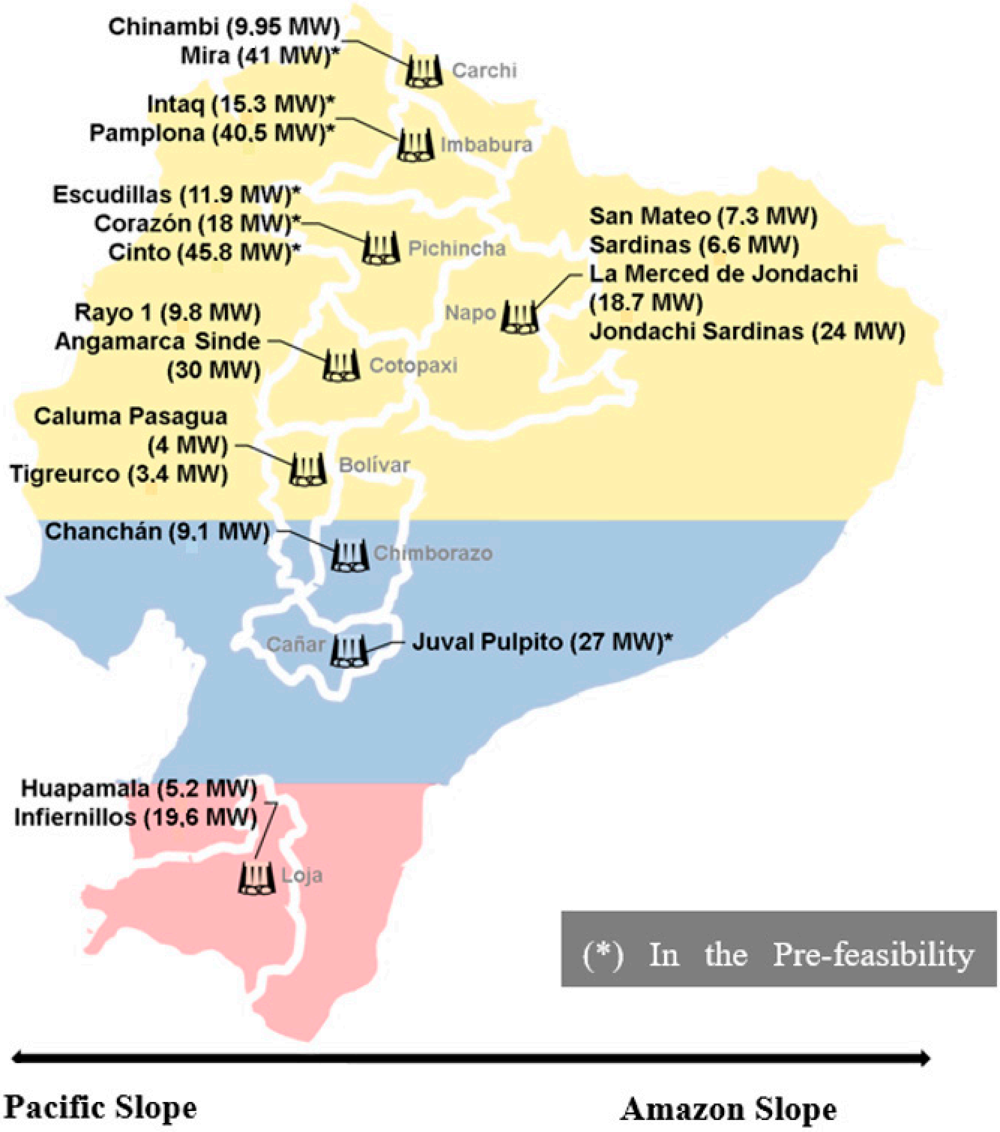


Figure 5. Hydroelectric projects, adapted from [69].

3.2.2. Solar Photovoltaic Power

Ecuador has a very high potential to generate energy, taking advantage of solar radiation because it is on the equator line where the sun's rays fall practically perpendicular since it is in the middle of the world. At least 660 photovoltaic MWp are estimated to be located in places with a high solar irradiation level. It is very feasible to connect with different cities and communities that do not have environmental or social limitations. The provinces of Pichincha, Carchi, Cotopaxi, Manabí, Imbabura, Chimborazo, El Oro, Loja, and Guayas are sites with high generation potential, as shown in Figure 6. The annual irradiance values are specified below the minimum, 2.8 Wh/m^2 day; maximum, 6.4 Wh/m^2 day; and a half, 4.5 Wh/m^2 day [40,70].

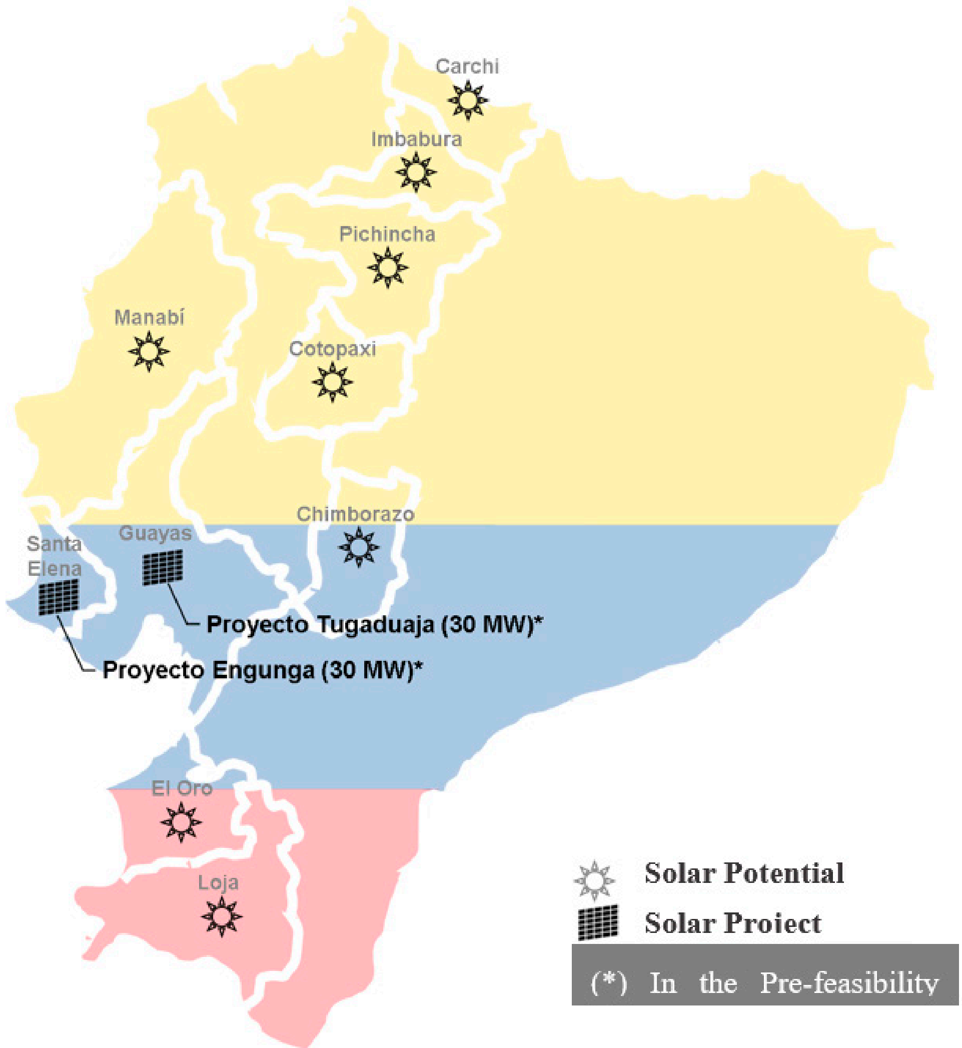


Figure 6. Solar photovoltaic projects in Ecuador, adapted from [69].

3.2.3. Wind Power

After analyzing the Ecuadorian wind atlas [69,71], the average annual wind speeds exceed 7 m/s at 3000 masl. Thus, the evaluated usable potential is 891 MW in the short term, see Figure 7.

3.2.4. Biomass Power

In Ecuador, biomass is an interesting resource that can be useful for generating electrical energy, especially from the African palm, sugar cane, and rice husk [69]; these resources are available in almost all regions of the country.

The Bioenergetic Atlas of Ecuador [72] highlights the main characteristics of the use of biomass in electricity generation. It considers 18.4 million tons of agricultural, livestock, and forest residues annually, and approximately 12,700 GWh/year can be extracted. The projects are illustrated in Figure 8.

In Ecuador, there is a high potential for electricity generation. Previously, specific planning was indicated, which may have a more significant connotation; the available energy potential can be much better exploited, and the project portfolio can be expanded to achieve the decarbonization of the country and better apply the concept of V2G, which is linked to the storage, but undoubtedly has a direct relationship with renewable generation systems.

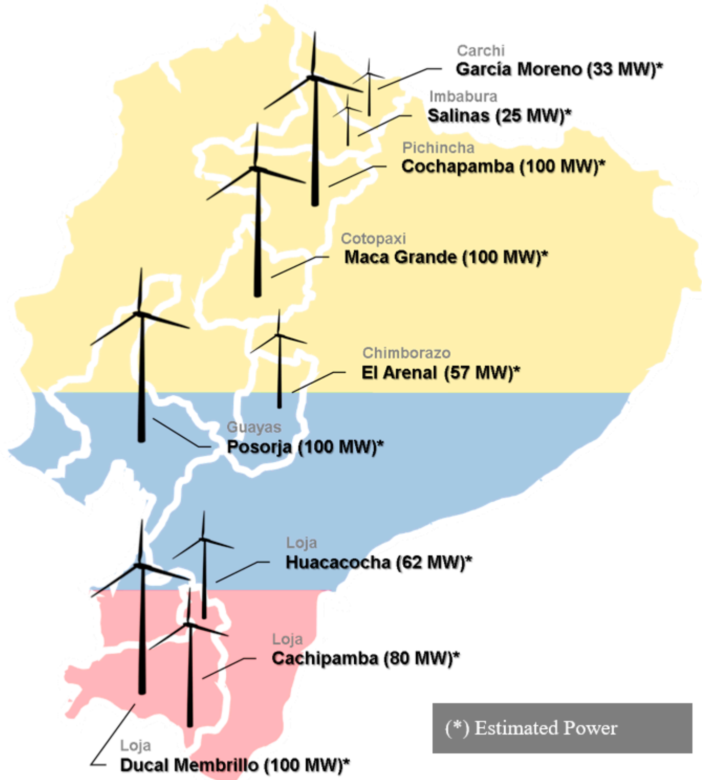


Figure 7. Wind projects for 25-year concession, adapted from [69].

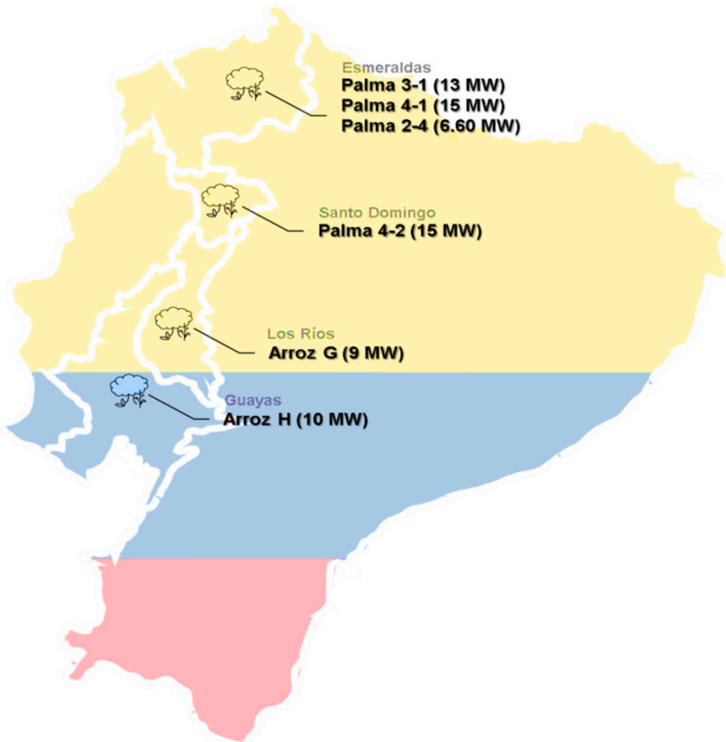
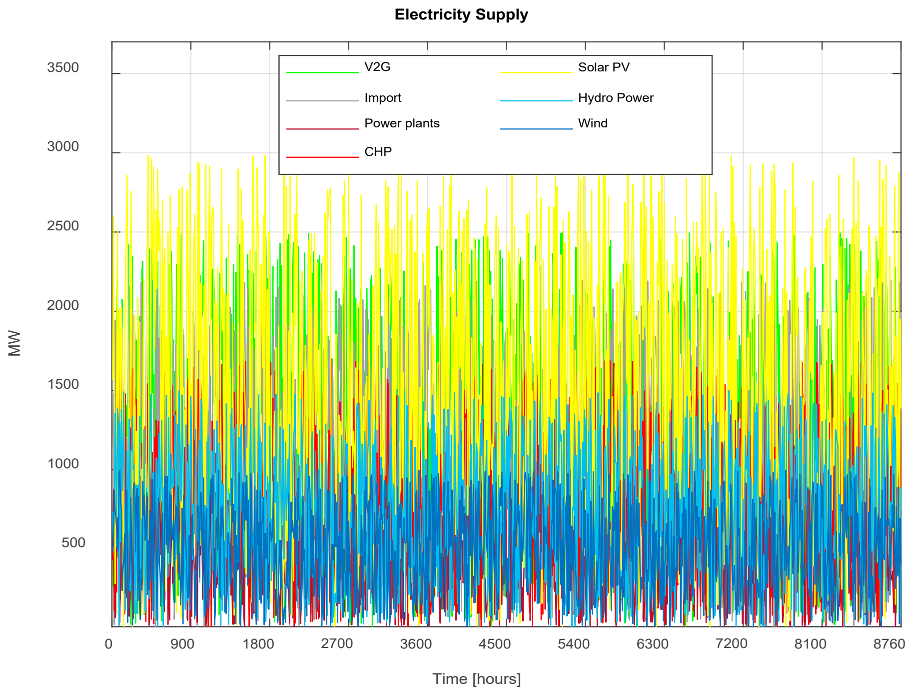


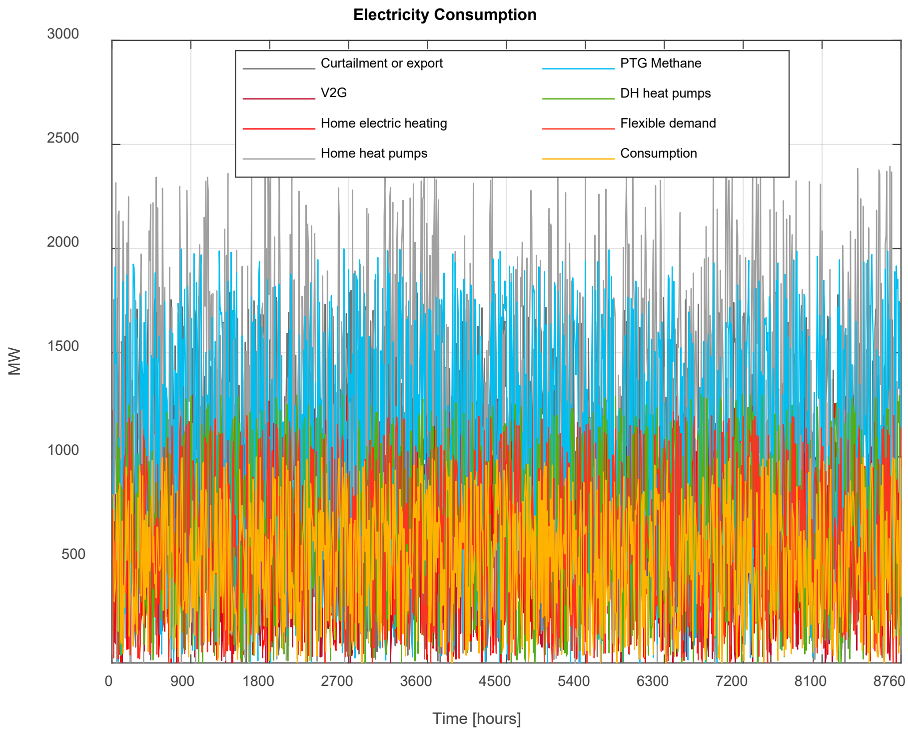
Figure 8. Projects of biomass 2018–2027, adapted from [69].

4. Results

Electricity supply and consumption are shown in Figure 9a,b, respectively. Solar photovoltaic generation is much higher in summer and is detailed at a one-hour resolution. Wind energy is less variable in summer, becoming a natural seasonality.



(**a**)

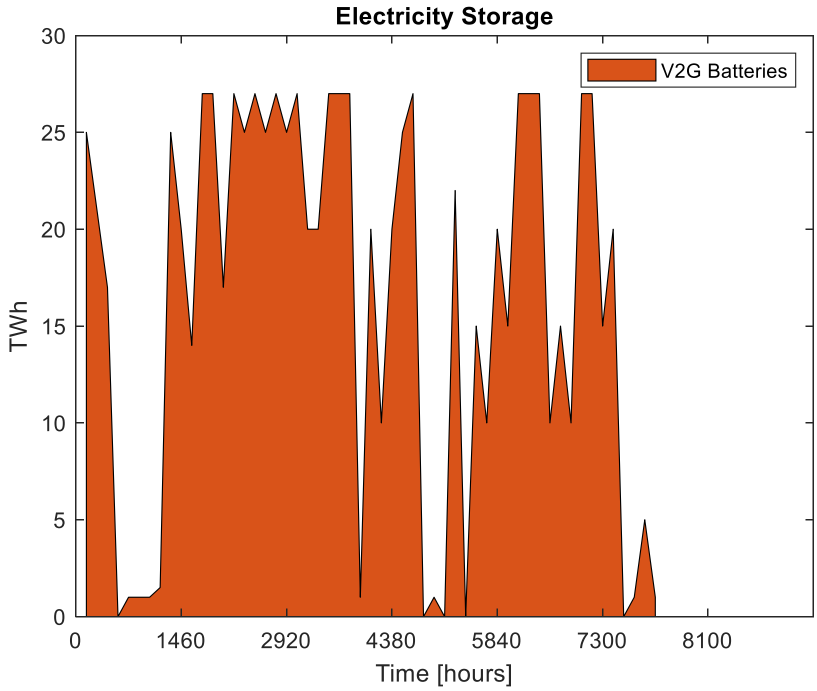


(**b**)

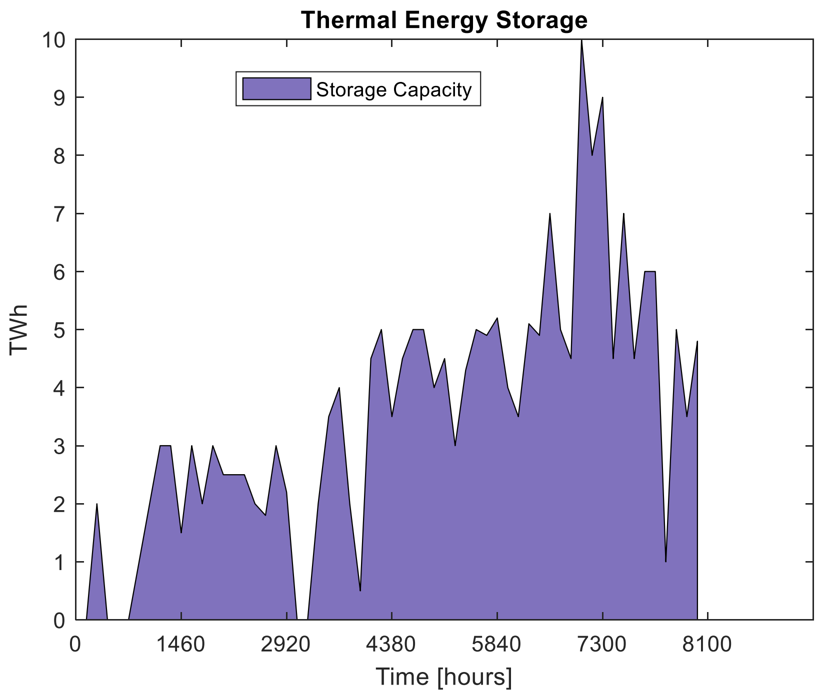
Figure 9. Annual profiles of electricity supply and consumption in an hourly resolution by 2050. (**a**) Supply profile. (**b**) Consumption profile.

Both wind power and photovoltaic solar power complement each other very well because it has historically become indispensable, such as hydroelectric power. Additionally, it is highlighted that combined heat and power plants (CHPs) can benefit our environment; it has not been a fundamental pillar, but it is contemplated within the results to maintain the balance between supply and consumption. The balance achieved by V2G and the existence of flexible demands also contributes to the system's stability, reducing peaks and valley filling at certain times of extremely high or low power.

The annual results are shown on an hourly scale in Figure 10 for electricity storage, thermal energy storage, and percentage of wind/solar PV production at hourly resolution by 2050. The results of the runs are displayed in Matlab with the purpose of a slightly broader presentation of the schemes that have been collected from EnergyPLAN.

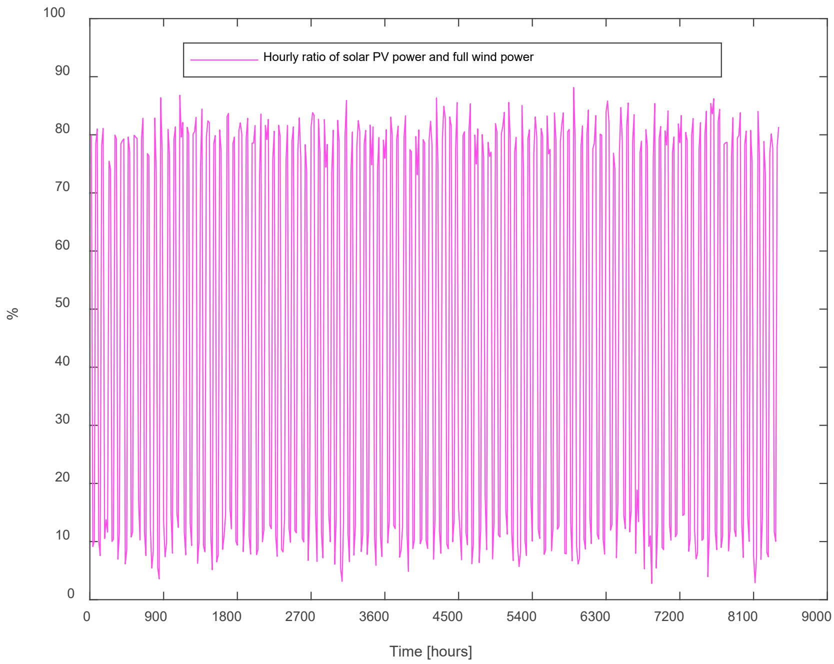


(**a**)



(**b**)

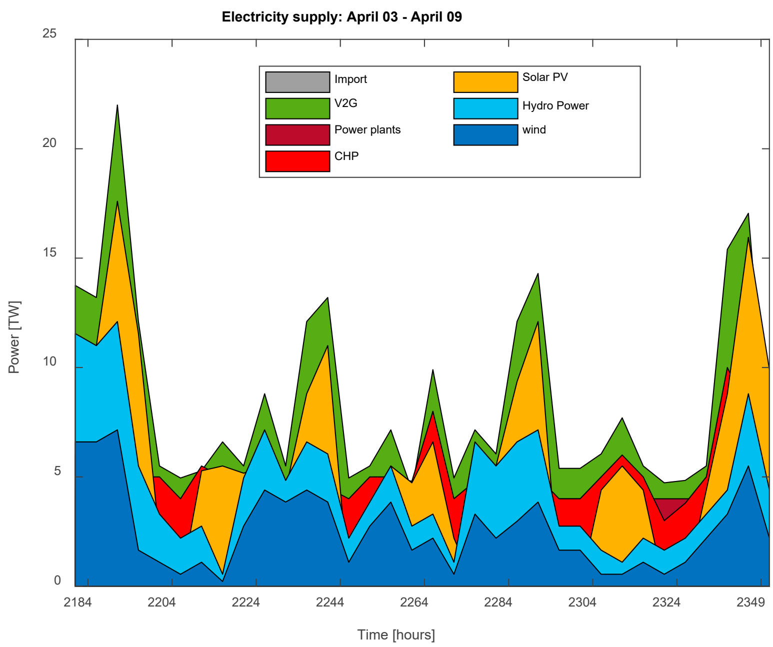
Figure 10. *Cont.*



(**c**)

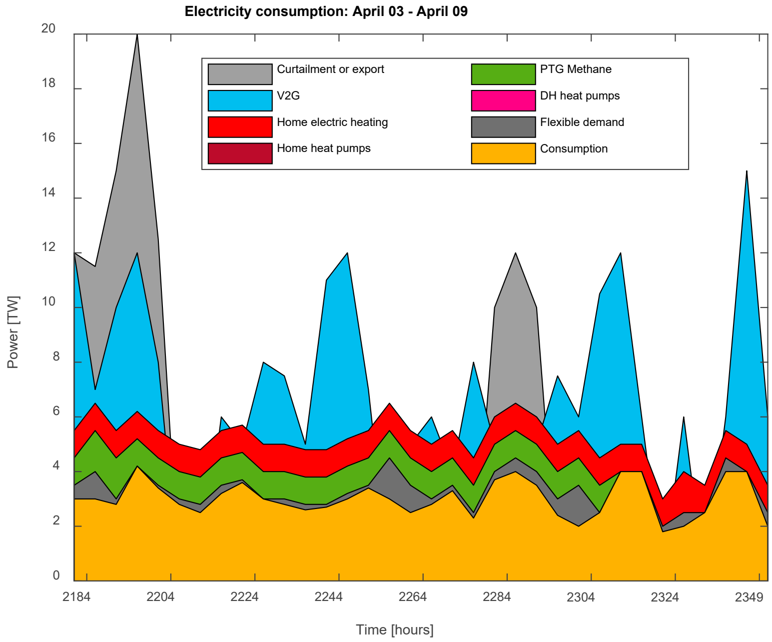
Figure 10. Annual storage profiles and wind and solar PV production percentages at hourly resolution by 2050. (**a**) Electricity storage. (**b**) Thermal energy storage. (**c**) Percentage of wind/solar PV production.

It was considered to analyze a shorter period and the existing relationships between production, consumption, and storage. Therefore, a specific week was analyzed from 3 April to 9 April 2050. Although these are long-term scenarios, it allows us to analyze the impact that V2G systems can have when there is a 100% renewable energy contribution. It is undoubtedly the most appropriate to take advantage of vehicle fleets and supply energy to the network, as shown in Figure 11.

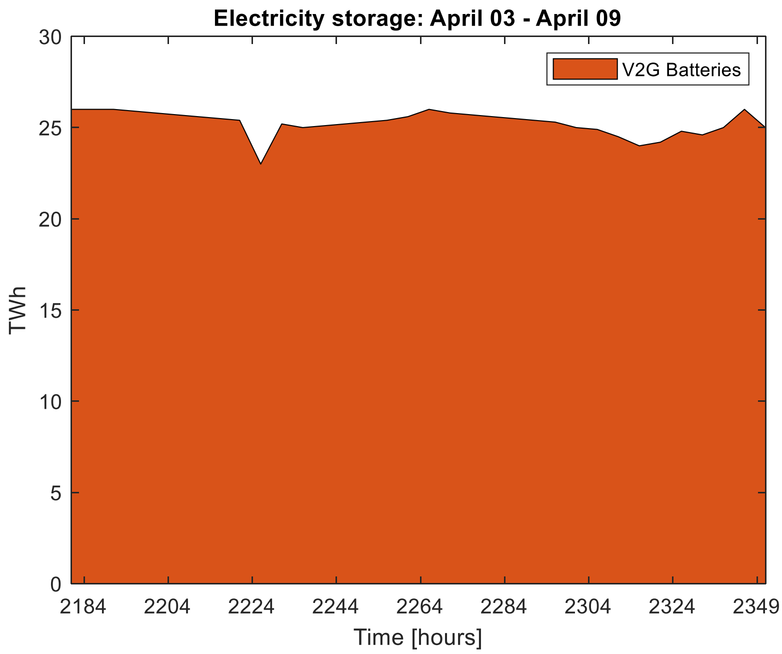


(**a**)

Figure 11. *Cont.*

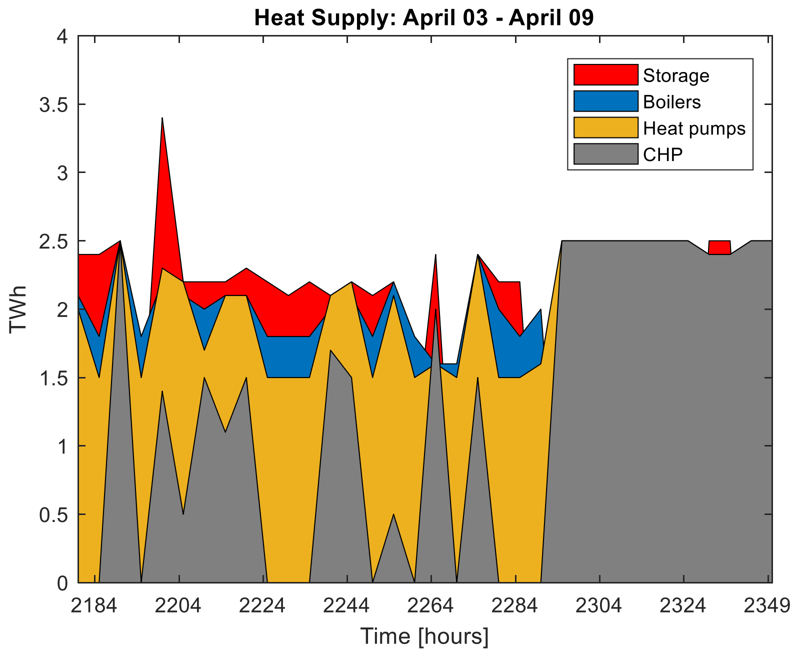


(**b**)

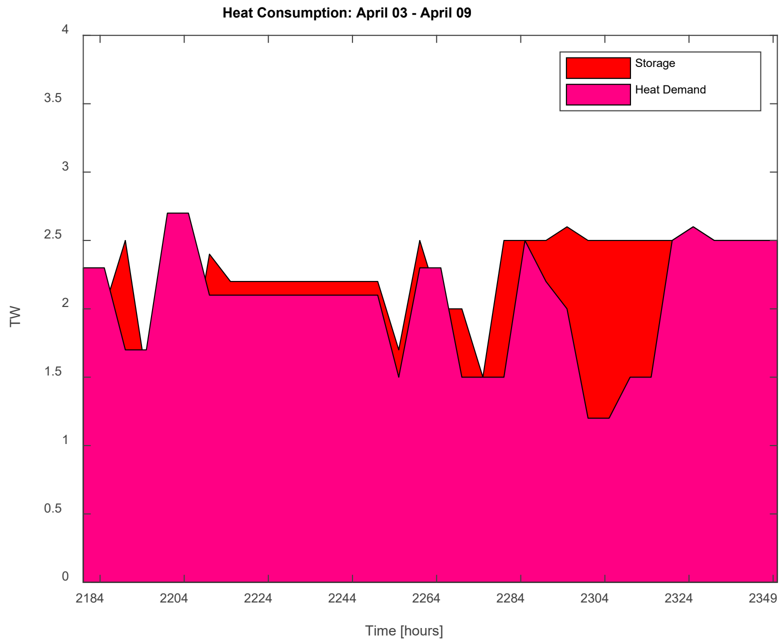


(**c**)

Figure 11. *Cont*.



(**d**)



(**e**)

Figure 11. Specific analysis scenario of the detailed profiles studied from 3 April to 9 April 2050. (**a**) Electricity supply. (**b**) Electricity consumption. (**c**) Electricity storage. (**d**) Heat supply. (**e**) Heat consumption.

5. Discussion

Wind and photovoltaic solar energy are called to be protagonists in the Ecuadorian electrical system. The Minas de Huascachaca wind and El Aromo solar projects will provide the roadmap for the energy transition. Hydroelectric power will continue to be a central part of the Ecuadorian energy mix, and several projects will be integrated in the future. After conducting the analyses and establishing a scenario for the year 2050 with the support of EnergyPLAN, the need for energy diversification and the three sources of hydraulic (42%), wind (28.7%), and solar (25%), and other small proportions (4.3%) that are expected to influence the Ecuadorian electricity sector by 2050 are highlighted. It is essential to indicate that energy generation is highly variable in all the months of the year, and several researchers recommend that surplus energy can be stored to be used in specific periods of scarcity. From the storage analysis, it has been conceived that a viable long-term alternative is the dynamic use of the batteries. It implies taking advantage of energy generation due to the increased load when circulating on the roads or due to excess energy from independent renewable sources typically located at the domestic level, injecting a proportion of that energy into the grid. In 2050, vehicles will be electric due to the factors already indicated in this study, such as the exact technological change and the limitation of fossil fuels. In this study, an approach has been given to the use of renewable energies in a high proportion, which is expected in the future in the face of the imminent shortage of oil and the conditions it brings to the environment and the health of living beings. Approximately 74% of renewable energy has a final consumption destination; the rest would go to storage (20%) and a small proportion to reduction (6%). V2G batteries are vital in the energy system and provide at least 70% of electrical storage. Expanding the storage level of V2G will be an aspect of future discussion, including a diversity of types of transport that would substantially benefit the Ecuadorian energy system.

V2G was generally assumed for modeling using the EnergyPLAN tool. No distinction was made between road vehicle-to-grid and vessel-to-grid as such differentiation cannot be made in the respective module. It is also important to indicate that a significant percentage of family or personal boats (8%) with solar panels would be completely inactive during some months of the year due to winter periods and swell caused by the presence of El Niño currents at certain times; therefore, their batteries could not offer storage to supply it to the grid. On the other hand, the electricity demands during the summer months can be able to provide more energy using V2G, which is represented in the profiles; this is the case for the regular droughts the country experiences and the low levels of hydroelectric energy production; here is a beneficial opportunity that would be found with V2G. A more comprehensive range of benefits and innovation options for extending V2G services can be determined. The sooner an energy transition is achieved in Ecuador, the greater the increase in electric vehicles will be, and the greater the benefits will be achieved with the noticeable increase in vehicle fleets. The vehicular electrification level could include other mobility items that may be partially electrified, including fishing canoes, water sports craft, ferries, and larger ships. Other types of vehicles may be integrated, considering a higher degree of innovation in the case of tractors, forklifts, forestry machines, agricultural machines, and mobile robots.

The results of this study determine that V2G batteries can play a significant role; this will depend on the inclusion of regulatory bodies at the country level to motivate the transportation sector to become an integral part of the Ecuadorian electrical system. The two sectors may achieve mutual benefits, and each sector is called to renew its systems, and the sooner they merge, the sooner they will be able to perceive their benefits. In the analyses of this research, around 58% of the electricity that circulates to the V2G batteries is injected into the grid, while 32% is used for mobility demand. Concerning electric vehicles and development prospects, it will depend a lot on the size of the batteries used. Having batteries with suitable storage capacities will also allow suitable proportions of electrical energy to enter the electrical grid. This situation can be very significant and will depend on the new models of vehicles that provide batteries with suitable characteristics to achieve these purposes and autonomy for driving the vehicle itself. Regarding current batteries, the first tests developed with a battery with nickel-cobalt chemistry have reached 207.3 kWh [73], a pack installed in a Tesla Model S occupying the same space as the original battery. The average battery sizes by 2050 are assumed to be conservative in this study, considering 150 kWh batteries for road vehicles. Assuming that large sizes (primarily used in the Ecuadorian mobility sector) are achieved, they can offer greater flexibility to the electrical network, and in turn, to the energy system than what is contemplated in this research.

In other countries, such as Germany [74], China [75], the U.K. [76,77], and even at the European level [78], there are already studies that identify long-term development opportunities of the V2G system involving the transportation and energy sectors. In South America, there is a lack of studies that go beyond implementing renewable energy plants. Instead, they need to analyze the scope of what a technological change implies in a planned way and somehow provide different approaches according to the reality of each country. The sharp rise in the prices of energy raw materials starting in 2008 highlighted the vulnerability of Western economies and the need to promote efficiency and energy savings, which also constitutes an instrument that generates new business opportunities and employment.

To achieve a sustainable future, the Ministry of the Environment, Water, and Ecological Transition of Ecuador, through the National Plan for Climate Change Mitigation (PLANMICC in Spanish) project, seeks to strengthen the various production sectors, including the energy sector. Besides governmental entities, private companies and academia generated strategies, models, and decarbonization scenarios. In this line, the scenarios identified by 2050 in this study focus on the purposes outlined in Ecuador; they will allow a significant penetration of renewable energies and an exchange of power flows with V2G to supply the demand in peak hours. This dynamic that can be established in the Ecuadorian energy market in the long term will generate sources of employment, the environment will be protected, and the energy demand will be guaranteed.

The National Energy Efficiency Plan 2016–2035 (PLANEE by its Spanish acronym) includes outstanding arguments applicable to the reality of Ecuador, based on international practices for the use and exploitation of technologies, as well as the experiences and lessons learned from the application of energy efficiency in Ecuador, in the period 2007–2015. PLANEE also promotes the progressive substitution of fuels and energy sources with a high environmental impact by others without carbon, including renewable energy sources. In addition, it shows the incredible commitment that our country has to the planet by promoting concrete actions to guarantee, for the population and future generations, sustainable economic development based on access to modern, clean, and affordable energy through the use of the resources available in the territory, to achieve a much more intelligent, efficient, and environmentally responsible electrical system. One of the findings that can be highlighted in the results of this study is that V2G can be applied in Ecuador without problems throughout the year. When the trend of solar PV is down, it is compensated by hydro and vice versa. Wind energy will maintain the expected variability within the combination with the other technologies and will not fall below 5TW; it is identified that there are no gaps between peaks by having this combination of energy sources. On the other hand, V2G storage systems increase the levels of availability of electrical power to around a minimum of 2TW throughout the year. Thus, they would ensure on-demand service at all hours of the day, especially during rush hours.

A two-way power flow gives an idea of the future for V2G technology: an interaction of flows between power generation and distribution companies and consumers. V2G technology is becoming more accepted as electric vehicles rapidly increase worldwide. In Ecuador, electromobility routes are already available; mainly, the city of Cuenca is a pioneer in these aspects and a benchmark for the rest of the country. There has been an increase in the number of electric vehicles in recent years; among them, the Cuenca mobility company has renewed its transport fleet with electric vehicles. V2G technology can be expected to be increasingly developed and adopted before 2050 to combat the problem of demand spikes. As technology advances, batteries are expected to charge faster, increasing network demand. As a result, there will be a more significant need to balance network systems, and V2G technology can solve most of the problems that arise in Ecuador.

Within the limitations, no legal regulation directly promotes V2G systems. This will be necessary for the future so that, based on clear regulations, benefits and duties can be established on the part of vehicle fleets integrated into the electricity supply network. It is necessary that the different sectors of the country that are familiar with the energy and transportation fields dialogue create general guidelines and make the integration of both sectors viable. Executive Decree No. 238 of 26 October 2021, in article 4, establishes a term for the execution of various immediate actions, among them: (a) Formulate and propose public policies and institutions, and reform the legal and regulatory framework, as pertinent to generate optimal, technical, economic, environmental, and social conditions that allow encouraging private investment in the different areas of the public electricity energy service, general public lighting service, electric vehicle charging service, and energy storage; (g) Formulate policies and propose regulations to seek better efficiency in the use of energy sources and the use of electrical energy by consumers and electrical companies owned by the state.

6. Conclusions

In Ecuador, there is a lack of high-impact research that provides alternatives to commit economic resources in a differentiated way and avoid the same practices of yesteryear. The worst that can happen is that not much will be achieved if one keeps thinking that the oil structure is the one that will change the country when it has not done so effectively for decades.

Countries seeking an orderly energy transition are called upon to consider within their approaches an analysis related to V2G batteries that can have a favorable impact depending on the reality of each country. The automotive industry is also concerned about achieving more remarkable product and service development. The study and development of electric batteries are crucial and go hand in hand with the electricity sector, which at some point, will intercept it, and together they can achieve mutual benefits. Developing a fully sustainable scenario for any region entails defining a framework of policies and strategies that mostly comes from the central government that must be in tune with technological changes.

In continental Ecuador, from 2025, all vehicles incorporated into the urban and interparochial public transport service must only be electric. In this studio, the appropriate combination of technologies was presented for Ecuador, which is facing a growing demand for energy and technological change, and will require storage systems. As discussed, V2G can immensely contribute in the medium and long term. The effective application of V2G will also allow lower installed electricity generation capacities. V2G services should continue to be investigated both from the technical and social approaches to identify development opportunities and minimize any weaknesses that may be found.

Variable renewable energy may be based on hydraulic energy, which will continue to be the primary generation source for final consumption electricity with 42%, followed by solar photovoltaic and wind energy with 53.7%, and other small contributions with 4.3%.

The importance of diversifying the energy matrix in Ecuador lies in reducing the risks due to the exclusive dependence on specific sources. In Ecuador, depending on hydroelectric energy carries a substantial risk; therefore, solar photovoltaic and wind energy will play a leading role. In times of drought, as has occurred in previous years, it can be compensated with higher levels of solar energy. Here, a consistent storage system must be available to supply at times of low production from any electricity generation sources. In this aspect, V2G will again become critical within the Ecuadorian electrical system.

Energy transition processes are becoming more efficient thanks to technologies that accelerate the delivery of reliable battery-based energy storage systems that will later be defined when applying V2G. Given that the state of the battery plays a fundamental role regarding the safety of the battery and its efficiency, the need to investigate technological and economic aspects to extend the life of the batteries is unavoidable, knowing that there will always be deterioration. However, the challenge is to make it last as long as possible. Another key but the challenging issue is promoting the broader applications of the battery that lie in the effective health of battery management. In Ecuador, it is transcendental, for example, that the roads be the most optimal for vehicles to travel normally and without extreme efforts that could affect their regular operation. AI-based management and manufacturing solutions are undoubtedly an acceptable way to improve battery health performance. High-precision algorithms have been developed, but it is necessary to continue developing better materials and systems that maintain the highest standards of battery efficiency. Ultimately, with the advancement of control and automation science and engineering, battery durability and efficiency are about to be structured by AI-based solutions, from manufacturing to their end uses.

Author Contributions: Conceptualization, D.I.; methodology, D.I. and S.P.G.; Data curation, D.I. and D.B.-D.; Validation, D.I., C.F.-V. and D.B.-D.; Writing—original draft, D.I., S.P.G. and D.B.-D.; Writing—review and editing, D.B.-D. All authors have read and agreed to the published version of the manuscript.

Funding: The University of León supported the contributions of D.B.-D. from the Department of Electrical, Systems, and Automation Engineering. D.I., S.P.G. and C.F.-V. are members of the GIRVyP Group, which received the support of the Catholic University of Cuenca in Ecuador.

Acknowledgments: Our gratitude to the University of León of Spain and the Catholic University of Cuenca for promoting this research and pleasantly promoting the internationalization processes, and to D.B.-D., a researcher at ULE, for his highest valuable contribution so that this research has had the expected success.

Conflicts of Interest: The authors declare no conflict of interest.

Abbreviations

BEV	Battery electric vehicles
CHP	Combined heat and power
CO_2	Carbon dioxide
ESS	Energy storage solution
GHG	Greenhouse gas
MERNNR	Ministerio de Energía y Recursos Naturales no Renovables (in Spanish)
PV	Photovoltaic
RE	Renewable energy
RES	Renewable energy system
TES	Thermal energy storage
V2G	Vehicle-to-grid

References

1. Jacobson, M.Z.; Cameron, M.A.; Hennessy, E.M.; Petkov, I.; Meyer, C.B.; Gambhir, T.K.; Maki, A.T.; Pfleeger, K.; Clonts, H.; McEvoy, A.L.; et al. 100% Clean and Renewable Wind, Water, and Sunlight (WWS) All-Sector Energy Roadmaps for 53 Towns and Cities in North America. *Sustain. Cities Soc.* **2018**, *42*, 22–37. [CrossRef]
2. Lalander, R. The Ecuadorian Resource Dilemma: *Sumak Kawsay* or Development? *Crit. Sociol.* **2016**, *42*, 623–642. [CrossRef]
3. Alarcón, P. Ex-redaktion Energy Transition-Quo Vadis—Revisiting Supply-Side Policies in Ecuador. 2023. Available online: https://extractivism.de/en/publications/extractivism-policy-briefs-en/energy-transition-quo-vadis-revisiting-supply-side-policies-in-ecuador-2/ (accessed on 4 April 2023).
4. Ponce-Jara, M.A.; Castro, M.; Pelaez-Samaniego, M.R.; Espinoza-Abad, J.L.; Ruiz, E. Electricity Sector in Ecuador: An Overview of the 2007–2017 Decade. *Energy Policy* **2018**, *113*, 513–522. [CrossRef]
5. Makarov, Y.V.; Du, P.; Kintner-Meyer, M.C.W.; Jin, C.; Illian, H.F. Sizing Energy Storage to Accommodate High Penetration of Variable Energy Resources. *IEEE Trans. Sustain. Energy* **2012**, *3*, 34–40. [CrossRef]
6. Clairand, J.-M.; Arriaga, M.; Cañizares, C.A.; Álvarez-Bel, C. Power Generation Planning of Galapagos' Microgrid Considering Electric Vehicles and Induction Stoves. *IEEE Trans. Sustain. Energy* **2019**, *10*, 1916–1926. [CrossRef]
7. Borge-Diez, D.; Icaza, D.; Açıkkalp, E.; Amaris, H. Combined Vehicle to Building (V2B) and Vehicle to Home (V2H) Strategy to Increase Electric Vehicle Market Share. *Energy* **2021**, *237*, 121608. [CrossRef]
8. Taiebat, M.; Xu, M. Synergies of Four Emerging Technologies for Accelerated Adoption of Electric Vehicles: Shared Mobility, Wireless Charging, Vehicle-to-Grid, and Vehicle Automation. *J. Clean. Prod.* **2019**, *230*, 794–797. [CrossRef]
9. İnci, M.; Savrun, M.M.; Çelik, Ö. Integrating Electric Vehicles as Virtual Power Plants: A Comprehensive Review on Vehicle-to-Grid (V2G) Concepts, Interface Topologies, Marketing and Future Prospects. *J. Energy Storage* **2022**, *55*, 105579. [CrossRef]

10. Ravi, S.S.; Aziz, M. Utilization of Electric Vehicles for Vehicle-to-Grid Services: Progress and Perspectives. *Energies* **2022**, *15*, 589. [CrossRef]
11. Dong, X.; Mu, Y.; Xu, X.; Jia, H.; Wu, J.; Yu, X.; Qi, Y. A Charging Pricing Strategy of Electric Vehicle Fast Charging Stations for the Voltage Control of Electricity Distribution Networks. *Appl. Energy* **2018**, *225*, 857–868. [CrossRef]
12. Ntube, N.; Li, H. Stochastic Multi-Objective Optimal Sizing of Battery Energy Storage System for a Residential Home. *J. Energy Storage* **2023**, *59*, 106403. [CrossRef]
13. Kamani, D.; Ardehali, M.M. Long-Term Forecast of Electrical Energy Consumption with Considerations for Solar and Wind Energy Sources. *Energy* **2023**, *268*, 126617. [CrossRef]
14. Feng, S.; Magee, C.L. Technological Development of Key Domains in Electric Vehicles: Improvement Rates, Technology Trajectories and Key Assignees. *Appl. Energy* **2020**, *260*, 114264. [CrossRef]
15. Amamra, S.-A.; Marco, J. Vehicle-to-Grid Aggregator to Support Power Grid and Reduce Electric Vehicle Charging Cost. *IEEE Access* **2019**, *7*, 178528–178538. [CrossRef]
16. Crozier, C.; Morstyn, T.; McCulloch, M. The Opportunity for Smart Charging to Mitigate the Impact of Electric Vehicles on Transmission and Distribution Systems. *Appl. Energy* **2020**, *268*, 114973. [CrossRef]
17. Sovacool, B.K.; Kester, J.; Noel, L.; Zarazua de Rubens, G. Actors, Business Models, and Innovation Activity Systems for Vehicle-to-Grid (V2G) Technology: A Comprehensive Review. *Renew. Sustain. Energy Rev.* **2020**, *131*, 109963. [CrossRef]
18. Rahman, M.M.; Gemechu, E.; Oni, A.O.; Kumar, A. The Development of a Techno-Economic Model for Assessment of Cost of Energy Storage for Vehicle-to-Grid Applications in a Cold Climate. *Energy* **2023**, *262*, 125398. [CrossRef]
19. Noussan, M.; Tagliapietra, S. The Effect of Digitalization in the Energy Consumption of Passenger Transport: An Analysis of Future Scenarios for Europe. *J. Clean. Prod.* **2020**, *258*, 120926. [CrossRef]
20. Berkeley, N.; Bailey, D.; Jones, A.; Jarvis, D. Assessing the Transition towards Battery Electric Vehicles: A Multi-Level Perspective on Drivers of, and Barriers to, Take up. *Transp. Res. Part A Policy Pract.* **2017**, *106*, 320–332. [CrossRef]
21. Philip, T.; Whitehead, J.; Prato, C.G. Adoption of Electric Vehicles in a Laggard, Car-Dependent Nation: Investigating the Potential Influence of V2G and Broader Energy Benefits on Adoption. *Transp. Res. Part A Policy Pract.* **2023**, *167*, 103555. [CrossRef]
22. Corradi, C.; Sica, E.; Morone, P. What Drives Electric Vehicle Adoption? Insights from a Systematic Review on European Transport Actors and Behaviours. *Energy Res. Soc. Sci.* **2023**, *95*, 102908. [CrossRef]
23. Nikitas, A.; Kougias, I.; Alyavina, E.; Njoya Tchouamou, E. How Can Autonomous and Connected Vehicles, Electromobility, BRT, Hyperloop, Shared Use Mobility and Mobility-as-a-Service Shape Transport Futures for the Context of Smart Cities? *Urban Sci.* **2017**, *1*, 36. [CrossRef]
24. Waltermann, J.; Henkel, S. Public Discourse on Automated Vehicles in Online Discussion Forums: A Social Constructionist Perspective. *Transp. Res. Interdiscip. Perspect.* **2023**, *17*, 100743. [CrossRef]
25. Markovska, N.; Klemeš, J.J.; Duić, N.; Guzović, Z.; Mathiesen, B.V.; Lund, H.; Yan, J. Sustainable Development of Energy, Water and Environment Systems. *Appl. Energy* **2014**, *135*, 597–599. [CrossRef]
26. Steinbuks, J.; Cai, Y.; Jaegermeyr, J.; Hertel, T.W. Assessing Effects of Climate and Technology Uncertainties in Large Natural Resource Allocation Problems. *EGUsphere* **2023**, *11*, 1–48. [CrossRef]
27. Ruggieri, G.; Andreolli, F.; Zangheri, P. A Policy Roadmap for the Energy Renovation of the Residential and Educational Building Stock in Italy. *Energies* **2023**, *16*, 1319. [CrossRef]
28. Whittington, D. Improving the Performance of Contingent Valuation Studies in Developing Countries. *Environ. Resour. Econ.* **2002**, *22*, 323–367. [CrossRef]
29. Pietzcker, R.C.; Longden, T.; Chen, W.; Fu, S.; Kriegler, E.; Kyle, P.; Luderer, G. Long-Term Transport Energy Demand and Climate Policy: Alternative Visions on Transport Decarbonization in Energy-Economy Models. *Energy* **2014**, *64*, 95–108. [CrossRef]
30. Martins, H.; Henriques, C.O.; Figueira, J.R.; Silva, C.S.; Costa, A.S. Assessing Policy Interventions to Stimulate the Transition of Electric Vehicle Technology in the European Union. *Socio-Econ. Plan. Sci.* **2023**, 101505. [CrossRef]
31. Hainsch, K.; Löffler, K.; Burandt, T.; Auer, H.; Crespo del Granado, P.; Pisciella, P.; Zwickl-Bernhard, S. Energy Transition Scenarios: What Policies, Societal Attitudes, and Technology Developments Will Realize the EU Green Deal? *Energy* **2022**, *239*, 122067. [CrossRef]
32. Prina, M.G.; Lionetti, M.; Manzolini, G.; Sparber, W.; Moser, D. Transition Pathways Optimization Methodology through EnergyPLAN Software for Long-Term Energy Planning. *Appl. Energy* **2019**, *235*, 356–368. [CrossRef]
33. Nielsen, S.; Thellufsen, J.Z.; Sorknæs, P.; Djørup, S.R.; Sperling, K.; Østergaard, P.A.; Lund, H. Smart Energy Aalborg: Matching End-Use Heat Saving Measures and Heat Supply Costs to Achieve Least Cost Heat Supply. *Int. J. Sustain. Energy Plan. Manag.* **2020**, *25*, 13–32. [CrossRef]
34. Connolly, D.; Lund, H.; Mathiesen, B.V. Smart Energy Europe: The Technical and Economic Impact of One Potential 100% Renewable Energy Scenario for the European Union. *Renew. Sustain. Energy Rev.* **2016**, *60*, 1634–1653. [CrossRef]
35. Lund, H. Large-Scale Integration of Wind Power into Different Energy Systems. *Energy* **2005**, *30*, 2402–2412. [CrossRef]
36. Lund, H. Large-Scale Integration of Optimal Combinations of PV, Wind and Wave Power into the Electricity Supply. *Renew. Energy* **2006**, *31*, 503–515. [CrossRef]
37. Cassetti, G.; Elia, A.; Gargiulo, M.; Chiodi, A. Reinforcing the Paris Agreement: Ambitious Scenarios for the Decarbonisation of the Central Asian and Caspian Region. *Renew. Sustain. Energy Transit.* **2023**, *3*, 100048. [CrossRef]

38. Ishaku, H.P.; Adun, H.; Jazayeri, M.; Kusaf, M. Decarbonisation Strategy for Renewable Energy Integration for Electrification of West African Nations: A Bottom-up EnergyPLAN Modelling of West African Power Pool Targets. *Sustainability* **2022**, *14*, 15933. [CrossRef]
39. County Energy Systems for Humboldt, California, USA, 2007. Available online: https://www.energyplan.eu/county-energy-systems-for-humboldt-california-usa-2007/ (accessed on 1 April 2023).
40. Icaza, D.; Borge-Diez, D.; Galindo, S.P. Analysis and Proposal of Energy Planning and Renewable Energy Plans in South America: Case Study of Ecuador. *Renew. Energy* **2022**, *182*, 314–342. [CrossRef]
41. Meschede, H.; Bertheau, P.; Khalili, S.; Breyer, C. A Review of 100% Renewable Energy Scenarios on Islands. *WIREs Energy Environ.* **2022**, *11*, e450. [CrossRef]
42. Korkeakoski, M. Towards 100% Renewables by 2030: Transition Alternatives for a Sustainable Electricity Sector in Isla de La Juventud, Cuba. *Energies* **2021**, *14*, 2862. [CrossRef]
43. Muharram, Y.; Riawan, D.C.; Kim, J.; Muljadi, E.; Nelms, R.M. Operational Issues of a Microgrid at Tomia Island Considering Photovoltaic Penetration Level. In Proceedings of the 2021 IEEE Green Technologies Conference (GreenTech), Denver, CO, USA, 7–9 April 2021; pp. 513–519.
44. Meschede, H.; Child, M.; Breyer, C. Assessment of Sustainable Energy System Configuration for a Small Canary Island in 2030. *Energy Convers. Manag.* **2018**, *165*, 363–372. [CrossRef]
45. Putranto, L.M. Generation Expansion Planning for High-Potential Hydropower Resources: The Case of the Sulawesi Electricity System. *Int. J. Sustain. Energy Plan. Manag.* **2020**, *28*, 37–52. [CrossRef]
46. Eras-Almeida, A.A.; Egido-Aguilera, M.A. Hybrid Renewable Mini-Grids on Non-Interconnected Small Islands: Review of Case Studies. *Renew. Sustain. Energy Rev.* **2019**, *116*, 109417. [CrossRef]
47. Gabbar, H.A.; Siddique, A.B. Technical and Economic Evaluation of Nuclear Powered Hybrid Renewable Energy System for Fast Charging Station. *Energy Convers. Manag. X* **2023**, *17*, 100342. [CrossRef]
48. Sabillón Antúnez, C.; Franco, J.F.; Rider, M.J.; Romero, R. A New Methodology for the Optimal Charging Coordination of Electric Vehicles Considering Vehicle-to-Grid Technology. *IEEE Trans. Sustain. Energy* **2016**, *7*, 596–607. [CrossRef]
49. Liu, K.; Niri, M.F.; Apachitei, G.; Lain, M.; Greenwood, D.; Marco, J. Interpretable Machine Learning for Battery Capacities Prediction and Coating Parameters Analysis. *Control Eng. Pract.* **2022**, *124*, 105202. [CrossRef]
50. Hu, T.; Ma, H.; Liu, H.; Sun, H.; Liu, K. Self-Attention-Based Machine Theory of Mind for Electric Vehicle Charging Demand Forecast. *IEEE Trans. Ind. Inform.* **2022**, *18*, 8191–8202. [CrossRef]
51. Liu, K.; Wei, Z.; Zhang, C.; Shang, Y.; Teodorescu, R.; Han, Q.-L. Towards Long Lifetime Battery: AI-Based Manufacturing and Management. *IEEE/CAA J. Autom. Sin.* **2022**, *9*, 1139–1165. [CrossRef]
52. Jia, B.; Guan, Y.; Wu, L. A State of Health Estimation Framework for Lithium-Ion Batteries Using Transfer Components Analysis. *Energies* **2019**, *12*, 2524. [CrossRef]
53. Liu, K.; Peng, Q.; Che, Y.; Zheng, Y.; Li, K.; Teodorescu, R.; Widanage, D.; Barai, A. Transfer Learning for Battery Smarter State Estimation and Ageing Prognostics: Recent Progress, Challenges, and Prospects. *Adv. Appl. Energy* **2023**, *9*, 100117. [CrossRef]
54. Kumari, A.; Gupta, R.; Tanwar, S.; Kumar, N. Blockchain and AI Amalgamation for Energy Cloud Management: Challenges, Solutions, and Future Directions. *J. Parallel Distrib. Comput.* **2020**, *143*, 148–166. [CrossRef]
55. Chen, Q.; Folly, K.A. Application of Artificial Intelligence for EV Charging and Discharging Scheduling and Dynamic Pricing: A Review. *Energies* **2023**, *16*, 146. [CrossRef]
56. Li, S.; Gu, C. AI-Based GEVs Mobility Estimation and Battery Aging Quantification Method. In *Automated and Electric Vehicle: Design, Informatics and Sustainability*; Cao, Y., Zhang, Y., Gu, C., Eds.; Recent Advancements in Connected Autonomous Vehicle Technologies; Springer Nature: Singapore, 2023; pp. 117–133. ISBN 978-981-19575-1-2.
57. Van den bergh, O.; Weekx, S.; De Cauwer, C.; Vanhaverbeke, L. Locating Charging Infrastructure for Shared Autonomous Electric Vehicles and for Vehicle-to-Grid Strategy: A Systematic Review and Research Agenda from an Energy and Mobility Perspective. *World Electr. Veh. J.* **2023**, *14*, 56. [CrossRef]
58. Østergaard, P.A.; Lund, H.; Thellufsen, J.Z.; Sorknæs, P.; Mathiesen, B.V. Review and Validation of EnergyPLAN. *Renew. Sustain. Energy Rev.* **2022**, *168*, 112724. [CrossRef]
59. Electric Vehicles. Available online: https://www.energyplan.eu/category/different-technologies/electricvehicles/ (accessed on 5 March 2023).
60. Lund, H.; Thellufsen, J.Z.; Østergaard, P.A.; Sorknæs, P.; Skov, I.R.; Mathiesen, B.V. EnergyPLAN—Advanced Analysis of Smart Energy Systems. *Smart Energy* **2021**, *1*, 100007. [CrossRef]
61. Operador Nacional de Electricidad CENACE—Página Oficial del Operador Nacional de Electricidad CENACE. Available online: http://www.cenace.gob.ec/ (accessed on 1 April 2023).
62. Rendición de cuentas—Agencia de Regulación y Control de Energía y Recursos Naturales no Renovables. Available online: https://www.controlrecursosyenergia.gob.ec/rendicion-de-cuentas/ (accessed on 1 April 2023).
63. GmbH, T.S. Sankey Flow Show—Attractive Flow Diagrams Made in Minutes! Available online: https://www.sankeyflowshow.com/ (accessed on 7 March 2023).
64. IEA Sankey Diagram. Available online: https://www.iea.org/sankey/#?c=Ecuador&s=Balance (accessed on 18 April 2021).
65. Línea, B. El 93.2% de Energía Que Genera el Ecuador es Renovable. Available online: https://www.bloomberglinea.com/2022/01/14/el-932-de-energia-que-genera-el-ecuador-es-renovable/ (accessed on 6 March 2023).

66. *A_Viloria Webinar: "Transición Energética, Una Visión Contrastada De Las Oportunidades En La Región Andina"*; Asociación Ecuatoriana de Energías Renovables y Eficiencia Energética: Quito, Ecuador, 2021.
67. Energía Renovable en Ecuador—Genera Renovables. Available online: https://generarenovables.com/energia-renovable-en-ecuador/ (accessed on 2 April 2023).
68. Observatorio Regional de Planificación para el Desarrollo Secretaria Nacional de Planificación y Desarrollo (SENPLADES) de Ecuador. Available online: https://observatorioplanificacion.cepal.org/es/instituciones/secretaria-nacional-de-planificacion-y-desarrollo-senplades-de-ecuador (accessed on 23 July 2022).
69. MERNNR Proyectos. Available online: https://proyectos.energiayminas.gob.ec/bloqueErnc.php (accessed on 17 July 2022).
70. *Escuela Politécnica Nacional (EPN), Mapa Solar del Ecuador*; Escuela Politécnica Nacional: Quito, Ecuador, 2020.
71. Posso, F.; Sánchez, J.; Espinoza, J.L.; Siguencia, J. Preliminary Estimation of Electrolytic Hydrogen Production Potential from Renewable Energies in Ecuador. *Int. J. Hydrogen Energy* **2016**, *41*, 2326–2344. [CrossRef]
72. Instituto Nacional de Preinversión. *Atlas Bioenergético del Ecuador, Portal Web Biomasa—Catálogo Virtual 3D*; Instituto de Investigación Geológico y Energético: Quito, Ecuador, 2015.
73. Este Tesla Model S tiene una Batería de 207 kWh y una Autonomía de 1.200 km Reales. Forococheselectricos 2022. Available online: https://forococheselectricos.com/2022/01/este-tesla-model-s-tiene-una-bateria-de-207-kwh-y-una-autonomia-de-1-200-km-reales.html (accessed on 2 April 2023).
74. Oldenbroek, V.; Wijtzes, S.; van Wijk, A.; Blok, K. Fuel Cell Electric Vehicle to Grid & H2: Balancing National Electricity, Heating & Transport Systems a Scenario Analysis for Germany in the Year 2050. In Proceedings of the 2017 IEEE Green Energy and Smart Systems Conference (IGESSC), Long Beach, CA, USA, 6–7 November 2017; pp. 1–6.
75. Wei, Y.; Huang, H.; Han, X.; Lu, L.; Ouyang, M.; Pang, K.; Qin, Y. Whole-System Potential and Benefit of Energy Storage by Vehicle-to-Grid (V2G) under Carbon Neutrality Target in China. In Proceedings of the 2022 IEEE 5th International Electrical and Energy Conference (CIEEC), Nangjing, China, 27–29 May 2022; pp. 4006–4012.
76. Dunn, R.; Shen, K. The Prediction of Flexible Load Demand in the UK in 2050. In Proceedings of the 2013 IEEE Power and Energy Society General Meeting (PES 2013), Vancouver, BC, Canada, 21–25 July 2013; pp. 1–5.
77. Kamran, M.; Raugei, M.; Hutchinson, A. A Dynamic Material Flow Analysis of Lithium-Ion Battery Metals for Electric Vehicles and Grid Storage in the UK: Assessing the Impact of Shared Mobility and End-of-Life Strategies. *Resour. Conserv. Recycl.* **2021**, *167*, 105412. [CrossRef]
78. Xu, L.; Yilmaz, H.Ü.; Wang, Z.; Poganietz, W.-R.; Jochem, P. Greenhouse Gas Emissions of Electric Vehicles in Europe Considering Different Charging Strategies. *Transp. Res. Part D Transp. Environ.* **2020**, *87*, 102534. [CrossRef]