Publisher: Sapienza Grupo Editorial
R. Santa Cruz, 2187, Vila Mariana
São Paulo, Brazil
editor@sapienzaeditorial.com

Sapienza
International Journal of Interdisciplinary Studies
ISSN: 2675-9780

Technical, regulatory and economic analysis for the installation of an alternative electricity supply system based on tidal energy

Análise técnica, regulamentar e económica para a instalação de um sistema alternativo de alimentação elétrica com base na energia das marés

Análisis técnico, regulatorio y económico para la instalación de un sistema alterno de suministro eléctrico basado en energía mareomotriz

Gloria Esmeralda Cabeza-Villón
https://orcid.org/0009-0005-1419-7152
Graduate Researcher. Pontificia Universidad Católica del Ecuador Sede Esmeraldas
gecabeza@pucese.edu.ec (correspondence)

Manuel Nevárez-Toledo
https://orcid.org/0000-0001-5628-3351
Graduate Researcher. Pontificia Universidad Católica del Ecuador Sede Esmeraldas.
manuel.nevarez@pucese.edu.ec

ABSTRACT

The general objective of this study is to develop the technical, regulatory and economic analysis for the installation of an alternative electricity supply system based on tidal energy in the canton of Esmeraldas, Ecuador. The methodology was descriptive with a documentary design. The population consisted of eleven (11) documents related to the topic that met the selection criteria based on rigor in contributions, relevance and pertinence. It was found in the texts consulted coincidence in the fact that tidal energy in the coming years will be considered within the range of renewable energies to produce great changes in the energy sector due to the great potential it offers. According to IRENA, the cost of current tidal technologies ranges between 0.17 €/kWh and 0.23 €/kWh, although the pilot projects underway point to a decrease of between 0.25 and 0.47 €/kWh. Thus, in the course of time it will become increasingly accessible to incorporate it into the energy matrix of countries such as Ecuador given its constant wave potential estimated at 14kW/m on average. Thus, the production of tidal energy in Ecuador and specifically in the canton of Esmeraldas should be considered more strongly, given the advantages it offers for environmental, social and in the near future economic quality, all of which is in line with the philosophy of energy efficiency for sustainable development.

Keywords: Renewable sources, tidal energy, energy efficiency.

RESUMO

O objetivo deste estudo foi propor um plano de manutenção preditiva e preventiva nas subestações elétricas La Propicia, Las Palmas e La Pradera pertencentes à Unidade de Negócio CNEL-EP Esmeraldas por meio do uso de termografia. A metodologia foi de abordagem qualitativa, sob o tipo de pesquisa documental-bibliográfica. A busca de informações foi realizada online em bases de dados científicas e acadêmicas. Constatou-se que as informações sobre os planos de manutenção no sistema de subtransmissão da Unidade de Negócio CNEL EP Esmeraldas, são escassas, são realizadas ações de manutenção preventiva e preditiva como revisão, lavagem, readequação e substituição de elementos em mau estado, porém sem informações foi encontrado na técnica de análise utilizada conduzindo às atividades de manutenção de equipamentos e instalações elétricas. Os resultados das investigações consultadas concordam que a técnica termográfica e suas ferramentas como drones, câmeras infravermelhas e programas de software são muito úteis para o diagnóstico, coleta e processamento de dados em sistemas elétricos para determinar requisitos de manutenção. Finalmente, a investigação produziu informações substanciais que permitiram a elaboração de um plano de manutenção para as mencionadas subestações elétricas La Propicia, Las Palmas e La Pradera da Unidade de Negócio CNEL-EP Esmeraldas por meio do uso de termografia infravermelha, para auxiliar em seu melhor funcionamento. desempenho ao permitir a avaliação do estado dos equipamentos que compõem o sistema elétrico das referidas subestações.

Palabras clave: Fontes renováveis, energia das marés, eficiência energética.

RESUMEN

El presente estudio tiene como objetivo general desarrollar el análisis técnico, regulatorio y económico para la instalación de un sistema alterno de suministro eléctrico basado en la energía mareomotriz en el cantón Esmeraldas, Ecuador. La metodología fue de tipo descriptiva con un diseño documental. La población estuvo conformada por once (11) documentos relacionados con el tema que cumplieron con los criterios de selección basados en rigor en aportes, relevancia y pertinencia. Se encontró en los textos consultados coincidencia en el hecho de que la energía mareomotriz en el devenir de los próximos años será considerada dentro de la gama de las energías renovables para producir grandes cambios en el sector de la energía por el gran potencial que ofrece. Se concluye que en la actualidad la generación de energía mareomotriz es costosa, según IRENA, el coste de las tecnologías mareomotrices actuales oscila entre 0,17 €/kWh y 0,23 €/kWh, aunque los proyectos piloto en curso apuntan a una disminución de entre 0,25 y 0,47 €/kWh, así, en el transcurrir del tiempo se volverá cada vez más accesible para incorporarla en la matriz energética de países como Ecuador dado su potencial constante de olas estimado en 14kW/m en promedio. Así, la producción de energía mareomotriz en Ecuador y en concreto en el cantón Esmeraldas debe considerarse de manera más firme, dadas las ventajas que ofrece para la calidad ambiental, social y en un futuro próximo económico, todo lo cual va en línea con la filosofía de eficiencia energética para el desarrollo sustentable.

Palavras-chave: Fuentes renovables, energía mareomotriz, eficiencia energética.

ARTICLE HISTORY

Received: 11-03-2023
Revised Version: 26-06-2023
Accepted: 30-06-2023
Published: 30-06-2023
Copyright: © 2023 by the authors
License: CC BY-NC-ND 4.0
Manuscript type: Article

ARTICLE INFORMATIONS

Science-Metrix Classification (Domain):
Applied Sciences
Main topic:
Tidal energy
Main practical implications:
The results presented can serve as a guide for the design of future public policies involving alternative electricity supply system based on tidal energy.
Originality/value:
The article addresses in detail a subject that has been little explored in applied sciences regarding the Ecuadorian context.

INTRODUCTION

Today, conventional fossil fuel energies have been used for decades in the economic development processes of countries around the world in an unsustainable manner, and have caused serious environmental problems with repercussions such as the pollution of ecosystems, the increase in greenhouse gases (GHG) and the destruction of the ozone layer, among others. Thus, in the search to reverse the damage caused to the natural environment and given that the economic growth of nations cannot be stopped and the energy demand to undertake such development actions is increasingly increasing, possible solutions have emerged from various sources that aim at greater energy diversification and the adoption of policies to reduce the emission of greenhouse gases, so as to combine the objectives of growth and economic development with obtaining high productive yields; this action has been called "sustainable development".

According to the Economic Commission for Latin America and the Caribbean (ECLAC), the concept of sustainable development, on which the new international development agenda is based, reflects a complex balance between different perspectives on the relationship between the environment and economic and social development. ECLAC, (2015). In this idea, countries are asked to ensure that activities aimed at the evolution and progress of their territories in all areas, for the benefit of the people, are carried out taking into account the protection and care of the environment.

These efforts have led to the worldwide consideration of renewable energies in the coming years in order to bring about major changes in the energy sector, which is considered one of the most polluting environments, towards the path of cleaner energies that are less polluting for the environment that surrounds living beings. To reaffirm what has been expressed, estimates emanating from the Intergovernmental Panel on Climate Change (IPCC) suggest that approximately 40% of the total emissions of carbon dioxide (CO_2), one of the most important GHGs are attributed to the energy sector. IPCC, (2019).

In the line of renewable energies, one of the least exploited is the one produced through sea energy, also considered one of the most profitable in the world, which is becoming known not only because of the need to experiment with clean energies, but also because of the ease with which coastal countries can use wave power to obtain marine energy as a source of electricity. According to Quintero and Quintero, (2016), tidal energy is understood as "that energy produced through the exploitation of the marine water resource, specifically through the benefit of the potential energy present in the masses of dammed water, energy that is harnessed through its kinetic transformation" (p. 39). Currently, on a global scale, different technological developments have been presented for the use of energy from marine and oceanic water bodies, with different potentials for use and aspects that influence the environment at different scales. Herrera and Quintero, (2017). In this way, technological innovation has made it possible to incorporate the tidal flow in coastal areas to the set of clean energies for their use.

In the national context, according to information obtained from the Oceanographic Institute of the Navy of Ecuador (INOCAR), the study of wave energy, currents and kinetic energy of rivers for electricity generation conducted by the Ministry of Electricity and other cooperation agencies, show that wave conditions in the Ecuadorian Territorial Sea are very favorable for the use of its energy. INOCAR, (2010). Preliminary calculations indicate that wave energy in the area is interesting, both in quantity and quality, therefore, it is feasible to develop a study for the availability of another source of electricity supply, specifically in the canton of Esmeraldas, taking advantage of the coastal profile where the province is located. INOCAR, (2010).

The Esmeraldas canton is located in a geographical area known as coastal region or coast belonging to the province of the same name, in the interest of finding a solution to the problem of electricity supply that affects this territory, because it is known that this town has a single distribution system, which has constant failures, this research arises from the need to find a source of renewable energy generation, clean and reliable as suggested by the tidal power. Thus, based on a technical, regulatory and economic analysis, the possibility of installing an alternative electricity supply system based on sea energy is sought, considering that the region has this natural resource in abundance and can be used for this purpose.

In view of the points made in the preceding paragraphs, the general objective of this work is to develop the technical, regulatory and economic analysis for the installation of an alternative electricity supply system based on tidal energy in the canton of Esmeraldas, in the light of the existing literature on the subject. The development of this article was structured in the following order: the first section presents the introduction and general objective; a second section corresponds to the theoretical basis and background; the third section establishes the methodology; the fourth section contains the results, discussion and conclusions.

Theoretical basis

Tidal energy

Wave energy is the energy produced by the undulatory motion of the surface of the sea water. Sea waves are a tertiary derivative of solar energy. The heating of the earth's surface generates wind, which in turn generates waves, so waves are a consequence of the friction of the air against the sea surface. Wave energy is concentrated on the coast and has the characteristic property of moving long distances with hardly any loss of energy. Pelayo Pire, (2018). The intensity of the wave depends on the strength of the wind, its duration and the length over which the wave is transmitted. It is a constant and predictable energy with a lower impact on the environment than other types of energy production facilities. Pelayo Pire, (2018).

The concept of tidal energy is mainly constituted by the tidal phenomenon of the oceans, being this its main source, which enjoys characteristics such as free, clean and inexhaustible energy. Méndez and Molina, (2020). The aforementioned authors also point out that various methods have been developed to take advantage of the potential offered by tidal energy, being the difference in height reached by seawater in reservoirs built for this purpose, the process currently most commonly used to make use of the potential energy and transform it into electrical energy.

Global Tidal Energy Potential

Estimates of the global potential offered by tidal energy, according to (Roca, 2021)predict a potential capacity of 100 GW. On this aspect, experts consider that it is a figure that may well have both commercial benefits for companies in the renewable energy sector, as well as to mitigate environmental pollution that has become a real challenge in the current era.

According to the International Renewable Energy Agency (IRENA) report, on a global scale, most of the installed ocean energy capacity comes from tidal barrage technology (521.5 MW), with Canada, France and South Korea leading the way. According to the predicted trend, ocean energy development may move towards tidal stream power generation, followed by wave energy and ocean thermal conversion (OTEC). (IRENA, 2020). In this sense, the figures indicate that the generation of tidal energy is still far below the energy production offered by other forms of renewable energy such as photovoltaic and wind, however, in an optimistic scenario and energy transition these statistics may increasingly favor tidal energy production.

Technology for harnessing ocean currents

For the operation of a tidal power plant, the difference in height between sea level and the level of the reservoir is essential to take advantage of the potential and kinetic energy of the rise and fall of the tide, hence the Institute for Energy Diversification and Saving (IDAE) states that only at those points on the coast where the high tide and low tide differ by more than five meters in height is it profitable to install a plant for the generation of electricity from the tidal potential. (IDAE, 2020). At present, technologies for harnessing marine currents are grouped into three types: a) Tidal current generator; b) Tidal barrage and; c) Dynamic tidal energy. (BBVA, 2021). For its part, Empresa Nacional de Electricidad, (Endesa, 2022) mentions within the range of marine renewable energy technologies: a) floating photovoltaic; b) wave energy; c) tidal energy; d) floating wind and e) fixed wind.

To this effect, reflecting the information issued from the report (BBVA, 2021)The Tidal Stream Generator (TSG) is a technology that harnesses the kinetic energy of moving water in a very similar way to wind turbines. This form of energy production has a lower cost and a lower environmental impact compared to other methods. As for the tidal barrage: they use the potential energy that exists in the rising and falling tides. It is a retention work along an estuary or a bay whose main mission is to impound the water of the incoming tide in the retention works. It is usually constructed to form two separate impoundments to facilitate the operation of the tidal power plant. The scarcity of suitable sites in the world and the environmental impact are two major drawbacks.

Dynamic Tidal Power (DTP) is a combination of the technologies described above. It is at a theoretical stage but consists of a system of large dams (between 30 and 50 km long from the coast to the sea) that induce the water by taking advantage of the different tidal phases, thus mobilizing their generating turbines. Each dam generates energy on a scale of 6 to 17 gigawatts (GW).

Tidal energy in the world

Globally, most wave energy is concentrated in the Atlantic and Pacific oceans, between latitudes 40°-65°N and 30°-60°S, where regular winds allow for higher energy potentials, in particular the swell coming from the west, with a potential of between 50-100 kW per meter of wave front. Pelayo Pire, (2018).

Tidal energy has been capturing a deep interest in terms of the growth potential of the energy sector on a global scale, thus it has significant presence in countries such as France, Canada, Switzerland, United Kingdom, United States and China, in which these energy production systems are already in operation and with expansion projection. Méndez & Molina, (2020).

In Latin America, Argentina has proposed to study the construction of a tidal power plant in Puerto Madryn, more precisely in the San José Gulf. This could replace large volumes of imported fossil fuels and carbon dioxide emitted into the atmosphere by thermal generators and contribute power to the National Interconnected System, so that the supply can once again operate with reserves. Chaparro, (2010).

Wave potential in Ecuador

According to studies and calculations made on the energy potential of the Ecuadorian sea, the average power per meter of wave front in Ecuador is 90.31 KW, although this distribution is far from being equal, since the existing coasts in the Ecuadorian nation tend to have different potentials. Rodriguez and Chimbo, (2017). Comparing this data with the potentials reached by Australia and New Zealand which are the countries with the highest potential in their seas reaching 100 KW per meter of wave front; it can be said that Ecuador has an excellent wave potential. Rodriguez and Chimbo, (2017).

Background

In order to carry out this research, the time period from 2010 to 2021 was used as a reference. Additionally, different document bases such as Google Scholar, Redalyc, Scielo, among others, were used, as they are simple platforms that allow an efficient tracking according to the interests of this research, thus obtaining a total of 40 documents between TFM, scientific articles, of which four of them were chosen for the development of the background.

In the first instance Guamán et al, (2017) presented the research entitled "Energy from the sea for its integration into the energy matrix of Ecuador" aimed to study the different types of energy from the sea and determine which of these is the most sustainable for Ecuador, using new technologies. The study shows many probabilities of the contribution of the energy generated through marine currents to the country's energy matrix, all this sustained by means of an electricity generation plant of 20 MW of power. The technologies were determined based on technical specifications adjusted to the country's current situation and then the economic-financial analysis of the proposal was carried out. Finally, it is concluded that the marine currents are directly related to the Cromwell current, determining that this type of project is viable and will provide an important contribution to Ecuador's energy matrix. This research is related to the topic of study, because it allows determining and identifying the different forms of energy from the sea and describing that which is available to be used, mainly in the coast of Ecuador, including the province of Esmeraldas.

On the other hand, Rodriguez and Chimbo (2017) in their study entitled "Harnessing wave energy in Ecuador" focuses on investigating wave energy through data obtained from the Oceanographic and Antarctic Institute of the Navy (INOCAR), data that allowed the researcher to perform calculations to obtain the energy potential of the seas, determining that in Ecuador there is a very high potential of wave energy resource. The referred study is related to the research topic, the information available from INOCAR, has allowed to create a database of the behavior of the seas of the Esmeraldas canton and identify the highest wave energy potential.

In this same framework, Saltos (2017) in the publication entitled "Analysis for the Generation of Electric Energy through a Wave Power System and its applicability in the Ecuadorian Coast", analyzed the wave potential and the types of technology available to take advantage of the energy potential of waves in Ecuador, It was established that there is a possibility for the design of a wave power generation plant using Power Buoy technology as a wave energy collector, since the territorial sea of Ecuador has the necessary characteristics for the application of this renewable and inexhaustible technology. In this way, this study is binding for this research, since the analysis carried out provides valuable information on the certain possibility that exists in the coastal areas of the country to carry out energy generation projects through the use of marine water resources.

Likewise, Calero and Viteri (2013) in the investigation called "Wave Energy, an Alternative for the Production of Electrical Energy in the Province of Santa Elena" focused their attention on elucidating with specific data on the morphology of the maritime zone in the province of Santa Elena, trying to predict if the characteristics of the place are suitable to produce electricity based on the implementation of wave energy as a non-conventional renewable source using current technologies for this purpose, proposing facilities with generation potential not so high (10Kw) because the current technologies are in the development stage. The aforementioned research is linked to this topic, since it sought to obtain reliable data for the use of marine energy in a coastal area of the country, such is the case of the province of Santa Elena.

METHODOLOGY

This research was framed in a descriptive type of research in correspondence with the theoretical foundations of Hurtado (2015), who defines this type of research as one whose intention is to expose the event studied, making a detailed account of its characteristics. According to the nature of the objectives in terms of the level of knowledge sought to be achieved (state of knowledge), this research was classified as documentary, in this regard Arias (2012) states, in this type of dissertation the information to carry out the research comes from specialized documents both national and international, in this case wave energy, as well as works developed by other researchers in the area of technological alternatives.

Based on the contributions of Hernández et al, (2014), for the purposes of this research, the population consisted of all those specialized publications, both national and international, in the energy field as well as patents and publications related to the object of study and its applications. Thus, it consisted of eleven (11) documents containing information considered of great value for this inquiry, which were adjusted to the variables under study, the objective of the research and the established criteria of year of publication from 2010 and 2021 elaborated in Spanish language; quality of relevant and pertinent information on the subject.

The search technique used for data collection was adjusted to a systematic review of primary, secondary and tertiary documents, thus scientific and technical reports, reports of international organizations such as ECLAC, IRENA, INOCAR, OES, IEA; theses and scientific articles in digital repositories of national and international universities; legal and regulatory documents of Ecuador such as the Constitution of the Republic; National Development Plan Toda una Vida 2017-2021 of Ecuador; Organic Law on Energy Efficiency (LOEE), among others, were accessed online. The documentary material in Rojas' estimates, (2011) constitute the sources of information used in the research and are people, institutions, documents, things, bibliographies, publications, states of the art, states of knowledge, theses, databases, electronic sources located on the web, etcetera. The information collected was selected with a criterion of scientific and academic rigor, the selected documents are presented under a data table format of bibliographic sources selected for the documentary analysis for subsequent analysis and discussion. In this regard, Sierra (2007) notes that the documentary analysis matrix is a research technique for the systematic and quantitative objective description of the content of publications, in order to interpret them.

Table 1. Variables related to the study and the documentary review

Variables related to the study	**Variables and indicators analyzed on the basis of documentary review**
*Technical, Regulatory and Economic Analysis *Tidal energy	***Technical analysis:** Wave Energy Potential Current velocity Available technologies ***Economic analysis** Economic feasibility (cost of plant designs, prototypes, cost $/kWh) ***Regulatory analysis** Regulatory documents (Constitution of the Republic, Organic Laws)

Source: author's elaboration

RESULTS AND DISCUSSION

In this section, the technical, regulatory and economic analysis of sea energy to be used in the Esmeraldas canton of Ecuador was formalized on the basis of documentary analysis and in accordance with the general objective outlined taking into account the nature of the research, and the following results were obtained:

Table 2. Selected Bibliographic Sources for Technical, Economic and Regulatory Analysis

TECHNICAL PARAMETERS		
Author(s)/year	**Title**	**Variables/indicators**
		Wave Energy Potential
Rodriguez and Chimbo, (2017)	Use of Undimotriz energy in Ecuador Universidad Politécnica Salesiana, Ecuador	In the Ecuadorian territory, the energy content of the waves has a value of 14 KW/m average power.
Hernandez and Tovar, (2015)	Business Plan: Feasibility Study for the Generation of Undimotriz Energy to Supply Electric Power to the Parish of Jambelí, Santa Rosa Canton, Province of El Oro Escuela Superior Politécnica del Litoral, Guayaquil - Ecuador	Wave conditions in the Ecuadorian Territorial Sea are very favorable for the use of wave energy. Preliminary calculations indicate that the wave energy in the area is interesting, both in quantity and quality. It can be said that it is around 14kW/m, on average. It has been possible to determine that there is little variability in the height of the waves entering the Ecuadorian sea, and that they could be maintained in shallower waters, which would indicate that if the appropriate technology were available, there would be a quasi-constant and permanent source.

FLOW VELOCITY		
Saltos, (2017)	Analysis for the Generation of Electric Energy by means of a Undimotriz System and its applicability in the Coast of Ecuador Universidad Católica de Santiago de Guayaquil, Ecuador	The height of the waves of the territorial sea of the equator reaching from 1 meter to 3 meters in height ideal situation to implement wave energy in Ecuador.
Noboa and Palacios, (2013).	Preliminary Characterization of Marine Currents to Determine Potential Power Generation Sites in Ecuador Oceanographic Institute of the Navy. Ecuador	In the port of Esmeraldas, maximum velocities of up to 2.9 m/s have been found with average velocities of up to 2 m/s in records of 6 hours of measurement.
AVAILABLE TECHNOLOGIES		
National Preinvestment Institute, (2013).	Study of wave energy, currents and kinetic energy of rivers in Ecuador.	The currently existing global technology for harnessing the potential of ocean currents could not be applied because it does not consider the bidirectionality of the tidal currents that affect the Ecuadorian coasts.
Gonzalez and Roman, (2020)	Design of an Experimental Prototype of Electricity Generation Based on Undimotriz Energy Escuela Superior Politécnica del Litoral	For the prototype that was designed at laboratory scale. A Wells type turbine was selected, due to its aerodynamic, symmetrical profile, which rotates in only one direction, optimizing the flow to the maximum, allowing to generate power gain at all times. Computational fluid dynamics software are very useful tools capable of reducing costs, since they allowed us to optimize the device and estimate its power without the need to make multiple prototypes for experimental tests.
Rodriguez and Chimbo, (2017)	Use of Undimotriz energy in Ecuador Universidad Politécnica Salesiana, Ecuador	There are different technologies worldwide to extract wave energy and convert it into electricity: OPT (Ocean Power Technologies), has a generation power of 150 KW; MUTRIKU (Oscillating Water Column Systems OWS); has a generation power of 269 KW; PELAMIS, has a generation power of 750 KW. However, it should be considered which converter is convenient from the data obtained, analyzing its advantages and disadvantages.
Hernandez and Tovar, (2015)	Business Plan: Feasibility Study for the Generation of Undimotriz Energy to Supply Electric Power to the Parish of Jambelí, Santa Rosa Canton, Province of El Oro Escuela Superior Politécnica del Litoral, Guayaquil - Ecuador	In the case of South America, there are technologies under development to harness the energy of ocean currents and transform it into electricity, the most prominent of which are in Argentina, Brazil and Chile.
ECONOMIC VIABILITY		
Rodriguez and Chimbo, (2017)	Use of Undimotriz energy in Ecuador Universidad Politécnica Salesiana, Ecuador	The installation cost of a wave power plant is a negative factor, since for the manufacture of this plant it would be necessary to use materials that withstand the corrosive effect of salt water and marine vegetation, knowing that these materials are more expensive than those generally used.
Saltos, (2017)	Analysis for the Generation of Electric Energy by means of a Undimotriz System and its applicability in the Coast of Ecuador Universidad Católica de Santiago de Guayaquil, Ecuador	The design of a wave power generation plant using Power Buoy technology as a wave energy collector, for the exploitation of wave energy off the coast of the province of Santa Elena in Ecuador, has an approximate cost of $21,086,340.
International Renewable Energy Agency (IRENA), (2014).	Ocean energy technology report	Various European studies indicate that by 2020 the cost of current tidal technologies will be between €0.17/kWh and €0.23/kWh, although ongoing pilot projects point to a cost of between €0.25 and €0.47/kWh. These prices are highly site-dependent, and the cost of both amplitude and tidal stream technologies could decrease by up to 40% if they are combined and integrated into the design and development of existing or new infrastructure.
REGULATORY FRAMEWORK		
Constitution of the Republic of Ecuador, (2008)	Article 15: The State shall promote, in the public and private sector, the use of clean environmental technology and low impact non-polluting alternative energies (...) (p.14). Article 313 establishes that energy in all its forms corresponds to the strategic sectors and that these are of exclusive decision and control of the State.	
Toda una Vida de Ecuador National Development Plan (2017-2021).	Goal 3: New global trends aim to make cities safer places (...) with the capacity to reduce vulnerability to the adverse effects of climate change and other natural and anthropogenic phenomena, controlling the development of human activities that directly or indirectly alter the composition of the global atmosphere (p. 65).	
Organic Law of the Electric Energy Public Service, (2015).	Article 12, paragraph 9: Establishes the promotion of scientific and technological research in the areas of electricity, renewable energy and energy efficiency.	
Organic Law on Energy Efficiency (LOEE), (2019).	Adequate use of renewable energy sources in the distributed generation mode is key, which can only be achieved with a strong political will for change and institutional support for projects aimed at using these resources.	

Source: author's elaboration

Discussion

Based on the compilation and analysis of the information available in documents published in academic web pages on tidal energy and its use for the installation of an alternative electricity supply system based on this renewable source, which can be applied in the canton of Esmeraldas, the context of this study, some variables were established that allow a technical, economic and regulatory analysis, based on these studies conducted on the subject, particularly in Ecuador, although valuable contributions from international publications were also taken into consideration.

Thus, for the technical analysis, the wave energy potential was considered as a first variable, since as Rodriguez and Chimbo, (2017 and Hernandez and Tovar, (2015) refer in their respective dissertations, the wave conditions in the Ecuadorian Territorial Sea are very favorable for the use of its energy, given that the estimates of the calculations of the power per meter of wave front indicate that it is around 14kW/m, on average, which, according to Reyes, (2020) means that if you had a device to generate electrical energy and if its efficiency were 100% you can get 14 kW per meter of wave front.

According to Hernandez and Tovar, (2015) it has been possible to determine the low variability of the height of waves entering the Ecuadorian sea, and that could be maintained in shallower waters, this is an interesting fact, since, in Vera's considerations, (2014) the constancy in the parameter of wave height is important for the purpose of obtaining energy from the sea, because it would represent a regular supply of energy that would influence the design of appropriate equipment for these conditions. Another variable of interest in the technical parameters is the speed of the tidal currents, because it is a fundamental data for the analysis of the hydrokinetic potential, thus, it is expected for the area of Esmeraldas, environment of this research, according to the estimates of Noboa and Palacios, (2013) that the most energetic areas are located in the estuary of the Esmeraldas River, at the height of the port and in the Gulf of Guayaquil, in the Morro Channel, Jambelí Channel and Estero Salado. Continuing with these contributions, in the port of Esmeraldas, maximum velocities of up to 2.9 m/s have been found, with average velocities of up to 2 m/s in records of 6 hours of measurement. Noboa and Palacios, (2013).

The above is relevant, given that according to Castellà, (2021) in various studies it has been calculated that for the economic viability of a project to generate electricity from marine currents, the average speed of the current flowing through the turbine should be between 2 and 2.5 m/s. Otherwise, the energy density would not be sufficient. The aforementioned author also points out that, although it is true that there are prototypes capable of working with a wide range of speeds, and that in certain circumstances, they will have more suitable characteristics than other similar ones for a specific location.

In a second category for the technical analysis, available technologies are included, being that worldwide there is currently an important development of technological projects for the use of the potential of maritime currents. Rodriguez and Chimbo, (2017). In the case of South America there are technologies under development for harnessing the energy of marine currents, and transforming it into electricity, within the most prominent countries are Argentina, Brazil and Chile.

Thus, in Ecuador, the country's electricity infrastructure map, specifically for the generation of energy from renewable sources, details the group made up of biomass, wind, hydro and photovoltaic ARCERNNNR (2021), but tidal energy is not yet included in the renewable sources template.

However, knowing the effective power of ocean currents in Ecuador, preliminary studies have been developed to determine the use of technologies for electricity generation based on wave energy in Ecuador, thus, Gonzalez and Roman, (2020) designed a scale prototype in a laboratory, using a Wells type turbine, and with the support of computational fluid dynamics software, they come to consider according to the criteria of the dimensional analysis of the scaled prototype, that it can be scaled to real size in shallow water locations with not very high wave conditions, therefore, any test model could be installed in areas with these characteristics where the horizontal scale is much larger than the vertical, that is, when the length of the wave is much greater than its height.

Likewise, Saltos (2017) designed a wave energy generation plant using Power Buoy technology for the exploitation of this energy on the coasts of the province of Santa Elena in Ecuador, which in the future can benefit approximately one thousand inhabitants, a significant number of settlers. In the same order Guamán et al, (2017) points out, the energy coming from marine currents in Ecuador, can be used through the use of cutting-edge technologies.

In sum, the referred authors agree on the fact that the tidal current can be fully exploitable in countries, as in fact it is already happening today in countries such as France, Canada, Switzerland, the United Kingdom, the United States and China. Méndez and Molina (2020), to generate tidal energy that can contribute significantly to meeting the energy demand around the world Romero et al, (2021) added to the advantageous characteristics it enjoys such as being free, clean and an inexhaustible source of energy. Méndez and Molina (2020).

In addition to the above, the economic dimension for the implementation of projects based on the use of tidal energy for the Ecuadorian nation was estimated in the analysis, thus, the research consulted shows that currently the economic viability of the use of tidal energy is possible, but at high prices, in this way, Rodriguez and Chimbo, (2017) consider that the cost of installation of a wave power plant, is a negative factor, since for the manufacture of the plant would have to use materials that withstand the corrosive effect of salt water and marine vegetation knowing that these materials are more expensive than those generally used. According to figures estimated by Saltos, (2017) the design of a wave power generation plant using Power Buoy technology for the province of Santa Elena in Ecuador has an approximate cost of

21,086,340US$.

In this same sense, the information contained in the document on ocean energy technology prepared by the International Renewable Energy Agency (IRENA) established a decrease in tidal technologies, which would range between 0.25 and 0.47 €/kWh, which are highly site-dependent, and the cost of both amplitude and tidal stream technologies could decrease by up to 40% if they are combined and integrated in the design and development of infrastructures. IRENA (2014).

More recently, from various Latin American countries, the feasibility of carrying out practices and projects for the productivity of renewable energy by taking advantage of the potential of waves is better projected, in this particular Romero et al, (2021) state about the high investment and maintenance costs involved in each technology to generate wave energy, however, also emphasizes on various prognostic studies that show a decrease in costs over the years. These same authors emphasize in their research that the cost-benefit analysis was carried out with qualitative elements, highlighting the social importance of the project. Romero et al, (2021).

In this regard, it can be mentioned that the implementation of the use of tidal energy in the canton of Esmeraldas would not only be beneficial in terms of energy generation for the inhabitants, but also covers the dimension of energy quality, since it would be providing users with clean energy for health, in addition to the fact that it would protect terrestrial ecosystems through processes that contribute to minimize pollution. In the same direction Zepeda, (2019) emphasizes, nowadays a tidal development is not profitable, however, some time ago wind and solar energy were not profitable either and currently they are the technologies with the largest number of projects in our countries. Thus, Pelayo Pire (2018) points out, the reduction of operation and maintenance costs is the key to the successful economic implementation of wave power stations.

On this specific aspect, Guamán et al, (2017) also emphasize that according to the estimates found in their research, it is feasible to include in the energy matrix of Ecuador, the contribution of energy from marine currents, through the investment of cutting-edge technologies for this purpose. In this framework of ideas, Jodar Hernandez (2020) considers, of all the natural forms of energy present on the planet such as the sun, wind, tides and waves, tidal energy is the one that seems to have the most future and has little environmental impact.

In view of the above, the canton of Esmeraldas, as well as the rest of the country's coasts, as has been emphasized in previous lines, has an important maritime potential, both in quantity and quality to be used for the generation of tidal energy, which can be incorporated into the nation's clean energy matrix and contribute greatly to the energy transformation that has been promoted for several years in Ecuador.

In another milestone of the proposed analysis, in the main mandates of the Ecuadorian legal and institutional framework on energy matters, the efficient use of energy in the country is based on public policy, which is oriented to the promotion and harmonic protection of the interests of consumers and users, to the improvement of the quality of life of the population, to the protection of health and the environment and to the rational and sustainable use of energy resources. Based on this premise, the adoption of measures for the implementation of tidal energy is fully consolidated in the legal norms related to this matter, which have their foundations in the Constitution of the Republic and, from there, a legal-normative order is derived (*Plan de desarrollo toda una vida; Ley orgánica del servicio público de energía eléctrica; Ley orgánica de eficiencia eléctrica,* others) that promote the use of clean energies in favor of the welfare of all citizens and in line with the world trends of environmental care and protection

CONCLUSIONS

It was found in the information provided by the literature consulted that the worldwide capacity to obtain tidal energy from oceanic water masses is quite large and Ecuador is part of that potential, an aspect that is very significant to respond to the energy demand that is increasingly higher and would also be aligned with the trend of using cleaner energies in favor of reducing the polluting effects generated by the traditional way of producing energy for the population and in favor of the care and protection of planetary ecosystems.

Likewise, evidence indicates that tidal energy generation is currently expensive, however, some experts believe that in the course of time it will become increasingly accessible to incorporate it into the energy matrix of the countries, especially in Ecuador, which for some time has been moving towards the transformation of energy generation in more environmentally friendly and sustainable ways.

Finally, it is important to point out that the management of tidal energy production in Ecuador and specifically in the canton of Esmeraldas should be considered more strongly, given the advantages it offers for environmental and social quality and in the near future, from the economic point of view, all of which is in line with the philosophy of sustainable development that drives the country from the energy efficiency point of view.

REFERENCES

ARCERNNR. (2021). Atlas del Sector Eléctrico Ecuatoriano. *Agencia de Regulación y Control de Energía y Recursos Naturales No Renovables (ARCERNNR). https://www.controlrecursosyenergia.gob.ec/wp-content/uploads/downloads/2022/04/Atlas2021.pdf*, pp.146.

Arias, F. (2012). *El Proyecto de Investigación. Introducción a la Metodología Científica.* Caracas. Venezuela: Editorial Epistemes, C. A. Sexta edición.

BBVA. (2021). Así funciona una central mareomotriz y genera energía. *https://www.bbva.com/es/sostenibilidad/asi-funciona-una-central-mareomotriz-y-genera-energia/*.

Calero, R., & Viteri, D. (2013). Energía Undimotriz, Alternativa Para la Producción de Energía Eléctrica en la Provincia de Santa Elena. *Universidad Estatal Península De Santa Elena (UPSE). https://repositorio.upse.edu.ec/xmlui/bitstream/handle/46000/7213/UPSE-RCT-2013-Vol.1-No.2-010.pdf?sequence=1&isAllowed=y*, pp.1-13.

Carta, J., Calero, R., Colmenar, A., & Castro, M. (2009). *Centrales de Energías Renovables: Generación Eléctrica con energías renovables.* Madrid: Editorial Pearson.

Castellà, A. (2021). Estudio de la Viabilidad de la Energía Undimotriz y de las Corrientes Marinas en Cataluña. *Universitat Politècnica de Catalunya. Barcelona, España. Trabajo Final de Grado. https://upcommons.upc.edu/bitstream/handle/2117/355571/159805_TFG_Albert_Castell_Puigdevall.pdf?sequence=1*, pp.110.

CEPAL. (2015). Acerca de Desarrollo Sostenible. *Comisión Económica para América Latina (CEPAL). https://www.cepal.org/es/temas/desarrollo-sostenible/acerca-desarrollo-sostenible* .

Chaparro, E. (2010). Generación de energía mareomotriz en la Argentina. *Instituto Tecnológico de Buenos Aires. Tesis de grado. https://ri.itba.edu.ar/bitstream/handle/123456789/972/Central%20Mareomotriz-%20Emiliano%20Chaparro-%2044053-%20Jul%202010.pdf?sequence=1&isAllowed=y*.

Constitución de la República del Ecuador. (2008). Asamblea Nacional. *https://www.asambleanacional.gob.ec/sites/default/files/documents/old/constitucion_de_bolsillo.pdf*.

Cornejo Ayón, F. (2021). Energía mareomotriz generada a partir del control de inundaciones con presas inflables en Guayaquil. *Universidad Católica Santiago de Guayaquil-Ecuador. Trabajo de Titulación. http://201.159.223.180/bitstream/3317/17432/1/T-UCSG-PRE-ING-IC-405.pdf*, pp.100.

Endesa. (2022). Energía mareomotriz o cómo generar electricidad con el movimiento de las mareas. *Empresa Nacional de Electricidad, S. A (ENDESA), España. https://www.endesa.com/es/la-cara-e/energias-renovables/energia-mareomotriz-que-es-y-como-genera-electricidad*.

Esteve Gómez, N. (2011). Energización de las zonas no interconectadas a partir de las energias renovables solar y eólica. *Pontificia Universidad Javeriana. Trabajo de Maestría. https://repository.javeriana.edu.co/handle/10554/6078*, pp. 99.

Fernández, J. (2020). Estudio de implantación de un Parque Eólico Offshore en la costa de Cádiz. *Universitat de Barcelona. Trabajo de Maestría. http://diposit.ub.edu/dspace/bitstream/2445/171034/1/TFM_MERSE_Juan_Fern%C3%A1ndez_Rinc%C3%B3n.pdf* , pp.53 .

González, J., & Roman, M. (2020). Diseño de un Prototipo Experimental de Generación Eléctrica Basado en Energía Undimotriz. *Escuela Superior Politécnica del Litoral. Guayaquil – Ecuador. Trabajo de Titulación. https://www.dspace.espol.edu.ec/bitstream/123456789/51620/1/T-109917%20GONZALEZ%20-%20ROMAN%20.pdf*, pp.107.

Guamán, J., Espinoza, J., & Ribeiro, E. (2017). Energía del mar para su integración en la matriz energética del Ecuador. *Maskana, 8(1). https://publicaciones.ucuenca.edu.ec/ojs/index.php/maskana/article/view/1990*, pp.313–318.

Hagerman, G., & Polagye, B. (2006). Methodology for estimating tidal current energy resources and power production by tidal in-stream energy conversion devices. *EPRI Guidelines for Preliminary Estimates of Power Production by TISEC Devices. EPRI – TP – 001 NA Rev 2.https://tethys.pnnl.gov/sites/default/files/publications/Tidal_Current_Energy_Resources_with_TISEC.pdf* , pp.57.

Hernández, J., & Tovar, L. (2015). Plan de Negocios: Estudio de Factibilidad de Generación de Energía Undimotriz Para Abastecer de Energía Eléctrica a la Parroquia Jambelí, Cantón Santa Rosa, Provincia del Oro. *Escuela Superior Politécnica del Litoral, Guayaquil – Ecuador. Trabajo de Grado de Maestría. https://undimotriz.frba.utn.edu.ar/wp-content/uploads/sites/61/2019/08/2015-ESPOL-Hern%C3%A1ndez-Ortiz-y-Tovar-Loo-Estudio-de-factibilidad-de-generaci%C3%B3n-de* , pp.156.

Hernández, R., Fernández, C., & Baptista, P. (2014). *Metodología de la Investigación.* México: Sexta edición. Editorial McGraw Hill.

Herrera, A., & Quintero, A. (2017). La energía de origen marino y su uso potencial en Venezuela. *Interciencia, vol. 42, núm. 6. https://www.redalyc.org/journal/339/33951621010/html/#:~:text=La%20utilizaci%C3%B3n%20del%20movimiento%20de,no%20existe%20o%20es%20insuficiente.*, pp. 393-399.

Hurtado, J. (2015). *Metodología de la Investigación Holística.* Caracas. Venezuela: Quirón Ediciones. Cuarta Edición.

IDAE. (2020). Energías del Mar. *Instituto para la Diversificación y Ahorro de la Energía (IDAE) de España. https://www.idae.es/tecnologias/energias-renovables/uso-electrico/energias-del-mar*.

INOCAR. (2010). Estudios de Generación Eléctrica a través de Energías Renovables no convencionales en todas sus formas como olas. *Instituto Oceanográfico y Antártico de la Armada del Ecuador (INOCAR). https://www.inocar.mil.ec/web/index.php/17-proyectos/inocar-inp/38-resumen-del-proyecto*.

INP. (2013). Estudio de la energía de las olas, corrientes y energía cinética de ríos en el Ecuador. *Instituto Nacional de Preinversión (INP). https://es.scribd.com/document/153981785/Estudio-de-la-energia-de-olas-corrientes-y-energia-cinetica-de-rios-en-el-Ecuador-para-generacion-electrica*, pp.1-20.

IPCC. (2019). Noticias del IPCC. *Panel Intergubernamental sobre Cambio Climático (IPCC)/Oficina de prensa Ginebra. https://www.ipcc.ch/2019/*.

IRENA. (2014). Informe sobre tecnología de energía oceánica. *Agencia Internacional de Energías Renovables (IRENA). https://www.greenfacts.org/es/energia-mareomotriz/index.htm*.

IRENA. (2020). Las Energías Renovables Marinas Impulsan la Economía Azul. *Agencia Internacional de Energías Renovables (IRENA). https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Dec/IRENA_Offshore_Renewables_2020_ES.pdf?la=en&hash=22E6CC605C56350E77258008CCA4CC95ABC9F64F*.

Jodar Hernandez, P. (2020). Diseño de una turbina para una central de energía mareomotriz. *Universitat Politècnica de Catalunya.Trabajo final de grado.https://upcommons.upc.edu/bitstream/handle/2117/328658/154616_dise%C3%B1o%20de%20una%20turbina%20para%20una%20central%20de%20energ%C3%ADa%20mareomotriz.pdf?sequence=1&isAllowed=y*, pp.88.

Ley Orgánica del Servicio Público de Energía Eléctrica. (2015). Asamblea Nacional. *http://www.regulacionelectrica.gob.ec/wpcontent/uploads/downloads/2015/11/mar/Ley%20Org%C3%A1nica%20del%20Servicio%20P%C3%BAblico%20de%20Energ%C3%ADa%20el%C3%A9ctrica%20-%20RO418%202015_ene_16.pdf*.

LOEE. (2019). Asamblea Nacional. *Ley Orgánica de Eficiencia Energética (LOEE). https://www.recursosyenergia.gob.ec/wp-content/uploads/downloads/2019/03/Ley-Eficiencia-Energe%CC%81tica.pdf*.

Méndez, L., & Molina, D. (2020). Estudio Preliminar de la Energía Mareomotriz en el Municipio de Pizarro- Chocó. *Universidad El Bosque Bogotá, Colombia. Trabajo de Titulación. https://repositorio.unbosque.edu.co/bitstream/handle/20.500.12495/8845/Mendez_Triana_Luisa_Fernanda_2020.pdf?sequence=2*, pp.77.

Moreno García, H. (2016). Estudio de pre-factibilidad para generación de energía mareomotriz en la Costa Pacífica Colombiana. *Universidad de La Salle. https://ciencia.lasalle.edu.co/ing_electrica/61/*, pp. 76.

Noboa, S., & Palacios, O. (2013). Caracterización Preliminar de las Corrientes Marinas Para la Determinación de Sitios Potenciales de Generación Eléctrica en el Ecuador. *Perfiles; (10) Art. 6. Instituto Oceanográfico de la Armada. http://ceaa.espoch.edu.ec:8080/revista.perfiles/faces/Articulos/Perfiles10Art6.pdf*, pp.28-33.

OES & IEA. (2017). Una Visión Internacional Para la Energía Oceánica. *Sistemas deEnergía Oceánica (OES)/Agencia Internacional de la Energía (IEA).*, pp.28.

Pelayo Pire, C. (2018). Aprovechamiento de la Energía Undimotriz en la Costa Asturiana. *Universidad de Oviedo Escuela Superior de la Marina Civil de Gijón. Trabajo Fin de Máster.https://digibuo.uniovi.es/dspace/bitstream/handle/10651/48378/TFM_PelayoPireCortes.pdf;jsessionid=F7F5D5A61E0C84A723458FD17CD17F05?sequence=3*, pp.100.

Plan Nacional de Desarrollo Toda una Vida de Ecuador. (2017-2021). *https://observatorioplanificacion.cepal.org/es/planes/plan-nacional-de-desarrollo-2017-2021-toda-una-vida-de-ecuador*.

Quintero, J., & Quintero, L. (2016). Sistemas de Producción y Potencial Energético de la Energía Mareomotriz. *Revista Ingeniería, Investigación y Desarrollo, Vol. 16, N° 1. https://revistas.uptc.edu.co/index.php/ingenieria_sogamoso/article/view/4078/4150*, pp. 39-45.

Reyes, J. (2020). Análisis de operación de un sistema de generación undimotriz conectado a un modelo de red. *Universidad de La Salle, Bogotá. https://ciencia.lasalle.edu.co/cgi/viewcontent.cgi?article=1577&context=ing_electrica*, pp.59.

Roca, J. (2021). La turbina mareomotriz más potente del mundo comienza a suministrar energía a la red. *El periódico de la energía. https://elperiodicodelaenergia.com/la-turbina-mareomotriz-mas-potente-del-mundo-comienza-a-suministrar-energia-a-la-red/*.

Rodríguez, R., & Chimbo, M. (2017). Aprovechamiento de la energía undimotriz en el Ecuador. *Ingenius. Revista de Ciencia y Tecnología; No.17, Cuenca-Ecuador. http://scielo.senescyt.gob.ec/scielo.php?script=sci_arttext&pid=S1390-860X2017000200023*.

Rojas, R. (2011). Elementos para el diseño de técnicas de investigación: una propuesta de definiciones y procedimientos en la investigación científica. *Tiempo de Educar. Vol. 12. Núm. 24*, pp. 277-297.

Romero, E., Guevara, R., & Amaya, A. (2021). Alternativa Tecnológica para el Aprovechamiento de la Energía Undimotríz. *RECITIUTM. Revista Electrónica de Ciencia y Tecnología. Vol.7. Núm.2. Universidad Politécnica Territorial de Maracaibo. Estado Zulia. Venezuela.http://recitiutm.iutm.edu.ve/index.php/recitiutm/article/view/185/html* .

Saltos, J. (2017). Análisis para la Generación de Energía Eléctrica mediante un Sistema Undimotriz y su aplicabilidad en el Litoral del Ecuador. *Universidad Católica de Santiago de Guayaquil, Ecuador. Trabajo de Titulación. http://repositorio.ucsg.edu.ec/bitstream/3317/7743/1/T-UCSG-PRE-TEC-IEM-98.pdf*, pp.100.

Sierra, R. (2007). *Técnicas de investigación social: Teoría y ejercicios.* Madrid, España: International Thomson Editores y Paraninfo, S.A. (14ava edición).

Vera, L. (2014). Análisis de Serie de Tiempo del Oleaje Frente a Salinas-Ecuador y su Relación Con el Potencial Energético. *Acta Oceanográfica del Pacífico. Vol. 19, N° 2. https://docplayer.es/41316994-Analisis-de-serie-de-tiempo-del-oleaje-frente-a-salinas-ecuador-y-su-relacion-con-el-potencial-energetico.html*.

Zepeda, M. (2019). Estado Actual de la Energía Mareomotriz en México. *Instituto Politécnico Nacional (IPN). Trabajo de Titulación*, pp.139.

Contribution of each author to the manuscript:

	% of contribution of each author	
Task	**A1**	**A2**
A. theoretical and conceptual foundations and problematization:	25%	25%
B. data research and statistical analysis:	25%	25%
C. elaboration of figures and tables:	25%	25%
D. drafting, reviewing and writing of the text:	25%	25%
E. selection of bibliographical references	25%	25%
F. Other (please indicate)	-	-

Indication of conflict of interest:

There is no conflict of interest

Source of funding

There is no source of funding

Acknowledgments

There is no acknowledgments.